



**FACULTY OF ENGINEERING AND ENVIRONMENTAL SCIENCES**

**OSUN STATE UNIVERSITY**  
**OSOGBO, OSUN STATE, NIGERIA**

# **PROCEEDINGS**

**OF THE**

***1<sup>ST</sup> INTERNATIONAL CONFERENCE ON  
ENGINEERING AND ENVIRONMENTAL SCIENCES***

**(NOVEMBER 5-7, 2019)**

**THEME**

**ADVANCING TECHNOLOGY AND ENVIRONMENTAL  
BURDENS: CHALLENGES AND SUSTAINABLE SOLUTIONS**

**EDITORS: Abidoeye, L.K.; Okedere, O.B.; Alawode, K.O.; Ibrahim, R.B.;**

**Adebanjo, A.U.; Thanni, M.O.; Adeyemo, K.A.**

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## **PREFACE**

The 1<sup>st</sup> International Conference on Engineering and Environmental Sciences was the first international conference organized by the Faculty of Engineering and Environmental Sciences, Osun State University. The aims of the conference include to foster interactions and collaborations among members of academia, industries and traditional stakeholders across the globe, with a view to tackling the challenges to sustainable development. To address socio-economic and environmental challenges facing our country and the world at large, the Faculty seeks to position itself strategically, using these formal and intellectual interactions, to proffer ingenious solutions and also initiate same with interested stakeholders. By so doing, the Faculty is promoting its ideals to the society and also fulfilling its part in the town and gown relationship.

As elucidated by the theme of the conference- *ADVANCING TECHNOLOGY AND ENVIRONMENTAL BURDENS: CHALLENGES AND SUSTAINABLE SOLUTIONS*, this conference brought to the fore, the burdens of development borne by the environment as a result of global strives for increased and improved production of building materials, automobiles, agriculture, healthcare, textiles and so on. During this conference, local, national and international participants have demonstrated the various approaches to the solutions theoretically, empirically and numerically.

Having evaluated, revised and edited the various submissions by the participants to produce this proceedings, it is believed that readers will find in this proceedings, intellectual treasures of inestimable values, to further push the frontiers of knowledge to the next level. It is hope that the last participants of the conference and readers of this proceedings will keep up the good work of research and intellectualism and produce qualitative works to qualify for the next edition of the conference.

Finally, our immense appreciations go to the members of the local organizing committee as well as the local, national and international participants for using their time, energy and material resources to make the event worthwhile.

**Engr. Dr. A.A. Bello**

Ag Dean, Faculty of Engineering and Environmental Sciences

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## **TIME HEADWAY AS INDICES OF TRAFFIC CONGESTION**

Emmanuel, A.A. and Mohammed, H. \*

Department of Civil Engineering, Obafemi Awolowo University, Ile - Ife, Nigeria

\*Email of Corresponding Author: [hmestem@yahoo.com](mailto:hmestem@yahoo.com)

### **ABSTRACT**

Urban mobility problem in Nigeria is on the increase, due to rapid growth in traffic that is not matched with the existing transport infrastructure, resulting in traffic congestion. Headway, a measure of level of service of a roadway, could be instructive in addressing this problem, hence this study. Headway, traffic flow and travel speed were collected for morning and evening peak periods for three consecutive weeks for two elected sections of a road in Ile-Ife, using normal procedure. The obtained headway data were subjected to statistical analysis. Headway models were developed using regression analysis and the developed models were evaluated using Adjusted Coefficient of determination ( $R^2$ ). The results showed that the traffic along the road was heterogeneous and was composed of 40% Motorcycles, 38% Buses, 21% Cars and Sport Utility Vehicles (SUVs), and 1% Trucks. The maximum and minimum travel speeds were 34 and 28 km/hr respectively, and the maximum safe speed (85th percentile speed) was 31.20 km/hr, while the minimum allowable speed (15th percentile speed) was 28.50 km/hr. The ratio of flow to capacity ( $v/c$ ) of the road was 0.65 and the road was characterised to operate at level of service C. The headway models were  $h = 0.001n^2 - 0.418n + 35.401$  and  $h = 0.002n^2 - 0.569n + 42.122$  for Sabo and Obafemi Awolowo University Teaching Hospital's Complex directions with corresponding R-square values of 0.942 and 0.928 respectively. The minimum headway values obtained were 5.35 sec. and 5.52 sec. for Sabo and Obafemi Awolowo University Teaching Hospital's Complex directions respectively. These values are higher than the 5 sec, postulated by HCM 2010. The road is therefore prone to congestion.

**Keyword:** Urban mobility, transport infrastructure, headway, congestion

### **1.0 INTRODUCTION**

Headway is defined as the time between two consecutive vehicles (in seconds) when they pass a single point on a roadway (HCM, 2010). Headway is measured as the time between the same common features of two consecutive vehicles (e.g. front bumper). Headway is one of the important microscopic traffic flow parameters which is extensively applied in planning,

analysis, design and operation of roadway systems (Michael *et al.*, 2000). Consequently, the distribution of headways has an effect on platoon formation and delays. In the Highway Capacity Manual (2000) the level of service on two-lane rural highways is approximated by the proportion of headways less than five seconds; thus, making a connection between the headway distribution and the level of service. Accurate modelling and analysis of vehicle headway distribution helps traffic engineers to maximize roadway capacity and minimize vehicle delays.

Urban mobility problems in Nigeria have been increasing significantly in the last few decades and this trend seems to continue. This is due to rapid increase in population in urban areas, which is not matched with growth in transport facilities such as road network, transport complimentary facilities, transport services and traffic management techniques (Ogunbodede, 2008).

Rothenberg (1985) defined urban congestion as “a condition in which the number of vehicles attempting to use a roadway at any given time exceeds the ability of the roadway to carry the load at generally acceptable level of service”. There are two types of congestion: recurring and non-recurring. Typically, recurring congestion occurs during the morning and afternoon rush hours as commuters travel to and from work. Non-recurring congestion is caused by random incidents, most often by disabled vehicles and accidents. Recurring congestion is most easily identified as the characteristics of rush hour traffic are well documented. Incidents are random events, and traffic patterns and characteristics are not well defined (Arnold, 1985).

Traffic congestion has a negative impact on the economy and on the quality of people’s lives. Road users experience delay and stress, and environmental pollution increases. Congested traffic flow is characterized by a situation in which road users cannot drive at their desired speed because they are constrained by the presence of other road users. In contrast, a free flow situation occurs when road users do not influence each other’s behaviour. Smooth traffic flow can suddenly change due to, for instance, a decelerating or slow-moving vehicle or a partial blocking of the road (Hoogendoorn, 2007). The basis of travel time measure is rooted in the interests of travellers and urban residents. Travel time indices are good measures of the effects of congestion; they rely on an estimate of the speed that travellers choose to travel if there is no congestion (in this case, 90 km/h (60 mph) for freeways and 45 km/h (30 mph) on streets (Lomax and Schrank, 2010). Lindley (1986) noted that, if the volume over capacity ratio ( $v/c$ ) is greater than or equal to 0.77, then there is congestion.

Management of traffic has become a critical issue as the number of vehicles in metropolitan areas is nearing the existing road capacity, resulting in traffic congestion. In some areas, the

volume of vehicles has met and/or exceeded road capacity (Möller, 2014). The development of headway models is therefore justifiable, because it helps traffic engineers to verify how traffic properties and characteristics such as speed, flow, headway and density among others can be used to determine the effectiveness of traffic flow. Among the factors that may justify a transportation project are improvements in traffic flow and safety, energy consumption, travel time, economic growth, and accessibility (Garber and Hoel, 2009). Time headways as indices of traffic congestion could give policy guide for the improvement on the quality services of urban traffic movement.

## **2.0 MATERIALS AND METHOD**

The data collection process was undertaken from the section (located between chainage 3+532 and 3+832) on an urban two-lane two-way road along Sabo junction – Obafemi Awolowo University Teaching Hospital's Complex (OAUTHC) section (Fajuyi road) in Ile-Ife city in Osun State, South-West of Nigeria. Figure 1 shows the study route. At the point of observation, the road alignment is on tangent with a clear sight distance of approximately 260 m, and there are no intersections that could cause diversion of traffic within 200 m. The roadway section chosen for this study was single carriageway (two-lane, two-way roadway) paved with asphalt concrete, free from commercial activities, and was a major urban road (not a bypass). This road carries a composite traffic volume of passenger car, truck, buses, pick up, coaster, motorcycles and minibuses; the road carries a large proportion of the daily traffic volume.

Headway measurement was conducted with an automatic stopwatch. Headways of vehicles traversing the road segment were measured at every 15-minute intervals throughout the duration of observation. Traffic volume was obtained at the selected sections using silicon (video) camera. The silicon (video) camera was mounted on the stand and placed at a vantage point (a storey building) so as to cover the entire length of trap. The recorded film was replayed in the laboratory to extract the traffic volume in both directions of the sections. The spot speeds were obtained using stopwatch with known two reference points. The data collected which included, spot speed, traffic flow and headway for the study period of 2 hours (6:30am – 8:30am) for morning peak, and 1 hour (3:30pm – 4:30pm) for evening peak condition, for three (3) weeks (Monday – Friday), consecutively (Mathew, 2014). The headway data collected were analysed, and traffic parameters were derived from equations 2.1 to 2.3 and reduced to characterize the road. Selection of the proper statistical techniques for analysing the headway results and utilization of the reduced data in the development of the regression models using

appropriate computer software. Adjusted coefficient of determination was used as the main evaluation in selecting the model that best fitted the field data.

$$\text{Traffic density: } K = \frac{Q_{agg}}{U_s} \quad (2.1)$$

Where:

$Q_{agg}$  = Mean traffic Flow (pcu/hr/ln),

$U_s$  = Max. Space mean speed (km/hr)

$$(i) \text{ Traffic Flow (vehicles per second)} = \frac{1}{h} \quad (2.2)$$

Where  $h$  = average headway.

(ii) The capacity which represents the maximum flow:

$$Q_m = K_o \times U_o \quad (2.3)$$

Where:

$U_o$  = Optimum Speed ,

$K_o$  = Optimum Density

### 3.0 RESULTS AND DISCUSSION

The selected road segment is 2.685 km long with a total carriageway of 12.10 m (lane width of 3.65 m) and unpaved shoulder of approximately 3.8 m, there are open line drains of 0.6 m x 0.9 m on both sides of the road and the roadway section was single carriageway (two-lane, two-way roadway) paved with asphalt concrete, free from commercial activities, and was a major urban road. The traffic flow ranged from 784 pcu/hr/ln to 1000 pcu/hr/ln. The composition of the traffic on this route is classified as heterogeneous and was composed of 40% Motorcycles, 38% Buses, 21% Cars and Sport Utility Vehicles (SUVs), and 1% Trucks, (Figure 2). Mohan and Tiwari (2000) reported that heterogeneous traffic flow consists of modes of varying dynamic and static characteristics sharing the road space, also, the large percentage for motor cycles is typical of urban passenger transport system (Ogunbodede, 2008). The speed pattern on the route is typical of movement trends of traffic in urban centres. The maximum travel speeds were 34 km/hr at the early part of the morning (6.30 am – 7.00 am) and dropping to 28 km/hr (7:01 am – 7:15 am), when most commuters join the traffic for their various places of work. The speed picks up thereafter and drops again (4.15 pm – 4.30 pm), when commuters

once again hit the road returning back home (Figure 3). The peak traffic flow on the road at morning peak period was 978 *pcu/hr/ln* between 7:31 am and 7:45 am, and the peak traffic flow for evening peak period was 946 *pcu/hr/ln* between 3:46 pm and 4:00 pm, (Table 1). These observed periods always serve as the time the number of vehicles near the existing road capacity and when people are urged to reach their various places of work or get back home from work. Also, the maximum headways on the road at morning peak period were 8.94 seconds and 9.32 seconds with observed flows of 784 *pcu/hr/ln* and 877 *pcu/hr/ln* for OAUTHC and Sabo directions respectively between 6:30 am - 6:45 am and 6:46 am – 7:00 am. The maximum headways on the road at evening peak period were 6.26 seconds and 8.42 seconds with observed flows of 946 *pcu/hr/ln* for OAUTHC and Sabo directions respectively between 3:46 pm - 4:00 pm. The theoretical traffic flow showed variability between the observed headway and theoretical headway. These values of headway obtained are suitable because they are higher than the minimum safe headway of 5 seconds as postulated in HCM, 2010.

An optimum speed ( $U_o$ ) and optimum density ( $K_o$ ) of 32.05 *km/hr* and 27.66 *pcu/km/ln*, were obtained respectively. The road operating capacity ( $Q_m$ ) value was therefore, 887 *pcu/hr/ln*.

Table 2 shows a comparison of the determined capacity and

operating speed with that recommended for a two-way two-lane road by the Highway Design Manual (2007). These values, 32.05 *km/hr* and 887 *pcu/hr/ln* for speed and operating capacity respectively were short of the specifications for an urban a two-way, two-lane road (HDM, 2007). Ratio of flow to capacity ( $v/c$ ) of the road was 0.65; the selected road operates at level of service C.

The international standards used to determine their degree of congestion are shown in Table 3.

Tables 4 and 5 show the model summary and parameters estimates. The best model is the Second Order Polynomial. The equations representing the headway models are  $h = 0.001n^2 - 0.418n + 35.401$  and  $h = 0.002n^2 - 0.569n + 42.122$  with their corresponding R-square values of 0.942 and 0.928 for Sabo and Obafemi Awolowo University Teaching Hospital's Complex directions respectively (Figures 4 and 5). Where  $h$  = average headway (Sec.), and  $n$  = number of headway observations (sample sizes).

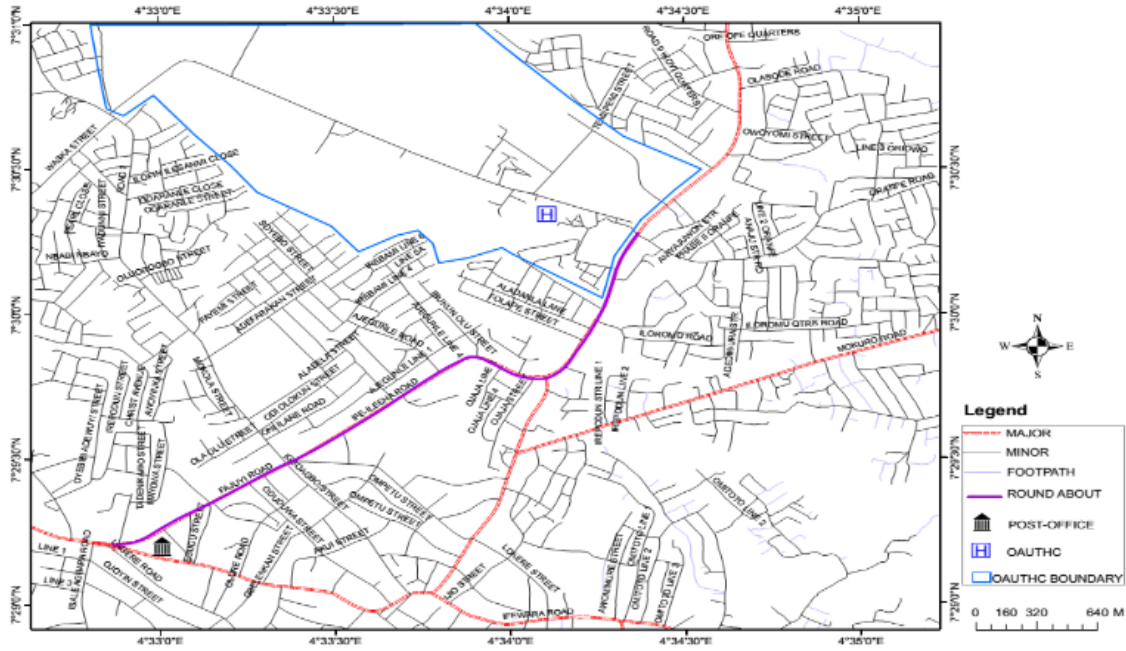


Figure 1: The Study Location with some Features

(Note; The blue line indicates the selected road)

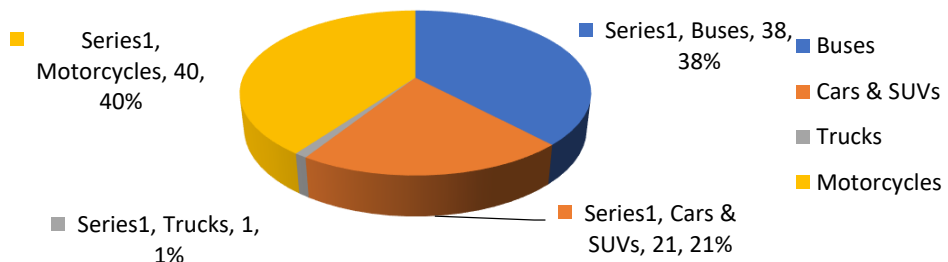


Figure 2: Traffic Composition for the Road

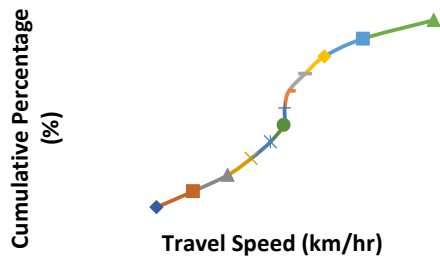


Figure 3: Percentage Cumulative of Average Travel Speed

Table 1: Average Headway, Observed and Theoretical Traffic Flow data

Time Interval	Observed Traffic Flow ( $Q_a$ ) 15 Days Average	Theoretical Traffic Flow	Average Headway ( $h_a$ ) (Sec)	
			Sabo Direction	OAUTHC Direction
6:30 – 6:45	784	865	9.23	8.94
6:46 – 7:00	877	859	9.32	8.39
7:01 – 7:15	922	954	7.98	7.43
7:16 – 7:30	954	1017	7.09	6.74
7:31 – 7:45	978	1070	6.36	6.09
7:46 – 8:00	910	978	7.65	6.87
8:01 – 8:15	896	928	8.35	7.64
8:16 – 8:30	862	876	9.07	8.00
3:31 – 3:45	909	865	9.23	7.23
3:46 – 4:00	946	923	8.42	6.26
4:01 – 4:15	893	855	9.37	7.99
4:16 – 4:30	895	889	8.90	8.45

Table 2: Capacity and operating speed (km/h) compared with the desired values

	Capacity (pcu/h/ln)	Operating Speed (km/h)
Federal Ministry of Works	1500	50 – 60
This study	887	39.71

Table 3: Standardized Measures of Traffic Congestion

V/C range	PAG standard	FHWA standard
$V/C < 0.50$	No or low congestion	Below capacity
$0.50 < V/C < 0.74$	Moderate congestion	Below capacity
$0.75 < V/C < 1.00$	Heavy congestion	Approaching capacity
$V/C > 1.00$	Severe congestion	Exceeding capacity

Source: PAG, 2005 and FHWA, 2014

Table 4: Model Summary and Parameter Estimates for Sabo direction

Equation	Model Summary					Parameter Estimates		
	R-Square	F	df1	df2	Sig.	Constant	b1	b2
Linear	0.833	890.476	1	178	0.000	22.646	-0.151	
Logarithmic	0.839	927.495	1	178	0.000	74.338	-14.524	
Quadratic	0.942	469.945	2	177	0.000	35.401	-0.418	0.001
Power	0.849	1001.107	1	178	0.000	29770.619	-1.804	
Growth	0.850	1006.382	1	178	0.000	3.888	-0.019	
Exponential	0.850	1006.382	1	178	0.000	48.808	-0.019	

Table 5: Model Summary and Parameter Estimates for OAUTHC direction

Equation	Model Summary					Parameter Estimates		
	R-Square	F	df1	df2	Sig.	Constant	b1	b2
Linear	0.794	684.573	1	178	0.000	20.371	-0.130	
Logarithmic	0.811	761.684	1	178	0.000	67.219	-13.010	
Quadratic	0.928	425.011	2	177	0.000	42.122	-0.569	0.002
Power	0.841	938.518	1	178	0.000	18551.322	-1.705	
Growth	0.832	884.201	1	178	0.000	3.697	-0.017	
Exponential	0.832	884.201	1	178	0.000	40.321	-0.017	



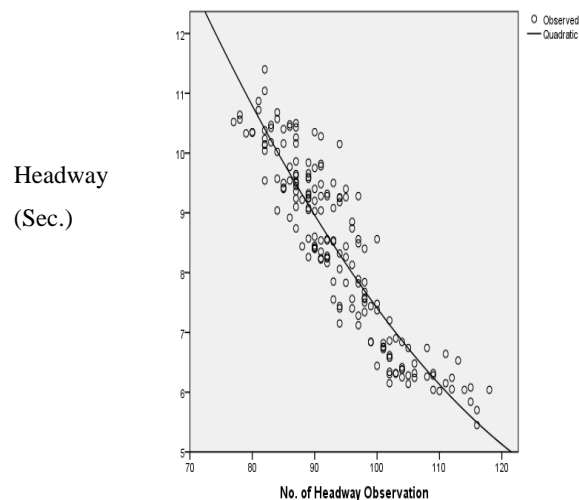


Figure 4: Headway model (Sabo direction)

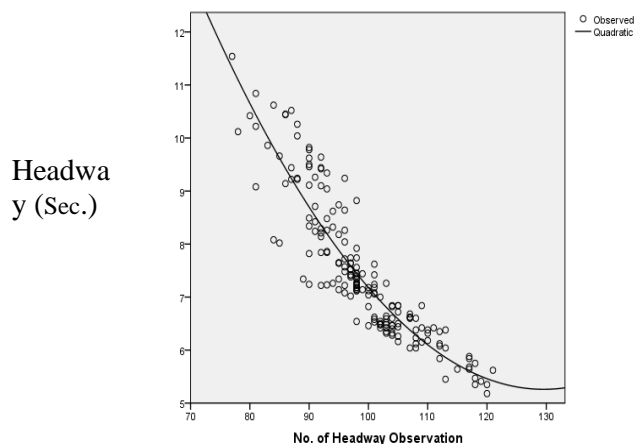


Figure 5: Headway model (OAUTHC direction)

#### 4.0 CONCLUSION

Based on the findings of this study, it can be concluded that:

- (i) The Second Order Polynomial model was best fitting the headway-traffic flow relationship for interrupted flow conditions.
- (ii) The results revealed that the capacity and operating speed of the road are short of the required values of 1500 pcu/hr/ln and 50 – 60 km / h respectively for an urban two-way two-lane highway. Furthermore, the minimum headway values obtained were 5.35 sec. and 5.52 sec. for Sabo and Obafemi Awolowo University Teaching Hospital’s Complex

directions respectively. These values are higher than the 5 sec, postulated by HCM (2010). The road is therefore prone from congestion.

(iii) The developed models could be used to predict the vehicles arrival patterns at a point.

## **REFERENCES**

- Arnold, E. D. (1985). *Congestion on Virginia's Urban Highways*. National Transportation Library.
- Federal Highway Administration. (FHWA). (2014). Freight Management and Operations, Chapter 5: Capacity and Performance Analysis, United States Department of Transportation (USDOT) - Federal Highway Administration.
- Garber, N. J. and Hoel, L. A. (2009). *Traffic and Highway Engineering*, 4th Edition, Centage Learning, 1120 Birchmount Road, Toronto. ON M1K 5G4, Canada.
- Highway Capacity Manual. (2000). *Transportation Research Board*, National Research Council, Washington, U.S.A.
- Highway Capacity Manual. (2010). *Transportation Research Board*, National Research Council, Washington, U.S.A.
- Hoogendoorn, S. and Bovy, P. (1998). A New Estimation Technique for vehicle-type Specific Headway Distributions in Transportation Research Record. *Journal of the Transportation Research Board (TRB)*, National Research Council, Washington, D.C. 1646, 18–28.
- Lindley, J. A. (1986). Quantification of Urban Freeway Congestion and Analysis of Remedial Measures, Federal Highway Administration, FHWA/RD-87/052.
- Lomax, T and Schrank, D. (2010). Developing a Total Travel Time Performance Measure, A Concept Paper. Texas Transportation Institute (TTI).
- Mathew, V. (2014). *Measuring Over a Short Section*. Transportation System Engineering, Department of Civil and Environmental Engineering, Institute of Information Technology, Bombay, India.
- Michael, P. G., Leeming, F. C. and Dwyer, W. O. (2000). Headway on urban streets: observational data and an intervention to decrease tailgating, Transportation Research Part F. *Traffic Psychology and Behaviour*, 3, (2), 55–64.
- Mohan, D. and Tiwari, G. (2000). *Injury Prevention and Control*. Taylor and Francis, London.
- Möller, D. P. F. (2014). *Introduction to Transportation Analysis, Modelling and Simulation, Simulation Foundations, Methods and Applications*. Springer Verlag, London.

Highway Design Manual. (2007). *Director Highway Planning and Design*, Federal Ministry of Works Headquarters, Abuja, Nigeria.

Ogunbodede, E. F. (2008). Urban Road Transportation in Nigeria from 1960 to 2006: Problems, Prospects and Challenges. *Ethiopian Journal of Environmental Studies and Management*, 1, (1).

Pima Association of Governments, PAG, 2005. Volume/Capacity Ratios, Tucson Arizona.

Rothenberg, M. J. (1985). Urban Congestion in the United States: What Does the Future Hold?. *ITE Journal*, 55, (7), 22-39.

## **SOME PHYSICAL PROPERTIES OF COMMON VARIETIES OF WATERMELON SEED**

Obi, O.F.

Agricultural and Bioresources Engineering Department, Faculty of Engineering,  
University of Nigeria, Nsukka.

Email of Corresponding Author: [francis.obi@unn.edu.ng](mailto:francis.obi@unn.edu.ng); [profran6@gmail.com](mailto:profran6@gmail.com)

### **ABSTRACT**

For the purpose of developing mechanized processing machines for watermelon seeds, some physical properties of three varieties of watermelon (*Citrullus lanatus*) seed namely, Sugar baby, Kaolack and Charleston grey at moisture content levels of 3.41, 3.29 and 4.08 % (w.b.), respectively were investigated. Values for the properties were determined using appropriate established methodologies widely used in the literature. The data obtained were all significantly different from each other ( $p < 0.05$ ) except for the thickness, degree of sphericity, bulk density. Charleston grey variety had the highest mean value for the length, width, thickness, arithmetic and geometric mean diameters, surface area and thousand seed weight (TSW) which were reported to  $12.35 \pm 0.48$  mm,  $7.66 \pm 0.35$  mm,  $2.11 \pm 0.28$  mm,  $7.37 \pm 0.21$  mm,  $5.83 \pm 0.28$  mm,  $107.21 \pm 10.33$  mm<sup>2</sup>, and  $97.51 \pm 0.39$  g, respectively. Also, the highest volume of  $133.33 \pm 0.57$  mm<sup>3</sup> was recorded for the Charleston grey variety, while Sugar baby had the highest true and bulk densities, and porosity which were reported to be  $1230.77 \pm 1.89$  kg/m<sup>3</sup>,  $540.53 \pm 4.83$  kg/m<sup>3</sup> and  $56.08 \pm 0.36$  %, respectively. For the angles of repose, the highest mean value was reported for Charleston grey while Sugar baby had the lowest mean value. However, for the static coefficient of friction, Sugar baby had the highest coefficient of 0.33 on plastic surface while Sugar baby and the Kaolack had the same highest mean value of 0.41 on aluminium surface. On plywood surface, Charleston grey had the highest coefficient of friction of 0.47. Generally, in most of the properties investigated, Charleston grey had the highest mean values, followed by Kaolack and then Sugar baby.

**Keywords:** Watermelon seeds, physical properties, variety, Nigeria

### **1.0 INTRODUCTION**

Watermelon (*Citrullus lanatus*) is a member of the cucurbit family (Cucurbitaceae). The crop is grown commercially in areas with long frost-free warm periods, and the fruit is usually large, oval, round or oblong shaped, having smooth skin with dark green rind (Koocheki et al., 2007).

It can be placed as a simple multi grains pulp fruits in the classification of edible fruits which are called "Pepo" fruits. Watermelon is cultivated in a wide range of tropical and semi tropical regions of the world with about 50 common varieties throughout the world (Razavi and Milani, 2006). The seeds are usually extracted from the fruit either by manual maceration and washing of decayed fruits in a basket or scooping out pulp from fruit. Watermelon seed plays an important role in people's diet due to its high nutritive value (Razavi and Milani, 2006; Koocheki et al., 2007). It has been reported that watermelon seed consists of about 31.9% protein, 4.4% carbohydrates, 57.1% fat, 8.2% fibre, 6.2% ash, 130 mg calcium, 456 mg phosphorus and 7.5 mg Iron (Razavi and Milani, 2006). It was further reported that the seed also contain amino acids such as Leucine, Isoleucine, Tryptophan and Valine which act as antioxidant during normal metabolism and protects against cancer (Perkins-Veazie and Collins, 2004). Watermelon has been noted to be a very rich source of vitamins which can be served for breakfast, as an appetizer or snack, depending on how it is prepared. Although watermelon fruit and the seed are multipurpose in use, the seed is considered a waste in Nigeria and its use is not well known.

A few articles have been published on the physical and frictional properties of common varieties of watermelon seeds; some of which were on Iranian varieties. Razavi and Milani (2006) investigated several physical properties of three major local Iranian varieties of watermelon seeds, Sarakhsi, Kolaleh and Red, at the moisture content of 4.55, 4.75 and 5.02% (w.b.). Their results showed that the Red variety had the maximum volume, length, width, arithmetic mean diameter, geometrical mean diameter, sphericity, surface area and funnelling angle of repose among the varieties, while the greatest thickness was observed for Sarakhsi variety and the highest bulk and true density was recorded for Kolaleh variety. Koocheki et al. (2007) investigated the physical properties of three common Iranian varieties of watermelon seeds as a function of seed moisture content varying from 4.75 to 47.6, 5.02 to 46.81, and from 4.55 to 45.22% (w.b.) for Ghermez, Kolaleh and Sarakhsi, respectively.

The physical properties of watermelon seeds are essential for the design of equipment for handling, processing, storing, sowing the seed, and most importantly in determining the optimum vacuum pressure of precision vacuum seeder (Karayel et al., 2004; Koocheki et al., 2007). Although there are just few published data on the physical properties of watermelon seeds (Razavi and Milani, 2006; Koocheki et al., 2007), there are no published data on the physical properties of major varieties of watermelon seeds in Nigeria. Razavi and Milani (2006) stated that the physical properties of watermelon seed vary with the cultivars which

could be attributed to the individual characteristics of these varieties, environmental and growth conditions. Thus, the objectives of the study were to investigate the physical properties of three major varieties of watermelon seeds cultivated in Nigeria and to compare the data obtained with those of other varieties cultivated in other parts of the world. The physical properties investigated were axial dimensions, mean diameters, degree of sphericity, surface area, volume, 1000 seed mass, bulk density, true density, porosity, angle of repose, and static coefficients of friction on various surfaces.

## **2.0 MATERIALS AND METHODS**

### **2.1 Sample preparation**

Several varieties of watermelon seed are cultivated in Nigeria but based on a survey by the author, there are only three major varieties widely cultivated and consumed in different parts of the country. These varieties are Sugar baby, Charleston grey and Kaolack. The seeds of these watermelon varieties were obtained from a local market in Enugu, Nigeria. The seeds were obtained cleaned; free of foreign matter such as dust, dirt, stones, immature and broken seeds.

### **2.2 Moisture content determination**

The initial moisture content of watermelon seeds was determined using the oven dry method at  $103\pm 2^{\circ}\text{C}$  (Samuelsson et al., 2006). The seed was weighed after every 30 minutes until the measured weight of the watermelon seed sample remained constant. The moisture content of the seed was then calculated using Equation 1.

$$\text{Moisture Content, } MC_{\text{WB}} = \frac{M_{\text{w}} - M_{\text{D}}}{M_{\text{w}}} \times 100 \quad (1)$$

Where,  $MC_{\text{WB}}$  = Moisture content in wet basis of the seed, %

$M_{\text{w}}$  = Initial weight of the seed, g

$M_{\text{D}}$  = Weight of the seed after drying to constant weight, g

### **2.3 Dimensions, size, degree of sphericity and surface area**

In determining the average size of the seed, the methodology described by Koocheki et al. (2007) was adopted. From the bulk of the experimental samples, ten sub-samples, each weighing 0.5 kg, were randomly drawn. From each of the ten sub-samples, 10 seeds were picked and thus 100 seeds were obtained. Measurements of the three major perpendicular

dimensions, namely length (L, mm), width (W, mm) and thickness (T, mm), were carried out using a SKOLE digital Vernier calliper, measuring to accuracy of 0.001 mm. The length (major diameter) was the highest dimension of the biggest surface of the seed. The thickness (minor diameter) was the shortest dimension of the smallest surface of the seed, and the width (intermediate diameter) was the shortest dimension of the biggest surface of the seed (Milani et al., 2007).

The arithmetic mean diameter ( $D_a$ , mm) and the geometric mean diameter ( $D_g$ , mm) of the seed were calculated using the following relationships, respectively (Mohsenin, 1978):

$$D_a = \frac{L+W+T}{3} \quad (2)$$

$$D_g = (LWT)^{1/3} \quad (3)$$

The degree of sphericity ( $\phi$ ) of the watermelon seed which measures the tendency of the seeds to roll over each other was obtained using the formula given by Mohsenin (1978) and Jain and Ball (1997) as follows:

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (4)$$

The surface area (S, mm<sup>2</sup>) of seeds was calculated using the following equation (McCabe et al., 1986):

$$S = \pi D_g^2 \quad (5)$$

#### **2.4 Thousand seed weight (TSW)**

An electronic digital balance (Model - SHIMADZU BZ 32 OH, Japan) with accuracy of 0.001 g was used to determine the one thousand (1000) seed weight, by samples size of 250 seeds randomly selected, weighed and multiplied by four (Sharma et al., 1985; Vilche et al., 2003).

#### **2.5 True density, bulk density and porosity**

True density ( $\rho_t$ ) – defined as the ratio of the mass to volume of particles – was determined using the water displacement method (Tabatabaeefar, 2003; Milani et al., 2007). In order to measure the bulk density, a container with known mass and volume was filled with the watermelon seeds to the top. The seeds were poured into the container in excess and at a

constant rate from a height of about 150 mm (Koocheki et al., 2007; Singh and Goswami, 1996). Dropping the seeds from a height of about 150 mm produces a tapping effect in the container to reproduce the settling effect during storage (Razavi et al., 2007a). After filling the container, excess seeds were removed by passing a flat stick across the top surface in zigzag motions and the container weighed. The bulk density ( $\rho_b$ ) was calculated from the ratio of the mass of the seeds in the container to its volume. The porosity ( $\varepsilon$ ) of the watermelon seed was computed from the values of the true and bulk densities using the relationship given by Mohsenin (1978) as follows:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) 100 \quad (6)$$

## **2.6 Angles of repose**

The filling angle of repose is the angle with the horizontal at which the material will stand when piled (Milani et al., 2007). This was determined using a topless and bottomless cylinder of 15 cm diameter and 50 cm height as was used in Koocheki et al. (2007). The cylinder was placed at the centre of a raised circular plate having a diameter of 35 cm and was filled with seeds. The cylinder was raised slowly until it forms a cone on the circular plate. The height of the cone was measured and the filling angle of repose ( $\theta_f$ ) calculated using the following equation (Razavi et al., 2007b):

$$\theta_f = \text{Arc tan}(2H/D) \quad (7)$$

Where: H is the height of the cone and D is the diameter of the cone.

To determine the funnelling angle of repose, a fiberglass box of 20×20×20 cm, having a removable front panel was used. The box was filled with the sample, and then the front panel quickly removed allowing the seeds to follow and assume a natural slope (Joshi et al., 1993). The funnelling angle of repose ( $\theta_e$ ) was calculated from the measurement of the depth of the free surface of the sample (H), and the corresponding horizontal distance of the slope (X), using the following equation (Paksoy and Aydin, 2004):

$$\theta_e = \text{Arc tan}(2H/X) \quad (8)$$

## **2.7 Static coefficient of friction**

The static coefficient of friction for the watermelon seeds was determined on three smooth test surfaces, namely plywood, plastic and aluminium. A plastic cylinder of 12 cm diameter, 8 cm



height and 0.06cm thickness was placed on an adjustable tilting plate having the test surface firmly placed on it. The plastic cylinder was filled with seed and raised slightly so as not to touch the surface (about 5 mm). The structural surface with the cylinder filled with the seed resting on it was inclined gradually, using a screw device until the cylinder just started to slide down (Obi and Offorha, 2015). The static friction angle ( $\alpha$ ) was read from a graduated scale and the tangent of this angle was recorded as the static coefficient of friction on that surface. For each replication, the sample in the container was emptied and refilled with a new sample (Joshi et al., 1993; Olajide et al., 2000). The static coefficient of friction ( $\mu_s$ ) was calculated using the following equation:

$$\mu_s = \tan \alpha \quad (9)$$

## **2.8 Statistical analysis**

All the properties of the varieties of the watermelon seed investigated were measured at the initial moisture level, with four replications for each of the properties and the mean values were reported. The properties of the three varieties were compared statistically at 5% level of significance to determine any significant difference among the varieties. Where significant differences were identified, the means were separated using Fisher's least significant difference at 5% significance level using GenStat analytical software.

## **3.0 RESULTS AND DISCUSSIONS**

### **3.1 Dimensions, size, degree of sphericity, surface area and TSW**

The mean values and the standard deviations recorded for the moisture content, axial dimensions, arithmetic and geometric diameters, degree of sphericity, surface area and the thousand seed weight (TSW) of three varieties of watermelon seed – Sugar baby, Kaolack and Charleston grey - are shown in Table 1. It was observed that Sugar baby had the lowest mean values followed by Kaolack and then Charleston grey for all the properties recorded in Table 1 except for the degree of sphericity. Charleston grey was observed to have the lowest degree of sphericity value of  $0.47 \pm 0.02$  compared to the mean value of  $0.55 \pm 0.03$  recorded for both Sugar baby and Kaolack. The mean value for length, L, recorded for the watermelon varieties were  $7.99 \pm 0.54$  mm,  $8.27 \pm 0.44$  mm and  $12.35 \pm 0.48$  mm for Sugar baby, Kaolack and Charleston grey, respectively. Sugar baby had a mean width and thickness of  $5.09 \pm 0.26$  and  $2.07 \pm 0.22$ , respectively, while Kaolack had a mean width and thickness of  $5.42 \pm 0.28$  mm and  $2.08 \pm 0.22$  mm, respectively. For Charleston grey, the mean values recorded for the width and

thickness were  $7.66 \pm 0.35$  mm and  $2.11 \pm 0.28$  mm, respectively. A mean surface area of  $107.21 \pm 10.33$  mm<sup>2</sup> was reported for Charleston grey while Sugar baby and Kaolack had mean values of  $60.34 \pm 5.87$  mm<sup>2</sup> and  $64.57 \pm 5.47$  mm<sup>2</sup>, respectively. The knowledge of the axial dimensions of seed or grains is important in the design of separation equipment.

**Table 1:** Mean values of some physical properties of three varieties of watermelon seed ( $\pm$ SD)

Seed properties	Watermelon seed varieties		
	Sugar baby	Kaolack	Charleston grey
Moisture content (w.b.), %	3.41a	3.29a	4.08b
Length, L, mm	$7.99 \pm 0.54a$	$8.27 \pm 0.44b$	$12.35 \pm 0.48c$
Width, W, mm	$5.09 \pm 0.26a$	$5.42 \pm 0.28b$	$7.66 \pm 0.35c$
Thickness, T, mm	$2.07 \pm 0.22a$	$2.08 \pm 0.22a$	$2.11 \pm 0.28a$
Arithmetic diameter, D <sub>a</sub> , mm	$5.05 \pm 0.22a$	$5.26 \pm 0.19b$	$7.37 \pm 0.21c$
Geometric diameter, D <sub>g</sub> , mm	$4.38 \pm 0.22a$	$4.53 \pm 0.20b$	$5.83 \pm 0.28c$
Degree of sphericity, $\phi$	$0.55 \pm 0.03a$	$0.55 \pm 0.03a$	$0.47 \pm 0.02b$
Surface area, S, mm <sup>2</sup>	$60.34 \pm 5.87a$	$64.57 \pm 5.47b$	$107.21 \pm 10.33c$
Thousand Seed Weight, TSW, g	$42.99 \pm 0.69a$	$51.12 \pm 1.11b$	$97.51 \pm 0.39c$

Mean values in the same row with different letters are significantly different at 5% significant level ( $P < 0.05$ ) using Fisher's Least Significant Difference (FLSD). Data recorded are mean values of 100 replicates except for TSW having 4 replicates. SD – Standard deviation

On statistical analysis of the data obtained for the physical properties of the Sugar baby, Kaolack and Charleston grey varieties of watermelon seeds shown in Table 1, it was observed that all the data obtained were significantly different from each other except for the thickness, T and degree of sphericity,  $\phi$ . The thickness, T, of the three varieties of the watermelon seeds were not significantly different from each other ( $P > 0.05$ ). While the degree of sphericity of

Sugar baby and Kaolack varieties were not significantly different from each other ( $P>0.05$ ), they were both statistically different ( $P<0.05$ ) from the mean value obtained for Charleston grey variety. The significant differences observed in the properties could be attributed to differences in the varieties of the seed.

### **3.2 True density, bulk density and porosity**

The mean values of the volume, true and bulk densities, and porosity for Sugar baby, Kaolack and Charleston grey varieties of the watermelon seed are shown in Table 2. The highest seed volume of  $133.33\pm 0.57 \text{ mm}^3$  was recorded for Charleston grey, followed by Kaolack,  $66.67\pm 0.67 \text{ mm}^3$ , and Sugar baby,  $33.33\pm 0.21 \text{ mm}^3$ . For the true density, Sugar baby had the highest mean value of  $1230.77\pm 1.89 \text{ kg/m}^3$  while Charleston grey had the lowest mean value of  $737.55\pm 1.44 \text{ kg/m}^3$ . The porosity recorded increased from  $28.57\pm 0.32 \%$  for Charleston grey to  $56.08\pm 0.36 \%$  for Sugar baby. The magnitude of porosity of seeds is greatly influenced by the true and bulk densities of the seed. The data shown in Table 3 were all observed to be statistically different ( $P<0.05$ ) except for the bulk density where the mean values recorded for Sugar baby and Kaolack were not significantly different from each other at 5 % level of significance but were both significantly different from the mean value recorded for Charleston grey variety. The significance in difference between the mean values recorded for the watermelon varieties investigated shows the importance of employing these data in the design of agro-processing equipment for these watermelon varieties. This suggests that a machine designed to handle a particular variety may not be effective for another variety.

**Table 2:** Mean values of volume, true and bulk densities, and porosity of three varieties of watermelon seed ( $\pm$ SD)

Seed properties	Watermelon seed varieties		
	Sugar baby	Kaolack	Charleston grey
Volume, $\text{mm}^3$	$33.33\pm 0.21\text{a}$	$66.67\pm 0.67\text{b}$	$133.33\pm 0.57\text{c}$
True density, $\text{kg/m}^3$	$1230.77\pm 1.89\text{a}$	$750.79\pm 0.80\text{b}$	$737.55\pm 1.44\text{c}$
Bulk density, $\text{kg/m}^3$	$540.53\pm 4.83\text{a}$	$536.32\pm 2.00\text{a}$	$454.76\pm 1.76\text{b}$
Porosity, %	$56.08\pm 0.36\text{a}$	$38.34\pm 0.28\text{b}$	$28.57\pm 0.32\text{c}$

Mean values in the same row with different letters are significantly different at 5% significant level ( $P < 0.05$ ) using Fisher's Least Significant Difference (FLSD). Data recorded are mean values of 4 replicates. SD – Standard deviation

### 3.3 Angles of repose and static coefficient of friction

Table 3 shows the mean values recorded for the filling and funnelling angles of repose as well as the static coefficient of friction on three material surfaces for Sugar baby, Kaolack and Charleston grey watermelon varieties. Charleston grey had the highest mean value for the filling and funnelling angles of repose which were  $26.33 \pm 0.60^\circ$  and  $33.70 \pm 1.44^\circ$ , respectively while Sugar baby had the lowest mean values of  $19.08 \pm 0.53^\circ$  and  $21.80 \pm 0.69^\circ$  for the filling and funnelling angles of repose, respectively. Differences in the filling angle of repose of seeds and grains are generally attributed to the degree of sphericity which determines the ease with which they slide and roll over on each other. Koocheki et al. (2007) reported that the filling angle of repose for Ghermez, Kolaleh and Sarakhsi, three varieties of watermelon seed at moisture content of 4.75, 5.02 and 4.55% w.b. were  $32.38^\circ$ ,  $27.09^\circ$  and  $30.57^\circ$ , respectively. These values were higher than that recorded for Sugar baby, Koalack and Charleston grey. The funnelling angle of repose for the watermelon varieties studied by Koocheki et al. (2007) at 4.75, 5.02 and 4.55% w.b. moisture content were reported to 28.15, 21.66 and 26.12 for Ghermez, Kolaleh and Sarakhsi, respectively. The mean value reported for Charleston grey was higher than that reported for those varieties. As noted by Koocheki et al. (2007), low angle of repose makes the seeds spread out wider on a plane surface compared to high angle of repose. Low angle of repose is often desirable when conveying the seed, while high angle of repose is more desirable when unloading onto a horizontal platform. The filling angle of repose for the varieties investigated in this study were different from those obtained by Razavi and Milani (2006) and Koocheki et al. (2007) for the seed varieties cultivated in Iran. However, the funnelling angle of repose determined for Sugar baby in this study and that of Kolaleh variety appeared to be equal.

**Table 3:** Mean values of the angles of repose and static coefficient of friction for three varieties of watermelon seeds ( $\pm$ SD)

Seed properties		Watermelon seed varieties		
		Sugar baby	Kaolack	Charleston grey
Angle of repose, °	Filling	19.08±0.53a	21.38±0.44b	26.33±0.60c
	Funnelling	21.80±0.69a	23.12±1.28b	33.70±1.44c
	Plywood	0.34±0.02a	0.42±0.02b	0.45±0.02c
	Plastic	0.31±0.02a	0.26±0.01b	0.26±0.02b

<b>Static coefficient of friction</b>	Aluminium	0.38±0.01a	0.39±0.01a	0.30±0.02b
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Mean values in the same row with different letters are significantly different at 5% significant level ( $p < 0.05$ ) using Fisher's Least Significant Difference (FLSD). Data recorded are mean values of 4 replicates. SD – Standard deviation

In the determination of the static coefficient of friction on plywood, plastic and aluminium surfaces, Sugar baby had the highest coefficient of  $0.38 \pm 0.01$  on aluminium surface while plastic gave the lowest coefficient of  $0.31 \pm 0.02$  for the same variety (Table 3). However, for Kaolack and Charleston grey, plywood surface gave the highest coefficient of static friction of  $0.42 \pm 0.02$  and  $0.45 \pm 0.02$ , respectively, while plastic gave the lowest as it was for Sugar baby variety. Razavi and Milani (2006), investigated the frictional coefficient of watermelon seed on the material surfaces of plywood, glass, fibre glass, rubber and galvanized sheet metal, and reported that rubber surface gave the highest coefficients of friction while glass gave the lowest static coefficient of friction. Koocheki et al. (2007) however reported that plywood showed the highest friction coefficient for three varieties of watermelon seed, followed by galvanized iron sheet, fibre glass, and then glass. The static coefficient of friction for squash seeds as was reported by Paksoy & Aydin (2004) ranged from 0.18 to 0.64 over the surfaces of different material while that of Karingda seeds ranged from 0.34 to 0.91 for plywood surface, 0.29 to 0.80 for mild steel and 0.23 to 0.67 for galvanized iron (Suthar & Das, 1996). The variation in the static coefficient of friction for the seed varieties on different surface could be attributed to the interaction of surface roughness of both the seed and the material surfaces.

Statistically, the mean static coefficient of friction on plastic surface for Kaolack and Charleston grey varieties were both statistically the same ( $p > 0.05$ ) but significantly different from the value recorded for Sugar baby (Table 3). Also, on aluminium surface, the mean value recorded for Sugar baby and Kaolack were not significantly different ( $p > 0.05$ ) but were significantly different from the mean value recorded for Charleston grey ( $p < 0.05$ ).

#### 4.0 CONCLUSIONS

In this study, some physical properties of three common varieties of watermelon seed cultivated in Nigeria, namely, Sugar baby, Kaolack and Charleston grey were investigated. The properties

studied include the axial dimensions, volume, degree of sphericity, surface area, thousand seed weight, true and bulk densities, porosity, angles of repose and the static coefficient of friction. It was evidenced that the physical properties of the watermelon seed varieties varied from one variety to another. Charleston grey variety had the highest mean value among the three varieties investigated for the axial dimensions, arithmetic and geometric diameters, surface area, thousand seed weight, volume, angles of repose and the static coefficient of friction on plywood. Generally, the mean values recorded for Charleston grey were highest followed by Kaolack and then Sugar baby. These values were significantly different from each other ( $p < 0.05$ ) except for the thickness, degree of sphericity, bulk density and the static coefficient of friction on plastic and aluminium surfaces. The significant differences in the mean values obtained in this study shows the importance of the use of scientific data in the design of agro-processing equipment for watermelon varieties for handling, storage, separation, conveying, drying, etc.

## **REFERENCES**

- Jain, R.K. and Ball, S., 1997. Physical properties of Pearl millet, *J Agric Eng Res*, 66, pp. 85-91.
- Joshi, D.C., Das, S.K. and Mukherjee, R.K., 1993. Physical properties of pumpkin seeds, *J Agric Eng Res.*, 54(3), pp. 219-229.
- Karayel, D., Barut, Z.B. and Ozmerzi, A., 2004. Mathematical modelling of vacuum pressure on a precision seeder, *Biosystems Eng*, 87, pp. 437-444.
- Koocheki, A., Razavi, S.M.A., Milani, E., Moghadam, T.M., Abedini, M., Alamatyian, S. and Izadkhah, S., 2007. Physical properties of watermelon seed as a function of moisture content and variety, *Int Agrophysics*, 21, pp. 349-359.
- Milani, E., Seyed, M., Razavi, A., Koocheki, A., Nikzadeh, V., Vahedi, N., MoeinFard, M. and GholamhosseinPour A., 2007. Moisture dependent physical properties of cucurbit seeds, *Int. Agrophysics*, 21, pp. 157-168.
- McCabe, W.L., Smith, J.C. and Harriott, P., 1986. *Unit Operations of Chemical Engineering*. New York, McGraw-Hill.
- Mohsenin, N.N., 1978. *Physical Properties of Plant and Animal Materials*. Gordon and Breach Sci. Publ., New York.
- Olajide, J.O., Ade-Omowaye, B.I.O. and Otunola, E.T., 2000. Some physical properties of shea kernel, *J. Agric. Eng. Res.*, 76, pp. 419-421.
- Paksoy, M. and Aydin C., 2004. Some physical properties of edible squash seeds, *J. Food Eng.*, 65(2), pp. 225-231.
- Perkins-Veazie, P. and Collins, J.K. 2004. Flesh quality and lycopene stability of fresh-cut watermelon, *Postharvest Biol. Technol.*, 31, pp. 159-166.

- Razavi, S.M.A., Mohammad, A.A., Rafe, A. and Emadzadeh, B., 2007a. The physical properties of pistachio nut and its kernel as a function of moisture content and variety: Part III. Frictional properties, *J. Food Eng.*, 81(1), pp. 226-235.
- Razavi S.M.A., Rafe A., Mohammad Amini A., and Mohammadi, M.T., 2007b. The physical properties of pistachio nut and its kernel as a function of moisture content and variety. Part II. Gravimetric properties, *J. Food Eng.*, 81(1), pp. 218-225.
- Razavi, S.M.A. and Milani E., 2006. Some physical properties of the watermelon seeds, *African J. Agric. Res.*, 1, pp. 65-69.
- Samuelsson, R., Burvall, J. and Jirjis, R., 2006. Comparison of different methods for the determination of moisture content in biomass, *Biomass and Bioenergy*, 30(11), pp 929-934.
- Sharma, S.K., Dubey, R.K. and Teckhandani, C.K., 1985. Engineering properties of black gram, soyabean and green gram, *Proc. Indian Soc. Agric. Eng.*, 3, pp. 181-185.
- Singh, K.K. and Goswami, T.K., 1996. Physical properties of cumin seed, *J. Agric. Eng. Res.*, 64, pp. 93-98.
- Suthar, S.H. and Das, S.K., 1996. Some physical properties of Karingda [*citrullus lanatus* thumb Mansf] seeds, *J. Agric. Engr. Res.*, 65(1), pp. 15-22.
- Tabatabaeefar, A., 2003. Moisture-dependent physical properties of wheat. *Int. Agrophysics*, 17, pp. 207-211.
- Vilche, C., Gely, M. and Santall, E., 2003. Physical properties of quinoa seeds. *Biosystems Eng.*, 86, pp. 59-65.

## **EFFECTS OF PALM OIL POLLUTION ON THE SUBGRADE CALIFORNIA BEARING RATIO UNDER SOAKED CONDITION**

Adeyinka, S.M.<sup>1</sup>, Adeyinka, A.I.<sup>2</sup>, Adeyinka, C.O.<sup>3</sup> and Sobo, K.S.<sup>4</sup>

<sup>1</sup>Department of Building Technology, Ogun State Institute of Technology, Igbesa, Ogun State.

<sup>2</sup>Department of Architectural Technology, Olabisi Onabanjo University, Ago Iwoye, Ogun State

<sup>3</sup>Department of Building Technology, Bell's University of Technology, Otta, Ogun State.

<sup>4</sup>Department of Geology and Mineral Science, Kwara State University, Molete, Kwara State.

Correspondence Author E-mail: [mails.stephen@gmail.com](mailto:mails.stephen@gmail.com) Phone No: +2348033033420

### **ABSTRACT**

The results of rapid economy growth are causing increasing technical challenges than before for Civil Engineers and other building professionals in performing their professional duties. Agricultural products as important it is to human existence has also been causing problem to the human environment as a result of pollution of the surrounding soils. The effects of palm oil pollution on the soaked California Bearing Ratio (CBR) of subgrade was investigated. The following objectives were set out in accordance with BS 1377 (2000); Particle Size Distribution, Atterberg Limits, Compaction and soaked CBR for palm oil contaminated and uncontaminated subgrade. Palm oil and subgrade soil are used in this research work, the subgrade soil was taken from a borrow pit in Ilaro, Ogun State. The air-dried samples were mixed with palm oil at a range of 0% to 10% of the dry weight of the subgrade soil for 7 days thereafter air dried for another 7 days. Laboratory experiment on the control (0%) and palm oil contaminated subgrade samples were conducted after 24 hours of soaking the samples in accordance with BS 1377 (2000). The soaked CBR result shows a decline in the CBR values when compared with the Un-soaked CBR results and also falls below the recommended standard. The soaked CBR values obtained ranges from 17.45% (EL1) to 49.50% (EL3). It is therefore concluded that palm oil has negative effect on the geotechnical properties and the mechanical strength of the soil hence it is not suitable in any Civil Engineering work.

**Keywords:** Palm Oil, Subgrade, California Bearing Ratio, Compaction, Contaminant.



## **1.0 INTRODUCTION**

Liew (2009), stated that the result of rapid economy growth is causing increasing technical challenges than before for Civil Engineers in performing their professional duties. He further stated that much challenges are coming from uncertainties in the ground conditions, which are sometimes the product of mother of nature or man-made, and the ability to adopt timely effective measures to reduce the inherent geotechnical risks.

Palm fruit is one of the most commercial agricultural produce after cocoa, cashew, and vegetable fruits. As important agriculture is to the existence of man, it is also posing a great concern as is responsible for many of the environmental ills facing the world today (Hansen et al., 2001). Awotoye et al., (2011), opined that the use of agrochemicals such as chemical fertilizers and synthetic pesticides as not only helped in the increase in production of agricultural products but as also causes negative effects; these include eutrophication of fresh and marine waters, excessive nitrate leaching into ground water and the persistence of pesticides residues in food, soil and water.

## **AIM AND OBJECTIVES**

The aim of this research work is to evaluate the Geotechnical properties of Palm Oil impacted soil. To achieve the above aim, the objectives are to:

- (1) To determine the compaction characteristics (MDD & OMC) of the uncontaminated and contaminated soil samples.
- (2) To determine the strength (CBR) characteristics of the un-soaked uncontaminated and contaminated soil samples.
- (3) To evaluate the soaked CBR characteristics of the contaminated soil samples prepared at OMC condition for the soil samples.

## **2.0 MATERIALS AND METHOD**

The materials used in this research work are the soil samples and the Palm Oil. Four different soil samples are collected for use in this study. The soil samples are collected at different location in Ilaro, Ogun state, Nigeria. During the sample collection process at each location, the top soil was stripped off to about 1.5m below ground level and the required quantity of

undisturbed soil was collected into clean bags. A total of 6 bags amounting to 300kg each were collected from each location in order to perform the laboratory test.

The palm oil (PO) used for this study was purchased from a local market in Ilaro (New Market). It was obtained into a clean yellow gallon and covered tightly to prevent being contaminated by with particles. Representative samples were immediately taken (2 per sample) with a label known weight moisture content can and oven dried to determine the Natural Moisture Content (NMC) of each soil samples.

Each collected sample (of about 300kg) were spread on clean floor as shown in PLATE 3.1 to air dried the soil samples for a period of 7 days, thereafter the samples were divided into 6 equal portion (about 50kg) and labelled. A portion of the divided soil samples were set apart for the control test and analysis, while the remaining portion of each samples were contaminated with the Palm Oil once per day for a period of 5 days at different percentage of 2%, 4%, 6%, 8% and 10% respectively and thereafter air dried for 14 days before laboratory test were conducted on the contaminated soil samples as shown in plate 2.

### **3.0 RESULT AND DISCUSSION**

The summary of the results of the preliminary tests (grain size analysis, specific gravity and Atterberg limit tests) as well as the Engineering (strength) test (compaction and CBR test) are presented in Tables 3-5.

The result of the consistency limit of the uncontaminated and palm oil contaminated soil is presented in Tables 1-2. The results show that the liquid limit of the uncontaminated (0% PO) soil samples ranges from 14.85% at (EL1) to 45% at (EL4) thereafter decreases with increase in the percentage of PO content for the four samples. The Plasticity Index (PI) of the uncontaminated samples ranges from 18.43% (EL3) to 25.98% (EL2) while sample from EL1 is Non- Plastic (NP).



Plate 1: Air drying of soil samples



Plate 2: Soil Contamination with Palm Oil

Addition of varying percentage of PO content to the soil samples gives a general trend in all the samples, such that the liquid limit decreases with increase in the PO content. However, PO content above 4% in sample from EL1 gives no positive result as it become less workable. The results of the contaminated plasticity index (PI) give slight differences in their trend. Sample from EL1 retain its Non-Plastic nature with increase in PO percentage, while the addition of PO causes an initial increase above the control value in sample from EL2 and EL4 up to 4% PO content and 2% PO content in Sample from EL3.

The addition of PO above these percentages causes a micro-structural transformation of the soil, which lead to inter layer expansion within the clay minerals. The results also show that the palm oil might have exposed both the clay minerals of the soil and the adsorbed water bonded to the soil surface thus leading to decrease in liquid limit. This is in agreement with the works of Akinwunmi et al. (2014). Akinwunmi et al. (2014), on the effects of crude oil contamination on the index properties, strength and permeability of lateritic clay and Oluremi

et al., 2017, on the effects of compactive efforts on geotechnical properties of spent engine oil contaminated Laterites soil.

As the clay particles carry a net negative charge, it attracts cations from the environment. Palm Oil being an organic compound contains a large amount of hydrogen ions. The decrease in liquid limit values may be due to the presence of water around the charged clay particles getting replaced by non-polarized liquid oil. PO would thus make earlier contact with clay particles causing a removal of interaction between water and the clay particles.

For the Natural soil samples (0% PO), the specific gravity ranges from 2.37 for sample D to 2.73 for sample A, the result obtained for sample D fall below standard of 2.60-2.80 as specified for laterites used as subgrade soil by BS 1377 (2000) and recorded by Wright, P.H. (1986), while the results of the PO contaminated soil shows that the specific gravity decreases from 2.69 for sample A to 1.86 for sample D with increase in the PO percentage for all the soil samples.

Based on the obtained results, increasing the percentage of PO contaminant causes a significant decrease in the specific gravity values, this is due to the low density of the contaminant (PO), therefore the contaminant leads to a slight decrease in the percentage of fine particles causing the formation of soil clods. Mahdi et al., (2017) obtained similar results when the impact of fuel oil on cohesive soil was investigated.

Table 1: Summary of preliminary test results

<b>Particulars</b>	<b>SAMPLE A</b>	<b>SAMPLE B</b>	<b>SAMPLE C</b>	<b>SAMPLE D</b>
<b>USCS/</b>	SP	SP	SP	SP
<b>AASHTO</b>	A-3(0)	A-2-4(0)	A-2-6(0)	A-2-7(0)
<b>Liquid Limit (%)</b>	14.85	30	35	45
<b>Plasticity Limit (%)</b>	NP	25.98	18.43	24.04

<b>Plasticity Index (%)</b>	-	4.02	16.57	20.96
<b>Specific Gravity (g)</b>	2.72	2.58	2.57	2.37

Table 2: Summary of compaction test result

Particulars	SAMPLE A	SAMPLE B	SAMPLE C	SAMPLE D
<b>O.M.C (%)</b>	14	16.5	14.5	17
<b>M.D.D (g/cm<sup>3</sup>)</b>	1.82	1.56	1.98	1.52

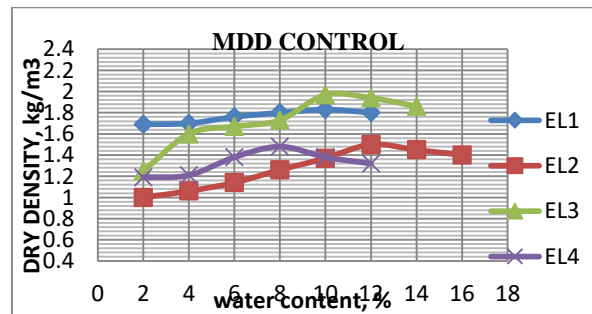


Figure 1: MDD Control

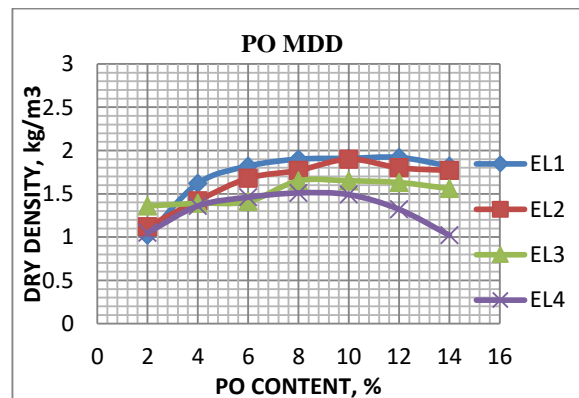


Figure 2: PO MDD

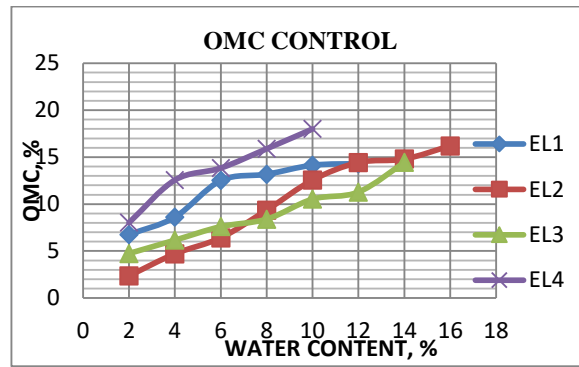


Figure 3: OMC Control

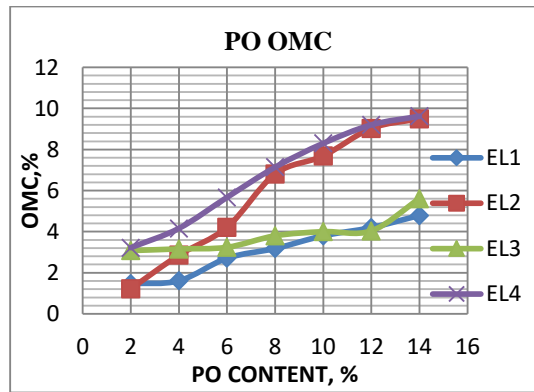


Figure 4: PO OMC

### California Bearing Ratio Test (Soaked)

The result shows that the CBR values decreases below the CBR value of the Un-soaked CBR values. The soaked CBR values obtained ranges from 17.45% (EL1) to 49.50% (EL3).

Table 3: CBR Result for Control Test

Soil Samples	CBR VALUE (%)
EL1	48.20
EL2	138.40
EL3	160.00
EL4	132.10

Table 4: CBR Result for un-soaked contaminated Soil

Soil Samples	CBR VALUE (%)
EL1	24.60
EL2	78.50
EL3	132.10
EL4	96.40

Table 5: CBR Result for Soaked Contaminated Soil

Soil Samples	CBR VALUE (%)
EL1	17.45
EL2	24.80
EL3	49.50
EL4	21.50

#### 4.0 CONCLUSION

Based on the preliminary investigations and various geotechnical tests conducted on the natural soil samples classified as SP and A-3, A-2-6, A-2-4 and A-2-7 soils according to USCS and AASHTO mode of soil classification respectively, the following conclusions were drawn;

- i- The natural soil samples have LL, PL, and PI ranging from 14.855-45%, 18.43%-25.98% and 4.02%-20.96% respectively. However, sample EL1 can be concluded to be NP. Increasing PO causes a decrease in the LL and PI values.
- ii- The MDD values decreases with increase in PO contents. However, a general trend was observed for the OMC such that with higher PO content the OMC decreases.

- iii- In the cases of the un-soaked CBR, decrease in CBR value with increase in PO content.
- iv- For the soaked CBR at OMC, the CBR value decreases for the contaminated soil at OMC.

## **RECOMMENDATION**

Based on the results of this present study, it is evident that the contamination of soil with PO causes a reduction in the bearing capacity of soil thus unsuitable for highway pavement design. Further study can be conducted under different compactive energy on PO contaminated soil so as to check CBR and MDD variation.

Similarly, addition of naturally available stabilizers such as jute fibres, etc can be added at different percentage to check its suitability on the geotechnical properties of soil.

## **REFERENCES**

Akinwunmi, I.I, Diwa, D. and Obianigwe, N. 2014. Effects of crude oil contamination on the Index properties, strength and permeability of lateritic clay. *International Journal of Applied Science and Engineering Research* 3.(4): 816-824.

Akinwunmi, I.I. 2014. Effects of waste engine oil contamination on the plasticity, strength and permeability of lateritic clay. *International Journal of Scientific and Technology Research* Vol. 3.(9): 331-335.

Awotoye, O.O, Dada, A.C. and Arawomo, G.A.O. 2011. Impact of Palm Oil processing effluent discharge on the quality of receiving soil and river in South Western Nigeria. *Jour. of Applied Sciences Research* vol.7.(2): 111-118.

Hansen, B. Alroe, H.F. and Kristensen, E.S. 2011. Approaches to assess the environmental impact of organic farming with particular regard to Denmark. *Agriculture, Ecosystem and Environment* 83.(12): 11-26.

Liew, S.S. 2009. Role of Geotechnical Engineer in Civil Engineering Works in Malaysia. CIE-IEM Joint Seminar on Geotechnical Engineering, 26-27 Aug., 2009. Yilan, Taiwan.



Mahdi, O.K. and Zainab, A.K. 2017. Investigating the impacts of Fuel oil on the Geotechnical Properties of Cohesive Soil. *Engr. Jour.* 21.(4):. 127-137.

Oluremi, J.R., Yohanna, P. and Akinola, S.O. 2017. Effects of compactive efforts on geotechnical properties of spent engine oil contaminated Laterite soil. *Journal of Engineering Science and Technology* vol. 12.(3): 596-607.

## **RAINFALL INTENSITY-DURATION-FREQUENCY MODELS FOR IBADAN USING OPTIMIZATION TECHNIQUE**

David, A.O.<sup>1\*</sup>, Nwaogazie, I.L.<sup>2</sup>, Opafole, O.T.<sup>1</sup>, Babalola, A.A.<sup>3</sup> and Lawal, N.S.<sup>3</sup>

<sup>1</sup>Department of Civil Engineering, Olabisi Onabanjo University, Ibofun campus, Ogun State, Nigeria.

<sup>2</sup>Department of Civil and Environmental Engineering, University of Port Harcourt, Rivers State, Nigeria.

<sup>3</sup>Department of Agricultural Engineering, Olabisi Onabanjo University, Ibofun campus, Ogun State, Nigeria.

\*Email of Corresponding Author: [adekunle.david@oouagoiwoye.edu.ng](mailto:adekunle.david@oouagoiwoye.edu.ng)

### **ABSTRACT**

The design of water resources engineering control structures is best achieved with adequate estimation of rainfall intensity over a particular catchment. Twenty-five (25) year Ibadan daily rainfall data (amount & duration) was collected from Nigerian Meteorological Agency (NIMET) Abuja and subjected to frequency analysis for the development of intensity – duration – frequency models. The annual maximum rainfall amounts with durations of 5, 10, 15, 20, 30, 45, 60, 90, 120, 180, 240, 300 and 420 minutes were extracted and subjected to frequency analysis using the Excel Optimization Solver wizard. Specific and general IDF models were developed for return periods of 2, 5, 10, 25, 50 and 100 years using the Gumbel Extreme Value Type 1 and Log Pearson Type 3 distributions. The Anderson Darling goodness of fit test was used to ascertain the best fit probability distribution. The  $R^2$  values range from 0.989 – 0.998 and the Mean Squared Error, MSE from 3.54 – 102.30 for the Gumbel and 0.978 – 0.989 with MSE of 6.09 – 213.10 for Log Pearson Type 3 distribution, respectively. The probability distribution models are recommended for the prediction of rainfall intensities for Ibadan metropolis.

Keywords: Excel Optimization Solver, Gumbel Extreme Value Type I, Goodness of fit test, IDF models, Log Pearson Type 3 distributions.

## **1.0 INTRODUCTION**

The adequate management of water resources in all river basins can be used as a tool to meet the United Nation's Sustainable Development Goals number one and two (Eradicate poverty and food security). The Rainfall Intensity Duration Frequency (IDF) relationship is one of the most commonly used tools for the design of hydraulic and water resources engineering control structures. An IDF model is a mathematical relationship between the rainfall intensity, duration and the frequency (return period). The establishment of such relationship was done as early as 1932 (Bernard, 1932). The knowledge of frequency of extreme events like floods, droughts, rainstorm and high winds assisted in planning and design for these extreme events (Hosking and Wallis, 1997). The planning and designing of various water resource projects require the use of rainfall intensity-duration-frequency (IDF) relationship (El-sayed, 2011). This relationship is determined through frequency analysis of data from meteorological stations. The IDF formulae are the empirical equations representing a relationship among maximum rainfall intensity (as dependent variable) and other parameters of interest such as rainfall duration and frequency (as independent variables). There are several commonly used functions found in the literature of hydrology applications (Chow et al., 1988). Owing to its wide applications, accurate estimation of intensity-duration-frequency relationship has received attention from researchers and scientists from all over the world (Mohammad, 2016). All functions have been widely applied in hydrology. In Nigeria, a lot of work has been done in South – East and South – South like the IDF models of Port Harcourt (Nwaogazie & Duru, 2002), Nwaogazie & Masi, 2019 and that of Eket in Awka Ibo State (Nwaogazie & Uba, 2001). All these models generated IDF curves confirm the theory for shorter recurrence periods of 2 to 10 years. Adequate knowledge of IDF helps in achieving a climate smart agricultural practice. Small-scale farmers face a series of challenges, to which climate change will be a risk-multiplier. They include poor natural resource management (especially of water and land), limited land tenure security, small farm sizes, low technological access, low market access and limited investment (Morton, 2007).

## **2.0 MATERIALS AND METHODS**

### **Study Area Description**

Ibadan is the capital of Oyo State in South – West Nigeria (about 128km inland northeast of Lagos and 530 km southwest of Abuja) covering an estimated metropolitan area of about 3,080 km<sup>2</sup>. It is located at 230m above the sea level and falls within latitude 7° 23' 47"N and longitudes 3° 55' 0"E. Ibadan lies completely within the tropical forest zone but close to the

boundary between the forest and the derived savannah. The area is properly drained by four rivers (Ona, Ogbere, Ogunpa and Kudeti Rivers) and it is characterized by relatively high temperature with mean annual temperature of 28°C and rainfall of 1,375 mm respectively. The study area is graphically illustrated in Figure 1.



Figure 1: Location map of Ibadan and adjoining cities in South-Western Nigeria

Source: Google map (2019)

### **Data Collection**

The twenty-five (25) year secondary rainfall data (amount and duration) covering 1986 to 2010 was sorted into various durations ranging from five (5) to four-twenty (420) minutes and ranked in ascending order before using it to compute the corresponding intensities used for model development.

### **Data Analysis**

The annual maximum data series are obtained by selecting the maximum amount of rainfall for each year for 5, 10, 15, 20, 30, 45, 60, 90, 120, 180, 240, 300, and 420 durations (minutes) for the 25-year period.

The IDF relation expressed by Chen, C.L. (1983) is mathematically expressed as follows:

$$I = f(T, d) \tag{1}$$

Where I = intensity; T = return period and d = duration.

The rainfall amount is converted to intensity (mm/hr) by dividing the amount by the duration (minutes) then multiplying by 60 as a conversion factor. For instance, given rainfall amount of 36.6mm for 10-minute duration yields an intensity of  $(36.6/10) \times 60 = 219.6$  mm/hr

Table 1 shows all the intensities for various durations.

Table 1: Ranked Observed Annual Rainfall Intensities (mm/hr) for different Durations (minutes) for Ibadan.

Year	Rainfall intensity (mm/hr)												
	5	10	15	20	30	45	60	90	120	180	240	300	420
1	333.3	219.6	170.8	143.1	108.4	84.0	69.5	50.7	40.1	30.6	26.8	24.4	26.2
2	274.8	209.9	160.2	133.8	106.2	79.5	69.4	48.9	40.0	30.1	25.2	21.7	17.4
3	258.0	205.2	159.2	132.3	104.4	77.5	66.9	48.5	39.6	26.6	23.0	21.4	17.4
4	221.7	180.6	149.2	128.1	100.9	77.0	66.2	48.3	39.3	26.4	22.6	18.4	16.6
5	219.6	153.0	136.8	119.4	89.2	76.1	65.4	47.9	38.1	26.2	20.0	18.1	15.5
6	211.7	139.7	120.4	111.9	85.4	72.3	63.6	46.3	36.7	25.7	19.8	16.0	13.4
7	197.0	133.4	106.6	105.0	83.0	70.8	63.0	46.3	36.2	25.4	19.6	15.8	13.1
8	183.6	129.0	104.4	102.6	79.6	70.0	58.1	44.9	36.0	24.4	19.3	15.7	12.9
9	180.0	124.1	101.8	90.3	74.6	69.6	57.8	44.1	34.8	24.1	19.0	15.4	12.0
10	171.0	120.6	94.7	88.0	68.4	55.3	53.1	43.6	34.7	24.0	18.3	15.2	11.7
11	166.8	107.7	86.0	84.0	67.1	53.1	52.5	42.7	33.7	23.2	18.1	14.8	11.6
12	164.4	105.1	82.2	78.2	64.1	51.2	52.2	42.0	33.1	23.1	18.0	14.7	11.4
13	164.1	103.4	80.4	67.9	60.8	49.7	42.3	38.7	32.7	22.4	17.4	14.5	11.3
14	152.1	95.8	80.2	66.2	60.4	48.9	41.5	38.5	32.1	22.1	17.4	14.5	11.3
15	148.8	93.8	78.9	65.1	59.7	45.5	40.4	35.4	31.5	21.8	16.8	14.4	11.2
16	145.2	91.5	73.1	64.5	51.8	40.5	39.8	34.8	29.1	21.1	16.8	13.9	11.0
17	143.9	90.7	71.5	60.4	50.5	40.3	37.6	32.3	29.1	20.3	16.6	13.9	10.9
18	143.2	90.2	69.8	60.3	49.7	39.5	37.3	30.8	28.9	19.4	16.0	13.8	10.6
19	142.6	90.0	69.2	59.1	46.1	38.6	32.6	28.7	27.5	19.4	15.8	13.6	10.5
20	138.3	89.9	68.8	57.6	45.1	37.9	32.4	27.7	26.6	19.3	14.9	12.9	10.3
21	134.3	87.1	68.6	57.1	44.0	35.2	31.8	26.5	26.1	18.3	14.5	12.6	10.3
22	133.2	84.6	67.6	56.8	43.6	34.4	31.3	24.9	25.7	18.1	14.5	11.6	10.3
23	131.6	83.9	66.5	56.6	43.4	33.6	30.2	24.9	25.4	17.4	13.8	11.6	9.9
24	130.7	82.9	64.6	54.9	43.2	33.3	29.0	24.3	23.7	17.1	13.1	11.2	9.7
25	126.1	82.3	64.0	53.3	41.9	33.1	28.4	23.9	20.6	15.7	12.9	11.0	9.0
Mean	176.6	119.8	95.8	83.9	66.9	53.9	47.7	37.8	32.0	22.5	18.0	15.2	12.6
Standard Deviation	51.8	42.5	34.0	29.5	22.2	17.6	14.6	9.2	5.6	3.9	3.6	3.3	3.7
Coefficient of Skewness	1.47	1.31	1.09	0.74	0.62	0.36	0.17	-0.24	-0.23	0.27	0.83	1.27	2.41

The magnitude of rainfall intensities was obtained using frequency analysis. Two probability distributions namely:

Gumbel Extreme Value Type I (GEVT-1) and Log-Pearson Type III were used to obtain the magnitude of rainfall intensities for different return periods.

**Gumbel’s Extreme Value Type I (GEVT- 1) Distribution**

Gumbel distribution is one commonly used probability distribution for obtaining the rainfall intensity values. The rainfall intensity values were obtained using Equation (2)

$$X_T = \bar{X} + K_T S \tag{2}$$

Where  $X_T$  = rainfall intensity values (magnitude of hydrologic event)

The resulting Gumbel  $K_T$  values for different return periods as calculated are shown in Table 2.

Table 2: Gumbel frequency factor for Ibadan IDF modelling

Return Period	2	5	10	25	50	100
$K_T$ values	0.1642	-1.1696	-1.3043	-2.044	-2.592	-3.156

**Calibration of Sherman (1932) IDF model**

Sherman’s (1931) IDF model is given as

$$I = \frac{cT_r^m}{T_d^a} \tag{4}$$

Equation (4) is non-linear power law that was calibrated for c, m and a (parameters using intensity, duration and return period values in Table 1 and Excel Optimization Solver)

**Goodness of fit test**

The result in Table 1 was subjected to Anderson-Darling test to ascertain the probability distribution that best fit the rainfall annual maximum amount. This is a nonparametric test of the equality of continuous, one dimensional probability distributions that can be used to compare a sample with a reference probability distribution. GEVT-1 and Log-Pearson Type 3 (LPT-3) best fit the rainfall intensities with significant values of 0.757 and 0.754 at 5% confidence level respectively.

### 3.0 RESULTS

The Anderson-Darling test shows that GEVT-1 and log Pearson Type III best fit the rainfall annual maximum amounts as shown in Table 3

The rainfall intensity values are computed by applying Equation (1). Rainfall intensity using GEVT-1 distribution with the mean and standard deviation are obtained from Table 1 For a 10-minute duration and 5 years return period, the probability equivalent of rainfall intensity via GEVT-1 is  $X_T = \bar{X} + K_T S \Rightarrow X_T = 119.75 + (-0.719 \times 42.54) \Rightarrow X_T = 150.34 \text{mm/hr}$

#### **Calibration of Sherman's IDF models for specific Return periods**

The calibrated Sherman equation (David, *et al*, 2019<sub>a</sub>) IDF models for specified return periods are as presented in Table 3. Equally included in the table are coefficients of determination  $R^2$  and mean square error (MSE) for model performance assessment.

Table 3: GEVT-1 calibrated IDF Models for different return periods for Ibadan.

<b>Return Period</b>	<b>IDF Model</b> ±	<b>Coefficient of Determination (R<sup>2</sup>)</b>	<b>Mean Squared Error (MSE)</b>
2	$I = \frac{4.762T_r^{6.416}}{T_d^{0.551}}$	0.998	3.54
5	$I = \frac{2.153T_r^{3.421}}{T_d^{0.552}}$	0.996	10.88
10	$I = \frac{1.642T_r^{2.571}}{T_d^{0.552}}$	0.995	23.43
25	$I = \frac{1.289T_r^{1.962}}{T_d^{0.554}}$	0.992	48.03
50	$I = \frac{1.167T_r^{1.666}}{T_d^{0.554}}$	0.990	72.60
100	$I = \frac{1.098T_r^{1.448}}{T_d^{0.555}}$	0.989	102.30

± return period specific IDF models

### Evaluation of iterative Equation Solver in Excel

Excel Solver model parameters trial solution for return period (50 year) specific IDF model has eleven (11) iterations before convergence (see Table 4). Similarly, there are twenty-eight (28) iterations in the development of the general IDF model given in Equation (7).



Table 4: Trial solution result for Sherman’s specific IDF model calibration

Iteration	C	m	A
1	1	1	1
2	1.1534	1.6	0.6733
3	1.1718	1.6833	0.6221
4	1.1624	1.656	0.5715
5	1.1441	1.6603	0.5719
6	1.1509	1.6855	0.5794
7	1.1509	1.6881	0.5835
8	1.1509	1.6882	0.5835
9	1.1509	1.6882	0.5835
10	1.1509	1.6882	0.5835
11	1.1509	1.6882	0.5835

The coefficient of determination is computed from Equation (5) and Table 5

$$R^2 = \frac{(\sum_{i=1}^n (y - y_{avg})^2) - \sum_{i=1}^n (y - y_{pred})^2}{\sum_{i=1}^n (y - y_{avg})^2} \quad (5)$$

$$R^2 = \frac{24974.16 - 45.975}{24974.16} = 0.998$$

Calculating the Mean Square Error (MSE) using Equation (6) we have;

$$MSE = \frac{\sum_{i=1}^n (y - y_{pred})^2}{n} \quad (6)$$

$$MSE = \frac{45.975}{13} = 3.54$$

A general IDF model was also developed. A total of 13 durations multiplied by 6 return periods yields 78 input data point. The entire input data were taken from Table 1.

The general IDF model was developed using Excel Optimization Solver. The least squares equations were programmed accordingly.

$$I = \frac{394.69T_r^{0.175}}{T_d^{0.554}} \quad (7)$$

Coefficient of determinant ( $R^2$ ) = 0.990; Mean Squared Error = 57.05 mm/hr

### Comparison of Observed and Predicted Rainfall Intensities

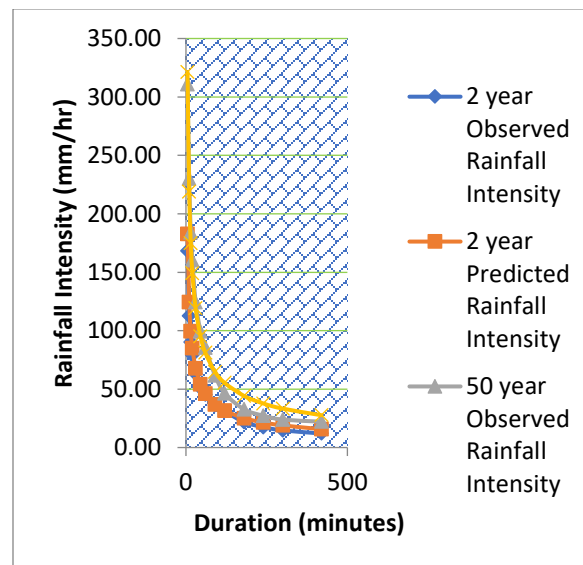


Figure 2: Observed rainfall intensity against predicted rainfall intensity for 2 and 50 year return periods for Gumbel Extreme Value Type I distribution for Ibadan.

This model enables one to predict the intensity of rainfall of any duration and any return period. The verification of the developed model is carried out by plotting the observed and predicted intensities on the same graph as shown in Figures 2.

### Comparison of Regression Approach and Excel Optimization Solver results for model parameters, $R^2$ and MSE

Table 6 (an extension of Table 5) clearly shows the result from Excel Optimization Solver option is more reliable than the normal regression method, the conventional simultaneous solution using matrix i.e. Gauss elimination, inverse or determinant approach.

Table 6: Results from regression approach and excel solver optimization approach (GEVT-1, 2-year return period)

Method	C	M	a	R <sup>2</sup>	MSE
Regression	64.20	3.42	0.695	0.887	13.83
Excel solver	4.762	6.416	0.551	0.998	3.54

#### **4.0 CONCLUSION**

The developed models for GEVT-1 and Log Pearson Type III are in agreement with PDF theory which shows higher intensity occurring at lower duration and lower intensity at higher duration. The prediction of rainfall intensity with the PDFs showed a good match with observed intensity values. The log Pearson Type III model ranked as the best with respect to MSE 6.09 and R<sup>2</sup> 0.997 in the return period specific model. The comparison of PDF and non-PDFs shows that the former has lesser MSE value than the later; 3.54 and 13.83 respectively.

#### **REFERENCES**

- Chen, C.L. (1983), "Rainfall intensity-duration –frequency formulas", journal of hydraulic Engineering. ASCE, 109(12), pp. 1603-1621.
- Chow, V.T. (1951), "Generalized Formula for Hydrologic Frequency Analysis", Trans. Am. Geophys. Union, Vol.32, pp.231 – 237
- Chow, V.T., Maidment, D.R and Mays, L.W. (1988), "Applied Hydrology" McGraw-Hill International Editions, New York, USA. 2. Hosking, J. R. M., and Wallis, J. R. (1997). Regional frequency analysis: an approach based on L-moments. Cambridge University Press, Cambridge, U.K.

Mohammad Z. (2016): “Application of Optimization Technique to Estimate IDF Parameters”, Water and Energy International,

Morton, J. 2007. The impact of climate change on smallholder and subsistence agricultural. Proceedings of the National Academy of Sciences of the United States of America, 104[50]: 19680 – 19685.

Nwaogazie, Ify L. and Duru, E. (2002): “Developing Rainfall Intensity-Frequency Model for Port Harcourt”. NSE Technical Transaction, Vol. 37, No. 2, pp. 19-32.

Nwaogazie, Ify L. and Masi, S.G. (2019): Probability and non-probability rainfall intensity – duration – frequency modelling for Port Harcourt metropolis, Nigeria. International Journal of Hydrology. 3(1): 66 – 75.

Nwaogazie, Ify L. and Uba, L. O. (2001). Urban Drainage Failures and Incidence of Flooding in Southern Nigeria. NSE Technical Transactions Vol 36 No. 3.

David, A. O., Nwaogazie, Ify L. and Agunwamba, J. C. (2019a). Modelling Rainfall Intensity by Optimization Technique in Abeokuta, South – West, Nigeria. Journal of Engineering Research and Reports. 6 (4): 1 – 10.

## **DEVELOPMENT OF AN INTELLIGENT BATTERY CHARGING SYSTEM BASED ON PIC16F877A MICROCONTROLLER**

Nwosu, E.U., Olalere, N.A., Shopade, G.N. and Ogbodo, J.I.

*Dept. of Industrial Maintenance Engineering, Yaba College of Technology, Yaba-Lagos.*

\*Email of Corresponding Author: [naolalere@yahoo.com](mailto:naolalere@yahoo.com)

### **ABSTRACT**

In this study, an intelligent battery charging system was developed to effectively charge batteries from 6-volt to 48-volt with automatic charging voltage selection. Major components of the system include AC-DC converter, buck converter, LCD module, voltage regulators, comparator circuit, sensors, feedback unit, and PIC microcontroller. The system senses terminal voltage of the battery to be charged and supplies the corresponding constant charging voltage by changing duty cycle of the PWM signal generated by the PIC16F877A microcontroller. The LCD was used for displaying parameters such as the initial voltage of the battery, as well as the charging current and voltage at any instant. Also displayed on the screen is the rise in battery voltage and temperature as charging progresses. The battery gets isolated immediately it is fully charged without human interference. The microcontroller also monitors and manages all the charging processes including the data displayed on the LCD screen. Circuitry were implemented to protect the battery from both overcharging and reverse current. Proteus software was used for the PCB design and simulation before commencement of the final construction. The developed model was subjected to tests under various charging conditions and the results were in accord with objectives of the research. A charging voltage of 56 volts was obtained, with a charging current of 9.8 amps when the system was used to charge four number of 12-volt, 100Ah fully discharged batteries connected in series.

**KEYWORDS:** Duty Cycle, Buck Converter, PWM Signal, Feedback.

### **1.0 INTRODUCTION**

Electric Vehicles (EVs) have been the present trend in automobile as a replacement for the internal combustion engine (Paridari et al., 2014). Thus, it is never too early to start preparing ahead of the possible challenges in implementation of this technology. Rechargeable (secondary) batteries are employed in EVs for storage of electrical energy in form of chemicals (Kularatna, 1998).

Sustenance of this source of energy for provision of motive power in the vehicles is of major concern. (Li, Han and Zhou, 2016). With the introduction of electric vehicles, our fuel stations will in no time be replaced by car charging stations. (Jia, et al., 2015). Batteries are expensive and a frequent replacement would become unaffordable by most motorists in developing countries. The resultant effect of this would be increase in the cost of transportation which will reflect on the cost of goods and services. Avoiding the dangers in pollution and global warming via the use of electric cars should not make so much negative impact on our economy (Chen Y., et al., 2014). This paper identifies poor battery charging system as the major cause of reduced cycle life as well as diminishing charge acceptance in batteries. It also presents a reliable, fast, and safe charging system as the most cost-effective means of preventing the need for frequent battery replacement. This is because the reliability and durability of rechargeable batteries depend largely on the performance and capability of the charging methodology employed (Abdollahi, et al. 2016).

This research is not restricted to electric vehicle charging only. In developing countries where access to twelve hours uninterrupted power supply is still a vision, the usage of inverters cannot be effective because the batteries rarely get fully charged before being subjected to full (if not extreme) discharge. Since the hours of power outage daily is often more than the hours for which power is usually available, a better alternative in such environment is to store as much energy as possible within the short period for which the public power supply is accessible. The stored energy can later be retrieved through the use of inverters if AC mains is required. Otherwise, it can be consumed directly using DC loads to avoid the usual losses associated with energy conversion. The property of getting more batteries charged within a short duration possessed by our developed model can be of great benefit in such situations.

### **1.1 Battery Charging Systems**

The advent of electric vehicles had made lithium-ion batteries more widely used. Consequently, various charging methods such constant-current (CC), constant-voltage (CV), constant-current constant-voltage (CCCV), and constant-trickle (CT) charging have been developed. There are numerous types of battery chargers but they all operate on similar basic principles. Fast-charge ability is one of the features that actually make a particular charging system different and better in performance than another (Ayoub and Karami, 2015). The purpose of fast charging is to put in as

much energy as it takes to bring a battery back to fully charged state within the shortest possible time without permanently affecting the long-term performance of the battery or causing any damage to it. An appropriately executed fast-charge, matched with the specifications of the battery rated for such charging, will deliver a long cycle life (Rutto, et al., 2014). Charge termination is another property of a good battery charging system whose relevance cannot be overemphasized (Shrestha, Chew, et al., 2007). When a battery is yet to be fully charged, the electrical energy of the charge current is transformed to chemical energy in the cells by the charging reactions. But, when all of the available active material has been transformed into stored charged, the energy present in the charging current then activates other unwanted chemical reactions, producing heat and gases from the cells (Kularatna, 1998). In a fast-charging system, the high charging rate involved causes rapid electrochemical reactions within the cells of the battery. Consequently, whenever the battery goes into overcharge, these reactions lead to a swift increase in temperature and pressure of the internal cells. Flooded lead-acid batteries do emit corrosive and explosive gases when experiencing overcharge (continued charging of a battery after it has become fully charged). The resultant effect of this is simply an irreversible battery damage (Lee, Moon, et al., 2011). To avert this damage, when a battery approaches full charge, the charging current is often reduced to a lower (top-off) level. Thus, charge termination is a unit of a fast-charge system for preventing the high-rate overcharge. The reliability of a battery charger depends on the method of charge termination put in place. (Xiong, Cao, et al., 2017). Temperature-Based and Voltage-Based charge termination methods are the two common practical approaches.

## **2.0 METHODOLOGY**

The intelligent battery charging system presented in this paper is a fast-charger designed to automatically sense battery terminal voltage in the range of 6-volt to 48-volt, supply the corresponding charging voltage, and terminate the charging process when a combination of temperature, voltage, and time shows that the battery is fully charged. The system is designed to prevent both undercharge and overcharge conditions. Human interference in operation of the system is absolutely minimized. This is not only to make charging of batteries more comfortable and speedier but also to eliminate human errors likely to occur in the process. The system monitors battery temperature, voltage, and time-under-charge to decide the ideal charging current at every

instant. Although, the output current of a battery charger generally depends on the capacity and state of discharge (SOD) of the battery. The maximum output current a charging system can offer is based on the rating of the charger itself. This factor determines the capacity of battery (or pack of batteries) the system can effectively charge within the shortest allowed duration.

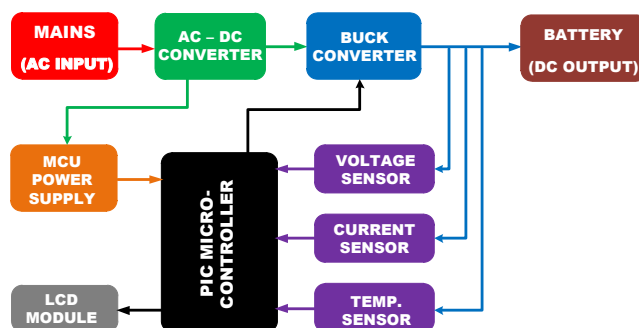
The developed model which has both hardware and software components contains a PIC16F877A microcontroller, a 16 x 2 LCD module and various circuitry divided into modules. These include the buck-converter, filter, charge controller, voltage-comparator, rectifier, regulator, feedback, sensing and switching circuitry. Each of the sensing circuits contains different types of sensors for voltage, current, and temperature. The switching circuits are basically made up of transistors and diodes.

In this research, the use of conventional power transformer was identified as a major source of energy loss in the traditional battery charger. Thus, a buck converter which is essentially a switch mode power supply (SMPS) was used as a replacement. LCD module was integrated into the system for displaying some essential parameters such as the initial battery voltage as well as the charging current and voltage at any instant. Also displayed by the module is temperature of the battery under charge and the instantaneous battery voltage as charging progresses. The microcontroller was used to run dedicated codes that control all the tasks involved in operation of the system including the data displayed by the LCD module. Before embarking on the actual constructions, computer simulations were carried-out to evaluate performance of the system and make required alterations.

## **2.1 System Overview**

The battery charging system is powered through a 220-volt, 50-hertz supply. When the system is connected to the mains via its power cord, the AC – DC converter produces a high frequency (i.e. 100Hz) pulsating dc voltage of minimal ripple content.





*Fig. 1: Simplified Block Diagram of the Battery Charging System*

This unregulated DC output voltage is fed to the buck converter and power supply of the microcontroller unit (MCU). The buck converter supplies an adjustable constant charging voltage to the battery (or pack of batteries) at its output.

The specific charging voltage to be made available at any instant is determined by the microcontroller in conjunction with some other circuitry not shown on the block diagram above, for the purpose of simplicity. The microcontroller was programmed to enable a charging voltage of 15-volt for a 12-volt battery, 30-volt for a 24-volt battery pack, 45-volt for a 36-volt battery pack and 60-volt for a 48-volt battery pack. However, magnitude of the charging voltage which is always constant at any instant depends on the terminal voltage of the battery to be charged sensed by the microcontroller.

A command to terminate the charging process at any moment is given by the microcontroller based on information available from the sensors. The MCU power supply produces a 5-volt regulated dc voltage to energize the microcontroller circuitry. The LCD helps to know status of the battery under-charge as well as performance parameters of the battery charging system itself. The components were interfaced with the microcontroller to create communication.

### ***1. AC-DC Converter***

This is basically a line rectifier and a capacitor. The line rectifier is a full wave bridge rectifier consisting of four number of 6A10 diode. This particular type of silicon rectifier was chosen in our design due to some of its unique characteristics. It can conveniently handle high voltage from

the mains without dissipating too much of heat. It has a maximum recurrent peak reverse voltage of 1000-volt, maximum average forward output current of 6-ampere, maximum forward voltage drop of 0.95-volt at 1.0A DC per element. 6A10 diodes possess a typical junction capacitance of 150 pico-farad. Also, their operating and storage temperature range is -65 to +175 °C.

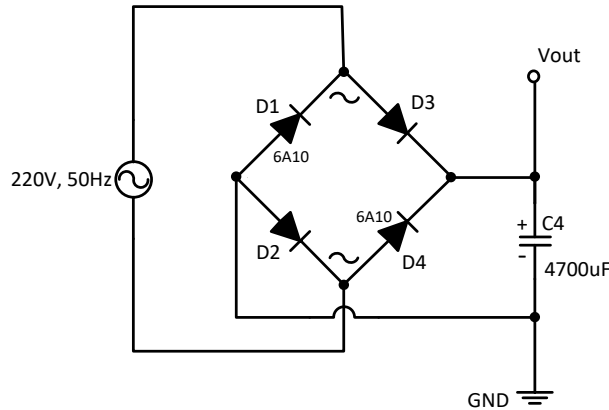


Fig. 2: AC-DC Converter Circuit

The rectifier converts the mains AC input voltage to a 100-hertz pulsating dc voltage.

The 4700 $\mu$ F electrolytic capacitor connected across the rectifier output serves as a filter capacitor. It smoothens the rectifier output for the least ripple content. The rectifier output voltage can be expressed as:

$$V_{out} = \frac{2V_p}{\pi}$$

But the peak voltage,  $V_p = \sqrt{2}V_{rms}$

Which implies that:  $V_{out} = \frac{2\sqrt{2}V_{rms}}{\pi}$

The root-mean-square voltage,  $V_{rms} = 220V$

$$\rightarrow V_{out} = \frac{2 \times \sqrt{2} \times 220}{\pi} = 198V$$

## 2. Buck Converter

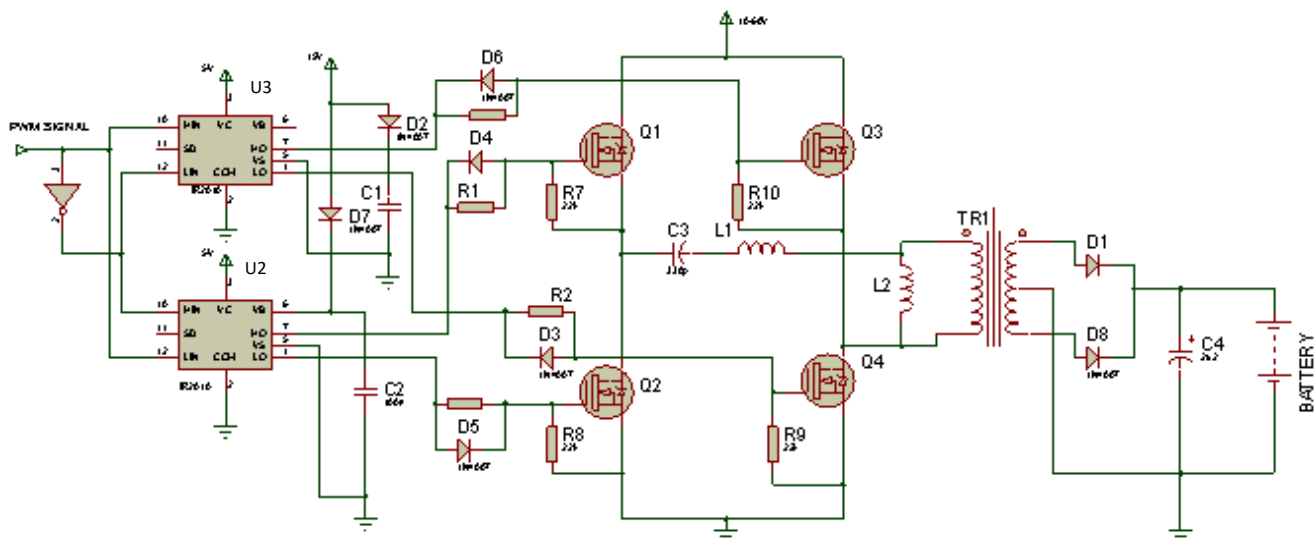
The buck converter actually serves the purpose of a step down **DC transformer**. **It is a DC-DC converter used to step down the DC output voltage of the AC-DC converter.** The **buck converter** can operate on a wide range of input voltages, it is capable of supplying multiple output voltages, it has the ability to regulate the multiple output voltages with a single control, and it uses fewer components compared to other types of switch mode power supplies. The choice of buck converter in our design was also due to its ability to handle high output currents and generate less radio frequency (RF) interference. In addition, **the buck converter has** higher efficiency and lower heat losses. **Pulse Width Modulation (PWM) technique was used** to control the DC voltage output ( $V_{out}$ ) of the buck converter which is essentially the charging voltage ( $V_C$ ) applied to the battery (Fig. 2). It can be analyzed that:

$$V_C = V_{out} = D \times V_{in}$$

Where:  $D$  = Duty cycle of pulse width modulation signal or square wave; and

$V_{in}$  = Input voltage of the buck converter.

The above expression indicates that the output voltage of the battery charger at any instant is directly related to duty cycle. Thus, the charging voltage can be varied by changing duty cycle of the square wave. The output voltage also depends on switching frequency of the switch. The  $V_{in}$  remains constant because it is determined by amplitude of the square wave. Major components of the buck converter include **a switch, a PWM driver circuit, a fly-back transformer, and a half wave rectifier.**



*Fig. 3: Circuit Diagram of the Buck Converter*

**a) The Switch**

This is one of the most important part of any DC-DC converter. The output voltage of the buck converter is actually being varied by controlling the turn-on and turn-off time of the switch. **MOSFET is the power switching device used in our buck converter and the** specific type selected for this work is IRFP22N50A due to its low on state resistance, high switch frequency and high-power handling competence (Fig. 3). These **transistors are** turned on and off by the pulse-width-modulation signal.

**b) The PWM Driver Circuit**

This is the MOSFET driver IC. It is used to control the duty cycle of a pulse width modulation signal which in turns determines the turn-on and turn-off time of the MOSFET. Two number of PWM driver ICs (IR2112) were used to drive the four n-channel power MOSFETs (Q1 to Q4) which are connected in a bridge configuration. The High and Low outputs (HO and LO) pins of  $U_2$  are connected to the gates of Q1 and Q2 respective such that  $U_2$  is only responsible for driving these two MOSFETs (Fig. 3). Also, the HO and LO pins of  $U_3$  are connected to the gates of Q3 and Q4 so that the second set of MOSFETs can be driven by the other driver IC. In other words, Q1 and Q2 are driven by  $U_2$ , while Q3 and Q4 are driven by  $U_3$ . The High Input (HI) pin of  $U_2$  was connected to the Low Input (LI) pin of  $U_3$ , while the LI pin of  $U_2$  is connected to the HI pin of  $U_3$ . Then, inputs to the two driver ICs were taken to pin 17 on port C of the PIC16F877A microcontroller via an inverter (NOT Gate). These connections are made to ensure only one MOSFET is conducting at a time in a pull-push pattern. Also,  $U_2$  and  $U_3$  which constitute a full bridge MOSFET driver also provide the required timing.

**c) The Fly-Back Transformer (FBT)**

This is known as a planar switching power transformer or a forward transformer. It can be visualized as an inductor with an extra winding (mutually coupled inductor) which stores energy when current passes through and releases the energy when power is removed. The primary winding of the fly-back transformer (TR1) is driven as a result of high-speed switching of the output DC voltage from the AC-DC converter. The input voltage of the transformer is converted into a magnetic field, whereas output voltage is generated by the periodically collapsing magnetic field. Fly-back transformers operate at frequencies ranging from 20 KHz to 200 KHz. Thus, they are

traditionally used to generate high voltage signals at a high frequency. The transformer polarity was reversed such that when the MOSFET is turned on, the primary inductance causes current flow in the primary winding. During this period, current does not flow in the secondary winding because the diode connected in series with it has been reverse biased. Without this diode being reverse biased, simultaneous current flow in the secondary winding would oppose the primary current ramp. Energy is therefore stored in the magnetic (ferrite) core until when the MOSFET is turned off. Then, current in the primary winding falls to zero and the stored energy is released to the secondary as the magnetic field in the core collapses. The released energy produces current that forward biases the diode which rectifies it to give a DC output.

#### **d) The Half-Wave Rectifier**

This rectifier was incorporated in order to get a regulated step-down voltage. It converts the pulse train coming from the fly-back transformer windings to direct current. A full-wave rectifier was not used because there are no corresponding pulses of opposite polarity. Schottky diode was used as the rectifier due to its fast reverse recovery time (switching time from turn on to turn off and vice versa) and low forward conduction losses. The capacitor connected across output of the rectifier (Fig.3) smoothens the rectified voltage for charging of batteries. A feedback circuit was implemented to monitor the output voltage using the operational amplifier LM358.

### **3. The LCD Module**

LM016L is a 14 pin, 16 x 2 LCD module utilized in our design. The reasons for choosing this particular type include the ease of programming it, its low power consumption, as well as its ability to display numbers, character, and graphics. The microcontroller communicates with the LCD module via its in-built HD44780 controller such that all the information to be displayed by the LCD are determined by the PIC 16F877A microcontroller. The in-built controller of the module was initialized before sending data to the LCD otherwise nothing would be displayed. Data was transferred using only 4 buses (D4-D7) while D0-D3 were not used. Using the entire 8 data buses (D0-D7) only becomes necessary when interface data is 8 bits long. The control lines of the LCD (RS and E) were connected to pins 38 and 39 (RB5 and RB6) of the microcontroller respectively, while the data buses of the LCD (D4 - D7) were connected to pins 34–37 (RB1–RB4) of the chip respectively. To power the LCD module, VSS, VDD and VEE were used as power pins. The

backlight pins were connected across a 1k $\Omega$  potentiometer and the output of the potentiometer was then connected to the VEE pin so that the LCD contrast can simply be adjusted by rotating the potentiometer knob forward and backward.

#### ***4. The Microcontroller***

This is the control unit that can be termed as heart of the entire system. PIC16F877A microcontroller is a four port, 40 pin PDIP (Plastic Dual Inline Package) used in the developed battery charging system. Thirty-three of its pins are available for input and output. Each of the pins can be used for both input (read data form devices) and output (send instruction to devices) as they are bi-directional. The microcontroller is also used for generating the PWM signal which is handled by its two CCP (capture compare PWM) modules. Its ability to generate variable duty cycle digital signals is of great benefit in this research. The PIC16F877A microcontroller was chosen because of its flash memory's multiple write-erase feature, support for up to eight analogue sensors, low cost and ease of handling. Programming of this controller was done in C language. Although, the official compiler developed by manufactures of PIC16F877A is MPLAB XC8, Mikro C was used to program it.



*Fig.4: Internal View of the Designed Model*

### **3.0 RESULTS AND DISCUSSION**

The entire hardware was assembled inside a covered PVC box as shown in Fig. 4. The battery charger was subjected to tests under various charging conditions and the results were in accord with objectives of the research. Equipment used for the tests include an oscilloscope, an ammeter, a voltmeter, and a timer. The oscilloscope was used to observe variations in duty cycle of the PWM signal which correspond to changes in charging voltage as the number of batteries connected in series is being varied. The ammeter and voltmeter were incorporated in order to measure the charging current and voltage respectively. This was necessary as a means of authenticating the values displayed by the LCD. A timer was used for taking readings at regular time intervals. Four number of 12-volt, 100Ah discharged batteries were used for the tests in the following order:

1. Charger connected across one battery (12-volt);
2. Charger connected across two batteries in series (24-volt);
3. Charger connected across three batteries in series (36-volt); and
4. Charger connected across four batteries in series (48-volt).

Each charging session lasted for six consecutive hours at approximately 28°C. Initial values of the voltages and currents were noted and subsequent values were recorded at half-hour intervals. A graph of charging current against time and that of battery terminal voltage against time were obtained.

#### **Test 1: (12-volt Battery Connected)**

Before Charging:     10.7v (voltmeter)  
                              11v (LCD)

Charging Voltage:    13.8v (voltmeter)  
                              13.3v (LCD)

Initial Charging Current: 8.5A (ammeter)  
                              7.8A (LCD)

Final Charging Current: 2.2A (ammeter)  
                              2.0A (LCD)

After Charging:     13.5v (voltmeter)

13.1v (LCD)

**Test 2: (24-volt Battery Connected)**

Before Charging: 20.9v (voltmeter)

21.3v (LCD)

Charging Voltage: 28.8v (voltmeter)

28.5v (LCD)

Initial Charging Current: 8.7A (ammeter)

8.0A (LCD)

Final Charging Current: 2.5A (ammeter)

2.1A (LCD)

After Charging: 13.2v (voltmeter)

12.9v (LCD)



*Fig.5: Laboratory Test Image*

**Test 3: (36-volt Battery Connected)**

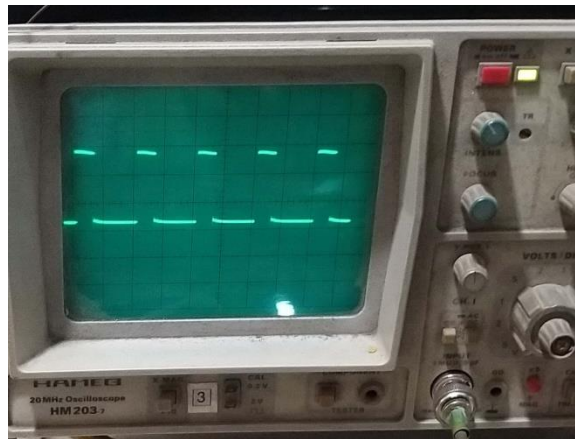
Before Charging: 32.4v (voltmeter)

32.9v (LCD)

Charging Voltage: 42.0v (voltmeter)



41.5v (LCD)  
Initial Charging Current: 9.1A (ammeter)  
8.8A (LCD)  
Final Charging Current: 2.7A (ammeter)  
2.3A (LCD)  
After Charging: 13.0v (voltmeter)  
12.8v (LCD)



*Fig. 6: Oscilloscope Display of Duty Cycle when charging a 24-volt Battery*

**Test 4: (48-volt Battery Connected)**

Before Charging: 42,9v (voltmeter)  
43v (LCD)  
Charging Voltage: 56.0v (voltmeter)  
56.2v (LCD)  
Initial Charging Current: 9.8A (ammeter)  
9.7A (LCD)  
Final Charging Current: 3.1A (ammeter)  
2.8A (LCD)  
After Charging: 13.5v (voltmeter)  
13.1v (LCD)

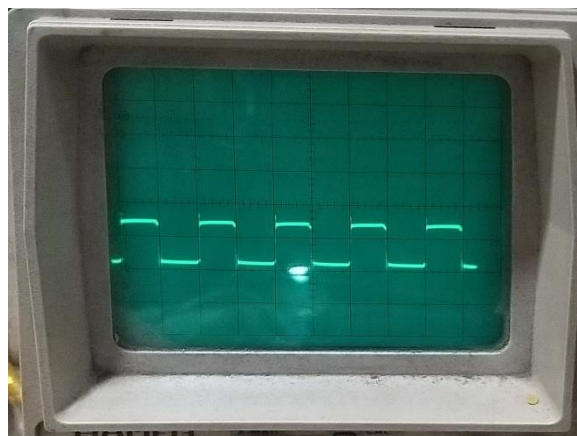


Fig.7: Oscilloscope Display of Duty Cycle when charging a 48-volt Battery

It was observed that the initial charging current is always high but depreciates with time. On the contrary, the initial battery voltage which is often low appreciates with time (Fig. 10). Following the trend, it is possible to reach a point where the charging current would be zero and the battery terminal voltage would no longer rise. Under such situation, the battery can be said to be fully charged and the charging process would be automatically terminated. Also, it was noted that the charging voltage for 24-volt battery was about twice that of a 12-volt battery. Likewise, the charging voltage for 48-volt battery was approximately twice that of 24-volt battery. As the charging voltage rises, duty cycle of the PWM signal increases correspondingly (Fig. 6 and 7) indicating that output of the buck converter is being varied through pulse width modulation technique. However, the charging voltage was constant throughout every charging session.

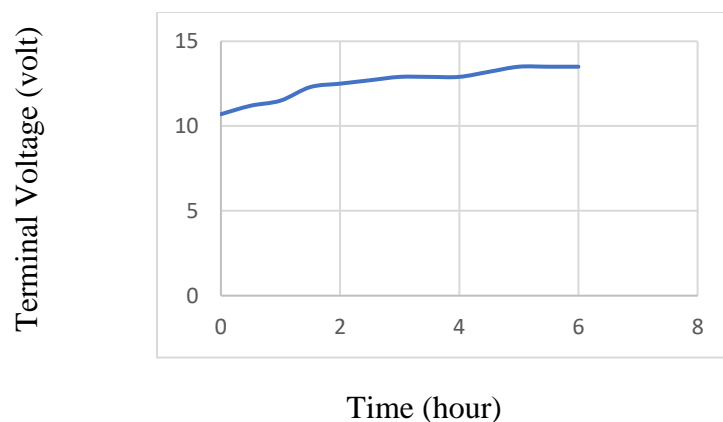


Fig. 8: A Graph of Battery Terminal Voltage against Time (Test 1)

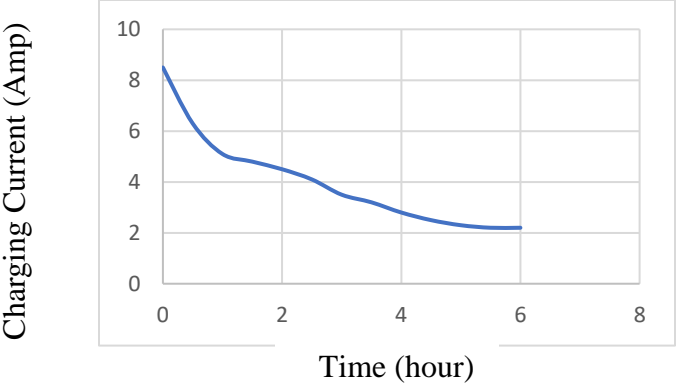


Fig. 9: A Graph of Charging Current against Time (Test 1)

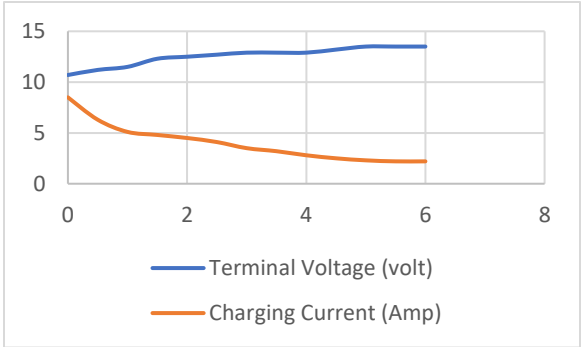


Fig. 10: A Graph of Battery Terminal Voltage and Charging Current against Time (Test 1)

#### 4.0 CONCLUSION

Battery chargers do not only replenish rechargeable batteries, they also preserve the battery life because wrong charging or handling can permanently damage even a brand-new battery. The consequences of exposing batteries to excessively high voltages while charging can be catastrophic in some cases. Likewise, charging of batteries using extremely low voltages can weaken and destroy the batteries. However, voltage selection error can occur when it is being done manually. This is just one of the major benefits of using an intelligent battery charging system. Replenishing batteries with the appropriate amount of charge will not only extend its use per charge, but will also increase the number of charge and discharge cycles during its entire working period. This means that the money frequently spent purchasing new batteries for replacement can be saved.

A critical challenge in usage of electric vehicles anchors on how to prevent long queues of vehicles at the charging stations. Every vehicle should get fully charged within the shortest possible duration. The cost of energy for charging of batteries is silent but very crucial. It is one of the elements that influence the price for vehicle charging. In order to make electric vehicle charging a lucrative business, the charging station should pay less for charging more vehicles. This implies that the battery charger must be energy efficient. This research was conducted to produce a reliable, fast, safe, and convenient charging system as the most cost-effective means of preventing the need for frequent battery replacement. Having attained our aim, the developed model is expected to enhance the usage of inverter in environment prone to long period power outage. It should reduce the cost of energy for charging of batteries. Also, it should address a major challenge in use of electric cars.

## **REFERENCES:**

Abdollahi, A., Han, X., et al., (2016). "Optimal Battery Charging, Part I: Minimizing Time-to-Charge, Energy Loss, and Temperature Rise For OCV-Resistance Battery Model". *Journal of Power Sources*, vol. 303; pp. 388–398.

Ankit Kumar Singh, et al., (2016) "An Improved Two-Stage Non-Isolated Converter for On-board Plug-in Hybrid EV Battery Charger". *IEEE International Conference on Power Electronics Intelligent Control and Energy Systems (ICPEICES)*, pp. 1-6.

Ayoub, E., and Karami, N. (2015). "Review on the Charging Techniques of a Lithium-Ion Battery". *Proceedings of the Third International Conference on Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE)*, Beirut, Lebanon; pp. 50–55.

Berndt, D. (1997) "*Maintenance-free Batteries: Lead-acid, Nickel-Cadmium, and Nickel-Metal Hydride*". Taunton Research Studies Press,

Chen, Y., Liu, Z., et al. (2014). "Review and Recent Advances in Battery Health Monitoring and Prognostics Technologies for Electric Vehicle Safety and Mobility". *Journal of Power Sources*, vol. 256; pp. 110–124.

Chia-Chun Tsai (2013). "A Reduced Li-Ion Battery Charger for Portable Applications". 9th International Conference on Natural Computation (ICNC); pp. 1718-1722.

Daniel Morogo Rutto (2015). "Battery Charger Efficiency and Voltage Behaviour in Vented Lead Acid Batteries in Kenya" International Journal of Sciences: Basic and Applied Research (IJSBAR).

Hua, A.C., and Syue, B.Z. (2010). "Charge and Discharge Characteristics of Lead-Acid Battery and LiFePO<sub>4</sub> Battery". Proceedings of 2010 International Power Electronics Conference (IPEC). Sapporo: IEEE, pp.1478–1483.

Jia, Y.Y., Vigna, K., et al., (2015). "A Review on State-of-the-Art Technologies of Electric Vehicle- its Impacts and Prospects", Renewable and Sustainable Energy Reviews, vol. 49, pp. 365.

Kularatna, Nihal (1998). "Power Electronics Design Handbook – Low Power Components and Applications" Newnes Boston, Oxford, Johannesburg, Melbourne, New Delhi, Singapore.

Lee, Y.S., Moon, J.S., et al., (2011). "Fast charging technique for EV battery charger using three-phase AC-DC boost converter," Proceedings of the 37th Annual Conference of the IEEE Industrial Electronics Society (IECON 2011), Melbourne, Australia. pp. 4577–4582.

Li J., Han Y., and Zhou S. (2016). "Advances in Battery Manufacturing, Services, and Management Systems". Hoboken: John Wiley-IEEE Press.

Paridari, K., Parisio, A., et al., (2014). "Energy and CO<sub>2</sub> Efficient Scheduling of Smart Appliances in Active Houses Equipped with Batteries," Proceedings of IEEE International Conference on Automation Science and Engineering, pp. 632-639.

Rutto, D., Okemwa, P., et al., (2014). "Influence of Charger-Type on Electrolyte Temperature during Charging in Eldoret Town, Kenya". International Journal of Computing and Technology, vol. 1, issue 8.

Shrestha, G. B., and Chew, B. C. (2007) "Study on the Optimization of Charge-Discharge Cycle of Electric Vehicle Batteries in the Context of Singapore", Power Engineering Conference". AUPEC 2007. Australasian Universities, pp. 1-7.

Xiong, R., Cao J., Yu, Q., et al. (2017) “Critical Review on the Battery State of Charge Estimation Methods for Electric Vehicles”. IEEE Access: Practical Innovations, Open Solutions. vol. 1; pp.99.

## **ASSESSMENT OF VOLUMETRIC SHRINKAGE AND HYDRAULIC CONDUCTIVITY OF LATERITE STABILIZED -COW BONE ASH ADMIXTURE AS LINER MATERIALS**

Bello, A. A.<sup>1\*</sup>; Raji, O.I.<sup>1</sup> and Ameen, I.O.<sup>2</sup>

<sup>1</sup>Department of Civil Engineering, Osun State University, Osogbo, Osun State

<sup>2</sup>Department of Civil Engineering, Federal Polytechnic, Ede, Osun State.

\*Email of Corresponding Author: [afeez.bello@uniosun.edu.ng](mailto:afeez.bello@uniosun.edu.ng)

### **ABSTRACT**

Compacted soil liners are widely used as hydraulic barriers in waste-containment facilities. “A compacted soil liner with low hydraulic conductivity, which in many cases is considered to be less than  $1 \times 10^{-7}$  cm/s is effective for use as hydraulic barriers”. In recent years, guidelines have been compiled for selecting appropriate soil properties and compaction methods that are likely to result in low hydraulic conductivity. This study is aimed at evaluating the suitability of using Cow Bone Ash (CBA) on the stabilization of A-7-6 lateritic soil as a liner. Geotechnical property tests such as compaction (British Standard Light compactive effort) , volumetric shrinkage and hydraulic conductivity tests were performed on the samples, both at the natural and stabilized states by adding 0 ,3, 6, 9 and 12% Cow Bone Ash (CBA) by weight of sample to the soils. The results showed that the addition of CBA improved the strengths of the samples.

The volumetric shrinkage of the specimens decreased with increasing CBA content at specified CBA contents to their minimum value at 6% CBA. The hydraulic conductivity of the specimens also decreased with increase in the ash content to their minimum value at 6% CBA content and beyond this point, the permeability slightly rises. These results indicate that not more than 6% CBA can be used to reduce both the volumetric shrinkage and hydraulic conductivity of the lateritic soil. Consequently, the soil can be used as waste containment barrier material.

**Keywords:** Cow bone ash, Hydraulic conductivity, Lateritic soil, Liner materials, Volumetric shrinkage.

## **1.0 INTRODUCTION**

Compacted soil liners are widely used as hydraulic barriers in waste-containment facilities. “A compacted soil liner with low hydraulic conductivity, which in many cases is considered to be less than  $1 \times 10^{-7}$  cm/s is effective for use as hydraulic barriers”.

In recent years, guidelines have been compiled for selecting appropriate soil properties and compaction methods that are likely to result in low hydraulic conductivity (Gordon *et al.*, 1984; Daniel, 1990). Some of these materials that can give low hydraulic conductivity include plastics, glass, scrap tires, fly Ash, cement kiln etc. According to Benson and Trast (1995), most regulatory agencies in the United States require that the hydraulic conductivity of clay liners be  $\leq 1 \times 10^{-9}$  m/s.

The main purpose of soil liner and cover is to serve as hydraulic barriers to impede flow of fluids and contaminants across them. They are therefore designed to have:

1. Low hydraulic conductivity
2. Minimal desiccation-induced volumetric shrinkage

Adequate shear (general mechanical) strength to ensure their structural integrity.

Stabilization has been defined as any process by which a soil material is improved and made more Stable (Bello, 2013). It is also the treatment of natural soil to improve its engineering properties. Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two (Sherwood, 1993). There are basically two principal methods of soil stabilization namely mechanical and chemical stabilization (Bello, 2013). Mechanical methods include proportioning and mixing of a soil sample with suitable material like gravel, sand and clay. The Methods used to achieve mechanical stabilization are: compaction, addition of graded aggregate materials, soil reinforcement, and mechanical remediation (Bello, 2013). Chemical stabilization is achieved by adding chemical or other materials to the existing soil. The chemicals can be cement, lime, fly ash, bitumen, etc.

Bone is a dynamic tissue that performs mechanical, biological, and chemical functions in the body. The main component of bone is hydroxyapatite as well as amorphous forms of calcium phosphate,



possibly including carbonate. Bone's chemical and physical properties are affected by age, nutrition, hormonal status, and diseases (Loveridge, 1999). Bone ash (BA) is a whitish powdery residue left from the burning (calcination) of bones. The ash is composed majorly of  $P_2O_5$  and  $CaO$ , in the form of calcium phosphate ( $Ca_3(PO_4)_2$ ) or modified hydroxyapatite ( $Ca_5(PO_4)_3OH$ ) (Tomáš *et al.*, 2011). The main chemical compositions of natural bone are expressed in terms of calcium oxide and phosphorus pentoxide.

## **2.0 MATERIALS AND METHODS**

### **2.1 Materials**

#### **2.1.1 Laterite**

The disturbed soil samples used for this study were collected at opposite Osogbo city stadium, Osogbo, Osun State, Nigeria. The top soil was removed to a depth of 1.2 m before the soil samples were taken. The soil samples were collected in large-to-medium-sized bags and thereafter transported to the Soil Mechanics Research Laboratory of the Department of Civil Engineering, Osun State University, Osogbo, Osun State. The soil samples were spread and allowed to air-dry under laboratory conditions.

#### **2.1.2 Cow bone Ash**

Cow bones used were collected from an Abattoir at Oke-Baale, Osogbo, State of Osun, Nigeria. This is a type of animal waste that is of great concern in both urban and rural areas in Nigeria abattoir or slaughter-house waste. Enough quantities of cow bones were collected, air-dried and burnt in open-air. The residues obtained were fed into furnace at  $1100^\circ\text{C}$  for about 4 hours. The calcinated bones from furnace after cooling were milled and sieved with sieve No 200 so as to get a fine CBA and was kept in sealed polythene bag to prevent moisture absorption. Oxide composition test was carried out on the CBA.

#### **2.1.3 Water**

The water used in this study was fresh portable water obtained from the water tap in Osun State University, Osogbo, Osun State.

## **2.2 Methods**

### **2.2.1 Index properties**

Laboratory tests were conducted to determine the index properties of the sample in accordance with British Standards (BS 1377, 1990).

### **2.2.2 Compaction**

Compactive effort used is the British Standard Light (BSL). Air dried soil samples passing through BS sieve with 4.76 mm aperture mixed with 0%, 3%, 6%, 9% and 12% CBA by weight of dry soil were used. The BSL compactive effort is the conventional energy level which consist of energy level derived from a 2.5 kg rammer falling through 450 mm height onto three layers and each receiving 25 uniformly distributed blows in a 1000cm<sup>3</sup>mould (Ola, 1980 and Osinubi, 1998).

### **2.2.3 Volumetric shrinkage**

The volumetric shrinkage upon drying was measured by extruding cylindrical specimens compacted using the BSL. The extruded cylindrical specimens were placed on a laboratory bench at a uniform temperature of 25 ± 2°C for 30 days to dry naturally. Measurements of diameter and height for each compacted specimen at different CBA contents (0%, 3%, 6%, 9% and 12%) using the BSL compactive effort were taken with the aid of a Vernier caliper accurate to 0.05mm every 5 days. The average diameters and heights were used to compute the volumetric shrinkage strain.

$$\text{Volumetric shrinkage strain} = \frac{\Delta V}{V} \times 100 \text{ --- (3.6)}$$

Where:  $\Delta V$  = reduction/change in volume

$V$  = original volume of the soil.

### **2.2.4 Hydraulic conductivity**

**Hydraulic conductivity** was measured using the rigid wall permeameter under falling head condition as recommended by Head (1992). A relatively short sample was connected to a standpipe

which provided the head of water flowing through the sample. The compacted soil – CBA samples at the different CBA contents (0%, 3%, 6%, 9% and 12%) using the BSL compactive effort were used. The height,  $h_1$  in the stand-pipe was measured and the valve was then opened as a stop clock is started. After a measured time,  $t$ , the height to which the water level has fallen,  $h_2$  was determined.

$$\text{Hydraulic conductivity, } K = 2.3 \frac{al}{At} \log_{10} \frac{h_1}{h_2} \text{ --- (3.7)}$$

Where: A = cross-sectional area of sample

a = cross-sectional area of stand-pipe

l = length of sample

$h_1$  = head at time,  $t_1$

$h_2$  = head at time,  $t_2$ .

### **3.0 RESULTS AND DISCUSSION**

#### **3.1 Properties of materials used in the study**

##### **3.1.1 Index properties of soil**

Preliminary tests conducted to determine the natural properties of the soil revealed that the soil has a natural moisture content of 7.48% and which shows the amount of open spaces (void) present in the soil mass. The index properties are summarized in Table 1 and the oxides composition of the natural soil and CBA used in this study is as shown in Table 2. The soil belongs to the CL group in the Unified Soil Classification System (BS 1377, 1990) and A-7-6 (8) soil group of the American Association of State Highways and Transportation Official soil classification system (AASHTO, 1986). The soil has specific gravity value of 2.25 with Halloysite being the dominant clay mineral present in it. The soil is reddish-brown in colour with a liquid limit of 51%, plastic limit of 32% and plasticity index of 18%.

The soil has a volumetric shrinkage value of 3.43% when compacted at the obtained OMC using the BSL compactive effort after air-drying for 30 days in the laboratory. Also, the compactive

effort yielded a hydraulic conductivity value of  $3.45 \times 10^{-3}$  cm/s at the obtained OMC. This shows that both the volumetric shrinkage and hydraulic conductivity of the natural soil itself satisfies the requirements of barrier materials used in waste containment structures.

The soil has specific gravity value of 2.25 with Halloysite being the dominant clay mineral present in it. The soil is reddish-brown in colour with a liquid limit of 51%, plastic limit of 32% and plasticity index of 18%.

### **3.1.2 Cow bone ash**

The chemical analysis revealed the oxide composition of CBA as shown in Table 1”.

The oxide test was conducted at Iwaloye Science Ventures, Gada Street Odo Ona, Ibadan. The higher concentration of silicon oxide in the CBA tends to improve the engineering properties of the lateritic soil used. Also, the Cow bone ash used in this study has a specific gravity of 2.57.

**Table 1: Properties of Natural soil**

<b>Properties</b>	<b>Quantity</b>
Natural moisture content (%)	7.48
Specific gravity	2.25
Liquid limit (%)	51
Plastic index (%)	32
% Passing BS No. 4 sieve	92
% Passing BS No. 200 sieve	53
Maximum dry density (g/cm <sup>3</sup> )	1.34
Optimum moisture content (%)	18.97
AASHTO Classification	A – 7 – 6 (8)
USCS classification	CL

Volumetric shrinkage (%)	3.43
Hydraulic conductivity (cm/s)	3.45 x 10 <sup>-3</sup>
Colour	Reddish brown
Dominant clay mineral	Halloysite

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Table 2: Oxide Composition of CBA

<b>Oxides</b>	<b>CBA (%)</b>
SiO <sub>2</sub>	68.92
Al <sub>2</sub> O <sub>3</sub>	3.46
FeO <sub>3</sub>	1.57
CaO	0.78
Na <sub>2</sub> O	0.92
K <sub>2</sub> O	1.34
MnO	0.69
Organic Carbon	1.17
MgO	1.26
EC(μS/cm)	2897.5
Ph	6.85

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### 3.2 Index properties of the lateritic soil

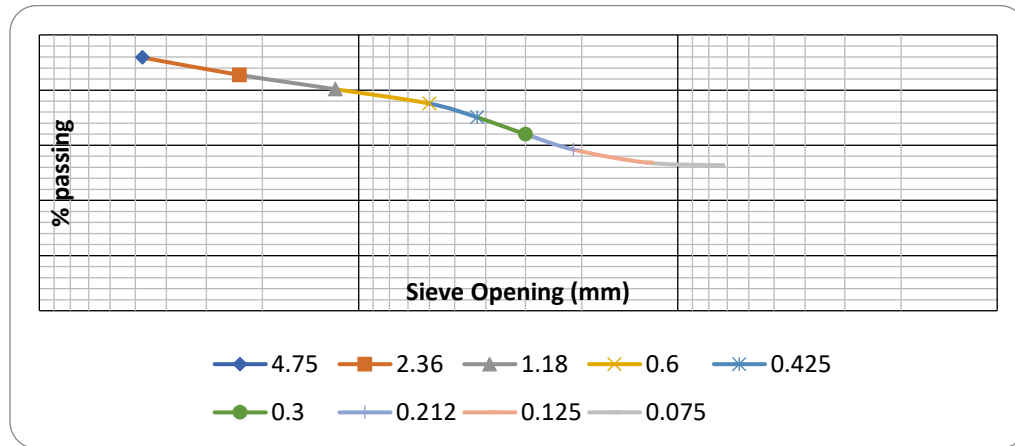


Figure 1: Particle size Distribution curve for the Soil Sample.

#### 3.2.1 Compaction characteristics

The effect of CBA content on the maximum dry density and the corresponding optimum moisture content and the lateritic soil are discussed below regarding their summary and variation

#### 3.2.2 Maximum dry density

The summary and variation of maximum dry densities of the soil-CBA mixture using BSL compactive effort are presented in Fig 2 respectively. Generally, MDD values obtained increases with increase in moisture content for 0%, 3% and 6% CBA content which eventually falls at 9% and 12% CBA content with increasing moisture content. The MDD increased from a value of  $1.34\text{g/cm}^3$  for the natural soil (0% soil-CBA mixture) to  $1.37\text{g/cm}^3$  at 3% soil-CBA mixture. This is so because the ash fills up the void within the soil matrix and in addition to the flocculation and agglomeration of the clay particles due to ion exchange (O' Flaherty, 1988).

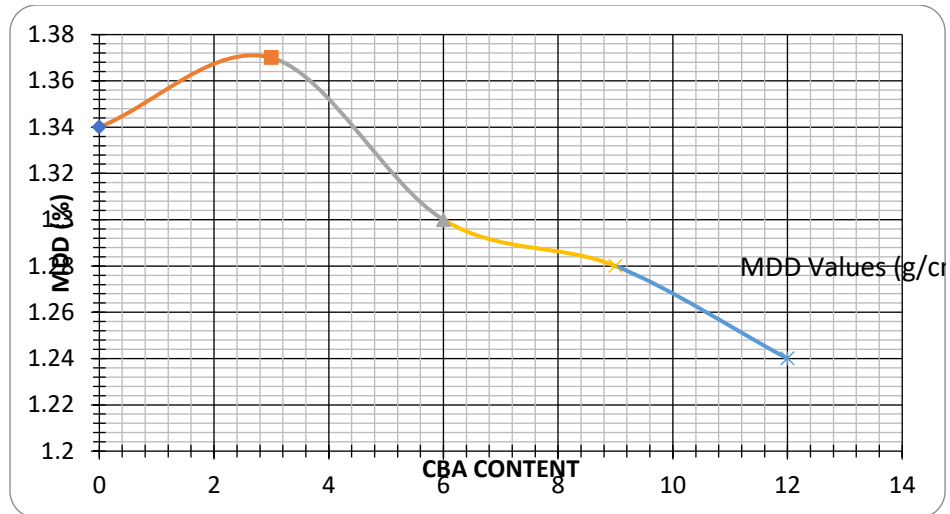


Fig. 2: Variation of MDD values of the Soil-CBA Mixture

### 3.2.3 Optimum moisture content

The summary of optimum moisture content values and their variations is as shown in Figure 2 respectively. The soil-CBA mixture yields optimum moisture content values which vary considerably with the dry densities of the sample. The increase in OMC with increasing CBA content conforms to the findings of Ola (1983) and Osula (1991). The reason advanced is that the increased desires for water is somewhat commensurate to the increasing amount of CBA as more water is needed for the dissociation of CBA into Ca and OH ions to supply more Ca ions for the cation exchange reaction.

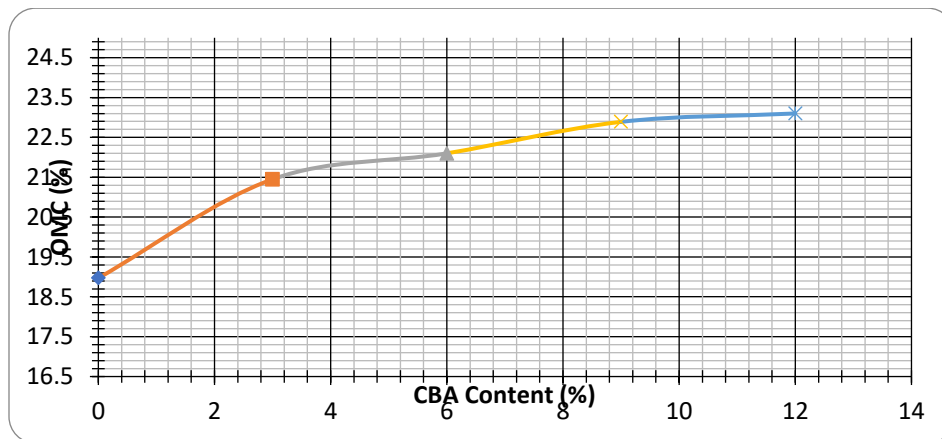


Figure 3: Variation of OMC values of the Soil-CBA Mixture

### 3.2.4 Volumetric shrinkage

The curve of volumetric shrinkage of the soil-CBA mixture is as shown in Figure 4. The soil-CBA mixture at various mix contents were compacted at the obtained OMC values. The volumetric

shrinkage values of the mixture after 30 days drying decreases with increase in CBA content. Also, peak reduction in volumetric shrinkage value was recorded at 3% CBA content after the drying period. This shows that the natural soil itself alongside the stabilized soil meet the requirement for materials used in waste containment structures

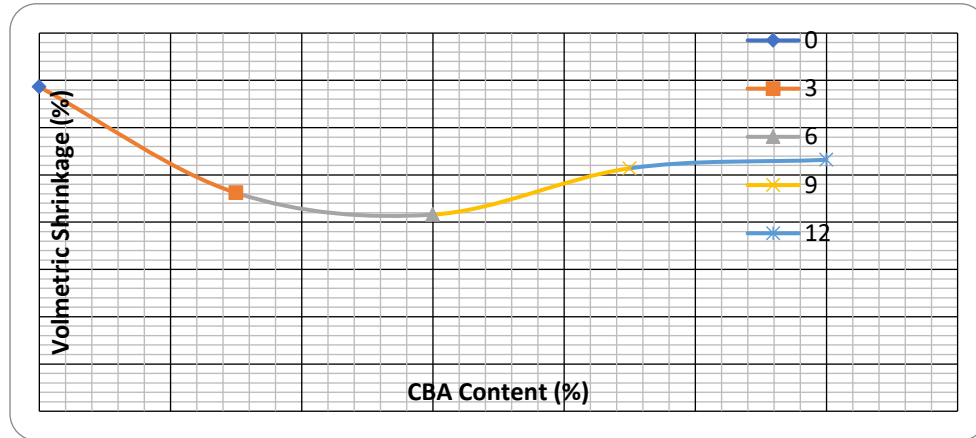


Figure 4: Variation of Volumetric Shrinkage values of the Soil-CBA Mixture

### 3.2.5 Hydraulic conductivity

The curves of hydraulic conductivities of the soil-CBA mixture are shown in Figure 5. The soil-CBA mixtures at various mix contents were compacted at the obtained OMC values so as to determine their hydraulic conductivities. The hydraulic conductivity values of the mixture decreases with increasing CBA content. Also, peak reduction in hydraulic conductivity was recorded at 6% CBA content. This also shows that the natural soil itself alongside the stabilized soil meet the requirement of materials used in waste containment structures.

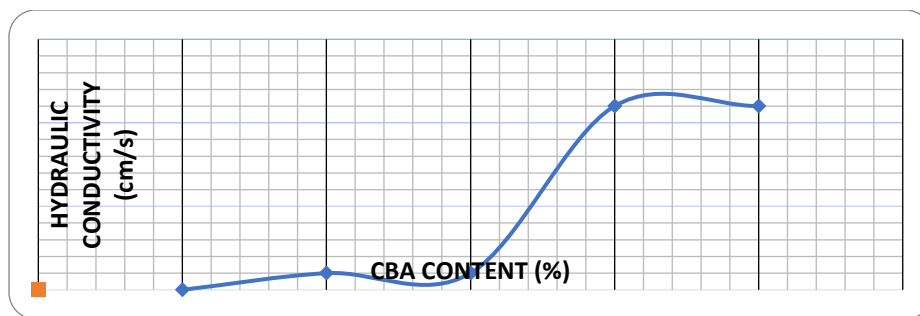


Figure 5: Variation of Hydraulic conductivities of the Soil-CBA Mixture



#### **4.0 Conclusions**

The investigations of CBA in improving the properties of lateritic soil for requirement for liners in waste containment structures have been presented. The soil classified as A-7-6 (8) and CL using the AASHTO and the USCS falls in the category of soils that are suitable for the construction of barrier systems for effective containment of hazardous wastes. The results obtained revealed that CBA is pozzolanic and beneficial in the improvement of the dry density with attendant decrease in moisture affinity of the soil specimens. The specimens replaced with 12 % CBA and compacted using the energy level of the BSL yielded the highest MDD value of 1.34 g/cm<sup>3</sup> with corresponding lowest OMC value of 18.97 %.

The volumetric shrinkage of the sample decreases to corresponding minimum value of 2.08% at 6% CBA content such that further increase in CBA content shows a minimal rise in the volumetric shrinkage value to 2.66% at 12% CBA content. Also, the hydraulic conductivity of the sample decreases to corresponding minimum value of  $1.07 \times 10^{-8}$  cm/s at 6% CBA content such that further increase in CBA content shows a minimal rise in the hydraulic conductivity.

The practical outcome of this study therefore shows that 6% CBA by dry unit weight of soil can be effectively used to stabilize A-7-6 lateritic soil in order to reduce volumetric shrinkage and hydraulic conductivity thereby justifying it as a good barrier material in waste containment structures.

#### **REFERENCES**

AASHTO (1986). Standard Specifications for Transport Materials and Methods of Sampling and Testing. 14<sup>th</sup> Edition, American Association of State Highways and Transportation Officials (AASHTO), Washington, D.C, USA.

Bello, A.A (2013). Introductory Soil Mechanics I, Tony Terry Prints, Lagos.

Benson, C.H. & Trast, J.M. (1995), "Hydraulic Conductivity of Thirteen Compacted Clays", Clay and Clay Minerals, 43(6), 669-681.

B.S. 1377 (1990). Methods of Testing Soil for Civil Engineering Purposes. British Standards Institute, London.

Daniel, D. (1990). "Summary review of construction quality control for earthen liners." Waste containment systems: construction, regulation, and performance; GSP No. 26, R. Bonaparte, ed., ASCE, New York, N.Y., 175-189.

Gordon, M., Huebner, P., and Kmet, P. (1984). "An evaluation of the performance of four clay-lined landfills in Wisconsin." Proc., 7th Annu. Madison Waste Conf., University of Wisconsin-Madison, Madison, Wisconsin, 399-460.

Head, K. H. (1992). Manual of soil laboratory testing. Soil classification and compaction tests.

Loveridge, N. (1999). Bone: more than a stick. J. Anim. Sci. 77(2), 190 – 196.

Ola, S. A. (1983). "Permeability of some compacted 131, No. 8, pp. 1034 – 1041.

Osinubi, K. J. (1998). "Lime modification of black cotton soils." Spectrum Journal, Vol. 2, Nos 1 and 2, pp. 112 – 122.

Sherwood, P. (1993). Soil stabilization with cement and lime. State of the Art Review. London: Transport Research Laboratory, HMSO

Tomáš I., Martin T. P., and Azelová Z. (2011). The influence of CaO and P<sub>2</sub>O<sub>5</sub> of bone ash upon the reactivity and the burnability of cement raw mixtures, ceramics Silikáty, 56(1), 6 – 84.

## **DESIGN AND FABRICATION OF A PLASTIC CRUSHER**

Adesina, A.O.<sup>1,\*</sup>, Adedeji, W.O.<sup>2</sup> and Ajiboshin, I.O.<sup>3</sup>

<sup>1</sup>Mechanical Engineering Department, Yaba College of Technology, Nigeria

<sup>2</sup>Mechanical Engineering Department, Osun State University, Nigeria.

<sup>3</sup>Chemical Engineering Department, Yaba College of Technology

\*Corresponding Author [oluwoleadesina@yahoo.com](mailto:oluwoleadesina@yahoo.com)

### **ABSTRACT**

Plastics materials are widely used for domestic and industrial application as such there are lots of plastics wastes littering the cities thereby causing serious environmental pollution. In an effort to address the aforementioned problem, a plastic recycling machine is hereby designed and developed with impact mechanism. The design analysis was carried out for the following machine parameters, the shaft diameter (D), the blades, the pulley and belt, Power to be transmitted by the prime mover. The machine is electrically operated and 7.5hp electric motor was selected with 1400rpm. The capacity of the plastic crusher is 2tons /8hrs. The efficiency of the plastic crusher was found to be 95%.

**Keyword** – Plastics, impact, crusher shaft, blade, electric motor.

### **1.0 Introduction**

Plastics materials though very cheap and readily available to serve the domestic needs and the society at large. Due to its nature, the plastic materials can be easily damaged unlike metal materials; as a result of this it constitutes menace in the environment. (Orhorhoro et al., 2016). The waste generated from plastics utensils such as washing bowls, foot wear, buckets and other domestic and industrial plastics container formed the solid wastes. Plastic waste pollutant has become an intractable problem because everywhere in the major cities and towns are littered with discarded plastic items. The synthetic nature of the plastics will not allow it to break down by micro-organisms unlike natural organic materials but by methods of recycling techniques. To solve the aforementioned problems, a local plastic crushing machine was designed and constructed. A crusher is a machine designed to reduce large particles into smaller sizes by means of impact forces on the blades and the wall of the crushing chambers. Crushers may be used to reduce the size, or change the form, of waste materials so that they can be more easily disposed of or recycled, or to reduce the size of a solid mix of raw materials so that pieces of different composition can be

differentiated. Crushing is the process of transferring a force amplified by mechanical advantage through a material made of molecules that bond together more strongly, and resist deformation more, than those in the material being crushed. Crushing devices hold material between two parallel or tangent solid surfaces, and apply sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate from each other (fracturing), or change alignment in relation to each other (deformation) (Ugoamali.et al., 2011). The crusher has capability of crushing the low density polyethylene (LDPE) and high density polyethylene (HDPE). The products from this machine can be used for the production of domestic plastics usage such as jerry can, food flask, nylon bags and also for industrial appliances.

## **2.0 Materials and Method**

The developed plastic crusher consists of feed hopper, power transmission unit, shaft, electric motor, blades mounted on rotating shaft, crushing chamber and the main frame to support the components, the materials used in the construction of the machine were sourced locally.

### **2.1 Description and operation of the plastic crusher**

The major components of the threshing machine are: Shaft, Electric Motor, Impact Blades, Belts, Pulley, Bearings and Frame Structure. The uncrushed plastic is fed into the crushing chamber of the machine through the hopper. The arrangement of the crusher blades allow the rotation movement such that it generates an impact force between the wall of the crushing chamber and the high velocity of the blades causing the plastic to be crush to smaller particles. The crushed plastic materials are passed through the mesh to the container for packaging. The sizes of the crushed plastic depend on the size of the mesh used.

### **2.2 Design Consideration**

The following factors were considered in the course of designing the plastic crusher.

The properties of the materials to be crushed

- a) Delivery of the material to the crushing chamber is dependent on the feed rate
- b) Cost effectiveness in design and construction
- c) Optimal power requirement

### 2.3 Load arrangement on crusher shaft.

The loads system for this study shows uniformly distributed loads arrangement on the shaft that supported by the bearing as shown in figure 1.

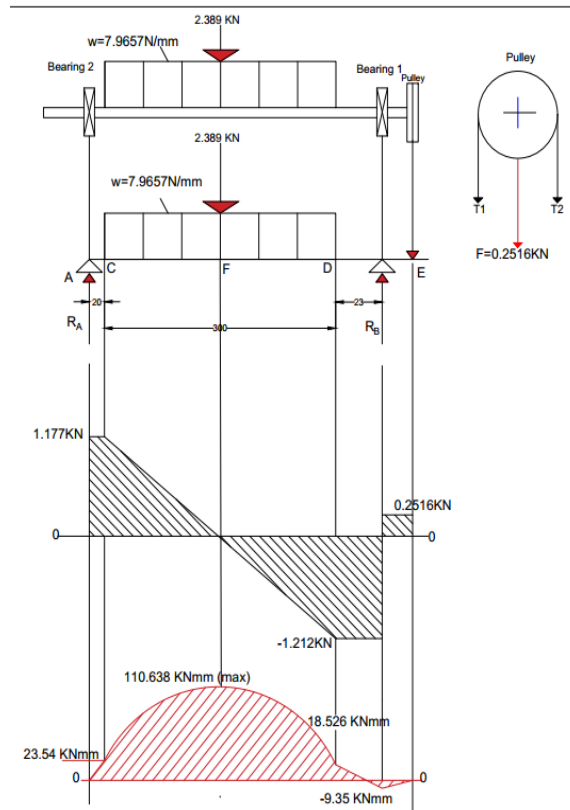


Figure 1: Shear force and bending moment diagram

### 2.4 Determination of shaft diameter

$$\sum M_A^{\downarrow+ve} \quad (1)$$

$$W = wl = \frac{7.9657kN}{mm} \times 300mm = 2.389kN$$

$$P = 0.2516kN$$

$$W \times (150 + 20) - R_B(23 + 300 + 20) + P(39 + 23 + 300 + 20) = 0$$

$$2.389 \times (150 + 20) - R_B(23 + 300 + 20) + 0.2516(39 + 23 + 300 + 20) = 0$$

$$406.13 - R_B(343) + 96.11 = 0$$

$$502.24 = R_B 343$$

$$R_B = 1.464kN$$

$$\sum \text{Upward forces} = \sum \text{Downward forces}$$

$$R_A + R_B = W + P$$

$$R_A = 2.389 + 0.2516 - 1.464 = 1.177kN$$

(2)

### 2.4.1 Shear Forces Calculation

$$S_A = 1.177kN$$

$$S_{C-D} = 1.177 - 2.389 = -1.212kN$$

$$S_B = -1.212 + 1.464 = 0.252kN$$

$$S_E = 0.252 - 0.2516 = 0$$

### 2.4.2 Bending Moment

$$M_A = 1.177 \times 20 = 23.54kNmm$$

$$M_{C-F} = 23.54 + \left(\frac{1}{2} \times 148 \times 1.177\right) = 110.638kNmm$$

$$M_{F-D} = 110.638 - \left(\frac{1}{2} \times 152 \times 1.212\right) = 18.526kNmm$$

$$M_{D-B} = 18.526 - (1.212 \times 23) = -9.35kNmm$$

$$M_{B-E} = -9.35 + (9.812) = 0$$

$$\text{Maximum Bending moment} = 110.638kNmm$$

## 2.5 Design of Crusher Shaft Diameter

The diameter of the crusher can be calculated according to the theory of maximum shear stress according to Khurmi and Gupta 1984.

$$d^3 = \frac{16}{\pi\tau_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (3)$$

Where d is the diameter of the shaft

$K_b$  is combined shocking and fatigue factors applied to bending moment

$K_t$  is combined shocking and fatigue factors applied to torsional moment

$\tau_s$  is allowed shear stress

$M_t$  is torsional moment

$M_b$  is bending moment

$$K_b = K_t = 1.5 \text{ and } \tau_s = 300 \text{ MPa}$$

$$M_t = 10.16Nm \text{ and } M_b = 0.110kNm$$

$$d^3 = \frac{16 \times 7}{22 \times 300 \times 10^6} \sqrt{(1.5 \times 0.110 \times 10^3)^2 + (1.5 \times 10.16)^2}$$

$d = 14mm$ , using a factor of safety of 2.0, the value adopted for the shaft diameter is 30mm.

## 2.6 Power Transmission and Belt Drives

Power required for the crusher is given by Eugene and Avallone (1999)

$$P = \frac{2\pi NT}{60 \times 1000} \quad (4)$$

Where T is the torque

$$P = \frac{2 \times 3.142 \times 1400 \times 10.16}{60 \times 1000}$$

$$P = 5.5kW = 7.5HP$$

Design horse power = Rated HP x Ks

Rated horse power = 5.54 (using the HP ratings chart the power which corresponds to the small pulley outside diameter).

$$5.54 \times 1.3 = 7.15HP$$

7.5HP.

The equation for the number of the belt required was obtained from Mahadevan and Reedy (2010) .and Gition and Pasrad (1986).

$$\text{Number of Belt} = \frac{\text{Design Horsepower}}{\text{Standard transmission on HP} \times \text{Coefficient of belt}} \quad (5)$$

$$\text{No of belt} = \frac{7.5}{2.54 \times 0.99 \times 0.86} = 1.5 \text{ belts}$$

Number of belts  $\approx$  2.

It is therefore recommended that two belts should be used to increase its service life and reduces slips of belts

## 2.7 Calculations for Belt Length and Centre Distance

The length of the belt was obtained using the expression given by Khurmi and Gupta (2004) and Singh (2000).

$$L = \pi(R_1 + R_2) + \frac{(R_1 - R_2)^2}{x} + 2x \quad (6)$$

$$L = 1064.9mm$$

The belt length of 1065mm was selected from the table which falls with A-class belt type according to 2492-1794 standard. (Khumi and Gupta, 2004) and Singh, 2000.

### 2.7.1 Angle of Wrap

The equation for the angle of wrap for the belt was given by Motts, 2004

$$\theta = 180 - 2 \sin^{-1} \left[ \frac{D_1 - D_2}{2x} \right] \quad (7)$$

$$\theta = 180 - 2 \sin^{-1} \left[ \frac{13 - 8.5}{2 \times 37} \right]$$

$$\theta = 173^{\circ}$$

$$\sin \alpha = \frac{D_1 - D_2}{2x}$$

$$\alpha = \sin^{-1} 0.06, \quad \alpha = 3.43^{\circ}$$

Belt tension

The design of the pulley is expected to be 1:2

$$N_1 = 1400rpm, \quad N_2 = 700rpm$$

Velocity of the belt drive is given by equation

$$V = \frac{\pi dN}{60} \quad (8)$$

$$V = \frac{\pi \times 2 \times 700}{60}$$

The centrifugal tension in the belt is given by the equation

$$T_c = mv^2 \quad (9)$$

Where: m=mass; v=velocity (9.52m/s); ρ=density (1000kg/m<sup>3</sup>); thickness (t) =0.013; width (w) =0.08mm; length (L) =0.37m

$$m = w \times t \times \rho \quad (10)$$

$$m = 0.08 \times 0.013 \times 1000 = 1.04\text{kg}$$

The centrifugal tension in the belt  $T_c=94\text{N}$

Maximum tension in the belt is given as

$$T = \sigma \times b \times t \quad (11)$$

$$T_1 = \sigma A \quad (12)$$

Where,  $\sigma$  is the maximum stress and A is the cross sectional area

$$T_1 = 7 \times 10^6 \times 0.013 \times 0.008 = 7280\text{N}$$

The power transmitted by belt is given by the equation

$$P = (T_1 - T_2)v \quad (13)$$

$$T_2 = 7280 - \left( \frac{1.491 \times 10^3}{9.52} \right) = 7123.4\text{N}$$

$$T = (T_1 - T_2)R \quad (14)$$

$$T = (7280 - 7123) \times 0.067 = 10.5\text{Nm}$$

## 2.8 Bearing Design and Selection

A ball bearing that will support both static load and dynamic load was selected from the bearing codes. It was designed based on the loads from the belt tension.

The radial loads of the bearing are determined from the equation of Mahadeed and Reddy (2010) and Senthlin and Kumar (2016).

$$C = \frac{RF}{F_s} \sqrt[4]{\frac{L}{Q}} \quad (15)$$

Where C is rated radial load, R is radial load on bearing, F and  $F_s$  are thrust factor and speed factor.

## 2.9 Design of Blade Torque

The impact force by the crusher is given by the equation

$$T = F \times r \quad (16)$$

T is torque, F is crushing force and r is radius of the blade

Force on the output of the crusher shaft  $F = 175\text{N}$

The radius is given as 11.8mm

$$\text{Total torque} = F_1r_1 + F_2r_2 + F_3r_3 \quad (17)$$



The results of the plastics crusher for two different mesh sizes are shown in Table 1.

$$\text{Machine throughput} = \frac{\text{mass of the plastics materials crushing}}{\text{machine crushing time}} \quad (18)$$

$$\text{Crushing efficiency} = \frac{\text{output}}{\text{input}} \times 100\% \quad (19)$$

### 3.0 Result and Discussion

The plastic crusher was tested with two different types of mesh sizes: 8.96mm and 12mm. It was observed that the crushing time for the mesh 8.96mm was higher than 12mm mesh size for the same quantities of plastics materials. The average diameter of crushed plastics materials for mesh size of 8.96mm was 8.86mm while average diameter of mesh size 12mm was 10.58mm. This means that increased in mesh size from 8.96mm to 12mm results in increase in average diameter of crushed materials. The machine throughput capacity is higher for bigger mesh size compared with smaller mesh size for the same plastics materials. These results are shown in Table 1.

The isometric views of the design of the crusher blades and that of the completely designed plastic crusher are shown in Figures 2 and 3 respectively. Also shown in Figure 4 is the exploded view of the plastic crusher.

Table 1: Results of plastics crushing using different mesh sizes

Mesh Size (mm)	Mass of materials to be crushed (kg)	Mass of crushed materials (kg)	Diameter of crushed materials (mm)	Average length of materials (mm)	Resident Time (s)	Machine throughput (kg/s)
8.96	20	18.5	8.80	49.25	90	0.22
	50	47.8	8.70	47.00	105	0.48
	85	82.5	8.55	46.50	110	0.73
12	20	19.50	11.50	38.50	50	0.40
	50	49.80	10.25	36.00	70	0.71
	85	89.75	10.00	35.50	90	0.94

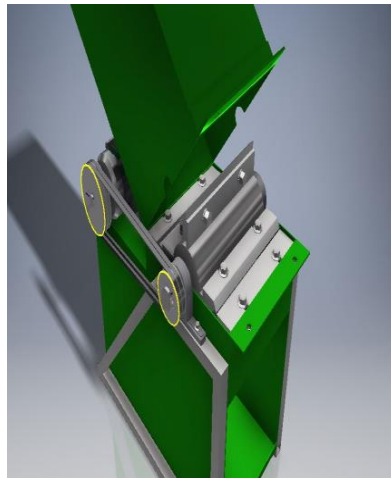


Figure 2: The designed of crusher blades

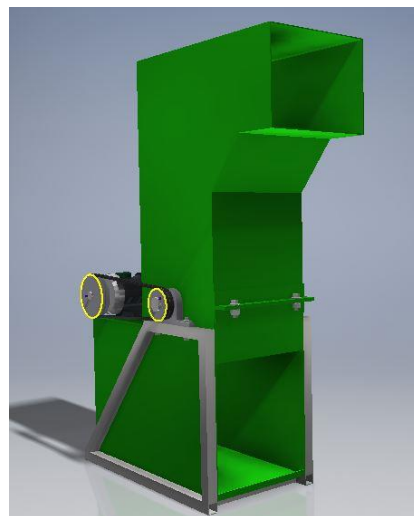


Figure 3: The designed plastic crusher

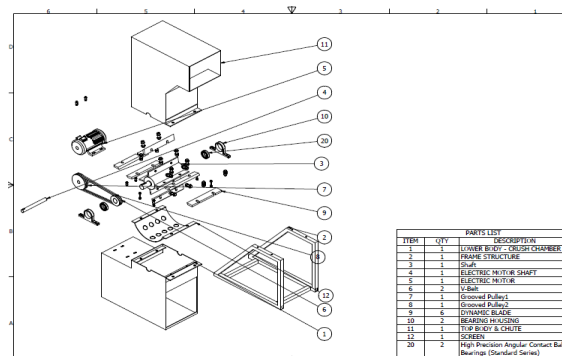


Figure 4: Exploded view of Plastic Crusher

#### 4.0 Conclusion

Plastic crushing machine has been designed and fabricated with the estimated capacity of 2tonnes per day and efficiency of 95%. The machine was designed to use different types of plastics materials. The development of this machine will serves as a means of reducing the

environment from littered plastics and it will conserve the foreign exchange by discouraging importation of this machine. It will also serve as means of job creation and poverty reduction in the society.

## **5.0 REFERENCES**

Eugene, A. and Avallone, A.(1999). Marks standard handbook for Mechanical Engineers. McGraw-Hill Company Inc.USA.

Gittion, M.M. and Prasad, L.V.(1986). Handbook of Mechanical Design, McGraw-Hill publishing New Dehli.

Khumi, R.S. and Gupta, J.K.(2004). A Textbook of Machine Design. 13th edition, Chand and company Ltd. New Dehli.

Khumi, R.S. and Gupta, J.K.(1984). A Textbook of Machine Design. 13th edition, Chand and company Ltd. New Dehli.

Mahadevan, K.and Balaveera, R.K. (2011). Design Data Handbook.

Mott, R.L. (2004). Machine elements in mechanical design 4th edition New Jersey

Orhororo, E.K., Ikpe, A.E.and Tamuno, R.I. (2016). Performance analysis of locally plastic machine for domestic and industrial use in Nigeria. European Journal of Engineering Research and Science, 1(2), pp 12-17.

Senthlin, K.D.and Kumar, R.N.(2016).Design of Mechanical crushing machine. International Research Journal of Engineering and Technology, 2 (3) pp 65-76.

Singh, S. (2000). Mechanical Engineering Handbook 6th edition

Ugoamadi,C.C. and Ihesiulor O.K.(2011). Optimization of the development of plastic recycling machine. Nigeria Journal of Technology, 3(3), pp 86-83.

## **EFFECTS OF UNREGULATED CONCRETE PRODUCTION PRACTICES BY NIGERIAN MASONS: A CASE STUDY OF OSOGBO, OSUN STATE, NIGERIA**

Oriaje, A.T.\* and Adeoye, A.A.

Department of Civil Engineering, Osun State University, Nigeria.

\*Email of Corresponding Author: [aremu.oriaje@uniosun.edu.ng](mailto:aremu.oriaje@uniosun.edu.ng).

### **ABSTRACT**

The causes of building collapse have generated many studies. Concrete work forms the bulk of building construction in Nigeria. Information on the roles of masons in building collapse is scarce. This study assesses the effects of concrete practices of masons on structural stability of buildings in Nigeria. Osogbo is used as a case study. Field studies of four construction sites, denoted as sites A, B, C, D, in Osogbo were carried out. Fresh concrete samples were also collected from each site. Slump tests and casting of concrete cubes were done in-situ with the fresh concrete. The cubes were water cured for 28 days. The compressive strengths of the cubes were determined in the Laboratory. In all the four sites, none cured the concrete and concreting was done on unpaved ground. Batching by weight was done only in one site, while others were by volume. Only one site used well water while others used tap water. Only one site used poker, others used iron rod for compaction. Slumps of 50.0, 38.0, 37.5, and 38.5 mm were recorded falling within the ACI recommendations. 28-days compressive strengths of 22.90, 18.09, 17.16, and 18.09 N/mm<sup>2</sup> were obtained indicating only one site met the ACI recommended 28-days compressive strength of 20.00 N/mm<sup>2</sup>.

**Key Words:** Concrete, Compressive Strength, Slump, Construction

### **1.0 INTRODUCTION**

Concrete is used widely in construction of building. It is obtained by mixing cement, aggregates, water and admixture (if required). The strength, durability and other characteristics of the concrete depend on the properties of its ingredients, the proportions of mix, the method of compaction and other controls during placing and curing (Falade, 2009). In any concrete, aggregates (fine and coarse) usually constitute about 70-75% (Gupta and Gupta, 2004; Neville and Brooks, 2004). The aggregates have to be graded so the whole mass of concrete acts as a relatively solid, homogeneous, dense combination with the smallest particles acting as inert

filler for the voids that exist between the larger particles (Nawy, 2008). Concrete meeting special combinations of performance and uniformity requirements cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices (Russell, 1999). Concrete fails when it can no longer provide the required strength to support the designed load. The failure of concrete can sometimes be mild with visible cracks and deflections or severe, leading to partial or total collapse of the structure either during or post construction stage (Mehta and Monteiro, 1993). Concrete will only become a quality material for construction when manufactured to regulated and standard practice procedures. Chudley and Greeno (2005) asserted that the proportions of each of concrete materials control the strength and quality of the resultant concrete. Errors in batching are partly responsible for the variation in the quality of concrete (Gupta and Gupta, 2004). Concreting practices could greatly affect the quality of concrete. Alizadeh *et al.* (2008) reported compressive strength increases of concrete cubes at 7 and 28 days.

Building collapse is very rampant in Nigeria with resultant huge loss of life and property. The quality of concrete could play a major role in the structural stability of buildings because concrete constitutes the bulk of building construction in Nigeria. According to Falade (2000), a good quality concrete can be obtained by effectively controlling both human and non-human factors. Various investigations into structural failure of buildings: Dare (2001), Salau (2005), Arum and Babatola (2006), and Arum (2008), reported the poor quality of materials, laxity in works supervision, poor construction practices, and employment of unqualified personnel, inadequate maintenance and unprofessional conduct. Jackson (1981) ascribed these deficiencies to poor quality control. Concrete practices by masons in Nigeria is not regulated. This study attempts to assess the effect of concrete practices in Nigeria on the quality of concrete using Osogbo as a study area.

**STUDY AREA** Osogbo is a city Southwest Nigeria, the capital of Osun State. Osogbo city seats the Headquarters of both Osogbo Local Government Area (situated at Oke Baale Area of the city) and Olorunda Local Government Area (situated at Igbonna Area of the city). The coordinate of Osogbo city is  $7^{\circ}46^1\text{N } 4034^1\text{E} / 7.767^0\text{N } 4.567^0\text{E}$ .



Figure 1 Map of Osogbo

Source: Google map (2019)

## 2.0 METHODS

Empirical and non-empirical data collection methods were used. Four construction sites, denoted as sites A, B, C, and D were assessed. The non-empirical data collection method was used to study the mode of curing the concrete, preparation of surface for mixing concrete, batching method, type of water used for mixing concrete, and method of compacting the concrete. These were recorded for each site. The empirical method of data collection was the experimental processes carried out on both fresh and hardened concrete in accordance to ACI 301 (2018) standards. Slump tests were carried out in-situ on the fresh concrete for each site in accordance to ACI 301 (2018) standards. Also, concrete cubes were prepared in-situ on each site in accordance to ACI 301 (2018) standards. The concrete cubes were water cured for 28 days. In the laboratory, 7, 14, 21, and 28 days compressive strength tests were carried out on the concrete cubes for each site.

### **3.0 RESULTS AND DISCUSSION**

#### **Field study**

- i. **Aggregate dump site:** Aggregates were dumped on clear ground surface. The fine and coarse aggregates were separated from each other. However, it was observed that towards the end of the concreting work, soil from the ground was batched along.
- ii. **Cement storage:** Cement bags are stored in a temporary place. One of the sites has a store for storing of cement which there were loaded with bags of cement and the others site they purchased their bags of cement the morning of their works.
- iii. **Batching of concrete:** The batching techniques observed in one of the sites was done by volume and others were done using head pans for the cement and aggregates.
- iv. **Water used for the concrete:** Purified water was used in three of the sites while others used impurified water. Purified water in the sense that it was from a running tap, well which is clean, drinkable and wholesome. Impurified water was gotten from runoff of rain which were deposited in the septic tank
- v. **Compaction of concrete:** Only one of the sites used concrete vibrator (poker) while some managed to use an iron bar to compact.
- vi. **Curing of concrete:** The following day after the concrete has been cast, none of the site cured the concrete.

#### **SLUMP TEST**

For site A of 1: 2: 4 concrete for slab of the structure which is 50 mm. Comparing the site slump with the standard slump of a slab range of 20-80 mm. This implies the workability of the site concrete is adequate.

For site B of 1: 10 concrete for slab of the structure which is 38mm. Comparing the site slump with the standard slump of a slab range of 20-80 mm. This implies the workability of the site concrete is adequate.

For site C of 1: 12 concrete for foundation of the structure which is 37.5 mm. Comparing the site slump with the standard slump of a slab range of 20-80 mm

Table 1: Results of slump tests

Site	Mix Ratio	Sub-structure Type	Type of slump	Height of slump (mm)	Standard Range of Slump for slab (mm)
A	1:2:4	Slab	True	60	20-80
			True	40	
				50	
B	2:10	Slab	True	41	20-80
			True	35	
				38	
C	2:12	Foundation	True	38	20-80
			True	37	
				37.5	
D	2:12	Slab	True	42	20-80
			True	35	
				38.5	

Table 1 shows the result of slump tests obtained from site A, B and C. This implies the workability of the site concrete is adequate. For site B of 1: 12 concrete for slab of the structure which is 38.5mm. Comparing the site slump with the standard slump of a slab range of 20-80mm. This implies the workability of the site concrete is adequate.

#### CONCRETE CUBE TEST / COMPRESSIVE TEST

Area of cube = 150mm \* 150mm

Volume of cube = 150mm \* 150mm \* 150 mm



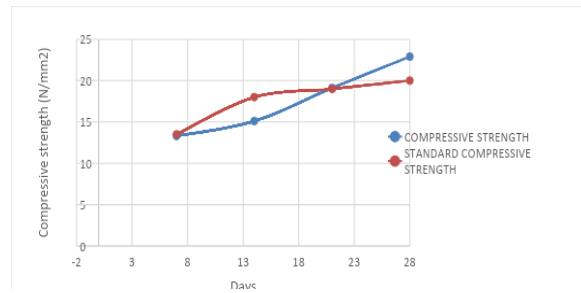


Figure 2a: Line graph of concrete compressive strength versus curing days for site A

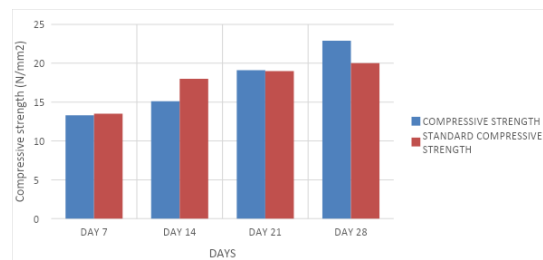


Figure 2b Bar chart of concrete compressive strength versus curing days for site A

Figure 2a and Figure 2b which are a graphical presentation of Table 2 results which indicated that the compressive strength values obtained from site A of 1: 2: 4 concrete mix were  $13.3\text{N/mm}^2$ ,  $15.1\text{N/mm}^2$ ,  $19.1\text{N/mm}^2$  and  $22.9\text{N/mm}^2$  as against standard compressive strength values  $13.5\text{N/mm}^2$ ,  $18\text{N/mm}^2$ ,  $19\text{N/mm}^2$  and  $20\text{N/mm}^2$ . This result implies;

Table 2: Result for concrete cube test for site A

Days	Weight of cube (kg)	Compressive load (kN)	Compressive strength (N/mm <sup>2</sup> )	Density of cube (kg/m <sup>3</sup> )
7	8.356	298.1	13.3	2428.44
	8.036	301.3		
	8.196	299.7		

21	8.782	399.6	19.1	2496.59
	8.070	459.7		
	8.426	429.65		
28	8.731	470.4	22.9	2547.26
	8.463	558.5		
	8.597	549.45		

At Day 7, the site compressive strength is  $0.2\text{N/mm}^2$  less than standard

At Day 14, the site compressive strength is  $2.9\text{N/mm}^2$  less than standard

At Day 21, the site compressive strength is  $0.1\text{N/mm}^2$  greater than standard

At Day 28, the site compressive strength is  $2.9\text{N/mm}^2$  greater than standard

Therefore, site compressive strength values of 1: 2: 4 concrete mix of site A is adequate when compared with the standard compressive strength of the same respective days.

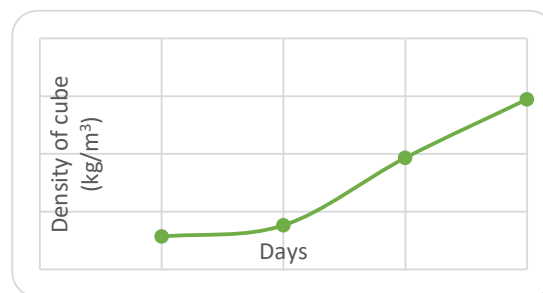


Figure 2c Line graph of density of concrete cube versus curing days for site A

Figure 2c which is graphical presentation of density of concrete cube result in Table 2 which were  $2428.44\text{kg/m}^3$ ,  $2438.22\text{kg/m}^3$ ,  $2496.59\text{kg/m}^3$  and  $2547.26\text{kg/m}^3$ . Comparing the values with the standard density of concrete  $2400\text{kg/m}^3$ . The site density of concrete cube is adequate.

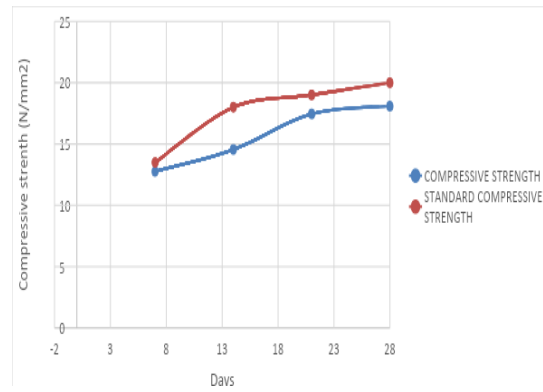


Figure. 2d Line graph of concrete compressive strength versus curing days for site C

Table 3: Result for concrete cube/compressive strength test for Site B

Days	Weight of cube (kg)	Compressive load (kN)	Compressive strength (N/mm <sup>2</sup> )	Density of cube (kg/m <sup>3</sup> )
7	7.103	276.5	12.77	2129.78
	7.273	298.3		
	7.188	287.4		
21	7.532	388.1	17.45	2208.30
	7.374	397.4		
	7.453	392.75		
28	7.796	431.3	18.09	2250.96
	7.398	382.6		
	7.597	406.95		

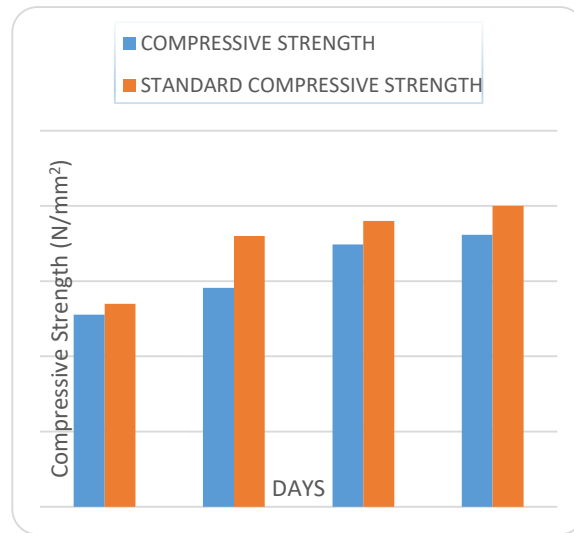


Figure 3a: Bar chart of concrete compressive strength versus curing days for site C

Figure 2c and Figure 2d which are a graphical presentation of Table 2 results which indicated that the compressive strength values obtained from site C of 2:12 concrete mix were 12.77N/mm<sup>2</sup>, 14.55N/mm<sup>2</sup>, 17.45N/mm<sup>2</sup> and 18.09N/mm<sup>2</sup> as against standard compressive strength values 13.5N/mm<sup>2</sup>, 18N/mm<sup>2</sup>, 19N/mm<sup>2</sup> and 20N/mm<sup>2</sup>. This result implies;

At Day 7, the site compressive strength is 0.73N/mm<sup>2</sup> less than standard

At Day 14, the site compressive strength is 3.45N/mm<sup>2</sup> less than standard

At Day 21, the site compressive strength is 1.55N/mm<sup>2</sup> less than standard

At Day 28, the site compressive strength is 1.91N/mm<sup>2</sup> less than standard

Therefore, site compressive strength values of 2: 12 concrete mix of site C is not adequate when compared with the standard compressive strength of the same respective days.

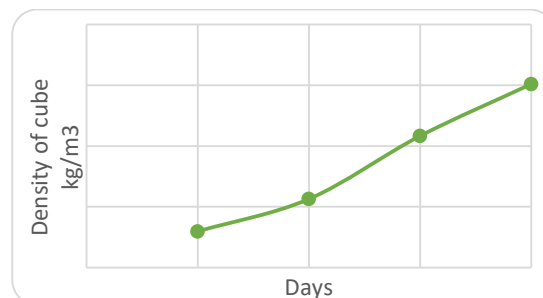


Figure 3b Line graph of density of concrete cube versus curing days for site D

Figure 3b which is graphical presentation of density of concrete cube result in Table 2 which were 2129.78 kg/m<sup>3</sup>, 2156.44kg/m<sup>3</sup>, 2208.30kg/m<sup>3</sup> and 2250.96kg/m<sup>3</sup>. Comparing the values with the standard density of concrete 2400kg/m<sup>3</sup>. The site density of concrete cube is not adequate.

#### **4.0 CONCLUSION**

The concrete practices of masons are inadequate. These undermine the quality of concrete and consequently the strength and durability of the structural members produce with the concrete. The numerous collapses of buildings in Nigeria as claimed many lives and property. It is therefore imperative that policies be put in place to ensure adequate certification of masons and thorough monitoring of concrete practices.

#### **REFERENCES**

- Alizadeh, R., Ghods, P., Chini and M., Hoseini (2005). "Effect of Curing Conditions on the Service Life Design of RC Structures in the Persian Gulf Region." *Journal of Materials in Civil Engineering vol. 20 No 1.* pp. 497–50
- Arum C. (2008). Quality Control and the Safety of Structural Concrete Buildings. *Indexed African Journals Online: [www.ajol.info](http://www.ajol.info), vol 2, No 4,* pp. 113-123.
- Arum C. and Alhassan Y.A. 2006). Combined Effect of Aggregate Shape, Texture and Size on Concrete Strength. *Journal of Science, Engineering and Technology, vol.13, No.2* pp.6863-6869.
- Chudley, R and Greeno, R. (2006): Construction Technology. 4th ed. Pearson Education Limited, Edinburgh Gate, Harlow, Essex CM20 2JE, England. Or [www.pearsoned.co.uk](http://www.pearsoned.co.uk)
- Dare S. (2001). Building Design, Buildability and Site Production, Paper presented at a workshop on "Building Collapse: Causes, Prevention and Remedies", NIOB, Akure.
- Falade, F.A. (2009): Alleviating Stress in Projects. Being an inaugural lecture delivered on Wednesday 6th May, 2009 at the University of Lagos, Nigeria.
- Falade F.A. (2000): Concrete Mix Design and Quality Control, Text of a lecture delivered on a course: Design of Concrete Bridges, The Nigerian Institution of Structural Engineers, Lagos.

Gupta, B.L and Gupta, A. (2004): Concrete Technology. A.K. John Publishers for Standard Publishers Distributors, Nai Sarak, Delhi, India.

Jackson, M. (1981): "Mix Design Formulas for Recycled Hot-Asphalt Plant Mixtures". *Journal of Civil Engineering* vol. 51, pp. 63-65

Mehta, K. P., and Monteiro, P. J. M. (1993). Concrete structure, properties, and materials. 2nd Ed., Prentice Hall, New Jersey.

Nawy, G.E. ed. (2008): Concrete Construction Engineering Handbook. 2nd edition. CRC Press, Taylor & Francis Group, Boca Raton, London, N York.

Neville, A.M & Brooks, J.J. (2004): Concrete Technology. Pearson Education limited, Edinburgh Gate, Harlow, Essex cm202JE, England.

Russell, P. (1976): Curing Hardened Concrete. Published by Cement and Concrete Association. Publication No. 47.020, London.

Salau M.A. (2005): Design, Construction and Maintenance Measures for Preventing the Collapse of Reinforced Concrete Structures, A paper presented at a National Workshop on the theme: Preventing Incidences of Collapsed Buildings and Structures in Nigeria, Lagos.

## **INFLUENCE OF COMPACTION ENERGIES ON SOIL SAMPLES FROM ABEOKUTA-SOUTH LOCAL GOVERNMENT AREA OF OGUN STATE, SOUTHWESTERN NIGERIA**

Bello, A. A.<sup>1\*</sup>, Oriaje, A. T.<sup>2</sup> and Raji, Z. A.<sup>3\*</sup>

Department of Civil Engineering, Faculty of Engineering, College of Science, Engineering and Technology, Osun State University, Osogbo.

\*Email of Corresponding Author: [afeez.bello@uniosun.edu.ng](mailto:afeez.bello@uniosun.edu.ng)

### **ABSTRACT**

This paper presents result of the influence of compaction energies on soil samples from Abeokuta South Local Government, Southwestern Nigeria. Three comparative efforts namely standard Proctor (SP), West African Standard (WAS) and modified Proctor (MP), were employed while other tests such as California bearing ratio (CBR) and Unconfined compressive strength (UCS) tests were carried out to determine the strength of the compacted soils. All the samples did not meet the minimum specified requirements with the exception of A<sub>1</sub>, A<sub>6</sub> and A<sub>8</sub>. Upon stabilizing with cement ranging from 2 – 10% of the soil, samples A<sub>2</sub> and A<sub>7</sub> did not also meet the minimum CBR value of 180% as specified by the Nigerian General Specification for roads and bridgeworks (1997) for stabilized soil using standard Proctor compactive effort at 4% cement content. However, all the soil samples met the requirement using WAS compactive effort at 4% cement content. The samples met the conventional UCS values of (1500-3000 kN/m<sup>2</sup>) for base course of lightly trafficked roads while only sample A<sub>4</sub> compacted at 10% cement content using WAS compactive effort met the minimum (3000-6000 kN/m<sup>2</sup>) for base course of highly trafficked road. It is thus recommended that 4% cement should be used as an optimal content to stabilize the soils, if they are to be used as road construction materials.

**Keywords:** California bearing ratio, Compactive efforts, Stabilization, Unconfined compressive strength.

### **1.0 INTRODUCTION**

The development of infrastructure cannot be made in an intelligent and satisfactory manner unless the designer has at least a reasonable and accurate conception of the physical properties

and general behaviour of the soil involved. Ogun State Government is actively involved in the construction of new roads within the state and in Abeokuta South Local government area, majority of soil materials are not yet explored. Rapid infrastructural development in terms of road construction, buildings and recreational centres are anticipated in the future within the studied area. This expectation calls for the knowledge of basic index and strength properties of the soils in question.

The highway pavement consists basically of four elements, namely: subgrade, subbase, base and wearing or surface courses. The subgrade course is the most important of the structural elements because the ultimate traffic load is transmitted to it through the intermediate layers. Hence, the durability of a highway pavement is a function of the bearing capacity and stability of the subgrade soil. Various previous workers have stabilized natural soil both chemically and mechanically. Ola (1975) noticed an increase in the compressive strength of lateritic soils with cement content. Adeyemi and Abolurin (2000) also stated that cement stabilized samples exhibited the highest cured strength when compared with lime and some mixture of both.

Cement acts as a binder and provides the much-desired hardening and strengthening properties. The addition of cement also increases compressive strength, the resistance of lateritic soils to freezing and thawing, wetting and drying. It also affects the particle size distribution of the soils by increasing the size of fine particles. In view of this, civil engineers must study the property of soil, such as grain size distribution, Atterberg limit, strength, durability and ability to drain water (Ackroyd, 1960; Braja, 1999; Bello *et al.*, 2016; Bello and Olaore, 2017). This research is therefore aimed at investigating and evaluating the index and strength property of the soils of Abeokuta South Local Government, Southwestern Nigeria with the aim of making recommendations as to the suitability of the soil as construction materials, procedures to improving them if they are found deficient, as well as the types of structures that could be built on such with minimal foundation problems.

## **MATERIALS AND METHOD**

### **Sample Collection**

The soil samples used for this study were obtained within Abeokuta South Local government area of Ogun State, Nigeria. The samples were collected via trial pitting at eight different



locations which include Itoko, Olumo rock, Oba Ademola Hospital, Ijeun, St. Pauls Igbore, Itoku and Imo Hill and these are represented as A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>, A<sub>4</sub>, A<sub>5</sub>, A<sub>6</sub>, A<sub>7</sub> and A<sub>8</sub> respectively.

### **Geology and description of the study area**

The geology in the western upland where Abeokuta South Local government is situated is underlain by rocks of the basement complex which forms a part of the African crystalline shield. The basement is composed predominantly of folded gneisses, schists and quartzite of the precambrian age to which have been emplaced by charnockitic rocks from older granite by extrusion and replacement (Morawo, 2008). Abeokuta South Local government of Ogun State is bounded in the west by Ayetoro, in the north by Abeokuta North Local government, in the east by Sagamu Local Government and in the south by Obafemi Owode. (Morawo, 2008).

### **Test Methods**

Eight trial pits of depth ranging from 0.6 – 1m were dug at various locations (Table 1). The following laboratory tests such as particle size distribution, Atterberg limits, specific gravity, natural moisture content, compaction and California bearing ratio. Three compaction efforts were used, the standard proctor (SP), West African standard (WAS) and the modified Proctor (MP) for the natural soil. The SP and WAS compaction efforts were considered for the stabilized soils. These laboratory tests were carried out in accordance with the procedures specified by the British Standard Institution (BS 1377, 1990; BS 1924, 1990) and Federal Republic of Nigeria General Specification (Road and Bridges) II of 1997. The samples that were deem unfit for subgrade construction were stabilized with ordinary Portland cement and thereafter compacted using SP and WAS.

## **2.0 RESULTS AND DISCUSSION**

### **Natural Moisture Content**

The natural moisture content of the samples ranged between 4.8 and 9.9% (Table 2). Sample A<sub>3</sub> has the highest moisture content while sample A<sub>5</sub> has the lowest moisture content. When comparing the natural moisture content with the optimum moisture content (OMC) obtained from various compaction energy levels, it was observed that all the (OMC) for modified proctor

**Table 1: Sample Location and Description.**

<b>Sample Description</b>	<b>Location No.</b>	<b>Depth (m)</b>	<b>Constituent</b>	<b>Materials</b>	<b>Colour</b>
A <sub>1</sub>	Itoko	0.7	Gravelly clay	Reddish brown	
A <sub>2</sub>	Olumu rock	0.7	Gravelly sand	Reddish brown	
A <sub>3</sub>	General Post Office	1.1	Silty clay	Yellowish brown	
A <sub>4</sub>	Oba Ademola Hospital	1.0	Silty clay	Dark brown	
A <sub>5</sub>	Ijeun	0.9	Sandy clay	Yellowish brown	
A <sub>6</sub>	St. Paul's Igbore	0.9	Silty clay	Reddish brown	
A <sub>7</sub>	Itokun	0.8	Sandy clay	Reddish brown	
A <sub>8</sub>	Imo Hill	1.0	Gravelly clay	Yellowish brown	

compactive efforts were either equal to or less than the maximum value obtained from the natural moisture content while for the West African Standard, only sample A<sub>2</sub> was found to be greater than the maximum value of the moisture content value. As for the standard Proctor, all the OMC of the samples are higher than the maximum value of the moisture content with the exception of samples A<sub>8</sub>. From these foregoing, it can be suggested that if the samples were to be used as construction material, little or no extra moisture will be required to obtain the OMC if West African Standard and modified Proctor compaction energy levels were to be used.

### **Specific gravity**

The results of the specific gravity range from 2.6 to 2.66. Samples A<sub>3</sub> and A<sub>5</sub> have the lowest values while sample A<sub>4</sub> has the highest value. The values fall within the range of specific gravity of solid of light-coloured sand, which is mainly made up of quartz as predominant mineral (Braja, 1998; Bello, 2012). This was also found to fall within the range of 2.55 to 4.6 as recommended by Maignien (1966) for lateritic soils (Table 3).

### Particle size analysis

The result of the particle size analysis is shown in Figures. 1a and b. Using the Unified Soil Classification System, sample A<sub>4</sub> has the highest value of 70.1% passing 0.075mm sieve size while sample A<sub>6</sub> has the lowest value of 23.1% passing 0.075mm sieve size. Out of all the samples, the percentage passing 0.075mm sieve size for samples A<sub>1</sub>, A<sub>6</sub>, and A<sub>8</sub> are less than 35% which showed that these samples are effective subgrade materials for Road and bridges. According to AASHTO (1986) soil classification system samples A<sub>2</sub>, A<sub>3</sub>, A<sub>3</sub> and A<sub>7</sub> were classified as A - 4, samples A<sub>1</sub>, A<sub>8</sub> were classified as A - 2 - 5, sample A<sub>6</sub> was classified as A - 2 - 7 while samples A<sub>5</sub> was classified as A - 7 - 5 soils.

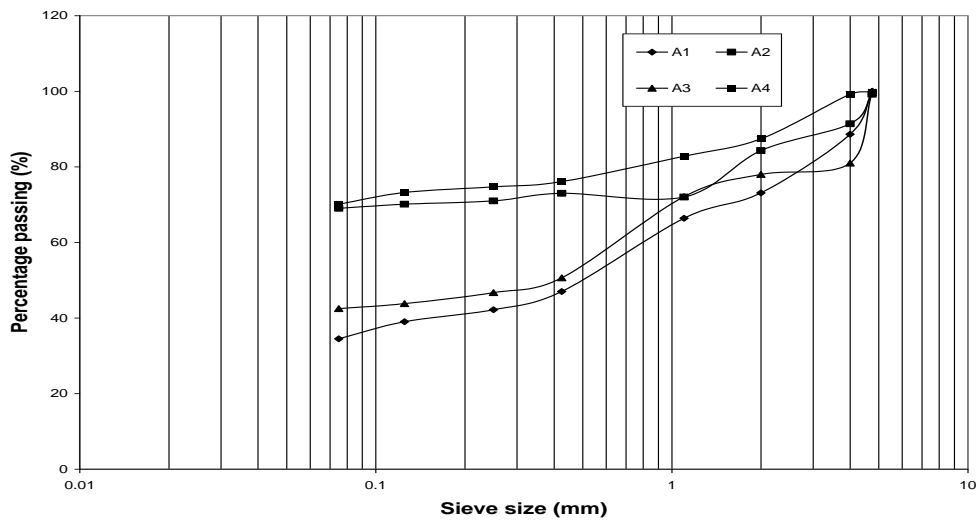


Figure. 1a: Particle size analysis for samples A<sub>1</sub> - A<sub>4</sub>

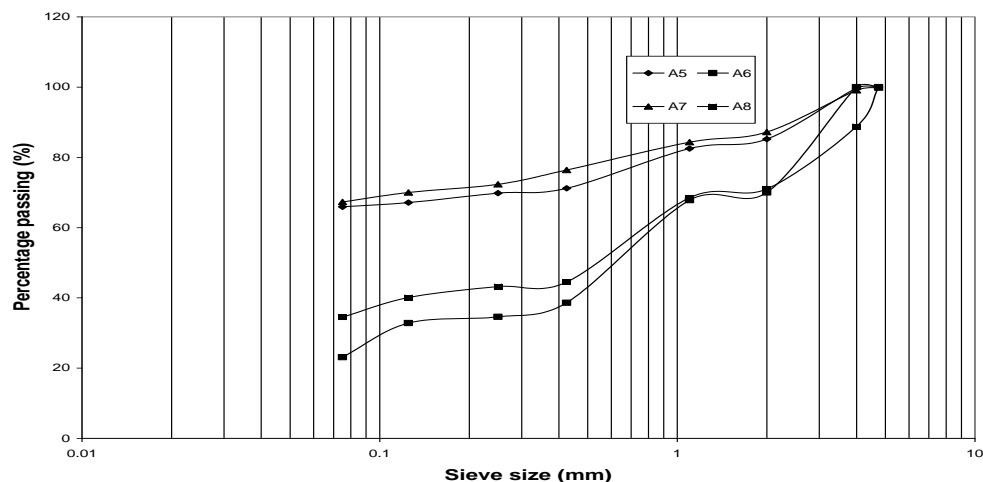


Figure 1b: Particle size analysis for samples A<sub>5</sub> – A<sub>8</sub>

Table 2: Summary of test results of soil samples

Property	Quantity range
Specific gravity, G <sub>s</sub>	2.60 – 2.66
Natural moisture content, %	4.8 – 9.9
Liquid limit, %	21.5 – 33.0
Plastic limit, %	15.4 – 20.3
Plasticity index, %	3.8 – 15.5
% Passing BS sieve, 2mm	70.0 - 87.4
% Passing BS sieve 0.425mm	38.6 – 76.4
% Passing BS sieve, 0.075mm	23.1 – 70.1
Maximum dry density (SP), Mg/m <sup>3</sup>	1.89 – 2.07
Maximum dry density (WAS), Mg/m <sup>3</sup>	1.98 – 2.10
Maximum dry density (MP), Mg/m <sup>3</sup>	1.98 – 2.18
Optimum moisture moisture (SP), %	8.90 – 12.50

Optimum moisture content (WAS), %	8.75 – 10.05
Optimum moisture content (MP), %	7.50 – 9.90
Unconfined compressive strength (SP), kN/m <sup>2</sup>	88 - 248
Unconfined compressive strength (WAS), kN/m <sup>2</sup>	152 - 240
Unconfined compressive strength (MP), kN/m <sup>2</sup>	201- 910
California bearing ratio (SP), %	5.0 – 24.50
California bearing ratio (WAS), %	7.0 - 9.0
California bearing ratio (BSH), %	9.0 – 71.5

Table 3: Natural moisture content and specific gravity of sample

Sample No.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>	A <sub>6</sub>	A <sub>7</sub>	A <sub>8</sub>
N. M. C, %	8.2	7.9	9.9	9.2	4.8	9.6	9.5	8.8
G <sub>s</sub>	2.61	2.63	2.69	2.66	2.60	2.62	2.63	2.63

### Atterberg limits

The results revealed that the liquid limit values ranged between 21.5 and 33.0% with samples having the highest and lowest values respectively A<sub>8</sub> and A<sub>6</sub> which according to Dillip and Subhrajit (2002) is non critical. Plastic limit value for sample A<sub>7</sub> was found to be 15.40% while that of A<sub>3</sub> was found to be 20.30% as the lowest and highest values respectively (Table 4). The highest and the lowest plasticity indices were found to be 3.8% and 15.5% for A<sub>2</sub> and A<sub>6</sub> respectively which were classified as marginal by Dillip and Subhrajit and (2002). Also, the soils have low swelling potential in accordance with Ola (1980).

**Table 4: AASHTO soil classification of the samples.**

Sample No.	Atterberg Limit (%)			% Passing BS sieve (mm)			Classification of soil
	LL	PL	PI	2	0.425	0.075	
A <sub>1</sub>	22.00	16.30	5.70	73.10	47.00	34.50	A – 2 – 5 (1)
A <sub>2</sub>	22.50	18.70	3.80	84.30	73.00	69.00	A – 4 (0)
A <sub>3</sub>	27.50	20.30	7.20	78.00	50.60	42.50	A – 4 (0)
A <sub>4</sub>	24.00	17.00	7.00	87.40	76.10	70.10	A – 4 (1)
A <sub>5</sub>	27.50	16.00	11.50	85.20	71.20	65.90	A – 7 – 5 (4)
A <sub>6</sub>	33.00	17.50	15.50	70.00	38.60	23.10	A – 2 – 7 (0)
A <sub>7</sub>	24.00	15.40	8.60	87.20	76.40	67.30	A – 4 (3)
A <sub>8</sub>	21.50	16.70	4.80	71.00	44.50	34.50	A – 2 – 5 (0)

### Compaction Characteristics

The maximum dry density ranged between 1.89 and 2.07Mg/m<sup>3</sup> when standard Proctor compaction energy was used It ranged between 1.98 and 2.10Mg/m<sup>3</sup> when West African Standard was used and ranged between 1.98 and 2.18Mg/m<sup>3</sup> when modified Proctor was used (Table 5). In all, the maximum dry density increased with an increase in compaction effort, while the optimum moisture content decreases with increase in compaction efforts. This has been found to be true in all soils (Braja, 1998; Bello *et al.*, 2015)

Table 5: Compaction characteristics for soil samples

Sample No.	SP		WAS		MP	
	MDD(Mg/m <sup>3</sup> )	OMC(%)	MDD(Mg/m <sup>3</sup> )	OMC(%)	MDD(Mg/m <sup>3</sup> )	OMC (%)
A <sub>1</sub>	1.90	10.60	1.99	8.90	2.10	8.90
A <sub>2</sub>	1.89	12.60	1.98	10.05	1.98	9.90

A <sub>3</sub>	1.91	11.50	2.05	9.15	2.05	8.20
A <sub>4</sub>	2.05	10.33	2.03	9.40	2.15	9.80
A <sub>5</sub>	1.98	12.21	2.0	9.70	2.15	9.20
A <sub>6</sub>	1.97	11.15	2.05	9.30	2.10	8.00
A <sub>7</sub>	1.77	11.15	2.05	9.30	2.10	8.00
A <sub>8</sub>	2.07	8.90	2.10	8.75	2.18	7.50

### **California Bearing Ratio characteristics**

Samples A<sub>1</sub>, A<sub>6</sub> and A<sub>8</sub> met the 15% minimum requirement to be used as a subgrade material using standard Proctor in accordance with Nigerian General Specification for roads and bridgeworks of 1997 (Table 6). No material met the requirement to be used as a subbase and base materials. When all compactive efforts were considered sample A<sub>8</sub> has highest CBR values followed by A<sub>1</sub> and A<sub>6</sub>. It was also observed that soils that had a higher liquid limit gave a lower California bearing ratio value which was found to agree with Gadzama (2009).

Table 6: CBR and Unconfined Compressive Strength of soil samples.

Sample No.	CBR (%)			UCS (kN/m <sup>2</sup> )		
	SP	WAS	MP	SP	WAS	MP
A <sub>1</sub>	19.20	25.3	63.50	200	580	870
A <sub>2</sub>	9.70	13.3	45.70	144	180	350
A <sub>3</sub>	9.2	12.7	28.50	120	440	550
A <sub>4</sub>	8.3	9.70	33.40	117	305	240
A <sub>5</sub>	5.0	7.0	9.0	88	152	210
A <sub>6</sub>	17.50	21.3	55.4	102	200	480
A <sub>7</sub>	7.5	11.5	25.9	195	490	770

A<sub>8</sub> 24.50 29.0 71.5 248 640 910

Attempts were made to improve the strength properties of other soil samples that failed to meet the minimum requirement for subgrade materials with ordinary Portland cement to stabilize the soils. The results are summarized in Table 7.

Table 7. California Beaming Ratio of cement stabilized soil

Sample No.	CBR (%)					CBR (%)				
	Standard Proctor					West African Standard				
	2%	4%	6%	8%	10%	2%	4%	6%	8%	10%
A <sub>2</sub>	98	170	220	249	298	115	197	213	270	340
A <sub>3</sub>	110	205	225	263	320	118	215	238	298	342
A <sub>4</sub>	125	227	280	325	408	140	269	302	394	470
A <sub>5</sub>	105	213	238	279	312	120	243	267	315	389
A <sub>7</sub>	90	172	210	270	315	110	236	259	302	357

### Unconfined compressive strength characteristics

It was also observed that sample A<sub>2</sub> and A<sub>7</sub> did not meet the minimum CBR value of 180% as specified by the Nigerian General Specification for roads and bridgeworks (1997) or stabilized soil using standard Proctor compactive effort at 4% Cement content. However, all the soil samples met the requirement using WAS compactive effort at 4% Cement content.

It was observed that (UCS) values increased with an increase in compaction energy. It was also observed that samples with lower optimum moisture content gave higher unconfined compressive strength and vice-versa which is in agreement with Braja (1999). Stabilized samples using the standard Proctor and West African Standard met the conventional UCS values of (1500-3000kN/m<sup>2</sup>) for base course of lightly trafficked roads not only at 2% Cement content but for all the ranges of stabilizers used (2-10%). Only samples A<sub>4</sub> using WAS



compactive effort at 10% cement content met the conventional UCS values of (3000-6000kN/m<sup>2</sup>) for base course of highly trafficked roads (Table 8).

Table 8. Unconfined Compressive Strength of cement stabilized soil.

Sample No.	UCS (kN/m <sup>2</sup> )					UCS (kN/m <sup>2</sup> )				
	Standard Proctor					West African Standard				
	2%	4%	6%	8%	10%	2%	4%	6%	8%	10%
A <sub>2</sub>	1550	1650	1650	1800	2000	1600	1800	1850	2000	2100
A <sub>3</sub>	1600	1700	1750	1950	2100	1650	1700	1750	2100	2000
A <sub>4</sub>	1580	1640	1800	2000	2200	1700	1900	2010	2800	3050
A <sub>5</sub>	1800	1850	1700	1850	2000	1600	1650	2000	2100	2300
A <sub>7</sub>	1700	1780	1700	1600	2000	1550	1800	1700	1950	2950

### 3.0 CONCLUSION

Soil samples from Abeokuta South Local government area, Southwestern Nigeria have been investigated. The soil samples met the minimum values of liquid limit as specified by the Nigeria general specification for roads and bridgeworks. Samples A<sub>1</sub>, A<sub>6</sub> and A<sub>8</sub> met the minimum 15% requirements for subgrade material in accordance with the Nigeria general specification for road and bridgework while the conventional CBR values of 80% minimum has not been met: but upon stabilizing with Cement at 4% cement content using standard Proctor, all the samples met the minimum CBR value of 180% with the exception of samples A<sub>2</sub> and A<sub>7</sub>. When the samples were compacted using West African Standard (WAS), all the samples met the requirement. The maximum dry density increases with compactive efforts while the optimum moisture content decreased with compactive effort for the samples. The Unconfined Compressive Strength (UCS) values increased with compactive effort and decreased with increase in degree of saturation of the soil samples. On stabilizing the soil samples with cement, the samples met the conventional UCS values of (1500-3000kN/m<sup>2</sup>) for

base course of lightly trafficked roads while only sample A<sub>4</sub> compacted at 10% cement content using WAS compactive effort met the minimum (3000 - 6000 kN/m<sup>2</sup>) for base course of highly trafficked road.

## **REFERENCES**

AASHTO (1986). Standard Specifications for Transportation Materials and Methods of Sampling and Testing, American Association for State Highway and Transportation officials, 14th Ed. Washington, D.C.

Ackroyd, L.W. (1967). The formation and properties of concretionary and concrectionary soils in Western Nigeria, Proceedings 4<sup>th</sup> Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Cape Town, South African.

Adeyemi, G.O. and Abolurin, SB. (2000). Strength Characteristics of a chemically stabilized lateritic soil from kilometer 4, Ile-ife/Sekona road, Southwestern Nigeria. *Journal of Mining and Geology*. 36(1):113-119.

Atkins, HN. (1980). Highway Materials, soil and concrete. Reston Publishing Company Incorporation, USA.

Bello, AA. (2012). Geotechnical Evaluation of Reddish brown Tropical Soil. *Journal of Geotechnical and Geological Engineering*, Springer publication, Heidelberg, Germany. 30(2):481-498

Bello, AA, Ige, JA and Adebajo, UA. (2015). Flexible Pavement Assessment of selected Highways in Orolu Local Government South Western Nigeria, *British Journal of Applied Science and Technology*, 7(1):46-61

Bello, AA., Awogboro, OS and Ajamagbiso, OA. (2016). Flexible Pavement Assessment of selected Roads in Odo-Otin Local Government, South Western Nigeria, *Journal of Advances in Technology and Engineering Research*, 2(3):66-80.

Bello, AA and Olaore, G. (2017). Geotechnical properties of Lateritic soils from Ipetu-Ijesa Campus of Osun State University. *Uniosun Journal of Sciences*, Publication of Osun State University, 2(1):74-83

Braja, M.D. (1998). Principles of Geotechnical Engineering, Fourth Edition by PWS Publishing Company, Boston. Pp. 69

- Braja, MD. (1999). Principle of Foundation Engineering, Fourth Edition by PWS Publishing Company, Boston. Pp.62.
- BSI (1990). 'Methods of testing soils for civil engineering purposes. British Standards Institution, BS 1377, London.
- BSI (1990). 'Methods of testing for stabilized soils'. British Standards Institution, BS 1924, London.
- Dillip, KB and Subhrajit, D. (2002). Gate – Civil Engineering. Cyber Tech. Publications ,New Delhi.
- Gadzama, EW (2009). Evaluation of soil sample from Federal University of Technology, Yola State,. Nigeria Journal of Engineering,15(2):80 – 88.
- Maignien, R. (1966). 'Review of research on laterites', UNESCO Natural Resources Research IV. Paris: 148
- Mc Knight, TL. (1993). Physical geography; a landscape appreciation. Fourth Edition, Englewood Cliff NJ:Prentice Hall.
- Morawo, SA. (2008). Geotechnical properties of lateritic soil as highway pavement construction materials in Abeokuta South Local government of Ogun State. Unpublished B. Tech. Thesis. Dept. of Civil Engrg., Ladoke Akintola University of Technology, Ogbomosho.
- Nigeria General Specification (1997). Bridges and Road Works. Federal Ministry of Works and Housing, Headquarters, Abuja, Nigeria. Vol. 11 (Revised)
- Ola, SA. (1975). Stabilization of Nigerian Laterite soils with cement, bitumen and lime. Proceedings of the sixth Regional conference for Africa on Soil Mechanics and Foundation Engineering, Durban,1:145-152.
- Ola, SA. (1980). Mechanical Properties of concretionary laterites from Rain Forest and Savannah Zones of Nigeria. Bulletin of International Association of Engineering Geology, Paris, 21-26.

## **EFFECT OF PH AND SUGAR LEVEL ON HEAT RESISTANCE OF *ESCHERICHIA COLI* IN SWEET ORANGE JUICE (*CITRIUS SINENSIS*) SOLD IN KAURA NAMODA MARKET.**

Hassan, A.B., Tanko, H.O. and Adegboye, Y..

Department of Science Lab. Tech & Department of Hotel & Catering Management, School of Science and Technology, Federal Polytechnic, Kaura Namoda. Zamfara State. Nigeria.

Email: [hassanadebayobamidele@gmail.com](mailto:hassanadebayobamidele@gmail.com) and [Hassanmmusaa@yahoo.com](mailto:Hassanmmusaa@yahoo.com)

Phone: +2348034269002

### **ABSTRACT**

The effect of pH and sugar levels on the microbiological properties of sweet orange juice was evaluated. Microbial analysis of the treated Orange juice (*Citrus sinensis*) sold in kaura namoda were determined using standard method. The standard method of Prescott [12] was used. The microbial load of the producer reduced as the concentration of the derived preservatives increased. Both pH and sugar level used had inhibitive effect on the test organism. The result revealed that the use of pH and sugar level as hurdles should be encouraged in processing food products.

***Key words: pH; sugar; hurdle technology; orange-juice.***

### **1.0 INTRODUCTION**

pH is a scale used to specify how acidic or basic a solution is. Acidic solution have lower pH, while basic solutions have a higher pH. The pH measurement is used in a wide variety of applications: Agriculture, waste water treatment, industrial processes, environmental monitoring and in research and development. It is the negative of the base10 logarithm of the activity of the hydrogen ion [1,2].

Sugar is the generic name for sweet tasting soluble carbohydrate, many of which are used in food. The various types of sugar are derived from different sources. Simple sugars are called monosaccharide and include glucose [dextrose], fructose and galactose. "Table sugar" or granulated sugar refers to sucrose a disaccharides of glucose and fructose. In the body, sucrose is hydrolyzed into fructose and glucose. Sugar are found in the tissue of most plant but sucrose is especially concentrated in sugar cane and sugar beet, making them ideal for efficient

commercial extraction to make refined sugar[3]. The microbial safety of orange juice is based on a combination of several empirically applied preservative hurdles, and more recently on knowing how to employ hurdle technology. Deliberate and intelligent application of hurdle technology allows gentle but efficient preservation of food is advancing worldwide. Hurdles are applicable not only to microbiological quality, but also other quality aspect of foods, although this area of knowledge has been much less explored than the microbiological aspects [4].

Orange juice refers to the juice of oranges. It is made by extraction from fresh fruits by desiccation and subsequent reconstitution of dried juice or by concentration of the juice and subsequent addition of water to the concentrate [5]. Orange comes in several varieties including blood oranges, navel oranges, Valencia oranges, Clementine and tangerine.

Gargia-Garcia et al. [6] investigated the effect of hurdle technology applied to prickly pear beverages for inhibiting *S.Cerevisiae* and *Escherichia coli*. Their findings revealed that the addition of Sodium benzoate and Potassium sorbate had a synergistic effect on the organisms which is desirable to maintain prickly pear beverages for 21 days /25°C. Further works by Ohlsson and Bengtsson [7] on vegetable fermentation indicated that the desired product quality and microbial stability were achieved by a combination of factors such as salt and acidifications. According to Ohlsson and Bengtsson[8] hurdle technology provides a framework for combining a number of milder preservation techniques to achieve and enhance level of products safety and stability and that hurdle technology is increasingly used for food design in industrialized and developing countries for optimizing fruits juices. Hurdle technologies the process of employing the intelligent combination of different hurdles or preservation techniques to achieve multi-target, mild but reliable preservation effects Velugoti [9] and Rahman [10]. The aim of this work was to determine the heat resistance of *Escherichia coli* in Orange juices as influenced by pH and Sugar level.

## **2.0 MATERIALS AND METHODS**

### **2.1 Source of Raw Material**

Citric acid (Food chem. brand) used was obtained from the Department of Food Science and Technology Federal Polytechnic, Kaura Namoda, Zamfara state, Nigeria. Sugar and Oranges was obtained from the Kaura Namoda main market. Graphs

1-6 reflects the logarithms of *E.coli* survivors at respective time and temperature 1-4 mins and

60°C-80°C respectively. The D value or decimal reduction time is the time (or dose) required data given condition or set of condition to achieve a log reduction of 90% (1 log) of relevant microorganisms. The D-Values for this study are reflected in the Graphs 7-12.

### **2.2 Processing Method**

#### **2.2.1 Processing of orange juice**

The modified method of Aurelie et al.[11] was used for orange juice production as shown in Fig.1. The oranges were sorted by hand, cooled and peeled with knife. It was then washed with water and the juice was extracted using the juice extractor and filtered using a Muslin Cloth.

#### **2.2.2 Microbiological analysis of the orange juice**

The method of Prescott [12] was used to determine the total viable count. The orange juice was seeded with *Escherichia coli* to determine microbial counts with the help of nutrient agar. A wire loop was used to extract the microorganisms into a test tube containing 10ml peptone water which was immediately covered with cotton wool. The samples were kept for 24 hours, at this time the microorganisms were evenly distributed among the peptone water. Pour plate method was used. 3ml of the diluents

was pour plated into Petri-dishes and then the number of colonies counted using the formula. TVC (CU/g) = (Number of colonies x original concentration) / (Dilution factor x volume of inoculum). CFU = Colony Forming Unit.

### 2.3 Statistical Analysis

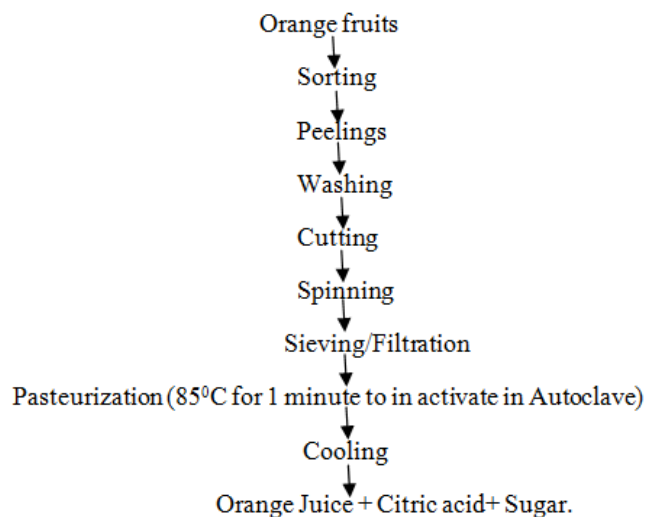
Data acquisition were subjected to Analysis of Variance (ANOVA) followed by Duncan's new multiple range test (DNMRT) to compare treatment means. Statistical significance was accepted at  $[p \geq 0.05]$  Steele and Torrie [13].

## 3. RESULTS AND DISCUSSION

Effects of chemical preservatives on the growth of *Escherichia coli* in orange juice are presented in Tables 1-6 at different levels of temperatures [60°C, 70°C, 75°C and 80°C] time [1.4 mins] in water bath respectively. As the concentration of the chemical preservatives increased, a remarkable decrease in the bacterial biomass was recorded. This agrees with the findings of [6]. In this study it was observed that concentration and combination of preservative alone reduced growth of the microorganism but was unable to prevent growth of the test organism [14]. The application of the heat reduced the population of the microorganisms and weakened their ability to germinate. The introduction to heat was vital as the combination

Of both chemical preservatives of pH4.0,5.5% and 0,2,4% sugar level respectively and heating for 1-4 mins in water bath reduced growths of the orange juice. The heat may have affected the DNA while the hostile environment, which include the presence of chemical preservatives, as another hurdle was difficult for the organism to overcome as reported by [14]. At a higher temperatures and higher time there was no significant growth at sample 6 recorded at four minutes at 80°C [4] as presented in Figure [6]. The growths generally in a strong acidic medium of pH4.0 were less than growth in a weakly acidic medium of pH 5.5, this is because microorganisms survive less in strong acidic medium and possibly due to the fact that citrus fruits are acidic plus the high sugar content of about 20-25% present naturally plus the 4% and 2% sugar added which bind the water in the Orange juice together. Making it difficult for microbial growth and multiplication than a weakly acidic medium.

Microbial result revealed Sample A and B have the highest growth, growth in sample C were not too different from sample D, but less compare to sample D, low counts were obtained in Sample E and F respectively which indicates low level of microorganisms in orange juices due to the acidic nature of the citrus fruit and high chemical preservative which probably inhibit some of the microbes.



**Fig.1. Production flowchart for orange juice**

*Source: Aurelie et al. [11]*



**Table1. Microbial count of *E.coli* pH 5.5 and 0% sugar in orange juice [SampleA]**

Heating Time(mins).	<i>E.coli</i> survivors (LogCfu/mL)			
	Temperatures (°C)			
	60	70	75	80
0	1.9X10 <sup>5a</sup>	1.9X10 <sup>5a</sup>	1.9X10 <sup>5a</sup>	1.9X10 <sup>5a</sup>
1	1.9X10 <sup>4b</sup>	11.1X10 <sup>4b</sup>	1.00X10 <sup>4b</sup>	9.90X10 <sup>3b</sup>
2	1.9X10 <sup>3b</sup>	1.112X10 <sup>3b</sup>	1.004X10 <sup>3c</sup>	9.91X10 <sup>2c</sup>
3	1.9X10 <sup>2b</sup>	1.05X10 <sup>2c</sup>	1.04X10 <sup>2c</sup>	99.4X10 <sup>2d</sup>
4	18.4X10 <sup>1c</sup>	11.0X10 <sup>1c</sup>	0.9X10 <sup>1d</sup>	9.3X10 <sup>0d</sup>
LSD	8.26	8.14	7.80	6.34

Means with same superscript down the column are not significantly ( $P \geq 0.05$ ) different

**Table 2. Microbial count of *E.coli*, pH 5.5 and 2% sugar [SampleB]**

Heating Time(mins)	<i>E.coli</i> survivors (Logcfu/ml)			
	Temperatures(°C)			
	60	70	75	80
0	5.80X10 <sup>4a</sup>	5.80X10 <sup>4a</sup>	5.80X10 <sup>4a</sup>	5.80X10 <sup>4a</sup>
1	8.810X10 <sup>3b</sup>	4.04X10 <sup>3b</sup>	4.04X10 <sup>3b</sup>	1488.1X10 <sup>1b</sup>
2	8.81X10 <sup>2b</sup>	4.39x10 <sup>2c</sup>	190.1x10 <sup>1c</sup>	148.1x10 <sup>1c</sup>
3	88.4x10 <sup>1c</sup>	4.4x10 <sup>1c</sup>	1.9x10 <sup>1d</sup>	14.5x10 <sup>1d</sup>
4	9.0x10 <sup>0c</sup>	4.2x10 <sup>0d</sup>	2.0x10 <sup>0d</sup>	1.2x10 <sup>0d</sup>
LSD	7.12	6.91	5.54	5.04

Means with same superscript down the column are not significantly ( $P \geq 0.05$ ) different

**Table 3. Microbial count of *E.coli* pH 5.5 and 4% sugar [SampleC]**

Heating Time(mins)	<i>E.coli</i> survivors (Logcfu/ml)			
	Temperatures(°C)			
	60	70	75	80

0	4.06X10 <sup>4a</sup>	4.06X10 <sup>4a</sup>	4.06X10 <sup>4a</sup>	4.06X10 <sup>4a</sup>
1	4.20X10 <sup>3b</sup>	3.50X10 <sup>3b</sup>	1.9x10 <sup>3b</sup>	1.009x10 <sup>3b</sup>
2	4.2X10 <sup>1b</sup>	3.51X10 <sup>2c</sup>	1.89X10 <sup>2c</sup>	1.01X10 <sup>2c</sup>
3	4.1X10 <sup>1c</sup>	3.3X10 <sup>1d</sup>	18.8X10 <sup>1d</sup>	9.9X10 <sup>1d</sup>
4	4.0x10 <sup>0c</sup>	3.2x10 <sup>0d</sup>	1.9x10 <sup>0d</sup>	1.0x10 <sup>0e</sup>
LSD	5.19	4.91	4.45	4.11

Means with same superscript down the column are not significantly ( $P \geq 0.05$ ) different

**Table 4. Microbial count of *E.coli* pH4.0 and 0%sugar [SampleD]**

Heating Time(mins)	<i>E.coli</i> survivors (Logcfu/ml)			
	Temperatures(°C)			
	60	70	75	80
0	4.2X10 <sup>4a</sup>	4.2X10 <sup>4a</sup>	4.2X10 <sup>4a</sup>	4.2X10 <sup>4a</sup>
1	6.04X10 <sup>3b</sup>	3.5X10 <sup>3b</sup>	1.901X10 <sup>3b</sup>	1.70X10 <sup>3b</sup>
2	6.03X10 <sup>2b</sup>	3.52X10 <sup>2c</sup>	1.91X10 <sup>2c</sup>	1.72X10 <sup>2c</sup>
3	6.1X10 <sup>1c</sup>	3.5X10 <sup>1d</sup>	1.9X10 <sup>1c</sup>	1.8x10 <sup>1d</sup>
4	6.0X10 <sup>0c</sup>	3.4X10 <sup>0d</sup>	2.0X10 <sup>0d</sup>	1.8X10 <sup>0d</sup>
LSD	5.28	5.01	4.91	4.13

Means with same superscript down the column are not significantly ( $P \geq 0.05$ ) different

**Table 5. Microbial count of *E.coli* pH 4.0 and 2% sugar [SampleE]**

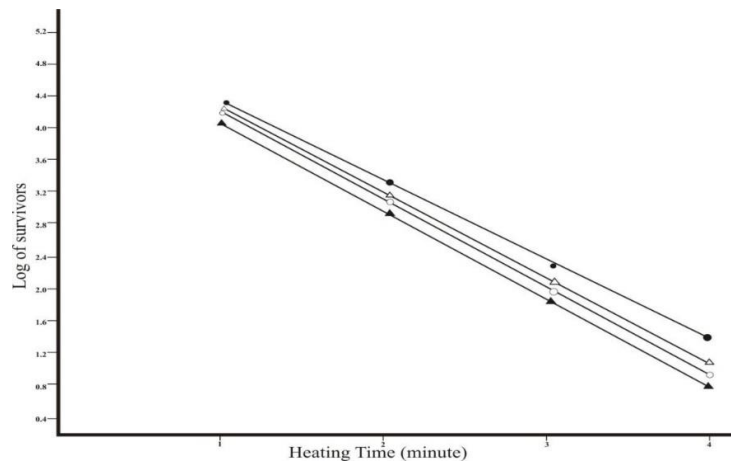
<b>Heating</b>	<b><i>E.coli</i> survivors(logcfu/ml)</b>			
<b>Time(mins)</b>	<b>Temperatures(°C)</b>			
	<b>60</b>	<b>70</b>	<b>75</b>	<b>80</b>
0	3.5X10 <sup>3a</sup>	3.5X10 <sup>3a</sup>	3.5X10 <sup>3a</sup>	3.5X10 <sup>3a</sup>
1	3.10X10 <sup>3b</sup>	1.990X10 <sup>3b</sup>	1.310X10 <sup>3b</sup>	6.20X10 <sup>2b</sup>
2	3.11X10 <sup>2b</sup>	1.99X10 <sup>2b</sup>	1.24X10 <sup>2c</sup>	62.2X10 <sup>1c</sup>
3	3.1X10 <sup>1c</sup>	2.0X10 <sup>1c</sup>	12.4X10 <sup>1d</sup>	4.9X10 <sup>0d</sup>
4	3.0X10 <sup>0d</sup>	1.9X10 <sup>0d</sup>	1.0X10 <sup>0e</sup>	–
LSD	3.14	2.05	2.05	1.45

*Means with same superscript down the column are not significantly (P≥0.05) different*

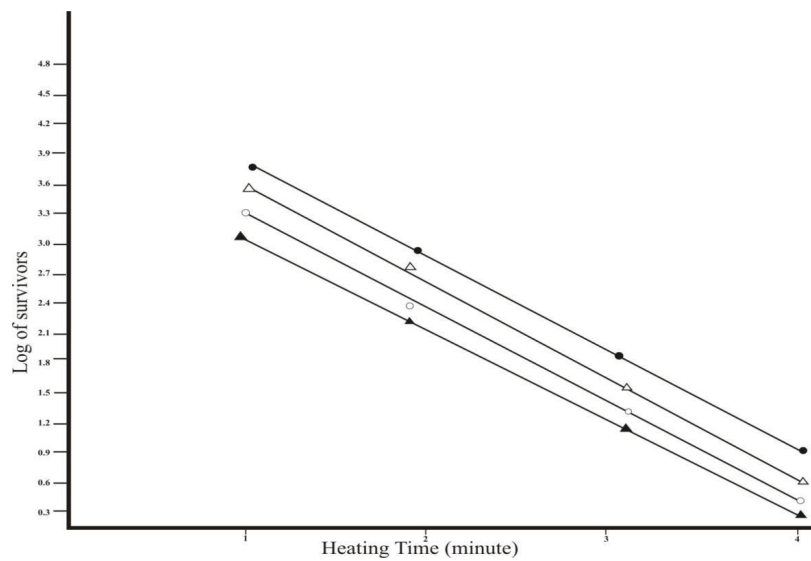
**Table 6. Microbial count of *E.coli* pH 4.0 and 4% sugar [SampleF]**

<b>Heating</b>	<b><i>E.coli</i> survivors (logcfu/ml)</b>			
<b>Time(mins)</b>	<b>Temperatures(°C)</b>			
	<b>60</b>	<b>70</b>	<b>75</b>	<b>80</b>
0	2.70X10 <sup>4a</sup>	2.70X10 <sup>4a</sup>	2.70X10 <sup>4a</sup>	2.70X10 <sup>4a</sup>
1	2.710X10 <sup>3 b</sup>	1.90X10 <sup>b</sup>	1.90X10 <sup>b</sup>	4.49X10 <sup>2b</sup>
2	2.69X10 <sup>2c</sup>	1.70X10 <sup>2b</sup>	120.1X10 <sup>2c</sup>	44.4X10 <sup>1c</sup>
3	2.7X10 <sup>1c</sup>	16.4X10 <sup>1c</sup>	11.9X10 <sup>1d</sup>	3.4X10 <sup>0d</sup>
4	2.3x10 <sup>0d</sup>	1.6X10 <sup>0d</sup>	1.0X10 <sup>0e</sup>	–
LSD	2.19	1.42	1.05	0.49

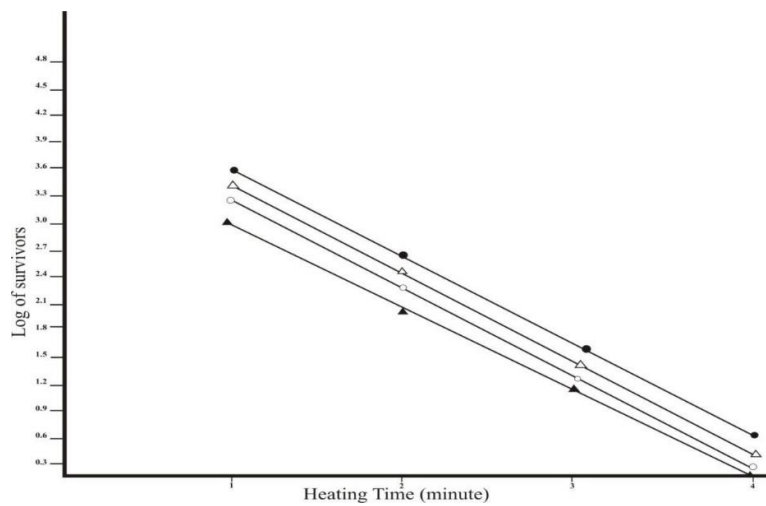
*Means with same superscript down the column are not significantly (P≥0.05) different*



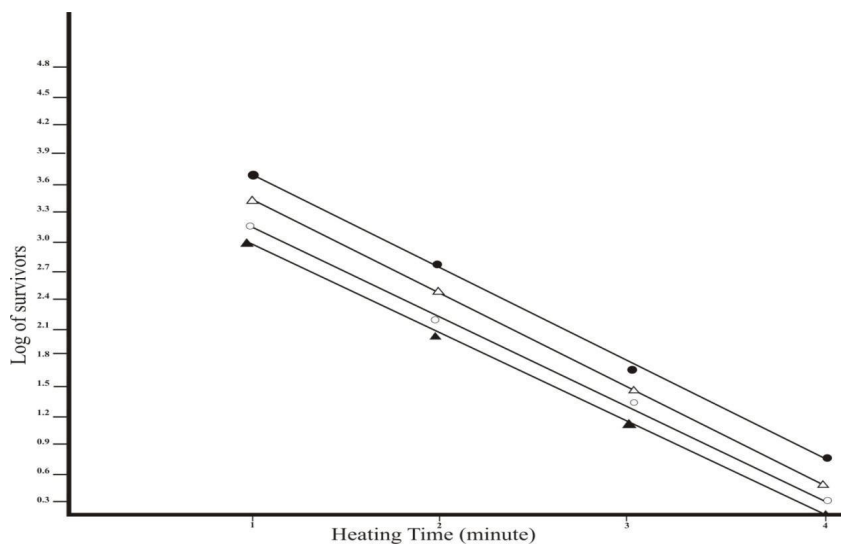
**Fig.1. Log of *E.coli* survivors against heating time (mins) in orange juice of pH 5.5 and 0% Sugar at 60(□),70(Δ),75(○)and80(▲)°C respectively**



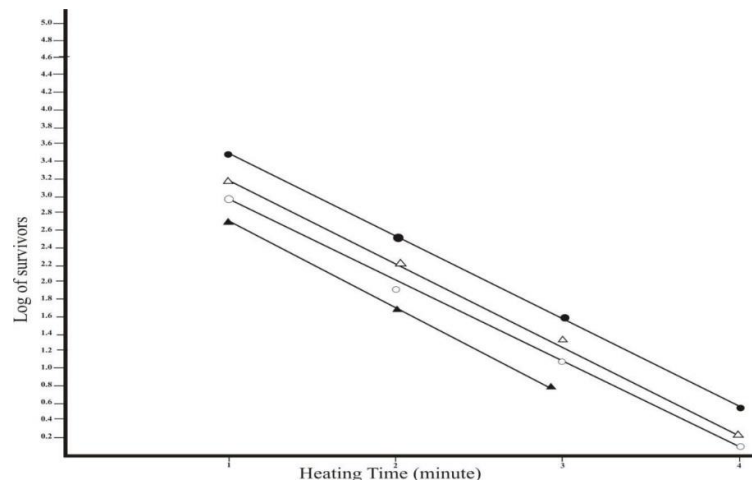
**Fig. 2. Log of *E.coli* survivors against heating time (Mins) in orange juice of pH 5.5 and 2% Sugar at 60(□),70(Δ),75(○)and80(▲)°C, respectively**



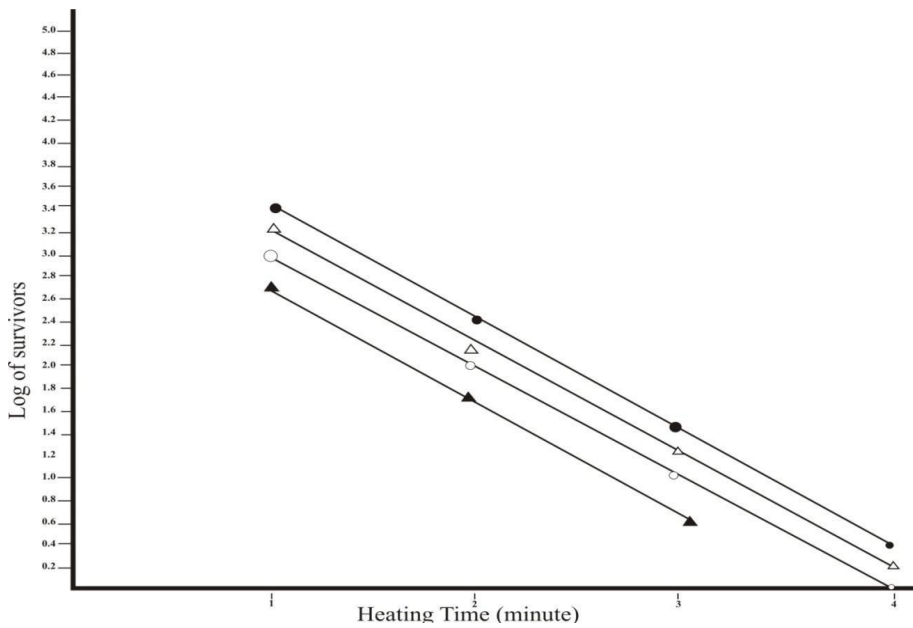
**Fig 3. Log of *E.coli* survivors against heating time (mins) in orange juice of pH5.5 and 4% sugar at 60(□), 70(Δ), 75(○) and 80(▲)°C respectively**



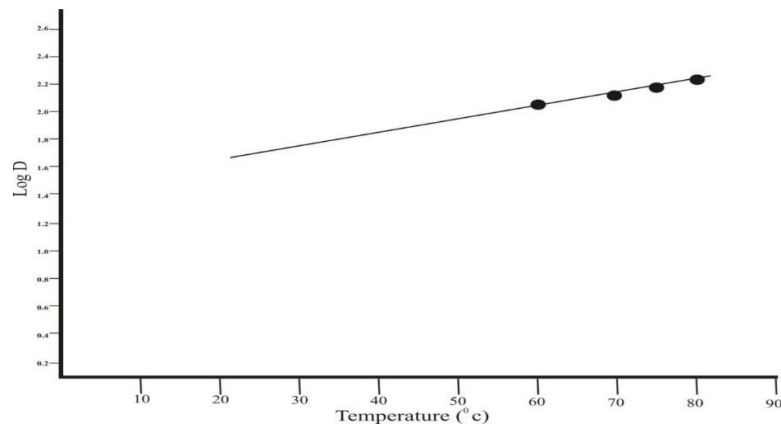
**Fig.4. Log of *E.coli* survivors against heating time (mins) in orange juice of pH4.0 and 0% Sugar at 60(□), 70(Δ), 75(○) and 80(▲)°C respectively**



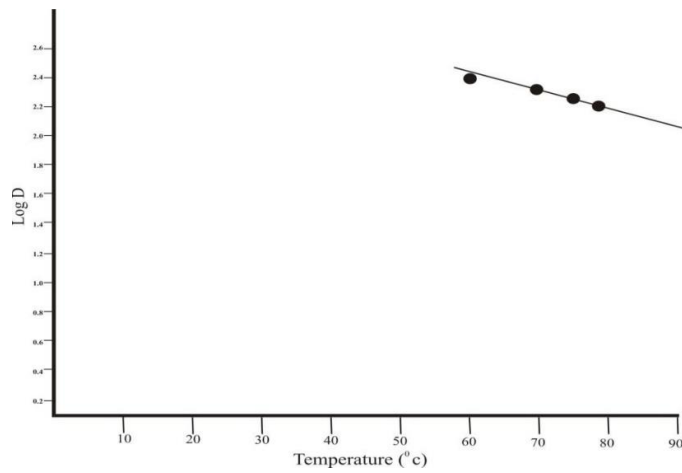
**Fig.5. Log of *E.coli* survivors against heating time (Mins) in orange juice of pH 4.0 and 2% Sugar at 60(□),70(△),75(○)and80(▲)°C respectively**



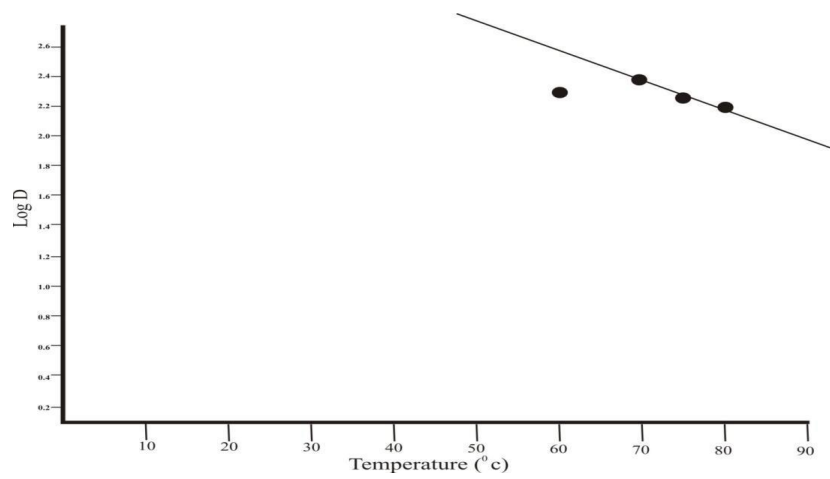
**Fig.6. Log of *E.coli* survivors against heating time (Mins) in orange juice of pH 4.0 and 4% Sugar at 60(□),70(△),75(○)and80(▲)°C respectively**



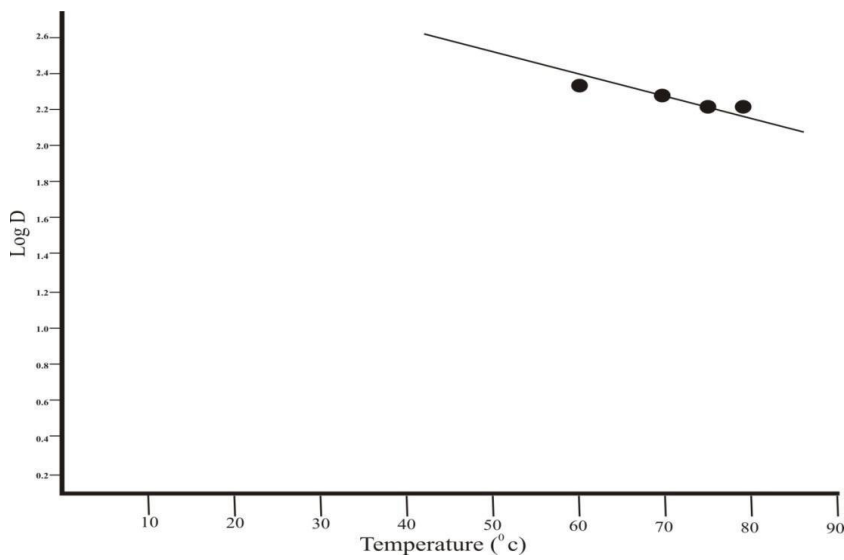
**Fig.7. Log D of *E.coli* survivors against temperature in orange juice of pH 5.5 and 0% sugar (Sample A)**



**Fig.8. Log D of *E.coli* survivors against temperature in orange juice of pH 5.5 and 2% sugar (Sample B)**

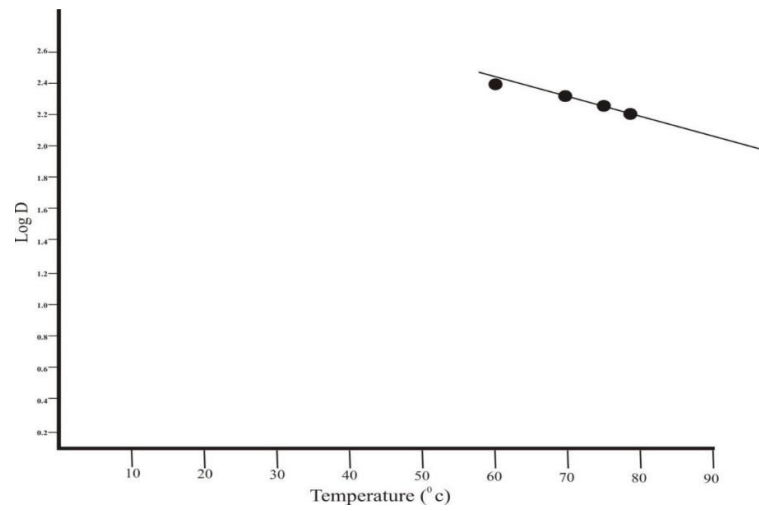


**Fig.9. Log D of *E.coli* survivors against temperature in orange juice of pH 5.5 and 4% sugar (Sample C)**

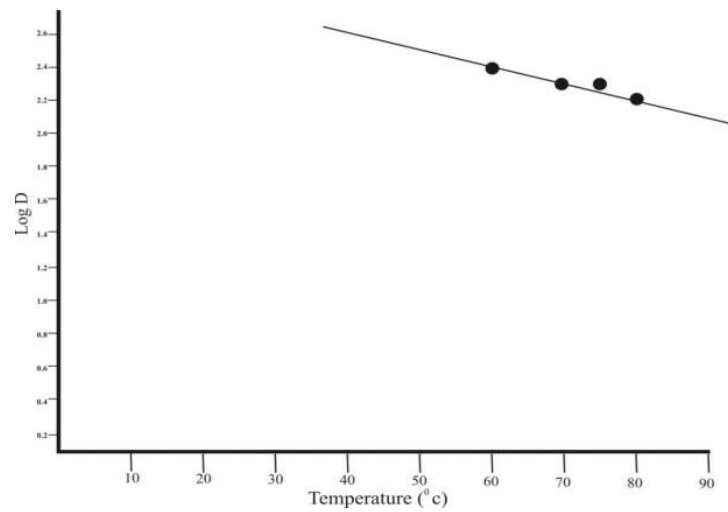


**Fig.10. Log D of *E.coli* survivors against temperature in orange juice of pH 4.0 and 0% Sugar (Sample D)**





**Fig.11. Log D of *E.coli* survivors against temperature in orange juice of pH 4.0 and 2% Sugar (Sample E)**



**Fig.12. LogD of *E.coli* survivors against temperature in orange juice of pH4.0 and 4% Sugar (Sample F)**

## CONCLUSION

The work has shown that there was drastic inhibition of the test micro-organism by the application of chemical preservatives and heat treatment. There were fewer growths in the orange juice samples when chemical preservatives were used at higher temperature. The bacteria growths of the treated samples were significantly affected by the hurdle treatment when compared to the control. This led to a significant reduction in the bacterial load. It is recommended that a single hurdle should not be used in the preservation of orange juice. Hurdle application improves greatly the microbial stability and safety of orange juice thus consumer safety. Commercial processors of orange juice is encouraged to apply these hurdles at a pH 4.0 and 4% sugar levels respectively.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Lim KF. Negative pH does exist. *Journal of Chemical Education*. 2006;83(10):1465-1469.
2. Myers RJ. One hundred years of pH. *Journal of Chemical Education*. 2010;87(1):30-32.
3. World Health Organization. Guideline on sugar intake for adults and children. Geneva;2005.
4. Leistner L. Combined method for food preservation. In: Rahman MS, (Ed). *Handbook of Food Preservation*. CRC. Boca Raon, FL. 2007;867-894.
5. U.S. Food and Drug Administration Inspection guides-sterilizing Symbols (D, Z AND F). Available: [www.Fda.gov](http://www.Fda.gov) (Retrieved 2018-09-28)
6. Garcia-Garcia R, Avelianeda E, Tejada- Ortigoza V, Martin-Belloso A. Hurdle technology applied in prickly pear beverages for inhibiting *Saccharomyces cerevisiae* and *Escherichia coli*. *Letters in Applied Microbiology*. 2015;60:558-564.

7. Ohlsson T, Bengston. The hurdle concept of minimal processing technology in the food industry. CrcPress, New York. 2013;175-195.
8. Ohlsson T, BengstonN. The hurdle concept of minimally processed foods. 2012;3:17-25.
9. Velugoti PR, Bohra LK, Juneja VK, Huang L, Wasseling AL, Subbiah J, Thippareddi H. Dynamic model for predicting growth of *Salmonella* spp. in ground sterile pork. Food Microbiol. 2011;28:796-803.
10. Rahman MS. Applications of macro-micro region concept in the state diagram and critical temperature concepts in determining the food stability. Food Chem. 2012;132:1679-1685.
11. Aurelie CR, Veronique B, Julien C. Nutritional composition of orange juice: A comparative study between French commercial and homemade juices. Food and Nutrition Sciences. 2016;7:252-261.
12. Prescott LM, Harely JP, Klein OA. Microbial nutrition, types of media. In: Microbiology, 6<sup>th</sup> Edition, McGraw-Hill Publishers, New York. 2005;95-105.
13. Steele RGD, Torrie JH. Principles and procedures of statistics. 2<sup>nd</sup> Ed. McGraw Hill Book Co. Inc. New York; 1980.
14. Carrasco E. Del, Rosal S, Racero JC, Gimeno RM. A review on growth/nogrowth *Salmonella* models. Food Research Int. 2012;47:90-99.

## **USERS' LEVEL OF AWARENESS ON GREEN FEATURES IN RESIDENTIAL BUILDINGS: EXPERIENCE FROM IBADAN MUNICIPALITY, NIGERIA**

Adejumo, A.O.<sup>1</sup>, Oyedele, D.J.<sup>2</sup> Adeosun, J.O.<sup>1</sup> and Eluleye, P.K.<sup>3</sup>

<sup>1</sup>Osun State University, Osogbo

<sup>2</sup> Obafemi Awolowo University, Ile-Ife

<sup>3</sup>Osun State College of Technology Esa Oke

Corresponding author: [abiodun.adejumo@uniosun.edu.ng](mailto:abiodun.adejumo@uniosun.edu.ng),

### **ABSTRACT**

The need for the society to be aware of various means available to help in conserving the environment is crucial. This gives rise to the current study on the need to determine the level of awareness on green features in residential buildings of Ibadan municipality, Nigeria with a view to providing information that could guide real estate investors to invest in green building and also serves as a tool for environmental sustainability. The study population comprised residents in the five local government area of Ibadan municipality. Using systematic sampling, 267 households were selected for questionnaire survey. Questionnaires were administered on household heads in the study area. Data obtained were analysed using descriptive and inferential statistics. The study established that only 24.7% of the populations were aware of green features in residential buildings, 34.5% had slight awareness and 37.5% were not aware of green features in residential buildings. Users mostly prefer features like: water conservation (4.35), indoor environmental qualities (4.25), material conservation (4.24), energy conservation (4.19), sustainable landscaping (4.21), and availability of regular maintenance schedule (3.90). The study reveals that there is low level of awareness especially among the poorly educated function of the population therefore there is need to improve education level of the population in order to improve the awareness of the population on green building features.

**Keywords:** Environmental degradation, Environmental Sustainability, Green buildings, Green features, Awareness, Ibadan Municipality.

## **1.0 INTRODUCTION**

The global production and consumption level of humans are depleting the nature and environment at a persistent and degrading higher rate. As the Population increases, humans rely more on the use of natural resources such as: minerals petroleum, coal, gas and so on. Also, natural ecosystem creation (birds, insects, mammals) declined and this has negative impact on human lives and system of living. In the same vein human developmental activities such as construction activities also contribute to environmental degradation. However, all these occurrence gives rise to needs for Environmental sustainability as this tends towards protecting and maintaining the environment for future generation through the shift to renewable energy resources, protect health of ecosystem, avoid excess pollution, making an appropriate decision based long-term consequences target welfare and GDP. In quest to find lasting solution to environmental challenges, global attention was drawn to green building initiative, lunched by the United Nations at a conference in 1992 held at Rio de Janerio Brazil in order to sustain the environment. Also, African nation forester her own initiative in 2010 at a conference held in Nairobi Kenya to promote green building rating in African cities and reduce the effect of climate change. As these draws more attention to green building initiative across globe.

Therefore Green Building has defined by World Green Building Council (WGBC) is a building that its design, construction and operation reduces or eliminate negative impacts and create positive impact on climate and natural environment and also preserve natural resources and improve quality of live and at the same time produce building that will serve its original purpose. More so, green building serves in the capacity of conserving the rate of energy consumption, material conservation and the likes. Certain qualities must be present in green building which is known as Green Features such as : energy conservation ( efficient use of renewable energy), waste conservation (recycling and re-use of waste), good environmental air quality ( well-ventilated area within the building space), material conservation (use of non-toxic and re-use of waste materials), consideration of the environment in design construction operation, consideration of quality of life to suite occupant designs, flexible design that enables the adaptation to a changing environment. For the building to be fully certified as green building it most possess all the above listed features (WGBC 2019).

In Nigerian cities, environmental degradation persists with serious problems as a result of construction activities. Tomori (2007) observed that environmental crises such as flooding,

pollution, climate change and global warming are causing serious problems in urban residential areas. These problems have implications on the urban residents and the environment. One of the important ways by which the effects of environmental crises emanating from construction activities can be ameliorated is through the incorporation of green features in residential buildings. Likewise, also there need for proper awareness on the stakeholders and the residents of Ibadan municipality about green building features the benefits on both lives and their immediate environment.

In Nigeria, most studies examined the incorporation of green features in commercial properties (Abolore, 2012; Ogunbode and Kate 2012; Waniko 2014; ; Oyewole and Komolafe, 2015). Nevertheless, existing literature have not extensively established the level of public awareness on green building features as this will be done to sensitize the public on the benefits derivable in embracing the concept of green building features. Therefore, the study seeks to examine the level of awareness on green features in residential buildings with particular reference to Ibadan municipality. Information obtained from this study would be a useful guide for real estate investors and developers in providing green buildings in the study and other cities of developing countries with similar physical, social and economic characteristics and also serves as a tool for environmental sustainability.

## **Literature Review**

Environmental sustainability is one of the recent challenges confronting humanities across the globe which seeks urgent attention. However, different means have been identified as a way to militate against environmental problems such as evolution of green buildings as a means of conserving the environment in a natural way.

Therefore Green building initiative has received a warm embrace across the globe, it has being confirmed by World Green Building Council that it's a great potential for significantly reduces greenhouse gas emission (UNEP 2009), studies reveals that green building has a saving potential of about 84 gigatons of CO<sub>2</sub> by the year 2050 through the direct measures such as energy efficiency, fuel switching (UNEP 2016). Also, Australia certified that 62% fewer green gases emissions, Indian Green Building Council results shows that the energy saving rate is at 40-50%, water saving rate is 20-30% when compare with the conventional building in use. In African, South African study reveals that the average saves of 30-40% energy and carbon

emission every year and 20-30% water every year. LEED (Leadership in Energy and Environmental Design) certified that in US and some other countries consume 25% less energy and 11% less water than non-green buildings, it's also has economic benefits such as low cost of building construction increase property value which will encourage the real estate investors or developer to embrace the initiative and also saving utility bills for tenants and households. On the other hand, Awareness can be said to create a base audience for a product, services or issue, it could also mean enlightening people and being exposed to a particular message severally before the message becomes successful. Therefore, formal knowledge and awareness for building users or residents is an important mechanism for developing green building knowledge and to also identifying the green building features.

Several studies ( Ameh, et al. 2007; Alnaser and flanager 2007; gale and Edward 2011; susilawati and al-surf 2011; Umar and Khamidi 2008, 2012, Ogunbode and Kate 2012; waniko 2014) have been conducted on awareness of green building in recent time.

Therefore, study according to Umar and Khamidi (2008) established that awareness on green building refers to ideal strategic model and promotion exercise which aids people to understand why a particular issue is essential and the desires of goals and what is necessary to accomplish a task. Ameh et al (2007) affirm that built environment professionals in Nigeria are aware of sustainability principles and sources of information on sustainable building practices are mostly drawn from personal research. In the same vein Susilawati and Al-surf (2011) investigated public knowledge and public awareness regarding the issue in the kingdom of Saudi Arabia where a higher percentage of the respondent are not fully aware of green building practices.

Usman and Khamidi (2012) further determined the level of green building public awareness, the survey conducted on this study reveals that general public is only aware of the growing problems on sustainability; minor efforts are developed from them in implementing it. However the study was based on a random investigation with no peculiar reference to any area which might not be substantial enough for Nigeria, therefore this current study lead emphasis on a particular area in sub-shara African which more is specific and more direct i.e. Ibadan municipality Nigerian.

Ogunbode and kate (2012) examine the environmental awareness and attitude in Ibadan, the study reveals that the level of education and occupation had feasible effect on environmental knowledge and attitudes, suggested that the most effective strategy for promoting environmentally responsible behaviour and positive attitude to increase the level of exposure to straightforward messages emphasizing their relevance. However, the study examines the fundamental problems without looking at possible solution to environmental problems in which people awareness of the available means to combat environmental issues which the current study is based upon.

Conversely, Waniko (2014) assess Nigeria built environment professionals' familiarity with green building it was reported in the study that a higher percentage of the respondents are aware of the green practice. However, it appears that the majority of new residential developments in Nigeria never plan to incorporate green features in their building, owned to the facts that the end users are not properly aware about this concept.

### **Study Area**

Ibadan, the capital city of Oyo state in Nigeria is the largest city in West Africa. It is located in south western part of Nigeria in a hilly environment. Majority of the residents are traders, civil servants and farmers producing variety of agricultural items to meet the food demand of the urbanites. Administratively, Ibadan municipality is divided into 11 local government areas (LGA) (Figure 1). These consist of five urban local government and six semi-urban local governments. However, the focus of this study is on urban residential properties in Ibadan. Hence, the five urban local government areas of the study area are considered. These are: Ibadan North, Ibadan North-East, Ibadan North-west Ibadan South-east and Ibadan South-west. The choice of Ibadan is most suitable because the city is peculiar with various environmental problems and construction activities which can be ameliorated through the incorporation of green features in the built environment.



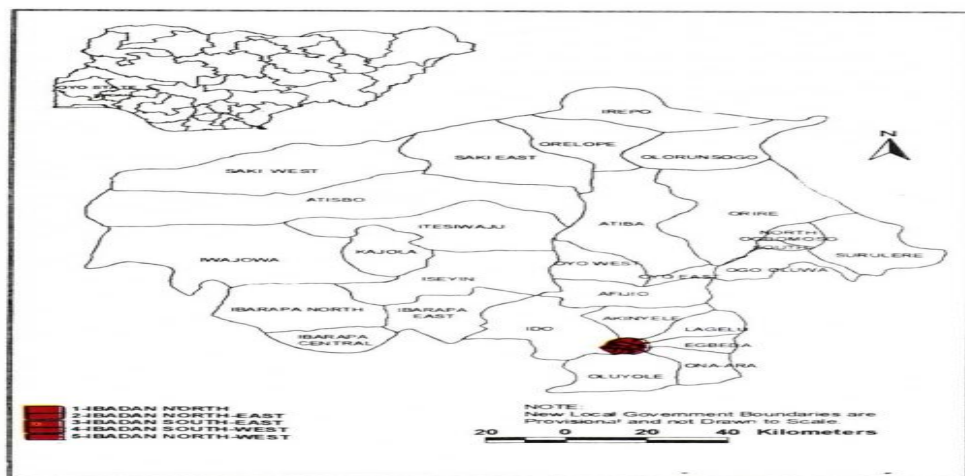


Figure 1: Map of Ibadan showing the local government areas.

Source: Google Map.

## 2.0 METHODOLOGY

Data required for this study were obtained through questionnaire administration. The target populations were the residents of Ibadan municipality which comprises of tenants and owner occupiers in the five urban local government areas identified in the traditional city. Through reconnaissance survey, 2,668 residential buildings were identified in the study area. One of every tenth buildings was selected from where household heads were surveyed for questionnaire administration using systematic sampling. This represents 10% of all residential buildings identified. In essence, the sample size was 267. The questionnaire sought information related to the users' levels of awareness, of green building, sources of awareness and levels of awareness on green features. Data were analysed using both descriptive and inferential statistics such as mean score and percentage.

## 3.0 ANALYSIS OF DATA

### Users Awareness of Green Building

It has been established in literature that the adoption of green buildings is influenced by users' level of awareness, (Whittle and Jones, 2013). In view of this, it is important to inquire first into users' level of awareness. The table below shows the users' level of awareness of green buildings in different residential zones of Ibadan municipality. Finding reveals that 29.3% of

the users were very much aware of green buildings, 35.1% and 33.5% of the users respectively were slightly aware and not aware. While 2.1% gave no response.

Tables 1.0 show the users' level of awareness of green buildings in different residential zones of Ibadan municipality. Findings reveal that 24.7% of the users were very much aware of green buildings in the study area. While 34.5% and 37.5% of the users respectively were slightly aware and not aware, 3.4% gave no response. The proportion of those that were very much aware in high density was 14.1% of the users. While in the medium density is 39.4% and 40.4% in low density area. Findings revealed that 28.2% and 42.6% of the users were slightly aware in the high, medium and low densities respectively. Those that were not aware accounted for 55.1% in high, 22.7% in the medium and 12.8% in low densities residential areas. It can be deduced from the result below that the low level of awareness in the high density is due to low level of educational factor.

Table 1.0: Users Level of Awareness of Green Building

Level of Awareness	Residential Zones			Ibadan Municipality
	High density f (%)	Medium density f (%)	Low density (%)	
Very much aware	11 (14.1%)	26 (39.4%)	29 (40.4%)	66 (24.7%)
Slightly aware	22 (28.2%)	30 (37.9%)	40 (42.6%)	92 (34.5%)
Not aware	63 (55.1%)	26 (22.7%)	11 (12.8%)	100(37.5%)
No response	7 (2.6%)	0 (0%)	2 (4.3%)	9 (3.4%)
<b>Total</b>	<b>103</b> <b>(100.0%)</b>	<b>82</b> <b>(100.0%)</b>	<b>82</b> <b>(100.0%)</b>	<b>267</b> <b>(100.0%)</b>

In view of the foregoing analysis, it is conclusive that the majorities of the users were not fully aware of green building features and as this corroborates the findings of Oyewole (2012) and Abolore (2012) that green building assumes a low level of awareness in Nigeria.

### **Source of Awareness of users on green building**

Summarized in table 1.1 are the sources of awareness of users on green features. Findings indicated that 5.2%, 1.0%, 6.8%, 3.7% 0.0%, 8.4% and 4.7% of the users were aware through sales offices, builder supplier, and real estate agent, parade of homes, homes, television and magazines respectively. Other sources of awareness were: newspaper (4.2%), radio (1.0%), internet (11.5%), friends and family (7.3%), brochure (1.6%) and others (11.0%). Parade of homes: is a showcase of new homes usually held annually. Model home: also called a show house or display home they are used for on a newly built home to show the living space and features available.

Table 1.1: sources of information on green building

<b>Sources of Awareness</b>	<b>Residential Zones</b>			<b>Ibadan town</b>
	High Density f (%)	Medium Density f (%)	Low Density f (%)	
Sales office/model home	1(1.3%)	7(10.6%)	7(4.3%)	15(5.6%)
Builder supplier	0(0.0%)	1(1.5%)	1(2.1%)	2(1.0%)
Real estate agent	2(2.6%)	4(6.1%)	7(14.9%)	13(6.8%)
Parade of homes	1(1.3%)	3(4.5%)	3(6.4%)	7(3.7%)
Home	0(0%)	0(0%)	5(9.6%)	5(1.9%)
Television	6(7.7%)	7(10.6%)	3(6.4%)	26(9.7%)

Magazines	2(2.6%)	3(4.5%)	10(8.5%)	15(5.6%)
Newspapers	1(1.3%)	4(6.1%)	8(6.4%)	13(4.9%)
Radio	0(0%)	2(3.0%)	0(0%)	2(1.0%)
Internet	4(5.1%)	12(18.2%)	21(12.8%)	37(13.9%)
Friends and family	5(6.4%)	5(7.6%)	4(8.5%)	14(7.3%)
Brochure	0(0%)	2(3.0%)	1(2.1%)	3(1.6%)
Others	10(12.8%)	5(7.6%)	16(12.8%)	31(11.6%)
No response	66(59.0%)	11(16.7%)	7(14.9%)	84(31.5%)
Total	78 (100%)	66 (100%)	52(100%)	267(100%)

The findings show that most of the users who were aware of green building got to know about it through the internet in the study area. The awareness through the internet was mostly common in the medium zone. The study also revealed that television was the common source of awareness in the high density while that of low density was through the real estate agents. This therefore implies that the

source of awareness on green buildings varies from one residential density to through the use of internet and majority are from medium and low-density area and this can be owned to their level of exposure and educational background of the residential building users.

#### **The Awareness of Users on Green Features**

Having established the level of users' awareness on green building, there is also need to establish users' level of awareness on green features. Therefore, the analysis is presented below: Table: 1.2

Table 1.2: the awareness of users on the features green building Features of Green Building

	Residential Zones									Ibadan Town		
	High Density			Medium Density			Low Density			TW V	Mea n	MD
	TW V	Mea n	MD	TW V	Mea n	MD	TW V	Mea n	MD			
Site selection, design and land ecology	238	3.05	0.07	229	4.87	0.22	309	4.68	0.22	776	4.06	0.08
Material use and conservation	233	2.99	0.01	214	4.55	-0.10	375	5.68	1.22	822	4.31	0.33
Indoor air quality	277	3.55	0.57	223	4.73	0.08	293	4.44	-0.02	793	4.15	0.17
Energy conservation	220	2.82	-0.16	218	4.64	-0.01	292	4.42	-0.04	730	3.82	-0.16
Water conservation	219	2.81	-0.17	215	4.52	-0.13	297	4.50	0.04	731	3.83	-0.15
Owner occupant education	207	2.65	-0.33	218	4.61	-0.04	281	4.26	-0.02	706	3.69	-0.29
Total		2.98			4.65			4.66			3.98	

#### 4.0 CONCLUSION

The table establishes that the most common features of green building known to users in all the residential densities of Ibadan were material use and conservation, indoor air quality and site selection, design and land ecology these features are more of the environmental features. This therefore implies that users were more aware of the environmental features of green building relative to social and economic features.

All these had positive deviations about the mean of the level of awareness in Ibadan municipality. The reason for variation in level of awareness across the densities is due to low level of educational factor of the respondent, especially users in high density area. Also, the quests to validate what they know of were not there. This finding corroborates Abolore (2012) that awareness of green building depends on the understanding of the individual actions, quest for knowledge and absolute involvement and commitment to the principle.

The study reveals that there is low level of awareness especially among the poorly educated function of the population therefore there is need to improve education level of the population in order to improve the awareness of the population.

## **REFERENCES**

- Abolore, A.A (2012). Comparative Study of Environmental Sustainability in Building Construction in Nigeria and Malaysia. *Journal of Emerging Trends in Economics and Management Science*, 3(6) 951-961.
- Alnaser, N.W. and Flanagan, R. (2007). The Need for Sustainable Buildings Construction in the Kingdom of Bahrain. *Building and Environment*, 42, 495-506
- Alsanad, S., Gale, G. and Edward, R. (2011). Challenges of Sustainable Construction in Kuwait: Investigating level of awareness of Kuwait Stakeholders. *Word Academy of Science, Engineering and Technology*, 59 (1) 2197-2204
- Ameh, O.J., Isijiola, S.J. and Achi, F.O. (2007). Assessment of the Sustainability of Public Buildings in Lagos Nigeria. *Construction Research Journal*, 1(1) 46-54
- Komolafe, O. and Oyewole, M.O. (2015). Perception of Estate Surveyors and Valuer on Users' Preference for Green Features in Lagos.
- Ogunbode, C. and Arnold, K. (2012), A study of Environmental Awareness and Attitudes in Ibadan Nigeria. *Human and Ecological Risk Assessment*. Vol 18. 669-684.
- Oyewole, M.O., Araloyin, F.M. and Sani, K.S. (2012), Sustainable property investment practice in Nigeria, *Proceedings of International Conference on construction and Real Estate Management (ICCREM)*, 01-02 October, 2012, University of Kansas, Kansas City, USA.

Susilawati, C. and Al-Surf, M. (2011). Challenges facing Sustainable Housing in Saudi Arabia: A current study showing the level of public awareness. Paper presented at the 17<sup>th</sup> Pacific Rim Real Estate Society Conference Gold Coast, Australia.

Tomori, M.O. (2007). Ibadan Metropolitan Area and the Challenges to Sustainable Development retrieved from: <http://www.macosconsultancy.com/ibadan%20metropolitan.html>

United Nation, (1992). United Nations Conference on Environment and Development (Earth Summit). Held in Rio de Janerio, Brazil. 3-14 June 1992.

Umar, U.A. and Khamidi, M.F. (2012). Determined the Level of Green Building Public Awareness: Application and strategies. International Conference on Civil, Offshore and Environmental Engineering, Kuala Lumpur Malaysia.

UNEP, (2009), United Nation Environment Programme 2009 Annual Report, Seizing the Green Opportunity UNT Digital Library

UNEP (2016) United Nation Environmental Programme (2016) Report: Emerging Issues of Environmental Concern <http://hdl.handle.net/20.500.11822/7664>

Waniko, D.P. (2014). Green Building in Nigeria: Emerging Opportunities for the Quantity Surveying Profession Retrieved from <http://www..alive2green.com/green> building.

World Green Building Council (2016, 2019) Retrieved from <https://www.worldgbc.org>

## **AN ASSESSMENT OF EXISTING GREEN FEATURES IN RESIDENTIAL BUILDINGS IN IBADAN MUNICIPALITY.**

Adejumo, A.O.<sup>1</sup>, Oyedele, D.J.<sup>2</sup>, Adedokun, A.R.<sup>2</sup>, Fayomi, I.<sup>3</sup>, Adeosun, J.O.<sup>1</sup>

<sup>1</sup>Osun State University, Osogbo

<sup>2</sup>Obafemi Awolowo University, Ile-Ife

<sup>3</sup>Lead City University Ibadan.

Corresponding author: [abiiodun.adejumo@uniosun.edu.ng](mailto:abiiodun.adejumo@uniosun.edu.ng),

### **ABSTRACT**

The study seeks to examine existing green features as one of the tools for environmental sustainability in residential buildings of Ibadan municipality, Nigeria. This is with a view to providing information that could guide real estate investors on the green features to incorporate in the existing residential buildings to enhance improvement on the existing residential investments. The study population consisted of residents in the five local government area of Ibadan municipality. Using systematic sampling, 267 households were carefully chosen for questionnaire survey. Questionnaires were administered on the household heads in the study area. Data obtained were analysed using descriptive and inferential statistics. The study established that only one feature is averagely present out of the six essential features under water conservation, likewise one out of the five essential features under indoor air was present in the existing residential buildings, also among nine other features under material use and conservation only one was present and only one is equally present among twenty other features under energy conservation. The study implies that the level of green features incorporation in the existing residential building especially in the study area is very low, hence, there is need to incorporate more green features into the existing residential buildings in order to improve on the standard of the existing residential buildings.

**Keywords:** *Green buildings, Green features, Environmental degradation, Ibadan Municipality*

### **Background of Study**

The building construction industry has been a great contributor to the depletion of natural resources. Through the emission of greenhouse gases and other harmful substances into



the environment with non-renewable resource use which causes environmental degradation such as climate change, environmental pollution, flooding and so on. Moreover, the development of buildings to provide accommodation for human destroys the environment (Umar and Khamidi, 2012).

In view of the growing concern of the society about the negative effects of human activities on the environment, green building initiative was launched by the United Nation in Rio de Janeiro in the year 1992 in quest to protect the environment from natural hazards. The moves made green building initiative to receive warm embrace across the globe (United State Environmental Protection Agency, 2008).

Therefore, green building is defined by the United Nation as a building project or construction activities that allows for the preservation of the natural environment around the project site. However green features are a set standard that green building must possess before a building can be certified as green. Therefore, green features as defined by Zafar (2013) is those elements that integrate sustainability considerations into every aspect of building construction process from inception to the completion stage and according to the United State Green Building Energy Council (USGBEC) recognizes green features as energy conservation, water conservation, material use conservation, indoor air quality, site selection and design, owners' occupant education. Most residential areas in Nigerian cities, such as Ibadan and the likes, where environmental degradation persists with serious problems as a result of construction activities.

Tomori (2004) observed that environmental crises as earlier mentioned above are causing serious problems in urban residential areas. These problems have implications on the urban residents and the environment. One of the important ways by which the effects of environmental crises emanating from construction activities can be ameliorated is through the incorporation of green features in residential buildings.

Past studies like (Davis, 2001; Atsusaka, 2003; Shafii et al, 2005; Dennis, 2006; Samari 2012) examined tools to improve green building, lack of awareness and barriers to green building development across globe especially in Asian countries. Moreso, most studies in Nigeria have examined the incorporation of green features in commercial properties (Abolore, 2012; Komolafe, 2015; Oyewole and Komolafe, 2015). Nevertheless, existing literature have not extensively assessed the level of incorporation of green features in existing residential buildings in the country with particular reference to Ibadan municipality. Hence, this study seeks to investigate the existing green features in the residential building in Ibadan

municipality. Information obtained from the findings of the study can be used by real estate investors to incorporate more green features into the existing residential buildings in order to improve on the standard of the existing residential buildings towards ensuring environmental sustainability.

### **Review of Past Studies**

A green building is one whose construction and lifetime of operation assures the healthiest possible environment while representing the most efficient and least disruptive use of land, water, energy and other resources. In the same vein green building features as a concept ensures environment protection, water conservation, energy efficiency, use of recycled products and renewable energy. (shafique and zeyaul, 2006)

Therefore, six features have been identified in the literature which are listed below: water conservation, indoor air quality, energy conservation, site selection, design and landscape ecology, building ecology, waste and recycling: integrated design: and owner occupant education. In view of this United States green building council (USGBC, 2007) identified various elements of the listed green features. Under Energy Conservation: energy efficient lighting, energy efficient heating, day lighting, illumination from light sources, cost of power source among others are regarded as the elements of energy conservation. Under indoor air quality: indoor ventilation, air conditioning and cooling systems, window types and positioning, position of ventilation source relative to pollution source and car park position and ventilation.

Element of Material use and conservation: use of natural and local materials in construction, use of recyclable/recycled materials in construction, availability of equipment on site to deal with environmental emergencies, use of durable materials, waste water treated from sinks and showers, freedom of building area from contamination, right channelization of water drains among all others.

Furthermore, studies also reveal that building construction activities consumes most of the natural resources which has negative effects on the environments and these calls for serious concerns. However, manufacturers, builders, designers, and consumers are creating an expanding market for housing and home products that pollute less and are more resources efficient (Yuanyuan et al. 2017).

For example, in 2009 Malaysia green building index (GBI) started at the green design forum, organized by the architectural association of Malaysia (pam). In order for the building construction industries to identified the importance of green features to reduce the effect

environmental degradation. Also, in Nigeria studies has not being able to established the level of incorporation of green features in existing residential buildings in order to determined how well people are informed about green building features.

Yuanyuan et al. 2017 reviewed studies on green building assessment method; the study was carried based on the fact that green building is receiving great attention in recent times. However, the study was a comparative analysis while the current study is based on the assessment of the existing green features in residential buildings and it is an empirical study.

Xiaohuan, Yi and Zhonghua (2017) examined green building pro-environmental behaviours. The study investigates the link between two green building pro-environmental behaviours that requires similar resources, energy saving that do not require money and environmentally friendly and willingness to pay for green features. The study established that two pro-environmental behaviours can be positively linked together. While this study will assess the availability of green features in existing residential buildings.

Study of komolafe (2015) investigate users' preference on green features in office properties in office properties in Lagos Nigeria, the study reported that, with some level of sensitization to increase office property users' level of awareness, incorporation of green features into office properties could engender users' preference for green features in Nigeria. While this study will assess the existing green features in residential building of Ibadan municipality.

Also, Otegbulu (2012) examined the extent of electricity power and flooding problem on the residents of 1040 households in 8 metropolitan local government areas in Lagos, Nigeria using averaging statistics and frequency counts, the result shows that flooding and loss of property in the area was due to lack of green and sustainable design traced to low adoption of green features in the area. The study also discovered that users were unsatisfied with the current building construction practices. However, the study only focusses on the electricity and building design, leaving out other fundamentals element of green building which is green features.

Furthermore, Oyewole, Araloyin and Sani (2012) study, investigate degree of involvement of Nigerian investors in the sustainable and responsible property investment practice. By surveying property companies in Nigeria, using frequency distribution and Likert scale, it was found that insignificant attention has been given to social and environmental issues in their investment activities. There is little advancement by investors to incorporate sustainability initiatives in their real property portfolios. They study left out an explicit examination of users

and their actual need for green features which is central to green building implementation in Nigeria.

### Study Area

Ibadan, the capital city of Oyo state in Nigeria is the largest city in West Africa. It is located in south western part of Nigeria in a hilly environment. Majority of the residents are traders, civil servants and farmers producing variety of agricultural items to meet the food demand of the urbanites. Administratively, Ibadan municipality is divided into 11 local government areas (LGA) (Figure 1). These consist of five urban local governments and six semi-urban local governments. However, the focus of this study is on urban residential properties in Ibadan. Hence, the five urban local government areas of the study area are considered. These are: Ibadan North, Ibadan North-East, Ibadan North-west Ibadan South-east and Ibadan South-west. The choice of Ibadan is most suitable because the city is peculiar with various environmental problems and construction activities which can be ameliorated through the incorporation of green features in the built environment.

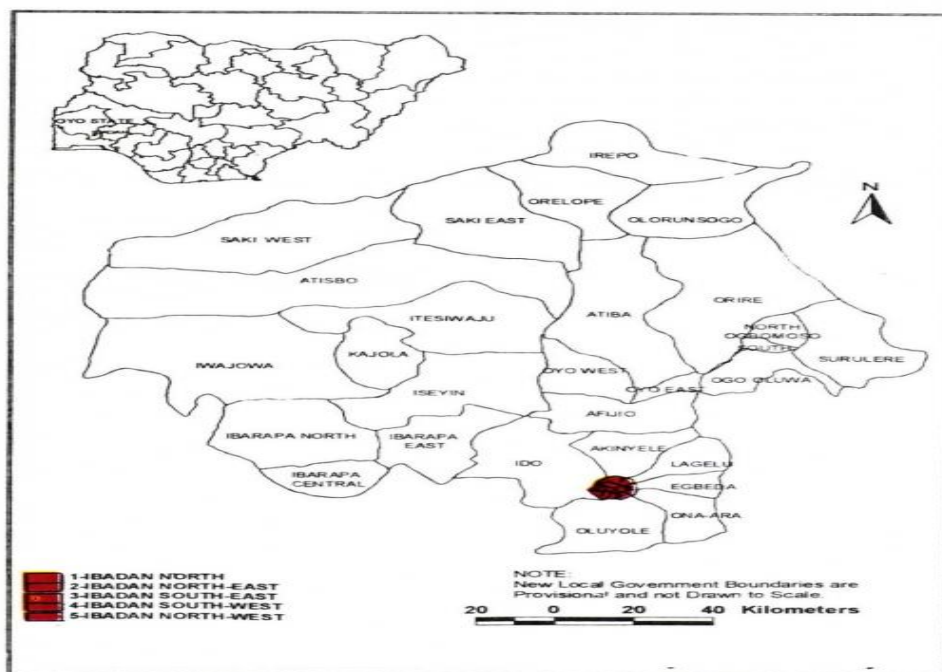


Figure 1: Map of Ibadan showing the local government areas.

Source: Google Map.

### METHODOLOGY

Data required for this study were obtained through questionnaire administration. The target populations were the residents of Ibadan municipality which comprises of tenants and owner occupiers in the five urban local government areas identified in the traditional city. Through reconnaissance survey, 2,668 residential buildings were identified in the study area. One of every tenth buildings was selected from where household heads were surveyed for questionnaire administration using systematic sampling. This represents 10% of all residential buildings identified. In essence, the sample size was 267. The questionnaire sought information related to the level of incorporation of green features in existing residential building, by examining each of the features one after the other as identified in the literature. Data were analysed using both descriptive and inferential statistics such as mean score and percentage.

### **ANALYSIS OF DATA**

#### **Existing Green Features in Residential Buildings**

A checklist was consequently drawn based on the green features identified in the literature. This was done to determine the availability of the features in residential buildings presently occupied by the users. The green building features (used as checklist) were compiled. Also, physical observation was carried out on the buildings and the availability of green features were rated on a five point Likert's scale of very much available, averagely available, fairly available, slightly and not available. Which were measured using relative availability index (RAI).

Table 1.1: Available green features in the sampled buildings across the three residential zones of Ibadan municipality.

INDOOR AIR QUALITY	Mean	Mean Deviation	Rank
Indoor ventilation	3.91	-0.08	1
Air condition/cooling systems	3.06	-0.93	5
Window types and positioning	3.73	-0.26	2
Position of ventilation source relative to pollution source	3.34	-0.65	3
Car park position and ventilation	3.20	-0.79	4

In the category indoor air quality, the table presents indoor ventilation and window types and positioning were the most available in the high, medium and low-density areas. The computed mean (RAI) for indoor ventilation, window types and position accounted for 3.91 and 3.73 across the three zones. Hence indoor ventilation and widow types and positioning were the most available green features in the category of indoor air quality.

Table 1.2: available green features in the sampled buildings in different residential zones of Ibadan municipality

<b>Material use and conservation</b>	Mean	Mean Deviation	Rank
Materials used for building construction	3.74	0.51	1
Emergency control system	3.05	-0.18	6
Building ecology, waste and recycling	2.89	-0.34	7
Treatment of waste water from building	2.87	-0.36	8
Mode of collecting solid wastes	3.30	0.07	4
Mode of treating solid wastes	3.10	-0.13	5
Mode of disposing solid wastes	3.31	0.08	3
Building position relative to source of contamination	3.31	0.08	3
Mode of water drain channelization	3.54	0.31	2

Table 1.2 present the most available green features in the group of material use and conservation were materials used for building conservation mode of water drain channelization

The findings therefore established that most commonly available green features in the residential, areas of Ibadan municipality were: materials used for building construction, mode of collecting

solid waste, mode of disposing solid wastes and mode of water drain channelization. From the findings the most existing green features in the study area is more functional features and other features are regarded to be of less important and not been obtainable most especially in the study area.

Table 1.3: available green features in the sampled buildings in different residential zones of Ibadan municipality

<b>Energy conservation</b>	Mean	Mean deviation	Rank
Cost of power source	3.41	0.16	5
Energy consumption rate of lighting equipment	3.80	0.55	1
Energy consumption rate of ventilation equipment	3.19	-0.06	11
Consistence of power source	2.93	-0.32	17
Site selection, site design and land space ecology	3.05	-0.2	14
Transportation within the building	3.40	0.15	6
Position of building relative to complimentary land uses	3.35	0.1	8
Landscaping	3.16	-0.09	12
Illumination from light sources	3.37	0.12	7
Day lighting	3.66	0.41	2
Lighting control	3.44	0.19	4
Allowance for privacy	3.45	0.2	3
Indoor sound/noise level	3.26	0.01	9
Accessibility to technical installations	3.04	-0.21	15
Ease of building facility inspection	3.24	-0.01	10
Ease of building conversion	3.16	-0.09	12

Availability of green common areas	3.02	-0.23	16
Building maintenance schedule/control	3.05	-0.2	14
Outdoor air intake control	3.10	-0.15	13
Pollution control	3.02	-0.23	16
Waste disposal schedule	3.10	-0.15	13
Energy metering/monitoring system	3.35	0.1	8

Furthermore, on energy conservation, table 1.3 the most available green building features common to all the three residential zones were: energy consumption rate of lighting equipment, day lighting, energy consumption rate of lighting equipment, conclusively the commonly available green features in the three residential zones of Ibadan in relation to energy conservation were cost of power source, energy consumption rate of lighting equipment, day lighting, lighting control, allowance for privacy and energy metering/monitoring system. This implies that the features available are the ones that are fundamental and the ones users were aware of, although not as green features but as part of building facilities which is far different from green features.

**CONCLUSION** In conclusion, the result of the Survey carried out on the existing green features in residential buildings presently occupied by the users showed that the level of incorporation of green features is relatively low in the study area and this validates existing studies about the extent of the green building practice in Nigeria revealed that some of these features were incorporated into the existing residential buildings. But it has not been established that the user of a residential building can actually identify some of the features present in their existing residential buildings especially in the study area. The study therefore implies that the level of green features incorporation in the existing residential building especially in the study area is very low, therefore there is need to incorporate more green features into the existing residential buildings in order to improve on the standard of the existing residential buildings.

## **Reference**



Abolore, A.A (2012). Comparative Study of Environmental Sustainability in Building Construction in Nigeria and Malaysia. *Journal of Emerging Trends in Economics and Management Science*, 3(6) 951-961.

Alnaser, N.W. and Flanagan, R. (2007). The Need for Sustainable Buildings Construction in the Kingdom of Bahrain. *Building and Environment*, 42, 495-506.

Alsanad, S., Gale, G. and Edward, R. (2011) Challenges of Sustainable Construction in Kuwait: Investigating level of awareness of Kuwait Stakeholders. *World Academy of Science, Engineering and Technology*, 59 (1) 2197-2204

Ameh, O.J., Isijiola, S.J. and Achi, F.O. (2007). Assessment of the Sustainability of Public Buildings in Lagos Nigeria. *Construction Research Journal*, 1(1) 46-54.

Komolafe, O. and Oyewole, M.O. (2015). Perception of Estate Surveyors and Valuer on Users' Preference for Green Features in Lagos.

Ogunbode, C. and Arnold, K. (2012), A study of Environmental Awareness and Attitudes in Ibadan Nigeria. *Human and Ecological Risk Assessment*. Vol 18. 669-684. Oyewole, M.O., Araloyin, F.M. and Sani, K.S. (2012), Sustainable property investment practice in Nigeria, *Proceedings of International Conference on construction and Real Estate Management (ICCREM)*, 01-02 October, 2012, University of Kansas, Kansas City, USA.

Susilawati, C. and Al-Surf, M. (2011). Challenges facing Sustainable Housing in Saudi Arabia: A current study showing the level of public awareness. Paper presented at the 17<sup>th</sup> Pacific Rim Real Estate Society Conference Gold Coast, Australia.

Tomori, M.O. (2007). Ibadan Metropolitan Area and the Challenges to Sustainable Development retrieved from: <http://www.macosconsultancy.com/ibadan%20metropolitan.html>

United Nation, (1992). United Nations Conference on Environment and Development (Earth Summit). Held in Rio de Janeiro, Brazil. 3-14 June 1992.

Umar, U.A. and Khamidi, M.F. (2012). Determined the Level of Green Building Public Awareness: Application and strategies. *International Conference on Civil, Offshore and Environmental Engineering*, Kuala Lumpur Malaysia.

UNEP, (2009), United Nation Environment Programme 2009 Annual Report, Seizing the Green Opportunity UNT Digital Library

UNEP (2016) United Nation Environmental Programme (2016) Report: Emerging Issues of Environmental Concern <http://hdl.handle.net/20.500.11822/7664>

Waniko, D.P. (2014). Green Building in Nigeria: Emerging Opportunities for the Quantity Surveying Profession Retrieved from <http://www..alive2green.com/green> building. World Green Building Council (2016, 2019) Retrieved from <https://www.worldgbc.org>

# **ASSESSMENT OF THE EXTENT OF PARTICIPATION OF INDIGENOUS CONTRACTORS IN MAJOR CONSTRUCTION ACTIVITIES IN OSUN STATE**

Adeosun, J.O., · Fadipe O.O. and Adejumo, A.O.

Osun State University, Osogbo

Corresponding author: [julieadeosun@gmail.com](mailto:julieadeosun@gmail.com)

## **ABSTRACT**

The study assessed the extent of participation of indigenous contractors in public construction project in Osun State, Nigeria. Professionals from ministry of works and housing, the contractors and the direct users of the projects in the study area were duly considered. To comprehensively undertake the research; one hundred (100) copies of questionnaire were administered by using stratified random sampling technique. The total number of usable responses received for the analyses was seventy-five (75), making 75%. The data was analysed using descriptive and inferential statistics. The result also revealed that indigenous contractors have not had a fair share of major construction activities in the study area (58.7%). Recommendations made in the study include: Government of the state of Osun should allocate a percentage of public projects to local contractors, government should focus political will to devise policies and create the enabling environment for improving indigenous content in the construction industry and establishing a “National Construction Bank” where indigenous contractors can get loans at subsidized interest rates to meet their working capital requirement that will enable them complete projects on time and so be able to compete with their foreign counterparts.

**KEYWORDS:** Extent of Participation, Indigenous Contractors, Construction Activities

## **1.0 INTRODUCTION**

The Construction process is capital intensive. From inception to completion, cost is incurred at every stage. However, the major cost is incurred during the actual construction stage where irreversible commitment of fund is undertaken in the procurement and deployment of resources such as labour, plant, materials and managerial expertise to achieve the finished product. The

contractor is the party who uses these resources to bring the works to fruition. These contractors are either foreigners or indigenes

Nigerian Indigenous contractors have not had a fair share of major construction activities in the country, as they are often awarded to their foreign counterparts whom are considered more technically and managerially more superior and efficient in funds acquisition and project execution (Ogbebor, 2002; Oseni,2002; Akintunde, 2003).Vis-a-vis this, indigenous contractors have over the years being plagued with under-capitalization, poor project performance in terms of meeting completion dates, work quality and capital management which has often led to bankruptcy and in extreme cases, project abandonment.

The performance of projects managed by Nigerian Indigenous Contractors' (NICs') are better and claimed they can be entrusted with large and highly technical projects, whereas most studies reports that their projects performance is replete with: project abandonment, cost and time overruns, poor workmanship, poor management capability, financial difficulties, poor planning, poor mechanization and high frequency of litigation (Adams,1997).Many researchers have attributed NICs' poor performance to incompetence, inexperience, poor innovation and dynamism, and the adoption of traditional management (Ekundayo, Jewell, & Awodele, 2013; Aniekwu & Audu, 2010; Muazu & Bustani, 2004; Achuenu E, Izam Y.D, & Bustani S.A (2000). These resulted in the few foreign firms, which constitute just 5% of the total number of contractors in the formal sector, control 95% of the major public projects in the construction market, giving the indigenous firms just 5% share of the market (Aniekwu & Audu, 2010; Muazu & Bustani, 2004).

The need for this study has become very crucial due to the high rate of cost and time overruns and shoddy quality of construction projects executed by indigenous contractors in Nigeria because of inefficient working capital management; a situation that has become embarrassing to Industry stakeholders. It is in the light of the foregoing, that the research studies the extent of indigenous participation on major construction projects in Nigeria, via percentage participation; empirical results, on major, recently awarded contracts and ranking the problems or challenges (obtained from literature and oral interviews) in order of severity that face indigenous contractors in the area of efficient working capital management and requirements which previous studies didn't properly address. This is with a view to proffering some strategies for mitigating them, thereby achieving optimum working capital throughout the construction period and realizing public projects within pre-planned cost, time and quality.

## **LITRATURE REVIEW**

The construction industry in Nigeria provides the driving force necessary for sustaining economic buoyancy. It contributes an average of 5 percent to the annual gross domestic product and an average of about one-third of the total fixed capital investment (Omole, 2000). Firms, companies or organizations that carry out construction works are called 'contractors'. They offer their skills and services and accept the challenge of executing the works in exchange for financial reward.

The concept of indigenous contractors came to limelight with the introduction of the Nigeria Enterprises Promotion decree of February 1972, and since then indigenous contractors have been playing an important role in the construction industry. An indigenous contractor in Nigeria is regarded as a person or private organization established under the Nigeria Enterprises Promotion Decree of February 1972, and has no other base than Nigeria and its capital base and ownership is entirely Nigerian. These firms range in size from the self-employed Craftsmen known as jobbers who engage mainly in repairs and maintenance of buildings to the very large multi-national or foreign-based construction company. Sadly, the Nigerian indigenous contractor base is largely incompetent and inexperienced (Adams, 1997; Ogbekor, 2002; Awoyinfa, 1991). Akintunde (2003) opined that for this reason, the Nigerian government still lacks confidence in its Construction sector. Ogunlana (2010) surmised that the combination of the small and medium sized construction firms makes up 90 percent of the total registered contractors in Nigeria. These indigenous contractors are characterized by under-capitalization, under capacity utilization, understaffing, and are generally managerially handicapped. Over the years, the poor performance of this category of contractors has been a source of concern and worry particularly when compared with their foreign counterparts.

Judging by the record of high number of bankruptcies in this group, poor quality work, mismanagement, diversion and embezzlement of project fund, and the general economic depression, the survival and growth of indigenous contractors may be difficult, particularly in view of inflationary trends, high cost of construction materials, high cost of borrowing capital, government policy change in favour of deregulation, and the current wave of global economic meltdown (Husseini, 1991).

Studies have shown that in Nigeria, few large companies control a large percentage of the total workload of the construction industry, while a large number of small and medium sized

companies which make up the class of indigenous contractors share a very low percentage of the construction workload

According to Ademoroti (1997), the Nigerian Society of Engineers conceived the idea of producing a draft recommendation for the “National Construction Policy” to back-up its long canvassed need for government to take the question of technological development of indigenous capacity more seriously. Later, other interested groups like the Nigerian Institute of Building, the Nigerian Institute of Architects, the Nigerian Institute of Quantity Surveyors etc organized seminars and workshops aimed at encouraging the development of indigenous capacity and participation and ultimately indigenous control of all facets of the construction industry in Nigeria. The situation however, is still far from encouraging. Olateju (1991) and Ademoroti (1997) also stressed, that relative to the volume of work available in Nigeria, the percentage in value of contract handled by the indigenous contractors is still too low compared to those handled by foreign and multi-national companies. This is indeed disheartening because most of the indigenous contractors have not lived up to expectation. Olateju (1991) further lamented that indigenous contractors are faced with several management problems in obtaining jobs, controlling its finance and successfully managing its project to completion within a scheduled time period. In an attempt to examine how much of the construction projects executed in Nigeria are given to indigenous contractors, their management strategies and the adequacy of these strategies in preparing them for the future challenges of the industry, Olateju (1991) embarked on a study of 1133 projects costing N11.25billion awarded by the Federal government between 1974 –1978, a period when construction activities were highest in the country. The results showed that while the indigenous contractors got awarded 77.2 percent of the number of contracts, they only had 6.95 percent of the value of the contracts. The study also showed that the indigenous contractor had created virtually no impact in the areas of heavy infrastructural development such as civil works in refineries, hydro- electric dams, airports etc. In fact, the foreign contractors averaged N40.75million per contract, as against an average of N890,000 per contract by indigenous contractors. The study attributed this low level of participation to perceived inability of local contractors to effectively manage large projects. Local contractors are generally seen as holding the greatest potential for increasing construction industry capacity and for general economic development. However, the construction industry in developing countries is dominated by foreign contractors and a few large local contractors (Larcher,1999). Adams (1997) further revealed that foreign construction firms dominate major projects in most developing countries as a result of deficiencies in

indigenous construction capacity. Similarly, Bala (2009) buttressed this point by surmising that indigenous construction companies in the African continent do not represent a strong source of competition and are thought to lack financial and technical capacity. In a similar vein, Oseni (2002) stressed that foreign construction companies dominate the Nigerian construction industry. To corroborate this, Ogbebor (2002) noted that 96% of the Nigerian Construction Industry is still dominated by foreign contractors on the grounds that indigenous contractors cannot be entrusted with complex project. Going down memory lane Somolu (2003) revealed that in the early seventies indigenous construction professionals enjoyed some patronage from the Government, but presently, the Nigerian Government has developed so much fondness and huge patronage for foreign companies thereby leaving their own contractors starved of work. According to Akintunde (2003), as foreign contractors carry out more jobs, they gain better expertise on the job while the Nigerian contractors remain inexperienced and therefore are unable to compete with their foreign counterparts. In the view of this, Somolu (2003) surmised that a complex construction job is only an aggregate of many simple tasks and experience can only be acquired by doing and trying ;an opportunity that has not been granted to the indigenous Nigerian contractor.

## **2.0 METHODOLOGY**

The target population of the study comprises of the professionals in Ministry of Works and Housing, Contractors and direct users of the projects in Osun state. The respondents were categorized into three namely:- the professionals from ministry of works and housing, the contractors, and the direct users of the projects. Using random sampling technique, one hundred (100) copies of questionnaire were administered in Osun state within the selected study area. The random sampling technique was adopted. The research instruments for the study were both structured and unstructured questionnaires. The questionnaire was designed to investigate the extent of participation of indigenous contractors in major construction activities in Osun state, Nigeria. The questionnaires comprised two sections, (Section A and Section B) Section A is the demographic variables and section B contains items constructed to guide the study. This is to take care of the questions raised in the study. Also, data was obtained through direct observation as sites were visited within the selected study area.

A total of one hundred (100) questionnaires were administered and seventy-five (75) retrieved from the respondents. Analysis of data was done using both descriptive statistics such as frequency, percentages and mean item scores. Data was analysed using SPSS version 20

software. The analysis of the extent of participation of indigenous contractors in major construction activities was done using Relative Importance Index (RII). This was used to examine and the rank the attributes in terms of their importance as perceived by the respondents. The Relative Importance Index (RII) was computed using the formula below. To rank determine the relative ranking of the criteria, the scores were transformed into important indices based on the formula:

$$\text{Relative Importance Index (RII)} = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}.$$

Where  $W$  is the weight given to each factor by the respondent, ranging from 1 to 5, ( $n_5$  = number of respondents for strongly agree,  $n_4$  = number of respondents for agree,  $n_3$  = number of respondents for disagree,  $n_2$  = number of respondents for undecided and  $n_1$ = number of respondents for strongly disagree).  $A$  is the highest weight (i.e. 5 in this study) and  $N$  is the total number of samples (respondents). The relative importance index ranges from zero to one. The closer the value is to 1, the higher the relative importance and vice versa.

### 3.0 RESULTS AND DISCUSSIONS

Table 1 presents the survey data showing the distribution of respondents according to professional qualification. The result revealed that highest percentage (34.7%) of the respondents had other qualification which they did not mention. However, the result further indicates that respondents who had MNIOB accounted for (24.0%), respondents with MNSE accounted for (21.3%), while respondents with MNIESV accounted for the least proportion. This indicates that the majority of the respondents are engineers and builders which imply that they have acquired adequate knowledge of the subject matter.

Table 1: Distribution of Respondents according to Professional membership

<b>Professional Membership</b>	<b>Frequency</b>	<b>Percent</b>
MNIOB	18	24
MNIESV	6	8
MNIA	9	12
MNSE	16	21.3
Others	26	34.7
Total	75	100



Table 2 presents the survey data on the extent of participation of the indigenous contractors in public construction projects in the study area. The result revealed that more than half (58.7%) of the respondents supported the claim that indigenous contractors have not had a fair share of major construction activities in the study area. Also, about half (45.3%) of the survey respondents supports the claim that indigenous contractors are characterized with under capitalization. Close to half of the respondents surveyed disagreed with the claim that indigenous contractors are incompetent and inexperienced, while simple majority (48.0%) disagreed with the statement that Nigerian Government lacks confidence in its construction sector. furthermore, the result revealed that close to half (42.8%) of the respondents support the claim that few large companies control large percentage of total workload of the construction industry, more than half of the respondents support the statement that indigenous contractors shared a very low percentage of the construction workload, while half of the respondents agreed that value of contract handled by the indigenous contractor is too low compared to those handled by foreign. Also, about two third (64.0%) of the respondents did not support the claim that indigenous contractor had created no impact in the areas of heavy infrastructure, while close to half (48.0%) of the respondents support the claim that foreign construction firms dominate major project in the study area.

**Table 2: Extent of participation of indigenous contractors**

Items	SD	U	D	A	SA	RII	Rank
	1	2	3	4	5		
Indigenous contractors have not had a fair share of major construction activities in Osun state	0	0	0	42	26	0.88	1
Indigenous contractor are characterized with under capitalization	0	5	6	22	40	0.87	2
Indigenous contractor are incompetent and inexperienced	0	2	3	40	25	0.85	3
Nigerian Government lacks confidence in its construction sector	0	10	6	25	34	0.82	4
Few large companies control large percentage of total workload of the construction industry	0	9	12	18	36	0.82	7
Indigenous contractors shared a very low percentage of the construction workload	3	7	5	30	30	0.81	7
Value of contract handled by the indigenous contractor is too low compared to those handled by foreign	0	11	9	23	32	0.80	7
Indigenous contractor had created no impact in the areas of heavy infrastructure	4	10	3	22	34	0.80	8
Foreign construction firms dominate major project in Osun state	6	6	9	18	36	0.79	11

Indigenous contractor cannot be entrusted with complex project	4	8	8	20	32	0.79	11
Foreign contractors carry out more jobs in Osun state	0	7	9	41	18	0.79	11
Local construction firm fail to compete due to value added tax (VAT) level	8	3	5	30	29	0.78	14

#### **4.0 CONCLUSION AND RECOMMENDATIONS**

Based on the findings it was concluded that limited finance is a major challenge encountered by indigenous contractors. They have limited access to funding sources, especially contractors in the small-and-medium bracket. One of the biggest consequences of this is that it prevents them from satisfying the financial requirements (e.g. bid and performance bonds) needed to win major contracts often awarded to their foreign counterparts. Inadequate facilities, machines, tools and equipment for effective work on the site work, over dependence on imported foreign materials and non-engaging of professionals also pose serious challenges to indigenous contractors during project execution. The result also revealed that indigenous contractors have not had a fair share of major construction activities in the study area.

From the above conclusion, the following recommendations were made:

- Government of the state of Osun should allocate a percentage of public projects to local contractors.
- Government should focus political will to devise policies and create the enabling environment for improving indigenous content in the construction industry
- Establishing a “National Construction Bank” where indigenous contractors can get loans at subsidized interest rates to meet their working capital requirement that will enable them complete projects on time and so be able to compete with their foreign counterparts.

## **REFERENCES**

- Achuenu, E., Izam, Y. D., & Bustani, S. A. (2000). Investigating the Activities of Indigenous Contractors in the Nigerian Construction Industry. *Journal of Construction Technology and Management*, 3(1):91-103.2.
- Adams, O. (1997). Contractor development in Nigeria: Perceptions of Contractors and Professionals. *Construction Management and Economics*, 15(1), 95-108
- Adams, S. O. (1997). Contractor Development in Nigeria: Perception of Contractors and Professionals. *Journal of Construction Management and Economics*, 15:95-108.3.
- Ademoroti, A. (1997). Indigenous Participation in Nigeria Infrastructural Development. *The Professional Builder*, 32 (1),11-15.
- Akintunde, I. (2003). *The Nigerian Construction Industry: Past, Present, Problems and Prospects*: Ibadan University Printery.
- Aniekwu, A. N., & Audu, H. O. (2010). The Effects of Management on Productivity: A Comparative Study of Indigenous and Foreign Firms in the Nigerian Construction Industry. *Proceedings of West Africa Built Environment (WABER) Conference, 27-18 July 2010 (pp. 567- 578)*. Accra- Ghana: WABER.
- Awoyinfra, O.(1991).Utilization of Engineering Manpower in Nigeria. In I. Akintunde (Ed.),*The Nigerian Construction Industry: Past, Present, Problems and Prospects (pp.17-55)*.Ibadan: Ibadan University Printery.
- Bala, K., Bello, A., Kolo, B. A., & Bustani, S. A. (2009). Factors Inhibiting the Growth of Local Construction Firms in Nigeria. *Procs25th ARCOM Conference, 7-9 Sept. 2009(pp.351-359)*.Nottingham U.K.: ARCOM.
- Ekundayo, D., Jewell, C., & Awodele, O. A. (2013). Executive Project Management Structure and the Challenges Facing its Adoption in the Nigerian
- Husseini,A.A.(1991).Construction in an Ailing Economy. *The Nigerian Quantity Surveyor*,15(2),20–22.
- Ogbebor, P.O. (2002). Enhancing Indigenous Construction Industry as a National Goal in Nigerian Development. In I. Akintunde (Ed.),*The Nigerian Construction Industry: Past,*

- Present, Problems and Prospects (pp.230-239). Ibadan: Ibadan University Printer.
- Olateju, B. (1991). Enhancing the Contract Managing Capability of the Indigenous Contractor. Paper presented at a seminar of the Nigerian Institute of Building on Effective Contract Management in the Construction Industry (p. 96– 101). Lagos: NIOB.
- Omole, A.O (2000). Surveying Input to Engineering Projects: The Need for Professionalism. *The Quantity Surveyor*, 30, 10-18. *International Journal of Civil Engineering, Construction and Estate Management* Vol.1, No.1, pp.1-21, March 2014. Published by European Centre for Research Training and Development UK ([www.ea-journals.org](http://www.ea-journals.org))
- Oseni, F. A. (2002). Need to Revive Our National Development Plans. In I. Akintunde (Ed.), *The Nigerian Construction Industry: Past, Present, Problems and Prospects* (pp.1755). Ibadan: Ibadan University Printery.
- Somolu, A.F. (2003). In I. Akintunde (Ed.), *The Nigerian Construction Industry: Past, Present, Problems and Prospects* (pp.67). Ibadan: Ibadan University Printery.

## **EXPERT WITNESSING IN REAL ESTATE LITIGATION PRACTICE IN IBADAN METROPOLIS: THE ESTATE SURVEYORS AND VALUERS' PERSPECTIVE**

Adedokun, A. R.\* and Oladokun, T. T.

Department of Estate Management, Obafemi Awolowo University, Ile Ife, Osun State.

\*Email of Corresponding Author: [daconsulting11@gmail.com](mailto:daconsulting11@gmail.com)

### **ABSTRACT**

The study examined the perception of estate surveyors and valuers of expert witnessing in real estate litigation in Ibadan metropolis with the aim of enhancing professional practice. Primary data was collected from respondents (103 estate surveyors and valuers (ESV) drawn from 158 financial members contained in Estate Surveyors and Valuers Registration Board of Nigeria (ESVARBON) directory. The data obtained were analysed using frequency, percentage distribution, mean scores and factor analysis. The result established that rent dispute was the commonest real estate litigation where expert witness had been involved in from estate surveyors and valuers' perspective. The result was that expert witnesses in the study area were experienced professionals who could sufficiently guide decision making in real estate litigations and give objective and sound evidence. Also, the findings showed that legal position of the expert witnessing is not only accepted, but strongly endorsed by the professional bodies in which the expert belongs to. The study recommended that for efficient expert witnessing in real estate litigations, estate surveyors and valuers need to understand the procedures of being an expert witness and develop sufficient knowledge in the area of expert witnessing.

**Keywords:** Expert Witnessing, Real Estate, Litigation, Estate Surveyors and Valuers, Ibadan Metropolis.

### **1.0 INTRODUCTION**

In litigations, real estate practitioners/professionals play series of critical roles as expert witness when testifying in court, and in preparing reports for attorney on real estate disputes that assist the judge in making sound decision during proceedings (Musil, 2008). This reflects in a number of cases of fraudulent acts relating to real estate being reported on a regular basis in Nigerian companies, institutions and in the government. As a result of many real estate litigations, businesses, individuals and large corporations are facing huge pressures to settle

such cases (Sanchez and Zhang, 2012). Practically, many of the cases that go to trial always require the testimony of expert witnesses (Samuel, 1991).

In real estate practice, litigations could arise from the planning stage to the completion stage. These stages require the services of professionals in built environment such as Land Surveyor, Town planner, Architect, Quantity Surveyor, Builder, Engineer and Estate Surveyor and Valuer as the case may be.

Real estate dispute and litigation have been in existence from time immemorial and Nigeria is not an exemption. It also surfaces in all stages from land ownership, development, rent determination to others such as rent collection, management, valuation, sales, (Enofe, Odigie, Onoyase, Omokhuale, 2015).

On many occasions in the real estate world, disputes between parties arise as result of conflict of interest, breach of contract, violation of laws and regulation, boundary disputes, value differences, etc. In majority of these cases, these issues can be easily resolved. However, in a few instances, it becomes necessary to manage the dispute through legal channels. In such cases, where the end result of any litigation is getting value for whatever the investment might be, which in some cases /litigation may not be pecuniary, professionals' advice of the estate surveyor and valuer versed in the legalities of real estate disputes can be essential. As such, litigation support is one of the most common reasons to hire an expert (Enofe *et al.*, 2015). This is essentially the process by which the estate surveyors and valuers who are familiar with commercial disputes provide consultation and advice to attorneys during legal proceedings. Since solving disputes through the traditional method of going to court (litigation) requires that the judge has oversight over cases filed in the court, he/she as the trier of fact, often requires the expert witnesses' opinion where the truth about real estate issues can only be obtained from the estate surveyor and valuer who are the trained professionals knowledgeable about real estate.

This study seeks to evaluate the practice of expert witnessing in dispute ensuing from real estate practice and the understanding of the professionals on how expert opinion are being prepared and presented in the court of law. Estate Surveyors and Valuers fall within the categories of professionals of expert witnesses whose actions and opinions are required at every stage in the proceeding of real estate litigations by Lawyers who prepared them for determination of cases before the court and how the evidence is admissible. Hence this study will examine the Estate Surveyors and Valuers' understanding of expert witnessing in real estate litigation in Ibadan

metropolis. The remaining part of the paper is structured as follows: following the background is a review of relevant concepts and papers relating to expert witnessing. While the third section deals with methodology, the result and discussion are contained in section four. Section five contains the conclusion.

## **LITERATURE REVIEW**

### **Concept of Real Estate**

Graaskamp (1992) defined real estate as "space delineated by man, relative to fixed geography, intended to contain an activity for a specific period of time". According to Coiacetto (2006), it is the multi-dimensional, characterized with distinct features of use, landscaping, slope, development potential, tenure, building (materials, design) and the pattern of externalities (access to resources such as labour, school and amenity) that includes bundles of goods or services which could not be traded or priced independently.

Real estate includes the land and the building thereon or any improvements subject to change in use or modification, alteration, and redevelopment on the land (Dabara, Anthony, Gbenga, & Adeyanju 2014). Thus, real practice could be referred to as the inclusion of real estate and the associated collection of legal rights therein which could be subject to use, or to enjoy, to transfer, to alienate or to benefit from any futuristic intended use (Galaty, Allaway, and Kyle, 2000)

### **Estate Surveyor and Valuer**

Atoyebi (2015) described an estate surveyor and valuer (ESV) as a professional trained in the art and science of estate management to direct and supervise an interest in landed properties with the sole aim of obtaining optimum returns for the owners of such properties. By his training and experience, he is an elected corporate member of the Nigerian Institution of Estate Surveyors and Valuers (NIESV) and legalized by the Estate Surveyors and Valuers (Registration, ETC) Decree No. 24 of 1975, now CAP E13 LFN 2007.

The Estate Surveyor and Valuer offers a number of professional services to both individuals and the society at large which no one else can provide without professional skill and expertise. The functions include among others the services such as property management, valuation of assets, feasibility and viability studies, estate agency, public lands administration, land use planning and management, project management, property investment counselling, arranging finance for investment, arbitration (ESVARBON, 2014 and Babawale,2002).



### **Preparation of Expert Witness**

The goal of expert witness preparation is to assist the expert in delivering the message he or she has to share in an effective and responsible manner. Faigman (2002) averred that the first method in preparing the testimony of an expert witness is to become an expert by acquiring an in-depth knowledge of the subject matter, speak expert's language and understand the basic concepts of the discipline. Brodsky (1991) suggested that expertise is a situation specific and an effective expert witness must prepare for the role. However, the author was of the opinion that expert witnesses are not necessarily experts at being witnesses. Various studies supported that expert who are less credible are less persuasive (Boccaccini, 2004; Boccaccini, Gordon and Brodsky, 2004 and Boccaccini, Gordon and Brodsky, 2005). In 2009, Neal argued that the commonest method of expert preparation is self-preparation. There are several literatures devoted to helping expert witnesses prepare themselves for testimony in court, such as Warren (1997), Lubet (1998), Austin (2014) and Brodsky (1991, 1999, 2004). The study added that attorneys also work with expert witnesses to prepare them for testimony by reviewing, discussing and modification of testimony material with the witness (Boccaccini, 2002). Boccaccini (2002) cited in (Neal, 2009) in his review of the state of witness preparation distilled three basic components of preparation method; witness education, attorney education and modification of testimony delivery.

### **Expert Witnesses' Competence**

A competent witness is one considered in law as a fit and proper person to testify. Section 155(1) of the Evidence Act stated that All persons shall be competent to testify, unless the Court considers that they are prevented from understanding the questions put to them or from giving rational answers to those question, by reason of tender years, extreme old age, disease, whether of body or mind, or any other cause of the same kind".

Every compellable witness is obviously a competent witness since court will not compel anyone who is not competent. However, there are exception to the rule such as children, public office holders though they are competent witness under S.155 (1) E.A., but they are not compellable while they are in office. See *Okon v. State (1988) 1 NWLR (Pt.69) 177*; *Okoye v. State (1972) 12 SC 115*; *Rotimi & Ors v.Mcgregor (1974) 9 NSCC 42*.

Gonzalez (2014) noted that the trial court will consider the witness's life experiences, education, professional standing, licenses, certifications, publications, actual knowledge, honours received, books written, chapters written, literature published, and other qualifying

matters to determine if a witness should be accepted as an expert in a given field. The witness must be competent in the subject matter; they must be qualified through knowledge, skill, practical experience, training, education, or combination of these factors (Sapir, 2007).

### **Roles and Duties of Expert Witness**

Sutherland (2009) found that the job of the expert witness is to assist the decision maker (a court, tribunal, or other related body) with the information about the specialized area which is before a decision can be made. In 2009, The Brenner Group observed that when an expert is called to witness in a court proceeding, the expert witness must consider the following: the requirements of the court concerning the role the expert is expected to play, the rules of evidence and procedure the expert must follow, and the standard of reliability and relevancy the work must satisfy; the ethical and professional responsibilities to which the expert must adhere; the need for effective communication in the form of written and oral testimony.

Also, the expert witness should consider carefully the requirements and expectations of the court or other venue in which the dispute may be decided or arbitrated. The expert's responsibility is to the "trier of fact", which may be the judge, arbitrator, or jury of the case. The expert is expected to be impartial with respect to the litigating.

## **2.0 METHODS**

The study made reference to 2017 Estate Surveying and Valuation Registration Board of Nigeria (ESVARBON) directory which comprises financial members that were entitled to practice estate surveying and valuation residing in Ibadan metropolis. The directory has the name of 158 financial registered estate surveyors and valuers as at 2017 in the study area. Hence, the sampling frame for the study will be 158 registered estate surveyors and valuers. Adopting systemic sampling technique by selecting of one out of every fifteen respondents, the sample size for the study was 103 estate surveyors and valuers for which questionnaires were administered. Eighty-seven (87) questionnaires were retrieved representing 84.4%. Data collected were analysed with the descriptive statistics of frequency, mean score and factor analysis. The author collected the data for the study in 2018.

### 3.0 RESULT AND DISCUSSION OF FINDINGS

In order to establish the reliability of the data collected, information on profile of respondent estate surveyor and valuer in Ibadan Metropolis was gathered, thus providing relevant details that enhanced the drawing of relevant inferences from the result.

Table 1: Profiles of Estate Surveyors and Valuers in Ibadan Metropolis

Variables	Frequency	Percentage
Years of Registration		
1989 – 1999	6	6.90
2000 – 2005	22	25.3
2006 – 2011	45	51.70
2012 – 2016	14	16.1
<b>Total</b>	<b>87</b>	<b>100</b>
Years of post-registration Experience		
5 and below	5	5.8
6- 10	27	31
11 -15	18	20.7
16 and above	31	35.6
No response	6	6.9
<b>Total</b>	<b>87</b>	<b>100</b>
Position Held		
Principal	16	18.4
Partner		
Managing Partner	9	10.4
Senior Manager	18	20.7

Manager	24	27.6
Others	17	19.5
No response	3	3.4
Total	87	100

Academic		
Qualification		
HND	23	26.4
B.Sc.	30	34.5
M.Sc./MBA	30	34.5
Others	4	4.6
Total	<b>87</b>	<b>100</b>

Professional		
Qualification		
ANIVS	73	83.9
FNIVS	6	6.9
ARICS	1	1.1
No response	7	8.1
Total	<b>87</b>	<b>100</b>

The result reflects that majority 45 (51.70%) of the respondents qualified within the period of 2006 and 2011. Also, the result in Table 1 showed that the respondents with more than 16 years of experience representing 31 (35.6%) were prevalent across the others and no response were 17 (19.5%) and 3 (3.4%) respectively.

Furthermore, the result of the academic qualifications of the respondents ESV in the study area showed that majority of the respondents had one form of higher formal education or the other, with those in the B.Sc. and M.Sc. category having larger percentages 30 (34.5%) that indicated sufficient understanding of the questionnaire given to them, thereby enhancing data reliability. In the same vein, the professional qualification of these respondents was also examined. The result showed that 73(83.9%) of the respondents were associate members of the professional body, which serves as one of the criteria for registration, while 6(6.9%) were at the fellowship cadre of the Nigerian Institution Estate Surveyors and Valuers.

### **Real Estate Litigations that Expert Witnesses have been involved with.**

The study examined various real estate litigations that expert witness had been involved and engaged in. This was done in terms of their level of involvement and engagement as rated or perceived by the respondents. The result of the involvement of the respondents in real estate litigations in Ibadan metropolis is contained in Table 2. The findings show that most of the estate surveyors and valuers were involved in real estate litigations. The findings reveal that 16.1% and 33.3% of the respondents were involved in real estate litigation in the study area as very often and often respectively. This could be as a result of their year of experience and high positions occupied by the respondents in their various organization.

Table 2: Level of engagement in Expert witnessing

Engagement of expert witness	Estate Surveyor & Valuer	
	Frequency	Percentage
Engaged	35	40.2
Not engaged	52	59.8
<b>Total</b>	<b>87</b>	<b>100</b>

The result in Table 2 reveals the frequency of engagement of the respondents in expert witnessing in the study area using direct rating response such as engaged and not engaged. The result showed that the level of respondents' involvement and engagement in expert witnessing practice was on the average with 35 (40.2%). However, the respondents who had significant level of involvement in real estate litigation, expert witness engagement was low. This could be attributed to the low level of real estate litigations that required the services of an expert witness to support the case evident before the court. The respondents that were involved or engaged in expert witnessing in real estate litigation in the study area were further examined to elicit information on the area of real estate litigations that they might have involved in.

The respondents' professional qualification and their level of engagement in real estate litigation in the study area were examined in order to determine whether or not there were variations between them. The result presented in Table 4 shows that there is no statistically significant variation between the professional qualification and their level of engagement in real estate litigation as the  $p > .05$  level for two respondents [ $F(2,76) = .067$ ,  $p = .935$ ] for ESV. This infers that the respondents' involvement in litigation was not a function of professional qualification of the respondents as shown in Table 4.

Further analysis was carried out to know if there was any relationship between the respondents' qualification and their level of engagement as expert witness in real estate litigation in the study area. The result is contained in Table 5.

Table 3: Percentage distribution on Level of involvement in real estate litigations by ESV in Ibadan metropolis

Level of involvement	VO (5)	O (4)	SW (3)	NO (2)	N (1)	No Response	Total	Mean	Std. Deviation	Variance
Frequency	14	29	12	18	13	1	<b>87</b>			
Percentage	16.1	33.3	13.8	20.7	14.9	1.1	<b>100</b>	2.85	1.342	1.8

**Key:** VO (Very Often), O (Often), SW (Somewhat), NO (Not Often), N (None)

Table 4: Relationship between respondents' professional qualification and their level of engagement in real estate litigations in Ibadan metropolis.

Respondents		Sum of Squares	Df	Mean Square	F	Sig.
ESV	Between Groups	.214	2	.107	.067	.935
	Within Groups	121.229	76	1.595		
	<b>Total</b>	<b>121.443</b>	<b>78</b>			

Table 5: Relationship between professional qualification and Level of engagement as expert witness in real estate litigation

ESV	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	Minimum	Maximum
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					<b>Lower Bound</b>	<b>Upper Bound</b>		
<b>ANIVS</b>	69	1.59	.495	.060	1.48	1.71	1	2
<b>FNIVS</b>	6	1.50	.548	.224	.93	2.07	1	2
<b>ARICS</b>	1	1.00					1	1
<b>Total</b>	<b>76</b>	<b>1.56</b>	<b>.499</b>	<b>.056</b>	<b>1.45</b>	<b>1.67</b>	<b>1</b>	<b>2</b>

The result from Table 5 shows that the mean for ESV professional qualification, mean

Table 6: Preparation procedures for Expert Witnessing in real estate litigation

Preparation method	Estate Surveyor & Valuer	
	Frequency	Percent
Self-preparation	13	28.9
Attorney assisted	14	31.1
Joint expert panel	6	13.3
Teamwork assisted	12	26.7
<b>Total</b>	<b>45</b>	<b>100</b>

for ANIVS is 1.59, the mean for FNIVS is 1.50 and the mean for ARICS is 1.00. The standard deviation for ANIVS is 0.495, the standard deviation for FNIVS is 0.548. This indicates that professional qualifications have significantly influence on the expert witnessing practice.

From the analysis in Table 6, the most widespread experience was in the rent dispute ranked 1<sup>st</sup> with a mean score of 3.48 followed by tenancy tenure disagreement ranking 2<sup>nd</sup> with 3.24 mean value. The result could be as result of number of parties involved in rent dispute issue, which could be in term of rent determination, rent review, rent collection, etc frequently leading to litigation. This appears that the respondents acted more as expert witness with the activities that ranked 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> and may be attributable to the fact that they are general day-to-day professional activities in real estate practice. Other real estate activities involving expert witnessing are compulsory acquisition disputes, compensation and Estate Taxation representing mean score of 2.5, 2.38 and 2.26 respectively, while partition of real estate interest, family property dispute and restrictive covenant such as easement were ranked least with mean score of 2 for each of them. The result from the analysis shows the feat that respondents rarely acted as an expert witness in these real estate litigations might be due to the government regulation and policies guiding them. In summary, it can be inferred from the analysis that the respondents involved more as expert witness in general real estate litigation than the core area of expertise in real estate such as valuation, appraisal.

Findings in Table 6 established that attorney assisted method with 14(31.1%) was ranked highest by the ESV followed by teamwork assisted and joint expert panel. This might be attributable to the fact that an expert witness prepares his evidence based on his experience and the facts at his disposal that would enable him to present and defend his evidence in the court,

meanwhile the legal practitioners believe that putting the expert through the procedures would be the best method of preparing expert witness for presentation of evidence in the court. The reason for these differences in preparation method could be as result of the professional ethics guiding each profession and the standard expected of any professional to meet when acting as expert witness and when engaging the service of expert witness.

Table 7 Ranking of Involvement of ESV as Expert Witness in the Real Estate litigation.

Real Estate activities	N (1)	R (2)	S (3)	O (4)	A (5)	TW V	Mea n	MD	Std. Dev	Varianc e	Ran k
Rent dispute	1	4	9	1	4	108	3.48	0.829	0.996	0.991	1 <sup>st</sup>
Tenancy tenure Disagreement	1	7	8	1	3	94	3.24	0.589	1.057	1.118	2 <sup>nd</sup>
Property Maintenance Dispute	1	6	1	9	2	95	3.17	0.519	0.95	0.902	3 <sup>rd</sup>
Land ownership Dispute	0	1	1	9	1	96	3	0.349	0.88	0.774	4 <sup>th</sup>
Service Charge Administration	4	5	1	8	2	86	2.97	0.319	1.149	1.32	5 <sup>th</sup>
Estate Agency Dispute	4	8	1	8	0	88	2.75	0.099	0.984	0.968	6 <sup>th</sup>
General valuation	6	4	1	5	1	84	2.71	0.059	1.071	1.146	7 <sup>th</sup>
Compulsory acquisition disputes	8	9	7	7	1	80	2.5	- 0.151	1.191	1.419	8 <sup>th</sup>
Compensation	9	1	6	6	1	76	2.38	- 0.271	1.185	1.403	9 <sup>th</sup>
Estate Taxation	1	8	8	5	1	77	2.26	- 0.391	1.189	1.413	10 <sup>th</sup>
Partition of real estate interest	1	1	6	2	0	58	2	- 0.651	0.926	0.857	11 <sup>th</sup>
Family Property Dispute	1	1	5	3	0	64	2	- 0.651	0.95	0.903	12 <sup>th</sup>
Restrictive covenant: easement,	1	9	5	4	0	62	2	- 0.651	1.065	1.133	13 <sup>th</sup>

Key: N (Never), R (Rarely), S (Sometimes), O (Often), A (Always)

Result from Table 7 established that there is positive correlation between years of registration/experience, position held and level of an expert witness's knowledge. Further findings revealed that the commonest real estate litigations were from rent dispute, tenancy



disagreement, property maintenance dispute, land ownership disagreement and valuation which were the day to day real estate activities engaged by the respondents. Also, the findings showed that legal position of the expert witnessing is not only accepted, but strongly endorsed by the professional bodies in which the expert belongs to, the duty of expert witness is reflected in professional certification which is mandatory for its members that could enhance the reliability and admissibility of expert witness evidence.

### **SUMMARY OF FINDINGS**

This study examined expert witnessing in real estate litigation. The result revealed that expert witnesses in the study area were experienced professionals, who could sufficiently guide decision making in real estate litigations. He or She gives objective and sound evidence of his or her knowledge and ability to act as expert witnesses effectively. Also, timely preparation of objective and impartial evidence that would be admissible in the court.

### **RECOMMENDATION**

The study examined the estate surveyors and valuers's understanding of expert witnessing in real estate litigation in Nigeria. The study recommends that practitioners should adequately prepared before appearance in court and experts should continue to strive to gain experience in the profession and strive to be at the top level so as to be engaged in the practice of expert witnessing. The study further recommends that practitioners should increase their interest in specialization. Specialization will help in improving teamwork should be encouraged so as to pool ideas together with other relevant professionals that would produce sound report that would not be rejected in the court.

### **4.0 CONCLUSION**

This study examined the expert witnessing in real estate litigation in Ibadan Metropolis based on the perspective of the respondents ESV, the work identifies there were low awareness level about the practice of expert witnessing, the real estate litigations and likelihood of factors and problems affecting the admissibility of the expert witness report. Thus, there is need for real estate practitioners to focus more on the act of witnessing in real estate litigation in order to ensure presentation of sound, objective and impartial evidence enhance expert witnessing in real estate professional practice.

## **REFERENCES**

- Atoyebi F., (2016). Role of Estate Surveyors and Valuers in Nigeria National Development, [https://www.Researchgate.net/publication/324942807\\_Role\\_of\\_Estate\\_Surveyors\\_and\\_Valuers\\_in\\_Nigeria\\_National\\_Development](https://www.Researchgate.net/publication/324942807_Role_of_Estate_Surveyors_and_Valuers_in_Nigeria_National_Development). Retrieved on May 14, 2017.
- Austin G.W. (2014). Select the Out-of-Town Appraisal: New Social Science Research on Real Estate Expert Witness Selection. *Land Use & Real Estate Law eJournal*, 6,180.
- Babawale G. K. (2002). The Position of the Estate Surveyor and Valuer as an Expert Witness, *Journal of the Nigerian Institution of Estate Surveyors and Valuers*, 25(1),21-25.
- Bello N. A. and Agbato S. E. (2005) Valuation Litigation: The Role of Estate Surveyor and Valuer as Expert Witness, *Journal of Land Use and Development Studies*, 1(1), 60-65.
- Boccaccini M.T. (2002). What do we really know about witness preparation? *Behavioural Sciences and the Law*, 20, 161-189.
- Boccaccini M.T. (2004). Impact of witness preparation training on the use of target testimony delivery skills, perceived credibility, and evaluations of guilt. *Dissertation ABSTRACTs International: Section B: The Science and Engineering*, 64(8-B0), 4023.
- Boccaccini M. T., Gordon T., and Brodsky S.L (2004). Effect of witness preparation on witness confidence and nervousness, *Journal of Forensic Psychology Practice*, 3, 39-51.
- Boccaccini M. T., Gordon T., and Brodsky S.L (2005). Witness preparation training with real and simulated criminal defendants, *Behavioural Science and the Law*, 23, 659-687.
- Brodsky S. L. (1991). *Testifying in Court: More maxims and Guidelines for testifying in court*. Washington, DC: American Psychological Association, 02(4),15-16
- Brodsky S. L. (1999). The Expert Witness: Guidelines and maxims for the expert witness. *Washington, DC: American Psychological Association*. 15(2) 18-19
- Brodsky S. L. (2004). Coping with cross-examination and other pathways to effective testimony. *Washington, DC: American Psychological Association*.
- Coiacetto E., (2006). Real Estate Development Industry Structure: Consequences for Urban Planning And Development. *Journal of Australian Capital Territory Land Development agency*, Vol 21, 2006, Issue 4.
- Couture G. W. and Haynes A W., (2010), *Litigators on Experts: Strategies for Managing Expert Witnesses from Retention through Trial*, American Bar Association, Chicago,
- Dabara D., Anthony A.,Gbenga O.,Adeyanju O.,(2014). Decision Theory and its Relevance to Real Estate Development Decision. *British Journal of Economic, Management and Trade*. 4 (12):1861-1869.
- Enofe, A. O., Odigie, A. O., Onoyase, O. J., Omokhuale, O. P. (2015), Expert Witness and the Court System, *Developing Country Studies*, 5 (12).

- ESVARBON (2015). *2015 Directory of registered individual and firms to practice of estate surveying and valuation made under the ESVARBON Act, 1978.*
- Faigman D. (2005). *Modern Scientific Evidence, The Law and Science of Expert Testimony, 2 Social and Behavioural Science*, 168.
- Galaty F, Allaway W, and Kyle R (2000). *Modern real estate practice*. 15th edn, Real Estate Education Company, Chicago.
- Graaskamp, J. A. (1992): Fundamentals of real estate development, in: *Journal of Property Valuation & Investment*, 10, 619-639.
- Lubet S. (1998). *Expert Testimony: A guide to expert witnesses and the lawyers who examine them. Nortre Dame, IN: National Institute for Trial Advocacy.*
- Musil T. A. (2008). The Role and Challenges of Real Estate Expert Witnesses, *Minnesota Real Estate Journal*, 24, 710.
- Neal T.M.S. (2009). Expert Witness Preparation: What Does the Literature Tell Us?, *The Jury Expert*, 2009, 21(2), 44-52.
- OECD/Eurostat (2014), "Real estate activities", in *Eurostat-OECD Methodological Guide for Developing Producer Price Indices for Services: Second Edition*, OECD Publishing, Paris.
- Samuel G. (1991). Expert Evidence, 1991 Wisc L. Rev 1113-1119.
- Sapir G.I. (2007), Qualifying the Expert Witness: A Practical Voir Dire. *Forensic Magazine*, February, 1 March.
- Sanchez, M. H. and Zhang, S. W. (2012). The role of the expert witness in accounting fraud cases. *Global journal of business research*. 6(1). Retrieved from; <http://ssrn.com/ABSTRACT=1946013>.
- Sutherland R. (2009). Expert Evidence- The Role, Duties and Responsibilities of the Expert Witness in Litigation, *Expert Witness Training Seminar, Terra Firma Chambers*, April.
- Warren R.A. (1997). *The Effective Expert Witness: Proven Strategies for Successful Court Testimony*, Lightfoot, VA: Gaynor Publishing, 21-25

## **HYDRAULIC MODELING OF A NATURE-BASED APPROACH TO SUBMERGED FLEXIBLE DRAINAGE LINING**

Suleiman, M. and Busari, A.O.

Federal University of Technology, Minna, Nigeria.

Department of Civil Engineering FUT Minna.

\*Email : [mammagi1385@gmail.com](mailto:mammagi1385@gmail.com)

### **ABSTRACT**

This study applies dimensional analysis to the hydrodynamics of vegetative channels. It further uses in-house one-dimensional (1-D) hydrodynamic model to replicate velocity profiles obtained from several laboratory experiments under varying hydraulic conditions and flexibilities. Based on the dimensionally scaled vegetative and flow parameters, the results show that velocity profiles, Reynolds stresses and deflected height of vegetation depends on the flow conditions and plant flexibility.

**Keywords:** Hydraulic roughness equation, velocity profile, 1-D model, dimensional analysis, flexible lining.

### **1. Introduction**

Natural river channels and wetlands have ecological importance in riverine landscapes (Newson, 1992; Ward *et.al*, 2001). Vegetation around the channels comprises a diverse and heterogeneous combination of herbs, shrubs and trees, which influence sediment, nutrient and pollutant transport (Nepf and Vivoni, 2000). Vegetation also reduces erosion and flooding because the velocity of flow in the vegetation zone of a drainage channel decreases with density. Two types of vegetation are usually defined: stiff (typically woody) and flexible (herbaceous plants).

Flexible herbaceous vegetation is widely used as a protective liner in agricultural waterways, flood channels or drainages. Effects of vegetation on flow are important and could cause difficulties in hydraulic design. Submerged conditions are distinguished, since flow phenomena become more complicated when the flow depth exceeds the height of plants.

The purpose of this paper is to use a hydrodynamic model to replicate velocity profiles, Reynold stresses and deflection obtained from several laboratory Experiments under varying hydraulic conditions of flow and flexibilities.

In Nigeria, a large number of people live in places where there are river channel and streams mainly because of farming occupation, so in the past for a long period of time, the flood discharge capacity of rivers was considered as the most important factor in the river management. In recent time, increasing in flooding has resulted to loss of lives and properties. Preventing flood could save large number of lives and economic losses can also be avoided. Therefore, flexible vegetation lining should be encouraged to be planted along water way or channel. The flexible linings on natural channel dissipate the energy and the velocity of the flow. So it is advisable to rebuild a healthy aquatic ecosystem. A great effort should be made to recover the healthy ecological environment of rivers and riparian zones. This paper presents a numerical model to replicate the hydraulic behaviour of a natural-based canopy along waterways.

The restoration of natural riverine environment is a significant task in river management worldwide. This prompts the hydraulic research in vegetated flows in streams, rivers and coastal waters. Vegetation is an indicator of richness and diverse living resources with possession of great environmental and socio-economic importance for many countries of the world (DSD/ Moc MacDonald, 2009). The growth of natural vegetation in waterway and wetlands is favoured because of its ecological and environmental importance (Lopez and Garcia, 2001; Li and Yu, 2010). Vegetation can trap and stabilize sediment along waterways as well as to reduce river bed erosion (Wilson, 2007).

In addition, it can improve water quality, reduce turbidity, induces biological purification processes, hence reduce discharged nitrates and phosphates in rivers (Velasco et al, 2003; Nezu and Sanjou, 2008). It can also attenuate flood waves and protect coastal and riparian against flooding (Cheng and Nguyen, 2011, Busari and Li, 2014); provide habitat resources and river aesthetics (Pirim et al, 2000; Li and Yan, 2007); balance the global ecosystem (Vassilios, 2000), and enhance ecological equilibrium (Defina and Bixio, 2005). Lastly, it can provide a source of livelihood for aquatic animals (Li and Xie, 2011) and interestingly, a valuable resource for public environmental education and scientific research (DSD/ Moc MacDonald, 2009). Therefore, the understanding of the hydrodynamics of vegetation for ecological and environmental sustainability is paramount.

### 3. Methodology

In this study-the 1-D version of the model developed by Busari and Li, 2015 is used, in most cases, vegetated flows are unidirectional and, with shallow flow depth. Multi-dimensional models require more computational effort and are not efficient for the generation of a large number of synthetic data.

#### 3.1 Governing equations

The primary quantities to describe an open-channel flow are the velocity and pressure. For water (a Newtonian fluid), the flow is incompressible and is governed by the Navier –Stokes equations (NSE). The 1D version of the equations can be written as follows.

*Continuity equation*

$$\frac{\partial u_i}{\partial x_i} = 0 \quad i=1 \quad (1)$$

*Momentum equation in horizontal direction:*

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = \frac{\partial}{\partial x_j} \left[ \nu_m \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) + \frac{\tau_{ij}}{\rho} \right] - \frac{1}{\rho} \frac{\partial p}{\partial x_i} - \frac{1}{\rho} F_i + g_i \quad i=1, j=3 \quad (2)$$

where  $x_i$  ( $= x_1$ ) = coordinate in horizontal direction ( $m$ );  $u_i$  ( $= u_1$ ) = time averaged velocity in horizontal direction ( $m/s$ );  $u_j = 0$ ;  $t$  = time ( $s$ );  $\rho$  = fluid density ( $kg/m^3$ );  $\nu_m$  = molecular viscosity ( $m^2s^{-1}$ );  $\tau_{ij} = -\rho \overline{u'_i u'_j}$  = Reynolds stresses ( $N/m^2$ );  $p$  = pressure ( $N/m^2$ ) is assumed to be a constant;  $F_i = F_x$  ( $N/m^3$ ) is the resistance force components per unit volume induced by vegetation in  $x$  directions.  $g_i$  is the  $x$ -component of the gravitational acceleration and is set to  $gS_o$ , where  $S_o$  = channel bottom slope.

The Reynolds stresses are represented by eddy viscosity model:

$$\frac{\tau_{ij}}{\rho} = -\overline{u'_i u'_j} = -2\nu_t \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \frac{2}{3} \delta_{ij} k \quad i=1, j=3 \quad (3)$$

where  $k = \frac{1}{2} \overline{u'_i u'_i}$  = turbulent kinetic energy ( $m^2s^{-2}$ ) which can be absorbed into the pressure gradient term and  $\nu_t$  = eddy viscosity ( $m^2s^{-1}$ ).

The eddy viscosity  $\nu_t$  is specified by the Spalart-Allmaras (SA) turbulence model which involves the solution of a new eddy viscosity variable,  $\nu$ . The version of the model used is for near-wall region and moderate Reynolds number, which is most relevant to the present problem (Spalart and Allmaras, 1994).

### 3.2 Closure model

The Spalart- Allmaras (S-A) one equation turbulence model is simpler compared to the well-known  $k - \varepsilon$  model and has been found successful in the modeling of vegetated flows (Li and Yan, 2007; Li and Yu, 2010; Li and Zhang, 2010; Paul et al, 2014). The model is applicable to near-wall region and for moderate Reynolds number. It describes the convective transport, along with the production, diffusion, and destruction of eddy viscosity. Detail of the closure model can be found in (Spalart and Allmaras, 1994; Sebastien et al, 2002; Li and Yan 2007; Li and Zeng, 2009; Busari and Li, 2015).

$$\frac{\partial \nu}{\partial t} + u_j \frac{\partial \nu}{\partial x_j} = C_{b1} \tilde{S}_\nu \nu + \frac{1}{\rho} \left\{ \frac{\partial}{\partial x_j} \left[ (\nu + \nu_m) \left( \frac{\partial \nu}{\partial x_j} \right) \right] + C_{b1} \left( \frac{\partial \nu}{\partial x_j} \frac{\partial \nu}{\partial x_j} \right) \right\} - C_{w1} f_w \left( \frac{\nu}{d} \right)^2 \quad (4)$$

The eddy viscosity is defined as

$$\mu_t = \rho \nu f_{\nu 1} = \rho \nu_t \quad (5)$$

Where  $f_{\nu 1} = \frac{\chi^3}{\chi^3 + C_{\nu 1}^3}$

$$\text{with } \chi = \frac{\nu}{\nu_m} \quad (6)$$

The vorticity magnitude  $S_\nu$  is modified as:

$$\tilde{S}_\nu = S_\nu + \frac{\nu}{\kappa^2 d^2} f_{\nu 2}$$

$$\text{with } S_\nu = \sqrt{\omega_j \omega_j} \quad (7)$$

$$f_{\nu 2} = 1 - \frac{\chi}{1 + \chi f_{\nu 1}} \quad (8)$$

$$f_w = g \left[ \frac{1 + C_w^6}{g^6 + C_w^6} \right]^{1/6} \text{ with } g = r + C_{w2}(r^6 - r), \quad r = \frac{\nu}{\tilde{S}_\nu \kappa^2 d^2} \quad (9)$$

Constants of the model are:

$\kappa = 0.41$ ;  $\sigma = 2/3$ ;  $C_{b1} = 0.1355$ ;  $C_{b2} = 0.622$ ,  $C_{v1} = 7.1$ ;  $C_{w1} = \frac{C_{b1}}{\kappa^2} + \frac{1+C_{b2}}{\sigma}$ ;  $C_{w2} = 0.3$ ;  $C_{w3} = 2$  and  $d$  =length scale.

The S-A closure model has been basically developed for aerodynamic flows. It is intrinsically a transport equation for the eddy viscosity was developed under the well-known Boussinesq hypothesis. It has been successfully applied in the modelling of free-shear flow, wall-bound flow and separated flow problems.

The resistance force due to vegetation is defined by the quadratic friction law. The average force per unit volume within the vegetation domain is given by:

$$f_i = \frac{1}{2} \rho C_d w u_i \sqrt{u_j u_j} \quad i=1 \quad (10)$$

Where  $C_d$  = drag coefficient of stem,  $w$  = width of stem. The drag force resulted from wake formation downstream of the stem. The average force per unit volume within the vegetation domain is obtained by

$$\begin{aligned} F_i &= N f_i = \frac{1}{2} \rho C_d N w u_i \sqrt{u_j u_j} \\ &= \frac{1}{2} \rho f_{rk} u_i \sqrt{u_j u_j} \quad i=1 \end{aligned} \quad (11)$$

where  $N$  = vegetation density (defined as number of stems per unit area,  $1/m^2$ ) and  $f_{rk} = C_d N w$ .

In case of wall bounded shear flow, the turbulence length scale  $d$  is proportional to the distance from the point of interest to the channel bed. In the presence of vegetation, the turbulence eddies above the vegetation layer may not reach the channel bed, thus there will be reduction in the turbulence length scale. One approach to simulate the reduction in the turbulence length scale is to introduce a zero plane displacement parameter,  $Z_o$ . The turbulence length scale of a point at level  $Z$  is obtained by

$$\begin{cases} L = Z - Z_o, & Z > h_d > Z_o \\ L = Z (h_d - Z_o) / h_d, & Z < h_d \end{cases} \quad (12)$$

where  $h_d$  is the deflected height of vegetation ( $m$ ).

### 3.3 Flexibility (Large deflection analysis)

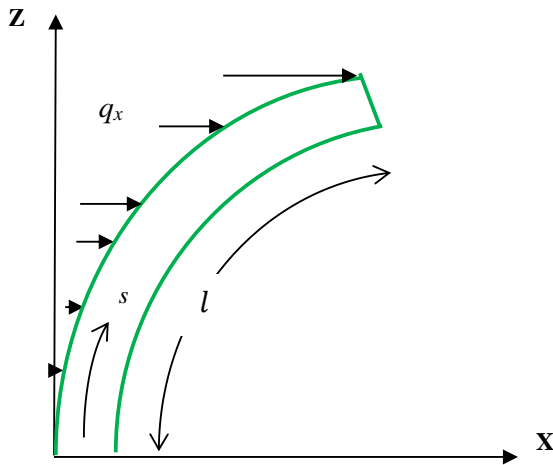


Natural vegetation bend easily in high flow and the deformation of the top of vegetation can be of the same order as the deflected plant height. Hence, the classical analytical expression for transducer deformation which is based on theory small deformation as previously used (Kutija and Hong, 1996; Erduran and Kutija, 2003; Kubrak, et al, 2008) may not be adequate for vegetation with high flexibility. The selected model uses a large deflection analysis based on the Euler-Bernoulli law for bending of a slender transducer has been used to determine the large deflection of plant stem (Li and Xie, 2011).

In the analysis each vegetation stem is modelled as a vertical in-extensible non-prismatic slender transducer of length,  $l$ . The water flows produce variable distributed loads  $q_x(s)$  on the transducer along the  $x$ -direction as shown in Figure (1). From Euler-Bernoulli law, the local bending moment is proportional to the local curvature.

$$M(s) = EI(s) \frac{\frac{d^2\delta}{ds^2}}{1 - \left(\frac{d\delta}{ds}\right)^2} \quad (13)$$

where,  $M$  is the bending moment ( $Nm$ ),  $s$  is the local ordinate along the transducer,  $E$  is the modulus of elasticity ( $N/m^2$ ),  $I$  is the Second moment of area ( $m^4$ ) and,  $\delta$  is the deflection in  $x$ -direction ( $m$ ).



**Figure 1:** Schematic diagram of large deflection of a transducer carrying distributed load.

The equilibrium of forces and momentum gives

$$\frac{d^2M}{ds^2} + \frac{dM}{ds} \frac{\frac{d\delta d^2\delta}{ds ds^2}}{\left[1 - \left(\frac{d\delta}{ds}\right)^2\right]} = -q_x(s) \sqrt{1 - \left(\frac{d\delta}{ds}\right)^2} \quad (14)$$

Combining of equations the Euler-Bernoulli law (13) and the equation of equilibrium of forces and moments (14) yielded a fourth order nonlinear equation in the deflection  $\delta$

$$\frac{d^2}{ds^2} \left[ EI(s) \frac{\frac{d^2\delta}{ds^2}}{1 - \left(\frac{d\delta}{ds}\right)^2} \right] + \frac{d}{ds} \left[ EI(s) \frac{\frac{d^2\delta}{ds^2}}{1 - \left(\frac{d\delta}{ds}\right)^2} \right] \frac{\frac{d\delta d^2\delta}{ds ds^2}}{\left[1 - \left(\frac{d\delta}{ds}\right)^2\right]} = -q_x(s) \sqrt{1 - \left(\frac{d\delta}{ds}\right)^2} \quad (15)$$

The vegetation stem is taken as inextensible as the total length remains constant. By dividing the stem into  $n$  equal part of constant length  $\Delta s$ , the  $z$ -ordinate of the  $i$ th node is obtained by

$$z_i = \sum_{j=1}^i \sqrt{\Delta s^2 - (\delta_j - \delta_{j-1})^2} \quad (16)$$

### 3.4 Numerical methods and Boundary conditions

The deflected height of the stem is then equal to  $z_n$ . The equation (15) is then solved using a quasi-linearized central finite difference scheme. In order to minimize computational effort, the solution is expressed in non-dimensional form relating the deflected height of vegetation to the applied force, and is approximated by a polynomial.

At the free surface, by neglecting the wind and surface tension, the dynamic condition can be satisfied by specifying zero pressure and zero gradients of velocity component:

$$p = 0 \quad \text{and} \quad \frac{\partial u_i}{\partial \sigma} = 0 \quad (17)$$

At the bottom, the logarithmic law wall function is imposed to calculate the wall shear stress used in diffusion step. The wall function is given by

$$u = u_w \left[ \frac{1}{\kappa} \ln \left( \frac{u_w z}{\nu_m} \right) + B \right],$$

$$\nu = \kappa z u_w \quad (18)$$

where  $u_w$  = wall shear velocity ( $m/s$ );  $z$  = distance from the wall ( $m$ ); and  $B = 8.5$ . By knowing the velocity at the point next to the wall with distance,  $z$  the wall shear stress can be computed iteratively. A detailed description of the model can be found in (Busari and Li, 2015)

### 3. Results and discussion

#### 3.5 Model Calibration

The number of (uniform) grids used is 81 and the time step size is in the order of 0.005s to ensure computational stability. Grid convergence study shows that further reduction of grid size does not affect the results practically. The 1-D model has been calibrated using data from previous experimental works conducted to investigate open channel flows with flexible or rigid submerged vegetation and the details of each laboratory investigation have been described (Busari and Li, 2016).

The following experimental cases were simulated using the model. Generally, the dataset contains eight variables, i.e., flow depth ( $h$ ), energy slope ( $S$ ), strip width or stem diameter ( $w$ ), vegetation height ( $h_v$ ), discharge ( $Q$ ), flexural rigidity ( $EI$ ) and number of strips or stems per unit area ( $N$ ). Two parameters are required to be calibrated: the bulk drag coefficient and the zero-plane displacement parameter. The latter is significant in the clear water zone while the former is important in the vegetation zone.

Table 1: Experimental conditions (Dunn et al, 1996)

<b>Experimental nbr.</b>	<b><math>N</math></b> (stems/ $m^2$ )	<b><math>H</math></b> ( $m$ )	<b><math>h_v</math></b> ( $m$ )	<b><math>Q</math></b> ( $m^3/s$ )	<b><math>S</math></b> (%)
2	172	0.23	0.1175	0.088	0.36
6	43	0.27	0.1175	0.178	0.36
13	172	0.37	0.152	0.179	0.36
15	43	0.26	0.132	0.179	0.36

The experiments consisted of flows through both flexible and rigid vegetation in a flume under uniform flow conditions. Detail can be found in Dunn et al, 1996. The hydraulic conditions are as shown in Table 1. Figures 2 and 3 showed that the numerical results match well with the experimental results.

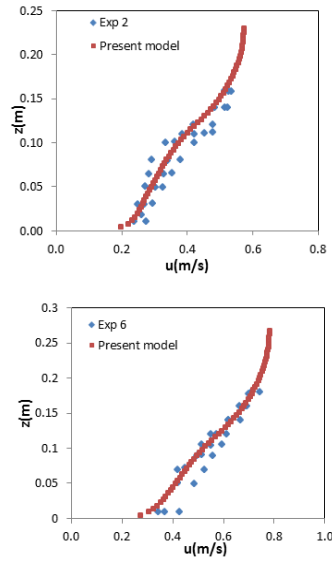


Figure 2: Comparison between computed results and measured mean vertical velocity distribution for flexible vegetation (Data from Dunn et al, 1996)

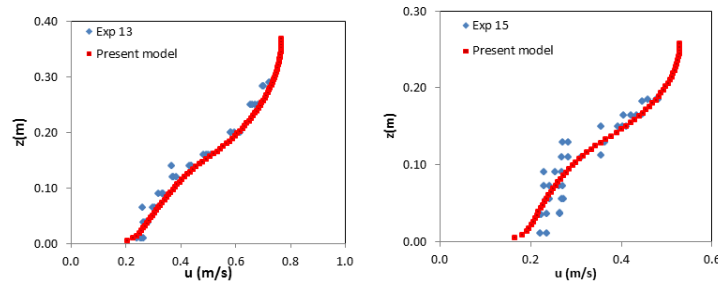


Figure 3: Comparison between computed and measured mean vertical velocity distribution for rigid vegetation. (Data from Dunn et al, 1996)

### 3.6 Numerical simulation

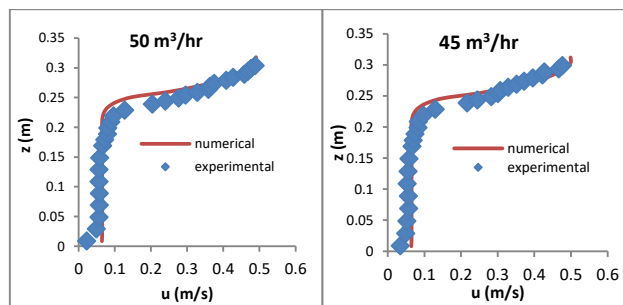
The Reynolds Averaging Navier – Stokes (RANS) model described in section (3.1) was used to simulate the flume experiments. A total of 12 simulations were shown under different hydraulic conditions using measured bulk drag coefficient. Five scenarios are presented in this paper. The key parameters are shown in Table 2. The exercise is to assess the accuracy of the S-A model to replicate the mean stream-wise fully developed vertical velocity profiles through and above vegetation patches of different areal densities as well as Reynolds stresses.

Table 2: Experimental hydraulic conditions and measured  $C_d'$  (sheltering effect)

$\lambda$ ( $m^{-1}$ )	$h$ (m)	$U$ (m/s)	$f_{rk}$ ( $m^{-1}$ )	$f_v$ (-)	$z_o/h_v$ (-)	$gS_w$ ( $m/s^2$ )	$C_d'$ (-)
12	0.283	0.10	46.65	11.6	0.900	0.054	3.8
24	0.318	0.15	99.68	23.8	0.937	0.010	4.1
48	0.312	0.14	120.53	30.1	0.946	0.013	2.5
48	0.319	0.16	131.17	32.8	0.949	0.017	2.7
72	0.357	0.13	131.51	32.9	0.949	0.022	1.8

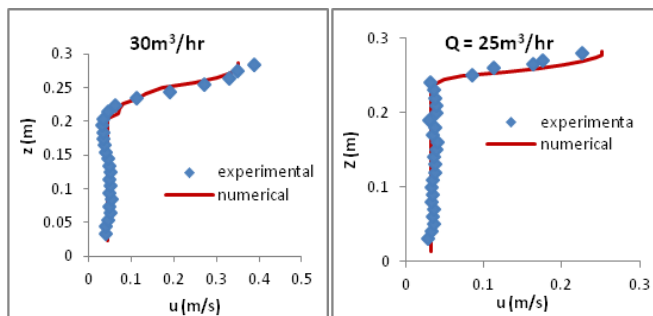
Note:  $S_w$  is the average water surface slope

The numerical model is used to replicate all the experimental dataset. Generally, the predictions are quite good. Figures 4 and 5 are representative results, showing the comparison between the numerical results and the experimental results of the velocity profiles and Reynolds stresses obtained in this study.



4a

4b



4c

4d

Figure 4: Comparison of vertical distribution of mean stream-wise velocity at various flow rates for varying vegetation densities.

The computed velocity profiles agree well with those measured in the experiments. From the Figure 4, it can be seen that the numerical model successfully replicate most of the characteristics of the flows.

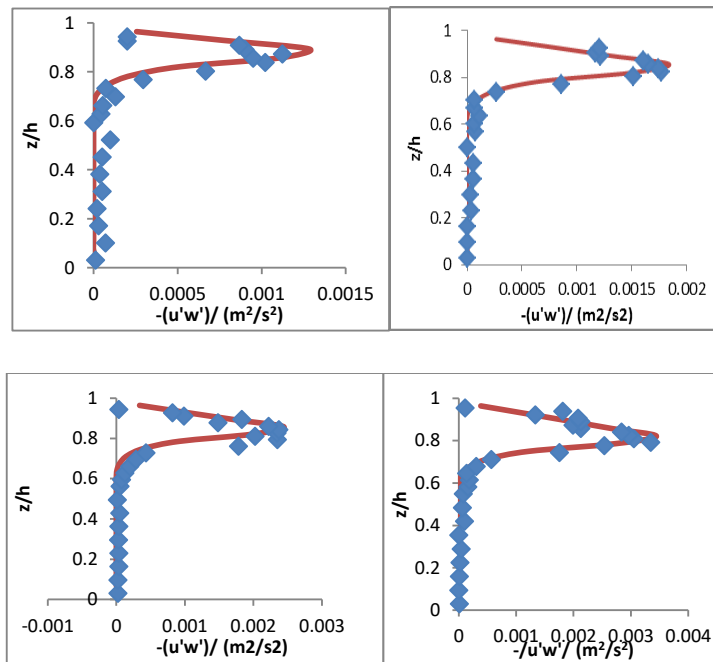


Figure 5: Comparison of vertical distribution of the Reynolds shear stresses

From the second-order velocity fluctuations  $u'$  and  $w'$ , in the longitudinal and vertical directions  $x$  and  $z$ , respectively, the Reynolds stress has been calculated for the measurement under varying hydraulic conditions. In Figures 5, the predictive capability of the numerical model is further examined by simulating part of the experimentally measured vertical profiles of the Reynolds Shear stress. The Figures 5 illustrate the comparison of the measured vertical profiles of the Reynolds shear stresses and the computed one for the channeling effect under different flow condition and vegetation densities. The model predicts the maximum Reynolds stress quite well.

#### 4. Conclusion

The hydrodynamic model has been used to simulate a vegetated open channel flow and the computed result shows that the increase in vegetation density reduces turbulence of the flow. The numerical model used to replicate all the experimental data are good. The comparison between the numerical result and Experimental results of the velocity profile and Reynold shear stresses obtained in this study are good in agreement. The mean vertical velocity distribution

profiles and Average Reynolds stresses are well predicted using the 1-D RANS model. The understanding of vegetation for Ecological and Environmental sustainability is important. Restoration of natural riverine and Environment is important task in water channel or river management worldwide.

## **REFERENCES**

Aberle, J., & Järvelä, J. (2013). Flow resistance of emergent rigid and flexible floodplain vegetation. *Journal of Hydraulic Research*, 51(1), 33-45.

Afzalimehr, H., Moghbel, R., Gallichand, J., & Sui, J. (2011). Investigation of turbulence characteristics in channel with dense vegetation. *International Journal of Sediment Research*, 26(3), 269-282.

Buckman, L. (2013). Hydrodynamics of partially vegetated channels: stem drag forces and application to an in-stream wetland concept for tropical, urban drainage systems. Delft (MSc thesis report).

Busari, A.O and Li, C.W., (2015). A hydraulic roughness model for submerged flexible vegetation. *Proceedings of 35<sup>th</sup> IAHR World Congress*, September 8-13, 2013 at Chengdu, China.

Busari, A.O and Li, C.W., (2016). A hydraulic roughness model for submerged flexible vegetation with uncertainty estimation. *Journal of Hydro-environment Research*, volume 9, issue 2, pp 268 – 280.

Cheng, N.S and Nguyen, H.T., (2011). Hydraulic radius for evaluating resistance induced by simulated emergent vegetation in open channel flows. *Journal of Hydraulic Engineering*, Volume.137, No.9. pp 995 - 1004.

Defina, A and Bixio, A.C., (2005). Mean flow and turbulence in vegetated open channel flow. *Journal of Water Resources research*, volume 41, pp 1 – 12.

Drainage Services Department/ Mott Macdonald report (2009). *Mangrove growth: Management and hydraulic impacts*, Hong Kong.

Dunn, C., Lopez, F and Garcia, M., (1996). Mean flow and turbulence in a laboratory channel with simulated vegetation. Civil Engineering studies. Hydraulic engineering Series No.51.

Erduran, K.S and Kutija, V., (2003). Quasi-three-dimensional numerical model for flow through flexible, rigid, submerged and non-submerged vegetation. Journal of Hydroinformatic. Volume 5, number 3, pp 189-202. IWA publishing.

Kubrak, E., Kubrak, J & Rowiński, P.M., (2008). Vertical velocity distributions through and above submerged, flexible vegetation. Journal of hydrological sciences. Volume 53, number 4, pp 905 – 920.

Kutija, V and Hong, H.T.M., (1996). A numerical model for assessing the additional resistance to flow introduced by flexible vegetation. Journal of Hydraulic Research, volume 34, number 1, pp 99 – 114.

Li, C.W and Xie, J.F., (2011). Numerical modelling of free surface flow over submerged and highly flexible vegetation. Advances in Water Resources, Volume 34, pp 468–477. Elsevier publishing.

Li, C. W and Yan, K., (2007). Numerical Investigation of Wave–Current–Vegetation Interaction. Journal of Hydraulic Engineering, Volume 133, number 7, pp 794–803.

Li, C.W and Yu, L. H., (2010). Hybrid LES/RANS modelling of free surface flow through vegetation. Computers & Fluids, volume 39, pp 1722–1732.

Li, C.W and Zhang, M. L., (2010). 3D modelling of hydrodynamics and mixing in vegetation field under waves. Journal of Computers and Fluids, volume 39, pp 604–614. Elsevier publishing.

Li, C.W and Zeng, C., (2009). 3D numerical modelling of flow divisions at open channel junctions with or without vegetation. Journal of Advances in Water Resources, Volume 32, pp 46-60.



Lopez, F and Garcia, M.H., (2001). Mean flow turbulence structure of open-channel flow through non-emergent vegetation. *Journal of Hydraulic Engineering*, Volume.127, number, 5, pp 392-402.

Nepf, H.M and Vivoni, E.R., (2000). Flow structure in depth-limited, vegetated flow. *Journal of Geophysical Research*, volume 105, number C12, pp 547 – 557.

Nezu, I and Sajou, M., (2008). Turbulence structure and coherent motion in vegetated canopy open-channel flows. *Journal of Hydro-environment Research*, volume 2, pp 62 – 90. Elsevier publishing.

Pirim, T., Bennett, S and Barkdoll, B., (2000). Effect of Riparian Vegetation Density on Stream Flow Velocity. *Water Resources* 2000.

Sébastien, D., Philippe, D., Paulo, E and Guillen, P., (2002). Development and application of Spalart–Allmaras one equation turbulence model to three-dimensional supersonic complex configurations. *Aerospace Science and Technology*, volume 6, pp 171–183.

Spalart, P. R., and Allmaras, S. R., (1994). A one-equation turbulence model for aerodynamic flows. *La Recherche Aerospaciale*, volume 1, number 1, pp 5-21.

Vassilios, A. T and Edgar E. M., (2000). Hydraulic Resistance Determination in Marsh Wetlands. *Journal of Water Resources Management*, volume 14, pp 285–309. Kluwer Academic Publishers.

Velasco, D, Bateman, A., Redondo, J.M and Medina, V., (2003). An open channel flow experimental and theoretical study of resistance and turbulent characterization over flexible vegetated linings. *Flow, Turbulence and Combustion*. Volume 70, pp 69–88.

Wilson, C.A.M.E, (2007). Flow resistance models for flexible submerged vegetation. *Journal of Hydrology*, volume 342, pp 213 – 222.

Zeng, C., (2012). Numerical and experimental studies of flows in open channels with gravel and vegetation roughnesses. PhD thesis, Department of Civil and Structural Engineering, The Hong Kong Polytechnic University.

Zhang, M., Li, C.W and Shen, Y., (2012). Depth-averaged modelling of free surface flows in open channels with emerged and submerged vegetation. *Journal of Applied Mathematical Modelling*, volume 37, pp 540 – 553. Elsevier publishing

## **EFFECT OF CONTINUITY OF REFINERY ON THE WORKING INDEX OF ELECTRIC ARC FURNACE**

Okediran, K. I.<sup>1</sup>, Idris, M.O.<sup>1</sup> and Adetunji, R.O.<sup>2\*</sup>

<sup>1</sup>Mechanical Engineering Department, Osun state University, Osogbo, Osun State

<sup>2</sup>Mechanical Engineering Department, Federal University of Agriculture Abeokuta

\*Email of Corresponding Author: [yinkus59@yahoo.co.uk](mailto:yinkus59@yahoo.co.uk)<sup>1</sup>,

### **ABSTRACT**

Day in day out of human life the need for metal is indispensable. Metal is needed for the construction of different infrastructures such as houses, roads, bridges etc. Despite the fact there is huge amount of metal available, it does not meet the global demand. Thus, this paper investigated continuity of refinery as a measure to improve the efficiency of Electric Arc Furnace. In order to achieve maximum precision during production, getting the product at relatively reduced price has remained a major problem to Scientists. The experiment was conducted at industrial scale whereby the time was varied from 20 to 40 minutes while energy consumption rose from 0.0542 to 0.1103 mW-Hour/ton and productivity fell from 253.0 to 99.2 ton/Hour .The data were collected from active furnace in Zerepaves Metallurgical plant, Russia and analysed with software package for accuracy

Keywords EAF, Steel, Furnace, price

### **1.0 INTRODUCTION**

Total continuity of melting period can be defined not only by the time of its location under current in the furnace, but also time used on auxiliary technological operation, fulfilled while the furnace was switched off ordinarily on the on-loading of second or the next budding scrap [1-3]. In metallurgical plant firm Vallurek in Anzene France already in 1972, judging by the result of self chronometry, 60 ton EAF stopped on each pot 3-4 minutes . Continuity of smelting on that furnace was 2 hours in February 1984. Stop time of furnace on each pot in 100 ton furnace plant in Haisewide was averagely 3 minutes, and interval between smelting conducted with ruminants in the furnace 15-25 ton liquid steel –9.1 minutes. End of smelting here lasted for 3minutes when total cycle of smelting 80.9 minutes. Interval pause when poring each of the pots by scrap was 3mins /0.05hour/and became typical so also for other high productivity furnace can be explained by the fast mechanisms of mixing pots by over-heading cranes,

electrodes(0.35-0.75)kW-Hour electric energy[4-7]. Theoretically, by the total energy usage of arc, for that it is necessary  $0.86\text{MJ/T}^0\text{C/}$  about  $0.24\text{KW-Hour/T}^0\text{C/}$ .

Judging by these data, in 100ton furnaces relative power 750KV.A/ton and oxygen usage  $1000\text{m}^3/\text{Hour}$  when 100%of its assimilation, speed of heating metal in the melting oxidizing period of smelting while using high degree, secondary voltage can attain  $(12-14)^0\text{C/minutes}$ . By increasing temperature from 1550 to  $1670^0\text{C}$  and oxidizing 0.2%of carbon, as it is accepted in energy balance , continuity of melting period can be reduced to 9-10 min, in average up to 15-20 minutes, with consideration of stop-over to furnace to take the specimen of metal and its temperature record [1]. Metal is needed for the construction of different infrastructures such as houses, roads, bridges etc .but despite the fact there is huge amount of metal available, it does not meet the global demand. Thus, this paper investigated continuity of refinery as a measure to improve the efficiency of Electric Arc Furnace.

From the above, we can value the average continuity of cycle smelting minute in the super high-powered furnace to take the super high powered furnace, contain the following operation;

## **2.0 METHODOLOGY**

The experiment was conducted at industrial scale whereby the time was varied from 20 to 40 minutes while energy consumption rose from 0.0542 to 0.1103 mW-Hour/ton and productivity fell from 253.0 to 99.2 ton/Hour .The data were collected from active furnace in Zerepaves Metallurgical plant, Russia and analysed with software package for accuracy

Table 1: Time for Furnace Operation

S/N	Operation	Time(s)
1	-Filling the furnace on-loading the first scrap, put on and charge of electrode	20
2	- Melting the budding materials including internal operation pause	55
3	-Oxidation period; Heating and de-carbonation of the metal	15
4	-Delivery of metal from the furnace	5
5	Total	95

This above continuity corresponds to the value of time of one smelting cycle/80-95minutes/; shown in the work on the basis of working index of high productive modern EAF/650-800kV.A/ton/, by authors of the furnaces of 3<sup>rd</sup> generation.

Continuity of smelting cycle reduced even in subsequent years; in 1985, better results for furnaces capacities (100-120)ton closed to 70minutes. Continuity reduced as a result of intensification of technological periods of smelting and organization of methods, directed to the reduction of delay caused by internal and inter-smelting breaks.

For cutting down the melting time of budding materials under current [2] nowadays, widely use addition of oxygen gas to the working plane of furnace, oxygen chamber, positioned in the wall of the furnace between electrodes and on the windows. Generally, use of oxygen rise to 30m<sup>3</sup>/ton, to be mentioned during the melting period up to (20-25) m<sup>3</sup>. Continuity of refinery is one of the basic variants of continuity of oxidizing period/ one slag process/, and was accepted to be equal to 20min. Value of temperature can be something else depending on the condition of the process.

Circumstances that have effects on the continuity of oxidizing period are as follows:

- Carbon content during melting.
- Content of phosphorus in the budding materials.
- Degree of alloying metal.
- Organization of holding the process.

Value of T defines the relative continuity of refinery  $t_{pa} = \frac{T-t}{G \cdot 60 \cdot KP \cdot T}$ , Hour/t0n.

Where T- total continuity of process of refinery (minutes)

$t_{nkt}$  -continuity of stopping the current for refining period (minutes)

G- Furnace capacity (ton)

$K_{t\ cu}$ - coefficient of throwing the current for oxidation period=1.09

By varying the T from 20-40 (minutes), we calculated /on the computer /electric and working characteristics according to methods used in [8-10]. Result of the calculation and optimization parameters of the refinery is as shown in the table 2. and Fig 1.

### 3.0 RESULTS

Table 2 Effect of continuity of refinery on usage of electric-energy and efficiency (productivity) of furnace for refinery period

T, minutes	T <sub>Tex</sub> , Hour/ton	I <sub>1</sub> ,A	q <sub>ref</sub> ,ton/Hour	T, Hour/ton	W <sub>ref</sub> , Hour/ton	mW-
20	0.00397	34934	253.0	0.00395	0.0542	
25	0.00527	33457	190.0	0.00526	0.0662	
35	0.00703	32293	142.5	0.00702	0.0823	
40	0.01009	31199	99.2	0.01008	0.1103	

Selection of type of empirical formula in the given section is shown in details as follows;

For definition of type of empirical formula, it is necessary by experimental data to construct graph [2]

More comfortable on a millimeter paper/. Then follow to join the points by line so that the points of the graph were closed to the line and /some of the points can fall on the line/. This will be the graph function,

approximately will be the dependence between the quantities x and y, and equation formed by the line will be the empirical formula. If the line is straight, then of course we can say that relation between x and y is linear;

$Y=AX+B$ , where A and B are constants.

For non-linear dependent types of formula, we can define through compare of the drawn with the curves.

Analytic criteria exist for checkup of linear dependence between X and Y; by experimental data defined.  $\Delta X_i = X_{i+1} - X_i$ ;  $\Delta Y_i = Y_{i+1} - Y_i$ ;  $K_i = \Delta Y_i / \Delta X_i$  (i=1, 2, ..., n-1). If  $K_1 = K_2 = \dots = K_{n-1}$ .

Then at point (Xi, Yi) position for example on a straight line: If Xi is constant, i.e. value of Xi are equally distributed, and then convinced enough that  $\Delta Y_i$  is also constant (or almost constant).

During analysis and writing chemical laws and physio-chemical processes and phenomenon of empirical formula is common choose within the following function:

$$Y = Ax + B \quad (\text{Linear});$$

$$Y = AB^x \quad (\text{Exponential});$$

$$Y = 1/Ax = B \quad (\text{Rotational});$$

$$Y = A \ln x + B \quad (\text{Logarithmic});$$

$$Y = AX^B \quad (\text{Exponential, which if } B \neq 0, \text{ graph is parabolic and if } B = 0, \text{ graph is Hyperbolic});$$

$$Y = A + \frac{B}{X} \quad (\text{Hyperbolic});$$

$$Y = \frac{X}{Ax + B} \quad (\text{Rational});$$

In order to define which of the function is better or suitable for the experimental data, it is necessary to perform the following operations:

$$X_{ap} = \frac{x_1 + x_n}{2} \quad (\text{average arithmetical } x \text{ and } y);$$

$$X_1 = 0.01407; X_4 = 0.02019$$

$$X_{ap} = \frac{0.01407 + 0.02019}{2} = 0.01713$$

$$X_{reom} = \sqrt{x_1 + x_n} \quad (\text{average geometrical});$$

$$X_{reom} = \sqrt{0.01407 + 0.02019} = 0.0168$$

$$X_{rapm} = \frac{2x_1 x_n}{x_1 + x_n} \quad (\text{average harmonic});$$

$$X_{rapm} = \frac{2 \times 0.01407 \times 0.02019}{0.01407 + 0.02019} = 0.01658$$

$$Y_{ap} = \frac{y_i + y_n}{2}$$

$$Y_{ap} = \frac{y_1 + y_4}{2} = \frac{126.499 + 71.26}{2} = 98.879$$

$$Y_{reom} = \sqrt{y_1 \times y_n} = \sqrt{y_1 \times y_4} = \sqrt{126.499 \times 71.26} = 94.9437$$

$$Y_{rapm} = \frac{2 \times y_1 \times y_n}{y_1 \times y_n} = \frac{2 \times y_1 \times y_4}{y_1 \times y_4} = \frac{2 \times 126.499 \times 71.26}{126.499 \times 71.26} = 91.1647$$

2. By close approximation construction graph function, surrounding of which fall the experimental point (Xi, Yi), or by founded value Y\*ap, Y\*reom, Y\*rapm, corresponding value Xap, Xreom, Xrapm. By these, if for example Xap (or Xreom, Xrapm) coincide with the table Xi, then the corresponding value Y\*ap (Y\*reom, Y\*rapm) will be equal to Yi; alternatively, Y\*ap can be defined using formula of linear interpolation:

Y	126.499	108.68	91.16	71.26
X	0.01407	0.01537	0.01713	0.02019

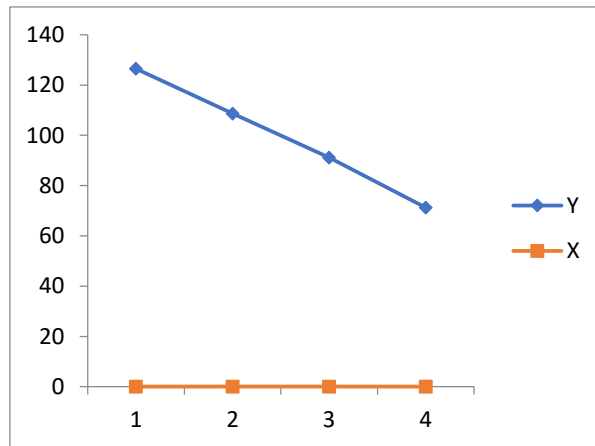


Fig.1

$$Y^*_{ap} = Y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i} (X_{ap} - X_i)$$

Where  $X_i, X_{i+1}$  - Given value among which falls within the range  $X_{ap}$  ( $X_i < X_{ap}$ );  $Y_i < Y^* < Y_{i+1}$  ( $i=1, 2, \dots, n$ )

$0.01713 < X_{ap} < 0.02019$ , then  $71.26 < Y_{ap} < 91.16$ ;

$$Y^*_{ap} = 71.26 = \frac{91.16 - 71.26}{0.02019 - 0.01710} (0.01713 - 0.01713) = 71.26$$

$0.01537 < X_{reom} < 108.68$ ;



$$Y^*_{roem} = 91.16 + \frac{71.26-91.16}{0.01713-0.01537} (0.01685-0.01537) = 74.42$$

$$0.01407 < X_{rapm} < 0.01537; 108.68 < Y_{rapm} < 126.499;$$

$$Y^*_{ap} = 108.68 + \frac{126.499-108.68}{0.01537-0.01407} (0.01658-0.01407) = 143.08$$

3. Find quantities

$$E_1 = | Y^*_{ap} - Y_{ap} | ;$$

$$E_2 = | Y^*_{ap} - Y_{reom} | ;$$

$$E_3 = | Y^*_{ap} - Y_{rapm} | ;$$

$$E_4 = | Y^*_{reom} - Y_{ap} | ;$$

$$E_5 = | Y^*_{reom} - Y_{reom} | ;$$

$$E_6 = | Y^*_{rapm} - Y_{ap} | ;$$

$$E_7 = | Y^*_{rapm} - Y_{rapm} |$$

And define minimum value of  $\epsilon = \min \{E_1, E_2, \dots, E_7\}$

$$E_1 = | 71.26 - 98.879 | = 27.61$$

$$E_2 = | 71.26 - 94.94 | = 23.68$$

$$E_3 = | 71.26 - 91.164 | = 19.90$$

$$E_4 = | 143.08 - 98.879 | = 44.20$$

$$E_5 = | 74.42 - 94.94 | = 20.52$$

$$E_6 = | 143.08 - 98.879 | = 44.20$$

$$E_7 = | 143.08 - 91.16 | = 51.92$$

4. Select empirical formula among the function 1-7. Known empirical formula will have the following form:

1.  $Y = Ax + B$  , if  $\epsilon = E_1$ ;

2.  $Y=AB^x$  ,if  $\epsilon = \epsilon_2$ ;

3.  $Y=1/Ax=B$  ,if  $\epsilon = \epsilon_3$ ;

4.  $Y=A\ln x+B$  ,if  $\epsilon = \epsilon_4$ ;

5.  $Y= AX^B$  ,if  $\epsilon = \epsilon_5$ ;

6.  $Y=A+\frac{B}{X}$  ,if  $\epsilon = \epsilon_6$ ;

7.  $Y=\frac{X}{Ax+B}$  ,if  $\epsilon = \epsilon_7$ ;

It follows that we must consider that functions 1-7 are monotonous, and therefore to answer them through experimental data  $(X_i, Y_i)$  when  $\Delta X_i = X_{i+1} - X_i > 0$  ( $i = 1, 2, \dots, n-1$ ). We must have permanent sign. Alternatively, dependence 1-7 will be opposite. This method of choosing the type of empirical formula is a crude form, so far it does consider all the value of  $(X_i, Y_i)$ . Apart from that, it can happen that variables X and Y obey another law, and the type of empirical formula will be different from function 1-7, so we choose function 3, as it is  $\min \{\epsilon = \epsilon_3 = 19.9\}$  and has form:

$$Y = \frac{1}{Ax+B}; \quad q = \frac{1}{0.9985t_{\text{TEX}} - 0.000006};$$

The remaining equations were chosen in the same way. By the derived equations, tables and graphs were plotted. From them it is clear that the calculation by equations corresponded to the initial data of graph. While varying the continuity of refinery, dependence of working index of the furnace were as presented in table 3

Table 3: Effect of increasing continuity of refinery on productivity of furnace and relative usage of electric through smelting.

T	trexc	I <sub>1</sub> paφ	Wpaφ	We	qpaφ	Qe
Min	Hour/ton	A	mW-Hour/ton	mW-Hour/ton	ton/Hour	ton/Hour
20	0.01405	6.1497	0.0542	0.5463	253.0	71.15

25	0.01536	33457	0.0662	0.5583	190.1	65.09
35	0.01712	32293	0.0823	0.5744	142.5	58.42
40	0.02018	31199	0.1103	0.6024	99.2	49.55

From the graph (Figure 1) plotted by data of this table, founded equation from those curves. They have the following form:

$$W'_{etTex} = 11.0t_{Tex} + 0.36Mw-Hour/ton.$$

$$q'_{etTex} = \frac{1}{0.99922t_{TEX} - 0.0000157}, \text{ ton/Hour.}$$

Calculate values received from those equations were presented in the table 2.40.

Table 4: Effect of continuity of refinery on productivity of furnace and relative usage of electric throughout the smelting.

T, Min	20	25	35	40
T <sub>TEX</sub> , Hour/ton	0.01405	0.01536	0.01712	0.02018
W'etTex, Mw-Hour/ton	0.5406	0.5550	0.5744	0.6079
qetTex, ton/Hour	71.15	65.09	58.40	49.59

Usage by limit can be defined as follows:

$$Ct_{TEX} = n/0.99922t_{TEX} + 0.0000157 = m/11t_{TEX} + 0.386 + A'$$

$$Ct_{TEX \min} = 1329.27/0.099922 \times 0.01405 + 0.0000157/ + 13.58/ 11 \times 0.01405 + 0.386/+14.938$$

$$= 40.96 \text{Rouble/ton.}$$

$$Ct_{TEX \max} = 1329.27/0.099922 \times 0.02018 + 0.0000157/ + 13.58/ 11 \times 0.02018 + 0.386/+14.938$$

$$= 50.02 \text{Rouble/ton.}$$

$$\Delta Ct_{TEX} = Ct_{TEX \min} - Ct_{TEX \max} = 50.02 - 40.96 = 9.06 \text{ Rouble/ton.}$$

Calculate values of dependence of expenditure by limit were presented in table 2 and on figure 1.

Table 5: Effect of continuity of refinery on expenditure by limit.

T, min	20	25	35	40
T <sub>Tex</sub> , Hour/ton	0.01405	0.01536	0.01712	0.02018
Ct <sub>TEX</sub> , Rouble/ton	40.96	42.89	45.49	50.02

#### **4.0 CONCLUSION**

We can conclude that with increase in continuity of refinery, cost of expenditure by limit also increased (see figure 2.26). Within the checking limit T rises from 20 to 40mins; increasing the continuity of the process of smelting within every 10minutes, the cost limit increases by 4.53Rouble/ton or by 11% thus productivity reduces.

#### **REFERENCES**

1. Muhlbaner A, VonStrack A, Kramer C. Handbook of thermo processing technologies Fundamental processes components. Safety Vulkan Verlag GmbH 2005.
2. Toulouevsk Y and Zibrov I. Innovation in Electric Arc Furnaces Springer Verlag Berlin, 2009.
3. Bowman B and Kruger K. Arc Furnace Physics Verlag Stahleisen, Dusseldorf, 2009.
4. Dittmar B and Kruger K. Theoretical approach to Electro heat International. Vol.4. 2009 ppl.195
5. Beites L, F Maya, R DOMO J. G., Hemandes, A. and Asensi, K 2001 Harmonics interharmonic unbalanced of arc furnaces, a new frequency domain approach IEEE Transactions on power Delievery, 16(4),2001,661-66
6. International Energy Agency (IEA), ed, World Energy outlook 2014, IEA publications, Paris, 2014. Google Scholar.
7. V. Logar, D. Dovzan, and D. Krjanc, ISIJ Int., 2012 vol. 52, 402-12 cross Ref Google Scholar
8. V. Logar, D. Dovzan, and I. Skrjanc ISIJ Int., 2012 vol. 52, pp. 1225-32 cross Ref Google Scholar
9. V. Logar and I. Skrjanc, ISIJ Int., 2012 vol. 52, pp. 1225-32 cross Ref Google Scholar
10. A. N. Morosov, Chelabinsk, metallurgy, 1997. Modern production of steel in Arc Furnace.

## **EVALUATION OF QUANTITY OF WATER SUPPLY IN MINNA METROPOLIS**

Illo , N.A and Busari A.O,

School of Engineering and Infrastructural Development, Department of Civil Engineering  
Federal University of Technology Minna, Niger State Nigeria.

\*Email of Corresponding Author: [greenbirdconsultancy@gmail.com](mailto:greenbirdconsultancy@gmail.com)

### **ABSTRACT**

The quest for portable and safe drinking water has continued to be a challenge to most Governments of West Africa. Since its inception in 1976, the state water board constructed three treatment plants in minna metropolis, the last been in 1992 with a total capacity of 77mlpd including Bosso treatment plant to cater for a population of 193,300. This volume is expected to fill all the eight storage elevated tanks per day. The aim of this paper therefore is to provide Analysis and hydraulic evaluation of the supply system considering an increase in population, rise in living standard of the populace and rapid urbanization. Remote Sensing was used in the Estimation of demand and karman- Prandtl- Colebrook Nomogram were used for pipe sizing. The studies revealed the capacity of the tanks to be insufficient and were even underutilized primarily due to connections from the transmission mains. The study also identified inadequacy of transmission pipes' internal diameter, and therefore concludes by recommending for a re-design of the system.

**Keywords:** water demand, water supply, population estimate, pipes network.

### **1.0 INTRODUCTION**

As the world's population is increasing, which give rise to rapid urbanization, environmental issues will continue to occupy centre stage in the development debate. Foremost, among these issues will be the issues of water supply which is essential for human life, economic development, social welfare and environmental sustainability.

Currently, the availability of this (water) vital resource is by no means assured for large sections of the world's population. Today, more than one billion people do not have access to an adequate supply of safe water and 1.7 billion people do not have adequate sanitation. Moreover, the poor pay the most for water and suffer the greatest in forms of impaired health and lost economic opportunities. In developing countries (e.g. West Africa) contaminated water causes millions of preventable deaths every year, especially among children. Generally, a country or

region is said to experience periodic water stress when its annual supplies of water per capita falls below 1,700 cubic meters, (Nasir 2001).

Today some 22 countries have renewable water resources of less than 1,000cubic meters, and 18 have less than 2,000 cubic meters. The expected growth of population over the next 30 years to at least eight (8) billion and increase in living standards and economic activity will combine to create an enormous increase in the demand for water. By 2025 as many as 52 countries with some three (3) billion people will be water-stressed,(Nasir 2001)

Furthermore, rapid urbanization is placing unprecedented pressures on water supply and quality. Between 1950 and 1990, the number of cities with population of more than one million nearly quadrupled from 78 to 290, adding some 650 million people. In the next few years, half the world's population will live in cities.

By 2025, 90% of population growth will have taken place in urban areas, increasing the demand for water of suitable quality for domestic, municipal and industrial use and for treatment of waste. Today in the developed world, industry uses between 40% and 80% of total water withdrawals, comparable figures for developing countries are 2-5%. This figure can be expected to grow significantly. Greater industrial use will also lead to more problems of water quality. Income growth will also put pressure on household water use because the rich use water than the poor,(Nasir,2001).

### **Background to the study.**

Minna, the Niger state capital has over the years experienced and still experiencing water scarcity primarily due to rapid increase in population and urbanization.

The pipe network system has nearly 70km of pipe that serve as transmission mains and were made up of ductile iron, with size varying from 300mm to 900mm. The distribution main with a diameter ranging from 100mm to 400mm has a total length of 210km. With a combine pumping from the three pumping stations at 558m<sup>3</sup>/hr (2 Nos), and 350m<sup>3</sup>/hr, it is possible to supply water for twelve hours daily. However, our on-site investigation revealed that due to epileptic power supply, only two out of three pumps are pumping for only four hours a day.

This records a slight improvement when compare to years back, where the supply is only four hours a day and to specific area on rationing bases. (Musa, 2014).

The sources of Minna water supply are Chanchaga water works and Bosso treatment plant with a capacity of 77,000m<sup>3</sup>/day and 1200m<sup>3</sup>/day respectively. However, as at today these design capacity were under-utilized due to inefficiency of pumps which operates at about 20% over the years. Recently the present Government has replaced the aging pumps, but yet the water supply is still inadequate to even the areas that are connected to the system. Vandalization of mains contributed to the overall failure of pumps to supply water to the storage tanks as designed, thereby creating a “NO PRESSURE” zones in the distribution system.

Most of the supplies from Chanchaga and Bosso treatment plant are by gravity with little having direct pumping (as shown in table 1). There is only one booster station at Dutsen-kura tank (Muhammad 2014). Another problem of inadequate supply is lack of metering.

Currently the board is operating manual billing of customers every month, ranging from ₦1000- ₦2000 per resident in Minna metropolis There are about 12,245 residents being supplied by the board and about 359 commercial and industries (which includes, schools and institutions, hotels, car wash, pharmacies, package water and block industries), charging them N200/m<sup>3</sup>. Others, are water tankers of 9000 litres, 7000 litres, and 6000 litres, and water vendors popularly known as ‘MAI RUWA.

The distribution network of Minna water supply is divided into 5 zones. Zone A, runs from Chanchaga town, Tungan goro, up to city gate with 2446 households and commercials of 72. Zone B comprises of Kpakungu to tipper garage having 1620 and 40 commercials respectively. Zone C consist of Tunga with 3,846 and 118. Zone D, runs from Maitumbi down to F/layout having a total of 2,820 and 61 commercials.

The last zone is Bosso to Tudun Fulani with 1,513 and 68 commercials. Reservoirs/tanks were constructed at strategic location with high level terrain so as to comprehend the distributions network by gravity. Each tank was designed to supply to certain area covering the whole areas and wards of Minna. The 10,000m<sup>3</sup> tanks at Dutsen Kura are meant to serve Bosso Estate,

Dutsen Kura Hausa and Dutsen Kura Gwari police Headquarter Fadikpe, London Street, Bosso Low-cost and Kwasau Primary School Area.

Similarly, the tank at Tunga near Shiroro Hotel, with a capacity of 2000m<sup>3</sup> is meant to serve, Tunga low-cost, Barkin Saleh, Shiroro road Deeper life church road and Shiroro Hotel area like, governor's residence at Talba crescent off peter sarki road and surroundings, Kolawole road etc. takes their water directly from the rising mains. Table 1.0 shows the properties of the reservoir.

### **Population of Minna**

The national population commission could not give the exact estimate of Minna metropolis, the census was conducted only on local government basis, and Minna is beyond Chanchaga local government (with HQ at Minna) and not fully covered Bosso local government with HQ at Maikunkele. However 1991 census gives 190750 (Sanusi 2006).

Muhammad,(2014) gives Minna population 358295, while sanusi (2006) gives 440250 in 2002. Also populationstatistics.com estimated population of Minna in 2019 to be 434,000 with 440250 in 2002 (sanusi 2000) at 7.9% growth rate surely gives higher estimation in 2019.

In this paper, the population of Minna metropolis was estimated using remote sensing, GIS technique. Water demand and requirement are function of population once population (i.e number of persons to be served) estimates is far below the actual per capital demand and requirement, then the system will fail. The per capital demand of Minna varies from areas of high living standards (i.e with water system sheer, bath tub toilet, kitchen sink gardener watering car washing) to area of medium standard of living. These areas like, G.R.A. F-layout, Tunga Low-cost, Bosso Estate, Bosso Low-cost brighter school area, commissioners quarters, Zarumai, London road, Okada road, farm centre, Army Barrack and Up-hill are area etc. are considers to be of high living standard.Areas with medium water usage are; New Tunga Chanchaga town, Tunga Gauro,M I Wishishi Estate, Talba Quarters, Bay clinic road, Niteco road Fadikpe, Dutsen Kura Hausa, Dutsen Kura Gwari, Morris fertilizer, Bosso town, unguwar Biri, Tayi village and some parts of Maitumbi.

Areas with or without water closet and may not possibly use water to flush toilet and shower system of bathing are Kpakungu Al-bishir, Shanu village, Gidan Mangoro, Sauka Karhuta, Limawa, Unguwar Daji, Kwalkwata, Marikici, and MYPA school area.



The aim of this paper therefore, is to provide an up – to – date assessment of the system including the hydraulic design to ascertain the quantity of water needed in Minna. Metropolis using remote sensing.

## **2.0 MATERIALS AND METHOD**

### **The study area:**

Minna city is the capital of Niger State in North central Nigeria location at  $90^{\circ} 38'06''$ , Lat. N and  $60^{\circ} 32'30''$ E Long., and is approximate  $324\text{km}^2$  (Muhammad 2014), with developed area of  $125\text{ km}^2$ . Though, Muhammad (2014) opined  $324\text{km}^2$ , it is pertinent to note that Minna is the capital of Chanchaga local government area, but its area of water supply extended to cover some part of Bosso local government area including the Chanchaga town where the water work is located. However as at today, the total developed land area is beyond even  $125\text{km}^2$ . In fact, a declaration was made by previous and present government that Minna metropolis should stretch  $20\text{km}$  from the centre of the city ( Mobil Roundabout) resulting to about  $1600\text{km}^2$  for the purpose of this analysis, however the existing pipe network cover up to  $125\text{km}^2$ .

### **Population Estimates Based on Dwelling Units**

The method of estimates based on dwelling units is made possible only if a large or medium scale aerial photography is available. In this paper Imagery of the study area was captured and measured through the use of Google Earth and ARC GIS software. Areas served by each tank was captured and the dwelling type was identified and counted.

The number of persons per dwelling was sampled through field survey, and compared with studies carried out in Yola town Adamawa state by Bashir, *et al* (2016). However the study adopt 7 persons per dwelling unit as obtained from Niger state water board headquarter(NSWB). An average plot size in Minna ranges from  $15\text{m} \times 30\text{m}$  to  $30\text{m} \times 30\text{m}$  of which per hectare gives an average of 9 to ten plots(units) including green areas.

### **Water Demand and Water Requirement**

The study area were classified in to three zones, that is highly dense areas (with low water consumption as a result of low life styles), Medium dense areas (with medium water requirement), and low dense areas (with high water requirement due to high living standards).

The average water demands of these areas were obtained and their overall average was used in the calculations of per capita demand.

Table 1: Service reservoirs with equivalent pipe length and diameter

Diameter (mm)	Length (m)	Types	Reservoir	Capacity(m <sup>3</sup> )	Area served
300	9624	DI	Dutsen Kura	10,000	Dutsen Hausa Dutsen Kura Gwari, Bosso Loc-Cost, Bosso Estate Shanu village Police London street
300	5665	DI	Biwater	4,500	Shango, Army barrack, new seet gidan madara kuna
700	7451	DI	Shiroro	2,000	Tunga, Tunga Low-Cost, Shiroro Road, Niteco Road
	9617	DI	Up hill tank	7000	Minna central, Maitumbi Bosso road 123 quarters old airport road okada road commission quarters
600 &450	1407 &11024 &9617	DI	Paida tank	4000	Unguwan daji unguwan sarki, F- layout, zarumai, abayi close.
450	7925	DI	INEC	1000	Police barrack, bay Clinic road, tunga sabon titi, tunga dan boyi & railway quarters
300	7125	DI	Tunga top medical	2000	Tunga, top medical road& sabon gari
300& 400	1648 &889	DI	From paida to bahago	1000	Bosso A, Goggo mai lalle, old ATC, old Abbatoir and MTP 59

Sources; Niger state Water Board

### Method of pipe sizing

The analysis and design of existing pipeline include assigning demand to nodes that are connected to the transmission line before the reservoir (tank) are filled up. From the tank, there are also distribution mains that distribute water to the area intended to serve and the configuration of the system used is branched system.

The determination and computation of the diameter of pipes is carried out using Nomogram and head loss coefficient is Hazen-William coefficient of 140 for the pipes type. The existing pipe factor of 0.1 for PVC and 0.4 for Asbestos cement) were used in the design.

The head loss or slope is given by;

$$f = \frac{I_{high} - I_{low}}{\epsilon L} \text{ -----(1)}$$

Where  $I_{high}$  = highest elevation of the pipe in metre

$I_{low}$  = lowest elevation of the pipe in metre

$\epsilon L$  = Summation of length of pipes. With the flow rate Q in L/s and head loss S in metres for each Node) the corresponding diameter of the pipe is obtained i.e  $\phi$  as a  $f(Q,S,K)$  from the nomogram.

An excel model called BOX FORMULA was also used to compare the result obtained from the nomogram. It is given by;

$$d = \left( \frac{q^2 \times 25 \times L \times 10^5}{H} \right)^{1/5} \text{ -----(2)}$$

Where d = pipe internal diameter in (mm)

q = flow rate in l/s

H = Head or pressure (m)

L = effective length = Actual length + equivalent pipe length (m)

### 3.0 ANALYSIS AND DISCUSSION

#### Domestic demand:

The maximum daily water consumption occurs before 8:00am to 2:00pm. Therefore, the average domestic needs for the three categories as listed above i.e. high living standard, medium and low living is 200 litres per capital for high, 120 litres per capita for medium and 80 litres per capita for low.

$$= 200 + 120 + \frac{80}{3} \Rightarrow \frac{400}{3} = \mathbf{133 \text{ litres/capital/day.}}$$

Hence ,other demands can be taken as 50% of domestic demand. Therefore per capita demand can be taken as 200 L.

The population of Minna as at today can be estimated using 7 persons per household = 70 persons /hectare. The declaration of 20km from centre of town is covers a total of 1600km<sup>2</sup>, that is from mobil roundabout 20km to north towards Zungeru road, covers the entire Maikunkele community to west along Bida road reaches F.U.T Minna main campus covering the whole of Gidan mangoro Beganu, Kolkata, shanu village and beyond then to the east towards maitumbi – kuta road, it extend up to shaguna with about 16km out of 20km declared, already developed. To the south the 20km extend to paiko junction with totungo and Pago already developed.

Therefore up to 80% of 1600km<sup>2</sup> is already developed as at today, which amount to 1280km<sup>2</sup> which is equal to about 128,000 hectares. Let us assumed 50% of this area which is 640km<sup>2</sup> (64000ha), the population can be 4,480,000.

Musa (2014) opined that Minna is 324km<sup>2</sup> = 2,268,000, while sanusi (2006) stressed that in 2002 Minna is 440,250 and 1991 census gives 190750 of which using arithmetic mean method of forecasting and the design period of 27 years (1992 – 2019), yields **1,045,644** people.

Therefore, by estimation, the population of Minna cannot be less than 1 million people.

Hence, Total water demand = 1,045, 644 x 200 = 209,128,800 litres/day  
**= 209,128m<sup>3</sup>/day.**

Table 2. Water requirement for storage tanks.

Storage tank	Tank capacity(m <sup>3</sup> )	Consumption /population	Litre/capita/day	Required water (m <sup>3</sup> )	Remark
Dutsen Kura	10,000	357,350	200	71,470	86%
Shiroro	2000	23100	200	46,200	96%
Top medical	2000	40,320	200	8,064	75%

Bi water	4500	170,590	200	34,118	87%
Uphill	7000	42,350	200	8,470	17%
Paida	4000	44,800	200	8,960	55%
Bahago	1000	26,950	200	5,390	81%
Inec	1000	30,660	200	6,132	84%
<b>Total</b>	<b>31500</b>	<b>736120</b>		<b>147224</b>	

The table 2, above shows that almost all the storage tanks are below storage capacity to supply the areas they are designed to serve. Uphill or IBB tank records slightly above the storage volume by 17%. This is due to the higher volume of 7000m<sup>3</sup> it is storing.

However with a total combine pumping rate of about 1466m<sup>3</sup>/h from the pumping stations, it can take almost 24hr to fill all the tanks (with total volume of 31500m<sup>3</sup>). While the pumps will take 4 days to fill the new volume of 147224m<sup>3</sup> furthermore there are areas that has direct supply from the main . The dutsen kura reservoir, though with higher storage volume ,is below requirement by more than 80%. The area covered by this reservoir has a well distributed connection with medium and low living standards which give rise to high water demand.

Shiroro Tank located near Shiroro Hotel, has the highest water demand of almost 100%. This indicates that people has changed their life style by demolishing and constructing modern buildings that require more water, while the area remain the same. All the connection in this area remain the same since commissioned.

Chanchaga town , Tungan gwauro Army Barrack,College of Education up to City Gate were served by direct supply from the water works.

**Table 3: Result of Analysis**

Tank supplied	Demand m <sup>3</sup> /day	Slope %	Flow rate L/S	Type	Diameter mm
Dutsen Kura	71,470	-0.8	827	DI	1200
Shiroro	46200	-0.4	535	DI	1000
Top medical	8,064	-0.8	93	DI	450
Bi water	34118	-0.8	395	DI	900
Uphill (IBB)	8,470	-0.8	98	DI	500
Paida	8960	+0.6%	104	DI	500
Bahago	5,390	-1.7%	62	Di	400
INEC	6132	-0.8%	71	A1	400
Direct supply to Chanchaga	1400	-0.2	16	PVC	
Army Barrack	2466	+0.2	28.5	AC	400
T/gwauro	2500	+0.2	28.9	PVC	400
College of Education	532	+0.6	62	AC	250
Shango	1064	0.2	124	AC	400

**4.0 CONCLUSION:**

In this study, the analysis of minna water supply has been carried out using available data obtained of Niger state water board and ministry of land. The population estimates, which is the main factor of water supply, was obtained by considering the areas that are already developed, and total water demand was calculated. The results of the analysis revealed a wide gap between the current water supply and water demand. The pipes' sizing was also carried out using a nomogram of 0.1mm for PVC and 0.4mm for ASBESTOS pipe respectively. The result indicates a slight increase in the internal diameter, which calls for a redesign of the system for optimum supply.

## **REFERENCES**

- Adekunle I.A; (2002). Estimation of the population of Ibadan municipality using Remote sensing M.Tech thesis 2002 Department of Geography Federal University of Technology Minna
- Adeniran, A.E & Oyelow,M.A, (2013): An Epanet Analysis of water distribution Network of the University of Lagos, Nigeria. Journal of Engineering Research, volume 18 No. 2.
- Mohammed, M (2014): An Appropriate pumping schedule for effective water supply in Minna metropolis: 7<sup>th</sup> International Conference of Nigeria Association of hydrological science 2014.
- Mohammed,M. (2014): Performance Enhancement of Water supply and distribution in Minna Metropolis, M.Eng Thesis, Department of Water Resources and Environmental Ahmadu Bello University Zaria
- Nasir A.I (2001). An Evaluation of Abuja water supply; PGD thesis, Department of Agricultural Engineering Federal University of Technology Minna 2001.
- Swamee & Sharma (2008). Design of water supply pipe Network; A John Wiley & Sons Inc. Publication Hoboken New Jersey
- Sanusi, Y,A. (2006). Patterns of urban Land Development central in Nigeria: A case study of Minna Niger State. Journal of the NITP vol xix, No. 1.

## **CARBON STORAGE IN CONCRETE: INFLUENCES OF HYDRATION STAGE, CARBONATION TIME AND AGGREGATE CHARACTERISTICS**

Abidoye, L.K. and Das, D.B.

Chemical Engineering Department, Loughborough University, Loughborough,  
Leicestershire, LE11 3TU, United Kingdom

\*Email of Corresponding Author: [abidoye.lugman@uniosun.edu.ng](mailto:abidoye.lugman@uniosun.edu.ng), [D.B.Das@lboro.ac.uk](mailto:D.B.Das@lboro.ac.uk);

### **ABSTRACT**

Carbonation of Portland cement concrete can serve as an easier and cheaper global-warming mitigation technique to complement carbon sequestration in deep geological aquifers, which is costly and technologically intensive. This study elucidates the effects of particle size, carbonation time, curing time and pressure on the efficiency of carbon storage in Portland cement concrete. Using pressure chamber experiments, our findings show how carbonation efficiency increases with decrease in particle size. Under similar conditions, approximately 6.4 and 8.2% (w/w) carbonations were achieved in the coarse-sand and fine-sand based concrete samples, respectively. For hydration/curing time of 7 hrs, up to 12% carbonation was achieved. This reduced to 8.2% at 40hrs curing period. On the pressure effect, for comparable curing conditions, 2 bar at 7hrs carbonation time gives 1.4% yield while 5 bar at comparable carbonation time gives up to 8.2%. Furthermore, analysing the effect of carbonation time, for comparable conditions, shows that 4hrs of carbonation time gives up to 8.2% yield while 64hrs of carbonation gives up to 18.5%. It can be reliably inferred that, under similar conditions, carbonation efficiency increases with lower-sized particles or higher-surface area, increases with carbonation time and higher pressure but decreases with curing/hydration time.

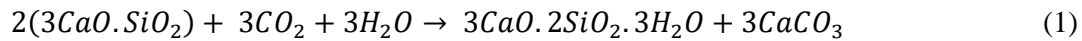
**Keywords:** Carbonation; Portland cement; XRD; global warming; CO<sub>2</sub>

### **1.0 INTRODUCTION**

Recent evidence reveals that carbonation of Portland cement concrete is a cheaper, easier and promising approach to carbon storage. Cement can serve as carbon sink from the reactions of CO<sub>2</sub> with tri- and di-calcium silicates (C<sub>3</sub>S, C<sub>2</sub>S) which are generally present in cement, as well as the reaction of CO<sub>2</sub> with Ca(OH)<sub>2</sub>, which is a product of concrete hydration (Lagerblad



2009;; Adedokun et al. 2013; Shao and Morshed 2015). Carbonation of concrete can occur at different stages of hydration. Dominant equations are expressed in equations (1) and (2).



Existing literature show that available microstructural space in the concrete is a key to determine the extent and the quantity of carbonation that can be achieved. According to Galan et al. (2010), as the carbonation process continues over time, calcium carbonate is formed, which is a larger molecule than calcium hydroxide and the available pore microstructure decreases for further diffusion of carbon dioxide into the sample as time progresses. Also, if the humidity is too high, the porous system can be blocked off by condensed water, so the carbonation could be obstructed (Pade and Guimaraes 2007). Zhang (2011) reports that the fastest carbonization rate will be reached in the relative humidity of 50%-70% while carbonization will stop when the relative humidity reaches to 100% (or in water) or be less than 25% (or in the dry environment). Thus, an effective management of concrete humidity and microstructural space will enhance carbonization of concrete.

Apart from humidity, the pore size of the concrete can also be affected by the precipitation of the carbonation reaction products. As the carbonation process continues over time, calcium carbonate is formed which is a larger molecule than calcium hydroxide and the available pore microstructure decreases for diffusion of the carbon dioxide into the sample as time progresses (Galan et al. 2010). This behaviour makes carbonization a surface-based reaction that discontinues after layer of calcium carbonate has covered the concrete, while calcium hydroxide lies underneath (Zhang 2011). Therefore, the task of improving carbonation efficiency in concrete is that of exposing the available calcium hydroxide, tri- and di- calcium silicates (C3S, C2S) for further reaction with incoming CO<sub>2</sub>. This can be achieved in various ways including the flow mixing of the concrete with CO<sub>2</sub>, before the concrete is set. In a semi-batch system, this involves turning the concrete continuously while CO<sub>2</sub> is being poured in. Increasing the surface area of the cement-aggregate phase is another viable means. Since the reactions take place at the exposed surface, use of particles with larger surface areas can bring about the improvement in carbonation efficiency.

El-Hassan and Shao (2014) showed the effect of curing and carbonation time on carbonation efficiency. They reported up to 24% carbonation with initial curing of up to 18hrs while 8.5%

carbonation was recorded without initial curing. Effect of carbonation time was also reported with up to 35% carbonation based on 4-day carbonation time with the use of slag in the concrete. Average carbonation of 15% was achieved by Shao and Morshed (2015) in hollow-core concrete slab following 2hrs of curing, 1 hr of cooling and 2hrs of carbonation.

Aside the ability to store carbon dioxide, carbonated concrete has also been shown to improve the mechanical response of concrete composite, both before and after accelerated aging, when compared with the non-carbonated samples (Junior et al. 2019; Ashraf et al. 2019). Thus, there are multiple benefits to be derived from the practice of concrete carbonation. The amount of calcium carbonate is a good indicator of the effect of carbonation on the strength development of cement-treated sand and that both these quantities are affected by the internal water content (Ho et al. 2018).

Scrutinizing the above reports, influences of particle sizes and pressures have not been involved in the earlier investigations. Meanwhile, managing the particle sizes of aggregates can lead to the creation of effective microstructural spaces in concrete, which can enhance pore-scale diffusivity of the CO<sub>2</sub>, leading to enhanced carbonation. Also, the surface areas offered by different particle sizes will present different performance perspectives of concrete to carbonation. In this work, the carbonation of concrete was performed using pressure chamber experiment. Attempt was made to vary microstructure pores and surface area of concrete particulates through the use of aggregates of varying sizes and then determine the carbonation levels. Effects of pressure, hydration/curing time and carbonation time were also investigated. Gravimetric and pyrolysis analyses were used to determine carbonation levels while the microstructures of the carbonated and uncarbonated concrete samples were examined with X-ray diffraction (XRD) instrument and scanning electron microscope (SEM).

## **2.0 METHODOLOGY**

### **2.1 Sample preparation**

Carbonation of cement concrete was performed in a pressure chamber using 99.9% pure CO<sub>2</sub> (BOC Gases, Leicester, UK). The concrete was made from Portland cement (Lafarge Nigeria Limited, CEM 11/B-L 32.5N), silica aggregates of two different sizes (4.9 mm and 0.9 mm mean particle diameters, respectively) and tap water. The concrete samples prepared with 0.9 mm particle size are referred to as fine-sand concrete while those prepared with 4.9mm particle size are referred to as coarse-sand concrete.

The concrete preparation followed the standard mix proportion recommended in *Building Materials in Civil Engineering* (Zhang 2011), i.e., Cement: sand: stone: water, at the ratio, 1: 2.21: 4.09: 0.60. The only modification made in this work to the mix proportion of Zhang (2011) was that the sand and stone ratios were merged for either fine sand or coarse sand. This modification was necessary because this work uses either fine sand or coarse sand, but not both, in each concrete sample. This is to enable the determination of particle size/surface area effect in carbonation of concrete. The concrete samples were prepared in mould of 1cm thickness and 5cm diameter. To ensure uniformity of weight in each sample, 40g of concrete mixture was weighed into the mould and then compacted uniformly using tamping rod, for each sample made. In order to investigate the effect of particle sizes, uniform-size aggregates were used in each concrete sample, i.e., in every sample either coarse or fine sand was used but not both. As a result, for each concrete sample, the combined ratios of both aggregates were used as either fine or coarse sand, i.e., 6.3 ratio of aggregate (i.e., 2.21 + 4.09) was used in each sample. The cement content in concrete was approximately 12.7% and water-cement ratio was 0.60. Both coarse and fine aggregates were mainly of silicate origin.

The concrete was formed by filling the 1cm-high and 5cm-diameter metallic mould with well mixed concrete mixture. It was then lightly compacted with tamping rod. To ensure fairness of compaction and weight, same amount (40g) of concrete was weighed into the mould each time. Figure 1 shows samples of the concrete and the sample holder for the experiment.

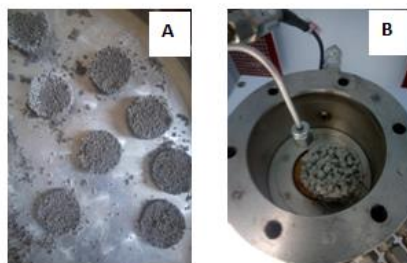
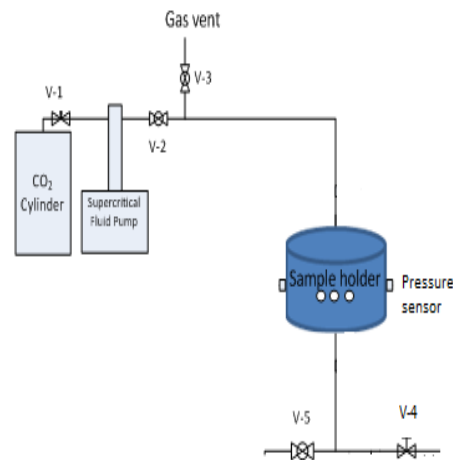


Figure 1: (A) Concrete samples of 5cm diameter and 1cm thickness (B) Sample holder with concrete sample, ready for carbonation experiment

## 2.2 Experimental Set Up and Carbonation Quantification

The carbonation experiment was performed in a CO<sub>2</sub> pressure chamber at the Chemical Engineering laboratory of the Loughborough University, UK. The schematic representation of the experimental set up is shown in Figure 2.

Constant temperature of 25°C was used in all experiments. The pump was filled with CO<sub>2</sub> gas at the beginning of the experiment and then set at constant pressure.



**Figure 2: Experimental Set Up for Concrete Carbonation**

Effect of hydration stage or curing time was investigated by subjecting the samples to carbonation after different curing period or different hydration stages, e.g., 12hrs, 24hrs, 100hrs, etc. Curing is the process in which the concrete is preserved in conditions that prevent excessive loss of moisture to promote hydration reaction and for the concrete to gain strength. In this work, the curing/hydration time, for experimented concrete samples, was taken to be the time between concrete preparation and the start of the carbonation experiment for the selected samples.

### 2.3 Pyrolysis and Micro structural Analysis

A pyrolysis analysis was conducted on carbonated and uncarbonated concrete samples by ramping temperature between 550°C and 1000°C in a Furnace (Carbolite, Eurotherm91e, Essex). X-ray diffraction (XRD) and scanning electron microscopy (SEM) analyses were performed on the carbonated and fresh (reference) concrete samples. Instrument used for the XRD was D2-Phaser Bruker (BX00412, Bruker, UK LTD) while that for SEM was FEGSEM (JSM-7100F, JEOL, Japan).

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Gravimetric/Pyrolytic Analysis

Table 1: Summary of the results from the carbonation experiments

Pressure (bar)	Temperature (°C)	+Curing Period (hrs)	Carbonation Duration (hrs)	Sand Type	%CO <sub>2</sub> (Gravimetry)	%CO <sub>2</sub> (Pyrolysis)
5	25	40	4	Coarse	6.39 (±0.08)	
				Fine	8.21 (±0.16)	
5	25	40	64	Coarse	16.63	
				Fine	18.56	
5	25	104	6	Coarse	6.19	6.81
				Fine	8.27	8.66
2	25	110	7	Fine	1.44	

Table 1 shows the summary of the results obtained from the carbonation experiments. The table shows the temperature and pressures used in the experiments. Also, shown are the hours of curing (i.e., time after casting or preparation of concrete), duration of carbonation in the pressure chamber as well as size of particulates used in the concrete (coarse or fine sand).

From the results, in the experiment no 1, following 4hrs of carbonation at 5bar and 25°C as well as 40hrs of curing, approximately 6.4 and 8.2% carbonations were achieved in the coarse-sand and fine-sand concrete samples, respectively. The results showed higher carbonation in fine-sand concrete. Ordinarily, owing to its higher porosity, it is expected that the coarse-sand based concrete will have more interstitial pore spaces to allow CO<sub>2</sub> penetration and carbonation reaction. However, the results show that the higher surface area present in fine-sand based concrete is a stronger factor to be considered. In experiment no 2, under similar conditions as above but with 64hrs of carbonation, the carbonation of concrete increased to 16.6 and 18.3%, for coarse-sand and fine-sand based concrete samples, respectively. This also gives higher

carbonation in fine-sand based concrete than the coarse-sand type, thereby, confirming the influence of particle sizes on the carbonation reactions in concrete. It further shows the influence of carbonation time on the reaction. Thus, under suitable conditions, longer exposure of concrete to CO<sub>2</sub> will improve carbonation reaction.

In experiment no 3, after 104hrs of curing and 6hrs of carbonation time, similar levels of carbonation were observed as 4hrs of carbonation (Experiment no 1), under similar conditions, but different curing periods. The results show that carbonation efficiency is reduced as curing time increases. In experiment no 3, there are 6.2 and 8.3% carbonations in coarse-sand and fine-sand based concrete samples, respectively, which, again, shows higher carbonation potential in fine-sand concrete. The results show that the carbonation time and particle sizes are stronger factors in carbonation than curing time. However, the slightly longer carbonation time (6hrs) with slightly lower carbonation yield with longer curing time compared to experiment no 1, implies that carbonation potential reduces as curing of concrete progresses. This means that as silicates are consumed during hydration of concrete, the carbonation potential reduces (Shao and Morshed 2015; [Khoshnazar and Shao 2018](#)). Early age carbonation of concrete has been reported to improve the mechanical strength of concrete composite (Junior et al. 2019). Thus, there is higher advantage in concrete carbonation at shorter curing period. Also, since the concrete samples used here are not rewetted with water after preparation, the result might imply that as carbonation progresses concrete loses water which reduces its potential for reaction with CO<sub>2</sub>, under dry condition (Zhang 2011). It should be noted that the works of Shao and Morshed (2015) as well as Elhassan and Shao (2014) employed rewetting of the concrete, which might have enhanced carbonation. Elhassan and Shao (2014) compensate for the water loss during initial curing and carbonation curing, with water spray, which was applied to restore the original water content. Early carbonation approach was also employed by Shao and Morshed (2015) by conducting the process after about 2hrs of curing. This approach is also expected to improve carbonation efficiency by making use of moderate moisture in the concrete. This obviously explains the difference in the results of the current work and earlier investigations.

Experiment no 4 was conducted at lower pressure of 2bar in order to test the influence of pressure on the carbonation yield in concrete. The results show that the carbonation yield becomes lower than before, ostensibly owing to the lower pressure of the experiment. Similar to the earlier observations, the influence of carbonation time reflects in the results with yield at

24hrs carbonation time (1.9%) obviously higher than that at 7hrs (1.4%). Other experimental results and discussions can not be displayed here owing to limitation of space.

Summary analysis of the results in the Table 1 shows that for hydration/curing time of 7hrs (Exp no 7), up to 12% carbonation was achieved. This reduced to 8.2% at 40hrs curing period (Exp no 1). On the pressure effect, for comparable curing conditions, 2bar at 7hrs carbonation time gives 1.4% yield (Exp no4) while 5 bar at 6hrs carbonation time gives up to 8.2% (Exp no3). Furthermore, analysing the effect of carbonation time for comparable conditions shows that 4hrs of carbonation time gives up to 8.2% yield while 64hrs of carbonation gives up to 18.5%.

In comparison, Shao and Morshed (2015) record up to 14.5% carbonation in 2hrs of carbonation following 2hrs of heat curing. This carbonation yield is comparable to the 64hrs of carbonation and 40hrs of curing in this work (experiment no 2). It may appear that the efficiency is higher in the work of Shao and Morshed (2015) but the consideration of the different experimental processes and conditions explain some underlining factors. Shao and Morshed (2015) used flow-through experiment where CO<sub>2</sub> was made to pass through the microstructural pores in the concrete, unlike in this work, where CO<sub>2</sub> has to overcome surface inhibition or pore blockage to diffuse further into the concrete matrix. That explains why the authors were able to report the carbonation yields at the top, core and bottom of the carbonated concrete. Furthermore, the carbonation by Shao and Morshed (2015) took place immediately following 2hrs of curing. This enhances the performance of the process, unlike in the current case, where carbonation took place after 40hrs of curing and has resulted in more loss of moisture. Furthermore, the cement content in the concrete used by Shao and Morshed (2015) was 155 compared to 12.7% used in this work. They used a water content of 0.3 compared to 0.6 in this work. Thus, concrete samples in Shao and Morshed (2015) has more pore space owing to lower water content and more binder cement, both of which contributed to their better carbonation performance.

El-Hassan and Shao (2014) reported up to 24% carbonation with initial curing of up to 18hrs. Effect of carbonation time was also reported with up to 35% carbonation based on 4-day carbonation time (96hrs). Again, this seems to show a better carbonation than recorded in this work. However, it should be noted that the authors used slag in their concrete mixture, which might have enhanced the carbonation efficiency. Pozzolana cement and blast-furnace slag cement readily undergo carbonization (Zhang 2011). Similar to the current findings, their work

corroborated the fact that carbonation increases with CO<sub>2</sub> exposure time. This is similar to the findings of Haselbach and Thomas (2014) on the carbonation of decades-old concrete sidewalk samples.

### 3.2 Microstructure Analysis

Summary of the findings in XRD show that the peaks of tricalcium silicate (C3S) were conspicuously stronger in uncarbonated concrete samples. The reason for this is that carbonation reaction consumes the silicates (Shao and Morshed, 2015). Furthermore, peaks for Ca(OH)<sub>2</sub> and C3S are conspicuously stronger in the uncarbonated samples than the carbonated. This implies that these compounds are consumed by the carbonation process leading to their reduced quantities in the carbonated sample. In SEM analysis, widespread distribution of needle form of C-S-H (Calcium silicates Hydrate) is visible together with the background Ca(OH)<sub>2</sub> phase. These patterns have disappeared in the carbonated concrete, leading to denser-looking structure of carbonated C-S-H phase (Figure 7(B)).

#### XRD Patterns

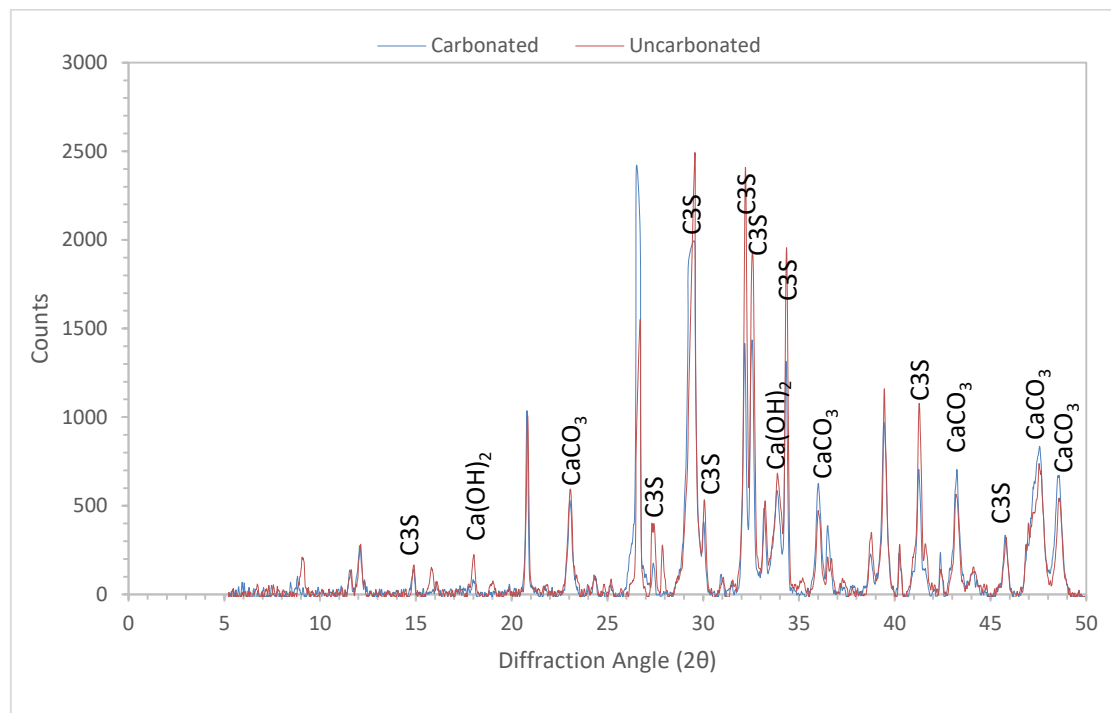


Figure 3: XRD showing tricalcium silicate (C<sub>3</sub>S), Ca(OH)<sub>2</sub> and CaCO<sub>3</sub> patterns in the carbonated and uncarbonated mortar samples. Carbonation took place at 2bar for 24hrs following 120hrs of curing.



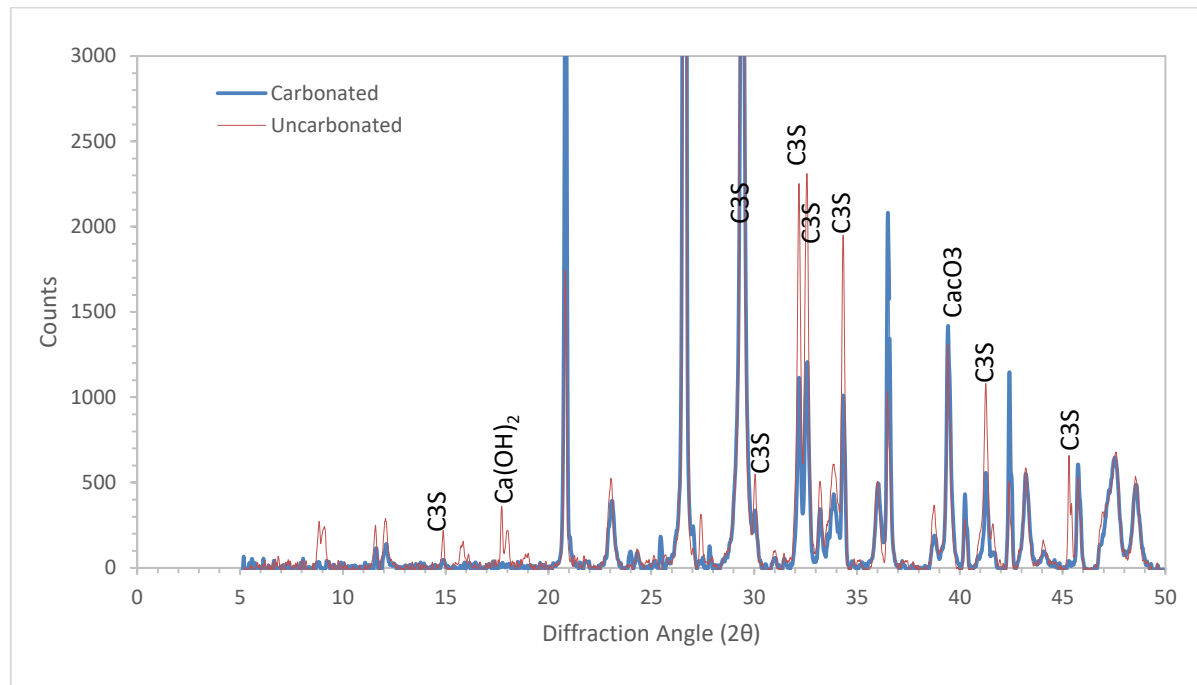


Figure 4: XRD showing tricalcium silicate (C3S),  $\text{Ca(OH)}_2$  and  $\text{CaCO}_3$  patterns in carbonated and uncarbonated mortar samples. Carbonation took place at 5bar for 24hrs

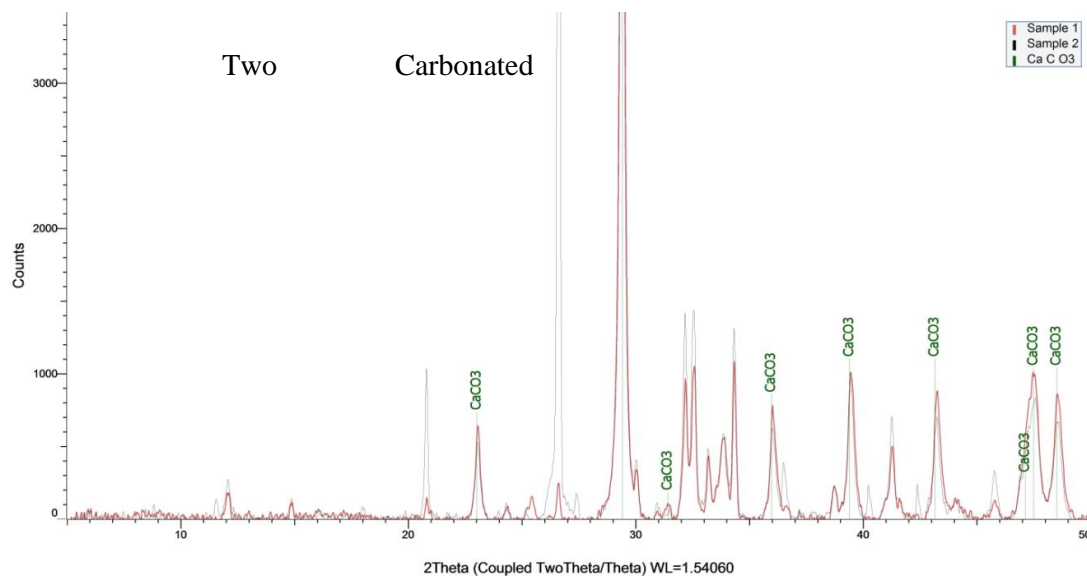


Figure 5: XRD showing  $\text{CaCO}_3$  peaks in carbonated mortar samples. Sample 1 (red line) is 6.55% carbonated while sample 2 (black line) is 1.94% carbonated.

This dense look can mean increased strength in the carbonated concrete. Carbonate reacts with tricalcium silicate (C3S) and this accelerates the setting and strength development (De Weerd et al. 2011; Nakarai and Yoshida 2015; Junior et al. 2019; [Khoshnazar and Shao 2018](#); Ashraf et al. 2019)

## CONCLUSION

Laboratory experiments and micro-structural analyses have been carried out to show the performance of Portland cement concrete for storage of carbon dioxide. Particle size, carbonation time, curing time and carbonation pressure exhibited various effects on the efficiency of carbon storage in Portland cement concrete. Carbonation efficiency increases with increased surface area, which resulted in higher carbonation in fine-sand based concrete samples. The results showed about 28% higher carbonation in fine-sand based concrete samples as compared to the coarse-sand based ones. The curing/hydration time has reversed effect on carbonation with reduction in carbonation level by about 31%, owing to a difference of about 33hrs hydration time in concrete samples. Carbonation efficiency increases with pressure from 1.4% to 8.2% for pressure rise from 2 bar to 5 bar. Similarly, the duration of carbonation shows positive effect, with carbonation efficiency rising from 8.2% to 18.5% for change in carbonation duration from 4 to 64hrs. It can be reliably inferred that, under similar conditions, carbonation efficiency increases with lower-sized particles or higher-surface area, increases with carbonation time, increases with higher pressure but decreases with curing/hydration time.

## REFERENCES

- Abidoeye, L.K. and Das, D. B., (2015). Geoelectrical characterization of carbonate and silicate porous media in the presence of supercritical CO<sub>2</sub>-water flow. *Geophysical Journal International*, 203 (1): 79-91 doi: 10.1093/gji/ggv283
- Adedokun D. A., Ndambuki J. M., and Salim R. W. (2013). Improving Carbon Sequestration in Concrete: A Literature Review. *International Scholarly and Scientific Research & Innovation* 7(4), pp. 269-271. scholar.waset.org/1999.3/13162
- Ashrafa, W., Olek, J. and Sahu, S. (2019). Phase evolution and strength development during carbonation of low-lime calcium silicate cement (CSC). *Construction and Building Materials*, 210, pp. 473-482.

- De Weerd, K., Ben Haha, M., Le Saout, G., Kjellsen, K.O., Justnes, H. and Lothenbach, B., (2011). "Hydration mechanisms of ternary Portland cements containing limestone powder and fly ash." *Cement and Concrete Research*, 41, 279-291.
- El-Hassan, H. and Shao, Y. (2014). Carbon Storage through Concrete Block Carbonation Curing. *Journal of Clean Energy Technologies*, Vol. 2, No. 3, pp. 287-291.
- Galan I, Andrade C, Mora P, Sanjuan MA. (2010). Sequestration of CO<sub>2</sub> by concrete carbonation. *Environ Sci Technol*, 44(8):3181-6.
- Haselbach, L. and Thomas, A. (2014). Carbon sequestration in concrete sidewalk samples. *Construction and Building Materials* 54 (2014) 47-52
- Haselbach, L. and Thomas, A. (2014). Carbon sequestration in concrete sidewalk samples. *Construction and Building Materials* 54 (2014) 47-52
- Ho, L.S. Nakarai, K., Ogawa, Y., Sasaki, T. And Morioka, M. (2018). Effect of internal water content on carbonation progress in cement-treated sand and effect of carbonation on compressive strength. *Cement and Concrete Composites*, 85, pp. 9-21. <https://doi.org/10.1016/j.cemconcomp.2017.09.016>
- Junior, A.N., Ferreira, S.R., Filho, R.D.T., Fairbairn, E.M.R and Dweck, J. (2019). Effect of early age curing carbonation on the mechanical properties and durability of high initial strength Portland cement and lime-pozolan composites reinforced with long sisal fibres. *Composites Part B: Engineering*, Vol. 163, pp. 351-362
- Khoshnazar, R. and Shao, Y. (2018). Characterization of carbonation-cured cement paste using X-ray photoelectron spectroscopy. *Construction and Building Materials*, 168, pp. 598-605. <https://doi.org/10.1016/j.conbuildmat.2018.02.175>
- Lagerblad, B. (2005). Carbon Dioxide Uptake during Concrete Life Cycle, state of the art. Swedish Cement and Concrete Research Institute -CBI, www.cbi.se, ISBN 91-976070-0-2, 2005. pp. 1 - 47.
- Nakaraia, K. and Yoshida, T. (2015). Effect of carbonation on strength development of cement-treated Toyoura silica sand. *Soils and Foundations*, 55(4), pp. 857-865
- Pade C. and Guimaraes, M., (2007). The CO<sub>2</sub> uptake of concrete in a 100 year perspective. *CemConcr Res*; 37(9):1348-56.
- Shao, Y. and Morshed, A. Z. (2015). Early carbonation for hollow-core concrete slab curing and carbon dioxide recycling. *Materials and Structures*, 48:307-319, DOI 10.1617/s11527-013-0185-3

Zhang, H. (2011). Building Materials in Civil Engineering. Woodhead Publishing Limited, Cambridge, ISBN 978-1-84569-955-0

## **SEPTIC PLUME CONTAMINATIONS OF GROUNDWATER IN NIGERIA LOCAL COMMUNITY: INFLUENCES OF SEASONS AND TOPOGRAPHY ON PLUME MOBILIZATIONS**

Abidoye, L.K.<sup>1\*</sup>, Alabi, O.O.<sup>2</sup> and Wahab, A.A.<sup>3</sup>

<sup>1</sup>Civil Engineering Department, Osun State University, Osogbo, Nigeria

<sup>2</sup>Department of Physics, Osun State University, Osogbo, Nigeria

<sup>3</sup>Department of Biological Sciences, Osun State University, Osogbo, Nigeria

\* Email of Corresponding Author: [kluqman2002@yahoo.co.uk](mailto:kluqman2002@yahoo.co.uk)

### **ABSTRACT**

Active mobilization of contaminants from septic sources down the valley side has resulted into elevated concentrations of nitrate and phosphorous in the groundwater and surface stream at Oke-Bale Community in Osogbo, Nigeria. Findings show elevated concentration of nitrate ions which is far higher than the standard limit by United States Environmental Protection Agency (USEPA). The Nitrate ions concentration was highest in the valley trough of the settlement which is occupied by a surface water stream. The surface stream also has the highest concentrations of ammonia and nitrite ions. This indicates active mobilization of the contaminants down the valley. The subsurface layer of the area shows oxic characteristics resulting in higher nitrate concentration (mean= 74.9mg/L) by the oxidation of ammonium and nitrite ions. Furthermore, it was found that the contamination levels of nitrate, ammonium and nitrite ions are higher in the rainy season than the dry season, which again shows the drainage mobilization of the contaminants in the subsurface during the rainy season than the dry season. Simple mathematical model was developed to predict and forecast nitrate concentration in a solution with known quantities of other key variables. The model can still serve to confirm the accuracy of any test on nitrate by comparing analytical test result with mathematical estimate.

**Keywords:** Septic tanks; leachate; groundwater; drainage; nitrate; hydraulic conductivity

### **INTRODUCTION**

Naturally, groundwater is composed of water from many sources that are filtered by porous media in the earth sediments while they flow from the surface through transition zone into the water table (Fetter et al.2017; Bear, 2013). While the flow path of the groundwater has a natural purification potential on the water, there are some subsurface contaminants that can also negate the quality. Some of these contaminants are from ubiquitous septic tanks in the neighborhoods.

The leachate from septic tank is the most frequently reported cause of groundwater contamination (Rana et al. 2017; Yates, 1985), especially in area of high septic tank density (Bremer and Harter, 2012). In Nigeria context, this is particularly worrisome, because septic tanks are indiscriminately erected contiguously to drinking wells. The increasing density of septic tanks around every water well, especially in crowded settlement, is alarming. In the US, the number of septic tanks is increasing globally (Abbassi et al. 2018), particularly at about one-half million per year, though, the relative percentage of homes using them are decreasing (Scalf et al., 1977). But in Nigeria, percentage of septic-tank users increase on a daily basis, owing to the fact that people have little or no option, since the municipal waste treatment is a rarity. In fact, the case is very bad in crowded communities where the number of septic tanks can even outnumber that of household wells. These septic tanks with the adjacent soakaways can easily fill up under intense use by people in crowded rented apartments. The spill from such overfilled septic tanks can easily be smelled by passersby and in the neighborhood. USEPA estimates that over 800 billion gallons of waste are disposed of via septic tanks per year in the US. This makes septic tanks leading contributor to the total volume of waste water discharged directly to the groundwater (Hwang et al. 2019; Yates, 1985). Unfortunately, such information about septic tanks in Nigeria is not always available.

The increasing dependence of Nigerians on groundwater as a source of potable water, together with the threats of indiscriminate and proliferated septic tanks installations, spurs the current efforts to investigate the impacts of these septic tanks and to protect groundwater quality. At Oke Bale community, in Osogbo, Osun State, Nigeria, several septic tanks can be found at less than 10 meters to household water wells. This study aims to expose the actual impacts of these septic tanks on groundwater in the community, through field investigations and laboratory analysis of the water samples from selected wells. Secondly, seasonal influence on the water quality will be assessed by sampling and analyses during the rainy and dry seasons.

## **1.0 METHODOLOGY**

The area of investigations is located behind the NNPC filling station, Oke Bale, Osogbo, Osun State, Nigeria. The area also has close proximity to the Osogbo campus of Osun State University. It is an old settlement of semi-modern architectural setting with congested lines of bungalow buildings. Many houses in this vicinity have no uniquely identified septic tanks and wells. Those with septic tanks and water wells have them contiguously located in a way that

can complicate the infiltration of the septic contaminants into the adjacent wells. Geographic details of the study area are shown in Table 1 and Figure 1.

Sampling was done in rain and dry seasons.

### Tests and Analysis

The laboratory used for the various tests and analysis was the Rural Water and Environmental Sanitation Agency Laboratory (RUWESA), Abeere, Osogbo, Osun State, Nigeria. The tests and analyses conducted included Nitrate, Nitrite, Ammonia, Chloride, Phosphate and pH. The tests were conducted following standard procedures.

## 2.0 RESULTS AND DISCUSSIONS

Table 1: Geographical parameters of the selected wells, septic tanks and the geographical boundary

	Groundwater Wells			Septic tank		
	Latitude (°)	Longitude (°)	Altitude (m)	Latitude (°)	Longitude (°)	Altitude (m)
<b>Minimum</b>	7.7621	4.5738	319	<b>7.7620</b>	<b>4.5736</b>	<b>316</b>
<b>Maximum</b>	7.7665	4.5778	361	<b>7.7668</b>	<b>4.5780</b>	<b>350</b>

Table 2: Depth of the water level in the wells to the ground surface

	Water Level (m)	
	Dry season	Rain Season
<b>Minimum</b>	<b>0</b>	<b>0</b>
<b>Maximum</b>	<b>5</b>	<b>7</b>

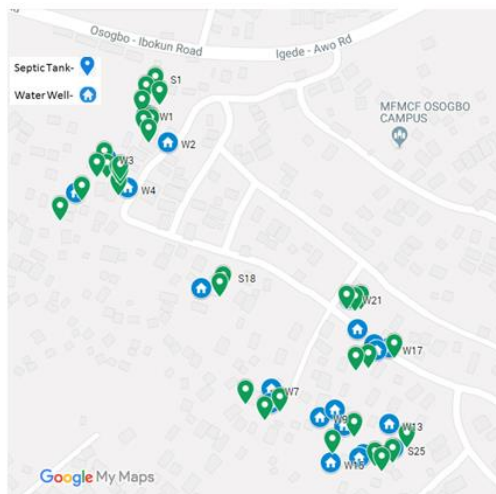


Figure 1: Cluster representation of the selected groundwater wells and septic tanks on Google map.

## 3.2 Laboratory Analyses

### 3.2.1 Rainy Season

The results of the key contaminants identified in the water samples around the selected sites during the rainy season are discussed in this subsection.

Distribution of nitrate concentrations among all the wells is shown in Figure 2. All the wells show high level of  $[\text{NO}_3^-]$ . In fact, the concentration can be classified as extreme in values, ranging from 74 to above 75 mg/L.  $[\text{NO}_3^-]$  in all the wells can be described as beyond human and animal consumption. United State Environmental Protection Agency (USEPA, 2012) and Health Canada put maximum  $[\text{NO}_3^-]$  in water for human consumption at 44.27 mg/L (10 mg/L as  $\text{NO}_3^-$ -N) while WHO puts it at 50mg/L (11.3 mg/L as  $\text{NO}_3^-$ -N) (Water Quality Association). Situation where all the wells, including surface water stream, exceeds the maximum concentration limit (MCL) is appalling. In their study of 20 domestic drinking water wells in Massachusetts, USA, Schaider et al. (2016) found minimal, moderate and high impact  $[\text{NO}_3^-$ -N] corresponding to <0.5 mg/L, 0.5-2.5 mg/L and >2.5 mg/L, respectively. Focazio et al. (2006) tested 3465 wells throughout the US while Schaider et al. (2016) tested 20 wells in Massachusetts, US. The results of the former found 8% of the wells had >10 mg/L  $[\text{NO}_3^-$ -N] while the later found 5% of the wells to be contaminated in the same range. In comparison to current study, 100% of the wells, in this work, have far beyond the normal nitrate concentration,



with mean concentration of  $[\text{NO}_3^-]$  in this study being 74.9 mg/L. This comparison shows that the contamination level in the study area is outrageous and calls for official action.

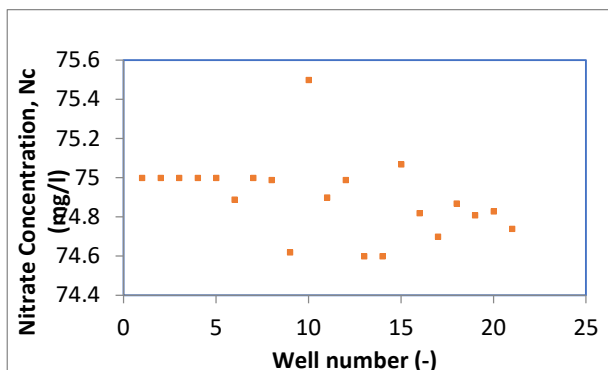


Figure 2: Nitrate concentration in the sampled wells water at 21 locations during the rainy season. Surface Water (Stream) is in location 10.

Furthermore, it is interesting to note that the highest concentration of  $\text{NO}_3^-$  was found in surface water (well number 10 in Figure 2), though all other well samples also have high  $[\text{NO}_3^-]$ . It must be noted that the surface water was at the lowest elevation level among the sampling points. This indicates that nitrate solution is being drained down the valley to the surface stream from the upstream part of the area. This might happen through plume mobilization from the ubiquitous septic tanks in the study area by rainwater, especially through the transition zone. Arnade (1999) reports the effect of rainfall on plume mobilization from septic tanks. The author reports how high level precipitation ( $>63\text{cm}$ ) resulted into the septic tank overflow and groundwater contamination. Also, it is possible that the nitrate solution came from refuse dumps by the households in the area. The high concentration of  $\text{NO}_3^-$  in this work can still be attributed to the shallow depths of the wells in the study area. As shown in Table 2, water levels in the wells range from 0m (surface water) to the maximum of 7m. This is a far cry if compared to the wells investigated in the work of Schaidler et al. (2016) which have the mean value of 18m in depth.

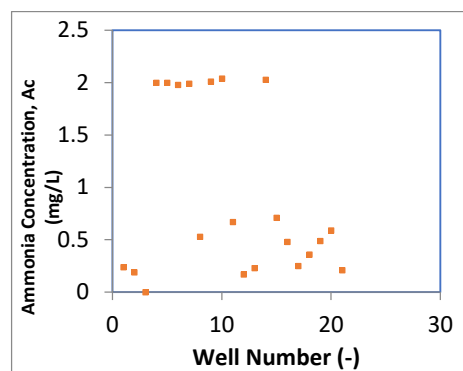


Figure 3: Ammonia concentration in the sampled wells at 21 locations during the rainy season.

In comparison to  $[\text{NO}_3^-]$ , the ammonia concentration is generally low in all the wells, ranging from 0 to 2.03 mg/L. This is shown in Figure 3. The low level of ammonia indicates the oxic condition in the study area. Oxic conditions enhance oxidation of ammonia to  $\text{NO}_3^-$  in the septic plumes (Schaidler et al. 2016). In non-oxic condition or at locations where septic tanks are too close to the water wells, there may not be enough opportunity for the oxidation to take place. Verstraeten et al. (2005) found that in wells  $\leq 15$  m from septic systems, concentrations of  $\text{NH}_4^+$  exceeded those of  $\text{NO}_3^-$ , indicating reducing conditions. However, in this study, the shallow water table, the valley-slope effects (i.e., drainage of septic plume down the valley side) and the high-drainage potential of the rainy season combine to spread the contaminants around the study area. Despite the relatively low concentration of ammonia, it can still be noted that the highest concentration of  $\text{NH}_3$  occurs in the surface stream. This can be understood to be as a result of valley-slope effect, resulting in high drainage of contaminants down the valley into the stream, similar to the observation in high concentration of  $\text{NO}_3^-$  found in the surface stream.

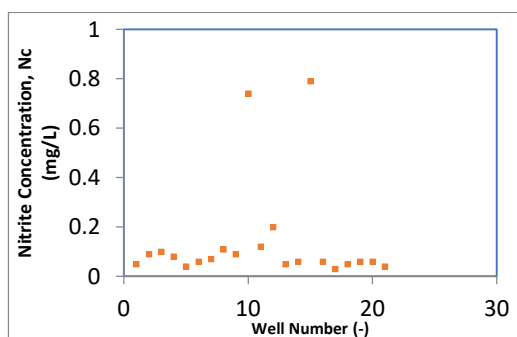


Figure 4: Nitrite concentration in the sampled wells at 21 locations during the rainy season.

Nitrite concentration is shown in Figure 4. Values of nitrite concentrations in the figure conform with USEPA's MCL of 1.0 mg/L. The nitrite concentration is low just like ammonia, ostensibly owing to the high concentration of  $\text{NO}_3^-$ . This is also due to the oxic condition of the area, leading to oxidation of nitrite ( $\text{NO}_2^-$ ) and  $\text{NH}_3$  to  $\text{NO}_3^-$ . The study area apparently has high hydraulic conductivity with good aeration. With high hydraulic conductivity, the drainage of the area will easily move leachate from septic tanks to water in the wells. This eventually culminated in the discharge of the contaminants in the river. Arnade (1999) found that the presence of high-porosity sandy soil in Palm Bay, Florida, was responsible for easy flow of leachate during rainy season, resulting in widespread contamination of groundwater.

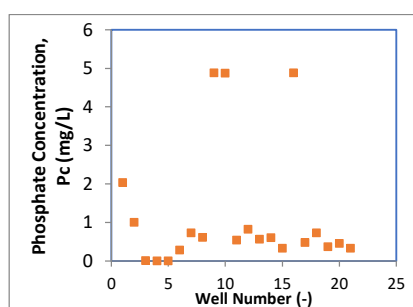


Figure 5: Phosphate concentration in the sampled wells at 21 locations during the rainy season.

The concentration of phosphate ions in the water is shown in Figure 5. The values range from 0 to 5 mg/L. Even though global water standards regulators (WHO, USEPA, EU) do not officially specify the MCL for phosphate, it is known that excessive consumption of the mineral in water solution may lead to severe conditions like osteoporosis and poor bone maintenance together with an increased risk of cardiovascular disease (Health impacts and Water pollutants, 2012). The phosphate found in groundwater can be from rock minerals in the study area, the human sewage, agricultural run-off from farms, sewage from animal feedlots, pulp and paper industry, vegetable and fruit processing, chemical and fertilizer manufacturing, and detergents (Hochanadel, 2010; Laws, 1993). The fact that the highest phosphate concentrations occur in the surface stream and the surrounding wells, which are at the lowest part of the valley indicate the valley-slope drainage effect, mentioned earlier. This also contributes to the fact that the nitrate, nitrite, ammonia and phosphate ions are probably from similar sources, e.g., septic tanks.

Meanwhile, Fadiran et al. (2008) categorised the risk level associated with the presence of phosphate in water body. The authors associate the phosphate level in the range 0.01-0.03mg/L to uncontaminated water bodies. The range 0.025 - 0.1mg/L was associated with onset of plant

growth or algal bloom while  $>0.1$  is associated with hyper-eutrophication. In the investigation of phosphate levels in two regions of Swaziland, Fadiran et al. (2008) found 83% of the analysed surface water sites and 93% of the ground water samples having phosphate levels that exceed the maximum acceptable level of 0.10 mg/L. From the analysis of Fadiran et al. (2008), it happens that virtually all the water bodies in the two regions of Swaziland are already under hypereutrophic state. Applying the analysis of Fadiran et al. (2008) to the current work, it follows that the current state of the surface water in study area in Nigeria is pathetic with the average concentration of phosphate in the study area being 1.17mg/L while about 20% of the wells have the phosphate level above 2mg/L and three of the wells including surface water has concentrations close to 5mg/L. As said earlier, the fact that the concentration phosphate concentration appears highest in the surface water stream, which is located at the lowest part of the valley, confirms the valley-slope effect that was discussed earlier. This implies that there is active drainage of the contaminants down the valley culminating in their high levels in surface stream. Arnade (1999) expressed strong correlation between high concentrations of nitrate, phosphate in groundwater samples and the decreasing distances of septic tanks. These facts point to the reality that some of the contaminants can be attributed to septic source.

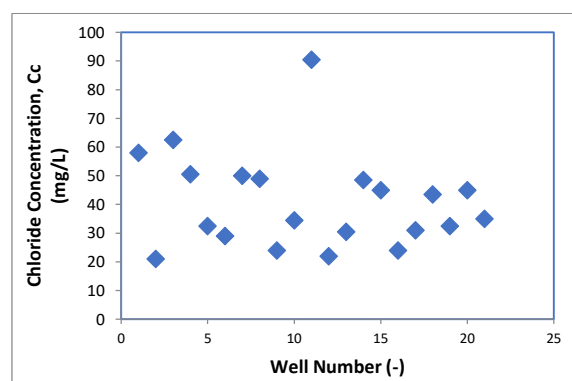


Figure 6: Chloride ion concentration in the sampled wells at 21 locations during the rainy season

Distribution of chloride ion in the sampled wells of the study area is shown in Figure 6. The results show that the chloride level is below the MCL of USEPA (250 mg/L). Thus, the chloride at the study area was taken to be normal.

Figure 7 shows that potassium concentration in the studied wells is within the normal range. USEPA does not specify MCL for potassium. But the potassium ion could have come from dissolution of rocks, fertilise salt and soil (Provin and Pitt, 2001). Pourfallah et al. (2014)

reported between 0.002 and 9.24 mg/L for potassium in Tehran groundwater. This range correlates well with the levels of potassium found in this study as shown in figure 7.

Figure 8 shows that the pH values of the sampled wells are largely acidic. Only about 15% of the samples are within the acceptable range of 6.5-8.5 stipulated for drinking and domestic purposes (WHO, 1993). The pH of the samples might have been acidified by high level of nitrates in the water. This was similar to the findings of Henriksen and Brakke (1988). Figure 8 further shows that the highest pH value occurs in and around the surface stream. This is related to the influence of the valley-slope effect discussed earlier.

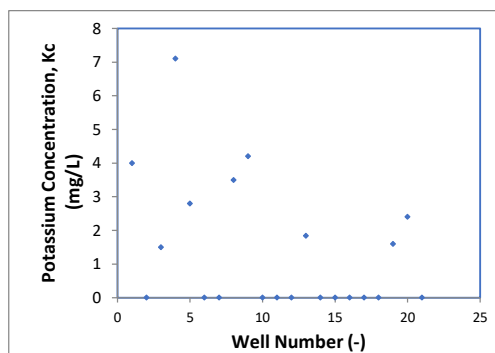


Figure 7: Potassium ion concentration in the sampled wells at 21 locations during the rainy season

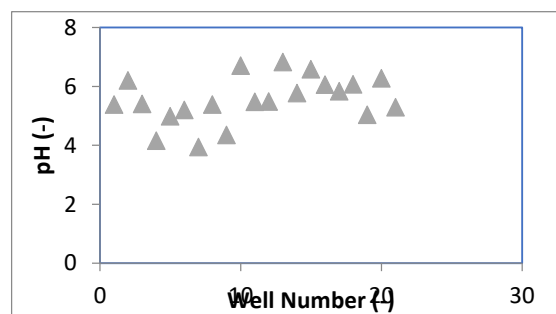


Figure 8: pH distribution in the sampled wells at 21 locations during the rainy season

### 3.2.2 Dry Season Analyses and Comparison with Rainy Season Results

Efforts were made to investigate the seasonal variations in water quality in the study area. The dry season sampling was conducted in February 2018.

Results show that the rainy season nitrate concentration was much higher than that of the dry season. In the dry season, all the sampled wells have their nitrate concentrations below the

MCL by USEPA & WHO with the average value of 31.4 mg/L while the rainy season has the mean value of 74.9 mg/L. The reason for the reduction in dry season values may be owing to low subsurface drainage potential of the contaminants during the dry season. Owing to little or no precipitation the mobilization of the contaminants from the septic and other sources remain at low ebb. To buttress this point, the concentration of nitrate in the surface stream, which used to be the highest in the rainy season has not been so in the dry season. This provides evidence on the reduced drainage activities down the valley side of the study area.

Seasonal effects also manifest in ammonia concentration. An average ammonia concentration in the dry season was 0.01 mg/L while that of the rainy season was 0.9 mg/L on the average. This was about 8900% difference between raining and dry seasons. Seasonal variations among contaminants were discussed by Pourfallah et al. (2014). They found that nitrate, nitrite and ammonia are season-dependent. In the work of Arnade (1999), it was made clear that the higher precipitation in the rainy season was responsible for plume mobilization and widespread distribution.

### **3.0 CONCLUSION**

Results of water quality in the study area show elevated concentration of nitrate ions which is far higher than the standard limit by United States Environmental Protection Agency (USEPA) and relatively lower concentrations of nitrite and ammonia ions are as a result of oxic characteristics of the subsurface in the study area, with mean nitrate concentration of 74.9mg/L. The Nitrate ions concentration was highest in the valley trough of the settlement which is occupied by a surface water stream. The surface stream also has the highest concentrations of ammonia and nitrite ions. This indicates active mobilization of the contaminants down the valley. Furthermore, it was found that the contamination levels of nitrate, ammonium and nitrite ions are higher in the rainy season than the dry season, which again shows the drainage mobilization of the contaminants in the subsurface during the rainy season than the dry season. Simple mathematical model was developed to predict and forecast nitrate concentration in a solution with known quantities of other key variables- of ammonia, nitrite, phosphate (PO) and pH. The model can still serve to confirm the accuracy of any test on nitrate by comparing analytical test result with mathematical estimate.

## **REFERENCES**

- Abbassi, B., Abuharb, R., Ammary, B., Almanaseer, N. and Kinsley, C., 2018. Modified septic tank: innovative onsite wastewater treatment system. *Water*, 10(5), p.578.
- Arnade, L.D., 1999. Seasonal Correlation of Well Contamination and Septic Tank Distance, *Ground Water*, 37(6), pp 920-923.
- Alabi, O.O., 2011. Fluid Flow in Homogeneous and Heterogeneous Porous Media. *Electronic Journal of Geotechnical Engineering*, 16.
- Bear, J., 2013. Dynamics of fluids in porous media, Courier Dover Publications.
- Bitton, G. and C.P. Gerba, 1984. Groundwater pollution microbiology: the emerging issue In: *Groundwater Pollution Microbiology*. G.Bitton and C.P. Gerba, eds. John Wiley & Sons, New York.
- Bremer, J.E. and Harter, T., 2012. Domestic wells have high probability of pumping septic tank leachate. *Hydrol. Earth Syst. Sci.* 16 (8), 2453–2467.
- Chapman, D. 1992. *Water Quality Assessments - A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*, Chapman and Hall: London; 1992; pp. 76-78.
- Craun, G.F., 1981. Outbreaks of waterborne disease in the United States: 1971-1978. *J.Amer. Water Works Assoc.* v.73, pp.360-369.
- Craun, G.F., 1984. Health aspects of groundwater pollution. In: *Groundwater Pollution Microbiology*. G. Bitton and C.P. Gerba, eds. John Wiley & Sons, New York.
- Craun, G.F., 1979. Waterborne disease-Status report emphasizing outbreaks in ground-water systems. *Ground Water*, v. 17, pp. 183-191.
- Fetter, C.W., Boving, T. and Kreamer, D., 2017. *Contaminant hydrogeology*. Waveland Press.
- Health impacts and Water pollutants, 2012. Center for science and environment. <http://www.cseindia.org/node/655>
- Henriksen, A. and Brakke, D.F. 1988. Increasing contributions of nitrogen to the acidity of surface waters in Norway. *Water, Air, and Soil Pollution*, 42(1–2), pp 183–201.
- Hwang, H.T., Frey, S.K., Park, Y.J., Pintar, K.D.M., Lapen, D.R., Thomas, J.L., Spoelstra, J., Schiff, S.L., Brown, S.J. and Sudicky, E.A., 2019. Estimating cumulative wastewater treatment plant discharge influences on acesulfame and *Escherichia coli* in a highly impacted watershed with a fully-integrated modelling approach. *Water Research*.
- John De Zuane, P.E. 1990. *Handbook of Drinking Water Quality-Standards and Controls*, Van Nostrand Reinhold: New York; 1990; pp. 132-134.

Pourfallah, F., Javadian, S., Zamani, Z., Siadat, S.D., Khatami, Sh, Saghiri, R. and Kordi, T., 2014. Physico-Chemical Analysis of Groundwater of Around Tehran by Seasonal Variation. *Pakistan Journal of Biological Sciences*, 17(2), 287-291.

Provin, T.L. and Pitt, J.L., 2001. What is in my water? <http://itc.tamu.edu/documnets/extensionpubs/E-176.pdf> retrieved on 2nd April 2019.

Gao, Q., Blum, K.M., Gago-Ferrero, P., Wiberg, K., Ahrens, L. and Andersson, P.L., 2019. Impact of on-site wastewater infiltration systems on organic contaminants in groundwater and recipient waters. *Science of the Total Environment*, 651, pp.1670-1679.



## **PARAMETRIC INVESTIGATION OF THE RELIABILITY OF ONE-WAY REINFORCED CONCRETE SLAB**

Olawale, S. O. A.<sup>1</sup>, Tijani, M. A.<sup>2\*</sup> and Ogunleye, O. E.<sup>3</sup>

<sup>1,2,3</sup>Department of Civil Engineering, Osun State University, Osogbo, Nigeria.

\*Email of Corresponding Author: [murtadha.tijani@uniosun.edu.ng](mailto:murtadha.tijani@uniosun.edu.ng)

### **ABSTRACT**

Reinforced concrete structures are subjected to several sources of uncertainties that highly affect their response to applied loads. These uncertainties are related to the structure geometry, material properties and the loads applied. Thus, it is necessary to incorporate them into the analysis in order to have a more realistic estimation of structural response. This paper presents a parametric investigation of the reliability of reinforced concrete one-way spanning solid slab at its service life. The development was based on advanced first order second moment (AFOSM) method of reliability analysis using ultimate limit state (ULS) function to represent the state of the structure. Monte Carlo simulation was used to verify the adequacy of representation of the structural slab. The results obtained showed that for flexural failure of slab, variation of slab depth, yield stress and moment of concrete had the greatest influence on the failure probability while reinforcement steel ratio had little or no influence on the failure probability. It was also found that increasing effective depth and steel stress of the slab had positive effect on the performance of the deflection response while increasing slab length and applied moment negatively affect the deflection response of reinforced concrete slab.

**Keywords:** Solid slab, Reliability index, AFOSM: Advanced First Order Second Moment, ULS: Ultimate Limit State.

### **INTRODUCTION**

A slab is a reinforced concrete structure which is more often subjected to bending (tensile and compressive) but in rare cases (such as, in bridge deck) subjected to shear. BS 8110 Part 1(1997) defined one way slab as a slab in which the area of each bay exceeds 30m<sup>2</sup> and has moments in only one spanning direction. According to Oyenuga (2011), a one-way spanning slab is a slab whose shorter side is less or equal to 4.5m and the live load of the slab is not up to 4.0kN/m<sup>2</sup>.

Lemaire (2013) defined reliability as the probability that a structure or system can perform a required function under a specified service condition during a given period of time. It is the

probability that a structure can be used without failure for a given period of time, under specific operational conditions (Kassem, 2015). Bastidas-Arteaga and Soubra (2014) stated that reliability offers the theoretical framework for considering uncertainties in engineering decision scheme. Conversely, failure probability is the probability that a structure does not perform satisfactorily within a given period of time (Lemaire, 2013).

Several researchers have worked on reliability analysis of reinforced concrete structural elements. Olawale *et al.* (2018) assessed the reliability of Ejigbo Campus Library Building at Osun State University. The result showed that safe reliability index of the building was dangerously low. Mohammed and Seyan (2016) studied the behavior of reinforced concrete triangular and T-beams. Concrete beams were tested experimentally and analysed analytically using the finite element method. Their reliability was also assessed using the reliability index approach. The results showed that the finite element vertical displacements compared well with those obtained experimentally. The triangular beams exhibited higher ductility at failure than did the T-beam. The experimental results validated the reliability analysis results, which stated that the triangular beams are more reliable than T-beams for equal areas of steel and concrete.

Baji and Ronagh (2015) investigated a reliability-based investigation into the ductility measures for reinforced concrete (RC) beams designed according to the current fib Model Code for Concrete Structures (2010). Based on the ductility ratio, a limit state to ensure adequate ductility in RC beams is proposed. Their results showed that the ductility ratio generally follows a right-skewed distribution, and due to variability in the material properties and model error, there is high variability in the strain ductility. This high variability in the ductility ratio leads to a high probability of non-ductile behaviour for RC beam designs. Eamon and Jensen, (2013) investigated the procedure for conducting reliability analysis of reinforced concrete beams subjected to a fire load. Using the suggested procedure, reliability was estimated from zero to four hours of fire exposure using Monte Carlo simulation. It was found that reliability decreased nonlinearly as a function of time. Hsin Yu Low (2001) investigated the reliability analysis of concrete slab under explosive loadings and the performance function was set up based on displacement, ductility and maximum strain limit state, Monte Carlo simulation using finite element software MARC was used to verify the adequacy of the Single Degree of Freedom (SDOF) representation of the structural slab.

Literature review showed that reinforced concrete structures are subjected to several sources of uncertainties that highly affect their response. These uncertainties are related to the structure geometry, material properties and the loads applied. Thus, it is necessary to

incorporate them into the analysis in order to have a more realistic estimation of structural response. Hence, this study is focused at developing a Java based program that would be used for assessing the performance and structural safety of a simply supported one way spanning solid slab to BS 8110 part 1: (1997).

## **METHODOLOGY**

A parametric investigation of the reliability of reinforced concrete one-way spanning solid slab at its service life was carried out to BS 8110 part 1: (1997). The development was based on AFOSM method of reliability analysis using ultimate limit state (ULS) function to represent the state of the structure. Monte Carlo simulation was used to verify the adequacy of representation of the structural slab.

### **Development for Moment**

From BS8110 Part 1: 1997, the nominal resistance for slab in bending is expressed as:

$$M_u = 0.95A_sF_yz \quad (1)$$

For Reliability and Structural Safety the Moment of Resistance must be greater than the Applied Moment i.e.  $M_R \geq M_A$ .

Hence the Limit State Equation for bending is expressed as:

$$g(A_s, z, F_y, M) = 0.95A_sF_yz - M_A \quad (2)$$

$$\text{Let } A_s = \gamma A_{sc}, \text{ and } A_{sc} = bh \quad (3)$$

Hence, equation 2 can be represented as,

$$g(b, h, z, F_y, M) = 0.95\gamma bhF_yz - M_A \quad (4)$$

Where,

$M_u$  = Ultimate Moment of Resistance of Slab

$M_A$  = Applied Moment on Slab

$b$  = Width of slab,  $b= 1000\text{mm}$

$h$  = Thickness of Slab

$z$  = Section Modulus for Slab

$A_s$  = Area of Steel Reinforcement

$A_{sc}$  = Area of Concrete

$\gamma$  = Steel Ratio

$F_y$  = Characteristic Yield strength of Steel

$$\text{Let } b = X_1, h = X_2, F_y = X_3, M_A = X_4 \text{ and } z = X_5 \quad (5)$$

Substituting equation (5) into equation (4) we obtain

$$g(X_1, X_2, X_3, X_4, X_5) = 0.95\gamma X_1 X_2 X_3 X_5 - X_4 \quad (6)$$

At  $g(x) = 0$ ,

$$X_5 = \frac{X_4}{0.95\gamma X_1 X_2 X_3} \quad (7)$$

Determining the Partial Derivates w.r.t variable

$$\frac{\partial g}{\partial X_1} = 0.95\gamma X_2 X_3 X_5 \quad (8)$$

$$\frac{\partial g}{\partial X_2} = 0.95\gamma X_1 X_3 X_5 \quad (9)$$

$$\frac{\partial g}{\partial X_3} = 0.95\gamma X_1 X_2 X_5 \quad (10)$$

$$\frac{\partial g}{\partial X_4} = -1 \quad (11)$$

$$\frac{\partial g}{\partial X_5} = 0.95\gamma X_1 X_2 X_3 \quad (12)$$

### Development for Deflection

From BS8110 Part 1: (1997), Deflection in slab is expressed as

$$\text{Actual } \frac{L}{d} \leq \text{Allowable } \frac{L}{d}$$

$$\frac{L}{d} \leq 20 \times M.F$$

$$\frac{L}{d} \leq 20 \times \left[ 0.55 + \frac{477 - F_s}{120 \times \left( 0.9 + \frac{M}{bd^2} \right)} \right]$$

$$\text{where } F_s = \frac{2}{3} F_y \frac{A_{s\text{required}}}{A_{s\text{provided}}}$$

Where,

L = Span of Slab

d = Effective Depth

M.F = Modification Factor  $\leq 2.0$

F<sub>s</sub> = Service Load

F<sub>y</sub> = Yield Stress

M = Applied Moment

B = width of slab

A<sub>srequired</sub> = Area of Steel Required

A<sub>sprovided</sub> = Area of Steel Provided

Span effective Depth Ratio = 20

Area of Steel Required is assumed the same with area of steel provided

The limit state equation for deflection is now given as:

$$g(b, d, l, F_s, M) = \frac{L}{d} - 20 \times \left[ 0.55 + \frac{477 - F_s}{120 \times \left( 0.9 + \frac{M}{bd^2} \right)} \right] \quad (13)$$

$$F_s = \frac{2}{3} F_y, \quad \text{since it is assumed that } A_{s\text{required}} = A_{s\text{provided}}$$

$$\text{Let } b = X_1, d = X_2, L = X_3, M = X_4, \text{ and } F_s = X_5 \quad (14)$$

Hence the Limit State Equation becomes

$$g(X_1, X_2, X_3, X_4, X_5) = \frac{X_3}{X_2} - 20 \times \left[ 0.55 + \frac{477 - X_5}{120 \times \left( 0.9 + \frac{X_4}{X_1 X_2^2} \right)} \right] \quad (15)$$

At  $g(x) = 0$ ,

$$X_5 = 477 - 120 \times \left[ 0.9 + \frac{X_4}{X_1 X_2^2} \right] \times \left[ \frac{X_3}{20 X_2} - 0.55 \right] \quad (16)$$

Determining the partial derivatives w.r.t the variables we obtain:

$$\frac{\partial g}{\partial X_1} = -2400 \times \left[ \frac{X_5 - 477}{\left(120 \times \left(0.9 + \frac{X_4}{X_1 X_2^2}\right)\right)^2} \right] \times \left[ \frac{-X_4}{X_1^2 X_2^2} \right] \quad (17)$$

$$\frac{\partial g}{\partial X_2} = \frac{X_3}{X_2^2} - \left( 2400 \times \left[ \frac{X_5 - 477}{\left(120 \times \left(0.9 + \frac{X_4}{X_1 X_2^2}\right)\right)^2} \right] \times \left[ \frac{-2X_4}{X_1 X_2^3} \right] \right) \quad (18)$$

$$\frac{\partial g}{\partial X_3} = \frac{1}{X_2} \quad (19)$$

$$\frac{\partial g}{\partial X_4} = -2400 \times \left[ \frac{X_5 - 477}{\left(120 \times \left(0.9 + \frac{X_4}{X_1 X_2^2}\right)\right)^2} \right] \times \left[ \frac{1}{X_1 X_2^2} \right] \quad (20)$$

$$\frac{\partial g}{\partial X_5} = \frac{-20}{\left(120 \times \left(0.9 + \frac{X_4}{X_1 X_2^2}\right)\right)} \quad (21)$$

## RESULTS AND DISCUSSION

### Flexural reliability analysis

Structural reliability is the probability of not attaining any of its limit states. It is usually measured by the Reliability Index. The slab flexural capacity depends on several parameters including variation of slab depth, yield stress, moment of concrete and reinforcement steel

ratio. Java based software of the one way slab flexural reliability analysis result is hereby presented in Figure 1 - 4. The results obtained showed that for flexural failure of slab, variation of slab depth, yield stress and moment of concrete had the greatest influence on the failure probability while reinforcement steel ratio had little or no influence on the failure probability.

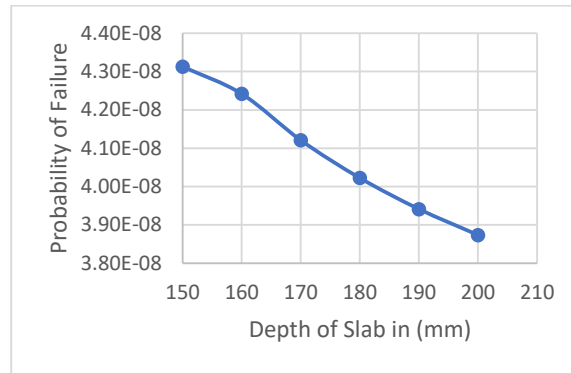


Figure 1: Probability of Failure against Depth

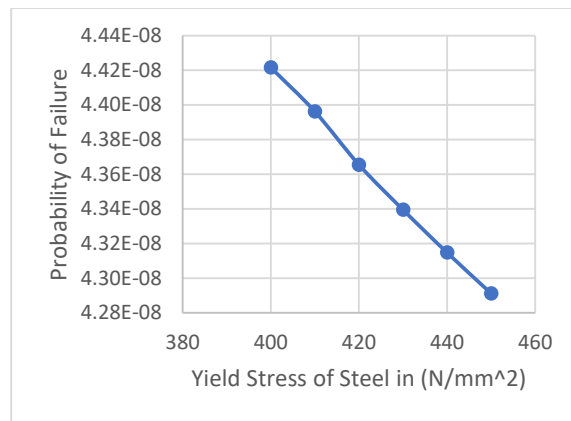


Figure 2: Probability of Failure against Yield Stress

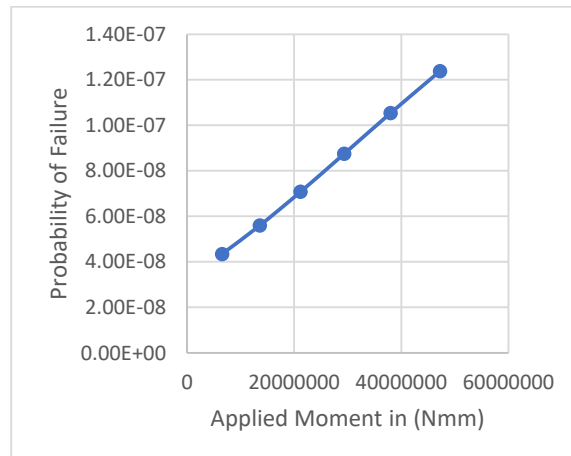


Figure 3: Probability of Failure against Moment

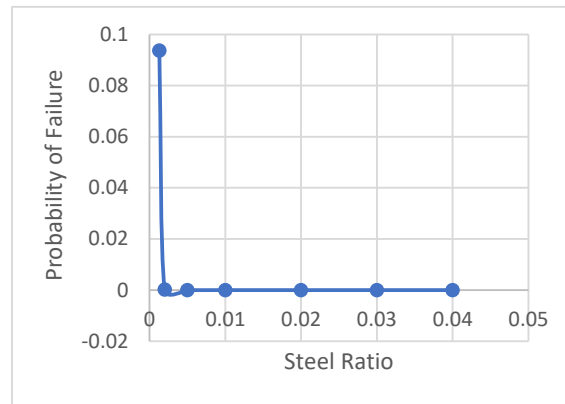


Figure 4: Probability of Failure against Steel Ratio

### Deflection reliability analysis

Figures 5 – 8 presented the probability of failure against effective depth, slab length, moment and service stress respectively. It could be observed that increasing effective depth and steel stress of the slab had positive effect on the performance of the deflection response while increasing slab length and applied moment negatively affect the deflection response of reinforced concrete slab.

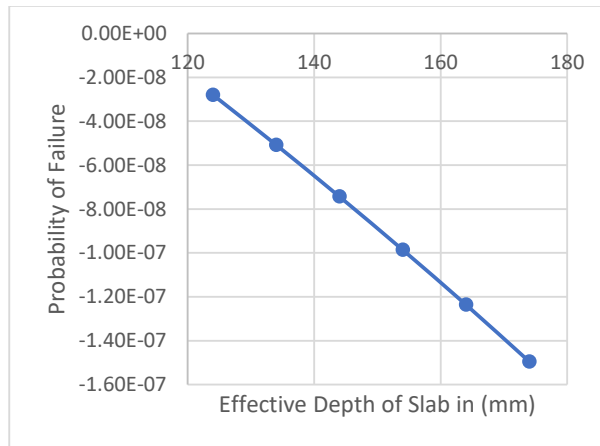


Figure 5: Probability of Failure against Effective Depth



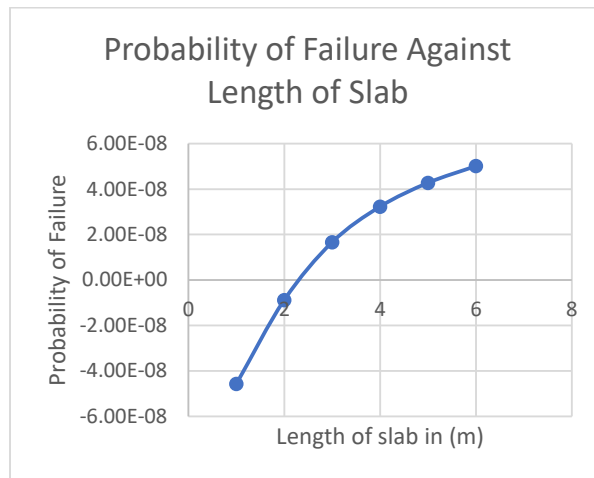


Figure 6: Probability of Failure against Length of Slab

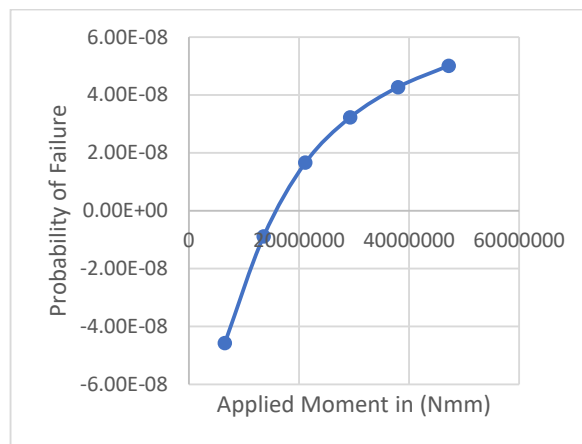


Figure 7: Probability of Failure against Moment

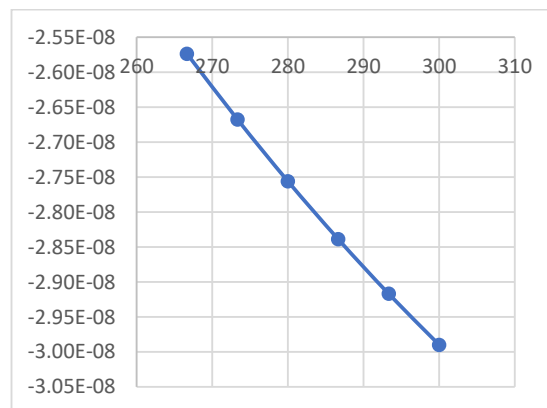


Figure 8: Probability of Failure against Service Stress

## **CONCLUSION**

A parametric investigation of the reliability of reinforced concrete one-way spanning solid slab at its service life was carried out. The results obtained showed that for flexural failure of slab, variation of slab depth, yield stress and moment of concrete had the greatest influence on the failure probability while reinforcement steel ratio had little or no influence on the failure probability. It was also found that increasing effective depth and steel stress of the slab had positive effect on the performance of the deflection response while increasing slab length and applied moment negatively affect the deflection response of reinforced concrete slab.

## **REFERENCES**

- Baji, H. and Ronagh, H. 2015. A reliability-based investigation into ductility measures of RC beams designed according to *fib* Model Code 2010. *Structural Concrete*. 16(4), pp. 546 – 557.
- Bastidas-Arteaga E. and Soubra A. H. 2014. Reliability Analysis Methods. *ALERT Doctoral School 2014-Stochastic Analysis and Inverse Modeling*, pp. 53-77.
- BS 8110 Part 1, 1997. Structural use of concrete, British Standard Institution, London
- Eamon, C. D. and Jensen, E. 2013. Reliability analysis of RC beams exposed to fire. *Journal of Structural Engineering*. 139(2), pp. 212 – 220.
- Hsin Y. L. and Hong H. 2001. Reliability analysis of reinforced concrete slabs underexplosive Loading, School of Civil and Structural Engineering, Nanyang Technological University, Singapore 639798, Singapore, 0167-4730/01/\$ - see front matter Elsevier Science Ltd.
- Kassem F. 2015. Reliability of reinforced concrete structure: case of slab subjected to impact, PHD Thesis, École doctorale : Mécanique, Énergétique, Génie Civil, Acoustique.
- Lemaire M. 2013. *Structural reliability*. John Wiley & Sons.
- Mohammad, F. and Seyan, D. 2016. Optimum design of reinforced concrete rectangular columns subjected to axial compression and biaxial bending moments. *Athens Journal of Technology and Engineering*. 3(3), pp. 225 - 239.
- Olawale S. O. A., Tijani M. A., Folayan O. I. and Bolaji E. O. 2019. Reliability Assessment of Ejigbo Campus Library Building of Osun State University, Osogbo. *USEP: Journal of Research Information in Civil Engineering*, 16(1), pp. 2511 -2526.
- Oyenuga V. O. 2011 Reinforced Concrete Design (A Consultant/Computer Based Approach), 7<sup>th</sup> Edition, Asros Limited Lagos, Nigeria. ISBN:978-36217-7-7.

## **MULTINOMIAL LOGIT APPROACH TO MODELLING CRASH SEVERITY ON SELECTED TWO-LANE HIGHWAYS IN ONDO STATE NIGERIA**

Ipindola, O.O

Department of Civil Engineering, Federal Polytechnic Ile-Oluji

Email of Corresponding Author: [olajideipindola@gmail.com](mailto:olajideipindola@gmail.com).

### **ABSTRACT**

Reducing the frequency and severity of road accidents has been a major goal of transportation agencies in developed and developing countries, considering their impact on the economy. Road transportation plays a major role in the socio-economic development of a developing country like Nigeria with over 80% of her freight transported by road. However, the safety of these public infrastructures, particularly two-lane single carriage highways remains a public health and social concern. Investigation of significant causal factors of road traffic crashes is a critical step towards improving the safety and sustainability of transportation systems.

This study employed a multinomial logit model to identify the significant factors influencing the severity of traffic crashes on selected two-lane single carriage highways in Ondo state Nigeria using a Four-year crash data retrieved from Federal Road Safety Corps, 3.11 command, Akure. The crash cases considered for this study comprised 26.2% fatal, 57.3% serious and 16.5% minor crashes. Descriptive statistics revealed that 77.8% of the total crash cases were caused by speed-related factors. The crash type comprised 54.4% two-vehicle crashes, 30.5% single-vehicle crashes and 15.0% multi-vehicle crashes. The logit model identified 85th percentile speed of vehicles, speed-related cause, the involvement of heavy vehicle, private car, single-vehicle and two-vehicle crashes as significant factors influencing the severity of crashes at the case study. Road safety agencies, traffic engineers and transportation planners will find the model developed in this study useful when considering safety decisions in the management of two-lane single carriage highways in Nigeria.

**Keywords:** Multinomial Logit Model, Crash Severity, Road Safety, Two-lane Single Carriage Highway

### **INTRODUCTION**

Traffic safety remains a major economic and public health concern in a developing country like Nigeria. Road traffic injuries will become the seventh leading cause of death by 2030 (WHO, 2015). Several number of roads accidents are experienced on Nigerian highways annually, some of which result in fatal, serious, and property damages. The number of road related accidents in Nigeria from 1960 – 2016 is reported to be 1125377, resulting in 350961

fatalities and 1,208,890 injuries (FRSC, 2017). Nigeria is ranked second-highest in the rate of accidents among 193 countries of the world with annual traffic accident death ranging from 8000 to 10,000 between 1980 and 2003 (Filani and Gbadamosi, 2007). In terms of traffic safety, there are on average 230 accidents per 10,000 vehicles in Nigeria. A large percentage of these crash cases are recorded on two-lane highways characterized by mixed traffic, speed violation, poor surface condition and weak lane discipline (Ipindola, 2018). According to FRSC annual report on causes of road crashes, speed violation accounted for 31.5% and 33.9% of the total crashes recorded on Nigerian highways in 2016 and 2017 respectively (FRSC, 2017). The significant factors influencing the frequency and severity of these crashes are not clearly and completely understood.

Considering the importance of road transportation to Nigerian economy and its attendant safety concerns, modelling the severity of road crashes in order to identify the significant causal factors is a critical step to evolving engineering-based countermeasures and effective safety decisions that will help improve road safety and the sustainability of road transport.

Several studies have previously employed various mathematical and statistical modelling techniques to investigate the severity of road crashes involving all categories of road users. Ordered probit and logit models have been used for crash severity modelling (Khattak *et al.*, 2002; Abdel-Aty, 2003; Zajac and Ivan, 2003; Rifaat and Chin, 2005; Clifton *et al.*, 2009). Multinomial logit model has been employed to identify significant causal factors of crash severity (Geedipally *et al.*, 2010; Sze *et al.*, 2011; Vijay *et al.*, 2017). Recently, machine learning techniques are gaining acceptance in crash severity analysis (Chang and Wang, 2006; Onaet *et al.*, 2011; Kashani *et al.*, 2011; Perone, 2015; Qasem and Esraa, 2018). These models have been identified by road safety researchers as the most suitable for modelling crash severity.

Several studies have documented the influence of categories of vehicles involved in a crash on the severity outcome of road Crashes (Ulfarsson and Mannering, 2004; Chang and Wang, 2006; Huang *et al.*, 2008; Yannis *et al.*, 2017). The impact of crash location on crash severity outcome has been studied (Al-Ghamdi, 2002). The difference in the causal factors of crash severity in urban (Vijay *et al.*, 2017) and rural (Kashani *et al.*, 2011) areas have been documented. The relationship between crash type (i.e. rear end, head-on, sideswipe, roll over) and injury severity of crashes has been investigated (Sze *et al.*, 2011; Yasmin and Eluru, 2013; Ranja and

Sudeshna, 2013). Literature has established that factors such as vehicle, traffic, roadway, environmental and driver characteristics influence the severity outcome of crashes.

However, most of the documented studies were carried out in developed countries with traffic, roadway and environmental characteristics differing from the conditions prevalent in Nigeria (Akintayo and Agbede, 2009; Ipindola and Falana, 2019). The crash severity models developed in other contexts cannot be generalized due to differences in local conditions. It is therefore important to calibrate crash severity models suitable and fitting to the Nigerian conditions, as there are only a few studies documented along these lines (Olutayo and Eludire, 2014). This study employed Multinomial Logit model to identify the significant factors influencing crash severity on selected two-lane single carriage highways in Ondo State Nigeria. Twelve variables namely: cause of crash, time of crash, season of the year, category of vehicle(s) involved, crash type, class of vehicle(s) involved, crash location, land use and traffic (ADT, posted speed, percentage of heavy vehicles and 85<sup>th</sup> percentile speed) were considered for model development (Table 2). It is hypothesized that these variables influence the severity of crashes on the selected routes.

## **1.0 METHODOLOGY**

### **Case Study**

Three single carriage highways namely: Akure - Ilesha, Akure - Owo and Akure - Ogbese located in southwest Nigeria were chosen for this study. These routes were chosen for study because of their importance to the socio-economic development of the region. More so, a considerable number of traffic crashes are recorded on these routes yearly.

### **Data Collection**

Four-year crash data recorded on the routes of study from 2014 to 2017 was retrieved from the Federal Road Safety Corps 3.11 command database and pre-processed using Microsoft excel. The severity of crashes in the study locations are observed in three levels according to FRSC database, namely: fatal injury coded as 1, serious injury coded as 2, and minor injury coded as 3 as described in Table 1.

In addition to crash information retrieved from the FRSC database, aggregated traffic parameters perceived to influence crash severity outcomes were recorded for each route under study through site surveys as described in Federal Highway Administration Traffic Monitoring

Guide (FHWA, 2016). The spot speed for built up and non-built up areas were recorded using smart phone technique and the 85th percentile speed calculated afterwards. The Annual Average Daily Traffic (AADT) and percentage of heavy vehicles were also recorded. It is assumed that the AADT and percentage of heavy vehicles remained constant during the period of study. The posted speed for built up and non-built up areas along the routes are 50 km/h and 80km/h respectively. Roadway geometric parameters were not considered in the model development because the FRSC crash database does not capture the exact location of crashes, they were only described in terms of landmarks and land use (e.g. close to filling station, 2km from FUTA Northgate, etc.).

### **Crash Severity Model development**

In a bid to identify the significant causal factors of crash severity on the selected routes of study, Multinomial Logistic Regression Model (MNL) was employed to establish a relationship between the severity of crashes and explanatory variables. The variables selected for model development and their corresponding codes are presented in Table 1.

The models were developed using the mathematical expressions in equations 1 and 2, as proposed by (Hosmer and Lemeshow, 2000). Where Y, is considered as the degree of severity of crash and  $X_1, X_2 \dots X_n$  as the explanatory variables. Y consists of three levels namely: minor injury, serious injury and fatal injury. Two logit functions –  $\text{logit}_1$  and  $\text{logit}_2$  are generated and expressed below:

$$\text{logit}_1 = \ln \left[ \frac{p(Y = \frac{1}{X})}{p(Y = \frac{0}{X})} \right] = \beta_{10} + \beta_{11}X_1 + \beta_{12}X_2 + \dots + \beta_{1n}X_n \quad (1)$$

$$\text{logit}_2 = \ln \left[ \frac{p(Y = \frac{2}{X})}{p(Y = \frac{0}{X})} \right] = \beta_{20} + \beta_{21}X_1 + \beta_{22}X_2 + \dots + \beta_{2n}X_n \quad (2)$$

Where:  $\text{logit}_1$  represents a logit function for fatal injury versus minor injury and  $\text{logit}_2$  represents serious injury versus minor injury.  $\beta_{10}$  and  $\beta_{20}$  represent the intercepts and  $\beta_{11}, \beta_{21},$  etc. represent the coefficients of the explanatory variables.

The odds ratio is the exponent of the coefficient obtained for characteristics in the logit model. When odds ratio is  $< 1$ , there is a higher chance of occurrence of minor crash. If the odds ratio is  $> 1$ , it implies that an increase in the level of explanatory variables lead to a higher chance of occurrence of fatal crash for  $\text{logit}_1$  and serious crash for  $\text{logit}_2$ . The significance of the MNL

model is tested using *likelihood ratio*. The model estimation was implemented using SPSS statistical package.

Table 1: Crash Severity Model Variables

S/N	Crash characteristics	Codes
1	Season	Dry (1), rainy (2)
2	Crash time	Day (1), night (2)
3	Land use	Built up area (1), non-built up area (2)
4	Crash location	Intersection (1), otherwise (2)
5	Crash type	Single vehicle (1), two-vehicle (2), multi-vehicle (3)
6	Vehicle(s) involved	Involving heavy vehicle (1), otherwise (2)
7	Vehicle category	Involving private car (1), otherwise (2)
8	Causal factor	Speed-related (1), otherwise (2)
9	Average Daily Traffic	Continuous
10	Percentage of heavy vehicles	Continuous
11	Posted speed limit	Discrete
12	85 <sup>th</sup> percentile speed	Continuous
13	Severity of crash	Fatal (1), serious (2), Minor (3).

## **2.0 RESULTS AND DISCUSSION**

The summary of crash characteristics on the selected routes is presented in Table 2. The level of severity of crash cases considered in this study comprised, 57.3% serious, 26.2% fatal and 16.5% minor crashes. The percentage of crash cases recorded in rainy season was 60.6% while 39.4% cases were recorded in dry season. This may be due to wet pavement, hazy weather and other environmental factors that are not captured in the FRSC database. Researchers have however documented the impact of weather and other environmental factors on crash severity (Anderson and Dong, 2017). Eighty-two percent of the crash cases occurred in the day while

17.9% occurred in the night time. This may be due in part to increased heterogeneity and volume of traffic, especially during rush hours. Built-up areas were responsible for 64.2% of the crashes at case studies. There is need to investigate the safety impact of land use along highways in Nigeria. Installing traffic calming measures at built-up areas also has the potential to reduce the frequency and severity of crashes around built up areas. In terms of vehicle category, 60.2% of the crashes recorded on the selected routes involved private cars. The use of public transport should be encouraged in a developing country like Nigeria where acquiring a private car is perceived as the hallmark of success. Promoting public transport will not only improve safety, it will also improve the environmental performance of the transportation infrastructure which is one of the major goals of sustainability (WHO, 2018). The dominant crash type was found to be two-vehicle crash which accounted for 54.5% of the total crash cases. Though the collision type is not captured in the crash database, past experiences and FRSC reports suggest that head-on collision is prevalent on two-lane highways in Nigeria due to speed-related factors such as wrongful overtaking, speed violation and dangerous overtaking (FRSC, 2018). It is recommended that the FRSC include type of collision in their crash recording process. The percentage of heavy vehicles involved in crashes on the selected routes was 39.4% during the period of study. These statistics are high compared to developed countries (Moridpouret *al.*, 2015). There might be a need for policy makers to look into freight transport rescheduling towards periods with less traffic. Development of rail transport and maritime for better access across state capitals in Nigeria has a huge potential to reduce heavy vehicle volume and its safety concerns on highways. The posted speed for built up and non-built up areas are 50km/h and 80 km/h respectively. However, the maximum percentile speed recorded on the routes under investigation was 118km/h which indicates that the majority of the vehicles traversing these routes are non-compliant with speed regulations. This is in tandem with the findings of (Ipindola, 2018). The maximum AADT on the selected routes is 2147 veh/day while the minimum is 1298 veh/day. The average percentage of heavy vehicles is 11.2%, however, they are involved in 39.4% of crashes. There is need to investigate separately the frequency and severity of crashes involving heavy vehicles in Nigeria. Researchers have opined that the causal factors of crash severity involving different vehicle classes differ (Huang et al., 2008; Yannis et al., 2017).



**Table 2: Summary of Crash Characteristic**

<b>S/N</b>	<b>Crash characteristics</b>		<b>%</b>
1	Severity level	Fatal	26.2
		Serious	57.3
		Minor	16.5
2	Season	Dry	39.4
		Rainy	60.6
3	Time of crash	Day	82.1
		Night	17.9
4	Land use	Built up area	64.2
		Non-built up area	35.8
5	Crash type	Single vehicle	30.5
		Two-vehicle	54.5
		Multi-vehicle	15.1
6	Vehicle class	Involving heavy vehicle	39.4
		Not involving heavy vehicles	60.6
7	Vehicle category	Involving private car	60.2
		Not involving private car	39.8
8	Causal factor	Speed-related	77.8
		Non-speed-related	22.2
9	Crash location	Intersection	36.2
		Non-intersection	63.8

Pearson correlation was carried out on the explanatory variables of crash severity. Land use and posted speed were found to highly correlate with 85<sup>th</sup> percentile speed. Hence, were excluded from the model development. Likelihood ratio test was conducted for the selected crash characteristics and the variables found to significantly influence the severity of crash at 95% confidence interval include: crash type, vehicle class, vehicle category, causal factor and 85<sup>th</sup> percentile speed. These five characteristics were used to develop the final crash severity model and the model fitting information presented in Table 3. The model fitting information indicates the parameters of the model for which the model fit is calculated. The difference observed in the -2log likelihood values associated with the “intercept only” and “final” models shows that the “final” improved upon the “intercept only” model. The log-likelihood measure of -256.740 for the final model is significant at 5% level of significance which infers that the model provides a good fit to the data. The Chi-square tests that at least one of the predictors’ regression coefficient is not equal to zero in the Multinomial Logit model. The chi-square statistic for this model was 49.931 which rejects the null hypothesis that all the predictor coefficients are equal to zero. The small p-value of 0.0001 indicates that at least one of the regression coefficients in the model is not equal to zero.

Table 3: Model Fitting Information

Model	Log-likelihood	Chi-square	p-value
Intercept only	306.670		
Final	256.740	49.931	< 0.0001

Multinomial Logistic model was developed to identify the significant causal factors of crash severity. The coefficients of crash characteristics along with their standard errors, significance and odds ratio were computed for two logit models and the results presented in Table 4. In  $\text{logit}_1$ , minor injury is treated as the reference group in relation to fatal injury. The intercept of  $\text{logit}_1$  is the estimate of fatal injury in relation to minor injury when the predictor variables in the model are evaluated as zero, i.e. zero estimates for crash characteristics reduce the chances of fatal injury outcome by 4.086. The coefficient of 85<sup>th</sup> percentile speed is estimated as 0.037, which signifies that a unit increase will likely increases the chances of fatal injury outcome by

0.037, provided all other variables in the model are held constant. All the characteristics of  $\text{logit}_1$  except single-vehicle crash have positive coefficients, implying that a unit increase in these characteristics is associated with an increase in the chances of crash severity being fatal. The coefficient of single-vehicle crash is -0.011, implying that a unit decrease in this variable will likely increase the chances of a fatal injury crash by 0.011 provided all other variables in the model are held constant. The odd ratios of all the characteristics except single-vehicle crash are greater than 1, which implies that, an increase in the coefficient of these characteristics increases the likelihood of a fatal injury severity outcome. The odds ratio for single-vehicle crash is less than 1; an increase in these characteristics increases the chances of minor injury severity outcome.

In the case of  $\text{logit}_2$ , minor injury is treated as the reference group in relation to serious injury. The intercept has a positive coefficient of 0.998, which indicates the likelihood of serious injury outcome provided that the coefficients of all the characteristics are zero. All the characteristics in  $\text{logit}_2$  have negative coefficients except 85th percentile speed which signifies an increase in the chances of serious injury outcome for every unit decrease in these characteristics. A unit increase in 85th percentile speed increases the chances of serious injury outcome by 0.029, provided all other characteristics are held constant. Furthermore, all the odds ratios except 85th percentile speed are  $< 1$ ; signifying that a unit increase in these characteristics increases the likelihood of a minor injury severity outcome. The odds ratio for 85th percentile speed is  $> 1$ , which indicates that a unit increase in 85th percentile speed increases the chances of a serious injury outcome by a factor of 1.029 provided all other characteristics are held constant. These parameters: multi-vehicle crash, not involving heavy vehicles, not involving private car and non-speed-related causes are set to zero in the final model because they are redundant.

Table 4: Parameter Estimates of Crash Severity Model

Mode	Characteristics	Coeff	SE	Sig.	Odds ratio
1					
Logit 1	Intercept	-4.086	1.485	0.006	
	85 <sup>th</sup> percentile speed	0.037	0.014	0.009	1.038
	Single-vehicle crash	-0.011	0.787	0.989	0.990
	Two-vehicle crash	0.893	0.704	0.205	2.441

	Involving heavy vehicle	0.360	0.495	0.467	1.434
	Involving private car	0.106	0.473	0.822	1.112
	Speed-related cause	0.776	0.547	0.156	2.173
Logit 2	Intercept	0.998	1.300	0.447	
	85 <sup>th</sup> percentile speed	0.029	0.013	0.028	1.029
	Single-vehicle crash	-1.706	0.699	0.015	0.182
	Two-vehicle crash	-0.687	0.625	0.271	0.503
	Involving heavy vehicle	-0.610	0.464	0.188	0.543
	Involving private car	-1.231	0.411	0.003	0.292
	Speed-related cause	-0.352	0.416	0.397	0.703

### 3.0 CONCLUSION

This study has identified the significant factors affecting the severity of road crashes on selected two-lane single carriage highways in Nigeria using Multinomial Logistics Regression model. The findings of this study suggest that factors such as 85<sup>th</sup> percentile speed, crash type, crash category, vehicle class and speed-related cause significantly influence the injury severity outcome of road crashes, with 85<sup>th</sup> percentile speed of vehicles being the most significant predictor variable. There is a need for the Federal Road Safety Corps (FRSC) to double their efforts at ensuring speed compliance, as speed-related causes such as speed violation, dangerous driving and dangerous overtaking were responsible for the immediate cause of 77.8% of the crash record used for this study. This result corroborates the claims of FRSC that speed violation is the chief cause of crashes on Nigeria roads. Another important finding of this study is the severity risk of private vehicles. One of the ways to solve this problem is for the ministry of transportation at federal, state and local levels to synergize and come up with a framework to encourage the use of public transport. The promotion of public transport is a

major goal of sustainable transportation. It promises safety improvement, better environmental performance and accessibility.

Transportation planners and government agencies will find the outcome of this study useful in the development of effective and localized countermeasures for the improvement of safety on two-lane single carriage highways in Nigeria. This study focused on all types of crashes and all categories of vehicles. Future research can investigate separately single-vehicle crash, two-vehicle crash, pedestrian-vehicle crash and multi-vehicle crash. Furthermore, different road types other than two-lane highways and the impact of road geometry on safety can be examined in future studies.

## **REFERENCES**

- Abdel-Aty, M. (2003): Analysis of driver injury severity levels at multiple locations using ordered probit models, *Journal of Safety Research*, 34: 597–603.
- Akintayo, F. O. and Agbede, A. O. (2009): Headway Distribution Modelling of Free-Flowing Traffic on Two-Lane Single Carriage Ways in Ibadan, Proceedings of the 1<sup>st</sup> International Conference on the Role of Engineering and Technology in Achieving Vision 20:2020, Obafemi Awolowo University, Ile-Ife, Nigeria, 240-246.
- Al-Ghamdi, A. S., (2002): Using logistic regression to estimate the influence of accident factors on accident severity, *Accident Analysis and Prevention* 34: 729–741.
- Anderson, J. C. and Dong, S. (2017): Heavy-Vehicle Driver Injury Severity Analysis by Time of Week: A Mixed Logit Approach Using HSIS Crash Data, *ITE Journal* 4: 41-49.
- Chang, L. Y. and Wang, H. W. (2006): Analysis of traffic injury severity: An application of nonparametric classification tree techniques, *Accident Analysis & Prevention*, 38(05): 1019-1027.
- Clifton, K. J., Burnier, C. V., and Akar, G. (2009): Severity of Injury Resulting from Pedestrian-Vehicle Crashes: What can We Learn from Examining the Built Environment? *Transportation Research Part D: Transport and Environment*, 14(06): 425-436.
- Federal Highway Administration (2016): Traffic Monitoring Guide, U. S. Department of Transportation.
- Federal Road Safety Corps (2017): Annual Report 2017. [www.frsc.gov.ng](http://www.frsc.gov.ng).
- Federal Road Safety Corps (2018): Annual Report 2018. [www.frsc.gov.ng](http://www.frsc.gov.ng)

- Filani, M. O. and Gbadamosi, K. T. (2007): Spatial and Temporal Pattern of Road Traffic Accident Occurrence in Nigeria, *Nigerian Geographical Journal*, 5 (1), 55-70.
- Geedipally, S., Patil, S., and Lord, D. (2010): Examination of Methods to Estimate Crash Counts by Collision Type, *Transportation Research Record: Journal of the Transportation Research Board* 2165: 12-20.
- Hallmark, S. L. (2002): Factors related to more severe older driver traffic crash injuries, *Journal of Transportation Engineering*, 128: 243-249.
- Hosmer, D. W. and Lemeshow, S. (2000): Applied Logistic Regression (2nd Ed.) Wiley. New York, USA 369.
- Huang, H., Chin, H. C., and Haque, M. M. (2008): Severity of Driver Injury and Vehicle Damage in Traffic Crashes at Intersections: A Bayesian Hierarchical Analysis, *Accident Analysis & Prevention* 40(1): 45-54.
- Ipindola, O. O. (2018): Modeling of 85th Percentile Speed at Selected Mid-Curves on Ondo-Ife Two-Lane Rural Highway in Southwestern Nigeria, *International Journal of Innovative Research and Advanced Studies (IJIRAS)*, 5(11): 158-160.
- Ipindola, O. O. and Falana, J. N. (2019): Traffic Stream Relationships of Two-Lane Highways: A Case of Akure-Ondo Road in Southwest Nigeria, *International Journal of Advanced Engineering, Management and Science*. 5(1): 87-93.
- Kashani, A. T., Shariat-Mohaymany, A. and Ranjbari, A. (2011): A Data Mining Approach to Identify Key Factors of Traffic Injury Severity, *Promet – Traffic & Transportation*, 23(1): 11-17.
- Khattak, A.J., Pawlovich, M., Souletrette, R., and Moridpour, S., Mazloumi, E. and Mesbah, M. (2015): Impact of Heavy Vehicles on Surrounding Traffic Characteristics, *Journal of Advanced Transportation*, 49 (4): 525-535.
- Olutayo, V.A., and Eludire, A.A. (2014): Traffic Accident Analysis Using Decision Trees and Neural Networks, *International Journal of Information Technology and Computer Science (IJITCS)*, 6(2): 22-26.
- Ona, J., Mujalli, R., and Calvo, F. J. (2011): Analysis of Traffic Accident Injury Severity on Spanish Rural Highways using Bayesian Networks, *Accident Analysis & Prevention*, 43(01): 402-411.
- Perone, C.S., (2015): Injury risk prediction for traffic accidents in Porto Alegre / RS, Brazil. arXiv preprint arXiv: 150200245.

- Qasem A. A. and Esraa J. D. (2018): Data Mining Methods for Traffic Accident Severity Prediction, *International Journal of Neural Networks and Advanced Applications*, 5: 1-12.
- Ranja, B. and Sudeshna, M. (2013): Modelling Severity Level in Multi-Vehicle Collision on Indian Highways, *Procedia - Social and Behavioral Sciences* 104: 1011 – 1019.
- Rifaat, S. M. and Chin, H. C. (2005): Accident Severity Analysis Using Ordered Probit Model, *Journal of Advanced Transportation*, 41(1): 91-114.
- Sze, N. N., Tsui, K. L., Wong, S. C. and So, F. L. (2011): Bicycle-related crashes in Hong Kong: is it possible to reduce mortality and severe injury in the metropolitan area?, *Hong Kong Journal of Emergency Medicine*, 18(3): 136-143.
- Ulfarsson, G., and Mannering, F. L., (2004): Differences in male and female injury severities in sport-utility vehicle, minivan, pickup and passenger car accidents, *Accident Analysis & Prevention* 36: 135–147.
- Vijay, G., Adepur, R., and Molugaram, K. (2017): Examining Crash Variable Based on Collision Type for Predicting Crash Severity on Urban Highways, *International Journal for Traffic and Transport Engineering*, 7(3): 381 – 390.
- World Health Organization (2015): Global Status Report on Road Safety 2015, [www.who.int/road\\_safety](http://www.who.int/road_safety).
- World Health Organization (2018): Global Status Report on Road Safety 2018, [www.who.int/road\\_safety](http://www.who.int/road_safety).
- Yannis, G., Theofilatos A. and Pispiringos, G. (2017): Investigation of Road Accident Severity per Vehicle Type, *Transportation Research Procedia* 25: 2076–2083.
- Yasmin, S. and Eluru, N. (2013): Evaluating Alternate Discrete Outcome Frameworks for Modelling Crash Injury Severity, *Accident Analysis & Prevention* 59: 506-521.
- Zajac, S.S., and Ivan, J. N. (2003): Factors influencing injury severity of motor vehicle crossing pedestrian crashes in rural Connecticut, *Accident Analysis and Prevention*, 35: 369–379.

**FACTORS INFLUENCING CORPORATE REAL ESTATE OUTSOURCING IN NIGERIA: AN EMPIRICAL STUDY FROM THE BANKING AND TELECOMMUNICATION SECTORS IN LAGOS, NIGERIA.**

Fayomi, I.\*, Oladokun T.T. and Adewolu T.O.

Department of Estate Management, Faculty of Environmental Design and Management,  
Obafemi Awolowo University, Ile-Ife, Nigeria

\*Email of Corresponding Author: [zodibi12@gmail.com](mailto:zodibi12@gmail.com)

**ABSTRACT**

This paper examines the factors that influence corporate real estate outsourcing in the banking and telecommunication sectors of Nigeria with a view to enhancing outsourcing practice. Primary data used for the study were obtained from the questionnaires administered on twenty-seven banks and six telecommunication operators who were assessed through their corporate real estate officers. Total enumeration of the selected business organisation was adopted. The data were analysed with the aid of descriptive and inferential statistics such as mean rating and factor analysis. Principal Component Analysis (PCA) was further conducted to reduce and regroup these factors using Kaiser-Meyer-Olkin (KMO) and Bartlett's test values. Adopting KMO greater than 0.5 criteria, the analysis showed a KMO of 0.561 at a significance level of 0.000 indicating data fitness and significance. The study showed that cost and risk; business and technological; flexibility; and time and value factors all explained a collective variance of 74.5% of the factors influencing outsourcing of corporate real estate services. The respective variances explained by the above factors were 38.32, 15.71, 11.5 and 9.0% respectively. The study thus established that the most important factors influencing outsourcing in the banking and telecommunication sectors were the cost and risk factor. This study will aid corporate real estate consultants in identifying areas where their services are required in the corporate world and make necessary adjustment to improve their skills. It will also help corporate organisations to understand the relevance of outsourcing non-core business functions.

**Keywords** – Corporate Real Estate, Outsourcing, Factors, Corporate Real Estate Management, Corporate Real Estate Outsourcing.



## **INTRODUCTION**

The drive, by organisations, for the provision of most efficient and effective services towards enhancing organisational set goals without disrupting core business activities seems to be a responsible factor for embracing the outsourcing of non-core business services as a strategy in delivery process. In order to assist in achieving business organisations goals, the need not to compromise their main competences will rather require that they let-go non-core functions for high efficiency levels and high-quality service.

It behoves organisations therefore to ensure proper and efficient use of organisational resources of people, capital, technology as well as Corporate Real Estate (CRE). Since no organisation could thrive without a space (CRE) to carry out their business, this important resource is vital to the success or otherwise of the business. In view of the stringent demands in corporate real estate coupled with its attending features, most corporate organisations engage external expertise to managed and operate corporate real estate on their behalf. This is done in order not to lose focus of their strengths and competence. In doing this, organisations will need to work in tandem with professionals in the effective and efficient delivery of non-core operational functions of the system such as real estate. The importance of real estate is shown in the fact that possessing a piece of property or leasing one is normal to most corporate companies, no matter the size of the corporation. Hence, Corporate Real Estate could be outsourced.

Corporate Real Estate (CRE), being the properties (land(s) and buildings) owned by companies or businesses not primarily involved in real estate business (Laloo, 2013) is said to account for about 25% of the total assets of an organisation with its cost being the second largest in their balance sheet. With this importance, coupled with the fact that the organisations in the banking and telecommunication sectors of African countries such as Nigeria can be said to be having substantial real estate holdings like their counterparts in the developed world, the manner with which they are sourced will be of interest. This becomes important in view of the global requirements for transparency and financial accountability in the use of resources.

A major way by which organisations successfully procure resources such as CRE is outsourcing. Outsourcing, which is the practice of contracting out (totally or partially) of a professional task, function or process to an external service provider, involves replacing the internal provision of services with the external provision of those services which includes out-

tasking, strategic alliances and partnership arrangements. In addition to affording organisations access to ‘world class’ professional services and expertise, it helps organisations to concentrate on their core services and allowing others with better skills in non-core services like CRE to be provided by experts.

CRE outsourcing in the banking and telecommunication industries would likely be very germane to the success or otherwise of the organisations in view of the importance and contribution of these sectors to the development of a nation. Not only would organisations in this sector be mindful of how the largest asset of their organisations are procured, they are likely to be interested in the cost implications of the practice and its impact on the overall process of the organisation. This would therefore demand a study to evaluate the factors that would influence the outsourcing of CRE in an emerging country like Nigeria.

Numerous studies have been conducted on the subject of corporate real estate management and outsourcing practices outside the shores of Nigeria. Recent studies investigated on corporate real estate outsourcing in the financial sector, corporate real estate management outsourcing and practices Bocian and Fortune (2010), Matsham and Heywood (2012), Lalloo (2013), Oladokun (2010), Adetokunboh, Aibinu and Agbato (2013) and Oladokun (2018). Little has however been done on corporate real estate outsourcing practices in Nigeria as a whole and in the study area in particular. Hence, this study intends to investigate factors influencing corporate real estate outsourcing in the banking and telecommunication sectors in Lagos, Nigeria.

## **REVIEW OF PAST STUDIES**

Current global corporate real estate management practice focuses on real estate benchmarking and outsourcing as well as the art of integrating CRE into the financial concepts of business requirements (Oladokun, 2013). Corporate Real Estate (CRE) outsourcing is a common practice among both private and public organizations and is a major element in business strategy. CRE outsourcing decisions are majorly motivated by three factors viz: cost, strategy, and politics. While the first two commonly drive outsourcing by private industry, political agendas drive outsourcing by public organizations (Kakabadse and Kakabadse, 2000). With many senior executives still perceiving the role of real estate assets as merely providing appropriate working environments for the least space costs (Gibler, Black, and Moon, 2002),

it shows clearly that executive attitudes are still entrenched in the idea that corporate real estate is solely a means of doing business negating the global trends and practice of using it as a means to enhancing the profitability of their business through outsourcing.

Krumm, Dewulf and Jonge (1999) studied on the impact of evolving structures on managing corporate real estate, arguing that outsourcing has changed the whole purpose and structure of CRE departments while also increasing the need to justify its in-house presence.

Kooymans (2000) studied the nature of the working relationship between the corporate real estate unit and the outsource service provider. Mcdonagh and Hayward (2000) work focused on the outsourcing of corporate real estate asset management in New Zealand. The study found that the organizations primarily outsource real estate functions to access skills, technology and best practices not available within the organization and because real estate is not their core business.

The study of Ernst and Young (2002) and Columbia University survey of CoreNet Global member corporate real estate professionals found that transaction management, project management, facilities management, and space planning/moves and changes are most often outsourced. The Outsourcing Institute (1998) as cited in Hayward (1999), lists the following main reasons for outsourcing by its member companies: to improve company focus, to gain access to world class capabilities, to free up internal resources for other purposes, the resources not being available internally, to reduce or control operating expenditures, to accelerate re-engineering benefits, the function being difficult to manage or out of control, to make capital funds available, to share risks, and for cash infusion.

Kiran, Richard and Heywood (2005) examined factors important for Western companies' outsourcing of organizational activities to India, and the effect of business outsourcing on corporate real estate locational requirements in India, using a survey of corporate real estate representatives in India and the UK respectively. The primary reasons found were the availability of low-cost, skilled, English speaking people, where India has a definite advantage over the other low-cost countries like China and Philippines.

Naidu, Heywood and Reed (2006) focused on the development factors of Corporate Real Estate Practices in India. A similar study by Barbara (2010) examined nine different groups of reasons why companies outsource their activities. They are: increasing revenues, business

development, organizational reasons, reduces costs, personnel reasons, the need to improve control and reduce risk, only occasional need for particular activities, the need for greater focus on core activities, and too high initial investment for the implementation of certain activities. Most companies therefore frequently outsource to focus on core business or activities, which means that they use outsourcing to supplement their own resources.

The study of Parker (1997) earlier examined outsourcing of CRE functions in both the United States and United Kingdom. The study listed sixteen things that a service provider needs to offer, besides the cost-effective provision of the CRE service itself: The service must be the core business of the service provider, superior knowledge, technology and experience, ability to access world best practice in technology and people, broad geographic capability combined with detailed and reliable local knowledge, established quality control including customer satisfaction programs and TQM and commitment to continuous improvement. Others were: appropriately capitalized business with an established philosophy, management depth and stability, a key contact person in the same city, the undivided attention of the service provider, mutual dependency, the willingness to share risk and the ability to build long-term relationships.

The study of Jacobs, Lickerman, Mackenzie and Yearley (2007) identified three stages in the development of outsourcing. While the first stage (task outsourcing) was aimed at seeking external providers for highly repetitive tasks that only would translate into time and cost savings, the second stage (transactional outsourcing) incorporated the feedback from the service supplier and consequently process refinement and customization. The final stage (integrated outsourcing) incorporates the idea of in-house CRE managers as strategic partners outsourcing certain activities while providing integrated solutions. In a similar study, Ilsjan (2007) identified two stages in the evolution of outsourcing. According to the author, the first one started in the 1970s when companies began outsourcing CRE services in order to emphasize their core competencies. The second stage emerged during the mid-1990s when companies began searching for advanced partnerships or taking back in-house certain CREM activities due to a renewed emphasis on service quality and to balance quality and costs.

Matsham & Heywood (2012) and Bocian & Fortune (2010) in relation to motivation to outsource, identified cost reduction, improved service quality, focus on management and

strategy and improved business flexibility as important factors justifying potential real estate outsourcing decisions in the study area.

There is scanty literature on the subject of CRE outsourcing practices in Nigeria like the study of Oladokun (2013) and Adetokunboh *et. al.*(2013), which focused mainly on the attitudes of business executives towards CRE and the developmental challenges of CRE respectively.

In 2018, the focus of the study of Oladokun was limited to an examination of the challenges of outsourcing in Nigeria. This study concentrated on the challenges in adopting outsourcing as a practice in major industries in Nigeria. Since the retail industries are largely differently run from the manufacturing industries, there is a need for a study of this nature on the banking and telecommunication industries in Nigeria. The foregoing indicated that many works had been done on CRE outsourcing especially in advanced countries. There are however little researches on CRE outsourcing in Nigeria. Also, since it might not be applicable to utilise the findings of those researches in advanced countries to developing countries like Nigeria, there is a need for a study of this nature to serve as guide for investors in the selected sectors on the appropriate use of CRE as an organisational resource.

## **METHODOLOGY**

Lagos been a mega city prompted the choice for the study as mega cities of the world usually serve as the headquarters of most business organisations. The study population was comprised of the heads of corporate real estate executives in the banking and telecommunication sectors in Lagos, Nigeria. The sample frame comprised 22 commercial banks, 4 merchant banks, 1 non-interest bank and 6 major Global System for Mobile Communication (GSM) organizations in Lagos, Nigeria. Total enumeration of the sample was adopted as sample size as it has been established in literature to use total enumeration when sample size is relatively small. Questionnaire administration was adopted for data collection. Information solicited include those factors influencing outsourcing of CRE services as have been identified in literature and information sourced from all the respondents ensured full analysis through both descriptive and inferential statistical techniques. Statistical tools such as frequency distribution, mean rating and mean deviation, and factor analysis were employed. Factor analysis was adopted to group the factors while the variance grouping of the factors was also examined with a view to know the weight of the group of variables. A total of 33 questionnaires were distributed which

represents the overall population of banks and telecommunication companies selected. In commercial banks (head offices) twenty-two (22) questionnaire were distributed and all of the questionnaire were retrieved which amounted to 100% retrieval rate. This was achievable due to the doggedness of the researchers and the number of the sample size. Four (4) merchant banks (head offices) were served questionnaire all of which were retrieved. Non-interest banks and telecommunication companies (GSM operators) also had 100% retrieval rate. In order to achieve the aim of this study, the respondents were asked to rate the different factors identified from literature that can drive the outsourcing of CRE in an organisation.

### **PRESENTATION AND DISCUSSION OF RESULTS**

As indicated in Table 1, the highest ranked reason for outsourcing among all the respondents in both sectors is cost control (4.52). Next to this are efficiency (4.36), access to skills, technology and best practices (4.33), competitive reasons (4.27), increased internal productivity (4.21), freeing up internal resources (4.15) and peace of mind (4.12). All these had positive deviations about the average RII of 4.12.

Table 1: Factors Influencing the Outsourcing of Corporate Real Estate

Reasons	Banking					Telecommunication					Both Sectors				
	S W V	M e a n	M D	S D	Ra nk	S W V	M e a n	M D	S D	Ra nk	S W V	M e a n	M D	S D	Ra nk
Cost control	126	4.67	0.5	0.832	1	23	3.83	-0.05	1.472	4	149	4.52	0.4	1.004	1
Business process re-engineering	111	4.11	-0.06	0.641	8	24	4.00	0.12	0.000	3	135	4.09	-0.03	0.579	8
Time compression	116	4.30	0.13	0.542	4	25	4.17	0.29	0.983	2	141	4.27	0.15	0.626	4

Value chain analysis	113	4.19	0.02	0.483	6	24	4.00	0.12	0.000	3	137	4.15	0.03	0.442	6
Organizational restructuring	112	4.15	-0.02	0.534	7	21	3.50	-0.38	1.378	5	133	4.03	-0.09	0.770	10
Increasing revenue	109	4.04	-0.13	0.587	10	25	4.17	0.29	1.602	2	134	4.06	-0.06	0.827	9
Competitive reasons	116	4.30	0.13	0.869	4	25	4.17	0.29	1.602	2	141	4.27	0.15	1.008	4
Changing technology	112	4.15	-0.02	0.534	7	23	3.83	-0.05	0.408	4	135	4.09	-0.03	0.522	8
Risk sharing	103	3.81	-0.36	0.622	12	20	3.33	-0.55	1.211	6	123	3.73	-0.39	0.761	14
Access to skills, technology and best practices	118	4.37	0.2	0.565	3	25	4.17	0.29	0.408	2	143	4.33	0.21	0.540	3
Efficiency	119	4.41	0.24	0.636	2	25	4.17	0.29	0.408	2	144	4.36	0.24	0.603	2
Improved risk management	102	3.78	-0.39	0.577	13	22	3.67	-0.21	1.366	4	124	3.76	-0.36	0.751	13

Freeing up internal resources	115	4.26	0.09	0.594	5	22	3.67	-0.21	1.366	4	137	4.15	0.03	0.795	6
Flexibility	108	4.00	-0.17	0.480	11	24	4.00	0.12	0.632	3	132	4.00	-0.12	0.500	11
Increased internal productivity	115	4.26	0.09	0.656	5	24	4.00	0.12	0.000	3	139	4.21	0.09	0.600	5
Access to big CRE data	111	4.11	-0.06	0.698	8	20	3.33	-0.55	1.211	6	131	3.97	-0.15	0.847	12
Improved customer/client experience	111	4.11	-0.06	0.424	8	21	3.50	-0.38	1.225	5	132	4.00	-0.12	0.661	11
Peace of Mind	110	4.07	-0.1	0.781	9	26	4.33	0.45	0.516	1	136	4.12	0	0.740	7
<b>RII</b>		<b>4.17</b>					<b>3.88</b>					<b>4.12</b>			

**Note:** SWV= Sum Weighted Value; MD= Mean Deviation; SD= Standard Deviation; RII = Relative Importance Index

**Source:** Field survey 2019

Findings further revealed that the most important reasons for outsourcing corporate real estate in the banking sector were cost control (4.11), efficiency (4.41), access to skills, technology and best practices (4.37), competitive reasons (4.30), freeing up internal productivity (4.26), value and chain analysis (4.19) Each of them had a RII with positive deviations about the sector's RII of 4.17.



In the telecommunication sector on the other hand, the most dominant reason for the outsourcing was peace of mind (4.67). Efficiency, time compression, increasing revenue, competitive reasons, access to skills, technology and best practice had RII value of 4.41 while business process re-engineering, value chain analysis, flexibility and increased internal productivity had the RII value of 4.00 respectively. The computed range (of the RII) of the sector was (4.33-3.33) 1.00 while that of the banking sector was (4.67-3.78) 0.89.

Having inquired into the factors influencing outsourcing in the banking and telecommunication sectors, further analysis was carried out to reduce and regroup these factors using principal component analysis. The analyses are put into two stages. The first stage was checking of the suitability and the adequacy of the variables. This was done using the Kaiser-Meyer-Olkin (KMO) and Bartlett's test values. The data was found fit for factor analysis since KMO was greater than 0.5 and significance level was less than 0.05. The analysis showed a KMO of 0.561 and significance level of 0.000 which indicated that the data were suitable and adequate for factors analysis as shown in Table 2. The communality table was also examined; all variables had their communality values greater than 0.6. These indicated that the variables were fit for factor analysis.

**Table 2: KMO and Bartlett's Test of factors influencing the outsourcing of CRE**

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.561
Bartlett's Test of Sphericity	Approx. Chi-Square	355.089
	Df	120
	Sig.	.000

**Source:** Field survey 2019

From the foregoing analysis, it is established that five most important reasons for outsourcing corporate real estate in both sectors were cost control, efficiency, access to skills, technology and best practices, competitive reasons and increased internal productivity in order of

importance. Findings however revealed that cost control, efficiency, access to skills, technology and best practices, competitive reasons and freeing up internal productivity were the most dominant reasons in the banking sector. On the contrary, peace of mind, efficiency, time compression, increasing revenue, competitive reasons, access to skills, technology and best practices, business process re-engineering, value chain analysis, flexibility and increased internal productivity were the most reasons in the telecommunication sector.

Findings thus established that the factors influencing outsourcing varied from the banking to the telecommunication sectors. Going by all these, it can be said that the reasons for outsourcing corporate real estate are dependent on the core business, ownership structure and other characteristics of an organization. Hence, outsourcing of corporate real estate can be influenced by the characteristics of an organization.

The factors analysis was carried out using principal component analysis where sixteen (16) components were loaded as shown on the rotated matrix table as shown in Table 3. Only factors with primary loading above 0.4 were observed. From table 3, component 1 had nine (9) variables loaded on it which were cost control, organizational restructuring, increasing revenue, competitive reasons, risk sharing, improved risk management, freeing up internal resources, access to big CRE data and improved customer/client experience. This variable pertains mostly to cost and risk hence named cost and risk factor.

Table 3.: Rotated Component Matrix<sup>a</sup> of Factors Influencing Outsourcing

<b>Factors Influencing Outsourcing</b>	<b>Components</b>			
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Cost control	.641			
Business process re-engineering		.788		
Time compression				.905
Value chain analysis				.680
Organizational restructuring	.811			

Increasing revenue	.853	
Competitive reasons	.860	
Risk sharing	.806	
Access to skills, technology and best practices	.661	
Efficiency	.899	
Improved risk management	.709	
Freeing up internal resources	.771	
Flexibility		.811
Access to big CRE data	.570	
Improved customer/client experience	.792	
Peace of Mind		.791

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. \*Rotation converged in 7 iteration **Source:** Field survey 2019

Business process re-engineering, access to skills, technology and best practices and efficiency were loaded in component two. These are very much related to business and technology. These were therefore termed business and technological factor. In the third component were flexibility and peace of mind. These are termed flexibility factors. The component 4 was termed the time and value factor as time compression and value chain analysis were in this category. In view of the above findings, the study established that the factors influencing outsourcing of corporate real estate in the banking and telecommunication sectors were cost and risk, business and technological, flexibility, time and value factors.

Further analysis was done to ascertain the proportion of variance explained by each of the identified that are influencing outsourcing in the sectors. From Table 4, cost and risk factor (component 1) explained 38.3% of the total variance as business/technological and flexibility factors were responsible for 15.7% and 11.5% respectively. Time and value factor explained

9.0% of the total variance. The study established that the most important factor influencing outsourcing in the banking and telecommunication sectors were the cost and risk factors.

Table 4: Total Variance Explained by Factors Influencing Outsourcing

Components	Factors	Extraction Sum of Squared Loading		
		Total	% of Variance	Cumulative %
1	Cost and Risk factor	6.131	38.318	38.318
2	Business/ Technological factor	2.513	15.707	54.024
3	Flexibility factor	1.839	11.491	65.515
4	Time and value factor	1.436	8.975	74.490

**Source:** Field survey 2019

## CONCLUSION

The study examined factors influencing CRE outsourcing in Nigeria. This was with a view to providing information that could enhance the practice. The findings of the study discovered that there were five important factors that influence the outsourcing of corporate real estate in the banking and telecommunication sectors and these are cost control, efficiency, access to skills, technology and best practice, competitive reasons and increased internal productivity. These findings collaborated the studies of Parker (1997), Bocain and Fortune (2010) and Barbara (2010).

The principal component analysis revealed that the drivers of outsourcing in both sectors are the cost and risk factor, business and technological factor, flexibility factor and the time and value factor and this finding confirms the study of Matsham and Heywood (2012). It is therefore essential for corporate real estate consultant to understand that corporate Real estate outsourcing relationship that minimizes cost and risk and embraces contemporary business and technological inputs is capable of enhancing the practice.

However, it is also vital to understand that a consultant that lacks flexibility factor, skills and technological knowhow will not reach a climax in terms of professionalism to provide real estate outsourcing services. From the foregoing therefore, it can be said that the reasons for outsourcing corporate real estate are dependent on the core business, ownership structure and other characteristics of an organization. Hence, outsourcing of corporate real estate can be influenced by the characteristics of an organization. Organizations therefore need to seek strategic business advantages from competent professional due to the competitive nature of their businesses.

## **REFERENCES**

- Adetokunboh, O., Aibinu, I., Agbato, S. (2013). Corporate real estate development in Nigeria. Issues and challenges of site acquisition. Paper presented at the Africa real estate society conference in Kigali, Rwanda from 23-26 October 2013.
- Barbara, B.H. (2010). Correlation between reasons and effects of outsourcing evidence from Slovenian Sme. Faculty of Economics and business, university of Maribor, Maribor, Slovenia.
- Bergsman S. (1994). Pace to Outsource Slows a Bit as Companies Assess Cost Savings. National Real Estate Investor, 36( 8),26 - 32,41- 42.
- Bocian, R. & Fortune, J. (2010). Corporate real estate outsourcing in the financial sector in Poland: the client's perspective. Page 70-86. Available from Sheffield Hallam University Research Archive (SHURA) at: <http://shura.shu.ac.uk/7581/>
- Burt, D. & Doyle, M. (1993). The America Keiretsu business one, Iriwen, Homewood II.
- Elmuti, D., Kathawala, Y. (2000). The effects of global outsourcing strategies on participants' attitudes and organizational effectiveness. International Journal of Manpower, 21/2, 112-128.
- Ernst & Young (2002). Corporate real estate survey results. Ernst & young corporate real estate survey. Pp 1-6.
- Gibler, K. M.& Black, R. T. (2004). Agency risks in outsourcing Corporate Real Estate functions. *Journal of Real Estate Research*, 26(2), 137-160.

- Gibler, K., Black, R., & Moon, K. (2002). Time, Place, Space Technology and Corporate Real Estate Strategy, *Journal of Corporate Research*, 24(3), 235 – 238.
- Hayward, T.J. (1999). *The Outsourcing of Corporate Real Estate Asset Management in New Zealand*. A dissertation submitted at Lincoln University in partial fulfilment of the requirements of the Degree of Master of Property Studies.
- Ilsjan, V. (2007). Corporate Real Estate Management (CREM) in Estonia. *Journal of Corporate Real Estate*, 9(4), 257-277.
- Jacobs, B., Lickerman, T., Mackenzie, I., & Yearley, P. (2007). *Beyond Boundaries - Leveraging Partners to Maximize the Value Chain*. Jones Lang LaSalle IP.
- Kakabadse, N, & Kakabadse, A. (2000). Outsourcing: a paradigm shift. *Journal of Management Development*, 19(8), 670-728.
- Kiran, N., Richard, R. & Chris, H. (2005): The Impact of Business Outsourcing on Corporate Real Estate in India. *Journal of Corporate Real Estate*, 7( 3), 234-245.
- Kooymans, R. (2000). The outsourcing of corporate real estate management – how do corporate real estate units and outsource service providers view each other and management issues? Paper presented at Pacific Rim Real Estate Society Conference, Sydney, January, Pg.1-13.
- Krumm, P. J., Dewulf, G., & De Jonge, H. (1999). The impact of Evolving Structures on Managing Corporate Real Estate. *Journal of Corporate Real Estate*, 2 (1), 58-67.
- Laloo, A. (2013). Corporate Real Estate practices in South Africa – a survey of the top 200 companies listed on the Johannesburg stock exchange. A dissertation report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfillment of the requirements for the degree of Master of Science in Property Development & Management.
- Manning, C., Rodriguez, M. & Roulac, C. (1997). Which corporate real estate function should be outsourced, *Journal of real estate research*, 14(3), pg 259-274.

- Matsham, A. & Heywood, C. (2012). An investigation of corporate real estate management outsourcing in Melbourne. Eighteenth Annual Pacific-rim Real estate Society Conference Adelaide, Australia, 15-18 January 2012
- McDonagh, J. & Hayward, T. (2000). Outsourcing corporate real estate asset management in New Zealand. *Journal of Corporate Real Estate*, 2(4), 351 – 37.
- Naidu, K., Reed, R. and Heywood, C. (2005). The impact of business outsourcing on corporate real estate in India, *journal of corporate real estate*, 7(3),pp 234-245.
- Oladokun, T.T. (2010). Corporate Real Estate Management: A need for paradigm shift in Nigeria. *Sri Lankan Journal of Real Estate*, 39-53
- Oladokun, T.T. (2013). Corporate Real Estate Management Practice in Nigeria: A survey of the Attitude of Business Executives. *Ife Journal of Science and Technology*, 1(1) 27-32.
- Oladokun, T. T. (2018). Challenges of corporate real estate outsourcing in Nigeria. *Journal of international real estate and construction studies*, 4(2) pg 111-121.
- Parker, D. (1997). CRE a major growth sector. in *Property Australia*, October Issue, 47-48
- Scroggins, R. M. (1994). Process Management and Outsourcing, *Corporate Real Estate Executive*, Nov/Dec. 24 -27.
- Sesia, C. I. O. (2014), Challenges Of Implementing Outsourcing Strategy By Commercial Banks In Kenya, Research Project Submitted In Partial Fulfilment Of The Requirements For The Award Of The Degree Of Master Of Business Administration, School Of Business, University of Nairobi.
- Yang, D. H., Seongcheol, k., Nam, C., & Min, J. W. (2007). Developing a decision model for business process outsourcing. *Computers & Operation research* 34 (12), 3769- 3778.

## **COMBINED INFLUENCE OF GRAVEL AND CRUSHED BURNT BRICKS ON THE PROPERTIES OF CONCRETE**

. Kareem, M.A <sup>1\*</sup>, Olawale, S.O.A. <sup>1</sup>, Bamigboye, G.O. <sup>2</sup>, Alade A. J. <sup>1</sup>

<sup>1</sup>Department of Civil Engineering, Osun State University, Osogbo, Nigeria.

<sup>2</sup>Department of Civil Engineering, Covenant University, Ota, Nigeria.

\*Email of Corresponding Author: [mutiu.kareem@uniosun.edu.ng](mailto:mutiu.kareem@uniosun.edu.ng)

### **ABSTRACT**

The quest for alternative materials in concrete production is ongoing as the demand for concrete using conventional material increases. This study investigates the properties of concrete produced with Crushed Burnt Bricks (CBB) as replacement for Unwashed Gravel (UG). Concrete mixes of 1:2:4 (cement, sand and gravel) mix ratio were produced using UG/CBB combination in varying proportion of 100:0, 75:25, 50:50, 25:75, 0:100 which were represented as sample A, B, C, D and E. The water-to-binder (w/b) ratio of 0.4, 0.5, 0.55 and 0.6 were used for each sample. Sample A without CBB (i.e. 100% UG) served as control. Slump test was carried out on the fresh concrete while compressive strength test was carried out on the hardened concrete specimens using 150 mm cubes at the curing in ages of 7, 14 and 28 days, respectively. The slump values of fresh concrete increases with increase in w/b and CBB contents. At 28 days, the compressive strength values were 26.7 N/mm<sup>2</sup> for concrete produced with sample B at w/b of 0.4 and 28.2 N/mm<sup>2</sup> for concrete produced with sample A (control). It was concluded that the optimum level of substitution of 25% CBB for gravel is viable for concrete production from a structural point of view.

**Keywords:** Compressive strength, Concrete, Crushed burnt brick, Unwashed gravel, Water-to-binder ratio,



## **1.0 INTRODUCTION**

Concrete is a composite material that consists of cement, fine aggregate coarse aggregate and water with or without admixture (Bamigboye *et al.*, 2019). Concrete's versatility, durability, and economy have made it the world's most used construction material (Kosmatka *et al.*, 2003). The properties of concrete are influenced by many factors which include the properties of aggregate used in the concrete, their sizes and texture, whether angular or sub- angular, other factors include the type of cement used, the water-cement ratio used, the method of mixing and curing, relative humidity and temperature. These factors must be adequately controlled to ensure that the desired properties of the concrete are obtained (Jimoh and Awe, 2007).

Aggregates occupy 70-80 per cent of the volume of concrete; hence, their impact on various characteristics of concrete cannot be underestimated (Neville, 2011). Aggregates are presumably inert mineral fillers such as crushed rock, gravel and sand for making concrete. It has been established that some of the aggregates exhibit chemical bond at the interface of aggregates and paste (Shetty, 2005). Aggregates are cheaper than cement; hence they are employed to the maximum advantage in concrete production. Aggregates can be classified as natural and artificial aggregates. Examples of natural aggregates include sand, gravel, crushed rock such as granite, quartzite, basalt while artificial aggregates include broken bricks, air-cooled slag, sintered fly ash, bloated clay (Yang and Huang, 1996). Gravel is one of the naturally occurring aggregates which has been used over the time for structural concrete construction as an alternative to granite, believing that it is either using granite alone or the mixture of the two coarse aggregates (granite and gravel) in a designed proportion can give the required strength and durability (Bamigboye *et al.*, 2016).

The cost of the provision of affordable housing depends largely on the price of the construction material. As a result of the high cost of cement and aggregates for the production of concrete, efforts have been made by many researchers (Khalaf, 2006; Rashid *et al.*, 2008; Apebo and Agunwanba, 2014; Bazaz and Khayat, 2012; Kulkarni and Momin, 2015; Raheem and Kareem, 2017a,b) in finding ways of reducing the cost of its production. This is achieved by finding alternative ways to reduce the cost of cement and coarse aggregates. The most commonly used coarse aggregates in concrete production in residential housing by low-income earner in Nigeria is gravel. This is due to the high cost of granite and the availability of abundant gravel

at a relatively lower cost in most areas of the country. Moreso, the availability and proximity of aggregate to the construction site also affect the cost of construction taking away the infrastructural development out of reach of the common man. Over the past decades, the cost of gravel has continued to increase owing to the cost of transporting gravel to the construction site and this factor tends to increase the cost of construction (European Environmental Agency, 2008). This necessitates the use of natural or manufactured material as an alternative to gravel in concrete production.

Debieb and Kenai (2008) investigated the properties of concrete with crushed bricks as a partial replacement for fine aggregates. Concrete with 25% crushed brick contents showed better properties that are comparable to that of the control specimen. Kanchiduria *et al.* (2017) studied the strength and durability of concrete produced with partial substitution of granite with over burnt brickbat wastes and concluded that 25 to 50% replacement was suitable for normal and mass concrete production. Rekha and Potharaju (2016) analysed the properties of concrete produced with recycled brick and granite. The results indicate that the crushed clay bricks are suitable for the replacement of the granite aggregate in concrete production. Similarly, Otoko (2014) used the crushed clay bricks as aggregate in bituminous mixtures for the production of asphalt concrete. The results showed that asphalt concrete of unused and recycled brick aggregate outperformed specimens made with granite aggregates, mainly because of the high porosity and roughness of the surface of crushed clay brick aggregates, which can absorb more bitumen and provide better bonding in asphalt concrete.

Several studies (Rashid *et al.*, 2008; Khalaf, 2006; Apebo and Agunwanba, 2014; Bazaz and Khayat, 2012; Kulkarni and Momin, 2015) have used crushed bricks as coarse aggregates in making concrete. Other studies have used crushed brick as a partial replacement for crushed stone (Rashid *et al.*, 2012; Nordin, 2014; Debieb and Kenai, 2008; Kanchiduria *et al.*, 2017; Rekha, 2016) and river gravel (Apebo *et al.*, 2013). In this study, the workability and compressive strength of concrete produced by the combined use of UG and CBB was investigated.

## **2.0 MATERIALS AND METHODS**

### **Materials**

The UG and river sand used in this study were obtained from borrow pits in Ibadan, Oyo State. CBB samples were collected from the bricks production site at Foyer Bricks, Ofatedo area of Osogbo Local Government Area, Osogbo, Osun State. The Aggregates used in this study is shown in Figure 1. Elephant Brand of ordinary Portland cement of 32.5 grade which conforms to BS 12 (1996) was purchased from a retail shop within Ibadan and used as a binding agent. Water used for mixing was collected from the tap at the Concrete Laboratory of the University of Ibadan, Ibadan, Oyo State Nigeria. Figure 2 shows the grading curves for UG, CBB and river sand.

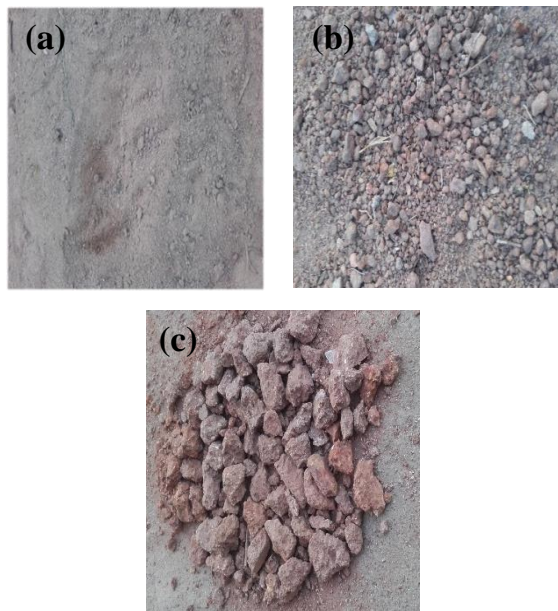


Figure 1: Aggregates used (a) River sand (b) UG (c) CBB

### **Sample Preparation**

Concrete of 1:2:4 (cement, sand and gravel) mix proportions were prepared in conformity with BS 1881-125 (1986). The coarse aggregate content of the concrete mixture contained the mixture of UG and CBB in varying proportion of 100:0, 75:25, 50:50, 25:75, 0:100 which were represented as sample A, B, C, D and E. The w/b of 0.4, 0.5, 0.55 and 0.6 were used for each sample.

Sample A without CBB (i.e. 100% gravel) served as control. Table 1 shows the mix proportion for the preparation of 1 m<sup>3</sup> concrete mix in terms of the weight of the components. A total

number of 144 concrete cubes of 150 mm size were produced for all the batches of concrete mixes. After casting, the specimens were stored in the Laboratory at  $27 \pm 5$  °C with 90% relative humidity for 24 hours and then demoulded and cured underwater until testing ages.

The above mix was repeated for water-cement ratio of 0.5 (150 kg), 0.55 (165 kg) and 0.6 (180 kg), respectively.

Table 1: Mix Proportion used for concrete mix (0.4 W/C)

Sample ID	UG/CBB Combination (%)	Cement (Kg)	Sand (kg)	Coarse Aggregates (kg)		Water (kg)
				UG	CBB	
A	100/0	300	600	1200	0	120
B	75/25	300	600	900	300	120
C	50/50	300	600	600	600	120
D	25/75	300	600	300	900	120
E	0/100	300	600	0	1200	120

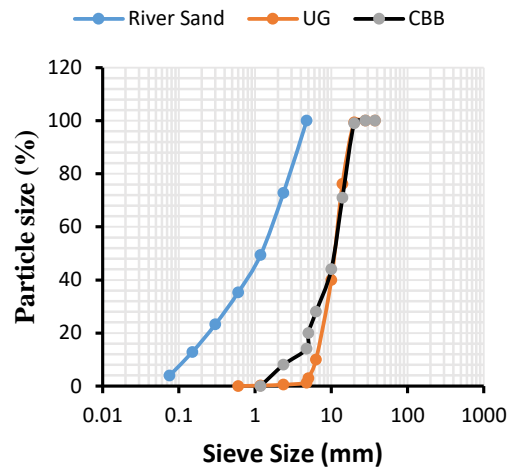
### Testing on Concrete

Slump test was carried out on fresh concrete in accordance with BS 1881: Part 102 (1983) to determine the effect of CBB on the workability of concrete and compressive strength test was carried out on the hardened concrete specimens at the curing in ages of 7, 14 and 28 days, respectively. These tests were carried out at the Concrete Laboratory of the University of Ibadan, Ibadan, Oyo State Nigeria

## 3.0 RESULTS AND DISCUSSION

### Workability

The result of slump indicating the workability of concrete mixes with different combinations of UG and CBB are presented in Table 2. The Table indicates that the concrete slump decreases as the CBB content increases and increases as the water/cement ratio increases.



**Figure 2:** Particle size distribution of the aggregates used

The reduction in slump is attributed to the change in particle shape and nature of aggregates when CBB replaced UG (El-hassan and Kianmehr, 2019). The dust content can also cause reduction in workability (Kesečić *et al.*, 2008).

Table 2: Slump values of fresh concrete mixes

Sample ID	Water/Cement Ratio	Slump (mm)
A	0.40	0
	0.50	40
	0.55	55
	0.60	70
B	0.40	10
	0.50	30
	0.55	45
	0.60	60
C	0.40	0
	0.50	9
	0.55	20
	0.60	50

D	0.40	0
	0.50	5
	0.55	10
	0.60	30
E	0.40	0
	0.50	0
	0.55	5
	0.60	15

**Compressive**

**strength**

The results of the compressive strength of concrete with different combinations of UG and CBB at the curing ages of 7, 14 and 28 days are presented in Figs. 3-5, respectively. The Figures generally showed that the compressive strength increases as the curing ages increases.

The result at 7 days as presented in Figure 3 indicate that the compressive strength of the concrete decreases with increase in CBB content and w/b ratio. The highest compressive strength was observed for concrete produced with Sample A (control) and w/b of 0.40 while the lowest was recorded for concrete produced with Sample E and w/b of 0.6. Nonetheless, the compressive strength values of concrete produced with different combinations of UG/CBB are lower compared to the control, a similar trend of decrease in compressive strength was observed as that of the control.

A similar trend was observed at 14 days as presented in Figure 4. This indicates an increasing rate of substitution of UG with CBB generally decreases the compressive strength of the concrete. Such characteristic is attributed to the higher water absorption of recycled crushed brick compared to natural aggregates (Kesegić, 2008).

The results for 28 days as presented in Fig. 2 also followed the same trend with the compressive strength ranging from 15.4 to 28.2 N/mm<sup>2</sup> for concrete produced with samples A

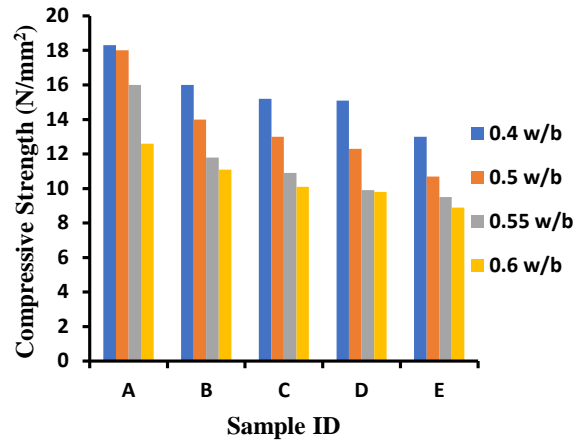


Figure 3: Compressive strength of UG/CBB concrete at 7 days curing age

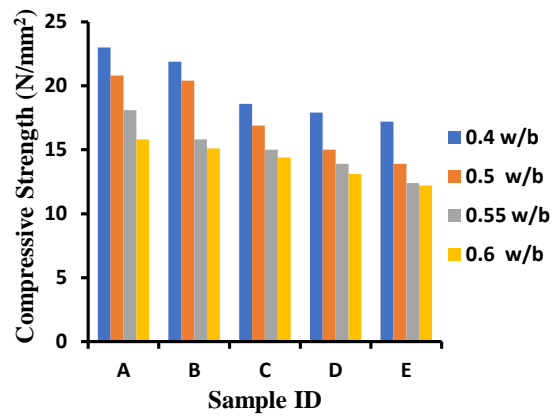


Figure 4: Compressive strength of UG/CBB concrete at 14 days curing age

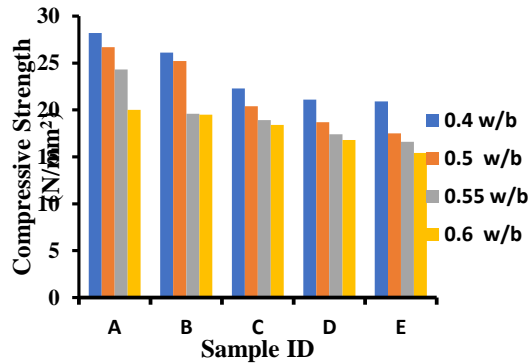


Figure 5: Compressive strength of UG/CBB concrete at 28 days curing age

to E as the CBB contents in UG increased from 0% to 100%. These values are lower compared to the values obtained from previous studies (Bhattacharjee *et al.*, 2011; Rashid *et al.*, 2009 and Apebo *et al.*, 2013) and this is attributed to the use of unwashed gravel as against the washed and granite. The compressive strength values of concrete containing the UG/CBB combination are generally lower compared to the control with the same w/b ratio. This is in agreement with the findings from previous studies (Bhattacharjee *et al.*, 2011; Rashid *et al.*, 2009 and Apebo *et al.*, 2013). Meanwhile, the highest compressive strength was observed for concrete produced with Sample B with 25% CBB content for the entire w/b ratio considered compared to samples with higher CBB content. About 87%, 82%, 74% and 88% of the control was developed by concrete produced with Sample B with the same water/cement ratio and curing ages.

#### **4.0 CONCLUSIONS**

From the results of the tests performed on the concrete, the following conclusions were drawn.

1. The concrete slump increases with increase in CBB content and decrease in UG content.
2. Increase in w/b ratio of concrete results in an increase in concrete slump.
3. The compressive strength of concrete decreases with increase in w/b ratio and CBB content in UG.
4. Concrete with 75% UG and 25% CBB content for all the w/b ratio considered attained the optimum compressive strength which is closer to the control with the same w/b ratio.
5. Concrete with the proportions of 75% UG and 25% CBB with 0.4 w/b ratio is suitable for producing concrete for non-load bearing structural applications.

#### **REFERENCES**

- Apebo, N.S. and Agunwambe J., 2014. The suitability of crushed over burnt brick as coarse aggregate, *International Journal of Engineering Science and Innovation Technology*, 3(1), pp. 316-321.
- Apebo, N.S., Iorwua, M.B. and Agunwamba, J. C., 2013. Comparative analysis of the compressive strength of concrete with gravel and crushed over burnt bricks as coarse aggregates, *Nigerian Journal of Technology*, 32(1), pp.7-12.
- Bamigboye, G.O., Adedeji, A.A., Olukanni, D.O., Omoleye, J.A. and Jolayemi, J.K. 2019. Influence of granite-gravel combination on the strength of self-compacting concrete:



- Toward a suitable construction material, *Journal of Engineering Science and Technology*, 14(7), pp. 2746-2760.
- Bamigboye, G.O., Ede, A.N., Raheem, A.A., Olofinnade, O.M. and Okorie, U., 2016. Economic exploitation of gravel in place of granite in concrete production, *Material Science Forum*, 866, pp. 73-77.
- Bazaz, J.B. and Khayat, M., 2012. Properties and performance of concrete made with recycled low quality crushed brick, *Journal of Material in Civil Engineering*, 24, pp. 164-175.
- Bhattacharjee, E., Nag, D., Sarkar, P. P. and Haldar, L., 2011. An experimental investigation of properties of crushed over burnt brick aggregate concrete, *International Journal of Engineering Research and Technology*, 4(1), pp. 21-30.
- BS 12, 1996. Specification for Portland Cement”, London, British Stand Institution.
- BS 1881-125, 1986. Method of mixing and sampling fresh concrete in the laboratory, London, British Stand Institution.
- Debieb, F. and Kenai, S., 2008. The use of coarse and fine crushed bricks as aggregate in concrete, *Construction and Building Materials*, 22, pp. 886–893.
- El-Hassan, H. and Kianmehr, P., 2019. Influence of recycled concrete aggregates and slag on the performance of pervious concrete. *Proceeding of the 4<sup>th</sup> World Congress on Civil, Structural and Environmental Engineering (CSEE' 19)*, No. ICSECT 124, April 7 - 9, 2019, Rome, Italy. DOI: 10.11159/icsect19.124.
- European Environmental Agency, 2008. Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries, Copenhagen. DOI: 10.2800/35981.
- Jimoh, A. A. and Awe, S. S., 2007. A study on the influence of aggregate size and type on the compressive strength of concrete, *Journal of Research Information in Civil Engineering*, 4(2), pp. 157–168.
- Kanchidurai, S., Bharani, G. and Mohan, K., 2017. Strength and durability studies on concrete with partial replacement over burnt brick bat waste, *IOP Conf. Series: Earth and Environmental Science*, 8, pp. 1-9. DOI:10.1088/1755-1315/80/1/012018.
- Kesegić, I., Netinger, I. and Bjegović, D., 2008. Recycled brick as an aggregate for concrete: Overview, *Technical Gazette*, 15(3), pp. 34-35.
- Khalaf, F.M., 2006. Using crushed clay brick as coarse aggregates in concrete. *ASCE*. 18(4). pp. 518-526.

- Kosmatka, S.H., Kerkhoff, B. and Panarese, W.C., 2003. Design and control of concrete mixtures, EB001, 14th edition, Portland Cement Association, Skokie, Illinois, USA.
- Kulkarni, S. Momin, A.A., 2015. Experimental study on the strength properties of concrete using brick aggregates, *International Journal of Advance Engineering and Research Development*, 2(1). Pp. 129-139.
- Otoko, G.O., 2014. Use of crushed clay bricks as aggregate in concrete, *International Journal of Engineering and Technology Research*, 2(4), pp. 1-9.
- Neville, A.M., 2011. Properties of concrete performance, 5th edition. Essex, England: Pearson Education Limited.
- Nordin, N., 2014. The use of brick waste as coarse aggregates partial replacement in concrete production”, An unpublished B.Eng. Thesis, Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang.
- Raheem, A.A. and Kareem, M.A., 2017a. Optimal raw material mix for the production of rice husk ash blended cement, *International Journal of Sustainable Construction Engineering and Technology*, 7(2), pp. 77-93.
- Raheem, A.A. and Kareem, M.A., 2017b. Chemical composition and physical characteristics of rice husk ash blended Cement, *International Journal of Engineering in Africa*, pp. 25-35, DOI: 10.4028/www.scientific.net/JERA.32.25
- Rashid, M.A., Salam, M.A., Shill, S.K. and Hasan, M.K., 2012. Effect of replacing natural coarse aggregate by brick aggregate on the properties of concrete, *DUET Journal*, 1(3), pp. 17-22.
- Rashid, M.A., Hossain, T. and Islam, M.A., 2008. Higher strength concrete using crushed brick as coarse aggregate, 82(10), pp. 18-23.
- Rekha, K. and Potharaju, M., 2016. Usage of recycled brick as coarse aggregate in concrete, *International Advanced Research Journal in Science, Engineering and Technology*, 3(9), pp. 95-100. DOI: 10.17148/IARJSET.2016.3918.
- Shetty, M.S., 2005. Concrete Technology, (Revised Edition), Ram Nagar, New Delhi, S.Chand.
- Yang, C.C. and Huang, R., 1996. A two-phase model for predicting the compressive strength of concrete, *Cement and Concrete Research*, 26(10), pp. 1567-1577.

## **GEOTECHNICAL INVESTIGATION OF THE SUITABILITY OF SOME SELECTED LATERITIC SOILS FOR ROAD CONSTRUCTION IN OSUN STATE**

Oluremi, J.R <sup>1</sup>, Ishola, K. <sup>2\*</sup>, Yohanna, P. <sup>3</sup>,. and Etim, R.K. <sup>4</sup>

<sup>1</sup>Department of Civil Engineering, Ladoké Akintola University of Technology, Ogbomosho, Nigeria

<sup>2</sup>Department of Civil Engineering, Osun State University, Osogbo, Osun State, Nigeria.

<sup>3</sup>Department of Civil Engineering, University of Jos, Plateau State, Nigeria.

<sup>4</sup>Department of Civil Engineering, Akwa Ibom State University, Ikot Akpadent, Nigeria.

\*Email of Corresponding Author [kazeem.ishola@uniosun.edu.ng](mailto:kazeem.ishola@uniosun.edu.ng)

### **ABSTRACT**

Lateritic soils are materials which possess secondary oxide of iron, aluminium, or both and thereby characterized with a reddish colour. However, its suitability for road construction needs to be assessed before application to forestall the occurrence of failure. The geotechnical properties and suitability of lateritic soils obtained along Osogbo-Ikirun road, Osogbo-Ilesha road and West By-Pass Okebale in Osogbo, Osun State were evaluated for use as a road construction material. Specific gravity, Geotechnical tests were performed on the samples to determine the following properties: particle size distribution, liquid limit, plastic limit and plasticity index, Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) in accordance with British Standard 1377 (1990). Percentages passing BS sieve No. 200 are 50.14, 54.84 and 54.00% for samples from Osogbo-Ikirun Road, Osogbo-Ilesha road and West By-pass, respectively. The liquid limit, plastic limit and plasticity index of the soil samples were (54.50, 58.40 and 53.10%), (25.56, 37.00, and 31.70%) and (28.94, 21.40, and 21.40%), for Osogbo-Ikirun road, Osogbo-Ilesha road, and West By-Pass, respectively, while their corresponding MDD and OMC values are (1.56, 1.51 and 1.45 Mg/m<sup>3</sup>) and (25.1, 22.9 and 20.4%). The three locations had the CBR (unsoaked) values of 15.50, 14.80 and 12.60%, respectively and did not meet the requirement of 80% for base material specified by the Federal Ministry of Works. However, UCS values of 202.60, 175.80 and 158.30 kN/m<sup>2</sup> were recorded for the three locations, respectively. While their MDD values are 1.56 Mg/m<sup>3</sup>, 1.51 Mg/m<sup>3</sup>, and 1.45 Mg/m<sup>3</sup>

with the OMC values of 25.1 %, 22.9%, and 20.4% respectively. Thus, these lateritic soils could be used as a subgrade material for light traffic road.

**Keywords:** Lateritic soils, Construction material, compaction, Atterberg limits, California bearing ratio

## **1.0 INTRODUCTION**

In Nigeria and other parts of the country, lateritic soils are reddish tropical soils that have gained a wide application as a material for construction. Laterite soils are utilized in roads, houses, airfield pavement, a landfill for foundations (Oluremi *et al.*, 2012; Bayewu, *et al.*, 2013; Amadi, *et al.*, 2015; Oluremi *et al.*, 2017; Ishola, *et al.*, 2019). The inadequate knowledge of soil behaviour in proffer solutions to engineering and environmental problem can cause significant damage to road construction and other engineering application (Abubakar, 2006; Oke and Amadi, 2008). In highway construction, the subgrade level needed to be considered for the accommodation of a wheel load. On the other hand pavement performance depends on the quality of the subgrade, as it is a layer on which the subbase or pavement is built. Additionally, provides support for other pavement systems. However, subgrade found unsupported for high amount of loading is considered as bad, especially in clay soil where there is tendency of swelling occurred in contact with water. One of the major causes of road accidents is bad road which is usually caused by wrong application of constructional materials especially laterite as base and sub-base material by construction companies (Oke *et al.*, 2009a; Nwankwoala *et al.*, 2014).

In recent times, the incessant rate at which life is lost to road accidents is alarming as a result of inappropriate application of constructional materials especially laterite as a base and sub-base material by contractors (Oke *et al.*, 2009a; Nwankwoala *et al.*, 2014) calls for remedy. The remedy could come from a thorough assessment of the engineering properties of soil. However, investigations on geotechnical and engineering properties of lateritic soils have been researched in Nigeria and some part of the various part of the country (Adeyemi, 2002; Oladeji and Raheem 2002; Bello *et al.*, 2007; Agbedeand Osuolale, 2005 and 2007). Hence there are few reports available on the geotechnical and engineering properties of lateritic soil within the study area. This prompted the study to investigate the suitability of lateritic soil obtained from

the Osogbo – Ikirun road, Osogbo – Ilesha road, and the western bypass road that is under construction in Osun state, southwestern Nigeria, for highway construction material.

## 2.0 MATERIALS AND METHODS

### Study soil

Lateritic soils used were obtained from three locations Osogbo-Ikirun Road, Osogbo-Ilesha Road, and West By-Pass Okebale respectively in Osun state by a disturbed sample from the trial pits and analysed in civil engineering laboratory, Osun State University, Osogbo, Nigeria for relevant geotechnical analysis. The geographical locations of the collected soil samples are shown in Fig. 1. Some of the samples collected were placed in an airtight plastic bag to avoid loss of moisture and determination of the natural moisture content. The soil samples were air-dried and passed through BS No. 4 sieve (4.75 mm aperture).

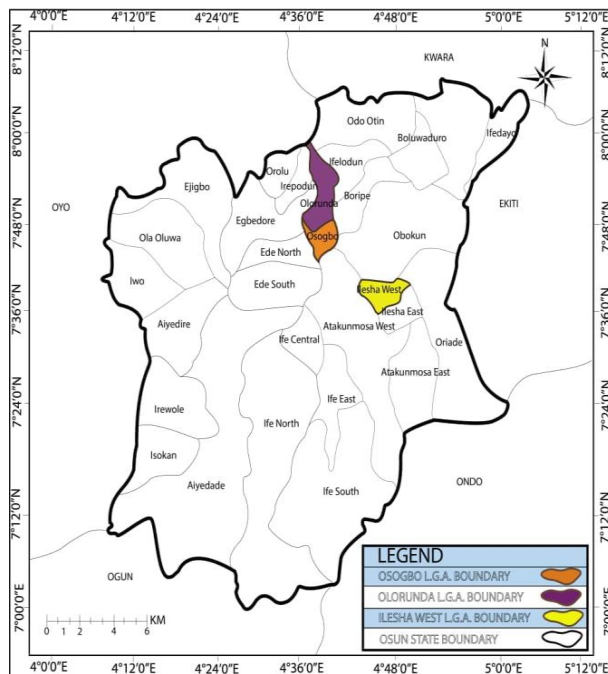


Fig. 1 Map showing the sample locations

### Index Properties

The laboratory tests were carried out on the soil samples from the three locations in accordance with the procedures outline in BS 1377 (1990) to determine the natural moisture content, specific gravity, Atterberg limit, and particle size analysis of the soil samples.

### Compaction

Moisture-density relationships were determined for the soil samples obtained from the three locations considered and compacted with British Standard light (BSL) or standard Proctor energy in accordance with BS 1377 (1990). The soils used were allowed to air dry, then pulverized for easy passage through BS No. 4 sieve (4.75 mm). The BSL compaction energy level consists of the energy derived from a 2.5 kg rammer falling through 450 mm onto three layers in a British Standard mould, each receiving (27) blows (Osinubi *et al.*, 2009).

### Strength Test

Unconfined compressive strength (UCS) test was conducted on the samples collected from the three locations on cylindrical specimens of soils with a diameter of 38 mm and a height of 76 mm obtained from trimmed larger compacted cylinder prepared with the BSL compactive efforts at OMC. The compacted specimens were kept in polythene bags to prevent moisture loss and kept for 28 days before trimming and testing. The specimens were cured for 7 days in the case of unconfined compression. The CBR tests were carried out in accordance with BS 1377 (1990) and specimens were cured for 7 days.

## 3.0 RESULTS AND DISCUSSION

### Index properties

The index properties of the soil samples are shown in Table. 1. The classification of the soils samples based on the American Association of State Highway and Transport Officer (AASHTO), and Unified Classification System (USCS) were depicted in Table.1

**Table 1.** Index properties of soil

Properties	Sample Locations

	Osogbo-Ikirun Road	Osogbo-Ilesha Road	Western Bypass Okebaale
Colour	Reddish Brown	Reddish Brown	Reddish Brown
Percentage passing No 200 sieve	50.14	58.84	54.0
Natural moisture content (%)	21.77	14.47	21.43
Specific gravity	1.850	1.92	2.20
Group Index	10	10	12
AASHTO Classification	A-7-6	A-7-5	A-7-6
USCS classification	CL	CL	CL
Liquid limit (%)	54.50	58.40	53.10
Plastic limit (%)	25.56	37.00	31.70
Plasticity Index (%)	28.94	21.40	21.4
Maximum dry density (Mg/m <sup>3</sup> )	1.56	1.51	1.45
Optimum moisture content (%)	25.1	22.9	20.4

**Natural moisture**

**content**

The natural moisture content of the soil samples were 21.8 %, 14.47 %, and 13.37 % for Osogbo-Ikirun Road, Osogbo-Ilesha Road, and West By-Pass Okebale respectively.

### Specific gravity

The specific gravity values obtained for the lateritic soils were 1.85, 2.0, and 2.5 for Osogbo-Ikirun Road, Osogbo-Ilesha Road, and West by-pass Okebale respectively as Bello *et al.*, (2015) stated that any value of soils that fall within the range of 2.0 – 2.55 is Halloysite.

### Particle size distribution

The particle size distribution curves for the soil samples collected in the three (3) locations were depicted in Fig 1. The percentage passing through sieve No 200 (0.075mm) for Osogbo-Ikirun road, Osogbo-Ilesha road, and Western By-Pass Okebale were 50.14, 54.8, and 54.0%, respectively. Samples from the three locations did not meet 35% maximum percentage passing through sieve No 200 (0.075mm) specified by the Nigerian General Specifications (1997) for subgrade requirements.

### Atterberg limit

The results of the laboratory test of the samples collected in the three different locations for the Atterberg limit were discussed in this section. The liquid limit of the soil samples obtained from Osogbo-Ikirun road, Osogbo-Ilesha road, and West By-Pass were 54.50, 58.40, and 53.10%, respectively while the plastic limit were 25.56, 37.00, and 31.70% respectively. The plasticity index of the soil samples were 28.94, 21.40, and 21.40% for Osogbo-Ikirun, Osogbo-Ilesha, and Western By-Pass, respectively. The plasticity index values obtained for the locations exceeded 12% set as upper limit for use as subgrade or base material.

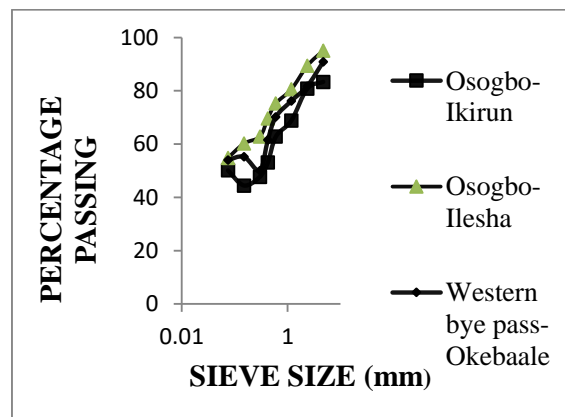




Figure.1. Particle Size Distribution Curves for the Lateritic soil samples

Based on the results of the sieve analysis and Atterberg limits, the lateritic soils were classified as A-7-6 (10), A-7-5 (10), and A-7-6 (12) respectively, and all classified as a CL in accordance with the American Association of State Highway and Transportation Officials (AASHTO) and Unified soil classification system (USCS).

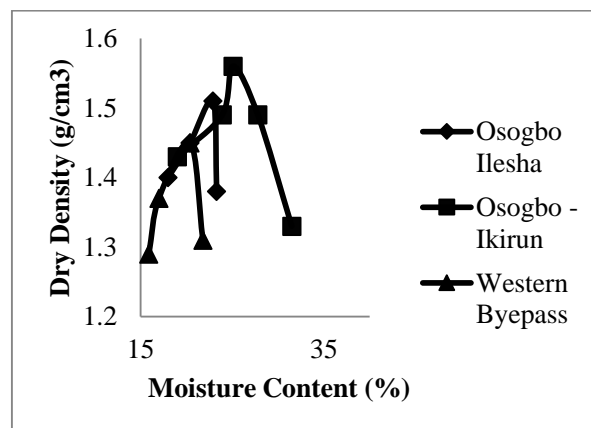


Figure 2. Compaction Characteristics for the Lateritic soil samples three locations

### COMPACTION TEST

The maximum dry densities of the samples collected from the three locations were presented in Figure 2. From the test results, MDD values for the locations were given as Osogbo-Ikirun (1.56 Mg/m<sup>3</sup>), Osogbo-Ilesha (1.51 Mg/m<sup>3</sup>), and West By-Pass Okebale (1.45 Mg/m<sup>3</sup>). The relationship between the maximum density and locations were depicted in Figure 3. The soil samples obtained from Osogbo-Ikirun road has the highest MDD compared with samples collected from Osogbo-Ilesha road and Western By-Pass.

Optimum Moisture Contents (OMCs) corresponding to Maximum Dry Densities (MDDs) for the three locations were presented in Fig 2. Highest Optimum Moisture Content value was recorded for Osogbo-Ikirun road with 25.1% compared to others: Osogbo-Ilesha (22.9%), and

West By-Pass Okebale (20.4) as depicted in Figure 4. showing the relationship between the optimum moisture content and locations.

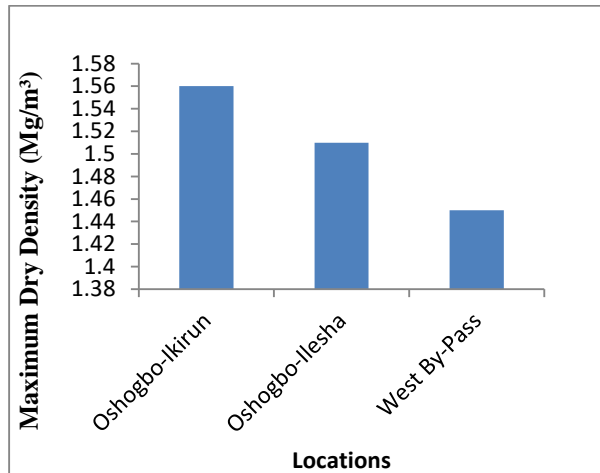


Figure 3: Variation of Maximum dry density with sample locations

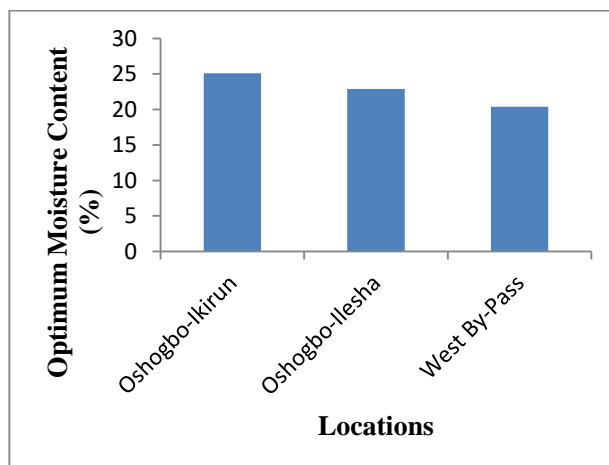


Figure 4: Variation of Optimum moisture content with sample locations.

### CALIFORNIA BEARING RATIO (CBR)

The results of un-soaked CBR of samples collected from three locations Osogbo-Ikirun road, Osogbo-Ilesha road, and Western By-Pass Okebale were 15.5, 14.8, and 12.6%, respectively. The CBR values obtained for the three locations is closer to the one reported by Bello and Adegoke (2010) as a good material for subgrade construction. The relationship between the California bearing ratio and locations were depicted in Fig 5.

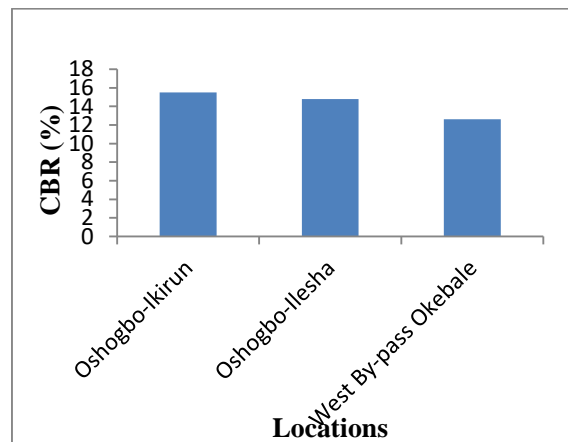


Figure 5: Variation of California Bearing Ratio and Sample Locations

### Unconfined Strength Test (UCS)

The results of Unconfined Compressive Strength (UCS) of the samples collected from the three locations were presented in Figure 6. The samples have UCS values Osogbo-Ikirun road (202.6kN/m<sup>2</sup>), Osogbo-Ilesha road (175.8kN/m<sup>2</sup>), and Western By-Pass (158.3kN/m<sup>2</sup>). The soil samples obtained from Osogbo-Ikirun road has the highest UCS value when compared with samples collected from Osogbo-Ilesha road and Western By-Pass.

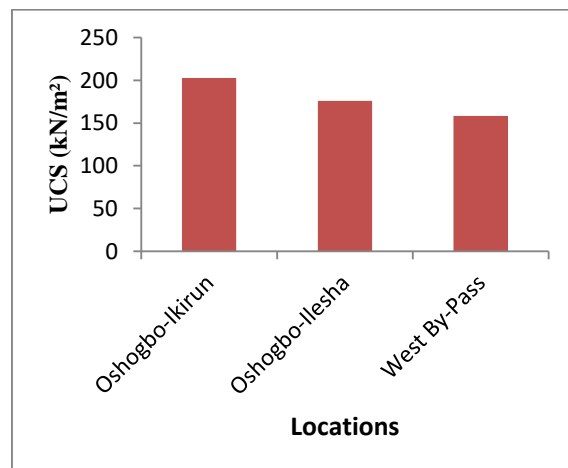


Figure 6: Variation of California Bearing Ratio and Sample Locations

## 4.0 CONCLUSION

Based on the results obtained for the three locations Osogbo-Ikirun road, Osogbo-Ilesha road, and Western By-Pass Okebale, the following conclusions were drawn

- i. The lateritic soils were classified as A-7-6 (10), A-7-5 (10), and A-7-6 (12) respectively, and all classified as a CL
- ii. The natural moisture content of lateritic soil from Osogbo-Ikirun road is higher than the other two locations while the specific gravity values of Osogbo-Ilesha Road and West by-pass Okebale are higher than that of Osogbo-Ikirun Road, and West by-pass Okebale.
- iii. The plasticity index values obtained for the three locations exceeded the requirement of not more than 12% maximum for use as subgrade or base material.
- iv. The lateritic soil sample of Osogbo-Ikirun road has the highest maximum dry density with optimum moisture content among the three other locations.
- v. The CBR (unsoaked) values for the three locations did not meet the requirement of 80% for base material by Federal Ministry of works.
- vi. The UCS value for Western By-Pass road is higher than the other two locations, thus fail to meet the requirement of 687-1373kN/m<sup>2</sup> for sub-base material.
- vii. The lateritic soil samples of the three locations could be used as a material for subgrade course of light traffic road.

## **REFERENCES**

- Abubakar, J.B., (2006). Geotechnical study of lateritic soil in Tipper garage, Katampe Area, Abuja Federal capital territory, pp 4-34.
- Adeyemi, G.O. (2002) Geotechnical properties of lateritic soil developed over quartz schist in Ishara area Southwestern Nigeria. *Journal of Mining and Geology* 38(1):65-69
- Agbede, O. A and Osulale, O.M (2005) Geotechnical properties of subgrade soil in Orire Local government area southwestern Nig. 10(12):137-141
- Amadi A.N. , Akande W. G., Okunlola I. A. , Jimoh M.O., Francis Deborah G. (2015) Assessment of the Geotechnical Properties of Lateritic Soils in Minna, North Central Nigeria for Road design and Construction *American Journal of Mining and Metallurgy*. 2015, 3(1):15-20

- Bayewu, O. O. Olufemi, S. T. and Adewoye, A. O. (2013) Permeability Characteristic of Some Sub-Grade Soils Along Part of the Sagamu-Ore Highway, Southwestern, Nigeria *Journal of Emerging Trends in Engineering and Applied Sciences* 4(4): 581-587.
- Bello, A, A (2007) Geotechnical Evaluation of some lateritic soil as foundation material in Ogbomoso North local Area south western Nigeria, Faculty of pure and Applied Science Lautech , Ogbomoso . 12(2):70-75
- Bello, A.A., Ige, A. and Tajudeen, S. (2007) Geotechnical Characterization of Lateritic soils in part of Ejigbo Local government Area, Southwestern Nigeria, Lautech, *Journal of Engineering and Technology*, 4(2):34-38
- Bello, A.A. and Adegoke, C.W. (2010) Evaluation of Geotechnical Properties of Ilesha East Southwestern Nigeria’s Lateritic Soil. *The Pacific Journal of Science and Technology*, 11(2): 617-624
- Bello, A. A., Ige, J.A. and Hammed, A., (2015). “Stabilization of Lateritic Soil with Cassava Peels Ash” *British Journal of Applied Science and Technology* vol. 7, no. 6 pp. 642-650
- British Standard Methods of Test for soils for Civil Engineering Purposes. B.S 1377: Part 2, 1990. Published by the British Standards Institution, pp 8 –200.
- Federal Ministry of Works and Housing (1997). General Specification for Roads and Bridges, Volume II, Federal Highway Department, FMWH: Lagos, Nigeria, 317 p.
- Ishola, K., Olawuyi, O.A., Bello, A.A. and Yohanna, P. (2019), Effect of Plantain Peel Ash on the Strength Properties of Tropical Red Soil *Nigerian Research Journal of Engineering and Environmental Sciences*, 4(1) pp. 447-459
- Nwankwoala, H.O., Amadi, A.N., Ushie, F.A. and Warmate, T., (2014). Determination of Subsurface Geotechnical Properties for Foundation Design and Construction in Akenfa Community, Bayelsa State, Nigeria. *American Journal of Civil Engineering and Architecture*, 2 (4), 130-135.
- Oke, S. A. and Amadi, A. N., (2008). An Assessment of the Geotechnical Properties of the Subsoil of parts of Federal University of Technology, Minna, Gidan Kwano Campus, for Foundation (Design and Construction. *Journal of Science, Education and Technology*, 1 (2), 87-102.

- Oke, S. A., Okeke, O. E., Amadi, A. N. and Onoduku, U. S., (2009). Geotechnical Properties of the Subsoil for Designing Shallow Foundation in some selected parts of Chanchaga area, Minna, Nigeria. *Journal of Environmental Science*, 1 (1), 45-54.
- Oluremi J.R., Adedokun, S. I. and Osuolale, O. M. (2012) Stabilization of Poor Lateritic Soils with Coconut Husk Ash Civil International Journal of Engineering Research and Technology, 1(8), 1- 9
- Oluremi. J.R., Yohanna. P., Ishola. K., Yisa. G.L., Eberemu. A. O., Ijimidiya. T.S., Osinubi. K.J (2017) Plasticity of Nigeria Lateritic Soil Admixed with Selected Admixtures, *Journal of Environmental Geotechnics*, 6 (3): pp.137-14
- Oladeji and Raheem (2002) Soil tests for road construction. *Journal of science Engineering and Technology*, 9(2):3971-3981

**ENHANCING TECHNO-ENVIRONMENTALISM AND UNIVERSITY  
ENTREPRENEURSHIP FOR DEVELOPMENT IN AFRICA: A POLYCENTRIC  
PLANNING PERSPECTIVE**

. Akinola, S. R. <sup>1\*</sup>, Olayode, O. <sup>1</sup>, Abiola, T. I. <sup>1</sup>, Adeosun, J. O. <sup>2</sup> and Adejumo, A. O. <sup>3</sup>  
<sup>1</sup>Department of Urban and Regional Planning, Osun State University, Osogbo, Osun State,  
Nigeria.

<sup>2</sup>Department of Building Technology, Osun State University, Osogbo, Osun State, Nigeria

<sup>3</sup>Department of Estate Management, Osun State University, Osogbo, Osun State, Nigeria

\*Email of Corresponding Author: [srakinola@yahoo.com](mailto:srakinola@yahoo.com) ; [samson.akinola@uniosun.edu.ng](mailto:samson.akinola@uniosun.edu.ng)

**ABSTRACT**

This paper used the Institutional Analysis and Development (IAD) framework in tandem with Knowledge Management (KM) tools and Robert Owen's Principles of Industrialisation (ROPI) to analyze the missing links in developmental strategies in Africa. The missing links resonate around the neglect of the potentials and capabilities of endogenous knowledge tools and techniques on the one hand and the problem of disconnect between African governments, universities, private/industrial sector and peasant farmers on the other hand. The type of resources within an environment, to a large extent and other things being equal, determines the fortunes of the people in that environment. It is on this note that this paper argues that Africa is endowed with diverse environmental and natural resources upon which African universities should base their intellectual inquiry for the application of endogenous knowledge, entrepreneurship and appropriate technology in turning raw materials into products rather being an importing continent. This paper shows findings of several studies and adopts pragmatic and problem-solving models to demonstrate principles and practices needed to make adaptive education resolve technologically-related environmental challenges in Africa. The paper, thereafter, charts a course of action that could be taken to ensure that African universities become "organic" in their activities and use endogenous knowledge as agents of change to impact positively on economic developmental transformation. It is in the light of this exigency that this paper suggests African Endogenous Knowledge Development Model and the mechanism for taking theories to the streets for self-reliant development and technologically inclined and environmentally friendly community in Africa.

**Keywords:** University Entrepreneurship, Endogenous-Knowledge, Techno-environmentalism, Theories-to-Streets, Africa

## **1.0 INTRODUCTION**

An important factor in understanding how a society functions is the peculiar and accidental situation, which providence places people (Tocqueville, 1966). This could refer to the environmental and material conditions that are available to people in fashioning their lives. The type of resources within an environment, to a large extent and other things being equal, determines the fortunes of the people in that environment. It is on this note that this paper argues that Africa is endowed with diverse environmental and natural resources upon which African higher institutions should based their intellectual inquiry for the application of endogenous knowledge and sustainable entrepreneurship in turning raw materials into manufacturing products rather being an importing continent. This is because society that pays attention to the application of endogenous knowledge makes full use of local resources and appropriates technology that produces self-reliant development and generates dignified local employment for its citizens.

Akinola (2007f) and HERANA (2011) note that there is a high level of dis-articulations between African governments, universities, industries and the people, which culminate into a high rate of unemployment (NGO News Africa, June 2 and 9, 2010; Kelvin Balogun cited in ACET, 2016; Adedokun, 2019; NBS, 2019, Tribune, Friday, 3/5/19, 1, 10), food insecurity (Dione 2010; NBS and Nwokoji, Jun 3, 2019) and poverty (Adejokun, 2018). Due to xenophobic attack, statistics confirmed that a total of 25,794 people were killed in South Africa in four years (May 2015 and May 2019 (Adedokun, 2019), while over 200 Nigerians killed in five years out of not less than 800,000 Nigerians resident in the country (Aborisade, *et. al.* 2019).

Unlike in Europe, America and Asia, where Knowledge Management (KM) tools have been deployed to generate development, African governments have relegated to the background the imperatives of endogenous knowledge, thus engendering gaps between knowledge and realities in the continent. The gap created by government apathy towards knowledge application to realities needs critical analysis. The central argument is that: it is what people are doing at home



that should form the basis of development in all sectors. It is not enough to learn from abroad; development cannot be imposed from above or from outside.

## **2.0 METHODOLOGY**

This paper used the Institutional Analysis and Development (IAD) framework in tandem with Knowledge Management (KM) tools and Robert Owen's Principles of Industrialisation (ROPI) to analyse the missing links in development strategies and proffers possible solutions. These missing links constitute areas that are neglected by scholars and policymakers in harnessing indigenous and endogenous knowledge towards people-centred development in Africa. The point of departure of this paper, therefore, is in problem solving and solution seeking. This paper, therefore, provides results of several studies and designs models to demonstrate principles and practices needed to make polycentric planning and adaptive education evolve endogenous-based development that meets African needs.

Polycentric planning is a deliberate act of setting up multi-layered and multcentred institutional mechanism that regards self-governing capabilities of local communities as foundation for reconstituting order from the bottom up. It can also be described as the process of ordering the use of environmental, physical, human and institutional resources as well as engaging the citizens in contractual relations with the public authority (Akinola, 2009a, 2010a:58, 2010i, 2011a:7). A polycentric approach to development emphasizes people-centred and community-oriented development in ways that prioritise endogenous knowledge, inclusiveness and popular participation. This is one of the reasons this paper is set to ensure synergetic interactions among strategic stakeholders in development.

The paper, thereafter, charts a course of action that could be taken to ensure that African scholars and African higher institutions become "organic" in their activities and use endogenous knowledge as agents of change to impact positively on their communities and reduce poverty. It is in the light of this exigency that this paper suggests an African Endogenous Knowledge Development Model (AKEDEM) designed for generating self-reliant development in Africa.

## **THE PROBLEMATICS OF DEVELOPMENT IN AFRICA: THE IAD PERSPECTIVE**

*Underdeveloped countries should not accept the inherited Western economic theory uncritically but remould it to fit their own problems and interests (Myrdal 1957:99)*

The present development dilemma in Africa is predicated upon the problems of disconnect and “parallelism” that separate the peoples of Africa from their leaders. As a result, policies adopted since political independence have reinforced the state institutional character and its inability to progressively enhance the living standards of majority of the African population. The elite are alienated in terms of the educational curriculum introduced by the colonial governments. The curriculum did not pay much attention to the study of African culture, its roots and adaptive education that can help the society to release the potentials and capabilities of the people. This problem still persists till today as higher institutions in the continent only train students for white collar jobs instead of creating jobs using local resources.

The argument is that African scholars should identify, study and record how African people craft shared strategies and problem-solving interdependencies from their old traditions to address problems of daily life. The findings of such studies should be filtered in the light of modern practices. The outcome of such exercise can then be used to design home-grown models of development which can then be passed on to government functionaries. It is government’s responsibility to take theories and knowledge, test them and turn them into action. Relying on African governments in this direction, however, may not lead to fruition as they have not fully realized the potentials and capabilities of KM and endogenous knowledge in particular.

How can one explain the situation of graduates in some parts of Africa riding motorcycle (*Okada* in Nigeria and *Boda-boda* in Kenya) as commercial taxi in order to survive economically? Evidence abounds of graduates of higher institutions that work as labourers in building industry – carrying blocks, water and cement. What a wasteful destiny and continent that de-prioritizes scholarship and knowledge!

### **3.0 THEORETICAL UNDERPINNING: INSTITUTIONAL ANALYSIS OF TECHNO-ENVIRONMENTALISM**

In order to contextualise the line of analysis in this paper, polycentric planning, an off-shoot of the Institutional Analysis and Development (IAD) framework is adopted. Institutional analysis helps us to better understand how individuals within communities, organizations and societies craft rules and organize the rule-ordered relationships in which they live their lives (Sawyer, 2005:3). Polycentric planning recognizes the fundamental defects in the centralist model of planning and the persistence failure of the state to meet the collective yearnings and aspirations of the citizenry. As a result, polycentric planning has called attention to the self-organising capabilities of the people that are rooted in collective action at community level. This line of thought recognizes that human beings can plan, organize and govern themselves based on appropriate institutional arrangements and mutual agreements in a shared community of understanding. The IAD believes in institutional arrangement designed by people who cooperate based on rules and constitution of their choice, and thereby are able to resolve socio-economic and techno-political problems which other people (external to their conditions) are not capable of doing for them.

The IAD framework is very useful to appropriating technological devices towards environmentalism, developmental drives, industrial processes, human development and sustainable development. The questions this paper raises border on how the stakeholders are interacting on utilization of environmental resources, industrialization and local economic development. However, there are some fundamental imperatives of collective action within development arena. These are collegiality, mutual trust, reciprocity and shared community of understanding. The realisation of these imperatives through effective planning and institutional arrangements can enable stakeholders on environmentalism and development process to work together so as to achieve efficient and sustainable development.

Studies have confirmed that local peoples in Africa engage in myriads of socio-economic and political activities which constitute the drivers of development but, unfortunately, they are neither properly documented nor recognized by official statistics in Africa. In spite of the robustness and resilience of African endogenous knowledge in crafting people-centred institutions, these potentials are excluded by African elite and educational curriculum (Akinola 2007f: 230). Such impositions of foreign ideas and the absence of appropriate mediums of

dialogue, knowledge and use of tools, either in relation to content, artefacts or vehicles of communication have tended to weaken and denigrate African institutions. These are fundamental issue affecting the potential effectiveness of all development programmes.

For models to respond to realities, people-oriented institutions and cultural traits of the people should constitute their essential components. It is the needs of the people within their environmental, socio-economic, technological and cultural contexts that should determine the contents of curriculum in higher education programme. This requires breaking the limits by scholars on knowledge application to utilize environmental resources for developmental purposes as demonstrated by *Irepodun* experiment in Nigeria (Akinola 2007f).

### **CASE STUDIES ON KNOWLEDGE GENERATION AND AFRICAN CAPABILITIES**

Penning de Vries. (2005) points out that the introduction of innovations by researchers to farmers on irrigation scheme, processing, packaging and export of products in Ng'uuru Gakirwe in Tharaka<sup>i</sup> district, Kenya enhanced the average incomes of over 430 farmers in 2000 from almost zero to over 300 USD per farmer per month (Penning de Vries 2005:87). Similarly, the Lare Water Harvesting Project, designed by researchers for water harvesting from roads into earthen pans for supplemental irrigation in Nakuru, Kenya benefitted over 4000 households in 2004 and consequently, family incomes increased from about 2000 to 6000 USD per year. Food security and household health had been improved as well due to better nutrition and clean drinking water which is treated for suspended sediments, boiled and filtered so that it is clean (Penning de Vries, 2005:93). The realization that wind energy is low cost has prompted William Kamkwamba, from Malawi, a born inventor, who at the age of 14, built an electricity-producing windmill from spare parts and scrap. The windmill he built powers four lights and two radios in his family home (Africa Focus, 2009b).

Investigation conducted on innovations that were carried out in the Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria shows that the work of about 20 days (using traditional methods) will take only one hour to accomplish with mechanical methods that were designed by agricultural engineers (Akinola, 2002:73; 2007f:228). Similarly, the Department of Food Science and Technology of this same Nigerian university, using physical principles, has developed effective and viable methods of food preservation (see Taiwo *et. al.*, 1997; Enujiugha, *et. al.*, 2002; Akanbi *et. al.*, 2006).

Further, the Department of Agricultural Engineering, Federal University of Technology, Akure (FUTA) designed and fabricated a fruit processing machine that could produce juice from a variety of fruits and a combined harvester that could either be powered by fossil fuel or solar energy. The harvester performs seven functions which include cutting and harvesting, conveying and threshing the crop, separating and cleaning and then storing it. Other machines developed include cocoa yam harvesters, multiple purpose tillage machine, crop weeding machine, juice extractor, self-fed cassava peeling machine, cassava washing machine (Adeyemi, 2011:22-24).

A study showed that importation of building materials makes Nigeria to be on deficit to the economy (see Akinola, *et. al.* 2013i). For example, the Israelis, though in the desert, triggered agricultural revolution and now one of the outstanding agricultural innovationists across the globe. Similarly, South Korea took palm fruits from Nigeria in 1960 and now one of the leading exporters of palm oil, while Nigeria is importing palm oil. Industrial wastes from rice and timber productions have been noted for production of building materials in countries such as Thailand, Malaysia and India (Columa 1970 cited in Okereke 2006:15). Whereas studies show that waste materials can be recycled for construction industry (Okereke and Obeng 1985; Okereke 1988; Edeh *et. al.*, 2012a; Edeh, *et. al.*, 2012b), they are bunt away in Nigeria only to cause air pollution. This confirms that Nigeria is not applying knowledge generated to solve problems of daily existence.

It is on record that civilization started in Egypt, one of the African countries. This historical fact is confirmed by the existing pyramids in Giza, Cairo, Egypt. The structures at pyramids of Giza were foremost among the wonders of the world. To appreciate the accomplishment, one must remember that the Egyptians used only tools of wood, stone and copper and employed no wheeled vehicles (they adopted the war chariot only after 1750 B.C (Roth, 2007:199).

The question that borders one's mind is on the source of the technology that was used in the construction of pyramids several centuries ago. What happened to that technology? Why was it not sustained for Africa's development? It is important, however, to note that there are sundry cases of talents, innovations and inventions in science and technology that had been killed in Nigeria due to government apathy and inertia (Adeyemi, 2011:22-24).

Examples of creative innovations from Nigeria that can be replicated to enhance the development of the construction sector abound: For example, scholars at the Department of Civil Engineering, Universities of Ibadan and Lagos, Nigeria have come out with series of innovative works on: (a) The use of Palm Kernel Shell, Sawdust and Rice Husk Ash as partial/full replacement for gravel sand and cement in concrete (Olutoge, 2009, 2010); (b) Structural characteristics of Bamboo (*Bambusa Vulgaris*) as reinforcement in concrete slabs (Alade & Olutoge, 2004; Alade & Olutoge, 2004; Alade, Olutoge & Alade, 2004); (c) The Production of concrete using Rice Husk Ash as a partial substitute for cement and palm kernel shell and sawdust as partial/full substitute for fine and course aggregates (Olutoge, 2009, 2010).

Scholars in the Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria established that Bitumen-Makuba<sup>1</sup> stabilized soil blocks are strong and durable and are more economical than the conventional sandcrete hollow blocks (Salisu and Jibrin, 2011). Similarly, scholars in the Department of Mechanical Engineering in University of Lagos, Nigeria designed a pyrolysis reactor for the treatment of municipal solid waste and for resource recovery. The machine has the potential to achieve a waste volume reduction of about 65% (Ojolo and Bamgboye 2005). At the Ladoke Akintola University of Technology, Ogbomoso, Nigeria, laboratory scale quantities of palm kernel oil (PKO) biodiesel were produced through transesterification process using 100g PKO, 20.0% ethanol (wt% PKO), 1.0% potassium hydroxide (KOH) catalyst at 60°C reaction temperature and 90 min. reaction time (Alamu, 2007).

Local people in Saki, Oke-Ogun area of Oyo State in Nigeria are transforming inherited indigenous knowledge (blacksmiths) to intermediate-technology – iron-smelters, iron-benders and welders for construction works (Akinola 2007f:229). In spite of the relevance of the intermediate-technology, there has been virtually no attempt by the Nigerian government to establish small scale industries where adapted technological skills can be used in the construction/building industry. Government fails to encourage the industrial production of machines and equipment; hence did not go beyond prototype. Consequently, Nigerian/African universities have become the cradle and graveyard for many innovations and inventions that could not go beyond prototypes (Adeyemi, 2011:22-24). The ideal thing is to empower these local innovators so that their skills and potentials can be

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<sup>1</sup> Makuba is extract from locust beans tree.

harnessed towards national and continental development. Yet vast local materials and resources are wasted because appropriate technologies for processing materials are not made available. If civilization started in Egypt, which is correct, the question we should be asking is: What actually went wrong with us in Africa?



Plate 1: Picture of Pyramids in Cairo, Egypt with Researcher in suit in the middle.

Source: Akinola, *et. al.*, (2013i).

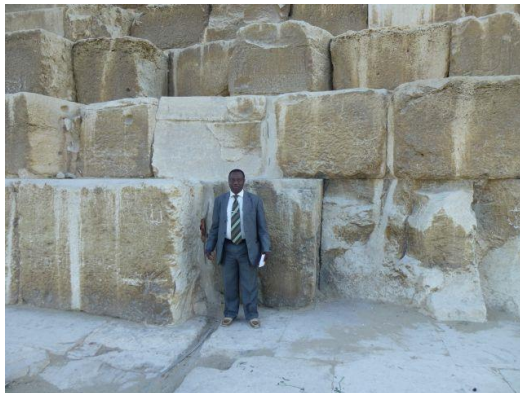


Plate 2: Picture of Pyramids in Cairo, Egypt with Researcher standing beside the blocks.

Source: Akinola, *et. al.*, (2013i).

What type of technology did Egyptians used in the construction of pyramids such that these structures exist till today? (Plate 1). When one considers the height of the researcher in relation to the height of the blocks, one can imagine the type of technology the Egyptians used in the construction of the pyramids (Plate 2).

The above cases confirm that these innovations and knowledge generated on the processing of crops for food security and raw materials to building materials are not utilized to address real life situations in Nigeria and other African countries. They only exist as an end instead of as a means to an end in developing the economy. Thus, the discussions, so far, have clearly demonstrated the missing links between and among the stakeholders in food production and construction sector.

## **ENDOGENOUS KNOWLEDGE AND PROBLEM-SOLVING ENTREPRENEURSHIP IN AFRICA**

According to World Prout Assembly (2005), endogenous knowledge makes people look inward and make full use of local resources through collective ownership of the means of production to achieve profits and reinvests surpluses for generating dignified local employment. Endogenous development model condemns the traditional economic model that focuses on independent accumulation of wealth, noting that wealth in Africa has traditionally been concentrated in the hands of few Africans and foreign investors. As an alternative, endogenous development, or internally directed development focuses on regional development, which incorporates humanistic values into the economic system and provides a democratic distribution of wealth.

Ideally, political leaders and scholars should work together when there is a problem to resolve rather than apportion blame when things have gone wrong. In my own view, there are two options. While in some instances both scholars and governments should work together, in other cases scholars should be concerned with how to take theories to the streets to prove and test their knowledge. It is not enough to critique the governmental system without offering an alternative workable strategy of how to solve the problems at hand. In this wise, African Endogenous Knowledge Development Model (AKEDEM) is designed to address this issue and for generating self-reliant development in Africa.

### **African Endogenous Knowledge Development Model (AKEDEM)**

African Endogenous Knowledge Development Model (AKEDEM) (Fig. 1) is designed for solving problems and generating self-reliant development in Africa. This becomes necessary



in the light of attendant effects of colonial intellectual syndrome that relies on exogenous development paradigm with its consequence of intellectual poverty and development dilemma in Africa.

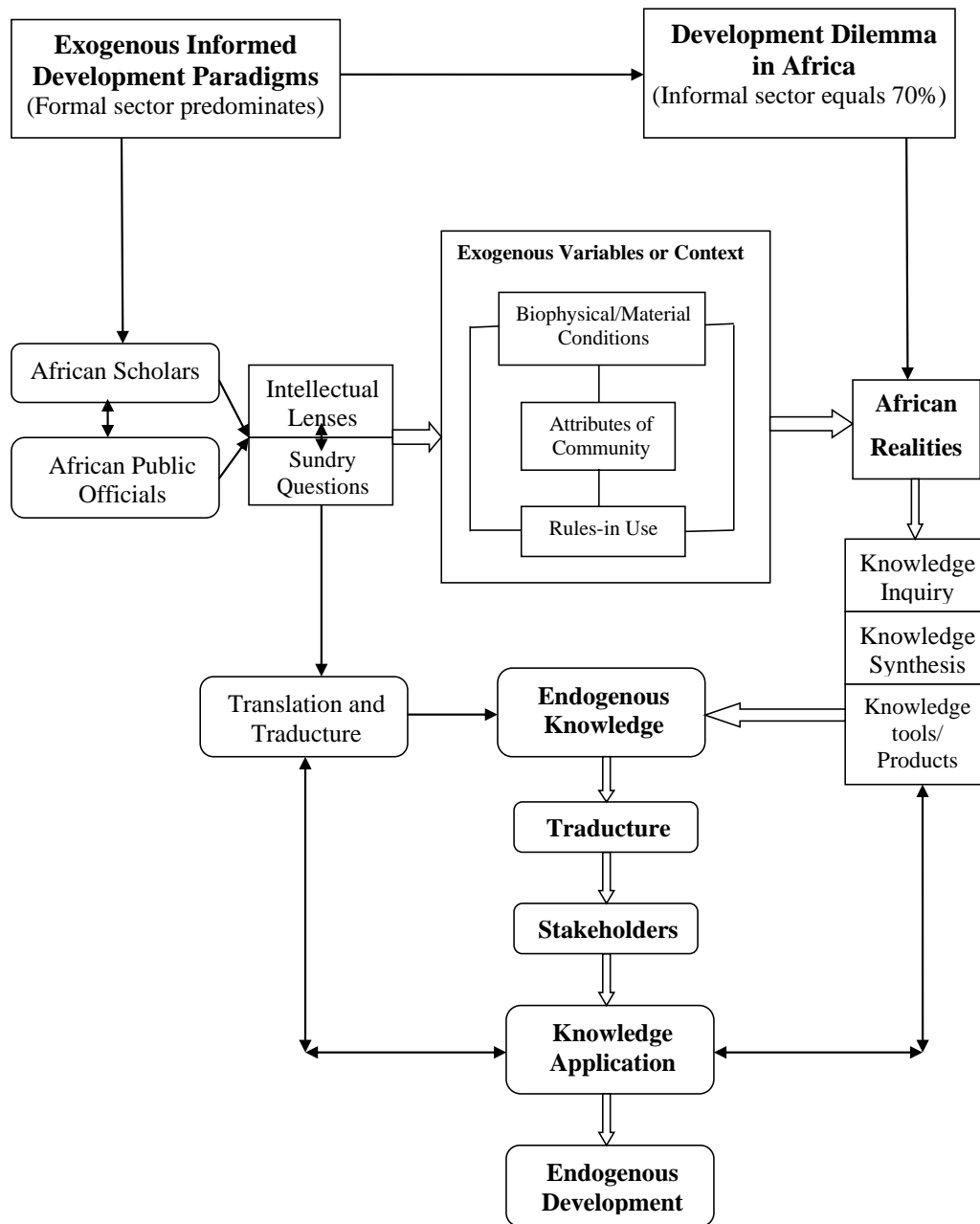


Fig. 1: African Endogenous Knowledge Development Model (AKEDEM)  
 Source: Adapted from E. Ostrom, Gardner and Walker (1994:37); Graham, et. al. (2006); Akinola (2007f:231; 2008p:18 2010i:53; 2011a).

Like African Education Reform Model (AERM) (Akinola 2010f), AKEDEM identifies the missing link in African educational system, especially, both at the university and governmental levels. While expatriates were(are) heavily relied upon by African governments, they (expatriates) did(do) not understand African realities, hence the failure of imported development paradigms. This failure calls for a rethink and paradigm shift in the orientations of both scholars and public officials in Africa. It is in the light of this exigency that AKEDEM suggests that scholars and public officials should work together when there is a problem to resolve rather than apportion blame when things have gone wrong.

AKEDEM conceptualizes knowledge system as knowledge funnel which represents knowledge creation and consists of the three major types of knowledge or research that exists and can be used in addressing specific problems (Haynes 2001; Graham, et. al. 2006:18). The three types are: knowledge inquiry, knowledge synthesis and knowledge tools or products. Armed with sundry questions (listed below), African scholars and public officials should view African realities with intellectual lenses through exogenous variables (of the IAD) – biophysical/material conditions, cultural and other attributes of a community, and rules-in-use (Akinola 2007f; 2008p).

Such questions include: (1) How are people navigating the crisis in food, housing, healthcare, clothing, education, transport, security, etc. that confronts them? (2) What is(are) the source(s) of initiatives for resolving challenges and crisis? (3) What kind of incentives favour trusted institutional arrangement among the people? (4) What lessons can be learnt from peoples' creativities and adaptive strategies they evolved over the years in addressing problems of daily existence? (5) How should African scholars relate with community and endogenous impulses and activities? (6) How can Africans mainstream indigenous and endogenous creativities into modern developmental agenda? (7) Are Africans universities in tandem with African governments capable of demonstrating their intellectual capability in resolving socio-economic and techno-political crisis in the continent? etc.

The outcome of intellectual inquiry will produce knowledge that reflects African realities. This is knowledge creation. As knowledge moves through the funnel, it is filtered; it becomes more

distilled and refined. In the end, only the most valid and useful knowledge is left and presumably more useful to stakeholders (Graham, et. al. 2006:18).

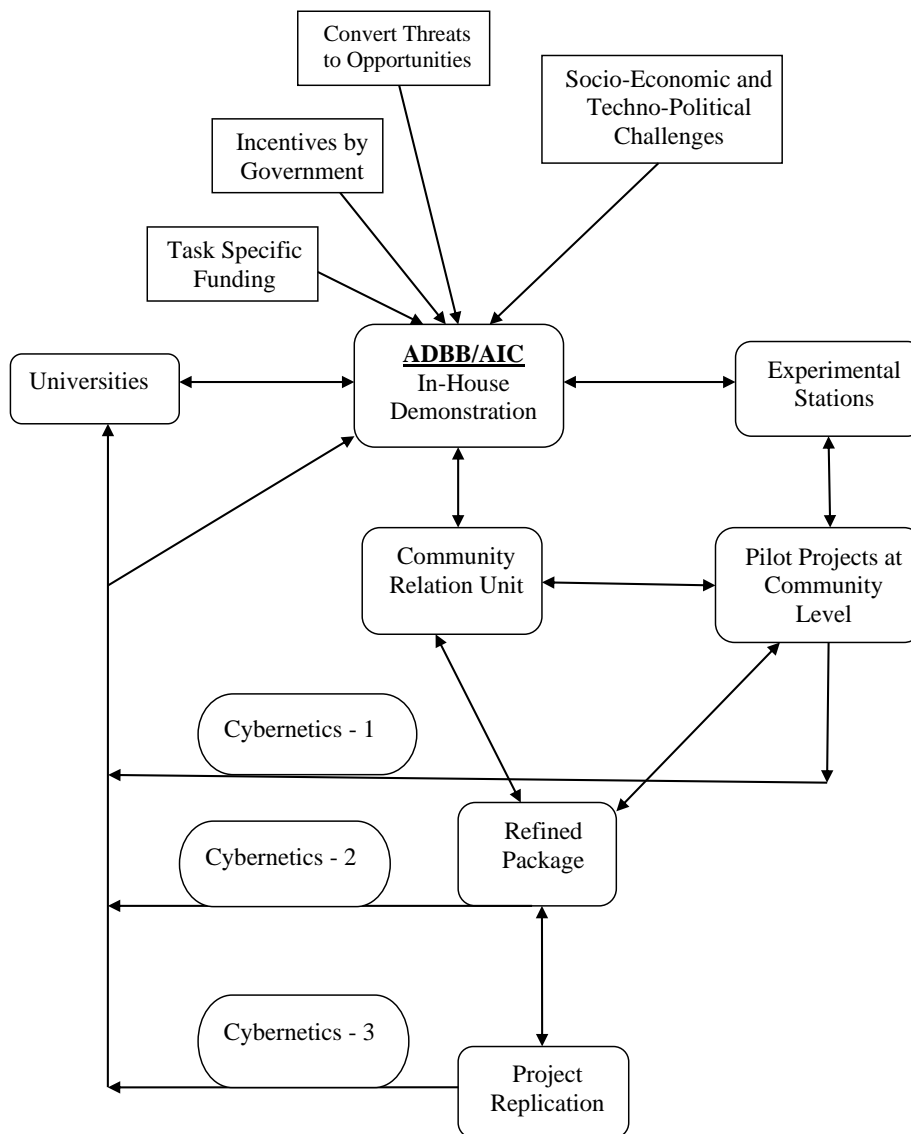


Fig. 2: African Education Reform Model (AERM): The Illustration of the Mechanism of ADBB/AIC in taking theories to African Streets

Source: Adapted from Akinola (2008p:187, 2010f; 2010i:51).

At each phase of knowledge creation, knowledge producers can tailor their activities to the needs of potential users. They can tailor their research questions to address the problems

identified by users. When the results are available, they can tailor or customize the message for the different intended users (e.g., repackage their products for specific user audiences: the public, practitioners, policymakers).

From Fig. 2, the resultant effect of both African Education Reform Mechanism and African Development Institutional Mechanism (ADIM) is that enabling environment for the key stakeholders in development – governments and universities (Akinola, 2007f, 2008p) makes the conversion of threats between the two groups to become possible. ADIM ensures that both public officials and scholars develop smooth working relations. With innovation coming from scholars and robust institutional arrangements, it will be easier for government to increase its presence and relevance at the community level. Training programmes in ministries of agriculture, works, health, education, etc., should be executed in the field, in conjunction with working associations on the ground.

According to Fig. 2, African scholars pass knowledge to African Development Brain-Box (ADBB) (Akinola 2008p:186-187; 2010i) where knowledge will be assessed on its strength to resolve specific problem. If the model is found to be good, then it will be experimented at the field. Universities, being in close contact with governments, should through its adaptive research, discover the needs of the society, develop new ideas and innovations and send them to ADBB, which is housed by African Innovation Center (AIC) that plays moderating influence for knowledge utilization. As shown in Fig. 2, it is ADBB/AIC that will adapt knowledge to reality through its experimental stations and pilot projects for every sector of African economy – social, economic, technological, and political spheres. AIC will have strong community relations such that any innovation coming to it will be quickly fixed up in relevant or demand communities where the idea is needed and can be demonstrated as pilot project.

After the pilot project, there is the need for feedback, called cybernetics which will occur at three levels as shown in Fig. 2. The feedback on the performance of pilot project will be sent to ADBB, which will lead to the refining of the model/package that will be demonstrated again at the field. The performance of the model shall be evaluated and the report sent to ADBB for further refinement. In order to properly drive the point home on how African scholars can engage in problem-solving entrepreneurship, food security and employment generation programmes on pilot scale are briefly discussed.

### **Pilot Project: Food Security and Employment Generation Programmes**

It is suggested that some universities and other organisations that have a vision on African liberation in tandem with specific governments could kick start food security and employment generation programmes by applying African Food Security Model (AFSM) and African Employment Generation Model (AGEM) (Akinola, 2008p:194-195; 2014o; Akinola, *et. al.*, 2014a) through the implementation of Polycentric Planning and Poverty Reduction Strategy (PPPRS) in selected countries in Africa. The proposal is designed to experiment food security project in specific food related areas and provide job opportunities for people at the community level by: (a) demonstrating how to develop entrepreneurial capability by combining factors of production (land, labour and capital) toward food production and employment generation in Africa; (b) establishing university/industry partnerships in translating innovative ideas into machines that are capable of enhancing agricultural productivity; and (c) establishing a strategic and robust corporate social responsibility by utilizing agricultural resources in agro-based industry to provide affordable food and generate employment for people at the community level.

Food-related activities and employment generating ventures that could be embarked upon include: (i) Large-scale mechanized farms in the cultivation of yam, cassava, maize, guinea corn, fruits, etc. (ii) Food processing plants – yam flour, cassava flour, maize, guinea corn, fruits, etc. and (iii) Animal husbandry section – fishery, poultry, rabbitry, piggery, goatery, cattle and other ruminants. The programme spans 11 to 15 stages (for details, see Akinola 2008p:194-195; 2014o). African universities should be entrepreneurial without divided loyalty to their cardinal objectives of teaching, research and community service. This seemingly new orientation/task falls under research and community service. If this is done universities in Africa would become creative and agent of change.

### **4.0 CONCLUSION**

This paper concludes that the high level of dis-articulation between African governments, universities, industries and the people has culminated into a high rate of unemployment, food insecurity, poverty and underdevelopment in the continent. This paper posits that African scholars and intellectuals should critically study indigenous and endogenous impulses that the people of Africa are exploiting in surmounting their daily challenges. These, however, should be analysed in the light of exogenous development process and methods. Findings and

experiences gathered from these exercises, including experiments, would invariably, be useful to refine African models and also to reform African educational curriculum. This would form the foundation upon which Africentric development would be built. The required thing is that scholars should show the way forward by becoming pragmatic in their intellectual pursuits.

The paper charts a course of action that could be taken to ensure that African scholars and African universities become “organic” in their activities and use endogenous knowledge as agents of change to impact positively on their communities and reduce poverty. It is in the light of this exigency that this paper suggests African Endogenous Knowledge Development Model (AKEDEM) designed for generating self-reliant development in Africa.

## **REFERENCES**

- ACET (2016). “Unemployment in Africa: no jobs for 50% of graduates.” ACET – African Centre for Economic Transformation. April 1, 2016. <http://acetforafrica.org/highlights/unemployment-in-africa-no-jobs-for-50-of-graduates/> (Accessed 13/08/2018).
- Adegun, Aanu (2018). “Nigeria states may face food crisis in 2018.” <https://www.naija.ng/1133685-nigeria-states-face-food-crisis-2018-report.html#1133685> (Accessed 13/08/2018).
- Adejokun, Sanya (2018). “Unemployment to rise as NBS prepares new data.” September 2, 2018. Top News, Tribune Business. <https://www.tribuneonlineng.com/162512/> (Accessed 05/09/18).
- Adeyemi, Ayodeji (2011) “A Nation Where Talents Die.” Tell Magazine, No. 1, January 10, 2011, pp. 22-24. On-Line: Thursday, January 06, 2011. [http://www.tellng.com/contentdisplay.aspx?page\\_id=31&id=23](http://www.tellng.com/contentdisplay.aspx?page_id=31&id=23) (Accessed 6/1/2011).
- Africa Focus (2009b). “The Boy who Harnessed the Wind.” Africa Focus Bulletin, October 4, 2009. (<http://www.africafocus.org/books/isbn.php?0061730327>) (accessed October 12, 2009).
- Akanbi, C. T., R. S. Adeyemi, and A. Ojo. 2006. ‘Drying and Sorption Characteristics of Dehydrated Sliced Tomato’, *Journal of Food Engineering* 73:157-153.
- Akinola, S. R. (2002): “University Education, Appropriate Technologies and Poverty Reduction in Nigeria: The Missing Link”. Proceedings of a Regional Workshop on Promotion of Appropriate Agro-Processing Technologies in West Africa, Obafemi Awolowo University, Ile-Ife, pp. 69 - 78.

- Akinola, S. R. (2007f). "Knowledge Generation, Political Actions and African Development: A Polycentric Approach." *International Journal of African Renaissance Studies*. Multi-, Inter and Transdisciplinarity, ISSN 1818-6878. Pretoria, South Africa: University of South Africa Press and Routledge. Volume 2, Number 2, 2007, pp 217-238.
- Akinola, S. R. (2008p). "Alternative Planning Models for Development in Africa." *Knowledge to Remobilise Africa*. The Development Bank of South Africa, Knowledge Management Division, Research and Information Division, Midrand, 2008, South Africa, pg.169-202.
- Akinola, S. R. (2009a). "The Failure of Central Policing and the Resilience of Community-Based Security Institutions in Nigeria." In Adekunle Amuwo, Hippolyt A.S. Pul and Irene Omolola Adadevoh, *Civil Society, Governance and Regional Integration in Africa*. Development Policy Management Forum (DPMF), Nairobi, Kenya, pp. 257-274.
- Akinola, S. R. (2010a). "Restructuring the Public Sphere for Social Order in the Niger Delta through Polycentric Planning: What Lessons For Africa?" *Journal of African Asian Studies*, Cornell University, Ithaca, NY, USA, Vol. 9, Nos. 1-2, pp. 55-82.
- Akinola, S. R. (2010f). "The Nexus between Spirituality, Intellectualism and Development in Africa: A Problem-Solving Perspective." Conference paper for the International Conference on "Politics, Poverty and Prayer: Global African Spiritualities and Social Transformation" scheduled to hold at Africa International University/NEGST, Nairobi, Kenya, 22-25th July 2010.
- Akinola, S. R. (2010i). "Institutional Crisis, Resources Governance and Economic Prosperity in Africa: Crossing the Great Divide through Polycentric Development Planning." *Social Science Research Consultancy Trust*, Midlands State University, Zimbabwe. Monograph Series, Volume 1, Number 2, December 2010, 87p.
- Akinola, S. R. (2011a) "Restructuring the Public Sphere for Democratic Governance and Development in Africa: The Polycentric Planning Approach." In Abdalla Bujra (ed.). *Political Culture, Governance and the State in Africa*. Development Policy Management Forum (DPMF), Nairobi, Kenya, pp. 1-61.
- Akinola, S. R., M. A. Ogunbiyi, O. A. Adeleye, A. O. Ajayi (2013i). "The Missing Links between Construction Sector and Development in Nigeria." In Laryea, Samuel and Agyepong, Sena Afi (eds). *The 5<sup>th</sup> West Africa Built Environment Research Conference (WABER) 2013*, held at the British Council in Accra, Ghana on 12<sup>th</sup> – 14<sup>th</sup> August, 2013, pp. 1113-1130.
- Akinola, S. R., M. B. Gasu, D. S. Ogundahunsi & T. I. Ojo (2014a). "Human Rights, Food and Employment Crises in Africa: Defusing the 'Time-Bomb' through Polycentric Planning and Poverty Reduction Strategy." *International Journal of Advanced Studies in Economic and Public Sector Management*, Coventry University, Coventry, UK, Vol. 2, No. 1, January 2014, pp. 209-229.
- Akinola, S. R. (2014o). "Institutional Analysis and Food Security Paradigm in Africa: A Polycentric Planning and Poverty Reduction Perspective." Paper presented at the International and Interdisciplinary Conference themed 'Food Security and Edible Spaces', organised by the Department of Urban and Regional Planning, University of Ibadan, Oyo State, August 12 – 14, 2014.



- Alade, G. A. and Olutoge, F. A. (2004) “Bamboo Fibre Reinforced Cement used as a Roofing Sheet”. *Journal of Civil Engineering Research and Practice JKUAT, Kenya*: Vol. 1 No 2 (2004) pp. 107 – 118. Read ABSTRACT.
- Alade, G. A. Olutoge, F. A. and Alade, A. A. (2004) “The Durability and Mechanical Strength Properties of Bamboo in Reinforced Concrete”. *Journal of Applied Science, Engineering and Technology, Faculty of Technology, University of Ibadan*. Vol. 4 No 1 (2004) pp. 35-40.
- Alamu, O. J. (2007) *Optimal Operating Conditions for the Production of Biodiesel from Palm Kernel Oil*, Ph.D. Thesis, Mechanical Engineering Department, LadokeAkintola University of Technology, Ogbomoso, Nigeria.
- Dione, Josue 2010. “Africa still hungry despite annual \$3 billion of aid and \$33 billion of food imports.” *United Nations Economic Commission for Africa (ECA)*. 11 March 2010. <http://www.un.org/apps/news/story.asp?NewsID=34050> (accessed 17/03/2010).
- Enujiugha, V. N. and Akanbi, C. T. (2002) ‘Adaptable Techniques for the Post-Harvest Processing and Preservation of African Oil Bean Seeds.’ *Proceedings of the Regional Workshop on Promotion of Appropriate Agro-Processing Technologies in West Africa*, 23rd -26th October 2002, Ile-Ife, pp. 164-169.
- Edeh, J. E., Eberemu, A. O., Abah, A. B. (2012a). “Reclaimed Asphalt Pavements-Lime Stabilization of Clay as Highway Pavement Materials.” Paper Presented at the 2<sup>nd</sup> International Conference On “Sustainable Development and Environmental Protection: Clean Technology Development and Environmental Sustainability for Developing Nations.” Organised by The Institute for Environment Research and Development (IERD) in Collaboration With Bells University of Technology, Ota, Ogun State, Nigeria, March 20-22, 2012.
- Edeh, J. E., Manasseh, J. & Ibanga, U. (2012b). “Palm Kernel Shell Ash Stabilization of Reclaimed Asphalt Pavements, as Highway Pavement Materials.” Paper Presented at the 2<sup>nd</sup> International Conference On “Sustainable Development and Environmental Protection: Clean Technology Development and Environmental Sustainability for Developing Nations.” Organised by The Institute for Environment Research and Development (IERD) in Collaboration With Bells University of Technology, Ota, Ogun State, Nigeria, March 20-22, 2012.
- Graham, Ian D.; Jo Logan; Margaret B. Harrison; Sharon E. Straus; Jacqueline Tetroe; Wenda Caswell; and Nicole Robinson (2006). *The Journal of Continuing Education in the Health Professions*, Volume 26, No. 1, Winter 2006, pp. 13–24.
- Haynes R. B. (2001). “Of studies, syntheses, synopses, and systems: The “4S” evolution of services for finding current best evidence.” *ACP J Club* 2001; 134:A11-A13.
- HERANA (2011). “Lack of Agreement over Role of Universities in Africa.” *Higher Education Research and Advocacy Network in Africa (HERANA)*. 13 March 2011, Issue: 73. <http://www.universityworldnews.com/article.php?story=20110313082330489> (Accessed 25/03/2011).
- Myrdal, G. (1957). *Economic Theory and Underdeveloped Nations*. London: Duckworth.

- Nwokoji, Chima (Jun 3, 2019). “‘Change’ to ‘next level’: Economic agenda for incoming government.” <https://tribuneonlineng.com/216118/> (Accessed 06/06/2019).
- Ojolo, S.J. and Bamgboye, A.I. (2005). Thermochemical conversion of municipal solid waste to produce fuel and reduce waste. *Agricultural Engineering International*, Vol. VII. Manuscript EE 05 006, Website: [cigr-ejournal.tamu.edu](http://cigr-ejournal.tamu.edu)
- Okereke, P. A. (1988). Agro-Industrial Waste for Low Cost Housing. Proceedings of 17<sup>th</sup> National Conference on Affordable Housing, Nigeria Society of Engineers Owerri.
- Okereke, P. A. (2006). “The use of sustainable materials and equipment for construction process.” Proceedings of the 36<sup>th</sup> annual conference general meeting - TIN CITY 2006, Sustainable development and the built environment, 9<sup>th</sup> -12<sup>th</sup> August, 2006.
- Olutoge, Festus Adeyemi (2006) “Structural characteristics of Bamboo (*Bambusa Vulgaris*) as reinforcement in concrete slabs.” University of Ibadan, Ph.D Thesis, 2006.
- Olutoge, Festus Adeyemi (2009) Bonding Characteristics of Oil Palm (*Elaeis guineensis*) Stem in Concrete: *Global Journal of Engineering and Technology*, India. Vol 2 no 3 (2009) pp 451-458.
- Olutoge, Festus Adeyemi (2010) Investigations on Sawdust and Palm Kernel shells as Aggregate Replacement *ARPN Journal of Engineering and Applied Sciences* Vool 5 No 4, April 2010. Asian Research Publishing Network.
- Ostrom, Elinor, Roy Gardner, and James Walker (1994). *Rules, Games and Common-Pool Resources*. Ann Arbor: University of Michigan Press.
- Penning de Vries, F. W. T. 2005. (ed.). *Bright spots demonstrate community successes in African agriculture*. Working Paper 102. Colombo, Sri Lanka: International Water Management Institute.
- Popham, Peter (2007). African Migrants are dying because no one wants to do anything about it.” *The Nation*, Friday, June 1, 2007, p. 9.
- Roth, L M (2007) *Understanding Architecture*, 2<sup>nd</sup> Edition, Westpress, Colorado.
- Sawyer, A. (2005). *Beyond Plunder: Toward Democratic Governance in Liberia*. Boulder, Colorado: Lynne Rienner, Inc.
- Taiwo, K. A., C. T. Akanbi, and O. O. Ajibola. (1997). ‘Establishing Processing Conditions for Canning Cowpea Seeds in Tomato Sauce’, *International Journal of Food Science and Technology* 32(4): 313-323.
- Tocqueville, Alexis de. (1966). *Democracy in America*. Translated by George Lawrence and edited by J. P. Mayer. New York: Harper Perennial.
- World Prout Assembly (2005). “What is Endogenous Development?” The World Prout Assembly, Proutist Universal Global Headquarters, Kolkata, India. On-Line - [http://www.worldproutassembly.org/archives/2005/09/what\\_is\\_endogen.html](http://www.worldproutassembly.org/archives/2005/09/what_is_endogen.html) (Accessed 15/03/2011).

Tharaka is an arid and semiarid district that can only accommodate dry land crops such as millet, sorghum and cowpea, and livestock keeping. In most cases, these crops suffer recurrent

moisture stress, leading to crop failure due to poor rainfall distribution. Thus, about 60% of the population in the area live below the poverty line (Republic of Kenya 2004). The Ng'uuru Gakirwe Water Project started out with poor disadvantaged members. The scheme covers an area of 60 km, accommodating a total of 430 farmers and has its own processing and packaging factory. The farmers have formed a company, Meru Herbs, which handles the factory as well as marketing of chamomile, carcade and lemongrass. These three herbs are grown organically and sold to the factory for processing, packaging and export to the EU (mostly Italy, Belgium and Germany). Training is an important component of the project as farmers come from a background of rain-fed cereal crops with little experience in irrigation or exotic herbs. In addition, farmers grow fruits like mango, banana and papaya which are also sold to Meru Herbs for making of various types of additive-free jams exported to the EU and Japan. Meru Herbs Company is the commercial arm of the Ng'uuru Gakirwe Water Project and is located in the project area.

## **ASSESSMENT OF RELIABILITY OF A CONCRETE COLUMN RESISTING AXIAL AND A COMBINATION OF AXIAL AND MOMENT LOADS**

Olawale, S.O.A., Adebajo, A.U. and Tijani, A.O.

*Department of Civil Engineering, Osun State University, Osogbo, Nigeria.*

*Corresponding Author: [abiola.adebanjo@uniosun.edu.ng](mailto:abiola.adebanjo@uniosun.edu.ng)*

### **ABSTRACT**

The safety of structural elements is of utmost importance as far as engineering is concerned. With the concept of reliability analysis various researchers have been able to ascertain to a certain degree of accuracy the reliability of some of the factors of safety stipulated in major design codes. In this paper effort was made to investigate the reliability of a concrete column resisting axial loads and a combination of axial and Moment Loads as provided by BS 8110: Part 1(1997), using Advanced First Order Second Moment AFOSM written in Java Programming Language. Results of the investigation revealed that for an increasing concrete strength, at a constant steel ratio, section and yield strength of steel had the most significant reliability index of  $2.1323514 \times 10^{-1}$  and the least probability of failure ( $4.1779849 \times 10^{-1}$ ). It was also observed that there exists a large margin of variations in the values of reliability obtained for the two conditions considered and suggests that such margins could account for a non-conservative design if not given due consideration in the design process.

**Keywords:** Reliability, Column Axial and Moment.

## 1.0 Introduction

Determination of the behaviour of structural elements under various loading conditions is quite difficult a task. This is primarily due to the fact that there are large number of uncertainties to be considered. Some of the uncertainties which may be difficult to account for are the magnitude of loads applied, choice and strength of materials used, conditions of exposure, modelling and statistical irregularities, shoddy supervision and construction methodology and natural disasters. These uncertainties if not given due consideration during the design stage could result to irreparable damages and monumental losses as was the case with Tay bridge (London), Tacoma Bridge (Kit sap Peninsula), Synagogue Church (Lagos), Reigners Bible Church (Uyo) and Unilag Library Complex (Lagos). In view of these uncertainties, for several years a prescriptive approach had been adopted to account for some of these uncertainties. Loads used for deigning a structural element are factored to an acceptable margin based on the provisions of the code of design to reduce the risk associated with under estimation. However, these deterministic approaches do not provide enough information for safety of the structure, hence the need for a performance-based engineering approach which is based on the simulation of real structural behaviour. One structural element that is of importance in a building are columns, columns are primarily compression members although in some cases may be subjected to bending either due to slenderness of the section or asymmetric loadings from adjoining beams (Oyenuga, 2011).

According to Bastidas-Arteaga and Soubra (2014), reliability analysis provides the theoretical outline for considering uncertainties in engineering decision. This decision could be expressed as the probability that a structure or system can perform a required function under a specified service condition during a given period of time and conversely by the failure probability that the structure does not perform satisfactorily within a given period of time (Lemaire ,2013). Reliability of the expected performance state is often assessed by using various methodologies based on finite element nonlinear static pushover analysis and specialized reliability software package (Abdelouafia *et al.*, 2015). There are several methods of analysing the reliability of a structural element. Some of them are Mean Value First-Order Second Moment (MVFOSM) method, First-Order Reliability Methods (FORM), Second-Order Reliability Method (SORM) and Response Surface Method (RSM) Hang *et al.* (2016). For instance, Benu *et al.* (2012) FORM written in FORTRAN language to ascertain the reliability of a square timber column. Torii *et al.* (2012) also used FORM to determine the reliability of nonlinear reinforced concrete

beams subject to ageing effects. One shortfall of FORM as pointed out by Bastidas-Arteaga and Soubra (2014) is that the information on the distribution of random variables is normally ignored thereby making the result less accurate when compared with that of Advanced First Order Second Moment (AFOSM). Jensen *et al.* (2013) worked on the reliability analysis of reinforced concrete columns with axial capacity exposed to fire with random variables taken as steel yield strength, concrete compressive strength, placement of reinforcement, and section width and height. It was found that the reliability rapidly decreased as a function of time for the first 1-2 hours after fire exposure, and continued to decrease at a slower rate thereafter, to become asymptotic to a minimum reliability index that ranges between 2 and 4 for most cases, though some exceptions exist. Priyanka *et al.* (2016) worked on the reliability analysis of an isolated reinforced concrete column footing designed using the limit state method. The reliability analysis was carried out using Monte Carlo Simulations using codes developed in Matlab. The probabilities of failure for different failure modes are estimated. The variation of reliability index with load factor as well as age of the structure was also studied. It was concluded that for structures designed with load factor of 1.5 reliability was not affected during the initial periods, probably due to the strength gain in concrete with age. Also, corrosion in steel and the subsequent reduction in the effective steel area results to a decrease in the reliability index.

Due to the simple design methods provided by BS 8110 part-1:(1997) for columns with axial loads only, some designers often ignore the effect of moment on the column during the design process thereby further creating uncertainties. Hence, this paper assessed the structural reliability of a concrete column under the action of axial load and a combination of axial and bending moment using AFOSM written in Java programming language.

## **2.0 Methodology**

### *2.1 Development of performance functions*

The performance function used in this study is based on the provision of BS 8110 part-1:(1997) for the design of column as stated in clauses 3.8.3.1 and 3.8.4.3. A parametric study on a column with a rectangular section was considered in this study.

#### *2.1.1 Development for Axial Load*

The ultimate loading capacity as given by BS 8110 part-1:(1997) is:

$$N = \left(0.67 \frac{f_{cu}}{\gamma_{mc}}\right) A_c + \left(\frac{f_y}{\gamma_{ms}}\right) A_{sc} \dots \dots \dots (1)$$

Where,

$f_{cu}$  = characteristics strength of concrete

$f_y$  = characteristics strength of steel

$\gamma_{mc}$  = factor of safety for concrete

$\gamma_{ms}$  = factor safety for steel

$A_c$  = Area of concrete

$A_{sc}$  = Area of steel in concrete

$N$  = The ultimate axial load

With  $A_{sc} = \frac{\rho bh}{100}$ ,  $A_c = bh$ , factor of safety for concrete ( $\gamma_{mc}$ ) = 1.5 and

factor of safety for steel ( $\gamma_{ms}$ ) = 1.05

Equation (1) now becomes:

$$N = 0.45f_{cu}bh + 0.95\rho bhf_y \dots \dots \dots (2)$$

The Limit State Equation is given by:

$$g(b, h, f_{cu}, f_y, N) = 0.45f_{cu}bh + 0.95\rho bhf_y - N \dots \dots \dots (3)$$

Let  $b = X_1$ ,  $h = X_2$ ,  $f_{cu} = X_3$ ,  $f_y = X_4$ ,  $N = X_5$

Hence the Limit State Equation then becomes:

$$g(X_1, X_2, X_3, X_4, X_5) = 0.45X_3X_1X_2 + 0.95\rho X_1X_2X_4 - X_5 \dots \dots \dots (4)$$

At  $g(X) = 0$

$$X_5 = 0.45X_3X_1X_2 + 0.95\rho X_1X_2X_4 \dots \dots \dots (5)$$

Determining the partial derivatives with respect to the variables, we obtain:

$$\frac{\partial g}{\partial X_1} = 0.45X_3X_2 + 0.95\rho X_2X_4 \dots \dots \dots (6)$$

$$\frac{\partial g}{\partial X_2} = 0.45X_3X_1 + 0.95\rho X_1X_4 \dots \dots \dots (7)$$

$$\frac{\partial g}{\partial X_3} = 0.45X_1X_2 \dots \dots \dots (8)$$

$$\frac{\partial g}{\partial X_4} = 0.95\rho X_1X_2 \dots \dots \dots (9)$$

$$\frac{\partial g}{\partial X_5} = -1 \dots \dots \dots (10)$$

2.1.2 Development for Short Column resisting Moments and Axial Forces

As provided in Clause 3.8.4.3

$$N = 0.4f_{cu}A_c + 0.8 A_{sc}f_y \dots \dots \dots (11)$$

Where,

$f_{cu}$  = characteristics strength of concrete

$f_y$  = characteristics strength of steel

$A_c$  = Area of concrete

$A_{sc}$  = Area of steel in concrete

$N$  = The ultimate axial load

With  $A_{sc} = \frac{\rho bh}{100}$ ,  $A_c = bh$ ,

Substituting the value for  $A_{sc}$ , equation (11) now becomes:

$$N = 0.4f_{cu}A_c + 0.8\rho bhf_y \dots \dots \dots (12)$$

Substituting  $A_c = bh$ , equation (13) now becomes:

$$N = 0.4f_{cu}bh + 0.8\rho bhf_y \dots \dots \dots (13)$$



The Limit State Equation is given by:

$$g(b, h, f_{cu}, f_y, N) = 0.4f_{cu}bh + 0.8\rho bhf_y - N \dots\dots\dots (14)$$

Let  $b = X_1$ ,  $h = X_2$ ,  $f_{cu} = X_3$ ,  $f_y = X_4$ ,  $N = X_5$

Hence the Limit State Equation then becomes:

$$g(X_1, X_2, X_3, X_4, X_5) = 0.4X_3X_1X_2 + 0.8\rho X_1X_2X_4 - X_5\dots\dots\dots (15)$$

At  $g(X) = 0$

$$X_5 = 0.4X_3X_1X_2 + 0.8\rho X_1X_2X_4\dots\dots\dots (16)$$

Determining the partial derivatives with respect to the variables, we obtain:

$$\frac{\partial g}{\partial X_1} = 0.4X_3X_2 + 0.8\rho X_2X_4\dots\dots\dots (17)$$

$$\frac{\partial g}{\partial X_2} = 0.4X_3X_1 + 0.8\rho X_1X_4\dots\dots\dots (18)$$

$$\frac{\partial g}{\partial X_3} = 0.4X_1X_2\dots\dots\dots (19)$$

$$\frac{\partial g}{\partial X_4} = 0.8\rho X_1X_2\dots\dots\dots (20)$$

$$\frac{\partial g}{\partial X_5} = -1 \dots\dots\dots (21)$$

## 2.2 Reliability Method

As stated in the objective the method of reliability adopted in this research was AFOSM which is also commonly referred to as ‘Hasofer-Lind’ method. In this method, the assessment of the reliability index is mainly based on the transformation/reduction of the problem to a standardized coordinate system. Hasofer-Lind method is an advanced first order second moment method. The key point in this method is that it estimates a design point in which is at minimum distance of failure function from the origin. The minimum distance is the safety index ( $\beta_x$ ). (Rackwitz 1976; Holicky 2009). The java program was developed in accordance with an algorithm as shown in Figure 1

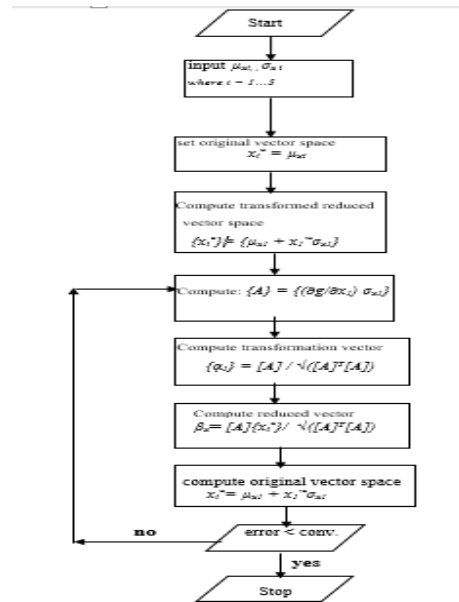


Figure 1 Algorithm of the code

### 2.3 Input variables

The mean and standard deviation values of the variables used for the various iterations were obtained using Monte Carlo Simulation. In the Monte Carlo method, random sampling is applied to create a set of realizations. These variables are presented as Tables 1 to 10

Table 1 Input variables at varying steel ratio of (0 – 0.06 at 0.005 increment) with varying axial loads from (1575 – 1607.718kN)

Variable	Mean	Standard Deviation
Width(mm)	280	28
Depth(mm)	500	50
Concrete Strength $f_{cu}$ (MPa)	25	7.5
Yield Strength of Steel $f_y$ (MPa)	410	123
Axial Load (kN)	1575	472.5

Table 2 Input variables at varying width of (200 – 500mm at an increment of 25mm)

Variable	Mean	Standard Deviation
Steel Ratio	0.06	0.06
Depth(mm)	500	50
Concrete Strength $f_{cu}$ (MPa)	25	7.5
Yield Strength of Steel $f_y$ MPa	410	123
Axial Load (kN)	1607.718	472.5

Table 3 Input variables at varying depth of (200 – 500mm at an increment of 25mm)

Variable	Mean	Standard Deviation
Steel Ratio	0.06	0.06
Width(mm)	280	28
Concrete Strength $f_{cu}$ (MPa)	25	7.5
Yield Strength of Steel $f_y$ MPa	410	123
Axial Load (kN)	1607.718	472.5

Table 4 Input variables at varying Yield Strength of Steel  $f_y$  MPa (300 -500 Mpa at an increment of 25 MPa)

Variable	Mean	Standard Deviation
Width(mm)	280	28
Depth(mm)	500	50
Concrete Strength $f_{cu}$ (MPa)	25	7.5

Steel Ratio	0.06	0.06
Axial Load (kN)	1607.718	472.5

Table 5 Input variables at varying Concrete Strength  $f_{cu}$  (15 -50Mpa at an increment of 5 MPa)

Variable	Mean	Standard Deviation
Width(mm)	280	28
Depth(mm)	500	50
Yield Strength of Steel $f_y$ (MPa)	410	123
Steel Ratio	0.06	0.06
Axial Load (kN)	1607.718	472.5

Table 6 Showing Input variables at varying steel ratio of (0 – 0.06 at 0.005 increment) with varying axial and moment loads from (1400 – 1427.552kN)

Variable	Mean	Standard Deviation
Width(mm)	280	28
Depth(mm)	500	50
Concrete Strength $f_{cu}$ (MPa)	25	7.5
Yield Strength of Steel $f_y$ (MPa)	410	123
Axial and Moment Load (kN)	1400	420

Table 7 Input variables at varying width of (200– 500mm at an increment of 25mm)

Variable	Mean	Standard Deviation
Steel Ratio	0.06	0.06

Depth(mm)	500	50
Concrete Strength $f_{cu}$ (MPa)	25	7.5
Yield Strength of Steel $f_y$ MPa	410	123
Axial and Moment Load (kN)	1427.552	428.2656

Table 8 Input variables at varying depth of (200– 500mm at an increment of 25mm)

Variable	Mean	Standard Deviation
Steel Ratio	0.06	0.06
Width(mm)	280	50
Concrete Strength $f_{cu}$ (MPa)	25	7.5
Yield Strength of Steel $f_y$ MPa	410	123
Axial and Moment Load (kN)	1427.552	428.2656

Table 9 Input variables at varying Yield Strength of Steel  $f_y$  MPa (300-500 Mpa at an increment of 25 MPa)

Variable	Mean	Standard Deviation
Width(mm)	280	28
Depth(mm)	500	50
Concrete Strength $f_{cu}$ (MPa)	25	7.5
Steel Ratio	0.06	0.06
Axial and Moment Load (kN)	1427.552	428.2656

Table 10 Input variables at varying Concrete Strength  $f_{cu}$  (15 -50Mpa at an increment of 5 MPa)

Variable	Mean	Standard Deviation
Width(mm)	280	28
Depth(mm)	500	50
Yield Strength of Steel $f_y$ (MPa)	410	123
Steel Ratio	0.06	0.06
Axial and Moment Load (kN)	1427.552	428.2656

### 3.0 Results and Discussions

At a section of 280 by 500 mm, concrete strength of 25 MPa and yield strength of 410MPa with a varying steel ratio ranging from 0 to 0.06 at an increment of 0.005, the reliability values obtained for the column under the action of varying purely axial load from (1575-1607.718kN) increased from 0.05258247 to 0.15099299 while the probability of failure decreased from 0.48012433 to 0.44207808 as the steel ratio increased, when the effect of moment was taken into consideration there was a decrease in the ultimate capacity (1400-1427.552kN) of the column for the same section been investigated with reliability values ranging from 0.05915526 to 0.16463895 while the probability of failure also decreased from 0.47761128 to 0.43675805 as the steel ratio increases. The variation between the values of reliability obtained for axial loading only and axial and moment became significant suggesting that the steel content is of importance especially when the column is anticipated to resist some form of moment.

When one of the sides of the column was made constant (500 mm) and the other side varied at an increment of 25 mm from 200 to 500 mm a similar trend as was obtained with the steel ratio was observed, the reliability values obtained at 200 mm for axial and axial with moment are 0.14629406 and 0.15982005 respectively while that obtained at 500 mm was 0.15465114 and 0.1683721 respectively. While the probability of failure obtained at 200 mm for axial and axial with moment are 0.44390878 and 0.43863727 respectively while that obtained at 500 mm was 0.44065239 and 0.43530193 respectively. A similar trend was obtained when the other side (280mm) was made constant and the other side varied from 200mm to 500mm at 25mm increment. Though there was a notable variation in reliability when comparing between the two conditions under consideration (i.e. axial only and axial with moment), it was observed

that the variation in reliability as the sectional area increases for a particular condition was relatively small when compared with the variation obtained as with the steel ratio.

The effect of the concrete strength was also observed in this research, as the concrete strength increases at a constant section of 280 by 500 mm, the column been considered showed a perfectly linear variation in reliability for the two conditions been studied. However, the column designed to resist Moments and Axial Forces had the optimum reliability for all the grades of concrete investigated See Figure 5 Also, it is important to note that the variation observed was almost uniform, suggesting that an increase in the concrete strength of a uniform concrete section is directly proportional to the ultimate capacity of the column irrespective of the conditions such column is subjected to.

Lastly, the yield strength of steel was varied from 300 – 500 Mpa for the same section, the result obtained indicated that the column became more efficient in resisting the applied load as the yield strength increases.

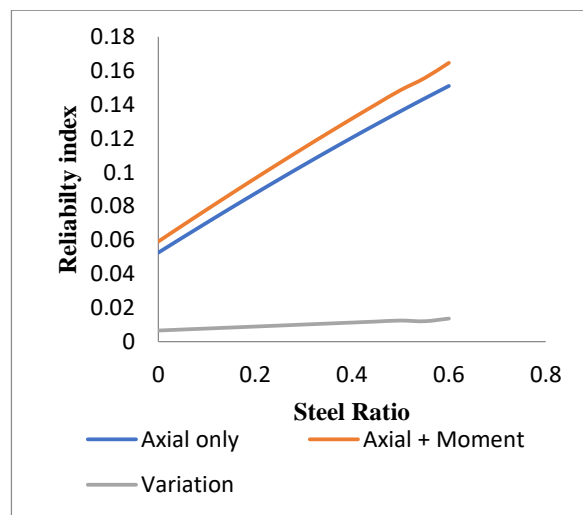


Figure 2 Effect of increasing steel ratio on reliability.

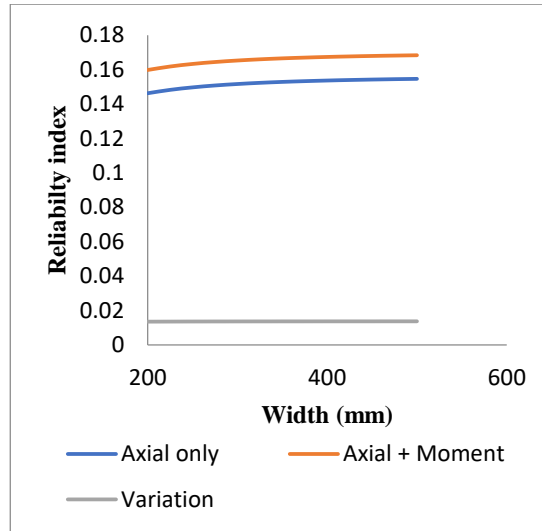


Figure 3 Effect of increasing width on reliability.

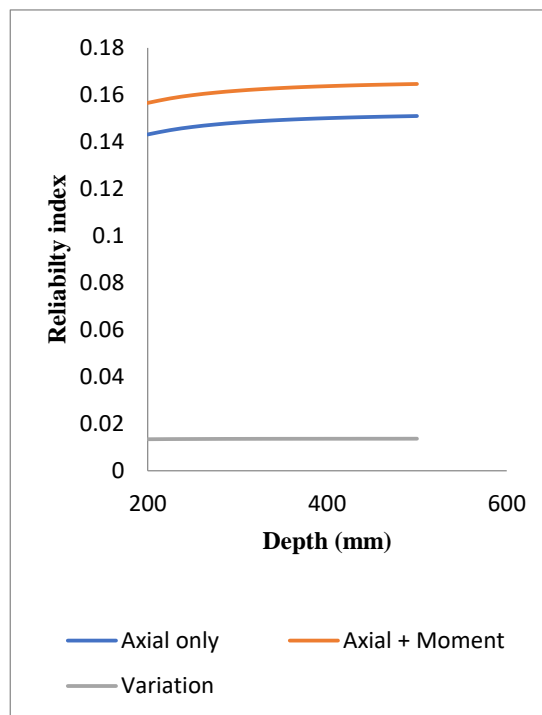


Figure 4 Effect of increasing depth on reliability.



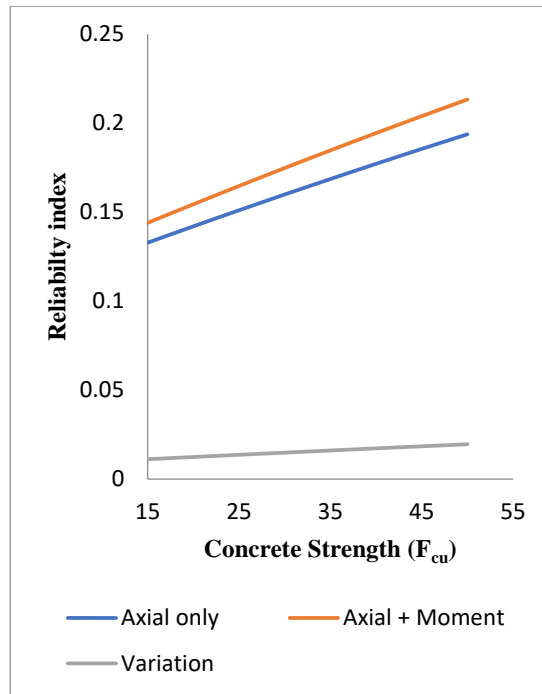


Figure 5 Effect of increasing concrete strength on reliability.

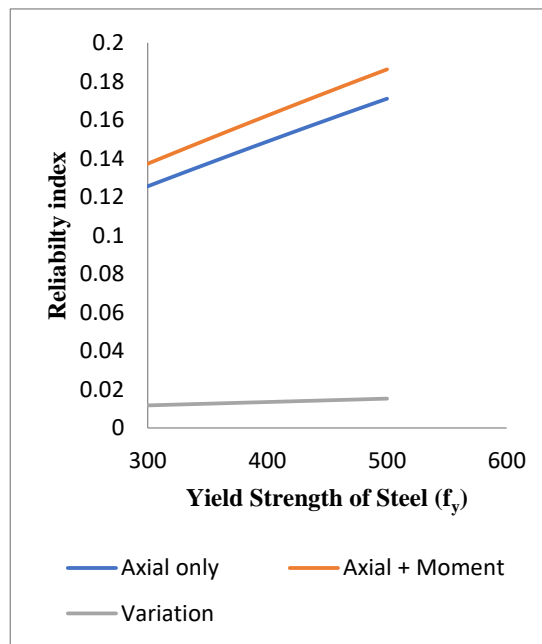


Figure 6 Effect of increasing yield strength of steel on reliability

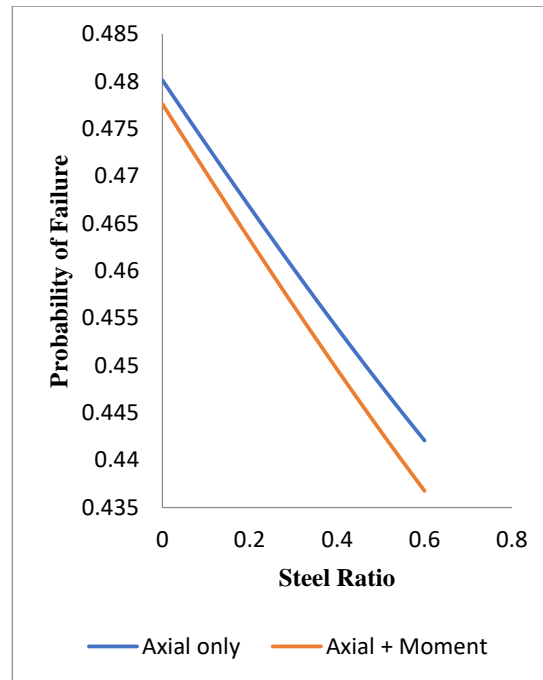


Figure 7 Effect of increasing steel ratio on probability of failure.

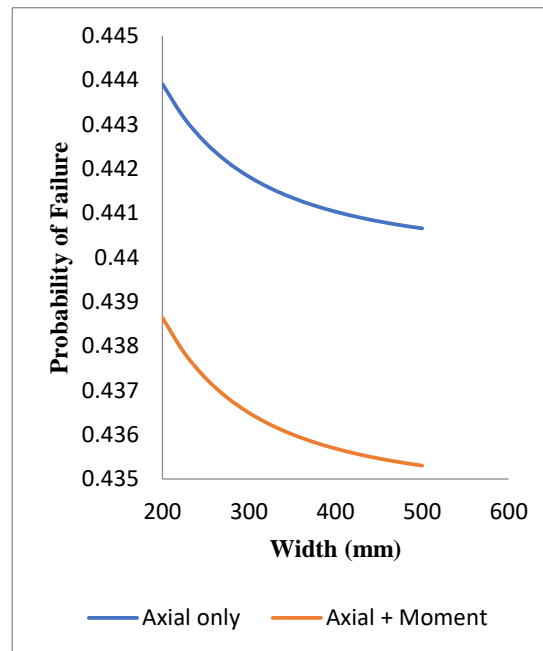


Figure 8 Effect of increasing width on probability of failure.

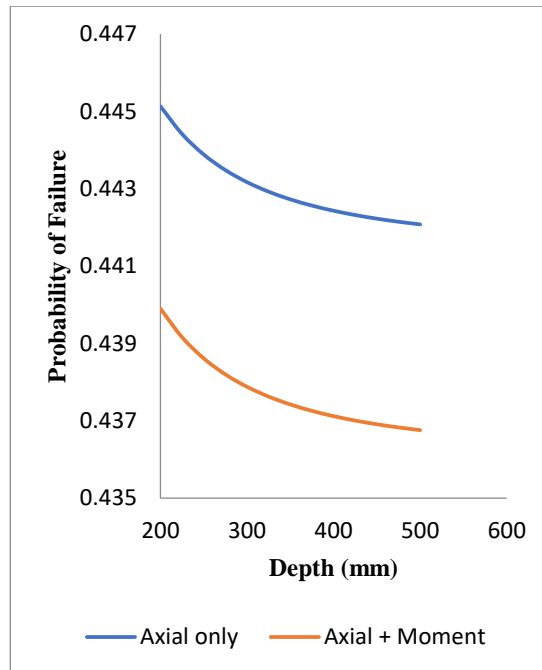


Figure 9 Effect of increasing depth on probability of failure.

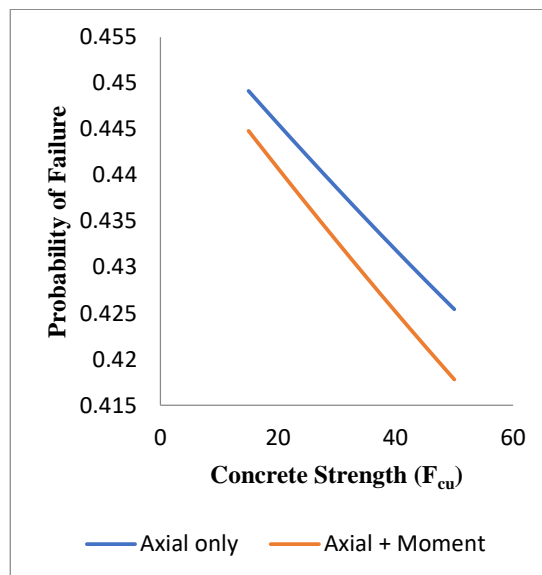


Figure 10 Effect of increasing concrete strength on probability of failure.

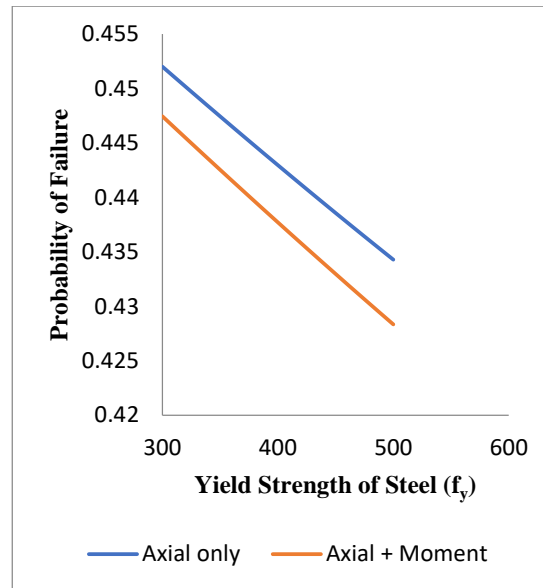


Figure 11 Effect of increasing yield strength of steel on probability of failure.

## Conclusion

From the findings of this research it can be rightly concluded that the provisions of BS 8110 part-1:(1997) for design of columns resisting axial and a combination of axial and moment is well sufficient, as it was observed in all the cases investigated. However, the provisions made by the code for columns resisting axial and moment loads was more reliable and that there exists notable margin of variation between these two conditions and such margins could account for a non-conservative design if not given due consideration in the design process.

## REFERENCES

- Abdelouafia El Ghoulbzouri ,Kissi Benaissab, Khamlichi Abdellatifc (2015) “Reliability Analysis in Performance-Based Earthquake Engineering”, 1st International Conference on Structural Integrity, Procedia Engineering 114 ( 2015 ) 643 – 649
- Bastidas-Arteaga E. and Soubra A. H. (2014): “Reliability Analysis Methods”. ALERT Doctoral School 2014-Stochastic Analysis and Inverse Modeling, pp. 53-77.

Benu M. J., Sule S. and Nwofor T.C.(2012) “Reliability Analysis Of A Square Solid Timber Column” Pelagia Research Library Advances in Applied Science Research, 2012, 3 (4):1997-2004

BS 8110: Part 1 1997. Structural use of concrete- Code of practice for design and construction

Chang Wu HUANG, Abdelkhalak El Hami and Bouchaïb Radi (2016) “Overview of Structural Reliability Analysis Methods — Part I: Local Reliability Methods” ISTE OpenScience Published by ISTE Ltd. London, UK – openscience.fr

Haldar A. and Mahadevan S. (2000) “Probability, Reliability and Statistical Methods in Engineering Design”, Jonh Wiley & Sons, Inc. 2000.

Holicky (2009) “Reliability analysis for structural design” ISBN: 978-1-920338-11-4 eISBN: 978-1-920689-34-6 DOI: 10.18820/9781920689346.

Lemaire M (2013), “*Structural reliability*”. John Wiley & Sons.

Oyenuga V. O. (2011): “Reinforced Concrete Design (A Consultant/Computer Based Approach)”, 7<sup>th</sup> Edition, Asros Limited Lagos, Nigeria. ISBN:978-36217-7-7.

Priyanka P., Vipin, S., Rohit, P., Mukesh, Y., and Santhy, K.S(2016), ‘Reliability Analysis of Isolated Column Footings using Monte Carlo Simulation’, International Journal of Scientific & Engineering Research, Volume 7, Issue 4, April-2016 62 ISSN 2229-5518.

Rackwitz, R. (1976) Practical probabilistic approach to design, Bulletin No.112, CEB, Paris France

## **ACOUSTIC BEHAVIOUR OF CRUMB-RUBBER MASONRY HOLLOW CONCRETE BLOCK “WALLETTE” BASED ON ITS INSTALLED SELF-WEIGHT**

Sanni, M.Y. <sup>1\*</sup>, Ocholi, A. <sup>2</sup>, Abdulkarim, A.A. <sup>3</sup>, Ejeh, S.P. <sup>4</sup> and. Amartey, Y.D <sup>5</sup>

<sup>1-5</sup> Department of Civil Engineering, Ahmadu Bello University, Zaria.

<sup>3</sup>, Department of Civil Engineering, The Federal Polytechnic, Offa.

\*Email of Corresponding Author [sannimukaila@yahoo.com](mailto:sannimukaila@yahoo.com)

### **ABSTRACT**

In this paper, i predicted the acoustic behavior of masonry hollow concrete block wallette’s doped with crumb-rubber from waste-tyre. Six different mixtures were prepared, with 0%, 5%, 10%, 15%, 20% and 25% crumb-rubber particles in their composition. Masonry hollow concrete block units containing crumb-rubber particles were manufactured for each mixture and used for the construction of the wallette’s which was cured as recommended. The weight of wallette samples from each mixture was use to predict the sound transmission class (STC) and the Outdoor/indoor transmission class (OITC) using conservative standard calculation methods. The result reveals that the STC and OITC of masonry hollow concrete block wallette’s decreases with an increase in the percentage of crumb-rubber content while the STC and OITC increases with increase in density and weight. The reference mixes (0%) for the masonry hollow concrete block wallette have a STC and OITC of 80dB each respectively compared to 79 and 78.9, 78 and 77.6, 77.6 and 76.8, 76.5 and 75.5 and 75.5 and 74.0dB obtained for 5%, 10%, 15%, 20% and 25% crumb-rubber masonry hollow concrete block wallette’s mixes respectively. STC and OITC for the masonry hollow concrete block wallette’s was observed to have been reduced by 5.6% and 7.5% respectively with 25% crumb-rubber particles content which is considered less effective and making it to have reduced sound absorption compared to the reference block wall; Nevertheless the STC and OITC of all the modified masonry wallette’s are above 50dB, therefore the typical hearing quality for the wall are describe as a very loud sounds such as musical instrument or stereo can be faintly heard, 99% of population not annoyed, therefore, considerable amount of crumb-rubber from waste tyre recycled could justify the application of the doped materials for the sake of the environment.

**Keywords:** Crumb-rubber, Masonry wallette’s, Compacting factor, Density, Compressive strength and Acoustic (Sound Transmission Class and Outdoor/Indoor Transmission Class).

## **1.0 INTRODUCTION**

Relevant researches have been conducted to find a practical and environmentally solution of the problem constituted by waste tyres.

According to Yang *et al.* (2000), each year about 9 million tonnes waste rubber-tyres are disposed of all over the world, which was also estimated to be around 1 billion tyres withdrawn from use in the world annually Erdogan *et al.*,(2010).

Ebewele *et al.*(1990) reported that an estimated 5 million scrap tyres from trucks, cars and motorcycles existed in Nigeria in 1983 with an annual generation rate of 15% each year. About 37, million scrap tyres were estimated to exist in Nigeria by 2018.

Masonry hollow concrete blocks is becoming widely accepted as a construction material for walling units in our buildings, hence the partial replacement of mineral aggregates with rubber-tyre particles in concrete blocks would be a very good and promising way to utilize the large quantities of waste rubber-tyres.

### **Crumb-Rubber Modified Concrete and Blocks**

The composite material which includes portland cement, sand, water and crumb-rubber mixed in a required ratio is known as Crumb-Rubber Modified Concrete (CR-MC) and has been branded with various types of names in the literature depending on the size of rubber tyre aggregate used.

Studies conducted in the past focused on the fresh and hardened crumb-rubber modified structural concrete with high water content and less researches were conducted on masonry concrete with lean water mix.

The objective of this study is to introduce crumb-rubber, in various proportions, as a coarse aggregate into masonry concrete mix to be used for the production of masonry concrete blocks units and wallette's and eventually predict the acoustic performance of the reference masonry concrete block wallette compared to the modified crumb-rubber masonry concrete block wallettes's to see if there is any changes in these performance.

### **Building Acoustic**

Building acoustics is the science of controlling noise in buildings, including the minimisation of noise transmission from one space to another and the control of noise levels and characteristics within a space.

The term ‘building acoustics’ embraces sound insulation and sound absorption. The two functions are quite distinct and should not be confused source: Boral masonry guide (2009).

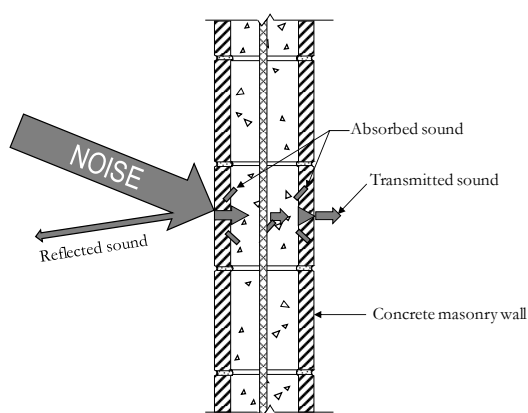
Noise has been defined as sound which is undesired by the recipient, but it is very subjective and it depends on the reactions of the individuals. However, when a noise is troublesome it can reduce comfort and efficiency and, if a person subjected to it for long enough periods, it can result in physical discomfort or mental distress. Boral masonry guide (2009).

There are two type of noise transfer through wall partitions, airborne transfer, and structure-borne transfer. Noise sources, such as voices, televisions and musical instruments, generate noise in the air in one room and this noise passes through the partition and into the room on the other side. This is known as airborne noise.

When a building element is directly or indirectly impacted or vibrated then some of the energy passes through the partition and is re-radiated as noise to the room on the other side. This is called structure-borne noise or impact noise which includes: cupboard doors fixed to party walls being closed, kitchen appliances being used on benches touching walls, plumbing fittings particularly taps being connected to walls, light switches being turned on and off etc. Boral masonry guide (2009).

Propagation of sound waves through masonry wall occur when a sound wave strikes a masonry wall, part of this wave is reflected, part is absorbed and part is transmitted as shown in Figure 1.

1



**Figure 1:** Sound Wave Propagation Through Masonry Concrete Wall



Sound Transmission Class (STC). Expressed in decibels (dB) is a single number rating that provides a measure of the sound insulating properties of walls. STC use decibel (db) levels measured between frequencies of 125Hz and 4000Hz.

The higher the STC rating the better the assembly can block or reduce the transmission of sound across it.

Outdoor/indoor transmission (OITC) rating is used to measure the sound transfer between outdoor and indoor spaces. It uses decibel (db) levels measured between frequencies of 80Hz and 4000Hz, making it a better measure for low sound frequencies such as road noise. As the OITC values increases, the better sound resistant the product is.

Both *OITC* and *STC* indicate a wall's ability to block the transmission of sound from one side of the wall to the other. *OITC* differs from the *STC* rating in that the *OITC* was developed specifically to indicate transmission of noise from transportation sources such as cars, train and aero-plane. *STC* was developed primarily for indoor noise sources, such as human speech. Unlike *OITC* and *STC*, *NRC* indicates the ability of a wall to absorb sound, which is useful for controlling sound reverberations within a room.

Malek *et al.*,(2014), conducted, an experimental study to provide more data on the effect of crumb-rubber on the acoustic properties of self-consolidating concrete (SCC). Crumb-rubber was replaced by percentages of 0 %, 10 %, 20 % and 30 % of the volume of gravel. The results showed that the sound absorption and noise reduction coefficient were increased according to the increase of the percentage of crumb-rubber, the STC decreases as the percentage of crumb-rubber replacement increases due to an increase in air voids in SCCR.

Mohammed *et al.* (2012), carried out acoustic test on concrete block by partially replacing the fine aggregate with crumb-rubber. The fine aggregate was replaced by volume using 0%, 10%, 25% and 50% crumb-rubber (CR) with mix ratio of 1:1:2 by volume ratio of cement was adopted in the study.

Sound absorption test was performed in accordance with the requirements of ASTM E1050 (ASTM, 2005k) using impedance tube method. STC calculation was performed according to the guideline of the ASTM E413 (ASTM, 2005l). The result shows that concrete block has better sound absorption with higher noise reduction factor than conventional concrete block. Although, STC for concrete block decreases as percentage of CR replacement increases, the

reduction in STC is marginal and can be partially restored by inclusion of higher percentage of silica fume.

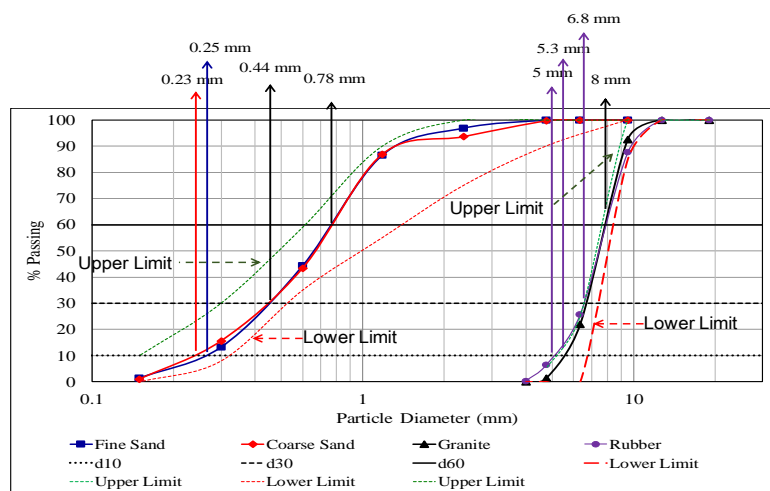
## **METHODOLOGY**

### **2.1. Materials**

Crumb-rubber masonry hollow concrete block units (CR-MHCBU) consists of cement, natural aggregate (fine and coarse), waste crumb-rubber tyre derived aggregate and water as shown in Figure 2.2. A general-purpose blended limestone portland cement CEM II (42.5R MPa) that conforms to BS EN 197-1:2011 with a specific gravity ( $G$ ) of approximately 3.15 was sourced from retail outlet in Zaria and used for this study. Ordinary tap water (potable drinking water) sourced from Civil Engineering Laboratory Ahmadu Bello University, Zaria Nigeria was used for all concrete mixes and curing.

Natural sharp river quartzite sand smaller than 4.76mm but larger than  $75\mu\text{m}$  that is free of clay, loam, dirt and any organic or chemical matter with average specific gravity (saturated surface dry) of 2.65 and bulk density of  $1,454\text{ kg/m}^3$  was used as fine aggregate.

The fine aggregate (sand) falls in zone two (medium sand) according to BS EN 12620:2002+A1:2008 specification. Natural crushed (granite) with nominal maximum sizes of 9.52-10mm as shown in Figure 1 and sourced from a local commercial quarry with specific gravity of 2.66 and bulk density of  $1635\text{ kg/m}^3$  was used as coarse aggregate. Coarse rubber aggregate (crumb rubber) from scrap tyres with nominal maximum sizes of 4 - 6mm, specific gravity of 1.14 and bulk density of  $528\text{ kg/m}^3$  was used for this research. Crumb-rubber surface treatment method by soaking in sodium hydroxide (NaOH) solution was adopted for this research due to its effectiveness in enhancing the hydrophilic properties of the rubber and increasing the intermolecular interaction forces between rubber and calcium silicate hydrate (C-S-H) gel which enhances strength of the composite matrix as reported by (Mohammedi, 2014).



**Figure 2:** Grading of Natural Aggregate and Crumb-Rubber

## 2.2. Mix Proportions

The mix design for the masonry hollow concrete block adopted was based on absolute volume BS EN 206:2013+A1:2016 design, a mix ratio of 1:1.5:3, compressive strength of 30 N/mm<sup>2</sup> at 28 days with water/cement ratio of 0.42 and aggregate/cement ratio of 4.5:1 was used to produce a trial mix which was tested for compacting factor, compressive strength and density; eventually the mix was subjected to adjustment, adopted and applied to all the concrete mixes. A total number of six (6) mixes were prepared: One control mix and five concrete mixes in which the 9.52-10 mm granite was replaced by crumb-rubber aggregate at 5%, 10%, 15%, 20% and 25% by volume. The mix proportions were constant in terms of mix design ratio, water/cement ratio, sizes, type of natural and crumb rubber-tyre aggregate used for the study. A total of 36 masonry hollow concrete blocks (average of six samples per mix according to BS EN772-1:2011+A1:2015) were tested for the compressive strength. Table 1 below showed the mix proportion.

**Table 1:** Quantity of Materials to 1m<sup>3</sup> of Concrete (Control Mix)

Mix Ratio	W/C Ratio	A/C Ratio	Cement (kg/m <sup>3</sup> )	Fine Aggregate (kg/m <sup>3</sup> )	Coarse Aggregate (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )
1:1.5:3	0.42	4.5	411.29	616.94	1,233.87	179.56

## 2.3. Manufacture of Masonry Hollow

### Concrete Block Units

The masonry concrete blocks (all hollow) were manufactured to the requirements given in BS 771-3:2011+A1:2015 with the use of a vibrating machine. The standard mix proportion of 1:1.5:3 cement-sand-granite ratio (1:4.5 cement aggregate ratio). The size of the block produced was 450 x 225 x 225mm with one-third of the volume void so as to produce the type of hollow concrete blocks commonly used for construction of buildings in Nigeria. Five various percentages of granite substitution with crumb rubber (5, 10, 15, 20 and 25%) by volume were used.



**Figure 3:** Mixing of Fresh Crumb-Rubber Masonry Concrete for Block Production

1

### 2.4. Testing of Masonry Hollow Concrete Block Samples

Tests were conducted to assess the compacting factor of the fresh (relatively dry) masonry concrete mix (control mixes) and that of crumb-rubber masonry concrete mixes at the department of Civil Engineering concrete laboratory Ahmadu Bello University, Zaria in accordance with BS EN 12350-4:2009. The density and compressive strength of the hardened masonry hollow concrete block samples were established in accordance with BS EN772 -13 (2000) and BS EN 772-1:2011+A1:2015 respectively after 28 days of standard curing with water.

### 2.5 Construction and Curing of the Masonry Wallette's

Masonry wallette's were constructed in accordance with BS EN 1052-1:1999. To construct the geometric shape of the masonry wallette's wooden pallets of a suitable size were prepared to be used as a flat base upon which to stand the masonry wallette's as shown in Figure 5. The total dimensions of the wallette's are 690 × 720 × 230 mm, constructed with three courses of blocks. Each course contains one and a half hollow concrete blocks for the wallette specimen. Two horizontal bed joints and three perpendicular head joints were used for each wallette constructed. For each masonry wallette, the magnitude of the overlap between the

concrete blocks was compliant with the limits of BS EN 1996-1-1 (2005) which defined it as greater than or equal to 0.2 times the block height or 225mm, whichever is greater. A total of 12 masonry wallette's were constructed. The masonry mortars used for the wallette's construction were mixed in accordance with EN 196-1:2005. M20 general purpose mortar with the mixture consisting of portland cement (CEMII) and sand in a proportion of 1:3 by volume and water/cement ratio of 0.6 was used for the mix and kept constant for all mixes.



**Figure 4:** Masonry Concrete Block



**Figure 5:** Masonry Hollow Concrete Block Wallette's

## **2.6. Acoustic Properties of Crumb-Rubber Masonry Hollow Concrete Block Wallette's**

In the absence of test data, standard calculation methods exist to predict the acoustic properties of masonry concrete wall although these tend to be conservative.

### **2.6.1 Sound Transmission Class (STC) of CR-Masonry Hollow Concrete Wall**

Sound Transmission Class (STC). Expressed in decibels (dB) is a single number rating that provides a measure of the sound insulating properties of walls; STC provides an estimate of the acoustic performance of a wall in certain common airborne sound insulation applications. The higher the STC rating the better the assembly can block or reduce the transmission of

sound across it. STC use decibel (dB) levels measured between frequencies of 125Hz and 4000Hz.

STC can be calculated using the installed weight of the assembly which is a function of the unit density, unit size and configuration, presence of surface finishes and presence of grout or other cell-fill materials such as sand.

It has been well established (Standard method for determine the sound Transmission class rating for masonry wall, TMS 0302-07 the masonry society, 2007). That the STC of concrete masonry walls is directly related wall weight.

In the absence of test data, Standard method for determining the sound transmission class rating for masonry walls TMS 0302 can be used to determine the sound transmission class (STC) of masonry concrete wall. The calculation in TMS 0302 is based on a best fit relationship between concrete masonry wall weight and STC based on a wide range of test results as shown in Equation 1:

$$STC = 14.1W^{0.234} (\text{Kg/m}^2) \quad (1)$$

Where W = the weight of masonry units (kg/m<sup>2</sup>).

### **2.6.2 Outdoor/Indoor Transmission Class (OITC) of CR-Masonry Hollow Concrete Wall**

The Outdoor/Indoor Transmission Class (OITC) rating is used to measure the sound transfer between outdoor and indoor spaces. It uses decibel (dB) levels measured between frequencies of 80Hz and 4000Hz, making it a better measure for low sound frequencies such as road noise. The OITC is intended for exterior building facades, and is an estimate of the wall's ability to reduce typical transportation noise such as automobile, aero plane, train etc. It is determined in accordance with ASTM E 1332, *Standard Classification for Determination of Outdoor-Indoor Transmission Class* (ref. 3). E 1332 presents a standard procedure to calculate OITC based on tested sound transmission loss (TL) across the wall or wall element at specific frequencies from 80 to 4,000 Hz. As the OITC values increases, the better sound resistant the product is.

Decibel (dB)-Decibel is a measure of the amplitude of sound. The higher the number of decibels signifies louder the sound. Decibel only quantifies the loudness of sound and does not quantify any other characteristics of sound.

Ideally OITC should be based on tested transmission loss values. In recognition that this data is not always available, however, the information from moving vehicles and close flying aircraft. is presented as a tool to help designer estimate OITC values.

It has been well established (Standard method for determining The Sound Transmission Rating for masonry walls, TMS 0302-12. The Masonry Society 2012) that the STC of concrete masonry walls is directly related to wall weight. Using this knowledge and the calculated OITC values a correlation between concrete masonry wall weight and OITC has been developed for walls at least 3in (76mm) thick. In the absence of test data OITC can be estimated using Equation 2:

$$OITC = 9.28W^{0.290} \text{ (Kg/m}^2\text{)} \quad (2)$$

Table 2 present typical hearing quality for a wall of rated STC (dB) while Figure 5 presents the masonry concrete block wall's which acoustic properties were predicted.

**Table 2: Typical Hearing Quality for Wall of Rated STC (dB)**

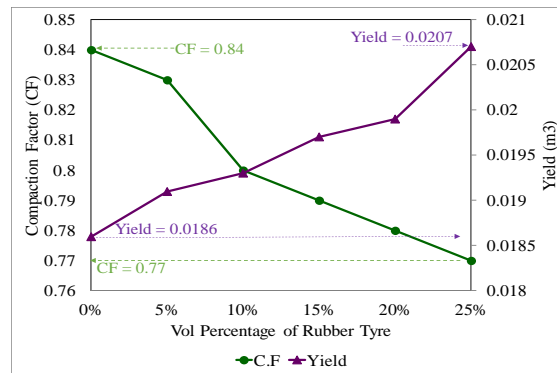
**Source: Malek *et al.*, (2014).**

STC (dB)	Hearing Quality Through Wall
25	Normal speech understood quite easily and distinctly through wall
30	Loud speech understood fairly well; normal speech heard but not understood
35	Loud speech heard but not intelligible
40	Onset of "privacy"
42	Loud speech audible, as a murmur
45	Loud speech audible, 90% of statistical population not annoyed
50	Very loud sounds such as musical instrument or stereo can be faintly heard, 99% of population not annoyed

## 2.0 RESULTS AND DISCUSSION

### 2.1 Compacting factor and Yield

The compacting factor (C.F) as shown in Figure 6 was observed to decrease significantly. Control masonry concrete mixes had C.F of 0.84 (low workability) while the 25% crumb rubber mix had C.F of 0.77 (very low workability) indicating 8.3% reduction. Yield value of fresh masonry concrete mix in Figure 3.1 was observed to increase slightly from 0.0186m<sup>3</sup> for control masonry concrete mix to 0.0207m<sup>3</sup> for mix with 25% crumb-rubber content, which indicates an increase by 10.2% and this can be attributed to low bulk specific gravity of crumb-rubber 1.14 and the increase in crumb-rubber volume.

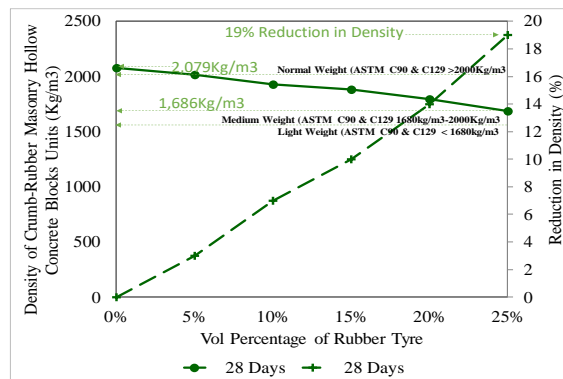


**Figure 6:** Compacting factor and Yield Vs % Crumb-Rubber Content

## 2.2 Density (Unit weight)

The density of control and crumb-rubber masonry hollow concrete blocks samples is presented in Figure 7. It can be seen that the crumb-rubber masonry hollow concrete blocks exhibited lower densities than the control mixes, also it can be deduced from the graph that density reduces by 19%, with the reference concrete block units having an average net density of 2079 kg/m<sup>3</sup> while 25% crumb rubber replacement masonry hollow concrete block units have an average of 1686 kg/m<sup>3</sup>.

This reduction was expected, as the specific gravity of crumb-rubber (1.14) is less than that of granite (2.66). The substitution of granite for crumb-rubber particles was done by volume, meaning that the obtained density would be lower than for those of the reference concrete mix.

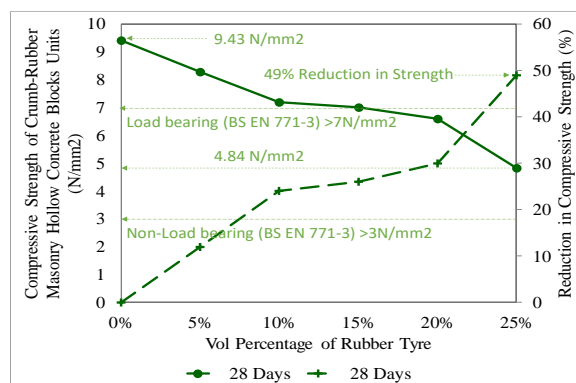


**Figure 7:** Net Dry Density of CR-MHCBU Vs % Crumb-Rubber Content



### 2.3 Compressive Strength

Compressive strength of CR-MHCBU tested with compression testing machine in accordance with BS EN 772 Part 1 (2000) after twenty-eight (28) days of curing with water indicates a decrease in compressive strength with increase in crumb-rubber content as shown in Figure 8 also a percentage loss of strength by 49% was observed with the reference units having a strength of 9.43N/mm<sup>2</sup> while 5, 10, 15, 20 and 25% crumb-rubber modified masonry concrete block units having a strength of 8.29N/mm<sup>2</sup>, 7.20N/mm<sup>2</sup>, 7.02N/mm<sup>2</sup>, 6.61N/mm<sup>2</sup> and 4.84N/mm<sup>2</sup> respectively. It can be clearly seen from Figure 8 that a load bearing CR-MHCBU can be produced with 15% (CR) content which is above the minimum requirement specified in accordance with the requirement of the BS EN 771-3 which specified a strength greater than or equal to 7N/mm<sup>2</sup>. Also, a Non load-bearing CR-MHCBU with strength above the minimum specified in accordance with BS EN 771-3 (>3N/mm<sup>2</sup>) can be produced with crumb-rubber content ranging from 16% to 25%.



**Figure 8:** Compressive Strength of CR-MHCBU Against % Crumb-Rubber Content

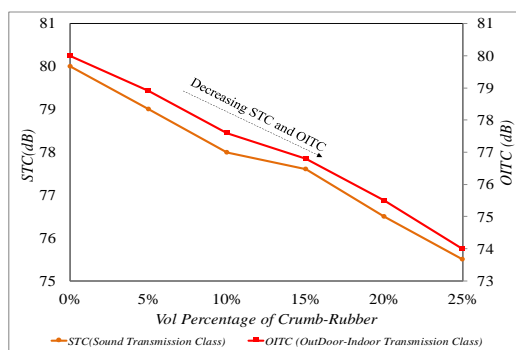
### 2.4 Acoustic Performance of CR-Masonry Masonry Hollow Concrete Block Wallete's

Results of predicted acoustic performance of crumb-rubber masonry concrete block wallete's in terms of sound transmission class (STC) and outdoor/indoor transmission class (OITC) using standard method for determining the sound transmission class rating for masonry wall (TMS 0302-07 the masonry society, 2007) and standard method for determining the sound

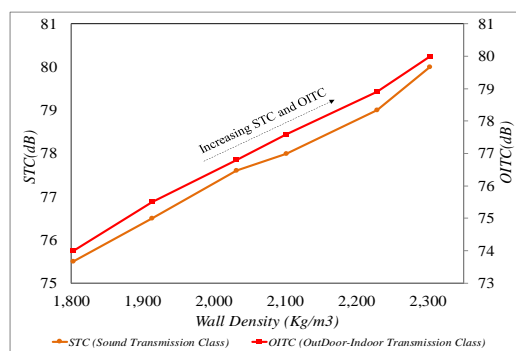
transmission rating for masonry walls (TMS 0302-12. The Masonry Society 2012) respectively are presented in Figure 9 - 11.

#### 2.4.1 STC and OITC of Crumb-Rubber Masonry Hollow Concrete Block Wallete's

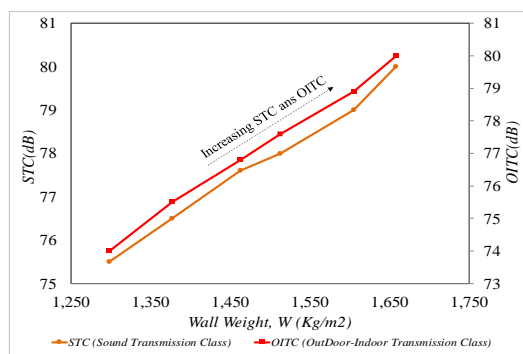
The results as presented in Figure 9, 10 & 11 indicate that the sound transmission class (STC) and outdoor/indoor transmission class (OITC) of masonry hollow concrete block wallete's decreased with an increase in the percentage of crumb-rubber content which is attributed to increase in air voids in the masonry concrete blocks with increase in crumb-rubber content Mohammed *et al.* (2012) and Malek *et al.* (2014) while the STC and OITC increases with increase in density and weight. STC and OITC for the masonry hollow concrete block wallete's was observed to have been reduced by 5.6% and 7.5% respectively with 25% crumb-rubber particles content which is considered less effective and making it to have reduced sound absorption compared to the reference wall.



**Figure 9:** Variation of Acoustic Properties with Rubber Content (% Crumb-Rubber Content) in Masonry Hollow Concrete Block Wallete's



**Figure 10:** Variation of Acoustic Properties with Density of Masonry Hollow Concrete Block Wallete's (Kg/m<sup>3</sup>)



**Figure 11** Weight of Masonry Hollow Concrete Block Wallete's (Kg/m<sup>3</sup>)

However, Table 2 gives the typical hearing quality for a wall of rated sound transmission class. The values found for the STC of all the modified mixtures are above 50dB, therefore the typical hearing quality for the block when used for wall are. “Very loud sounds such as musical instrument or stereo can be faintly heard, 99% of population not annoyed”.

### 3.0 CONCLUSION

The following conclusions are drawn on the compressive strength and acoustic performance of masonry hollow concrete block wallete's containing crumb-rubber particles from waste automobile tyre as partial replacement for granite by volume.

1. The compacting factor (C.F) of masonry concrete was observed to decrease significantly by 8.3% with 25% crumb-rubber content. Reference masonry concrete mixes had C.F of 0.84 (low workability) while the 25% crumb rubber mix had C.F of 0.77 (very low workability)
2. Density and compressive strength of masonry of masonry hollow concrete block unit reduced by 19% and 49% respectively.
3. Sound transmission class (STC) and outdoor/indoor transmission class (OITC) of masonry hollow concrete block wallete's decreases with percentage increase in crumb-rubber content, with reduction of 5.6% and 7.5% respectively for 25% crumb-rubber particles content which is considered less effective and making it to have reduced sound absorption compared to the reference block.

4. STC and OITC of all the modified mixtures are above 50dB, which makes the reduction insignificant as the modified masonry concrete hollow block wall's remain in the same class with the reference masonry concrete block; therefore, considerable amount of crumb-rubber from waste tyre recycled could justify the application of the doped materials for the sake of the environment.

## **REFERENCE**

- ASTM E 1332, "Standard Classification for Determination of Outdoor-Indoor Transmission Class", ASTM International, West Conshohocken.
- ASTM E1050-98, "Standard Test Method for Impedance and Absorption of Acoustical Materials Using A Tube, Two Microphones and A Digital Frequency Analysis System",
- ASTM E413-04, "Classification for Rating Sound Insulation", ASTM International, West Conshohocken.
- Boral, (2009). "Masonry Design guide," (structural, fire and acoustics) Victoria Book1 E Fire and Acoustic Systems.
- BS EN 197-1:2011 Cement. Composition, Specifications and Conformity Criteria for Common Cements.
- BS EN 206:2013+A1:2016. Concrete. Specification, Performance, Production and Conformity.
- BS EN 12350-4:2009. Testing fresh concrete. Degree of Compactability.
- BS EN 12620: 2002+A1:2008. Aggregate for Concrete.
- BS EN 772-1:2011, "Methods of test for masonry units". Part 1: Determination of compressive strength. British Standards.
- BS EN 771-3: 2003, "Specification for masonry units". Aggregate concrete masonry (dense and light-weight aggregates), BSI, London, 2003.
- BE EN 772-13:2000, "Methods of Test for masonry units". Determination of net and gross dry density of masonry units (except for natural stone).
- BS EN 1052-1:1999, "Method of test masonry", Determination of compressive strength.
- BS EN 1996-1: 2005, Eurocode 6 -Design of masonry structures-Part 1-1: General rules for reinforced and unreinforced masonry structures. CEN.

- Ebewele, R.O. and Dzung L.H. (1990). "Potential Application of Recycled Rubber". Nigeria Journal of Engineering, 6(1) 1–3.
- Erdogan, S. O. Mohammed, L. and Umur. K. S. (2010). "Compressive Strength Abrasion Resistance and Energy Absorption Capacity of Rubberized Concrete with and without slag".
- Malek, J., Ali B., Omrane B. and Chokri, S. (2014). "Crumb Rubber Effect on Acoustic Properties of Self- Consolidating Concrete," Int. J. of Thermal & Environmental Engineering Volume 8, No.2 69-76.
- Mohammed, B.S, Khandaker M. Anwar Hossain, Jackson Ting Eng Swee, Grace Wong, M. Mohammadi, I. (2014). "Investigation on the Use of Crumb Rubber Concrete (CRC) for Rigid Pavements," Thesis submitted for fulfilment of requirements for the degree of Master of Engineering University of Technology Sydney.
- TMS 0302-07: Standard method for determining the sound transmission class rating for masonry walls.
- TMS 302-12: Standard method for determining the sound transmission class rating for masonry walls.
- Yang, Y. Chen, J. and Zhao, G. (2000). "Technical Advance on the Pyrolysis of Used Tires in China," Dept. of Chem. Eng., Zhejiang University YuQuan Campus, Hangzhou, 310027, P.R. CHINA.

## **EXPERIMENTAL STUDY ON THE PROPERTIES OF SORGHUM HUSK ASH PERVIOUS CONCRETE**

Tijani, M.A.<sup>1\*</sup>, Ajagbe, W.O.<sup>2</sup>, Olawale, S.O.A.<sup>1</sup>, Ganiyu, A.A.<sup>3</sup> and Agbede, O.A.<sup>2</sup>

<sup>1</sup>Department of Civil Engineering, Osun State University, Osogbo, Nigeria

<sup>2</sup>Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria

<sup>3</sup>Department of Civil Engineering and Quantity Surveying, Military Technological College,  
Muscat, Oman

Email of Corresponding Author: [murtadha.tijani@uniosun.edu.ng](mailto:murtadha.tijani@uniosun.edu.ng)

### **ABSTRACT**

Pervious concrete is an environmental friendly product for regulation of water runoff and contaminants from storms. This study focused on producing a more sustainable and ecofriendly granite pervious concrete with improved strength and hydraulic properties. A total of 54 cylindrical test specimens were cast to undergo density, compressive strength, porosity and permeability tests. Sorghum husk ash was added to replace cement at with varying percentages of 5, 10, 15, 20 and 25. The result shows that varying percentages of sorghum husk ash mix exhibit good hydraulic properties with acceptable strengths.

Keywords: Pervious concrete, sorghum husk ash, strength, hydraulic properties.

### **INTRODUCTION**

Pervious concrete is a special material with high permeability made by removing or reducing the amount of fine aggregate in the concrete composition (Tijani *et al.*, 2019 and Qin *et al.*, 2015). Its unique structure makes it not only have good air and water permeability but also have good ecological and environmental benefits such as heat island effect mitigation and noise reduction. According to ACI 522R (2010), pervious concrete permeability ranges from 1.4 mm/s to 12.2 mm/s along with moderate strength, 2.8 to 28MPa, and durability. Its application is commonly in parking lots, sidewalks, joggers' tracks, pathways and low-volume roads (Ajagbe *et al.*, 2018).

Husks of the large quantity of sorghum produced in Nigeria (6.55 million metric tons per year according to USDA, 2017) are mostly disposed-off by open air burning. Tijani *et al.* (2018a) stated that instead of irrational burning of sorghum husk that poses environmental hazards to the surroundings, appropriate burning of them will give up to 11% sorghum husk ash (SHA) content with good pozzolanic property. Pozzolanic materials are capable of reacting with the lime produced as by-product of hydration of Ordinary Portland Cement to produce additional Calcium Silicate Hydrate (C-S-H) thereby enhancing the compressive strength of the concrete whilst reducing the amount of cement required and the resulting CO<sub>2</sub> emissions (Tijani *et al.*, 2018a).

According to Joshaghani *et al.* (2015) and Chandrappa and Biligiri (2016), lack of adequate permeability of pervious concrete pavement has brought great negative effects on the urban ecological environment including waterlogging and traffic congestion. Thus, this research provides a way of improving the hydraulic properties (porosity and permeability) of granite pervious concrete at satisfactory strengths through the partial replacement of cement with sorghum husk for sustainability.

## MATERIALS AND METHODOLOGY

### Materials

Cement of grade 42.5R with specific gravity 3.15 which conform with the requirement of ASTM C150 (2016) was used for this study. Granite used was obtained from Irepodun Quarry, Awo, Osun State, Nigeria. A single sized granite aggregate with grain size of 4.75-9.50 mm (passed through the 9.50 mm sieve and retained on the 4.75 mm sieve) was adopted for pervious concrete production. The aggregate presented a bulk density, specific gravity and water absorption of 1559 kg/m<sup>3</sup>, 2.76 and 0.30 % respectively.

In addition, Sorghum Husk was collected from a local sorghum farm in Ogbomoso, Oyo State, Nigeria. The collected sample was burnt in an electric furnace at 700°C for 3 hours to obtain SHA. The chemical properties of SHA are shown in Table 1. Ordinary tap water was used for this study with a fixed water/cement ratio 0.4 for all mixes.

Table 1: Results chemical analysis of SHA

Chemical constituents	Percentage composition (%)
SiO <sub>2</sub>	55.34

Al <sub>2</sub> O <sub>3</sub>	10.08
Fe <sub>2</sub> O <sub>3</sub>	11.87
SO <sub>3</sub>	0.50
MgO	1.18
K <sub>2</sub> O	4.48
Na <sub>2</sub> O	0.71
CaO	10.44
SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub>	77.29
Loss on ignition	6.8
Specific gravity	2.1

### Methodology

The total of six mixes designed for SHA pervious concrete production consisted of a control (OPC) and five pervious concrete mixes containing SHA as cement replacement (5, 10, 15, 20 and 25PC). Table 2 shows the mix proportion adopted for the study. Pervious concrete samples were cast in plastic cylinder moulds (100 x 200 mm) to conduct porosity, permeability and compressive strength. Samples were compacted by filling in three layers using 25 drops of a 16mm diameter steel rod and 10 drops of a 2.5kg standard proctor hammer. The amount of water to cement was kept constant at 0.4 for all mixes. The mixture proportioning was based on the volume of paste required to bind aggregate together while maintaining a 20% void ratio. All samples were cured at room temperature in the lab for 24 hours after casting before being removed and cured in water for 7, 28 and 56 days. The result of each property tested is the average of at least three specimens.

**Table 2: Mix Proportions**

Mix	Rate	Cement (kg/m <sup>3</sup> )	SHA	Water (kg/m <sup>3</sup> )	Granite
	SHA		(kg/m <sup>3</sup> )		(kg/m <sup>3</sup> )



<b>0PC</b>	0	390.83	0	156.33	1563.40
<b>5PC</b>	5	371.29	19.54	156.33	1563.40
<b>10PC</b>	10	351.75	39.08	156.33	1563.40
<b>15PC</b>	15	332.21	58.63	156.33	1563.40
<b>20PC</b>	20	312.66	78.17	156.33	1563.40
<b>25PC</b>	25	293.12	97.71	156.33	1563.40

The compressive strength test was conducted at 7, 28 and 56 days in accordance with (ASTM: C39/C39M-15a 2015). The samples for compressive strength tests were dried at room temperature for about 2 hours before being crushed at a constant rate loading of 0.06 MPa/s in the machine.

The porosity of the pervious concrete samples was determined using ASTM C1754 (2012). The diameter and length of the sample were measured to obtain the total volume of the cylinder. The samples were weighed in both dry (A) and submerged conditions (B) and the void content was calculated using the following:

$$\text{Porosity \%} = \left[ 1 - \left( \frac{A-B}{\rho_w \text{Vol}} \right) \times 100\% \right]$$

Where:

A is the dry weight (g),

B is the weight under water (g),

Vol is the volume of sample (cm<sup>3</sup>) and

$\rho_w$  is the density of water at 21°C (kg/cm<sup>3</sup>).

A falling-head permeameter was used to measure the permeability of each sample. The following Darcy's law equation was used to determine coefficient of water permeability:

$$K = \frac{A_{tube} \times L}{A \times t} \times \ln \frac{h_1}{h_2}$$

Where:

K is the water permeability coefficient in mm/s

A and  $A_{tube}$  are the areas of the cross-sections of the sample and tube in mm<sup>2</sup>

L is the length of sample in mm

t is the time required for water to fall from an initial water level  $h_1$  (mm) to a final water level  $h_2$  (mm) in mm.

## RESULTS AND DISCUSSION

### Density of Pervious Concrete Mixes

Figure 1 presents the results of hardened density of pervious concrete at different replacement levels of SHA. It could be observed that hardened densities slightly decreased up to 3.2% as the amount of SHA addition increased from 0 to 25%. The decrease in densities with increase in the amount of SHA could be attributed to the lower specific gravity of SHA (2.1) than that of cement (3.15). However, the values of densities obtained were above 2000kg/m<sup>3</sup> specified by Tennis *et al.* (2004).

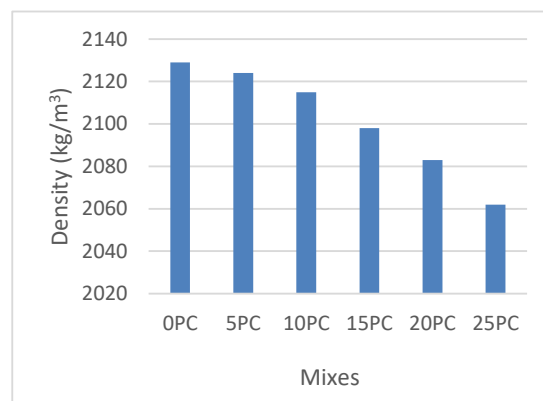


Figure 1. Density of Pervious Concrete Mixes

### Porosity and Permeability of Pervious Concrete Mixes

Figure 2 shows the porosity and permeability of SHA pervious concrete mixes. The figure shows that increase in the percentage SHA (from 0 to 25%) lead to increase in porosity (from 0.3 to 20.1%) and permeability (from 0.2 to 92.5%) of the mixes. The increase in porosity can be attributed to the high porosity of SHA particles. The water permeability increased as the amount of SHA increased, this may be due to increase in porosity of pervious concrete mixes. Tennis *et al.* (2004) showed similar results with typical permeability ranging from 2 to 12mm/s. Result of porosity is in agreement with Tijani *et al.* (2018b) and Subramanian *et al.* (2017).

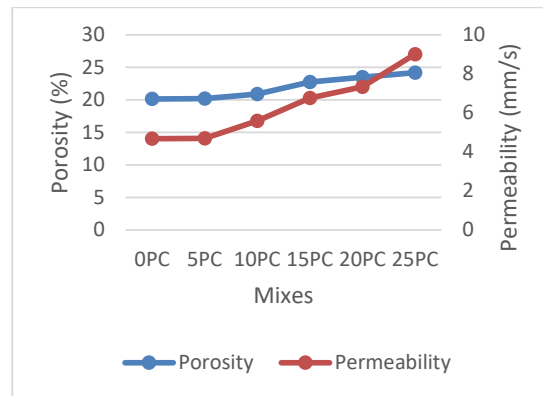


Figure 2. Porosity and Permeability of Pervious Concrete Mixes

### Compressive Strength of Pervious Concrete Mixes

The compressive strength pervious concrete mixes at 7, 28 and 56 days are presented in Figure 3. It could be seen that increase in number of days of curing leads to increase in strength. It could also be noticed that compressive strength increases from OPC to 5PC before it started to decline at 10, 15, 20 and 25PC respectively. This suggests 5PC as the best mix at all testing days. The rise in compressive strength at low level of SHA may be due to increased packing ability of the fine particles and pozzolanic reaction of SHA. At 28 days, the compressive strength of 5PC was 13.3% greater than control while that of 10, 15, 20 and 25PC reduced by 6.79, 23.52, 25.53 and 28.46% respectively.

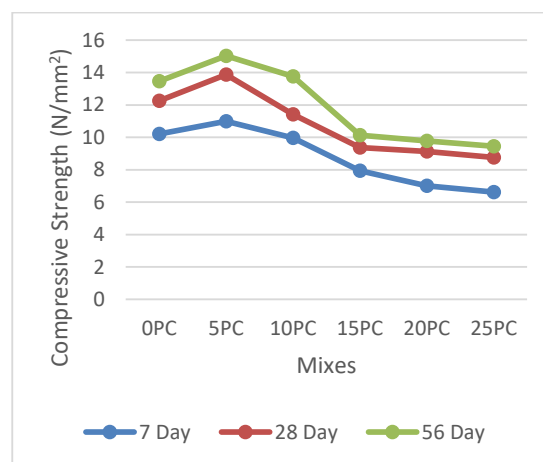


Figure 3. Compressive Strength of Pervious Concrete Mixes

Conversely, compressive strength of both 5 and 10PC were higher than the control at 56 days suggesting that more strength could be gained due to pozzolanic reaction at later age. However,

compressive strength of the six investigated mixes fulfilled the requirements of 2.8 to 28 N/mm<sup>2</sup> reported for pervious concrete by ACI522R (2010).

## **CONCLUSION**

The properties of a more sustainable and ecofriendly granite pervious concrete were investigated using sorghum husk ash to replace cement at varying percentages of 5, 10, 15, 20 and 25. The porosity and permeability increased slightly with increasing SHA. The compressive strength declined with increase in SHA level except for the 5% level that showed a noticeable increase, thereby suggesting that the best mix for strength is that of 5% level. Moreover, the 5 and 10% SHA substitutions were greater than the control mixture at 56 days signifying that further strength may be obtained owing to pozzolanic effect at future time. However, compressive strengths of all mixes were within the acceptable range reported for pervious concrete by American Concrete Institute. It is concluded that hydraulic properties (porosity and permeability) of granite pervious concrete can be improved with adequate strength through the partial replacement of cement with sorghum husk ash for environmental sustainability.

## **REFERENCES**

- ACI Committee 522, 2010. Report on pervious concrete. ACI522R. American Concrete Institute, Farmington Hills, Michigan.
- Ajagbe, W. O., Tijani, M. A. and Ganiyu, A. A. 2018. Adopting pervious concrete for stormwater management in Nigeria: An overview. Book of Abstracts, NCCAE2018 Conference, Sultan Qaboos University, Muscat, Oman, pp 65-66.
- ASTM C150/C150M, 2016. Standard Specification for Portland Cement. ASTM International, West Conshohocken, PA.
- ASTM Standard C1754/C1754M, 2012. Standard test method for density and void content of hardened pervious concrete, Annual Book of ASTM Standards, Vol. 09.49, ASTM International, West Conshohocken, PA.
- ASTM Standard C39/C39M, 2015. Standard test method for compressive strength of cylindrical concrete specimens, Annual Book of ASTM Standards, vol. 09.49, ASTM International, West Conshohocken, PA.

- Chandruppa, A. K. and Biligiri, K. P. 2016. Pervious concrete as a sustainable pavement material- Research findings and future prospects: a state-of-the-art review. *Construction and Building Materials*, 111, pp. 262-274.
- Joshaghani, A., Ramezani-pour, A. A., Ataei, O. and Golroo, A. 2015. Optimizing pervious concrete pavement mixture design by using the Taguchi method. *Construction and Building Materials*, 101, pp. 317-325.
- Qin, Y., Yang, H. Deng, Z. and Hi, J. 2015. Water permeability of pervious concrete is dependent on the applied pressure and testing methods. *Advances in Material Science and Engineering*, 404136, pp. 1-6.
- Subramanian, E. S., Govindarasu, P. and Shulamite, P. Q. 2017. Experimental investigation of mineral admixtures in pervious concrete *International Journal of Advance Engineering and Research Development* 4(1), pp. 166-168.
- Tennis, P. D., Leming, M. and Akers, D. 2004. Pervious concrete pavements, Portland Cement Association Skokie Illinois and National Ready Mixed Concrete Association, Silver Spring, Maryland.
- Tijani, M. A., Ajagbe, W. O. and Agbede, O. A. 2018a. Modelling the Effect of burning temperature and time on chemical composition of sorghum husk ash for optimum pozzolanic activity. *Journal of Engineering and Engineering Technology (FUTAJEET)* 12(2), pp. 273 – 281.
- Tijani, M. A., Ajagbe, W. O. and Agbede, O. A. 2018b. Recycling wastes for sustainable pervious concrete production. *Proceedings of the 17th National Conference of the Nigerian Institution of Environmental Engineers (NIEE)*, Ogba Lagos. pp. 1-7.
- Tijani, M. A., Ajagbe, W. O., Ganiyu, A. A. and Agbede, O. A. 2019. Effect of aggregate type on properties of pervious concrete. *Journal of Modern Technology and Engineering* 4(1), pp. 37 - 46
- United States Department of Agriculture (USDA) 2017. Nigeria now second world's leading producer of Sorghum. *Vanguard*, 28 September, 2017. Available at <https://www.vanguardngr.com/2017/09/nigeria-now-second-worlds-leading-producer-sorghum/> Assessed on 24/11/2017.

## **TRAFFIC ANALYSIS AT A MULTILEGED INTERSECTION IN OSUN STATE, NIGERIA**

Olawuyi, O.A.<sup>1\*</sup>, Busari, A.<sup>2</sup>, Akintayo, F.O.<sup>3</sup> and Ojagbule, T.E.<sup>1</sup>

<sup>1</sup>Department of Civil Engineering, Faculty of Engineering and Environmental Science,  
Osun State University, Osogbo, Osun State, Nigeria.

<sup>2</sup>Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria

<sup>3</sup>Department of Civil Engineering, University of Ibadan, Oyo State, Nigeria

\*Email of Corresponding Author: [oluwole.olawuyi@uniosun.edu.ng](mailto:oluwole.olawuyi@uniosun.edu.ng)

### **ABSTRACT**

The transportation system plays an important role in modern life throughout the universe; however, the undesirable myriad of traffic congestion has caused a number of problems in the society. This study aimed at evaluating the flow of traffic at Okefia intersection in Osun State. The present level of service was obtained to evaluate the road capacity. The traffic volume survey of the intersection was done using manual count procedure, volumes were taken at peak period of the day for 7 days at each approach, the peak hour factor was used to obtain the level of service. Approaches A and B were dual carriage with lane width of 7.3m each at both bound separated by a kerb, approaches C, D and E are single carriageways with road widths of 7.3m, 6.5m and 5.5 respectively. The average traffic volume counts for the 7 days at peak hour was 2632, 2517, 625, 3197 and 1694 veh/hr for approaches A,B,C,D, and E respectively. Therefore, the average peak hour factor at the intersection is 0.83 and this corresponds to an overall level of service (LOS) C. This LOS implied that there will be delay between 15.1 and 25.0 seconds per vehicle and thus witnessed longer cycle lengths and fair progression. In order to reduce congestion and to improve the road capacity there is need to build good parking facility and introduce traffic control system.

**Keywords:** Traffic Analysis, Level of Service, Intersection, Traffic flow, Traffic Volume.

### **INTRODUCTION**

Presently, our dependence on roads had resulted in rapid deterioration of the road network, affecting the economy, with goods and services being delayed. This in turn has resulted in high

transportation costs translating to high cost of goods and services, thus leading to a surge in not just the number of vehicles, but even motorcycles and other road transportation means. According to, Odeleye, 2008, the rate of vehicle ownership and use is growing faster than the population in many places, with the vehicle ownership growth rates increasing by 15 to 20 percent per year, which has made traffic management quite poor in many developing countries. This has led to increasing congestion on major highways, trunk B and trunk C roads.

The operation of an intersection is influenced by its capacity, queue length and delay, accident potential, vehicle operating characteristics and traffic control. (Garber and Hoel, 2009). It had long been recognized that intersections are the elements of the roadway system that experiences the greatest number and severity of crashes, at least one third and as much as one-half of all crashes occur at intersection. This is expected because different traffic streams meets and conflicts with each other. Various crashes also occur in intersections involving high-speed multilane divided highway and minor streets with two-way stop control. (Singh and Khubani, 2018).

Intersections may be classified by the number of road segments, traffic controls, and/or lane design. These intersections are being controlled by either signs or signals. (Garber and Hoel, 2009). An intersection that is non functional affects the flow of traffic which could in turn lead to congestion. (Ajibade and Mohammed, 2016). Congestion is an increase in traffic demand which exceeds the supply, it can also be said to be deficiency in traffic management at junctions, leading to queuing and increase in travel time.(Ogunbodede 2015). Road traffic congestion according to Godwin, (1997) can be defined as the impedance vehicles imposed on each other due to the speed flow relationship, in conditions where the use of transport system approaches its capacity.

Ogunsanya, (2002), conceptualized road traffic congestion as a situation where urban road network could no longer accommodate the volume of traffic on it. Traffic congestion is a growing problem in all forms of traffic facilities all over the globe (NAS, 2002). Repeated surveys in many countries of the world have revealed that the number of vehicles on highways keeps on increasing in volume; hence, the problem continues to persist (Hook, 2002)

It has equally created an artificial barrier to a cost-effective flow of goods and persons along our roads linking major town's together (Popoola *et al.* 2013). As various means of

transportation demand approaches the capacity of a road (or of the intersections along the road), extreme traffic congestion occurs, and can lead to drivers becoming frustrated.

Choice of geometric parameters that control and regulate the vehicle path through the intersection could ensure reduced congestion (Roger, 2003; Mohammed *et.al*, 2019)

Capacity analysis therefore involves the quantitative evaluation of the capability of a road section to carry traffic, and it uses a set of procedures to determine the maximum flow of traffic that a given section of highway will carry under prevailing roadway traffic and control conditions.

The capacity at a signalized intersection is given for each lane and is defined as the maximum rate of flow for the subject lane group that can go through the intersection under prevailing traffic, roadway, and signalized conditions. Capacity is given in vehicles per hour (veh/h) but is based on the flow during a peak 15-minute period. (Garber and Hoel, 2009)

Capacity therefore is applied meaningfully only to major movements or approaches of the intersection. As the interaction among vehicles increases, motorists are increasingly influenced by the actions of others. Individual drivers find it more difficult to achieve their desired speeds and perceive deterioration in the quality of flow as the density increases. (Garber and Hoel, 2009).

The level of operating performance changes with traffic density. The measure of quality of flow is the “level of service” (LOS), a qualitative measure, ranging from A to F, which characterizes both operational conditions within a traffic stream and highway users’ perception. The Highway Capacity Manual (HCM 2010). (LOS) expresses the performance of a highway at traffic volumes less than capacity.

Okefia intersection is a typical circular intersection that provides a circular traffic pattern at the central area of Osogbo, Osun state, Western Nigeria. This intersection exhibit a typical characteristic associated with various intersections such as congestion especially at peak hours. Moreover, it is noticeable that the demand for the road intersection usually exceeds the capacity of the intersection at that period, although roads are continually being created for the road transport system, they have far less capacity to contain the number of vehicles being used daily leading to road traffic congestion. These concerns often lead to the creation of more road networks to address such concerns. However, the continuous increase in the number of vehicles



renders this effort ineffective. The aim of this study is to assess the road capacity level at the intersection.

## MATERIALS AND METHODS

The studied area is a five leg intersection comprising of two dual carriageways, and 3 two lane single carriageway with roundabout as the conflict control at the intersection. The road map showing the study location is given in Figure 1.

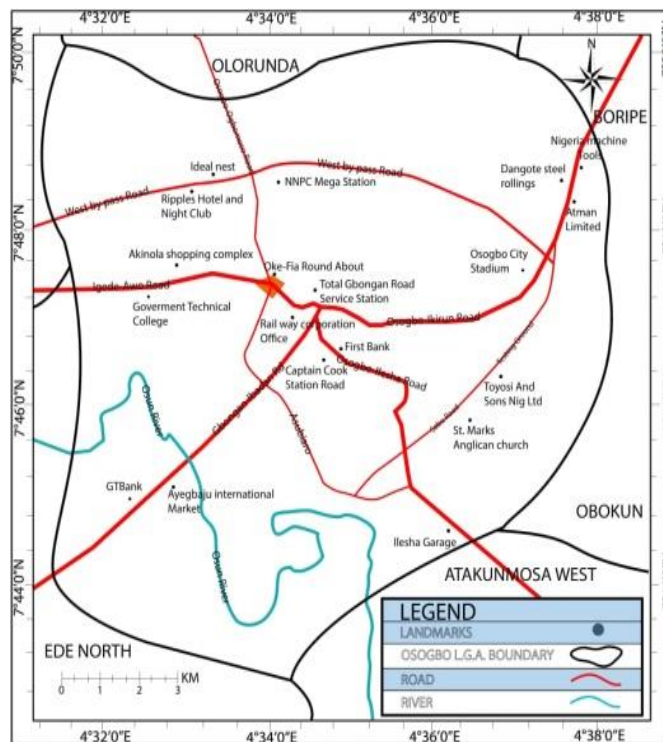


Fig 1. Road map showing Okefia Intersection

### Traffic Volume Studies

Manual counts was typically used to gather data for determination of vehicle classification, turning movements, direction of travel, pedestrian movements, or vehicle occupancy.

Traffic volume studies were conducted to collect data on the number of vehicles that passed the intersection at a specified period of 12 hours daily for seven (7) days. Vehicles were

recorded at 15 minutes interval. The data collected were classified into subclasses of various vehicle types. Traffic volume study conducted was used to estimate the volume characteristics needed.

### **Percentage Car Unit**

Percentage of car unit was calculated so as to present vehicles in terms of standard type of vehicle using certain conversion factors given in Table 1

**Table 1: PCU Values For Urban Roads**

<b>S/N</b>	<b>Types of Vehicle</b>	<b>Equivalency factor</b>
1	Passenger car, tempo, auto rickshaw and agricultural tractor.	1.00
2	Bus, truck and agricultural tractor-trailer unit.	3.00
3	Motor cycle, scooter, and peddle cycle.	0.50
4	Cycle rickshaw.	1.50
5	Horse drawn vehicles.	4.00

**Source:** IRC.(Ref. 2)

### **Volume and Delay Study**

The delay study was done using the stopped vehicles count survey following Overseas road note 11 (TRL, 1993). The number of stopped vehicles queuing on approaches to the road intersections was counted at an interval of fifteen seconds (15secs).

### Level of Service

The level of service (LOS) of the intersection was calculated based on Peak hour factor method

#### Peak Hour factor (PHF) method.

Peak-hour traffic volume was used to evaluate the capacity and other parameters of the road because it represented most critical time. This analysis of level of service was based on peak rates of flow of vehicle occurring within the peak hour because substantial short-term fluctuations typically occur during an hour. Common practice was to use a peak 15-minute rate of flow. But in this study the rate of flow was taken at 30 minutes interval. The relationship between the peak 15-minute flow rate and the full hourly volume was given by the peak-hour factor (PHF) as shown in the following equation (Authority, 2003, Abdulla *et.al.* 2018). Peak-hour factors in urban areas generally range between 0.80 and 0.98. Peak-hour factors over 0.95 are often indicative of high traffic volumes.

PHF was evaluated by the following formula

$$PHF = \frac{\text{Hourly volume}}{\text{Peak rate of flow within the hour}} \quad \text{Eqn 1}$$

$$PHF = V / [4 \times V_{15}] \quad \text{Eqn 2}$$

Therefore for 30 minute interval the

$$PHF = V / \{2 \times V/30\}$$

Table 2: LOS with respect to its PHF.

Peak Hour Factor Value	LOS
0.7 or less	A
0.8 or less	B
0.85 or less	C
0.90 or less	D
0.95 or less	E
>1 or less	F

Source: Authority 2003

## RESULTS AND DISCUSSION

Okefia intersection consists of five legs which includes: Approach A (Old garage road), Approach B (Ilobu road), Approach C (G.R.A road), Approach D (Alekuwodo road) and Approach E (Estate road) as presented in Figures 2 and 3. The road is a flexible pavement with no major pavement defect except for the some potholes at the roundabout area. Approaches D and E are dual carriageways with lane width of 7.3m at each bound separated by a kerb, approaches A, B and C are single carriage ways with a road width of 7.3m, 6.5m and 5.5 respectively



Fig 2. Okefia intersection view

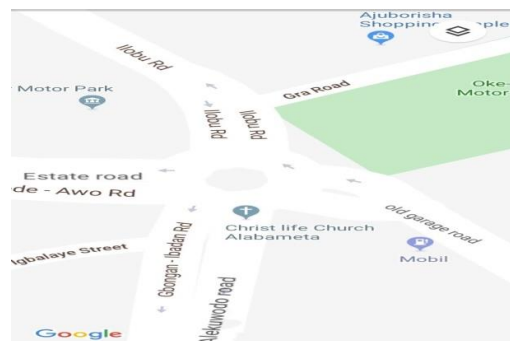


Fig 3. Okefia intersection

The volume count obtained from the traffic volume study showed that the intersection is a busy area with various vehicular flow. The vehicles plying the road are passenger cars, motorcycles, mini buses, coaster buses and two axle's trunk. The vehicular flow percentage is presented in

Figures 4, this shows that the mini-bus had the highest percentage of flow throughout the week while the two axles had the lowest.

The averages peak hour traffic volume counts for the 7 days was 2632, 2517, 625, 3197 and 1694 veh/hr for approach A, B, C, D, and E respectively.

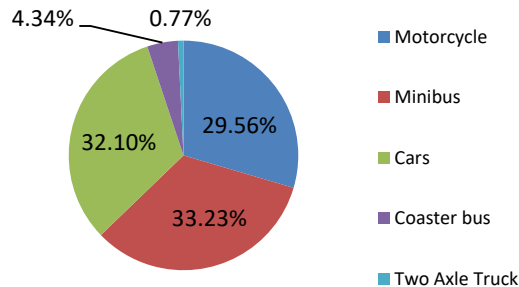


Fig.4. Percentage Vehicular flow from Monday – Sunday

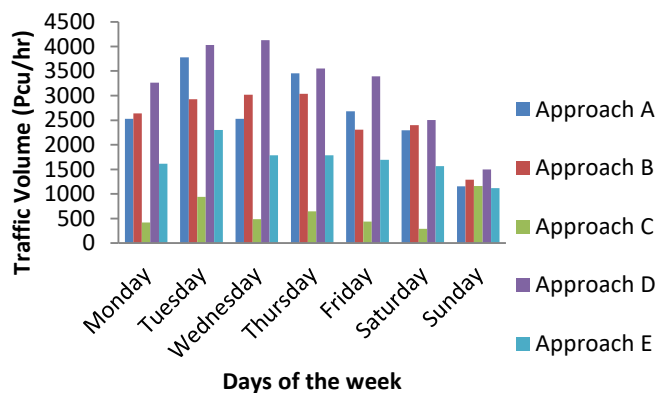


Table 5: Traffic volume showing flow for different classes of vehicle against the days of the week

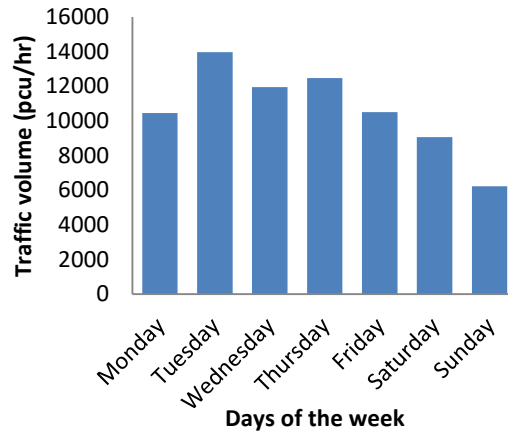


Fig.6. Total traffic volume count from Monday – Sunday

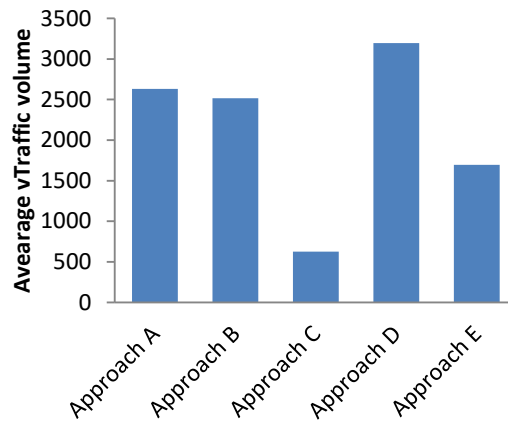


Fig.7. Average daily No. of vehicles per approach

Figure 7 shows that traffic distribution at each approach. Approach D apparently **had** the highest traffic volume which was due to the fact that it is a major approach for people returning home from their places of work to their various residences.

Furthermore, the traffic flow at approaches B and C had an average peak hour factor of 0.71 and 0.74 respectively and therefore made the level of service to be B. Approaches D and E, both had peak hour factor of 0.89 which put the level of service to correspond to LOS D. Approach A traffic flow **had** a peak hour factor of 0.95 which made the road to be operating at LOS E, this approach was the busiest due to the fact that the road is a single carriageway with a road width of 7m and most cars parked along the road width. This roads also leads to various commercial centres such as banks, e.t.c.

## **Conclusion**

In summary, traffic volume counts and analysis was done at Okefia intersection being one of the major intersections in Osogbo, Osun State. its multi-legged junction with 5 connecting roads and a roundabout at the intersection.

The road has two dual carriageways and 3 single carriageways. Approach A did not have parking space thereby the road capacity, thereby accounting for the level of service of the road. The averages the average peak hour factor at for intersection was 0.83 and this corresponds to level of service (LOS) at the intersection to be C (Authority, 2003)

This implies that will be delays between 15.1 and 25.0 seconds per vehicle. This LOS showed longer cycle lengths and fair progression. (HCM, 2000).

Properly built parking management and traffic control system should be introduced to increase the capacity of road and thus decrease road congestion at the intersection.

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## **REFERENCES**

Abdulla, A., Lamia F., Saleha , A.P., Mahmud, A., Sherazum, M., Shazzu, R., Nashid, R., Farzana, A., Farhana, M., Tofael, A, Nahid A.K., Hossain, M. and Nazia, H. (2018). Estimating Traffic Volume to Identify the Level of Service in Major Intersections of Rajshahi, Bangladesh Volume 2 - Issue 4

*Ajibade, M.and Mohammed, H. (2016). Operational Performance Evaluation of Post Office – Teaching Hospital road, Ile - Ife, Nigeria. Civil and Environmental Research, 8(7), 18–27.*

[Authority, SCCT \(2003\) Traffic Level of Service Analysis Guidelines.](#)

*Garber, N. J. and Hoel,L. A., (2010) “Waste tyre rubber in asphalt pavement modification,” Materials Research Innovations, vol. 18, no. S6, pp. S6-6, 2014*

*Highway Capacity Manual. TRB, (2010) National Research Council, Washington, D.C,5<sup>th</sup> Edition*

*Hook P. (2002), Go with the flow, Traffic technology International, Aug/Sept. Edition, pp. 72-73.*

*Mohammed, H, Oyebode I. A and OyefesoB.D. (2019) Operational evaluation of Obafemi Awolowo university Main gate–ede road intersection, Proceedings of the OAU Faculty of Technology Conference 2019 pp 261-165*

- National Academy of Science (NAS). (2002), Capacity of Interchange Ramp Terminals, Retired 3<sup>rd</sup> January 2004 form*  
<http://www.nap.edu/openbook/ucho12html/1.html>.
- Nelson, L.J. (2002), aught Red Handed, Traffic Technology Internal Aug/Sept. Edition, pp. 46-48*
- Odeleye , J. A. (2008): A Study of Road Traffic Congestion in selected Corridors of Metropolitan Lagos, Nigeria. Unpublished Ph.D. Thesis, University of Lagos, Nigeria,*
- Ogunbodede, E.F (2015), Assessment of Traffic Congestion in Akure (Nigerian) Using GIS Approach: Lessons and Challenges for Urban Substances.*
- Ogunsanya A.A (2002) Maker and Breakers of Cities.59th Inaugural Lecture, University of Ilorin.*
- Popoola, M.O. Abiola, S.O. and Adeniji, W.A (2013), “Traffic Congestion on Roads in Nigeria Causes, Effects and Remedies”. Vol. 10, No 5, pp. 25 – 37.*
- Roger, M. (2003).Highway Engineering (1st ed.).USA: Blackwell Publishing.*
- Singh, S.K and Khubani,P. (2018) “Traffic Analysis of Grade Intersections and Measures of Congestion Mitigation at Indore”, Pyrex Journal of Engineering and Manufacturing Technology Vol 3 (2) pp.10-19*
- Tom, V. Mathew, and K V Krisha Rao (2007),Introductionto Transportation Engineering.*
- Transportation Research Laboratory, TRL, (1993), Urban Road Traffic Survey: Overseas Road, Note11, Transportation Research Laboratory, United Kingdom.*



## **AN ASSESSMENT OF URBAN HOUSEHOLD OUTDOOR RECREATIONAL BEHAVIOURS IN OSOGBO, OSUN STATE, NIGERIA**

Adedotun, S.B., Yakubu, D.A., Ajayi, O.A., Adedotun, D.O. and Tewogbade, M.

Department of Urban and Regional Planning,  
Faculty of Engineering and Environmental Sciences,

Osun State University, Osogbo

[Samuel.adedotun@uniosun.edu.ng](mailto:Samuel.adedotun@uniosun.edu.ng)

### **ABSTRACT**

This paper discusses urban households' outdoor recreational behaviours in Osogbo, Osun State, Nigeria. The study assesses the socio economic characteristics of residents, the factors that affect participation of households in recreation activities, the level of participation in outdoor recreation activities and the type of recreation the people engage in. Two set of data were collected for the study. A sample size of 0.19% (262) of the total household population (83816) in the selected neighbourhoods was used for questionnaire administration in a random systematic order. Another one hundred and five (105) samples were accidentally made at the visited recreational centers. Data collected was analyzed using descriptive and inferential statistical techniques. The result reveals gender and household size as the major socio economic characteristics that affect level of participation of residents in outdoor recreation activities. On the other hand, work schedule and interest in outdoor recreation activities are the major factors hindering regular participation in outdoor recreation. Addressing these hindrances, well landscaped open arena relaxation centres should be built in different part of the city, the elderly ones should be taken into consideration when designing recreational facilities and people should be enlightened on the benefit and importance of outdoor recreation in order to encourage more participation in outdoor recreation activities in the study area.

**Keywords:** *Recreation, Outdoor recreation, Behaviour, Household, Osogbo.*

## **INTRODUCTION**

Recreation is an activity in which an individual or group of persons engages by choice to derive personal satisfaction in terms of relaxation, entertainment, personal development and well-being (Barde, 2005). Recreation is multifaceted activity that involves exercises of physical, cognitive, mental, emotional and social interaction which could be a means of achieving family togetherness or pursuing interesting hobbies, social activities or a place of growth and development for all ages (Broadhurst, 2001). Recreation provides urban residents with a refreshing break from the monotonous city life by providing opportunities to socialize and pursue hobbies that are source of joy and relaxation to the body and mind.

Recreational activities can be classified into indoor and outdoor recreation. Indoor recreation can be referred to as the activities that take place on the comfort of one's home or more specifically indoor and they are to recreate the mind and soul which include listening to music, reading, gardening, watching television, playing indoor games like play station, dancing. Outdoor recreation on the other hand can be referred to as the leisure pursuits engaged in the outdoors, often in natural or semi-natural settings out of town and it includes visiting arts galleries, exhibitions, museums, theatres, jogging, running, camping, fishing, cycling, rock climbing, tennis, picnicking, sightseeing, driving for pleasure (Curry & Brown, 2010). Outdoor recreation touches all aspects of health and can enhance not only physical health but also emotional well-being.

### **Literature review**

Recreation is as old as man and everybody needs it. This is due to its vast and fundamental importance. According to Zuowei (2014), recreation is the expenditure of time with the intent to gain some refreshment. It is a break from monotony and a diversion from the daily routine. It is a positive change from the stereotypical lifestyle and involves an active participation in some entertaining activity.

Recreation is an activity in which an individual or group of persons engages by choice to derive personal satisfaction in terms of relaxation, entertainment, personal development and well-being (Barde, 2005).

Behaviour in relation to recreation is the way an individual acts towards the use of their leisure time. (Wilma & John, 2000). Recreational behaviour reflect the ways in which people of different social status compose themselves during leisure time and respond to their recreational needs in terms of their inclination towards certain recreational areas, and recreational activities

(Sulyman & Iorliam, 2016). This is central to sustainable outdoor recreational planning. This is because according to Zandersen and Tol (2008), understanding recreational behaviour of the residents of different socio-economic strata ensures the development of only desirable recreation infrastructure in the communities that are adequate and can be maximally utilized by all residents.

Root causes of behaviour differences are individual differences, differences in family patterns, impairment/disabilities, environmental factors, psychological factors. The key aspects of individual difference include sex differences, intellectual differences, physical differences, personal and emotional differences. However personal and emotional difference is the root cause that affects human behaviour towards outdoor recreation because people differ in interests, ability, aspirations, belief, attitudes and other personality traits (Wilma & John, 2000). Differences in family patterns is another root cause that highly affects human behaviour i.e. socio economic status of the family (Wilma & John, 2000).

### **Study Area**

Osogbo, the capital city of Osun State is located between latitudes 7°49'39.95" and 7°43'57.62" North of the equator, and longitude 4°28'12.47" and 4°38'30.53" East of the Greenwich Meridian. It comprises of both Osogbo and Olorunda Local Governments and part of Egbedore Local Government. National Population Commission of Nigeria (National Population Commission, 2006) put the population at 287,156 with total land area of 47kmsq.

### **Methodology**

Primary and secondary data were used for this study. Primary data were derived through personal observation and the administration of two set of questionnaires to households in their residents and at the recreational centers. The sample size of 0.19% (157) of the total households' population (82,812) in the selected areas was used for questionnaire administration.

In each zone, the streets selected were chosen randomly while random systematic sampling techniques was employed to select each housing unit in one of every 20<sup>th</sup> building where head of the households were selected for questionnaire administration. On the other hand 105 respondents were accidentally sampled at the variously identified outdoor recreation centres across the city.

The descriptive techniques such as percentages, frequency tables, cross-tabulations (with

Chi-square test) and means were used to describe the extent to which the Socio-economic Characteristics of the households can be used to explain their involvement in outdoor recreational activities in Osogbo. Multiple Regression Analysis was employed to test the assumption that there is no relationship between the socio-economic characteristics of the households and their participation in outdoor recreation activities.

### **Findings and Discussion**

The study provided an understanding of household's behaviour towards outdoor recreation activities in Osogbo, Nigeria. Data on household's socio-economic characteristics and their outdoor recreational behaviour were obtained from 157 households in their residents and 105 respondents from various recreational centers across the city of Osogbo. Five elements of socio-economic characteristics considered are: gender, age, marital status, monthly income, and household size.

Factors influencing outdoor recreation participation by the households discussed in this paper are: Time, finance, work schedule, interest, distance, entrance fee and physical disability. Periods of recreation and nature of outdoor recreation activities people engage in were equally discussed.

#### **Gender and level of participation in outdoor recreation activities**

Table 1 shows the relationship between gender of respondents in Osogbo and their involvement in outdoor recreation. The study indicates that 49% of the respondents are male while the remaining 51% are female and 78% of male respondents participate in outdoor recreation while 31% of female respondents participate in outdoor recreation activities. Also 70.6% of the respondents that participate in outdoor recreation are male and the remaining 29.4% are female.

The analysis however reveals that male respondents are more involved in outdoor recreation activities compared to their female counterpart. The variation could be as a result of female's domestic responsibilities and also females in most cases are under the control of their husbands and thereby engaged more in indoor recreation activities, such as watching television and playing of Ludo game.

**Table 1: Gender and level of participation in outdoor recreation activities**

Gender	Participation in outdoor recreation		Total
	Yes	No	
Male	60	17	77
Female	25	55	80
Total	85	72	157

Source: Author's Field Survey, July, 2018.

**Age and level of participation in outdoor recreation activities**

Age is another socio economic characteristic considered in this study. Table 2 indicates that 9.4% of the respondents that engage in outdoor recreation activities falls between the ages below 18 years, 40% of the respondents that participate in outdoor recreation falls between the ages of 18 to 30 years while 45.9% and 5.9% of the respondents who participate in outdoor recreation falls between the ages of 31 to 50 years and 51 and above respectively. The study reveals that respondents in active age (18-50) are more involved in outdoor recreation activities.

**Table 2: Age and level of participation of outdoor recreation activities**

Age	Participation in outdoor recreation		Total
	Yes	No	
Below 18	8	2	10
18- 30	34	25	59
31- 50	39	36	75
51 & above	5	8	13
Total	85	72	157

Source: Author's Field Survey, July, 2018.

**Marital Status and level of participation in outdoor recreation activities**

The study also reveals the relationship between marital status of respondents and their involvement in outdoor recreation activities. The table 3 indicates that 62.4% of the respondents that involves in outdoor recreations are married while 36.5% are single. This is a

confirmation of the assertion that married people do take out their families on outdoor recreation most especially during festivals.

**Table 3: Marital Status and level of participation in outdoor recreation activities**

Marital status	Participation in Outdoor Recreation		Total
	Yes	No	
Single	31	22	53
Married	53	44	97
Widow(er)	1	6	7
Total	85	72	157

Source: Author's Field Survey, July, 2

**Monthly income and level of participation in outdoor recreation activities**

Table 4 shows the relationship between respondent's level of income and their involvement in outdoor recreation activities. The study however, indicates that 38.5% of the respondents that earn below 20,000 per month participate in outdoor recreation activities, 61% of the respondents that earns 21,000 to 40,000 recreates followed by 54.2% of the respondents that earn 41,000 to 60,000 naira per month. In addition, 80% of respondents within the income group of 61,000 to 80,000 per month do involve in outdoor recreation and about 78% and 31% of respondents with average income of 81,000 to 100,000 and 101,000 and above respectively participates in outdoor recreation activities.

The analysis however shows that monthly income of households' influences their involvement in outdoor recreation activities.

**Table 4: Monthly income and involvement in outdoor recreation activities**

Level Of Income	Participation in Outdoor Recreation		Total
	Yes	No	
Below 20,000	10	16	26
21,000- 40,000	25	21	41

41,000- 60,000	13	11	24
61,000- 80,000	20	5	25
81,000- 100,000	7	2	9
101,000 above	10	22	32
Total	85	72	157

Source: Author's Field Survey, July, 2018.

### Household size and level of participation in outdoor recreation activities

Household size could determine one's involvement in outdoor recreation activities. Table 5 shows that 81.5% of the respondents with family size between 1 to 3 participates in outdoor recreation activities, 56% and 33.3% of the respondents with household size between 4 to 6 and 7 to 10 respectively participates in outdoor recreation activities. The study reveals that respondents with fewer household sizes do participate more in outdoor recreation activities when compared with household with large size.

**Table 5: Household size and level of participation in outdoor recreation activities**

Household Size	Participation In Outdoor Recreation		Total
	Yes	No	
1-3	22	5	27
4-6	47	37	84
7-10	15	30	45
11 & Above	1	0	1
Total	85	72	157

Source: Author's Field Survey, July, 2018.

### Relationship between Respondent's Socio Economic Characteristics and Level of Participation in Outdoor Recreation Activities

The hypothesis was formulated to examine the relationship between household's socio economic characteristics and level of their participation in outdoor recreation activities. The

result of multiple linear regression model used in analyzing the relationship between the variables is summarized in Table 6, 7 and 8.

Table 6: Regression model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.570 <sup>a</sup>	.325	.279	.424

a. Predictors: (Constant), Household Size, Gender, Religion, Occupation, Marital Status, Level Of Income, Educational Status, Age

**Table 7: Test of Statistical Significance (ANOVA)**

Model	Sum of Squares	Df	Mean Square	F	Significance
Regression	10.270	8	1.284	7.156	.000 <sup>b</sup>
Residual	21.348	119	.179		
Total	31.617	127			

Source: Author's Field Survey, July, 2018.

a. Dependent Variable: Do you participate in outdoor recreation



b. Predictors: (Constant), Household Size ,  
Gender, Marital Status, Income, Age

Source: Author’s Field Survey, July, 2018.

From Table 6 the R – squared statistic indicates that about 32.5% of the variability in level of participation is explained by the level of socio economic characteristics of residents. The analysis of variance of the relationship between household’s socio economic characteristics and level of participation in table 7 shows that the F- ratio is 7.156 and a P-value of .000, which indicates that relationship between socio-economic characteristics of households and their level of participation in outdoor recreation activities are statistically significant.

**Table 8: Regression Coefficients**

Model	Model	Unstandardi	Standardiz	T	Si
	B	zed	ed		
		zed	ed		
		Coefficients	Coefficient		g.
		Std. Error	s		
			Beta		
(Constant)	.883	.511		1.726	.087
Gender	.386	.081	.388	4.791	.000
Age	.016	.087	.019	.182	.856
Marital status	.026	.078	.035	.338	.736
Level of income	-.025	.031	-.077	-.790	.431
Household size	.166	.069	.227	2.422	.017

a. Dependent Variable: Do you participate in outdoor recreation P<0.05

Source: Author’s Field Survey, July, 2018.

In addition, table 8 shows that gender and household size are statistically significant in household participation in outdoor recreation activities while other variables such as age, marital status and level of income are influential but not statistically significant.

**Factors that Affects Regular Participation in Outdoor Recreation Activities**

Table 9: Factors that Affects Regular Participation in Outdoor Recreation Activities

Factors	Frequency	Percentage (%)
Time	30	19.1
Finance	20	12.7
Work schedule	38	24.2
Interest	34	21.7
Distance	8	5.1
Entrance fee	2	1.3
Physical disability	4	2.5
Total	136	100

Source: Author's Field Survey, July, 2018.

Table 9 shows the factors that affects regular participation in outdoor recreation activities. The table reveals that work schedule and interest obtains the highest percentage among the factors that hinders regular participation in outdoor recreation with 24.2% and 21.7% respectively.

**Table 10: The Period of Recreation**

Time	Frequency (%)		
	Weekdays	Weekend	Festive period
8-11am	4 (3.8%)	12 (11.4%)	2 (1.9%)
12-4pm	6 (5.7%)	11 (10.5%)	6 (5.7%)
5-9pm	7 (6.7%)	50 (47.6%)	6 (5.7%)
Full day	—	1 (1%)	—
Total	17 (16.2%)	74 (70.5%)	14 (13.3%)
	105 (100%)		

Source: Author's Field Survey, July, 2018.

The table 10 shows that majority (60%) of respondents participates in the evening outdoor recreational activities. Others (40%) opined that they use day to enjoy their outdoor recreations. Table 10 also reveals that 70.5% participate in outdoor recreation during the weekends, 16.2% use week days while the other 13.3% only recreate during the festival period such as Christmas and EidKabir.

**Table 11: The Type of Outdoor Recreation Activities People Engage In**

Option	Frequency	Average time spent	Percentage (%)
Swimming	10	1-3hours	12.3%
Drinking and dancing	8	3-5 hours	9.9%
Relaxing and drinking	20	1-3 hours	24.7%
Games	3	4-6 hours	3.7%
Picnic	2	2- 4 hours	2.5%
Jogging	3	1-3hours	3.7%
Physical fitness (gym)	2	1-3 hours	2.5%
Playing football	6	1-4 hours	7.4%
Relaxing	20	1-3 hours	24.7%
Playing at the park	7	1-3hours	8.6%
Total	81	—	100%

Source: Author's Field Survey, July, 2018.

Table 11 shows the types of outdoor recreation activities of the respondents which include relaxing and drinking and relaxing either at the bar or pool side (49.4%). This is followed by the respondents that engage in swimming (12.3%). Other outdoor recreation activities are as enumerated in Table 11.

### Summary and Conclusion

The study reveals that socio economic characteristics of respondents have significant influence on the households' involvement in outdoor recreation activities. Gender and household size are the two socio- economic variables that statistically impacts households' participation in outdoor recreations. The analysis also indicates that work schedule and individual interest are the major factors that hinder regular participation in outdoor recreation activities in the study area. Most of the outdoor recreation activities in Osogbo are carried out during the weekends and mostly in the evening between 5 and 9 pm. The commonest types of outdoor recreation in the study area are majorly bar, club house and pools.

Based on the findings people should be enlightened on the benefit and importance of outdoor recreation and emphasis must be made on the fact that it is not only men that needs to recreate rather both sexes need to engage in outdoor recreation regularly.

### REFERENCE

Adedotun, S. (2016). *Urban Form And Household's Mobility Patterns In Osun State, Nigeria.*

Akogun, J. (2006). *Community Knowledge and Use of Existing Recreational Facilities in Bida, Niger State, Nigeria.* Ekiti: An Unpublished Master's Thesis, University of Ado-Ekiti, Ado-Ekiti, Nigeria.

Austin, D. (2003). *Therapeutic Recreation: Processes and Techniques. Champaign, II: Sagamore publishing* , 181.

Barde, J. D. (2005). *Planning for recreation in Gombe.* Zaria.

Bob, D. L., Alan, G., & Roberts, B. (2006). AN EXPLORATORY STUDY OF THE OUTDOOR RECREATION PARTICIPATION OF FAMILIES WHO HAVE A CHILD UNDER SIXTEEN. *Northeastern Recreation Research Symposium* .

Broadhurst, R. (2001). *Managing Environments for Leisure and Recreation.* London: GBR: Routledge.

Curry, N., & Brown, K. (2010). *Differentiating Outdoor Recreation.*

Government, Q. (2009). *what is outdoor recreation* . Retrieved 2018, from <http://www.qorf.org.au>

Hinch, T., & Higham, J. (2001). Sport tourism: a framework for research. *International Journal of Tourism Research* , 45-58.

Horning, E. (2005). Bring family back to the park. *Parks and Recreation* , 40(7): 47-50.

Kara, F., & Demirci, A. (2010). An assessment of outdoor recreational behaviors and preferences of the residents in Istanbul. *Scientific Research and Essay* , Vol. 5 (1), 93-94.

Kara, F., & Demirci, A. (2010). An assessment of outdoor recreational behaviors and preferences of the residents in Istanbul. *Scientific Research and Essay* , 93-94.

Landon, E., & Locander, W. (2009). *Acrwebsite.* Retrieved from [www.acrwebsite.org/volumes/display.asp?id=9546](http://www.acrwebsite.org/volumes/display.asp?id=9546)

National Bureau of Statistics. (2012). *Annual ABSTRACT of Statistics.*

National Population Commission. (2006). *National Population Census of the Federal Republic of Nigeria.* Abuja.

Oak, M. (2010). *List of Different Recreational Activities*. Retrieved from <http://www.buzzle.com/articles/listofdifferentrecreationactivities.html>.

Obateru, O. (2003). *Space Standard for Urban Development*. penthouse Nigeria Ltd.

Obinna, V., Owei, O., Ayodele, A., & Okwakpam, I. (2009). *PATTERNS AND DETERMINANTS OF RECREATIONAL BEHAVIOUR IN PORT HARCOURT. RIVER STATE*.

Ononogbo, K. (2014). *ASSESSMENT OF RESIDENTS' ATTITUDES TOWARDS RECREATION IN BIDA-NIGERIA*. Zaria.

Parks, C. S. (2005). *The Health and Social Benefits of Recreation*.

Ramesh, G., Gary, T., Neelam, C., Poudyal, H., & Cordel, K. (2014). Do outdoor recreation participants place their lands in conservation easements. *Nature Conservation* 9 , 1-18.

Razack, A., T.A, N., Martins, V., & Bello, L. (2013). An Assessment of Preference and Behaviour of Minna City Dwellers to Outdoor Recreation. *International Journal of Humanities and Social Science Invention* , 17.

Roberts, I. (2001). *Advanced leisure and recreation*. Oxford: Heinemann.

Suleiman, A. (2004). *Understanding Recreation, Leisure and Tourism Practices in Nigeria*. Zaria: Ahmadu Bello University Press.

Sulyman, A., & Iorliam, S. (2016). Outdoor Recreational Behaviour and Preferences of Abuja Residents, Nigeria. *Ethiopian Journal of Environmental Studies and Management* , 579-592.

Tim, K. (2005). Outdoor Recreation Participation Survey Of Minnesotans.

Umoru, T. (2003). *Basic Research Methods: Competencies and Application (2nd ed.)*. Lokoja: Gloti Publishers.

Wikipedia. (2017). *Wikipedia*. Retrieved December 21, 2017, from wikipedia Web site: <https://en.m.wikipedia.org>

Wilma, G., & John, A. (2000). Behaviour Modification. *Regional Training Seminar on Guidance and Counselling* .

Zandersen, M. &. (2008). A Meta-analysis of Forest Recreation. *Journal of Forestry Economics* , 52-74.

Zuwei, .. (2014). *AN ASSESSMENT OF PARTICIPATION IN OUTDOOR RECREATION ACTIVITIES IN YENAGOA TOWN*. Zaria.

Zuwei, D. (2014). *AN ASSESSMENT OF PARTICIPATION IN OUTDOOR RECREATION ACTIVITIES IN YENAGOA TOWN*. Zaria.

## **REDEFINING THE SCALE OF ENVIRONMENTAL POLLUTION IN NIGERIA USING SUSTAINABLE DEVELOPMENT GOALS**

Gbadegesin, O.A.

Department of Public and International Law, College of law, Osun State University, Osun State. [opeyemigbadegesin84@gmail.com](mailto:opeyemigbadegesin84@gmail.com)

### **ABSTRACT**

The current technological growth being witnessed around the globe tends to put the environment at great risk thereby defeating the main aim of sustainable development. To reduce this negative impact on the environment, there is the need for effective legislation. The goal of this paper is to see how the scale of environmental pollution can be redefined in Nigeria by incorporating the 2030 Sustainable Development Goals particularly Goals 6, 7,13,14,15;17 into our existing and future environmental legislation. A review of existing environmental legislation was done to assess the current level of impact and as a way of improvement infuse the objectives of the itemized goals into these laws with a view to achieve maximum impact on addressing the current trajectory of environmental pollution in Nigeria. Environmental pollution in Nigeria has continued unabated despite several legislation targeted at reducing the negative impact of Man's interaction with the environment. The reviewed laws advocate a holistic change which is yet to be fully achieved till date despite several attempts and strategies by successive governments to implement fully the letters of the law. A step by step approach as advocated by the 2030 goals if infused into environmental legislation will enable proper monitoring and allow for effective implementation in phases which will culminate in achieving the overall target of reducing the negative impact of man's activities on the environment by the year 2030.

**Key Words:** Technology, Sustainable Development Goals, Legislation, Nigeria.

## **Introduction**

Environmental pollution has continued to generate unpleasant challenges for health and economic development in Nigeria (Akintayo and Akinbola 2012). A plethora of environmental laws and policies targeted at solving these environmental issues have been enacted with a view to safe guarding the environment both for the present and future generations. The situation however does not seem to abate and this has been traced to the proper enforcement of these laws. The issue continues to degenerate with no visible solution in sight.

According to Olatunbosun (2016), ensuring a sustainable use of the environment is one of the focus of the 2030 Sustainable Development Goals. The Sustainable Development Goals (SDGs) otherwise known as the Global Goals are a universal call to action to end poverty, protect the environment and ensure that all people enjoy peace and prosperity. The concept of the SDGs was raised for the first time at the United Nations Conference on Sustainable Development in 2012. One of the objectives was to produce a set of universally applicable goals that will balance the three dimensions of sustainable development, that is, environmental, social, and economic. The SDGs are a set of 17 global goals with 169 targets between them. The programme aims to guide policy and funding for the next 15 years, that is, 2015 to 2030 and beginning with a significant undertaking to end poverty everywhere permanently. The focus of this paper is to attempt to investigate if the integration of the 2030 sustainable development goals into existing and future environmental legislation will spur a drive to reduce the impact of pollution on the environment. To achieve this goal, the paper will adopt the doctrinal approach to research. The primary source of data are the various legislation as it relates to environmental pollution activities. Secondary data that will be considered include books, journals, articles etc.

This paper is divided into four sections. Section one examines the definitions of key terms which will help to sharpen the focus and streamline the discussion in the paper. Section two discusses the various environmental protection laws in Nigeria. The third section looks at the aims of sustainable goals 6,7,13,14,15,17 and the benefits of integrating them into existing and future legislation towards reducing environmental pollution in Nigeria. The fourth section recommends strategies that can be adopted to ensure that the integration produces the desired the result of reducing the scale of environmental pollution in Nigeria.



## **Clarification of Concepts**

### ***Environmental Pollution***

Section 37 of the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act 2007 defines “Pollution” as any man-made or man aided alteration of chemical, physical or biological quality of the environment beyond acceptable limits and pollutants shall be construed accordingly.” It can thus be inferred from this definition that any human intervention which affects the natural state of the environment to such an extent that the society finds it unacceptable, qualifies as pollution (. It is clear that the law does recognize that in our modern industrial society especially with the technological advancements being witnessed pollution of some kind or to some degree is inevitable. What is objectionable and intolerable however is that it does not exceed certain limits where it would pose hazardous and deleterious effect on man and his surroundings (Okonkwo,2005).

The impact of man’s activities without considering potential consequences have resulted in a lot of environmental disasters throughout the world. Environmental Pollution can therefore be summarized as any discharge of material or energy into water, land, or air that causes or may cause an ecological imbalance or that lowers the quality of life either on a short or long term.

The following are the common types of pollution perceived in our environment:

- Water pollution; Water is an essential factor in environmental sustainance, can be polluted through various means. Oil operations contribute greatly to the pollution of water resources when produce water and other pollutants are discharged into the ocean, rivers, streams and lakes. Water pollution also occurs through the indiscriminate deposit or dumping of waste products such as like mud, sand or silt.
- Land pollution; Land pollution is the degradation of the earth's land surface through misuse of the soil by poor agricultural practices, mineral exploitation, industrial waste dumping, and indiscriminate disposal of urban wastes.
- Air pollution; Air pollution is caused by the emission of a variety of harmful gases into the atmosphere thereby altering its natural state and posing danger to the environment. In the oil industry, the continued flaring of associated gas has contributed immensely to the pollution of our atmosphere. Increased vehicular activities in our urban dwellings have contributed equally

to air pollution through the emission of carbon dioxide and other gases. Indiscriminate burning in our various localities including markets, abattoirs and refuse dump sites have all been identified as sources of air pollution.

- Noise pollution; this type of pollution is now a common occurrence in urban areas where commercial and industrial activities are part of everyday life. Causes of noise pollution include: excessive music from variety of sources advertising their wares or products, especially cassette and CD traders, excessive noise and sound emanating from a variety of churches and prayer houses in the course of worshipping, excessive domestic noise emanating from social and cultural activities like burials, concerts, bazaars, wedding ceremonies etc.

#### Sustainable Development Goals

The Sustainable Development Goals (SDGs), the centerpiece of the 2030 Agenda for Sustainable Development, were adopted by the United Nations Sustainable Development Summit in September 2015(Olatunbosun,2016). The SDGs are a build upon the expired Millennium Development Goals (MDGs): eight targets which guided global action on the reduction of extreme poverty in its multiple dimensions from 2000-2015. While the MDGs only applied to developing countries, the SDGs apply universally to all UN member states, and are considerably more comprehensive and ambitious than the MDGs. The SDGs are 17 goals focused on a global development with and-for sustainability, and demonstrate an understanding that the environment is not an add-on or in opposition to sustainable development, but rather the base that underpins all other goals. As a result, whereas the MDGs maintained a retrospectively narrow focus on poverty reduction, the SDGs include new themes which reflect an approach that sees the environment, economy and society as embedded systems rather than separate competing “pillars”: e.g. urban areas, water and sanitation, energy, and climate change are all prominently featured.

It is worthy to note that the idea is for all the goals to work together in sync and not to be isolated from each other in order to achieve the aim of a future just 15 years off that would be rid of poverty and hunger, and safe from the worst effects of climate change.

#### Environmental Pollution Prevention Legislation in Nigeria:

In order to be sustainable, development must combine three main elements: fairness, protection of the environment, and economic efficiency therefore in order to reduce the scale of

environmental pollution in Nigeria, there is the need for a robust legal framework to tackle the issue of pollution(Ola,1980). A plethora of laws exist in Nigeria for the protection of the Environment, the section will review the major legislation as it relates to environmental pollution in Nigeria.

The Constitution of the Federal Republic of Nigeria 1999 (as amended)

The Constitution is the fountain of all laws in Nigeria. The environment is regarded as important as such the constitution contains provisions that signify the importance of protecting and improving the environment. The relevant sections include;

- Section 20 which makes it a fundamental objective for the Nigerian Government to make laws that improve and protect the air,land,water,forest and wildlife of Nigeria.

The National Environmental Standards and Regulations Enforcement Agency (Establishment) Act (No.25 of 2007).

The essence of the NESREA Act is to improve and achieve a better level of environmental regulation through legislation. This Act repealed the Federal Environmental Protection Agency Act and is perhaps the major Federal legislation on the environment as its main focus is the protection and the sustainable use of the environment and its natural resources.

Environmental Impact Assessment Act (EIA) Act Cap E12 LFN 2004

The objective of the EIA Act is to empower NESREA(the Successor to FEPA) to make assessment of any project intended to be carried on in the country by any person, authority, corporate or unincorporated including the government which is likely to affect the environment and determine the extent of the effect which such activity might have on the environment.

The main problem with the EIA Act is the fact that the penalties are not stringent enough to make the impact of the Act to be felt. Secondly rather than prepare an accurate report to the minister of environment, investors tailor their report to meet the requirements of the Act thus not providing a true picture of the impact of their intended activity on the environment

Harmful Waste (Special Criminal Provisions) Act Cap H1, LFN 2004

The Harmful Waste Act was enacted to prohibit, without lawful authority, the carrying, dumping or depositing of harmful wastes in the air, land or waters of Nigeria. It was the

immediate legislative reaction to the Koko toxic waste incident where in 1988 about 3880 tons of toxic and hazardous waste made up principally of polychlorobiphenyls (PCBS) on behalf of an Italian company were dumped in Koko a town close to the old Bendel State.

Exclusive Economic Zone Act, Cap E11, LFN 2004

The purport of this Act is to make it illegal to explore or exploit natural resources within the Exclusive Zone without lawful authority. The right to regulate the activities within this Zone lies exclusively with the Federal government.

Petroleum Act, Cap P10, LFN 2004

This Act is the primary legislation on the regulation of oil and gas activities in Nigeria. The Act was established among other things to promote public safety and environmental protection as it relates to the oil and gas sector.

Oil in Navigable Waters Act.

The primary aim of this legislation is to reduce the incidence of pollution of the world's high seas generally and of Nigeria waters in particular. The following sections are significant

- Section 1 (1) prohibits the discharge of oil from a Nigerian ship into territorial waters or shorelines
- Section 6 provides for penalties for breach of the Act.

Associated Gas Re-injection Act, Cap 20 LFN 2004

This Act deals with the gas flaring activities of oil and gas companies in Nigeria. In relation to pollution prevention, section 3(1) prohibits without lawful permission any oil and gas company from flaring gas in Nigeria.

Having examined the existing laws on prevention of environmental pollution, the next section will examine the aims of Sustainable Development Goals 6, 7, 13, 14, 15 and 17 and how integrating them into our existing legislation and future policies and legislation will help re-scale the level of environmental pollution in Nigeria

The Role of Sustainable Development Goals in Reducing Environmental Pollution in Nigeria

The previous section has examined various legislation as relating to environmental pollution in Nigeria. It goes without saying that the environmental laws exist and contains several provisions which if followed to the letter would drastically reduce the pollution of the environment. The reverse is however the case as these laws have largely failed in attaining their aim of environmental sustainability. The Nigerian government is noted for good policy formulation but the implementation is usually grossly inadequate.

The sustainable development goals are a carefully thought out plan to within 15 years reduce poverty and hunger, and save the world from the worst effects of climate change (occasioned by environmental pollution), it is important that we rigorously integrate the sustainable development goals into our legislation to inspire commitments and drive implementation. The Nigerian Environmental governance structure needs to embrace the sustainable development goals as a culture in order to reduce the nagging plague of environmental pollution

The following goals are the focus of the paper

**Goal 6-Ensure availability and sustainable management of water and sanitation for all;**

This goal has at its main focus improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated waste water, and increasing recycling and safe reuse globally. The goal recognizes that countries' social development and economic prosperity depend on the sustainable management of freshwater resources and ecosystems and acknowledges that ecosystems and their inhabitants, including humans, are water users and that their activities on land can compromise the quality and availability of fresh water.

Infusing this goal into our water legislation in Nigeria will focus the attention on water-related ecosystems addressed in SDG 6 which include wetlands, rivers, aquifers and lakes, which sustain a high level of biodiversity. Where this effectively done, the resultant effect will be a well-managed water-related ecosystems which would culminate to addressing the competing demands for water, mitigate climate change risks and help to build community peace and trust. This integration would also ensure that the quality and safety of surface and ground water used for drinking, working, cooking, bathing and agriculture is no longer threatened by pollution which is usually caused by solid waste, unsafe runoff, waste water treatment, mining, manufacturing and other industrial sources.

**Goal 7-Ensure access to affordable, reliable, sustainable and modern energy for all;** The focus of Goal 7 is ensure that by the year 2030, the world has become more energy-efficient investing in clean energy sources such as solar and wind such that electricity needs are meet and the environment is protected.

Taking a cue from the focus of this goal which is to ensure that every one has access to affordable, reliable and cheap energy while ensuring that the environment is protected should drive the legislative arm of government and our policy makers to make laws and policies targeted at improving understanding of science and the links between energy and the environment. The drafters of the law need to recognize that energy is a contributor to human health problems, primarily from air pollution caused by the combustion of fuels and thus when the laws drives sustainable energy it presents an opportunity to transform lives and the economy while safeguarding the planet.

**Goal 13- Take urgent action to combat climate change and its impacts;** the effect is climate change has been a subject of international discuss. The concept has left its theoretical realm and the practical reality of the need to address the issue is being felt all around the globe. Urgent action has to be taken globally to strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries, integrate climate change measures into national policies, strategies and planning and improve education, awareness-raising and human and institutional capacity on climate. There is the need to understand that pollution endangers planetary health, destroys ecosystems, and is linked to global climate change therefore the need for a new policy focus in this direction. The need to urgently come up with policies that would create awareness that our daily activities such as use of electricity-generating plants, chemical manufacturing facilities, mining operations, deforestation, and the use petroleum-powered vehicles, are a major source of pollution. This awareness will drive down the incidence of air pollution and ultimately combat climate change and its effect locally and translate globally.

**Goal 14- Conserve and sustainably use the oceans, seas and marine resources for sustainable development;** the target of this goal is the management and protection of life below water. The main focus of this goal is the development or drive towards adopting a “blue economy”. The blue economy is a concept that seeks to promote economic growth, social inclusion, and the preservation or improvement of livelihoods while at the same time ensuring environmental sustainability of the oceans and coastal areas. The goal is primarily designed to reduce pollution

of water and water bodies while ensuring its sustainable use. A law that has this goal as a component will seek primarily to restore, protect, and maintain the diversity, productivity, resilience, core functions, and intrinsic value of marine ecosystems. It would also provide social and economic benefits for current and future generations as in relates to the ocean and its resources. It would also contribute to food security, poverty eradication, livelihoods, income, employment, health, safety, equity, and political stability. The result is a massive reduction in the incidence of water pollution and safeguard the waters of Nigeria.

**Goal 15-** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation, and halt biodiversity loss; The focus of this goal is to promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally. The goal also intends to combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

To ensure that by 2030, Nigeria is not left behind, we must endeavor to secure healthy and productive land through the instrument of legislation. The protection of our land resources must be a high priority if we are to make a transition to a more sustainable society and redefine our pollution scale. There is the need for sustainable land management laws that will integrate cross sector participation. The aim of the law would be to; a) combat desertification and land degradation effectively; b) promote sustainable policies and use of natural resources; and c) improve adaptation to climate change.

**Goal 17** -Strengthen the means of implementation and revitalize the global partnership for sustainable development; The control and reduction of air, water and soil pollution contributes to the effective realization of several human rights, including the right to life, the right to health, the rights to clean water, food, adequate housing and safe and healthy working conditions, the right to information, and the right to participation and freedom of association all which are all entrenched in the constitution of the Federal Republic of Nigeria. It is important that subsequent legislation be channeled and focused on the control of pollution in all its forms to ensure that these rights are made a reality.

## **Recommendations**

In order for this integration of Nigeria's pollution prevention legislation and the aforementioned sustainable development goals to successfully re-scale the plague of environmental pollution, the following are suggested strategies;

*A Step by Step Focused Approach.*

Our laws advocate for a holistic change and one shoe size fits all approach to the issue of environmental pollution however a step by step approach as advocated by the 2030 goals if infused into environmental legislation will enable proper monitoring and allow for effective implementation in phases which will culminate in achieving the overall target of reducing the negative impact of man's activities on the environment by the year 2030. The problem of environmental pollution is multifaceted thus there is a need to tackle the issues strategically with a time frame in mind like the SDGs. Each SDG has a major goal subdivided into minor goals and a step by step approach to achieving the goals and each goal has a time frame for it to be achieved. With the each minor goal achieved, the impact is highlighted and celebrated then achieving the next goal becomes a lot easier. As each step towards the achievement is completed and celebrated, the ultimate aim of the each goal will eventually be accomplished.

*Environmental Education and People Participation*

The attitude of Nigerians towards environmental protection is indeed a cause for deep concern. There is the need to develop an environmental conscious culture and aggressively instill it into the populace. Most citizens and facilities owners believe that the environment is the sole responsibility of the government as such management and protection lies on the shoulders of the government. For this integration to yield the desired result, there is the need for an elaborate campaign especially at the grassroots level to raise the level of environmental consciousness by educating them on the negative impact of their day to day activities and the attendant effect on the environment. There is the need to take the campaign to streets, markets, schools, religious organizations, restaurant owners, traditional rulers etc. The use of advertisements in print and local media in the language which can be easily understood by the local populace can also be used to drive home this consciousness. It is one thing to have an elaborate legal framework for the protection of the environment. If however the aims and objectives are not clearly understood by the intended audience, the law would have failed even before implementation and the impact may never be fully felt.



### *Effective Implementation of the Laws*

Having looked at the laws available in the environmental jurisprudence in Nigeria, it is safe to conclude that the laws are largely adequate to tackle the issue of pollution in Nigeria. When the SDGs are infused it would present a much stronger force at tackling the problem. The problem however lies in the effective implementation of these laws. This problem has largely hindered the impact of these laws in solving the problem. There is a need for the government and the relevant agencies saddled with the responsibility of environmental protection to stand up and be counted. The laws are made to be obeyed and not to be flouted. The laws contains sanctions and penalties for failure to comply. These sanctions must be invoked fully on any offender irrespective of tribe, status or affiliation. When this is done the laws would no longer be seen as a toothless dog but a tool for the protection of the environment.

### *Incentives for Compliance*

Another strategy to reduce the incidence of pollution is by creating a system of incentives for compliance for individuals, communities, companies who buy into the idea of environmental protection. Individual should be recognized, communities be showcased and companies be given tax reliefs/holidays to serve as an example to others. The laws should not always be about punishments. While we punish offenders, those who comply should be celebrated.

### **Conclusion**

The environment is our collective heritage as such we must see it as our responsibility to protect it. In spite of having a number of laws targeted at the reduction of environmental pollution in Nigeria the problem still persists. The laws are largely seen as ineffectively because of the problem of implementation. The SDGs are a global commitment and Nigeria cannot afford to be left behind in its plan to make the world a better place. Infusing the aims of SDGs 6, 7,13,14,15 and 17 will assist in making the laws on environmental pollution reduction more robust. There is the need however to fashion out ways to improve on the implementation level of the laws. There is more that still needs to be done by the policy makers to make the laws to be management oriented rather than rule oriented. There is a case to be made for the codification of all environmental laws in Nigeria into one robust environmental code that would cover rules governing every area of pollution including gas flaring, oil spillages etc. The

judiciary also needs to take a prominent role in environmental law enforcement by ensuring that cases involving environmental matters are dispatched promptly and judiciously.

## **REFERENCES**

Adeboyejo, A.T et al (eds) (2017) Sustainable Environmental Management and Planning in Nigeria, Faculty of Environmental Sciences, Ladoké Akintola University of Technology, Ogbomoso, Nigeria. ISBN 978-978-52485-5-3

Adejumo. A.V & Adejumo, O.O (2014) Prospects for Achieving Sustainable Development Through the Millennium Development Goals in Nigeria , European Journal of Sustainable Development 3(1), pp33-46 ISSN: 2239-5938 Doi: 10.14207/ejsd.2014.v3n1p33

Akintayo, J.O.A & Akinbola, B.R. (2012). Legal and Regulatory Reforms to Enhance the Nigerian Environment in Ivbijaro, M.F.A & Akintola, F. 2012 (eds) Sustainable Environmental Management in Nigeria. Book Builders Africa Ibadan, pp 363-407

Das R.C (1998). The Environmental Divide: The Dilemma of Developing Countries. Ashish ISBN 9788170249948

Efobi, K.O (1994) Studies in Urban Planning. Enugu, Fidelity Publishers and Printers Co ltd.

Gupta, J & Vegelin, C (2015) Sustainable development goals and inclusive development. Int Environ Agreements DOI 10.1007/s10784-016-9323-z

Ijaiya, H. & Joseph, O. T. (2014) Rethinking Environmental Law Enforcement in Nigeria, Beijing Law Review 5 ,pp306-321.

Okonkwo, 2005. The Law of Environmental Liability. Afrique Environmental Development p7. Afrique Environmental Development and Education , Lagos Nigeria

Okorodudu Fubara, M.T. Law of Environmental Protection, Materials and Cases. Ibadan, Caltop Publishers

Olatunbosun, A.I. 2016. Sustainable Development Goals: Exploring law and policy for a shared future. The Nigerian Law Journal 19 (1) pp 67-89

Ola, C.S., 1984. Town and Country Planning and Environmental Laws in Nigeria. 2nd Edition: University Press, pp 152-165

## **APPRAISAL OF ENVIRONMENTAL SANITATION PRACTICES IN SELECTED MARKETS IN AKURE, NIGERIA**

Ibrahim, R. B. <sup>1\*</sup>, Adedotun, S. B. <sup>1</sup>, Waheed, F. I. <sup>2</sup> and Akinbosoye, B.O. <sup>1</sup>

<sup>1</sup>Department of Urban and Regional Planning, Osun State University Osogbo, Nigeria

<sup>2</sup>Department of Science Laboratory Technology, Ladoke Akintola University of Technology  
Ogbomoso, Nigeria

\*E-mail of Corresponding Author: [rafiu.ibrahim@uniosun.edu.ng](mailto:rafiu.ibrahim@uniosun.edu.ng)

### **ABSTRACT**

This study examines environmental sanitation practices of the traders in the selected markets in Akure Ondo State, Nigeria. It assesses the socio-economic characteristics of the market users, environmental sanitation facilities and practices of market users as well as the factors influencing environmental sanitation practices. Data were obtained from two purposively selected markets. A traditional (Adedeji) and modern (Nepa) market. Random Systematic sampling techniques was used to administer a total of 151 structured questionnaires for the traders in the study area. Therefore, 57 questionnaires were administered in Adedeji market and 94 questionnaires were administered in Nepa neighborhood market, using the shop/stalls as the sampling units. Descriptive statistics and inferential statistics were used to analyze the data collected. The study revealed that most of the market users in Nepa (67.5%) and Adedeji (61.4%) market were females respectively. It was also revealed that some of the goods selling in the market includes; foodstuff, livestock, electronic, supermarket and textile products. This indicated that waste are generated on daily basis in both markets and collected on daily and weekly basis, where 95.4% of traders adopted waste collection services. Findings reveals that sanitation facilities were fairly (47.7%) provided. Cleaning of toilets, drainage, waste collection among others are the sanitation practices carried out mostly on weekly basis. With mean weighted value of (4.74), avoidance of penalty is the dominant factor influencing participation in the sanitation exercise. The study concludes by recommending among others that market management and government should be actively involved in the provision of sanitation facilities in the markets to enhance proper hygiene.

**Key Words:** Environment, Sanitation Practice, Traditional Market, Modern Market

## **INTRODUCTION**

Environmental sanitation has remained an intractable problem in the developing nations particularly Nigeria with serious public health consequences. This is due to poor sanitation practice as a result of improper refuse disposal, inadequate water supply and gross inadequacy of sanitary facilities especially in the market areas (Federal Ministry of Health, 2011). Generally, markets occupy an important position in the lives of Nigerians and activities involved in buying and selling generate large quantities of solid waste that contains a large proportion of decomposing vegetable and animal matter (Parks, 2007). Ogwueleka (2011) added that market centres do not only serve as places for commodity exchange but also centres of information exchange, local administration, health delivery, education, and entertainment centre, etc. where buying and selling are carried out among others.

These activities generate large quantities of solid waste which cause unpleasant odor, excellent breeding grounds for vectors of communicable diseases including rodents and insects, and also being eyesores which all have direct unpleasant environmental consequences (Federal Ministry of Health, 2011). It is quite common to observe mountains of refuse at market places this heaps of refuse provide excellent breeding grounds for vectors of communicable diseases including rodents, insects, etc. which increases the potential for the spread of infectious diseases (Ayoola et al., 2012).

It has been acknowledged that many of the diseases that affect Nigerians such as (malaria, tuberculosis and diarrhea) are direct effect of poor sanitation and are due to unhealthy environmental conditions which most times are resultant of contaminated food stuffs (World Health Organization WHO, 2004). Thus, poor environmental and sanitary conditions at market centres in the country portend adverse public health implications for and market users.

Environmental sanitation is a concept explaining activities to ensure safe disposal of excreta, solid waste and other liquid waste and the prevention of disease vectors to ensure a hygienic environment (Acheampong, 2010); which also involves both behaviors and facilities which work together to form a hygienic environment (WHO, 2004). Furthermore, environmental sanitation generally encompasses all conditions that affect health which includes water, wastewater, personal and food hygiene, public health etc.

Hence, activities carried out in public places like markets and other public places of insanitary conditions pose adverse health hazards to the operators in these activity centres. This study therefore assesses the existing environmental sanitation practices of markets users in selected markets in Akure, Ondo State, Nigeria. It could be noted that market users are the traders and their clients.

## **MATERIALS AND METHODS**

### **The Study Area**

Akure is a city in south-western Nigeria and is the largest and the capital city of Ondo state. It is located in the South Western Zone of Nigeria. It is geographically located within Latitudes 7°15'N and 7°28'N North of the Equator and Longitudes 5°06'E and 5°21'E East of the Greenwich Meridian. The increased relative political influence of Akure as a state capital since 1976 has greatly promoted its rapid growth and increased socio-economic activities resulting in its spatial expansion from an area of about 16 squares kilometers in 1980 to about 30 square kilometers in 2000 (Ondo State Ministry of Works, Lands and Housing, 2000). As a capital city of Ondo state it is a medium- sized urban centre which has three residential settlement patterns the core area, the peripheral neighborhoods to the core and the suburbs. Akure town which is mainly embedded in Akure South Local government Area has witnessed immense growth in the size of built-up areas, number of immigrants, transportation, and commercial activities and has attracted both major investors and private developers into the city. The last census conducted in 2006 put the town's population at 353,211 i.e. Three hundred and fifty three thousand, two hundred and eleven (NPC, 2006).

### **Methods of Data Collection and Analysis**

The sample frame for this study comprises of the shop/stall users in Nepa neighborhood market and Adedeji traditional market in Akure. First, the sample size was drawn from two (2) selected markets which are Nepa neighborhood market and Adedeji traditional market in Akure. These were selected by purposive sampling methods. In the market there is identification of lock-up stalls, open stalls and open space. The next stage involves the administration of questionnaire for traders in the selected shops and stalls. Random Systematic Sampling technique was adopted in selecting every 3rd respondent from the lock/open stalls and open space. Using this procedure, a total of 151 questionnaire were administered in the two markets. The data

collected were analyzed using descriptive statistics of frequency and percentage to examine socio-economic characteristics of market users; environmental sanitation facilities and practices of market users as well as factors influencing market sanitation practices.

## **RESEARCH FINDINGS**

### **Socio-Economic Characteristics of Traders**

Under this sub-section of the study, attempt is made to examine the socio-economic characteristics of respondents, in this case the market users in Adedeji and Nepa neighborhood market. The knowledge of the socio-economic characteristics of developers will no doubt sharpen our understanding of how they're being enlightened when it comes to the issue of market environmental sanitation practices.

The gender of respondents as obtained and presented in Table1 revealed that most of the respondents (67.5%) are female in both market compared to male (32.5%) respondents. The bulk of the respondents interviewed were between the ages 31- 40years and 41- 50 years. It is clearly expressed that most respondents are married. Expectedly, trading is the dominant occupation, where respondent in the Nepa market earns more on monthly basis compared to respondents in Adedeji market. The highest proportion (77.3%) of respondents in Nepa market have tertiary education, while most of the respondents (70.6%) in Adedeji market have no formal education.

The nature of goods sold sometimes determines level of sanitation in a market. As shown in Table2, foodstuff, livestock, electronic, supermarket and textile products which generate large quantity of waste were sold by the market users. The study reveals that 33.1% of foodstuff, 17.8% of livestock, 13.9% operates supermarket, 8.6% engage in restaurant, 7.9% sells snacks, 6.6% stationery, 3.9% textiles/boutique, 3.3% sells plastics and electronics while 1.3% sells vehicular part in both markets.

In Nepa market 35.1% sell foodstuff and 14.9% sells livestock and supermarket, 10.6% rated for restaurant while 7.4% and 5.3% accounted for snacks and stationery and 3.2% accounted for electronics, plastics and textiles respectively. Respondent in Adedeji market also sells

foodstuffs (29.8%), livestock (22.8), operates supermarket (12.2%), snacks and stationery (8.7%), restaurant and textile/boutique (5.2%), electronics and plastics (3.5%) respectively.

**Table 1: Socio-Economic Characteristics of Traders**

Socio-economic variables	Percentage (%)	
	Adedeji Market	Nepa Market
<b>Gender</b>		
Male	20.0	12.5
Female	45.3	22.2
<b>Age</b>		
18-30 years	15.6	84.4
31-40 years	46.3	53.7
41-50 years	48.8	51.2
51-60 years	21.4	78.6
61 years & above	40.0	60.0
<b>Marital status</b>		
Single	29.2	70.8
Married	40.7	59.3
Widowed	0.0	100
<b>Occupation</b>		
Trading	23.9	76.1
Self-employed	48.1	51.9
Civil servant	0	100
Artisan	68.4	31.6
Retired	50.0	50.0
<b>Income</b>		
N18,000 & below	37.2	62.8
N18,000-N40,000	39.5	60.5
N41,000-N60,000	35.0	65.0
N61,000 & above	0	100
<b>Education</b>		
No formal education	70.6	29.4
Primary education	37.5	62.5
Secondary education	39.4	60.6
Tertiary education	22.7	77.3

*Source: Authors' fieldwork, 2018.*

The nature of goods sold sometimes determines level of sanitation in a market. As shown in Table 2, foodstuff, livestock, electronic, supermarket and textile products which generate large quantity of waste were sold by the market users. It was indicated that 33.1% are of foodstuff, 17.8% of livestock, 13.9% operates supermarket, 8.6% engaged in restaurant, 7.9% sells snacks, 6.6% stationery, 3.9% textiles/boutique, 3.3% sells plastics and electronics while 1.3% sells vehicular part in both markets. In Nepa market 35.1% sell foodstuff and 14.9% sells livestock and supermarket, 10.6% rated for restaurant while 7.4% and 5.3% accounted for snacks and stationery and 3.2% accounted for electronics, plastics and textiles respectively. Respondent in Adedeji market also sells foodstuffs (29.8%), livestock (22.8%), operates supermarket (12.2%), snacks and stationery (8.7%), restaurant and textile/boutique (5.2%), electronics and plastics (3.5%) respectively.

#### **Environmental Sanitation Practices of Market Traders.**

The list of method of waste disposal and the ones adopted by the market users is contained in Table 3. It can be deduced that 95.4% adopted waste collection service method, 2.6% adopted nearby bush while 0.7% adopted open space dumping. Burning designated dump site, inside drainage, nearby bush, barrow or cart pusher and nearby bush are not adopted by the market users in both market, respectively.

The sources of water supply to the market varies according to the respondents in both markets as shown in Table 4. The study reveals that water is supplied to the Nepa markets through Tap water point and bore hole while Adedeji market source water from well water respectively. Furthermore, 47.9.0% and 36.2% of respondent in Nepa market source water from Tap point and borehole respectively. While 89.5% and 5.3% of respondent in Adedeji market source water from Well Water as shown in Table 4. It can be inferred that, the well water in Adedeji market was provided by the residential houses within and around the market most especially the residential buildings that were converted for commercial use.

The adequacy of toilet facility in the selected market as rated by the respondent as presented in Table 5, the respondent revealed that 46.7% is partially adequate, 38.7% is fully adequate, and 6.7% is inadequate. The study further accounted that 46.2% of the respondent in Nepa market rated the provision of toilet facilities as partially adequate, 34.4% rated it adequate. While in Adedeji market 47.4% of the respondent rated the toilet facilities partially adequate and 45.6% adequate respectively. Therefore, the analysis reveals that these facilities are relatively partially adequate.



Concerning frequency of toilet and drainage cleaning, it can be inferred that the drains are kept clean on daily basis. 65.9% and 91.2% of respondent in Nepa and Adedeji market respectively reveals that the drains are cleaned on daily basis, as presented Table 6

**Table 2: Types of Goods being sold in the Markets.**

Name of Market	Activities and Types of Goods Sold										Total
	Livestock	Foodstuffs	Electronics	Super market	Snacks	Plastics	Stationery	Restaurant	Vehicle Part	Textiles/Books	
Nepa F	14	33	3	14	7	3	5	10	2	3	94
%	14.9	35.1	3.2	14.9	7.4	3.2	5.3	10.6	2.1	3.2	100
Adedeji F	13	17	2	7	5	2	5	3	0	3	57
%	22.8	29.8	3.5	12.2	8.7	3.5	8.7	5.2	0.0	5.2	100
Total F	27	50	5	21	12	5	10	13	2	6	151
%	17.8	33.1	3.3	13.9	7.9	3.3	6.6	8.6	1.3	3.9	100

Source: Authors' fieldwork, 2018.

**Table 3: Method of Waste Disposal**

Name of Market		Nearby Bush		Burning	Designated Dumpsite	Open Space	Inside Drainage	Nearby stream	Barrow or Cart Pusher	Waste Collection Service	
		Yes	No	No	No	Yes	No	No	No	Yes	No
		Nepa F	4	90	94	94	1	93	94	94	94
% of Rows	4.3	95.7	100	100	1.1	98.9	100	100	100	93.6	100
% of Column	100	61.2	62.3	62.3	100	62.0	62.3	62.3	62.3	58.3	62.3
Adedeji F	0	57	57	57	0	57	57	57	57	56	57
% of Rows	0.0	100	100	100	0.0	100	100	100	100	98.2	100
% of Column	0.0	38.8	37.7	37.7	0.0	38.0	37.7	37.7	37.7	38.9	37.7
Total F	4	147	151	151	1	150	151	151	151	144	151
% of Rows	2.6	97.4	100	100	0.7	99.3	100	100	100	95.4	100
% of Column	100	100	100	100	100	100	100	100	100	100	100

Source: Authors' fieldwork, 2018.

**Table 4: Sources of Water Supply in the Market**

Name of Market	Sources of water supply				Total
	Tap Water	Borehole	Well Water	Water Vendor	
Nepa F	45	34	15	0	94
% of Rows	47.9	36.2	16.0	0.0	100
% of Column	93.8	94.4	22.7	0.0	62.3
Adedeji F	3	2	51	1	57
% of Rows	5.3	3.5	89.5	1.8	100
% of Column	6.3	5.6	77.3	100	37.7
Total F	48	36	66	1	151
% of Rows	31.8	28.8	43.7	0.7	100
% of Column	100	100	100	100	100

Source: Authors' fieldwork, 2018.

**Table 5: Adequacy of Toilet Facility**

Name of Market		Adequacy of toilet facility				Total
		Fully Adequate	Partially Adequate	Inadequate	Others	
Nepa	F	32	43	7	11	93
	% of Rows	34.4	46.2	7.5	11.8	100
	% of Column	55.2	61.4	70.0	91.7	62.0
Nepa	F	26	27	3	1	57
	% of Rows	45.6	47.4	5.3	1.8	100
	% of Column	44.8	38.6	30.0	8.3	38.0
Nepa	F	58	70	10	12	150
	% of Rows	38.7	46.7	6.7	8.0	100
	% of Column	100	100	100	100	100

Source: Authors' fieldwork, 2018.

**Table 6: Frequency of Toilet and Drainage Cleaning**

Name of Market		Frequency of Drainage Cleaning			Total
		Daily	Weekly	Monthly	
Nepa	F	60	28	3	91
	% of Rows	65.9	30.8	3.3	100
	% of Column	53.6	87.5	75.0	61.5
Adedeji	F	52	4	1	57
	% of Rows	91.2	7.0	1.8	100
	% of Column	46.4	12.5	25.0	38.5
Total	F	112	32	4	148
	% of Rows	75.7	21.6	2.7	100
	% of Column	100	100	100	100

Source: Authors' fieldwork, 2018.

**Table 7: Frequency of environmental sanitation exercise**

Name of Market		If yes, when			Total
		Weekly	Fortnight	Monthly	
Nepa	F	89	1	4	94
	% of Rows	94.7	1.1	4.3	100
	% of Column	61.0	100	100	62.3
Adedeji	F	57	0	0	57
	% of Rows	100	0.0	0.0	100
	% of Column	39.0	0.0	0.0	37.7
Total	F	146	1	4	151
	% of Rows	96.7	0.7	2.6	100
	% of Column	100	100	100	100

Source: Authors' fieldwork, 2018.

**Table 8: Factors Influencing Sanitation Practices**

S/N	Factors	Ranking					NRF	FWV	MWV	Rank
		5	4	3	2	1				
1.	Market Sanitation Policy	495	192	12	0	0	151	526	3.48	5 <sup>th</sup>
2.	Availability of Sanitation Facilities	190	288	96	18	0	151	592	3.92	4 <sup>th</sup>
3.	Constant Sanitation Schedule	480	192	12	4	1	151	689	4.56	2 <sup>nd</sup>
4.	Health Purpose/ Hygiene	250	288	78	6	0	151	622	4.11	3 <sup>rd</sup>
5.	Avoidance of Sanitation Penalty	600	104	9	4	0	151	717	4.74	1 <sup>st</sup>
	Total								20.81	

Mean of  $\sum MWV/n = 20.81 / 5 = 4.162$

Source: Authors' fieldwork, 2018.

Frequency of environmental sanitation exercise is presented in Table 7 indicated that 96.7% of the total respondents says that the environmental sanitation exercise in the selected markets are on weekly basis, specifically every Thursday of the week to be precise within the hours of 7am and 10am. Hence, this environmental sanitation exercise is on weekly basis in both markets.

### Factors Influencing Sanitation Practices

It is observed in table 8 that avoidance of sanitation penalty has the highest mean weighted value of 4.74. This implies that avoidance of sanitation penalty is highest factor influencing market environmental sanitation practices in Nepa and Adedeji market. This situation is followed in decreasing order by market sanitation policy which has mean weighted value of 3.45, availability of sanitation facilities (3.92); health purpose/ hygiene (4.11); constant sanitation schedule (4.56).

Specifically, it could be observed however, that none of the responses of market users on each of the factor were below average in their opinion on the environmental sanitation practices within the market. Nevertheless, the overall mean value of responses of factors influencing market sanitation, as obtained from the users is 4.162. This implies that mean responses of the people were far more above average indicating that the factors were highly functional in the study area. This situation is very good because certain factors are meant to influence people to engage in market sanitation.

## **CONCLUSION AND POLICY ISSUES**

The study concluded that the level of environmental sanitation practices in the selected markets is high but the sanitation exercise is not convenient for the market users, due to inadequate sanitation facilities and services in the market. Inadequate sanitation facilities was a prime problem they encountered during sanitation exercise in the market. Thus, adequate investment should be made in the provision of necessary sanitation facilities. The government alone cannot provide the needed sanitation facilities; private agency and market association should also be encouraged through incentives to provide such facilities such as toilet and urinal facilities.

Adequate Hygiene behavior and health promotion is crucial in preventing disease. Hence, improving infrastructure and facilities without a basic improve in hygienic behaviour of market users will rarely result in effective environmental sanitation practices. Therefore, hygiene education is integral to environmental sanitation. Hygiene education seeks to support sustainable behavior improvements through increased awareness and knowledge. It will influence the extent of the market sellers' adaptation to environmental sanitation regulations, policy issues, use of modern facilities and participation. Hygiene education should therefore be integrated into environmental sanitation planning for market.

## **REFERENCES**

- Acheampong, P. T. (2010): Environmental Sanitation Management in the Kumasi Metropolitan Area. An Unpublished M.Sc. Thesis Submitted to the Department of Planning, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
- Ayoola, H A; Lawal, A F and Akinluyi, M L (2012): An assessment of housing sanitation and Waste Management Practices in the residential Core Areas of Oshogbo, Osun state Nigeria Conducted in 2006 Final Results.
- Ministry of Health. (2011): *Hygiene and environmental health, part 2: Blended learning module for the health extension Program*. Addis Ababa: Ministry of Health (MoH).
- National Population Commission (2006): National Population Commission Census Report,
- Ogwueleka T. Ch. (2011): Municipal Solid Waste Characteristics and Management in Nigeria. *Iran. J. Environ. Health. Sci. Eng.*, 2009, Vol. 6, No. 3, pp. 173-180.

Ondo State Ministry of Lands and Housing, Akure; 2010.

Parks, K.P. (2007): Textbook Of Preventive and Social Medicine. M/s Banarsidas Bhanot Publishers 19th Ed. 609.

World Health Organization WHO (2004): Sanitation and hygiene links to health: facts and figures. November 2004.

## IMPACT ASSESSMENT OF SMOKING DURATION ON POLYCYCLIC AROMATIC HYDROCARBONS (PAH'S) CONTAMINATIONS OF CATFISH (*Clarias gariepinus*)

Abiona, O. O. \*, Awojide, S. H., Adegunwa, A. O. and Tayo, A. S

Department of Pure and Applied Chemistry, Osun State University, Osogbo, Nigeria.

Corresponding author: [oluseye.abiona@uniosun.edu.ng](mailto:oluseye.abiona@uniosun.edu.ng)

### ABSTRACT

A comparative study was carried out on smoked catfish (*Clarias gariepinus*) with the aim of investigating the effect of smoking duration on the extent of accumulation of the 16 US EPA priority polycyclic aromatic hydrocarbons (PAHs). Concentrations of PAHs in the samples were determined using Gas chromatography - flame ionization detector (GC-FID) after extracting with n-hexane by soxhlet extraction technique and chromatography cleaned-up. All the 16PAHs analyzed were detected in the smoked catfish samples. The results showed that higher molecular weight PAHs with  $\geq 4$  rings were considerably higher in concentration as compared to low molecular weight PAHs with  $\leq 4$  rings. Total mean concentration of the analyzed PAH for the five smoking days gave the values 1.74  $\mu\text{g}/\text{kg}$ , 1.91  $\mu\text{g}/\text{kg}$ , 2.10  $\mu\text{g}/\text{kg}$ , 2.32  $\mu\text{g}/\text{kg}$ , 2.58  $\mu\text{g}/\text{kg}$  respectively. This is an indication that the smoking duration has direct proportionality effect on the rate at which the fish muscle accumulate PAH.. With Ant/(Ant+Phen) ratio  $< 0.10$ , the diagnostics ratios predicted wood combustion as the main source of PAHs contamination in the analyzed smoked catfish. The  $\Sigma\text{BaP}_{\text{eq}}$  and  $\Sigma\text{PAH}_4$  levels are within the maximum acceptable risk limits of 2 and 5  $\mu\text{g}/\text{kg}$  respectively, as recommended by European Commission Regulations for smoked fish muscle.

**Keywords:** *catfish, smoking, gas chromatograph, carcinogenic potency and polycyclic aromatic hydrocarbon*

### INTRODUCTION

Food processing involving thermal treatments at high temperature and/or direct contact with combustion gases has received much attention over the years (Moret *et al.*, 2005).

However, different processing methods have different effects on the nutritional compositions of fish. Smoking is a major processing and preservative methods for fish, which involves

exposing fish to smoke from smoldering wood or plant materials. It is also accompanied by an integrated combination of salting, drying and heating in a smoking chamber. During this process, partial drying is achieved coupled with the precipitation of aliphatic and aromatic vapors on fish surface (Duedahl-olesan *et al.*, 2006). The amount of PAHs generated during the thermal food processing depends on several parameters such as temperature, duration of the treatment, distance from the source of heating, oxygen accessibility, fat content, and type of combustible used (Visciano *et al.*, 2006).

PAHs are a group of fused benzene ring compounds formed during domestic and industrial combustion, they also exist as natural phenomenon such as volcanic eruptions (Akpambang *et al.*, 2009). PAHs are ubiquitous environmental contaminants that are formed during the incomplete combustion of carbonaceous materials (Suchanová *et al.*, 2008). They are formed when complex organic substances are exposed to high temperature or pressure or by the incomplete combustion of woods, coal or oil (Linda *et al.*, 2011).

The U.S. Environmental Protection Agency (EPA) selected 16 priority PAHs based on their occurrence and carcinogenicity. The potentially carcinogenic PAH benzo(a)pyrene is often used as an indicator of the presence of PAHs in water and foodstuffs (Derache, 1990). Some PAHs that do not exhibit carcinogenicity have been reported to act as synergists (Simko, 2002). The aim of this study was to investigate PAH levels in smoked catfish and to estimate the potential risk associated with consumption of such traditionally processed foodstuffs commonly consumed in Nigeria.

### **Materials and Methods**

**Fish samples and sampling:** Similar sizes (250 g) of freshly harvested catfish (*Clarias gariepinus*) were obtained from fish market in Oke-Baale, Osogbo, Osun State, Nigeria. The raw samples were stored at  $-20^{\circ}\text{C}$  in a refrigerator prior to analysis.

### **The fish smoking process**

The samples (catfish) was descaled and washed with clean water. They were subsequently rinsed with distilled water and brined with 10 % salt solution and placed on wire gauze placed on drum type smoking kiln. Smoking temperature was measured with a mercury-in-glass thermometer and smoking was done for a period of 8 h at temperature range of  $70\text{-}80^{\circ}\text{C}$  per day continuously for 5 days. Every day after 8 hours of drying two of the fish samples were removed and made to cool; they were then packed in polythene bags to reduce pest/microbial infestation and kept in the refrigerator.

### **Soxhlet Extraction method**

The extraction was carried out through Soxhlet extraction technique using 150 cm<sup>3</sup> dichloromethane for 16 h as recommended by USEPA 3540 (USEPA, 1996). Pulverized fish muscle sample (10 g) was weighed and mixed thoroughly with 5 g of anhydrous sodium sulphate in a laboratory crucible until a complete homogenate was obtained. The homogenate was carefully transferred into the extraction thimble placed in the extraction chamber of the Soxhlet extraction unit. The extract was concentrated to 2 cm<sup>3</sup> using a rotary evaporator in a water bath that was pre-set to a temperature of 35°C and was stored in amber bottle and kept in a refrigerator to avoid oxidation. The method was repeated for other samples obtained from other days.

### **Sample Purification**

The extracted samples were purified to remove the very polar lipids off the extract by passing them through a column packed with silica gel. The column (1 cm internal diameter) was prepared by loading 10 g of activated silica gel (100- 200 Mesh) to about 5 cm. This was topped with 1cm of anhydrous Na<sub>2</sub>SO<sub>4</sub> which was then conditioned with dichloromethane. 2 cm<sup>3</sup> of the concentrated extract was loaded and eluted with 20 cm<sup>3</sup> of dichloromethane. Prior to analysis with GC/MS, the extracts obtained were preserved in an amber bottle to avoid oxidation.

### **GC-FID Analysis**

PAHs determination was carried out using Agilent GC 7890A. Chromatographic separation of the sixteen PAHs was accomplished within a DB-1 fused-silica capillary column (30m x 0.32 mm I.D, 1 µm film thickness). Helium was used as a carrier gas at a flow rate of 0.45 mL/min. sample injection was in the splitless mode with an injection volume of 2 µL. The GC oven temperature program was optimized: initial temperature at 70°C was held for 2 min and then ramped at 10°C/min to 220°C. It was maintained at this temperature till the end of the run (33 min). The injection port temperature was set at 250°C and that of the FID detector was set at 300°C. The hydrogen and air flow rates were set at 40 mL /min and 400mL/min, respectively.

### **B<sub>a</sub>P Equivalent**

Toxic equivalency factor (TEF) is an estimate of the relative toxicity of individual PAH fraction compared to benzo (a) pyrene. TEFs have been applied as a useful tool for the regulation of compounds with a common mechanism of actions (e.g PAHs). The BaPeq value



was calculated for each PAH from its concentration in the sample (PAH) multiplied by its TEF (Nisbet and LaGoy, 1992).

$$BaP = \Sigma BaP = \Sigma C_{PAHi} \times TEF_{PAHi}$$

$C_{PAHi}$ : Concentration of each PAH in the sample,

$TEF_{PAHi}$ : Toxic equivalency factor for each individual PAH.

### Statistical Analysis

The PAH analysis was carried out for each sample in triplicate ( $n = 3$ ). The obtained results were statistically analyzed using SPSS (version 20.0) windows software. Mean concentration and standard error of the mean were calculated for each PAH.

### Result and Discussion

The mean concentrations of 16PAHs analyzed in the smoked catfish at different smoking time intervals are presented in Table 1. The PAHs were grouped according to their molecular weights. The high molecular weights PAHs were benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene benzo(ghi)perylene, Chrysene, indeno(1,2,3-cd)pyrene, and anthranthrene. The medium molecular weights are fluoranthene and pyrene and the low molecular weights are naphthalene, acenaphthylene, acenaphthene, fluorene, anthracene and phenanthrene. Total mean concentrations of 0.948  $\mu\text{g}/\text{kg}$ , 0.614  $\mu\text{g}/\text{kg}$  and 0.105  $\mu\text{g}/\text{kg}$  were recorded for high molecular weight, medium molecular weight and low molecular weight respectively.

### Molecular weight of PAHs in the smoked catfish samples

As observed from Table 1, the total concentration of the high molecular weights (HMW) PAHs were higher than the other molecular weights in all smoked fish samples from the same location as a result of temperature range of 70 - 80  $^{\circ}\text{C}$  which is known to favor the production of HMW PAHs due to thermal breakdown of lignin in lignocelluloses during wood combustion used in smoked fish preparation (EFSA, 2002). It has been reported that pyrolysis of fish leads to increasing accumulation of PAHs (Guillen and Sopelana, 2004).

### Source Characterization and Assessment of PAHs

The diagnostic isomer ratios and the indices obtained for apportioning different sources for PAHs source identification are as shown in Table 2. Some polycyclic aromatic hydrocarbons have been identified as markers for various sources in environmental matrix (Dickhut *et al.*, 2000) and assigned to possible sources such as pyrolytic (incomplete combustion of organic

matters – combustion of fossil fuel, Vehicular engine combustion, smelting, waste incinerators, forest fire and coal combustion) and Petrogenic (unburned petroleum and its product – gasoline, kerosene, diesel, lubricating oil and asphalt) (Soclo *et al.*, 2000).

The PAH ratio as presented in Table 2 shows that Phen/Anth in this study is in the range 1.25 – 1.53. This value is much lower than 10 which was considered indicative of a predominance pyrogenic sources. The Phen/Anth concentration ratios indicate that the PAHs in this study are derived from pyrolytic rather than petrogenic sources. PAH isomer pair ratio Fl<sub>a</sub>/Fl<sub>a</sub> + Pyr which gives a distinct chemical tracer to infer possible source of PAHs in environmental sample according to Yunker *et al.*, (2002) shows values ranging between 0.4 - 0.6 which deduce that petrogenic and pyrogenic sources contributed to the distribution of these contaminants but predominantly pyrogenic.

### B(a)P Equivalent of PAHs Found in the Smoked catfish Samples

TEF is an estimate of the relative toxicity of individual PAH fraction compared to benzo(a) pyrene. The toxic equivalent factors (TEFs) and B(a)P (BaPeq<sub>i</sub>) Equivalent of PAHs in smoked fish are present in Table 3. The total B(a)P Equivalent(BaPeq<sub>i</sub>) was 0.113.

**Table 1: Total mean concentration (µg/kg) of PAHs in smoked catfish**

PAHs	Abbrev.	S1	S2	S3	S4	S5
Naphthalene	Nap	0.021±0.001	0.022±0.001	0.028±0.002	0.029±0.001	0.035±0.020
Acenaphthylene	Acy	0.139±0.005	0.168±0.002	0.173±0.005	0.159±0.001	0.196±0.001
Acenaphthene	Ace	0.054±0.002	0.057±0.001	0.067±0.001	0.076±0.010	0.080±0.005
Fluorene	Flu	0.135±0.001	0.150±0.020	0.158±0.001	0.161±0.004	0.208±0.025
Phenanthrene	Phe	0.233±0.010	0.283±0.012	0.310±0.002	0.344±0.002	0.352±0.012
Anthracene	Ant	0.182±0.003	0.187±0.050	0.212±0.001	0.243±0.010	0.281±0.010
Fluoranthene	Fla	0.104±0.001	0.315±0.100	0.358±0.004	0.410±0.005	0.439±0.100
Pyrene	Pyr	0.154±0.028	0.200±0.050	0.256±0.003	0.332±0.001	0.303±0.005
Benzo(a)anthracene	BaA	0.002±0.001	0.003±0.001	0.004±0.001	0.004±0.001	0.005±0.001
Chrysene	Chr	0.006±0.001	0.007±0.002	0.008±0.001	0.009±0.004	0.009±0.001
Benzo(b)flouranthene	BbF	0.004±0.001	0.004±0.001	0.006±0.002	0.006±0.001	0.007±0.002
Benzo(k)flouranthene	BkF	0.010±0.005	0.011±0.001	0.013±0.002	0.016±0.001	0.019±0.001
Benzo(a)pyrene	BaP	0.059±0.003	0.061±0.001	0.063±0.002	0.071±0.014	0.075±0.015
Indeno(1,2,3-cd)pyrene	IcdP	0.002±0.001	0.003±0.001	0.003±0.001	0.004±0.001	0.004±0.001
Dibenzo(a,h)anthracene	DahA	0.035±0.001	0.036±0.012	0.039±0.001	0.044±0.002	0.054±0.001
Benzo(g,h,i)perylene	BghiP	0.001±0.001	0.002±0.001	0.003±0.001	0.007±0.002	0.009±0.001
∑16PAH		1.741	1.909	2.101	2.315	2.576

**Table 2: PAH isomer ratios of sampled smoked fish**

Sample/Isomer ratio	Phen/Ant	An/An+Phe	Flu/Flu+Phe	Nap/Phe	BaA/BaA+Ch	Ind/Ind+BghiP
S1	1.280	0.439	0.403	0.090	0.25	0.667
S2	1.513	0.398	0.612	0.078	0.30	0.600
S3	1.462	0.406	0.538	0.090	0.33	0.571
S4	1.416	0.414	0.553	0.084	0.31	0.363
S5	1.253	0.444	0.592	0.099	0.36	0.285
Total	6.924	2.101	2.698	0.441	1.550	2.486

**Table 3. Toxic Equivalent factors (TEFs) and BaP Equivalent of PAHs in the smoked catfish**

PAH	Na p	Ace	Acy	Flu	Phen	Ant	Fla	Pyr	Ba A	Chr	Bb F	BkF	Ba P	Icd P	Dah A	Bgh iP	Tot al
TEF	0.0	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.1	0.01	0.1	0.1	1.0	0.1	1.0	0.00	2.4
F	01	1	1	1	1		1	1								1	28
BaP eqi	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	-	0.00	0.0	-	0.0	-	0.1
		01	01	02	03	22	04	03		08		14	66		41		13

## CONCLUSION

In this study, freshly smoked fish samples processed for 8 h at temperature range of 70-80<sup>0</sup>C per day for 5days were analyzed for polycyclic aromatic hydrocarbon contamination. Sixteen priority PAH types were identified and quantified using GC-FID. Individual polycyclic aromatic hydrocarbon concentrations varied from 1.74 - 2.58 µg/kg. The levels of PAHs in the samples were in increasing total mean concentration from day 1 to day 5. The total concentration of the high molecular weights (HMW) PAHs were higher than the other molecular weights in all smoked fish samples at different smoking period as a result of thermal breakdown of lignin in lignocelluloses. From the study, sources of polycyclic aromatic hydrocarbon contamination indicate that wood combustion is the main source of PAHs due to Ant/(Ant+Phen) ratio which is >0.10. It could be inferred that the smoking process generally increased the mean total PAH levels in the fish samples across the days. The result of this research work revealed that the accumulation of PAHs by the catfish samples is directly proportional to smoking duration showing increasing order of total PAHs concentrations. Generally, the smoked fish is fit for human consumption as the total PAHs falls within 2-5 µg/kg set by European commission as tolerable limit but due to increase in PAH levels as smoking temperature and duration rises, there is possibility of the PAH level exceeding the tolerable limit.

## **REFERENCES**

Akpambang V.O.E, Purcao G, Lajide L, Amoo I.A., Conte L.S, Moret,S. (2009). Determination of polyaromatic hydrocarbons in commonly consumed Nigerian smoked/grilled fish and meat. *Fd. Addit. Contam.* 26(07):1090-1103.

Dickhut, R.M., E.A. Canuel, K.E. Gustafson, K. Liu, K.M. Arzayus, S.E. Walker, G. Edge, M.O. Gaylor and Macdonald, A.H. (2000). Automotive sources of carcinogenic polycyclic aromatic hydrocarbons associated with particulate matter in the Chesapeake Bay Region. *Environmental Science Technology*, 34: 4635-4640.

Duedahl-Olesen L, White S, Binderup M.L (2006). Polycyclic aromatic hydrocarbons (PAH) in Danish smoked fish and meat products. *Polycycl Aromat Comp* 26: 163-184

European Food Safety Authority EFSA (2002). Scientific Committee on Food. Opinion on the risks to human health of polycyclic aromatic hydrocarbons in food, Italy.

Guillen, M.D. and P. Sopelana, (2004). Occurrence of polycyclic aromatic hydrocarbons in smoked cheese. *Journal of Dairy Science*, 87: 556-564.

Linda M.N, Carboo P.D, Yeboah P.O, Quasie W.J, Mordecai A., Gorleku M.A, Darko A. (2011). Characterization of Polycyclic Aromatic Hydrocarbons (PAHs) Present in Smoked Fish from Ghana. *Advance Journal of Food Science Technology* 3(5):332-338.

Moret S, Purcaro G, Conte L.S (2005). Polycyclic aromatic hydrocarbons in vegetable oils from canned foods. *European Journal Lipid Science Technology* 107: 488-496.

Nisbet I.C.T, LaGoy P.K (1992). Toxic equivalency factor (TEFs) for polycyclic aromatic hydrocarbons (PAHs). *Regulatory Toxicology Pharmacology* 16: 290-300.

Simko P (2002). Determination of polycyclic aromatic hydrocarbons in smoked meat products and smoke flavouring food additives. *J. of Chromatogr.*, B 770: 3-18

Soclo, H., P. Garrigues and M. Ewald, (2000). Origin of polycyclic aromatic hydrocarbons (PAHs) in coastal marinesediments: Casestudyin Cotonou (Benin) and Aquitaine (France) areas. *Marine Pollution Bulletin*,40: 387-396.

Suchanová, M., L. Jana Haj, M. Tomaniová, V. Kocourek and L. Babika, (2008). Polycyclic aromatic hydrocarbons in smoked cheese. *Journal Science food Agric.*, 88(8): 1307-1317.

Visciano P, Perugini M, Amorena M, Ianieri A. 2006. Polycyclic aromatic hydrocarbons in fresh and cold-smoked Atlantic salmon fillets. *Journal of Food Prot.* 69:1134-1138.

Yunker, M.B., R.W. Macdonald, R. Vingarzan, R.H. Mitchell, D. Goyette and S. Sylvestre, (2002). Polycyclic Aromatic hydrocarbons in the Fraser River basin: a critical appraisal of PAH ratios as indicators of PAH source and composition. *Org. Geochem.*, 33: 489-551.

Yurchenko S, Mölder U. (2005). The determination of polycyclic aromatic hydrocarbons in smoked fish by gas chromatography mass spectrometry with positive-ion chemical ionization. *Journal Food and Analytical Chemistry* 18: 857-869.

## **ENVIRONMENTAL MANAGEMENT POLICIES IN NIGERIA**

Adewoye, O.A.<sup>1</sup>, Oyewole, O. D.<sup>2</sup> and Lawal, O. O.<sup>3</sup>

<sup>1</sup>Dept. of Surveying & Geoinformatics , Osun State College of Technology, Esa Oke

<sup>2</sup>Dept. of Urban and Regional Planning Osun State College of Technology Esa Oke

<sup>3</sup>Dept. of Civil Engineering Osun State College of Technology, Esa Oke

Corresponding author: [waleadewoye@gmail.com](mailto:waleadewoye@gmail.com)

### **ABSTRACT**

The study takes a critical look at environmental management and sustainable development in Nigeria. The data used in this study were acquired from both primary and secondary sources. While the primary data were gotten from focus group discussions, the secondary data were acquired from applicable reading material, journals and magazines. The findings show that environmental management policy gaps, poor responsibility to the usage of natural resources, practices, policies are compelling factors to sustainable development in Nigeria. The study made some valuable recommendations including development agenda that is environmentally socially and economically considerate for sustainable development.

Keywords: Environmental management, sustainable Development.

### **Introduction**

Environmental management has been perceived and acknowledged universally as basic to sustainable development. This depends on the understanding that the environment is at the core of advancement and the development is just an instrument and a procedure that tries to accomplish a reasonable harmony between environment and development on a sustainable basis.

Sustainable development that is inseparably connected to nature was advanced by the World Commission on Environment and Development (WEED) report of 1987 titled "Our Common Future". The report eminently emphasizes the certainty human advancement is to be

accomplished. The study prompted an emphasis on topical issues like population, tourism industry, human settlement, quality of life and productive and effective management of environmental resources.

Regardless of the ostensibly significant connection between environmental management and sustainable development, environmental pollution and degradation as well as the socio-economic and political effect that pose serious challenges to man, environment and development, that have stayed topical and of grave consequences to governments at various levels, non-governmental organization, experts and people especially academics. In Nigeria, environmental management and sustainable development, issues have created a genuine concern to a great extent on account of policy gaps, absence of political will to uphold environmental policies and poor development agenda.

### **Objectives of the Study**

The objectives of the study are to:

- i. examine the relationship between the commitment of the Nigerian Government to Environmental Management policies and Sustainable development.
- ii. assess the connection between real development agenda and sustainable development in the country.
- iii. Make valuable suggestions that will engender sustainable development through proper environmental management strategies and practice in the country.

### **Environments Management and Sustainable Development**

The effective management of natural resources is the way to achieving sustainable development in all parts of the global economy. Global and National Agencies have for quite some time been at the forefront of promoting environmental management. The thrust of natural resources management is to support environmental services promote sustainable management of land, water and genetic resources and to strengthen research and development endeavours. The urgent need for today is to utilise our natural resources in a sustainable manner focusing on their exhaustion and pollution.

The welfare of human societies and personal satisfaction is legitimately connected to the feasible utilization of natural resources. This worry has been properly perceived all-inclusive

in Agenda 21, where it expressed that uncommon consideration ought to be paid to the interest for characteristic assets created by unsustainable utilization and to the proficient utilization of the assets in a manner that is pair to limit consumption and decrease pollution.

The broad object has been solidified into two UN convention managing preservation of natural resources: The Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD). These concerns were motivated by the growing global commitment to sustainable development and represented a dramatic step forward in the conservation of environmental diversity.

Besides, the sustainable development of any nation is firmly connected to its industrial progress, with the energy sector being the significant main thrust. Also, accomplishing reasonable development without radically upsetting the environmental parity of nature is the difficult issue confronting humankind today (Narayanan. 2009). Any modern action will represent some level of environmental effect that could prompt environmental debasement and dangers to prosperity and strength of living beings with the plausibility of environmental emergency.

Discerning of the above mentioned, all sustainability endeavours studies should fuse the industrial, legitimate, political, natural, financial and moral measurements in their approach heading and reactions. Since reasonable improvement focuses on amplifying and ideally disseminating the net advantages of financial advancement, it requires fitting normal the board procedures that will oblige preservation standards to keep up the regenerative limit of assets and guide industrial change in order to change from non-sustainable to renewable assets any place physically conceivable and to build up a staging strategy for the important utilization of non-renewable resources (Brookfield, 2008).

The obvious increment in the demand for environmental resources is to a great extent associated with the worldwide sustainability question. The supply-side displays a reasonable picture where monetary development and advancement highlighted by population increment have altogether decreased the accessible stock of environmental assets (Moravidi,2008)

### **Research Methods**

The study environmental management and sustainable development in Nigeria utilised primary and secondary sources of data, the primary data used in this research were gotten from focus



group discussions session conducted by the researcher. Focus group have demonstrated to be a profoundly smart research procedure for connecting with a gathering of individuals with an inquiry, item or thought. Bringing together a specific subject gives a more characteristic setting than a one-to-one interview, as it enables members to share their thoughts and encounters and through exchange new strands of an idea can develop (Stone, 2015). To ensure strong and clever exchange sessions, the blend of people that partook was painstakingly dictated by the scientist who encouraged during the discourse sessions. The significance of this approach is obvious in the way that additionally intriguing thoughts can rise out of a differing scope of people, as their encounters and dispositions might be more extensive as Bolt (2011) appropriately enunciated.

The six gathering were comprised of academic and students. While academic had five groups and live discussion sessions, students had and one discussion session. The thirty academics (with six members in five gatherings) were from five higher institutions in the state Osun State College of Technology Esa-Oke, Osun State Polytechnic Iree College of education Ilesa, College of education Ila and Federal polytechnics Ede. Then again, the students in one of the six focus discussion group were from Osun state college of Technology Esa Oke.

The discussion was guided by the selected topic "environmental management and sustainable development in Osun State, Nigeria" and it was introduced by the researcher as the facilitator. Various questions important to the above theme were asked and the discourses occurred in a friendly and productive way with an observer in every one of the three focus group sessions secondary data in this examination were derived through content analysis instrument. This instrument was used in gathering pertinent data from texts, journals, newspapers, magazines in an

investigative way that is useful for the study.

### **Data Analysis**

Analysing focus group discussion involves revisiting aim and objectives and looking at the detailed note or a full transcript. The analysis is planned for distinguishing key topics and points of consensus or disagreement as noticing valuable quotation reflects the reasons for the research work (Woods, 2015). In this study, all the notes taken at the focus group discourse sessions were perused and translated. The translated adaptations of the focus group sessions

were contrasted and the notes were taken during FGD sessions to fill the identified gaps. The accord in the assessments and the shared trait in the thoughts communicated and exhibited during the focus group discussion session comprised the reason for noting the research questions brought up in this study. This process was supported with the qualitative data generated in the study through in-depth content analysis of cognate textbooks and journals (Richard, 2015) premised on the topical talk "Environmental management and Sustainable Development in Osun State Nigeria.

### **Environmental Management Policies in Nigeria**

The discussant renewed the Federal Government policy on Environment for sustainability. It was revealed that in 1989, Federal Environmental Protection Agency (FEPA) was established with a legal framework of protecting the environment integrating biological diversity considerations into the national planning policy and decision making as well as conserving and enhancing the sustainable use of the nation's biological diversity (Business day, 2007).

However; FEPA performed below the expected standards and NESREA was established. This is the National Environmental Standards and Regulation Enforcement Agency. This was accrued the obligation of upholding natural laws, guidelines and norms in hindering individuals, ventures and associations from contaminating and debasing the environment. From the expert's discussion, the panel revealed that the Federal Government set out activities organized around the framework programme for environmental protection agencies. The discussants discussed the following: the clean energy bill which was founded in legislation to promote rapid expansion of environmental engineering for sustainability. The law when passed, will enhance improved environmental services, security, address climate change and focus on all the environmental issues.

Civil society reform this is where the menace of climate change was considered with strong advocacy in Mitigation and adaptations. The reform made it mandatory to reappraise the various land uses with a view of addressing the vulnerability and ensure that the mitigating and adapting mechanism are put in place (Nigeria, 2011).

Community development input was not left out because of the need to incorporate the traditional rulers, the community youth leaders on advocacy campaign capacity building and orientation building (Parikh, 2012)

Issues of Generic erosion was not left out where there is biodiversity loss and changes in natural habitat vegetation clearance, forest exploitation which expose the land to the agent of denudation thereby causing erosion of various types and intensity (Business day, 2007). Nigeria as a member of the United Nation Conference on Environment and Development (UNCED) signed a convention in accordance with customary international law. The constitution makes provision for the environmental protection and clearly identifies the components of the environment the section of the Constitution of the Federal Republic +makes provisions for the protection of the environment and safeguard the water, air, forest and wildlife. As a feedback from the (UNCED), Nigeria has put in place various policies and legislation on the environment which include Forest Ordinance, National Parks Decree, Federal Environmental Impact Assessment Decree and Environmental Impact Assessment etc. (Etiosa, 2006; Nigeria, 2001; Nigeria, 2012).

### **Environmental Management and Sustainable Development in Nigeria**

To become environmentally sustainable, the region, country or state must ensure that all environmental sustainability parameters must be taken care of. Poverty must be tackled, Food security must be ensured, clean technology must be encouraged in the industrial sector.

Nigeria has a country is facing a lot of environmental challenges in her developmental studies. To promote environmental sustainability, the government formulated the National Environment Policy of 1999 to stipulate the principles for sustainable development. They formulated policies on forestry, control biodiversity maintenance, pollution control, land degradation, water management, climate change, marine and coastal environment, clean energy etc.

The country through the ministry of environment created the National Oil Spill Detection and Response Agency (NOSDRA) and National Environmental Standards and Regulations Enforcement Agency (NESREA) in 2006 and 2007 respectively. The two agencies have the mandate to implement the national oil spill contingency plan and to enforce all environmental laws and guidelines, policies standards and regulations in the country. NESREA also ensure compliance with the provisions of all international agreements, protocols, conventions and treaties on the environment to which Nigeria belong (FGN Report, 2012).

For examples, in Nigeria, while addressing climate change through the implementation of the UNFCCC and the Kyoto Protocol addressing sustainable development within the tenet of green economy, through the promotion of the elimination of environmentally harmful subsidies and replacing them with market-based incentives:

- Employing near market-based instruments with target instructions to green key sector
- Enforcing its environmental rules and regulations in important sectors such as agriculture, biodiversity, forestry, water resources, fisheries and renewable energy
- Strengthening the economic programmes by adopting the System of Environmental and Economic Accounting (SEEA) which has been prepared by the UN statistics division

However, to achieve sustainability, despite all the efforts, environmental pollution still persists. In the Niger Delta region with Adriene political, economic, health, social and developmental effects. The flora and fauna have been affected (Abdullahi and Mohammed, 2006; Eneh, 2011).

Also, in Oloibiri Kokori, Sangama, Boma, and other oil-bearing communities land degradation has been a testimony (Ejumds and Nirador, 2014).

The Federal, State and Local government in the country are the contributions to the non-compliance with EIA regulations. They approve project before considering the environmental impact. There by only accept a post mortem documents to fulfil all righteousness (Anago, 2002).

In the South East, sheet erosion, gully erosion occurs mostly. For examples, Anambra and Enugu state have over 500 active gully complexes long 20 meters wide and 15 meters deep coastal and marine erosions also occur like the Bar-Beach in Lagos. Drought and Desertification is another thing about 15 states in the North are suffering from drought and desertification.

However, these limitations can be attributed to poverty, over dependence on extractive industries, rapid population growth, inability to enforce appropriate laws and regulations, outdated laws and inadequate penalties and most of all the attitude of the Nigeria legal system with no clear-cut law on the safe keeping of the environment.

Others include, inappropriate agricultural practices, uncontrolled logging, bush burning, mining waste and land mining pits, dumping of non-national expired, contraband chemicals and uncontrolled use of agrochemicals.

## **REFERENCES**

- Abudullahi, M.E and Mohammed, N.D (2006). A review of legislative provisions on environmental safety in the oil producing areas of Nigeria. *Landju Journal of Engineering and Appropriate Techhnology*, 3(2) pp 49 – 52
- Anago, I (2002). Environmental impact assessment as a tool for sustainable development in the Nigerian experience fig xxii. *International Congress Washington D.C. USA*, pp 1-13.
- Business day (2007). *Revisiting January 2008 Environmental Pollution deadline*. Pp 18.
- Bolt, B. (2012). *Research and statistical methods*. London Grade Publishers
- Brookfield, H. (2008). *Environmental sustainability with development*. New Delhi: Chand and Company
- Ejumudo, K.B. and Narador, F.O. (2014). Environmental management and sustainable development in Nigeria. *Niger Delta Journal of Economic and Sustainable Development*, 5(15), pp 26 – 40.
- Eneh, O.C. (2011). Managing Nigeria’s environment: the unresolved issues. *Journals of Environmental Science and Technology*, 4(3), pp 250 – 263.
- Etiosa, U. (2007). *Proceedings of a one-day seminar on environmental laws. The key to sustainable development in Nigeria*. CREDE, pp 37 – 44.
- FGN Report (2012). *Nigeria’s path to sustainable development through green economy, country report to riot 20 Summit by the Federal Government of Nigeria*.
- Karpagan, M. (2010). *Environmental Economics*. New Delhi: Sterling Publication
- Movaridai (2008). *Sustainable Development: The Environment and Development Debate in P.C. and B. Morvaridi (eds). Environmental policy planning*, Ibadan: NCEMA
- Nigeria (2001). *First National Biodiversity Report*, July
- Punch (2012). *Germany sign #3.5 bn pact on the environment 8th August*
- Parikh, J. (2008). *Mainstreaming Gender in Environmental Policy IRAD*. Pp 6 – 28.

Richards, C.N. (2015). *Research Methodology: Quantitative and Qualitative Approaches*: New York Free Press.

Stone, A.P. (2015). *Quantitative Research Methods and Analysis*. Toronto: Thompson Publishers.

Woods, W.O. (2015). *Data Generation and Analysis*. Toronto: Charlson Publishers

## **ACCESSIBILITY AND PATRONAGE OF URBAN OPEN SPACES IN A SOUTH-WESTERN NIGERIA CITY.**

Ajayi, A.O.<sup>1\*</sup> and Amole, O.O.<sup>2</sup>

<sup>1</sup>Department of Urban and Regional Planning, Osun State University, Osogbo,

<sup>2</sup>Department of Architecture, Obafemi Awolowo University, Ile-Ife.<sup>2</sup>

*\*Email: [ayodeji.ajayi@uniosun.edu.ng](mailto:ayodeji.ajayi@uniosun.edu.ng)*

### **ABSTRACT**

This paper examines the patronage and utilization of urban open spaces in Osogbo, Nigeria. Data were obtained through a multi-stage sampling technique. The study area was divided into high, medium and low density areas and 553 (5%) of buildings were systematic selected from 11,022 buildings identified through preliminary survey and satellite images. One teenager and two adults (a male and female) were selected in each building resulting in the total sample size of 1,659. Information on respondent's socio-economic characteristics, frequency of utilization open spaces, travel time, means of transportation and time spent in open spaces were obtained from the questionnaire. Descriptive and inferential statistics were used to analyze the data. The results show that most of the respondents (60.8%) were occasional users of open spaces, 2.2% of respondents never used the open spaces while 37% were frequent users. In addition, the most frequently used open space was the neighborhood park (42.1%), followed by school playgrounds (39.2%) and pocket parks (32.7%). Incidental open spaces had the lowest proportion of patronage(20.9%). The longest duration of use occurred in school playgrounds while the neighbourhood park was the most accessible to the respondents. The frequency of use varies across typologies and residential densities. The mean travel time of respondents across all open spaces was 13.62 seconds, the variations in travel time across typologies were not statically significant ( $F=3.802$ ,  $p =.010$ ). Recommendations to make open spaces more accessible were suggested.

**Keywords:** Proximity, Accessibility, Open space utilisation, Open space typologies, Urban neighbourhoods.

## **1. INTRODUCTION.**

Urban open spaces are multifunctional in nature because they are avenues through which people are able to interact with nature, recreate and socialise (Omoleke, 2012). They exist in various forms in the urban environment. Common classifications of open spaces include parks, gardens, school playgrounds, amenity space, incidental space, recreational space, plazas and streets (Stanley et al.,2012; Aziz, 2012; Schipperijn, 2010; Mell, 2010). However, in most developing countries like Nigeria, school playgrounds are the most common open space typology (Ajayi,2018). Open spaces have different characteristics or attributes which can also be used for classification. These are sizes, aesthetics, facilities, amenities and conditions of open spaces.

The fact that various open spaces in the urban environment influence human health and well-being, physical, social and psychological, community, and sustainable environment is well reported in literature (Wolf, 2010; Regional Public Health, 2010; Bell et al.,2008). Access to open spaces, such as parks, playgrounds and recreational facilities are particularly important for children and young people. This is because children who have better access to such safe places are more likely to be physically active, and less likely to be overweight, compared to those living in neighbourhoods with reduced access to such facilities (Croucher et al.,2007).

Despite the substantial evidence on which attributes influence the use of open spaces, there are contradictions in these studies. For example, a large number of studies report residential proximity to open spaces as the most important attribute that influences use (Jahdi and Khanmohamad, 2013; Lachwycz, 2013; Witten et al., 2008; Regional Public Health, 2010; Abraham et al., 2010). It is well reported in literature that the rate of use decreases as distance increases from open spaces (Sotoudehnia, 2013, Ord, 2013; Kellet and Rofe, 2009; Cohen et al, 2007). In contrast to these submissions, some studies conclude that residents choose to visit open spaces that they find most attractive, well maintained and safe rather than the nearest ones (Forounzande and Motallebi, 2012; Sugiyama et al., 2010; Coorey, 2007). In the same vein, Schipperijn, (2010) concluded that distance to green spaces is not a limiting factor for the majority of the Danish population. Beany (2009), reported that people generally employ an incidental way of using open space, that is open spaces are often not destinations in themselves, but generally, used on the way to somewhere else. Hence, it remains largely unclear the whether the distance of residents to open spaces might influence their patronage in the Nigerian context.



## **2.0 LITERATURE REVIEW**

One of the most studied attributes of open space is proximity or accessibility. In simple terms, accessibility is a concept that measure the distance between individuals and some other physical entities in the geographical space. Accessibility is the ease with which people can reach desired activity sites, it has been widely used as an important indicator to evaluate the extent to which planning has been able to adequately respond to population's demand for urban open space (Johnston et al., 2009). Coorey (2007) construed travel time, proximity to residents, good visibility from streets, shortest network paths, Euclidean-straight line distance, coverage method and public space dispersion as common accessibility measures. Research on distance of open spaces from respondents' homes either objectively or by self-report or both ways have been employed to by scholars (Lestan et al., 2014; Jahdi and Khanmohamad, 2013; Witten et.al, 2008).

Lachowycz (2013), studied the relationship between open spaces and use. Results showed that living nearer open space is associated with recording more physical activity within it (for children) and higher levels of recreational walking (for adults). There is also evidence that the distance from open space is associated with use and physical activity (Kaczynski et al., 2008). This suggests that creating more open spaces within walking distance may increase use and physical activity of residents (McCormark et al.,2010).

However, residents' preferences may influence their opinion for not using the nearest open spaces. Sotoudehnia (2013) explored the spatial and social analysis of green space in Leicester, UK, results showed that 31% of the participants travel to open spaces rather than using their local facilities and that the route respondents took to their preferred open space were not the shortest path as determined by a GIS-based network analysis. In another related study significant relationship between people age, occupation, car ownership, actual travel time and mode of travel with the frequency of use was reported (Sotoudehnia and Comber, 2011). The study concluded that access and access perceptions are related to a number of different but significant factors, including spatial, environmental and socio-demographic factors and are reflected in respondents' preferences.

Wang et al. (2013) posits that accessibility is a complex concept, difficult to define and more difficult to measure. As presented in Figure 1, accessibility goes beyond place and geographic

boundaries (Wang et al.,2013). The framework shown in Figure 1 consists of four major components: people accessibility, perceived accessibility, place use/non-use behaviour and place accessibility.

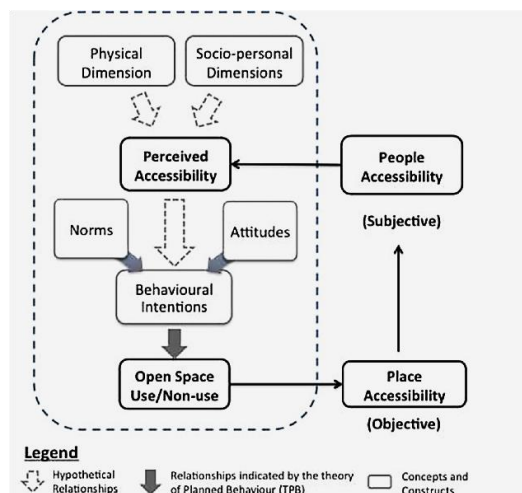


Figure 1: The Integrative Framework for Urban Open Space Accessibility

Source: Wang et al., (2013).

Although no universal standard exists, studies on accessibility generally show that distance from place of residence to nearest open space should be between 0.4km and 0.8km in a neighbourhood. This is considered to represent a walkable distance (Brunnet et al., 2012; Kellet and Rofe, 2009; Cohen et al., 2007b). Beyond this distance threshold, the literature advances that willingness to travel declines with a corresponding impact on physical activity rates in such open space.

Although most studies on open spaces are inclined towards accessibility, other factors have been attributed to affect use of open spaces. For example, attributes such as personal safety, aesthetics, amenities and maintenance are important for encouraging open space use (McCormack et al. 2010). It also reported that perceptions of the social environment entwine inextricably with perceptions of the physical environment. Similarly, in a study carried out by Coorey (2007), social qualities such as interaction, privacy, safety and crowding were reported to be significant in a study of open spaces in high density zones of public housing estates in Hong Kong.

A study shows that having something beautiful or interesting to look at while visiting an open space can be a powerful motivator for patronage (Bedimo-Rung et al., 2005). Some studies have suggested aesthetics of open space as the most important attribute that influence use. For instance, Sugiyama et al. (2010) posits that attractiveness of open space may be more important for physical activity than is size or number of open spaces alone. Thus, simply increasing the numbers of open spaces in neighbourhoods may not be effective in promoting residents' use, unless it has features that make them attractive.

In a qualitative review of the characteristics of open space associated with use and physical activity, presence of trees and hedges, flowers, grass, flowers, natural settings, water features, presence of distinctive smell in open spaces were attributed as aesthetic qualities (McCormack et al., 2010).

### **3.0 METHODOLOGY**

This study used a survey research method. Primary data were obtained through a multi-stage sampling technique. The study area was divided into high, medium and low density areas and 553 (5%) of buildings were systematic selected from 11,022 buildings identified through preliminary survey and satellite images. One teenager and two adults (a male and female) were selected in each building resulting in the total sample size of 1,659. A set of pre-tested questionnaire designed to elicit information on respondent's socio-economic characteristics, frequency of utilization open spaces, travel time, means of transportation and time spent in their most utilized open spaces were administered on the respondents. Respondents were requested to indicate the neighbourhood open space they regularly used, and this was done to identify the location in addition to the frequency of their activities. Respondents evaluated the frequency of use on a 3-point likert scale: never, occasionally, frequently and always. Percentages were used to present the proportion of residents who were frequent users of open spaces (always + frequently), occasional users and those that never used the neighbourhood open space. Descriptive and inferential statistics were used for data analysis.

### **4.0 DISCUSSION OF FINDINGS**

#### **4.1 Demographic characteristics of respondents**

Gender classifications of the respondents as depicted in Table 1 reveals that 54.5% of the total respondents in the study area were male while 45.5% were female. The results show that 50.9% were single, 42.7% were married, 2.1% were divorced, 2.9% were widowed and 1.3% were separated.

Table 1: Demographic characteristics of respondents

		Total
Gender	Male	689 (54.5%)
	Female	576 (45.5%)
	Total	1265 (100.0%)
Age	14-19 Years	320 (25.3%)
	20-40Years	588 (46.5%)
	41-65 Years	344 (27.2%)
	65 And Above	13 (1.0%)
	Total	1265 (100%)
Marital status	Single	643 (50.9%)
	Married	540 (42.7%)
	Divorced	27 (2.1%)
	Widowed	37 (2.9%)
	Separated	17 (1.3%)
	Total	1265 (100%)

#### 4.2. Frequency of use of neighbourhood open spaces

Overall, as presented in Table 2, the results show that most of the respondents (60.8%) were occasional users of open spaces, 2.2% of respondents never used open spaces while 37% were frequent users. This means that open spaces are used by people although not frequently by most, but by at least a third. The low frequency of activities reported in neighbourhood open spaces might be related to the likely fact that residents used other types of spaces like stadiums, gymnasium, streets, events centres and residential open spaces. This relatively low level of utilisation of open spaces in the city is similar to the findings of Simon (2015). The implication of this is that most residents in the city do not use neighbourhood open spaces frequently. This also suggests that respondents might not be taking full advantage of the health benefits possible

from neighbourhood open spaces. Chi square results revealed statically significant variations in pattern of use across the residential densities ( $\chi^2 = 45.133$ ,  $df = 6$ ,  $p < 0.001$ ).

The most frequently used open space typology by respondents in the city was the neighborhood park (42.1%), this was followed by school playgrounds (39.2%) and pocket parks (32.7%). The incidental open spaces had the lowest proportion of frequent use (20.9%).

Table 2: Frequency of utilization in typologies of open spaces

Open Space Typology	Frequency of use	Residential Density			Total	$\chi^2$
		High	Medium	Low		
Playgrounds	Never	4(0.9%)	6(2.6%)	4(3.3%)	14(1.8%)	.000
	Occasionally	231(53.1%)	149(65.6%)	83(68.0%)	463(59.1%)	
	Frequently	141(32.4%)	38(16.7%)	17(13.9%)	196(25.0%)	
	Always	59(13.6%)	34(15.0%)	18(14.8%)	111(14.2%)	
	Total	435(100.0%)	227(100.0%)	122(100.0%)	784(100.0%)	
Neighbourhood Park	Never	4(4.3%)	0(0.0%)	1(6.7%)	5(4.4%)	.198
	Occasionally	45(47.9%)	4(80.0%)	12(80.0%)	61(53.5%)	
	Frequently	28(29.8%)	1(20.0%)	2(13.3%)	31(27.2%)	
	Always	17(18.1%)	0(0.0%)	0(0.0%)	17(14.9%)	
	Total	94(100.0%)	5(100.0%)	15(100.0%)	114(100.0%)	
Incidental Open Space	Never	0(0.0%)	3(3.3%)	0(0.0%)	3(2.3%)	.122
	Occasionally	26(68.4%)	73(80.2%)	0(0.0%)	99(76.7%)	
	Frequently	10(26.3%)	10(11.0%)	0(0.0%)	20(15.5%)	
	Always	2(5.3%)	5(5.5%)	0(0.0%)	7(5.4%)	
	Total	38(100.0%)	91(100.0%)	0(0.0%)	129(100.0%)	
Pocket Park	Never	0(0.0%)	0(0.0%)	1(3.8%)	1(2.9%)	.076
	Occasionally	4(50.0%)	0(0.0%)	18(69.2%)	22(64.7%)	
	Frequently	1(12.5%)	0(0.0%)	6(23.1%)	7(20.6%)	

	Always	3(37.5%)	0(0.0%)	1(3.8%)	4(11.8%)	
	Total	8(100.0%)	0(0.0%)	26(100.0%)	34(100.0%)	
Total	Never	8(1.4%)	9(2.8%)	6(3.7%)	23(2.2%)	.000
	Occasionally	306(53.2%)	226(70.0%)	113(69.3%)	645(60.8%)	
	Frequently	180(31.3%)	49(15.2%)	25(15.3%)	254(23.9%)	
	Always	81(14.1%)	39(12.1%)	19(11.7%)	139(13.1%)	
	Total	575(100.0%)	323(100.0%)	163(100.0%)	1061(100.0%)	

The proportion of frequent users of school playgrounds was 39.2%, while 59.1% were occasional users while 1.8% of respondents never used the playgrounds in the last 6 months. The neighbourhood park had 42.1% of frequent users in the city, 53.5% of respondents visited the park occasionally, whereas 4.4% stated they never visited it in the last 6 months. The proportion of respondents who used incidental spaces frequently, occasionally and those that never used these spaces in the city were 20.9%, 76.7% and 2.3% respectively. Results also show that 2.9%, of respondents in the city never used the pockets parks in the last 6 months while 64.7% and 32.4% respondents were occasional and frequent users of pockets parks. In addition, statically significant variations were recorded in the respondents' frequency of use in the four types of open spaces across the residential densities in the city ( $\chi^2 = 32.207$  df = 6,  $p < 0.001$ ). The highest frequently used was the neighbourhood park while the least was incidental open spaces. This finding is similar to the results of direct observations which showed that the neighbourhood park was the most utilised open space in the city. This finding corroborates Schipperijn (2010) which asserts that parks are the most visited open spaces in Denmark.

#### 4.3 Time spent in neighbourhood open spaces.

From literature review, time spent in open spaces is a good indicator of how the users find the open spaces useful. In this study responders were asked to state the amount of time spent (in hours) on each visit to their mostly utilized open space. For ease of analysis, three categories of users were classified. Short-time users (1-2 hours per visit), medium- time users (3-4 hours) and long-time users (5-7 hours). The results show a prevalence of short-time open space users

in the city (63.6%), the proportion of respondents that spent between 3-4 hours and 5-7 hours respectively in neighbourhood open spaces were 32.3% and 4.1%.

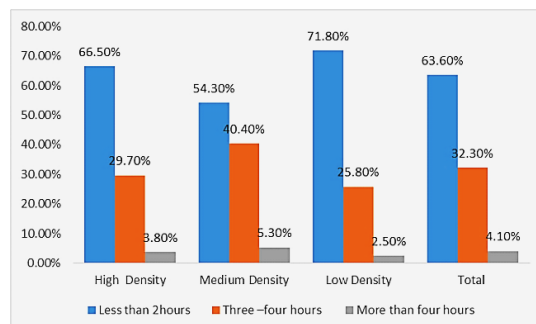


Figure 3: Time spent in neighbourhood open spaces.

The results also show that respondents in the low density area had the highest portion of users (71.8%) that spent less than 2 hours in their neighborhood open spaces. Further analysis was done to ascertain if variations existed in the time spent by respondents across various open space typologies. The results are presented in Table 3.

Table 3.: Time spent in neighbourhood open space typologies

Open Space Typology	Duration (hours)	Residential Density			Total	$\chi^2$
		High	Medium	Low		
School Playground	1-2	284(65.6%)	107(47.3%)	89(73.0%)	480(61.5%)	.000
	3-4	129(29.8%)	104(46.0%)	29(23.8%)	262(33.5%)	
	5-7	20(4.6%)	15(6.6%)	4(3.3%)	39(5.0%)	
	Total	433(100.0%)	226(100.0%)	122(100.0%)	781(100.0%)	
Neighbourhood Park	1-2	62(66.0%)	3(60.0%)	12(80.0%)	77(67.5%)	.590
	3-4	31(33.0%)	1(20.0%)	3(20.0%)	35(30.7%)	
	5-7	1(1.1%)	1(20.0%)	0(0.0%)	2(1.8%)	
	Total	94(100.0%)	5(100.0%)	15(100.0%)	114(100.0%)	

Incidental Open Space	1-2	30(78.9%)	65(71.4%)	0(0.0%)	95(73.6%)	.168
	3-4	8(21.1%)	25(27.5%)	0(0.0%)	33(25.6%)	
	5-7	0(0.0%)	1(1.1%)	0(0.0%)	1(0.8%)	
	Total	38(100.0%)	91(100.0%)	0(0.0%)	129(100.0%)	
Pocket Park	1-2	5(62.5%)	0(0.0%)	16(61.5%)	21(61.8%)	.023
	3-4	2(25.0%)	0(0.0%)	10(38.5%)	12(35.3%)	
	5-7	1(12.5%)	0(0.0%)	0(0.0%)	1(2.9%)	
	Total	8(100.0%)	0(0.0%)	26(100.0%)	34(100.0%)	
Total	1-2	381(66.5%)	175(54.3%)	117(71.8%)	673(63.6%)	.001
	3-4	170(29.7%)	130(40.4%)	42(25.8%)	342(32.3%)	
	5-7	22(3.8%)	17(5.3%)	4(2.5%)	43(4.1%)	
	Total	573(100.0%)	322(100.0%)	163(100.0%)	1058(100.0%)	

The results show that the longest duration of use (more than 4 hours) occurred in school playgrounds. It became evident that among the respondents that used school playgrounds, 61.5% spent less than 2 hours, and 33.5% and 5% spent 3-4 hours and more than 4 hours respectively. This might indicate that respondents find it most suitable for multipurpose uses such as vigorous physical activities and avenues for social events in the neighborhoods.

### **Open space utilisation in groups or alone**

Duration and types of activities of respondents in open spaces can be related to whether the respondents used open spaces alone or in the company of others. Respondents were asked to state if they used open spaces in a group, alone or both (group and individual use) in the past 6 months. From the summary presented in Figure 3, most (47%) of the respondents in the city used the open space in a group while only 19% of respondents used open spaces alone.



Findings show that the patterns of open space utilisation differed by typology (Figure 3).

The results show that pocket parks had highest proportion (24.2%) of respondents that used the open space alone while the neighbourhood park had the least (16.7%). This suggests that attributes of pocket parks may encourage more individual activities than other type of open spaces.

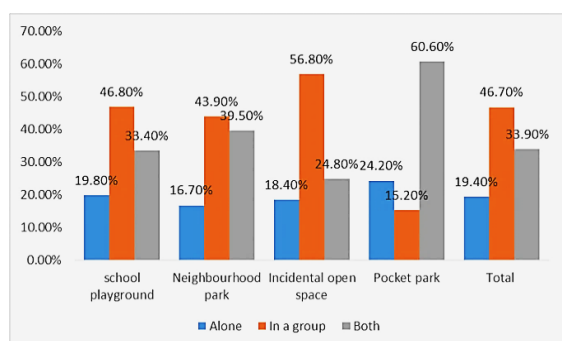


Figure 3: Pattern of open space utilisation by typologies

#### 4.5 Accessibility of neighbourhood open spaces

Respondents were asked to indicate approximate time taken to get to the most utilised open spaces in their neighbourhood in minutes, this was used to estimate ease of access. Two levels of analyses were done. The first level was the computation of mean, minimum and maximum travel time in minutes using the raw values supplied by respondents. Subsequently, the values were put into categories for frequencies and percentages to discover the amount of time taken by respondents to travel to various typologies of open spaces in their residential densities. Table 4 shows the summary of travel time(s) in the study area. Results show that the minimum, maximum and mean travel time were 1, 50 and 13.6 minutes respectively.

Table 4: Travel time of respondents' visits to open spaces

Travel time in minutes	High Density	Medium Density	Low Density	Total
------------------------	--------------	----------------	-------------	-------

Minimum time	1	1	2	<b>1</b>
Maximum time	50	45	45	<b>50</b>
Mean time	14.23	12.30	13.91	<b>13.60</b>
Standard Deviation	8.6	6.4	7.2	<b>7.8</b>

Significant variations were found in the travel time across residential densities according to the results of One-way ANOVA ( $F=6.370$ ,  $p=.002$ ). The mean travel time in high, medium and low densities were 14.2, 12.3 and 13.9 minutes respectively. This indicates that time taken to get to open spaces differed across the densities. The medium density had the lowest travel time (12.3 minutes), this may be due to the fact that the frequency of incidental open spaces observed in the city was highest in this residential area. It is therefore likely that residents had more choices of open spaces to utilise in the medium density area and also these spaces were close by. This also suggests that residents of the medium density area are likely to visit their chosen open spaces more than other residents and may perform more activities there.

In addition, figure 4 shows travel time of respondents to various open space typologies. The overall findings reveal that most of respondents (55.3%) spent less than 15 minutes to get to their open spaces locations in the city. Only 18.9% of respondents spent more than 30 minutes to access open spaces in the city. Results also indicate that 56.0%, 57.9%, 50.0% and 50.0% of respondents spent less than 15 minutes to get to the playgrounds, the neighbourhood park, incidental open space and pocket parks respectively. These findings suggest that the neighbourhood park was the most accessible for the respondents who used it.

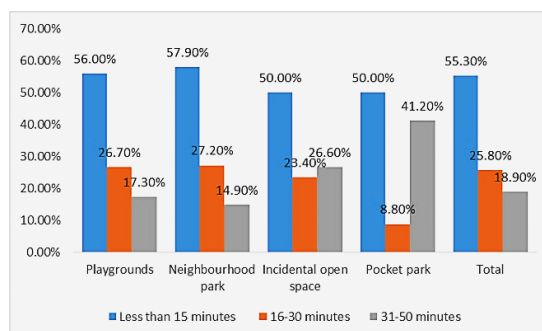


Figure 4: Travel time of respondents' visits to open spaces

In summary, these findings suggest that open spaces in the city were accessible because the reported average travel time to open spaces by most of the respondents was less than 15 minutes which is the maximum distance threshold in literature (Brunnet et al.,2012; Kellet and Rofe, 2009; Cohen et.al, 2007; Obateru, 2003).

#### 4.6 Respondents’ means of transportation to open space

The level of accessibility of open spaces can also be measured by the forms of transport the respondents used to get to open space locations. Basically, transportation means can be motorised and non-motorised. As presented in Table 6, findings show that 35.7% of residents assessed open spaces by foot, while 33%, 19.6% and 11.7% of respondents’ modes of transportation to open spaces in the city were motorbikes, cars and buses respectively.

According to the chi-square test results statically significant variations exit in the means of access across residential densities ( $\chi^2 = 39.482$ ,  $df = 6$ ,  $p < 0.001$ ). It was observed that non-motorised means of transportation (foot) to open spaces was the highest in the city. Results also show that the proportions of respondents in this category were 38.4%, 31.6% and 34.2% in the high, medium and low density areas respectively.

Table 5: Respondents’ Means of transportation to open spaces

Means of transportation	Residential Density			Total
	High	Medium	Low	
Foot	224(38.4%)	101(31.6%)	55(34.2%)	380(35.7%)
Motorbike	205(35.2%)	111(34.7%)	35(21.7%)	351(33.0%)

Car	91(15.6%)	61(19.1%)	57(35.4%)	209(19.6%)
Bus	63(10.8%)	47(14.7%)	14(8.7%)	124(11.7%)
Total	583(100.0%)	320(100.0%)	161(100.0%)	1064(100%)

$$\chi^2 = 39.482, df = 6, p < 0.001$$

The prevalence of non-motorised mode of access suggests that most neighbourhood open spaces were within walkable distance from respondents and thus very accessible. This high percentage of residents walking to open space may also be connected to the high proportion of teenagers and youths who have high energy and physical strength.

#### 4.7 Pattern of respondents' trips to neighbourhood open spaces

Presented in Table 6, are the origins of residents trips made to neighbourhood open spaces in the city. Findings show that overall, most (57%) of respondents set out for open spaces from their residential homes while small proportions: 13.5%, 11.3%, 11.2% ,4.5% and 2.5% of residents set out from work, shops, school, church and mosque respectively. Therefore, respondents' homes were the most common origins for these open spaces.

Table 6: Origin of respondents' trips to neighbourhood open spaces

Origin of respondents' trips	Residential Density			Total
	High	Medium	Low	
Home	354(60.8%)	184(57.7%)	68(41.7%)	606(57.0%)
Work	67(11.5%)	46(14.4%)	31(19.0%)	144(13.5%)
Shops	66(11.3%)	34(10.7%)	20(12.3%)	120(11.3%)

School	53(9.1%)	30(9.4%)	36(22.1%)	119(11.2%)
Church	23(4.0%)	21(6.6%)	4(2.5%)	48(4.5%)
Mosque	19(3.3%)	4(1.3%)	4(2.5%)	27(2.5%)
Total	582(100.0%)	319(100.0%)	163(100.0%)	1064(100%)

Results also show that a higher proportion of the respondents in the high density (60.8%), medium density (57%) than those in low density (41.7%) set out to open spaces from their homes. A breakdown of the respondents that used open spaces on their way to workplaces show very few proportions. Only 19%, 14.4% and 11.5% of respondents in the low, medium and high density areas were in this group. In addition, it is interesting to note that only 11.3% of respondents' trips to open spaces in the city originated from shops.

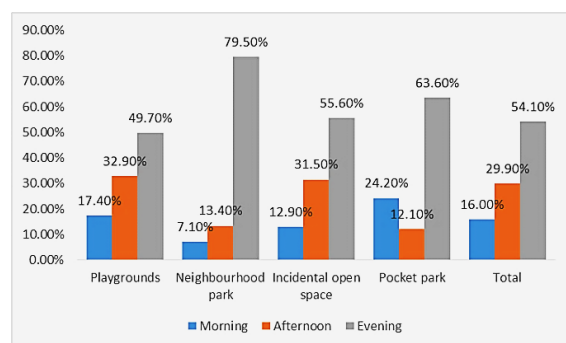


Figure 5: Period of respondents' visits to neighbourhood open spaces

Results on the respondents' time of trips to open space typologies are shown in Figure 5. Findings, overall show that most respondents (54.1%) used the open spaces in the evening. About a third of the population (29.9%) patronised open spaces in the afternoon and very few (16.0%) of respondents in the study area utilised open spaces in the morning. This pattern of use was very similar across the different types of open spaces except the pocket park where there were more morning users than afternoon. The results also indicate that the neighborhood park had the highest proportion of evening patrons (79.5%). This was followed by pocket parks (63.6%) incidental spaces (55.6%), while only (49.7%) of respondents used school playgrounds in the evening. The observed predominance of evening visits may be connected

to the high proportion of students and self-employed respondents who may have academic, economic and other forms of engagements in the morning/afternoon.

Further analysis show that out of the open space typologies, school playgrounds and incidental spaces had high proportions of utilisation in the afternoon, accounting for 32.9% and 31.5% of total respondents. On the other hand, 13.4% and 12.1% of respondents utilized neighborhood and pocket parks in the afternoon respectively. The observed relatively high usage of playgrounds and incidental spaces in the afternoon may be related to the high percentage of teenagers and the proximity of these open spaces. This result suggests that parks and incidental spaces were mainly used in the evening while playground are used in the afternoon by respondents.

## **5.0 CONCLUSION**

Despite the closeness of quite a number of open spaces to residents, only few use them regularly. This study asserts that proximity to locations of urban open spaces does not necessary stimulate increased patronage in this context. It is therefore possible that other factors may be responsible for the residents' occasional utilisation of open spaces in Osogbo. Further studies are needed to investigate the factors influencing utilisation patterns of urban open spaces.

The low level of patronage observed in the study area can be improved if government, health and religious organisations can sensitise the public on the positive health potentials of outdoor activity. Outdoor programmes or competitions that promote activities for all age groups especially children, women and the aged should be organised by private and public organisations in the neighbourhoods. This will provide social support and encouragement for a more active living. In addition, mixed land use that prioritizes the safety of pedestrians' en-route open spaces and integrates other land use types in the neighbourhood should be embraced by architects.

## **REFERENCES**

Ajayi, A. O. (2018). "A Study of Urban Open Spaces and Self-Rated Health in Residential Neighborhoods of Osogbo, Osun State. Unpublished Ph.D Thesis submitted to the Department of Architecture, Obafemi Awolowo University, Osun State, Nigeria

- Abraham, A., Sommerhalder, K. and Abel, T. (2010). Landscape and Wellbeing: A Scoping Study on the Health-Promoting Impact of Outdoor Environments, *International Journal of Public Health*, 55, 59-69.
- Aziz, N. A. A. (2012). Green Space Use and Management in Malaysia, *Forest & Landscape Research*, 51, 127.
- Beaney, K. (2009). Green Spaces in the Urban Environment: Uses, Perceptions and Experiences of Sheffield City Centre Residents, *Doctoral Thesis*, School of Architecture, University of Sheffield.
- Bell, S., Hamilton, V., Montarzino, A., Rothnie, H., Travlou, P. and Alves, S. (2008). *Greenspace and Quality of Life: A Critical Literature Review*, Scotland, Stirling.
- Bennet, S. A. and Yiannakoulis, N. (2012). Playground Accessibility and Neighbourhood Social Interaction among Parents. *Social*
- Cohen, D. A., Lapham, S., Evenson, K. R., Williamson, S., Golinelli, D., Ward, P., Hillier, A., Comber, A., Brunson, C., and Green E. (2007b). Using a GIS-Based Network Analysis to Determine Urban Greenspace Accessibility for Different Ethnic and Religious Groups.
- Coorey, S. B. A. (2007). Design of Open Spaces in High Density Zones: Case Study of Public Housing Estates in Hong Kong, *Unpublished thesis*, University of Hong Kong, Pokfulam, Hong Kong
- Croucher, K. (2007). Health and the Physical Characteristics of Urban Neighbourhoods: a Critical Literature Review. *Final report, Glasgow centre for population health*
- Fermino, R. C. Reis, R. S., Hallal, P. C and Cazuza de Farias, J. (2013). Perceived Environment and Public Open Space Use: A Study with Adults from Curitiba, Brazil. *International Journal of Behavioural Nutrition and Physical Activity*, 10, 35
- Forouzandeh, A. J and Motalleb, G. (2012). The Role of Open Spaces in Neighborhood Attachment Case Study: Ekbatan Town in Tehran Metropolis, *International Journal of Architecture and Urban Development*, 1 (3)

[Kaczynski, A. T.](#), [Potwarka, L. R.](#) and [Saelens, B. E.](#) (2008). Association of Park Size, Distance, and Features with Physical Activity in Neighbourhood Parks, *American Journal of Public Health*, 98(8)

Kellett, J. and Rofe, M. W. (2009). Creating Active Communities: How Can Open and Public Spaces in Urban and Suburban Environments Support Active Living? A Literature Review

Lachowycz, K. (2013). An Exploration of the Relationship between Green Spaces, Physical Activity and Health, *Doctoral Thesis*, School of Environmental Sciences, University of East Anglia, UK

Lestan, K., Eržen, I. and Golobič, M. (2014). The Role of Open Space in Urban Neighbourhoods for Health-Related Lifestyle, *International Journal of Environmental Research and Public Health*

.McCormack, G. R., Rock, M., Toohey, A. M. and Hignell, D. (2010). Characteristics of Urban Parks associated with Park Use and Physical Activity: a Review of Qualitative Research, *Health and Place* 16, 712–726

Mell, I. C. (2010). Green Infrastructure: Concepts, Perceptions and its Use in Spatial Planning, *Doctoral Dissertation*, Newcastle University, Newcastle

Omoleke. S. A. (2012). Green Space, Gender and Health: A Re-Examination of the Literature, *Bulletin of Environment Pharmacology Life Science*, 1 (9), 03 – 11

Ord, K., L. (2013). Physical Activity in Green Space: A Mechanism for Reducing Health Inequalities? *Doctoral Thesis*, College of Medical, Veterinary and Life Sciences, University of Glasgow

Regional Public Health, (2010). Healthy Open Spaces: A Summary of the Impact of Open Spaces on Health and Wellbeing, *Regional Public Health Information Paper*, Lower Hutt.

Saw, L. E., Lim, F. K. S. and Carrasco, L. R. (2015). The Relationship between Natural Park Usage and Happiness Does Not Hold in a Tropical City-State. *PLoS ONE*, 10(7), e0133781.

Schipperijn, J. J. (2010). Use of Urban Green Space, Skov and Landskab, Københavns Universitet. *Forest and Landscape Research*, 45



Sotoudehnia, F. (2013). A Spatial and Social Analysis of Green Space Access: a Mixed-Methods Approach for Analysing Variations in Access Perceptions, *Doctoral Thesis*, University of Leicester. Department of Geography University of Leicester

Stanley, B. W., Barbara, L., Stark, B. L., Katrina, L., Johnston, K. L. and Smith, M. E. (2012). Urban Open Spaces in Historical Perspective: A Trans-Disciplinary Typology and Analysis, *Urban Geography*, 33 (8), 1089–1117

[Sugiyama, T.](#), [Francis, J.](#), [Middleton, N. J.](#), [Owen, N.](#) and [Giles-Corti, B.](#) (2010). Associations between Recreational Walking and Attractiveness, Size and Proximity of Neighborhood Open Spaces, *American Journal of Public Health*, 100(9), 1752–1757.

Wang, D., Mateo-Babiano, I. and Brown, G. (2013). *Rethinking Accessibility in Planning of Urban Open Space Using an Integrative Theoretical Framework*, Final Paper Submitted to State of Australian Cities Conference

Witten, K., Hiscock, R., Pearce, J. and Blakely, T. (2008). Neighbourhood Access to Open Spaces and the Physical Activity of Residents: a National Study, *Preventive Medicine* 47, 299–303

Wolf, K. L. (2010). *Active Living - A Literature Review in: Green Cities: Good Health*, College of the Environment, University of Washington. Retrieved from: [http://depts.washington.edu/hhwb/Thm\\_ActiveLiving.html](http://depts.washington.edu/hhwb/Thm_ActiveLiving.html)

## **MAPPING OF THE SUSCEPTIBILITY AREAS TO LANDSLIDE IN JOS SOUTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA.-GIS APPROACH**

Fadipe, O.O.<sup>1\*</sup> Shitta, N.<sup>2</sup> Okeke, O.J.<sup>3</sup> Adeosun, J.O.<sup>4</sup>

<sup>1\*</sup>Department of Civil Engineering, Osun State University, Osogbo, Osun State, Nigeria.

<sup>2</sup>Centre for Geodesy and Geodynamics Toro, Bauchi State, Nigeria.

<sup>3</sup>Propcom Mai-Karfi, DFID Project, Abuja Nigeria.

<sup>4</sup>Department Civil Engineering , Osun State University, Osogbo, Osun State, Nigeria.

\* [olayemifadipe@yahoo.com](mailto:olayemifadipe@yahoo.com), <sup>3</sup> [okaykaygeoinfo@gmail.com](mailto:okaykaygeoinfo@gmail.com) ,<sup>4</sup> [julieadeosun@gmail.com](mailto:julieadeosun@gmail.com)

\*corresponding author (+234-8034539764)

### **ABSTRACT**

Landslide is a natural disaster and can distort the entire ecosystem but it is area dependent. It has negative and adverse multiple effects which can reduce the social-cultural and economic standards of the people, hence predicting the occurrence and setting measures for reducing the impact is imperative. This study presents the report of the mapping of the susceptibility areas to landslide in Jos south LGA using geospatial method and multi-criteria analysis. The data set for the study were obtained from topographic, soil and geology maps, satellite images, digital elevation model (DEM) generated from the digitised contour. The data were analysed using ArcGIS 10.1. Eight contributing factors were examined; geology, slope, soil types, landcover, land-use, drainage length, geomorphology and lineament density. The Analytic Hierarchy Process (AHP) of Multi Criteria decision making method was used to extract the weights for the different layers. The contributing percentages for the factors are; slope (21%), soil (19%), landuse/ landcover (9%) geology (13%) drainage length (16%) geomorphology (10%) and lineament density (12%). The landslide susceptibility mapping was carried out by running the standard weighted overlay model and the map revealed that 0.06% of the study area is severely high, 3.88% is high, 46.01% is moderate, 34.39% is low and 15.66% is very low. There is a need for periodic mapping and spatial measurement to ascertain the dynamic pattern of landslide in this region; this will assist prediction of risk potentials and preventive measures to reduce the magnitude of any future occurrences.

Keywords : Landslide, Jos South, GIS, susceptibility map, weighted overlay

## **1.0 INTRODUCTION**

Landslides are geological phenomenon and it occurs as a result of rock falls, ground movement, and failure of unstable slopes (Agbor, 2014). The movement can cause a lot of damages with direct and indirect effect on human settlements and physical infrastructure. It is believed to be a very destructive geological processes but classified as natural disaster. It can destroy properties worth of millions and can take lives if caught unaware. Natural disaster are most times uncontrollable and forecasting or predicting of occurrences prove difficult because the preparation of a map showing landslide-prone areas call for collection of the relevant spatial data. Landslide susceptibility mapping is the method of identifying areas which are subject to landslides. There are different methods of creating a susceptibility map; the direct mapping method involves identifying regions susceptible to slope failure, by comparing detailed geomorphological and geological properties with those of landslide sites. The indirect mapping methods involve integrating many factors and weighing the importance of different variables using subjective decision-making rules, based on the experience of the geoscientists involved (Lei and Jing-feng, 2006).

The reliability of landslide susceptibility maps mainly depends on the amount and quality of available data, the working scale, and the selection of methodology of modeling (Baezo and Corominas ,2001). Almost every landslide has multiple causes. There are no universal guidelines for selecting parameters that influence landslides in susceptibility mapping (Yalcin 2008; Feizizadeh *et al.*, 2012b), because it can exhibit a combination of two or more types of movements, resulting in a complex type (Varnes, 1984) thus landslide is area dependent. In Nigeria, no map or guideline currently exist to assess the relative landslide potential hence, people are caught unaware and there are often no mitigation efforts by the government (Gbadebo, 2018). Some cases of landslides have been reported in Nigeria; the landslide, which occurred in Oko Community of Anambra State, rendered more than 150 people homeless (<https://www.premiumtimesng.com>) and no fewer than 60 houses and historical sites were been destroyed by landslides at Calabar (<https://dailypost.ng>) At least nine people died and many more received injuries in a landslide at Edim Otop community in Calabar (<https://reliefweb.int/report/Nigeria>), four persons, including three

children, were killed by a landslide at an excavation site in Funtawa village and Agbor *et al.* (2014) reported landslide on the Azenge mountain in Benue State, Nigeria.

The use of Geographical Information System (GIS) has greatly simplified the assessment of natural disasters and environmental concerns. GIS technology provides effective tools for the handling, integrating and visualizing diverse spatial data sets (Brimicombe, 2003). GIS Multi Criteria Decision Making (MCDM) is one of the important methods of spatial analysis in GIS that allows knowledge derived from different sources to be combined in order to support landslide analysis. One multi-attribute technique that has been incorporated into the GIS based landslide analysis procedures is the Analytical Hierarchy process that is presented by Saaty (1980). Among the GIS-MCDA methods, the AHP gained high popularity due to the ease in obtaining the criterion weights, as well as its capacity for integrating heterogeneous data. It is therefore applied in a wide variety of decision-making problems (Fehizizadar and Blaschke, 2013) Normally, the determination of the values of the criteria relative to each other is subject to the choices of the decision-maker.

In literature, there have been many studies ( Oluwafemi *et al.*, 2017; Gbadebo *et al.*, 2018) carried out on landslide susceptibility evaluation using GIS. The present study used GIS to map the land slide of Jos south using different causative factors because it has been reported that possible landslide event in the hot spots could be pronounced and could destabilize the natural and man-made environmental systems of the study area.

## **2.0 METHODOLOGY**

### **2.1 Study Area**

The study area (Figure 1) is Jos South local government area (LGA) in Plateau State, Nigeria. It lies with  $9^{\circ}40'00''\text{N}$  to  $9^{\circ}50'00''\text{N}$  and  $8^{\circ}45'00\text{E}$  to  $9^{\circ}0'00\text{E}$ . It has an area of  $510\text{km}^2$  and a population of 306,716 at the 2006 census. The headquarter is located in Buruku. Geologically the LGA is characterised by quartz porphyry, granite gneiss, hornblende gneiss, basalts, trachyte and

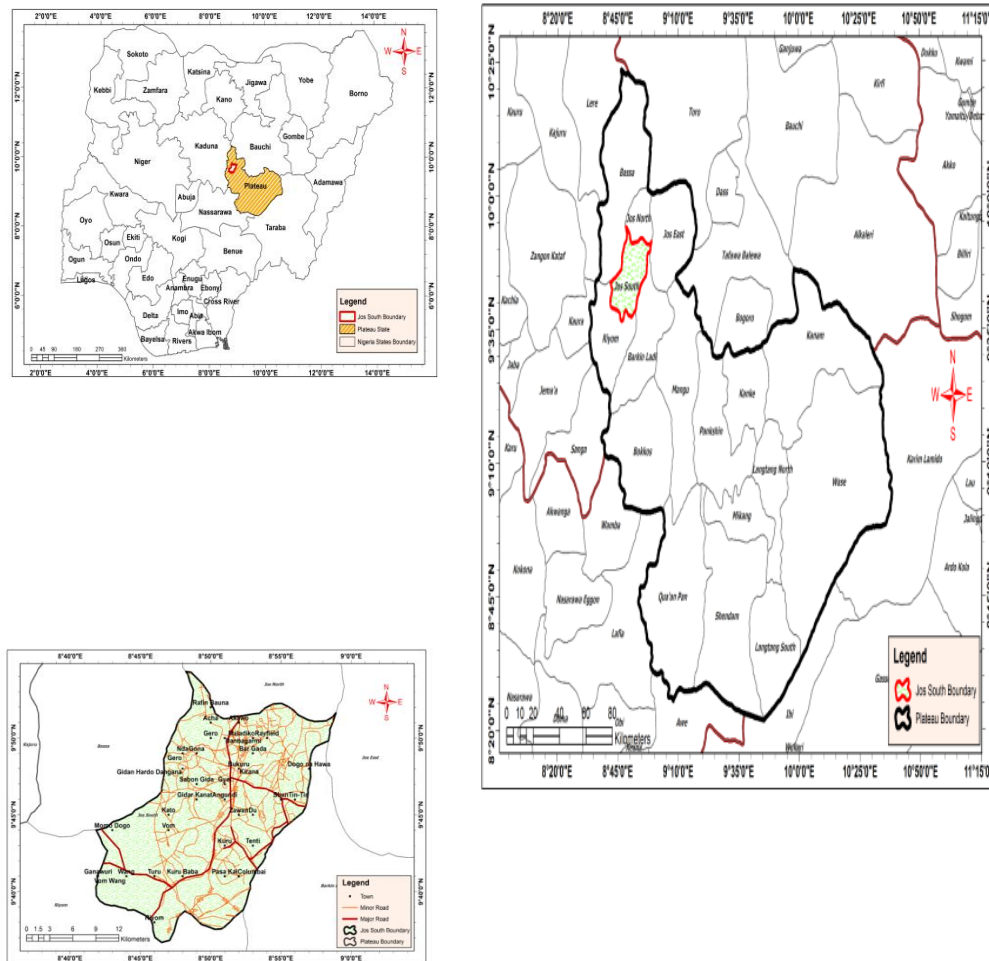


Figure 1: Study Area Map

Source: Adopted from Oluwafemi *et al.* ( 2017)

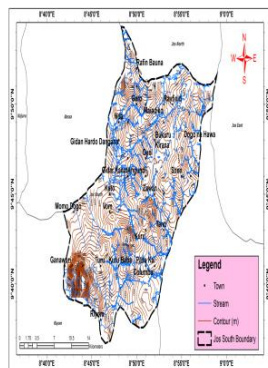
Rhyolite Mignonette gneiss, fine-grained biotite granite. The soil types are gleysol, lixisols, luvisols, cambisols and acrisol mining. The months with the highest number of rainy days is July. Months with the lowest number of rain are January, February, and December ([www.weather.nga.com](http://www.weather.nga.com)). The average annual temperature is 22.8°C and the average annual rainfall is 1324mm (<http://www.en.climate.data.org>)

## 2.2 Selection of Contributing Factors

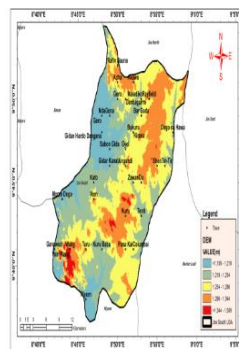
Eight contributing factors were considered based on literature (Gbadebo *et al.*, 2018; Wu and Li, 2015, Schlagel, 2018). They are geology, slope, soil types, landcover/land use, drainage length, geomorphology and lineament density.

### 2.3 DATA acquisition

This involves collection of necessary data acquisition of satellite images. The Landsat 8 ETM imagery obtained from United State Geological Survey (2014) ([www.glovis.com](http://www.glovis.com)) USGS was used. The geologic and the topographic maps are projected with the Minna National UTM datum and the Landsat-ETM used the WGS 1984 ZONE 31. The Digital Elevation Model (DEM) used for this work, has a spatial resolution of 15m. It was generated



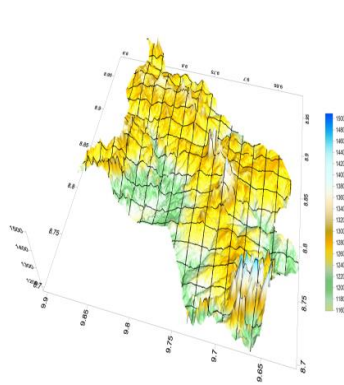
a) Contour map of Jos South



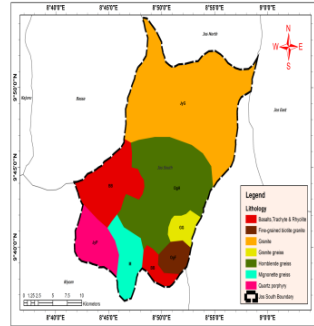
b) DEM of Jos South



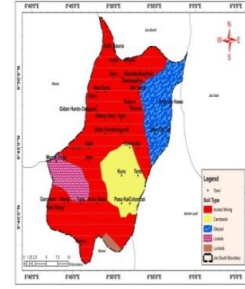
c) Lineament of Jos South



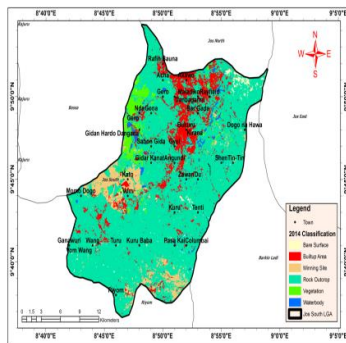
d) Geomorphology of Jos South



e) Geology map of Jos South



f) Soil map of Jos South



g) Landuse/landcover of Jos South

Figure 2: Landslides causative factors maps

from a digitized contour with 50 feet interval extracted from 1:50,000 topographic map (figure 2a). After the error editing and validation of the DEM (Figure 2b) data, the ArcGIS10.1 3D-surface analysis was used to generate the drainage length and the slope. The lineament and geomorphology (Figure 2c and 2d) was obtained from the Landsat, geology maps(Figure 2e) and drainage maps respectively. All the data including the landuse/landcover and soil map (Figures 2f and 2g) were processed into a geo database using Arc 10.1 (Figure 2). These formed the spatial data. All the input criteria were converted into grid raster in order to combine them in a single layer using overlay technique. Because of the difference in the numbering

system, each of the cell for each of the criterion was reclassified into a common preference scale between 1 and 6. The number 6 was the most landslide causative factor and the number 1 the least. Analytic Hierarchy Process (AHP) of Multi Criteria decision making method was used to extract the weights for the different layers. The landslide susceptibility mapping was carried out by running the standard weighted overlay model. The different weighted ranking for each of the causative factors are slope (21%), soil (9%), drainage (16%), geology (13%), lineament (12%) geomorphology 10%, and landuse /landcover (9%).

#### 4.0 RESULT AND DISCUSSION

The result of the weighted overlay analysis model gave the susceptibility map. A small fraction (0.06%) of the study area is severely high, 3.88% is high, 46.01% is moderate 34.39 % is low and 15.66% is very low (Figure 3). The areas that have tendency for high landslide susceptibility are Gidar Kanat, Sabon Gida, Gidan Hardo Dangana, Gona, Nda and Gerowhile Acha , Akawo, Angundi, Bar Gada ,Bukuru, Danbagarmi , Du , Gero, Gona, Gyel, Kato, Kirana, Kuru Baba, Maiadiko, Momo Dogo, Rafin Bauna, Rayfield, Riyom, Sabon Gida Riyom & Sabon Gida are moderately susceptible to landslide. Dogo na Hawa, Ganawuri, Shen, Tenti, Tin-Tin, Turu & Zawan are classified as area with low level of susceptibility to landslide. Lastly, Columbai, Kuru, Pasa Kai, Vom Wang & Wang are categorized as very low. The result statistics (Table 1) revealed the susceptibility maps in terms of area. The percentage of susceptibility almost agree with Oluwafemi *et al.* (2017) but the different methods of mapping the area might have contributed to the variation.

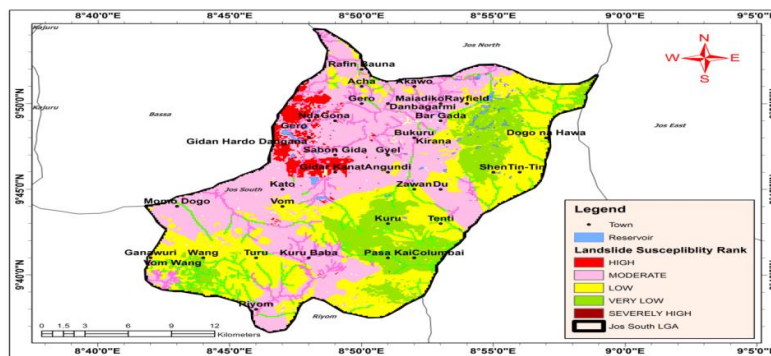


Figure 3: Landslide susceptibility map of Jos South Local Government



Table 1: Results Statistics

S/N	Ranking	Area (Km <sup>2</sup> )	%	Mean/S.D	Max (Km <sup>2</sup> )	Min (Km <sup>2</sup> )
1	SEVERELY HIGH	0.31	0.06	0.01±0.01	0.01	0.01
2	HIGH	19.79	3.88	0.13±0.75	7.31	0.01
3	MODERATE	234.85	46.01	1.13±15.71	226.66	0.01
4	LOW	175.51	34.39	0.63±4.69	50.68	0.01
5	VERY LOW	79.94	15.66	0.97±5.01	36.53	0.01
Total		510.40	100.00			

## 5.0 CONCLUSION AND RECOMMENDATION

The susceptibility map of the study area revealed that the causative factors modelled the landslide situation in the local government and the area is at low risk of occurrence of landslides. A periodic assessment is recommended for decision makers on areas with very high susceptibility. The results of the mapping could be very useful for planning and mitigation of future landslide occurrence.

## REFERENCES

- Baeza C, Corominas J (2001) Assessment of Shallow Landslide Susceptibility by Means of Multivariate Statistical Techniques. *Earth Surf Procedia* (26):1251-1263
- Brimicombe, A., 2003, GIS, Environmental Modelling and Engineering, London, New York, Taylor & Francis, p 312
- Feizizadeh B, Blaschke T, Rezaei Moghaddam M.H (2012b) Landslide Susceptibility Mapping for the Urmia Lake basin, Iran: A Multi-Criteria Evaluation Approach using GIS. *International Journal of Environmental Residual*.
- Feizizadeh B, Blaschke T, (2015) GIS- Multicriteria Decision Analysis for Landslide Susceptibility Mapping: Comparing Three Methods for the Urmia Lake Basin Iran. *Natural Hazards* 65: 2105-2128

Gbadebo, A.M, Adedeji, O.H, Edogbo, A.S. (2018). GIS-Based Landslide Susceptibility Assessment in Eyinoke Hilly Area of Okeigbo, SW, Nigeria. *Journal of Applied Science and Environmental Management*. Vol. 22 (6) 917–924

<http://www.en.climate.data.org>

<https://www.weather.nga.com>.

<https://www.weather.nga.com>.

<https://www.premiumtimesng.com>)

<https://dailypost.ng>

<https://reliefweb.int/report/Nigeria>

Lei Z, Jing-feng H (2006). GIS-Based Logistic Regression Method for Landslide Susceptibility Mapping in Regional Scale. *J Zhejiang Univ Sci A*. 7(2):2007–2012

Oluwafemi O.A , Yakubu T.A, Muhammad M.U, Shitta N, and Akinwumiju A.S (2017).

Mapping Landslides Susceptibility in a Traditional Northern Nigerian City. *Proceedings of the International Cartographic Association/ica –proc*

Yalcin A (2008) GIS-Based Landslide Susceptibility Mapping using Analytical Hierarchy Process and Bivariate Statistics in Ardesen (Turkey): Comparisons of Results and Confirmations. *Catena* 72:1–12

Saaty T.L (1980). *The Analytic Hierarchy Process*. McGraw-Hill, New York, p 437

Schlagel N (2018). Development of a Preliminary Landslide Susceptibility Model for Afghanistan using Multi- Criteria <https://www.researchgate.net/publication>

Wu Y, Li W (2015). A GIS Based Landslide Susceptibility Mapping Using Multi-Criteria Decision Analysis Model at a Regional Scale 2: 4445-4461

## **A STUDY OF SPATIAL ACCESSIBILITY TO PUBLIC SECONDARY SCHOOL EDUCATION IN OSUN WEST SENATORIAL DISTRICT, NIGERIA**

Adeyinka, S.A.<sup>1</sup>; Ojo, A.O.<sup>1</sup>, Olayode, O.<sup>2</sup> and Ogundahunsi, D. S.<sup>2</sup>

<sup>1</sup>Department of Urban and Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria

<sup>2</sup>Department of Urban and Regional Planning, Osun State University, Osogbo Osun State

[Olayiwola.olayode@uniosun.edu.ng](mailto:Olayiwola.olayode@uniosun.edu.ng) Tel.: 07060591466

### **ABSTRACT**

This study used the application of Geographic Information System (GIS) to analysed spatial accessibility to Public Secondary Schools (PSSs) education in Osun West Senatorial District (OWSD), Nigeria with a view to providing information that could enhance future secondary school education planning and development. The specific objectives are to determine the location of public secondary schools in the district and examine the area coverage.

Data for this study were obtained through direct field observation using the Global Positioning System (GPS) to identify and examine coverage areas of these 116 PSSs in the study area, settlements with PSSs were stratified into three categories based on population density: suburb (less than 10,000 people), semi-urban (between 10,000-19,999 people) and urban (20,000 people and above). The data acquired were analysed using GIS and descriptive statistics. Findings of the study established that across the settlements categories that PSSs at the buffer of 1km Radius (Rs), majority (81.8%) were clustered in the urban while majority (20%) and (70.0%) in both semi-urban and suburb were dispersed. Findings further revealed that majority PSSs at the buffer of 2km Rs, in urban (64.8%) were clustered while 21.4% and 71.4% were dispersed in the semi-urban and suburb. Moreover, findings showed that PSSs were clustered at the buffer of 3km Rs (63.3%) in the urban and dispersed (23.1% and 69.2%) in both semi-urban and suburb. Furthermore, it is evident from the findings that PSSs at the buffer of 4km Rs, majority (55.9%) were clustered in the urban while majority (35.7% and 56.1%) in the semi-urban and suburb were dispersed. The study concluded that PSSs were not evenly

accessible in OWSD. It is therefore recommends that, Government, stakeholders and private investors should come together to make PSSs education available to all category of settlements.

**Keywords:** Public Secondary Schools, Spatial Planning, Accessibility, Settlements Categorization

## **1.0. INTRODUCTION**

Education distribution is an integral part of planning which has contributed immensely to all sphere of human and socio-economic development of nations. Harnessing the benefits that education offers is premised on the availability and accessibility of educational infrastructure to the target beneficiaries, which characterises their distribution explained by spatial analysis (Ogundahunsi and Olayode, 2018; Ojo, 2018).

The concept of accessibility to educational facilities attempt to underscore the spatial distribution, threshold population required and patronage pattern by the users (Khalid, Hamdy and El-Gamily, 2013; Olubadewo, Abdulkarim and Ahmed, 2013; Fabiyi and Ogunyemi, 2015; Ogundahunsi, 2014; Agrawal and Gupta, 2016). In addition, spatial analysis of educational facilities is not only critical in land use planning but it could also be employed to predict user's distance travelled, school coverage, travel time (as determined by availability, distribution and location), knowledge, beliefs, information and preferences among others to fully harness the benefits of inherent in education (Ikoya & Onoyase, 2008; Onuka & Arowojolu, 2008).

Among the categories of educational facilities, secondary school plays a cardinal role. According to World Bank (2005), secondary school education serves as the bridge between the primary and tertiary education, as it prepares individuals for higher education.

In Nigeria, effort towards improved access to and harnessing the abounding potentials of education in urban and rural environment has necessitated the evolution of various policies and modifications in educational system over the years (Ojedele, & Ilusanya, 2006). Hence, equal distribution and accessibility to education is of high concerns for effective sustainable development.

The problem of inadequate education facilities has immense contribution to human and national development justifies the importance attached to it. This has remained the global

concern in the provision of quality education, which necessitated effort at ensuring that the progress made in the Millennium Development Goals (MGDs) is sustained, thus becoming the fourth agenda of the Sustainable Development Goals (SDGs) of the United Nations. Consequently, studies have attempted to unravel the dynamics of education provision and delivery worldwide (Allard, 2008; Amsterdam, 2010; Aliyu, Shahidah, & Aliyu, 2013; Maangi, 2014; Mustapha, *et al.* 2016; Meskarian *et al.*, 2017; Ojo, 2018).

Meskeraian *et al.*, (2017) observed that patronage of educational facilities is hindered by factors such as distance, proximity and location, which are not only determined in the distribution of the schools. Studies on spatial distribution of educational facilities have noted that ensuring equitable spatial distribution is critical to improved access by the users. For instance, Naidoo, Van, and Munch (2014) examined spatial variation in the location of schools in Cape Town, study of this nature are best defined using up-to-date Geographic Information System (GIS). Therefore, this study adopt the use GIS to analyse spatial accessibility to public secondary school education in OWSD with a view to providing information that could enhance future secondary school education planning and development.

The specific objectives are to determine the location of public secondary schools in the district and examine the area coverage in the study area. These are with a view to providing information that could enhance education distribution and planning.

### **1.1. Study Area**

OWSD comprises of 56 settlements (11 urban settlements with 20,000 and above people, 11 semi-urban with 10,000-19,999 people and 28 suburb with less than 10,000 people) with 116 PSS 59 in the urban, 16 in the semi-urban and 41 in the suburb. The district is situated in Osun State of Western Nigeria. It is located between Latitudes  $7^{\circ} 30'N$  and  $7.5^{\circ}N$ , and Longitudes  $4^{\circ} 30'E$  and  $4.5^{\circ}E$ .

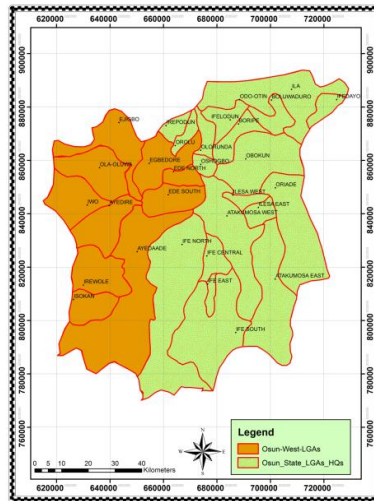


Figure 1: Osun West Senatorial District in the Context of Osun State

Source: Ministry of Lands and Physical Planning, Osun State.

## 2.0. Methodology

Data used for this study were obtained from both primary and secondary sources. The primary data was obtained using Germain GPS 72h to pick the coordinates (latitude and longitude) of the schools. The secondary data included population figure collected from National Population Commission Osun state used to categorised settlements into three categories: urban (20,000 and above people), semi-urban (19,999-10,000 people) and suburb (bellow 10,000 people). In addition, secondary schools directories were obtained from Osun State Ministry of Education. Table 1 revealed that, there were 116 PSS in the study area.

Table 1 revealed a total of 116 PSSs in OWSD, 50.9% in the urban, 13.8% in the semi-urban and 35.3% in the suburb.

### 2.1. GIS Analysis Procedure

The following GIS techniques were used in achieving Buffer Analysis:

1. Digitisation of OWSD from Osun State Map;
2. Georeferencing of the digised map;
3. Creation of Database on the acquired PSS coordinates using Microsoft Excel;
4. Saving of the Database as shape for GIS enablement;

5. Exporting and overlaid of the database as point map on OWSD area map in ArcGIS environment;
6. Transformation of the points to shape files for further analysis; and
7. Creation of buffer analysis to assess settlements and users accessibilities and patronage pattern within the range of 1km RS, 2km RS, 3km RS and 4km RS in the study area.

### **3.0. Discussion of Findings**

Table 1 revealed that, within 1km RS, PSSs were clustered (91.5%) in the urban settlements and dispersed both in semi-urban (62.5%) and suburb (85.4%) settlements. In addition, findings showed that only 8.5% of the PSS in the urban was dispersed while just 37.5% in the semi-urban and 14.6% in the suburb settlements were clustered. Furthermore, findings revealed that only 56.9% of the PSS in OWSD were clustered within 1km RS while as much as 43.1% were dispersed.

Table 1 showed that, at 2km RS, PSS were clustered both in urban (91.5%) and semi-urban (62.5%) settlements but dispersed (51.2%) in the suburb settlements. Moreover, it is evident from the findings that only 8.5% and just 37.5% of the PSS in the urban and semi-urban respectively were dispersed while just 48.8% in the suburb settlements was clustered. Furthermore, findings revealed that the highest proportion (75.9%) of the PSS in OWSD were clustered within 2km RS while just 24.1% were dispersed.

It is evident from Table 1 that, PSSs were clustered at 3km RS across the settlement categorization, in the urban (96.6%), semi-urban (62.5%) and suburb (56.1%). Findings established that only 4.4% of the PSSs in the urban was dispersed, just 37.5% in the semi-urban and 43.9% in the suburb. Furthermore, findings showed that the highest proportion (77.6%) of the PSS in OWSD was clustered while few (22.4%) were dispersed.

The study also revealed as shown in Table 1 that, within the RS of 4km PSS were clustered across the settlements, in the urban (96.6%) and semi-urban settlements (68.7%) while it is dispersed in the suburb (82.9%). In addition, findings show that only 4.4% of the PSS in the urban, 31.3% in the semi-urban and 17.1% in the suburb were clustered. Findings, furthermore established that 87.9% of the PSS in OWSD was clustered while just 12.1% were dispersed.

This study established that both the students and staff (users’) of PSS in OWSD traveled between 1km to 4km and above. In addition, the study revealed that PSS were clustered at 1-2km RS in most of the urban settlements at the detriments of semi-urban and suburb settlements and how PSS were highly clustered at 3-4km RS both in the urban and semi-urban while suburb settlements are lagging. It is evident from the findings that there is inequality in the establishment and distribution of PSS in OWSD which has resulted to unequal accessibility to educational services and facilities as places to include: Olufirin, Anajere, Islamia Abebi Area, Sango in Ikire; Oke-Elerin, Oke-Odo, Isale-Gbeke, Apeena in Gbongan; Ogburo, Obajoko, Hospital Road, Agoro, Idi-Oke in Iwo; Idi Ape area, Aba Ramotu, Logun Oke – Ola, Isoko, Olosinmo, Ikan, Ado Ori – Oke, Aponla, Aato in Ejigbo; Oke-Osun, Tantoloun, Station, Alaya, Gbandu, Adenlere in Ayedire Area; include Idere, Olota, Idiya, Olodo, Ololulolu, Obamoro, Isero, Owoyalesun in Ola-oluwa many more, existed without access to PSS. In addition, people in these areas travelled long distance to use PSS.

**Table 1: Distribution of PSS in OWSD**

1KM Radius		Settlements			Total
		Urban	Semi-urban	Suburb	
Clustered	Count	54	6	6	<b>66</b>
	% within Clustered	81.8%	9.1%	9.1%	<b>100%</b>
	% within Settlements	91.5%	37.5	14.6%	<b>56.9%</b>
Dispersed	Count	5	10	35	<b>50</b>
	% within Dispersed	10.0%	20.0%	70.0%	<b>100%</b>
	% within Settlements	8.5%	62.5%	85.4%	<b>43.1%</b>
	<b>Count</b>	<b>59</b>	<b>16</b>	<b>41</b>	<b>116</b>
<b>Total</b>	<b>% within</b>				
	<b>Clustered/Dispersed</b>	<b>50.9%</b>	<b>13.8%</b>	<b>35.3%</b>	<b>100%</b>
	<b>% within Settlements</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

2KM Radius		Settlements			Total
		Urban	Semi-urban	Suburb	
Clustered	Count	57	10	21	<b>88</b>
	% within Clustered	64.8%	11.4%	23.8%	<b>100%</b>
	% within Settlements	91.5%	62.5%	48.8%	<b>75.9%</b>
Dispersed	Count	2	6	20	<b>28</b>
	% within Dispersed	7.1%	21.4%	71.4%	<b>100%</b>
	% within Settlements	8.5%	37.5%	51.2%	<b>24.1%</b>
	<b>Count</b>	<b>59</b>	<b>16</b>	<b>41</b>	<b>116</b>



<b>Total</b>		<b>% within</b>			
	<b>Clustered/Dispersed</b>	<b>50.9%</b>	<b>13.8%</b>	<b>35.3%</b>	<b>100%</b>
	<b>% within Settlements</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>
<b>3KM Radius</b>		<b>Settlements</b>			<b>Total</b>
		<b>Urban</b>	<b>Semi-urban</b>	<b>Suburb</b>	
	Count	57	10	23	<b>90</b>
Clustered	% within Clustered	63.3%	11.1%	25.6	<b>100%</b>
	% within Settlements	96.6%	62.5%	56.1%	<b>77.6%</b>
	Count	2	6	18	<b>26</b>
Dispersed	% within Dispersed	7.7%	23.1%	69.2%	<b>100%</b>
	% within Settlements	4.4%	37.5%	43.9%	<b>22.4%</b>
	<b>Count</b>	<b>59</b>	<b>16</b>	<b>41</b>	<b>116</b>
<b>Total</b>		<b>% within</b>			
	<b>Clustered/Dispersed</b>	<b>50.9%</b>	<b>13.8%</b>	<b>35.3%</b>	<b>100%</b>
	<b>% within Settlements</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>
<b>4KM Radius</b>		<b>Settlements</b>			<b>Total</b>
		<b>Urban</b>	<b>Semi-urban</b>	<b>Suburb</b>	
	Count	57	11	34	<b>102</b>
Clustered	% within Clustered	55.9%	10.8%	33.3%	<b>100%</b>
	% within Settlements	96.6%	68.7%	82.9%	<b>87.9%</b>
	Count	2	5	7	<b>14</b>
Dispersed	% within Dispersed	14.3%	35.7%	50.0%	<b>100%</b>
	% within Settlements	4.4%	31.3%	17.1%	<b>12.1%</b>
	<b>Count</b>	<b>59</b>	<b>16</b>	<b>41</b>	<b>116</b>
<b>Total</b>		<b>% within</b>			
	<b>Clustered/Dispersed</b>	<b>50.9%</b>	<b>13.8%</b>	<b>35.3%</b>	<b>100%</b>
	<b>% within Settlements</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

Source: Author's Field Work, 2019

### 3.1: Buffer Operation on PSSs in OWSD

The buffer operation creates a new polygon data set, where a specified distance is drawn around specific features within a layer. The distances can either be constant or can vary depending upon attribute values. However, when features are close together, their buffers may overlap. Vagale (1971) established 4km maximum walking distance for students to travel from home to school within Nigeria settings. Giles-Corti et al. (2011) established 2km walking distance for student that regularly walking to school. Furthermore, researchers have revealed cases of desirable and acceptable distance for students to travel from home to school. In

Belgian students, walking distances vary based on age and grade/class respectively which ranges from 1.5 km and 2 km for age 11–12 and age 17–18, respectively (D’Haese et al., 2011, Van Dyck et al., 2010), however, Nelson et al. (2008) reported walking distance of 2.4 km for students within the age range of 15–17. In the case of this research, buffering distance of 1km, 2km, 3km and 4km radius was used to identify the clustering situation of the available PSSs in OWSD.

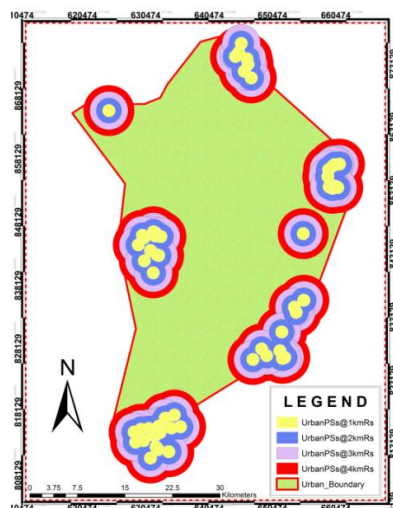


Figure 1: PSS Spatial Buffer in Buffer of Urban Settlements

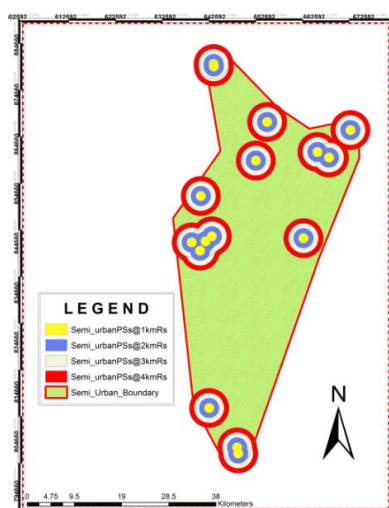


Figure 2: PSS Spatial Buffer in Semi-urban Settlements

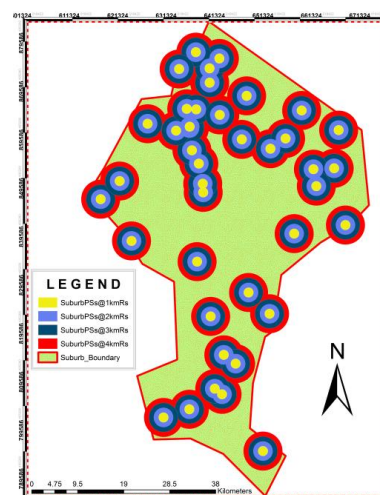


Figure 3: PSS Spatial in Suburb

#### 4.0. Conclusion

This study analysed the spatial accessibility of PSS in OWSD which categorized into Urban, Semi-urban and Suburb Settlements. The study revealed that, PSS were not evenly distributed to be equally accessible by the users in three settlements. It was evident that majority (50.9%) of the PSS were in the urban, while just 13.8% were in the semi-urban and 35.3% in the suburb. It can be deduced from the findings that, Semi-urban and Suburb were highly underserved as against urban settlements. Furthermore, findings established that, PSS at 1km RS, 2km RS, 3km RS and 4km RS clustered in the urban (81.8%, 64.8%, 63.3% and 55.9%) and dispersed in the suburb (70.0%, 71.4%, 69.2% and 50.0%). This implies that users travels longer distance to access education in semi-urban and suburb as against urban where people can easily access education.

## 5.0. Recommendations

Based on the findings, the study therefore recommends that government, stakeholders and private investors should come together to make PSSs education available to all category of settlements. In addition to make available transportation means for users that lives far from PSSs to ensure easy accessibility to secondary school education.

## 6.0. REFERENCES

- Agrawal, S. & Gupta, R. D. (2016). School Mapping and Geospatial Analysis of the Schools in Jasra Development Block of India: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLI-B2, 2016 XXIII ISPRS Congress, 12–1*, Prague, Czech Republic.
- Allard, S. W. (2008). *Out of Reach: Place, Poverty, and the New American Welfare State*. New Haven: Yale University Press.
- Aliyu, A., Shahisah, M. A., & Aliyu, R. M. (2013). Mapping and Spatial Distribution of Post Primary Schools in Yola North Local Government Area of Adamawa State, Nigeria. *International Journal of Science and Technology, 2(5), 405-422*
- Amsterdam, C. (2010). School Infrastructure in South Africa: Views and Experiences of Educators and Learners.
- D’Haese, S., De Meester, F., De Ourdeaudhuij, I., Deforche, B., and Cardon, G. (2011). Criterion Distances and Environmental Correlates of Active Commuting to School in Children. *International Journal of Behavioural, Nutrition Physical Activity.*, Vol. 8, p. 88
- Fabiyi, O. O. & Ogunyemi S. A. (2015). Spatial Distribution and Accessibility to Post Primary Educational Institution in Ogun State, Southwestern Nigeria: Case Study of Yewa South Local Government Area, Nigeria. *Journal of Scientific Research & Reports 5(7): pp, 542-552.*
- Giles-Corti B, Wood, G., Pikora, T., Learnihan, V., Bulsara, M., Van Niel, K. et al. (2011). School Site and the Potential to Walk to School: the Impact of Street Connectivity and Traffic Exposure in School Neighborhoods. *Health and Place 17(2).*
- Ikoya, P. O. & Onoyase, D. (2008). Universal Basic Education In Nigeria: Availability of Infrastructures for Effective Programme Implementation. *Educational Studies: 34, 11-24.*
- Khalid, A., Hamdy, I. & El-Gamily. (2013). GIS as an Efficient Tool to Manage Educational Services and Infrastructure in Kuwait: *Journal of Geographic Information System, 2013, 5, 75-86*

- Maangi, E. N. (2014). Factors Influencing Parental Patronage of Private Primary Schools in Kenya Despite Free Primary Education (FPE) in Public Schools. *Journal of Education and Practice*, 5(26), 119-128. Retrieved from www.iiste.org
- Meskarian, R, Penn, M. L, Williams, S, and Monks, T. (2017). A Facility Location Model for Analysis of Current and Future Demand of Sexual Health Service. *Journal Plos.org*.
- Mustapha, O. O., Akintunde, O. S., Alaga, A. T., Badru, R. A., Ogbole, J. O., Popoola, O. S., & Samuel, S. A. (2016). Spatial Distribution of Primary Schools in Ilorin West Local Government Area, Kwara State, Nigeria. *Journal of Scientific Research & Report*, 9(6), 1-10.
- Naidoo, A. G. V., Van E. & Munch, Z. (2014). Spatial variation in school performance, a local analysis of socio-economic factors in Cape Town. *South African Journal of Geomatics*, 3(1): 78-94.
- Olubadewo, O. O., Abdulkarim, I. A. and Ahmed, M. (2013). The Use Of Gis as Educational Decision Support System (Edss) for Primary Schools in Fagge Local Government Area of Kano State, Nigeria; ISSN-L: 2223-9553, ISSN: 2223-9944; Vol. 4 No. 6
- Ogundahunsi, D. S. (2014). Locational Analysis of Fuel Stations, in Ilesa, Osun State, Nigeria. *International Journal of Development and Strategies in Humanities, Management and Social Sciences Vol. 2, July 2014. Page 249, and 252-254*
- Ogundahunsi, D. S. and Olayode O. (2018). An Assessment of Public Secondary School Infrastructure in Osogbo, Osun State, Nigeria. *Journal of Geography and Planning Sciences* 3(1), pp. 112-124.
- Ojedele, P and Ilusanya, G (2006). Planning and Policy of Higher Education in Nigeria. In J. B. Babalola, A. O. Ayeni, S. O. Adedeji, A. A. Suleiman and M. O. Arikewuyo (eds). *Educational management: thoughts and practice*. Ibadan: Codat Publications.
- Ojo, A. O. (2018). A Study of Accessibility to Secondary School Facility in Lagos Metropolis, Nigeria, A *PhD. Thesis, Submitted to the Department of Urban and Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria*, Unpublished.
- Onuka, A. O. and Arowojolu, A. F (2008): An Evaluation of Parents' Patronage of Private Primary Schools in Abeokuta, Nigeria. *International Journal of African & African American Studies* Vol. 2, 58-70
- Nelson, N. M., Foley, E., O'Gorman, D. J., Moyna, N. M. and Woods, C. B. (2008) Active Commuting to School: *International Journal of Behavioural, Nutrition Physical Activity.*, Vol. 5, p. 1

- Vagale, L. R. (1971). *Manual of Space Standards for Urban Development*. Ibadan, Nigeria: Ministry of Lands and Survey.
- Van Dyck, D., De Bourdeaudhuij, I., Cardon, G. and Deforche, B. (2010). Criterion Distances and Correlates of Active Transportation to School in Belgian Older Adolescents. *International Journal of Behavioural, Nutrition Physical Activity.*, Vol. 7, p. 87
- World Bank (2005): *World Development Report 2006: Equity and Development*. New York: Oxford University Press.

## **THE INFLUENCE OF CRUMB-RUBBER ADDITIONS ON THE WATER SORPTIVITY AND POROSITY OF MASONRY CONCRETE**

Sanni, M.Y.<sup>1\*</sup>, Ocholi, A.<sup>1</sup>, Abdulkarim, A.A.<sup>2</sup>, Ejeh, S.P.<sup>1</sup> and Amartey, Y.D.<sup>1</sup>

<sup>1</sup>Department of Civil Engineering, Ahmadu Bello University, Zaria.

<sup>2</sup>Department of Civil Engineering, The Federal Polytechnic, Offa.

\*Corresponding Author: [sannimukaila@yahoo.com](mailto:sannimukaila@yahoo.com)

### **ABSTRACT**

This paper experimentally investigate water sorptivity and porosity of masonry concrete with varying percentage additions of crumb-rubber particle ranging from 0%, 5%, 10%, 15%, 20% and 25% partially replaced by volume of coarse granite. A total number of six mix batches (using a mix ratio of 1:1.5:3 and a water-cement ratio of 0.42) was used for the investigation. The bulk density, sorptivity and porosity were determined after 28 days of water curing. The results show that bulk density of crumb-rubber masonry concrete decrease gradually with the increase in crumb-rubber content compared to reference masonry concrete. The reference masonry concrete recorded a 2,578Kg/m<sup>3</sup> while 25% crumb-rubber modified masonry concrete have a bulk density of 2,439Kg/m<sup>3</sup> which indicates a decrease of 5.4%. Capillary suction of masonry concrete as assessed by sorptivity was found to increase with percentage increase in crumb-rubber content. The reference masonry concrete recorded sorptivity of 0.15mm/min<sup>1/2</sup> while 25% crumb-rubber modified masonry concrete have a sorptivity of 0.35mm/min<sup>1/2</sup> which indicates an increase of more than 100%.

Porosity (f) of masonry concrete (24 hours water absorption, vacuum saturation, satiation, and vacuum satiation porosity) increases with increase in crumb-rubber content. These results signify an increase in the capacity of modified masonry concrete to drain water from the concrete surface and also a decrease in its resistance to flow of water; which makes it very good for use as a pervious concrete for reducing storm water runoff and recharge ground water.

**Keywords:** Crumb-rubber, Masonry concrete, Bulk density, Sorptivity and Porosity

## INTRODUCTION

Waste automobile tyres occupies a large space in our environment due to its size and shape and as such constitute environmental nuisance and health risk as it stores water which serve as a breeding ground for mosquitos, rodents and reptiles which are responsible for malaria and other related diseases.

According to Yang *et al.*, (2000), each year about 9 million tonnes waste rubber-tyres are disposed of all over the world, which was also estimated to be around 1 billion tyres withdrawn from use in the world annually Erdogan *et al.*, (2010).

Ebeweleet *al.*, (1990) reported that an estimated 5 million scrap tyres from trucks, cars and motorcycles existed in Nigeria in 1983 with an annual generation rate of 15% each year. About 37, million scrap tyres are estimated to exist in Nigeria by 2018.

In Nigeria one of the most common ways of disposing waste tyres is through open field disposal. open air combustion most especially in our abattoir and local commercial quarry where they serve as source of fire for processing slaughtered animals and mining activities. Scientists, engineers and technologists look out for using different types of solid waste as alternative for some ingredients of civil engineering materials such as asphalt and concrete according to Khalid *et al.* (2008). Many researchers have studied and developed various recycling methods for re-use of waste rubber-tyres in construction materials. Some of these methods are: use of waste rubber-tyres in asphalt concrete mixture; use of waste rubber-tyres in some plastic and rubber products; utilizing waste rubber-tyres in portland cement concrete; use of waste rubber-tyres as a visco-elastic material for vibration dampers and utilizing waste rubber-tyres in ordinary cement mortar according to Yunpinget *et al.*, ( 2010).

Application of waste rubber in the construction industry is now well-developed as it helps in improving the sustainability in two ways. First, reuse of the materials which otherwise will burden the environment and will be occupying scarce land resource Guneyisi, *et al.*, (2011). Secondly, it minimizes the degradation of land and the environment as a result of comparatively less digging. ‘‘Recycling’’ is an all prevailing practice now as it conserves the planet’s resources Terro, (2006).

The objective of this study is to introduce crumb-rubber, in various proportions, as a coarse aggregate into masonry concrete mix and also investigate the sorptivity and porosity of the reference masonry concrete compared to the modified crumb-rubber masonry concrete to see if there is any changes in these properties, crumb-rubber particles partially replaced the coarse

aggregate (granite) at six designated contents of 0%, 5%, 10%, 15%, 20% and 25% by coarse aggregate volume. Totally, 18 masonry concrete samples (average of three per mix) were cast and tested for sorptivity and porosity.

Masonry concrete in form of concrete blocks is becoming widely accepted as a construction material for walling units in our buildings, hence the partial replacement of mineral aggregates with rubber-tyre particles in concrete blocks would be a very good and promising way to utilize the large quantities of waste rubber-tyres. The use of waste rubber-tyres particles in masonry hollow concrete blocks would not only make good use of such waste materials by converting a waste into a resource, but will help to enhance some masonry hollow concrete blocks inherent properties such as thermal insulation.

Masonry concrete in form of blocks are porous material which interacts with the surrounding environment. The durability of masonry mortar and concrete depends largely on the movement of water and gas as it flows through it. The uptake of water by unsaturated masonry concrete may be defined by the sorptivity. This is a simple parameter to determine and is increasingly being used as a measure of concrete resistance to exposure in aggressive environments. Sorptivity, or capillary suction, is the absorption and transmission of liquids (water) in porous solids due to surface tension acting in capillaries and is a function of the viscosity, density and surface tension of the liquid and also the pore structure (radius, tortuosity and continuity of capillaries) of the porous solid. It is measured as the rate of uptake of water. Transport mechanisms act at the level of the capillary pores and depend on the fluid and the solid characteristics.

The term porosity relates to the total volume of voids in a material. It is defined as the ratio of the volume of the pore space /bulk volume of the material Hall and Hoff (2002). Porosity so defined has the symbol  $f$  and it is given as a % by volume.

The porosity of concrete is the characteristic whereby liquids can penetrate the material by capillary action, and depends on the total volume of the spaces occupied by air or water between the solid matter in the hardened concrete. The narrower and widely distributed these spaces are, the less easily can liquids diffuse in the concrete.

### **Crumb-Rubber Modified Concrete and Blocks**

The composite material which includes portland cement, sand, water and crumb-rubber mixed in a required ratio is known as Crumb-Rubber Modified Concrete (CR-MC) and has been branded with various types of names in the literature depending on the size of rubber tyre



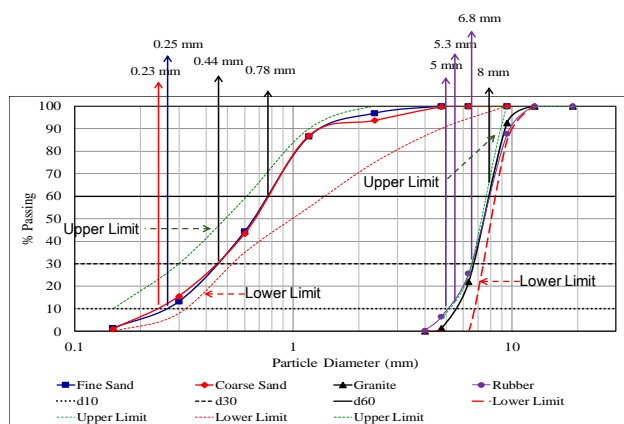
aggregate used. Studies conducted in the past focused on the fresh and hardened crumb-rubber modified structural concrete with high water content and less research conducted on masonry concrete with lean water mix.

The objective of this study is to introduce crumb-rubber, in various proportions, as a coarse aggregate into masonry concrete mix and eventually determine the sorptivity and porosity of the reference masonry concrete compared to the modified crumb-rubber masonry concrete to see if there are any changes in these performances.

## 2. METHODOLOGY

### 2.1. Materials

Crumb-rubber masonry concrete consists of cement, natural aggregate (fine and coarse), waste crumb-rubber tyre derived aggregate and water as shown in Figure 2.2. A general-purpose blended limestone portland cement CEM II (42.5R MPa) that conforms to BS EN 197-1:2011 with a specific gravity ( $G$ ) of approximately 3.15 was sourced from retail outlet in Zaria and used for this study. Ordinary tap water (potable drinking water) sourced from Civil Engineering Laboratory Ahmadu Bello University, Zaria Nigeria was used for all concrete mixes and curing. Natural sharp river quartzite sand smaller than 4.76mm but larger than  $75\mu\text{m}$  that is free of clay, loam, dirt and any organic or chemical matter with average specific gravity (saturated surface dry) of 2.65 and bulk density of  $1,454\text{ kg/m}^3$  was used as fine aggregate.



**Figure 2.1:** Grading of Natural Aggregate and Crumb-Rubber

The fine aggregate (sand) as falls in zone two (medium sand) according to BS EN 12620:2002+A1:2008 specification. Natural crushed (granite) with nominal maximum sizes of 9.52-10mm and sourced from a local commercial quarry with specific gravity of 2.66 and bulk density of  $1635\text{ kg/m}^3$  was used as coarse aggregate.

Coarse rubber aggregate (crumb-rubber) from scrap tyres with nominal maximum sizes of 4 - 6mm, specific gravity of 1.14 and bulk density of 528 kg/m<sup>3</sup> was used for this research. Crumb-rubber surface treatment method by soaking in sodium hydroxide (NaOH) solution was adopted for this research due to its effectiveness in enhancing the hydrophilic properties of the rubber and increasing the intermolecular interaction forces between rubber and calcium silicate hydrate (C-S-H) gel which enhances strength of the composite matrix as reported by (Mohammedi, 2014).

## 2.2 Experiments

### 2.2.1 Mix Proportions

The mix design for the masonry concrete and crumb-rubber modified masonry concrete adopted was based on absolute volume method according to BS EN 206:2013+A1:2016. Based on preliminary estimate of the concrete mix design, a mix ratio of 1:1.5:3 with water/cement ratio of 0.42 and aggregate/cement ratio of 4.5:1 was used to produce a trial mix which was tested for compacting factor, strength, density and finishing properties and eventually subjected to adjustment, adopted and applied to all the concrete mixes. A total number of six (6) mixes were prepared: One control mix and five concrete mixes in which the 9.52-10 mm granite was replaced by crumb-rubber aggregate at 5%, 10%, 15%, 20% and 25% by volume. The mix proportions were constant in terms of mix design ratio, water/cement ratio, sizes, type of natural and crumb rubber-tyre aggregate used for the study. A total of 18 masonry concrete samples (average of three samples per mix) were tested for the water permeability. Table1 below showed the mix proportion.

**Table 2.1:** Quantity of Materials to 1m<sup>3</sup> of Concrete (Control Mix)

Mix Ratio	W/C Ratio	A/C Ratio	Cement (kg/m <sup>3</sup> )	Fine Aggregate (kg/m <sup>3</sup> )	Coarse Aggregate (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )
1:1.5:3	0.42	4.5	411.29	616.94	1,233.87	179.56



**Figure 2.2:** Material for Crumb Rubber Masonry Concrete

### 2.2.2 Sample Preparations

The six set of hardened masonry concrete blocks prism used in this work with dimensions 160 x 40 x 40mm, were derived from masonry hollow concrete blocks using masonry cutting machine as shown in Figure 2.3.



**Figure 2.3:** Masonry Concrete Samples for Sorptivity and Porosity Test

### 2.2.3. Compacting factor, Yield and Unit weight Test

Tests were conducted to assess the compacting factor of the fresh (relatively dry) masonry concrete mixes; control and that of crumb-rubber modified masonry concrete mixes at the department of civil engineering concrete laboratory Ahmadu Bello University (A.B.U) Zaria in accordance with BS EN 12350-4:2009, the unit weight of the fresh masonry concrete samples was established in accordance with BS EN 12350-6:2009 using the 0.01m<sup>3</sup> cylinder while the yield of each concrete mix was computed from the unit weight and the sum of the weight of constituent materials based on ASTM C138-09.

### 2.2.4. Compressive Strength Test

The compressive strength tests of masonry concrete cube (150 x 150 x 150) mm samples were determined according to BSEN 12390-3:2009 after 7, 14, 21 and 28 days of standard curing in water and computed using the Equation 2.1:

$$f_c (N/mm^2) = \frac{P_{max}}{A} \quad \text{Equation 2.1}$$

Where  $f_c$  = compressive strength;  $P_{max}$  is the maximum load that cube sustained and A = the cross-sectional area of the cube.

### 2.2.5. Bulk Density ( $\rho$ )

Bulk density of masonry concrete was determined from the sample cured, oven dried and heated until a constant weight was achieved. It was then cooled in a desiccator and weighed to

the accuracy of 0.0018 after which they were transferred to a beaker and heated for 30 min to release the trapped air. They were cooled and the soaked weight ( $w$ ) was measured.

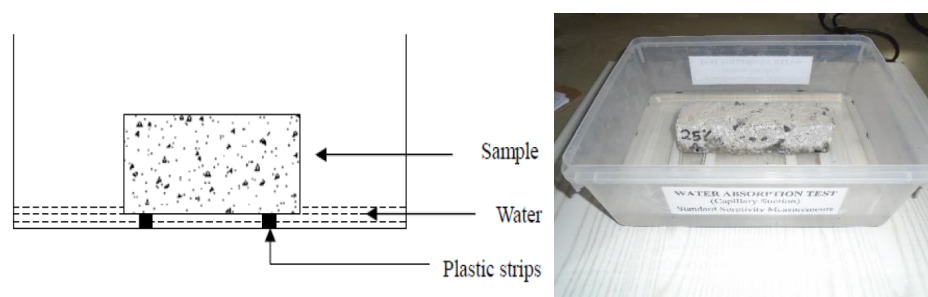
They were suspended in a beaker containing water placed on a balance. The suspended weight was taken and the bulk density was calculated from Equation 2.2: BulkDensity

$$= \frac{\rho w}{w - s}, \text{ Kg} / \text{m}^3 \quad \text{Equation 2.2}$$

Where:  $w$  = Soaked weight,  $s$  = Suspended weight, and  $\rho$  = Density of water.

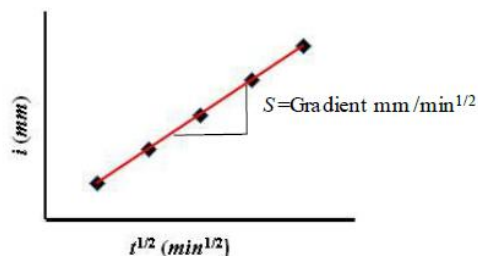
### 2.2.6. Sorptivity ( $s$ )

The measurement of sorptivity for rectangular masonry concrete bar (prism) was carried out using the standard sorptivity method has been described by Gummerson *et al.* 1980 and Hall and Tse 1986. The masonry concrete prism samples, after drying the sample to constant mass at  $70 \text{ }^\circ\text{C} \pm 5 \text{ }^\circ\text{C}$  in an air oven, the area of the absorbing face is measured to  $\pm 1\text{mm}$  with a ruler. The sample is placed on plastic supports in a shallow tray containing water to an immersion depth of approximately 5 mm as shown in Figure 2.4. A stop clock is started simultaneously and the sample removed from the water at intervals for weighing. Surface water is dried off with a damp cloth and the sample weighed on a top loading balance measuring to 0.01 g. Each weighing operation is completed as quickly as possible (within 30 seconds) and the clock not stopped during this procedure. The water in the tray is maintained at constant level by adding a little at intervals. The mass of the water absorbed is obtained at minimum of six different times (normally 1, 4, 9, 16, 25 and 36 minutes) and the volume of water absorbed per unit area at each time is calculated. The unit of  $i$  is therefore  $\text{mm} (\text{mm}^3/\text{mm}^2)$ .



**Figure 2.4:**Sorptivity Test Set up and Measurement

The sorptivity was determined from the gradient of a graph of  $i$  versus the square root of time  $t^{1/2}$  as shown in Figure 2.5.



**Figure 2.5:** Sorptivity  $S$  shown to be the gradient of an  $i$  versus  $t^{1/2}$  plot

### 2.2.7. Porosity( $f$ )

The porosity of masonry concrete was determined by four methods: water absorption (24 hours soaking in water), vacuum saturation, saturation and saturation under vacuum.

#### 2.2.7.1. Vacuum Saturation Porosity ( $f$ ) Test:

Total accessible open porosity ( $f$ ) was measured using this method as detailed in RILEM, CPC 11.3 and Wilson *et al* (1999), although it is not a standard test method. In this method the block was dried to constant mass at  $70\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$  before being allowed to cool and weighed. The volume was determined, either from measuring the dimensions or by water displacement (using an Archimedes displacement vessel). The sample was then placed in a vacuum chamber which was connected by a hose to a rotary vacuum pump capable of producing a vacuum of  $\approx 100$  kPa. The chamber (and therefore the samples) was evacuated and pumping was continued for 30 minutes. After which water was drawn into the vacuum chamber. When the sample had become fully immersed in the water drawn, the hose was removed from the water and air allowed to enter the vacuum tank so that atmospheric pressure forces water into the evacuated pores of the bricks. After 24 h of soaking the sample was removed from the water and weighed. The pumping and soaking times (30 min and 24h) are sufficient according to an early investigation for clay bricks Prout (1989) which states that 6 min pumping followed by 15 min soaking gave essentially complete saturation. The mass and hence the volume of water absorbed was determined. The vacuum saturation porosity ( $f$ ) was then calculated using Equation 2.3.

$$f' = \frac{\text{volume of water absorbed}}{\text{volume of sample}} \times 100\% \quad \text{Equation} \quad 2.3$$

### 2.2.7.2. Water Absorption (24 Hours Soak) Porosity ( $W_m$ ) Test:

The water absorption porosity according to BS EN 772-21:2011 (Methods of test for masonry units: determination of water absorption of clay and calcium silicate masonry units by cold water absorption) is defined as the percentage by mass of pore volume filled in a 24-hour soak. The masonry concrete samples in this test method were dried to constant mass in an air oven at 70°C and allowed to cool to ambient temperature before being weighed and the dry mass ( $m_d$ ) recorded. Then they are placed on small pads in a tank of water at room temperature to allow water to be in contact with all faces. The masonry concrete blocks are left submerged for the desired time (24h in this study) then taken from the tank and surplus water is removed from their surfaces using a damp cloth. They are weighed and the wet mass ( $m_w$ ) is recorded. The water absorption,  $W_m$  is calculated to the nearest 1% using Equation 2.4:

$$W_m = \frac{m_w - m_d}{m_d} \times 100 \quad \text{Equation 2.4}$$

Where:  $m_w$  = Mass of wet sample,  $m_d$  = Mass of dry sample

The percentage was calculated at soaking times of 1min, 9 min, 25 min, 1 h and 24 h.



**Figure 2.6:** Water Absorption (24Hour Soak) Porosity Measurement

### 2.2.7.3. Satiation Porosity ( $f'$ ) Test:

The satiation porosity also known as effective porosity was determined from one-dimensional capillary absorption using the same simple procedure of sorptivity measurement as shown in Figure 2.4 but with only one weighing needed at the point when the water has reached the top face of the sample. Blocks were dried at 70 °C to constant mass, allowed to cool to ambient temperature, their volume determined before they were weighed and the dry mass recorded. They were placed on their bed faces on small pads in a tank to an immersion depth of approximately 5 mm of water at room temperature to allow water to be absorbed from the bed face only until water reached the top of the block. They were then taken from the tank, surplus water removed using a damp cloth, weighed and the wet mass was recorded and converted to

volume. In this work saturation porosity is denoted by  $f'$  and it is equal to the percentage of the bulk volume filled with water calculated from Equation 2.5.

$$f' = \frac{\text{volume of water absorbed}}{\text{volume of sample}} \times 100 \% \quad \text{Equation 2.5}$$

#### **2.2.7.4. Satiation Porosity ( $f''$ ) Under Vacuum Test:**

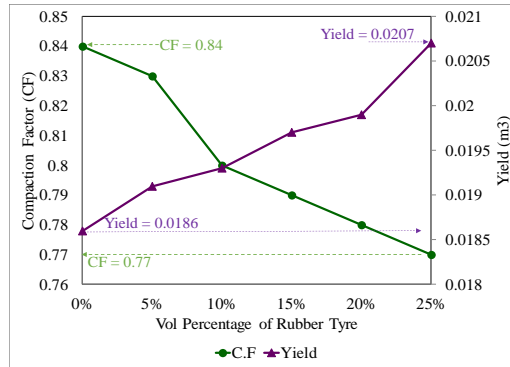
In this method the saturation porosity was determined in the same way as the vacuum saturation porosity. The difference is that water was fed into the bottom of a vacuum tank and stopped when the block bed-face had an immersion depth of approximately 5 mm. The block remained under vacuum until the water reached the top of the block sample. Then air was allowed to enter the vacuum tank and the block was removed from the water and weighed. The vacuum saturation porosity  $f''$  was then calculated from Equation 2.5.

### **3. Results and Discussion**

#### **3.1. Compacting factor, Yield and Unit Weight**

The compacting factor (C.F) as shown in Figure 3.1 was observed to decrease significantly. Control masonry concrete mixes had C.F of 0.84 (low workability) while the 25% crumb rubber mix had C.F of 0.77 (very low workability) indicating 8.3% reduction.

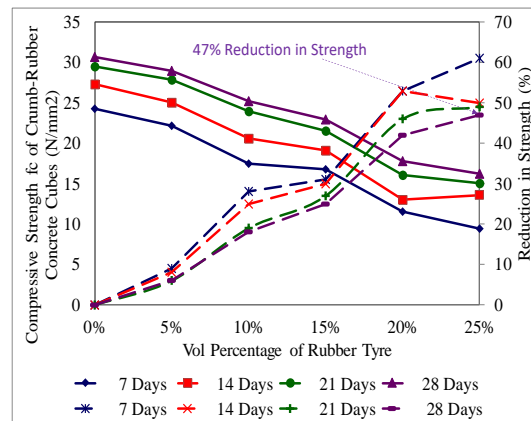
The modified masonry concrete mixes exhibited lower unit weight than the reference mix, it was deduced that unit weight of fresh masonry concrete mixes reduces by 10.1% and this was expected, as the specific gravity of crumb-rubber, at 1.14, is less than that of natural coarse aggregate (granite), at 2.66. Yield value of fresh masonry concrete mix in Figure 3.1 was observed to increase slightly from  $0.0186\text{m}^3$  for control masonry concrete mix to  $0.0207\text{m}^3$  for mix with 25% crumb-rubber content, which indicates an increase by 10.2% and this can be attributed to low bulk specific gravity of crumb-rubber 1.14 and the increase in crumb-rubber volume.



**Figure 3.1:** Compacting factor and Yield Vs % Crumb-Rubber Content

### 3.2. Compressive Strength of Crumb-Rubber Masonry Concrete

Compressive strength of crumb-rubber modified masonry concrete results is plotted and shown in the Figure 3.2, indicates that the addition of crumb-rubber aggregates in the masonry concrete mixes decreases the compressive strength significantly by 49% with percentage increase in the crumb-rubber tyre particles up to 25%.



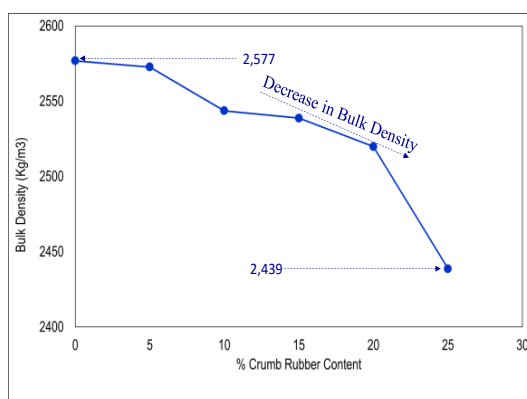
**Figure 3.2:** Compressive Strength and % Reduction in Strength of Masonry Concrete Cubes with % increase in Crumb-Rubber

### 3.3. Bulk Density ( $\rho$ )

The test results of bulk density for crumb-rubber masonry concrete blocks determined from the samples is presented in Figure 3.3 which show that the bulk density of crumb-rubber masonry concrete decrease gradually with the increase in rubber content compared to reference masonry concrete. The average bulk density of the reference masonry concrete is  $2,577\text{Kg/m}^3$  while the



crumb-rubber masonry concrete with 5, 10, 15, 20 and 25% crumb-rubber content recorded bulk density of 2,573kg/m<sup>3</sup>, 2,544kg/m<sup>3</sup>, 2,539kg/m<sup>3</sup>, 2,520kg/m<sup>3</sup> and 2,439Kg/m<sup>3</sup> respectively which indicates 5.4% decrease in density with 25% replacement of crumb-rubber. With the specific gravity of crumb-rubber (1.14) less than that of natural coarse granite aggregate (2.66), and by replacing portions of the coarse aggregate with crumb-rubber, the masonry concrete density decreased.

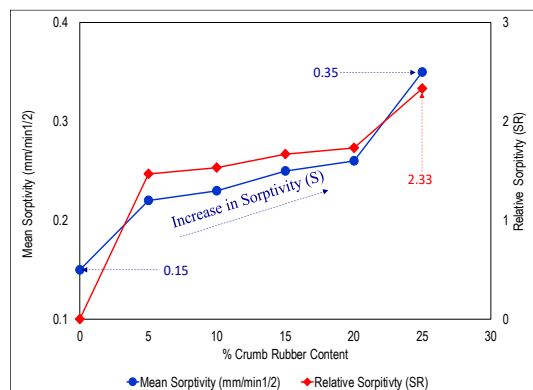


**Figure 3.3:** Bulk Density (Kg/m<sup>3</sup>) of CR-MCB Against %CR Content

### 3.4. Sorptivity (s)

The sorptivity coefficient and relative sorptivity of crumb-rubber masonry concrete samples with various percentage of crumb-rubber content is shown in Figure 3.4. Sorptivity was found to increase with percentage increase in crumb-rubber content up to 25%. The reference masonry concrete samples recorded a sorptivity of 0.15mm/min<sup>1/2</sup> while 5, 10, 15, 20 and 25% crumb-rubber modified masonry concrete samples have a sorptivity of 0.15mm/min<sup>1/2</sup>, 0.22mm/min<sup>1/2</sup>, 0.23mm/min<sup>1/2</sup>, 0.25mm/min<sup>1/2</sup>, 0.26mm/min<sup>1/2</sup> and 0.35mm/min<sup>1/2</sup> respectively which indicates an increase of more than 100% in sorptivity for 25% crumb-rubber content. The relative sorptivity also indicate an increase of 2.33 for 25% crumb-rubber content replaced in coarse granite aggregate by volume.

The increase in sorptivity simply indicate an increase in the rate of water absorption by the crumb-rubber masonry concrete which can be attributed to the lack of proper bonding between the crumb-rubber and the cement composite which brings about increase in voids and porosity.

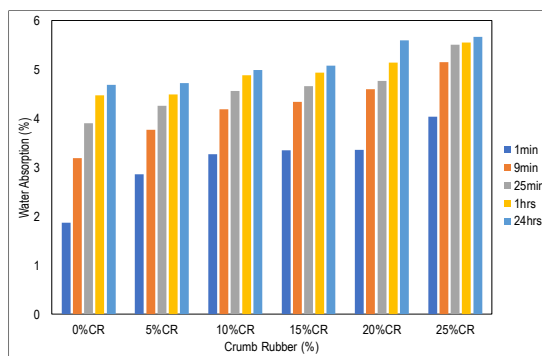


**Figure 3.4:** Sorptivity  $S$  ( $\text{mm}/\text{min}^{1/2}$ ) and Relative Sorptivity of CR-MCBA against % CR Content

### 3.5. Porosity( $f$ )

#### 3.5.1 Water Absorption (24Hours Soak) Porosity ( $f$ )

The 24 hours water absorption porosity test of masonry concrete is presented in Figure 3.5. The results indicate that increase in crumb-rubber content increases the porosity of masonry concrete samples with about 21% for 25% crumb-rubber replaced in coarse granite aggregate.



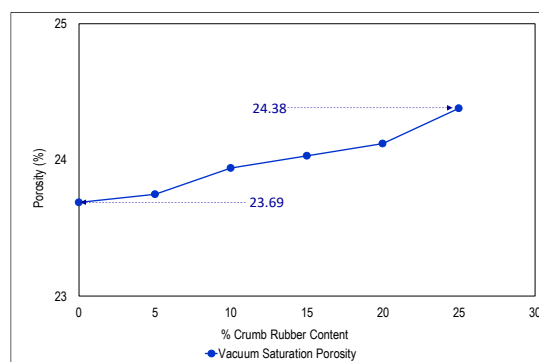
**Figure 3.5:** Water Absorption Porosity Test (24hrs) of CR-MCBA Against % CR Content

#### 3.5.2 Vacuum Saturation Porosity ( $f$ )

Porosity of masonry concrete blocks using vacuum saturation test is presented in Figure 3.6. The result of the vacuum saturation porosity measurements provides a true porosity, i.e. percent by volume, unlike the 24 hours soaking porosity test which many others do refer to as substitute for porosity but not a porosity. The results which shows that the reference masonry concrete samples (0%<sub>CR</sub>) have a porosity of 23.69% while the 5, 10, 15, 20 and 25% have porosity of

23.75, 23.94, 24.03, 24.12 and 24.38% respectively. Furthermore, the results indicate that increase in crumb-rubber content increases the porosity of masonry concrete samples with about 3% for 25% crumb-rubber replaced in coarse granite aggregate which is quite low and considerable compared to the 24-hour soak water absorption porosity with 21%.

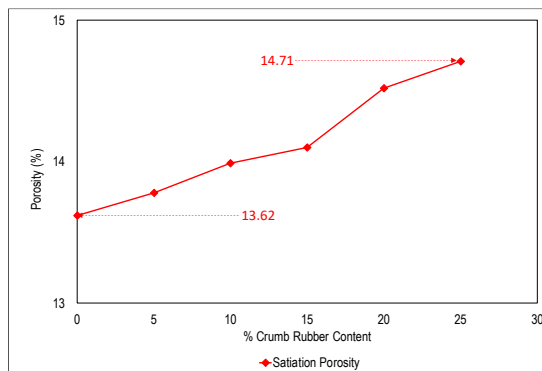
The amount of water absorbed by the masonry concrete samples during this method is much higher than the absorption by soaking test. The 24-hour soak water absorption porosity represents only 19.8%, 20%, 20.84%, 21.14%, 23.22% and 23.26% of vacuum saturation porosity for the 0, 5, 10, 15, 20 and 25% crumb-rubber masonry concrete samples respectively. This can be attributed to the insufficiency for the time allocated for the soaking test (24 hours).



**Figure 3.6:** Vacuum Saturation Porosity ( $f$ ) of CR-MCB Against %CR Content

### 3.5.3 Satiation Porosity ( $f'$ )

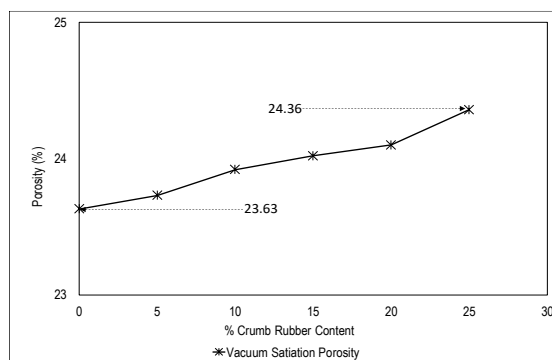
The results of satiation porosity also known as effective porosity of crumb-rubber masonry hollow concrete blocks is presented in Figure 3.7. The results which shows that the reference masonry concrete blocks (0%<sub>CR</sub>) have a porosity of 13.62% while the 5, 10, 15, 20 and 25% have porosity of 13.78, 13.99, 14.10, 14.52 and 14.71% respectively. These values are far less than the values of the vacuum saturation porosity, which indicates that not all the interconnected pore spaces become filled with water and some pores remaining contain air. Furthermore, the results indicate that increase in crumb-rubber content increases the porosity of masonry concrete blocks with about 8% for 25% crumb-rubber replaced in coarse granite aggregate which is also quite low and considerable compared to the 24-hour soak water absorption porosity with 21%.



**Figure 3.7:** Satiation Porosity ( $f$ ) of CR-MCBA against %CR Content

### 3.5.4 Vacuum Satiation Porosity ( $f'$ )

The result of the vacuum satiation porosity measurements provides values very close to the vacuum saturation porosity ( $f$ ) as shown in Figure 3.8. The results which shows that the reference masonry concrete (0%<sub>CR</sub>) have a porosity of 23.63% while the 5, 10, 15, 20 and 25% have porosity of 23.73, 23.92, 24.02, 24.10 and 24.36% respectively. Furthermore, the results indicate that increase in crumb-rubber content increases the porosity of masonry concrete with about 3.1% for 25% crumb-rubber replaced in coarse granite aggregate which is also quite low and considerable compared to the 24-hour soak water absorption porosity with 21%. The amount of water absorbed by the masonry concrete samples during this method is also higher than the absorption by soaking test. The 24-hour soak water absorption porosity represents only 19.8%, 20%, 20.86%, 21.15%, 23.24% and 23.28% of vacuum satiation porosity for the 0, 5, 10, 15, 20 and 25% crumb-rubber masonry concrete samples respectively. This can also be attributed to the insufficiency for the time allocated for the soaking test (24 hours).



**Figure 3.8:** Vacuum Satiation Porosity ( $f'$ ) of CR-MCBA against %CR Content

## CR-MCB Against %CR Content

### CONCLUSION

1. The compacting factor and unit weight of fresh (relatively dry) masonry concrete mixes reduce by 8.3% and 10.1% respectively with percentage increase in crumb-rubber aggregates content up to 25%.
2. Yield of fresh concrete mix increases slightly by 10.2% with percentage increase in crumb-rubber aggregate content up to 25% which can be attributed to low specific gravity (SSD) of crumb-rubber aggregate (1.14) and increase in volume of crumb-rubber in-terms of weight compared to the same weight of aggregate replaced with.
3. Compressive strength of masonry concrete cubes decreases from 30.71N/mm<sup>2</sup> to 16.25N/mm<sup>2</sup> indicating 47% loss in strength with 25% crumb-rubber content after 28 days of standard curing with water.
4. Bulk density of masonry concrete decreases with percentage increase in crumb-rubber content up to 25%. The reference masonry concrete recorded 2,578Kg/m<sup>3</sup> while 25% crumb-rubber modified masonry concrete have a bulk density of 2,439Kg/m<sup>3</sup> which indicates a decrease of 5.37%. The reduction in the bulk.
5. Sorptivity (s) of masonry concrete was found to increase with percentage increase in crumb-rubber content up to 25%. The reference masonry concrete recorded a sorptivity of 0.15mm/min<sup>1/2</sup> while 5, 10, 15, 20 and 25% crumb-rubber modified masonry concrete have a sorptivity of 0.15mm/min<sup>1/2</sup>, 0.22mm/min<sup>1/2</sup>, 0.23mm/min<sup>1/2</sup>, 0.25mm/min<sup>1/2</sup>, 0.26mm/min<sup>1/2</sup> and 0.35mm/min<sup>1/2</sup> respectively which indicates an increase of more than 100%.
6. Porosity (f) of masonry concrete samples (24 hours water absorption, vacuum saturation, saturation, and vacuum saturation porosity) increases with increase in crumb-rubber content varying from 5, 10, 15, 20 and 25%. The increase in the porosity is related to: the higher content of entrained air along with poor interfacial contact between the crumb-rubber particles and the cement paste, the masonry concrete mixes caused by the hydrophilic (non-polar) nature of crumb-rubber particles attracting air around the surface of the aggregate during the mixing process causes a weaker bond between the non-polar and the polar particles, pores in crumb-rubber particles and the complex (rough surface) morphology of crumb-rubber. Furthermore, porosity alone cannot be used to predict the sorptivity or water

movement in porous materials while the values of vacuum saturation porosity are almost equal to the vacuum saturation porosity because there is no air resistance to capillary rise.

7. The result signifies an increase in the capacity of the modified masonry concrete to drain water from the concrete surface and also a decrease in the resistance to flow of water.
8. Crumb-rubber masonry concrete can be use as a pervious concrete to reduce runoff and recharge ground water.

## **REFERENCE**

1. ASTM C138/C138M-09 (2009). ‘‘Standard Test Method for Density (unit weight), Yield, and Air Content (gravimetric) of Concrete’’, ASTM International, West Conshohocken.
2. BS EN 197-1:2011 *Cement*. Composition, specifications and conformity criteria for common cement.
3. BS EN 206:2013+A1:2016. *Concrete*. specification, performance, production and conformity.
4. BS EN 772-21:2011, ‘‘Methods of test for masonry units’’, Determination of water absorption of clay and calcium silicate masonry units by cold water absorption.: Milton Keynes: BSI London.
5. BS EN 12350-4:2009. *Testing fresh concrete*. Degree of Compactibility.
6. BS EN 12350-6:2009. *Testing fresh concrete*. Density.
7. BS EN 12620:2002+A1:2008. *Aggregate for Concrete*.
8. BS EN 12390-3:2009. *Testing hardened concrete*: Compressive strength of test specimens.
9. BS EN 12390-2:2009. *Testing hardened concrete*. Making and curing specimen for strength tests.
10. Ebebele, R.O. and Dzung L.H. (1990). ‘‘Potential Application of Recycled Rubber’’, Nigeria Journal of Engineering, 6(1) 1–3.
11. Erdogan, S. O. Mohammed, L. and Umur. K. S. (2010). ‘‘Compressive Strength Abrasion Resistance and Energy Absorption Capacity of Rubberized Concrete with and without slag’’.
12. Gummerson, R., Hall C., and Hoff W. (1980). ‘‘Water movement in porous building materials—II. Hydraulic suction and sorptivity of brick and other masonry’’.
13. Guneyisi. E and Mehmet G (2011). ‘‘Permeability properties of self-compacting rubberized concretes’’, Construction and Building Materials 25 3319–3326.

14. Hall, C. & Hoff, W. D. (2002). “*Water Transport in Brick, Stone and Concrete,*” London: Spoon Press.
15. Hall, C. and Tse, T. K.M. (1986). “*Water Movement in Porous Building Materials-VII. The Sorptivity of Mortars,*” *Building and Environment*,21(2), pp. 113-118.
16. Khalid, B. N. (2008). “*Mechanical Properties of Fibre Waste Tyre Concrete*”, *International Journal of Civil Engineering IJCE-12<sup>th</sup> Issue* pp. 97-110.
17. Mohammadi, I. (2014). “*Investigation on the Use of Crumb Rubber Concrete (CRC) for Rigid Pavements,*” Thesis submitted for fulfilment of requirements for the degree of Master of Engineering University of Technology Sydney School of Civil and environmental engineering Centre for Built Infrastructure Research.
18. Prout, W. (1989). “*Studies of frost damage in masonry,*” PhD Thesis. UMIST Manchester.
19. RILEM, CPC 11.3. Absorption of water by immersion under vacuum. *Materials and Structures* 1984. 117: p. 391-394.
20. Terro, M.J. (2006). “*Properties of concrete made with recycled crushed glass at elevated temperatures*”, *Build Environ* 41:633–9.
21. Wilson, M., Carter, M. & Hoff, W. (1999). “*British Standard and Rilem Water Absorption Tests,*”: A Critical Evaluation. *Materials and Structures*,32(8), pp. 571-578.
22. Yang, Y. Chen, J. and Zhao, G. (2000). “*Technical Advance on the Pyrolysis of Used Tires in China,*” Dept. of Chem. Eng., Zhejiang University YuQuan Campus, Hangzhou, 310027, P.R. CHINA.
23. Yunping, Xi, PariaMeshin, Okpinna, and Yue Li. (2010), “*Premixed Rubberized Insulation Mortar (PRIM)*”, University of Colorado at boulder.

## **EVALUATION OF STRENGTH CLASSES OF TWO SELECTED LESS-USED NIGERIAN TIMBER SPECIES FOR STRUCTURAL APPLICATIONS**

Rahmon, R. O. \*, Jimoh, A. A., Babatunde, O. Y.

Department of Civil Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Nigeria

\*Email of Corresponding Author: [rorahmon2222@gmail.com](mailto:rorahmon2222@gmail.com)

### **ABSTRACT**

As a result of increase in population growth and urbanization, the demand for timber in construction industry has exponentially increased. Common and popular timber in the industry do not meet up with the high demand and attention has been shifted to unpopular timber species such as Bush mango and Ire but their properties are yet to be fully researched and documented. This research therefore aimed at characterizing and grading of two less-used timber species in Kwara State, Nigeria for structural applications. The selected timber species were obtained from Irewolede sawmill in Ilorin, Kwara State and various test specimens were prepared according to the BS 373: 1957 using Small Clear Size Specimens of Timber. A total of 200 specimens free from visible defects were used for the determination of the strength properties using the Universal Testing Machine of 300 kN capacity at the Department of Agricultural and Biosystems Engineering, University of Ilorin. Twenty (20) specimens from each timber species were tested for bending strength parallel to grain, compression parallel, and perpendicular to the grain, tension parallel to grain and shear parallel to grain in accordance with BS 373: 1957. It was revealed that Bush mango and Ire had average moisture contents of 13.95 and 12.71 %, respectively. For density classification, Bush mango and Ire were classified as medium and light wood, respectively. The results provided quantitative information on the mechanical properties of selected wood species which can be used in determining the application of these timber species for either heavy construction or other purposes. Bush mango and Ire were therefore graded according to NCP 2 (1973) and BS 5268 (2002) and assigned to their corresponding strength classes. Hence, Bush mango can be apply as bridge beam, column, and railway sleepers while Ire can be used for lightweight furniture.



**Keywords:** Bush mango, Ire, Less-used, Strength classes, Timber species

## **INTRODUCTION**

Timber refers to wood in the form that is suitable for construction of carpentry, joinery or for reconversion for manufacturing purposes (Rahmon, *et al.*, 2017). Timber is a structural material used for the construction of different types of structures and the major mechanical property considered in its selection is the strength (Rahmon, 2018). For timber members to be designed intelligently, the knowledge of the strength of timber under loads of different nature is important (Aguwa, 2010). The strength characteristics of timber depend on the species, density, moisture content, presence and type of wood defects as well as on the dimension of the structure (Aguwa, 2016; Ibitolu and Jimoh, 2017).

Nigeria is one of the countries that have timber in surplus quantity (Jimoh *et al.*, 2017a). It is called the world's only renewable natural resource since a new one can be grown where one has been cut down. The world has just less than 4 billion hectares of forest which cover approximately 20% of the world's land area as reported by Obasi *et al.* (2015). Alamu, and Agbeja (2011) stated that forest reserves take possession of approximately 10 million hectares, standing for about 10% of a land area of approximately 96.2 million hectares in Nigeria. If this natural resource is properly utilized, it will be of immense benefit to the country in terms of reduction in the cost of construction (Aguwa, 2012; Rahmon, *et al.*, 2017; Ibitolu and Jimoh, 2017). Different wood species have different strength characteristics, and also within a species, these characteristics may vary. Therefore, in practice, a classification system of strength classes is used (Jamala, *et al.*, 2013; Jimoh *et al.*, 2017b).

The need for local content in the construction of engineering infrastructure is now a serious engineering challenge in Nigeria. Due to vast quantities of local raw materials, which must be processed and used for cost-effective structures (Aguwa, 2016; Rahmon *et al.*, 2017). Construction activities based on these locally available raw materials are major steps towards industrialization and economic independence for developing countries. This explains huge interest and considerable intellectual resources being invested in understanding the mechanical or structural properties of the Nigerian timber (Aguwa and Sadiku, 2011).

Fuwape (2000) reported that, if adequate information on the magnitude of the load, the rate of loading and the duration of load are provided, the appropriate timber species may be selected from the different timber strength groups and natural durability classes. The lack of sufficient information on some timbers has been the basis for their misuse and failure as a structural

member. Information on the strength behaviour of these two less-used Nigerian timber species will help validate the structural viability of the species. Data of this type will serve as a guide for design and specification of these timbers for use as construction material. With adequate mechanical data on given specie of timber, loading information, the rate of loading and duration of loading can be so managed such that design of such timber will be the adequate and safe use of such timber will be guaranteed. Hence, the need to study the mechanical properties of these timber species.

*Irvingia gabonensis* (Bush mango) is a species of African trees in the genus *Irvingia*, sometimes known by the common names wild mango, African mango, bush mango, dika or ogbono. They bear edible mango-like fruits and are especially valued for their fat-and protein-rich nuts. *Irvingia gabonensis* is indigenous to the humid forest zone from the northern tip of Angola, including Congo, DR Congo, Nigeria, Cote d'Ivoire and south-western Uganda. It is planted in parts of this area, such as in southeastern and south-western Nigeria and southern Cameroon. It grows straight, up to a height of 40 m and 1 m in diameter. It has buttresses to a height of 3 m. The wood is hard and therefore used for heavy construction work as making ships decks or railway ties. Dead branches are used as firewood (Rahmon, 2018).

*Funtumia elastica* (Ire) is a tree of height up to 30 m, with not quite straight, cylindrical, unbuttressed bole, 2.50 m in girth, of the deciduous forest from Guinea to West Cameroons and in the Congo basin, and along the Nile basin in Egypt, Sudan, and Uganda. It belongs to the family Apocynaceae. The wood is white and soft, and undifferentiated between sap and heart. Though it was traded under the name of 'Lagos rubber' and the Yoruba name 'Ire' and variations, the tree appears to have been first exploited to a limited extent in this way Cameroon (Jimoh and Rahmon, 2018).

Strength classification of timber species offers a number of advantages both to the designer and the supplier of timber. The designer can undertake his design without the need to check on the availability and price of a large number of species and grades which he might use. Suppliers can supply any of the species/grade combinations that meet the strength class in a specification. The concept also allows new species to be introduced onto the market without affecting existing specifications for timber. The assignment of timber species to a strength class allows engineers to use the mechanical properties of the strength class in limit state design of timber structures. Material properties for grading include density, bending modulus of elasticity and

bending strength that is obtained from laboratory experiments. In this research, the grading of timber species was in accordance with BS 5268: 2002 and NCP 2: 1973.

The determined properties such as density, grade bending stress and mean modulus of elasticity was used for grading and assigning strength class according to the national and international code of practice (NCP 2: 1973; BS 5268 part 2: 2002). The aim of this study was to characterize and grade Nigeria grown *Irvingia gabonensis* (Bush mango) and *Funtumia elastica* (Ire) timber species in accordance with BS 5268 (2002) and NCP 2 (1973). The specific objectives were to obtain, season, prepare samples of *Irvingia gabonensis* and *Funtumia elastica*, determine their physical and mechanical properties according to BS 373 (1957) and to grade *Irvingia gabonensis* and *Funtumia elastica* timber specie in accordance with BS 5268 (2002) and NCP 2 (1973).

## **MATERIALS AND METHODS**

### **Materials**

Timber materials used in this study were obtained from matured *Irvingia gabonensis* and *Funtumia elastica* trees in green condition from Irewolede Sawmills, Ilorin, Kwara State and sawn to size 100 x 150 x 3600 mm. Five logs of timber free from visible defects were selected and they were reduced to 100 x 150 x 1800 mm for easy transportation to the Wood section of the Department of Civil Engineering Laboratory, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Nigeria for seasoning, preparation, and physical testing.

### **Preparation of Test Specimens**

Test specimens were seasoned for six months to attain equilibrium moisture condition (EMC) at Wood section of Department of Civil Engineering Laboratory, University of Ilorin, Nigeria. Natural seasoning method was adopted in line with Aguwa (2010). Twenty (20) samples were prepared for different laboratory tests which include three-point bending strength parallel to the grain, shear strength parallel to the grain, tension strength parallel to the grain, compressive strength parallel to the grain, compressive strength perpendicular to the grain, natural moisture content, specific gravity, and density according to BS 373 (1957) Methods of Testing Small Clear Specimen of Timber.

### **Determination of Physical and Mechanical Properties**

Physical and mechanical/strength properties for the various mechanical tests were determined using the prepared samples at the Department of Agricultural and Biosystems Engineering Laboratory, Faculty of Engineering and Technology, University of Ilorin, Ilorin using Universal Testing Machine (UTM), Testometric Model of 300 kN capacity with computer interface for data acquisition and analysis. Tests carried out to include three-point bending strength parallel to the grain, shear strength parallel to the grain, tension strength parallel to the grain, compressive strength parallel to the grain, compressive strength perpendicular to the grain, natural moisture content, and density according to BS 373 (1957). In each set of the tests, failure loads were recorded for computation of failure stresses, mean failure stress, standard deviation and coefficient of variation.

### Stresses at 12% and 18% Moisture Content

Failure stresses for bending parallel to the grain, tension parallel to the grain, compression parallel to the grain, compression perpendicular to the grain and shear parallel to the grain were adjusted to values at 12% and 18% moisture content in accordance with BS 5268 (2002) and NCP 2 (1973). Equation (1) and (2) was used for the adjustment.

$$F_{12} = F_w(1 + \alpha(W - 12)) \quad (1)$$

$$F_{18} = F_w(1 + \alpha(W - 18)) \quad (2)$$

where  $F_{12}$ = failure stress at 12% moisture content,  $F_{18}$ = failure stress at 18% moisture content  $w$  = experimental moisture content in (%),  $F_w$  = experimental failure stress,  $\alpha$  = correction factor (Bending = 0.04, compression = 0.05, shear = 0.03, tension = 0.05 and MOE = 0.02) (Rahmon, 2018).

### Modulus of Elasticity

Based on three points bending test, Equation (3) from the strength of materials applied to straight beams was used, in conformity with Aguwa *et al.* (2015).

$$E_{L3} = \frac{l^3}{4eh^3} k \quad (3)$$

where,  $E_{L3}$  is the three-point bending modulus of elasticity,  $l$  is the distance between the two supports (280 mm),  $e$  is the width of the beam (20 mm),  $h$  is the height of the beam (20 mm) and  $k$  is the slope of load-deformation graph that is. Minimum modulus of elasticity was

determined by Equation (4) which shows the relationship between mean modulus of elasticity,  $E_{mean}$  and the minimum modulus of elasticity,  $E_{min}$ .

$$E_{min} = E_{mean} - \frac{2.33\sigma}{\sqrt{N}} \quad (4)$$

where N is the number of specimens,  $\sigma$  is the standard deviation

### Modulus of Elasticity at 12% and 18% Moisture Content

Moduli of elasticity at experimental moisture content was adjusted to values at 12% and 18% moisture content in conformity with BS 5268 (2002) and NCP 2 (1973). The adjusted values were computed with Equation (5) and (6).

$$E_{m12} = \frac{E_{measured}}{1 + 0.0143(12 - u)} \quad (5)$$

$$E_{m18} = \frac{E_{measured}}{1 + 0.0143(18 - u)} \quad (6)$$

where  $E_{measured}$  = the modulus of elasticity at experimental moisture content,  $E_{m12}$  = Modulus of elasticity at 12% moisture content,  $E_{m18}$  = Modulus of elasticity at 18% moisture content and  $U$  = experimental moisture content.

### Determination of Moisture Content

Samples of size 20 x 20 x 40 mm were cut from the seasoned timber and used for the determination of the moisture content in accordance with BS 373 (1957). The oven temperature was maintained constantly at  $103 \pm 2^{\circ}\text{C}$  for several hours until a stable mass was obtained. Equation (7) was used for the calculation of moisture content.

$$MC = \frac{m_1 - m_2}{m_2} \times 100\% \quad (7)$$

where MC = moisture content,  $m_1$  = Initial mass of timber before oven dried,  $m_2$  = final mass of timber after oven drying.

### Determination of Density

Five samples of the timber with size 20 x 20 x 20 mm were used for the determination of the density in accordance with BS 373 (1957). Density was calculated using Equation (8).

$$\rho = \frac{m}{v} \quad (8)$$

where,  $\rho$  = density of the timber specimen,  $m$  = the mass of the timber specimen, and  $v$  = volume of the timber specimen.

### Density at 12% and 18% Moisture Content

The densities computed from test results in  $\text{kg/m}^3$  were adjusted to values at 12% and 18% moisture content in accordance with BS 5268 (2002) and NCP 2 (1973). Equation (9) and (10) was used for the adjustment.

$$\rho_{12} = \rho_w \left[ 1 - \frac{(1 - 0.5)(u - 12)}{100} \right] \quad (9)$$

$$\rho_{18} = \rho_w \left[ 1 - \frac{(1 - 0.5)(u - 18)}{100} \right] \quad (10)$$

where is  $\rho_{12}$  = density at 12% moisture content in  $\text{kg/m}^3$ ,  $\rho_w$  = density at experimental moisture content,  $U$  = experimental moisture content in %.

### Basic and Grade Stresses

Basic stresses for bending, tensile, compressive, shear parallel to the grain, compressive stress perpendicular to the grain, were calculated from failure stresses. Equation (11) was used for the computation. Various grade stresses at 80 %, 63 %, 50 % and 40 % values respectively were calculated according to BS 5268 (2002).

$$f_b = \frac{f_m - k_p \sigma}{k_r} \quad (11)$$

where  $f_b$  = basic stress, mean failure stress at 12% moisture content,  $\sigma$  = standard deviation of failure stress,  $k_r$  = reduction factor and  $k_p$  = modification factor = 2.33,  $K_r$  for bending, tension and shear parallel to the grain = 2.25.  $K_r$  for compression parallel to the grain = 1.4 while  $K_r$  for compression perpendicular to the grain = 1.2 (Aguwa *et al.*, 2015; Ozelton and Baird, 1981).

### Test specimen arrangements

Figure 1-4 show the test specimen arrangement for various mechanical/strength tests carried on the timber species using Testometric Universal Testing Machine (UTM) of capacity 300 kN

at the Agricultural and Biosystems Engineering Laboratory, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Ilorin, Nigeria.



Figure 1: Tension Test arrangement



Figure 2: Compression Test arrangement



Figure 3: Bending Test arrangement



Figure 4: Shear Test arrangement

## RESULTS AND DISCUSSION

### Physical Properties

Table 1a and 1b show the results obtained from the laboratory experiments carried out for the Physical of the timber species under consideration. The Physical and mechanical properties of the timber species tested are presented in Table 1. It was revealed that the density obtained for Bush mango and Ire were 714.50 and 389.13 kg/m<sup>3</sup>, respectively which implies that the timber species investigated, that is Bush mango and Ire were hardwood and softwood according to Nigeria Code of Practice, NCP 2 (1973) classification. Also, moisture content results show that the values obtained which are 13.95 and 12.71 % for Bush mango and Ire, respectively were below Fibre Saturation Point (FSP) that is, below 25 % moisture content as stated by Nabade, 2012.

Table 1a: Density of the Timber Species

Timber species	Density (kg/m <sup>3</sup> )						
	Min.	Max.	Mean	Std. Dev.	Coef. of Var.	Confidence Limit	
						95%	99%
Bush mango	686.7	734.2	714.5	10.8	1.51	710.26 ≤ x ≤ 718.7	708.93 ≤ x ≤ 720.0
Ire	321.2	463.3	389.1	25.9	6.67	378.95 ≤ x ≤ 399.3	375.76 ≤ x ≤ 402.5
	8	6	3	6		1	0

Table 1b: Moisture Content of the Timber Species

Moisture content (%)	
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Timber	Min.	Max.	Mean	Std. Dev.	Coef. of Var.	Confidence Limit	
						95%	99%
<b>Bush mango</b>	10.85	17.16	13.95	1.43	10.28	13.39≤x≤14.51	13.21≤x≤14.69
<b>Ire</b>	9.67	16.23	12.71	1.73	13.64	12.03≤x≤13.39	11.82≤x≤13.60

### Mechanical Properties

#### Tension parallel to grain

The mean values for Tension parallel to grain strength of the species at 12 % moisture content are presented in Table 2. It was observed that Bush mango, recorded higher mean Tension parallel to grain which was 62.39 N/mm<sup>2</sup> (that is, it has higher resistance to failure in Tension parallel to grain than Ire at the same moisture content.) while Ire gave the lower Tension parallel to grain strength value which was 59.20 N/mm<sup>2</sup>. When compared Tension results to some known species, Neem has 5.69 N/mm<sup>2</sup>, Xylopia aethiopica 90.85 N/mm<sup>2</sup>, *Terminalia ivorensis* 26.74 N/mm<sup>2</sup>, Vitellaria Paradoxa 101.00 N/mm<sup>2</sup>, Hexalobus crispiflorus 77.02 N/mm<sup>2</sup>, it was found satisfactory.

Table 2: Result of Tension Parallel to Grain Strength of the Species

	Bush mango	Ire
Mean failure stress (N/mm <sup>2</sup> )	56.85	57.17
Standard deviation	6.86	6.25
Moisture content (%)	14.21	13.69
Strength @ 12% MC	62.39	59.20
Strength @ 18% MC	45.34	42.05
Basic stress (N/mm <sup>2</sup> )	18.16	18.94
80% Grade stress (N/mm <sup>2</sup> )	14.53	15.15

### Compression perpendicular to grain

The mean values for Compression perpendicular to grain for the species at 12% moisture content are given in Table 3. It was observed that Bush mango, recorded higher mean compression perpendicular to grain which was 50.16 N/mm<sup>2</sup> while Ire gave the lower compression perpendicular to grain strength value which was 37.11 N/mm<sup>2</sup>, meaning that the resistance of Bush mango to failure in compression perpendicular to grain was higher than the other specie at the same moisture content. When compared compression results to some known species, *Neem* has 20.23 N/mm<sup>2</sup>, *Xylopia aethiopica* 17.98 N/mm<sup>2</sup>, *Terminalia ivorensis* 7.75 N/mm<sup>2</sup>, *Vitellaria paradoxa* 18.73 N/mm<sup>2</sup>, and *Hexalobus crispiflorus* 8.44 N/mm<sup>2</sup>, it is satisfactory.

Table 3. Result of Compressive Strength Perpendicular to Grain of the Species

	Bush mango	Ire
Mean failure stress (N/mm <sup>2</sup> )	45.70	35.84
Standard deviation	13.10	8.42
Moisture content (%)	14.52	12.69
strength @ 12% MC	50.16	37.11
strength @ 18% MC	36.45	26.36
Basic stress (N/mm <sup>2</sup> )	16.69	16.11
80 % Grade stress (N/mm <sup>2</sup> )	13.35	12.89

### Compression Parallel to Grain

The mean Compression parallel to grain strength values for the three species at 12% moisture content are given in Table 4. It was observed that Bush mango recorded higher mean compression parallel to grain which was 71.97 N/mm<sup>2</sup> while Ire gave the lower compression parallel to grain strength value which was 20.01 N/mm<sup>2</sup>, that is, the resistance of Bush mango to failure in compression parallel to grain was higher than that of Ire species at the same moisture content. When compared compression results to some known species, *Neem* has compression parallel to grain strength of 19.95N/mm<sup>2</sup>, *Xylopia aethiopica* has 66.10 N/mm<sup>2</sup>,

*Terminalia ivorensis* 44.51 N/mm<sup>2</sup>, *Vitellaria paradoxa* 45.70 N/mm<sup>2</sup>, *Hexalobus crispiflorus* 30.86 N/mm<sup>2</sup>, the result was ok.

Table 4: Result of Compression Parallel to Grain Strength of the Species

	Bush mango	Ire
Mean failure stress (N/mm <sup>2</sup> )	65.58	19.32
Standard deviation	5.68	1.82
Moisture content (%)	13.69	11.99
strength @ 12% MC	71.97	20.01
strength @ 18% MC	52.30	14.21
Basic stress (N/mm <sup>2</sup> )	37.39	10.77
80% Grade stress (N/mm <sup>2</sup> )	29.91	8.62

### Shear parallel to grain test

The shear parallel to grain strength values of the species at 12% moisture content are shown in Table 5. It was observed that, Bush mango recorded highest mean shear parallel to grain which was 4.48 N/mm<sup>2</sup> while Ire gave a mean value of 3.69 N/mm<sup>2</sup>. It is observed from the results that, the resistance of Bush mango to failure in shear parallel to grain was higher than that of the other specie at the same moisture content. When compared the shear results to the some known species, Neem has 7.40N/mm<sup>2</sup>, *Xylopia aethiopica* 14.04N/mm<sup>2</sup>, *Terminalia ivorensis* 14.5 N/mm<sup>2</sup>, *Hexalobus crispiflorus* 5.16 N/mm<sup>2</sup> and *Vitellaria paradoxa* 11.71 N/mm<sup>2</sup>, the values are both less than the values obtain.

Table 5: Result of Shear Parallel to Grain Strength of the Species

	Bush mango	Ire
Mean failure stress (N/mm <sup>2</sup> )	4.23	3.61
Standard deviation	1.16	0.89
Moisture content (%)	14.57	13.69
Strength @ 12% MC	4.48	3.69
Strength @ 18% MC	3.72	3.04

Basic stress (N/mm <sup>2</sup> )	0.68	0.68
80% Grade stress (N/mm <sup>2</sup> )	0.54	0.55

### Modulus of elasticity (MOE)

Modulus of Elasticity (MOE) is a measure of resistance to bending and is calculated by formula  $PL^3/4bd^3$  (method A) of BS 373: 1957. This is the amount of deflection of timber in response to a load. The Modulus of elasticity strength values of the two species at 12% moisture content are shown in Table 6. Bush mango timber showed higher strength values than resistance to bending than the other species. The overall order of decreasing MOE of the species was as follows: Bush mango > Ire. When compared to known species, *Xylopiya aethiopia* has 11951 N/mm<sup>2</sup>, *Terminalia ivorensis* 4686 N/mm<sup>2</sup>, *Neem* 4338 N/mm<sup>2</sup>, *Vitellaria paradoxa* 11136 N/mm<sup>2</sup>, and *Hexalobus crispiflorus* 4564 N/mm<sup>2</sup>, it was found to be satisfactory.

Table 6: Result of Modulus of Elasticity of the Species

	Bush mango	Ire
Mean failure stress (N/mm <sup>2</sup> )	20573.88	7430.90
Standard deviation	1048.38	1145.40
Moisture content (%)	12.73	11.82
Strength @ 12% MC	21376.26	7536.42
Strength @ 18% MC	18907.40	6644.71
Basic stress (N/mm <sup>2</sup> )	8058.29	2116.50
80% Grade stress (N/mm <sup>2</sup> )	6446.63	1693.20

### Modulus of Rupture (MOR)

From Table 7, at 12% moisture content, the average modulus of rupture of Bush mango was 190.40 N/mm<sup>2</sup> while Ire has the lower value of 60.33 N/mm<sup>2</sup>. It is therefore obtained from the result that the resistance of Bush mango to static bending (MOR) was higher than that of the other specie at the same moisture content. When compared to some species, MOR in *Aningeria altissima* had 93.00 -130.00 N/mm<sup>2</sup>, *Terminaria ivorensis* had 83.00 N/mm<sup>2</sup> and *Antiaris*

*toxicaria* had 59.00 N/mm<sup>2</sup>. Also, 12.5, 15.8 and 22.8 (N/mm<sup>2</sup>) were recorded for *Gmelina arborea*, *Parkia biglobosa* and *Prosopis africana*, respectively, it is ok.

Table 7: Result of Modulus of Rupture of the Species

	Bush mango	Ire
Mean failure stress (N/mm <sup>2</sup> )	176.62	58.66
Standard deviation	16.18	6.46
Moisture content (%)	12.13	11.69
Strength @ 12% MC	190.40	60.33
Strength @ 18% MC	148.01	46.25
Basic stress (N/mm <sup>2</sup> )	61.74	19.38
80% Grade stress (N/mm <sup>2</sup> )	49.39	15.51

Regarding wood mechanical properties, the arrangement and proportions of ground tissues (axial and ray parenchyma, fibres and vessels) in hardwood species are considered to play a key role (Bowyer et al., 2003). From Table 8, it can be concluded that at 12% moisture content, the mechanical properties of the species vary from one another, this can be associated with a considerable difference in density between the species. Also from the Table, Bush mango has highest modulus of rupture, modulus of elasticity and compression perpendicular to grain strength.

Table 8: Principal Mechanical Properties of the Timber Species at 12% Moisture Content

Mechanical properties	Bush mango	Ire
MOE [N/mm <sup>2</sup> ]	21376.26	7536.42
MOR [N/mm <sup>2</sup> ]	190.40	60.33
Compression // to grain [N/mm <sup>2</sup> ]	71.97	20.01
Compression ⊥ to grain [N/mm <sup>2</sup> ]	50.16	37.11
Tensile strength [N/mm <sup>2</sup> ]	62.39	59.20

Shear parallel to grain	4.48	3.69
[N/mm <sup>2</sup> ]		

### Strength Classification

According to NCP 2:1973, the 80% Grade stresses of the two Nigerian timber species are given in Table 9, using the Bending parallel to grain strength values. Comparing these values with Table 7 of NCP 2:1973 Dry Grade stresses of Timbers, the following strength groups were obtained. This shows that Bush mango is stronger than Ire timber species. The strength classes for Nigerian timber species in general range from the highest grade N1 to the weakest grade N7 strength classes. Grade stresses obtained for *Bush mango* and *Ire* timber species in modulus of rupture, had been allocated to strength class N1 and N5 which implies that *Bush mango* is suitable for use in load bearing structures such whereas *Ire* species is suitable for use in furniture components, plywood and joineries.

Table 9: Strength class allocation (NCP 2:1973)

Timber species	Experimental Stresses (N/mm <sup>2</sup> )	NCP 2 80% Grade Stresses (N/mm <sup>2</sup> )	Strength Classes
Bush mango ( <i>Irvingia gabonensis</i> )	176.62	49.39	<b>N1</b>
Ire ( <i>Funtumia elastica</i> )	58.66	15.51	<b>N5</b>

According to BS 5268 (2002), strength class may be assigned to a specie, if its characteristic value of grade bending stress and mean density equal or exceed the value for that class giving in Table 8 of BS 5268-2 (2002) and its mean modulus of elasticity in bending equal or exceed 95 % of the value given in that strength class. Based on these criteria, Bush mango and Ire were assigned to strength class D70 and C14 respectively due to their material properties such as grade bending stress parallel to the grain, mean density as well as mean modulus of elasticity as specified by the code. Table 10 shows the strength allocation according to BS 5268 (2002).

Table 10: Material properties for BS 5268 classification

Timber species	Grade stress 80 (N/mm <sup>2</sup> )	Mean Modulus of Elasticity (N/mm <sup>2</sup> )	Density (kg/m <sup>3</sup> )	Strength Classes
Bush mango	49.39	20573.88	714.50	<b>D70</b>
Ire	15.51	7430.90	389.13	<b>C14</b>

## CONCLUSIONS

Laboratory experiments were conducted to determine the physical and mechanical properties of two (2) less-used Nigerian timber species, namely: Bush mango (*Irvingia gabonensis*), and Ire (*Funtumia elastica*), in accordance with BS 373: 1957. The density classification of the timber species according to Findlay (1975) are as follows: heavy/medium wood for *Bush mango* and light wood for *Ire*. The mean values of MC with respect to all the two timber species were found to fall below the fibre saturation point (FSP) which is usually between 25 - 30 % MC according to Nabade (2012). From the results, the physical and structural (strength properties) were established. The two (2) timber species were successfully characterized and graded accordingly. *Bush mango* and *Ire* timber species were, therefore graded according to NCP 2 (1973) and assigned to their corresponding strength classes as N1 and N7, respectively. However, in accordance to BS 5268 (2002), *Bush mango* and *Ire* were assigned to strength classes D70 and C14, respectively. Hence, the two timber species were successfully characterized and graded. The results also compare favourably with other commonly used species. The results of this work will help Structural Engineers to design and construct timber structures using locally available timber instead of foreign ones. More research should be carried out on ways in which timber can be improved for construction purposes, development of software tools for timber building professionals.

## REFERENCES

- Aguwa, J.I. (2010). Reliability studies on the Nigerian timber as an orthotropic structural material, Thesis submitted to Department Civil Engineering, Federal University of Technology, Minna. pp. 50-103.
- Aguwa, J.I. (2012). Reliability assessment of the Nigeria Apa (*Afzelia bipindensis*) timber bridge beam subjected to bending and deflection under limit state of loading, International Journal of Engineering and Technology, 2(6), 1076-1087.
- Aguwa, J. I. (2016). The Nigerian Timber Structures. Ahmadu Bello University press Limited, P.M.B. 1094 Samaru, Zaria, Nigeria, ISBN: 978-978-54683-2-5, pp. 5 and 6.
- Aguwa, J.I., Chukwu, P.C. and Auta, S. (2015). Characterization and Grading of South Eastern Nigeria grown *Irvingia gabonensis* Timber in accordance with BS 5268. USEP: Journal of Research Information in Civil Engineering, 12(2), 720 – 731.
- Aguwa, J.I. and Sadiku, S. (2011). Structural reliability analysis on the Nigeria Ekki timber bridge beam subjected to shearing force under Ultimate limit state, Research Journal in Engineering and Applied Sciences, 1(4), 240-246.
- Alamu, L. O and Agbeja, B. O. (2011). Deforestation and endangered indigenous tree species in South-West Nigeria. International Journal of Biodiversity and Conservation (Ed.). Academic Journals, Vol. 3(7). ISSN 2141-243X, ©2011, pp. 291-297.

- British Standards, BS 373, (1957). Method of Testing Small Clear Specimens of Timber, British Standard Institute, London.
- British Standards, BS 5268 (2002). Structural Use of Timber. Part 2 code of practice for permissible stress design, materials, and workmanship. British Standard Institute, London.
- Bowyer, L.J., Shmulsky, R, Haygreen, G.J. (2003). Forest products and wood science: an Introduction, 4th Edition. Blackwell Publishing Company. Iowa.
- Findlay, W.P.K. (1975). *Timber Properties and Uses*. Forest Product Research Laboratory, Granada Publishing by Crosby Lockwood Staples, London, Toronto, Sydney, New-York, United State of America. pp. 1 – 589.
- Fuwape, J.A. (2000). Wood Utilization: From Cradle to the Grave, 25th Inaugural Lecture of the Federal University of Technology, Akure. <http://www.nuc.edu.ng>.
- Ibitolu, B. J and Jimoh, A. A (2017). Characterization and Grading of some Potential Nigerian Timber Species in accordance with Eurocode EN 338 (2009). 2nd International Engineering Conference (IEC 2017). Federal University of Technology, Minna, Nigeria, 433 – 440.
- Jamala, G. Y., Olubunmi, S. O., Mada, D. A. & Abraham, P., (2013). Physical and Mechanical Properties of Selected Wood Species in Tropical Rainforest Ecosystem, Ondo State, Nigeria. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS). eISSN: 2319-2380, p-ISSN: 2319-2372, 5(3), 29 – 33.
- Jimoh, A.A. and Rahmon, R.O. (2018). Mechanical Characterization and Grading of Irvingia gabonensis timber specie according to British and Nigerian Standards from Kwara State, Nigeria. *ANNALS of Faculty of Engineering, Hunedoara – International Journal of Engineering*. Vol. 16, No. 2, pp. 117 – 123.
- Jimoh, A. A., Rahmon, R. O. and Joseph, S.G. (2017): *Evaluation of Compressive Strength Characteristics of Structural-sized Apa (Afzelia bipindensis) and Opon (Lannea schimperi) Timber species columns found in Nigeria*. Journal of Applied Science and Environmental Management (JASEM), Vol. 21, No. 7, pp. 1281-1285.
- Jimoh, A. A., Rahmon, R. O., Babatunde, O. Y. and Tazou, O. L. (2017): *Characterization and Classification of Ayunre (Albizia zygia) Timber Specie grown in Kwara State Nigeria in accordance to BS 5268 and NCP 2*. Epistemics in Science, Engineering and Technology (ESET), Vol. 7, No. 1, pp. 549-557.
- Nabade, A. M. (2012). Development of Strength Classes for Itako (Strombosia pustulata), Oporoporo (Macrocarpa bequaertii), Opepe (Nauclea diderrichii) and Ijebu (Entandrophragma cylindricum) Nigerian Timber species based on EN 338 (2009). M. Sc. Thesis submitted to Department of Civil engineering, Ahmadu Bello University, Zaria, Nigeria.
- NCP 2 (1973). Nigerian standard code of practice; the use of timber for construction, Nigeria Standard Organisation , Federal Ministry of Industries, Lagos, Nigeria, 10-18.
- Obasi, F. A. Agbo, F. U. and Oyenekwe, C. S. (2015). Environmental and Socio-Economic Effects of Timbers Harvesting in Ebonyi State, Nigeria. African Journal of Agricultural Research (Ed.).



- Academic Journals, Vol. 10(11), DOI: 10.5897/AJAR2014.9461, Article Number: CC0DCE551407.  
Department of Agricultural Economics, University of Nigeria. ISSN 1991-637X, pp. 1233-1238.
- Ozelton, E. C., and Baird, J. (1981). *Timber Designer's Manual*,. Great Britain: Granada Publishing Limited, Technical Books Division.
- Rahmon, O. O., Jimoh, A. A., Babatunde, O. Y. and Tazou, O. L. (2017): *Strength Characteristics and Grading of Eku (Brachystegia eurycoma) Timber grown in Kwara State, Nigeria in accordance to BS 5268*. USEP: Journal of Research Information in Civil Engineering, Vol. 14, No. 4, pp. 1891-1905.
- Rahmon, R.O (2018). *Characterization and Grading of Four Timber Species Sourced from Timber Markets in Kwara State, Nigeria for Structural Applications*. M. Eng Thesis submitted to the Civil Engineering Department, University of Ilorin, Ilorin, Nigeria. Pp. 1- 84.

## **LAND USE CHANGES BETWEEN 1986 AND 2016 IN OBA HILL FOREST RESERVE, OSUN STATE, NIGERIA**

Asifat, J.T.<sup>1\*</sup> and Ogunbode, T.O.<sup>2</sup>

<sup>1</sup>Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria

<sup>2</sup>Department of Environmental Management and Crop Production, Bowen University, Iwo,  
Nigeria

\*Email of Corresponding Author: [janetasifat2@gmail.com](mailto:janetasifat2@gmail.com)

### **ABSTRACT**

This study examines land use changes in Oba Hill forest reserve, Osun State, Nigeria between 1986 and 2016 using remote sensing technique. The study utilised satellite imageries from Landsat TM 1986, 1996, ETM 2006, and OLI 2016. The investigation revealed that the undisturbed forested area declined from 26.169 km<sup>2</sup> in 1986 to 15.318 km<sup>2</sup> in 2016. Also, the cultivated/ disturbed forest land increased from 22.238km<sup>2</sup> to 41.499 km<sup>2</sup> in 2016 whereas the built up areas decreased from 12.215 km<sup>2</sup> to 3.805 km<sup>2</sup>. The forested lands were decreasing while the cultivated/disturbed land areas were on the increase. This implies that more of the forested lands were opened up for cultivation and other purposes while part of the built-up areas were also taken over by shrubs. Thus, there is degradation in the forest as a result of excessive and unguided exploitation of resources endowed. It is recommended that government should put in place appropriate policies and management strategies towards slowing down the rate of forest loss and degradation in Oba Hill Forest Reserve to ensure that the reserve achieve its purpose.

**Keywords:** Oba Hill, land use, land use change, forest degradation, Remote sensing and Osun State

### **INTRODUCTION**

Land use is the exploitation of the land cover by man to satisfy his social, cultural, spiritual, economic and physical needs (Lambin, et al., 2000). Jensen (2005), also asserted that land use is the activities that take place on the land and represent the current use of property such as residential purposes, shopping centres, tree nurseries, parks, reservoirs, etc.

Forests, globally are home of diverse benefits such as regulation of climate, habitat for plants and animals and sources of fodder, timber and non-timber forest products (Bazezew et al., 2015, United Nations Framework Convention on Climate Change (UNFCCC, 2015)) but have suffered unprecedented destruction due to unsustainable use and management of resources (Foahom, 2001, Food Agriculture Organisation, 2014).

The World forest resources have continued to reduce basically because of anthropogenic activities that are caused by the need to meet the demand for industrial and social development necessary for economic growth. According to Gasu et al., (2016), forest covers are getting depleted daily at a greater rate due to serious anthropogenic activities that made the earth surface also to be significantly altered in several ways. Man's needs for social, economic and cultural development resulted in to resources and environmental degradation through deforestation of tropical forest (Enaruvbe et al., 2014).

In recent times, roughly a third of the world landscapes are being used for crop productions or grazing of cattle (Ramankutty, et al., 2005). Major changes in human activities, especially through large scale agriculture have been identified as the major cause of the drastic changes in land cover and land use patterns globally. Another major consequence of the globally recognized rapid land cover change is the loss of biodiversity and ecosystem functioning. The rate of biodiversity loss has been accelerating rapidly throughout the industrial era. Mukete and Sun (2014), among other scholars observed that, species are now becoming extinct at 1.000 – 10.000 times the natural rate. The consequence of this is general ecosystem degradation which is often measured using the Natural Capital Index (NCI) framework which involves calculating the extent of natural area which is determined from land-use maps (Ademiluyi et al., 2008). According to FAO (2010), conversion of forest land for uses like cultivation, mining, and human structures such as urban infrastructure other than its natural cover, ~~always~~ resulted in to deforestation. Natural vegetation are altered through the use of land for various purposes such as logging, building, agriculture and other forest related activities (Mukete et al., 2017).

According to Enaruvbe et al., (2014), it was asserted that increasing population pressure on the natural environment, the need for fertile agricultural land and the search for more forest products and services as industrial raw materials have increased the forest disturbances and eventual deforestation and degradation. Ogunleye et al., (2004) and Akinyemi (2013) stated that increasing intensity of agricultural activity was the main driver of deforestation in which most of the native forest has been converted to agricultural land. Low

diversity in the Olokemeji forest reserve was as a result of farming activity which has led large hectares of forest land to become impoverished secondary forest, bare and degraded land, grasslands and plantation of exotic species (Ogunleye et al., 2004).

Shifting cultivation as practiced for forest conservation among indigenous people living around tropical forest is also a main driver of tropical forest cover changes (Asselen and Verburg, 2013). Furthermore, Mukete et al., (2017), asserted that the driving forces of land cover changes could be food preferences, demand for specific products, environmental conditions, land policy and developmental programs and that no single cause can solely lead to deforestation. Also, Geist et al., (2005) asserted that, multiple factors in synergetic interactions dominate land change processes and that these causal clusters vary from one region to another and time, and that agricultural expansion is one of the probable causes of land use and land cover changes.

Therefore, changes in land use/land cover and the need for biodiversity conservation are important issues that have gained attention in tropical forest research in recent years. This however, has led to intense debate on the most appropriate approach to be adopted in tropical forest conservation (Terborgh, 2000). Land use data are necessary in the analysis of environmental processes and problems in order to understand the living conditions and standards which will be used to improve the present conditions (Olaleye et al., 2009). Land use change detection is therefore, necessary for the identification of major processes of change and the characterization of land use dynamics which occurred as a result of over-dependence on primary resources. In corroborating this assertion, Fasona et al; (2005) stated that, the study on land use and land cover dynamics is important in order to examine various ecological and developmental consequences of land use change over a space of time. Such a study as this will invariably make land use mapping and change detection useful inputs for decision-making and implementation of appropriate land use management policy. Hence, the aim of this study is to assess the changes in the land use pattern in Oba Hill Forest Reserve, Osun State, Nigeria with a view to propose a sustainable methods of conserving this forest.

The specific objectives of this research were to assess the characteristics of land use over a period of 30 years (1986 to 2016) using remote sensing techniques in the study area and also to examine the implications of the changes on the forest environment.

## MATERIALS AND METHODS

### STUDY AREA

The study was conducted in Oba Hill Forest Reserve located between latitude  $7^{\circ} 45'$  to  $8^{\circ} 30'N$  and longitude  $4^{\circ} 70'$  to  $5^{\circ} 61'E$  in Iwo local Government Area of Osun State, Nigeria. It is bounded in the north-east by Ola-Oluwa Local Government Area, in the north-west by Oyo State in the south by Ayedire LGA and in the east by Ejigbo LGA. Some communities such as Olori, Owu-Ile, Ifeodan, Ikonifin, Akinleye, Ipatara, Idi-Iroko among others surrounded this Forest Reserve. It was established in 1955 as a gazette forest reserve. It is located in the humid sub-equatorial climatic region which is characterised by high humidity and torrential down pour between March and October annually. The rainfall distribution of the study area is of double maxima with maximum rainfall in June/July and September/October while the mean annual rainfall is between 1200mm and 1450mm and the mean annual temperature is about  $27^{\circ}C$  (Akinsanola et al., 2014). The characteristic climate therefore encourages the growth of tropical evergreen rainforest with tall trees and dense undergrowth. Valuable woody trees found here are, *Anogeissus leiocarpus*, *Bridelia micrantha*, *Blighia sapida*, *Cinnamom aromaticum*, *Tectona grandis*, and *Gmelina arborea*, The communities around this FR are majorly agrarians and concentrate more on food crop farming. Types of the food crops are cassava, yam, coco yam, vegetables and the like and are majorly for subsistence farming. In other to boost agricultural production in the area the state government embark on farm settlement programme and almost all the forest reserve have been converted to farms and plantations (Greengrass, 2009). The programme which made land accessible to interested farmers. Since then agricultural produce from this area have been finding their ways to markets in major urban centre such as Iwo, Ibadan, Osogbo and so on.

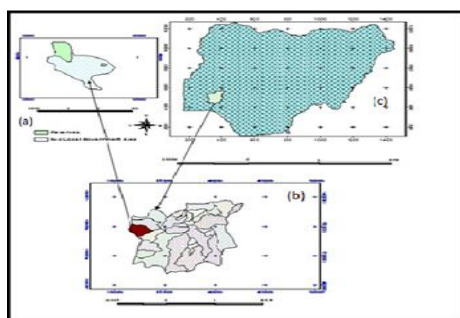


Figure 1: Map of Osun State (b) showing the location of Oba Hill FR (a). Inset: Map of Nigeria(c) showing Osun State. Source: Author

## **METHODS OF DATA COLLECTION**

### **Data collection and analysis**

Landsat images of ten years interval were used, which are; Landsat images of 1986, 1996 ETM 2006 and OLI of 2016 covering the study area, were obtained from the United States Geological Survey website on Earth Resources Observation and Science Centre. The satellite imageries of the area were processed using ArcMap 10.1 software to bring out the classes of land use types in the study area. The secondary data utilised was the map of Osun State showing the study area; Oba Hill forest reserve. This map was acquired from the Ministry of Environment, Department of Forestry, Osun State. And was geo-referenced to extract the shape fill and get the areal extent of the study area using Google Earth.

The satellite imageries (Landsat TM 1986, 1996, ETM 2006 and OLI 2016) covering the entire study area were used to produce the land cover map using ArcMap 10.1. Supervised classification was adopted and maximum distance algorithms method were used to classify the land use and land cover into undisturbed/ forest, disturbed/cultivated land and built- up areas respectively. The maximum likelihood algorithm was used in this study because it was an accurate (Perumal et al., 2010) and reliable method of image classification (Akgun, et al., 2004, Patil et al., 2012, and Vanjare et al., 2014).

## **RESULTS AND DISCUSSION**

### **Classification of land use in Oba Hill Forest Reserve**

Table 1 presents the major categories of land uses identified in the study area between 1986 and 2016 these are undisturbed forest land, cultivated/disturbed forest land and built-up/developed areas. The pixel statistics of land use in Landsat TM 1986 shows that the undisturbed forest land was 26.169km<sup>2</sup> representing (43.16%) of the total area. The cultivated/disturbed forest land otherwise referred degraded forest accounted for 22.238km<sup>2</sup> (36.69%) and the built-up/developed area accounted for 12.215km<sup>2</sup> (20.1%) of the study area. The undisturbed forest land was higher than any other features and the built-up/developed area was smaller. The field observation revealed that most portions of the forest reserve were set aside for agro- forestry to serve as forest management strategy. In 1996, the undisturbed forest land was 12.5334km<sup>2</sup> (20.7%) and the cultivated/disturbed forest land was 38.555km<sup>2</sup>(63.6%). The built-up/developed forest land decreased to 9.5337km<sup>2</sup> (15.7%) from 12.215km<sup>2</sup> of 1986. This showed that more developed land had been cultivated because the land area cultivated increased from

(36.69%) in 1986 to (63.6%) in 1996. The images of 2006 showed that the undisturbed forest land was 11.18km<sup>2</sup> (18.4%), the cultivated/disturbed forest land was 33.34km<sup>2</sup> (55.0%) and the built –up/developed area increased to 16.087km<sup>2</sup>(26.6%). This suggested that more land had been developed more than what it was in 1996. The pixel representing undisturbed forest land constituted 15.318km<sup>2</sup>(25.27%) of the entire study area in 2016. The cultivated/disturbed forest land shared off 13.44% of the size in 2006 but (68.44% in 2016) and the built-up/developed area reduced drastically to 3.805km<sup>2</sup>(6.29%). This suggested that probably developed areas which might be huts were cleared for farming, cultivation of forest trees or left fallowed. Also reported land dispute between Oyo and Osun state (Daily Independent, 22 Sep, 2014) (because the forest reserve is located at the boundary) such dispute which often claimed lives and could have led to the abandonment of farms and other infrastructures. This could have equally implies the usurpation of the built up area by forest

Table 1: Land use/ Land cover of Oba Hill FR between 1986 and 2016

Feature Classes	1986		1996		2006		2016	
	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%
Undisturbed	26.169	43.16	12.5334	20.7	11.1861	18.4	15.318	25.27
Cultivated/Disturbed	22.2378	36.69	38.5551	63.6	33.3486	55.0	41.499	68.44
Built-Up/Developed	12.2154	20.1	9.5337	15.7	16.0875	26.6	3.8052	6.29
Total	60.6222	100	60.6222	100	60.6222	100	60.6222	100

### **Land use and Land cover changes comparison Analysis**

Table 2 represents the changes in the land use and land cover of the study area between 1986 and 2016. The changes in the undisturbed forest land between 1986 and 1996 was -13.635km<sup>2</sup>. The cultivated and disturbed forest land showed changes of 16.312 km<sup>2</sup> while the built –up area

had a difference of  $-2.6817 \text{ km}^2$ . These changes showed decrease of forest land that was reserved, increase of the cultivated land and the built-up area receded. The implication of this was that more undisturbed forest land were cultivated thereby reducing the original size of the undisturbed forest land and the cultivated forest land increased. This scenario could have probably be attributed to increasing population growth, increasing demand for arable land for food crops and other human activities such as logging in the study area. This corroborated Mengistu and Salami (2007) that, disturbed or degraded forest constituted the largest land cover type in some parts of southwestern, Nigeria which the authors attributed to increasing population and economic activities. This also inferred that deforestation had occurred since the size ( $26.169\text{km}^2$ ) in 1986 receded to ( $12.53.33\text{km}^2$ ) in 1996. Changes in the land use in 1996 and 2006 showed that undisturbed forest land was  $-1.3347\text{km}^2$  and the cultivated forest land and built - up area were  $-5.2065\text{km}^2$  and  $6.5538\text{km}^2$  respectively. Both the undisturbed and disturbed forest land differences reduced further in 1986 and 1996. However, the built-up area gained more areal extent and increased from  $9.54\text{km}^2$  in 1996 to  $16.09\text{km}^2$  in 2006. The result further revealed that more than the size of built- up land areas in 1996 encroached had been gained back in 2006. This observation implies that there were increase in infrastructures that were put in place between 1996 and 2006. The changes in the size of undisturbed forest land between 2006 and 2016 was  $+4.1319\text{km}^2$  indicating natural regrowth/regeneration. The result further revealed that the undisturbed forest land increased from  $11.19\text{km}^2$  in 2006 to  $15.32\text{km}^2$  in 2016, the cultivated forest land increased from  $33.35\text{km}^2$  in 2006 to  $41.50\text{km}^2$  in 2016 and the built-up reduced from  $16.09\text{km}^2$  to  $3.81\text{km}^2$ . The increase in undisturbed and cultivated forest land between 2006 and 2016 was attributed to natural regeneration of woody trees and subjecting the area to be fallowed in line with Osun State government directive in 2012 to close the forest from logging. (Plate 1). It was obvious from the result that the rate of regeneration that occurred from 2006 to 2016 for undisturbed forest land ( $+4.1319\text{km}^2$ ) had not fully compensated for the undisturbed forest trees lost between 1986 and 2016( $-10.849 \text{ km}^2$ ).

Table 2: Changes in Land use/land cover of Oba Hill FR between 1986 and 2016

Category	Changes between 1986 &1996 ( $\text{km}^2$ )	Changes between 1996 &2006 ( $\text{km}^2$ )	Changes between 2006 & 2016 ( $\text{km}^2$ )	Changes between 1986 &2016 ( $\text{km}^2$ )
Undisturbed	-13.635	-1.3347	+4.1319	-10.849
Cultivated/Disturbed	16.312	-5.2065	8.1504	19.262



Built-Up/Developed	-2.6817	6.5553	-12.2823	-8.405
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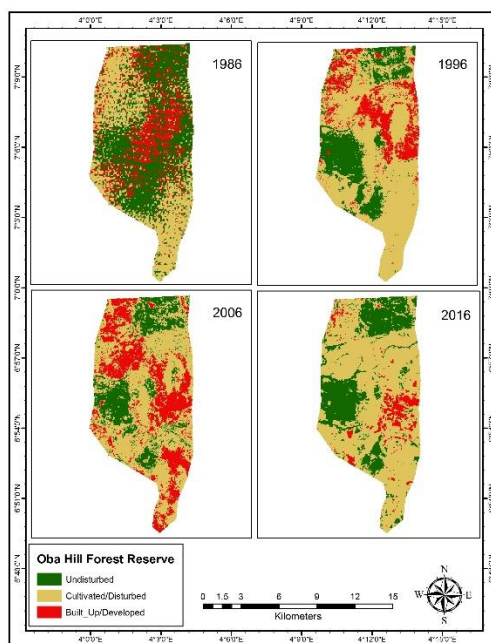


Figure 2: Changes in Land use /Land cover changes between 1986 and 2016

### **Environmental Implications of Land use and Land cover change in Oba Hill FR**

This study revealed that the undisturbed or forested land reduced drastically from 26.169km<sup>2</sup> in 1986 to 15.318km<sup>2</sup> which implies that the forested land had been exposed to soil erosion which can lead to reduction of soil quality. The study area was also exposed to the climate change scenario since woody trees that can serve as carbon sink had been cut without replacement. Biodiversity in term of flora and fauna are endangered anywhere the woody trees are cut. The forested land that had served as habitant for animals had been removed therefore, animals taking shelter had either been killed or fled to other places.

In view of the consequences of land use changes in Oba Hill Forest Reserve, it is therefore recommended that government and other relevant stakeholders should put in place appropriate legal instrument and relevant policies to encourage the resuscitation of Oba Hill Forest Reserve to its initial and intended status.

## **CONCLUSION**

Land use changes in the forest reserve of Oba Hill over a period of 30 years were examined with the use of satellite imageries. The results showed that the FR has undergone immense anthropogenic incursions over the period to the extent that the entire forest has almost been degraded due to agricultural activities and or shrubs growth in place of economic trees that were initially planted there. The implication of these findings is that carbon release into the atmosphere from the forest could have contributed to the global warming scenario being experienced globally. This is apart from the exposing the soil to surface wash through the deforestation activities, degraded biodiversity and fauna displacement from the forest. It is therefore imperative that government and other stakeholders put in place necessary legal tools and education towards checkmating the degradation effects which such anthropogenic activities could cause the natural environment.

## **REFERENCE**

- Ademiluyi, I.A. Okude, A.S. and Akanni, C.O. (2008). An appraisal of land use and land cover mapping in Nigeria. *African Journal of Agricultural Research* Vol. 3 (9), pp. 581-586, September 2008 Available online at <http://www.academicjournals.org/AJAR> ISSN 1991-637X © 2008 Academic Journals
- Akinyemi, F. O. (2013). An assessment of land-use change in the cocoa belt of south-west Nigeria. *International Journal of Remote Sensing*, 34, 2858–2875. doi:10.1080/01431161.2012.753167
- Akgün, A., Eronat, A.H. and Türk, N. (2004) Comparing Different Satellite Image Classification Methods: An Application in Ayvalik District, Western Turkey. *20th ISPRS Congress Technical Commission IV, Istanbul, 12-23 July 2004*, 1091- 1097. <http://www.isprs.org/proceedings/xxv/congress/comm4/papers/505.pdf>
- Akinsanola, A.A and Ogunjobi, K.O. (2014). Analysis of Rainfall and Temperature over Nigeria. *Global J. Human-Social Science: Geography, Geo-Sciences, Environmental Disaster*, 14(3):1- 18.

- Asselen, V and Verburg, H (2013). Land cover change or land-use intensification: simulating land system change with a global-scale land change model. *Global Change Biology* 19 (12): 3648-3667.
- Bazezew, M.N, Soromessa, T. and Bayable, E. (2015). Carbon stock in Adaba-Dodola community forest of Danaba District, West-Arsi zone of Oromia Region, Ethiopia: An implication for climate change mitigation. *Journal of Ecology and the Natural Environment*. Vol.7 (1), pp14- 22. DOI: 10.5897/JENE2014.0493
- Daily Independent, (2014). Communal Crisis in Oba Hill Forest Reserve. September, 2014.
- Enaruvbe, G. O., & Ige-Olumide, O. (2014). Geospatial analysis of land-use change processes in a densely populated coastal city: The case of Port Harcourt, south-east Nigeria. *Geocartan International. Advance* doi:10.1080/10106049.2014.8834 35
- Foahom B. (2001). Biodiversity Planning Programme, integrating biodiversity in the forestry sector: Cameroon case study Paperprepared for the international workshop on “Integration of Biodiversity in National Forestry Planning Programme”. CIFOR Headquarters August 13– 16. 24 pp
- Food and Agriculture Organisation (2010). Global Forestry Resources Assessment 2010. Main Report FAO forestry paper163. <http://www.fao.org/docrep/013/i1757e/i1757e.pdf>
- Fasona M.J and Omojola A.S (2005). Climate Change, Human security and Communal Clashes in Nigeria. Paper presented at an International Workshop on Human Security and Climate Change, Asker, Norway, 21-23 June, 2007.
- Gasu, M.B, Ebehikhalu, N, Bidmus, M.A and Dawam P. (2016). Geospatial Analysis of Land use Dynamics in Osogbo between 1986 and 2012. *Abuja Journal of Geography and Development* Vol. 4 No... 1 January, 2016

- Geist H, Lambin E, McConnell W, Alves D (2005). Causes, Trajectories and Syndromes of Land – Use/Cover Change, UPDATE *Newsletter of The International Human Dimensions Programme on Global Environmental Change*, 03/2005, pp. 6-7
- Greengrass, E.J. (2009). ‘Chimpazees are close to Extinction in Southwestern Nigeria’. *Pimate Conservation* (2009) 24, pp 77-83. Retrieved 2010-10-21
- Jensen, J. R. (2005). *Introductory Digital Image Processing: A Remote Sensing Perspective*. Pearson Education, Inc., New Jersey.
- Lambin, E. F., Rounsevell, M. D. A., and Geist, H. J. (2000). Are agricultural land-use models able to predict changes in land-use intensity? *Agriculture, Ecosystems and Environment*, 82, 321–331. doi:10.1016/S0167- 8809(00)00235-8
- Mengistu, D. A. and Salami, A. T. (2007). Application of remote sensing and GIS in land use/land cover mapping and change detection in a part of south western Nigeria. *African Journal of Environmental Science and Technology*, 5, 99–109.
- Mukete, B and Sun, Y (2014). Assessing the Effectiveness of Urban Nature Reserves on Biodiversity Conservation. *Applied Ecology and Environmental Sciences* 2 (6) 130- 134.
- Mukete, B., Sun Y, Baninia, Y., Achem B., Bakia M., Saijad S. and Chalwe P. (2017). **Perspectives of remote sensing and GIS applications in tropical forest management.** *American journal of agriculture and forestry*. Am. J. Agric. For., 5 (3) (2017), pp. 33- 39, [10.11648/j.ajaf.20170503.11](https://doi.org/10.11648/j.ajaf.20170503.11)
- Ogunleye, A. J., Adeola, A. O., Ojo, L. O., and Aduradola, A. M. (2004). Impact of farming activities on vegetation in Olokemeji forest reserve, Nigeria. *International Journal of Global Nest*, 6, 131– 140.
- Olaleye, J.B., Abiodun, O.E. and Igbokwe, Q.C. (2009) Land Use Change Detection and Analysis using Remotely Sensed Data in Lekki Peninsula Area of Lagos, Nigeria, *FIG Working week, Surveyors Key Role in Accelerated Development, TS 8B – SIM in Planning and Development, Eliat, Isreal*, 3-8 may 2009.
- Patil, M.B., Desai, C.G. and Umrikar, B.N. (2012) Image classification tool for land use/land cover analysis: A comparative study of maximum Likelihood and Minimum

Distance Method. *Int. J. Geology, Earth and Environmental Sci.*, 2(3): 189-196.

Perumal, K. and Bhaskaran, R. (2010). Supervised classification performance of multispectral images. *Journal of Computing*, 2, 124–129.

Ramankutty N, Archard F, Aves D, Turner II B.L, Defries R, Goldewijk K.K, Graumlich L. and Reid R.S (2005). Global Changes in Land Cover, *UPDATE Newsletter of the International Human Dimensions Programme on Global Environmental Change*, 03/2005, pp. 4-5.

Terborgh, J. (2000). The fate of tropical forests: A matter of stewardship. *Conservation Biology*, 14, 1358–1361. doi:10.1046/j.1523-1739.2000.00136.

UNFCCC (2015). United Nations Framework Convention on Climate Change. *Report of the conference of the parties on its twentieth session, held in Lima, Peru 1st – 14th December 2014.*

<http://unfccc.int/resource/docs/2014/cop20/eng/10a02.pdf>. Accessed 14th November, 2015.

Vanjare, A., Omkar, S.N. and Sathilmath, J. (2014) Satellite image processing for land use and land cover mapping. *I.J. Image, Graphics and Signal Processing*, 10:18-28.

## **EFFECT OF COMPACTIVE EFFORTS ON THE DESSICATION-INDUCED VOLUMETRIC SHRINKAGE OF BLACK COTTON SOIL TREATED WITH CASSAVA PEEL ASH**

Adeyemo, K. A.<sup>1\*</sup>, Yunusa, G. H.<sup>1</sup>, Bello, A. A.<sup>2</sup> and Muhammad, A.<sup>3</sup>

<sup>1\*,2</sup>Department of Civil Engineering, Osun State University, Osogbo, Nigeria

<sup>1,3</sup>Department of Civil Engineering, Bayero University, Kano, Nigeria

\*Email: [adeyemokazeem59@gmail.com](mailto:adeyemokazeem59@gmail.com)

### **ABSTRACT**

The effect of cassava peel ash (CPA) on desiccation-induced volumetric shrinkage of black cotton soil (BCS) using three different compactive efforts was investigated. This paper presents the laboratory investigation results when the CPA and moulding water contents are varied; 0, 4, 8, 12, 16, 20 and 24% CPA contents at 2% dry, Optimum Moisture Content (OMC), 2% wet and 4% wet of optimum moisture content (OMC) using British Standard Light (BSL), British Standard Heavy (BSH) and West African Standard (WAS) compactive efforts. Index properties, volumetric shrinkage Strain (VSS) and Scanning Electron Microscopy (SEM) tests were carried out on natural CPA treated black cotton soil. From the results, there are noticeable changes in the index properties. The Plasticity Index (PI) produced minimum value of 11% at 16% CPA content, at the same blend; the maximum values of MDD are 17.9 kN/m<sup>3</sup>(BSL), 18.9kN/m<sup>3</sup>(BSH) and 18.1kN/m<sup>3</sup>(WAS), the minimum values of OMC are 13.4% (BSL), 9.8% (BSH) and 15.3% (WAS). The outcome of the investigation revealed that at 16% CPA treatment, values of VSS reduced by 73% (BSL), 92% (BSH) and 74% (WAS). SEM analysis also showed improved bonding between the soil grains and inter-grain porosity closed up at 16% CPA treatment.

**Keywords:** volumetric shrinkage, cassava peel ash, compactive efforts, moulding water content.

## **1.0 Introduction**

Black cotton soil (BCS) is an expansive soil with poor geotechnical properties, these poor characteristics can be improved via various methods of stabilization. Stabilization can be through mechanical means which include partial or total replacement of weak soils with good quality materials but this is unwise economically. Stabilizing expansive soils with chemical additives is one of the various methods of addressing its excessive swelling and shrinkage potential (Osinubi *et al.*, 2012). Chemical stabilization is used to enhance bonding of particles, reduce swelling and shrinkage potential and so on through the addition of chemicals or other materials from industrial and agricultural wastes.

In recent time, the use of industrial waste (cement kiln dust, fly ash, glass waste etc.), and agricultural waste (rice husk ash, groundnut shell ash, corn cob ash, cassava peel ash etc.) in finding remedies to problematic soils are becoming study focus of researchers. Many research works (such as Etim *et al.*, 2017; Ahmad *et al.*, 2017; Oriola and Moses, 2011) have been carried out using industrial and/or agricultural waste to modify/stabilize BCS, reports from these previous works showed that the poor properties of black cotton soil can be modified to make it useful for engineering applications.

Oriola and Moses (2011), used cement kiln dust (CKD) to treat BCS in 0%, 4%, 8%, 12% and 16% of dry soil weight, and it was observed that the hydraulic barrier parameters such as hydraulic conductivity, volumetric shrinkage and shear strength were modified and met the regulatory requirements of a hydraulic barrier. Etim *et al.* (2017), also used the combination of lime and iron ore tailings (IOT) in the treatment of BCS, and 8% lime/8% IOT treatment of BCS was recommended for use as sub-base material in traffic road on the basis of strength criterion. Experiment carried out by Ahmad *et al.* (2017) to investigate the effect of sugarcane Baggasse Ash (BA) as admixture to cement stabilized BCS also show positive outcomes at 5% BA with 8% cement blend by attaining 73% 7-day soaked CBR and 851 kN/m<sup>2</sup> UCS values which satisfied sub-base requirements of the Nigeria Federal Ministry of Works.

## **2.0 Material and Method**

### **2.1 Materials**

**2.1.1 Cassava peels ash (CPA):** The cassava peel used in this study was dried in open air, burnt into ash and eventually calcined at 700°C for 90 minutes in an electric furnace. At these conditions, the CPA possesses pozzolanic reactivity (Salau and Olonade, 2011). The ash was



sieved through BS Sieve 75 $\mu$ m, collected and stored under room temperature until it is needed to prevent moisture and contaminations from other materials. The oxide composition test of CPA was carried out using X-Ray Fluorescence method at the National Geosciences Research Laboratory (NGRL), Kaduna, and the result is presented in Table 1.

**2.1.2 Black cotton soil (BCS):** The BCS samples were collected from Deba town in Yamaltu-Deba local government area of Gombe state, through the disturbed method of sampling at a depth between 0.5-1.0 m. The index properties of the soil sample are summarized in Table 2 and they are in agreement with those obtained by Osinubi (2000) and Etim *et al.*, (2017) for soils from the study area.

## 2.2 Methods

**2.2.1 Index properties:** particle size distribution, specific gravity of soil solids and Atterberg limit tests conducted on the soil samples were in accordance with the procedures outlined in British Standard Institution, BS, 1377 (1990).

Table 1: Percentage Oxide Composition of CPA.

<b>Chemical Constituent</b>	<b>Percentage Composition</b>
<b>SiO<sub>2</sub></b>	54.40
<b>Al<sub>2</sub>O<sub>3</sub></b>	11.86
<b>Fe<sub>2</sub>O<sub>3</sub></b>	5.80
<b>CaO</b>	10.4
<b>MgO</b>	0.13
<b>SO<sub>3</sub></b>	0.45
<b>K<sub>2</sub>O</b>	13.10
<b>Na<sub>2</sub>O</b>	1.04
<b>LOI</b>	2.82

Table 2: Properties of the Natural Black Cotton Soil

<b>Property</b>	<b>Quantity</b>
<b>Natural moisture content, %</b>	9.7
<b>Specific gravity</b>	2.52
<b>Liquid limit, %</b>	62

<b>Plastic limit, %</b>	24
<b>Plasticity index, %</b>	38
<b>Linear shrinkage, %</b>	17.4
<b>% passing BS No. 200 sieve</b>	78.8
<b>Free swell, %</b>	68
<b>AASHTO classification</b>	A-7-6 (31)
<b>USCS classification</b>	CH
<b>OMC for BSL, BSH and WAS respectively, %</b>	18.6, 11.6 and 16
<b>MDD for BSL, BSH and WAS respectively, Mg/m<sup>3</sup></b>	1.65, 1.87 and 1.75
<b>Activity</b>	9.9 (active clay)
<b>Ph Value</b>	7.1
<b>Colour</b>	Dark Grey
<b>Dominant Clay Mineral</b>	Montmorillonite

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**2.2.2 Compaction:** this involves moisture – density relationship and volumetric shrinkage tests carried out using British Standard Light (BSL), British Standard Heavy (BSH) and West African Standard (WAS) compactive efforts in accordance with BSI (1990) and NGS (1997). The specimens were prepared by passing air – dried soil sample through BS sieve with 4.76mm aperture as outlined by Head (1992) as well as Albrecht and Benson (2001) and then mixed with 0, 4, 8, 12, 16, 20 and 24% CPA by weight of dry soil used.

**2.2.3 Volumetric shrinkage:** sample specimens were compacted using different compactive efforts at 2% dry, OMC, 2% wet and 4% wet of optimum moisture content of BSL, BSH, and WAS energy levels. The samples were carefully extruded from the 1000 cm<sup>3</sup> mould and left on a table to dry gradually at laboratory room temperature  $25 \pm 2$  °C. The weights and dimensions of the specimens were measured for 30 days until when no change dimension or weights were observed.

**2.2.4 Microstructural composition:** Scanning Electron Microscopy (SEM) is a common technique used to determine the micro-structural properties of soil fabric, providing information

on the size, shape and the state of orientation and aggregation of soil particles (Eisazadeh *et al.*, 2013). Microstructural studies of specimens were carried out using SEM at the Central Laboratory, Faculty of Natural and Applied Science, Umar Musa Yar’adua University, Katsina State.

### 3.0 RESULT AND DISCUSSION

#### 3.1 Atterberg Limits

The Atterberg limits of CPA stabilized BCS was studied and their variations with CPA dosage are as shown in Figures 1 and 2. Soil with high plasticity has liquid limit that ranges between 50% - 70% (Bello *et al.*, 2014). From Figure 1, the liquid limit of the natural soil is 62% which shows that the sample is of high plasticity. The addition of CPA to the natural soil caused changes in the plasticity indices and linear shrinkage of the sample, as shown in Figures 1 and 2. The reductions in plasticity indices as shown in Figure 1 are indicators of soil improvement (Bello *et al.*, 2015).

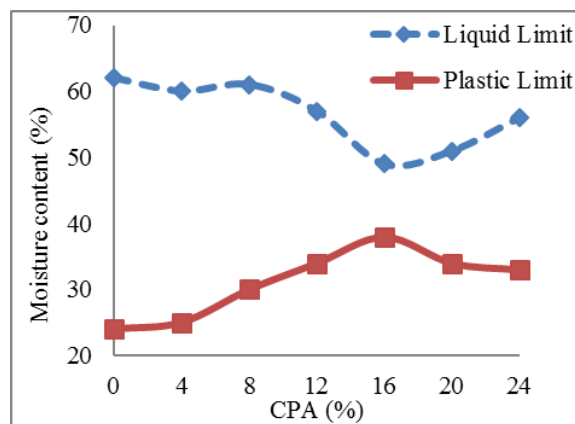


Figure 1: Variation of Atterberg Limits with CPA Content

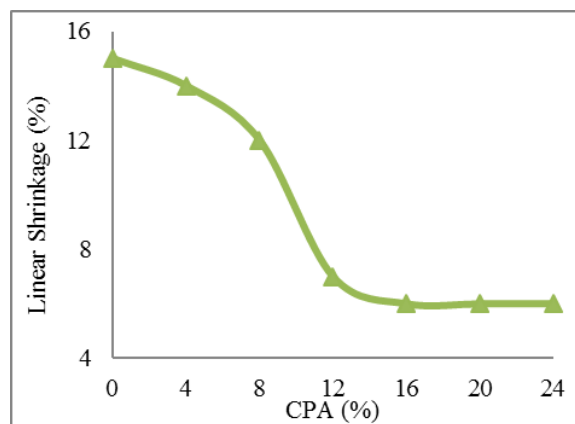


Figure 2: Variation of Linear Shrinkage with CPA Content

#### 3.2 Compaction Characteristics

The summary of the maximum dry density (MDD) and optimum moisture content (OMC) of varying CPA content using three different compactive efforts (BSL, BSH, and WAS) are shown Figures 3 and 4.

**3.2.1 Maximum dry density:** The addition of CPA brought about some changes in MDD values as appeared in Figure 3. At 16% CPA dosage maximum value of MDD for the BSL compactive effort was attained. But the BSH and WAS compactive efforts are of the same trends as there is increase in the MDD value at 4% CPA, then an abrupt fall at 8% CPA after which progressive increment up to the maximum value at 16% CPA was accomplished. It tends to be found that the MDD increment was because of voids inside the specimen being filled up by ash particles (Ahmad *et al.*, 2017 and Moses and Osinubi, 2013), while the decrease could be the contribution of increasing low specific gravity material as the CPA particles taking the place of higher specific gravity BCS (Ahmad *et al.*, 2017 and Kharade *et al.*, 2014).

**3.2.2 Optimum moisture content:** similarly, increasing the CPA content brought about some changes in OMC values as shown in Figure 4. For the BSL compactive effort, the OMC gradually decrease with increasing CPA content up to minimum at 16% CPA. While the BSH and WAS compactive efforts are of the same trend as there is decrease in the OMC value at 4% CPA, then an abrupt increase at 8% CPA after which gradual decrease was noticed up to the minimum value at 16% CPA was attained. The sudden increase at 8% CPA dosage is likely due to increased moisture demand by cations in the CPA and the BCS clay mineral particles for hydration. While the decrease in OMC on the other hand could have been due to cations exchange (Ahmad *et al.*, 2017 and Moses and Osinubi, 2013) with resulting flocculation of the clay particles.

**3.3 Volumetric shrinkage strain (VSS):** the variation of VSS values of BCS with various mix content of CPA compacted at OMC of three different compactive energies is shown in Figure 5.

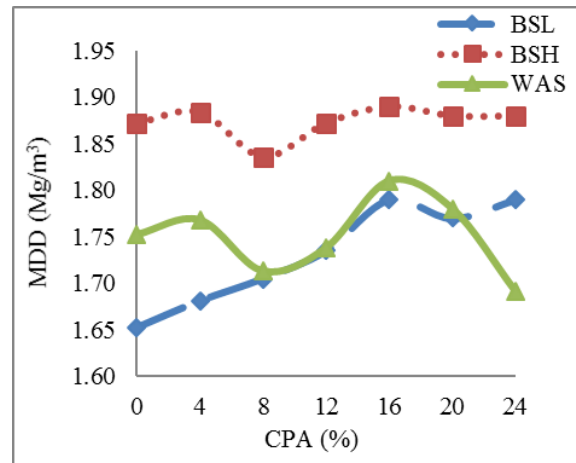


Figure 3: Variation of Maximum Dry Density with CPA Content

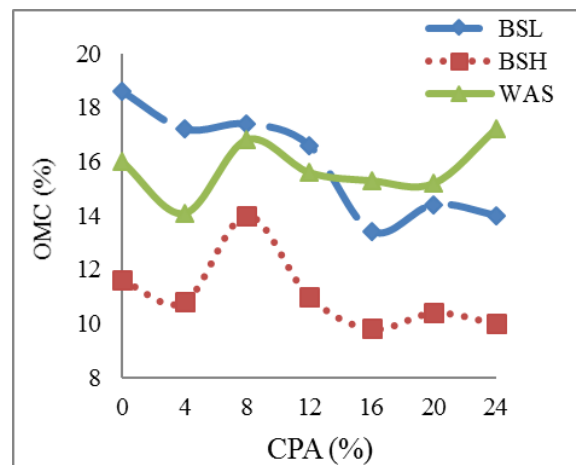


Figure 4: Variation of OMC with CPA Content.

The VSS values ranges between 3.3-15.5%, 1.1-13.7%, and 2.7-14.1% for BSL, BSH and WAS compactive efforts, respectively. Also, as appeared in Figure 5 the VSS of BSL, WAS and BSH show significant changes (reduced) up to 16% CPA content with values approximately less/equal 4% at 16% CPA inclusion.

Generally, decrease in the volumetric shrinkage strain with increasing CPA dosage for BSL, BSH and WAS energy levels was observed; this can be attributed to the pozzolanic input of pozzolana (Osinubi and Eberemu, 2009) which reduces the fine grained soils.

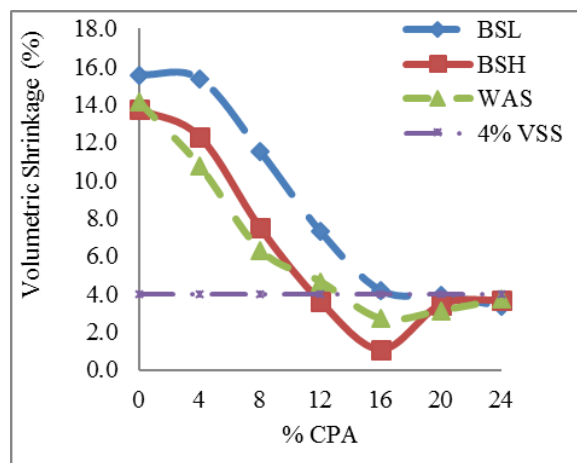


Figure 5: Variation of Volumetric Shrinkage with CPA Content.

**3.4 Moulding water content versus volumetric shrinkage strain:** desiccation of compacted clayey soil is usually accompanied by shrinkage and/or cracking, depending on the moulding water content of the compacted soil samples (Osinubi and Nwaiwu, 2005). This is because as the moulding water content of the compacted soil is increased, the shrinkage potential of the soil increases as well. The influence of moulding water content and compactive effort on volumetric shrinkage strain on natural and CPA-treated-BCS are shown in Figures 6, 7 and 8.

Generally, volumetric shrinkage increased with higher moulding water content which aligns with the results of Daniel and Wu (1993) and Alberechet and Benson (2001). Also, researchers such as Daniel and Wu (1993), Tay *et al.* (2001) suggested that cracking do not likely occur in soil when compacted cylinders of the same soil undergo less than about 4% volumetric shrinkage strain upon drying. The VSS of specimen compacted between 2% dry to 4% wet of the OMC ranged between 6.51% - 19.18% up to 12% CPA treatment at BSL compactive effort as shown in Figure 6. However, at 16, 20 and 24% CPA contents, results less than 4% VSS were achieved for BSL compactive effort as shown in Figure 6. Also, Specimens compacted between 2% dry to 4% wet of the OMC for BSH compactive effort produced VSS results less than 4% that ranged between 0.9% - 3.68% at CPA contents of 12, 16, 20 and 24% as shown in Figure 7. These VSS values were attained at moulding water contents of 2% dry, OMC and 2% wet of optimum as shown in Figure 7. Similarly, specimens compacted between 2% dry to 4% wet of the OMC for WAS compactive effort produced VSS values less than 4% that ranged between 2.03% - 3.71% at CPA treatment content of 12, 16, 20 and 24% as shown in Figure 8. These values were attained at moulding water contents of 2% dry of optimum and at OMC as shown in Figure 8.

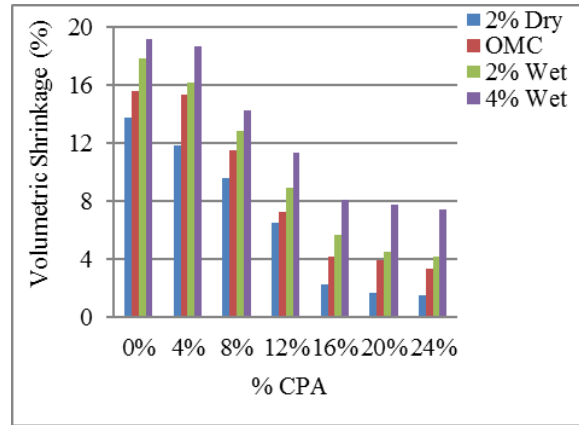


Figure 6: Variation of Volumetric Shrinkage with Compaction Water Content Relative to Optimum for BSL Compactive Effort.

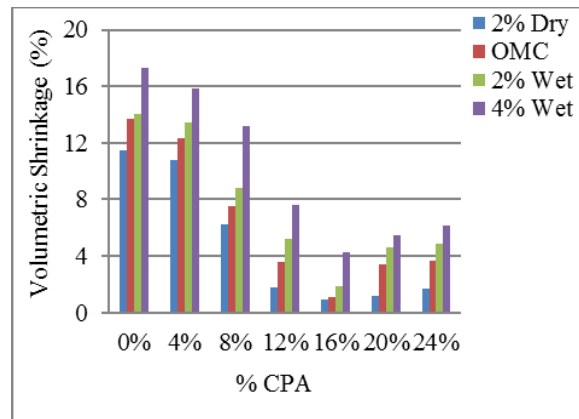


Figure 7: Variation of Volumetric Shrinkage with Compaction Water Content Relative to Optimum for BSH Compactive Effort.

**3.5 Microstructural study:** The micrographs of natural BCS and BCS treated with optimal 16% CPA are shown in Plate 1 and 2. As shown in Plate 1, the micrograph of natural BCS shows a surface morphology with well-developed cracks, inter-particle porosity caused by drying and microstructure alteration.

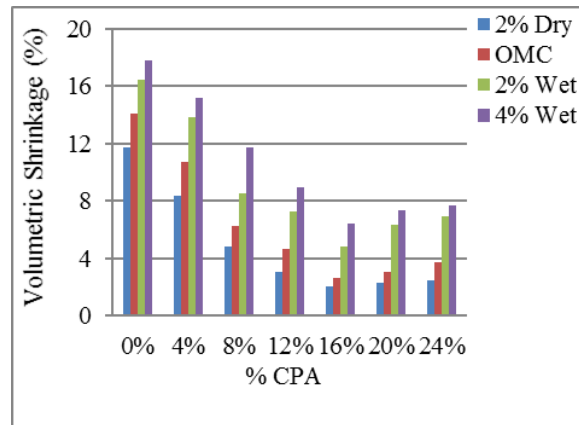


Figure 8: Variation of Volumetric Shrinkage with Compaction Water Content Relative to Optimum for WAS Compactive Effort.

This is similar to the findings of Romero and Simms (2008) and Etim *et al.* (2017). The micrograph of BCS treated with optimal 16% CPA as shown in Plate 2 indicates that the soil interacted with the CPA and has undergone some morphological improvement such as improved bonding between the soil grains and inter-grain porosity closed up. These improvements may be as a result of cation exchange, flocculation-agglomeration, pozzolanic reaction and filling of inter-grain porosity (Deneele *et al.*, 2010 and Etim *et al.*, 2017). This is thus responsible for the optimal decrease in the volumetric shrinkage strain at 16% CPA treatment level.

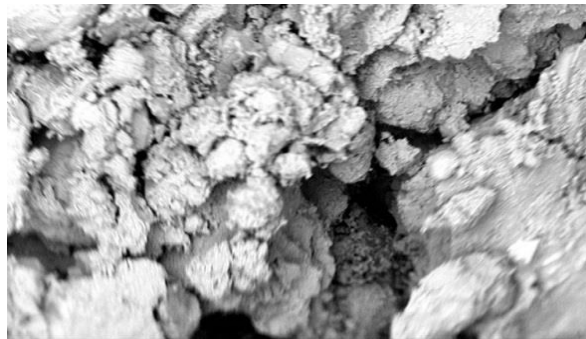


Plate 1: Micrographs Showing Natural BCS at 320 Magnification.



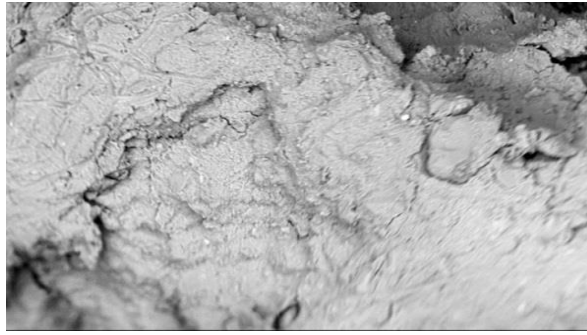


Plate 2: Micrographs Showing BCS Treated with 16% CPA at 320 Magnification.

#### 4.0 Conclusion

The addition of CPA to the soil sample caused significant improvement in the sample qualities following a minimum reduction in the PI value at 16% CPA treatment. Also at 16% CPA inclusion there are notable increases in the MDD values and reductions in the OMC values. The reduction in the PI value is an indication of weak properties improvement such as reduction in the linear and volumetric shrinkage. The volumetric shrinkage reduces to minimum values of less than/equal to 4% VSS at 16% CPA blend for all the compactive efforts considered. At this treatment level the blend fulfils one of the conditions required of a material to be used in hydraulic barrier system. Based on results from laboratory investigations and careful study of micrographs from SEM analysis it can be concluded that the use of CPA in treatment of black cotton soil yields positively at optimal 16% CPA blended with optimum moulding water content, when the volumetric shrinkage parameter of a barrier material is considered.

#### REFERENCES

- AASHTO. *Standard specification for transportation materials and methods of sampling and testing*, 14<sup>th</sup> Edition, Washington, D. C.; 1986.
- Ahmad, B., Adamu, U. C., Saeed, M. S., Ibrahim, A. I., Nasir, K., and Abubakar, M. "Effect of Bagasse Ash on the Properties of Cement Stabilized Black Cotton Soil". *International Journal of Transportation Engineering and Technology*. Vol. 3, No. 4, 2017, pp. 67-73. doi: 10.11648/j.ijtet.20170304.14
- Albrecht, B. A., and Benson, C. "Effect of Desiccation on Compacted Natural Clay". *Journal of Geotechnical and Geo-environmental Engineering*, Vol. 127, No. 1, 2001, pp. 67-75.
- ASTM. "Annual Book of Standards", *American Society for Testing and Materials*, Vol. 4(8), 1992, Philadelphia.
- Bello A. A., Ige, J. A., and Hammed A. "Stabilization of Lateritic Soil with Cassava Peel Ash", *British Journal of Applied Science and Technology*. Vol. 7, Number 6, 2015, pp.642-650.
- Bello A. A., Ige, J. A., and Ibitoye, G. I. "Geotechnical Properties of Lateritic Soil Stabilized with Cement-Bamboo Leaf Ash Admixture", *International Journal of Applied Engineering Research*. Vol. 9, Number 21, 2014, pp.9655-9665.
- BS 1377. *Methods of Testing Soils for Civil Engineering Purposes*. British Standard Institution, London; 1990.

- Daniel, D. E. and Wu, Y. K. "Compacted Clay Liners and Covers for Arid Sites". *Journal of Geotechnical Engineering*, 119(2), 1993, pp. 228-237.
- Deneele, D., Cuisinier, O., Hallaire, V. and Masrouri, F. "Microstructural evolution and physico-chemical behavior of compacted clayey soil submitted to an alkaline plume". *Journal of Rock Mechanics and Geotechnical Engineering*, Vol. 2, 2010: pp. 169–177.
- Eisazadeh, A., Kassim K. A., and Nur, H., (2013). "Morphology and BET surface area of phosphoric acid stabilized tropical soils". *Engineering Geology*, 154: pp. 36–41.
- Etim, R. K., Eberemu, A. O., and Osinubi, K. J. "Stabilization of black cotton soil with lime and iron ore tailings admixture." *Transportation Geotechnics* (2017),doi: <http://dx.doi.org/10.1016/j.trgeo.2017.01.002>
- Kharade A. S., Suryavanshi V. V, Gujar B. S., and Deshmukh R. R. "Waste Product 'Bagasse Ash' From Sugar Industry Can Be Used As Stabilizing Material for Expansive Soils", *IJRET Int. J. Res. Eng. Technol.*, Volume 1, Number 1, 2014, pp. 506–512.
- Moses G., and Osinubi K. J. "Influence of Compactive Efforts on Cement- Bagasse Ash Treatment of Expansive Black Cotton Soil", *Int. J. Civil, Environ. Struct. Constr. Archit. Eng.*, Volume 7 Number 7, 2013, pp. 1541–1548.
- Osinubi, K. J. "Lime Modification of Black Cotton Soil", *Spectrum Journal*, Volume 2, 1995, pp. 112-122.
- Osinubi, K. J. "Lime Modification of Black Cotton Soil", *Spectrum Journal*, Volume 2, 1995, pp. 112-122.
- Osinubi, K. J. "Stabilization of tropical black clay with cement and pulverized coal bottom ash admixture". In: *Advanced in Unsaturated Geotechnics*. Edited by Cheuler, D., Sandra, L. H., and Nien-Yui Chang. ASCE GSP, (99), 2000; pp. 289-302.
- Osinubi, K. J. and Nwaiwu, C. M. "Hydraulic conductivity of compacted lateritic soils". *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, Vol. 131, No. 8, 2005, pp. 1034 – 1041.
- Osinubi, K. J., and Eberemu, A. O. "Desiccation-induced Shrinkage of Compacted Lateritic Soil treated with bagasse ash." *The Twenty-Fourth International Conference on Solid Waste Technology and Management CD-ROM*, 15-18 March, Philadelphia, PA, U.S.A. Session 5C: Bioreactors and Innovative Landfills, 2009 pp.856-867.
- Osinubi, K. J., Diden, R., Ijimdiya, T. S., and Eberemu, A. O. (2012). "Effect of Elapsed Time after Mixing on the Strength properties of Black Cotton Soil Cement Blast Furnace Slag Mixtures." *Journal of Engineering Research*. 17, 4. Pp.
- Romero, E. and Simms, P. H. "Investigation in unsaturated soils: A review with special attention to contribution of mercury intrusion porosimetry and environmental scanning electron microscopy." *Journal of Geotechnical and Geological Engineering*, Vol. 8, 2008; pp. 1-23.
- Salau, M. A. and Olonade, K. A. "Pozzolanic Potentials of Cassava Peel Ash", *Journal of Engineering Research*, Vol. 16, Number 1, 2011, pp. 10-21.

## **EVALUATION OF THE EFFECT OF PRECIPITATION VARIATION ON GROUNDWATER QUALITY IN ILORIN METROPOLIS, NIGERIA**

Ayanshola, A.M.<sup>1</sup>, Sossou, P.M.<sup>2</sup>, Bilewu, S.O.<sup>1</sup>, Abdulkadri, T.S.<sup>1</sup>, Oluwaseun, V.O.<sup>1</sup> and  
Owolabi, S.O.<sup>3</sup>

<sup>1</sup>Dept. of Water Res. & Env. Engg University of Ilorin, Ilorin, Nigeria

<sup>2</sup>Dept. of Civil Engg University of Ilorin Ilorin, Nigeria

<sup>3</sup>Dept. of Civil Engg Adeleke University Ede, Nigeria

Corresponding author: [engramayanshola@gmail.com](mailto:engramayanshola@gmail.com)

### **ABSTRACT**

Groundwater is an essential part of the hydrological cycle serving as the primary source of water where public water supply is neither available nor adequate. This study evaluated the seasonal variability of water quality with respect to monthly rainfall depth in Ilorin metropolis, Nigeria. This was achieved by the determination of the month with minimum and maximum rainfall depth as well as determination of the concentration of Physico-chemical and bacteriological parameters of water sample in the study area. Twenty years historical data of monthly rainfall depth was obtained and analysed and a total of 32 water samples were collected from Shallow wells in the month with minimum and maximum rainfall depth from 8 different locations in year 2018 to determine their concentration. The Physico-chemical and bacteriological properties of water samples were analysed using Standard Methods. The potability of the water samples were assessed with respect to WHO standard. The study revealed that Turbidity, Fe<sup>2+</sup>, Dissolved Oxygen, Total Viable Count and Total Coliform Count concentration exceeded the World Health Organization (WHO) standard in all the samples. Hence, the Shallow well water sources are polluted and the concentration of these pollutants increased in the month with minimum rainfall depth. The reduction in the pollutant concentration during the month with higher rainfall depth might be as a result of dilution through groundwater recharge from precipitation. The study also shows that the wells are not safe sources for drinking purposes and some form of treatment will be required before consumption.

***Keywords – well water; rainfall depth; bacteriological; physicochemical***

## **I. INTRODUCTION**

Groundwater is an essential resource that cannot be ignored in any part of the world (Llamas, 2005). It is indispensable for human survival and sustaining societal development. Changes in the Earth's climate

or seasonal variation have the potential to affect both the quality and the quantity of available groundwater, primarily through impacts on recharge, evapotranspiration and (indirectly) on pumpage and ABSTRACTION. The provision of clean potable drinking water, especially in developing countries like Nigeria, has always been a major challenge (Raji and Ibrahim, 2011) and many people rely on well and borehole water for their domestic drinking purpose due to the lack of access to potable water (Shittu, *et al*, 2008). According to Gronwall, *et al* (2010), an estimated 269 million urban dwellers depend on wells as their principal source of drinking water. In urban Nigeria, it is estimated that almost 60 per cent of the population rely on local wells. There is an increasing trend of groundwater overexploitation and deterioration at both the regional and global scales, mainly due to anthropogenic activities (MacDonald, *et al*, 2016). Groundwater usually requires less microbiological and physicochemical treatment owing to its good quality and it is better protected against pollution than surface waters. The seasonally different intensities in precipitation considerably influence both water quantity and quality (Sakakibara, *et al*, 2017). Therefore, evaluating seasonal variability effects of groundwater quality has gradually become the focus of research on groundwater source areas.

In Nigeria and particularly in Ilorin, groundwater is an important source of water for drinking and other purposes. Ifabiyi and Ashaolu (2013) reported that the coverage of public water supply in Ilorin is limited to some area while others lack access to this service. Based on all these evidences, greater portion of the city rely more on groundwater (shallow, borehole and deep well) to meet their domestic and drinking water needs since groundwater is often potable at source and does not require heavy investment.

## **II. DESCRIPTION OF THE STUDY AREA**

Ilorin, the capital of Kwara State is located on latitude 8°30' and 8°50'N and longitude 4°20' and 4°35'E of the equator (Figure 1). It occupies an area of about 468sqkm and it is situated in the transitional zone within the forest and the guinea savannah regions of Nigeria. It is about 300 kilometers away from Lagos and 500 kilometers away from Abuja the federal capital of

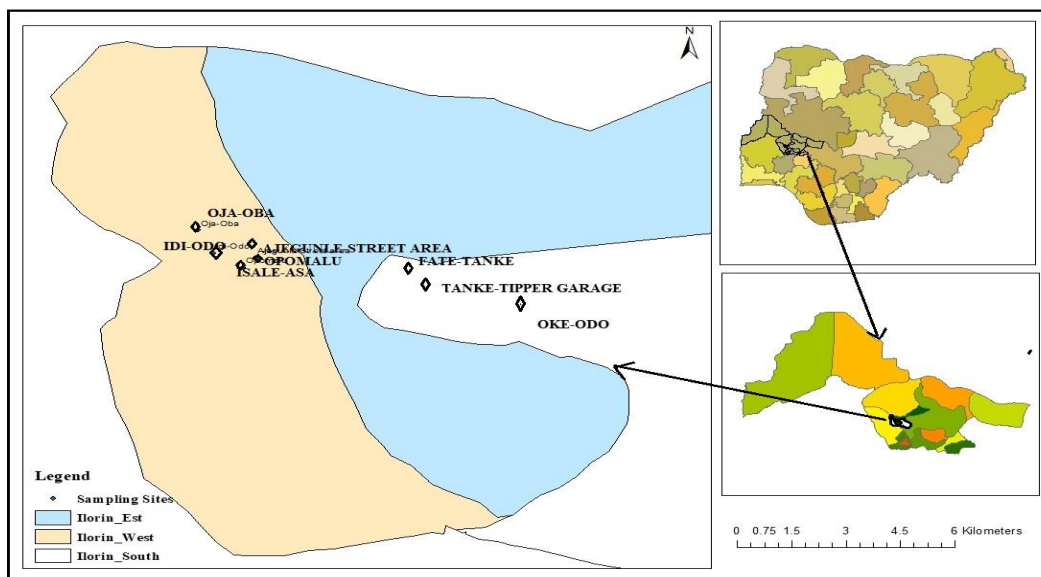
Nigeria. The climate of Ilorin is tropical under the influence of two trade winds prevailing over the country. Ilorin metropolis experiences two climatic seasons (rainy and dry season). The rainy season is between March and November and the annual rainfall varies from 1000 mm to 1500 mm, with the peak between September and early October. The total annual rainfall in the state ranges from 800mm to 1,200mm in the northwest and 1,000mm to 1,500mm in the southeast. Ilorin had a population of 847,582 making it the 13th largest city in Nigeria by population (The World Gazzetter, 2013).

## 1. MATERIALS AND METHODS

Historical daily rainfall data of Ilorin Metropolis spanned from 1999 to 2018 was obtained from the Nigerian Metrological Agency (NIMET) in order to determine the month with average minimum and maximum rainfall depth. Water samples from selected wells in the study area were then obtained in the months with average minimum and maximum rainfall depths earlier determined.

A total of 32 waters samples were collected from open wells for the month with maximum and minimum rainfall depth within ilorin metropolis (16 samples each) in the months of Septemer and December, 2018. The analyses was done at the chemistry and bateriological Laboratory of University of Ilorin. Water samples were collected using standard method as described by Aminu annd Amadi (2014) and tested according to Standard Methods (APHA, 2002). Water parameters considered include temperature, pH, Total Dissolved Solide (TDS), Total Dissolved Oxygen (TDO), Total Solid (TS), Total Suspended Solid (TSS), Total Hardness (TH), Alkalinity, Electrical Conductivity (EC), turbidity, iron ( $\text{Fe}^{3+}$ ), chloride, magnesium, Nitrate ( $\text{NO}_3^{2-}$ ), Sulphate ( $\text{SO}_4^2$ ), calcium and zinc. The occurrence of Fecal Coliform, Total Viable Counts (TVC) and Total Coliform Counts (TCC) were also rxamined.

Laboratory results of the samples were subjected to statistical analysis and the results were then compared with the standards set by WHO.



**Figure 1:** Geographical map of Ilorin showing the sampling sites.

### III. RESULTS AND DISCUSSION

#### A. Monthly Rainfall Variation

The monthly variation of rainfall depth analysis shows that the minimum and maximum rainfall depths occurred in the months of December and September respectively between years 1999 and 2018. This is the reason why the samples were obtained for the study in the months of December and September respectively for dry and wet season.

#### B. Physico-chemical Parameters

The statistical summary of Physico-chemical Parameters of the water sample for the months with minimum and maximum rainfall depth for the study area is as shown in Table 1.

The monthly physicochemical analysis results indicate that the temperature of all the water samples falls within recommended values set by the WHO for groundwater (0-30°C). The temperature of groundwater is lower in the month with minimum rainfall depth than in the month with maximum rainfall depth. The higher temperature values recorded may be due to the prevalent atmospheric conditions. On the other hand, pollutants, among many other factors

may cause temperature increase in water in the present situation and similar result was also recorded by Al Sabahi, *et al.* (2009)

The results of analyses of water samples show that the pH of groundwater is all within the WHO allowable limit of 6.5-8.5 for drinking water for both months. The concentration of pH was found slightly high in December than September in each sample respectively from A to H except in samples E, G and H for the month of September. This lower pH of the groundwater in wet season may not be unconnected with dilution of rainfall with carbon dioxide as a result of aquifer recharge. The increased pH in samples E, G and H may be due to the increase of pollutant concentration occurring in these point sources of water. However, the result is in consonant with the finding of Ogbona, *et al* (2010) for various groundwater samples.

Electrical conductivity (EC) is viewed as a valuable indicator of the amount of dissolved materials in water (Olajire and Imepeoria, 2011). Potable water should not have high electrical conductivity as opined by Hutton (1983). The analyses show that electrical conductivity in all the water samples was below 1000  $\mu\text{S}/\text{cm}$  recommended by the WHO for potable water. EC in the wells are noted to be higher in December than in the month of September. Conductivity in groundwater is dictated primarily by the geology of the area through which the water flows.

**Table 1:** Descriptive Statistics of Physico-chemical Parameters of Water samples for the month with maximum and minimum rainfall depth Ilorin metropolis.

Code	Month of September					Month of December					
	Min	Max	Mean	STD	CV	Min	Max	Mean	STD	CV	WHO
TP	27	28.5	27.88	0.5	1.79	26	29	27.19	0.83	3.06	0-30
PH	5.98	7.5	6.93	0.67	9.7	6.65	7.55	7.19	0.3	4.16	6.5-8.5
TBD	5.33	6.38	5.82	0.42	7.14	5.53	6.84	6.05	0.41	6.75	5
TDS	1.97	3.93	2.84	0.64	22.61	2.94	3.5	3.29	0.2	6.05	500

TSS	1.73	2.39	1.88	0.23	12.4 4	2.25	3.94	2.82	0.58	20.3 7	500
EC	40.3	41.8 1	41.09	0.54	1.31	40.4 2	41.9 8	41.2 8	0.55	1.33	1000
TS	3.75	5.75	4.72	0.72	15.2 9	5.65	6.87	6.12	0.39	6.37	1500
Cl <sup>-</sup>	2.36	8.26	5.53	2.09	37.7 6	1.48	8.38	5.2	2.21	42.4 3	200
Ca <sup>2+</sup>	0.51	1.41	1.07	0.33	30.3 7	0.65	2.36	1.4	0.62	44.3 6	75
Mg <sup>2+</sup>	0.57	2.36	1.37	0.59	43.0 9	0.81	2.55	1.64	0.55	33.3 8	50
TH	1.08	3.74	2.44	0.88	36.1	1.46	4.14	3.04	0.97	31.9 5	500
Fe <sup>2+</sup>	0.42	0.79	0.54	0.14	26.3 7	0.63	0.83	0.76	0.07	9.1	0.1
NO <sub>3</sub> <sup>2-</sup>	0.88	1.54	1.09	0.23	21.2	1.2	1.35	1.26	0.05	4.01	50
SO <sub>4</sub> <sup>2-</sup>	39.2 6	41.9 7	40.76	1.04	2.55	41.0 2	44.8	42.4 9	1.33	3.13	200
Zn <sup>2+</sup>	0.36	0.56	0.42	0.06	15.1 3	0.51	0.67	0.59	0.05	9.12	5
DO	88.8	145. 6	116.9 4	21.2 9	18.2	86.8	125. 2	109. 2	13.3 2	12.2	7.5
AKL	3.18	5.55	4.62	0.96	20.9 1	3.81	4.36	4.21	0.21	5	50

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. The turbidity of all the water sample collected in the study area did not comply with the standard requirements. Their values exceeded the 5-NTU recommended by WHO (2006). Turbidity concentrations in groundwater are noted to be higher in December (dry season) than in the month of September (wet season). This may be due to



parental rock activities and the level of water in the wells. Excessive turbidity, in drinking water, may represent a health concern.

The results of Total dissolved solids (TDS), total suspended solids (TSS) and Total solids (TS) in the study area fall all within the prescribed limit set by WHO. But their values are higher in the month with minimum rainfall than the month with maximum rainfall depth. High total dissolved solids give objectionable odour or offensive taste in water (Aydin, 2007). Also the highest concentrations of TSS in sample H and F respectively in September and December may be attributed to accidental discharges entering the water from local drainages.

As for chloride ion, all the samples were below the WHO limit of 200 mg/l for drinking water. The chloride concentration is higher in September than December. High concentrations of chloride make water unpalatable and unfit for drinking and livestock watering.

The Calcium and Magnesium concentration is high in December than in the month of September but all the wells sampled have calcium and magnesium concentration below the WHO's highest permissible limit of 75mg/l and 50mg/l respectively. Higher concentrations of calcium and magnesium in water causes poor lathering during washing and deterioration of the quality of clothes. High intake of magnesium causes gastro-intestinal irritations and it also contributes to the hardness of water (WHO, 2006).

Total hardness in water samples as shown by the analyses have concentrations all below the WHO guideline (500mg/l) for drinking water both for the month of September and December. From the mean concentration of total hardness, concentration in water is higher for the month of minimum rainfall depth than the month with maximum rainfall. The water in the study area is soft. Hard water is useful and also detrimental to the human health. Hard water causes poor lathering with soap, deterioration of the quality of clothes, scale forming, skin irritation, and boiled meat and food become poor in quality. Soft water also increases the chances of heart failure in humans.

The iron concentration was higher for the month with minimum rainfall than the month September and the analyses result did not comply with the maximum permissible limit set by the WHO. The iron occurs naturally in the aquifer but levels in groundwater can be increased by dissolution of ferrous borehole and handpump components. Long term consumption of drinking water with a high concentration of iron can lead to liver diseases (hemosiderosis).

High concentration of iron in water is not suitable for processing of food, beverages, ice, dyeing, bleaching and many other items.

The results showed that nitrate level in water sampled was higher for the month of December than the month of September. However, the values obtained in this study were well below the maximum permissible limits set by WHO. Water that is contaminated with nitrate is harmful especially to infants causing methemoglobinemia, otherwise called infantile cyanosis or blue baby syndrome if consumed.

From the result, sulphate concentrations have a mean and coefficient of variation of 40.76mg/l and 2.55% against 42.49mg/l and 3.13% respectively for the month of September and December. The sulphate concentration is higher for the month of December than the month of September. Sulphates are a compound containing Sulphur and oxygen ions and are a part of naturally occurring minerals in some formations of soil and rock that contain groundwater. The minerals dissolve over a period and are released into groundwater (Okpokwasili, *et al*, 2013). The sulphate levels of the water samples were below the 200mg/l recommended value by WHO (2006).

The concentrations of Zinc have a mean and coefficient of variation of 0.42mg/l and 15.13% against 0.59mg/l and 9.12% respectively for the month with maximum and minimum rainfall depth. Its values is higher in December than September but fall below the maximum permissible limit of 5.0mg/l standardized by WHO. Higher zinc application appears to protect people from cadmium poisoning. Zinc may also decrease lead absorption.

Measures of dissolved oxygen (DO) refers to the amount of oxygen contained in water. All the water sampled have a high concentration of dissolved oxygen. The result exceeded the recommended 5mg/l set by WHO (2006). Dissolved oxygen is one of the most important parameters of water. Direct and indirect information such as nutrient availability, the level of pollution, metabolic activities of microorganisms, stratification, and photosynthesis can be deduced from its correlation with water body [17]. The concentration of DO is higher for the month with maximum rainfall depth than the month with minimum rainfall.

The results of analyses of water samples for alkalinity have a mean and coefficient of variation of 4.62 mg/l and 20.91% against 4.21mg/l and 0.21% respectively for September and December. alkalinity concentration in the sampled water in the study area was below the WHO

allowable limit (50mg/l) for drinking water but higher in the month with maximum rainfall than in the month with minimum rainfall depth.

### C. Bacteriological Parameters

The Total Viable Counts (TVC) of the water samples within the eight (8) different sampling sites range from  $1.30 \times 10^5$  to  $7.00 \times 10^5$  cfu/ml and from  $3.10 \times 10^5$  to  $5.20 \times 10^5$  cfu/ml for the month of September and December respectively (Table 2). The mean of TVC is higher in the month of December ( $4.19 \times 10^5$  cfu/ml) than in the month of September ( $3.68 \times 10^5$  cfu/ml). The Total Coliform Count (TCC) in water increase also from  $1.20 \times 10^5$  to  $4.00 \times 10^5$  cfu/ml for the month of September and from  $1.60 \times 10^5$  cfu/ml to  $3.55 \times 10^5$  cfu/ml for December (Table 2). FCC was totally absent for both the month with maximum and minimum rainfall depth in the study area. This result contradicts the conclusion of Afolayan and Kolawole (2017), who reported that detected coliforms, primary bacterial indicator for fecal pollution in all samples. The absences of activities that leads to the the sources of coliforms in groundwater such as agricultural runoff, effluent from septic systems or sewage discharges, infiltration of domestic or wild animal fecal matter may be responsible for the result (Somaratne and Hallas, 2015). The microbial load observed in the well water samples are much higher than the recommended values set by WHO. However, the results comply with other studies across Nigeria which showed the presence of coliforms in most freshwater sources (Aminu and Amadi, 2014; Anyanwu and Okoli, 2012). The alarming increase in microbial loads may be as a result of increasing nutrients and aeration during the decomposition of organic matter. Coliforms are the most abundant bacteria in water responsible for water-borne diseases such as typhoid, dysentery, diarrhea and have also been implicated in mortality across the world (WHO, 2000), therefore drinking from any of the open wells used for this study will lead to serious health conditions.

**Table 2:** Descriptive Statistics of Bacteriological Parameters of the Water samples in the month of September and December

	Month of September			Month of December		
Parameters						FCC

	TVC (cfu/ml) x 10 <sup>5</sup>	TCC (cfu/ml) x 10 <sup>5</sup>	FCC (cfu/ml) x 10 <sup>5</sup>	TVC (cfu/ml) x 10 <sup>5</sup>	TCC (cfu/ml) x 10 <sup>5</sup>	(cfu/ml) x 10 <sup>5</sup>
Minimum	1.3	1.2	-	3.1	1.6	-
Maximum	7	4	-	5.2	3.55	-
Mean	3.68	2.5	-	4.19	2.37	-
WHO Standard	100	0 - 10	0	100	0 - 10	0
Standard Deviation	1.84	1	-	0.84	0.66	-
Coefficient of Variation	50.11	39.83	-	20.09	27.7	-

#### IV. CONCLUSION

The physicochemical and bacteriological properties of the well water samples examined in this study are on the reflection of man-made materials, country rocks through which has come into contact with and the influence of rainfall depth. The results of bacterial loads were higher in all the water samples especially in the month with minimum rainfall depth in Total Viable Counts and lower in Total Coliform Counts for the same month, but the results exceeded the maximum permissible limits recommended by WHO except for Fecal Coliform Counts that was totally absent in the study area. It was also found out that dissolved oxygen is the most abundant element found in all the sampled wells followed by turbidity and iron, and their values did not comply with the WHO Standards. Their occurrence in groundwater can be traced to their abundance in the earth crusts, through pollution by human impact on the environment and the intensity rain that falls. It is confirmed from the analyses that open well of Ilorin metropolis is more polluted in the month with minimum rainfall depth than the month with maximum rainfall. The life of residents in Ilorin Metropolis is endangered as long as people depend on ABSTRACTion of polluted water from open wells for domestic and drinking purposes.

#### REFERENCES

Afolayan, O., Kolawole, O.M., 2017. Assessment of Groundwater Quality in Ilorin, North Central Nigeria. *Arid Zone Journal of Engineering, Technology and Environment*, 13(1), pp. 11-126

Al Sabahi E, Abdul RS, Wan ZWY, Al Nozaily F, Alshaebi F., 2009. The Characteristics of Leachate and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen, *Amer. J. Environ. Sci.*, 5(3), pp. 256-266.

Aminu, T. and Amadi, AN., 2014. Bacteriological contaminations of ground water from Zango Local Government Area, Katsina State, North Western Nigeria. *Journal of Geoscience and Geomatics*, 2(5), pp. 186-195.

APHA, 2002. *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, Washington DC (20).

Gronwall, J.T.; Mullenga, M; McGranaham, G., 2010. *Groundwater, Self-Supply and Poor Urban Dwellers: A Review With Case Studies of Bangalore and Lusaka*. Human Settlements Programme, International Institute for Environment and Development (IIED), London.

Hutton, L., 1983. *Field testing of water in developing countries*, Water Resources Center, Unwin Brothers Limited, Britain.

Ifabiyi, I.P & Ashaolu, E.D., 2013. Analysis of the Impacts of Rainfall Variability on Public Water Supply in Ilorin, Nigeria. *Journal of Meteorology and Climate Science*, 11(1), pp. 18-26.

Llamas, M.R., 2005. Intensive Groundwater Use: A Silent Revolution that cannot be Ignored, *Water Science and Tech Series*, 51(8), pp. 167-174

MacDonald, A. M., H. C., Bonsor, K. M. Ahmed, W. G. Burgess, M. Basharat, R. C. Calow, A. Dixit, S. S. D. Foster, K. Gopal, D. J. Lapworth, and R. M. Lark. 2016. Groundwater Quality and Depletion in the Indo-Gangetic Basin Mapped from in Situ Observations. *Nature Geoscience* 9: 762–766.

Ogbonna, CE., Njoku, HO., Onyeagba, RA. and Nwaugo, VO., 2010. Effects of seepage from drilling burrow Pit wastes on Orashi River, Egbema, Rivers State, Nigeria. *Nigerian Journal of Microbiology*, 24(1), pp. 193-200.

Okpokwasili, G.C., Douglas, S.I. And Inengite, AK., 2013. Seasonal variations of some physicochemical parameters of groundwater in crude oil flow stations. *Journal of Environment, Science and Water Resources*, 2(1), pp. 22-26.

Olajire, AA. and Imepporia, FE., 2001. Water quality assessment of Osun River: Studies on inorganic nutrients. *Environmental Monitoring Assessment*, 69, pp. 17-28

Raji, MIO. and Ibrahim, YKE., 2011. Prevalence of water-borne infections in North Western Nigeria: A retrospective study. *Journal of Public Health and Epidemiology*, 3(8), pp. 382-385.

Sakakibara, K.; Tsujimura, M.; Song, X.; Zhang, J., 2017. Spatiotemporal variation of the surface water effect on the groundwater recharge in a low-precipitation region: Application of the multi-tracer approach to the Taihang Mountains, north China. *J. Hydrol*, 545, pp. 132–144.

WHO. 2006. *Guidelines for drinking water quality*. 3rd edition, WHO press, Geneva, Switzerland. Pp.355 – 398.

Somarathne, N. and Hallas, G., 2015. Review of Risk Status of Groundwater Supply Wells by Tracing the Source of Coliform Contamination, *Water* 7(7), pp. 3878-3905

## **REMOTELY CONTROLLED CAR SPEED GOVERNOR**

Alonge, O.I.\* , Abiola, O.A., Onigbogi, A.O., Akinbode, F.O., Okediji, A. P. and Alabi, I. O.

Department of Mechanical and Automotive Engineering, Elizade University, Ilara-mokin,  
Ondo State.

**\*Email of Corresponding Author: [alongeoluwasanmi@gmail.com](mailto:alongeoluwasanmi@gmail.com)**

### **ABSTRACT**

This study modifies a Car Speed Limiting Device (CSLD) based on a pre-existing design with a view to avoiding car over speeding and reduce possible accident on highway. The speed limiter was modified by incorporating a carrier chip into the device using an Arduino Nano to coordinate the activities of the carrier chip and the speed limiter. The function of the carrier chip is to send and receive notification message from owner's phone number. The components were connected in between the two wires of the car fuel line using existing design. Two different cars were used and tested on a highway. The result obtained for the two vehicles showed different responses. When the speed of the car exceeds the designed speed limit of the device, it was transmitted by the speed limiting device, the speed governor came into action and restricted the car from going beyond the pre-set speed by actuating the relay to reduce the current flowing through the fuel line and reduced the rate of flow of fuel into the combustion chamber which reduces the power output of the engine. The speed limiter became active. Warning signal in the form of alarm was activated, and the receiver sends a message to the owner through the carrier chip. The study concluded that the modified speed governor design is better, safer and remotely controlled compared to the existing design.

Keywords: Car, Speed Limiter, Carrier chip, Relay, Speed.

### **INTRODUCTION**

Road accidents have become something normal due to its consistent happening and ubiquitousness. Even in our present world, we believe any mechanical device could fail or show sign of misbehaviour, especially if not properly manage. Every minute someone is killed or seriously injured on the major roads because of terrible accidents (Ahmed et al., 2015). A report by the International Road Federation (IRF) shows that about 2.4 million people have died in road accidents across the world with over 1.3 million road death every year and daily record of 3, 000 deaths (IRFAR, 2012). This is a worldwide pestilence practically identical to

Malaria or Tuberculosis, which go after the youthful, poor people and the defenceless (Varshith, 2011). The primary explanation behind these mischances is the fast and careless driving of motorist. The World Health Organisation raised an alarm on this figure and believes that it may increase to 1.9 million if deliberate and solid action is not taken (Tribune, 2009). Safety has become principal focus of government agencies and private organizations concerned with transportation. In Nigeria, the Federal Road Safety Commission (FRSC) is the government agency with statutory responsibilities for road safety administration. Nigeria is the most populous country in Africa with a total land area of 910,771 km<sup>2</sup> and human population of about 167 million and a high number of vehicles estimated at over 7.6 million, with a total length of about 194, 000 km, the country has suffered severe loss of manpower and economy to fatal car accidents (Sumaila, 2013). Undoubtedly, this population create immense pressure that contributes to the high road traffic accidents in the country (FRSC, 2012).

The factors that induces fatal car accidents in Nigeria have been classified into human, mechanical and environmental factors. Human factor accounts for up to 90 % of accidents while the mechanical and environmental factors sum-up to 10 % (Assum, 1998). Human factors include visual acuteness, driver fatigue, poor knowledge of road signs and regulations, illiteracy, health problems, excessive speeding, drug abuse and over-confidence while on the steering. Mechanical factors include poor vehicle maintenance, tyre blowouts, poor lights, and broken-down vehicles on the road without adequate warning. The environmental factors are summed up into heavy rainfall, harmattan, sun reflection, heavy wind, pot holes and un-tarred roads. These factors have independently and/or collective contributed to the high prevalence rate of fatal car accidents in Nigeria (Ukoji, 2017). With the deadly crashes encountered everywhere throughout the world, vehicle safety has been set up to check them. One of the approaches to lessen such vehicle crashes is to avoid over speeding in streets and expressways. Vehicle safety is a basic issue in the car business and there are two existing sorts of vehicle security frameworks: dynamic wellbeing and detached wellbeing frameworks (Ogasawara and Ueno, 1995). Dynamic security keeps accidents from happening and detached frameworks are worked in the auto to ensure the tenants or clients after the mishap has happened. Dynamic security frameworks contribute considerably to lessening of extreme wounds and fatalities in rush hour gridlock and as the level of dynamic wellbeing innovation in vehicles is expanded, the quantities of mischances diminish. Vehicle speed sensor is a standout amongst the most critical gadgets in the dynamic security framework (Fleming, 2001). It is a gadget in vehicles that restricts the speed of a vehicle. Vehicle devices today assume a key part in the ergonomics



and safety highlights. The appearance of electronically controlled actuators has added to development of vehicle sensors (Ogasawara and Ueno, 1995). A portion of the devices set up to control inordinate speeding incorporate Intelligent Speed Adaptation (ISA) devices (Fleming, 2001) and the speed governors. The ISA gadget screens the speed of the vehicle. The ISA devices are actualized utilizing worldwide situating system collectors, radio recurrence beneficiaries or optical acknowledgment system which requires extensive infrastructural venture.

A few vehicle speed sensor systems have been created for use inside the vehicle for speed checking and control purposes. Customary vehicle speed sensor presently being used incorporate Variable Reluctance (VR) sensor. The yield of VR sensor is a simple flag whose frequency and amplitude are corresponding to vehicle speed. Another issue with the current electronic vehicle speed governors is that fuel supply to the motor is all of a sudden cut when vehicle top speed is accomplished due to the on/off control strategy which results to vehicle jerking. The automobile is likewise one of the primary methods for transportation, and individuals make broad utilization of it for the duration of their lives. This reason, among others, justifies the need of use of the advances in sensors, instrumentation and control in vehicles with the goal of enhancing road safety. The problem of automotive speed limiter/governor was considered by many investigators and researchers. Most research work concentrated on the impact of the speed limitation on the reduction of accidents and casualties (Han et al., 2005). Few articles are available that concern the technical aspect of the speed limiting system. Some of the articles or publications handled the technical perspectives of the automotive speed governor system in the recent years. Croitoru et al., (2014) introduced an order of speed limiting device demonstrating the advantages and disadvantages each type. He found that appropriately design ISA can be exceedingly successful in urging drivers to obey speed limits and ought to be supported by governments. Pérez et al., (2010) exhibited another Infrastructure to Vehicles communication and control system for intelligent speed control, which depends on Radio Frequency Identification (RFID) technology for identification of traffic signals on the road. Their outcomes recommended that an automatic intelligent control system can be used to keep any sudden activity conditions and enhance the safety of the occupants of the vehicle.

Burje et al., (2012) presented a design to control the speed of the automobiles at remote places for fixed time. Their proposed model used a microcontroller unit that gets the pedal position

and after that exchanges appropriate signal to the Electronic Control Unit (ECU) that thus controls the cars' throttle position. They expressed that their theoretical study needs further extension to more than one vehicle. The objectives of this work is to modify a speed governor by adding a speed notifier and SMS controller into it and evaluate a prototype of the device through experiments.

## **TYPES OF ROAD SPEED LIMITER**

Based on the Functionality (Ahmed et al., 2015)

### **(1) Top-speed limiting**

It prevents the vehicle from exceeding a set speed. Most modern vehicle engine-management systems have a top speed setting but it is usually well in-excess of maximum national speed limits and could not be regarded as a safety device.

### **(2) Speed alarm and speed limit set by the driver**

It alerts the driver if a selected speed is exceeded. Some vehicles have this feature. It also prevents the vehicle from going beyond the pre-set speed, except for temporary over-ride situations. These are also known as "Adjustable Speed Limitation Function (ASLF)".

### **(3) Intelligent speed alarm and speed limiter**

The system "knows" through an application like google map, the speed limit of the section of road and direction of travel and alerts the driver if that speed is exceeded by an audible alarm, a visual signal or a vibrating throttle pedal or a combination of these. It also prevents the vehicle from being accelerated beyond this speed.

## **2.2 Based on the Control Technique (Ahmed et al., 2015).**

(1) **Throttle Control:** The throttle control is a type of technique used in limiting the speed of a vehicle through throttle body of the engine. A throttle body is the intake system component in fuel-injected engines that the drivers controls with the accelerator. The throttle regulates or limits the amount of air that enters the combustion chamber with the fuel delivered from the injector.

(2) **Direct Fuel Control:** The direct fuel control is the most type technique used to regulate the speed of a vehicle. Also, the fuel control is the most effective of all types. In this type of method, the fuel is the source of control. The speed is limited by reducing the amount of fuel that is released into the combustion chamber for combustion.

**(3) Electronic Speed Governor:** In this type, electric signal is utilized by using a magnetic pick up sensor. The magnetic pick up sensor is installed alongside a drive shaft gear made of material that responds to a magnetic field. As each gearing tooth passes the sensor, the gear interrupts the sensors magnetic field. This, thus, creates an Alternating Current signal, which compares to the speed of the shaft. The signal is sent to the electronic control module to build up the measure of fuel that ought to be infused to the combustion chamber of the engine.

### 2.3 Basic Vehicle speed measurement System

The basic measurement system consists mainly of three blocks: Sensing element, Signal conditioning element and signal processing element. An electronic speed limiter/governor contains three key components in particular the vehicle speed sensor, Electronic Control Unit (ECU) and a fuel flow control valve. The speed sensor creates electronic pulses in relation to the vehicle speed and transmits the same to the ECU. In this examination, the sensing component convert the non-electrical signal (mechanical rotational motion) into electrical signal (voltage pulses). The reason for the signal conditioning component is to convert the variety of electrical signal into a voltage level suitable for additionally preparing. This is accomplished using amplifier circuit and digital logic circuit. The following stage is the signal condition component which is a microcontroller which takes the output of the signal conditioning component and convert it into a shape appropriate for presentation and different uses (display, recording and feedback control). Based on the installed algorithm, the electronic control unit processes the speed of the vehicle also, persistently monitors the same. At whatever point the vehicle accomplishes the most extreme set speed, the electronic control unit enacts the actuator which directs the fuel stream and henceforth the vehicle speed is constrained.

## **METHODOLOGY**

Materials used are speed limiting device, relay, connecting cables, GPS antenna while tools used are cutting plier, testing lamp, razor blade and black tape

### **Description of Major Components**

**Speed Limiting Device:** Speed limiter is an Electronic / Electro-Mechanical device fitted on a vehicle with the purpose of regulating the maximum speed of a vehicle to a set limit. A Speed Limiter is shown in Figure 1. Table 1 shows the speed limit for vehicles in Nigeria (Nigeria Highway Code, 2015-2019). The speed limiter used in this work was pre-set to 95km/h and

programmed with the receiver phone number. Speed Limiters are of different types based on the vehicle category on which it is used. The two most important types are the Drive by Wire System (RDPS) and the Fuel Type System. The Fuel type system was used in this project. The speed limiter was built to have a port for the GPS antenna and the GSM antenna for receive signal. It also has another cable port for the connection of the wire that would be connected to the vehicle system.

**Table 1 Speed Limits for Vehicles in km/hr**

<b>Types of Vehicles</b>	<b>Build-up</b>	<b>High way</b>	<b>Express -way</b>
Motorcycles	50	50	-
Private Cars	50	80	100
Taxis & Buses	50	80	90
Tankers & Trailers	45	50	60
Two Vehicle (While Towing)	45	45	45
Two Vehicle (not Towing)	50	60	70



**Fig. 1 Speed limiter**

**Connection Cables:** The connection cables were used to connect the speed limiter to the relay and to the vehicle. The connection cable had different cables with different colours on it, namely: blue, white, black, red, brown and yellow. The connection cables are as shown in Figure 2.



**Figure 2: Connection Cables**

**Relay:** Relay is a switch that opens and closes circuit electromechanically or electronically. The relay used controls one electrical circuit by opening and closing contact in another circuit. The relay came with four (4) wires, two (2) thick green wires, a red wire and black wire. The Relay is shown in Figure 3.



**Figure 3: Relay**

**GPS Antenna:** The Global Positioning System is a worldwide radio-navigation system formed from a constellation of 24 satellites that continuously orbit the earth. All GPS receivers use an antenna to receive these signals. The GPS Antenna is shown in Figure 4.



**Figure 4: GPS Antenna**

**GSM Antenna:** is an antenna to receive GSM signal to the device. It is as shown in Figure 5.



**Figure 5: GSM Antenna**

The specification of cars used in this research are shown in Table 2 and 3. First thing done was to identify the fuel line cable (yellow cable with green stripes) using a Tester which is a device used to test for the flow of current in a wire or circuit. The fuel line cable was cut into two, making the wires one carrying current from the source and the other without any current in it. The divided wires were then connected to the relay. Connection of the relay to the fuel line was carried out by connecting the two thick green wires from the relay to the two ends of the fuel line cables. One of the thick green cables was connected to the fuel line cable from the power source and the other green cable to the second wire of the fuel line. The black wire from the relay to the black wire of the connection cable were joined together because the black wire is the grand wire. Both black wires were connected to any other grand in the vehicle. The red wire from the relay was connected to the brown cable from the connection cable. At the end the connection cable is plugged into the speed limiter. The red and white wire from the connection cable is connected to the thick green cable of the relay (the current source). The GPS and GSM antennas were connected to the speed limiter.

**Table 2: Engine Specification (HONDA ACCORD, 2003)**

Fuel tank capacity	17.1 Gal
EPA mileage estimates	26 city/ 34 Highway
Base engine size	2.4 litres
Base engine type	I-4
Horsepower	160 Hp
Horsepower rpm	5,500
Torque	161 Lb.Ft
Torque rpm	4,500
Maximum Towing capacity	1,000Lbs
Drive type	Front wheel

\*EPA- Environmental Protection Agency

**Table 3: Engine Specification (TOYOTA COROLLA, 2009)**

Fuel tank capacity	17.1 Gal
EPA mileage estimates	26 city/ 34 Highway
Base engine size	1.8 Litres
Base engine type	I-4
Horse power	132 Hp
Horsepower rpm	6,000
Torque	128Lb-Ft
Torque rpm	4,400
Maximum Towing capacity	950Lbs
Drive type	Front wheel

\*EPA- Environmental Protection Agency

## RESULT AND DISCUSSION

### Honda Accord and Toyota Corolla Response

Table 4 and Table 5 show the interrelation between the car speed, engine speed, speed limiter, alarm and the receiver for Honda Accord and Toyota Corolla, respectively. They basically show the response of each component as the car speed changes. The engine speed in the case of Toyota Corolla was quite different from Honda Accord due to some factors like engine capacity, vehicle weight, and material selection.

**Table 4: Interrelation between car speed and components for Honda Accord**

Car Speed (km/h)	Engine Speed (Rev/min)	Speed Limiter	Alarm	Receiver
0	1000	On (NA)	No	No
20	1100	On (NA)	No	No
40	1500	On (NA)	No	No
60	2000	On (NA)	No	No
80	2500	On (NA)	No	No

95      3000      On (NA)    Yes      Yes (Msg)

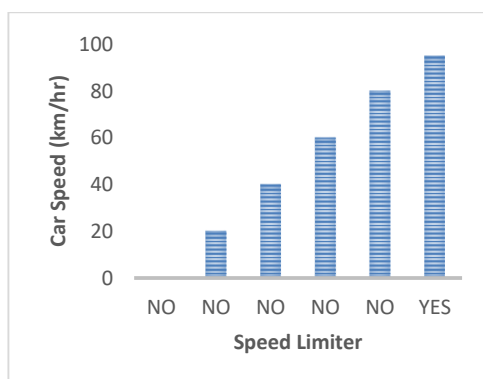
- NA-Not Active, Msg- Message

**Table 5: Interrelation between car speed and components for Toyota Corolla**

Car Speed (km/h)	Engine (Rv/min)	Speed Limiter	Alarm	Receiver
0	1100	On (NA)	No	No
20	1300	On (NA)	No	No
40	1500	On (NA)	No	No
60	2100	On (NA)	No	No
80	2400	On (NA)	No	No
95	2800	On (NA)	Yes	Yes (Msg)

\*NA-Not Active, Msg- Message

The two vehicles showed similar response to the speed limiter, alarm and receiver. Figure 6 shows the histogram of car speed against speed limiter for Honda Accord and Toyota Corolla.



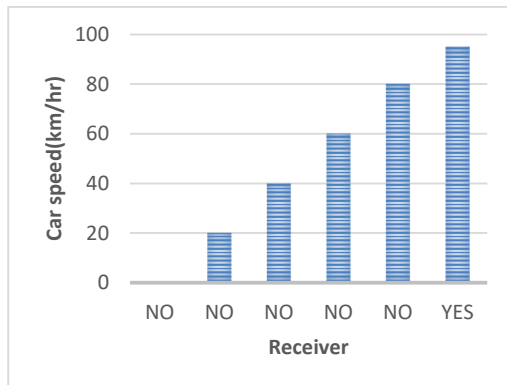
**Figure 6: Histogram of Car Speed against Speed Limiter for Honda Accord and Toyota Corolla.**

At 0 km/h, the engine was idle. There was no load on the engine yet. Speed limiter was on but was not active. Because the speed has not been accomplished at which it will be active. At 20 km/h, Engines of the two vehicles started running at speed higher than 0 km/h because load has been applied to it (Transmission was on drive). At 20 km/h, the speed limiter was on but was not active. Tracker was able to get signal and vehicles were able to be tracked at this speed.

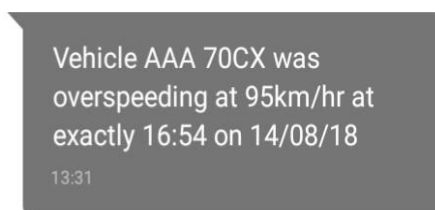


At 40 km/h, vehicle was moving at the constant speed while the speed limiter was not active but on. Tracker from the speed limiter was on and was able to track vehicle at that speed. At 60 km/h, no activity from the speed limiter aside the tracker been able to locate the exact location of vehicle at that point. At 80 km/hr, vehicle approaches maximum speed limit and speed limiter still not responsive while it is on. At 95 km/h, Engine of each car running at higher speeds, the speed limiter became active immediately it sensed the pre-set speed, reduced the current in the flow line circuit leading to reduction in the flow rate of the fuel being supplied to the combustion chamber making the mixture a lean mixture and limits the speed of the vehicle at 95 km/h. The tracker was able to track the vehicles location as well. When trying to exceed the pre-set car speed, the car refuses to exceed the speed because of the shortage in current of the flow line.

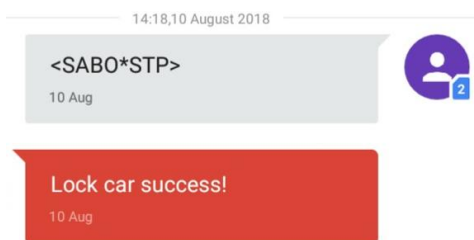
Figure 7 shows the effect of car speed on the receiver for the two vehicles. As the speed of the car increases and approaches the maximum speed pre-set already in the speed limiter, the receiver responded variably. At 0 km/h when the vehicle is idle, the receiver is on but not responsive at 0 km/hr. At 20 km/h, the engine was under load and vehicle was moving and yet the receiver is still not responded. At 40 km/h, the vehicle was still being driven and no output from the receiver from the speed limiter. At 60 km/h, receiver was on but no output from it. At 80 km/h, the vehicle was approaching the maximum speed limit and receiver was yet to respond to the speed at which the vehicle was been driven at. At 95 km/h, receiver is fully functional and responsive. The speed limiter stored the data to its history and when the network was restored, the speed limiter sent the message through the carrier component to the owner's phone as a text message as shown in Figure 8 and at that time the message was seen from the owner's phone. The vehicle was shut down by sending a code "<SABO\*STP>" and a confirmation message saying "lock car successful" was received as shown in Figure 9, then vehicle shut down immediately. The vehicle started again as the owner restores the vehicle by sending "<SABO\*RES>" and the owner (person sending the message receives a message too saying "unlocked successfully" as shown in Figure 10, then the vehicle will start again.



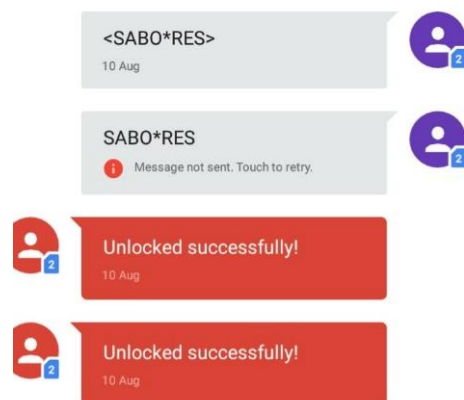
**Figure 7: Histogram of Car Speed against Receiver for Honda Accord and Toyota Corolla.**



**Figure 8: Message from the Receiver**

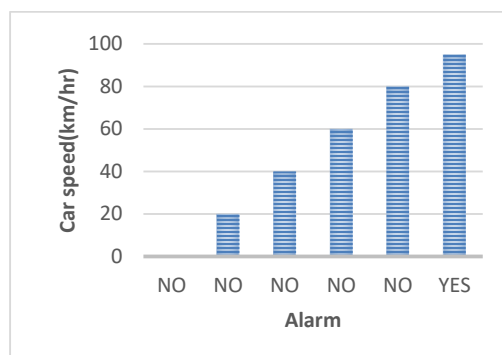


**Figure 9: Message from the Speed Limiter after Sending the STOP Code**



**Figure 10: Message gotten after sending restore code**

Figure 11 shows the response of the alarm at different car speed for the two vehicles. The alarm is the sound notifier that alerts the driver when the vehicle approaches or reaches the maximum pre-set speed on the speed limiter. At 0 km/h, car was on and running but alarm wasn't ringing. At 20 km/h, vehicle was moving and alarm wasn't responsive. At 40 km/h, still running the car and the speed limiter was still not responsive. At 60 km/h, vehicle was still working and running but the alarm was not working. At 80 km/h, vehicle approached maximum speed and the alarm was yet to respond. The alarm started working when speed exceeded 80 km/h and above. The sound became more pronounced when the speed got closer to the maximum speed. At 95 km/h, the car was at its maximum speed and the alarm was beeping continuously till the speed drops below the pre-set speed. When the speed drops below the maximum speed, the alarm reduced gradually. Between the speeds of 0-80 km/h, the alarm is inactive.



**Figure 11: Histogram of car speed against alarm for Honda Accord and Toyota Corolla**

## CONCLUSION

This project has improved an existing speed limiting system by adding a notifier and SMS controller. The prototype programmed to limit speed at Federal Road Safety maximum speed at highway to be 95 km/h was able to limit vehicle speed at its maximum speed (95 km/h). The transmitted alarm sounds when the vehicle approaches 95 km/hr and the receiver also gives or sends a text message when the car gets to its maximum speed, alerting the owner the speed activity of the vehicle. The relay, showed that once the speed drops below 95 km/h the engine picks up again. The improvement basically provided an economic solution to deadly car crashes, save vehicle fuel consumption and also monitor the activities of the driver. The project was focused more on limiting the speed of the vehicle and informing the owner about vehicle over-speeding activities. The project can further be improved by considering the system with google map road speed limits to know areas with their speed limits.

## **REFERENCE**

- Ahmed, F. A., Talal S. M., 2015. Proposed simple electro-mechanical automotive speed control system, American Journal of Aerospace Engineering, Special Issue: Hands-on Learning Technique for Multidisciplinary Engineering Education, 2, 1-10.
- Assum, T., 1998. Road safety in Africa: An appraisal of road safety initiatives in five African countries, In The World Bank and United Nations Economics Commission for Africa, 33(2), THE GLOBAL IMPACT, 67.
- Burje, S. R., Kulkarni, S. A. and Dhande, N. B., 2012. Design and development of microcontroller based electronic speed governor for Genset /Automotive Engine, International Journal of Engineering and Science, vol. 1, pp. 26-33.
- Croitoru, B., Tulbure, A. and Abrudean, M., 2014. Microcontroller- based multiple platform PWM signal generation procedures for industrial use. Automation, Quality and Testing, Robotics, 2014 IEEE International Conference.
- Federal Road Safety Commission (FRSC), 2012. Research Monogram, No. 2, Road Mirror.
- Fleming, W. J., (2001). Overview of automotive sensors, IEEE sensors journal, vol. 1(4), pp. 296-308.
- Han, M, Liang, D. F. and Deng, J., 2005. Sensor development using its unusual properties of Fe/co copper based amorphous soft magnetic wire. Journal of Materials Science, 40(21), pp. 5573-5580.
- International Road Federation Annual Report (IRFAR) on the state of accidents in the world, 2012.
- Nigeria Highway Code, 2015-2019.
- Ogasawara, I. and Ueno, S., 1995. Preparation and properties of amorphous wires, IEEE Transactions on magnetics, 31(2), pp. 1219-1223.
- Sumaila, A. F., 2013. Road crashes trends and safety management in Nigeria, Department of Transport Management Technology, Federal University of Technology, Minna.
- Tribune - Road Safety Nigeria. March 13<sup>th</sup>, 2009.
- Ukoji, V. N., 2017. Trends and patterns of road accidents in Nigeria: (June 2006 – May 2014). Online Article. [www.nsrp-nigeria.org](http://www.nsrp-nigeria.org).
- Varshith, H., and Navale, D. J., 2011. Automobile speed limiter and reliever for automobiles, PES Institute of Technology and Management, Shivamogga, Project No.:37S1003.

## STALL CONTROL ON THE NACA 23012 AIRFOIL VIA SINGLE AND DOUBLE SUCTION

Alonge, O. I.<sup>1\*</sup>, Akinneye, A.O.<sup>1</sup> and Julius, M. O.<sup>2</sup>

<sup>1</sup> Department of Mechanical Engineering, Elizade University, Ilara-Mokin, Ondo State, Nigeria.

<sup>2</sup> Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

\* Email of Corresponding Author: [alongeoluwasanmi@gmail.com](mailto:alongeoluwasanmi@gmail.com)

### ABSTRACT

Flow separation due to adverse pressure gradients is the driving agent for the stalling of wings and consequently aircraft which may lead to disaster. Therefore, this paper focuses on the control of the negative effects of stall on the aerodynamic performance of a NACA 23012 airfoil through the implementation of suction on the upper surface of the airfoil. The suction is carried out at a Reynolds number of  $Re = 6 \times 10^6$ , at angles of attack from  $0^\circ$  to the critical angle. Considering the suction position, and the suction width for a single suction, the capability of suction to control stall is studied. Also, double suction was implemented to determine the effect of multiple slots. The numerical analysis was carried out using the Reynolds Averaged Navier-Stokes equations (RANS) in conjunction with the k-omega (SST) turbulent model. The results from this investigation show that suction is more effective closer to the leading edge by boosting lift by as much as 25% and reducing drag by over 70%. The use of double suction offered no improvements over single suction other than extending the critical angle of attack to  $28^\circ$ .

**Keywords:** flow control, airfoil, suction, boundary layer separation

### NOMENCLATURE

$\alpha$	airfoil angle of attack
$\alpha_{stall}$	stalling angle of attack, coincident with the maximum lift coefficient
$c$	airfoil chord length
$C_\mu$	suction coefficient
$H$	dimensionless jet width
$C_d$	drag coefficient

$C_L$	lift coefficient
AOA	angle of attack
$x/c$	separation position
Re	Reynolds number based on chord surface length along with airfoil profile
$L_j$	suction width
$\Lambda$	suction jet amplitude
$L_p$	suction position
$\rho$	the density of the fluid
N	number of element
$\bar{P}$	the mean pressure
$\nu$	the kinematic viscosity
$u_{jet}$	the suction jet velocity
$u_\infty$	the free stream velocity
$\bar{u}$	the mean velocity
$\overline{u_i u_j}$	the Reynolds stress tensor
$F_1$	the blending function
$S$	the invariant measure of the strain rate
$P_\infty$	mainstream static pressure
$P_c$	local static pressure of the slot
$C_{d,s}$	equivalent suction drag coefficient
$C_{d,baseline}$	drag coefficient without suction
$C_{d,suction}$	drag coefficient with suction

## INTRODUCTION

Stall is a direct consequence of airflow separating from the surface of lift generating bodies such as airfoils (Anderson, 1987). Airflow separates due to the adverse pressure gradients which occur in the boundary layer of airfoils. Stalling reduces the lift force that keeps the airfoil airborne while simultaneously increasing the drag force that slows the airfoil, which decreases the lift even more (White, 2011). The balance of pressure forces acting on the rear and front surfaces of the airfoil is crucial to the onset of flow separation as an imbalance would cause flow separation (Anderson, 2011). The combination of the adverse pressure gradient and skin friction forces at high angles of attack give rise to poor aerodynamic performance of aircrafts and drones alike. There have been various investigations which have been carried out in the past with regards to how separation of airflow can be controlled. Loftin and Smith (1948) experimentally studied the aerodynamic characteristics of NACA 23012 wing under various aerodynamic conditions with trailing edge flaps and at varying Reynolds numbers from

$7 \times 10^5$  to  $6 \times 10^6$ . They concluded that NACA 23012 has very good aerodynamic characteristics. Zha et al., (2007) developed novel control methods which involve the use of a co-flow jet (CFJ) on the top surface of the airfoil. The co-flow jet consists of an injection slot where high velocity air is fed to supplement the external air and increase the overall kinetic energy of the flow on the airfoil top surface. A suction slot is also present at the trailing edge which sucks the air in. The results from this setup show enhanced lift and increased stall margin. The CFJ differs from other circulation techniques which rely on larger leading or trailing edges to utilize the Coanda effect and enhance circulation. Kirk (2009) used both experimental and computational methods to evaluate a NACA 6415 airfoil. Analysis was carried out on the enhanced model of the airfoil which possessed injection and suction slots on the top surface of the airfoil. The results of the wind-tunnel experimentation and the computational simulation showed an improvement in the aerodynamic performance of the airfoil when the suction and injection was employed. Azim et al., (2015) carried out numerical analysis on the NACA 4412 airfoil to determine its aerodynamic characteristics and aimed to delay flow separation via suction alone. The suction slot with a width of 2% of the chord was moved across the length of the chord to find the best position to achieve the best results. It was observed that suction at the 0.68 c position for a constant AoA=120° and M=0.6, moves the separation position to 0.96c of the airfoil. Also, suction with 65kPa makes lift to drag ratio 35% higher than that of suction at 80kPa. Yousefi et al., (2014) carried out CFD analysis to determine the effects of jet width on blowing and suction flow control for a NACA 0012 airfoil. Tangential and perpendicular blowing methods were employed via suction slots which varied from 1.5 % to 4% of the chord length with the jet velocity at the slots set at half of the free stream velocity. By employing the suction control flow technique, the lift coefficient increased by approximately 75% and the drag coefficient decreased by 56%. The most effective jet widths for achieving all desirable effects are 2.5% to 3% of the chord length for suction at the airfoil leading edge. Huang *et al.*, 2004 numerically investigated blowing and suction on the NACA 0012 airfoil, with a jet width of 0.025c. The physical mechanisms that govern suction and blowing flow control were determined and analyzed, and the critical values of suction and blowing locations, amplitudes, and angles were discussed. They concluded that suction created a larger and lower pressure zone than blowing and was more effective at the leading edge and that blowing was very effective further downstream of the airfoil surface. Chen et al., (2014) experimentally worked on the suppression of vortex shedding on a circular cylinder via the suction flow control method. They concluded that the suction control method excellently

suppressed the alternative vortex shedding from the circular cylinder model and the fluctuations of the lift coefficients and drag coefficients of the cylinder model were reduced intensely. Carnarius et al., (2004) numerically investigated the steady flow field around a NACA 4412 at Reynolds number =  $10^6$ . They concluded that separation was successfully controlled by steady suction upstream of the separation and when the suction angle was varied from  $\beta = 20^\circ$  to  $\beta = 160^\circ$ , it was found that suction perpendicular to the slot surface was optimal. Atik and Walker (2005) worked on a series of numerical simulations to explore the effect of suction and suction/blowing as control mechanisms of leading-edge separation at high Reynolds number. They revealed that a single suction control has better suppression effects than the blow/suction control. The investigations have shown that suction located at an appropriate position modifies pressure distribution over an airfoil surface as such produce a satisfactory effect on lift and drag coefficients, hence mitigating the streamwise momentum loss in the growth of the separation thickness. In the current study, the effects of main parameters of suction control, such as suction location, coefficient, and slot size, on flow separation and aerodynamic performance of a NACA23012 aerofoil is numerically analysed at Reynolds number  $6 \times 10^6$ .

## **METHODOLOGY**

The geometry of a NACA 23012 aerofoil, suction jet location, suction jet angle and the jet length are shown in Figure 1. The chord length of the aerofoil was  $1m$ ; the suction jet length for this investigation was 2% of the chord length (Yousefi, 2014) and the suction jet amplitude ( $\Lambda$ ) which is the ratio of the suction jet velocity to free stream velocity) was 0.5. The fluid was modelled as a two dimensional, steady, turbulent and viscous incompressible flow with constant temperature and ambient pressure. The equations which govern the motion of fluids are the Navier-Stokes equations.

$$\frac{\partial \bar{u}_i}{\partial x_i} = 0 \quad (1)$$

$$\frac{\partial (\bar{u}_i \bar{u}_j)}{\partial x_j} = -\frac{1}{\rho} \frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j} \left[ \nu \frac{\partial \bar{u}_i}{\partial x_j} - \bar{u}_i \bar{u}_j \right] \quad (2)$$

where  $\bar{u}_i \bar{u}_j$  is the Reynolds stress tensor that incorporates the effects of turbulence (Alfonsi, 2009).



Turbulence models are mathematical equations which predict turbulence and its accompanying effects in fluid flows. Due to the closure problem presented by the fluctuations of velocity in the RANS Equations, turbulence models are needed to close the equations and only obtain mean values of velocity and pressure (Alfonsi, 2009). The turbulence model used in this project is the Menter  $k - \omega$  two-equation model which incorporates Shear stress transport modelling. This turbulence model is excellent in its ability to predict flow separation; a critical characteristic necessary for the sake of accuracy in this project. The model has the ability to switch between the  $k - \varepsilon$  and  $k - \omega$  models when considering the flow away from the surface to the boundary layer (Menter, 1994). The equations are expressed as;

$$\frac{\partial}{\partial x_i} (\rho U_i k) = \widetilde{P}_k - \beta^* \rho k \omega + \frac{\partial}{\partial x_i} \left[ (\mu + \sigma_k \mu_t) \frac{\partial k}{\partial x_i} \right] \quad (3)$$

$$\frac{\partial}{\partial x_i} (\rho U_i \omega) = \alpha \rho S^2 - \beta \rho \omega^2 + \frac{\partial}{\partial x_i} \left[ (\mu + \sigma_\omega \mu_t) \frac{\partial \omega}{\partial x_i} \right] + 2(1 - F_1) \rho \sigma_{\omega 2} \frac{1}{\omega} \frac{\partial k}{\partial x_i} \frac{\partial \omega}{\partial x_i} \quad (4)$$

where  $\beta^*$  is 0.09 and  $\sigma_{\omega 2}$  is 0.856.  $\widetilde{P}_k$ , a production limiter, was used in the SST model to prevent the build-up of turbulence in the stagnation regions (Menter, 1992 and Menter, 2003). This research was carried out using ANSYS FLUENT. Values for the Reynolds number and the free stream velocity were  $6 \times 10^6$  and 85.242 m/s respectively. The second-order upwind scheme was employed to discretize the governing equations. In the simulations, second-order upwind discretization in space was used and then, the resulting system of equations was solved through Semi-Implicit Method For Pressure Linked Equations (SIMPLE) procedure until a convergence criterion of reduction in all dependent residuals was satisfied (Kirk, 2009). A C-type structured grid was generated as a computational domain as shown in Figure 2. The computational area was large enough to ensure that there were no interactions between the flow close to and around the airfoil and the outer domains. The total length of the flow domain was set at 10 chord lengths (10c) and the diameter of the flow domain front arc was 10 chord lengths as well. The arc, upper, and lower boundaries of the flow domain were set as an inlet and prescribed a uniform velocity boundary condition of 85.242 m/s. The back of the flow domain was prescribed as an outlet boundary condition with constant atmospheric pressure of 101.325 kPa. No slip boundary condition was used on the airfoil surface. A low free-stream turbulence intensity of 0.01% was used to match the characteristics of a wind tunnel with finely straightened air flow or typical external airflow where the air is initially still and the mesh of  $y^+ < 1$  around the airfoil/ wing was ensured to ensure the viscous effects around the boundary

layer were properly captured by the simulation and for the turbulence model to work effectively.

The computations of variable density meshes were performed for the NACA 23012 aerofoil at Reynolds number  $1 \times 10^6$  to ensure mesh independence test to the calculated results through the analysis of the lift and drag coefficients at angle of attacks of  $4^\circ$ , and  $14^\circ$  for a baseline airflow over the airfoil without the use of suction on the aerofoil surface as shown in Table 1. From Table 1, the mesh size with the fine mesh following a grid independent result that produces a reasonable accuracy was selected to be 111,560 cells where lift and drag ceased to have significant change as the number of elements increased. For the validation of the data, the residuals in all simulations were continuing until the lift and drag coefficients converged. The lift and drag coefficient were studied and compared with the experimental values of Loftin and Smith (1945), the variation in values between the experimental and CFD results can be attributed to factors such as choice of Turbulent model, the airfoil geometry (particularly the asperities present in physical models) and the sensitivity or calibration of the equipment used for the experiments. The suction jet location ( $L_j$ ) was investigated for optimum performance of the NACA 23012 wing, once the best position for suction was determined; a second slot was placed with the same jet width of  $0.02c$  and a spacing of  $0.01c$  to test the effects of multiple suction slots on airfoil performance. The suction spacing was chosen so as to not only minimize interaction between the two slots but also ensure the slots were not placed too far apart and could not be considered as being in the same position which gave the best results from the single suction simulations. Since stall occurs on NACA 23012 at around  $18^\circ$  AOA, and flow separation begins around  $10^\circ$ , the single slot investigations were carried out between  $0^\circ - 18^\circ$  angles of attack. The jet entrance velocity components are defined using Eq. 5 and 6:

$$u_j = V_\infty \Lambda \cos(\beta + \theta) \quad (5)$$

$$v_j = V_\infty \Lambda \sin(\beta + \theta) \quad (6)$$

$\theta$  represents the angle of flow entrance irrespective of slot position ( $-90$  degrees in the case of suction) and  $\beta$  is the angle between the free-stream velocity direction and the local jet surface

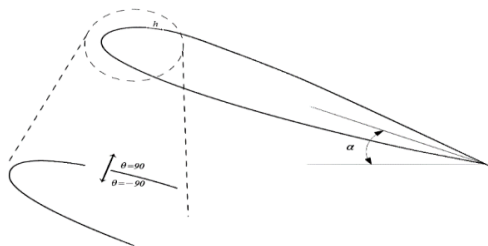


Figure 1: design of the suction mechanism on NACA 23012 with suction parameters.

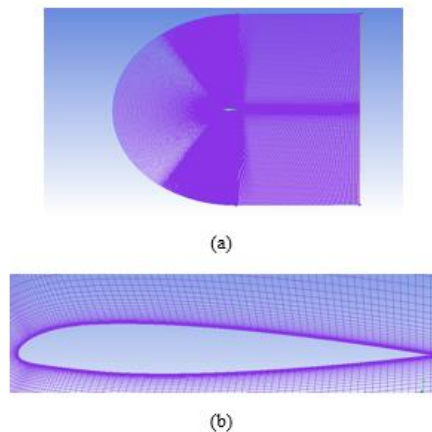


Figure 2: Structured Mesh of a NACA 23012 Aerofoil (a) full view of mesh (b) close-up view of mesh close to airfoil.

Table 1: Mesh Independence Study at Angle of Attack (AOA) of  $4^{\circ}$  and  $14^{\circ}$

No. of cells	$4^{\circ}$ AOA		$14^{\circ}$ AOA	
	$C_L$	$C_D$	$C_L$	$C_D$
20,960	0.54320	0.0129	1.409	0.034
39,860	0.54176848	0.012873387	1.4164643	0.033025406
59,760	0.54147471	0.012845724	1.4164998	0.032525105
83,660	0.53850916	0.012789595	1.4075339	0.032657886
111,560	0.53845817	0.012813948	1.4187399	0.032496861
143,460	0.53843519	0.012840244	1.4177279	0.032590479

## RESULTS AND DISCUSSIONS

### Flow characteristics without suction

The suction amplitude is used to quantify the energy control consumption as expressed in Equation 9.

$$C_{\mu} = \frac{\rho \times h \times u_j^2}{\rho \times C \times u_{\infty}^2} = \frac{h}{c} \times \frac{u_j^2}{u_{\infty}^2} \quad (7)$$

$$H = \frac{h}{c} \quad (8)$$

$$C_{\mu} = H \times \Lambda^2 \quad (9)$$

The mesh structure of the suction slot is shown in Figure 3. The first slot was located at 0.05c and moved further downstream to 0.50c and 0.95c. The redesigned airfoil makes use of suction to create a low pressure (relative to the ambient pressure) environment. This causes the air to flow towards the low-pressure region in an attempt to balance the pressure. Ultimately, the suction induced high kinetic energy into the boundary layer flow.

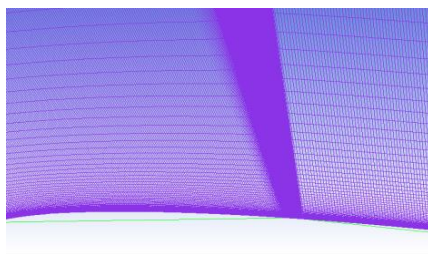


Figure 3: Dense meshes around the suction slot

Figure 4 shows the Comparison between lift coefficient of present work and experimental work by Lofin and Smith (1949) while Figure 5 illustrates the changes in the velocity distribution over the airfoil as it increases its angle of attack. At 6 deg., the flow separation is minimal, as the angle of attack increases, the lift equally increases and the flow separation begins to move further upstream of the airfoil, hence the progressively increased deep blue regions of low velocity going from Figure 5 (a-d). In Figure 5(d) the flow has completely separated from the

airfoil and the lift begins to drop. This is the critical angle of attack of the airfoil, and is the angle wherein the airfoil generates maximum lift. Also, the drag increases as the angle of attack increases due to the increase in pressure drag brought about by flow separation.

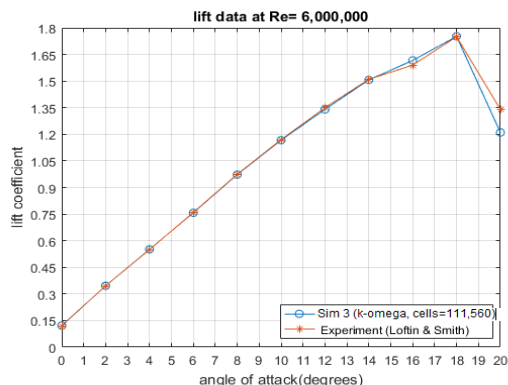


Figure 4: Comparison between lift coefficient of present numerical work, and experimental results by Loftin and Smith.

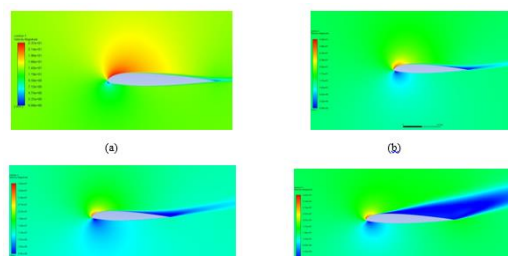


Figure 5: Velocity distribution around the airfoil for single suction at angle of attack (a) 6° (b) 12° (c) 15° (d) 18

#### Stall Control using Single Suction

The control of the stall of the NACA 23012 airfoil through suction is dependent on the optimised suction parameter used. The suction width is taken as 0.02c and the slots were placed in three locations on the airfoil top surface at 0.05c, 0.50c and 0.95c. Figure 6 shows the velocity contours ranging from no suction to the suction occurring at various positions on the airfoil upper surface at  $Re = 6 \times 10^6$  and  $\alpha = 16^\circ$ . The flow separation is controlled as the thickness of the high pressure (very low velocity) region representing separation region are smaller, for the suction at 0.05 and 0.50c, however at 0.95c the suction is not effective and produces a similar velocity profile about the airfoil as the case of no suction. Figure 7 and 8 show the variations in drag coefficient and lift coefficient. As the suction slot moves further downstream, the drag coefficient increases. The drag coefficient is the sum of pressure drag

coefficient and friction drag coefficient (Anderson, 1987), here, the pressure drag is dominant. However, the decrease in drag coefficient was due to a large decrease in the pressure drag coefficient gradient. However, as previously observed in Figure 8, the drag experiences an increase for the slot at 0.95c. This can be attributed to the build-up of the skin friction drag as the air travels over the airfoil surface. The maximum lift coefficient  $C_l$  increases with the use of suction as well and the critical angle is extended. Lift coefficient  $C_l$  increases only when the flow separation has been reduced which has occurred in this case via the increase in momentum of the fluid through suction or the greater pressure difference between the upper and lower surfaces brought about by the lower (relative to ambient,  $P_\infty$ ) suction pressure ( $P_s$ ). Although, per angle of attack, the suction at 0.95c produces greater lift it has a lower critical angle of attack and lower maximum lift coefficient than the slots placed further upstream. Fig. 9(a) and (b) shows the variation of lift and drag coefficient with suction and without suction at different angle of attack. For the slot at 0.05c, the use of suction at the leading edge gave better combined lift and drag coefficient results than the slots placed further downstream. The maximum lift coefficient is increased by 25% while the critical angle of attack is  $24^\circ$ . The effects of the suction are more pronounced at angles of attack above  $14^\circ$ . The drag coefficient drastically reduces at higher angles of attack, at an angle of attack of  $20^\circ$ ; the drag is reduced by 72%. While remaining relatively similar to the values of the baseline airfoil at angles of attack below  $10^\circ$ .

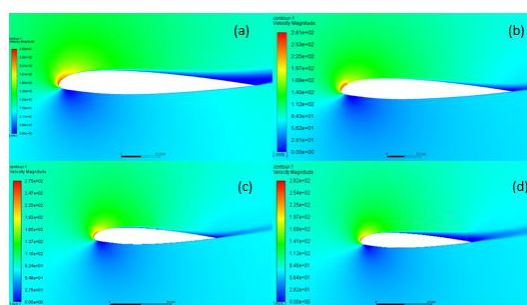


Figure 6: Velocity contours for single suction at AoA =  $16^\circ$  for (a) Baseline (top left) (b) slot at 0.05c (top right) (c) 0.50c (bottom left) (d) 0.95c (bottom right)

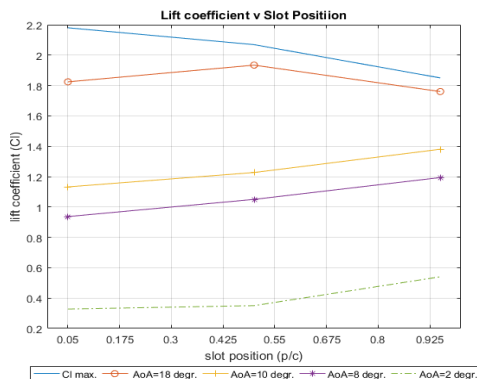


Figure 7: Lift coefficient values for different Angles of attack (AoA) for different slot positions

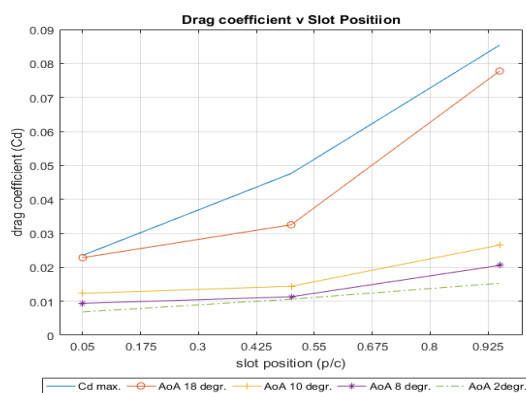
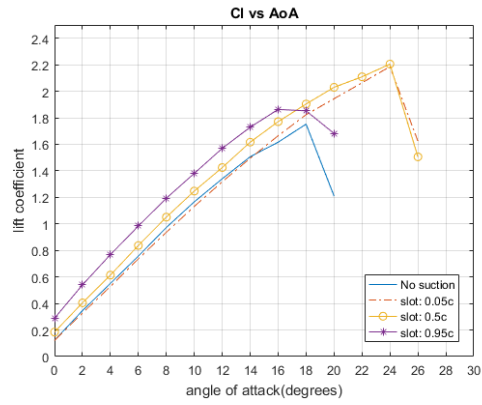


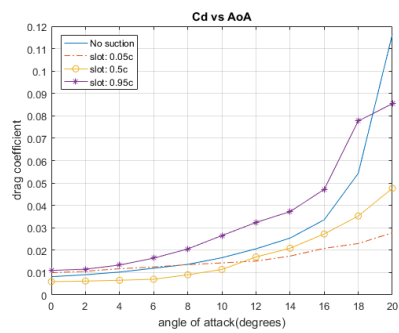
Figure 8: Drag coefficient values for different Angles of attack (AoA) for different slot positions

### Stall control using double Suction

The best position for suction based on the simulations conducted with single suction was at 0.05c. At this position two slots were placed to determine the effect of double slots on flow separation and ultimately airfoil aerodynamic performance. The two slots have a slot width of 0.02c and were separated by a distance of 0.01c. The Suction jet amplitude 0.5 was used and the Reynolds number of the flow was kept at 6,000,000. Figure 10 and 11 show the lift and drag coefficient while Figure 12 (a&b) shows the static pressure and velocity contour at different angle of attack. Figure 13 & 14 show the lift and drag coefficient values for all conditions. The double-slot does not increase the maximum lift coefficient, although it increases the critical stall angle to 28°. The Drag coefficient, although lower in the case of the double-slot, offered no improvements to the single-slot case, rather it produced more drag than a single slot at the same position (0.05c). The double slot produced a fairly similar drag profile to the case of no suction for angles of attack below 10°.



(a)



(b)

Figure 9: Variations of (a) lift coefficient and (b) drag coefficient with angle of attack without and with suction conditions

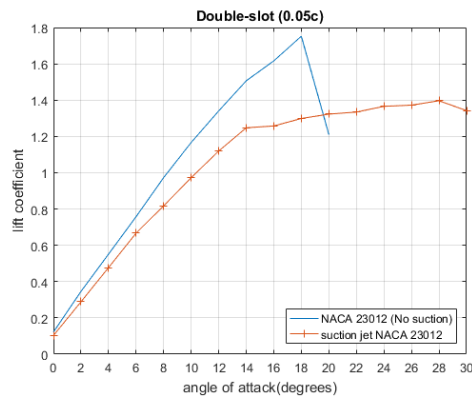


Figure 10: Lift coefficient values for double-slot at 0.05c



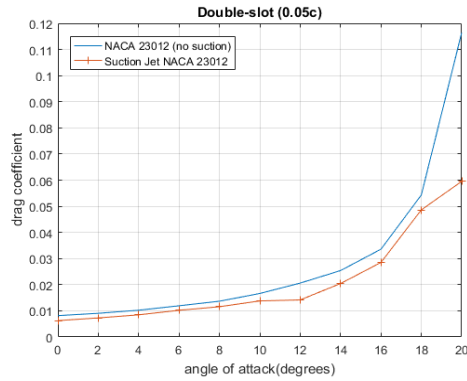


Figure 11: Drag coefficient values for double-slot at 0.05c

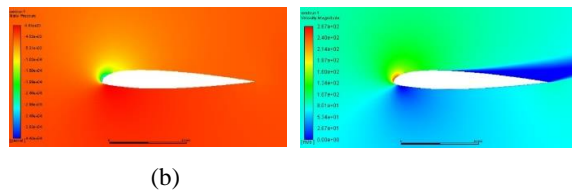


Figure 12: (a) Static pressure and (b) velocity pressure at AoA=16 for double slot

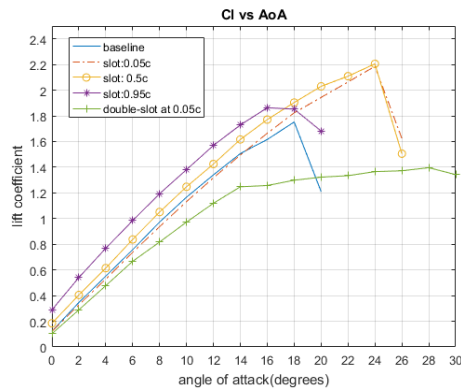


Figure 13: Lift coefficient values for all flow conditions

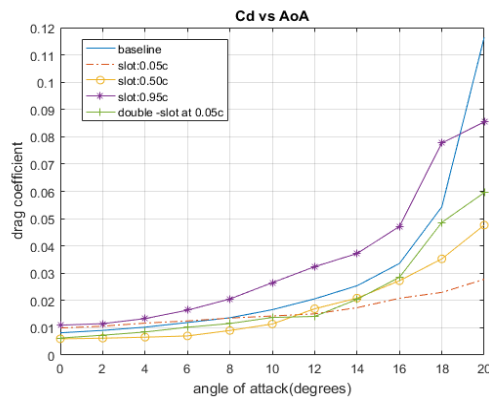


Figure 14: Drag coefficient values for all flow conditions

## **CONCLUSION**

Suction increased the lift on the airfoil and simultaneously reduced the drag on the airfoil by inducing higher energy flow that helped the fluid to traverse the adverse pressure gradients. The suction also created a lower pressure region on the upper surface of the airfoil which created a larger pressure difference necessary for increasing lift. The suction slot close to the leading edge (0.05c) gave the best results, although the suction slots at the downstream slots gave higher lift values per angle of attack. The drag was higher for these downstream slots and for the slot at 0.95c the airfoil stalled at a lower angle of attack than the baseline airfoil. From this investigation, doubling of the suction slot at the best suction position (0.05c) did not reduce flow separation although it extended the critical angle of attack. It however offered no advantages to the single slot suction at that same position.

## **REFERENCES**

- Alfonsi, G., 2009. Reynolds-Averaged Navier–Stokes Equations for Turbulence Modeling, *Journal of Applied Mechanics*, 62, 4, 040802.
- Anderson, J. D., 1987. *Introduction to flight*. McGraw-Hill Education.
- Anderson, J. D., 2011. *Fundamentals of aerodynamics*. McGraw-Hill Education.
- Atik, H., and Walker, D., 2005. Boundary-layer Separation Control Using Local Suction and Injection. In *4th AIAA Theoretical Fluid Mechanics Meeting* , 4937.
- Azim, R., Hasan, M. M., and Ali, M., 2015. Numerical investigation on the delay of boundary layer separation by suction for NACA 4412, *Procedia Engineering*, 105, 329-334.
- Carnarius A, Bert G., Wachsmuth D. F. Tr, and. Reyes J. C. D. L, (2004). Numerical Study of the Optimization of Separation Control, *American Institute of Aeronautics and Astronautics*, pp. 1–17.
- Chen, W., Liu, Y., Xu, F., Li, H., and Hu, H., 2014. Suppression of vortex shedding from a circular cylinder by using a traveling wave wall, In *52nd Aerospace sciences meeting* (p. 0399).
- Huang, L., Huang, P. G., LeBeau, R. P., and Hauser, T., 2004. Numerical study of blowing and suction control mechanism on NACA0012 airfoil, *Journal of aircraft*, 41(5), 1005-1013.
- Kirk, D., 2009. *Experimental and Numerical Investigations of a High Performance Co-Flow Jet Airfoil*, A Masters thesis.

Loftin Jr, L. K., and Smith, H. A., 1945.

Aerodynamic Characteristics of Fifteen NACA Airfoil Sections at Seven Reynolds Numbers from  $0.7 \times 10^6$  to  $9 \times 10^6$ , National Advisory Committee of Aeronautics, Technical Report Note.

Menter, F. R., 1994. Two-equation eddy-viscosity turbulence models for engineering applications, AIAA Journal 32,8, 1598-1605.

Menter, F. R., 1992. Improved Two-Equation Turbulence Models for Aerodynamic Flows,” Moffett Field.

Menter, F., Kuntz, M., and Langtry, R., 2003. Ten Years of Industrial Experience with the SST Turbulence Model, Turbulence Heat and Mass Transfer, 4, 625–632.

White, F. M., 2011. Fluid Mechanics, New-York, MacGraw-Hill.

Yousefi, K., Saleh, R., and Zahedi, P., 2014. Numerical study of blowing and suction slot geometry optimization on NACA 0012 airfoil. Journal of Mechanical Science and Technology, 28(4), 1297-1310.

Zha, G., Gao, W., and Paxton, C. D., 2007. Jet effects on coflow jet airfoil performance. American Institute of Aeronautics and Astronautics Journal, 45(6), 1222-1231.

## **BUS STOPS CHARACTERISTICS IN SELECTED LOCAL GOVERNMENT AREAS IN IBADAN METROPOLIS**

Akintayo, F. O.<sup>1\*</sup>, Adibeli, S. A.<sup>1</sup>, Oyewale, P. K.<sup>1</sup> and Olawuyi, O. A.<sup>2</sup>

<sup>1</sup>Department of Civil Engineering, University of Ibadan, Nigeria

<sup>2</sup> Department of Civil Engineering, Osun State University, Osogbo, Nigeria

\*Email of Corresponding Author: fo.akintayo@ui.edu.ng

### **ABSTRACT**

Bus stops are essential elements of sustainable public transport system. Efficient and effective operation of on-street bus stops facilitates free flow of traffic and promotes social-economic activities of people. Studies have shown that ideal bus stops should satisfy accessibility and safety requirements including quality user-experience. This study involves an assessment of the state of bus stops in Ibadan metropolis, Oyo State, using a sample of fifty bus stops from the five urban local government areas in Ibadan metropolis. Interviews conducted with 200 bus stop users reveal that users are not satisfied with the chaotic state of bus stops. A field survey of the bus stops shows that all bus stops are not clearly designated; no signs; no markings; no lighting system; no shelters; and no trash bins. Only a few bus stops have walkway facilities; at 40%, Ibadan North-West LGA has the highest percentage of bus stops with walkway facilities. Approximately all bus stops have been turned into commercial centres and havens for hoodlums. Bus stops are used for other purposes such as taxi parks, parking lots, vulcaniser stands and market outlets especially in Ibadan North-West and Ibadan South-East which have the highest rate of multipurpose usage at 90%. The multipurpose usage of bus stops causes chaotic situations for road users during morning and evening peak hours. There are no developed guidelines or manuals for design, location and spacing of the stops. It is not possible to determine conclusively the level of coordination that exists between main stakeholders (State, local government and commercial road transport officials) in the design, location, operation and overall management of the bus stops. Optimal performance and quality user-experience can be achieved when there is improved synergy between stakeholders to upgrade bus stops facilities.

Keywords: Bus stops, bus stops facilities, Ibadan metropolis

## **INTRODUCTION**

Bus stops represent the starting or final points in the bus transportation service process. In bus stops, passengers have the first impression of the offered transport service. The safety and accessibility conditions of a bus stop are the first

outlook of bus passengers and as well influence future modal choices (Marco and Tommaso, 2012). There are several bus stop features that influence passengers' perceived safety at bus stops. These include; shelters, benches, lighting, location, design, maintenance and cleanliness of the bus stops, surrounding environment and the access provided to and from it (Roberto et al., 2018).

Bus stop location is essential but even more essential is the design of bus stops and the availability of necessary facilities to ensure waiting passengers feel safe and comfortable (Marco and Tommaso, 2012). When bus stops are problematic, it becomes an impediment to public transportation. The design and location of bus stops is seen as an important element in the overall quality of public transportation (Olowosegun and Okoko, 2012). Bus stops should have necessary facilities for safe boarding and alighting of passengers. A well-designed bus stop platform should facilitate safe and free flow of traffic, allowing passengers to board and alight without any impediment to adjacent traffic (Kirkpatrick et al., 1997; Prathibaa and Gunasekaran, 2016).

Bus stops are therefore a key element in increasing the efficiency of public transportation. In this study, a field survey was carried out on fifty bus stops within the five urban local government areas in Ibadan metropolis, Oyo State, in order to obtain characteristics of the bus stops.

## **MATERIALS AND METHODS**

### **Study Area**

Ibadan is located in the South-Western part of Nigeria, approximately on longitude 3°5 East of the Greenwich Meridian and latitude 7°2 North of the Equator. Ibadan metropolis is made up

of 11 local government areas (LGAs). The study covered five local government areas in the inner part of metropolis: Ibadan North, Ibadan North-East, Ibadan North-West, Ibadan South-East and Ibadan South-West (Figure 1).

### **Method**

This study made use of the non-proportional stratified sampling method in order to ensure adequate and equal representation of each of the five urban local government areas in Ibadan metropolis. Ten bus stops were selected in each of the five LGAs. Interviews were conducted with 200 bus stop users to determine their user experience. A field survey was conducted at each of the bus stops to collect primary information on the characteristics of the bus stops. Characteristics observed include bus stop type; bus stop designation which include signs (SN) and markings (MK); facilities including light (LG), shelter (SH), walkway (WK), and seats (SE); and unsafe acts performed in bus stops such as double parking (DP), haphazard parking (HP), and multipurpose usage (MU). The bus stop characteristics for each LGA were converted into percentages and modelled using bar charts for vivid illustrations.

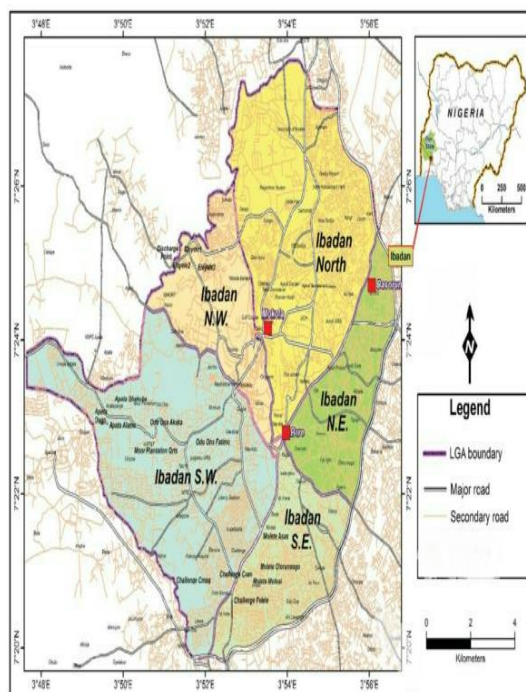


Figure 1: Map of Ibadan (Source: Salami et al., 2016)

## RESULTS AND DISCUSSION

### Bus stop guidelines

There are no developed guidelines or manuals for design, location and spacing of the stops. At the time of this study, it is not possible to determine conclusively the level of coordination that exists between main stakeholders (State, local and commercial road transport officials) in the design, location, operation and overall management of the bus stops.

### Bus stop characteristics

The characteristics of the fifty bus stops surveyed in the five LGAs are shown in Table 1. Ibadan South-East and South-West comprise of curbside bus stops only, but a mixture of curbside, lay-by, and bus turnout bus stops is observed in the other three LGAs as shown in Figure 2. There is no form of designations like signs and markings in all the bus stops. All the bus stops have no lighting facilities, making them unsafe for use at night. Shelter facilities and seats are not available in all the bus stops. Users have to stand and wait in open spaces, sometimes for 30 minutes before they can access the bus services. Ibadan North-West LGA has the highest percentage (40%) of bus stops with walkway facilities as shown in Figure 3.

### User-experience

All the 200 users interviewed to determine their user-experience complained of the chaotic state the bus stops are operated. It appears that no particular agency is responsible for proper operation and management of the stops. The bus stops are used for other purposes such as taxi parks, parking lots, vulcaniser stand and market outlets especially in Ibadan North-West and Ibadan South-East which have the highest rate of multipurpose usage at 90%. Generally, for buses plying the same route, a single line order ('first in first out') is expected to load passengers. No particular order is in place at the time of this study. Cases of haphazard parking are observed in all the bus stops. Users have to move around many times particularly in morning and evening peak hours to locate buses going to their routes. Figure 4 is an illustration of the three different classified acts that affect user-experience.

Table 1: Characteristics of bus stops in selected five LGAs in Ibadan metropolis

S/N	LGA	BUS STOP TYPE (%)			DESIGNATION (%)		FACILITIES (%)				UNSAFE ACTS (%)		
		CB	LB	BT	SN	MK	LG	SH	WK	SE	DP	HP	MU
1	Ibadan North	60	20	20	0	0	0	0	20	0	0	60	70
2	Ibadan North-East	60	20	20	0	0	0	0	10	0	0	60	40
3	Ibadan North-West	60	20	20	0	0	0	0	40	0	80	90	90
4	Ibadan South-East	100	0	0	0	0	0	0	30	0	0	30	90



5	Ibadan South- West	100	0	0	0	0	0	0	10	0	20	40	40
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LGA = Local government area, CB = Curbside, LB = Lay-by, BT = Bus turnout, SN = Signs, MK = Markings, LG = Lighting, SH = Shelter, WK = Walkway, SE = Seats, DP = Double parking, HP = Haphazard parking, MU = Multipurpose usage.

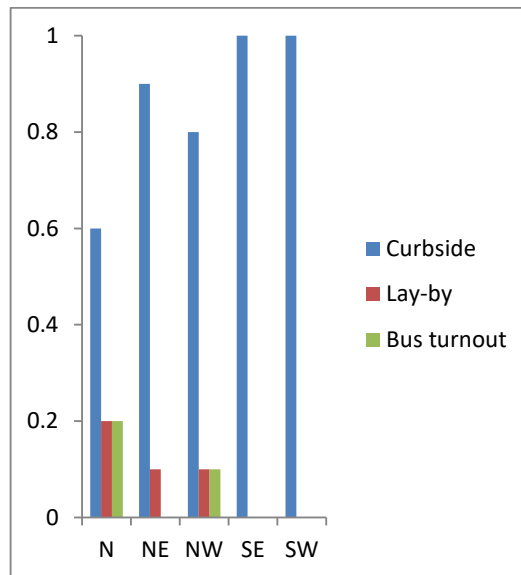


Figure 2: Bus stop types

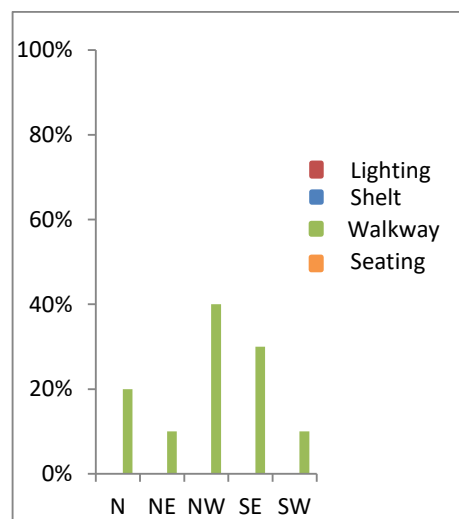


Figure 3: Bus stop facilities

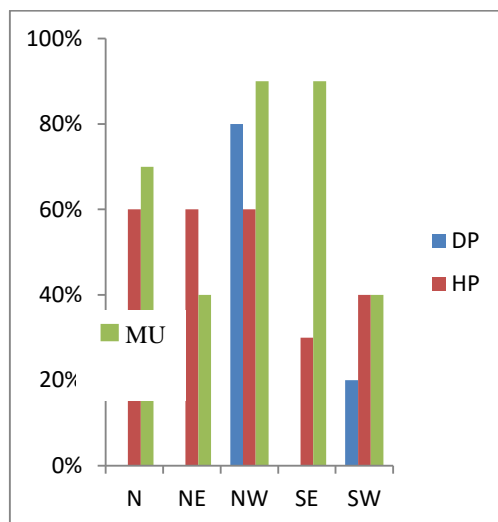


Figure 4: Unsafe acts perpetrated at the bus stops

## CONCLUSION

The assessment of bus stops in selected five local government areas in Ibadan metropolis shows that the stops lack basic facilities and are poorly managed, resulting in low quality user-experience. Optimal performance and quality user-experience can be achieved when there is improved synergy between stakeholders to upgrade bus stops. Improved Synergy can be inferred when the State, Local government and road transport officials (such as officials of the National Union of Road transport Workers, NURTW) work together to ensure the efficient and effective operation of bus stops. It is recommended that the three main stakeholders meet to clarify their individual and joint roles in the design, location, operation and overall management of bus stops as they synergize to fulfil these roles.

## REFERENCES

- Fitzpatrick, K., Perkinson D., and Hall K. 1997. Findings from a Survey on Bus Stop Design *Journal of Public Transportation* 1(3): 17-26.
- Marco, A. and Tommaso, B. 2012. A methodology to define the level of safety of public transport bus stops, based on the concept of risk. *Procedia - Social and Behavioral Sciences* 48: 653–662.
- Olowosegun, A. and Okoko, E. 2012. Analysis of bus-stops locations using geographic information system in Ibadan North L.G.A Nigeria. *Industrial Engineering Letters* 2(3): 20-38.

- Prathibaa, K. and Gunasekaran, K. 2016. Planning of bus stops for safe and efficient passenger boarding and alighting. *International Journal of Engineering Research and Technology (IJERT)* 5(6): 296- 304.
- Roberto, F. A., Vania, C., Yusak, O.S., and Oded, C. 2018. Individual, travel, and bus stop characteristics, influencing travelers' safety perceptions. *Transportation Research Record* 1-10.
- Salami, R., Von Meding, J., and Giggins, H., 2016. Assessing habitats of vulnerability in African cities: a case of poverty housing in Ibadan metropolis, Nigeria. *University of Maryland Project Management symposium, Maryland, USA.* <https://doi.org/10.13140/RG.2.1.31.85.3683>.

## **THE USE OF BAGASSE ASH AS A SUITABLE RAW MATERIAL FOR PRODUCTION OF CONTAINER GLASS**

Muhammed, J.O. and Alemaka, E.M

Department of Glass and Silicate Technology,

Ahmadu Bello University, Zaria

Corresponding Authors e-mail: [jamiu111@gmail.com](mailto:jamiu111@gmail.com)

### **ABSTRACT**

The study was carried out on sugarcane bagasse ash (SCBA) from Samaru, Sabon-Gari Zaria, Kaduna State to determine its properties and suitability as a major raw material for production of container glass. The study reports the feasibility results of recycling sugarcane bagasse ash (SCBA) to produce container glass. The bagasse was burnt in an open atmosphere; the ash formed contained a lot of carbon, which was further calcined through a Gallenkamp muffle furnace at 600<sup>0</sup>C and then held at 700<sup>0</sup>C for 1 ½ hrs. The organic compounds decomposed off and large amount of bagasse ash with high active silica content was obtained. The major component of this solid residue is SiO<sub>2</sub> (>76%). The ash was sieved with 30 mesh (<0.59mm) and other raw materials like calcium carbonate and soda ash were passed through 100 mesh sieve simultaneously to produce a fine powdered of the materials. 5g of SCBA was analyzed using Atomic Absorption Spectrophotometer (AAS) to determine the chemical composition; it was found to contain SiO<sub>2</sub> 76.34wt%, Al<sub>2</sub>O<sub>3</sub> 8.55wt%, Fe<sub>2</sub>O<sub>3</sub> 2.93wt%, Na<sub>2</sub>O 0.12wt%, TiO<sub>2</sub> 0.80wt%, K<sub>2</sub>O 1.50wt%, CaO 0.07wt%, SO<sub>3</sub> 2.25wt%, Cr<sub>2</sub>O<sub>3</sub> 0.05wt%, Mn<sub>2</sub>O<sub>3</sub> 0.06wt% and LOI 6.42wt%. The analysis revealed that the ash contained high amount of silica of 76.34wt% which could supply all of the SiO<sub>2</sub> needed to produce soda lime silica glass. A container glass batch composition was formulated from 95.899g of SCBA, 19.220g of CaCO<sub>3</sub> and 25.556g of Na<sub>2</sub>CO<sub>3</sub> and fired in muffle furnace at temperature between 1100<sup>0</sup>C-1200<sup>0</sup>C for 3 hours. The resulting glass was amber in colour which signifies the presence of iron and sulphate in the ash. The result indicates that sugarcane bagasse ash can be used to produce amber glass for beverages and for storing pharmaceutical drugs especially those which are sensitive to light.

**Keywords:** Bagasse, bagasse ash, glass batch, container glass, soda lime silica

## **INTRODUCTION**

Nigeria industries and energy production always produce waste. Nowadays, there is worldwide consensus that there is a need to recycle and reutilize these waste residues for an efficient utilization of natural resources (Teixeira and Romero, 2010). A wide variety of industrial residues have been used as a substitute for flux in glassmaking, glass ceramic production, additive in concrete mixture. (Rawlings *et al.*, 2006) published a review on the re-use of residues containing silica for the production of glass.

In sugar mill bagasse is a residue after the sugar cane juice extraction. Bagasse is used as a fuel in boilers for thermal power generation in the industry. The ash produce in the process is called as bagasse ash (BGA). The sugar cane bagasse ash (SCBA) waste can be characterized as a non-biodegradable solid waste material rich in crystalline silica and aluminum, calcium, iron, potassium and magnesium oxides are the main minor components (Harihaam *et al.*, 2014). In addition to recycling these wastes and preventing them from being discharged in to the environment, natural resources used by industries are saved.

Bagasse ash is part of sustainable power from biomass and contributes to the green image, while landfill with bagasse ash may be interpreted as waste of valuable material. The search for utilization option must deal largely with bagasse ash. Fuel composition and installation type are the primary factors that influence ash quality. Variations in the inorganic fraction of fuels are directly reflected in ash compositions. A large proportion of it has been recycled as a raw material for cement, glass, and glass ceramics and soil stabilizers. Nevertheless, the demand of silica tends to fluctuate periodically with the construction industry while the generation of bagasse ash increases gradually. Therefore, it is necessary to search for a new option for industry while the generation of ash increases gradually. Therefore, it is necessary to search for a new option for the treatment of the ash. On the other hand, bagasse ash with a silica content of >78 wt. % can be used as a substitute source for silica in the manufacturing process of a silicate glass (Park and Taniguchi, 2009) in Tagwoi (2009), in which the glass product can immobilize and stabilize the heavy metals in the glass matrix. Several studies have reported the recycling of bagasse ash as glass-based materials (Boccaccini, (1999) in Tagwoi (2009)).

In Nigeria today, sugarcane waste (bagasse) is found littering in the streets, causing the prevalence of flies. It constitutes environmental nuisance as they form refuse heaps in areas they are disposed and resulting in the general contamination of the environment. In order to prevent this, a lot of investigation has been made by some authors such as Bahurudeen et al., (2015); Sales and Lima (2010); Tagwoi (2009); Teixeira et al., (2008); on utilization of bagasse, it was reported that the major components of bagasse ash is silica greater than 78%. As a student of glass and silicate technology, silica is a major raw material used to manufacture glass, ceramics and glass ceramic products which have led to high demand of silica materials in the development of glass. As a consequence there are massive destruction of land which has been one of the major causes of landslides and flashfloods during earthquakes and typhoons resulting to loss of thousands or even millions of lives. The result of this study is to provide an alternative means of using bagasse ash as a substitute for silica. This study will encourage them to study other materials that can be used in glass making material and awaken their minds regarding environmental protection. It is against this background that the study explored the following research objectives: analyze the composition of bagasse ash, formulate and design container glass batch using bagasse ash as a source of silica and test-melt the formulated glass batch.

## **Methodology**

### **Materials**

The raw material that was used in carrying out the research includes: Bagasse ash (BGA), Limestone and Soda ash, Muffle furnace, AAS Machine, Sieve and Weighing Scale

### **Bagasse Ash (BGA)**

Bagasse was collected from Samaru Sabon Gari Zaria. The bagasse was carefully beneficiated which means that it was thoroughly washed with water to do away with dirt and some unwanted particles that came with it. Typically the bagasse was dried and burnt in an open atmosphere, the ash formed contained a lot of carbon on it. It was further calcined through a Gallenkamp muffle furnace through a heating rate of 600<sup>0</sup>C and then held at 700<sup>0</sup>C for 1 ½ hrs. At 700<sup>0</sup>C the organic compounds decomposed off and large amount of bagasse ash with high active silica content was obtained. This process took place at department of Chemical Engineering Ahmadu Bello University Zaria. Small amounts of powdered ash were characterized using Atomic

Absorption Spectroscopy (AAS) at National Research Institute for Chemical Technology (NARICT) Bassawa Zaria to determine its chemical composition.



Plate 1: Bagasse Sample



Plate 2: Burning Process



Plate 3: Bagasse Charcoal



Plate 4: Bagasse Ash

### **3.2 Limestone and Soda ash**

In this work, a material which is widely available and affordable (such as limestone and sodium carbonate) was sought in order to make the process viable on an industrial scale. Therefore, SCBA was mixed with limestone and a fluxing agent to obtain a glass material with properties comparable to those which would be useful to the construction industry. The result analyses were used in formulation of a container glass batch. Sample of SCBA, limestone and sodium carbonate was pass through 18 mesh sieve (1mm); Limestone ( $\text{CaCO}_3$ ) and soda ash ( $\text{Na}_2\text{CO}_3$ ) gotten from Department of Glass and Silicate Technology Ahmadu Bello University Zaria (analytical grade), were used as source of calcium oxide ( $\text{CaO}$ ) and Sodium oxide ( $\text{Na}_2\text{O}$ ) respectively. The result of the analysis was used in formation of glass batch.

### **3.3 Chemical Analysis**

The essence of the chemical analysis is to find the percentage of iron impurities and amount of silica as well as other oxides in the sample. The analysis was carried out using AAS which is an energy dispersive microprocessor controlled analytical instrument designated for the detection and measurement of elements in a sample (liquid).

### **3.4 Sieve, Weigh and Furnace**

The bagasse ash was sieved with 30 mesh ( $<0.59\text{mm}$ ) simultaneously to produce a fine powdered of the materials. The other raw materials like limestone and soda ash were passed through 100 mesh sieve and also weighed on analytical weighing scale at department of glass and silicate technology Ahmadu Bello University Zaria. The SCBA were used as a source of silica to obtain the glass. The glass was prepared mixing SCBA ( $<0.59\text{mm}$ ) with 100 mesh of

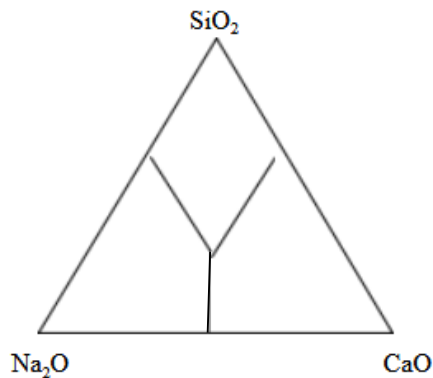


limestone ( $\text{CaCO}_3$ ) and sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) (fluxing agent) using melting method. The mixtures were melted at  $1400^\circ\text{C}$  in an electrical laboratory furnace at Department of Glass and Silicate Technology Ahmadu Bello University Zaria.

### 3.5 Formulation of Batch

Batch formulation is defined as the proportion or weight of particular quantities of glass containing the individual component calculated for a previously defined total quantity. Composition of the bagasse ash as and all other raw material were calculated by percentage to formulate a batch.

The glass composition adopted was that of soda-lime glass. Due to the high presence of silica in BGA which is evident in the result from the AAS analysis and the silica content requirement of such soda-lime silicate glass as deduced from literature; the batch formulation was prepared using a ternary phase diagram of three component system ( $\text{SiO}_2$ -  $\text{CaO}$ - $\text{Na}_2\text{O}$ )



Ternary Phase Diagram

The composition of the soda-lime silicate glass which forms the basis of the calculation is as follows:

$\text{SiO}_2$  - - - - - 73.21wt%  
 $\text{Na}_2\text{O}$  - - - - - 15.96wt%  
 $\text{CaO}$  - - - - - 10.83wt%

Bagasse ash (BGA) was analysed to contain the following oxides in their percentages: 76.34wt%  $\text{SiO}_2$ ; 8.55wt%  $\text{Al}_2\text{O}_3$ ; 1.93wt%  $\text{Fe}_2\text{O}_3$ ; 0.12wt%  $\text{Na}_2\text{O}$ ; 0.80wt%  $\text{TiO}_2$ ; 1.50wt%  $\text{K}_2\text{O}$ ; 0.07wt%  $\text{CaO}$  [LOI = 6.42wt%]

### Calculation

From the result of the analysis the calculation is this:

100g of BGA introduces 76.34g of SiO<sub>2</sub>

Xg of BGA will introduce 73.21g of SiO<sub>2</sub>

$$= \frac{100 \times 73.21}{76.34} = \frac{7321}{76.34} = 95.899\text{g of BGA}$$

Next stage is to calculate the quantity of the Al<sub>2</sub>O<sub>3</sub>; Fe<sub>2</sub>O<sub>3</sub>; Na<sub>2</sub>O; TiO<sub>2</sub>; K<sub>2</sub>O; and CaO will the 95.899 of BGA contained.

Al<sub>2</sub>O<sub>3</sub>: since 100g of BGA introduces 8.55g of Al<sub>2</sub>O<sub>3</sub>, therefore 95.899g of BGA will introduce

$$\frac{95.899 \times 8.55}{100} = \frac{819.936}{100} = 8.199\text{g of Al}_2\text{O}_3$$

Fe<sub>2</sub>O<sub>3</sub>: since 100g of BGA introduces 1.93g of Fe<sub>2</sub>O<sub>3</sub>, then:

$$95.899\text{g of BGA will introduce } \frac{95.899 \times 1.93}{100} = \frac{185.08507}{100} = 1.851\text{g of Fe}_2\text{O}_3$$

Na<sub>2</sub>O: since 100g of BGA introduces 0.12g of Na<sub>2</sub>O, then 95.899g of BGA will introduce

$$\frac{95.899 \times 0.12}{100} = \frac{11.50788}{100} = 0.115\text{g of Na}_2\text{O}$$

TiO<sub>2</sub>: since 100g of BGA introduces 0.80g of TiO<sub>2</sub>, then 95.899g of BGA will introduce

$$\frac{95.899 \times 0.80}{100} = \frac{76.7192}{100} = 0.767\text{g of TiO}_2$$

K<sub>2</sub>O: since 100g of BGA introduces 1.50g of K<sub>2</sub>O, then 95.899g of BGA will introduce

$$\frac{95.899 \times 1.50}{100} = \frac{143.8485}{100} = 1.438\text{g of K}_2\text{O}$$

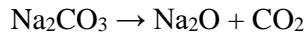
CaO: since 100g of BGA introduces 0.07g of CaO 95.899g of BGA will introduce

$$\frac{95.899 \times 0.07}{100} = \frac{6.71293}{100} = 0.067\text{g of CaO}$$

**For Sodium Carbonate (Na<sub>2</sub>CO<sub>3</sub>)**

The required amount of Na<sub>2</sub>O in the batch is 15.96g. But 0.115g has been introduced by BGA respectively. The required amount of Na<sub>2</sub>O from Soda ash (Na<sub>2</sub>CO<sub>3</sub>) will be:

$$15.96\text{g} - 0.115\text{g} = 15.845\text{g}$$



100g of Na<sub>2</sub>CO<sub>3</sub> will give 62g of Na<sub>2</sub>O

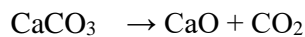
Xg of Na<sub>2</sub>CO<sub>3</sub> will be 15.845g of Na<sub>2</sub>O

$$X = \frac{100 \times 15.845}{62} = \frac{1584.5}{62} = 25.556\text{g of Na}_2\text{CO}_3$$

**For Calcium Oxide (CaO)**

The required amount of CaO in the batch is 10.83g. But 0.067g has been introduced by BGA respectively. The required amount of CaO from limestone (CaCO<sub>3</sub>) will be:

$$10.83\text{g} - 0.067\text{g} = 10.763\text{g}$$



100g of limestone will give 56g of CaO

Xg of limestone will be 10.763g of CaO

$$X = \frac{100 \times 10.763}{56} = \frac{1076.3}{56} = 19.220\text{g of CaCO}_3$$

**3.6 Batch composition**

From the result AAS analysis, it can be seen that the oxides present in the bagasse collected from Samaru location were used in the formulation of glass batch as shown in Table 1 below.

**Table 1: Summary of Raw Materials and Oxides Supplied**

Raw materials	Amount of raw materials (g)	Oxides (g)						
		SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	Na <sub>2</sub> O	TiO <sub>2</sub>	K <sub>2</sub> O	CaO
Bagasse ash	95.899	73.210	8.199	1.851	0.115	0.767	1.438	0.067
Limestone	19.220	—	—	—	—	—	—	10.763

Soda ash	25.556	—	—	—	15.845	—	—	—
	140.675	73.210	8.199	1.851	15.960	0.767	1.438	10.830

### 3.7 Melting process

A melting test was carried out to evaluate the suitability of bagasse ash as the main source of silica in the glass batch. The raw material was accurately weighed out and mixed thoroughly in order to facilitate homogeneity in the glass. The batch was then transferred into crucibles for melting in an electric muffle furnace at a temperature of 1400<sup>0</sup>C. A test melting was carried out to determine the suitability of bagasse ash as the main source of silica in the glass batch. The next reason for test melting is to ascertain the accuracy of the result of chemical analysis of the bagasse ash. The analysis of the raw materials used for the glass batch provided data for the formulation of the batch. The batch formulated is a three-component system (SiO<sub>2</sub>-CaO-Na<sub>2</sub>O), which is acquired from Bagasse ash, limestone and soda ash.

## RESULT AND DISCUSSION

**Table 2: Chemical Analysis of Bagasse Ash (BGA)**

Oxides	Weight (wt)%
SiO <sub>2</sub>	76.34
Al <sub>2</sub> O <sub>3</sub>	8.55
Fe <sub>2</sub> O <sub>3</sub>	2.93
CaO	0.07
Na <sub>2</sub> O	0.12
TiO <sub>2</sub>	0.80
K <sub>2</sub> O	1.50
SO <sub>3</sub>	2.25
Cr <sub>2</sub> O <sub>3</sub>	0.05

Mn <sub>2</sub> O <sub>3</sub>	0.06
LOI	6.42

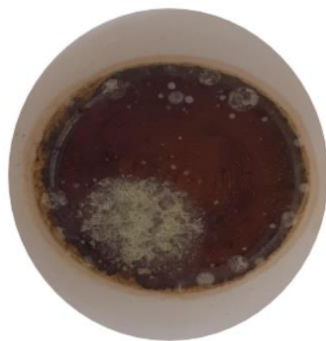
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The chemical analysis of the bagasse ash (BGA) is shown in Table 2 above. This composition was obtained from the AAS machine analysis. As shown in the Table sugarcane bagasse ash contained silica as the major compound with minor concentration of aluminum, sodium oxide, calcium oxide and iron oxides. The obtained results are similar with the results reported by Teixeira *et al.*, (2011).



**Plate 5: Formulated Batch composed of 95.899g of SCBA, 19.220g of CaCO<sub>3</sub> and 25.556g of Na<sub>2</sub>CO<sub>3</sub>**

The raw materials that were used in the preparation of this batch are silica from bagasse ash, soda ash and calcium carbonate. These glass batch was fired in muffle furnace at National Metallurgical Development Center Jos, in a small refractory crucible to the temperature 1100<sup>0</sup>C - 1200<sup>0</sup>C instead of 1400<sup>0</sup>C due to lack of furnace facility in the environment available to fired at that temperature.



**Plate 6: Melted Glass**

### **Melted Glass**

The melted glass shown in Plate 6 above is an evidence of an achievement of a largely homogeneous melt, but not without the presence of whitish scum at the corners. A good melt is one which is homogeneous. Compatibility of the constituents is essential for a system in order to obtain a homogeneous glass. The presence of whitish scum usually results from the rapid melting of alkali i.e. when alkali melts too rapidly, it prevents proper sequence of glass forming reactions; foam or silica scum prevents heat from penetrating into the glass thus hindering refining and homogenizing. Whitish scum can occur as a result of rapid firing, the required temperature is about  $1400^{\circ}\text{C}$ . The resulting glass obtained from the test-melting process was fired at temperatures between  $1100^{\circ}\text{C}$  -  $1200^{\circ}\text{C}$  for 3hours; an amber colour was also observed signifying the presence of iron and sulphate in the ashes. This glass can be used to produce amber bottles for beverages and for storing pharmaceutical drugs especially those which are sensitive to light of certain wavelengths.

### **Conclusion**

Based on findings of this work, the study concludes that the major component of SCBA is  $\text{SiO}_2$  (a glass network former) while  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$  and  $\text{Na}_2\text{O}$  which are generally used in glass melting process were found in ashes. Certain transition metal oxides particularly  $\text{Fe}_2\text{O}_3$ ,  $\text{Mn}_2\text{O}_3$  and  $\text{Cr}_2\text{O}_3$  were found in minor quantities in the bagasse ash. Further test carried out through the formulation of glass batch and test melting, confirmed that bagasse ash can be used as a substitute for silica in glass making. Glass produced from SCBA was amber in colour due to the presence of iron and sulphate in the ashes and is recommended for the production of

container glass for beverages and for pharmaceutical drugs especially those which are sensitive to light of certain wavelengths.

## **REFERENCES**

- Bahurudeen, A. and Santhanam, M. (2014): "Performance Evaluation of Sugarcane Bagasse Ash Based Cement for Durable Concrete". Proceedings of the 4<sup>th</sup> International Conference on the Durability of Concrete Structures (ICDCS'14), pp. 275-281
- Hariharam, V., Shanmugam, M., and Amutha, K. (2014): "Preparation and Characterization of Ceramic Products Using Sugarcane Bagasse Ash Waste", (ISC-2013), Vol.3, pp. 67-70
- Rawling, R.D., Wu, J.P., and Boccaccini, A.R. (2006): "Glass-Ceramic: Their Production from Wastes-A Review". *J.Mater.Sci...*, 41,733-761
- Sales, A., and Lima, S.A. (2010) "Use of Brazilian Sugarcane Bagasse Ash in Concrete as Sand Replacement Sand Waste Management". Vol.30 No.6 pp. 1114-1122
- Tagwoi, J.T. (2009): "Investigation of Bagasse Ash for Glass Making". Unpublished Thesis Project Department of Glass and Silicate Technology, Ahmadu Bello University Zaria.
- Teixeira, S.R, Romero, M., Rincon J. Ma. (2010): "Crystallization of SiO<sub>2</sub>-CaO-Na<sub>2</sub>O Glass Using Sugarcane Bagasse Ash (SCBA) as Silica Source". *Journal of the American Ceramic Society*, 93
- Teixeira, S.R, Romero, M., Rincon J. Ma. (2011): "Glass-Ceramic Material from the SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub>-CaO System Using Sugarcane Bagasse Ash (SCBA)". *IOP Conf. Series Materials Science and Engineering* 18

## **PRODUCTION OF A DUAL-PURPOSE WASTE GLASS PROCESSING MACHINE FOR SMALL TO MEDIUM ENTERPRISE (SME)**

Olasehinde, O. S.<sup>1</sup>, Gonah, C. M.<sup>2</sup> and Fwatwmol, A. D.<sup>3</sup>.

<sup>1,2,3</sup> Department of Glass and Silicate Technology, Ahmadu Bello University, Zaria, Nigeria

\*Email of Corresponding Author: [bstephen169@gmail.com](mailto:bstephen169@gmail.com)

### **ABSTRACT**

Glass is 100 percent recyclable and the technology for recycling glass is relatively simple and well established. The isometric projection and orthographic projection of the machine were designed using software known as solid works. The major material used for fabrication was mild steel and the assembly was done by separable and permanent fixed joints. The machine has a length of 996mm, height of 700mm and width of 696mm. The waste glass were collected in Ahmadu Bello University, Zaria, Samaru main campus. The beneficiation process of the waste glass involved sorting, soaking, washing and drying. Each of the waste glass were weighted to 2300g, and were used to test run the machine. The performance of the machine was tested using the sieves of 4mm, 3mm, 2mm and a collector. The weight of processed flint glass on the sieves and collector were 434g, 528g, 680g and 646g; the weight of processed amber glass were 188g, 602g, 400g and 632g; while the weight of processed green glass were 194g, 508g, 628g and 492g. The grain sizes of 4.9mm-3.0mm can be used for glass melting. The grain sizes of 2.9mm-2mm can be used for surface texture design. The grain sizes on the collector can be used for partial replacement of cement, glass paint and glass tiles. Less than hundred thousand Naira; was used to fabricate the machine and it can be used to process animal feeds. The Small to Medium Enterprise (SME) can adopt this machine for pilot plant.

**Keywords:** Machine, Recycling, Waste Glass, Dual-Purpose



## **INTRODUCTION**

Waste management methods cannot be uniform across regions and sectors because individual waste management methods cannot deal with all potential waste materials in a sustainable manner. Conditions vary; therefore, procedures must also vary accordingly to ensure that these conditions can be successfully met. Waste management systems must remain flexible in changing economic, environmental and social conditions. A variety of approaches have been developed to tackle waste issues; the economic and environmental performance of the entire system can be impacted by the way the materials are collected and sorted. In many instances, the collection point will be an interface where waste generators and waste collectors that must be carefully managed if the system is to be effective. Waste generators require waste collection with minimal inconvenience, while collectors must be able to collect waste in a way that is compatible with the planned treatment and processing methods if the waste management system is to be sustainable (Olasehinde, 2017).

Contaminants are materials present in waste glass that are unwanted for its further use. Contaminants can be classified in two groups; non-glass material components and glass material components that are detrimental for new glass manufacturing. Non-glass material components are metals (ferro-magnetic and non-ferro-magnetic). Non-metal non-glass inorganic is ceramics, stones and porcelain. Organics are food remains, plastic, wood, textiles and so forth. Hazards are hazardous materials contained in bottles, jars, medical or chemical refuse contained within needles and syringes. Glass material components; glass product quality is severely affected by the presence in glass cullet of glass types different from the main glass cullet type. For example; to manufacture flint container glass, there is a limit on what percentage of green container glass cullet is used. Above that limit, the green glass cullet is adverse for new flint glass manufacturing (Elena *et al.*, 2011)..

The first phase of treatment upon arrival of waste glass at the reprocessing plant is visual inspection. Visual inspection is undertaken by experienced staff with good knowledge of the processing technology of the plant. If inspection results in acceptance, the material is crushed. Crushing reduces the glass piece size to the size suitable for further sorting or cleaning. Afterwards the organics may be dried at ambient air, or removed by washing, before the material passes sieves to reduce the organic content as well as magnetic separators and Eddy current separators to reduce the metal content. Manual sorting can also be part of the sorting

steps, removing by handpicking large pieces of foreign material such as plastics, paper, stone and so forth (Elena *et al.*, 2011).

The reuse of cullet is complicated, however, by the fact that different types of glass are not always compatible for recycling. The glass produced by different manufacturers differs in both form and chemical composition. The form variations are familiar because glass can be pressed and blown into shapes, or in more complicated applications, such as fiberglass or fiber optics. Although glass can be re-melted and changed from one form into another with ease, a problem arises in separating the glass from other materials in a product (for example; separating the glass in a light bulb from other non-glass components). Although all glasses are composed of silica and sodium oxide (soda ash), the type and quantity of other compounds added vary slightly in different types of glasses. These differences frequently cause problems in recycling glass because producers of some types of glass have strict specifications for the chemical make-up of any cullet they might use (McCarthy, 2015).

Waste glass exists in three forms which are off-specification cullet, pre-consumer cullet and post-consumer cullet. Off-specification cullet is generated as glass producers slowly change the ingredient mix in their giant melting vats, and finished glass that breaks at the manufacturing plant. Pre-consumer cullet is the finished glass that breaks at a bottling or distribution facility. Both of these types of waste glass are reused within the glass plants. Post-consumer cullet consists of the glass bottles or other glass products discarded by consumers after use. Glass is 100 percent recyclable and it can be melted repeatedly to produce the same product, and the technology for recycling glass is relatively simple and well established (Olashinde, 2017). Recycled glass must meet quality standards to ensure it can be marketed and made into new glass products. Contaminants must be kept out of glass recycling articles. Contaminants such as ceramics, glass metal rings, and caps cause problem in the recycling process (Jekada, 2013).

Indigenous technology enhances a nation's development and reduces its dependence on importation of equipment and machineries. It addresses the local need and to an extent, meets international standards (Morakinyo, 2012). As with several key concepts like science and technology, innovation and entrepreneurship, there seems to be no single universal definition

of indigenous knowledge but the fundamentals are clear. Contrasting indigenous knowledge with globalized knowledge, Warren *et al* (1995), noted that it is the local knowledge that is unique to a given culture or society. Focusing on the sources of indigenous knowledge, it was defined by Grenier (1998), as the unique, tradition, local knowledge existing within and developed around specific conditions of women and men indigenous to a particular geographic area. A particular commonality to be noted is that indigenous knowledge generally refers to the matured long-standing traditions and practices of certain regional, indigenous, or local communities as well as the wisdom, knowledge, and teachings of the communities. At its most basic level, technology is defined as the application of knowledge to provide solutions to problems, mostly of mankind. Some forms of traditional knowledge are expressed through stories, legends, folks-lore, rituals, songs and even laws while other forms are often expressed through different means (Archarya *et al.*, 2008).

When indigenous knowledge finds applications in tools, techniques, processes and methods that help in solving problems, indigenous technologies arise. Notable examples include the making of talking drums in Oyo (South-Western Nigeria), the fabrication of aluminium pottery in Saki (South-Western Nigeria), the production of beads in Bida (North-Central Nigeria). Nigeria is greatly blessed with gifted hands that are laboriously engaged in various types of indigenous technologies. There is hardly any part of the country that does not have a remarkable indigenous technology to show for its existence. The indigenous industries among others include the production of pots from clay and aluminium metal scraps, textile making, cloth weaving, bronze casting, leather tanning, and the like, in various parts of the country. The indigenous knowledge supporting these industries is generally passed on from generation to generation and hence it is a tradition in specific locations to produce specific products.

The method of indigenous knowledge transmission and skills acquisition is largely through observation and apprenticeship. In today's industrial world man's innovative ideas has taken him towards all directions concerning the production and safety in industrial establishments. Some instruments are of sheer excellence where as others are the result of long research and persistent work, but it is not the amount of time and money spend in the invention of device or the sophistication of it operation, but its convenience, utility and operational efficiency that are important in considering the device (Anant *et al*, 2014).

The processes used in glass crushing for recycling involves the same methods used by the aggregate industry for crushing rock into sand. The glass crushing begins when a user drop a glass jar, bottles and other waste glass into the feeder, the waste glass travel down into the glass crusher itself, which contains an integral conveyor belt to transport the glass. Steel hammers pulverize the glass into smaller pieces and the glass exists into storage containers or bin at the opposite end. The pulverizing action will not only break the glass, but tumbles it around within the machine to eliminate sharp edges and give the cullet a smooth texture. The crushing machine will help reclaim valuable space, minimize noise pollution and reduce occupational health and safety risks (Mark, 2001).

Glass industries in Nigeria are in need of technological equipment; so the availability of a waste glass processing machine will boost the working processes of the glass industries in the country. Waste glass is useless until when graded by crushing into desired size known as cullet, which is not only added to glass melt, but the cullet as raw materials in other industries, particularly building and construction work (Gonah, 2001). The procedures for upgrading and grading of the glass waste are collection, washing, magnetic separation, crushing and sieving respectively. The particle sizes of the cullet which stemmed from the upgrading and grading are used in different applications like melting, casting, partial replacement of sand in concreting, ceramics glazing, surface texture design, and partial replacement of cement. However, the processes of upgrading and grading require two or more machines, which add to the cost of production. Therefore, a dual-purpose waste glass processing machine is imperative to reduce the cost of production.

The objective of the research was to design; produce and test run the waste glass processing machine using the waste glass for small to medium enterprise (sme).

## **MATERIALS AND METHODS**

The research covered the design using software known as solid works, fabrication using mild steel as the major material in Old Panteka, Kaduna and the test running of the machine with the waste glass that was sourced from different locations in Ahmadu Bello University, Zaria, Samaru main campus. The engineering materials are mainly classified as: metal and their

alloys, such as iron, steel, aluminium and so forth, while non-metals such as glass, rubber, plastics and so forth (Khurmi, 2005). The materials used for fabrication were readily available and the cost was affordable. The equipment that were used are hand and industrial drilling machine; measuring tape; hammer; grinding machine; industrial cutting machine; electric welding machine; square; saw; turn; industrial folding machine; pliers; dark safety goggle; spraying machine; vice; spanners; and scissors.

### **Design Considerations**

The appropriate electric motor for the machine based on its capacity was 3 horse power (Hp). For the purpose of the design; 1740 rpm was chosen as the speed of the hammer mill in the waste glass processing machine.

### **Design of the Machine**

The waste glass processing machine has a hammer mill for the crushing, because it is not easily damaged. The isometric projection and orthographic projection showing the major components hopper, beater shaft, eccentric shaft, beater, sieve stry, door, lower crushing, upper crushing chamber, machine frame and assembly drawing of the dual-purpose waste glass processing machine were designed using Solid Works software application.

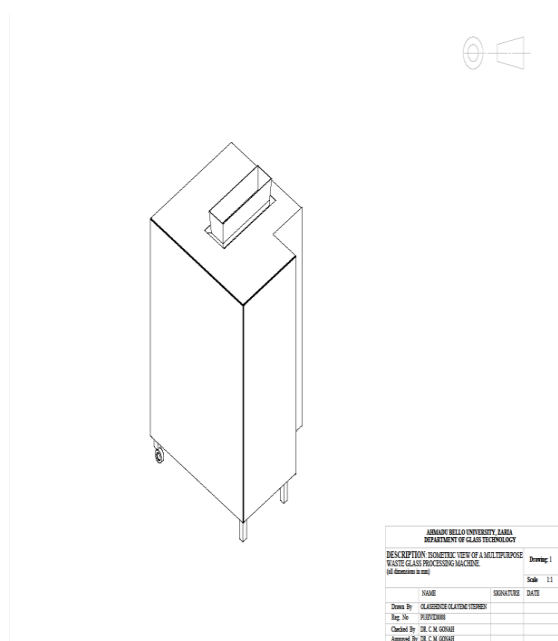


Figure 1 The Isometric View of the Waste Glass Processing Machine

### **Production Processes of the Components of the Waste Glass Processing Machine**

The hopper was made of mild steel. It was cut and welded into a rectangular shape with a bend at the middle. The separator plates were made using mild steel with a thickness of 4mm. The shaft was made using mild steel. The eccentric shaft was made by machining using mild steel. The hammers were fabricated using mild steel by cutting and drilling. The pin was made by cutting and machining the mild steel to a length of 240mm and thickness of 15mm. The revolving beaters are a unit assembly consisting of 18 hammers, 24 spacers, 2 pins, 4 separator plates and the shaft. The perforated screen was made using mild steel by drilling and cutting to the appropriate length. It was been perforated by drilling holes of 5mm in diameter and the number of holes on the screen were determined by the diameter of the holes. The sieve was produced using mild steel by cutting and hammering. The sets of sieves have 320mm length, 35mm height and 285mm width. Mesh sizes of 4mm, 3mm and 2mm was assembled to the sieves.

The top cover was fabricated using mild steel. It was cut, machined. The front door was made using mild steel. The collector was made using mild steel by cutting and welding. The housing case was made using mild steel by cutting and welding. The electric motor bed was made of mild steel by cutting and machining. The machine frame was produced by welding angular bar of different lengths together. The dimension of the machine frame are; length 996mm, height 700mm and width 696mm. After the fabrication of the components of the machine was done, the general assembly was done by separable or permanent fixed joints. The machine was sprayed with a mixture of red oxide and an orange colour.



Plate I: The Assemble Machine



Plate II: The Painted Assembled Machine

## RESULTS AND DISCUSSION

After the waste glass processing machine was fabricated and assembled, test running was done by connecting the fuse of the waste glass processing machine to the socket to generate electricity to power the machine due the fact that the machine is a single phase. Each of the beneficiated waste glass was weighed to 2300g and was loaded into the crushing chamber through the hopper. The hopper has magnets behind it to remove any magnetic material in the waste glass before conveying the waste glass into the crushing chamber. The sets of hammers in the crushing chamber pulverized the waste glass which passed through the screen of 5mm to the discharger, for the pulverized waste glass to fall into the 3 sets of sieves from 4mm, 3mm and 2mm and the collector. The machine was operated for some minutes to process the waste glass and was allowed to shake the sieves before the processed waste glass was collected from the 3 sets of sieves and the collector; after which the processed waste glass were poured into the 12 containers and weighed to know their quantity.

### **Discussion**

The waste glass processing machine was designed using software known as solid works and each components of the machine was fabricated using mild steel. The assembly of the components of the machine was done by separable and permanent fixed joint. The machine was test run using waste glass that was sourced and beneficiated. During the test running of the machine 2300g of each of the waste glass; green, amber and flint were loaded into the machine and the sieves and collector retained some grain particle sizes. The total weight of the flint glass retained on the sieves and collector is 2288g, while the total weight retained on amber and green glasses are 1822g respectively. The flint had more weight retained than the amber and green because it has more silica during the batch formation. The sieve analysis was carried out to determine the grading of waste glass for use as aggregates.

## CONCLUSION

Based on the design, fabrication and test results, the following conclusions can be deduced; the aim of this research, which was to design and fabricate a dual-purpose waste glass processing machine, has been achieved. The automatic operation saves time and does not require high skilled labour. The dual-purpose waste glass processing machine can be used for



glass recycling in any recycling workshop or industries. The machine is simple and is made from easily available materials from Old Panteke, Kaduna State. The parts are coupled in such a way that they can be easily dismantled for quick and easy maintenance.

The Post-consumer waste glass was used to test run the processing waste glass machine; because they are waste glass bottles or other waste glass products discarded by consumers after use. The design created matched the fabrication of the dual-purpose waste glass processing machine. The machine processes the waste glass properly and simultaneously sieves it into desired particle sizes. After fabrication, the machine was found to be simple and the parts were coupled in such a way that they can be easily dismantled for quick and easy maintenance.

#### **REFERENCES**

- Anant, J. G. and Arunkumar, P. (2014). Design, development and fabrication of low cost corn deseeding machine. *International Journal of Research in Engineering and Technology*. Retrieved January, 30, 2016 from <http://www.ijret.org>.
- Elena, R. Peter, E. Alejandro, V. and Hans, S. (2011). End-of-waste criteria for glass cullet: technical proposal. *JRC Scientific and Technical Reports*. Retrieved January, 30, 2016 from <http://www.pharosproject.net/uploads/files.pdf>.
- Grenier L. M. (1998). Indigenous technologies and innovation in Nigeria. Retrieved January, 9, 2015 from <http://www.scirp.org/journal/paperdownload.aspx>.
- Gonah, C. M. (2001). Design and fabrication of glass waste processing machine. *Unpublished M.Sc Industrial Design (Glass Technology) Thesis, Department of Industrial Design, Ahmadu Bello University, Zaria, Nigeria*.
- Jekada, J. Z. (2013). effect of physico-chemical changes on coloured glass. *Unpublished M.Sc Industrial Design (Glass Technology) Thesis, Department of Industrial Design, Ahmadu Bello University, Zaria, Nigeria*. Pp (1, 2).
- Khurmi, R. S. (2000). Strength of materials (mechanics of solids). *S. Chand and Company Limited (AN ISO 9001 - 2000 COMPANY) Ram-Nagar, New Delhi-110055*. Pp (722, 723).
- Mark, C. T. (2001). Glass Crushers, Oxford University Press, London.

McCarthy, G. (2015). Characterization of municipal solid waste in the united states. Environmental Protection Agency (U.S.EPA 1990). Retrieved November, 06, 2015 from <http://www.epa.gov/epawaste/nonhaz/municipal/pubs/cok.pdf>.

Morakinyo, A. D. (2012). The design and fabrication of tile making machines. *Unpublished M.A Industrial Design Thesis, Department of Industrial Design, Ahmadu Bello University, Zaria, Nigeria.* Pp (12, 20, 25, 33, 40, 43)

Warren, D. M. Slikkerveer, L. J. and Brokensha, D. M. (1995). *The Cultural Dimensions of Development: Indigenous Technologies and Innovation in Nigeria.* Retrieved January, 9, 2015 from <http://www.scirp.org/journal/paperdownload.aspx>.

## **OPTIMAL PLACEMENT AND SIZING OF CAPACITOR IN NIGERIAN RADIAL DISTRIBUTION NETWORKS USING CUCKOO SEARCH ALGORITHM**

Salimon, S. A.<sup>1\*</sup>, Suuti, K. A.<sup>2</sup> and Aderinko, H. A.<sup>3</sup>

<sup>1,3</sup>Department of Electrical and Electronic Engineering, Ladoké Akintola University of  
Technology, Ogbomoso, Nigeria

<sup>2</sup>Electrical and Electronic Engineering Department, University of Ibadan, Ibadan, Nigeria

\*Email of Corresponding Author: sunnydexs.sa@gmail.com

### **ABSTRACT**

Installation of capacitors in power networks are generally used for the improvement of the network power factor, improvement of the voltage profile and the voltage stability index, maximizing flow through cables and transformer, and minimization of total power losses due to the compensation of the reactive component of power flow. These benefits depend to a very large extent on the size and location of the capacitor in the radial distribution network as wrong placement can lead to the opposite effects. Furthermore, the appropriate placement of capacitors will reduce the total capacitor costs and the running expenses of Distribution Companies (DISCOs). In this paper, the problem of optimal placement and sizing of capacitor in the buses of Nigerian distribution network is addressed. The proposed methodology uses the Cuckoo Search Algorithm (CSA) to determine the size and the location satisfying the operating constraints. To demonstrate the capability of the proposed method, it was tested Imalefalafia 32 bus radial distribution network of the Ibadan Electricity Distribution Company (IBEDC). The simulation results obtained with compensation was compared with that of the base case (without compensation) and found to be encouraging.

**Keywords:** Cuckoo Search algorithm, Loss sensitivity factor, Radial distribution network, Capacitors.

### **INTRODUCTION**

Radial distribution networks consist of a main feeder and lateral distributors which act as a link between high voltage transmission line and low voltage consumers. The low resistance to reactance ratio of the radial distribution network leads to a high power losses compared to that

of transmission networks (Moradi and Abednie, 2010). Research have revealed that installation of capacitor banks in the radial distribution network has some advantages which include power factor correction, improvement of the network voltage profile, power and energy loss reduction, feeder and system capacity release as well as power quality improvement (Elsheikh *et al*, 2014). The extent to which capacitor banks reduce power system loss, the cost of reactive power compensation and improves the voltage profile depends on the size and location of the capacitors. The reactive power supplied by the shunt capacitor affect the reactive power in the network and enable it to provide voltage support. The support however depends on the deliberate placement and size of capacitor to improve the voltage profile of the network, reduce power loss and the reactive compensation cost (Ocha *et al*, 2006). Optimal placement and sizing of capacitor is a complex combinatorial problem which can be solved with an optimization technique.

Numerous optimization techniques and models have been proposed for the solution of the optimal sizing and placement of capacitors in a radial distribution network for power loss reduction and improvement of voltage profile by several researchers. The early proposed approaches are the analytical numeric programming optimization techniques like local variation method (Ponnavaiko and Prakassa Rao, 1989) and mixed integer linear programming techniques (Baran and Wu, 1985; Khodr *et al*, 2008) have been used for solving the problem of optimal placement and sizing of capacitor. In recent years, various meta-heuristics population-based approaches have been introduced by researchers for capacitor placement problem.

Raju *et al.* (2012) proposed direct search algorithm for optimal placement and sizing of capacitors in a radial distribution system to maximize the savings and minimize the power loss. The proposed method was tested on standard 22, 69 and 85 bus systems and the results were compared with the results of PSO. Prakash *et al.* (2007) presented loss sensitivity factor and particle swarm optimization for the placement of capacitor with the objective of minimization of power loss. The method was implemented on standard 10-bus, 15-bus, 34-bus, 69-bus and 85-bus systems. Rao *et al.* (2011) proposed plant growth simulation algorithm for capacitor sizing and placement in radial distribution systems with the objective of improving the voltage profile and reduction of power losses. It was tested on 10, 34 and 85 bus standard IEEE radial distribution systems. Ahmed *et al.* (2014) proposed a combination of LSF and fuzzy real coded Genetic Algorithm for the optimal placement of capacitor on standard IEEE 33-bus. The

objective of the work is minimization of power losses and total energy cost. Binary honey bee foraging approach was proposed to solve optimal capacitor placement problem of radial distribution systems by Sedighzadeh *et al.* (2012). The proposed method was implemented on IEEE 9-bus test system and its performance was compared with Binary Particle Swarm Optimization (BPSO) and Genetic Algorithm. Tamilselvan *et al.* (2015) used the clonal selection algorithmic approach to minimize power loss and energy cost by optimal placement and sizing of capacitor in radial distribution network. The feasibility of the method was tested on standard 33 and 69 bus radial distribution systems.

All the aforementioned studies achieved encouraging results in solving the capacitor placement problem in radial distribution system. The effectiveness of the various methods was tested on standardized IEEE distribution systems. However, there is the need to use optimal placement and sizing of capacitor to solve the inherent problems of real Nigerian radial distribution system. This paper therefore focuses on optimal placement and sizing of capacitor on the Imalefalafia 32-bus Nigerian radial distribution system Cuckoo Search Algorithm (CSA) with the objective of minimizing the total power loss and the total cost of compensation.

## METHODOLOGY

### Load flow for radial distribution networks

Common load flow procedures like Newton-Raphson (NR) and Gauss-Seidel (GS) have less accuracy and take many times to get convergence in distribution network, because the ratio of resistance to reactance is high in respect of the distribution network. In order to analysis capacitor effect on the network and calculating the active power loss of the grid, backward-forward (BF) load flow method for distribution system (Moeini, 2010) is adopted for use in this work. The main idea of Backward-forward load flow is based on Kirchhoff Voltage and Current laws. This method derived from the single line diagram in Fig. 1 determines the current of any feeder and the voltage of any node in four following stages:

#### Step 1- Node Injection Current

Whereas the load data are available it is possible to calculate injected current of each node by

$$I_i^k = \frac{S_i^*}{(V_i^{k-1})^*} \quad (1)$$

Where  $S_i$  - Given apparent load of the  $i^{\text{th}}$  node,  $I_i$  - the current of  $i^{\text{th}}$  node in iteration  $k$  and  $V_i^{k-1}$  -The voltage of  $i^{\text{th}}$  node in iteration  $k-1$

### Step 2- Backward Sweep

In this step the current of all branches can be calculated from the end-customer nodes towards the root node by:

$$I_L^K = I_i^K + \sum \text{branches derived from node } K \quad (2)$$

Where  $L$  is the branch index and  $I_L^K$  is the current of  $L^{\text{th}}$  branch in iteration  $K$

### Step 3 – Forward Sweep

Update the voltage magnitude of all nodes by the computed current in step 2 using:

$$V_i^k = V_{i+1}^k - Z_L \times I_L^k \quad (3)$$

Where  $V_i^k$  and  $V_{i+1}^k$  are the voltages of two nodes that

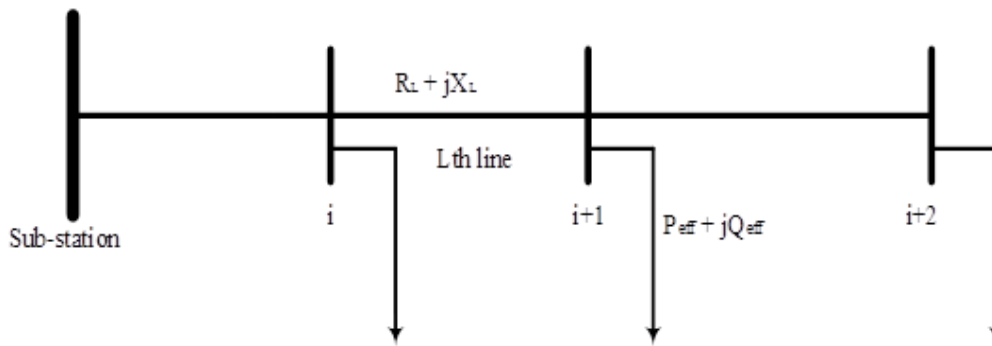


Fig. 1: Sample Radial Distribution Network

are connected through a branch with impedance equal to  $Z_L$

### Step 4 – Convergence Indexes

Calculate the apparent power of loads with new obtained voltages of all nodes. Computing the active power and reactive power mismatch using equations (4), (5) and (6) respectively:

$$S_i^k = V_i^k (I_L^k)^* \quad (4)$$

$$\Delta P_i^k = \text{Real}[S_i^k - S_i] \quad (5)$$

$$\Delta Q_i^k = \text{Imag}[S_i^k - S_i] \quad (6)$$

Where  $\Delta P_i^k$  is active power mismatch in iteration  $k$ ,  $\Delta Q_i^k$  is reactive power mismatch in iteration  $k$  and  $S_i$  is the apparent power of load.

Repeat step 1, 2, 3 and 4 until results satisfies the convergence indexes. BF Load flow program is set to stop repetition when mismatch power  $\Delta P_i^k$  and  $\Delta Q_i^k$  reach initially defined boundary. The capacitor bank is a reactive source in any possible node which injects reactive power to

the network. Active powers of the capacitors are taken to be zero. With capacitor imbedded into the network, equation (1) should be revised to equation (7)

$$I_i^k = \frac{(S_i - Q_c)^*}{(V_i^{k-1})^*} \quad (7) \text{ Where } Q_c \text{ is the capacitor assigned to } i^{\text{th}} \text{ node.}$$

Power loss in the Lth line (where L is the branch index) between two immediate buses 'i' and 'i+1' is given by Eq. (8)

$$P_L = I_L^2 R_L \quad (8)$$

The total power loss,  $P_{\text{loss}}$  in the radial distribution network is given by Eq. (9)

$$P_{\text{loss}} = \sum_{i=1}^{n_b} P_L \quad (9)$$

Where  $n_b$  is total buses in the distribution network.

### Objective Function

The objective of the capacitor placement and sizing problem in the radial distribution network is to minimize the total annual cost due to the network power losses and reactive power compensation subject to the operating constraints. The cost of reactive power compensation includes purchase, installation and operation cost of capacitors. As the location and size of capacitors are to be treated discrete, the mathematical model can be expressed as constraint nonlinear integer optimization problem:

$F_{\text{min}} = \text{Cost of power loss} + \text{Cost of reactive power compensation}$

$$F_{\text{min}} = K_p \times P_{\text{loss}} + \alpha [(C_{\text{inst}} \times N) + C_{\text{cap}} \sum_{i=1}^N Q_{ci}] + (C_{\text{ope}} \times N) \quad (10)$$

Where  $P_{\text{loss}}$  is the total power losses, where  $K_p$  is the annual cost per unit of power losses (#/kW),  $C_{\text{inst}}$  is installation cost,  $N$  is the total number of candidate buses for capacitor placement,  $C_{\text{cap}}$  is the purchase cost of capacitor,  $Q_{cn}$  is the shunt capacitor size placed at bus  $n$  and  $C_{\text{ope}}$  is the operating cost of the capacitor.

In order to measure the value of the voltage stability in the radial distribution network, the Voltage Stability Index (VSI) is determined. Inspecting the VSI performance exposes the buses which undergoing huge voltage drops are weak and within the condition of corrective actions. VSI at line section 'L' between buses 'i' and 'i+1' in the single line diagram shown in Fig. 1 can be calculated using Eq. (11) as given by (Tan *et al*, 2012).

$$\text{VSI}(i,i+1) = \frac{|V_i|^4 - 4[P_{i+1}R_{i+1} + Q_{i+1}X_i] |V_{i+1}|^2 - 4[P_{i+1}R_{i+1} + Q_{i+1}X_{i+1}]^2}{|V_i|^4} \quad (11)$$

Where  $V_i$  is the sending node voltage; while  $P_{ni}$ ,  $Q_{ni}$ ,  $R_{ni}$ , and  $X_{ni}$  are real power, reactive power, resistance, and impedance for the receiving node.

The reactive power support provided by the capacitors also helps to enhance the voltage stability of the distribution network.

### 3.3 Constraints

Each capacitor size minimizing the objective function, must satisfy the following constraints.

#### (i) Shunt capacitor limits

$$Q_{\min} \leq Q_c \leq Q_{\max} \quad (12)$$

Where  $Q_{\min}$  is the minimum compensation limit and  $Q_{\max}$  is the maximum compensation limit

#### (ii) Bus bar voltage limits

$$V_{\min} \leq V_i \leq V_{\max} \quad (13)$$

In radial distribution networks  $V_{\min} = 0.95$  and  $V_{\max} = 1.05$

#### (iii) Total reactive power injected

$$\sum_{n=1}^N Q_{cn} < Q_{\text{total}} \quad (14)$$

Where  $Q_{\text{total}}$  is the total reactive load

### Overview of Cuckoo Search Algorithm

Cuckoo Search Algorithm (CSA) is a meta-heuristic optimization technique whose birth was claimed from inspiration surrounding the brood parasitism of cuckoo species, which lay their eggs in the nests of other host birds. CS Algorithm was developed by Yang and Deb (2009) and it has been applied to various engineering optimization problems. The fundamental ideas in modelling this algorithm was borrowed from the fact that if a host bird discovers foreign egg in its nest, it will either abandon the nest and build a new elsewhere or throw the foreign egg away.

Three rules are taken into account in cuckoo search algorithm as follows:

- (i) At one time, each cuckoo only lays one egg, and leaves it in a randomly chosen nest;
- (ii) The algorithm will carry over the best nest with high quality eggs (solutions) to the next generations;
- (iii) A host bird can discover a foreign egg with a probability,  $p_a = [0, 1]$  while the number of available host nests is fixed. In this case, the host bird can either abandon its nest and build a completely new nest elsewhere or simply throw the eggs away (Yang and Deb, 2010).

A Lévy flight is performed in other to produce new solutions,  $x^{i(t+1)}$  for a cuckoo  $i$  as given in the equation.

$$x^{i(t+1)} = x^{i(t)} + \alpha \oplus \text{Levy}(\lambda) \quad (17)$$



where  $\alpha$  is the step size which should be associated to the problem of interests scales;  $\alpha$  can be set to value 1 in most situations (Yang and Deb, 2009). The random step length of Lévy flight, which fundamentally provides a random walk, is derived from a Lévy distribution with an infinite variance and infinite mean (Yang and Deb, 2010).

$$\text{Levy} \sim u = t^{-\lambda} \quad (18)$$

Here, the sequential jumps of a cuckoo fundamentally form a random walk process with a power law step length distribution with a heavy tail.

### **Application of Cuckoo Search Algorithm to Capacitor Placement**

Application of CSA to the capacitor placement problem is discussed here. The available discrete sized banks could be placed at any location and could be any size. Hence, capacitor placement in a radial distribution network is a complex combinatorial problem which can be solved with any suitable optimization algorithm. This paper reports the successful application of CSA for capacitor placement problem in a practical Nigerian distribution system to minimize the cost due to the system total power loss and reactive power compensation. The details of the solution procedure are provided below:

(1) Input data: the data to be fed as input are listed below.

(a) Number of buses.

(b) Load demand active (kW) and reactive (kVAr) power at each bus.

(c) Bus voltage limit ( $V_{\min}$  and  $V_{\max}$ ).

(d) Distribution lines' impedances (resistance and reactance).

(e) CS parameters (number of nests,  $n=25$ , step size,  $\alpha=1$ , maximum number of iterations, probability to discover foreign eggs,  $P_a = 0.6$ ).

(2) Perform the initial load flow analysis using the Backward/Forward Sweep load flow for radial distribution networks without capacitor compensation (base case). (3) Generate initial population of the hoist nest (solution vector) X

An individual solution is defined as

$[x_1 \quad x_2]$  where  $x_1$  represents the location index for capacitor banks where  $1 \leq x_1 \leq L_b$ , and  $L_b$  is the highest location index; assuming that the location considered for capacitor placement are numbered successively from 1,  $L_b$  is the index number of the last bus. The second part,  $x_2$  carries the integer representing size of the capacitor bank to be placed. To extract the size of the capacitor bank, a multiplication factor is employed as in  $\text{KVar} = x_2 * 50 + 100$ .

$$X = \begin{bmatrix} x_{11} & x_{12} \\ \vdots & \vdots \\ x_{n1} & x_{n2} \end{bmatrix} \quad (19)$$

Each row of the solution vector is one complete solution having information on locations and sizes of capacitor banks. Consider the a solution vector, say  $X = [12 \ 4]$ . The first part gives the location and the second part gives the capacitor banks to be placed at the corresponding location which implies that a capacitor bank of size 300kVAr ( $4*50 + 100$ ) will be placed at bus 12 of the radial distribution network.

(4) Evaluate the solutions  $X$  using load flow and get the following for each solution.

(a) the total active power losses,  $P_{loss}$

(b) The voltage at each bus,  $V_{bus}$

(c) Distribution line flows to determine the overloaded lines.

(5) Calculate the annual cost function for each nest (solution) using the objective function in Eq. (10).

(6) Calculate the fitness function for each nest.

$$FF = \{F_{min} + \sum_{i=1}^{nb} (\text{penalty factor}) \times (V_i - V_{max})^2 + \sum_{i=1}^{nb} (\text{penalty factor}) \times (V_i - V_{min})^2 + \sum_{i=1}^{nb} (\text{penalty factor}) \times (\text{Flow}_i - \text{Flow}_i^{max})^2\} \quad (20)$$

Where the penalty factor is assigned as follows for radial distribution systems.

$$\text{penalty factor} = \begin{cases} 0 & \text{if constraints are not violated} \\ 500 \times F_{min} \times \text{iteration}^2 & \text{if constraints are violated} \end{cases} \quad (21)$$

(7) Generation of Cuckoo: A cuckoo,  $x^{i(t+1)}$  which is a new solution is generated by Levy flight as given in Eq. (17).

(8) Evaluate the cuckoo, new solution, using the load flow to obtain its  $P_{loss}$ ,  $V_{bus}$  and line flows. Calculate the annual cost function for the cuckoo using Eq. (10) and its fitness function, FF using Eq. (20) to determine the quality of the cuckoo.

(9) Replacement: A nest is selected among  $n$  randomly, if the quality new solution in the selected nest is better than the old solution, it is replaced by the new solution (cuckoo).

(10) Generation of new nest: The worst nest are abandoned based on the probability ( $P_a$ ) and new ones are built using Levy flight.

(11) The stopping criterion is set to a tolerance value of  $1 \times 10^{-6}$  and maximum generation of 100 iterations. If the maximum number of iterations is reached or specified accuracy level is achieved, the iterative process is terminated and the result of the CSA displayed. Otherwise, go to step 7 for continuation.

## RESULTS AND DISCUSSION

The network used to test the algorithm is the Imalefalafia 32-bus Nigerian radial distribution networks. The data for the network were obtained from Ibadan Electricity Distribution Company (IBEDC), Ibadan, Nigeria. The loads were modelled using steady state values of the real and reactive power they consumed.

Imalefalafia 11-kV feeder is an outgoing feeder from Imaleafalafia 15 MVA, 33/11-kV injection substation located at Ibadan Oyo State. Imaleafalafia 11-kV feeder has thirty-two buses with thirty-one branches with a total real power loads and reactive power of 3.17 MW and 1.04 Mvar respectively. The single-line diagram of the Imalefalafia 32-Bus feeder is as depicted in Fig. 2.

To achieve the objective function, Backward-Forward sweep algorithm was utilized to obtain the power flow solution, the total power losses and total annual cost. Matlab code was written to add the capacitor bank to the network by suitably modifying the network bus data.

The loads are treated as constant power load and considered as balanced. Design period of one year is taken at full load condition for the purpose of analysis. The various constant assumed in the calculations are (Gnanasekaran et al, 2016): annual cost per unit of power losses( $K_p$ )=183,960 #/kW, purchase cost of capacitor  $C_{cap}$  =8,750 #/kVAr, Installation cost  $C_{inst}$ = 560, 000 #/location and operating cost  $C_{ope}$ = 105,000 #/year per location. Depreciation factor ( $\alpha$ ) of 10% is applied to installation and purchase cost of capacitor banks.

The total power loss and annual cost of operation of the system for the base case are 94.8842kW and #17,454,897.40 respectively. The number of stages (number of iterations),  $K_{max}$  = 100 and the number of nest,  $n$ =25. The possible capacitor banks in discrete sizes are assumed to be from 150 kVAr up to 1000 kVAr in multiples of 50.

After running the algorithm, the returned optimal solution was given as  $X$ = [18 13] to minimize the total annual cost of the radial distribution network. The physical meaning of this is that 750 kVAr of capacitor bank placed at bus 18 will result in the best reduction in the total annual cost of

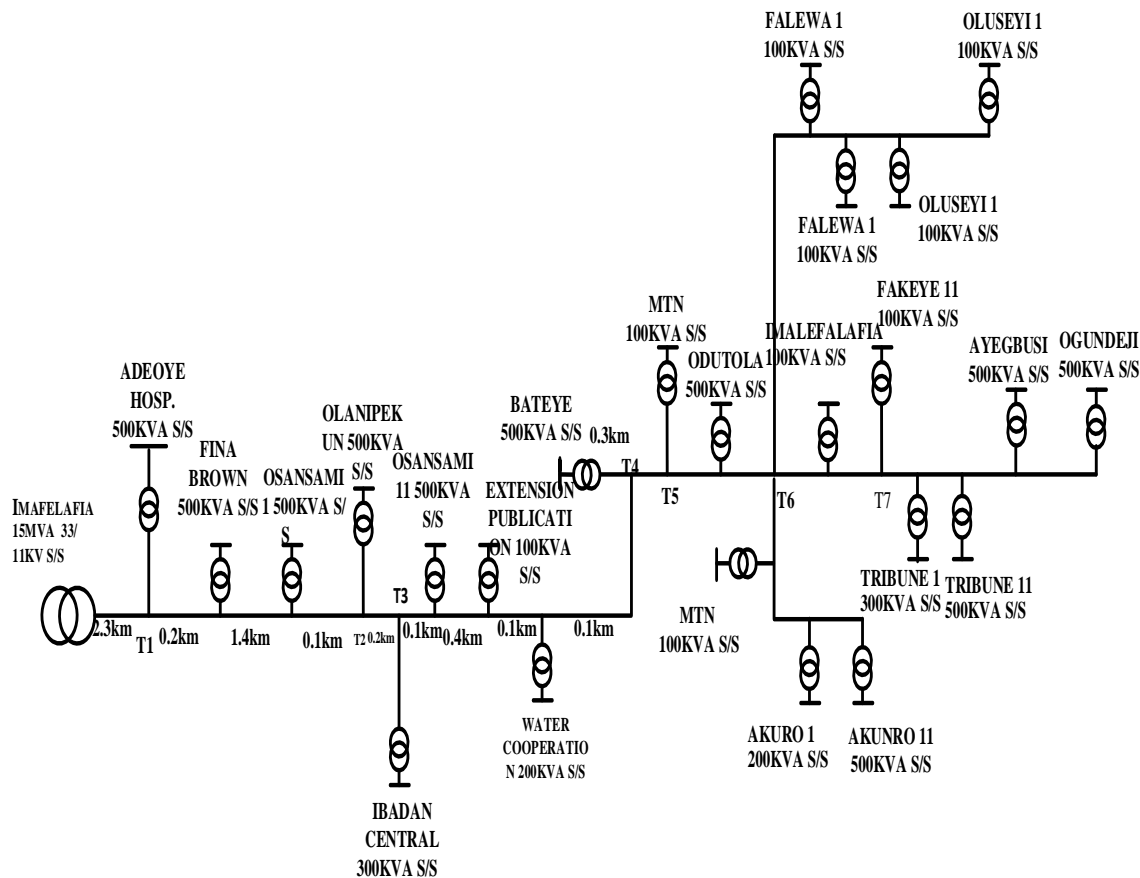


Fig. 2: Imalefalafia 32-bus

The distribution network. The total power loss and annual cost of operation of the system for the optimum case are 84.20 kW and #16, 322, 506.77 respectively. The net cost saving per year is #1,132,390.63. Table 1 summarises the results of the distribution network before and after compensation. The voltage profile of the of the system before and after compensation are is shown in Fig. 3; the voltage shows improvement after compensation. Figure 4 illustrates the voltage stability index for the Imalefalafia 32-bus before and after compensation. It clearly shows that VSI values in the radial distribution system were poor before compensation. After compensation, the VSI values are improved. It is crystal clear from Table 1 that there is significant reduction of cost and total power loss compared to base case. Fig. 5 shows the convergence characteristics of the CSA algorithm for the test system.

Table 1: Summary of Results before and after Compensation for Imalefalafia 32-Bus

	Base Case	After Compensation
Optimal Bus	----	18
Capacitor Size (kVA)	----	750
Power Loss (kW)	94.88	84.20
Total Annual Cost (#)	17,454,897.40	16,322,506.77
Annual Net Saving	----	1,132,390.63
Min. Voltage	0.9502	0.9654
Minimum VSI	0.8152	0.8687
Loss Reduction (kW)	----	10.68
% Loss Reduction	----	11.26
% Net Annual Saving	----	6.49

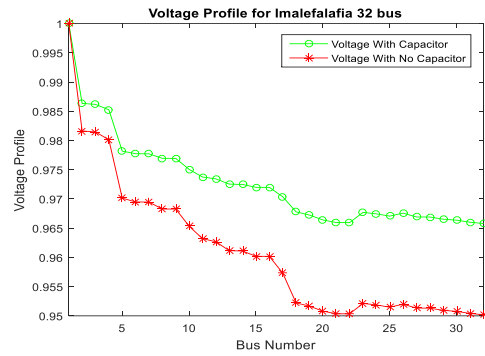


Fig. 3: Voltage profile for Imalefalafia 32-bus

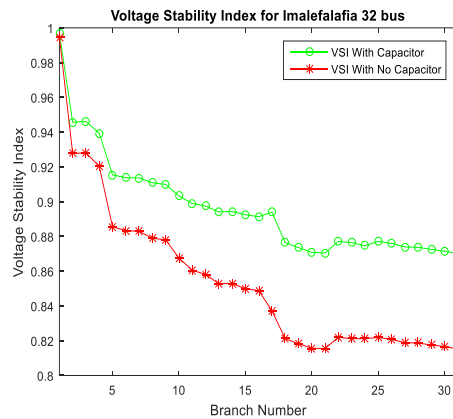


Fig. 4: Voltage stability index for Imalefalafia 32-bus

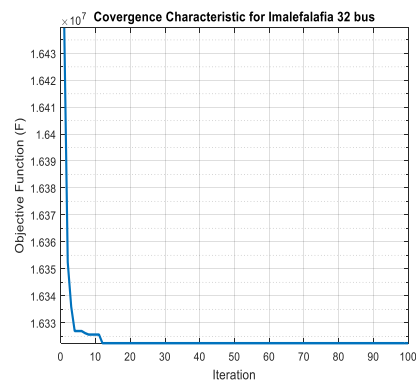


Fig. 5: Convergence characteristics for Imalefalafia 32 bus

## CONCLUSION

A cuckoo search algorithm (CSA) for capacitor placement and sizing problem in the Nigerian radial distribution system to reduce total annual compensation cost with imposed voltage constrained is proposed in this paper. The CSA provides both optimal location and sizing of

capacitor as the outputs. It is demonstrated that the proposed method is capable of saving a significant amount of total annual compensation cost, reducing total power loss, attain improvement in voltage stability, and voltage profile by comparing the results before and after compensation in a practical Nigerian distribution network.

## **REFERENCES**

- Moradi, M. H. and Abedini, M., 2010. Optimal Multi-distributed Generation, Trans, location and capacity by Genetic Algorithms. 4<sup>th</sup> International Power Engineering and Optimization Conference (PEOCO), pp. 400 – 404.
- Elsheikh, A., Helmy, Y., Abouelseoud, Y. and Elsherif, A., 2014. Optimal Placement and Sizing in Radial Electric Power Systems, Alexandria Engineering Journal, 53, 809-816.
- Ochoa, L.F., Padilha-Feltrin, A. and Harrison, G.P., 2006. Evaluating distributed generation impacts with a multi-objective index. IEEE Transactions on Power Delivery, 21(3), pp. 1452– 1458.
- Ponnaivaiko M., Prakasa Rao KS, 1989. Optimal Placement of Fixed and Switched Shunt Capacitors on Radial Distributors by the Method of Local Variations. IEEE Transaction Power Application System, 102, pp. 725-734.
- Baran, M.E. and Wu, F.F., 1985. Optimal Capacitor Placement on Radial Distribution Systems. IEEE Transaction Power Delivery, 4, 725-34.
- Khodr, H.M., Olsina, F.G., De Oliveira-De Jesus, P.M. and Yusta, J.M., 2008. “Maximum Savings Approach for Location and Sizing of Capacitors in Distribution Systems.” Elect Power Energy System Research, 78, pp. 1192-203.
- Raju M.R, Murthy KVSR, Avindra KR., 2012. Direct search algorithm for Compensation in radial distribution systems. Int. J Elect Power Energy, 42(1), pp. 24-30.
- Prakash, K. and Sydulu, M., 2007. Particle swarm optimization based capacitor placement on radial distribution systems, in Power Engineering Society General Meeting, pp. 1-5.
- Rao, R.S., Narasimham, S.V.L. and Ramalingaraju, M. (2011). Optimal capacitor placement in a radial distribution system using plant growth simulation algorithm. International Journal of Electrical Power & Energy Systems, 33(5), pp. 1133-1139.
- Ahmed, A. and Abul’Wafa, A.R., 2014. Optimal capacitor placement for enhancing voltage stability in distribution systems using analytical algorithm and Fuzzy-Real Coded GA, International Journal of Electrical Power & Energy Systems, 55, pp. 246-252.

- Sedighzadeh M, Kalmias F., 2012. A honey bee foraging approach to optimal capacitor placement with harmonic distortion consideration. *Electrical Power System Research*, 7(1), 35-42.
- Tamilselvan, V., Muthilakakshmi, K. and Jayabarathi, T., 2015. Optimal Capacitor Placement and Sizing in a Radial Distribution System using Clonal Selection Algorithm, *ARPN Journal of Engineering and Applied Science*, 10(8), pp. 3304-3312.
- Moeini, A., Yassami, A. M., Owlady, M. and Sadeghi, M. H. 2010. Disco Planner Flexible DG Allocation in MV Distribution Networks using Multi- Objective Optimization Procedures. 12<sup>th</sup> International Conference on Optimization Procedures, pp. 240-245.
- Tan, W. S., M.Y Hassan, M. Y., Majid, M. S. and Rahman, H. A., 2012. Allocation and Sizing of DG using Cuckoo Search. *IEEE International Conference on Power and Energy (PECon)*, Kota Kinabalu Sabah, Malasia, pp. 133 – 138.
- Yang, X. S. and Deb, S., 2009. Cuckoo Search via Levy Flights in Nature and Biologically Inspired Computing”, *NaBIC World Congress*, pp. 210-214.
- Yang, X. S. and Deb, S., 2010. Engineering Optimization by Cuckoo search, *Int. J. Mathematical Modelling and Numerical Optimization*, 1, pp. 330-343.
- Gnanasekaran, N., Chandramamohan, S., Kumar, P.S. and Imran, A. M., 2016. Optimal Placement of Capacitors in Radial Distribution System using Shark Smell Optimization Algorithm, *Aim Shams Engineering Journal*, 7, pp.907-911.



## **DEVELOPMENT OF A DUST EXTRACTOR**

Adeboye, B. S. <sup>1\*</sup> and Raji, A.W.<sup>1</sup>

<sup>1</sup> Department of Mechanical Engineering, Osun State University, Osogbo, Nigeria

Email of Corresponding Author: busayo.adeboye@uniosun.edu.ng

### **ABSTRACT**

The air quality across many cities of the world has reduced drastically as a result of anthropogenic causes. Many production outfits most especially in developing economies like Nigeria generate a lot of dust which reduces air quality, pollutes the environment and ultimately affects the health of man adversely. This study developed a simple, low cost dust extractor to help in extracting dust from production environment. The dust extractor was designed bearing in mind the negative impact of dust to human health with a view to helping in the improvement of the air quality in production environments by extracting and capturing dust and other solid pollutants of related sizes. .

**Keyword:** dust, extractor, development, air, quality

### **INTRODUCTION**

Dust has always been a subject of attraction for human beings due to its effects on human health and also because of the environmental pollution that occurs as a result of dust generation. Dusts are fine particles of solid matter (Merriam-Webster, 2017) generally consisting of particles in the atmosphere that comes from various sources such as soil, dust lifted by wind, volcanic eruptions, and pollution. Dust in homes, offices, and other human environments contains small amounts of plant pollen, human hair, animal hairs, textile fibers, paper fibers, minerals from outdoor soil, human skin cells, burnt meteorite particles, and many other materials which may be found in the local environment (Hess-Kosa, 2002).

The production of dust results in the pollution of the environment. Dusts can be produced as a result of human activities such as road construction, the processing of solid materials (solid minerals, coal, wood, grains and cereals), milling of flours and so on (Ogbeide, 2015). The generation of dusts is influenced by material properties such as hardness, particle size, particle hardness, moisture, and mechanical working processes such as scale of handling, energy used in operation, drop from height and solid mass flow rate (Jia and Huang, 2008). Generation of dusts from these processes if left unchecked can be detrimental to the wellbeing and health of the people in the environment.

Several laws have been enacted to control the indiscriminate pollution of the environment via dust generation and the attendant health risks to human beings. There are diverse methods available for the control of dust emission to the atmosphere; however, most of these methods are only available to large scale industrialist who can afford them. Several small production outfits exist who also generate dust during production and cannot afford the expensive dust extractor available. The need to provide a dust extractor that is both cheap and efficient to cater for the needs of small scale production outfits and commercial enterprises have prompted this study. A dust extractor is used to improve the quality of air released from industrial and commercial processes through the collection or precipitation of suspended dust and other impurities from mechanical equipment (Shaisundaram *et al.*, 2018). They are used in various systems to remove granular solids or powder from industrial processes.

The development of dust extractors are made possible through the use of existing and new technologies (Khurmi and Gupta, 2005). Four major factors affect the performance of dust extractors. They are:

- i. Dust variables
- ii. Fluid variables
- iii. Operational variables
- iv. Collector variables

Dust variables include the size; shape and weight of dust particles are also dependent on the linear dimensions and the density of dust particles. Fluid variable include viscosity and density which are dependent on the composition, temperature and pressure of air in the environment. Operational variables can be specified as velocity of air through the collector or the capacity of the collector.

Shaisundaram *et al.* (2018) designed and fabricated a unit modular dust collector or bag collector for controlling the dust generated in the processing of granular solids. The dust collector extracts dust at the point of generation and conveys the dusts through a filtration system to protect both the personnel operating the production equipment and the equipment itself. This machine successfully captured dust generated with the air stream and conveyed it to the dust collector.

Ogbeide (2015) designed and constructed a dust extractor machine to capture dust-laden air emanating from processing operations such as limestone, crushing, cement production, corn and cassava flour milling. Result from tests carried out on the machine indicated that the machine is very efficient and convenient to use.

Nagaraju and Jatadhara (2018) designed and fabricated a dust collector for city buses to help in controlling Residual Suspended particulate Matters (RSPM) which were generated as a result of agitation of particulate matters on the road by moving vehicles. The Computational Fluid Dynamics (CFD) analysis of the model developed showed that the collector was efficient and the collector was fabricated based on the model.

## **MATERIALS AND METHODS**

### **Design Methodology**

All components were design and constructed in line with the design value that was obtained with respect to the flow rate of the fine dust generated. A proper size for the constructed container was estimated. Then, appropriate choices of materials for all these parts based on cost, functionality and availability were selected, these parts were constructed and assembled together.

### **Principle of operation**

One end of the hood for capturing dust is placed in a dusty atmosphere while the other end is attached to the inlet of the blower/fan by means of a pipe. The blower is then connected to an induction motor. When the machine is powered on, the motor rotates thereby making the blower to also rotate. With the rotation of the blower, dusty air is sucked from the surrounding into the hood for capturing dust. This dust-laden air sucked into the hood then travels into the top of cyclone separator, makes several revolution due to the shape of the entry forming a vortex having a high tangential velocity which accelerates dusty particles outward to the wall of the cyclone. This action causes the dust to be separated from the air which escapes into the atmosphere while the dust particles are collected at the base of the cyclone.

## Component of machine

The main components of the machine are

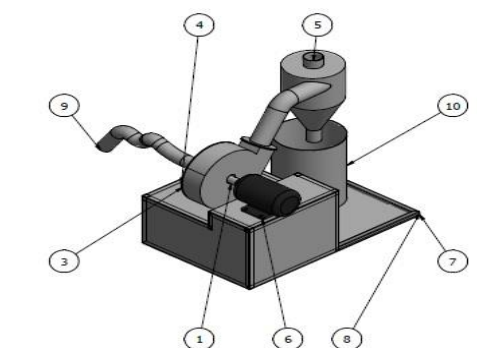
- i. Dust capture hood
- ii. Centrifugal blower
- iii. Air duct
- iv. Cyclone separator

## Design specifications of component parts

The components parts were designed and the dimensions of the main components are listed in Table 1. A complete assembly of the dust extractor is shown in Figure 1

Table 1: Dimensions of component parts

S/N	Component	Dimension
1	Cross sectional area of dust capture hood	0.0025 m <sup>2</sup>
2	Diameter of centrifugal blade	0.2 m
3	Length of air duct	0.4 m <sup>2</sup>
4	Cross sectional area of air duct	0.225 m <sup>2</sup>
5	Cyclone diameter	0.254 m
6	Cyclone length	0.403 m



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Bushing for blade
2	1	cyclone blade
3	1	cyclone casing 2
4	1	cyclone casing cover
5	1	Cyclone
6	1	1-2 HP Electric Motor
7	1	Frame cover
8	1	Main frame
9	1	Flexible inlet
10	1	Dust collector bucket

Figure 1: Complete assembly of dust extractor

## RESULTS AND DISCUSSION

The equipment was fabricated to capture dust laden air in processing environments. A performance evaluation was carried out to determine the quantity of saw dust extracted over a period of time for two particle sizes of saw dust. The result of the performance evaluation is as presented in Table 2

The result showed that the dust extractor constructed was able to extract dust particles efficiently for the two particle sizes considered in the study. However, the machine has a greater efficiency when extracting dust particles with coarse grains compared with the finer dust particle sizes.

Table 2: Performance evaluation of the dust extractor

		<b>Fine dust particle</b>	<b>Coarse dust particle</b>
Weight of particle entrained (kg)		2.997	2.776
Weight of particle		2.332	2.252

deposited

(kg)

Efficiency      77.8%      81.1 %

(%)

---

## **CONCLUSION**

This study successfully constructed and tested a dust extractor. Standard design specifications were adhered to in the design of the equipment. Performance evaluation carried out on the equipment showed that the machine is capable of extracting dust from an environment effectively.

## **REFERENCES**

- Hess-Kosa, K., 2002. *Indoor Air Quality: Sampling Methodologies*. CRC Press, pp 216.
- Jia, Q. and Huang, Y., 2008. Coarse dust around mining areas - a study of available dust collectors and their efficiencies, Unpublished M.Sc Thesis, Luleå University of Technology, Sweden.
- Khurmi R. S and Gupta J. K., 2005. *A Textbook of Machine Design*, Eurasia Publishing House, New Delhi. pp. 2-17.
- Merriam-Webster, 2017. Dust. Archived from the original on 2017-03-14.*
- Nagaraju and Jatadhara, G. S., 2018. Design and construction of dust collectors for city buses, *International Journal for Research in Applied Science and Engineering Technology*, 6(3), pp. 1972-1980.
- Ogbeide, S. O., 2015. Design and construction of a dust extractor machine, *Journal of Multidisciplinary Engineering Science and Technology*, 2(10), pp. 2765-2768.
- Shaisundaram, V. S., Chandrasekaran, M., Mohan Raj, S., Muraliraja, R., and Vinodkumar, T., 2018. Control of carbon dioxide emission in automobile vehicles using CO<sub>2</sub> scrubber, *International Journal of Ambient Energy*, pp. 1-10.

## **HEALTH IMPAIRMENT OF CLIMATE CHANGE AMONG AGED PEOPLE IN IBADAN, NIGERIA**

Kehinde, O. J.<sup>1\*</sup> and Adeboyejo, A. T.<sup>2</sup>

<sup>1</sup>Department of Estate Management, Lead City University, Ibadan and

<sup>2</sup>Department of Urban and Regional Planning, Ladoko Akintola University of Technology, Ogbomosho

\*E-mail of Corresponding Author: olamijukehinde@gmail.com

### **ABSTRACT**

Susceptibility to ill health of the vulnerable groups (children, women and the aged) had been linked with the impacts of climate change especially in rapidly urbanising cities in Nigeria. Therefore, this study evaluates aged peoples' vulnerability to health impacts of climate change in Ibadan, Nigeria. The incidence of clinically diagnosed climate related diseases (CRDs) (2000 - 2014) among aged people (>50 years) in Ibadan and available climatic parameters of temperature and rainfall (1970 - 2014) were obtained and projected to year 2050. Also, the relationship between the climatic parameters and incidence of five most prevalent CRDs was analysed using multiple regression. The increasing trend of mean maximum temperature ( $r = 0.47$ ) and rainfall ( $r = 0.15$ ) is found associated with incidences of hypertension (34.4%), respiratory diseases (21.2%) and diarrhoea (14.3%) among aged people (> 60 years) and especially among the male folk (67.2%). The incidence (46.4%) and mortality (54.8%) owing to the CRDs are both highest for high residential density. The linear composite of disease communalities extracted 84.0% variance of the data set with the following component scores: skin disease (0.98), hypertension (0.96), respiratory disease (0.92), diarrhoea (0.89) and malaria (0.45). Further, CRDs ( $R^2 = 27\%$ ,  $p = 0.012$ ) in Ibadan among aged people could be significantly attributed to influences of climatic parameters. The need to build the aged resilience to emanating impacts through health and nutritional improvement programs and provision of neighbourhood parks and gardens were suggested.

**Keywords:** Vulnerable Group, Climate Change, Aged People, Health Impairment, Climate Related Diseases

### **INTRODUCTION**

The physical, environmental, economic and social factors in any nation are known to contribute immensely to the state of health of the people especially the vulnerable ones which include children, women and the aged (Lee *et al.*, 2015; Niang *et al.*, 2014). However, the uncontrollable rate of urbanisation and its attendant problems had further exacerbated impairments that the vulnerable suffered in the face of existing precarious situations impressed on them by factors operating in most developing nations and those of changes in climate (Appiah *et al.*, 2014; Lwasa, 2014 and Linard *et al.*, 2013). The aged people become more susceptible to impacts around them owing to the ageing of their immune system, their weakened economic viability and lack of special attention on their health in terms of health care services in the nation.

Given aged peoples' susceptibility to emerging impacts of climate change, they had become sickly having suffered from food- and water-borne diseases like diarrhoea, cholera, respiratory diseases, malaria, typhoid and blindness among others (Mattah *et al.*, 2017; Barnes *et al.*, 2013; D'Amato *et al.*, 2013; and Comrie, 2007). The aged are further faced with life threatening health risks due to increasing heat waves and fluctuating rainfall pattern. This was largely resulting from their decreased mobility, irregularities in usual supply of nutritional food and safe water and haphazard distribution of and limited access to health care facilities on the one hand and the existing precarious poverty, economic dislocation and deaths of promising and bread winners in the family (Lee *et al.*, 2015 and Kehinde, 2017).

These aged vulnerable individuals having been left at the mercies of their environment, available inadequate and less functioning resources and their immediate relatives and neighbours who may not be able to aid them when they are in distress; had often resorted to using unsafe sources of water for domestic chores, cooking and even drinking. Their immunities become further broken down as they survived on less nutritious and imbalanced diet. Worst still, they cannot even afford to attend hospitals to seek medical interventions for their ailments as quickly as possible and within threshold distances nor purchase drugs for their recuperation. They are even mostly unable to link their predicaments to climate change impacts neither do they have understanding of salient issues (Mattah *et al.*, 2017 and Lwasa, 2014). Against this backdrop the study evaluates the health impairment of aged people to the impacts emanating from climate change in Ibadan, Nigeria with a view to mitigating the impacts and enhancing their capacities to further cope.

## **MATERIALS AND METHODS**



## Brief of the Study Area

Ibadan is situated in the rainforest, along longitude 3°5' East and latitude 7° 23' North, covering a distance of 145km northeast of Lagos and extends across northwest to southeast direction. The peaks of the town range from 160 - 275m above sea level at Mapo, Mokola and Aremo with mean annual temperature and rainfall of about 26.46°C and 1420.06mm respectively with the hottest month July having temperature beyond 27°C and the coolest period in the raining season in August (Kehinde, 2017). Ibadan metropolis has a population of 1,343,147 (NPC, 2006) while the total population of the study area is 855,426. This study focuses on health impacts of climate change on the aged people ( $\geq 50$  years) in Ibadan. A thirteen (13) years hospital record of clinically diagnosed climate change related diseases (CRDs) (2000 to 2012) was obtained from the University College Hospital (UCH), Ibadan being a teaching hospital with wide catchment area, availability of crops of equipment and high calibre personnel.

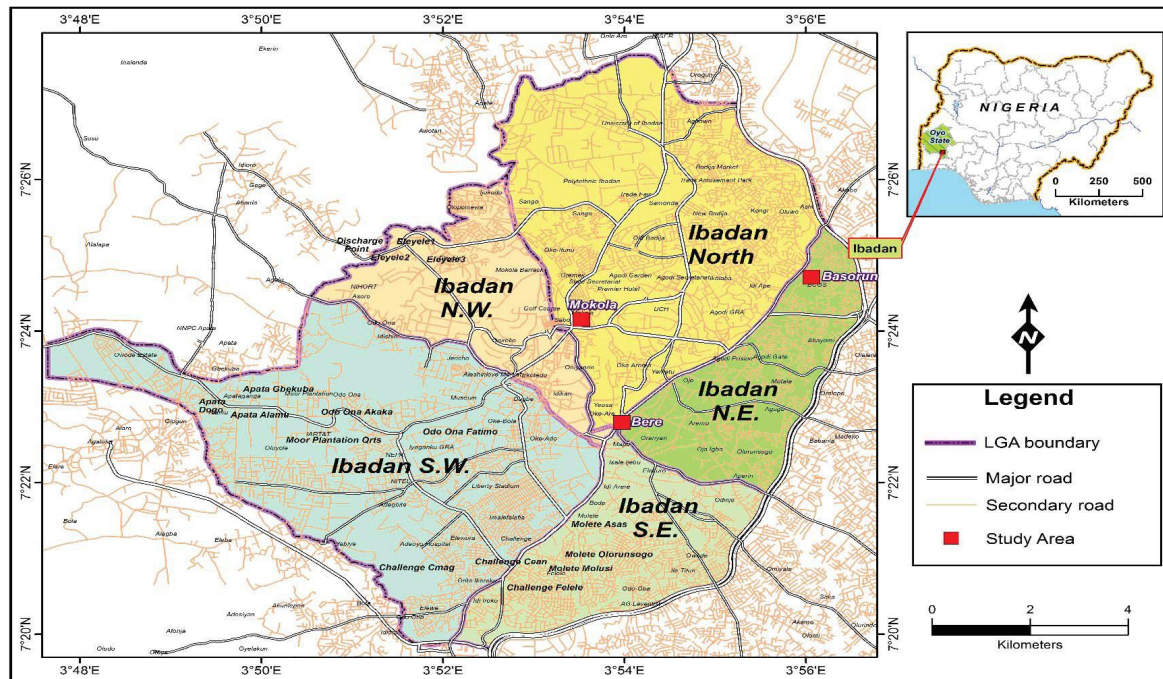


Fig.1: Ibadan Metropolis

Source: Adopted from Salami *et al.*, 2016

## Methods of Data Collection

A pro-format questionnaire was designed to record observations on clinically diagnosed climate related diseases (such as malaria, typhoid, diarrhoea, cholera, respiratory diseases and blindness) among old age people from Central Records Unit of University College Hospital, Ibadan; and data on temperature and rainfall patterns were also obtained from Nigeria Meteorological Agency (NIMET) (2000 - 2012). Elicited information from the questionnaire include but not limited to addresses and residential densities of patients, climate related illnesses suffered, sex of patients, month and year of admission, diagnosis and prognosis among others.

### **Method of Data Analysis**

The study however, uses frequency tables, cross tabulations and charts to illustrate such information as spatial variations in the incidences and prevalence of climate related diseases. This was done to enhance visual impression of results. While Chi-Square test was specified to establish the significance of any observable variation in relationship among variables, Pearson Correlation was used to test the relationship between the incidences of Climate related diseases and their years of occurrence on the one hand and the relationships between temperature and rainfall, and their year of occurrences on the other hand. Principal Component Analysis was also used to factor analyse the incidence of climate related diseases for a disease factor and to know their variances. However, Multiple Regression analysis was employed to examine and test the strength of relationship between climatic parameters (independent variable) and the incidences of climate related diseases (dependent variables). Generalization and conclusions were thus carefully inferred from the results of findings of this study.

## **RESULTS AND DISCUSSION**

### **The Trend in Climatic Parameters in Ibadan**

The observed fluctuations in climatic parameters in Ibadan within 1970-2007 review period show that the mean maximum temperature ranged from 30.3<sup>0</sup>C in 1976 to 33.3<sup>0</sup>C in 1998 with an annual increase of 0.08<sup>0</sup>C while the mean minimum temperature ranged from 21.24<sup>0</sup>C in 2006 to 23.68<sup>0</sup>C in 2005. The observed variability increases with years given mean maximum ( $r = 0.47$ ) and mean minimum ( $r = 0.34$ ) temperatures. However, within the same review period, the trend of rainfall distribution was irregular with sharp increases in quantities observed in 1970 (80.0mm) and 1980 (163.8mm), and an unprecedented drop in 1982

(63.4mm) despite the flood in the city that year. The existence of a weak but positive Pearson's Correlation Coefficient ( $r = 0.16$ ) is a pointer to the continuous but slow increase in rainfall with those years (see fig. 2 and 3).

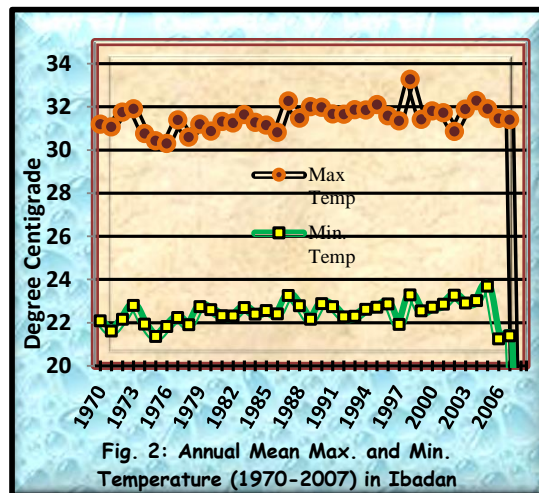


Figure 1: Temperature change with time

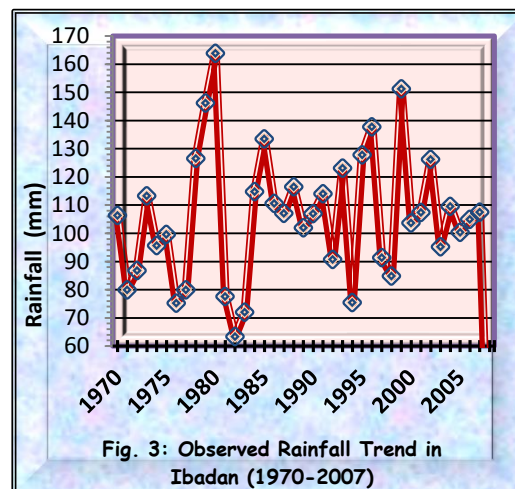


Figure 2: Rainfall change with time

Source: Author's field work, 2017

With continuing urban expansion and encroachment of Ibadan city into the hinterlands, the warming tendency of the city is bound to escalate with years. The predictions of the mean maximum and minimum temperatures with Pearson's Correlation Coefficients  $r = 1.0$  and  $0.99$  respectively and that of rainfall  $r = 1.0$  signified that the warming of the city will continue to

2050 though, increasing quantity of rainfall have/may not culminate into an easement of water stresses especially given the bottleneck in the services of the State Water Corporation in Ibadan.

### **The Incidence and Typology of Climate Related Diseases (CRDs) in Ibadan**

This study within a review period (2000-2014), identified eight (8) climate related diseases (CRDs) among the aged people ( $\geq 50$ years) admitted and treated at the University College Hospital (U.C.H), Ibadan. The CRDs include: Hypertension (35.1%), Respiratory Disease (21.7%), Diarrhoea (14.6%), Malaria (7.5%), Skin Disease (7.3%), Asthma (6.9%), Typhoid Fever (4.5%) and Blindness (2.4%) of which the first five, representing 86.1% were most prevalent in that order. The evident increase in local warming had its toll on incidences of these CRDs, making the aged people more vulnerable especially given their weak adaptive capacities.

For the first three most prevalent CRDs, Ibadan North (IBN) was worst hit with respiratory disease (29.4%) and hypertension (28.6%), and following next to the worst hit by diarrhoea (19.4%); while Ibadan South-west (IBSW) had followed IBN in the incidences of hypertension (22.4%) and of respiratory disease (23.1%) and was worst hit by diarrhoea (27.8%) whereas, Ibadan South-east was third placed with the incidences of diarrhoea (13.0%) and respiratory disease (8.8%) whilst the third worst hit by in the incidence of hypertension was Egbeda (8.1%). Notedly, though not statistically significant, the intra-urban differentials in CRDs incidences were more pronounced in the metropolis than elsewhere given the  $X^2 = 58.848$  and  $p = 0.519$ , except at places outside Ibadan and Egbeda LGA. Also, it was clear that patronage for CRDs treatment at the College Hospital decreases with distance away from the clinic. However, given numbers of referral cases and patronages for treatment of all sorts, it was obvious that the University College Hospital, Ibadan is notable for its crop of professionals and medical equipment acquisitions among others.

### **Temporal and Spatial Variations in Climate Related Diseases (CRDs) Incidences in Ibadan**

The trend of climate related diseases (CRDs) incidences increases with years in a dinosaur trajectory motion given the Pearson's Correlation Coefficient ( $r = 0.93$ ) though, with

drops during years 2002, 2004, 2006, 2007, 2010 and 2013. One would observe the tendency for a drop in incidence between 2-3 years (not statistically proven). The total incidences of CRDs ranged from 0.7% in 2000 to 12.5% in 2014 and with Pearson’s Correlation Coefficient (r) of 0.99, projected trend suggests increasing incidences of CRDs to year 2050 (see fig. 4).

Generally speaking, the incidences of CRDs was highest in April (10.3%) during the wake of the rainy and lowest in February (5.4%) at the tail end of dry seasons. For highest incidence (highest patronage for CRDs treatment) across spatial units, the high residential density had three top incidences in March (11.4%), November (10.8%) and September (9.9%); the medium residential density had top incidences in April (11.5%), October (10.6%) and in each of July and August (10.1%); the low residential density had its top incidences in May (18.7%), September (11.0%) and in each of April, October and December (8.8%) whilst at places outside Ibadan, the incidences were pronounced in August (19.5%), May (16.1%) and January (9.2%).

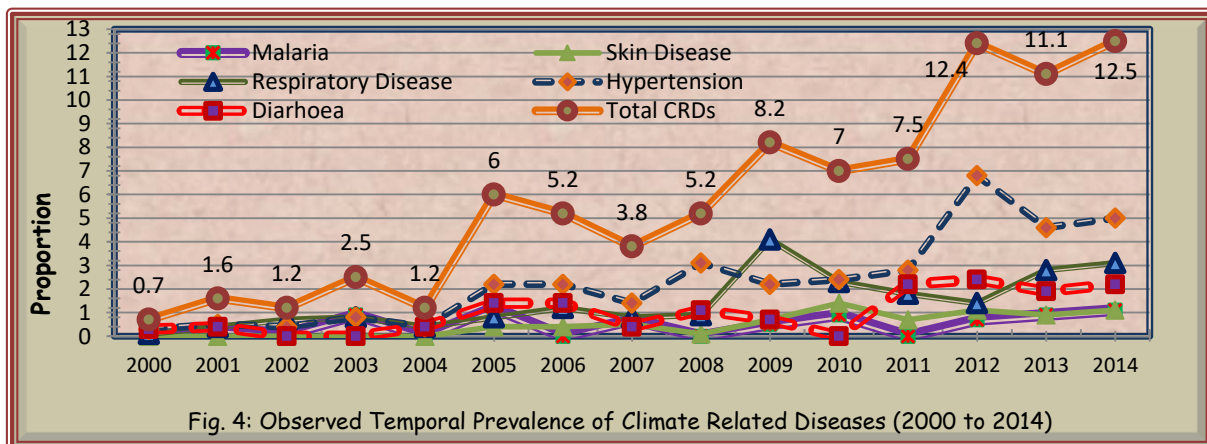


Fig. 4: Observed Temporal Prevalence of Climate Related Diseases (2000 to 2014)

Source: Author’s field work, 2017

### Gender and Age Specificity of Climate Related Diseases (CRDs) Incidence in Ibadan

This study observed that more men (55.9%) than women (44.1%) were hit by CRDs in Ibadan. More explicitly (58.1%) and (55.7%), and (60.3%) among men from high and medium residential densities and from outside Ibadan respectively were susceptible to the incidences of CRDs compared with women. However, at the low residential density more women (56.1%) than men were significantly worse hit ( $X^2 = 15.426$  and  $p = 0.031$ ).

Furthermore, majority of the aged people (37.8%) treated with any CRDs in Ibadan were aged 50-60 years followed by age 61-70 years (35.0%) and age 71-80 years (19.6%). A cursory look shows that residents aged 50-60 years were most susceptible to malaria (40.0%); diarrhoea (39.8%), hypertension (39.4%) and respiratory disease (36.9%) whereas, skin disease was highest among those aged 61-70 years. One would observe that incidences of CRDs decreases with age consequent upon the facts that most aged people died before any notice of their ailments on the one hand for reason of weakened physiology and agility, and because few people survived beyond the life expectancy age of 55 years and dearth of records on causes of death among aged people on the other hand.

### **Variation in Climate Related Diseases (CRDs) Induced Mortality in Ibadan**

Only less than one-fifth (12.6%) of those diseased with any climate related disease (CRD) had expired within the review period [indicating more men (66.7%) than women (33.3%)] implying that recuperation rate for any of the CRDs was higher. The high residential density held the highest record of death (54.8%) blamed on CRDs incidences while the medium and low residential densities, and places outside Ibadan had 26.9% and 11.8%, and 6.5% records of death from CRDs incidences respectively. By gender, more men in the high (66.7%) and medium (76.0%) residential densities and from places outside Ibadan (83.3%) than women had significantly expired whereas, at the low residential density more women (63.6%) than men had expired owing to CRDs incidences ( $X^2 = 3.950$ ;  $p = 0.047$ ).

### **Relationship between Climatic Parameters and Climate Related Diseases in Ibadan**

The tested relationship between climatic parameters (temperature and rainfall) and CRDs incidences extracted 84.0% variance of linear composites of disease factor with component scores of skin disease (0.979); hypertension (0.959); respiratory disease (0.917); diarrhoea (0.893) and malaria (0.453). Results further show that with  $r = 0.519$  and coefficient of multiple determination  $R^2 = 0.270$ , about 27.0% incidence of CRDs are attributed to changes in climatic parameters. Consequently, other 73.0% incidence of CRDs in Ibadan may be due to other factors not here explained. The significance of relationship attested by  $F = 5.169$  and  $p = 0.012$ . The calibration of predictive model  $y = a + b_1x_1 + b_2x_2 + e$ ; where  $y$  = the linear

composite of the diseases (malaria, hypertension, diarrhoea, skin and respiratory diseases) and  $x_1$  and  $x_2$  are maximum temperature and average rainfall; weighs:

$$y = - 62.812 + 1.74 (\text{max. Temp.}) + 0.106 (\text{av. rainfall}) + e \dots\dots\dots (1)$$

This shows that a unit increase in temperature will result in over 100% (1.74 fold) increase in incidence of the five most prevalent CRDs whereas, a unit increase in rainfall distribution will only yield about 10.6% (0.106 fold) increase in CRDs incidences. However, a 35years projection show that with correlation coefficient ( $r = 0.99$ ), incidence of CRDs will increase with years, ranging from 12.5% in 2015 to over 42% in 2050.

## **CONCLUSION**

The impacts of climate change as observed had been severe on the health of the aged people in Ibadan, Nigeria especially given existing pervasive poverty because on the one hand, they had to spend the little resources at their disposal for treatment of CRDs. On the other hand, the dearth of information on health care services and inadequate health facilities with focus on the aged had added to their susceptibility while some of them had expired owing to their exposure to such CRDs within the review period.

Therefore, this study recommends that provisions should therefore be made for comprehensive health care programmes coupled with nutritional supports for the aged, the use of certified care givers to cater for registered aged people owing to their decreased mobility; this will solve the problem they face having to travel over some inconvenient distances to get treatment for their CRDs. In addition, alternative transportation options can be arranged for them. Lastly, educating the aged people and their relations on resilience (psychological, physical, mental and social) building is pertinent just as much as bringing them close to nature.

## **REFERENCES**

T. M. Lee, E. M. Markowitz, P. D. Howe, C.-Y. Ko, and A. A. Leiserowitz, (2015), “Predictors of Public Climate Change Awareness and Risk Perception around the World,” *Nature Climate Change*, vol. 5, no. 11, pp. 1014–1020.

I. Niang, O. C. Ruppel, M. A. Abdrabo (2014), “Climate Change, 2014: Impacts, Adaptation, and Vulnerability,” in *Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change*, V. R. Barros, C. B. Field, D. J. Dokken et al., (eds.), pp. 1199–1265, Cambridge University Press, Cambridge, UK and New York, NY, USA.

D. O. Appiah, J. T. Bugri, E. K. Forkuor, and P. K. Boateng (2014), “Determinants of Peri-Urbanization and Land Use Change Patterns in Peri-Urban Ghana,” *Journal of Sustainable Development*, vol. 7, no. 6, pp. 95–109.

S. Lwasa (2014), “Managing African Urbanization in the Context of Environmental Change,” *Interdisciplina*, vol. 2, no. 2.

C. Linard, A. J. Tatem, and M. Gilbert (2013), “Modelling Spatial Patterns of Urban Growth in Africa,” *Applied Geography*, vol. 44, pp. 23–32.

P. A. D. Mattah, G. Futagbi, L. K. Amekudzi (2017), “Diversity in Breeding Sites and Distribution of Anopheles Mosquitoes in Selected Urban Areas of Southern Ghana,” *Parasites & Vectors*, vol. 10, no. 1, article no. 25.

O. J. Kehinde (2017), “*Household Vulnerability and Response Patterns to Climate Change and Poverty in Ibadan, Nigeria*” An Unpublished Ph.D Thesis submitted to the Department of Urban and Regional Planning, Ladoke Akintola University of Technology, Ogbomosho.



R. O. Salami, J. K. Von Meding and H. Giggins (2016), “Assessing Habitats of Vulnerability in African Cities: A Case of Poverty Housing in Ibadan Metropolis, Nigeria” A Paper Presented at the University of Maryland Project Management Symposium held on May 12 – 13, 2016.

## **COMBATTING ENVIRONMENTAL BURDENS THROUGH ANAEROBIC DIGESTION OF SELECTED ANIMAL WASTES CO-DIGESTED WITH FOOD WASTES AT MESOPHILIC TEMPERATURE**

Oladejo, O.S.<sup>1</sup>, Salami, A.<sup>1</sup> and Adebayo, A.O.<sup>2\*</sup>

<sup>1</sup>Department of Civil Engineering, Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomosho, Nigeria.

<sup>2</sup>Department of Agricultural Engineering, Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomosho, Nigeria.

\*Email of Corresponding Author: [aoadebayo57@lautech.edu.ng](mailto:aoadebayo57@lautech.edu.ng)

### **ABSTRACT**

A shift to biogas appears to be one of the leading alternatives to combatting environmental burdens associated with the use of conventional sources of energy (fossil fuels) and agricultural wastes. The livestock industry is one of the priority targets of agricultural pollution. Also, food wastes have been enlisted as the largest contributor to Municipal Solid Wastes (MSW). To this end, this study investigated biogas production potentials of selected animal wastes (pig wastes and cow dung) co-digested with food wastes at mesophilic temperature (35°C) in a computerized Edibon anaerobic digester. Samples 1 and 2 which consisted of the mixture of pig slurry /food waste and cow dung / food waste at ratios 3:1 respectively were anaerobically digested. The sample/water mixing ratio was 1:1. For sample 1, the Total solid (TS), Volatile Solid (VS), Fixed Solid (FS) and Organic Carbon (C) were found to be 48.70, 92.50, 7.49, 22.64 and 50.22, 75.82, 24.18 and 18.52 % before and after digestion respectively. Similarly, the TS, VS, FS and C for sample 2 were 11.43, 94.26, 5.74, 19.80 and 21.14, 88.49, 11.51 and 11.9% respectively before and after digestion. The biogas potentials of samples 1 and 2 were found to be 0.085 and 0.098 m<sup>3</sup>/kg respectively. Thus, the environmental burdens could be combatted through anaerobic digestion of pig waste and cow dung co-digested with food wastes at mesophilic temperature.

**Keywords:** Energy, biogas, anaerobic digestion, pig waste, cow dung, mesophilic

### **INTRODUCTION**

The degradation witnessed by our environment due to the negative effect of the conventional sources of energy is a major concern that has necessitated researching into alternative sources which are mostly renewable. Renewable energy is being advocated globally to replace conventional energies and to reduce the effects of global warming. Waste to energy is a renewable and environmentally sound process that has been proven to be reliable as an energy substitute in developed and developing nations (Dennis and Burke, 2001).

Municipal Solid Waste (MSW) disposal is a major environmental challenge confronting many developing countries. According to Babayemi and Dauda (2009), the problem of waste management has two components: Collection and disposal. Disposal methods such as: dumping sites, incineration and home garbage disposal units have been used in different society (Sha'Ato *et al*, 2006). Increased global urbanization and economic expansion of developing countries are leading to accelerating rates of municipal solid waste production.

Excessive energy demands from both rural and urban dwellers imply that natural sources of energy must be explored. Hence, the conversion of agricultural wastes and animal wastes into biogas could be a leeway to solving some of these energy problems (Ofoefule and Uzodinma, 2009).

A large quantity of wastes (both liquids and solids) is being generated by urban, municipal and industrial sectors. These wastes are being disposed generally into ponds, rivers, lands and so on, causing environmental impacts. Waste disposal has become a major environmental problem (Olaniyan, Ige and Akeredolu, 2015). The practice of waste disposal to landfill site has generally been favoured because of cost advantage. However, there's a realization of the possible environmental impacts and concerns on ground water, air quality, disease transmission, operational safety and so on (Ravindranath and Usha, 2000). Burning MSW produces nitrogen oxides and sulphur dioxide as well as trace amounts of toxic pollutants, such as mercury compounds and dioxins.

The difficulty in disposing the pig waste (which emits toxic ammonia into the atmosphere when disposed carelessly); in large intensive rearing houses, has become a huge source of concern to the safety of the environment. The livestock industry has been set as a priority target of agricultural pollution control. Its untreated wastes when applied directly to farmland would result to a huge environmental challenge (Zhang *et al.*, 2016). The animal wastes can be used as manure

and applied to enrich the cropland's nutrient, especially because of the nitrogen (N) nutrient content. However, if it's untreated and applied in excess, it can lead to surface and groundwater contamination (Song *et al.*, 2012).

Likewise, food waste has been established to be one of the leading sources of municipal solid waste (MSW) pollution (USEPA, 2008). Thus, this study would co-digest both the pig waste and food waste with the application of both anaerobic digestion and aerobic composting. This is not only to generate biogas but also to reduce the weight/volume of the biowaste and to produce a biofertilizer which would be environmentally acceptable.

However, to ascertain that the co-digested pig waste and food waste has good biogas production potentials, this study also co-digested cow dung and food waste of equal weight/volume alongside during the anaerobic digestion. This is because from several studies cow dung has been known to be a good source of biogas production through anaerobic digestion (Nelson, 2008).

Several researchers have produced biogas through mono and co-digestions of various agricultural residues (Adebayo *et al.*, 2013, Adebayo *et al.*, 2014 a, b, Adebayo *et al.*, 2015 a, b, c and Jekayinfa *et al.*, 2015)

According to WRAP (2010), anaerobic digestion is "a process of controlled decomposition of biodegradable materials under managed conditions where free oxygen is absent, at temperatures suitable for naturally occurring mesophilic or thermophilic anaerobic and facultative bacteria and archaea species, that convert the inputs to biogas and whole digestate". Gregor and Grilc (2012) stated that, there are four biological and chemical stages (biochemical reaction stages) of anaerobic digestion which includes: Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis.

## **METHODOLOGY**

### **Anaerobic Digestion**

The cow dung and food waste were gotten from the farm and cafeteria of the Landmark University (LMU), Omu-aran, Kwara State, Nigeria. Also, the pig waste was collected from the pig rearing farm close to the same institution (LMU). Both samples were brought to the Environmental laboratory of the Civil Engineering Department and the soil laboratory of the Agricultural Engineering Department of the institution.

The physicochemical properties of all the samples were determined. The determined properties included %TS, %VS, %FS, %C, N (mg/l), pH, Total alkalinity and ammonia-nitrogen. This was done using standard methods. After this, the weight of both samples was weighed before loading into the anaerobic digester simultaneously. Samples 1 and 2 consisted of the mixture of pig slurry /food waste and cow dung / food waste at ratios 3:1 respectively.

Both Samples were first pre-treated before loading them into the anaerobic digester. The pre-treatment was achieved by heating both samples to 90°C for 1 hour in a laboratory oven (model: DHG-9053A) and allowed to cool down for 12 hours. The pretreatment process was aimed at sterilizing, pasteurizing and reducing the surface area of the biowaste for better biodigestion (Tanaka and Kamiyama, 2002). The samples were then anaerobically digested in a computerized Edibon anaerobic digester (PDANC 007/14) operated at mesophilic temperature (35°C). The sample/water mixing ratio was 1:1.

The reactor was maintained at 35°C (mesophilic temperature). The reactor was maintained at this temperature because a sharp fluctuation in temperature can affect the methanogenetic bacteria which are very sensitive to temperature change.

Likewise, the pH value of the anaerobic digestion system was maintained between 6.5 - 8.5, by collecting samples of the substrates regularly from the anaerobic digester to carry out pH-tests with the aid of a pH meter (model: PHS-3C). The pH test was to avoid system failure or ammonium build-up within the anaerobic system during the digestion process.

During the anaerobic digestion, the temperature and the pH were used to monitor the stability of the process, this makes us know what corrective measure to put in-place in case of pH fluctuation (Esposito *et al*, 2012). However, the total alkalinity was ensured to be above 20mg/l by series of concurrent tests of the substrates with the aid of a photometer (model: Palintes 7100).

The biogas production was monitored until a sharp decline was noticed from both samples. The pH was again measured, and the experiment was terminated after it was observed that the anaerobic microbes had exhausted the biodegradable fraction of the loaded samples.

Then samples were taken from both waste-samples to carry-out the physicochemical properties as earlier done before loading both samples into the anaerobic digester. Likewise, the weight of the digestate was immediately measured by a weighing scale, so that the weight/volume loss due to the anaerobic process could be noted. Comparison was thus, made

between the changes of the physicochemical properties/parameters of both samples, before and after anaerobic digestion, likewise their degree of weight-loss.

### **Aerobic Composting**

The digestate (the left-over biowaste which couldn't be biodegraded to biogas by the anaerobic microbes) of sample 1 alone was loaded into the aerobic digester for aerobic composting 24 hours after the anaerobic digestion process ended. This is because sample 2 (co-digested cow dung) was simply used for comparison of biogas production potentials at the anaerobic digestion stage alone.

A sample was taken from the waste-sample (sample 1) each day for the five days the aerobic process lasted, to obtain some physicochemical parameters. These physicochemical parameters included: Organic nitrogen (N), Ammonia content, Total alkalinity, DO, BOD and COD of the aerobic compost. Likewise, it was ensured that there was adequate aeration penetration into the compost-pile by proper agitation and, that the compost pile was damp enough for the aerobic compost process.

The aim of the daily analysis experiment was to investigate if aerobic microbes could further degrade the digestate of the anaerobic digestion, with further reduction in waste weight/volume. This was also to ascertain if the compost to be harvested as biofertilizer, was up to the acceptable limits, set by FAO (1996) and FEPA (2004).

After five days of aerobic composting, the process was halted, compost harvested and weighed immediately. This was to ascertain if there was a notable reduction in the weight/volume of sample 1. Thus, the weight/volume of the compost and digestate were both compared, likewise was the final physicochemical property of the compost compared. Both the weight/volume change and change in the physicochemical properties of Sample one was noted for analysis and proper conclusions about the study.

## **RESULTS AND DISCUSSION**

### **Anaerobic Digestion**

Tables 1 and 2 present the physicochemical characteristics of Samples 1 and 2 respectively. From Tables 1 and 2, it was observed that the % TS increased. It increased from 15 % to 50.22 % for Sample 1 and from 11.43 % to 21.14 % for Sample 2. Although according to Igoni *et al.*, (2008), increment in TS does not necessarily determine the production capacity of biogas, as several other anaerobic digesters showed increment in TS which in most cases,

corresponded to reduction in biogas production while a few others experienced the opposite. It only makes it vivid that, the process leads to reduction in the moisture content of both samples (Motte *et al*, 2003).

It was also observed from Tables 1 and 2 that, the % VS reduced from 92.50 % to 75.82 % for Sample 1 and from 94.26 % to 88.4 % for Sample 2. This is an evidence that biodegradation occurred (VS is the biodegradable fraction of the TS in %). Although, biodegradation occurred in both samples, the high VS % left still shows that, more biodegradation could still take place on both samples. This can be achieved by employing microbes other than the anaerobic microbes, for example in this case-study aerobic microbes were employed.

Figure 1 presents the biogas production potentials of Samples 1 and 2. It could be seen that the biogas production began in Sample 1 after 13 days both samples were loaded into the bio-digester. It took Sample 2 about 5 days more to begin gas production thus, Sample 2 began gas production 18 days after being loaded into the bio-digester since both samples were loaded-in simultaneously. The biogas potentials of samples 1 and 2 were found to be 0.085 and 0.098 m<sup>3</sup>/kg respectively.

This obviously shows that, the co-digesting pig waste with food waste is a good biogas source just like co-digesting cow dung with food waste; under mesophilic temperature range, which was adopted for this study.

Table 1: Physicochemical Parameters of Sample 1 before and after Anaerobic Digestion

Parameters	Before Digestion	After Digestion
%TS	48.70	50.22
%VS	92.50	75.82
%FS	7.49	24.18
VS/TS	1.90	1.51
%C	22.64	18.52
N (mg/l)	20.0	18.70

pH		7.70	8.48
Total Alkanity (mg/l)		340	320
Ammonium- (mg/l)	N	0.28	0.21

**Table 2: Physicochemical Parameters of Sample 2 before and after Anaerobic Digestion**

Parameters	Before Digestion	After Digestion
%TS	11.43	21.14
%VS	94.26	88.49
%FS	5.74	11.51
VS/TS	8.25	4.19
%C	19.80	11.9
N (mg/l)	30.0	27.56
pH	7.85	7.91
Total Alkanity (mg/l)	370	310
Ammonium- N (mg/l)	0.40	0.32



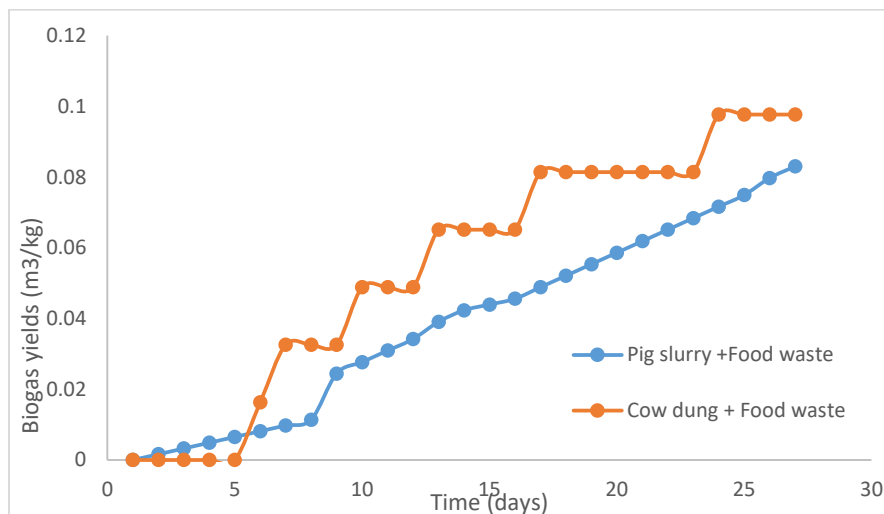


Figure 1: Biogas production potentials of Samples 1 and 2

### Aerobic Composting for Waste Reduction

The waste reduction in volume/weight is shown in Table 3 for anaerobic digestion and aerobic composting. The bar chart representation of the initial weight, final weight, reduction in weight and percentage reduction in weight of Sample 1 through anaerobic digestion and aerobic composting are shown in Figures 2,3, 4 and 5.

### Waste reduction in anaerobic digestion

It was observed that the anaerobic digestion process reduced Sample 1 from 3824.69g to 2406.1g. This means about 1418.59 g of Sample 1 was biodegraded, equivalent to 37 % reduction (Table 3). While Sample 2 reduced from 3752g to 3362.1g. This was about 389.9g equivalent to 10.4 % reduction. The volume/weight of waste reduction in both samples corresponded to the cumulative biogas produced (also inclusive is the water vapour produced which was seen as steam, condensing at the collection chamber of the anaerobic digester).

Table 3: Waste Reduction through Anaerobic Digestion and Aerobic Composting

Samples	Initial Weight (g)	Final weight (g)	Reduction in weight (g)	% Reduction
<b>Anaerobic Digestion</b>				
1	3824.6	2406.1	1418.59	37.0
2	3752.0	3362.1	390.00	10.4
<b>Aerobic Composting</b>				
1	2406.1	1218.0	1188.1	49.4

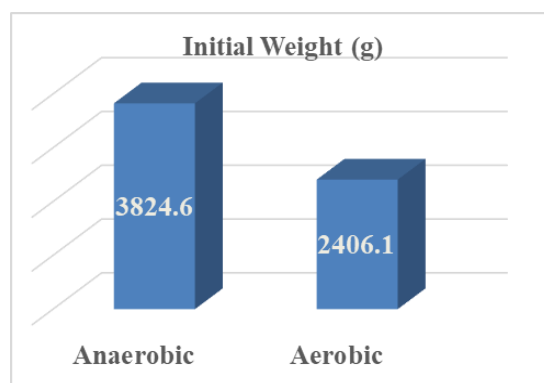


Figure 2: Initial Weight of Sample 1 for Anaerobic Digestion and Aerobic Composting

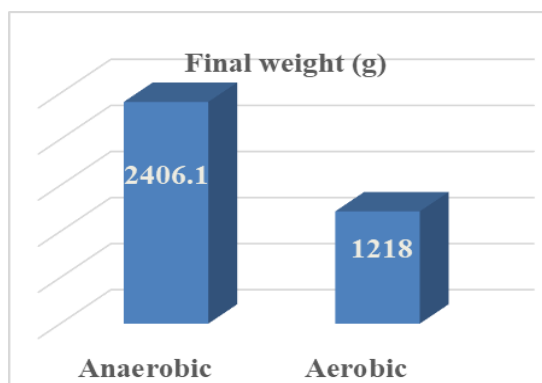
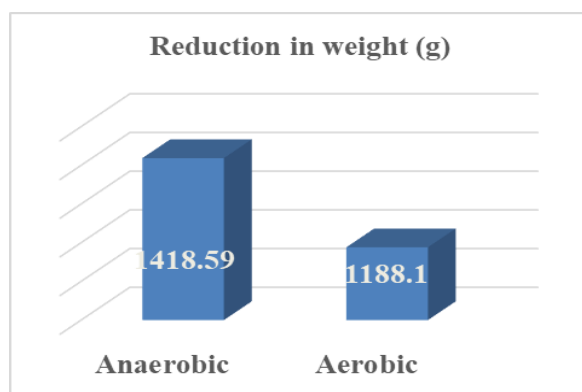


Figure 3: Final Weight of Sample 1 for Anaerobic Digestion and Aerobic Composting



.Figure 4: Reduction in Weight of Sample 1 for Sample 1 for Anaerobic Digestion and Aerobic Composting

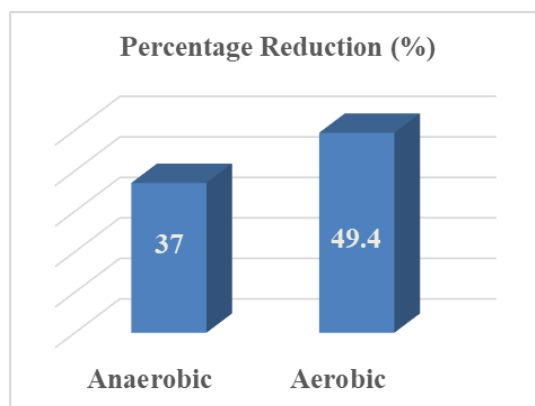


Figure 5: Percentage Reduction in Weight of Anaerobic Digestion and Aerobic Composting

### **Biofertilizer Production Through Aerobic Composting**

After five days of aerobic composting, the final by-product (compost) was harvested and tested to know if it is acceptable to the environment by USEPA (2012), FAO (1996) and FEPA (2004). The test as recorded in Table 4, was carried out each day for the five days of aerobic composting.

From Table 4, ammonia reduced from 0.86 mg/l to 0.31 mg/l which was lesser than the 1.5 mg/l as set by the WHO (Etim and Adie, 2012). The DO was observed also in Table 4, to increase from 5.1 mg/l to 7.0 mg/l, the rapid increment was due to the fact that sample 1 had been in an environment which had no oxygen (anaerobic). The DO which was 5.1 mg/l and found to be above the 2.0 mg/l limit set by Federal Environmental Protection Agency (FEPA) (Amenagbawo *et al.*, 2013). Below the 2.0 mg/l set by FEPA, aquatic life/habitat would be

affected negatively. So, in case, it gets washed-off by surface run-offs from farmlands where it has been applied as manure into water bodies with aquatic habitats, no harm would be incurred.

Table 4: Physicochemical Parameters of Aerobic Composting of Sample 1

Days	Nitrogen	Ammonia	Total Alkalinity	DO	BOD	COD
1 <sup>st</sup>	0.875 mg/l	0.86 mg/l	370 mg/l	5.1 mg/l	3.1 mg/l	7.6 mg/l
2 <sup>nd</sup>	0.65 mg/l	0.49 mg/l	340 mg/l	5.8 mg/l	3.3 mg/l	8.3 mg/l
3 <sup>rd</sup>	0.62 mg/l	0.42 mg/l	320 mg/l	6.3 mg/l	3.7 mg/l	9.3 mg/l
4 <sup>th</sup>	0.59 mg/l	0.35 mg/l	312 mg/l	6.7 mg/l	4.0 mg/l	10.0 mg/l
5 <sup>th</sup>	0.48 mg/l	0.31 mg/l	310 mg/l	7.01 mg/l	4.1 mg/l	10.3 mg/l

## CONCLUSIONS

From the analysis of both biowaste treatment processes, the following conclusions were made:

- i. From the physicochemical parameters of both samples, anaerobic digestion did reduce the inherent and harmful constituents such as ammonia to an acceptable level and also, raised the total alkalinity of both samples above the minimum acceptable limit of 20 mg/l and hence combated environmental burdens.
- ii. The co-digestion of food waste served as a buffer for the disadvantage of a low C/N ratio characterized by the pig waste. Thus, pig waste is as good as cow dung in biogas production
- iii. provided it is co-digested with a feedstock which can buffer its low C/N ratio well enough.
- iv. The combination of anaerobic digestion and aerobic composting in the reduction of biowaste, has been proven to be a very effective method of waste reduction by weight/volume.
- v. The high % VS present in both samples after anaerobic digestion shows that, the samples can still be further biodegraded by microbes other than anaerobic microbes.

Examples of such are aerobic microbes, which can biodegrade constituents such as lignin contents which anaerobic microbes are not capable of decomposing.

## **REFERENCES**

- Adebayo AO, Jekayinfa SO, Linke B. 2013. Effect of Co- Digestion on Anaerobic Digestion of Cattle Slurry with Maize Cob at Mesophilic Temperature. *Journal of Energy Technologies and Policy*. 5(7): 47-54.
- Adebayo AO, Jekayinfa SO, Linke B. 2014a. Anaerobic Co-Digestion of Cattle Slurry with Maize Stalk at Mesophilic Temperature. *American Journal of Engineering Research (AJER)*. 3(1): 80-88.
- Adebayo AO, Jekayinfa SO, Linke B. 2014b. Effect of Co-Digestion on Anaerobic Digestion of Pig Slurry with Maize Cob at Mesophilic Temperature. *Journal of Natural Sciences Research*. 4(22): 66-73.
- Adebayo AO, Jekayinfa SO, Linke B. 2015a. Effect of Co-Digesting Pig Slurry with Maize Stalk on Biogas Production at Mesophilic Temperature. *Journal of Multidisciplinary Engineering and Technology*, 2(8):2295- 2300.
- Adebayo AO, Jekayinfa SO, Linke B. 2015b. Anaerobic Digestion of Selected Animal Wastes for Biogas Production in a Fed-Batch Reactor at Mesophilic Temperature. *Journal of Multidisciplinary Engineering Science and Technology*, 2(7): 1875-1880.
- Amenagbawon, A. N., Asegame, P. A. and Obahiagbon, O. K. (2013). Potential Application of Urea and NPK 15:15:15 Fertilizer as Biostimulants in the Bioremediation of Domestic Wastewater. *Science and Education Publishing*, 1(4), 91-95.
- Babayemi, J. O. and Daudu, K. T. (2009). Evaluate of Solid Waste Generation, Categories and Disposal Option in Developing Countries: A Case Study of Nigeria. *Journal of Applied Sciences and Environmental Management (JASEM)*, 13(3), 83-88.
- Dennis, I. J. and Burke, P. E. (2001). *Dairy Waste Anaerobic Digestion Handbook*. Olympia: *Environmental Energy Company*, W.A 98516, p. 20.
- Esposito, G., Frunzo, L., Giordano, A., Liotta, F., Panico, A. and Pirozzi, F. (2012). Anaerobic Codigestion of Organic Wastes. *Rev. Environ. Sci. Bio/Technol.*, (11), 325-341.

- Etim, E. U. and Adie, G. U. (2012). Assessment of Qualities of Surface Water, Sediments and Aquatic Fish from Selected Major Rivers in South-Western Nigeria. *Research Journal of Environmental and Earth Sciences*, 4(12), 1045-1051.
- Food and Agriculture Organization (FAO) of the United Nations (1996). Biogas Technology: A training Manual for Extension. Kathmandu, Nepal: *Consolidated Management Services Nepal P Ltd.* (FAO/TCP/NEP/4451-T).
- Gregor, D. Z., and Grilc, V. (2012). Anaerobic Treatment and Biogas Production from Organic Waste. Slovenia: *Institute for Environmental Protection and Sensors*. ISBN: 978-953-307-925-7.
- Igoni, A. K., Abowei, M. F., Ayotamuno, M. J. and Eze, C. L. (2008). Effect of Total Solids Concentration of Municipal Solid Waste on the Biogas Produced in an Anaerobic Continous Digester. *Agricultural Engineering International: The CIGR Ejournal*, EE07010.
- Jekayinfa SO, Linke B. PecenkaR. 2015. Biogas Production from Selected Crop Residues in Nigeria and Estimation of its Electricity Value. *Int. J. of Renewable Energy Technology*. 6(2): 101-118.
- Luostarinen, S. A. (2005). Anaerobic On-site Wastewater Treatment at Low Temperature. *Department of Biological and Environmental Science*. Finland: University of Jyvaskyla, p. 85.
- Motte, J. C., Delgenes, J. P., Trably, E., Renaud, E., Hamelin, J., Steyer, J. P., Bernet, N. and Dumas, C. (2013). Total Solid Content: A Key Parameter of Metabolic Pathways in Dry Anaerobic Digestion. *Biomed Central*. 164(6), 1-9.
- Nelson, R. L. (2008). Methane Generation from Anaerobic Digester: Considering Different Substrate [online]. Available from: <https://www.google.com.ng>.
- Ofoefule, A. U. and Uzodinma, E. O. (2009). Biogas Production from Blends of Field Grass.(*Panicum Maximum*) with Some Animal Wastes. *Internal Journal of Physical Science*, 4(2), 091-095.
- Olaniyan, O. S., Ige, J. A. and Akeredolu, D. A. (2015). Solid Waste Management of Omi-Ado, Ibadan, Oyo State, Nigeria. *International Journal of Research in Engineering and Technology*, 3(2), 21-26.
- Ravindranath, N. H. and Usha, R. K. (2000). *Environmental Effects of Energy from Biomass and Municipal Wastes*. UNESCO: EOLSS.

- Sha'Ato, R., Aboho, S. Y., Oketunde, F. O., Eneji, I. S., Unazi, G. and Agwa, S. (2006). Survey of Solid Waste Generation and Composition in a Rapid Growing Urban Area in Central Nigeria. *Waste Management*, 27(3), 352-358.
- Song, K. Y., Li, Y., Ouyang, W., Hao, F. H. and Wei, X. F. (2012). Manure Nutrient of Pig Excreta Relative to the Capacity of Cropland to Assimilate Nutrients in China. *Elsevier, Procedia Environmental Sciences*, (13), 1846-1855.
- Tanaka, S. and Kamiyama, K. (2002). Thermochemical Pretreatment in the Anaerobic Digestion of Waste Activated Sludge. *IWA Publishing*, 46(10), 173-179.
- USEPA (2008). *Anaerobic Digestion of Food Waste*. USEPA, Region 9. No: EPA-R9-WST-06-004.
- USEPA (2012). *Clean Energy: Air Emission* [online]. Available from: <http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html>. [Accessed 10<sup>th</sup> October, 2019].
- Waste and Resources Action Program, WRAP (2010). Specification for Whole Digestate, Separated Digestate, Separated Liquor and Separated Fibre Derived from the Anaerobic Digestion of Source-Separated Biodegradable Materials. UK: *Publicly Available Specification*, (PAS 110).
- Zhang, S., Hua, Y. and Deng, L. (2016). Nutrient Status and Contamination Risks from Digested Pig Slurry Applied on a Vegetable Crops Field. *International Journal of Environmental Research and Public Health*, 406(13), 1-11.

## **OPTIMUM AND NUTRITIVE UTILIZATION OF *OREOCHROMIS NILOTICUS* FED DIFFERENTLY PREPARED HOUSEFLY MAGGOT SUBSTITUTED DIETS.**

Mustapha, A.K.

Department of Zoology, Osun State University, Osogbo, Osun state, Nigeria

E-mail address: [mustaphaak2525@gmail.com](mailto:mustaphaak2525@gmail.com)

### **ABSTRACT**

In an attempt to search for a good quality, but relatively inexpensive and readily available feedstuff as alternative to the expensive ingredients in the fish diets, housefly maggot which is regarded as ordinary waste by Nigerians was used as the protein source in the diets for *Oreochromis niloticus* fingerlings. *O. niloticus* fingerlings (mean weight  $0.52 \pm 0.062$  g) were randomly assigned at 20 fingerlings per bowl. Five diets were formulated to substitute fish meal at 0%, 25%, 50%, 75% and 100% for each of the oven-dried, sundried and fresh maggots' diets and tested on the fingerlings fed for 12 weeks. The data were analyzed using One-way Analysis of Variance (ANOVA) test followed by the least significant (LSD) test for comparison among treatment mean of 5% probability ( $P = 0.05$ ). Analyses of various growth parameters revealed that diets substituted at 25% up to 75% maggot for both Oven-dried and Sundried maggot diets and 50% up to 100% fresh maggot diets were not significantly different in weight gained by fish fed with fish meal diets ( $p > 0.05$ ). Quality parameters showed that maggot did not pollute the water media. The study showed that maggot is rich in proteins and minerals required for *Tilapia* growth and that fish diets containing crude protein of oven-dried, sundried and fresh maggot (irrespective of the method of preparation) are suitable for the growth of the fish. It also showed that maggot meal could be successfully used to replace fishmeal wholly or partially in the diet of *O. niloticus* fingerlings for optimal growth and nutrient utilization.

**KEYWORDS:** Fishmeal; Housefly maggot; Optimum growth; Diet; Weight gained; Specific Growth Rate,

### **INTRODUCTION**

Several factors militate against the efforts being made to develop fish farming in developing nations in order to increase fish supply. Such factors include scarcity, irregular supply and high



cost of fishmeal and feed ingredients. High cost of fish feed ingredients reduces profit and discourages many fish farmers. In Nigeria, many fish farmers are faced with the problem of availability of cost effective fish feed, as such there has been advocacy for the use of by-products and wastes which are not directly used by human being and alternative and less expensive sources of good quality protein sources that are readily and locally available to replace or partially substitute for a portion of the expensive fishmeal (Fagbenro, 1996). Fish feed is a factor that has much to do with the success of fish culture in Nigeria and it represents the greatest proportion of cost in aquaculture production. Maggots have only been associated with waste products, with decay and worthlessness in Nigeria (Adesulu and Mustapha, 2000). Maggot is one of the alternative sources of protein that is being evaluated or has potential to replace fishmeal in fish diets. It has potential of becoming a source of commercial fish feed within few years. There is a good potential for raising maggot, as it take very short time to generate and easy to cultivate on continuous bases without any interference of the climate during the decomposition of poultry manure and agricultural waste products (Pillay, 1993). Maggot has been reported to contain very high amount of protein with a well-balanced essential amino acid spectrum. Amino acid composition of the maggots is about the same as that of fishmeal (Spinelli, 1978). There are numbers of reports which show that maggots would compare favourably with other protein sources {(Adesulu and Mustapha, (2000); Idowu *et al* (2003); Olaniyi and Salau (2013) ; Sing *et al* (2014) ; Ezewudo et al., 2015 and Emilie *et al.* 2017}. The main purpose of the study is to find out that fish diets containing crude protein of oven dried, sundried and fresh maggot (irrespective of the method of preparation) could be successfully used to replace fishmeal wholly or partially in the diet of *O. niloticus* fingerlings for optimal growth and nutrient utilization.

**MATERIALS AND METHODS:** Collection of Maggots: Maggots used were those of housefly (*Musca domestica*). Developed maggots were harvested using a modified floatation technique where manure impregnated with maggots was put in a sieved plastic bowl immersed in a basin of water. The manure was dissolved by gentle manual vibration of the sieved plastic bowl in the water and washed off leaving clean maggots. The maggots were thoroughly washed until they show their characteristics white colour and free from waste. The maggots were killed by subjecting them to low temperature at 5<sup>0</sup>C. Part of the sample was ovedried, another part sundried .and the remaining were kept as fresh maggot in refrigerator for further use. Sources of other Feedstuff: Yellow maize and dried fish for the fishmeal were obtained from market.

The minerals vitamin premixes and other ingredients were obtained from a livestock feed store. Feedstuff Preparation: The sun-dried maggot, oven dried, fresh maggot and maize were milled and packed separately and stored for use. The fish after being degutted and discaled was boiled for ten minutes. It was dried in the oven at 95<sup>0</sup>C for 12 hours and then milled and packed for use. The various ingredients were weighed and thoroughly mixed together. It was wet mixed with water at 50<sup>0</sup>C. The mixtures containing oven dried and sundried maggot meal were pelleted and dried but the one with fresh maggot was kept the refrigerator for dispensation as required Proximate analysis was carried out to determine moisture content, ash and crude protein of the different diets using (AOAC, 2012). It was then packed and dispensed as required. Feed Formulation: Pearson square method (Pulin and Jhingran, 1985) was used to formulate a 35% crude protein diet for fingerlings. The proportionate contribution of each of the feedstuff was determined and four diets of 25%, 50%, 75% and 100% maggot meal in the protein fraction for each of the differently preserved maggot meal were prepared. The diet containing fish meal as the only protein source (0% maggot inclusion) was taken as control (Table 1). Experimental Set-up: The experiments were carried out in 39 indoor plastic bowls (240 litre each) in the aquaculture center laboratory of Obafemi Awolowo University, Ile-Ife. Each bowl was filled with filtered water from Opa dam up to three-quarter of the volume. 780 fingerlings of *Oreochromis niloticus* with a mean weight of  $0.52 \pm 0.062$  were acclimatized in the laboratory for one week. Those still surviving after one week were weighed and randomly assigned to the bowl at a stocking, so as to ensure that all the stocked fish empty their gastrointestinal tract. There were three replicates for each diet treatment. The fish were fed for 12 weeks at 3% body weight with their respective diet twice daily. The entire population of each bowl was weighed bi-weekly and the feeding rate adjusted according to the mean fish weighed in each tank.. The bowls were monitored daily, dead fish number in each bowl was recorded and percentage survival was estimated. Water quality was controlled by replacing the water loss by evaporating, daily cleaning and changing the water weekly and removal of uneaten food weekly. Water temperature, pH and dissolved oxygen were monitored weekly using standard methods (APHA, 1985).

### **DATA ANALYSIS**

Growth performance and nutrients utilization were evaluated from data on weight gain, SGR, FCR, PER. The data were analysed using One-way Analysis of Variance (ANOVA) test followed by the least significant (LSD) test for comparison among treatment mean of 5%

probability ( $P = 0.05$ ). Specific Growth Rate (SGR), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER) were calculated according to the method of Eyo (2005) and Olaniyi and Salau (2013) as follows:

$$SGR = \frac{W_1 - W_0}{T} \times 100,$$

where  $W_1$  = final weight,  $W_0$  = initial weight,  $t$  = time in days.

$$PER = \frac{\text{Weight gain}}{\text{Protein fed}},$$

where protein fed = % protein in diet x total diet consumed/100.

$$FCR = \frac{\text{Fish feed intake}}{\text{Weight of fish}}.$$

## RESULT AND DISCUSSION

The physico-chemical parameters of the culture media were found suitable for fish. The water temperature range of 26.01 to 27.52<sup>0</sup>C was within the range described by Komolafe and Arawomo (2008) for Osinmo reservoir. The pH range of 7.40 to 7.60 were within the range of 7 – 7.69 recommended for *Tilapia* culture (Burn and Stickney (1980) and the range of 6.6 and 8.5 known for most streams and lakes of the world (Boyd, 1979). Oxygen concentration was found to reduce with time in the culture media with the value ranging from 4.10 to 5.50mg/l. dissolved oxygen range of 1 to 4.99 mg/l makes fish survive, but slows the growth on prolonged exposure of the fish to the condition and the value above 5 mg/l is desirable (Huner and Dupree, 1988). The dissolved oxygen content recorded during the current study were however well within the acceptable range of 1.75 - 11.20 mg/l<sup>-1</sup> obtained by Atobatele and Ugwumba (2008), which have been found to be suitable for fisheries resources development in the reservoir. .

**Table 1: Composition of Experimental diets (dry weight)**

	A (Oven-dried maggot diets)				B A (Sun-dried maggot diets)				C (Fresh maggot diets)				D (Control)
Feedstuff	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	D
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	

Fish meal	28.63	19.085	9.54	-	28.63	19.085	9.54		28.63	19.085	9.54	-	38.17
Maggot	9.54	19.085	28.63	38.17	9.54	19.085	28.63	38.17	9.54	19.085	28.63	38.17	-
Yellow Maize	56.83	56.83	56.83	56.83	56.83	56.83	56.83	56.83	56.83	56.83	56.83	56.83	56.83
Vit. Premix	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Palm oil	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt(NaCl)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Starch (Binder)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

**Table II: Proximate composition of the experiment diet (% weight)**

Feedstuff	A (Oven-dried maggot diets)				B A (Sun-dried maggot diets)				C (Fresh maggot diets)				D (Control)
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	D
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	
Moisture	6.52	5.98	5.82	6.80	6.90	6.82	6.08	5.95	36.05	40.43	43.01	20.40	8.90
Protein	35.80	35.45	34.99	35.90	35.60	35.40	35.01	36.20	35.90	35.50	34.90	36.50	36.67
Ether extract	9.02	10.53	12.20	15.85	9.82	10.02	11.08	15.80	4.32	4.98	5.60	18.10	10.28
Crude oil	3.95	6.52	5.40	6.50	3.86	6.13	5.80	7.10	1.02	1.16	1.32	7.40	7.34
Ash	36.83	28.63	30.53	24.54	7.65	12.22	11.02	11.80	4.99	5.21	5.89	16.30	5.77
NFE	36.83	28.63	30.53	24.50	36.71	29.41	31.01	23.75	17.72	12.72	9.28	1.30	43.04

Energy Kcal/kg	4908	4858	4798	4678	4764	4764	4708	4695	5272	5243	5243	5234	4562.5
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\*Values are mean of three replicates

**Table III: Bi-weekly growth record of the fingerling fed for 12 weeks**

\*\*Values are mean of three replicates

	A (oven-dried maggot diets)				B (Sun-dried maggot diets)				C (Fresh maggot diets)				D (Control)
Week	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	D
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	
0	0.52	0.51	0.54	0.52	0.52	0.53	0.54	0.51	0.51	0.53	0.52	0.52	0.53
2	0.65	0.62	0.68	0.62	0.62	0.67	0.66	0.64	0.61	0.65	0.65	0.64	0.63
4	0.89	0.85	0.92	0.73	0.86	0.91	0.80	0.76	0.72	0.86	0.87	0.87	0.93
6	1.23	1.23	1.29	0.85	1.22	1.31	1.22	0.09	0.84	1.19	1.22	1.25	1.36
8	1.60	1.62	1.72	1.03	1.60	1.79	1.62	1.13	0.97	1.49	1.54	1.69	1.82
10	1.87	1.92	2.05	1.19	2.15	2.00	1.62	1.31	1.11	1.70	1.78	2.04	2.19
12	2.13	2.20	2.35	1.35	2.18	2.50	2.24	1.51	1.26	1.94	2.05	2.38	2.55
Mean Weight Gain	1.61	1.69	1.81	0.85	1.66	1.97	1.70	0.98	0.75	1.41	1.53	1.86	2.02

**Table IV: Growth performance of *O. niloticus* fingerlings fed for 12 weeks**

	A (Oven-dried maggot diets)				B A (Sun-dried maggot diets)				C (Fresh maggot diets)				D
IMW	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D
	0.52 <sup>a</sup>	0.51 <sup>a</sup>	0.54 <sup>a</sup>	0.52 <sup>a</sup>	0.52 <sup>a</sup>	0.53 <sup>a</sup>	0.54 <sup>a</sup>	0.53 <sup>a</sup>	0.51 <sup>a</sup>	0.53 <sup>a</sup>	0.52 <sup>a</sup>	0.52 <sup>a</sup>	0.53 <sup>a</sup>
FMW	2.13 <sup>b</sup>	2.20 <sup>ab</sup>	2.35 <sup>a</sup>	1.37 <sup>b</sup>	2.18 <sup>a</sup>	2.50 <sup>a</sup>	2.24 <sup>ab</sup>	1.15 <sup>b</sup>	1.26 <sup>b</sup>	1.94 <sup>a</sup>	2.05 <sup>b</sup>	2.38 <sup>a</sup>	2.55 <sup>a</sup>
MW G	1.61 <sup>a</sup>	1.69 <sup>ab</sup>	1.87 <sup>a</sup>	0.85 <sup>b</sup>	1.66 <sup>ab</sup>	1.97 <sup>a</sup>	1.70 <sup>ab</sup>	0.98 <sup>b</sup>	0.75 <sup>b</sup>	1.41 <sup>b</sup>	1.53 <sup>ab</sup>	1.86 <sup>a</sup>	2.02 <sup>a</sup>

SGR	1.68 <sup>a</sup>	1.74 <sup>a</sup>	1.75 <sup>a</sup>	1.15 <sup>b</sup>	1.71 <sup>a</sup>	1.85 <sup>a</sup>	1.69 <sup>a</sup>	1.25 <sup>b</sup>	1.08 <sup>b</sup>	1.54 <sup>a</sup>	1.63 <sup>a</sup>	1.81 <sup>a</sup>	1.87 <sup>a</sup>
FCR	105.8 <sup>a</sup>	100.6 <sup>a</sup>	100.2 <sup>a</sup>	116.5 <sup>a</sup>	102.0 <sup>b</sup>	94.2 <sup>b</sup>	102.3 <sup>b</sup>	135.5 <sup>a</sup>	159.9 <sup>a</sup>	114.7 <sup>a</sup>	108.4 <sup>b</sup>	94.9 <sup>b</sup>	93.1 <sup>a</sup>
PER	1.83 <sup>a</sup>	1.99 <sup>a</sup>	1.60 <sup>a</sup>	2.05 <sup>b</sup>	1.94 <sup>a</sup>	1.69 <sup>a</sup>	1.72 <sup>ab</sup>	2.10 <sup>b</sup>	1.88 <sup>a</sup>	1.74 <sup>a</sup>	1.38 <sup>ab</sup>	1.63 <sup>b</sup>	1.61 <sup>a</sup>
% S	95.0 <sup>a</sup>	96.7 <sup>a</sup>	100.0 <sup>a</sup>	91.7 <sup>a</sup>	98.3 <sup>a</sup>	98.3 <sup>a</sup>	100 <sup>a</sup>	93.3 <sup>a</sup>	95.0 <sup>a</sup>	95.0 <sup>a</sup>	95.0 <sup>a</sup>	95.0 <sup>a</sup>	96.07 <sup>a</sup>

Figure in the same row having similar superscript are not significantly different from one another (p>0.05)

IMW=Initial Mean Weight; FMW = Final Mean Weight; MWG = Mean Weight Gain; SGR = Specific Growth Rate; FCR=Feed Conversion; PER = Protein Efficiency Ratio; %S= Percentage survival;

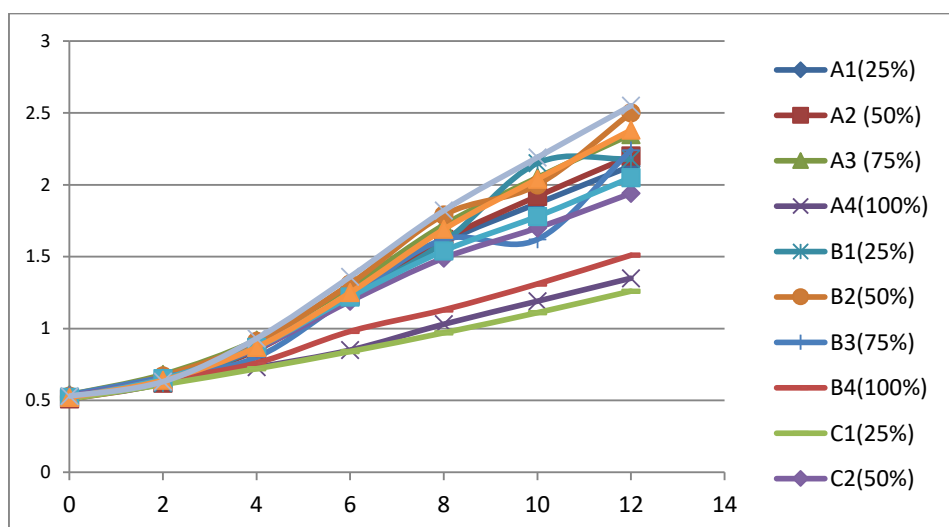


Fig. 1: Bi-weekly records of weight increment (g) of *O. niloticus* fingerlings fed for 12 weeks.

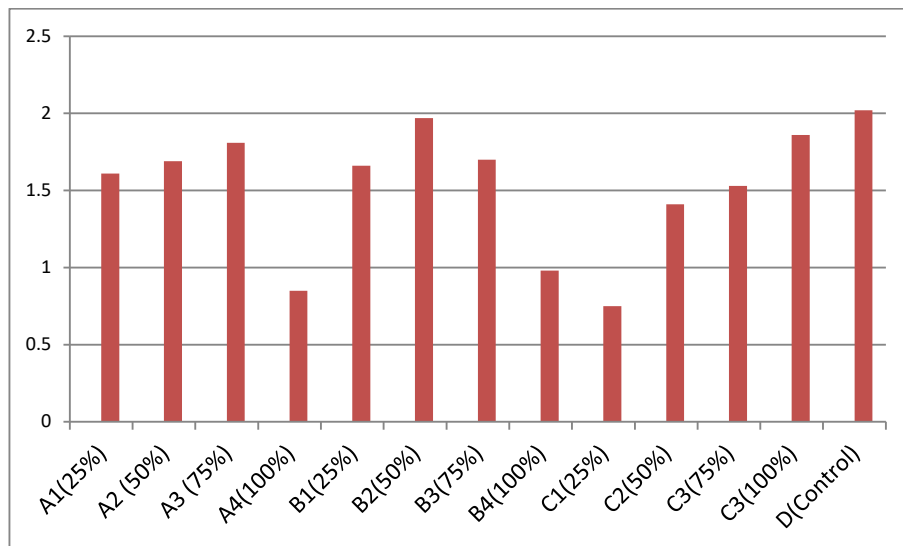


Fig. 2: Bi-weekly records of weight increment (g) of *O. niloticus* fingerlings fed for 12 weeks.

**Table V: Initial and final carcass composition of *O. niloticus* fed different protein of maggot diets**

Nutrients	Initial	A (Oven-dried maggot diets)				B (Sun-dried maggot diets)				C (Fresh maggot diets)				D (Control)
		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	
		25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	
Protein (%)	19.42	21.7	21.9	22.9	20.4	22.6	23.3	22.2	20.9	20.3	21.0	21.4	23.0	23.8
Fat (%)	4.92	2.95	3.05	2.67	2.53	3.07	2.67	2.53	2.22	4.01	3.95	4.22	3.67	2.52
Crude fibre (%)	3.72	3.60	3.70	3.77	3.54	3.73	3.83	3.68	3.72	3.69	3.81	3.68	3.74	3.69
Ash (%)	3.72	3.60	3.70	3.77	3.54	3.73	3.83	3.68	3.72	2.48	2.67	2.63	3.31	3.69
Moisture (%)	2.95	2.80	2.85	3.10	2.57	2.87	3.10	2.91	3.13	70.9	69.7	69.8	68.4	3.22

Table VI: Records of water quality parameters in the experimental bowls

Physico-chemical parameter	Initial	A (Oven-dried maggot diets)				B (Sun-dried maggot diets)				C (Fresh maggot diets)				D (Control)
		A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	D
		25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	
Temp.(°C)	25.53	26.5	26.0	27.0	27.5	27.0	26.5	26.0	26.5	27.5	26.5	26.5	26.5	26.5
pH	7.63	7.42	7.60	7.53	7.58	7.52	7.50	7.60	7.50	7.60	7.56	7.51	7.54	7.50
Dissolved oxygen	7.55	5.50	5.20	5.48	4.80	5.30	5.42	5.03	2.90	5.20	5.35	4.60	4.10	5.59

Proximate analysis of the maggot meal and test diets was carried out. The composition of the experimental diets and the proximate analysis of the diets including calorimetric energy termination are shown in Table I and II respectively. Table III shows Bi-weekly growth performance of *O. niloticus* fingerlings fed diet of different protein levels of maggots for 12 weeks and illustrated in figure 1. Table IV shows growth performance of the fingerlings with respect to the mean weight gain, specific growth rate, feed conversion ratio and % survival and illustrated in figures 2(a and b) and 3. Table V shows the initial and in the experimental bowls final carcass composition of *O. niloticus* fed different protein levels of inclusion of the maggot meal diet for 12 weeks. And Table VI shows the records of water quality parameter. Results from this study show that housefly maggots meal is well utilized and suitable source of protein in fish feed. This dietary protein level of the maggot substituted diets in this study fall within suitable level reported by Idowu *et al* (2003) and Sing *et al* (2014). Rumsey (1998) had earlier reported that maggot meal help to increase growth of fish. *O. niloticus* fingerlings are capable of utilizing compounded diet effectively as shown by the general low feed conversion ratio in all treatment. The SGR, FCR and PER value for most of the maggot diets were indication of the acceptability of maggot-supplemented diet to *O. niloticus*. This study reveals that maggot meal can be successfully used to replace fishmeal in diet of *O. niloticus* fingerlings and for



optimum growth. *Oreochromis niloticus* like other cichlid is highly adaptable and can tolerate adverse condition. The results obtained suggest that maggot contains all the necessary growth promoting factors. According to Agbede and Falaye (1998) feed ingredient of 20% protein level and above could be regarded as good protein source. The dietary protein requirement *Oreochromis niloticus* were 35% (Santiago, 1985). There has been report that tilapias required relatively low protein level (Nwadukwe, 1991). *O. niloticus* according to this experiment are capable of utilizing maggot-compounded diets at various substitution rate, but its best-feed conversion ratio was obtained at 75% oven dried, 50% sun-dried and 100% fresh maggot inclusion level. Maggot has been reported to contain the essential amino acid found in fishmeal. The use of maggot from ecological point of view according to Idowu et al (2003) appear to be cheaper means of reducing the population of adult housefly, *Musca domestica* thereby reducing the risk of disease transmission on the part of the insect vector. Crucially, the values for maggot meal are similar to those of locally produced fishmeal. Proximate analysis of fishmeal and housefly maggot meal suggested crude lipid was higher in maggot meal, a finding consistent with a previous study (Ogunji *et al.*, 2008) where the nutrient composition of housefly maggot meal was evaluated. The result of SGR indicated an increase in the weight gain and food utilization by the fish fingerling. The reason for the superiority of 100% fresh maggot diet over other diets was attributed to the relatively large amount of soft tissue contain in the whole diet. This is in accordance with Adesulu and Mustapha (2000) who reported that the superiority of maggot over other protein sources in fish was due to tender and easily digested nature of maggot. The value of FCR and PER becomes better as the protein level increased. This is favourably compared with those obtained by Faturoti et al (1995) who found that fish fed 100% life poultry during maggot had the highest percentage mean weight gain, SGR and lowest FCR than those artificial diets. *O. niloticus* fingerlings are capable of utilizing compounded diet effectively as shown by the low feed conversion ratio. The best-feed conversion ratio was obtained with 100% fresh maggot diets. This is in contrast to Olaniyi and Salau (2013) who reported that fingerling performed better when fed with diet containing 75% maggot protein inclusion level for fingerling of *Clarias gariepinus*. In another research conducted by Mustapha (2001), the best growth rate was recorded among fingerling fed with diet containing 75% oven dried maggot meal, followed by 50% maggot inclusion and the least growth was exhibited by fingerlings fed diet containing 100% oven dried maggot meal as the protein source. . High levels of fishmeal replacement with housefly maggot meal have been associated with low body weight gain in both fish and chickens (Oyelese, 2007; Ogunji *et al.*, 2008). Earlier studies

indicated that housefly maggot meal should only partially substitute fishmeal in the diets of omnivorous fish species such as catfish and Nile tilapia (Oyelese, 2007; Ogunji *et al.*, 2008). Some authors reported replacement of fishmeal with housefly maggot meal at 50% or less provided the optimum level in chicken feed (Awoniyi *et al.*, 2003; Adenji, 2007). These earlier studies contrast with the present study which showed increased substitution of fishmeal by housefly maggot meal improved the growth, survival and feed efficiency of juvenile tilapia with the total replacement diet giving the optimal results with Diet C (fresh maggot diet) only. Although palatability of the maggot meal was not directly tested, these results and the observations in the laboratory indicated that there was no food rejection by the fish. High survival of fish was consequent of water quality parameter being within the optimum range for the fish. *Oreochromis niloticus* like other cichlids is highly adaptable and can tolerate adverse condition within their habitat. The mortality, though very insignificant was attributed to stress encountered during frequent sampling and faeces collection. The study revealed that oven-dried maggot could replace from 25% up to 75% of the protein incorporated in *Oreochromis niloticus* diet, though diet containing 75% maggot meal as the protein source is the most suitable for optimal growth performance and feed efficiency. Fish diet containing 100% fresh maggot followed by Diet containing 75% maggot as crude protein ( in the diets containing fresh maggot) is most suitable for optimal growth and performances and it showed a comparable weight gain, growth performance and feed efficiency to the control diet. It is shown from this study that maggot meal is favourably compared with fish meal in term of protein and nutrient content. It also showed that maggot meal could be successful used to replace fishmeal partially or wholly in the diet of *Oreochromis niloticus* fingerlings for optimal growth and nutrient utilization. The study indicated that fish diets containing crude protein of fresh, oven dried and sun-dried maggot (irrespective of the method of preparation) are suitable for optimum growth and performance of *Oreochromis niloticus*. There was no significant ( $p > 0.05$ ) difference between the maggot meals and the control diet. Low mortality and suitable water quality showed that maggot did not pollute the water media. Fish meal is expensive, less economically viable and not easily affordable by fish farmers where as maggot meal is less expensive, economically viable and easily affordable. Maggot meal inclusion could be utilize in place of the fish meal for adequate growth and survival of Tilapia. Maggot meal will be more profitable for use in large-scale fish production.

## **REFERENCES**

- Adeniji AA (2007). Effect of replacing groundnut cake with maggot meal in the diet of broilers. *Int J Poult Sci*, 6: 822-825.
- Adesulu EA, and Mustapha, AK (2000). Use of Housefly maggots as a fish meal replacer in Tilapia culture: A recent vogue in Nigeria. *Proceeding from the fifth international symposium on Tilapia Aquaculture*. Rio Janeiro-RJ Brazil. 3 – 7 2000.
- Agbede SA, and Falaye AE (1998). Nutritive value of three aquatic weeds as diets for Nile Tilapia (*Oreochromis niloticus*). *Journal of Tropical Forest Resources* Vol. 14:19 – 28.
- AOAC(Association of Official Analytical Chemists) International (2012). Official Methods of Analysis of AOAC International, 19th Edition. Gaithersburg, Maryland, USA, AOAC International. 1230 Pp.
- APHA – AWWA - WPCF (1985). *Standard Method for the examination of water and waste water* 16<sup>th</sup> Edition. Prepared jointly by the American Public Health Association, American water works association and Water Pollution Control Federation..
- Atobatele, O. E. and Ugwumba, O. A. (2008). Seasonal variation in the physicochemistry of a small tropical reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology* 7 (12): 1962-1971.
- Awoniyi T, Aletor V, Aina J (2003). Performance of broiler chickens fed on maggot meal in place of fishmeal. *Int J Poult Sci*,2: 271-274
- Boyd, C E.(1979). *Water quality in warm water fish ponds*.Agricultural Experiment station, AuburnUniversity, Alabama, pp 58.
- Burns RG, Stickney, RR. (1980): Growth of *Tilapia aurea* in pond receiving poultry waste: *Aquaculture*, Amsterdam, Netherland 20:117 - 121

Emilie S, Will L, Francis JM, David CL (2017). Growth performance, feed utilization and body composition of advanced nursing Nile tilapia (*Oreochromis niloticus*) fed diets containing Black Soldier Fly (*Hermetia illucens*) laevae meal. *Journal of Aquaculture Nutrition*, 1-8.

Eyo JE (2005). Effects of substituting soya bean meal for maggot meal on acceptability of diets, Growth Performance and Cost benefits of diet fed to hybrid Catfish *Heterobranchu bidorsalis* and *Clarias gariepinus*. *Journal of Science and Technology Research*, 4: 37-43.

Ezewudo BI, Monebi CO, Ugwumba AAA. (2015). Production and utilization of *Musca domestica* maggots in the diet of *Oreochromis niloticus* (Linnaeus, 1758) fingerlings. *African Journal of Agricultural Research* 10(23): 2363- 2371.

Fagbenro OA. (1996). Presence of potentials of Cocoa Pod Husk used in low-cost fish diet in Nigeria (pages 104 – 110), *In the role of Aquaculture in worfisheries – Proceeding of the world fisheries congress*. Theme 6: Edited by Tor. G. Heggberget Calcutta Oxford and IBH publishing co PVT Ltd. Pp.104 – 110.

Idowu AS, Amusan S, Oyediran AG (2003). The Response of *Clarias gariepinus* fingerlings (Burchell 1822) to the diet containing housefly maggot (*Musca domestica*) (L) *Nig. J. Anim. Prod.* 30(1):139 – 144.

Mustapha A. K, (2001). An Investigation into the Value of Oven-dried Maggot as Protein Source in the Diet of *Oreochromis niloticus* Fingerlings. *Journals of Pure and Applied Science*. 3(1 and 2): 63 – 74.

Nwadukwe FO (1991). Brook stock management and seed production. *Proceeding of fish seed propagation course conducted NIOMR*. (Edited by A.O. Ayinla)..

Ogunji J.O., W. Kloas, M. Wirth. C. Schulz., B. Rennert. (2008). Housefly maggot meal. An emerging substitute of fishmeal in Tilapia Diets. Conference on International Agricultural Research for Development; Deutscher Tropentag, Bonn, Germany. pp. 11-13.

Oyelese O.A (2007). Utilization of compounded ration and maggot in the diet of *Clarias gariepinus*. *Res J Appl Sci*, 2: 301- 306.

Olaniyi CO , Salau BR ( 2013). Utilization of maggot meal in the nutrition of African cat

fish. African Journal of Agricultural Research Vol. 8(37): 4604-4607.

Pillay, T. V.R (1993). *Aquaculture and practices*. Fishing News book Ltd. London.

Pullin RSV, Jhingran VG (1985): *A hatchery Manual for the Common Chinese and Indian major Carps* Asia development Bank ICLARM.

Rumsey GL (1998). History of early Diet Development fish culture: 100BC to AD 1995. *In the Progressive Fish Culturist*. Vol 56.

Santiago CB (1985). *Amino acid requirement of Nile tilapia* Ph.D. Dissertation Auburn University. Auburn. Alabama, 126.pp

Sing KW, Kamarudin MS, Wilson JJ, Azirun MS (2014). Evaluation of blowfly (*Chrysomyamegacephala*) maggot meal as an effective, sustainable replacement for fishmeal in the diet of farmed juvenile red tilapia (*Oreochromis* sp.). Pak Vet J, 34(3): 288-292.

Spinelli J (1978). Unconventional fed ingredients for fish feeds. *In Fish Feed Technology Aquaculture Development and Co-ordination Programme* (ADCP/REP/80/11 (UNDF/FAO) 395

## **GEOSPATIAL ANALYSIS OF URBAN HEAT ISLAND OVER BAUCHI METROPOLIS AND ITS ENVIRONS**

Isioye, O. A., Akomolafe, E. A. \*, Abubakar, A. Z., Aliyu, A. O. and Maiwayo, T.

<sup>1</sup> Department of Geomatics, Ahmadu Bello University, Zaria, Kaduna state, Nigeria

\*Corresponding author's email: [goldera2787@gmail.com](mailto:goldera2787@gmail.com)

### **ABSTRACT**

Rapid urbanization, population explosion and anthropogenic activities exact much pressure on available land and other resources and as a result, heat in these areas increase exponentially in intensity. This increase in temperature amounts to Urban Heat Island (UHI) and this has negative effects on the livelihood of urban residents and the effects sometimes spreads to the surrounding rural areas. The aim of this study is to analyse the UHI over Bauchi metropolis, Nigeria using geospatial technique. To achieve this, the study utilized Landsat ETM+ data and Landsat OLI/TIRS remotely-sensed data for a 10-year period (2008 – 2018), to retrieve Land Surface Temperature (LST) and the Land Use Land Cover (LULC) of the study area. The spatial distribution of LST was retrieved to examine how it affects UHI. Furthermore, the relationship between LST, LULC and Normalized Difference Vegetation Index (NDVI) was analysed and results show that there exist significant LST difference over different LULC classes. In addition, findings show that bare land surface and built-up area retained maximum temperature over the study area and that there is a negative correlation between LST and ND VI which implies that green vegetation can weaken the effect of urban heat island. On the average, temperature increased by 9°C between 2008 and 2018 over the city, attributed mainly to increased human activities such as the nature of materials used for building and anthropogenic activities which has led to increased thermal radiation over the land surface.

**Key words:** *UHI, Landsat OLI/TIRS/ETM+, NDVI, LST, Correlation.*

## **INTRODUCTION**

An Urban Heat Island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities, which is the direct representation of environmental degradation (Lu *et al.*, 2009). The main cause of the urban heat island effect is from the modification of land surfaces, (Solecki *et al.*, 2005) and waste heat generated by energy usage (Li and Zhao, 2012). As the population of a city grows, it tends to expand the city area and increase its average temperature. Recently, with the development of society and acceleration of the process of urbanization, the UHI has become more and more significant and has had severe impact on urban development and human living environments (Chen *et al.*, 2009).

The causes of UHI are many, including the modification of land surfaces through urban development by using materials that effectively retain heat. Land cover types that contribute to the increase of heat retention include pavement, rooftops, sidewalks, roads, parking lots and other impervious surfaces (Adebayo *et al.*, 2017). Replacing natural land cover with pavements, buildings and other infrastructures takes away the natural cooling effects. In addition, fume from vehicles in the form of carbon dioxide (CO<sub>2</sub>) and other gases like methane (CH<sub>4</sub>), ozone (O<sub>3</sub>), nitrous oxide (N<sub>2</sub>O) and chlorofluorocarbons add warmth to the surroundings, further exacerbating the heat island effect.

LST is a key indicator for measuring surface urban heat islands, estimating building energy consumption and evaluating heat related risks (Mathew *et al.*, 2016). As urbanization is the main driving factor of land cover changes, consequently, the rise of LST can disturb the human and animals habitat and disrupt the ecosystem. Consequently, acquiring LST is the primary and key step to the urban heat island analysis.

It has been estimated that more than 50% of the world population live in urban areas, and this percentage is expected to reach to 69.6% by 2050 (United Nations, 2010). As urbanization is accelerating across the world, especially in developing countries, UHI effect has gained an importance to be investigated (Kalnay and Cai, 2003). In our local context, the pattern, trend and characteristics of urbanization in Nigeria have been alarming. Towns and cities have grown unbelievably with pace of urbanization in Nigeria showing high growth rates of 5% - 10% per annum (Egunjobi, 1999). The rapid population growth in Bauchi has brought about urban expansion resulting in the increased exploitation of natural resources. As Bauchi State

witnessed a steady growth in its population over the years, at the current growth rate of about 3.6% per year, the population of Bauchi is expected to double in about 19 years (Alkassim, 2017) and by extension, this will alter the surface temperature due to the release of harmful gases (CO<sub>2</sub> and methane) and pollutants into the atmosphere, resulting to urban heat island. Therefore, an understanding of the processes leading to the formation of the UHI is needed so that effective mitigation strategies can be developed and implemented.

It is against this background that this research seeks to use remotely sensed surface temperature data to analyse UHI in Bauchi metropolis and its environs and to analyse the relationship between UHI phenomena, NDVI, and LULC using quantitative approach.

## **MATERIALS AND METHODS**

### **Description of the study area**

Bauchi is located in the North-Eastern part of Nigeria, it is the administrative centre of Bauchi state and also a Local Government Area (LGA) in the state. At an elevation of 616m above mean sea level, Bauchi state lies between latitudes 9°30'N and 12°30'N and between longitudes 8°45'E and 11°0'E. Within these coordinates, however, the state metropolis covers a total land area of about 3,687km<sup>2</sup> and has a population of about 493,730 residents based on the 2006 population census. A map of the study area is shown in the figure 1.

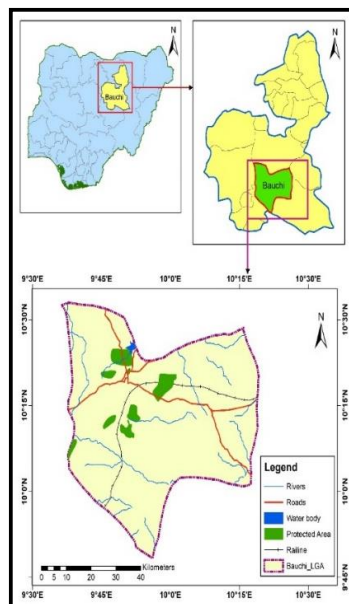




Figure 1. Map of the Study Area.

According to Koppen climate classification system, the study area enjoys a tropical savannah climate with an average annual rainfall of about 1,095mm and 37% - 68% of humidity. Mean daily maximum temperatures in Bauchi ranges from 29.2°C in July and August to 37.6°C in March and April. The mean daily minimum ranges from about 11.7°C in December and January to about 24.7°C in April and May. The rainy season months are May to September (Mohammed, n.d.).

The topography of Bauchi is characterized by a rugged terrain with rocks, hills and valleys; being part of the central Nigeria highlands and Jos plateau complex and it is a hub of many tourist sites including the popular Yankari Game Reserve. At the current growth rate of about 3.6% per year, the population of Bauchi has grown from 493,730 in 2006 to about 693,700 in 2016. Population projections estimate that the population will grow almost four times larger by 2050 (Health Policy Plus, 2017). The unprecedented population growth coupled with developmental activities, has led to urbanization of the study area.

### **Data acquisition**

Cloud-free Landsat ETM+ and Landsat OLI/TIRS images (Path: 187, Row: 53) courtesy of the U.S. Geological Survey, were obtained, processed to generate land use/cover changes (LULC) maps, retrieve LST, detect the changes in LST and to compute the NDVI in the study area. The summary of the Landsat images selected for this study are presented in Table 1.

Table 1. Details of the Landsat data used in this study

S/N	Satellite	Sensor	Acquisition date	Spatial resolution of Spectral and TIR bands
1	Landsat 7	ETM+	May 2008	30m/60m
2	Landsat 7	ETM+	March 2013	30m/60m
3	Landsat 8	OLI/TIRS	April 2018	30m/100m

### **Image correction**

Geometric correction was carried out on all Landsat images as they were projected into the same coordinate system (UTM Zone 32N) to analyse the changes in LULC, LST and NDVI in the study area. In this study, the software ArcGIS 10.3 and ENVI 5.3 were used for image pre-

processing, processing and spatial analysis. The scan line error of Landsat 7 images of years 2008 and 2013 was removed using Landsat gap-fill tool in ENVI environment. The study area – Bauchi was clipped out as a subset from the Landsat full scene images. Then, true and false colour composite images were created for visual interpretation and in order to perform correct image classification.

#### Land Surface Temperature (LST) Retrieval

Band 6H of Landsat 7 (ETM+) and Band 10 of Landsat 8 (OLI/TIRS) are the two commonly used bands to retrieve LST, thus making them effective for urban climate analysis (Adebayo, *et al.*, 2017). In this study, the data used to estimate the LST were acquired for the months of March, April and May, as temperature is relatively high in the study area in these months.

To retrieve the LST, first, radiometric correction was carried out on each band of the Landsat imagery before LST retrieval by converting the digital numbers (DN) of each band to spectral radiance using the following equation (Landsat Project Science Office, 2016):

$$L_{\lambda} = M_L \times QCal + A_L \quad (1)$$

Where:

$L_{\lambda}$  is TOA spectral radiance in Watt/(m<sup>2</sup>sr $\mu$ m),

$M_L$  = Band-specific multiplicative rescaling factor from the metadata. (RADIANCE\_MULT\_BAND 6 (For Landsat 7 ETM+). While BAND 10 is for Landsat 8 OLI/TIRS).

QCal = Quantized and standard product pixel value (DN).

$A_L$  = Band-specific multiplicative rescaling factor from the metadata (RADIANCE\_ADD\_BAND 6 (For Landsat 7 ETM+). While BAND 10 is for Landsat 8 OLI/TIRS).

After the Digital Numbers (DNs) were converted to radiance, the TIRs band data were further converted from spectral radiance to Top of Atmosphere Brightness Temperature ( $T_B$ ) using the thermal constants provided in the metadata file. The following equation was used to compute the brightness temperature (USGS, 2017).

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} \quad (2)$$

Where:

$T_B$  = Top of atmosphere brightness temperature in kelvin (K).

$K_1$  and  $K_2$  = band specific thermal conversion constant.

#### Derivation of Normalized Difference Vegetation Index (NDVI)

NDVI is a measurement of the amount and vigour of vegetation at the surface. NDVI is computed using the equation below.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (3)$$

Where:

NIR and RED are the reflectance bands in the near-infrared and red portion of the electromagnetic spectrum respectively.

Having derived the NDVI, the proportion of vegetation (Pv) was computed and was further used to compute the land surface emissivity (e) using the following equations:

$$Pv = \left[ \frac{(NDVI - NDV_{min})}{(NDV_{max} - NDV_{min})} \right]^2 \quad (4)$$

$$e = 0.004 * Pv + 0.986 \quad (5)$$

The LST is derived from the Top of Atmosphere Brightness Temperature ( $T_B$ ) as follows (USGS, 2017):

$$LST(^{\circ}C) = \frac{T_B}{\left[ 1 + \left( \lambda \times \frac{T_B}{\rho} \right) \ln(e) \right]} - 273.15 \quad (6)$$

Where:

$\lambda$  = wavelength of emitted radiance

$\rho = h \times (c/s) = 1.4388 \times 10^{-2} \text{m K} = 14388 \mu\text{m K}$

$h$  = plank's constant =  $6.626 \times 10^{-34} \text{Js}$

$s$  = Boltzmann constant =  $1.38 \times 10^{-23} \text{J/K}$

$c$  = velocity of light =  $2.998 \times 10^8 \text{m/s}$

### Image classification

The visible and near-infrared bands of the pre-processed images were used to carry out supervised classification of the LULC types in the study area, per epoch, utilizing the maximum likelihood classification algorithm in ArcGIS 10.3.

## RESULTS AND DISCUSSIONS

### Land Use/Cover Changes

The LULC maps for the year 2008, 2013 and 2018 were generated from supervised classification of Landsat 7 and Landsat 8 images covering Bauchi as seen in Figure 2. The area occupied by each LULC class was also computed and are presented in Table 2.

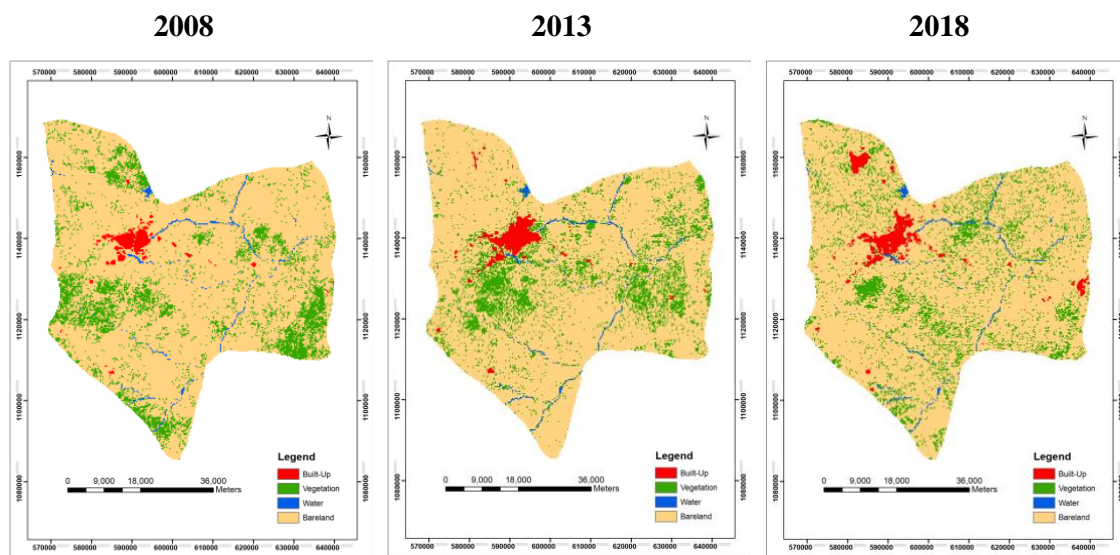


Figure 2. Results of Land use land cover classification for the year 2008, 2013 and 2018.

The total area of the study area is estimated to be  $3685 \text{km}^2$ . As seen in Table 2, in 2008, built-up covers an area of  $59 \text{km}^2$  which was 1.6% of the total land mass. Vegetation, water body and bare land occupy  $1856 \text{km}^2$ ,  $42 \text{km}^2$  and  $1729 \text{km}^2$  respectively. The area is mostly covered by vegetation which accounted for 50.35% of the total area.

Table 2. Area statistics of LULC classes in the study area from 2008 to 2018

Land Use/ Land Cover classes	2008		2013		2018	
	Area (km <sup>2</sup> )	Area (%)	Area (km <sup>2</sup> )	Area (%)	Area (km <sup>2</sup> )	Area (%)
Built-Up	59	1.60	85	2.31	112	3.04
Vegetation	1856	50.35	516	14.00	491	13.32
Water Body	42	1.14	41	1.11	42	1.14
Bare land	1729	46.91	3043	82.58	3040	82.50
<b>TOTAL</b>	<b>3686</b>	<b>100.00</b>	<b>3685</b>	<b>100.00</b>	<b>3685</b>	<b>100.00</b>

However, in 2013, built-up area had increased by 0.71% from 1.60% (59km<sup>2</sup>) to 2.31% (85km<sup>2</sup>) of the total study area. Bare land and vegetation now cover 82.58% (3043km<sup>2</sup>) and 14% (516km<sup>2</sup>) respectively, an increase of 35.67% for bare land and a decrease of 36.35% for vegetation. Meanwhile, water body experienced just a little change between 2008 and 2013 which is a 0.03% decrease from 1.14% (42km<sup>2</sup>) in 2008 to 1.11% (41km<sup>2</sup>) in 2013.

Furthermore, between 2013 and 2018, the built-up area had more increment (0.73%), with a value of 3.04% (112km<sup>2</sup>) from 2.31% (85km<sup>2</sup>) of the total LULC in 2013. Vegetation decreased from 14% (516km<sup>2</sup>) to 13.32% (491km<sup>2</sup>) of the total LULC area while water body slightly increased from 1.11% (41km<sup>2</sup>) to 1.14% (42km<sup>2</sup>). The dominant land cover; bare land in the study area appeared to have reduced a little in 2018 by 0.08% amounting to 82.50% (3040km<sup>2</sup>) of the total LULC (see Table 2).

Generally, over a 10-year period between 2008 and 2018, the total built-up area increased from 1.60% (59km<sup>2</sup>) of the total land area in 2008 to 3.04% (112km<sup>2</sup>) in 2018, an increase of 1.44% over the study period. It was observed that the built up area has significantly increased in the centre of Bauchi metropolis and also in areas away from the centre. The dominant vegetation in 2008 has reduced drastically to 13.32% (491km<sup>2</sup>) from 50.35% (1856km<sup>2</sup>) in 2008 while bare land increased to 82.50% (3040km<sup>2</sup>) from 46.91% (1729km<sup>2</sup>) in 2008.

It is observed from the results that there has been drastic increase in built-up from 2008 to 2018, which is of course as a result of need for more residences in addition to increased anthropogenic activities over the region resulting from dynamic population growth. Table 2 shows that in 2008, vegetation and bare surface constitutes the largest LULC categories in Bauchi Local government area. They collectively occupy an area of 3586km<sup>2</sup>, representing 97.26% of the total land cover of the study area. The least cover types are the built-up areas and water body which both occupy 101km<sup>2</sup>, representing 2.74% of the total land cover of the study area.

Dynamic population growth and rapid urbanization have been the major causes for the built-up land use increment. Bare land appears to be the predominant land cover type in the area under study though it increased from what was obtainable in 2008 and compared to 2018, even though vegetated area reduced. This is attributed to vegetated areas shrinking as a result of increase in built-up area due to the need for residences and more human activities within the region. This can be seen evidently in Figure 2 as well.

### Spatial distribution of LST in Bauchi

LST provides relevant information about the surface physical properties and climate which plays a significant role in many environmental processes. Figure 3 shows the spatial distribution of day-time LST in Bauchi metropolis and environs between 2008, 2013 and 2018.

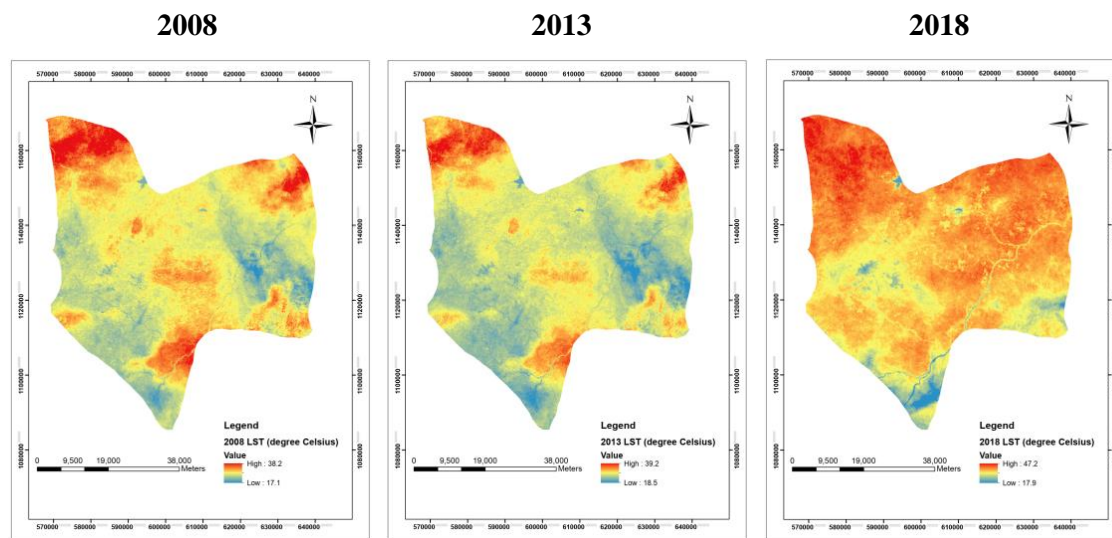


Figure 3. LST distribution of Bauchi metropolis and environ in 2008, 2013 and 2018.

Figure 3 shows that the temperature ranges between 17.1°C to 38.2°C in 2008, 18.5°C to 39.2°C in 2013 and 17.9°C to 47.2°C in the year 2018. In 2018, the LST not only increased but the core areas have

expanded towards the North-west of the study area. High temperatures were observed in the city centre as there exist more thermal properties. The construction of the new Bauchi airport, which is an anthropogenic activity in 2018 which wasn't there in previous years could be a cause. Lowest temperature correspond to areas that are highly vegetated and also consist of water body. Indeed, surface temperature will always be lower over the vegetated area compared to bare or exposed soil because the canopy intercepts the incoming short wave solar radiation (Adebayo *et al.*, 2017).

However, it was observed in the study area that there was little expansion in built up land use within the city centre as compared to surrounding rural areas which have experienced expansion and urban sprawl over the years. This among other factors such as topography, cost of living, nature of materials used for building and also clearing of vegetation has led to the increase in the temperature of the surrounding areas of the metropolis against the usual perception that the urban areas is an island of heat amidst its surrounding rural areas.

Table 3. Summary of LST values obtained in the study area

Year	LST Range (°C)		Mea n	Standar d deviatio n
	Min.	Max.		
<b>2008</b>	17.1	38.2	26.8	2.5
<b>2013</b>	18.5	39.2	27.8	2.6
<b>2018</b>	17.9	47.2	37.3	3.1

Table 3 revealed that 2008 has the lowest mean temperature of 26.8°C while 2018 has the highest mean surface temperature of 37.3°C. This implies that urban development, increase in non-evaporating, non-transpiring surfaces such as bare land (soils) among others, bring about increase LST. The non-evapotranspirative materials and topography is responsible for increased surface temperature.

### **Vegetation distribution in Bauchi**

Normalized Difference Vegetation Index (NDVI) is a measure of the vegetation density of an area and tend to reduce with increase in the alteration of natural surfaces and replacing

them with impervious (Adebayo *et al.*, 2017). Figure 4 shows the NDVI in the study area between 2008 and 2018, with highly vegetated areas in green and low vegetated areas in red.

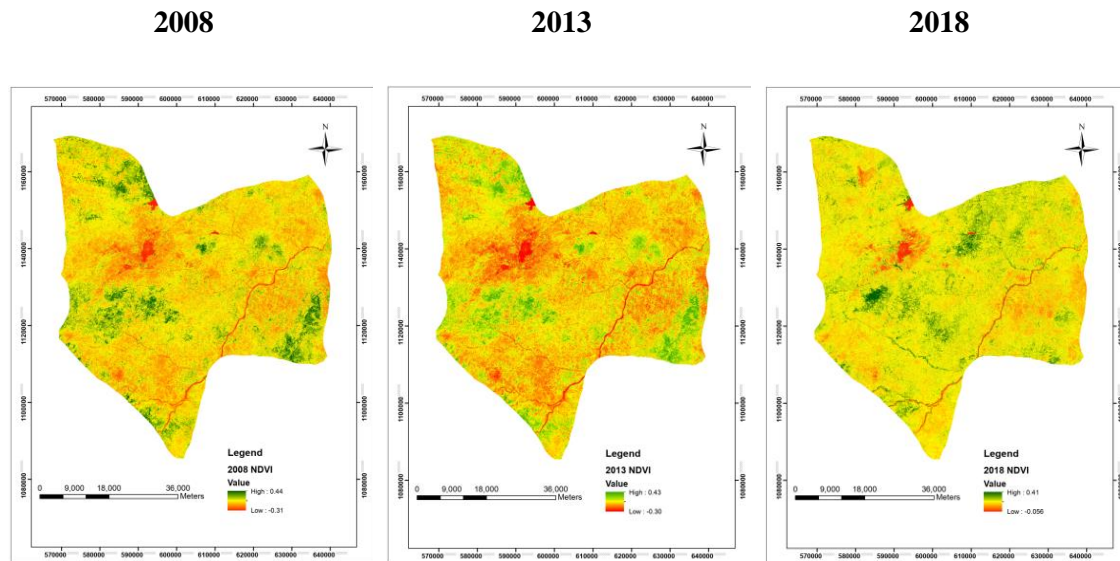


Figure 4. NDVI distribution of Bauchi metropolis and environs

Table 4. Summary of NDVI values in the study area.

Year	NDVI		Mean	Standard deviation
	Min.	Max.		
2008	-0.30	0.44	0.020	0.06
2013	-0.31	0.43	0.020	0.06
2018	-0.06	0.42	0.016	0.03

It is observed that lower NDVI corresponds to built-up areas, water body and bare surface, while high NDVI value is associated with the less developed natural surfaces. This is as a result of vegetated areas being replaced with residential areas for the growing population.

### Relationship between LST and NDVI



The relationship between the NDVI and the LST was established to test the correlation between these two variables. This was achieved by running a regression analysis. Results are presented below.

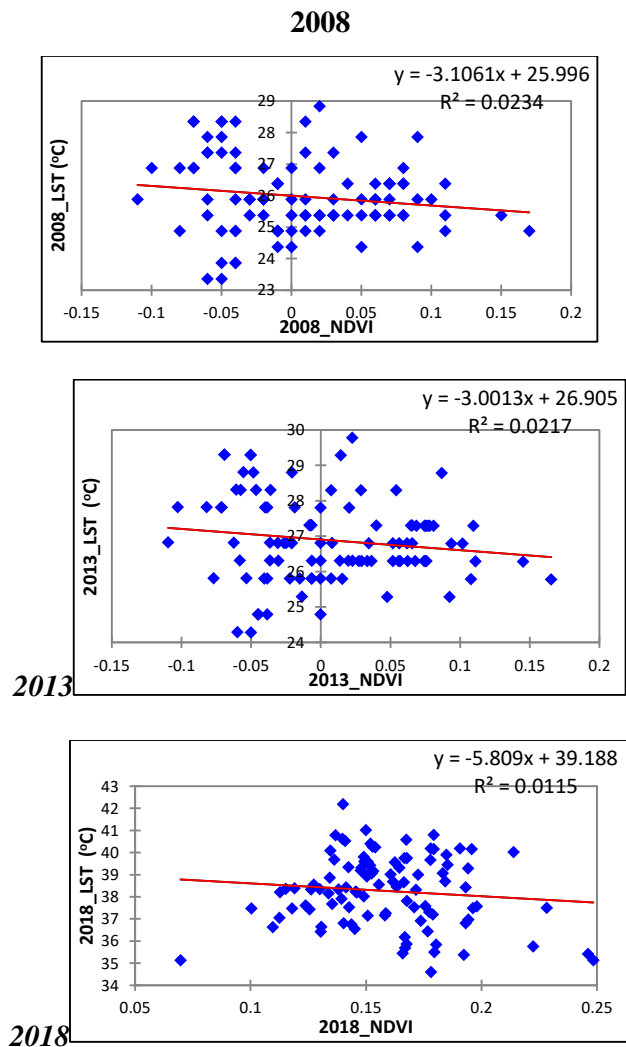


Figure 5. Relationship between LST and NDVI in 2008, 2013 and 2018.

From the results obtained as shown in Figure 5, it was observed that generally, there exists a weak negative correlation between LST and NDVI with Pearson correlation coefficient values of  $R = -0.1529, -0.1473, -0.1072$  for the years 2008, 2013 and 2018 respectively at 95% confidence interval. This implies that the surface temperature reduces as vegetation amount increases and vice versa. Thus, the impact of green area on UHI is negative, which means that the green area can weaken the UHI effect. Weng (2005), rightly noted that spatial variation of NDVI is not only subject to the influence of vegetation amount, but also topography, solar radiation availability, and other factors. The correlation between surface temperatures with

NDVI observed indicate that, with known NDVI values, surface temperature can be predicted using linear regression with reasonable accuracy.

### Urban Heat Island Analysis

Urban Heat Island (UHI) is a phenomenon in which the temperature of an urban area is relatively higher than that of rural or suburban area. It can be calculated as the difference between the temperature of urban area and rural area or the increase in urban temperature over the years. In this study, the later approach is adopted; considering the surface temperature change between 2008 and 2018. Based on this approach, the LST maps are relevant to validate this theory to check if the phenomenon does exist in Bauchi metropolis and its environs. In order to check for the presence of UHI in the study area, 30 random points were selected within the metropolis on the overlaid LST maps of 2008, 2013 and 2018 and their corresponding temperature values extracted using the “extract multiple values to points” tool in ArcGIS. Line graphs were generated from these values to show the temperature change at these points across the 3 epochs as shown in Figure 6.

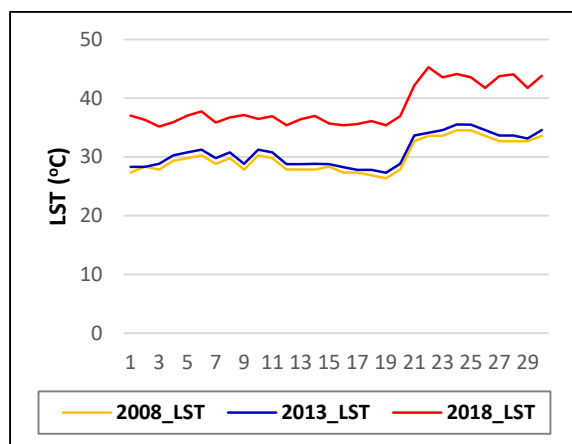


Figure 6. Surface temperature change between 2008 and 2018.

The lowest temperature for 2008 and 2013 are 27°C and 28°C respectively, and the highest are 34°C and 35°C respectively, therefore effect was not noticeable between 2008 and 2013. However, between, 2013 and 2018, there is a significant increase in temperature values in the study area. The lowest temperature for 2013 and 2018 are 28°C and 37°C respectively while the highest temperature values are 35°C and 44°C respectively, amounting to an increase of 11°C. It is very clear that the UHI exist in Bauchi metropolis, as the observed temperatures in 2018 are much higher than those of the 2008. It is also obvious that the UHI effect has caused an increase in surface temperature in the study area in the last decade.

## **CONCLUSION**

This study evaluated the presence of UHI over Bauchi metropolis and environs using geospatial analysis. The split-window algorithm was applied to retrieve the LST in Bauchi using the Landsat ETM+ and Landsat OLI/TIRS data to study the concept of UHI in that region. Findings showed that the increase in surface temperature between 2008 and 2018 is evident of the presence of UHI in Bauchi metropolis. There was an average increase of 10.5°C in temperature between 2008 and 2018. This is attributed to the rapid urbanization and population growth in the study area, thus, leading to an increase in thermal radiation from land surface over built up and bare surface areas. The correlation test between LST and NDVI in the study area showed that, LST and NDVI are negatively correlated which implies that the green vegetation can weaken the effect of UHI in an area. In other words, NDVI can be a measure control of LST, because increase in vegetation will decrease temperature and vice versa. Developmental activities are inevitable in cities. However, proper urban planning could avert the effects of urban heat island phenomenon in Bauchi metropolis. There is need to investigate the LST over various surfaces in order to understand the contributors according LULC changes of the study areas. Furthermore, tree planting and cultivation should be encouraged to reduce the effect of UHI.

## **REFERENCES**

- Adebayo, F. F., Balogun, I. A., Adediji, A.T., Akande, O., Abdulkareem S. B., 2017. Assessment of Urban Heat Island over Ibadan Metropolis Using Landsat and MODIS. *International Journal of Environment and Bioenergy*, 12(1): 62-87, ISSN: 2165-8951.
- Alkassim, B., 2017. Bauchi population to double in 19 years-Report. Retrieved September 4, 2019, from Daily Trust website: <https://www.dailytrust.com.ng/bauchi-population-to-double-in-19-years-report.html>
- Chen, Q., Ren, J., Li, Z. and Ni, C., 2009. *Urban Heat Island Effect Research in Chengdu City Based on MODIS Data*. In Proceedings of 3rd International Conference on Bioinformatics and Biomedical Engineering, ICBBE 2009, Beijing, China, 11–13 June 2009, pp. 1-5.
- Egunjobi, L., 1999. *Our Gasping Cities*, An Inaugural Lecture delivered at the University of Ibadan on Thursday, 21st October 1999.
- Health Policy Plus, 2017. Nigeria Population and Development: Bauchi State Fact Sheet. Available online at: [http://www.healthpolicyplus.com/ns/pubs/7149-7284\\_BauchiRAPIDFactSheet.pdf](http://www.healthpolicyplus.com/ns/pubs/7149-7284_BauchiRAPIDFactSheet.pdf).

Kalnay, E. and Cai, M., 2003. Impact of Urbanization and Land-Use Change on Climate. *Nature*, 423(6939), 528–531.

Landsat Project Science Office, 2016. Landsat 8 science data user's handbook. Retrieved 13 May 2018, from <https://landsat.usgs.gov/documents/Landsat8DataUsersHandbook.pdf>.

Li, Y., and Zhao, X., 2012. An empirical study of the impact of human activity on long term temperature change in China: A perspective from energy consumption. *Journal of Geophysical Research*.117.Bibcode:2012JGRD..11717117L.

Lu, Y., Fend, P., Shen, C., and Sun, J., 2009. Urban Heat Island in Summer of Naijing Based on TM Data. *In Proceedings of 2009 Joint Remote Sensing Event, Shanghai, China*. 1-5.

Mathew, A., Sreekumar, S., Khandelwal, S., Kaul, N., and Kumar, R., 2016. Prediction of surface temperatures for the assessment of urban heat island effect over Ahmedabad city using linear time series model. *Energy Build.*, 128,, 605–616.

Mohammed, S. (n.d.). Bauchi state climate. Retrieved September 5, 2019, from <https://afribary.com/works/bauchi-state-climate-4950>

Monserud, R.A., Leemans, R., 1992. Comparing global vegetation maps with the Kappa statistic. *Ecol. Model.* 62. 275e293.

Solecki, W.D., Rosenzweig, C., Parshall, L., Pope, G., Clark, M., Cox, J. and Wiencke, M., 2005. *Mitigation of the heat island effect in urban New Jersey. Global Environmental Change Part B: Environmental Hazards*. 6(1): 39–49. [doi:10.1016/j.hazards.2004.12.002](https://doi.org/10.1016/j.hazards.2004.12.002).

United Nations, 2010. World urbanization prospects: *The 2009 revision population database*.<http://esa.un.org/unpd/wup/index.htm>.

USGS, 2017. *What Are the Band Designation for Landsat Satellite?* Available at: [https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites-0?qt-news\\_science\\_products=7#qt-news\\_science\\_product](https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites-0?qt-news_science_products=7#qt-news_science_product). Accessed on June 4, 2018.

## **MOTORISTS' COMPLIANCE WITH ROAD TRAFFIC SIGNS IN IKEJA LOCAL GOVERNMENT AREA, LAGOS STATE**

Ogundahunsi, D. S., Adedotun, S. B. and Usman, A. A.

Department of Urban and Regional Planning, Osun State University Osogbo, Nigeria  
Email of Corresponding Author: dele.ogundahunsi@uniosun.edu.ng

### **ABSTRACT**

The study examines the compliance of motorists with road traffic signs in Ikeja, Lagos State. Primary and secondary data sources were used for this research while accidental sampling techniques was used in the selection of respondents in the area. Data obtained for the study were analyzed using descriptive and inferential statistics. Findings reveal that about 55% of the respondents comprehend the road traffic signs, 52% agreed that the road signs were effective in maintaining traffic orderliness and 98% level of compliance by road users was recorded. The high level of compliance, the paper discover, was due to the deterrent nature of fines and penalties imposed on non-compliance to the traffic regulations and the effectiveness of the cognate agencies. The paper concludes that the institutional framework for the issuance of driver's license should be strengthened in order to ensure that intending applicants have full knowledge of road traffic signs. In addition, record of road traffic offenders should be digitally referenced for effective monitoring, control and evaluation of non-compliance to traffic rules.

**Keywords:** Motorists, Compliance, Traffic signs, license

### **INTRODUCTION**

Transportation is a crucial and derived demand of the modern society which encourages the spatial distribution of people and activities in the quest for meeting the essential needs for sustenance. Transportation involves movement of vehicles, persons and goods but it also entails friction with the environment, people, goods and other vehicles. Such frictions often result in road traffic accidents which occur when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or utility pole (GIS Resources, 2014). Road traffic accidents are a growing critical issue globally; an estimated 1.25 million people are killed around the world each year in road accidents while over 50 million people sustain varying degrees of injuries from such crashes (WHO, 2015). It is projected that this figure will increase by 65% over the next twenty years if no serious

preventive measure is taken. The impact of road traffic accidents in many societies, and in developing countries in particular, is likely to outstrip other threats such as communicable diseases and malnutrition (The Research Council, 2013). Of the estimated 1.25 million people killed globally, 90% occurred in low- and middle-income countries especially in Africa (Penden et al, 2004, WHO, 2018). The situation in the developing countries such as Nigeria is critical because they are experiencing high rates of increase in vehicle ownership, population and demands for enhanced mobility and challenges in controlling other factors of road traffic accidents. For instance, NBS (cited in Asadu & Ayuwo, 2018) says that Nigeria recorded 11,363 road accidents in 2016 in which 5,053 were killed and 30,105 injured. Also, the first half of 2017 recorded 2,673 fatalities and 8,270 injuries. One of the integral parts of the road traffic environment is the road traffic code or signs which are erected at the side of or above roads to give instructions or provide information to road users. Traffic signs play a vital role in directing, informing and controlling road users' behaviour in an effort to make the roads as safe as possible for everyone.

The Code includes road signs, road markings, computerized traffic lights, traffic control signals, among others, with communicative symbols where necessary or applicable. Accordingly, the language of road traffic code is sign-dependent, and is designed in a manner that could easily be understood by all categories of road users. These signs, with or without inscriptions could be iconic, indexical, symbolic, or any combination of these and are placed on or by the road for safety purposes with the expectation that road users' understanding could affect a corresponding compliance which to a larger extent, would reduce the rate of road accidents. Obedience to the road signs is expected to ensure a safe road traffic environment for people, vehicles and property but compliance by road users is an on-going challenge in Nigeria. This study evaluates motorists' compliance with road traffic signs in Ikeja Local Government Area, Lagos state.

### **STATEMENT OF PROBLEM**

Compliance with road safety is the act of obedience to rules guiding the usage of the road by the road users. The failure of users to comply with this basic road safety legislation is the main cause of most serious crashes (Kumuyi, 2012). Most of the road signs alert motorists on significant road conditions such as a sharp bend ahead, failed or narrow bridge etc. The essence is to reduce the rate of road traffic conflict and crashes. In spite of these, unfortunately, accidents continue to occur, and somehow tend to be on the increase (Yeman and Kirmizioghi,

2012). It is widely adjudged that motorists on Lagos road fail to respect traffic signs which is attributed to their nonchalant attitude. (LASTMA,2014). It is in the light of this that this study is germane; to evaluate the compliance of road users in the study area to road traffic signs. Could it be that many road users are ignorant of the meanings of the signs, or do road users intentionally violate the traffic rules? Could the situation be blamed on the illegibility of these signs? Or are the signs not communicative enough?

## THE STUDY AREA

The study area is Ikeja, the capital city of Lagos State in the south western part of Nigeria shown in Figure 1 and 2.



Figure 1: Ikeja within the context of Lagos

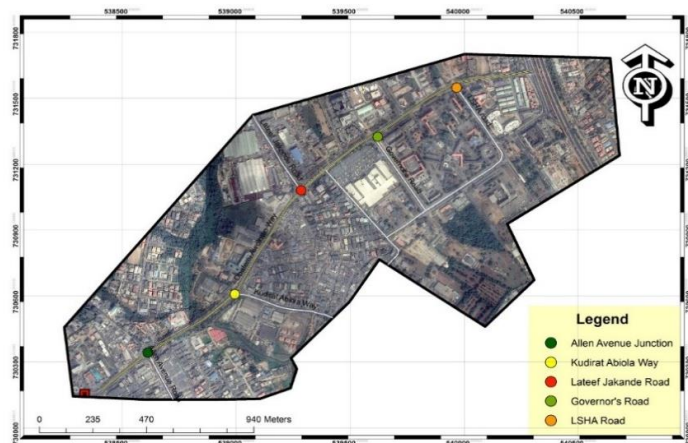


Figure 2: Aerial Image of the study area.

It houses the seat of government where administrative functions are primarily domiciled. The administrative function brought about rapid development in both infrastructural facilities and socio-economic activities leading to high volume of traffic.

### **RESEARCH METHODOLOGY**

The study relies on quantitative as well as qualitative primary and secondary data. The primary data encompasses motorists' socio-economic characteristics, compliance affirmation to traffic signs, reliability status of available traffic signs, understanding of the various traffic signs by motorist in the study area, presence and identification of various traffic signs in the study area. The secondary data comprised of archival report of Lagos State Traffic Management Authority and other information from the Lagos State Ministry of Transportation. Five routes were purposively selected for observation and measurement. This was coupled with administration of a structured questionnaire administered to 296 accidentally sampled public and private motorists, pedestrians plying the route as well as traffic officials at major road intersection within the study area. The sampled routes and the processed average traffic volumes per minute for the duration of seven days traffic count are shown in Table 1.

**Table 1: Sampled Roads and Average Traffic Volume per minute**

<b>S/N</b>	<b>Sampled Roads</b>	<b>Traffic Volume/Hour</b>
1	Allen Avenue road	12,035
2	Kudirat Abiola way	11,981
3	Lateef Jakande road	10,145
4	Governors' Road	301
5	Lagos State House of Assembly road (LSHA)	1,931

**Source: Authors fieldwork, 2018**

### **DATA ANALYSIS AND PRESENTATION**

#### **Socio-economic Characteristics**

The sampled respondents were made up of 62% male and 38% female. This is due to the fact that there are more male drivers than the female counterpart. The age distribution consisted of 39.9% of persons within 31 – 40 years age group, 32.5% of 41 – 50 age bracket, 21.4% of 18 – 30 age group while the remaining 6.4% were above 50 years of age. About a third of the respondents were civil servants followed by commercial drivers 26.5%, traders, 16.7% and the remaining consisted of other occupations. One important attribute that aids comprehension and appreciation of societal regulations is education. 70% of the respondents had tertiary education while about a third had basic education. However, 1.3% had no formal education.



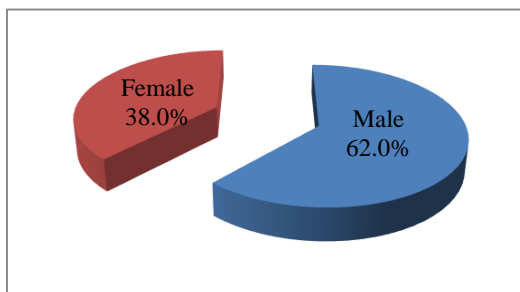


Figure 3: Respondents' Gender

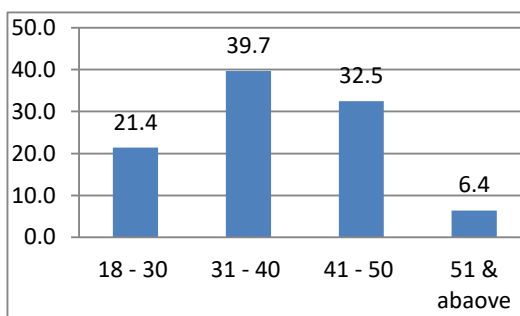


Figure 4: Respondents' Age Distribution

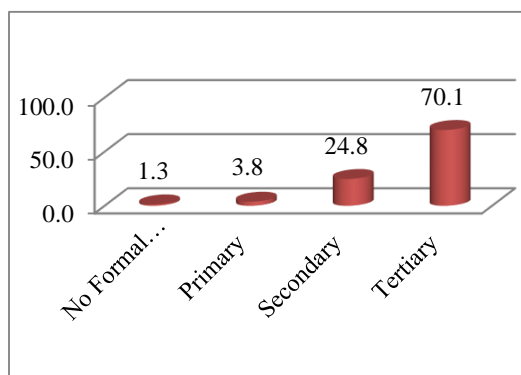


Figure 5: Educational Qualification of Respondents

### Traffic Signs Identified in the Study Area

Table 2 shows the traffic signs observable in the study area. These are normal road signs expected on busy roads such as the ones in the study area. It must be pointed out that there were traffic wardens at each junction to ensure strict compliance with the traffic guidelines and to apprehend offenders.

**Table 2: Traffic Signs in the Study Area.**

<b>Mandatory signs</b>
Speed limit
Pedestrian crossing
No entry sign
Horn prohibited

Roundabout
Narrow road ahead
Right/left hand curve
<b>Information Signs</b>
Indication Sign/Traffic light
Direction sign
Road/Land markings
<b>Prohibitory signs</b>
Height limit for vehicle
Vehicle parking prohibited
Unauthorized vehicle prohibited signs
Left/right turn prohibited
Motorcycle prohibited sign

### Reliability of Traffic Signs

The respondents were asked to rate the traffic signs on each of the selected roads on a four-level scale. On average, 53% rated the traffic signs reliable while 8.5% rated it unreliable and 38.5% rated it fairly reliable. It could be deduced that the traffic signs in the study area were reliable and communicated significantly with the road users.

**Table 3: Reliability of Traffic Signs**

Location	Reliability of traffic signs				Total
	Very reliable	Reliable	Fairly reliable	Unreliable	
Allen Avenue road	4	24	22	8	58
%	6.9	41.4	37.9	13.8	100
Kudirat Abiola way	6	29	18	4	57
%	10.5	50.9	31.6	7.0	100
Lateef Jakande road	3	18	24	3	48
%	6.3	37.5	50.0	6.3	100
Governor’s road	5	14	14	3	36
%	13.9	38.9	38.9	8.3	100
LSHA road	8	13	12	2	35
%	22.9	37.1	34.3	5.7	100
Total	26	98	90	20	234
%	11.1	41.9	38.5	8.5	100.0

**Source: Authors’ fieldwork 2018.**

### Motorists’ Compliance with Traffic Signs

Compliance implies that the motorists abide by the requirements of the road signs. The study revealed 98.3% compliance by the motorists. This high recorded compliance rate was obviously due to the presence of traffic wardens and Lagos State Traffic Management Agency (LASTMA) personnel at the respective junctions in the study area and the strictness of the officers whenever an offender was apprehended. Defaulters pay a minimum of ₦50,000 as a first offender; this could go up to between ₦75,000-₦100,000 irrespective of the vehicle mode. The penalties for various offences regarding road traffic signs are backed by Lagos State Traffic Law Official Gazette (2012).

**Table 4: Motorists’ Compliance Affirmation with Traffic Signs**

Location	Compliance affirmation with traffic signs		Total
	Yes	No	
Allen Avenue road	58	0	58
%	100.0	0.0	100
Kudirat Abiola way	57	0	57
%	100.0	0.0	100
Lateef Jakande road	46	2	48
%	95.8	4.2	100
Governor’s road	35	1	36
%	97.2	2.8	100
LSHA road	34	1	35
%	97.1	2.9	100
Total	230	4	234
%	98.3	1.7	100.0

Source: Authors’ fieldwork 2018.

### Comprehension of Traffic Signs

Respondents were asked about their understanding of and the message the traffic signs convey. Table 5 reveals that 54.3% reported that they fully comprehend the message and importance of traffic signs while 45.7% reported that they complied with the traffic signs because they were directed to do so especially with the presence of the enforcement officers. It is important to note that proper understanding of the purpose of the road signs will help engender full compliance and ensure a safe road traffic environment.

**Table 5: Motorists’ Comprehension of Traffic Signs**

Location	Motorists’ understanding of most traffic signs		Total
	Yes	No	
Allen Avenue road	32	26	58
%	55.2	44.8	100
Kudirat Abiola way	31	26	57
%	54.4	45.6	100
Lateef Jakande road	21	27	48
%	43.8	56.3	100
Governor’s road	20	16	36
%	55.6	44.4	100
LSHA road	23	12	35
%	65.7	34.3	100
Total	127	107	234
%	54.3	45.7	100.0

Source: Authors’ fieldwork 2018.

## **CONCLUSION**

The study examined motorists' compliance with road traffic signs in Ikeja area of Lagos and discovered very high rate of compliance due to the presence of road traffic law enforcement agencies in the city and the deterrent nature of the penalties meted to offenders.

## **RECOMMENDATIONS**

It is recommended that the cognate authorities continue to intensify efforts to achieve optimal compliance in order to ensure a safe urban road traffic environment for all road users. In addition, public enlightenment programme to educate road users about the importance of road signs is a necessity.

## **REFERENCES**

- Asadu, Clement Afamefuna & Ayuwo, Jones Gilbert (2018). Knowledge and Observance of Road Communication Signs among Commercial Drivers in South-South, Nigeria. *New Media and Mass Communication*. Vol.67, pp81-87. [www.iiste.org](http://www.iiste.org)
- GIS Resources (2014). *Total Station to Investigate Traffic Collision*. Retrieved from <http://www.gisresources.com/total-station-to-investigate-traffic-collision/>.
- Kumuyi, W.F. (2012). *Watch these signs, youth counsel series*. National Open University, Social Art and Social Sciences Department (2013) Concept of Road Safety.
- Lagos State Traffic Management Authority (LASTMA) 2014 Archive Reports.
- Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A.A., Jarawan, E., & Mathers, C., (2004). *World Report on Road Traffic Injury Prevention*. World Health Organization (WHO), Geneva.
- The Research Council (2013). *Road Safety Research Program*. Retrieved from The Research Council website: <http://home.trc.gov.om/tabid/314/language/en-US/Default.aspx> .
- World Health Organization (WHO) (2015). *Global Status Report on Road Safety 2015*. Retrieved from World Health Organization website: [http://www.who.int/violence\\_injury\\_prevention/road\\_safety\\_status/2015/en/](http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/).
- World Health Organization (WHO) (2018) *Road Traffic Injuries; Fact Sheet*. Retrieved from World Health Organization website: <http://www.who.int/mediacentre/factsheets/fs358/en/>
- Yeman, H. & Kirmizioghi, E. (2012). Comprehensibility of traffic signs among urban drivers in Turkey, *Accident Analysis and Prevention*. Vol. 45, pp131-141.

## **IMPACT OF ROAD EXPANSION ON THE SOCIO ECONOMIC ACTIVITIES IN OSOGBO METROPOLIS**

Yakubu, D. A.<sup>1\*</sup>, Adedotun, S. B<sup>1</sup>. and David, O. J.<sup>2</sup>

<sup>1</sup>Department of Urban and Regional Planning, Osun State University, Osogbo

<sup>2</sup>Department of Urban and Regional Planning, Kogi State Polytechnic Lokoja

\*Corresponding Author: [deborah.yakubu@uniosun.edu.ng](mailto:deborah.yakubu@uniosun.edu.ng)

### **ABSTRACT**

Excellent road infrastructure is the backbone and chief driver of socio-economic development. Investment in road construction or rehabilitation helps to connect people, drive commerce and opens room for other developments. At the aggregate level, good road network reduces cost in many economic sector by providing better accessibility to market and increasing employment opportunity. Osogbo is one of the urbanizing city in Nigeria in which development is still ongoing. The study examined the impact of road expansion on the socio economic activities in Osogbo metropolis. The study used primary data obtained through random sampling techniques of 400 respondents to obtain information from respondents. Descriptive statistics in the form of frequency table and percentage were used to describe the results. The study finds that the expansion of Old Garage to Kobongbogbo area of Osogbo has brought positive development and various changes to the social-economic activities of the households, business owners, artisans and institutions in the study area. The result revealed that 23.5% of the respondents have better access to costumers, 22.8% attested to free flow of traffic, The road expansion increased accessibility and connectivity of the different part of the Osogbo and provided better out-look of the demolished houses during road expansion in the area. It is recommended that government should invest more in road construction, expansion/ rehabilitation of the existing ones and road infrastructural development that will boost the state's internal revenue and create employment opportunity in the area.

Keywords: Road, Expansion, Transportation, Urbanization, Economic, Activities, Osogbo

### **Introduction**

Transport plays an important part in economic growth and globalization. Roads remain the major tool for facilitating the mode of moving goods and people across the country to accelerate economic and business activities, response to the rapid urbanization and increase in motorization. The rapid growth of cities and increase in Gross Domestic Product (GDP) in

developing nations, has necessitated the development of transportation facilities to accommodate the key drivers of road expansion (Meijer, *et al*, 2018).

Road construction remains the major symbols of development, it associated with numerous social, economic and political benefits (Akinola and Awotona, 1996). Road construction has the characteristic of connecting people from different parts of the city, ensure their participation in all aspects of life together with free movement of goods and passengers, helps in boosting the economy development of the city. However, Ojekunle (2000) maintained that the transport sustains urban centres at the same time constitute agent of urban problems. Extreme traffic congestion sets in as demand approaches the capacity of a road. Traffic congestion can lead to drivers becoming frustrated and engaging in road rage.

Expansion of the existing narrow road has great impact as it facilitates access to basic human needs, greater exploitation of natural environments and adversely impact communities and economies (Laurance, *et al* 2014). Road expansion reduces travel time between locations, increase the robustness of the transportation network and hence reduce the travel costs (Rosa 2014). Oruonye (2012) and Ajayi *et al* (2013) affirmed that impacts of road expansion affects the informal sector of the economy.

Osogbo is located between latitude  $7^{\circ}46'$  -  $7^{\circ}76'$ N and longitude  $4^{\circ}34'$  -  $4^{\circ}567'$ E with an area of 47kmsq. The estimated population is 434,413 (Projected from 2006 NPC). Being the Osun State capital, rapid urbanization has transformed the transport network, making the city one of the fastest growing metropolitan regions in Nigeria. This in turn leads to significant socio-economic and environmental stress on the existing road infrastructure. In response to this, the past administration initiated road construction and expansion in some parts of the city to reduce traffic congestion which led to the demolition of some structures and shops built on the road setback. The road expansion prompted greater increase to accessibility, connectivity and better out-look of the demolished structures during road expansion because most businesses are located along the major roads that deliver much of the vehicular and pedestrian movements while road users are more safe than before. It is against this background that this research analysed the impact of road expansion on the socio-economic activities in Osogbo metropolis.

## **Literature Review**

The networks of road existed since ages in all parts of the world. Historically people have travelled and goods have been moved by road. Improved road infrastructure reduces poverty

by facilitating higher production. The road network consists of a system of interconnected paved carriageways which are designed to carry buses, cars and goods vehicles; generally, forms the basic level of transport infrastructure within urban areas (Meijer, 2018).

Expansion of road has many impacts which can be either negative or positive in the life of residence as it allows greater exploitation of natural environments, and can negatively impact communities and economies (Laurance *et al.*, 2014). Pius *et al.*, (2014) noted that good road network increase marketing activities, as the new marketing patterns arise with road improvements during the construction stage labour may be employed from the community to support economic empowerment at a local level. Construction of new roads to give access to different communities which create more opportunities for economic activities, better access to community's facilities and enhancement of the social order.

Improved road infrastructure has reduced poverty by facilitating higher production and exports, improved market access facilitates, increased commercialization of agriculture results in economic gains for communities Dorosh *et al.*, (2011) and Claudi, *et al.* (2015). Road expansion done without proper planning has threatened traditional settlements, many with heritage sites, and led to loss of public spaces and temple courtyards to make space for increasing demand for parking. Kerali (2003) appraised economic of road projects in developing countries discovered that improving existing road infrastructure is more beneficial than construction of new road infrastructure. Meijer *et al.*, (2018) identified increases in population sizes and GDP in developing nations as the key drivers of road expansion. Douven and Buurman (2013) argue that increased road expansion motivates people to purchase cars and use roads to a greater degree which results in further degradation of the roads, leading to higher maintenance costs, accidents and air pollution.

Road expansion could result in loss of businesses and customers due to the demolition of business premises (Ajayi, *et al.* 2013). Road investments have adverse long-term effects on traffic congestion during the construction process, create new trips due to the land-use development, disturbs densely-built urban areas as a result of buildings demolition. Traditional modes of transport may be disrupted by changes accompanying a road project which impede road crossings, control bus stopping points, and restrict parking of informal public transport vehicles near busy markets. The effect of widened roads can increase travel time for short local trips and affecting access for non-motorized transport. Resettlement takes place when major construction or projects, which are important elements of development, force people to leave

their homes, and society, economic activities, opportunities and any other immovable properties for other place (Oruonye, 2012). The use of by-pass roads can overcome some problems of conflict between road use and community welfare by reducing the immediate impacts of traffic on the community, and commercial activities.

### **Methodology**

For the purpose of this research, personal observation of the study area was carried out, the sampling frame for this research include shops along the major road which numbers about 800 out of which 50% was used as the sample size. Shops were picked using simple random sampling to select the sample size of 400 traders from Old garage to kobo area of Osogbo where the main road expansion work took place. The 400 structured questionnaires were randomly administered to people whose socio-economic activity lies along the affected road. The data were analyzed quantitatively using descriptive analysis.

### **Results and Discussion**

Table 1: Mode of transportation use before and after the road expansion

Mode	Before the Road Expansion		After the Road Expansion	
	Frequency	Percent	Frequency	Percent
Motorcycle	183	45.7	123	30.7
Private Car	86	21.5	102	25.5
Mini Bus	69	17.3	121	30.3
Trekking	62	15.5	54	13.5
Total	400	100.0	400	100

Table 1 compared the mode of transportation use by respondents before and after the road expansion, it revealed that 45.7% make use of motorcycle as a result of its flexibility, fast and ability to ply through narrow road in case of traffic jams. This figure later reduced to 30.7% after the road expansion.

The amount spent by respondents reduced after the expansion of road as indicated in Table 2. Respondents who spend #30-50 before the road expansion increased from 34.7% to 55.2% after



the road expansion while those who spend above #100 before the road expansion increased from 16.4% to 18.4% after the road expansion.

Table 2: Cost of transportation before and after road expansion

Item	#30-50	#50 -100	Above #100
Before the Road Expansion	34.7%	48.9%	16.4%
After the Road Expansion	55.2%	26.4%	18.4%

The only exception are respondents who spend #50-100 before the road expansion decreased from 38.9% to 25.4% after the road expansion.

Table 3: Informed before the expansion

Response	Frequency	Percentage
Yes	316	79
No	84	21
Total	400	100

Table 3 shows that 79% of the respondents claimed they were informed before the expansion which equally led to demolition of building along the major road while 21% claimed that the work met them unaware. This implies that the government made awareness to the people before the expansion began in 2012 and necessary compensation were paid.

Table 4: Effects of road expansion during construction

Item	Frequency	Percentage
Demolition of shops	98	24.5
Loss of customers	76	19.0
Demolition of Apartment	67	16.7
Environmental Pollution	56	14.0

Traffic Congestion	45	11.3
Others	58	14.5
Total	400	100.0

During the expansion work on the road, respondents were affected in one way or the other as indicated in table 4, shops demolition accounted for 24.5%, followed by loss of customers (19%) while the least affected case was that of traffic congestion (11.3%). The road expansion crippled most of the commercial activities. For instance, the area covered by bank, filling station and other services were like hotels were blocked, disorganised with dusty atmosphere. All these reduced the amount of daily profit made by customers.

Table 5: Compensation by Government

Response	Frequency	Percentage (%)
Yes	122	30.5
No	278	69.5
Total	400	100

Majority of the affected respondents whose shops and properties were affected during the expansion work claimed they were not compensated (69.5%) while only few were compensated (30.5%).

Table 6: Adequacy of Compensation by Government

Response	Frequency	Percentage
Adequate	37	8.3
Average	85	22.2
Inadequate	278	69.5
Total	400	100

Table 6 shows the inadequacy of the compensation paid to the respondents by the government. 69.5% claimed that the compensation paid to them was inadequate while only 8.3% agreed to the adequacy of the compensation made. Those having a small kiosk or shops attested to adequate compensation because the money was sufficient enough to get them a better place for their businesses. Majority of those who said that the compensation was inadequate were the owners of the demolished structures because the amount given to them was not sufficient for the reconstruction of the structures.

Table 7: Age of the affected Buildings

Age (years)	Frequency	Percentage (%)
10 & Below	128	32.0
11 – 20	90	22.5
21 – 30	114	28.5
31 & Above	68	17.0
Total	400	100

Table 7 indicates the age of existence of the affected structures that were demolished. The result shows that 32.0 % of the affected buildings were 10 years and below. This is followed by 21-30 years (28.5%), 11-20 years (22.5%) and 30 years and above (17%). Information from oral interview showed that majority of the structures had been built long before most of the present occupants of the buildings were born.

Table 8: Setback of the affected structure to the road

Distance (metre)	Frequency	Percentage
5 –10	178	44.5
11– 15	132	33.0
16 –20	63	15.8
21 and Above	27	6.7
Total	400	100

Response on the distance of the affected structure to the road network is showed in Table 8. 44.5% respondents indicated 5-10m while 21m and above is 6.7%. Other responses fall in-between. (the standard set back should be showed here for the different roads). Majority of these structures are built very close to the road network so the expansion has to claim some part of or all the structures affected structures.

Table 9: Benefits of the Expanded Road

Response	Frequency	Percentage
Easy Packing	78	19.5
Access to Customers	94	23.5
Free flow of traffic	91	22.8
Increase Profit	84	21.0
Better out-look of the demolished houses	53	13.2
Total	400	100

The expansion of the road in Osogbo has tremendous impacts positively on the people whose socio-economic activities lies along the major route as shown in Table 9. However, the completion of the expansion work gave Osogbo better outlook of road, bring customer closer, increase profit making of business people and added physical aesthetic to the landscape from Old Garage to Kobo area of Osogbo.

## **Conclusion**

This paper showed the impact of road expansion on the socio-economic activities in Osogbo. Customers were lost during the demolition of structures for the expansion of the road due to inaccessibility to business locations and traffic jam in the area. However, the completion of the expansion work has greatly reduced road accidents and traffic congestion, creating better access to commercial activity, enhance free flow of movement of people, goods and services regardless of distance within Osogbo metropolis. The road expansion has increase the flexibility and mobility of the workforce, better outlook for the demolished structures among others. This study recommends that government should invest more in road construction, expansion and rehabilitation of the existing ones because road infrastructural development

boasts the internal revenue of the state and create employment opportunity. Landlordsshould abideby stipulated 30m setback from the centre road while speedy completion of the left over buildings partially demolished to give room for easy patronage of commercial activities and better outlook of the area.

## **REFERENCES**

- Ajayi M, Ojo B, Olukolajo M, Oyetunji A. (2013) "Impact of Road Expansion Projects on the Informal Sector in Akure, Ondo State". A paper presented at FIG Working Week of Environment for Sustainability from May 6-10, Abuja.
- Akinola, S.R, Awotona.A. (1996). The Impact of Road construction on the local environment in Nigeria: A case study of Road projects in Osun state Nigeria. The Small City and Regional Community.
- Claudi, N., B. Deichmann K.W.; Yishen, L. and Harris, S. (2015). "Transport policies and development": 1–45
- Dorosh, P.; Wang, H. G.; You, L .and Schmidt, E. (2011). "Road connectivity, population, and scrop production in Sub-Saharan Africa". *Agricultural Economics*. 43 (1): 89–103. [doi:10.1111/j.1574-0862.2011.00567.x](https://doi.org/10.1111/j.1574-0862.2011.00567.x). [ISSN 0169-5150](https://doi.org/10.1111/j.1574-0862.2011.00567.x).
- Kerali, H. (2003). "Economic appraisal of road projects in countries with developing and transition economies". *Transport Reviews*.23 (3): 249–262. [doi:10.1080/0144164032000068920](https://doi.org/10.1080/0144164032000068920). [ISSN 0144-1647](https://doi.org/10.1080/0144164032000068920)..
- Laurance, W.F., Clements, G.R., Sloan, S., O’Connell, C.S., Mueller, N.D., Goosem, M., Venter, O., Edwards, D.P., Phalan, B.and Balmford, A. (2014). A global strategy for road building. *Nature* 513, 229–232.
- Meijer, J.R., Huijbregts, M.A.J., Schotten, C.G.J. and Schipper, A.M. (2018). Global patterns of current and future road infrastructure. *Environmental Research Letters*, 13(6), 064006. <https://doi.org/10.1088/1748-9326/aabd42>
- Douven, W., Buurman, J., 2013. Planning practice in support of economically and environmentally sustainable roads in floodplains: the case of the Mekong delta floodplains. *Journal of Environmental Management* 128, 161–168
- Ogeah F. N, Omofonmwan S. I (2013) "Creation and Demolition of Illegal Structures in Nigerian Cities" Department of Geography and Regional Planning, University of Benin, Benin City, [online journal], June 2013, <http://www.transcampus.org/journals; www.ajol.info/journals/jorind> accessed 08/07/14
- Ojekunle, J.A. (2000) 'Transport and urban environmental quality in Nigeria' In H. I. Jimoh, And I. P. Ifabiyi, (eds.) Contemporary Issues in Environmental Studies, Haytee Press and Publishing Co. Ilorin, Nigeria.

Oruonye E. D. (2012) "An Assessment of the Socio-Economic Impact of Urban Development-Induced Resettlement Scheme in Nigerian Cities: A Case Study of the Nyamusala – ATC Road Construction in Jalingo Metropolis, Taraba State. *International Review of Social Sciences and Humanities Journal*. Vol. 3, No. 1, pp. 9.

Pius, T. Tanga, L. R. (2014). *The Impact of Improved Road Infrastructure on the Livelihoods of Rural Residents in Lesotho*.

Rosa, S. (2014) *Driving up Wages: The Effects of Road Construction in Great Britain*. (LSE, SERC, Grantham).

## **COMPRESSIVE STRENGTH CHARACTERISTICS OF STRUCTURAL-SIZE AKOMU (*Pycnanthus angolensis*) AND ERIRI (*Vitex doniana*) AS TIMBER COLUMN UNDER COMPRESSION**

Rahmon, R. O.\* and Jimoh, A. A.

Department of Civil Engineering, Faculty of Engineering and Technology, University of Ilorin, Nigeria

\*Email of Corresponding Author: [rorahmon2222@gmail.com](mailto:rorahmon2222@gmail.com)

### **ABSTRACT**

Structural reliability was examined on the lesser-used timber species such as Akomu (*Pycnanthus angolensis*) and Eriri (*Vitex doniana*) which can be good substitute to the well-known species. The strength and physical properties of these timber species were determined to predict the suitability of the species as structural material. Forty lengths of timber species of 50 mm x 50 mm cross-section were purchased from timber markets in Ilorin, Kwara State, Nigeria. The prevailing environmental conditions during the test were 31 °C and 64 % relative humidity. The properties tested included; air dry density, moisture content and compressive strength parallel to grain of forty test specimens each of lengths, 200, 400, 600 and 800 mm done in accordance with the British Standard BS 373 (1957). Mean air-dried moisture content for Akomu and Eriri were 11.12 % and 13.29 %, respectively, both were less than the Fibre Saturated Point (FSP) recommended value of 25 – 30 %. Mean density of Akomu and Eriri were 644.58 and 889.84 kg/m<sup>3</sup>, respectively. The typical derived equations to relate the stress and strain for Akomu and Eriri were  $y = 1097.8x - 2.9858$  and  $y = 1033.7x - 2.5309$ , respectively. The results of reliability analysis show that Akomu and Eriri timber have reliability index of 0.68 and 0.63 respectively for a service life of 50 years, provided other serviceability conditions are met. The paper therefore recommends the adoption of these equations for the design of compression members from these timber species in Nigeria.

**Keywords:** Akomu, Buckling characteristics, Compressive strength, Eriri, Reliability

### **INTRODUCTION**

Timber, a natural and renewable material, has a high strength-to-weight ratio and is easy to work on (Apu, 2003). Different timber species have different strength characteristics, and also

within a species these characteristics may vary. Therefore, in practice, a classification system of strength classes is used. Strength properties mean the ultimate resistance of a material to applied loads. Timber strength varies significantly depending on species, loading condition, load duration, and a number of assorted material and environmental factors (Jimoh *et al.*, 2018). The exact quantity of wood and non-wood forest products in Nigeria cannot be easily estimated (Alamu and Agbeja, 2011). However, studies have revealed that forest reserves occupy about 10 million hectares in Nigeria, which accounts for about 10% of a land area of approximately 96.2 million hectares (Alamu and Agbeja, 2011; NPC, 2006). Physical properties are the quantitative characteristics of timber and its behaviour to external influences other than applied forces. Familiarity with physical properties is important because they can significantly influence the performance and strength of wood used in structural applications (Winandy, 1994).

Mechanical properties are the characteristics of a material in response to externally applied forces. They include elastic properties, which characterize resistance to deformation and distortion, and strength properties, which characterize resistance to applied loads (Rahmon, *et al.*, 2017). Since timber is anisotropic, mechanical properties also vary in the three principal axes. Property values in the longitudinal axis are generally significantly higher than those in the tangential or radial axes. Flexural (bending) properties are critical. Bending stresses are induced when a material is used as a beam, such as in a floor or rafter system (Jamala *et al.*, 2013).

The main characteristic of these timber species under investigation is their buckling characteristics when subjected to compressive loading (Jimoh *et al.*, 2017). The environment, the weather condition and the soil affect the growth of trees as well as their strength properties. Most of the timber strength properties recorded in British and European codes were based on timber obtained from trees on those areas and the laboratory tests were conducted there. Since all our timber structures are constructed of timber from Nigeria, there is the great need to determine their strength properties and subject them to structural reliability analysis in order to prove their degree of structural performances (Aguwa, 2010).

The reliability,  $R(t)$  of an item is defined as the ability of an item to perform a required function under stated conditions without failure for a stated period of time. Reliability coefficients range from 0.00 to 1.00, with higher coefficients indicating higher levels of reliability. However, reliability specifically measures the consistency of an item. According to Leitch 1988,



reliability index using constant failure rate (CFR) model is as given in equation (1) and  $\lambda$  is assumed constant with time.

$$R(t) = e^{-\lambda t} \quad (1)$$

where:  $R(t)$  = reliability index;  $\lambda$  = constant rate of failure;  $t$  = variable time and the failure rate ( $\lambda$ ) is express as in equation 2:

$$\lambda = \frac{1 - d}{T} \quad (2)$$

where:  $T$  is the time (years), expected life span of timber, and  $d$ : the average compressive strength rate.

Nowak, 2004 reported that the structural reliability is the probability that a structural system will satisfy the purpose for which it was designed and efficiently serve the period for which it was designed to without attaining a given limit state. One of the Objectives for structural design is to fulfill certain performance criteria related to safety and serviceability. One of such performance criteria is usually formulated as a limit state, that is, a mathematical description of the limit between performance and non-performance (Thelandersson, 2003). Parameters used to describe limit states are loads, strength and stiffness parameters, dimensions and geometrical imperfections; since the parameters are random variables, the outcome of a design in relation to limit state is associated with uncertainty (Aguwa, 2010). A significant element of uncertainty is also introduced through lack of information about the actual physical variability. The evaluation of structural safety requires therefore, the consideration of the uncertainties (Benu *et al.*, 2004).

The aim of this study is to evaluate the structural reliability of Nigerian grown Akomu and Erii timber species as a column material under compression. The specific objectives are; to conduct experiments on the Nigerian Akomu and Erii timber species with a view to establishing their physical and strength properties, to determine the buckling behaviours of the selected timber species for different heights, to predict the critical buckling load for the selected timber species, derive continuous equations for the selected timber species as column structural material, to estimate the reliability of the Nigerian Akomu and Erii timber species, and to add value to our locally available and affordable structural material thereby increasing the local content of the construction industry in Nigeria, resulting in less dependence on foreign materials.

## **MATERIALS AND METHODS**

The study was conducted in Kwara State, North Central, Nigeria. It is a state that lies within longitudes 5<sup>00</sup>'00'' East of Greenwich meridian and latitudes 8<sup>03</sup>'00'' North of the Equator. To achieve the aims and objectives of the project, the physical and mechanical properties were carried out in accordance with BS EN 408 (1995) and BS 373 (1957).

A survey was carried out at eight timber markets within Ilorin, Nigeria. Forty lengths of each sample was cut from six randomly picked logs of timber from sawmills. It was ensured that the logs selected were free of defects and were as straight as possible before purchase. The timber samples were marked to distinguish individual timbers from different logs.

The tests were carried out on pieces which were conditioned at the standard environmental temperature of  $(30 \pm 2)$  °C and  $(65 \pm 5)$  % relative humidity. The timber species were naturally seasoned for seven months to attain moisture content equilibrium environmentally in accordance with BS 373: 1957 which specified a minimum of six months for natural seasoning of timber.

The wood species were sized to standard size of 50 x 50 mm with heights of 200, 400, 600 and 800 mm at the University of Ilorin wood workshop for the compression test, 50 x 50 x 25 mm for the determination of moisture content of the timber specimens. Forty test specimens were prepared for each test.

### **Physical Properties**

**Density determination** - In this study, only the air dry density has been determined. The specimens for density determination were completely free from knots, checks, flaws and any other defects. The volume of the specimens was calculated measuring the dimensions of length, width and thickness with the help of a Vernier scale. The density was obtained by determining the air-dry mass per unit volume for each of the test specimens.

**Moisture Content** - The moisture content of the test piece was determined on each section taken from each test pieces. The sections were full cross section (50 x 50 mm), free from knots and resin pockets. And also those pieces were cut from a region where failure occurred for moisture content determination. The test specimen has dimension 50 x 50 x 50 mm. The pieces

were weighed and then dried in an oven at a temperature of  $103 \pm 2$  °C ( $217 \pm 4$  °F) until the weights were constant.

The percentage moisture content is mathematically calculated from equation (3) as;

$$W = \frac{M_1 - M_2}{M_2} \times 100 \quad (3)$$

where:  $M_1$  is the initial weight; in grams and  $M_2$  is the mass, in grams, after oven drying.

### Determination of Compressive Strength Parallel to Grain

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, at the Department of Agricultural and Biosystems Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin was used to test the compressive strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures.

#### **Buckling load determination**

UTM was used to determine the mechanical properties of Akomu (*Pycanthus angolensis*) and Eriri (*Vitex doniana*).

**Procedures:** i. Preparation of specimens, nominal size (50 x 50 x 200 mm), (50 x 50 x 400 mm), (50 x 50 x 600 mm) and (50 x 50 x 800 mm)

ii. Placing the specimen vertically between the Cross heads.

iii. Input specimen dimensions and weight.

iv. Input the speed rate of the applied load (13.02, 26.04, 39.06 and 52.08 mm/min) for (200, 400, 600 and 800 mm) respectively.

v. Run test.

vi. A load-deflection curve and other relevant data (stress and strain at yield, stress and strain at failure, maximum load and young's modulus etc.) are generated and shown on the output device.

vii. Stop test at the point of failure. Point of failure was observed from load-deflection curve.

viii. Failure mode of specimen such as shear, split, lateral deflection and crushing were recorded before the applied load is lifted.

$$\text{Speed rate} = \frac{A_2 \times l_2}{A_1 \times l_1} \times v \quad (4)$$

where,  $A_1$  is standard cross-sectional area and its equal to  $(20 \times 20 \text{ mm}^2)$ ,  $L_1$  is standard specimen height and its equal to  $(60 \text{ mm})$ ,  $A_2$  is the nominal cross-sectional area of test specimen and its equal to  $(50 \times 50 \text{ mm}^2)$ ,  $L_2$  is the nominal height of test specimen and its equal to  $(200, 400, 600 \text{ and } 800 \text{ mm})$ ,  $v$  is the standard load speed rate and its equal to  $0.625 \text{ mm/min}$ .

Example: For 200 mm specimen,  $\text{Speed rate} = \frac{50 \times 50 \times 200}{20 \times 20 \times 60} \times 0.625 = 13.02 \text{ mm/min}$

### Stress and Strain Relationship

Stress and strain values are generated from Load against deflection curves which plotted automatically by the Universal Testometric Machine.

$$\text{Stress } (\sigma) = \frac{\text{Force}(N)}{\text{Area}(\text{mm}^2)} \quad (5)$$

$$\text{Strain } (\epsilon) = \frac{\text{Deflection}(\text{mm})}{\text{Length}(\text{mm})} \quad (6)$$

## RESULTS AND DISCUSSION

### Results of Density

The density of timber is its mass per unit volume at a specified value of moisture content of each sample. The density of an air-dried timber has a direct relationship with the strength of the timber. Hence, the strength properties increase as the timber density increases, that is, the higher the density, the higher the strength of the timber. From the experimental results, it was observed that the average density of Akomu is  $644.58 \text{ kg/m}^3$  with standard deviation of  $59.72$  and coefficient of variation of  $9.22$  while that of Eri is  $887.84 \text{ kg/m}^3$  with standard deviation of  $31.05$  and coefficient of variation of  $3.48$  as presented in Table 1. This implies that Eri has higher yield strength than Akomu. This can be confirmed from the results of compression test.

**Table 1: Average density of Timber species**

Average Density ( $\text{kg/m}^3$ )
-------------------------------------

Species	Akomu	Erii
Minimum	487.87	851.04
Maximum	720.02	957.75
Mean	644.58	887.84
S. D	31.05	59.72
COV (%)	3.48	9.22
95% Confidence limit	$634.96 \leq x \leq 654.20$	$869.33 \leq x \leq 906.34$
99% Confidence limit	$631.93 \leq x \leq 657.23$	$863.52 \leq x \leq 912.16$

### Results of Moisture Content

Moisture content is the ratio of the weight of water present in the air-dried timber sample to the oven-dry weight. It was observed that the average moisture content for Akomu timber was 11.12 % with standard deviation of 16.42 and coefficient of variation of 14.75 and for Erii was 13.29 % with standard deviation of 10.77 and coefficient of variation of 8.14 as can be seen in Table 2. This result is satisfactory, since it is less than the maximum recommended moisture content of 25 - 30 % for an air-dry sample. At this moisture content the likelihood of decay of the timber is greatly reduced. The strength of timber is also affected by its moisture content, an increase in moisture content leads to corresponding decrease in the strength of timber and vice versa.

**Table 2: Average moisture content of Timber species**

Species	Average Moisture Content (%)	
	Akomu	Erii
Minimum	9.09	5.26
Maximum	13.73	45.68
Mean	11.12	13.29
Standard Deviation	10.77	16.42
COV (%)	8.14	14.75
95% Confidence limit	$7.78 < x < 14.46$	$8.20 < x < 18.38$
99% Confidence limit	$6.73 < x < 15.51$	$6.60 < x < 19.98$

### Failure modes of Akomu and Erii samples

A structural size timber will normally fail by buckling, compression or a combination of both buckling and compression depending on the ratio of its height to its cross-sectional dimension. The slenderness ratio affords a means of classifying columns and their failure mode. A short column under the action of an axial load will fail by direct compression before it buckles, but a long column loaded in the same manner will fail by buckling. The buckling mode of

deflection generally occurs before the axial compression stresses can cause failure of the material by yielding of that compression member. This is demonstrated in Table 3. It was observed that the long sections (400, 600 and 800 mm) exhibited buckling while the short sections (200 mm) failed mostly due to shear. Fig. 1 – 3 shows the various failure modes experienced.

**Table 3: Failure modes of specimens**

Akomu				Eri			
Specimen ID	Height (mm)	Failure mode	Observed deflection (mm)	Specimen ID	Height (mm)	Failure mode	Observed deflection (mm)
A1	208.00	Shear	-	D1	200.00	Shear	-
B1	205.00	Shear	-	E1	200.00	Shear	-
C1	200.00	Shear	-	F1	202.00	Splitting	-
A2	402.00	Buckling	5.0	D2	398.00	Buckling	13.0
B2	403.00	Buckling	5.0	E2	397.00	Shear	-
C2	402.00	Buckling	10.0	F2	401.00	Buckling	3.0
A3	597.00	Buckling	25.0	D3	598.00	Buckling	14.0
B3	598.00	Buckling	10.0	E3	600.00	Buckling	14.0
A4	801.00	Buckling	14.0	F3	595.00	Buckling	5.0
B4	800.00	Buckling	40.0	D4	803.00	Buckling	22.0
C4	801.00	Buckling	23.0	E4	801.00	Buckling	15.0
				F4	812.00	Buckling	21.0



**Figure 1: Failure mode of 200mm (Shear)**



**Figure 2: Failure mode of 200mm (Splitting)**



Figure 3: Failure mode of 200mm (Buckling)

#### Stress-strain relationship results

The results of the stress-strain relationship are presented in the Table 4 and 5. The mean stress in compression at yield for 200, 400, 600 and 800 mm heights of Akomu were; 30.104, 29.544, 18.530 and 15.434 N/mm<sup>2</sup> respectively. The mean stress in compression at yield for 200, 400, 600 and 800 mm heights of Erii were; 26.429, 30.774, 33.311 and 26.365 N/mm<sup>2</sup> respectively.

The equations of stress-strain relationship of Akomu and Erii timber species are shown in equation (7) and (8) as presented in the Fig. 4 and 5.

The maximum stress of Akomu sections can be estimated using the equation:

$$y = 1097.8x - 2.9858 \quad (7)$$

The maximum stress of Erii sections can be estimated using the equation:

$$y = 1033.7x - 2.5309 \quad (8)$$

Table 4: Typical Stress-Strain Relationship for Akomu

Strain	Stress (200mm)	Stress (400mm)	Stress (600mm)	Stress (800mm)	Average Stress
0.000	0.000	0.000	0.000	0.000	0.000
0.001	0.065	0.052	0.078	0.086	0.070
0.002	0.296	0.237	0.404	0.295	0.308

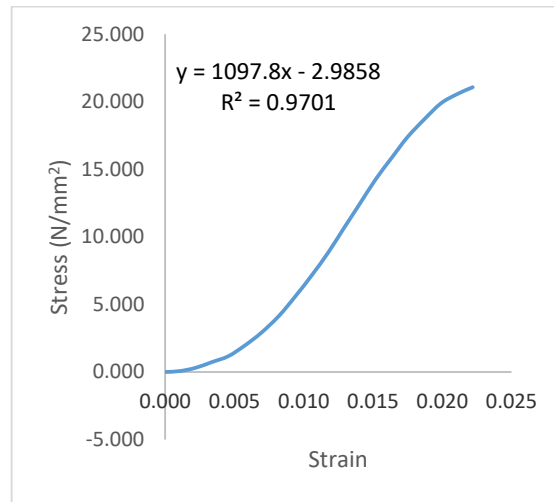


0.003	0.772	0.657	0.905	0.591	0.731
0.005	1.228	1.162	1.449	0.859	1.174
0.006	2.153	2.089	2.290	1.294	1.957
0.007	3.265	3.363	3.204	1.817	2.912
0.008	5.037	4.782	4.288	2.509	4.154
0.009	7.051	6.498	5.380	3.431	5.590
0.011	9.117	8.391	6.709	4.310	7.132
0.012	11.509	10.313	8.126	5.444	8.848
0.013	13.958	12.484	9.693	6.588	10.681
0.014	16.375	14.511	11.193	7.684	12.441
0.015	18.758	16.635	12.688	8.930	14.253
0.016	20.864	18.580	14.006	10.052	15.875
0.017	22.787	20.435	15.270	11.016	17.377
0.019	24.405	22.244	16.218	12.014	18.720
0.020	25.818	23.944	17.066	12.691	19.880
0.021	27.003	24.622	17.605	12.985	20.553
0.022	27.828	25.435	17.903	13.133	21.075

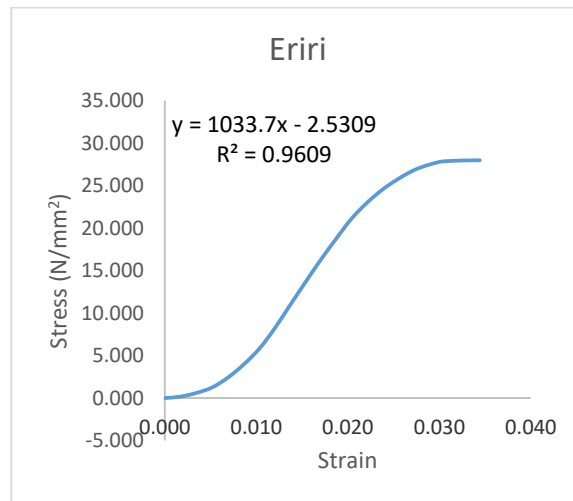
**Table 5: Typical Stress-Strain Relationship for Eri**

<b>Strain</b>	<b>Stress (200mm)</b>	<b>Stress (400mm)</b>	<b>Stress (600mm)</b>	<b>Stress (800mm)</b>	<b>Average Stress</b>
0.000	0.000	0.000	0.000	0.000	0.000
0.002	0.041	0.052	0.454	0.077	0.156
0.003	0.365	0.260	1.420	0.275	0.580
0.005	1.103	0.699	2.519	0.679	1.250
0.007	2.735	1.387	4.116	1.380	2.405
0.009	4.471	2.764	6.001	2.515	3.938
0.010	6.827	4.559	8.193	3.827	5.852
0.012	9.393	7.209	10.550	5.536	8.172
0.014	12.201	10.393	13.097	7.527	10.805
0.015	15.047	13.876	15.745	9.647	13.579
0.017	17.539	17.295	18.443	12.048	16.331
0.019	19.618	20.476	20.940	14.237	18.818
0.020	21.093	23.297	23.425	16.531	21.087
0.022	22.245	25.527	25.748	18.630	23.038
0.024	23.095	27.190	27.790	20.390	24.616
0.026	23.708	28.352	29.374	21.944	25.845
0.027	24.255	29.178	30.655	23.235	26.831
0.029	24.677	29.728	31.296	24.259	27.490

0.031	24.973	29.924	31.504	25.092	27.873
0.034	25.336	29.400	31.504	25.686	27.982



**Figure 4: Typical Stress-strain curve for Akomu**



**Figure 5: Typical Stress-strain curve for Erii**

Table 6 presents the relationship that exist between the timber species stress, strain, slenderness ratio and Young’s Modulus. The stress at which a column buckles decreases as slenderness ratio increases and the mean length increases as well.

**Table 6: Slenderness ratio, Stress @ Yield and Young’s Modulus relationship for Akomu and Eri**

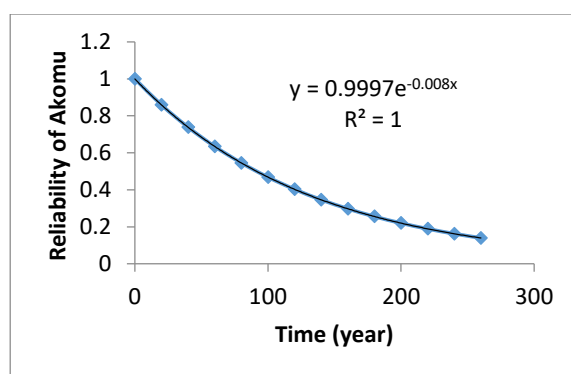
Mean Height (mm)	Mean Slenderness ratio, $\lambda$		Mean Stress @ Yield, $\sigma$ (N/mm <sup>2</sup> )		Young’s Modulus (N/mm <sup>2</sup> )	
	Akomu	Eri	Akomu	Eri	Akomu	Eri
	<b>202.50</b>	15.93	14.25	30.10	26.43	2045.71
<b>400.50</b>	31.94	28.80	29.54	30.77	1465.74	1350.13
<b>599.67</b>	45.73	43.55	18.53	33.31	723.13	1091.83
<b>803.00</b>	58.31	57.77	15.43	26.37	418.43	918.17
<b>Average</b>			<b>23.40</b>	<b>29.22</b>	<b>1163.25</b>	<b>1223.80</b>

**3.5 Reliability Analysis results**

The Tables 7, 8, 9 and 10 show the reliability analysis of Akomu and Eri timber species using Constant Failure Rate model, while Figure 6 and 7 show the reliability index of the studied specimens.

**Table 7: Strength Analysis of Akomu timber**

Height (mm)	Average Strength ( $\sigma$ ) (N/mm <sup>2</sup> )	Cumulative Strength ( $Q_i$ ) (N/mm <sup>2</sup> )	Remaining Strength ( $R_i$ ) (N/mm <sup>2</sup> )	Strength Rate ( $d_i$ )
200.00	30.104	30.104	63.508	0.4740
400.00	29.544	59.648	33.964	0.4652
600.00	18.530	78.178	15.434	0.5456
800.00	15.434	93.612	0	1.0000



**Figure 6: Reliability of Akomu timber**

The results of the reliability analysis show that the timber species Akomu and Eri has reliability index of 0.68 and 0.63 respectively (which are both greater than 0.5, the minimum

index for a reliable structure according to Abdulraheem (2016), Adedeji (2008) and Ajamu (2014). for a service life of 50 years, assuming other serviceability conditions are met.

Average Strength rate,

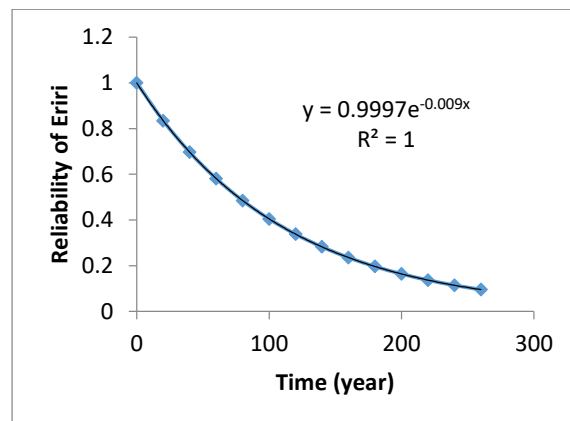
$$d = \frac{0.4740+0.4652+0.5456+1.0000}{4} = 0.6212$$

Failure rate,  $\lambda = \frac{1-d}{t}$ , assuming a service life of 50 years and that other serviceability conditions are met, the reliability of the Akomu timber column is evaluated as shown below using Constant Failure Rate (CFR).

$$\lambda = \frac{1 - 0.6212}{50} = 0.007576/\text{years}$$

**Table 8: Reliability of Akomu using CFR**

Time (years)	$\lambda t$	$e^{-\lambda t}$	Time (years)	$\lambda t$	$e^{-\lambda t}$
<b>0</b>	0	1	<b>140</b>	1.061	0.3461
<b>20</b>	0.152	0.8590	<b>160</b>	1.212	0.2976
<b>40</b>	0.303	0.7386	<b>180</b>	1.364	0.2556
<b>60</b>	0.455	0.6345	<b>200</b>	1.515	0.2198
<b>80</b>	0.606	0.5455	<b>220</b>	1.667	0.1888
<b>100</b>	0.758	0.4686	<b>240</b>	1.818	0.1624
<b>120</b>	0.909	0.4029	<b>260</b>	1.970	0.1395



**Figure 7: Reliability of Erii timber**

**Table 9: Strength Analysis of Eriro timber**

<b>Height (mm)</b>	<b>Average Strength (<math>\sigma</math>) (N/mm<sup>2</sup>)</b>	<b>Cumulative Strength (<math>Q_i</math>) (N/mm<sup>2</sup>)</b>	<b>Remaining Strength (<math>R_i</math>) (N/mm<sup>2</sup>)</b>	<b>Strength Rate (<math>d_i</math>)</b>
200.00	26.429	26.429	90.450	0.2922
400.00	30.774	57.203	59.676	0.3402
600.00	33.311	90.514	26.365	0.5582
800.00	26.365	116.879	0	1.0000

**Table 10: Reliability of Eriro using CFR**

<b>Time (years)</b>	<b><math>\lambda t</math></b>	<b><math>e^{-\lambda t}</math></b>	<b>Time (years)</b>	<b><math>\lambda t</math></b>	<b><math>e^{-\lambda t}</math></b>
<b>0</b>	0	1	<b>140</b>	1.266	0.2820
<b>20</b>	0.181	0.8344	<b>160</b>	1.447	0.2353
<b>40</b>	0.362	0.6963	<b>180</b>	1.628	0.1963
<b>60</b>	0.543	0.5810	<b>200</b>	1.809	0.1638
<b>80</b>	0.724	0.4848	<b>220</b>	1.990	0.1367
<b>100</b>	0.905	0.4045	<b>240</b>	2.171	0.1141
<b>120</b>	1.086	0.3376	<b>260</b>	2.352	0.0952

Average Strength rate,  $d = \frac{0.2922+0.3402+0.5582+1.0000}{4} = 0.5477$

Failure rate,  $\lambda = \frac{1-d}{t}$ , assuming a service life of 50 years and that other serviceability conditions are met, the reliability of the Eriro timber column is evaluated as shown below using Constant Failure Rate (CFR).

$$\lambda = \frac{1 - 0.5477}{50} = 0.009046/\text{years}$$

**CONCLUSION**

The overall conclusions emerging from this study are;

1. The result shows that Eriro has higher yield strength than Akomu and thus will be more suitable for Structural use. The result further illustrates the direct relationship that exists between physical properties such as moisture and density, and mechanical properties such as yield strength and elastic modulus.

2. The maximum stress of Akomu and Eri sections can be estimated using the equation:  
 $y = 1097.8x - 2.9858$  and  $y = 1033.7x - 2.5309$  respectively. The stress at which a column buckles decreases as slenderness ratio increases.
3. A short column under the action of an axial load will generally fail by shear, but a long column will fail by buckling.
4. With the results obtained and the associated equations derived, the strength of both timber species can be accurately predicted, thereby encouraging the use of these natural and sustainable construction materials.
5. The result of the reliability analysis show that the timber species Akomu and Eri has reliability index of 0.68 and 0.63 respectively for a service life of 50 years, assuming other serviceability conditions are met.
6. However further research is required to determine other strength properties such as bending strength, tensile strength and the determination of these strength properties for different structural sizes should also be carried out. This will enable not only an effective design, but also a holistic design procedure to be developed for both Akomu and Eri timbers.

#### **REFERENCES**

- Abdulraheem, K. K. (2016). Reliability Index Assessment of Solid and laminated teak Wooden Deep I-Beam for residential Building. M. Eng. Thesis report submitted to the Department of Civil Engineering, Faculty of Engineering and Technology, University of Ilorin, Nigeria.
- Adedeji A. A. (2008). Reliability-Based Probability Analysis for Predicting Failure of Earth Brick Wall in Compression. *Nigerian Journal of Construction Technology and Management*, 9(1), 25 – 34.
- Aguwa, J. I. (2010). Reliability Studies on the Nigerian Timber as an Orthotropic, Elastic Structural Material. A Ph.D. Thesis submitted to Postgraduate School, Federal University of Technology, Minna, Nigeria.
- Aguwa J. I. and Sadiku S. (2011). Reliability Studies on the Nigerian Ekki timber as bridge beam in bending under the ultimate limit state of loading. *Journal of Civil Engineering and Construction Technology (JCECT)*, 2(11), 253-259.
- Ajamu, S. O. (2014). Optimal design of cement-lime plastered straw bale masonry under vertical load and thermal insulation for a residential building, Ph. D Thesis report submitted to the Department of Civil Engineering, faculty of Engineering and Technology, University of Ilorin, Nigeria.

- Alamu, I. O. and Agbeja, B. O. (2011). Deforestation and endangered indigenous tree species in South-West Nigeria. *International Journal of Biodiversity and Conservation*, 3(7), 291-297.
- Apu, S. S. (2003). Wood Structure and Construction Method for Low-cost Housing, *International Seminar/Workshop on Building materials for Low-cost Housing, Indonesia*, 7-28.
- Benu, M. J., Sule, S. and Nwofor, T. C. (2012). Reliability analysis of a square solid timber column. *Journal of Advances in Applied Science Research*, 3(4), 1997-2004.
- British Standard, BS 373 (1957). Methods of Testing Small clear Specimens of Timber, British Standards Institution, 2 Park Street, London W1A 2BS.
- British Standard, BS 5268-2 (2002). The Structural Use of Timber part 2; for Permissible Stresses, Materials and Workmanship, 5th Edition British Standards Institution, 2 Park Street, London W1A 2BS, 1 - 176.
- British Standard European Standard, BS EN 408 (2003). Timber Structures – Structural Timber and Glue-laminated Timber – Determination of some Physical and Mechanical Properties. London: British Standard Institution. 1 – 33.
- Jamala, G. Y., Olubunmi, S. O., Mada, D. A. and Abraham, P. (2013). Physical and Mechanical Properties of Selected Wood Species in Tropical Rainforest Ecosystem, Ondo State, Nigeria.
- Jimoh, A. A., Rahmon, R. O. and Ajide, S. O. (2018). Reliability-Based Investigation on Compressive Strength Characteristics of Structural-Sized Iroko (*Meliceae excelsa*) and Mahogany (*Khaya ivorensis*) Timber Column found in Nigeria. *Journal of Computational Engineering and Physical Modeling*, 1(1), 23 – 27.
- Jimoh, A. A., Rahmon, R. O. and Joseph, S. G. (2017). Evaluation of Compressive Strength Characteristics of Structural-sized Apa (*Afzelia bipindensis*) and Opon (*Lannea schimperi*) Timber species columns found in Nigeria. *Journal of Applied Science and Environmental Management*, 21(7), 1281 – 1285.
- Leitch, R. D. (1988). Basic reliability engineering analysis, 1<sup>st</sup> Edition, McGinley, 13-86.
- National Population Commission, NPC (2006). Federal office of Statistics, Abuja, Nigeria.
- Nigerian Standard Code of Practice, NCP 2 (1973). The use of Timber for Construction, Nigerian Standards Organisation, Federal Ministries of Industries, Lagos, Nigeria, 1 - 71.

Nowak, A. S. (2004). Survey of Textbooks on Reliability and Structure, Report on the Special Project sponsored by The Structural Engineering Institute of ASCE.

Rahmon, R. O., Jimoh, A. A., Babatunde, O. Y. and Tazou, O. L. (2017). Strength Characterization and Grading of Eku (*Brachystegia eurycoma*) Timber Grown in Kwara State, Nigeria in accordance to BS 5268. *USEP: Journal of Research Information in Civil Engineering*, 14(4), 1891 – 1905.

Thelandersson S. (2003). Introduction: Safety and Serviceability in Timber Engineering, In Thelandersson S. and Larsen H.J. (Eds) *Timber Engineering*, John Wiley and Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, England.

Timber Research and Development Association (1979). *Timbers of the World*, Longman, New York, 8-9.

Winandy, J. E. (1994). Wood properties. In: Arntzen, C. J. ed. *Encyclopedia of Agricultural Sciences*, Orlando, FL: Academic press, 4, 549-561.



## **VISCOUS FLOW EFFECT FOR SIMULTANEOUS SQUEEZE AND SLIP FLOW OF A POROUS EMBEDDED NON-NEWTONIAN FLUID.**

Ilegbusi, A.O.<sup>1</sup> and Akinshilo, A.T.<sup>2</sup>

<sup>1</sup>Department of Mechanical Engineering, Yaba College of Technology, Yaba, Lagos, Nigeria.

E-mail: [illegbusi@gmail.com](mailto:illegbusi@gmail.com)

<sup>2</sup>Department of Mechanical Engineering, University of Lagos, Akoka- Yaba, Lagos, Nigeria.

E-mail: [ta.akinshilo@gmail.com](mailto:ta.akinshilo@gmail.com)

### **ABSTRACT**

In this study, an electrically conducting squeezing Casson fluid embedded in a porous medium under slip condition is considered. The Casson fluid, a non-Newtonian fluid category whose viscosity is not constant with the shearing rate is considered. Practical applications of the Casson fluid include chemical and flow processes such as drill mud, polymer solution, tomato sauce, paint, jelly amongst others. The momentum equation formulates the flow process, which is transformed using similarity variables to nonlinear higher-order differentials; this is analyzed utilizing the homotopy perturbation method. The effect of the embedded porous media on the squeezing fluid flow is studied using the obtained analysis. Important parameters such as Darcy number and slip are investigated. As reported from graphical representation, there is indication that the porous medium effect increases viscosity as this limits flow rate, therefore increasing the energy required for fluid transport. Results obtained from the analytical solution prove to be in good agreement with literature. Results from the study provide useful insight into relevant applications including power transmission, lubricating system, compression and food processing amongst others.

Keywords: Casson fluid; slip; Porous medium; Parallel plate; Homotopy Perturbation Method.

### **1. Introduction**

The Casson fluid is a subclass of non-Newtonian fluid whose rheological properties cannot be described by a single model as obtained for Newtonian fluid but higher-order nonlinear complex models. This realistic model describes the Casson fluid as a shear-thinning liquid with infinite viscosity at zero shear rate and the infinite shear rate at zero viscosity. Studies have proven that this fluid model can describe jelly, tomato sauce, honey, drill mud and paint solutions flow. However, it best describes blood flow (Mrill *et al*, 2008). (MacDonald, 1874) in efforts to study Casson fluid flow considered arterial blood flows. (Stefan, 1984) pioneered

the study of squeeze flow between parallel surfaces for varying flow situations. Shortly after (Reynolds, 1886) analyzed squeezing flows for elliptic and rectangular plates. However, the squeezing fluid flow model developed by (Reynolds, 1886) was proven to be insufficient; consequently (Zang, 1979), (Kirchoff, 1960) and Wang and (Watson, 1979) improved upon Reynold's model utilizing similarity transform to present Navier Stokes equation as order four nonlinear equations. (Mustafa *et al*, 2012) investigated the heat and mass transfer between parallel disks undergoing unsteady squeezing fluid flow while (Hayat *et al*, 2011) presented the squeezing flow of second-grade fluid between parallel plates in the presence of the magnetic field. Domairry and (Aziz, 2009) applied the homotopy perturbation method to study the effects of suction and injection on MHD squeeze flow between parallel disks. Viscous squeezing fluid flow between plates under unsteady conditions was analyzed by (Siddiqui *et al*, 2008). Analytic approximate solutions were adopted by (Rashidi *et al*, 2008) to study unsteady squeezing flow between parallel plates. (Khan and Aziz, 2011) presented the flow of nanofluid between parallel plates due to natural convection. Shortly after (Khan and Aziz, 2011) presented double-diffusive natural convective boundary layer fluid flow through porous media saturated with nanofluid. (Kuznetsov and Nield, 2010) also studied natural convective flow through a vertical plate. The analytic solution was also applied by (Hashimi *et al*, 2014) to study the squeezing fluid flow of nanofluid. The effect of the stretching sheet wall problem adopting natural convective boundary conditions was investigated by different authors ranging from (Gul and Afridi, 2018) to (Ellahi *et al*, 2010). The slip boundary condition states that the tangential component of fluid velocity to the wall boundary is proportional to tangential stress. Upon this other researchers have built upon.

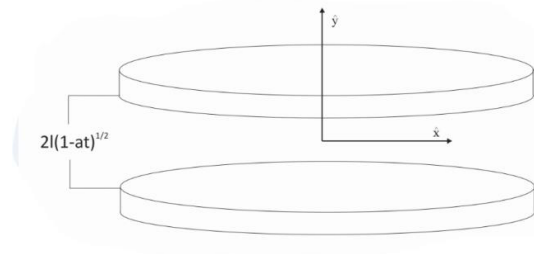
In the light of past research works, this study investigates the electrically squeezing Casson fluid flow embedded in a porous medium under slip condition.

## **2. Methodology**

An incompressible Casson fluid embedded in a porous medium is considered. The parallel plates separated by a distance  $H$ , dilate when  $S > 0$  but collapse when  $S < 0$  till both plates touch each other as shown in Fig.1. Constant magnetic field flux is applied perpendicularly to the plates, assuming the effects of magnetic and electrical fields generated due to the electrically conducting Casson fluid flow are negligible; plates are at a constant temperature, the non-Newtonian fluid structure is thermodynamically compatible.

## 2.1 Problem Formulation

Based on the above conditions, model development for the Casson fluid flow is introduced as follows:



**Fig. 1.** Physical model of the problem [37].

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (1)$$

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \nu \left( 1 + \frac{1}{\gamma} \right) \left( 2 \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 v}{\partial x \partial y} \right) - \frac{\mu u}{K_p} - \frac{\sigma B_0^2 u}{\rho} \quad (2a)$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = -\frac{1}{\rho} \frac{\partial p}{\partial y} + \nu \left( 1 + \frac{1}{\gamma} \right) \left( 2 \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 u}{\partial x \partial y} \right) \quad (2b)$$

Where components of velocity in the x and y directions are u and v respectively, pressure is p; dynamic viscosity is represented as  $\nu$ ,  $\gamma$  is the Casson parameter,  $K_p$  is the permeability of the porous medium,  $B_0$  is the magnetic flux intensity applied on the fluid and  $\sigma$  is the electrical conductivity.

Taking boundary condition as

$$u = \beta_1 \frac{\partial u}{\partial y}, \quad v = v_h \left( \frac{dh}{dt} \right) \quad \text{at } y = h(t) \quad (3)$$

$$u = -\beta_1 \frac{\partial u}{\partial y}, \quad v = \frac{v_0}{\sqrt{1-at}} \quad \text{at } y = 0$$

$\beta_1$  is taken as the velocity slip parameter.

The Eq. (4) connotes the rheological equation for the isotropic flow of the Casson fluid, where  $\mu_B$  connotes plastic kinematic viscosity of the non-Newtonian fluid,  $p_y$  is fluid yield stress,  $\pi$

is component of deformation,  $\pi_c$  represent the critical values of thin product based non-Newtonian model,  $e_{ij}$  is the component of deformation.

$$T_{ij} = \begin{cases} 2\left(\mu_B + \frac{p_y}{\sqrt{2\pi}}\right)e_{ij}, \pi > \pi_c \\ 2\left(\mu_B + \frac{p_y}{\sqrt{2\pi_c}}\right)e_{ij}, \pi < \pi_c \end{cases} \quad (4)$$

Introducing the similarity variables as [31]:

$$\bar{u} = \frac{\alpha x}{[2(1-\alpha t)]} F'(\eta), \quad \bar{v} = \frac{-\alpha l}{[2(1-\alpha t)^{1/2}]} F(\eta), \quad \eta = \frac{y}{[l(1-\alpha t)^{1/2}]} \quad (5a)$$

The non-Dimensional parameters are defined as:

$$G = \frac{\mu u}{K_p}, \quad S = \frac{\alpha l^2}{2\nu}, \quad M^2 = \frac{\sigma B_0^2 H}{\mu} \quad (5b)$$

Where  $\bar{u}$  and  $\bar{v}$  are the dimensionless velocity component in x and y directions respectively,  $\eta$  is the dimensionless normal distance, G is the Darcy parameter measuring inertial effects on flow embedded in the porous medium, S is the dimensionless squeezing number which measures effect of dilating and collapsing plates on fluid flow and  $M^2$  is the Hartman parameter which depicts the influence of magnetic force on fluid flow. Simplifying systems of equations, Eqs. (2)- (3). Eliminating pressure gradient term, then applying the non-dimensional transforms the governing equation for the Casson fluid can be written as [23] introducing the Darcy parameter:

$$\left(1 + \frac{1}{\gamma}\right) \frac{d^4 f}{d\eta^4} - S \left( f + 3 \frac{d^2 f}{d\eta^2} + \frac{df}{d\eta} \frac{d^2 f}{d\eta^2} - f \frac{d^3 f}{d\eta^3} - \left(M^2 + \frac{1}{G}\right) \frac{d^2 f}{d\eta^2} \right) = 0 \quad (6)$$

With slip boundary condition given as

$$f = 0, \quad \frac{df}{d\eta} = -\beta \frac{d^2 f}{d\eta^2} \text{ at } \eta = 0 \quad (7a)$$

$$f = 1, \quad \frac{df}{d\eta} = \beta \frac{d^2 f}{d\eta^2} \text{ at } \eta = 1 \quad (7b)$$

Effect of skin friction is defined as

$$C_{fr} = v \left( 1 + \frac{1}{\gamma} \right) F' \quad (8)$$

## 2.2 Application of the Homotopy Perturbation Method

The HPM, which is an analytical scheme for providing approximate solutions to the ordinary differential equation has been explicitly explained by (Akinshilo and Ilegbusi, 2019), is adopted in generating solutions to the coupled ordinary nonlinear differential equations. Upon constructing the homotopy, the Eqs. (6) can be expressed as:

$$(1-P) \left( \frac{d^4 f}{d\eta^4} \right) + P \left( \begin{array}{l} \left( 1 + \frac{1}{\gamma} \right) \frac{d^4 f}{d\eta^4} - S \\ f + 3 \frac{d^2 f}{d\eta^2} + \frac{df}{d\eta} \frac{d^2 f}{d\eta^2} \\ -f \frac{d^3 f}{d\eta^3} - \left( M^2 + \frac{1}{G} \right) \frac{d^2 f}{d\eta^2} \end{array} \right) = 0 \quad (9)$$

Power series of velocity fields yields

$$f = P^0 f_0 + P^1 f_1 + P^2 f_2 + O(P^3) \quad (10)$$

Substituting Eq. (9) into (10) yields

$$P^0 : \frac{d^4 f_0}{d\eta^4} \quad (11)$$

$$P^1 : \frac{d^4 f_1}{d\eta^4} + \frac{1}{\gamma} \frac{d^4 f_0}{d\eta^4} + - \left( \begin{array}{l} f_0 + 3 \frac{d^2 f_0}{d\eta^2} + \frac{df_0}{d\eta} \frac{d^2 f_0}{d\eta^2} - f_0 \frac{d^3 f_0}{d\eta^3} \\ - \frac{d^2 f_0}{d\eta^2} \left( M^2 + \frac{1}{G} \right) \end{array} \right) \quad (12)$$

$$\begin{aligned}
 P^2 : & \frac{d^4 f_2}{d\eta^4} + \frac{1}{\gamma} \frac{d^4 f_1}{d\eta^4} - S f_1 - 3S \frac{d^2 f_1}{d\eta^2} - \\
 & S \frac{df_0}{d\eta} \frac{d^2 f_1}{d\eta^2} - S \frac{df_1}{d\eta} \frac{d^2 f_0}{d\eta^2} - S f_0 \frac{d^3 f_1}{d\eta^3} + \\
 & S f_1 \frac{d^3 f_0}{d\eta^3} f_2 + S \frac{d^2 f_1}{d\eta^2} \left( M^2 + \frac{1}{G} \right)
 \end{aligned}
 \tag{13}$$

Taking the leading order boundary condition as

$$f_0 = 0 \quad \frac{df_0}{d\eta} = -\beta \frac{d^2 f_0}{d\eta^2}, \text{ at } \eta = 0 \tag{14a}$$

$$f_0 = 1, \quad \frac{df_0}{d\eta} = \beta \frac{d^2 f_0}{d\eta^2} \text{ at } \eta = 1 \tag{14b}$$

Simplifying Eq. (11) applying the leading order boundary condition Eq. (14) yields

$$f_0 = \eta + \left( \frac{\eta(\eta-1)(6\beta+2\eta-1)}{(12\beta^2-1)} \right) \tag{15}$$

The coefficient  $P^1$  and  $P^2$  for  $f(\eta)$  in Eqs. (12-13) were too long to be mentioned here but it is expressed graphically in all the results and the result validation, Table 1. Therefore, final expressions for flow profile can be expressed as

$$f(\eta) = f_0(\eta) + f_1(\eta) + f_2(\eta) \tag{16}$$

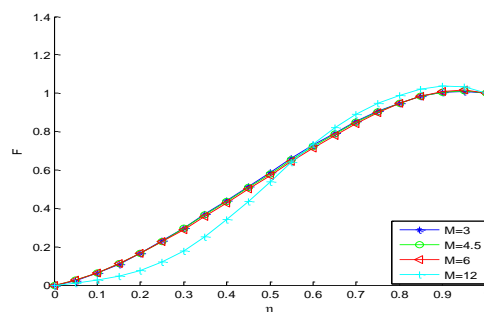
**Table 1.** Comparison of various values of  $\eta$  for  $f(\eta)$ . When  $\gamma=0.4$ ,  $M=1$ ,  $G=\beta=0$ .

$\eta$	S=5			
	Numerical	VPM (37)	Present work	Error
0	0	0	0	0
0.1	0.139081	0.139081	0.1391	0.000019
0.2	0.276358	0.276358	0.2764	0.000042

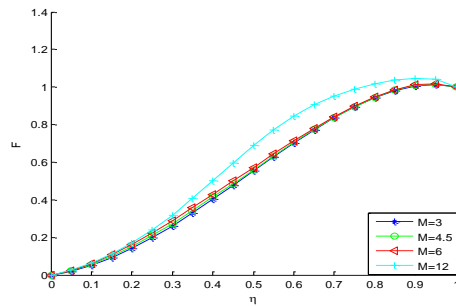
0.3	0.409918	0.409918	0.4099	0.000018
0.4	0.537628	0.537628	0.5376	0.000028
0.5	0.657014	0.657014	0.6570	0.000014
0.6	0.765125	0.765125	0.7651	0.000025
0.7	0.858383	0.858383	0.8584	0.000017
0.8	0.932408	0.932408	0.9324	0.000008
0.9	0.981819	0.981819	0.9818	0.000019
1.0	1	1	1	0

### 3.0 Results and Discussion

Table 1. expresses the validity of solutions obtained utilizing the homotopy perturbation method (HPM) as compared against the fourth-order Runge Kutta numerical and variational parameter method (VPM) for the simplified case, i.e.  $\beta=G=0$ . It can be observed from Fig. 2a that as the plates move apart, (i.e.  $S>0$ ) effect of increasing magnetic parameter ( $M$ ) shows decreasing velocity distribution towards the lower plate while the upper plate is approached towards  $\eta=0.55$  (not accurately determined) the velocity distribution increases towards the upper plate. When the plate collapses (i.e.  $S<0$ ) effect of the magnetic parameter is observed in Fig.2b, which depicts increasing velocity distribution. However, as the upper plate is approached, a rapid increase in velocity distribution is seen. This phenomenon can be physically explained as a result of Lorentz force which is a resistive force category that slows fluid motion at the boundary due to electrical conducting fluid.

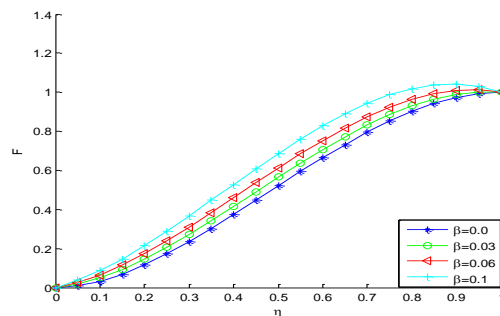


**Fig. 2a.** Effect of Hartmann parameter on velocity profile when  $S>0$ .



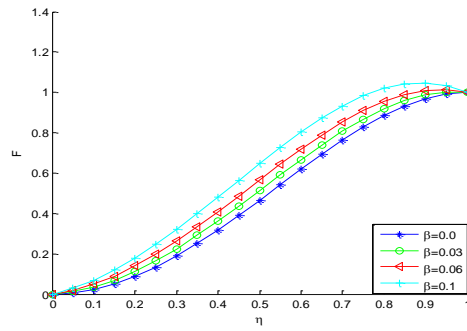
**Fig. 2b.** Effect of Hartmann parameter on velocity profile when  $S < 0$ .

The influence of slip parameter ( $\beta$ ) as the Casson fluid is conveyed through the parallel plates is observed in Fig. 3. As illustrated the plate recedes and dilates as shown in Fig. 3a (i.e.  $S > 0$ ), slip increases significantly towards the upper plate, also as the plate collapses as seen in Fig 3b (i.e.  $S < 0$ ) a similar trend is observed due to rapid fluid motion towards the boundary. At the center of the plate, increasing fluid velocity is compensated by fluid decrease near-wall due to conservation of mass. The squeeze flow effect ( $S$ ) is demonstrated in Fig.4. A significant increase in velocity distribution is observed, which is physically explained due to an increase in fluid velocity as plates move further apart for  $S > 0$  in Fig. 4a compared with plates coming together as a result of decreasing fluid velocity observed in Fig. 4b. Casson parameter ( $\gamma$ ) effect during flow is observed for receding plate in Fig.5a which shows a slight decrease in velocity profile due to increased plastic dynamic viscosity which enables fluid to behave as a shear-thinning liquid with infinite viscosity at zero shear rates. However, a significant increase in velocity profile for increasing  $\gamma$  parameter is shown in Fig. 5b as a result of decreased plastic dynamic viscosity.

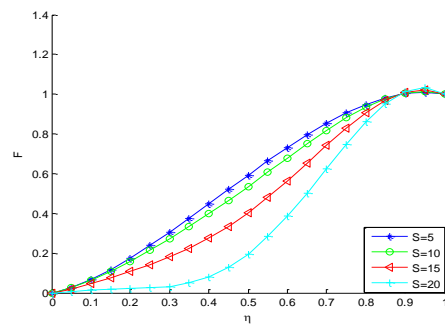


**Fig. 3a.** Effect of slip parameter on velocity profile when  $S > 0$ .

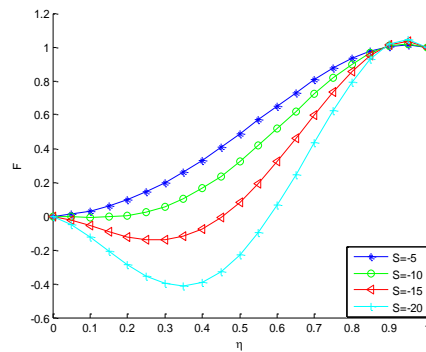




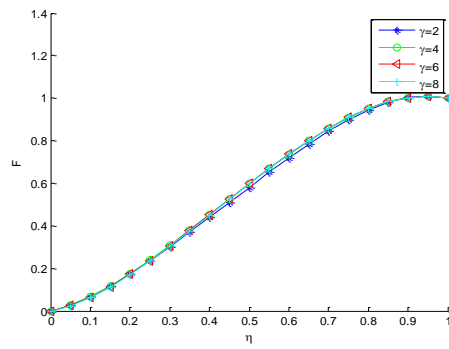
**Fig. 3b.** Effect of slip parameter on velocity profile when  $S < 0$ .



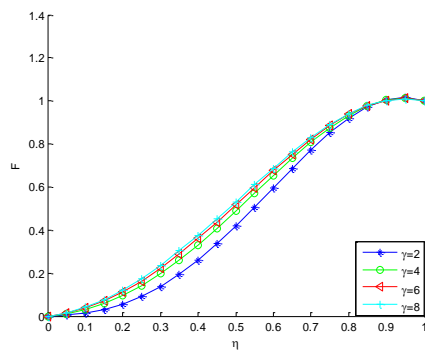
**Fig. 4a.** Effect of squeeze parameter on velocity profile when  $S > 0$ .



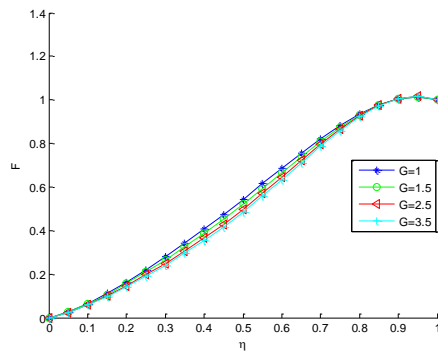
**Fig. 4b.** Effect of squeeze parameter on velocity profile when  $S < 0$ .



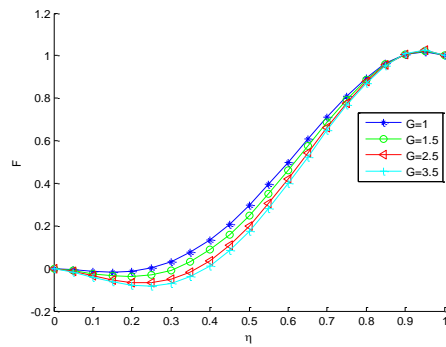
**Fig. 5a.** Effect of Casson parameter on velocity profile when  $S>0$ .



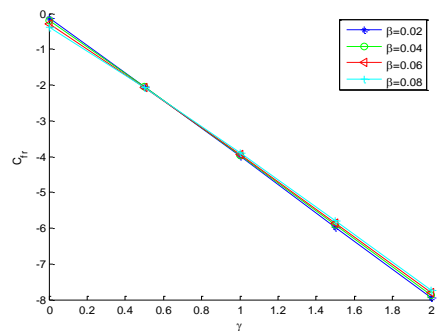
**Fig. 5b.** Effect of Casson parameter on velocity profile when  $S<0$ .



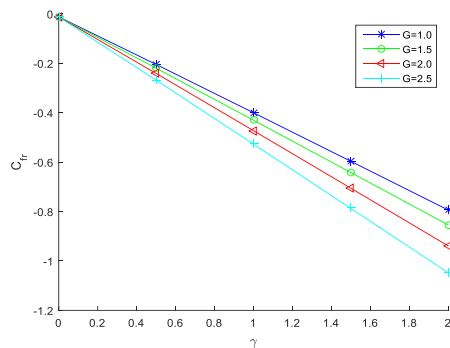
**Fig. 6a.** Effect of Darcy parameter on velocity profile when  $S>0$ .



**Fig. 6b.** Effect of Darcy parameter on velocity profile when  $S < 0$ .



**Fig. 7a.** Effect of slip parameter on skin friction.



**Fig. 7b.** Effect of Darcy parameter on skin friction.

The effect of the Darcy parameter ( $G$ ) on fluid flow is observed in Fig.6. As shown for the dilating plate motion represented by Fig. 6a, increasing  $G$  parameter causes a slight decrease in velocity profile while plates collapse represented by Fig.6b rapid decrease in velocity profile is observed. This can be explained physically due to increasing dynamic fluid viscosity which limits fluid flow. Consequently, the velocity decreases. The slip effect on skin friction is

illustrated in Fig.7a, which shows a slight decrease towards the lower plate and a slight increase towards the upper plate as observed. The effect of the Darcy parameter on skin friction is illustrated in Fig.7b which shows the increasing magnitude of the Darcy parameter leads to skin friction decrease, similarly rapid decrease in skin friction is seen for a quantitative increase in the Casson parameter.

#### **4. Conclusion**

This study investigates the viscous flow effect of slip and squeeze on the Casson fluid embedded in a porous medium. Obtained approximate analytical solutions generated from the coupled system of the nonlinear equation, which describes fluid rheological properties are used to examine the effects of parameters such as slip and magnetic field on viscosity. Results reveal reduced viscosity as the slip parameter increases when plates are receding as well as moving together. As porosity increases the viscosity is enhanced. Therefore the rate of flow is reduced during collapsing plate motion, as well as receding. It is proposed that further investigations may be performed considering different flow channels and extensive rheological properties of fluids.

#### **Nomenclature**

- $z$  Distance between plates,m
- $u$  x direction velocity component,m/s
- $v$  y direction velocity component,m/s
- $\rho$  Density,kg/m<sup>3</sup>
- $\alpha$  Diffusivity coefficient
- $B$  Magnetic field intensity
- $\pi$  Deformation component
- $\pi_c$  Deformation component critical value
- $e_{ij}$  Components of deformation
- $\mu$  Dynamic viscosity,N.sm<sup>-2</sup>
- $\mu_B$  Plastic dynamic deformity
- $p_y$  Fluid yield stress,N/m<sup>-2</sup>
- $M$  Magnetic parameter
- $\gamma$  Casson Parameter

S	Squeeze Parameter
$u$	Dimensionlessx velocity component
$v$	Dimensionlessyvelocitycomponent
$\eta$	Dimensionless normal distance
$G$	Darcy parameter
$K_p$	Permeability of porous medium
B	Slip parameter

### **Competing Interest**

The authors declare no competing interests as regards the publication of this paper.

### **REFERENCES**

Akinshilo, A.T., Ilegbusi, A.O. (2019), “Investigation of Lorentz Force Effect on Steady Nanofluid Flow and Heat Transfer through Parallel Plates”, *Journal of Thermal Engineering*, 5 (5) 740-748.

Domairry, G., Aziz, A., (2009), “Approximate analysis of MHD squeeze flow between two parallel disks with suction or injection by homotopy perturbation method”, *Mathematical Problems in Engineering*, doi: 1155/2009/603916.

Ellahi, R., Hayat, T., Mahomed, F.M., Asghar,S., (2010), “Effects of slip on nonlinear flows of a third grade fluid”, *Nonlinear Analysis: Real world Applications* 11 ( 139-146.

Gul, T., Afridi,S., (2018), “The heat and mass transfer analysis during bunch coating of a stretching cylinder coated with liquid filmspray”,*IntechOpen DOI:10.5772/79772*.

Hashimi, M.R., Hayat, T., Alsaedi,A., (2014), “On the analytic solutions for squeezing flow of nanofluids between parallel disks”, *Nonlinear Analysis Modeling and Control* 17 418-430.

Hayat, T., Yousaf,A., Mustafa, M., Obadiat,S., (2011), “MHD squeezing flow of second grade fluid between two parallel disk”, *International Journal of Numerical Fluids* 69 399-410.

Hussain, A., Mohyud-Cheema, S.T., Din, T.A. (2012), “Analytical and numerical approaches to squeezing flow and heat transfer between two parallel disks with velocity slip and temperature jump”, *China Physics Letter* 29 pgs 1-5.

Kandasamy, R., Loganathanb, P., PuvArasub, P., (2011), "Scaling group transformation for MHD boundary layer flow of a nanofluid past vertical stretching surface in the presence of suction/injection", *Nuclear Engineering and Design* 241 2053-2059.

Khan, W.A., Aziz, A., (2011), "Natural convective boundary layer flow over a vertical plate with uniform surface heat flux", *International Journal of Thermal Sciences* 50 1207-1217.

Khan,W.A., Aziz, A., (2011), "Double diffusive natural convection boundary layer flow in a porous medium saturated with a nanofluid over a vertical plate, prescribed surface heat, solute and nanofluid fluxes", *International Journal of Thermal Sciences* 50, 2154-2160.

Kirchhoff, T.G., (1960), "Hydrodynamics: a study in logic, fact and Similitude", *Princeton University Press, New York, USA*.

Kuznetsov, A.J., Nield, N.D. (2010), "Natural convective boundary layer flow of a nanofluid past a vertical plate", *International Journal of Thermal Sciences* 49 243-247.

MacDonald, D.A., (1874), "Blood flow on arteries", *Arnold, London*.

Makinde, D., Aziz, A. (2011), "Boundary layer flow of a nanofluid past a stretching sheet with convective boundary conditions", *International Journal of Thermal sciences* 50 1326-1332.

Martin, M.J., Boyd, L.D., (2006), "Momentum and heat transfer in a laminar boundary layer with slip flow", *Journal of Thermo physics and Heat Transfer*, 20 710-719.

Mrill, E.W., Benis, A.M., Gilldand, E.R., Sherwood, T.K., Salzman, E.W., (2008), "Pressure relation on human blood flow rates", *Journal of Applied Physics* 20 954-967.

Mustafa, M., Hayat, T., Obadiat, S., (2012), "On heat and mass transfer in the unsteady squeezing flow between parallel plates", *Mechanica* 47 1581-1589.

Rashidi, M.M., Shahmohamadi H., Dinarvand, S. (2008), "Analytic approximate solutions for unsteady two dimensional and axisymmetric squeezing flows between parallel plates", *Mathematical Problems in Engineering*, doi:10.1155/2008/935095.

Reynolds, O. (1886), "On the theory of lubrication and its application to Mr. Beauchamp Tower experiments including an experimental determination of olive oil" ,*Philos Transaction of Royal Society* 177 157-234.

Shashikumar, N.S., B.C. Prasanna Kumara, B.C., Gireesha, B.J., Makinde, O.D., (2018), “Thermodynamic analysis of MHD Cassonfluid slip flow in a porous microchannel with thermal radiation”, *Diffusion Foundations*, 16 120-139.

Siddiqui, A.M., Irum, S., Ansari, A.R., (2008), “Unsteady squeezing flow of a viscous MHD fluid between parallel plates”, *Mathematical Modeling and Analysis* 13 565-576.

Stefan, M.J. (1984), “Versuch Uber die scheinbare adhesion, Sizungsberichie der Akademie der Wissenschaften in Wien” *Mathematik-Naturwissen* 69 713-721. Wang, C.Y., Watson, L.T., (1979), “Squeezing of viscous liquid between elliptic plates”, *Applied Science Research* 35 195-207.

Yao, S., Fang, T., Zhang, Y., (2011), “Heat transfer of a generalized stretching/shrinking wall problem with convective boundary condition”, *Communications in Nonlinear science and Numerical simulation* 16 752-760.

Zang, K.T. (1979), “Unsteady laminar flow in incompressible stagnation flow”, *Journal of Applied Mathematical Transaction: ASME* 80 421-427.

## **INNOVATING ENGINEERING STUDENT CURRICULUM WITH ENTREPRENEURSHIP**

Adeyemi, O.A.<sup>1\*</sup> and. Idris, M.O.<sup>2</sup>

<sup>1</sup>Department of Mechanical Engineering, First Technical University, Ibadan, Oyo State. Nigeria.

<sup>2</sup>Department of Mechanical Engineering, Osun State University, Osogbo, Osun State. Nigeria.

\*Email of Corresponding Author: oaadeyemi@tech-u.edu.ng

### **ABSTRACT**

Innovating Engineering Students' Curriculum with Entrepreneurship introduces the framework of entrepreneurially minded learning (EML) centred on observations, curiosity, connections, and creating value. Exploration of each of these components, instil a variety of different active learning techniques that can be applied to encourage engineering students towards entrepreneurship. Key components for making a strong learning experience for the students including learning objectives, problem statements/opportunity recognition, and teamwork are applied so as to foster the principles learned to create value and share a teaching technique for particular topics in their discipline.

This paper presents a model towards producing entrepreneurial engineers. The identification of opportunities for entrepreneurship, integration into existing courses and implementing continual improvement of particular entrepreneurship practices (i.e., mechanisms, procedures, tools, frameworks) are presented for adoption to promote entrepreneurship to engineering students. As such a case study methodology is adopted for this study with summaries and case analysis of four cases of entrepreneurial learning in the Premier Technical University in West Africa (Alpha) in order to unravel the relationship between technical skills, theoretical knowledge and opportunities recognition and exploitation skills. Their relative advantages and disadvantages are discussed based on the interviews with students of Alpha undergoing different phases of entrepreneurial training. The analyzed cases help to identify various positions in the integration stage and mind-set transformation era of the engineering students. This paper concludes with some propositions and a robust model for implementation towards producing entrepreneurial engineers.



**Keywords:** Entrepreneurial Engineers, Curriculum, Learning, Innovative, Case study

## **INTRODUCTION**

In Africa, enterprise creation and entrepreneurship are considered as vital in terms of their contribution to economic development, regional economic development and employment generation. As such, there is a growing understanding in Africa that it is important to encourage an entrepreneurial culture with the right mindset, entrepreneurial skills and career possibilities. The communique on the African Engineering Education Association (AEEA) highlighted some of the current issues and modifications required in teaching engineering students so that they are not just engineering students but also entrepreneurially minded. Issues connected with such transition was one of the several workshops discussion in the September, 2019 International Conference of AEEA recently in Lagos, Nigeria. Some of the highlights emphasized that engineering education needs to take cognizance of local applications. Another is that, the curricula in engineering and technology education in Africa need to be improved by integrating technology enabled teaching and learning environments particularly with Information and Communication (ICT) systems and internet-based systems. One other assertion is the fact that engineering and technology education could integrate aspects of entrepreneurship as that would be vital to the well-being of the economies and societies in the African context. That motivation, that is, the importance of entrepreneurship and engineering education for a more conscious next generation of decision makers and the need for effective pedagogy for entrepreneurship to develop the manufacturing sector are the basis for this study. In this study, the repertory grids which are part of George Kelly's (1955) Personal Construct Theory (PCT), were used to facilitate the analysis of entrepreneurial networks during the pre-organization stage and a similar application can, however, be assumed in a post-creation setting. That pedagogical approach is different from the system where entrepreneurship courses are either electives or standalone courses with little or no integration into the main curriculum.

### 1. Description of the tool

The repertory grid technique is a method for discovering personal construct systems. Its purpose is to provide some information about the manner in which the system of personal constructs is as well as showing its barriers and potential benefits (Beail, 1985). In general such matrix tables contain:

*Elements:* the presented stimuli for discussion.

*Constructs or concepts* derived from the participants.

*Ratings*, that is, hierarchical values given by the interview participant (Aranda and Finch, 2003). Beail (1985) refers to the ratings as “linking mechanisms” as they reveal the assessment of each element on each construct. One of the advantages of repertory grids is that though they have qualitative data, they can be analysed statistically. Hence, it is possible to identify correlations between elements and concepts within a grid and links between the grids themselves (Aranda and Finch, 2003; Bryman and Bell, 2003).

## 2. Entrepreneurship among undergraduates in Africa

Enterprise creation by higher education graduates is still a marginal phenomenon in Africa. Open change is needed to transform the mindset of undergraduates from a managerial society: where managers do things right — to an entrepreneurial society, where leaders do the right things. That could be a possibility through entrepreneurial minded learning and a shift from reliance on deterministic and stochastic change, to a situation of open change. The dream of manageability is coming to an end. The system dynamics become chaotic - rather than rigid - and a creative leadership approach based on structural knowledge is adopted and delivers competence, instead of a reactive one, based on information, existing behavior and learnings from past mistakes.

Entrepreneurial minded learning is results oriented, rather than rule oriented, and follows that educating engineering undergraduates as managers portrays efficient avoidance of mistakes, while educating them as entrepreneurial engineers is focused on effective learning from past mistakes, information and observations. A curriculum contains structured document that depicts the philosophy, objectives, learning experiences, instructional resources and assessments that comprise a specific educational programme. Evaluating the present engineering undergraduates’ curriculum reveals the importance of recognizing the entrepreneurial elements of the engineering education and how to instill some practical skills and mindset transformation in engineering undergraduates before infusing such learning into their curriculum towards the development of an entrepreneurial engineer (Idris & Adeyemi, 2018).

### 3. Innovating engineering education with entrepreneurship

In 2017, Alpha created a Directorate for Technical, Vocational and Entrepreneurship Education (TVET) in teaching and research to help the different stakeholders in education such as professionals and decision makers at different levels to deal with the multifaceted challenges influencing the educational systems towards producing entrepreneurial engineers among others. One of the vital issues of concern was how various teaching methods and the acquisition of knowledge and skills could be developed in line with entrepreneurship, scientific progress, new technologies and the diversification of the undergraduate students. Other perspectives related to the role of innovation in the lecture room and the question of which educational systems and universities would be suitable in the future (Istance and Shadoian, 2009). These issues are still relevant today, given the sphere of uncertainty created by the economic crisis. There is no doubt, as Istance and Shadoian (2009) concluded, that the recent social and political changes have triggered questions about the suitability of analysis and methods of teaching in Europe. This perhaps, is no different in the present African situation. Given such situation which makes experimentation and innovation in pedagogy imperative, Istance and Shadoian (2009) concluded that the aim to experiment in education (particularly in engineering education) has caused a wave of innovation around the world. As a reaction to the potential positive social and economic effects of entrepreneurship, Alpha is advancing entrepreneurial minded learning and behavior in the West African context by integrating practical entrepreneurship programs with the engineering curricula. Moreover in this context it is important to enhance the engineering undergraduates' awareness of the definition of entrepreneurship as related to their primary engineering course of study. As a result, there is a need to introduce entrepreneurship courses into every degree programme for at least two – three years in order to encourage and maintain an entrepreneurial culture in the continent. Though, the level of innovation of such programmes and courses varies, however. For Alpha, apart from the regular lecture room courses, a two weeks practical sessions is adopted at the beginning and end of each semester. In fact, as Verzat et al. (2009) and Wankat et al. (2002) highlight that there is not much literature available about innovative approaches to Entrepreneurship teaching and much less entrepreneurial engineering teaching. Against this background the four cases presented here from Alpha aim to fill a gap in the existing literature. The innovative pedagogy experimentation is placed in the context of four entrepreneurial activities in Alpha.

## **METHODOLOGY**

As Yin (2009) argued, qualitative methods are suitable for exploratory studies and the case study method has been part of this trend. Indeed Stake (2003) confirmed that case studies have become one of the typical ways to do qualitative inquiry and they “are not a methodological choice, but a choice of what is to be studied”. This study is based on four case studies and aims to compare and contrast innovative entrepreneurial pedagogy among engineering undergraduates in Alpha. The sampling criteria is the degree of technicality involved in their choice entrepreneurship activities. The underlying objectives were to learn from the different pedagogical and cultural approaches, that is, derive learning in terms of recognizing individual strengths and weaknesses, opportunities and threats for the institutional partners. Entrepreneurial skills acquisition program was conducted for all students in Alpha but our focus was on the engineering students in activities such as systems security, cosmetology, shoemaking, electrification, refrigeration and air conditioning, automation, ankara craft, advanced product development/3D printing, fashion designing, event management, agriprenurship, paints and paints production just to mention a few. This particular study considered four cases of: advanced product development, automation and systems security due to the degree of technical skills involved in the training. Ankara craft was the fourth entrepreneurial activity chosen to provide theoretical sampling.

The cases discussed in this study represents two opposite ends of the spectrum of innovative pedagogical tools available in Entrepreneurial teaching ranging from three fully-fledged cases of a “practice firm” to an individual innovative teaching module, taught as a stand-alone course. The two approaches were chosen as they contrast the traditional approach of understanding entrepreneurship as a process requiring holistic and action-oriented teaching with an approach that draws on cognition and in particular on repertory grids, the methodological tool of Personal Construct Theory (PCT) which was developed by George Kelly (1955).

## **DISCUSSION AND FINDINGS**

Case One: Ankara craft was started in order to use Ankara fabrics to make different accessories and different outfit combinations as in Figure 1.0. The company is in the production of: Neck chokers, Neck lace, Ankara Ties, Ankara wrist bands, Ear rings, and other house hold commodities with different shades of Ankara Fabrics

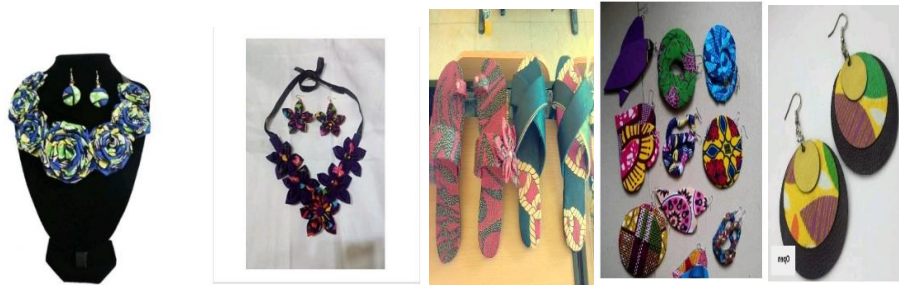


Figure 1.0: Various products with Ankara crafts

Students acquire knowledge on how to design and make affordable cultural products both for fashion and the beautification of homes. The cultural products perspectives could be instilled into the engineering curriculum so as to encourage the adaptation of products to meet societal needs before extension as international brands. The mode of teaching reveals the facilitator as an initiator, moderator empowerment coach and observer in the entrepreneurial process.

Case Two: Advanced product development involves designing products in 3D models and later producing the physical products with the aid of a 3D printer. The teaching process helps the conceptualization skills of the engineering undergraduates. It further develops their ability to brainstorm with an unknown customer towards the production of innovative products. Professional skills and competences of the practice-firm does not only include expert knowledge in enterprise management but also multidisciplinary elements going beyond, the so-called key qualifications. The latter include methodological competences such as problem solving capabilities and social competences such as the capabilities to network, interact and to take responsibility (Rita Klapper, 2010) specifically in acquiring customers or when negotiating delivery terms or loans application. The mode of teaching portrays the facilitator as initiator, moderator and observer, while students learn by self-driven initiatives. Engineering undergraduates could improve their professional skills through the iterative process of practice - theory - practice and a higher level of autonomy and fresh insights towards developing into an entrepreneurial engineer. The concept of hands-on, practice, skills are dominant across the four cases. Considering Case One, the instillation of products adaptation through an integration of practice and theory with hands-on approach to meet societal or cultural demands is stressed for inclusion in the engineering curriculum while case two, touched development of products through the practice-theory-practice philosophy as in Figure 1.1. As such, it is evidenced that both case one and two have more emphasis on the practice concept that leads to a proposition

as: *The iterative process of practice-theory-practice is a fundamental requirement in the engineering curriculum for developing entrepreneurial engineers.*

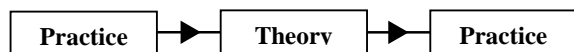


Fig. 1.1 EML Iterative Process

Case Three: Automation is the technology by which a process or procedure is performed with minimal human assistance. Automation involves the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching on telephone networks, steering and stabilization of ships, aircraft and other applications and vehicles with minimal or reduced human intervention. In teaching the entrepreneurial aspects of engineering, an appropriate methodology is vital as that could help students to immediately understand and learn entrepreneurial actions. Teaching concepts that are action-oriented, holistic, appealingly, participant-orientated, and promote reflection become increasingly important in entrepreneurship education (Rita Klapper, 2010) and much more in entrepreneurial minded learning of engineering.

In teaching automation and its principles, the simulation method is often used because it is an activity-based didactical concept, used to teach students different competences simultaneously. Simulation of automation is the process of providing students with entrepreneurial minded learning of real operations in an imitational setting but often leads students to practical experience through a cyclic process of practice-theory-practice as in Figure 1.2. Such a cyclic process enable engineering students' possibilities to understand, experience and evaluate the outcomes of risky and costly decisions in a simplified model situation reproducing reality but with no exposure to any risk per se. The simulation methods used in teaching automation are manifold and versatile and include action based methods like role plays, case studies, practice firms, junior companies and computer simulations.

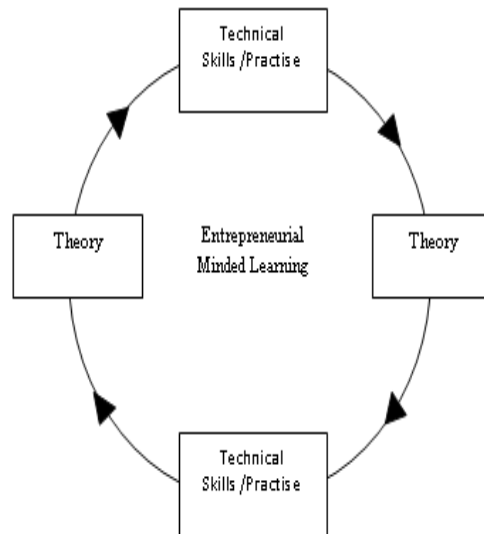


Fig. Fig 1.2: EML PathDependencyCycle

Case Four: System security (SS) is used in securing properties and/or individual with the aid of close circuit television (CCTV) and other accessories as represented in Figure 1.3.



Fig 1.3: Accessories for systems security projects

Some of the systems security programs involves access controls - which prevent unauthorized personnel from entering or accessing a property. SS also involves protecting information no matter where that information is, that is, in transit (such as in an email) or in a storage area. The detection and remediation of security breaches, as well as documenting those events is another SS program. The system security program aims to educate entrepreneurial engineers through an activity-based and participant-orientated didactic approach (Fig 1.4). That will help in the development of entrepreneurial engineers (Goldberg, 2006) through a cyclic and iterative process.

Table 1.0: Similarities and differences between Alpha innovative teaching practices

Approach	Ankara Craft	Advanced Product Development	Automation	System Security
<b>Objective/Opportunity Recognition</b>	Using local fabrics to design and make affordable cultural products	Simplify the production of complex products in good time	Fast and smooth operations without human assistance	Enhancing security levels in challenging or risky environments
<b>Tool</b>	Course component and activities based	Integration of stand-alone course components, activities based, conceptualization and machine learning	Course component, simulation and activities based	Course component, intuition and activities based
<b>Role of Facilitator/Student</b>	Facilitator as initiator, moderator and observer, but later empowerment of student	Facilitator as initiator, moderator and observer, self-driven learning by Student	Facilitator as initiator, moderator and observer, but later empowerment of student	Facilitator as initiator, moderator and observer, but later empowerment of student
<b>Initiators</b>	Developed by a graduate at a University and applied in entrepreneurial pedagogy	Developed by a graduate at a University and applied in entrepreneurial Pedagogy	Developed by a professional as an entrepreneurial pedagogy	Developed by one researcher, tested in Ph.D research, later applied in entrepreneurial didactics
<b>Activities</b>	Encourage understanding of business reality through start-up; promote personal development; promote a realistic view of entrepreneurship	Encourage critical reflection and options development; make complex thought processes visible; elicit student perception of network members; promote personal development	Encourage critical reflection and options development; make complex processes simplified; promote personal development	Understand members role in start-up, encourage critical reflection and make complex hidden processes visible; elicit student perception of network members; promote personal development
<b>Underlying theories / Theoretical skills</b>	Entrepreneurship as a Process, Interdisciplinary approach	Interdisciplinary approach linking entrepreneurial Network theories and cognition-based approach (PCT)	Interdisciplinary approach and PCT (cognition-based approach)	Interdisciplinary approach linking entrepreneurial Network theories and PCT (cognition-based approach)
<b>Focus of training / Technical Skills/ Value</b>	Holistic, activity and participant orientated	Importance of entrepreneurial network for a start-up; bringing concepts to reality.	Importance of entrepreneurial network for a start-up; simplifying interconnected processes	Importance of entrepreneurial network for a start-up; discovering unclear activities in real time without previous understanding
<b>Work pattern</b>	Teamwork	Teamwork	Teamwork	Teamwork



<b>Entrepreneurial Intention of students</b>	Not fully developed	Not fully developed	Not fully developed	Not fully developed
<b>Software Use</b>	No	Yes	Yes	Yes
<b>Advantages</b>	Encourages independent acting and self-employment; empowers independence, confidence, creativity and team work;	Evaluates the complete process of network analysis, ending with recommendations of how to adapt network for a successful start-up; makes the complexity of start-up activities visible, creativity, confidence and team-work.	Makes the complexity of start-up activities visible	Makes the complexity of start-up activities visible cost effective, if with monitoring services
<b>Disadvantages</b>	Potentially time-consuming	Potentially time-consuming	Does not reproduce true to life situation potentially time consuming	Potentially time-consuming

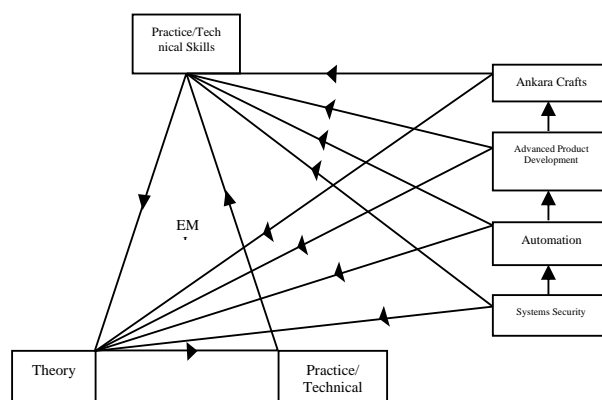


Fig. 1.4: Interlinking EML Skills Triangle with Entrepreneurial Activities

Figure 1.4 presents the frameworks towards promoting entrepreneurial minded learning to engineering students. The blending of the engineering curriculum with entrepreneurship activities provides undergraduates with a curriculum oriented towards entrepreneurial minded learning suitable to produce entrepreneurial engineers who can solve societal, environmental, and technological challenges. Such curriculum provides students with:

- Evidence-based thoughts in order to empower the students in order to support or reject ideas based on logic, experimentation and data.
- Skills to develop self-direction through self-driven lifelong learning especially from previous mistakes.

- Calculated risk taking abilities to consider multiple options and weigh against possible negative results before making a decision or choice.

## **CONCLUSION**

This paper has provided two examples with innovative pedagogy in teaching engineering students' entrepreneurship, in a singular context but with multiple dimensions. The examples from all the entrepreneurial learning in Alpha focussed on practice, cyclic processes and activity based learning with all its various activities and decision-making processes. Table 1.0 above shows the similarities and differences in the innovative teaching pedagogy in Alpha. One of the key lessons from this study which is innovative to the continent's standard teaching strategies is the 'activity-based' didactical concept of teaching the entrepreneurial perspective of their primary engineering course of choice. The researchers concluded that the conventional theoretical approach and the activity based concept, though different in focus, application and extent, are potentially complementary. Thus, the activity based didactic concept could be integrated in the curriculum of future entrepreneurial engineers as the merits of the concept and its application in entrepreneurial learning situations were recognised. Also interesting, is the wider concept of: 'practice-theory-practise', which underlines the possibility for further collaborative attempts in developing joint innovative pedagogical tools.

This study proves the transferability of the repertory grid teaching as an innovative pedagogical approach which has already been experimented within European, but also Asian contexts. Although further research is required so as to decide whether these approaches are unadaptably transferable to different cultural contexts especially in Africa, both authors remain very positive about cross-cultural collaboration in engineering entrepreneurial pedagogy as this encourages learning and exchange of innovative ideas and concepts at an international level. One venue where such engineering entrepreneurial learning has been emphasized is the African Engineering Education Association's Forum which has been happening for about seven years formed at the University of Lagos, Nigeria. Through this forum, researchers and teachers have been collaborating in multi-cultural research activities aiming to exchange ideas and tools about engineering education in Africa and in particular, entrepreneurship learning studies, but also innovative engineering entrepreneurship pedagogy across African frontiers.

Other findings of this study is similar to that of: Rita Klapper, 2010 who noted that entrepreneurial intention is not very developed among young people in France, and that is

similar to students of Alpha in Nigeria. The majority of Alpha engineering students are not well developed in their entrepreneurial intention but, they are in the disruptive thinking phase where they are shifting preference from a career as a worker in a large company, consultancy firm, becoming a civil servant or entering the public sector towards a career as an entrepreneurial engineer where they recognize and exploit entrepreneurship opportunities in their primary engineering course of study and/or in entrepreneurial activities based on their interest.

## **REFERENCES**

Aranda, G. and Finch, E. (2003), "Using repertory grids to measure changes in risk-taking behaviour", *Journal of Construction Research*, Vol. 4 No. 1, pp. 101-14.

Beail, N. (1985): *Repertory Grid Technique and Personal Constructs: Applications in Clinical and Educational Settings*, Croom Helm, Beckenham.

Bryman, A. and Bell, E. (2003), *Business Research Methods*, Oxford University Press, Oxford.

Goldberg, D.E. 2006. *The Entrepreneurial Engineer*. Hoboken, NJ: John Wiley & Sons.

Istance, D. and Shadoian, V. (2009), "Education innovante", *L'Observateur de l'OCDE*, Nos 270/271, De'cembre.

Idris, M.O. and Adeyemi, O.A., (2018), *Imparting Entrepreneurial Mindset Into Future Engineers Through An Integrated Entrepreneurial Engineering Curriculum: Proceeding of 2018 SEET Conference*. Akure. Nigeria.

Kelly, G.A. (1955): *The Psychology of Personal Constructs*, Vol. I, Norton, New York, NY.

Rita Klapper Silke Tegtmeier, (2010), "Innovating Entrepreneurial Pedagogy: examples from France and Germany", *Journal of Small Business and Enterprise Development*, Vol. 17 No. 4, pp. 552 – 568

Stake, R.E. (2003), "Case studies", in Denzin, N.K. and Lincoln, Y.S. (Eds), *Handbook of Qualitative Research*, 2nd ed., Sage Publications, Newbury Park, CA, pp. 435-54.

Verzat, C., Byrne, J. and Fayolle, A. (2009), "Tangling with spaghetti: pedagogical lessons from games", *Academy of Management Learning and Education*, Vol. 8 No. 3, pp. 356-69.

Wankat, P.C., Felder, R.M., Smith, K.A. and Oreovicz, F.S. (2002), “The scholarship of teaching and learning in engineering education”, in Huber, M.T. and Morreale, S. (Eds), *Disciplinary Styles in the Scholarship of Teaching and Learning: Exploring Common Ground*, AAHE/Carnegie Foundation for the Advancement of Teaching, Washington, DC, pp. 217-37.

Yin, R. K. (2009), *Applications of case study research* (2nd ed.), Thousand Oaks, CA: Sage.

## **A REVIEW OF WOVEN NATURAL FIBRE COMPOSITE FOR SPIRAL ANKLE FOOT ORTHOSIS**

Oyewo, A.<sup>1</sup>, Ajide, O.<sup>1</sup>, Odusote, J.<sup>2</sup>, Adefajo, A.<sup>3</sup> and Fakorede, D.<sup>4</sup>

<sup>1</sup> Department of Mechanical Engineering, University of Ibadan, Ibadan, Oyo State, Nigeria;

<sup>2</sup> Department of Materials and Metallurgical Engineering, University of Ilorin, Ilorin, Nigeria.

<sup>3</sup> Department of Mechanical Engineering, Osun State University, Osogbo, Osun State, Nigeria;

<sup>4</sup> Department of Mechanical Engineering, Cross River State University of Technology, Calabar, Cross River State, Nigeria.

*\*E-mail of Corresponding Author: [oyewoat@gmail.com](mailto:oyewoat@gmail.com)*

### **ABSTRACT**

Ankle foot orthosis (AFO) may be required by individuals with neuro-muskuloskeletal disorder so as to achieve normal gait. These problems of muscle weakness and impaired balance can be restored with the aid of orthosis. Synthetic fibres such as carbon, glass and aramid fibres are often used as reinforcement in orthosis production. However, the possibilities of using natural woven fibres have not been fully investigated. The advantages of woven natural fibres are non irritation of the skin, eye, respiratory track and high strength. For this study, woven natural fibres such as banana pseudo stem fibre are considered because of their environmental, low cost and high mechanical properties. Using lamination method, natural woven fibres reinforced composites, obtained at no or low cost, have almost equivalent strength with the existing materials which can be used various medical applications,. The results of this study are based on the compatibility of the properties of existing and proposed materials which contribute towards providing alternative materials that are more cost efficient, eco-friendly and yet maintaining the features required for orthosis. These findings are expected to assist patients with cost effective materials especially in low income countries in Africa.

**Keywords:** *Lamination, woven natural fibre, spiral ankle foot orthosis, bio-composite material.*

### **INTRODUCTION**

Ankle foot orthosis (AFO) is a artificial device worn on the lower leg to assist and support the weak part of the body such the limbs and ankle foot (Samir, 2011). Thus, practically, AFO

must be light in weight, easy to don and doff, affordable, cosmically satisfying, functioning properly, comfortable to wear, and presents reasonable maintenance (Patar, Jamlus, Makhtar, Mahmud J, & Komeda T., 2012). Odusote & Oyewo (2015) and Phillips & Craelius (2005) reported that all the above qualities for AFO can be achieved but the cost of manufacturing are costly and thus are not affordable to most users. Thus, there is need to search for less expensive parts and component to enable the wearer to enjoy more comfortable gaiting and high quality orthosis (Phillips & Craelius, 2005). The type of the orthosis used is determined by the degree of deterioration and location of the muscle of the limb. Samir (2011) reported that AFO may be required for sundry reasons including muscle weakness, loss of balance, accident, infirmity in mobility and neuro-muskuloskeletal. These symptoms are visible with patient with stroke, with old ages, and thus are found prevalently in many developing countries, including Africa Nations (Samir 2011). Thus, the need for AFO is increasing sough for many wearers around the world. As discussed by Odusote and Oyewo (2015), as the human body changes over time, AFO have to be replaced due to growth and changes in body weight and size, thus, AFO have to be replaced at some time (Patar, 2012)

The periodical quest for change of AFO may not be affordable to patients if the materials involved in the production of the components are expensive irrespective of the method of production. Different part of AFO requires different standards and specification based strength, usage, aesthetic requirements and durability, and thus, they are made of materials which may be different from one region to another. These materials can either be synthetic or bio-based. Presently, none of the AFO manufacturers has exploited bio-based materials to produce AFO (Odusote and Oyewo, 2015; and Oyewo et al, 2018). Therefore, this study focuses on the lamination method of the AFO by exploring lamination derived from the woven natural based fiber composite. Thus, there is need to develop AFO made from eco-friendly base materials since the current materials are synthetic. Synthetic materials including carbon (Irawan , 2006), keplar, aramind and glass fibre are non biodegradable, causes irritation to the skin and eye, and equally expensive (Irawan , 2006 & Patar, 2012).

In order to support a clean environment and low cost of production without compromising on the quality, this study intends to exploit, develop and test bio-composite using woven natural fibres such as woven banana fibre pseudo stem. As shown in Figure 1, woven fibres are members of continuous fibre which have preferred orientation. Unlike discontinues fibres – chopped and mat form, continuous fibres – unidirectional, woven or roving – exhibit higher

strength due to high aspect ratio and ability to withstand high torsional and stiffness strength in the direction of applied force (Campbell, 2010). However, raw banana pseudo stem fibres, copiously available, contains by mass, 70 – 77 % cellulose, 6 – 19 % hemicelluloses, 5 – 10 lignin, 8 – 12 % moisture content and 3 – 5 % pectin (Table 1). Using surface modification, such as sodium hydroxide, will increase the surface roughness and strength of banana fibre by reducing the presence of hemicelluloses and lignin, major impediments to all natural fibres. They are light in weight, non-expensive and recyclable (Campbell, 2010).

Table 1: Chemical Composition of some Natural Fibres (Odusote and Oyewo, 2015)

Type	Fibre	Cellulose (wt.%)	Hemicellulose <sup>s</sup> (wt. %)	Lignin (wt. %)	Pectin (wt. %)	Moisture Content (%)
STALK	Bamboo	26-43	15-26	21-31	-	-
	Wood	45-50	23-30	27	2-2.5	-
BAST	Kenaf	44-57	21	15-19	2	-
	Abaca	61-64	21	12	0.8	-
	Ramie	68-76	13-15	0.6-1	1.9-2	7.5
	Flax	60-81	14-19	2-3	0.9	5-10
	Hemp	70-92	18-22	3-5	0.9	6 - 9
	Jute	51-84	12-20	5-13	0.2	8
LEAF	Banana	70-77	6-19	5-10	3-5	8
	Phormium	67	30	11	-	-
	Pineapple	80-81	16-19	4.6-12	2-3	14
	Sisal	43-78	10-13	4-12	0.8-2	10-12
FRUIT/ SEED	Coir	46	0.3	45	4	10-11
	Cotton	82-96	2-6	0.5-1	5-7	7.85-7.5

Nigeria is the highest producer of banana in West Africa with 2, 700 million tons per year and 6<sup>th</sup> highest producer in the world. The leftover of these fruits, with proper processing can be converted to usefulness such as reinforcement in composite (FAO, 2005; Wan, 2012 & Wan, 2014).

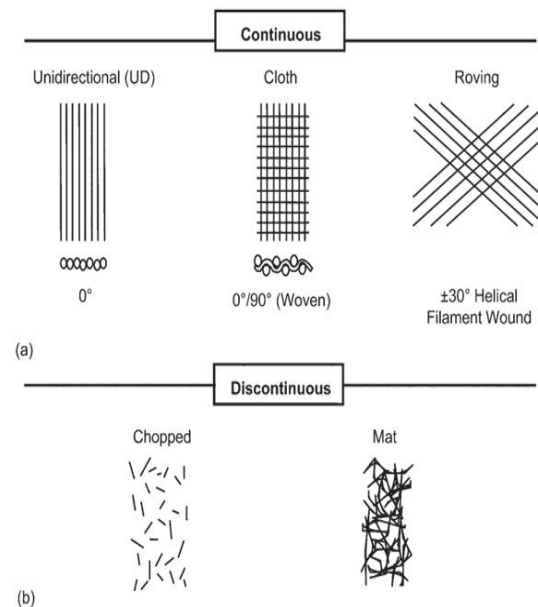


Figure 1: Type of Reinforcement fibres (a) continuous (b) discontinuous (Campbell, F.C, 2010)

As reported by Odusote and Oyewo (2015), the cost of AFO, among the importers, ranges between N 50, 000 –to 200, 000 depending on the quality and aesthetic features (News, 2012). Wan et al, (2014) and FAO (2005) stated that up to 30% of the cost of AFO production could be saved if locally sourced materials are used. Thus this research proposes that alternative materials should be used as a replacement for the synthetic materials thereby reducing the overall cost of production. (Navdeep, Khalid and Sona, 2012). The objectives of this study are to lessen the manufacturing cost of the AFO; and to promote the use of woven fibre based which is biodegradable and eco-friendly. Ultimately, this study this focuses on AFO manufacturing method and the materials involves including the need to alternative materials which will be eco- friendly and lost production cost for AFO (Nuanji, 2013).

## ANKLE FOOT ORTHOSIS

Ankle foot orthosis is a device worn on the lower leg and foot to support the ankle. They help to assist the ankle and foot to correct the foot part and foot drop. AFO increases control and reduce pressure on the skin and increase weight bearing through the affected side during standing and walking. Ankle foot orthosis improves the ankle at initial contact and swing phase.



Ankle foot orthosis designs are weight of the orthosis reduction, better on durability and weight ratio, easier to clean, cosmetic and can easily be change to different shoes (Nuanji, 2013)

AFO are prescribed for stroke patients by an orthotics for patients have weakness, absence of plantarflexor and dorsiflexion and spasticity. Orthotics is a medical professional that focuses on design and application orthosis. While the patient is walking with the ankle foot orthosis, there are some biomechanical actions to prevent foot slap at heel strike, assist toe clearance in the swing phase, push – off in the phase, a control of inversion and eversion and provide extension moment at the knee to assist stability. These indications are applicable to patients with motor weakness of ankle dorsiflexors and plantar flexors, moderate medial-lateral instability and motor weakness of the knee extensor (Phillips & Craelius, 2005).

An orthosis which can assist in knee extension improves stance stability during a decrease of muscle tone. AFO improve gait mechanics and efficiency by prevention of the active plantar flexion in swinging and stance phases. There is also less need for hip and knee flexion and pelvic elevation to gain foot clearance (Augustus, Tezera, Danladi, Mohamed, 2009).

There are various types of ankle foot orthosis including posterior leaf-spring, Hemi spiral and posterior Solid and Spiral AFO. The choice of either of the forgoing devices depends on pathomechanic at conditions, degree of spasticity and biomechanical actions.

Spiral ankle foot orthosis, as shown in Figure 2 ((a) orthosis and (b) orthosis on patient) prevents foot slap at heel strike, assists toe clearance in swing phase and push off in stance phase with control of inversion and eversion, provides extension moment at knee assist stability. These spiral ankle foot orthosis provide dorsiflexion and plantar flexion in the neutral patients. Spiral AFO, a perfect selection for a stroke patient, is used for patient with degree of spasticity mild to moderate (Arvela, Sderstm, Albck, Aho, Venormo and Lepntalo, 2012).

. A spiral ankle foot orthosis have properties including the following items; being lightweight, having a strong structure under tension, flexibility to absorb torque, firmness to resist bending, shearing stress durability to resist fracture under impact, capability for resistance stress in all planes, low cost and ease to apply a resin lamination with a composite material reinforcement by carbon fibre materials (Navdeep et al, 2012).



Figure 2: Spiral Ankle Foot Orthosis. (a) orthosis (b) orthosis on a patient (Navdeep et al, 2012)

However, the AFO, for instance, cannot be produced in large quantity because they are specially made based on patient's specification. Therefore, satisfaction of the AFO wearer is contingent upon the orthosis part (Nuanji, 2013).

### **MANUFACTURING AND MATERIALS OF ORTHOSIS**

AFO demands increases in the market, and there are tremendous transformations in the production of AFO, some of these centre on the material selection used in producing the AFO. AFO device should be light weight, most of it part if made of plastic. This is often made from the polypropylene which is non-reactive to chemical, acid and base. , much of it is made from plastic. In the past (Augustus et al, 2009)

AFO were made with metals such as steel but were recently replaced with more light weight metal including aluminum and titanium. However, carbon fibre is now widely accepted as the latest development in the AFO production, to from the foot-plate and other component (Phillips & Craelius, 2005 and Newman, Walsh,, Sullivan, Jenkinson, Bennett, Lynch &Brien, 2007).

Before the advent of composite and polymer – themoset and thermoplastics resins which is widely used today, AFO part were produced majorly from metal, wood and leather but to be more economical and avert environmental hazard, wood and leather has been supplanted lately by the adoption of polypropylene-centered materials, such as polyethylene, polypropylene, acrylics, and polyurethane (Odusote, 2016 & Wang, Zhang, Cheng, Ma, Zhang, W).

AFO must be prescribed by a medical doctor in collaboration with an orthotics, similar to the ways other components of the body are recommended. This is closely followed by the advice of a physiotherapist to assure a swift recovery as reported by (Odusote et al, 2016).

Recent development demands the AFO to be used for a patient must be custom made by the taking the measurement of the concerned parts so as to snugly fit the patient (Oyewo et al, 2018).

Choice of materials must balance with the need of an orthotics so as to give the patient an optimal satisfaction. For low income wearer, the overall cost of the AFO must be affordable so as to ensure the device is readily available since materials selected contribute to the total cost of production. Thus, critical examination must be done on the materials to be used as replacements for synthetics fibres (Navdeep et al, 2012).

### **MANUFACTURING METHOD OF ANKLE FOOT ORTHOSIS**

In production of AFO, the construction of the positive cast on the patients from foot ankle to the knee will be initiated (Odusote at al, 2016). This can be achieved by manually filling the negative impression on the patient ankle and other concerned parts using POP (Plaster of Paris) and other required materials as described by the manufacturer. More accurately, the usage of software involving computer aided design and manufacturing (CAD/CAM) can be adopted (Odusote et al, 2016; and Irawan et a l, 2006).

As such, in a large oven, a required sheet of cut out of a thermoplastic is heated to the required temperature in a large and spacious oven so that the vacuum can form around the perimeter of the positive cast. The heated thermoplastic sheet is spread over the top of the cast in the vacuum chamber (Lai and Mariati, 2008). The mould may be re heated is necessary to avoid the presence of void. The entrapped air within the mould must be forced out and one must ensure that the heated sheet snugly fits the mould so as to form the exact shape required (Odusote et al, 2016 & Patar et al, 2012).

This study proposed natural woven fibre composite as a replacement for the thermoplastic materials used in the above heating methods. According to Odusote et al, (2016), there are three distinct types of thermoplastic heating materials which include a polypropylene polymer material, a clear thermoplastic material as well as flexible thermoplastic materials. The former requires sophistication and a dedicated machine to achieve and raise it melting point. Thus, elevated temperature which is known with the thermoplastic molding technique as reported by Ramakrishna et al, (2001), may not be suitable for a natural fibre reinforced composite as its physical and mechanical properties could be negatively affected. Thus, a feasible replacement is lamination method (Odusote et al, 2016).

## **LOW COST MANUFACTURING OF ORTHOSIS**

The main objective of the use AFO is to replicate normal human motion and to assume proper gaiting system with a limited time. It is possible to have comfortable, water resistant and aesthetically appealing AFO which the wearer can use in a moisture environment but at higher cost (Phillips and Craelius, 2005). The persistent cost of production and application of computer aided design and manufacture software high accuracy with model design – are still expensive. Development of low cost software will benefit many users from less economical advantage region in developing countries. Moreover, apart from lamination method, there are some other methods such as injection molding plastic which gives more accuracy, low cost, light weight without the use of expensive computer aided method (Patar et al, 2012 & Faustini, Neptune, Crawford, Stanhope, 2012). The injection molding plastic method can afford the user within the aged wearers and stroke patient satisfactory performance to have a limited ambulation (Nuanji, 2013).

Orthotics in Nigeria relies on importation of the materials involved for AFO production such as the carbon fibre and glass fibers. If most of the component and materials used are sourced and produced locally it will greatly reduce the production cost and thereby reduce the quest for foreign currencies. Although most imported quality orthosis are used in high application with satisfaction, the high cost will deny most users in less economic advantage nations in the third worlds from availing this device (Oyewo et al, 2018). There is need to search for method that requires less sophisticated technology that will produce less expensive Ankle foot orthosis which will be aesthetically attractive without sacrificing the quality of the orthosis (Arvela, et al 2012).

Thus, affordable orthotic parts and materials and devices produced using this less-cost intensive method is needed. Therefore, affordable AFO should be promoted by government and concerned individuals. However, in Nigeria, the expensive synthetic materials are still imported and this, this study intends to sensitize the public to search for replacement of affordable orthosis (Augustus et al, 2009). Thus, Lamination method, Figure 2, with the aid of a roller which ensures saturation of the resin – epoxy – into the fibre as well as removing entrapped air which might cause defect. This method produces high strength composites which are affordable and does not require elevated temperature to cure the mould (Hetal, Srinivasulu and Subhas, 2013 & Faustin et al, 2012).

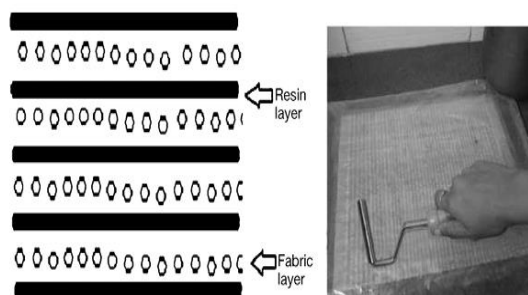


Figure 2: Composite Preparation (a) required of layer (b) Hand Lay-up method (Hetal et al, 2013 & SAFO, 2019)

### NOVEL WORK IN MANUFACTURING ORTHOSIS

The lower manufacturing cost of orthosis devices may permit the less fortunate and financially disabled wearers in most developing and Third World countries the chance to get affordable prosthetic legs. For this to happen, the cost of production should be lessened (Oyewo et al, 2018). The field of prostheses and orthosis are interrelated. While some notable works have been reported in the area of prostheses in exploring bio-composite, little is known in the field of orthosis. Thus, since both fields are related, literatures in the prostheses will be viewed in relation to orthosis. For instance, Samir (2011) worked on banana pseudo stem fibre reinforced in thermoset for transtibial socket application. They adopted lamination method, and later found that the thermoset banana composite has higher mechanical properties than the polyester glass fibre composite. Tuanji, (2013) investigated the physical, mechanical properties, production of the model spiral AFO as well as the patient satisfaction of hybrid bombyx silk fibre reinforced resin composites as a possible replacement for glass fibre and carbon fibre in AFO application (Tuanji, 2013). The above properties were found to be higher in Silk composites and orthosis than the glass and carbon fibre products. Irawan, (2006) used jute fibre in socket application which was found to have almost equivalent strength with the synthetic fibre products. Others like Patar, 2012), in order to have lighter weight and cost efficient AFO have used aluminum in construction of a pylon proved to be a success. More so, Phillips and Craelius, (2005) developed new pylon material for transtibial prosthesis. The author used bamboo tree for pylon in the quest to replace the conventional steel being used. The former

was reported to be cheap and easily sourced and has performed better in term of strength than the later (Tuanji 2013; and Wan, 2007).

Augustinus et al (2009) explained that the strength of a composite depends on many factors including the aspect ratio, nature of the fibre, chopped, woven, plain, unidirectional method of fabrication, fibre treatment with coupling agent and fibre content.

Natural fibres consist of cellulose, lignin hemicelluloses and other minor contents. The presence of lignin makes nature fibres to be hydrophilic – the absorb water and swell up because of many depending on the number of lignin sites. In contrast, resins are hydrophobic (Ramakrishna, 2001 and Mazumar, 2002). Thus, reaction between the hydrophilic natural fibres and hydrophobic resin – thermosets and thermoplastics limits the strength of the resulting composite. In order to address appropriate coupling agent should be used such as sodium hydroxide, hydrochloric acid, silane and others. Coupling agents are effective chemical treatment as it reduces/closes the lignin sites and hydroxyl formation thereby compacting the fibres and allows better interaction between the fibre and the matrix (Thimothy, 2007; Kirsti, 2012 & Faustini, 2012)

Those successful findings suggest that low-cost materials applied in prosthetic applications could reduce the cost of manufacturing. Although much strives have been reported in the field of prostheses using natural fibres, to the best knowledge of the author, no literature so far has been found using bio-composites in orthotic application. These results have precipitated this proposed study in a search for low cost manufacturing process where the required materials can be sourced locally, discarding the imported materials and as well as maintaining quality of the resultant orthosis. These findings have inspired the present study to probably produce low-cost manufacturing of prostheses made of the proposed composite.

## **CONCLUSION**

In conclusion, from the survey of similar literatures on prosthetics and orthotics, we have found out that blending of natural fibres with existing materials can produce high quality orthosis. Sisal, kenaf and jute fibres reinforced resin composite have been used in socket application. Moreover, Aluminium and titanium bamboo has been used as a pylon which was lighter than the conventional materials. We can come out with following submission that it is necessary to design and produce an affordable spiral ankle foot orthosis as well as to find the most suitable

biomaterials such as woven banana pseudo stem fibres to produce AFO which will benefit the less privilege wearer from the third world countries in the south.

Thus, this study suggests a new approach in production of ankle foot orthosis which will be affordable and the standard and the quality will not be compromised. The materials used are recyclable, renewable; less expensive and biodegradable – overall cost of production will be reduced. Therefore, the outcome is expected to tremendously help the third world countries who may not be able to afford the expensive orthotic device.

## **REFERENCES**

1. Augustus, P.S., Tezera, C., Dandi, B., Mohd, R.M.R., 2009. Tensile properties of pineapple leaf fibre reinforced unsaturated polyester. Malaysia: University of Malaysia Pahang. 1-27.
2. Arvela, E., Sderstrm, M., Albck, A., Aho, P., Venermo, M. and Lepntalo, M., 2012. Arm Vein Conduit vs Prosthetic Graft in Infrainguinal Revascularization for Critical Leg Ischemia. *Journal of Vascular Surgery*: 52(3):616-623.
3. Campbell, F. C., 2010. Introduction to Composite. ASM International. [www.asminternational.org](http://www.asminternational.org).
4. Faustini, M.C., Neptune, R.R., Crawford, R.H., Stanhope, S.J., 2012. Manufacture of passive Dynamic Ankle-foot Orthoses Using Selective Laser Sintering, *IEEE Transactions of Biomedical Engineering*, 55(2): 784-790.
5. Food and Agriculture Organization of the United State (FAO)., 2005. Banana: Post Harvest Operation. Venezuela: FAO.
6. Hetal, S., Srinvasulu, B. and Subhas, C. S., 2013. Influence of banana fibre chemical and morphological properties woven banana fabric/unsaturated polyester resin composites. *Polymers from renewable resources*, Vol. 4(2), pp. 61 – 84.
7. Irawan, L.Y., 2006. Review of the History, Properties and Application of Plant Fibres. *Africa journal of science and technology (AJST)*; 7(2): 120-133
8. Kirsti I., 2012. Adhesion between Fibers and Thermoset. M sc. Tampere university of Technology.
9. Lai W.L. and Mariati, M., 2008. *Journal of Reinforced Plastics and Composites*, 27(9), pp. 925 – 938.

10. Mazumbar, S. K., 2002. Composite Manufacture: Material, Product and Process Engineering. CRC press; Washington D.C.
11. Newman, C.J., Walsh, M., Sullivan, R., Jenkinson, A., Bennett, D., Lynch, B., Brien, T., 2007. The Characteristics of Gait in Charcot-marie-tooth Disease Types I and II", *Gait and Posture*, 26(1):pp. 120-127.
12. News, August 28, 2014. Nigerian National Bureau of Statistics. Available from <http://nigerianstat.gov.ng/ncidoc/6991.htm>.
13. Navdeep, M., Khalid, S. and Sona, R., 2012. A Review on Mechanical Characterization of Natural Fibre Reinforced Polymer Composites. *Journal of engineering Research and Study*; vol. 3(1): pp. 75-80.
14. Odusote, J. K., Oyewo, A.T., Adebisi, J.A. and Akande, K.A., 2016. Mechanical properties of Banana Pseudo Stem Fibre Reinforced Epoxy Composite as a Replacement for Transtibial Prosthetic Socket. *Journal of Professional Engineers of Trinidad and Tobago*. Vol. 44, no 2. Pp. 4-10.
15. Oyewo A.T., Oluwole, O. O., Odusote, J.K., & Fakorede, D. O., 2018. Tensile and Flexural Properties of Banana Pseudo Fibre and Pineapple Leaf Hybrid Reinforced Socket Application. *Proceedings of 4th International Conference of Mechanical Engineering, Energy Technology and Management (IMEETCON2018)*, University of Ibadan, Sept., 4 – 7, 2018. Book of ABSTRACT No 49, pp. 23.
16. Patar, A., Jamlus, N., Makhtar, K, Mahmud J, & Komeda, T., 2012. Development of Dynamic Ankle Foot Orthosis for Therapeutic Application. *Procedia Engineering*, 41, 1432 – 1440.doi:10.1016/j.proeng.2012.07.332.
17. Phillips, S.L. and Craelius, W., 2005. Material Properties of Selected Prosthetic Laminates. *Journal of Prosthetics and Orthotics*: pp. 27-32.
18. Ramakrishna, S., Mayer, J., Wintermantel, E. and Leong, K.W., 2001. Biomedical Applications of Polymer-Composite Materials: A review. *Composites Science and Technology*; vol. 61(9): pp.1189-1224.
19. Samir, H.A., 2011. Numerical and Experimental Investigation of Ankle-Foot Orthoses using (Perlon-Carbon Fibres-Acrylic) Materials. PhD dissertation, College of Engineering of Nahrain University, Baghdad, Iraq.
20. Spiral Ankle Foot Orthoses (SAFO). Cited 10 Oct., 2019. Available from: [www.hindawi.com/journal/rerp/2019/2978265](http://www.hindawi.com/journal/rerp/2019/2978265).



21. Timothy, T. and Caroline, B., 2007. Influence of Fibre Extraction Method, Alkali and Silane Treatment on the Interface of Agave Americana Waste HDPE Composites as Possible Roof Ceilings in Lesotho. *Composite Interfaces*; Vol. 14(79), Pp. 821–836.
22. Toole, B., Hawkins, K., Neumann, E., Warner, M., 2009. Strain Analysis of a Composite Ankle-Foot Orthosis (AFO), *World Journal of Engineering*, 757-758.
23. Tuanjit, N.R., 2013. Hybrid Composite of Bomby Silk Fiber for Ankle Foot Orthoses in Stroke Patient. Msc dissertation, College of Biomedical Engineering, Prince of Songkla University, Thailand.
24. Wan et al. International Institute of Tropical Africa (IITA). Banana and Plantain. <http://iita.org/banana-and-plantain>. Accessed 18th December, 2014.
25. Wan, H.W.M., 2012. The Physical and Mechanical Properties of Kenaf-Reinforced Polypropylene Composites Treated with Compatibilizers. Msc: university of Technology, MARA.
26. Wang, Y., Zhang, L, Cheng, L., Ma, J., Zhang, W., 2008. Tensile performance and damage evolution of a 2.D C/SiC composite characterized by acoustic emission”, *Applications of Composite Materials*, 15: pp.183-188.

## **DETERMINANTS OF PROPERTY INVESTMENT INFLOW IN AN EMERGING ECONOMY: THE PERSPECTIVE OF REAL ESTATE DEVELOPERS IN LAGOS, NIGERIA**

Adebara, O. B.\* and Olaleye, A.

<sup>1</sup>Department of Estate Management, Obafemi Awolowo University, Ile-Ife, Osun State,  
Nigeria

\*Email of Corresponding Author: [adebaraoyinloluwa@gmail.com](mailto:adebaraoyinloluwa@gmail.com)

### **ABSTRACT**

The ability for a property market to improve the influx of both local and international investors is reliant on the availability of quality and dependable information on factors determining investment Inflow into such market. In view of this, the current study seeks to examine the determinants of property investment inflow in Nigeria from the perspective of real estate developers in Lagos metropolis. To obtain data for the study, the metropolis was stratified into two: Lagos Island and Lagos Mainland property markets. Eighty-seven (87) property development companies registered with Real Estate Developers Association of Nigeria (REDAN) were surveyed through questionnaire administration. This comprised forty-seven (47) and forty (40) development companies in Lagos Island and Lagos Mainland respectively. The study adopted both descriptive and inferential statistical methods such as frequency, Principal Component Analysis (PCA) and regression to analyse the data collected. The result of the PCA showed that the three most important determinant of the property investment inflow were technological and political, macro-economic, and economic growth factors with percentage variance of 30.80, 21.58 and 17.91 respectively. The regression analysis further established that the three factors had significant relationship with the inflow of property investment into Nigeria. The study therefore concluded that macro-economic, technological and political and economic growth factors were the major determinants of property investment inflow into the Nigerian property market. The study recommended that there is need to focus on the macro-economic variables in the country such as exchange rate and inflation rate; develop technologies that can be useful in the property sector and encourage growth in the country's economies.

**Keywords:** International Investors, Investment Analysis, PESTLE, Property Investment, Real Estate

## **INTRODUCTION**

The advantages that a property market presents cannot be over-emphasised. These advantages can include: economic growth, increased commerce, provision of employment and developed rural and urban housing to mention few (Aguilar, 2008; Gholipour, Al-mulali & Mohammed, 2014; Masron & Kipili, 2016). However it appears that the ability for a property market to provide these advantages is dependent on its ability to attract and also retain both local and international investors. A property market that can attract and also retain an investor must be characterised with the availability of quality and dependable information on the nature and characteristics of investment in such market. This assertion tallies with the submission of Lee (2004, 2005) and Lieser and Groh (2011) that an investor both local and international must be sure of his gains before making a decision to tap into the opportunities accrued in a market. In other words, the influx of both local and international investors into a market is dependent on the quality of information available about the prospects in the proposed market. Where this information is not available, investors tend to be weary of investing in such market.

Evidences from United Nations Conference on Trade and Development (UNCTAD) (2011) revealed that the property market of many countries has been enjoying investment inflow. For example in United States of America (USA) property investment inflow has been increasing since 1980 (Liang & Yoon, 2011). Also in African countries such as South Africa, Egypt, and Mauritius among others the involvement of international investors cannot be over-emphasised and thus these markets had gained various advantages attached to it (Rothacher, 2013; Jones Lang LaSalle, 2014; Royal Institute of Chartered Surveyors, 2014). The case is however different in the Nigerian property market where the property Investment inflow was only 9% compared to finance sector which accounted for 63% and transport, storage and communication which accounted for 26% (UNCTAD, 2015). This indicates that the Nigeria property market has received little attention from investors' especially international ones. The reasons for this little attention call for concern of policymakers and researchers.

Various studies have been carried out to examine the determinants of Foreign Direct Investment (FDI) in various economies. Such studies Jadhas (2012), Ojong, Arikpo and

Anthony (2015), and Ekpo (2016) among others. Having achieved their objectives, these studies were limited in that they focused on general FDI rather than determinants of local and international investment inflow into the real estate sector of the various economies. Also studies such as Castro (2006), Liang and Yoon (2011) and Ahmad, Mei and Iman (2015) have examined the factors that determine the inflow of investment of various property markets such as USA, Ireland, UK, Canada, and France among others. However, the determinants of investment inflow into the Nigerian property market were not documented. To improve the inflow of investment into the Nigerian property market, investors, especially the international ones, need to have access to accurate data on the determinants of investment inflow.

It has been said that availability and correctness of information encourages inflow of international investment into any economy (Lee, 2001, 2005; JLL, 2014). In an attempt to achieve these, few studies such as Muhammad (2016), Okoro and Kalu (2017) and Elile, Sunday and Raju (2019) were conducted in the Nigerian property market. These studies mostly focused on non-economic and economic factors that determine the investment inflow into the Nigerian property market. The current study attempts to investigate the determinants of property investment inflow in the Nigerian property market using the PESTEL analysis.

According to Fahey and Randall (2000), PESTEL analysis is an important tool that can be used to carry out market and environmental analysis from which relevant conclusion as regarding strategic decision making can be made. The acronym word stands for Political, Economic, Social, Technological, Environmental and Legal. Studies such as Bryan (2011), Emam (2011) and The Institute of Company Secretaries of India (ICSI) (2018) have adopted this tool in making strategic decisions as regarding investment in real estate sector in their various markets. Hence to ensure that investors make accurate decision on property investment inflow in the Nigerian property market, it is deemed necessary to adopt PESTEL analysis.

In view of the foregoing, the perspective of real estate developers in Lagos property market was inquired. This market was deemed accurate for the study because it is known to be the center of all commercial activities in the country and also the model for measuring the country investment prospects overtime (Rothacher, 2008; JLL, 2010; Olaleye & Adebara, 2019).

The information from this study bear relevance in various areas: it will increase the Foreign Direct Investment (FDI) into the real sector of the Nigeria economy which will influence the growth of the economy in terms of improved level of employment, increased Gross Domestic

Product (GDP), increased exportation, tax revenues and also inflow of knowledge transfer from the international investors. Also, if the determinants of property investment inflow are explored the Nigerian property market could be one of the major contributors to the national economy in the nearest future making the effect of the dwindling oil prices ineffective.

## **MATERIALS AND METHODS**

This study obtained primary data through questionnaire administration. Information on property investment inflow in Nigeria was obtained from real estate developers in Lagos Metropolis which was stratified into Lagos Island and Lagos Mainland property markets. The real estate developers ascertained their perception of political, economical, socio-cultural, technological, legal/institutional and environmental factors as they affect property investment inflow in Nigeria.

The primary data were sourced from Property Development Company registered under the professional body known as Real Estate Developers Association of Nigeria (REDAN). This choice was informed by the relevance of the study group to direct investment in Nigeria (Muhammad, 2016). In administering the questionnaire, 87 property development companies were identified from REDAN Directory (2015). Forty- seven (47) of the development companies were in Lagos Island while forty (40) were in Lagos Mainland.

The selection of sample size was informed by the submission of Watson (2001). The author opined that for population above 100, sample size could be selected at 50% and for population below 100, total enumeration should be adopted. Hence, total enumeration was adopted in this study.

To collect the data representative (preferably the head of the company) of the sampled property development companies were asked to rank the variable components of the PESTEL factors. A total of Fifty-five (55) sub-variables were ranked by the respondents. Scores 1 to 5 was assigned to each of the variables on a five point Likert scale; where 5 represented strongly agree, and 1 represented strongly disagree.

The Fifty-five (55) sub-variables were subjected to Principal Component Analysis (PCA) to reduce the factors and determine the proportion of the reduced factor to property investment inflow in Nigeria.

Further analysis was carried out using multiple regression. The components were regressed with property investment inflow. This was to determine the significance of each of the components to the dependent variable (property investment inflow).

The multiple regression model is presented below:

$$Y = a + b_1x_1 + b_2x_2 + \dots + b_nx_n \dots \dots \dots \quad .(1)$$

Where:

Y= property investment inflow

$x_1 - x_n$ = determinants of investment inflow

$b_1 - b_n$ = regression coefficient which indicated the significance of each factors

a= y intercept

## **RESULTS AND DISCUSSION**

Discussed in this section is the result of analysis carried out. Before the presentation of the major findings, it is expedient to explain the characteristics of the respondents. In doing this, the respondent's position, years of experience and professional qualification were investigated. The result of the findings is presented in Table 1. In terms of respondent's position, the results of the findings revealed that majority (47.13%) of the respondents were senior officers in the various development companies. Also 39.08% of the respondents were head of departments while 13.79% were branch head. This implies that the respondents were higher cadre employees in the development companies. Thus, they are expected to know much about the determinants of property investment. In terms of experience, the majority (49.43%) of the respondents had been working for 6 to 10 years in their respective companies. Following this were respondents that had worked in their various companies for 1 to 5 years (32.18%). Other respondents had spent 11 to 15 years (12.64%), 16 to 20years (1.14%) and 21 to 25 years (4.60%) in their various organisations. This implies that all the respondents are conversant with the dealings in their companies. In terms of professional qualification, the result of the findings revealed that all the respondents were members of a professional body. For instance, 12.64% were members of NIESV, and 32.18% were members NICE, 36.78% were member of IPMP, 18.89% were members of NITP and 32.18% were members of NICE. Putting together the

foregoing, it can be said that the respondents were qualified to give information as regarding the study.

**Table 1: Profile of the Respondents**

<b>Profile of the Respondents</b>	<b>Frequenc y</b>	<b>Percentage</b>
<b>Respondent's Position</b>		
Branch Head	12	13.79
Head of Department	34	39.08
Senior Officer	41	47.13
<b>Total</b>	<b>87</b>	<b>100.00</b>
<b>Years of Experience</b>		
1-5 years	28	32.18
6-10 years	43	49.43
11-15 years	11	12.64
16-20 years	1	1.14
21-25 years	4	4.60
<b>Total</b>	<b>87</b>	<b>100.00</b>
<b>Professional Qualification</b>		
NIESV	11	12.64
IPMP	32	36.78
NITP	16	18.39
NICE	28	32.18
<b>Total</b>	<b>87</b>	<b>100.00</b>

*Note:*

*NIESV stands for Nigerian Institution of Estate Surveyors and Valuer;*

*IPMP stands for International Project Management Program;*

*NITP stands for Nigerian Institute of Town Planners;*

*NICE stands for Nigerian Institute of Civil Engineers*

Furthermore, the indicators that attract investment into the Nigerian economy were computed from literature and respondents were asked their perception on property investment inflow into

the market. Nevertheless, finding the salient determinants of property investment was also imperative. In doing this, the Principal Component Analysis (PCA) was employed. This was carried out in different stages.

In the first stage of this analysis, the 55 sub-indicators identified from the literature were loaded and screened. This was done to examine the inter-correlation between variables. Where the variable did not correlate with the other variables at ( $.3 \geq R \leq .9$ ) such variable should be excluded from the analysis (Field, 2005). Having excluded such variables the communalities table should be checked. After these tests, the variables were reduced to 20 sub-indicators which were then re-loaded for the analysis.

The suitability test was then carried out using Kaiser-Meyer-Olkin (KMO) and Bartlett's test values. For acceptability of data in factor analysis, the KMO must be greater than 0.5 while the Bartlett's test must be less than 0.1. Specifically, for this analysis, the KMO was 0.776 while the Bartlett's test was 0.000 as presented in Table 2. This indicated that the data were suitable and adequate for factor analysis.

**Table 2: KMO and Bartlett's Test**

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.776
Bartlett's Test of Sphericity	Approx. Chi-Square	1911.2
	Df	52
	Sig.	190
		.000

Furthermore, there was need to validate the variables based on communality of the variable. According to Field (2005) communalities figures should be above 0.5. However, all the 20 sub-indicators were retained because of their high communality figure hence they fit well for the analysis.

The variables inputted were twenty (20) in all. The variables were collapsed into 5 factors using the Principal Component Analysis. For the purpose of this study, factor loading of variables below 0.4 were not observed. Furthermore there is possibility for some variable to be highly loaded on one factor and low on the other factors. In this case there is need for rotation of the



matrix. This was used for factor interpretation. Table 3 showed the five (5) factors that were extracted.

On component 1 five (5) variables were strongly and positively loaded. These variables were ‘positive impact of technology on the country’ (0.795), ‘availability of internet facilities’ (0.792), ‘emerging level of technological development’ (0.759), ‘stable political environment in the country’ (0.626) and ‘presence of industry specific legislation in the country, (0.599). Component 1 could therefore be termed **technological and political factor**.

Factors loaded on component two (2) were ‘low and stable naira/dollar rate overtime’ (0.812), ‘decreasing level of inflation in the country’ (0.809), ‘low and attractive country's interest rate for investment’ (0.709), ‘increasing country's employment rate with country's population’ (0.667) and ‘increasing country's internal cash flow overtime’ (0.619). Factor 2 was associated with **macro – economic factors** and was named so.

Four factors were loaded on component three. These were ‘stability in the trend of our economy’ (0.874), ‘growth of country economy in same pace with oversea economies and trade’ (0.786), ‘favorable economic situation of the country’ (0.783) and ‘the encouragement of the economic condition for international trade’ (0.587). The variables suggested the growth that occurred in the economy overtime and was hereby be termed **economic growth factor**.

Variables such as ‘the country economic condition supports market and trade cycles’ (0.808), and ‘freedom of press in the country’ (0.550) were loaded on component four (4). This factor was a mix of commercial and communication attribute of the country, hence was termed **commerce and communication factor**.

The fifth component included, ‘presence of stable legislation in the country’ (0.682), ‘presence of competitive regulations guiding investment in the country’ (0.655), ‘availability of consumer protection in the country’ (0.597), ‘high level of socio-cultural changes in the country’ (0.536). This factor has a mix of legal/ institutional and socio-cultural factor hence termed **socio-legal factor**.

Table 3 also revealed that the most important factor that can encourage the inflow of property investment in Nigeria was technological and political integration with percentage variance 30.80. This factor was followed by the macro-economic factor with variance percentage 21.58.

**Table 3: Rotated Component Matrix<sup>a</sup> of Determinants of Property Investment Inflow**

Factors	Component				
	1	2	3	4	5
There is positive impact of technology on the country.	.795				
There is availability of internet facilities.	.792				
The level of technological development is emerging.	.759				
The political environment in the country is stable.	.626				
The presence of industry specific legislation in the country.	.599				
The naira/dollar rate is low and stable overtime		.812			
The level of inflation in the country is decreasing overtime		.809			
The country's interest rate is low and attracts investment		.709			
The country's employment rate is on the increase as population increases		.667			
The country's internal cash flow is increasing overtime		.619			
There is stability in the trend of country's economy			.874		
The country economy is growing with same pace with oversea economies and trade			.786		
The economic situation of the country is favorable			.783		
The economic condition of the country encourages international trade			.587		
The country economic condition supports market and trade cycles				.808	

There is freedom of press in the country.				.550	
There is presence of stable legislation in the country					.682
There is presence of competitive regulations guiding investment in the country.					.655
There is availability of consumer protection in the country					.597
There is high level of socio-cultural changes in the country.					.536
<b>Eigen Value</b>	<b>6.160</b>	<b>2.916</b>	<b>1.591</b>	<b>1.353</b>	<b>1.063</b>
<b>Value of Variance (%)</b>	<b>30.80</b>	<b>21.58</b>	<b>17.91</b>	<b>10.77</b>	<b>8.32</b>

Extraction Method: Principal Component Analysis.

The other factors were economic growth factor (17.91%), commerce and communication factor (10.77%) and socio-legal factor (8.32%). These five (5) factors were seen to have explained 89.38% variance of all the determinants of property investment inflow in Nigeria. This implies that to increase the level of investment into the Nigerian market by both local and international investors, it is important that these factors are put in consideration.

To determine the significance of each of the components to property investment inflow (Y) the determinants were regressed. The result of the analysis is presented in Tables 4 and 5. Table 4 showed the regression model summary.

**Table 4: Regression Model Summary**

<b>Model</b>	<b>*R</b>	<b>**R Square</b>	<b>Adjusted R Square</b>
1	0.876	0.726	0.63

From the result of the analysis, it was established that the relationship between property investment inflow and the factors examined was jointly significant at  $P= 0.000005$ . Also with  $R^2$  0.726, it was established that 72.6% of the property investment inflow into Nigeria was determined by technological and political, macro-economic, economic growth, commerce and communication and socio-legal factors. The remaining 28.44% might be attributed to other factors such as market maturity, real estate peculiarities and market transparency among others.

The significance of each of the components is presented in Table 5. Table 4 also showed the weight of each of the components as relations to inflow of investors into the Nigerian property market.

Using the standardized beta coefficient, the regression model for the study was:

$$Y = a + 0.622x_1 + 0.731x_2 + 0.221x_3 + 0.198x_4 + 0.089x_5 \dots\dots\dots(2)$$

Table 5 indicated that the regression coefficient for component 1, component 2, component 3, component 4, and component 5 were 0.622, 0.731, 0.221, 0.198 and 0.089 respectively.

**Table 5: Significance of the Individual Independent Variables**

Model	Unstandardised Coefficient		Standardised Coefficient Beta	T	Sig.
	B	Std.error			
(Constant)	5.421	0.258		7.348	
Component 1	0.743	0.095	0.622	0.452	0.000
Component 2	0.321	0.078	0.731	4.670	0.003
Component 3	0.161	0.292	0.221	3.118	0.001
Component 4	0.749	0.019	0.198	0.098	0.222
Component 5	0.912	0.086	0.089	-9.765	0.421

From the result of the analysis it was established that component 1, component 2 and component 3 had significant relationship with the inflow of investment in the Nigerian property market as seen in the result of their P-Values which were 0.000, 0.003 and 0.001 respectively. Component 3 and component 4 had high P-Value and were not significant in determining the inflow of property investment into Nigeria.

For component 1, the beta was 0.622 at significance level of 0.000. This result implies that a unit change in the technological and political characteristics of the country will increase property investment inflow into Nigeria by 62.2%. Linking the result with result presented in Table 3. It can therefore be implied that if the technology relating to property is improved and new ones are introduced, the investors both local and international might be attracted to the Nigerian property market.

For component 2, this had beta of 0.731 at a significance level of 0.003 showed that a unit change in the macro-economic factors will influence the inflow of local and international investors in to the Nigerian property market by 73.1%. The significant of this component was higher compared to the other determinant of investment inflow. Explicitly it was established in Table 3 that exchange rate improvement and inflation rate factor had the highest loading in the principal component analysis. Hence, the improvement of these factors might create a good property investment platform for investors.

For component 3, the beta was 0.221 at significance level of 0.001. This result implies that a unit change in economic growth characteristics of the country will increase property investment inflow into Nigeria by 22.1%. Linking the result with result presented in Table 3. It can be inferred that if economy of Nigeria is growing with other international counties, investors both local and international might be attracted to the Nigerian property market.

The factors loaded under component 3 and component 4 does not have a significant relationship with the improvement of local and international investor's inflow in the Nigeria property market. The P-values for the components were 0.222 and 0.421 respectively. This can also be deduced from the variance (10.77% and 8.32%) explained by these factors presented in Table 3.

Hence the commerce and communication factor and socio-legal factor had less significance to the inflow of property investment by both local and international investors compared to the technological and political factor, macro-economic factor, and economic growth factor.

## **CONCLUSION**

The determinants of investment inflow into the Nigerian property market was investigated by loading the PESTEL factors into principal component analysis (PCA) to determine the important factors in an emerging economy like Nigeria. Regression was further used to determine the significance of the factors. The result of the analysis indicated that out of the fifty-five variables loaded, twenty (20) were fit for the principal component analysis and was loaded under five (5) components. The 5 components explained 89.38% of the determinants of investment inflow into the Nigerian property market. The components were named accordingly. technological and political, macro-economic, and economic growth factors had higher percentage variance of 30.80, 21.58 and 17.91 respectively. The regression analysis also

established that technological and political, macro-economic, and economic growth factors had significant relationship with the inflow of property investment into Nigeria. The macro-economic factor was seen to have the highest beta of 0.731.

Hence, the study concluded that the major factors that determine the inflow of investors into the Nigerian property market were macro-economic, technological and political and economic growth factors.

In the light of the above, the following recommendations were put forward: to improve the inflow of investors both local and international ones into the Nigerian property market, there is need to focus on the macro-economic variables in the country such as exchange rate, interest rate and inflation rate. Also in terms of technology, there is need to introduce useful technologies that can help promote the property sector so as to create a standardised property market with the global world. Furthermore focus should be on improving the growth in the country's economies which can be made possible by ensuring high level of security, developing relevant investment policies and reduction of political uncertainty.

## **REFERENCES**

Aguilar, L.O. (2008): Investment opportunities in Costa Rica and Panama: an insight into central American real estate development". Masters Thesis, Department of real estate and construction management, Costa Rica.

Ahmed, N.F., Mei, J.L. and Iman, A.H. (2015).: "The determinants of Asean countries attractiveness to Foreign Direct Investment in real estate" 21<sup>st</sup> Annual Pacific Rim Estate Societies Conference, Kuala Lumpur, Malaysai, 18-21, January, 2015, 1-17

Bryan, A.P. (2011): "What is the Best Way to Enter Florida's Real Estate Market in Today's Economy?" B.Sc Thesis, Tampere University of Applied Science, Finland

Castro, J.O. (2006): "Strategic framework for real estate investment in emerging market: the case of commercial real estate in Bogeta, Colombia", Massachusetts institute of technology, Colombia

Ekpo, V.N. (2016): " Determinants of private investment in Nigeria: An empirical exploration ", *Journal of Economics and Sustainable Development*, 7, 80-92

Elile, R. U., Sunday, A. and Raju, V. (2019): “Real estate investment performance and macroeconomic dynamics in Nigeria: AA sectoral analysis”, *World Journal of Research and Review*, Vol.8, pp18-26

Emam, H. (2011): “Real Estate Industry in Egypt: Segmentation, Targeting and Positioning Approach” Masters Thesis, University of Manchester, United Kingdom

Fahey, L. and Randell, M.R. (2000). “The Portable MBA in Strategy (2nd ed.)”, New York: Wiley and Sons

Field, A. (2005): “Discovering statistics using SPSS (2nd ed.)”, London: Sage

Gholipour, H.F., Almulali, U. and Mohammed, A.H. (2014): “Foreign investments in real estate economic growth and property prices: evidences from OECD countries”, *Journal of Economic Policy Reform*, DOI: 10.1080/17457870.2013.8286133

Jadhav, P. (2012): “Determinants of foreign direct investment in BRICS economies; analysis of economic, institutional and political factors”, *Procedia- social and behavioral science*, 37, 5-14. Retrieved from [www.sciencedirect.com](http://www.sciencedirect.com)

Jones Lang LaSalle (JLL) (2010): “China’s property market- fast tracking to maturity”, China, Jones Lang LaSalle publication. Retrieved from [www.joneslanglasalle.com](http://www.joneslanglasalle.com)

Jones Lang LaSalle (JLL) (2014): “Real Estate Transparency Improves in Sub Saharan Africa”, Real Estate Transparency Report , South Africa. Retrieved from [www.joneslanglasalle.com](http://www.joneslanglasalle.com)

Lee, S.L. (2001): “The Risks of Investing in the Real Estate Markets of the Asian Region”. Working paper series of real estate and planning, the University of Reading Vol.6.

Lee, S.L. (2005): “Gauging the Investment Potential of International Real Estate Markets”. Working paper series of real estate and planning, the University of Reading, Vol.19.

Liang, M. and Yoon, S. (2011). The Determinants of Foreign Direct Investment in US real estate: An Empirical analysis” Masters Thesis, Massachusetts Institute of Technology

Lieser, K. and Groh, A.P. (2011): “The Determinants of International Commercial Real Estate”. *IESE Business School- University of Navarra*, WP-935.

Masron, T.T. and Kipili, E.F. (2016). “Can Foreign Investment in real estate improve host country’s affordability?”, *Asian Academy of Management Journal of Accounting and Finance*, 12, 1-21

Muhamad, A. (2016): “An evaluation of factors driving property investment decision by private developers in Nigeria” Masters thesis, Ahmadu Bello University, Zaria, Nigeria

Ojong, C.M., Arikpo, O. and Anthony, O. (2015): “Determinants of Foreign Direct Investment Inflow to Nigeria”, *IOSR Journal of Humanities and Social Science*, 20, 34-43

Okoro, R. and Kalu, A. (2017): “Issues of foreign real estate investment in Nigeria”, *International Journal of Humanities and Social Sciences*, 6, 6-11

Olaleye, A. and Adebara, O.B. (2019): “Another look at property maturity framework and its application to Lagos property market, Nigeris”, *Journal of property investment*”, 37, 486-502

Rothacher, N. (2013): “Maturity of real estate market in sub-Saharan Africa: a comparison between Tanzania and South Africa”, *European Real Estate Society (ERES)*. 1, 1-21

Royal Institute of Chartered Surveyors (2014): *Unleashing Sub-Saharan Africa Property Market*”, September ,RICS parliament square , London SW1P3AD.

The Institute of Company Secretaries of India (ICSI) (2018): “Real Estate Sector”, New Dehli: ICSI

United Nations Conference on Trade and Development (2015): “ World investment report: reforming international investment governance”, United Nations publications, Geneva

Watson, J. (2001): “How to determine a sample size”, Pennsylvannia State Cooperative Extension. Retrieved from <http://www.extension.psu.edu.evaluation/pdf/TS60.pdf>



## **FRONT AND REAR YARDS OF RESIDENTIAL BUILDINGS AS OPEN SPACES IN ILE-IFE, NIGERIA: SOME IMPLICATIONS FOR DEVELOPMENT CONTROL**

Adebara, T. M.

Department of Urban and Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria

\*Email of Corresponding Author: adebaratemitope@gmail.com

### **ABSTRACT**

Front and rear yards of residential buildings are used as open spaces for different activities in urban areas. Nevertheless, the implications of the activities on development control have not been properly examined and documented. This study therefore explored the uses of front and rear yards of buildings in Ile-Ife, Nigeria with a view to identifying the implications on development control. Data for the study were obtained through questionnaire survey. To obtain the data, 563 residential buildings with front and rear spaces were identified along the selected streets in the study area. Every fifth building was selected using systematic sampling. From this technique, 113 copies of questionnaire were administered to household heads in the selected buildings to obtain information on the uses of the spaces. The data obtained were mainly analyzed using descriptive statistics such as frequency and mean. Findings showed that the two most important uses of the front yard were domestic (30.4%) and economic (23.9%). Similarly, the dominant uses of the rear yard were domestic (79.2%) and recreational (13.0%). The study also established that despite the existence of the development control strategies, there were illegal conversions of the open spaces for various purposes with negative effects in the residential environments. It is therefore concluded that the existing development control strategies were not effective in regulating the uses of the spaces. This calls for the reassessment of the strategies to take cognizance of the reality and local conditions in the urban centres.

**Keywords:** Open space, front and rear yards, development control, local planning authorities, built environment

### **INTRODUCTION**

Open spaces are key urban environmental quality indicators. They are areas of land not built upon irrespective of their sizes, but important to the accomplishment of attractiveness, ecological services and enjoyable landscape (Falade, 1985; Adebara, 2017). In the built

environment, open spaces can be created either by governments through formal legislation or by community and individuals for certain purposes. Thus, the ownership of open space in the built environment can be public or private.

Public open space is accessible to urban residents for use without restrictions (UN-Habitat, 2015). This includes: recreational parks, squares, streets, traditional market and beaches with public access. On the contrary, private open space is accessible and available to owners and limited users (Jurkovič, 2014). In this category are front and rear yards of individual buildings.

Front and rear yards of buildings are important determinants of open space quality in residential environments. The size of the yards determines the amount of open spaces around individual buildings (Adedeji and Fadamiro, 2011). In view of this, local planning authorities often specify the minimum requirements for front and rear setbacks of buildings. Primarily, the open spaces provide better condition for circulation of air around buildings and serve as buffer areas for preventing incidents such as fire outbreak from spreading from one building to another. In addition to these, Raji and Attah (2017) noted that residential yards can be utilised to introduce soft landscape elements (trees/shrubs) to create aesthetic and shading effects in home environment. Besides these primary functions, front and rear yards of buildings are used as open spaces for diverse activities in Nigerian urban centres. Such activities can include: informal trading, ancestral worship, social ceremonies and animal rearing among other things. However indiscriminate occupation of any available open spaces around buildings may generate environmental problems in residential areas. Along this line, Adedeji and Fadamiro (2015) asserted that the illegal conversion and misuse of open spaces has exerted a major strain on the physical appearances of most urban areas and serious negative effects on the environment.

The notable issues of the use of open spaces in Nigerian urban centres may be attributed to weak development control. Moreover, many urban areas are poorly organised in terms of modern physical planning and characterised by poor open spaces, if they exist at all (Officha *et al.*, 2012). Thus, there is a need for quick intervention from government at all levels, urban planners and scholars vis-à-vis the uses and management of the open spaces in urban areas. Several studies have investigated the uses of open spaces in urban areas within and outside Nigeria (Ahmadi *et al.*, 2011; Adedeji and Fadamiro, 2011; Brown *et al.*, 2015). Nevertheless,

the planning implications of the use of front and rear yards of buildings as open spaces have not been properly documented, particularly in Nigeria.

In the light of the foregoing, this study examined the use of front and rear yards of residential buildings as open spaces in Ile-Ife, Nigeria. This is with a view to providing information that could improve development control with regard to the regulation of open spaces around buildings.

## **MATERIALS AND METHODS**

### **Study Area Description**

The study is focused on Ile-Ife, a traditional urban centre in Osun State, Nigeria (See Figure 1). Ile-Ife is referenced as the cradle of the Yoruba civilization. It occupies a unique position in the history and mythology of Yoruba people. It is rich in culture and tenacious in tradition.

Ile-Ife is located between latitude 7°28'N and 7°45'N and longitude 4°30'E and 4°34'E. According to the National Population Commission (2006), the city has a population of about 502, 952 people. It is made up of two local government areas (LGAs). These are Ife Central and Ife East.

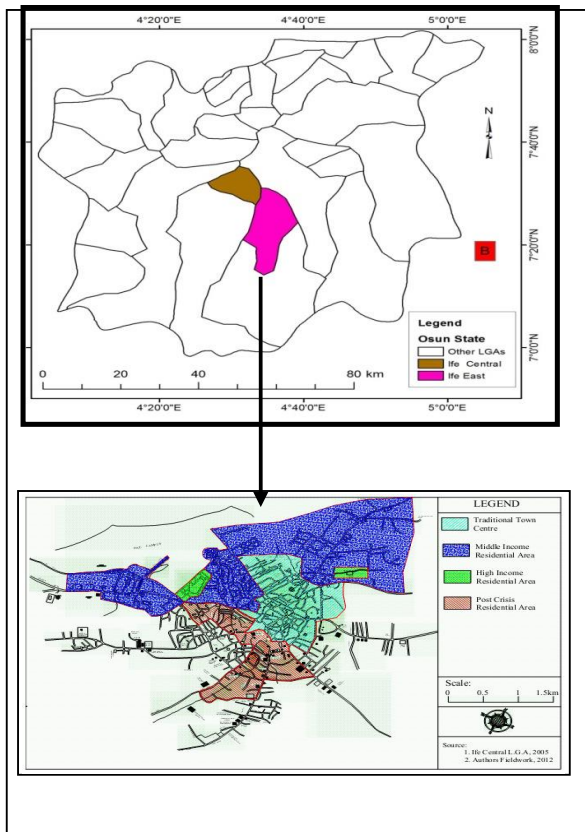
Like in any urban area of Nigeria, front and rear yards of residential buildings are put into diverse uses in Ile-Ife. Such uses are expected to have some implications on development control.

### **Methodology**

Data for this study were obtained through questionnaire survey, field observation and photographic recording. To obtain the data, multistage sampling technique was adopted. The first stage was the estimation of streets in Ile-Ife. Through reconnaissance survey and findings from the Google Earth, 391 streets were identified. Using systematic sampling, one of every five streets (20%) was selected.

The second stage involved the estimation of residential buildings with front and rear spaces along the selected streets. Investigation showed that there were 563 buildings with front and rear spaces. The last stage was the selection of buildings to determine where households will be surveyed. One of every five buildings was selected after the first building was chosen at random. Questionnaire was administered to the household heads in the selected buildings. A

total of 113 copies of questionnaire were administered. The respondents provided information on the activities taking place in front and rear yards of their houses and the factors determining the use of the spaces.



**Figure 1:** Map of Osun State indicating Ile-Ife  
Source: Badiora (2014)

Field observation and photograph recording were carried out to complement the questionnaire survey. Furthermore, questionnaires were administered to head of local planning authorities in Ile-Ife. This was done to obtain information on the development control strategies employed by the planning authorities for regulating the use of the spaces. The data obtained were analyzed using descriptive statistics such as frequency, mean and percentage. It is important to state that every tables and plates in the next section emanated from the author's fieldwork of 2018, except otherwise stated.

## **RESULTS AND DISCUSSION**

Discussed in this section are the uses of front and rear yards of buildings and development control strategies for regulating the uses. These are discussed under two subsections as follows.

### *Front and rear yard utilisation*

Presented in Table 1 are the uses of front and rear yards of buildings in Ile-Ife. To obtain information on the uses, household heads were instructed to identify different activities taking place in the open spaces around their houses. The respondents were allowed to indicate as many of the uses as they could recognise. This thus gave rise to multiple responses.

The uses to which the open spaces could be put were grouped into five. The grouping comprised recreational, domestic, socio-cultural, economic and religious uses. The research findings on each category mentioned are hereby discussed.

As summarized in Table 1, the most important function of front space in Ile-Ife was domestic. It accounted for 30.4% of the uses to which the space was put (See Plate 1 and Figure 2). The explanation for this could be attributed to the fact that facilities such as kitchen, toilet and bathroom were external to many residential buildings in Ile-Ife, especially in the core area. Hence, the outdoor spaces around the house served domestic purpose. In the category of domestic use were outdoor cooking (13.2%), washing/drying of clothes (8.0%), food drying and preservation (6.3%) and collection/storage of water (2.9%). A life example of front space of a building used for domestic activities in the study area is presented in Plate 1.



**Plate 1:** Front yard used for domestic purpose  
in Irewo, Ile-Ife

The second important use of the front yard was economic. Trading and artisanship were the economic activities. Findings showed that trading accounted for 16.5% of the economic

use while the proportion of artisanship was 7.4% of the use. That the most dominant economic use of the front space was trading suggested that:

- (a) the users might consider the cost of renting shops for businesses too expensive. Hence, they opted for the use of front space of their houses or rent such space from the owner in order to reduce cost;
- (b) the owner could rent out such space in order to generate income;
- (c) the users might consider trading within their home environments more convenient and profitable; and
- (d) a way of keeping vigil to intruders (thieves) especially during the day when majority could have gone out.

It was observed that temporary structures were erected in order to carry out trading activities in the front spaces. These temporary structures included: kiosks, sheds, and metal containers. They provided security and protection from harsh weather conditions for the open space users. However, the construction of such structures in the front spaces was an indication that development control regulations were violated.

**Table 1: Uses of front and rear yards of buildings**

Uses	Front f (%)	Rear f (%)
<b>Recreational</b>		
Relaxation	22 (4.9)	--- (0.0)
Children’s Play	63 (14.1)	48 (11.3)
Playing Ayo Games	6 (1.3)	--- (0.0)
Story-telling	--- (0.0)	7 (1.7)
<b>Sub-total</b>	<b>91 (20.3)</b>	<b>55 (13.0)</b>
<b>Domestic</b>		
Outdoor Cooking	59 (13.2)	64 (15.1)
Washing/Drying	36 (8.0)	75 (17.7)
Food /Preservation	28 (6.3)	68 (16.0)
Water collection/Storage	13 (2.9)	73 (17.2)
Burning of refuse	--- (0.0)	25 (5.9)
Bathing	--- (0.0)	31 (7.3)

<b>Sub-total</b>		<b>136 (30.4)</b>	<b>336 (79.2)</b>
<b>Socio-cultural</b>			
Ceremonies		62 (13.8)	--- (0.0)
Reception of visitors		21 (4.7)	--- (0.0)
Family Meetings		17 (3.8)	19 ( 4.5)
<b>Sub-total</b>		<b>92 (22.3)</b>	<b>19 (4.5)</b>
<b>Economic</b>			
Trading		74 (16.5)	---(0.0)
Artisanship		33 (7.4)	9 (2.1)
<b>Sub-total</b>		<b>107 (23.9)</b>	<b>9 (2.1)</b>
<b>Religious</b>			
Ancestral	Worship/	14 (3.1)	5 (1.2)
Ritual			
<b>Sub-total</b>		<b>14 (3.1)</b>	<b>5 (1.2)</b>
<b>Grand total</b>		<b>448 (100.0)</b>	<b>424(100.0)</b>

\* Note: The total exceeded the number of respondents ( $n=113$ ) since multiple responses were allowed

It was also noticed in some areas of Ile-Ife that the temporary structures constructed as appendages to main buildings have eaten up the spaces for road setbacks, spilling over to the road edges. Consequently, this was causing immense problems to vehicular and pedestrian movements. Clearly shown in Plates 2 and 3 are temporary structures employed in the utilisation of front space for informal trading and artisanship in Ile-Ife.



**Plate 2:** Temporary structures used for informal trading at the front of a house in Oranfe, Ile-Ife



**Plate 3:** Space used as a furniture workshop in Mokuro Area, Ile-Ife

Socio-cultural use ranked third in importance. It represented 22.3% of the uses of the front space in the study area. Ceremonies, reception of visitors and family meetings were the socio-cultural activities taking place in the front space of buildings. Ceremonies and reception of visitors accounted for 13.8% and 4.7% respectively while family meetings represented 3.8% of the socio-cultural use of the front space. Therefore, ceremonies were the most important socio-cultural activities taking place in the front space. The reason for this could be attributed to Yoruba cultural practice of holding ceremony in the family house. Examples of ceremonies were: child's naming, house warming, introduction, engagement and marriage. Presented in Plate 4 is an example of the use of front space of buildings for social ceremony.



**Plate 4:** Front space of a building used for social ceremony in Road 7 Area, Ile-Ife

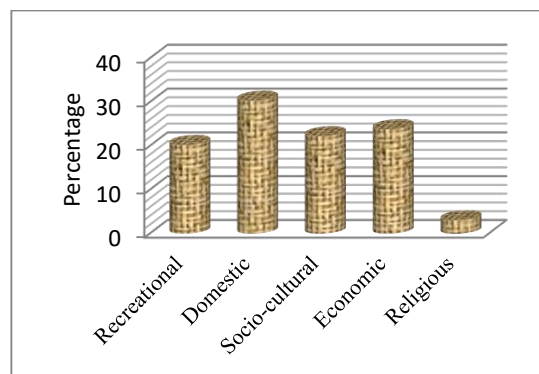
Other uses of the front yard were recreational and religious accounting for 20.3% and 3.1% of the entire uses of the space respectively. The use of front space of buildings for recreational pursuits is an indication of the demand for designated recreational spaces in Ile-Ife. An example of front space of building used for recreation is presented in Plate 5.



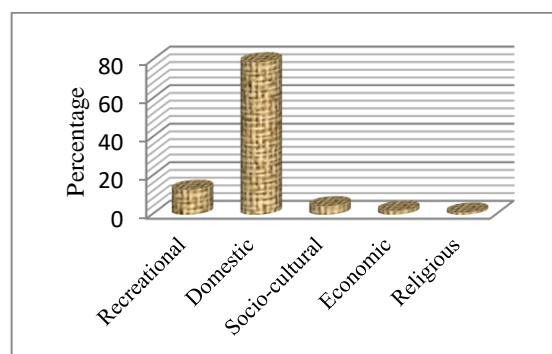


**Plate 5:** Typical front space usage for playing Ayo game (passive recreational pursuit) in Irewo, Ile-Ife.

Like in the front space of buildings, findings showed that the most important use of the rear space was domestic. However, the proportion that the use accounted for differed. Domestic activities accounted for 79.2% of the use of the rear space (see Figure 3). The result therefore showed that occurrence of domestic activities was higher in the rear space than in the front space of buildings. The explanation for this could be the fact that the rear space can offer households an access to outdoor area with a high degree of privacy. Moreover, people may feel more comfortable to utilize the rear space of their houses for domestic chores than the front.



**Figure 2:** Summary of the uses of front yards



**Figure 3: Summary of the uses of rear yards**

However, the occurrence of recreational, socio-cultural, economic and religious activities were very low in the rear spaces (see Figure 3). Each of the above respectively accounted for 13.0%, 4.5%, 2.1% and 1.2% of the use of rear space of buildings.

#### *Development Control Strategies for Regulating the Use of front and Rear Yards of Buildings*

It is considered important to investigate the level of awareness of the local planning authorities on the environmental effects of the uses of front and rear spaces of buildings before examining the development control strategies they have put in place. This is because environmental degradation is a necessary antecedent to the development of intervention programs (Okanlawon and Odunjo, 2016). To this end, this study investigated the environment effects of the uses of the front and rear yards of buildings based on the perspective of the town planners. In order to achieve this, the town planners were asked to express their level of agreement with the different environmental problems identified in the literature using one of the 5-point Likert scale of *strongly agreed, agreed, just agreed, disagreed and strongly disagreed*. From this rating, Town Planners' View Index (TPVI) was generated for each of the environmental problems identified.

As shown in Table 2, the two most notable effects perceived by the town planners were: “*odour from uncollected waste in open spaces around the house*” and “*breeding of diseases vectors from insanitary open spaces*”. Each of these environmental effects had a TPVI of 4.50 which is greater than the group mean (TPVI = 4.15). Therefore, they had positive deviation about the group mean. Other environmental effects with positive deviations were: “*circulation disturbance within the premises*” and “*noise pollution*” with TPVI of 4.44 and 4.42 respectively. The least perceived environmental effect was “*blockage of drainage by wastes*”. This had a TPVI (3.50) lower than the group mean (4.15). Impliedly, it had a negative deviation about the mean.

**Table 2:** Environmental effects of the uses of front and rear yards

<b>Environmental Effects</b>	<b>TPVI</b>	<b>MD</b>
Odour from uncollected waste	4.50	0.35
Breeding of disease vectors	4.50	0.35
Circulation disturbance	4.44	0.29
Noise pollution	4.42	0.27
Deface of aesthetic quality	4.00	-0.15
Air pollution	4.00	-0.15
Contamination of water source	4.00	-0.15
Open space defecation	4.00	-0.15
Blockage of drainage by wastes	3.50	-0.65
<b>Mean TPVI</b>	<b>4.15</b>	

**MD** is the deviation about the mean

Furthermore, town planners at the local government areas of Ile-Ife were interviewed to obtain information on the strategies adopted for ordering the use of the residential open spaces. According to the town planners, the development control response strategies put in place were as follows:

- a. Screening of the design plan of residential development before approval. Planning authority always check the design plan of buildings properly in order to ensure that minimum planning requirements (standards) for open spaces are not contravened. In other words, buildings to be approved must meet the minimum requirement for open spaces.
- b. Constant monitoring and inspection of physical development on a daily basis to ensure that minimum requirements for open spaces are observed and that structures are not erected in open spaces.
- c. Contravention notice is served on the breach of planning regulations with regards to open spaces. The contravener is expected to stop work immediately after the receipt of this notice. However, non-compliance with this notice attracts demolition notice after 21 days.

In view of the above, it could be deduced that there were planning strategies in place for controlling the use of open spaces in Ile-Ife. It was however established earlier in this study that there were contraventions of minimum planning requirements for open spaces in the study area. These included illegal conversion and erection of temporary structures for economic

activities in the open spaces among others. This suggests that the development control response strategies put in place were ineffective. The likely reasons responsible for the ineffectiveness of the extant strategies could be attributed to four main factors:

- (a) the use of open space in Ile-Ife is part of culture and tradition (Adebara, (2017). It is therefore possible that the planning regulations put in place were not in harmony with the cultural practice of the people. Besides, some of the residential areas in the traditional city had been in existence before the advent of modern planning regulations;
- (b) inadequate funding of the development control authority;
- (c) the town planning officers might be characterized with bribery and corruption. This would not allow them to discharge duties diligently; and
- (d) poor implementation and lack of competent staff in the development control department.

## **CONCLUSION AND POLICY ISSUES**

The study concluded that the front and rear yards of buildings are put into different uses in Ile-Ife, Nigeria. It is also concluded that the local planning authorities were aware of the uses and their environmental problems. However, the development control strategies put in place for controlling the uses of the residential open spaces were not effective. This therefore calls for the reassessment of the existing control strategies to take cognizance of the reality and local conditions in regulating and managing the uses of the open spaces. The local planning authorities need to devise cautious response strategies to address the issues of unauthorized utilisation and development of the open spaces.

In order to improve the development control activities with regards to the uses of the open spaces, the following are recommended. First, urban residents should be enlighten and educated on the proper usage of the open spaces in home environments. Second, government officials and politicians should create a conducive environment for the implementation and enforcement of development control regulations. Development control officials should be allowed to perform their duties effectively without interference by the politicians. Finally, the development control department should be adequately funded by the government. Revenue generation should not be lumped together with development control activities.

## REFERENCES

- Adedeji, J. A. and Fadamiro, J. A. (2015): "Urban Open Space Transition and Management in Lagos, Nigeria", *Management of Environmental Quality: An International Journal*, Vol. 26, No. 6, pp. 929- 950.
- Adebara, T. M. (2017). Physical Planning Implications of Open Space Utilization in Ile-Ife, Nigeria. Unpublished M. Sc. Thesis Department of Urban and Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria.
- Adedeji, J. A. and Fadamiro, J. A. (2011): "The Duo, Building Setback and Landscape Quality: Lautech (Nigeria) Neighbourhood Examined" *Journal of Architecture and Built Environment*, Vol. 38, 1, pp. 23-30.
- Afon, A. O., and Badiora A. I. (2013): "Spatial Distribution of Delinquent Behaviour in a Yoruba Traditional City: The experience from Ile-Ife, Nigeria", *Research on Humanities and Social Sciences*, Vol. 3, No. 1, 229-238.
- Ahmadi, V., Che-Ani, A. I., Farkisch, H. and Surat, M. (2011): "The Identity of Open Space: Adapting From the Model of Traditional Neighborhood Centre", *Journal Design + Built*, Vol. 4, pp. 74-84.
- Badiora, A. I. (2014). Intra-Urban Variation in Residents' Responses to Crime in Ile-Ife, Nigeria. *Journal of Scientific Research & Reports*, Vol. 3, No. 19, pp. 2543-2561.
- Brown, I., Chikagbum, W. and Owanate Boyle, K. (2015): Assessing the use and Adequacy of Public Open Spaces in Old Port Harcourt Township. *International Journal of Scientific & Engineering Research*, Vol. 6, No. 6, pp. 657-665.
- Falade, J. B. (1985). Nigeria's Urban Open Space: An Inquiry into their Evolution, Planning and Landscape Qualities. PhD Thesis, University of Edinburgh.
- Okanlawon, S. A., and Odunjo, O. O. (2016). Residents' Evaluation of Road Utilization as Space for Holding Social Ceremonies in Indigenous Residential Area of Ogbomoso. *Procedia-Social and Behavioral Sciences*, 216, 316-329.
- Officha, M. C., Onwuemesi, F. E. and Akanwa, A. O. (2012): "Problems and Prospect of Open Spaces Management in Nigeria: The Way Forward", *World Journal of Environmental Biosciences*, Vol. 2, No. 1, pp. 7-12.
- Raji, A. U. and Attah, U. A. (2017). Enforcing Building Setbacks as a Viable Strategy for an Emerging City. *Trajectoriâ Nauki = Path of Science*, Vol. 3, No. 6, pp. 21-27.

United Nations Habitat (2015). Conference on Housing and Sustainable Urban Development Habitat III Issue Paper, 11-Public Space. New York. Retrieved from [www.unhabitat.org](http://www.unhabitat.org).

## **ROTOR ANGLE DYNAMICS IN MULTI-MACHINE GRID- INDEPENDENT DISTRICT MINIGRID**

Ajewole, T.O.\*, Lawal, M.O., Alawode, K.O. and Omoigui, M.O.

Department of Electrical and Electronic Engineering, Osun State University, Osogbo, Nigeria

\*Email of Corresponding Author: [toajewole2002@yahoo.com](mailto:toajewole2002@yahoo.com)

### **ABSTRACT**

Emerging developments in electric power systems are fast changing the production of utility electricity from large centralized power plants to localized off-grid generating units that are dispersed over well-defined geographical area. While power supply security in the conventional grid systems has been well researched, the need for security assessment of mini integrated power systems deployed in the standalone mode has also turned out to become very essential, that measures could be devised to mitigate possible transient instabilities that might crop up in the operation of such systems. In this study, system security of multiple-generator island minigrid is investigated using a real time simulator. Rotor angular variations and frequency responses of the rotating generating units of the system are examined under a fault simulated at the terminals of one of the machines. The post-disturbance steady state behaviours of the rotors shows that none of the generators had its synchronism compromised, showing that integrating a number of rotating machine based micro-energy sources would not compromise the stability of grid-independent minigrids.

**Keywords:** minigrid, security, disturbance, stability, grid-independent, angular variations, angular frequencies

### **INTRODUCTION**

It has been identified that under-development and improper management of the traditional grid infrastructures are the major reasons for the challenges facing electricity supply (Nyirenda-Jere *et al.*, 2018; Avilla *et al.*, 2017). Electric power systems across the globe are, therefore, being re-defined to accommodate more and more island minigrids (Baurzhan and Glenn, 2017), while at the same time, a number of off-grid minigrids are getting linked together to enhance the quality and the quantity of the supplied power. However, as it is obtained in the conventional grid structures, operation of island minigrids also requires some security

assessment, especially when such system is excited by a number of different but complimentary energy sources that are hybridized.

Literature on the dynamic security assessment (DSA) of the traditional grid architecture abounds (Oyekanmi *et al.*, 2014), as varying methodologies are employed to study the concept. Authors in Fu and Bose (1999) obtained an index for the DSA using mean and variance of the load's uncertainty, while wide-area security assessment that considers numerous essential constraints is presented in Makarov *et al.* (2012), and a systematic approach that is based on decision trees is employed in Liu *et al.* (2014) to obtain online power system dynamic security. A preventive control contingency selection is done in Roy and Jain (2013) by calculating active- and reactive power performance indices for single transmission line outage using fast-decoupled load flow analysis, with the ranking of the most severe contingency done based on the values of these indices. Shamar *et al.* (2013) considers contingencies based on the maximum loading parameter point to focus on analyzing the static voltage stability using continuation power flow method together with the MATLAB's power system analysis toolbox. In Akwukwaegbu, Nosiri, and Ezugwu (2017), voltage stability investigation was carried out using eigenvalue method with the positive and the negative eigenvalues as representing stable and unstable systems respectively.

As extensive as power system security has been studied, it is submitted in Zarei and Parniani (2017) that the conventional protection schemes will not work successfully on minigrd systems. Therefore, one of the major challenges with autonomous implementation of minigrds is designing a proper protection scheme (Sortomme, Venkata and Mitr, 2010), and this must be given proper attention for the technology to be able perform as required. Keyhani (2011) studied fault behaviours in single-source grid-intertied minigrd using the symmetrical analysis method, while on autonomous minigrd with a number of hybridized energy sources, Rikos, Tselepis and Neris (2008) carried out an assessment from the perspective of real- and reactive power sharing among the component micro-generating units in order to ensure safe and reliable balance between the supplied power and the load demand. A hybrid-source island minigrd has also been investigated for stability under different scenarios of variations in system's loading (Ajewole *et al.*, 2018) and, presented in Wang, Painemal and Sun (2017) is an online method of analysing voltage security in a minigrds using the convolutional neural networks (CNN) with the method reported as having better performance than each of the back-propagation neural network (BPNN) and the decision tree and support vector machine



(DTSVM), thereby considering the proposed algorithm as having great potential in future applications.

In this current study, transient stability of the rotating machines contained in multiple-machine minigrids is investigated using a minigrid test system (MTS). Angular variations and frequency responses of the rotors under a large disturbance are obtained through real time simulation. The rest of this paper is organized as follows: Section 2 provides overview of the structural design of the MTS employed for the study as well as describing the dynamic simulation of the minigrid; while Section 3 presents the responses of the perturbed system; and Section 4 concludes the study.

## EXPERIMENTATION USING A MINIGRID TEST SYSTEM

The MTS employed for the study is made of three interconnected micro-generators and a control centre (Ajewole *et al.*, 2018) as shown in Figure 1. While two of the generators are synchronous machines, the third is an asynchronous-based wind turbine. A real time digital simulator combines the three and an interface converter connects each to a local grid formed by one of the synchronous sources that is in this study referred to as the Grid Former (G-FMR). Both the magnitude and the frequency of the operating voltage of the MTS is dictated by the grid-forming source, while the other two sources supply this local grid as Grid Feeder 1 and Grid Feeder 2 (G-FDR 1 and G-FDR 2).

### Model Description of the MTS

The dynamics of the salient pole wound rotor synchronous machines that are employed in the MTS enable rotor speed feedback control on the rotor circuits, using the maximum torque per ampere technique, as given in Equation 1.

$$\left. \begin{aligned} v_{ds} &= -R_s i_{ds} + \omega_r L_q i_{qs} - L_d p i_{ds} \\ v_{qs} &= -R_s i_{qs} - L_d i_{ds} + \omega_r \lambda_r - L_q p i_{qs} \end{aligned} \right\} \quad (1)$$

Where  $v_{ds}$ ,  $v_{qs}$ ,  $i_{ds}$ ,  $i_{qs}$ , are  $dq$ -axes stator voltages and currents respectively;  $L_d$ ,  $L_q$ , are  $dq$ -axes stator self-inductances,  $R_s$ , is the stator resistance,  $\omega_r$ ,  $\lambda_r$ , are rotor electrical angular speed and rotor flux linkage respectively.

A variable-speed wound rotor asynchronous generator with reduced-capacity converter has the rotor side controlled by direct field oriented method described in Equation 2, for a decoupled control of the rotor flux and the electromagnetic torque in order to achieve a high dynamic performance.

$$\left. \begin{aligned} P_m &= K\omega_i^3 \\ v_{ds} &= R_s i_{ds} + p\lambda_{ds} - \omega\lambda_{qs} \\ v_{qs} &= R_s i_{qs} + p\lambda_{qs} - \omega\lambda_{ds} \\ v_{dr} &= R_r i_{dr} + p\lambda_{dr} - (\omega_m - \omega_r)\lambda_{qr} \\ v_{qr} &= R_r i_{qr} + p\lambda_{qr} - (\omega_m - \omega_r)\lambda_{dr} \end{aligned} \right\} \quad (2)$$

Maximum mechanical power of wind turbine is described by  $P_m$ , while  $\omega_i$  is its rotational speed and  $v_{ds}$ ,  $v_{qs}$ ,  $i_{ds}$ ,  $i_{qs}$ ,  $\lambda_{ds}$ ,  $\lambda_{qs}$  are the  $dq$ -axes stator voltage, current and flux respectively;  $v_{dr}$ ,  $v_{qr}$ ,  $i_{dr}$ ,  $i_{qr}$ ,  $\lambda_{dr}$ ,  $\lambda_{qr}$  are the  $dq$ -axes rotor voltage, current and flux respectively; and  $\omega_m$ ,  $\omega_r$  are the mechanical speed and the electrical speed, respectively, of the rotor.

The MTS has a digital simulator as the coordinating device, with the system's circuitry developed using real-time simulation computer aided design platform. A visual display unit at the control centre provided interaction with the responses of the system as the system is perturbed.

In the pre-perturbation steady state condition of the system, G-FDR 2 supplied power to the local grid at its maximum rating, while G-FMR and G-FDR 1 collectively made up for the excess power demand of the entire system, particularly during low wind speeds.

### Contingency Screening of the Minigrid

The three micro-generators were in this study examined for synchronism in the angular variations and frequency responses of their rotors when the system was subjected to a severe short circuit. The fault was introduced across the terminals of the G-FDR 2 when the TS was still at its steady operating condition, at time  $t = 0.5s$  into its operation, and cleared after  $0.6s$ .

## RESULTS AND DISCUSSION

Fault behaviours of the three generating units of the minigrid are presented in Figure 2 and Figure 3 that are show the angular variations and frequency responses respectively. It is revealed from this study that a disturbance on the G-FDR 2 has effects on both the rotor angular variations and the rotor frequency responses of all the generators contained in the entire minigrid. However, the post-fault steady state condition of the system shows that none of the generators, including the faulted one, had its synchronism compromised in any way, after the clearance of the fault. This investigation, therefore, shows that properly designed protection schemes will work successfully on the entire minigrid system.

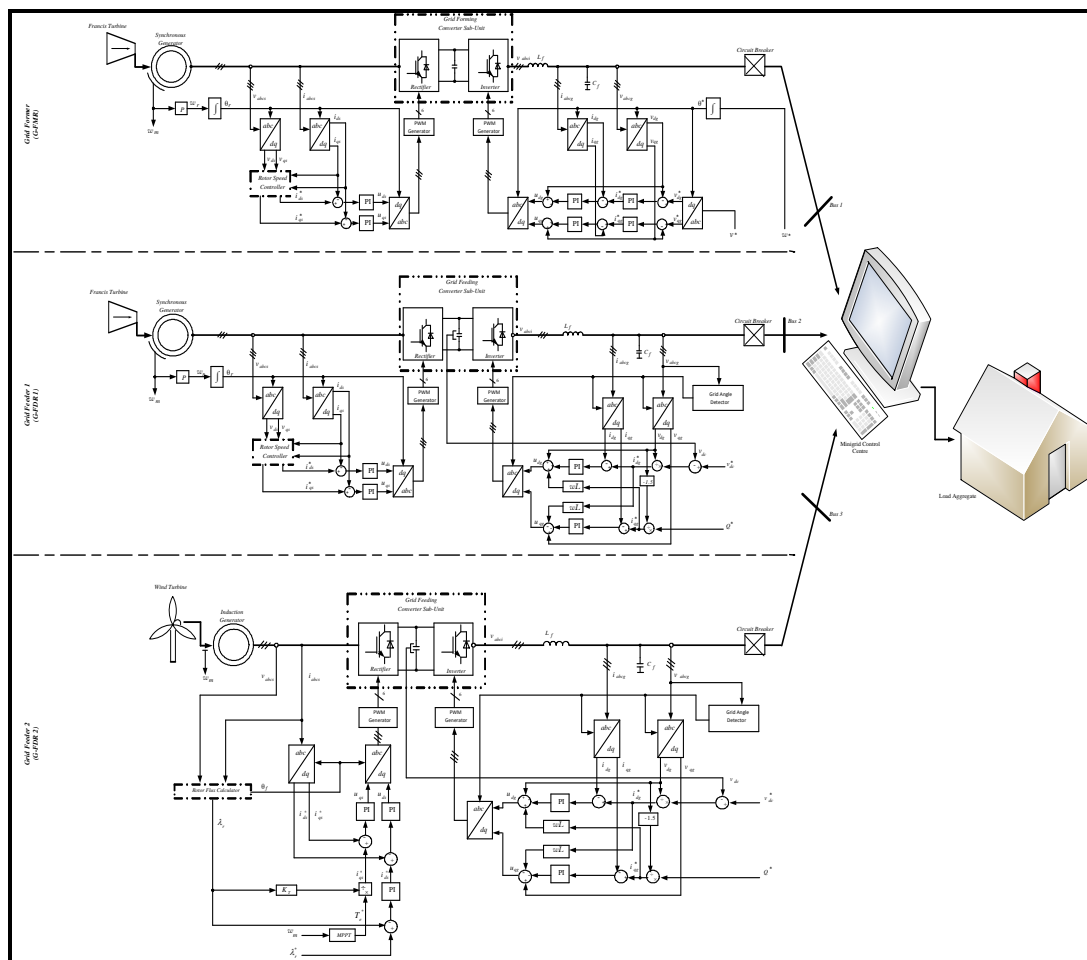


Figure 1: Complete Architecture of the Minigrid Test System

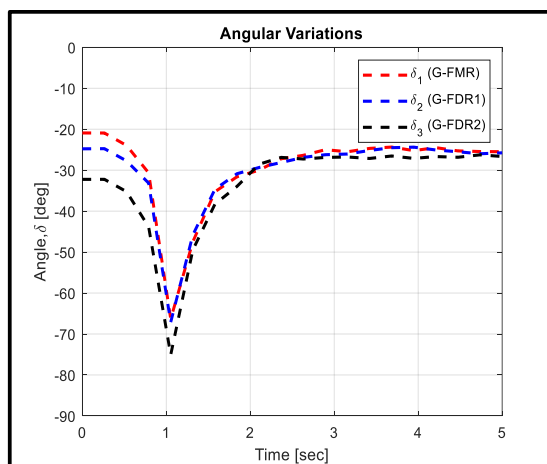


Figure 2: Rotors Angular Variations under the Disturbance

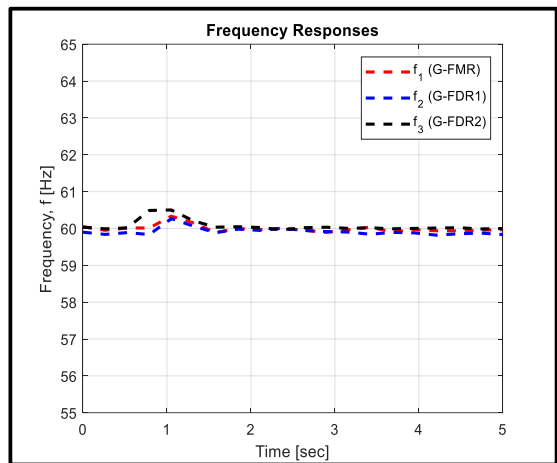


Figure 3: Rotors Frequency Responses under the Disturbance

## **CONCLUSION**

Deployment of district minigrids in electric utility is on the increase and this has resulted into making the security assessment of such systems pivotal in power systems management. A real time simulation test-rig is employed in this study as a tool for investigating the system security of multiple-generator island minigrid and the screening conducted using the simulation tool shows that:

- 1) large disturbance simulated at the terminals of one of the machines contained in the system produced a great influence on both the rotor angle variations and the rotor frequency responses of all the rotating machines in the entire system.
- 2) post-fault steady state condition of the system shows that none of the generators contained in the system had its synchronism compromised.

It is, therefore, deduced from this study that a number of rotating machine-based micro-sources can be safely integrated into a district minigrid. Also, the test-rig employed in the study is capable of providing simple and generic approach for assessing the dynamic security of multi-machine standalone district minigrids. Further investigations, involving screening all other likely contingencies that could lead to instability in freestanding minigrid, could be carried out using the approach of this study.

## **REFERENCES**

- Ajewole, T.O., Craven, P.M.R., Kayode, O. and Babalola, O.S, 2018. Simulation of load-sharing in standalone distributed generation system, In the proceedings of the 7<sup>th</sup> International Conference on Clean and Green Energy, February 7 – 9, Paris, France, <https://dx.doi.org/10.1088/1755-1315/154/1/012014>
- Akwukwaegbu, I.O., Nosiri, O.C. and Ezugwu, E.O., 2017. Voltage stability investigation of the Nigeria 330kV interconnected grid system using eigenvalues method, *American Journal of Engineering Research*, 6(4), pp. 168-182.
- Avila, N., Carvalho, J.P., Shaw, B. and Kammen, D.M., 2017. The energy challenge in sub-Saharan Africa: a guide for advocates and policy makers (part 1); generating energy for sustainable and equitable development?. *Oxfam Research Background Series*. [https://www.oxfamamerica.org/static/media/files/ofam\\_xfam-RAEL-energySSA-pt1.pdf](https://www.oxfamamerica.org/static/media/files/ofam_xfam-RAEL-energySSA-pt1.pdf)

- Baurzhan, S. and Glenn, P.J., 2017. On-grid solar pv versus diesel electricity generation in sub-Saharan Africa: economics and GHG emissions, *Sustainability*, 9, pp. 372-381, <https://dx.doi.org/10.3390/su903037>
- Fu, C. and Bose, A., 1999. Contingency ranking based on severity indices in dynamic security analysis, *IEEE Transaction on Power Systems*,14(3), pp. 980-986.
- Keyhani, A., 2011. *Smart power grid renewable energy systems*, John Wiley and Sons Inc., Hoboken, pp. 467-531.
- Liu, C., Sun, K., Rather, Z.H., Chen, Z., Bak, C. L., Thogersen, P. and Lund, P., 2014. A systematic approach for dynamic security assessment and the corresponding preventive control scheme based on decision trees, *IEEE Transaction on Power Systems*, 29(2), pp. 717-730.
- Makarov, Y.V., Du, P., Lu, S., Nguyen, T.B., Guo, X., Burns, J.W., Gronquist, J.F. and Pai, M.A., 2012. PMU-based wide-area security assessment: concept, method, and implementation, *IEEE Transaction on Smart Grid*, 3(3), pp. 1325-1332.
- Nyirenda-Jere, T., Ajewole, T.O., Mutale, J., Dauenhauer, P. and Ambali, A., 2018. Microgrids: empowering communities and enabling transformation in Africa, high-level report by the African panel on emerging technologies (APET). <https://www.nepad.org/file-download/download/public/114349>
- Oyekanmi, W.A., Radman, G., Babalola, A.A. and Ajewole, T.O., 2014. Power system simulation and contingency ranking using load bus voltage index, in the proceedings of the IEEE 11<sup>th</sup> International Conference on Electronic, Computer and Computation, September 29 – October 1, Otta, Nigeria, <https://dx.doi.org/10.1109/ICECCO.2014.6997553>.
- Rikos, E., Tselepis, S. and Neris, A., 2008. Stability in mini-grids with large pv penetration under weather disturbances – implementation to the power system of Kythnos, in the proceedings of the 4<sup>th</sup> European PV-Hybrid and Mini-Grid Conference, May 29-30, Glyfada, Greece.
- Roy, A.K. and Jain, S.K., 2013. Improved transmission line contingency analysis in power system using fast decoupled load flow, *International Journal of Advances in Engineering and Technology*, 6(5), pp. 2159-2170.
- Shamar, N.K., Phulambrikar, S.P., Prajapati, M. and Shamar, A., 2013. Contingency ranking and analysis using power system analysis toolbox, in the proceedings of the International Conference

on Recent Trends in Applied Sciences with Engineering Applications, Innovative Systems Design and Engineering, 4(6), pp. 59-63.

*Sortomme, E., Venkata, S.S. and Mitr, J., 2010. Microgrid protection using communication-assisted digital relays, IEEE Transactions on Power Delivery, 25(4), pp. 2789-2796, <https://dx.doi.org/10.1109/TPWRD.2009.2035810>.*

*Wang, Y., Painemal, H. P. and Sun, K., 2017. Online analysis of voltage security in a microgrid using convolutional neural networks, IEEE Power and Energy Society's General Meeting, July 25-27, Chicago, USA.*

*Zarei, S.F. and Parniani, M., 2017. A comprehensive digital protection scheme for low-voltage micro grids with inverter-based and conventional distributed generations, IEEE Transactions on Power Delivery, 32(1), pp. 441-452.*

## **STUDY OF GLOBAL USE OF GEOSYNTHETICS TECHNOLOGY AND IMPLICATIONS FOR NIGERIA**

Oginni, F.A.<sup>1\*</sup> and Dada, T. T.<sup>2</sup>

<sup>1</sup>Faculty of Engineering, Department of Civil Engineering, Adeleke University, Ede, Nigeria

<sup>2</sup> Faculty of Engineering and Environmental Sciences, Department of Civil Engineering, Osun State University, Osogbo, Nigeria

\*Corresponding Author, [kafnog@gmail.com](mailto:kafnog@gmail.com)

### **ABSTRACT**

Geosynthetics are materials made from various types of polymers, used with geological materials like soil, rock etc. to enhance, improve or stabilize earth terrains. This study presents the properties and the various applications of the now available synthetic products for earth stabilization purposes.

Data of Clients that are involved in the geosynthetic technology are collected and analyzed according to their Country and percentage distribution of Clients per Continent. Comparative study of the involvement levels in the use of the geosynthetic technology economy by the various continents was undertaken. In all, 181 Clients globally were analysed. Appropriateness of Nigeria's involvement was then highlighted. Results indicated that North America, Europe and Asia, Continents with 76.98% world's population accounted for 88% of the 181 Clients global involvement in the usage of Geosynthetics technology economy. Africa, Australia and South America with 23.02% world's population accounted for only 12% of geosynthetic technology usage. Africa's share of the 12% was 7%, followed by Australia with 4%, while South America had only 1% involvement level. This shows that Africa's exposure level to Geosynthetics technology of 7% only is grossly non commensurable with the Continents population. Nigeria's share of 5 out of 181 global Geosynthetics Clients indicates only 2.76%. This is not adequately enough, when further considering the additional negative impact of her population on her low comparative GDP. This implies that Nigeria needs to rise up to tap opportunities that abound in this context to improve her infrastructure. The Geosynthetic Industry should also begin to eye Nigeria as a prospective Client for greater infrastructure development business, which will further solve some economic issues.



**Keywords: Geosynthetics Soil Reinforcement Continental Use Client**

## 1.0 INTRODUCTION

Geosynthetics are synthetic products used to stabilize terrain. They are generally polymeric products used to solve civil engineering problems. The polymeric nature of the products makes them suitable for use in the ground where high levels of durability are required. Inclusions of different sorts mixed with soil have been used for thousands of years. They were used in roadway construction in Roman days to stabilize roadways and their edges. Early workers in this field include, Bertachi and Cazzuffi, (1985); Barksdale et. al., (1989); Holtz et. al., (1997) Rowe, (2001); Montestruque, (2002); Button and Lytton, (2003); Giroud and Han, (2004).

These early attempts were made of natural fibers or vegetation mixed with soil to improve road quality, particularly when roads were built on unstable soil. They were also used to build steep slopes as with several pyramids in Egypt and walls as well. When properly formulated, lifetimes of centuries can be predicted even for harsh environmental conditions (Zanten, 1986; Cancelli and Cazzuffi, 2006).

Geosynthetics are available worldwide and the activity is robust and steadily growing (Jewell, 1996). They are also available in a wide range of forms and materials. These products have a wide range of applications and are currently used in many civil, (Perkins et. al. 2010); (Thompson, 2010); (Choudhari, et. al.,2011); (Sarika and Valunjkar, 2011); geotechnical, transportation, geoenvironmental, hydraulics and private development applications including roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfill, liners, landfill covers, mining, aquaculture and agriculture. Recent Researchers in geosynthetics works are Ullagaddi, (2013); Vaishali et. al., (2013); Zornberg, (2013); Christopher, (2014); Correia and Zornberg, (2015); Muller and Saathoff, (2015) and the works of Construction review online, (2018)As very useful as these materials are, they are supposed to be commonly tapped for their usefulness in civil infrastructure developments. The technology and the business of the materials production are presently handled and show cased by Non-Nigerians. There is the need to go to town with these products, their uses, advantages and disadvantages to sensitize awareness. This study will assess the global usage of the geosynthetics and come up with implication for Nigeria. Studies in these directions should answer questions relating to global areas

of uses,. It will also assess where Africa and Nigeria in particular stand in getting involved with the technology and its business. This will obviously open up new areas of enterprises.

## 2.0 Materials and Methods

### 2.1 Materials

The materials required for this study are as follows:

1. Brochures of a few Geosynthetic Companies as collected during exhibitions of Engineering Project construction Materials.
2. Internet browsing of Geosynthetic Manufacturers and their Clients.
3. Extraction of addresses of these Companies and their Clients.
4. More fact finding surveys were embarked upon in order to study the various types/categories of this product. The areas of need and the various advantages and disadvantages. need to be highlighted in this study so as to come up with dependable deductions from the study.
5. Some periodicals and current development in the areas concerned in this study were obtained too.
6. Tools for analysing the collected data for the study include the excel spread sheet to be able to handle large data.

### 2.2 Approach used in the study.

Method that was used for the purpose of this project involved the following:

1. A catalogue of the various categories of geosynthetics was developed This included some representative images for each type.
2. Uses for particular category of the geosynthetics will be discussed.
3. Advantages and disadvantages are considered in this manuscript.
4. Obtained data of Client by Country and Continent they belong to were analyzed to determine visibility/patronage of the geosynthetic products.
5. The number of Client per Continent involved in Geosynthetics Technology were determined.
6. The various countries so determined in 5, above were compared with the country's population in order to assess effectiveness of the analysis.

7. Percentages of the continental distribution were then determined and effectively presented graphically.

The approach used in this study is similar to the one used in Oginni, (2014).

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Types of Geosynthetic Products

##### 3.1.1 Geotextiles

In the Figure 1 below, Geotextiles form one of the two largest groups of geosynthetics. They are textiles consisting of synthetic fibres rather than natural ones such as cotton, wool, or silk. This makes them less susceptible to bio-degradation.



**Figure 1: Geotextile -**

These synthetic fibres are made into flexible, porous fabrics by standard weaving machinery or are matted together in a random non woven manner. Some are also knitted. Geotextiles are porous to liquid flow across their manufactured plane and also within their thickness, but to a widely varying degree. There are at least 100 specific application areas for geotextiles that have been developed; however, the fabric always performs at least one of four discrete functions: separation, reinforcement, filtration, and/or drainage (Pilarczyk, 2000).

##### 3.1.2 Geogrids

In the Figure.2 below represent Geogrids a rapidly growing segment within geosynthetics. Rather than being a woven, nonwoven or knitted textile fabric, geogrids are polymers formed into a very open, grid like

they have between the transverse either improved

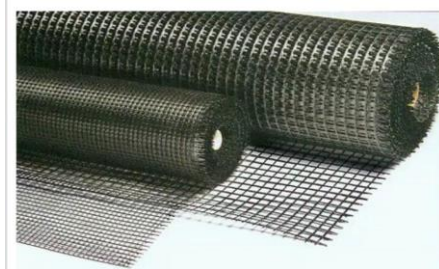


Figure 2: Geogrids (Source: Civilblog.org 21/04/2015)

configuration, i.e., large apertures individual ribs in



Figure 3: Geonets – Civilblog.org –

and longitudinal directions. Geogrids are (a) stretched in one, two or three directions for physical properties, (b) made on weaving or knitting machinery by standard textile manufacturing methods, or (c) by laser or ultrasonically bonding rods or straps together. There are many specific application areas; however, geogrids function almost exclusively as reinforcement materials (Pilarczyk, 2000).

### 3.1.3 Geonets

Figure.3 shows Geonets, and related Geospacers by some, constitute another specialized segment within the geosynthetics area. They are formed by a continuous extrusion of parallel sets of polymeric ribs at acute angles to one another. When the ribs are opened, relatively large apertures are formed into a netlike configuration. Two types are most common, either biplanar or triplanar. Alternatively many very different types of drainage cores are available. They consist of nubbed, dimpled or cusped polymer sheets, three-dimensional networks of stiff polymer fibers in different configurations and small drainage pipes or spacers within geotextiles. Their design function is completely within the drainage area where they are used to convey liquids or gases of all types (Pilarczyk, 2000).

### 3.1.4 Geomembrane

Figure 4 is a Geomembrane. It represents the other largest group of geosynthetics, and in dollar volume their sales are greater than that of geotextiles. Their growth in the United States and Germany was originally stimulated by governmental regulations enacted in the early 1980s for the lining and sealing of solid-waste landfills. The materials themselves are relatively thin, impervious sheets of polymeric material used primarily for linings and covers of liquids- or solid-storage facilities. This includes all types of landfills, surface impoundments, canals, and other containment facilities.



Figure 4: Geomembrane - Civilblog.org 21/04/2015

The primary function is always containment as a liquid or vapor barrier or both. The range of applications, however, is great, and in addition to the environmental area, applications are rapidly growing in geotechnical, transportation, hydraulic, and private development engineering (such as aquaculture, agriculture, heap leach mining, etc (Pilarczyk, 2000)).

### 3.1.5 Geosynthetic Clay Liners

Figure 5 below is a Geosynthetic clay line, which is also called GCL. It is an interesting juxtaposition of polymeric materials and natural soils.

They are rolls of sandwiched geomembrane and the subsequent stitching or



Figure 5: Geosynthetics Clay Liner -Civilblog.org

factory fabricated thin layers of bentonite clay between two geotextiles or bonded to a impermeable to water. Structural integrity of composite is obtained by needle-punching, adhesive bonding.

GCLs are used as a composite component beneath a geomembrane or by themselves in geoenvironmental and containment applications as well as in transportation, geotechnical, hydraulic, and many private development applications (Pilarczyk, 2000).

### 3.1.6 Geofom

In the Figure 6 by a polymeric a “foam” The skeletal nature

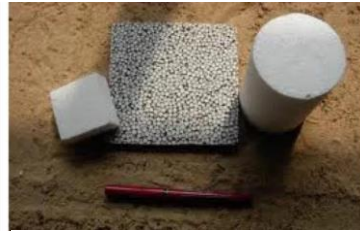


Figure 6: Geofom - Civilblog.org

The resulting product is generally in the form of large, but extremely light, blocks which are stacked side-by-side providing lightweight fill in numerous applications (Pilarczyk, 2000).

### 3.1.7 Geocells

In the Figure 7 below, Geocells (also known as Cellular Confinement Systems) are three-dimensional honeycombed cellular structures that form a confinement system when in filled with compacted soil. Extruded from polymeric materials into strips welded together ultrasonically in series, the strips are textured and mattress. In filled from the cell-soil



Figure 7: Geocells - Civilblog.org, 214/2015

The cellular confinement reduces the lateral movement of soil particles, thereby maintaining compaction and forms a stiffened mattress that distributes loads

made from advanced polymers are being increasingly adopted for long-term road and rail load support. Much larger geocells are also made from stiff geotextiles sewn into similar, but larger, unit cells that are used for protection bunkers and walls (Pilarczyk, 2000).

### 3.1.8 Geocomposites

In the Figure 8 below shows a geocomposite. It consists of a combination of geotextiles, geogrids, geonets and/or geomembranes in a factory fabricated unit. Also, any one of these four materials can be combined with another synthetic material (e.g., deformed plastic sheets or steel cables) or even with geotextiles both soil. As examples, a geonet or geospacer with on both surfaces and a GCL consisting of a geotextile/bentonite/ geotextile sandwich are geocomposites.

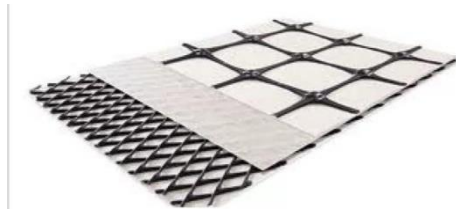


Figure 8: Geocomposites - Civilblog.org - 21/4/2015

This specific category brings out the best creative efforts of the engineer and manufacturer. The application areas are numerous and constantly growing. The major functions encompass the entire range of functions listed for geosynthetics discussed previously: separation, reinforcement, filtration, drainage, and contain (Pilarczyk, 2000).

### 3.2 Uses of Geosynthetics in Civil Engineering and Construction Works

#### 3.2.1 Separation of Soil Layers

In order to keep the imported material separated from the in-situ soil, a separating layer of geosynthetic is laid between the geotechnical entities. This is done to keep the properties of the imported material intact which otherwise could have altered under the action of applied loads.

Depending upon the surrounding conditions, nonwoven geotextile, geofoam and geocomposites can be laid in between the imported material and the in-situ soil. They are usually applied at subgrade/sub-base interfaces in temporary and permanent roads, between rail-road blast and foundation soil, and between embankment fill and soft foundation soil (Koerner, 2012). In addition, for most applications of geofoam and geocells, separation is the major function (Ziaie, 2011).

#### 3.2.2 Filtration of Water

The mismanagement of water on site is capable of causing extreme harm; erosion of soil in a particular area is one of the most harmful repercussions that carelessness could lead. It often results in the formation of irreparable gullies hence to help prevent that from happening, a geocomposite clay liner (GCL) is placed underneath all the hydraulic structures. This is a costly option therefore

to remain within budget, it is also suggested to use nonwoven geotextile (Sarsby, 2007), (Van, 1995).

### 3.2.3 Drainage Works

If water isn't contained properly on the sides of, say an embankment, an increase in the water table is observed that further brings pore pressure into the play. The increase in the pore pressure often requires a surplus amount of reinforcement of about 50%. To avoid this, geocomposite liner is installed usually at the back of the reinforced structure with a perforated pipe at the bottom to collect water. The pipe is then connected to the hydraulic structures (Sarsby, 2007)

### 3.2.4 Soil Reinforcement

#### 1) Basal reinforcement

Basal reinforcement is provided at the foundation level of the reinforced structure. A standard penetration test is conducted to assess the soil's bearing capacity. If the bearing capacity comes out between 10 and 60 Kpa, basal reinforcement is have provided in the form of Geogrid reinforcement, which is laid out to counter for the failure that could occurred due to the un-drained shear stress of the foundation (Akshay, 2000).

#### 2) Soil reinforcement

The technology of soil reinforcement, using geosynthetics, involves labor force to cut the geogrid to the required length, place it on site. Soil reinforcement is usually laid in one of the following scenarios: when either the soil bearing capacity is low or the layers are compressible; when in a landslide-prone zone; when there is excessive rutting and; when there are uneven settlements. It allows the steepening of the slope, enabling to maintain the construction within the boundaries, as well as saving on earthmoving and importing of soil. The geogrids used are high-tensile polyester, encased in a LLDPE (linear low-density polyethylene) coating to prevent installation damage acting as primary reinforcement. A secondary reinforcement in-between is given by a double-



twisted mesh. Where hydraulic structures were required, a gabion face is used, (Akshay, 2000), (Kumar, 2012).

### **3.2.5. Soil erosion control**

Usually, gabions, geotextiles and mattresses are used for erosion protection. Furthermore, geotextile filter and geotextile reinforcement ensure stability during saturation in the rainy season and sudden drawdown conditions. Nonwoven geotextiles act as filter separator, drains and reinforcements. An economical pre-formed unit made of double-twisted mesh to provide primary reinforcement is used for erosion control (Zornberg, 2006).

### **3.2.6 Containment**

Containment involves geomembranes, geosynthetic clay liners, or some geocomposites which function as liquid or gas barriers. Landfill liners and covers make critical use of these geosynthetics. All hydraulic applications (tunnels, dams, canals, surface impoundments, and floating covers) use these geosynthetics as well (Pilarczyk, 2000).

## **3.3 Advantages of Geosynthetics**

1. The manufactured quality control of geosynthetics in a controlled factory environment is a great advantage over outdoor soil and rock construction. Most factories are ISO 9000 certified and have their own in-house quality programs as well.
2. The low thickness of geosynthetics, as compared to their natural soil counterparts, is an advantage insofar as light weight on the subgrade, less airspace used, and avoidance of quarried sand, gravel, and clay soil materials.
3. The ease of geosynthetic installation is significant in comparison to thick soil layers (sands, gravels, or clays) requiring large earthmoving equipment.
4. Published standards (test methods, guides, and specifications) are well advanced in standards-setting organizations like ISO, ASTM, and GSI.

5. Design methods are currently available from many publication sources as well as universities which teach stand-alone courses in geosynthetics or have integrated geosynthetics in traditional geotechnical, geoenvironmental, and hydraulic engineering courses.

6. When comparing geosynthetic designs to alternative natural soil designs there are usually cost advantages and invariably sustainability (lower CO<sub>2</sub> footprint) advantages.

### 3.4 Disadvantages of Geosynthetics

1. Long-term performance of the particular formulated resin being used to make the geosynthetic must be assured by using proper additives including antioxidants, ultraviolet screeners, and fillers.

2. The exposed lifetime of geosynthetics, being polymeric, is less than unexposed as when they are soil backfilled.

3. Clogging or bioclogging of geotextiles, geonets, geopipe and/or geocomposites is a challenging design for certain soil types or unusual situations. For example, losses soils, fine cohesionless silts, highly turbid liquids, and microorganism laden liquids (farm runoff) are troublesome and generally require specialized testing evaluations.

4. Handling, storage, and installation must be assured by careful quality control and quality assurance.

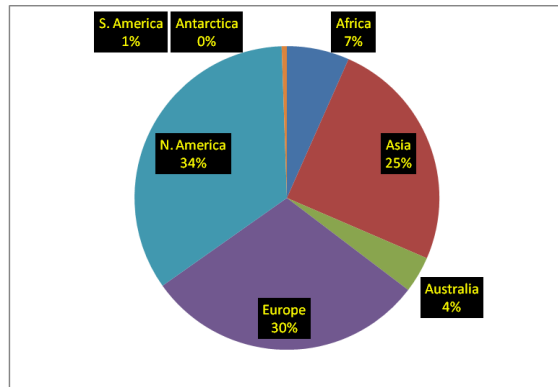
### 3.5 Analysis of Continental Distribution of Clients Involved in Geosynthetics Technology

Table 1 below shows summary of continental distribution of 181 Clients involved in the Geosynthetics technology.

From the Table 1 above North America has the highest No. of 62 Clients, followed by Europe and Asia as indicated. These three Continents accounted for 88% Contribution. Africa, Australia and South America could only account for the remaining 11%. One can understand the plight of Antarctica with no contribution. Graphically this is shown in Figure 9.

<b>Table 1: Continental Distribution of Geosynthetics Technology Clients, (CTC)</b>				
<b>S/N</b>	<b>Continent</b>	<b>No</b>	<b>%</b>	<b>Remarks</b>
1	Africa	12	<b>7</b>	Too poor
2	Asia	45	<b>25</b>	Good

3	Australia	7	<b>4</b>	Fair
4	Europe	54	<b>30</b>	Very Good
5	North America	62	<b>34</b>	Very Good
6	South America	1	<b>1</b>	Very Poor
7	Antarctica	0	0	No Data



**Figure 9: Percentage Continental Share of Geosynthetics Economy**

### 3.6 Africa and Global Usage in Geosynthetics Technology Economy and Implication for Nigeria

Officine Maccaferri S.P.A, Alessandro Maccaferri who has worked with hundreds of Clients in over 14 Countries, has presented a representative list of a few Alessandro Maccaferri equipment’s Clients and their Countries. Summary of this list shows that there are only 5 Clients in Nigeria out 36 States and

FCT. The 5 Clients only cover two States, Lagos and Kaduna and Abuja, the FCT. South Africa is the leading user of Geosynthetics in Africa, with most of the application focused in the mining sector. Nigeria therefore needs to also take the advantage of the technology for infrastructure developmental programmes like their counterparts in USA, China, South Africa and Germany.

Continent	Population (Billion)	GDP (\$Billions)	GDP/Population
Africa	1.288	2.19	1.700311
Asia	4.545	28.23	6.211221
Australia	0.041	1.58	38.53659

Europe	0.743	20.2	27.18708
N. America	0.588	22.29	37.90816
S. America	0.428	3.94	9.205607

Considering that only 7% was returned as the share of Africa in the global Geosynthetics usage, this is weighted with Africa's population, compared to other

Continents. Table 2 gives the Continental population as well as the Continental Gross Domestic Products, GDP to be variation of each of these parameters as shown.

The Continental population and Continental GDP are shown in Figures 10 and 11 respectively. Figure 10 indicates that Africa is the second largest Continent after Asia. Figure 11 shows that Africa is second to the last in GDP while Australia is the last, without consideration to Antarctica with zero GDP.

with zero  
Africa's 7%  
grossly not  
continent  
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programmes  
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Fig. 10 above  
times greater  
doing badly

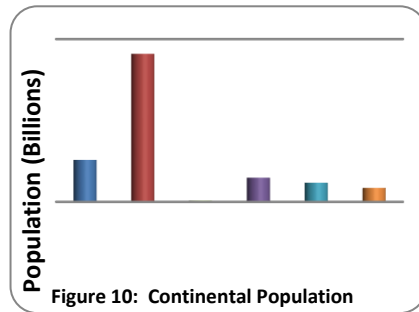


Figure 10: Continental Population

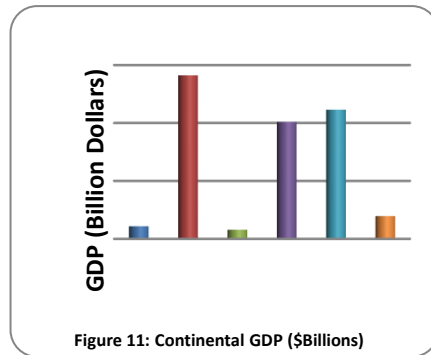


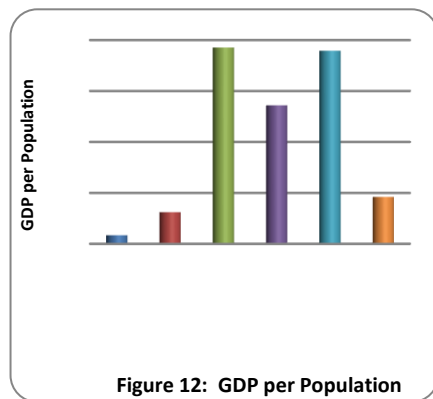
Figure 11: Continental GDP (\$Billions)

exposure level for Geosynthetics technology is commensurable to the population within the compared with shares from other parts.

therefore needs to also take the advantage of technology for infrastructure developmental like their counterparts in North America, Asia.

shows that, Population of Africa is like 3 than that of South America i.e Africa is not when compared to South America.

From Figure 12 below, Continental ratio of GDP and Population shows that Asia and Africa have the lowest involved in compared to Clients. Africa is 4.0



trend in the continental distribution of Clients the Geosynthetics Technology Economy that of percentage continental distribution of Comparing both of them together shows that lagging behind the other Continents.

## CONCLUSIONS AND RECOMMENDATIONS

### 4.1 Conclusion

This study has indicated that three of all the Continents, North America, Europe and Asia, alone accounted for 88% of global usage in geosynthetics technology economy. Africa, Australia and South America has a share of 12%. From Figure 10 above shows that, Population of Africa is like 3 times greater than that of South America, indicating that Africa is not doing badly when compared to South America.

From Table 2, Africa's population is about 31 times that of Australia. It further shows that Africa is still lagging behind. From Table 1 if Australia had 7 Geosynthetics Clients, Africa is expected to have 217 Geosynthetics Clients as against 12 presently recorded. This stresses that Africa's exposure level to geosynthetics technology of 7% only is grossly non-commensurable to the population on the Continent compared with the division of GDP and Population from other parts of the globe. The world experience shown that the special technological feature of Geosynthetics allows it to be used for multipurpose applications in the Geotechnicals and other infrastructure developmental projects as explained and highlighted in the result. There are also opportunities for new ventures on the platform applications and usage of the product of geosynthetics.

Nigeria's share of 5 out of 181 global Geosynthetics Clients indicates only 2.76% involvement. This indicates that Nigeria needs to rise up to tap opportunities that abound in this context to improve her infrastructure development rates.

### 4.2 Recommendations

It is recommended that more work should be carried out to unlock a strategy for tapping on both technology and business ventures that are to accompany the usage of Geosynthetics Technology in Nigeria. There may also be areas of synergising with other Countries that are already involved in the technology to further come up with research and business proposals to open up new areas on geosynthetics usage.

## REFERENCES

Akshay, Akshay, D.A. (2000). "Geosynthetics in Civil and Construction Works". Sixth ed., Vol. 1 and 2. Xlibris Corporation.

Barksdale R.D, S.F. Brown, F. Chan, (1989). Potential Benefits of Geosynthetics in Flexible Pavement Systems, National Cooperative Highway Resarche Program Report No. 315, Transportation Research Board, National Research Council, Washington DC, USA, 56p.

Bertacch Bertacchi, P. and Cazzuffi, D. (1985) Geotextile filters for embankment dams, Water bituminous concrete waterproofing systems in earth structures.

Button J.W, R.L. Lytton, (2003). Guidelines for Using Geosynthetics with HMA Overlays to Reduce Reflective Cracking, Report 1777-P2, Project Number 0-1777, Texas Department of Transportation, Austin, TX.

Cancelli, A. and Cazzuffi, D, (2006). Environmental aspects of geosynthetics applications incase Histories, ISSMFE-TC 9, BiTech Publishers, Richmond, BC, 10-11.

Choudhary A.K, Gill K.S. and Jha J.N, (2011). "Improvement in CBR values of expansive soil subgrades using geo-synthetics" IGC J-233.

Christopher B.R, (2014, September 21-25). Cost savings by using geosynthetics in the construction of civil works projects, Proceedings of the 10th International Conference on Geosynthetics, 10ICG, Berlin, Germany, (CD-ROM).

Construction Review Online, (2018, October 29). How Geosynthetics add value to infrastructure in Africa. Retrieved from <https://constructionreviewonline.com/2017/3/geosynthetics-add-value/>

Correia N.S., J. G. Zornberg, (2015). Mechanical response of flexible pavements enhanced with geogrid-reinforced asphalt overlays, *Geosynthetics International*. 23(3):183-193.

Giroud J.P, J. Han, (2004). Design method for Geogrid reinforced unpaved roads, I.Development of design method & II. Calibration and applications. *Journal of Geotechnical and Geoenvironmental Engineering*. Aug;130(8):775-797.

Holtz R.D, B.R. Christopher, R.R. Berg, (1997). *Geosynthetic Engineering*, Bitech Publishers Ltd., Richmond, British Columbia, Canada, pp. 452.

Jewell, R. A. (1996). *Soil Reinforcement With Geotextiles*, CIRIA Publishers, London, England.

Koerner R. M, (2012). *Designing with Geosynthetics*, sixth ed., Vol. 1 and 2.Xlibris Corporation.

*Koerner, R. M.(2012). Designing With Geosynthetics (6th ed.). Xlibris Publishing Co., 914 pgs.*

Koerner, R. M. (2012). *Designing With Geosynthetics* (6th ed.). Xlibris Publishing Co., 914 pgs.

Kumar P.Senthil, R.Rajkumar, (2012). “Effect of Geotextile on CBR Strength of Unpaved Road with Soft Subgrade”,*EGJE* Vol. 17,

Bund. J. Montestruque G, (2002). Contribution to the Development of a design method to retrofit pavements using geosynthetics in anti-reflexion cracks. Ph. D. Dissertation, Aeronautic Institute, Brazil.

*Müller, W. W.; Saathoff, F. (2015). "Geosyntheticsingenvironmentalengineering". ScienceandTechnologyofAdvancedMaterials. 16 (3): 034605.*

Oginni F.A, (2014). “Continental Application of Foamed Concrete Technology: Lesson for Infrastructural Development in Africa”.*British Journal of Applied Science & Technology*. 5(4): 417-424, 20155, Article no BJASt.2015.040, SCIENCEDOMAIN International, www.sciencedomain .org.

Perkins S.W, B.R. Christopher, N. Thom, G. Montestruque, L. Korkiala-Tanttu, A. Want, (2010). Geosynthetics in pavement reinforcement applications, *Proceedings of 9th International Conference on Geosynthetics*, Vol. 1, Guaruja, Brazil, 2010, pp. 165-192.

Pilarczyk, K. W. (2000). *Geosynthetics and Geosystems in Hydraulic and Coastal Engineering*, A. A. Balkema Publ., Rotterdam, The Netherlands.

Rowe, R. K. (Ed.), (2001). *Geotechnical and Geoenvironmental Engineering Handbook*, Kluwer Academic Publishers, Boston, US.

Sarika B. Dhule and S.S.Valunjkar, (2011). “Improvement of flexible pavement with use of geo-grid” *EJGE* Vol.16.

Sarsby, R. W. Ed. (2007). *Geosynthetics in Civil Engineering*, Woodhead Publishing Ltd., Cambridge, England.

Thompson J. G, (2010). Guide for the Application and Selection of Geotextiles, Document 0-5812-P1, Center for Transportation Research (CTR), Austin, Texas, 16 p.

Ullagaddi P.B, Nagara T.K., (2013). “Investigation on geosynthetic reinforced two layered soil system “, Missouri University of Science and Technology.

Vaishali S. Gor, L. S. Thakur, Dr. K.R. Biyani, (2013). ”study the typical characteristic of expansive soil with geotextile and cushion materials”, Missouri University of Science and Technology.

Van Santvoort, G. P. T. M., Translator (1995). *Geosynthetics in Civil Engineering*, A. A. Balkema Publ., Rotterdam, The Netherlands.



Zanten, R. V. (1986). *Geotextiles and Geomembranes in Civil Engineering*, A. A. Balkema Publ., Rotterdam, The Netherlands.

Ziaie M. R and M. Nazari, (2011). "Effect of Utilization of Geosynthetic of Reducing the Required Thickness Subbase Layer of a Two Layered Soil", World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:5, No:1.

Zornberg J. G, B. R. Christopher, (2006). Chapter 37: Geosynthetics, In *The Handbook of Groundwater Engineering*, second ed., Jacques W. Delleur, CRC Press, Boca Raton, FL.

Zornberg, J.G. (2013). "The International Geosynthetics Society (IGS): No Borders for the Good Use of Geosynthetics." 25-Year Retrospectives on the Geosynthetic Industry and Glimpses Into the Future, Twenty-fifth Geosynthetic Research Institute Conference (GRI-25), April 01-02, Long Beach, California, pp. 342-357

## **AN IMPROVED MATHEMATICAL MODEL FOR ECOLOGICAL SURVEILLANCE OF PREY-PREDATOR.**

Omotosho, L.O.<sup>1</sup>; Olayiwola, M.O.<sup>2</sup> and Olaleye, V.O.<sup>1\*</sup>

<sup>1</sup>Department of Information and Communication Technology, Osun State University, Osogbo, Nigeria.

<sup>2</sup>Department of Mathematical Sciences, Osun State University, Osogbo, Nigeria.

\*Email of corresponding author: olaleyeseyivictor@gmail.com

### **ABSTRACT**

The Lotka-Volterra equations were developed to describe the dynamics of biological systems, one specie is the prey and the other predator, the most significant problem of the equations as a biological model is the ability of a prey population to “bounce back” even when subjected to extremely low population numbers, being a system of first order non-linear differential equations, its solution to this model has periodic meaning that the cycle will continue ad infinitum with the rise and fall of both populations.. The aim of this research work is to design and simulate a computational ecological surveillance system, with specific objective to provide an improved numerical solution of the ecological Lotka-Volterra predation model, by applying the mathematical Eigen-value and vector method to simplify the understudy model into linear equations. Results of the numerical solutions are presented to show the operational behaviour of the model and was also favourable with other existing models. It is known that prey-predator activities are arguably building blocks of the bio and ecosystems as biomasses are grown out of their resource masses. Species contend, evolve and disperse merely for the aim of seeking resources to sustain their struggle for survival. To further this research, the ecological surveillance simulation is implemented in Java to show visual interactions between predator and preys.

**Keywords:** Predation, mathematical modelling, ecology, population.

## INTRODUCTION

Ecology is the study of the relationships between organisms and their environment. The concept of environment includes other organisms and physical surroundings. It involves relationships between people within a population and between people of various populations. These interactions between individuals, between populations, and between organisms and their environment form ecological systems, or ecosystems. Ecology has been outlined variously as “the study of the interrelationships of organisms with their surroundings and each other,” as “the economy of nature,” and as “the biology of ecosystems.” (Robert & Stuart, 2019).

Roth (2016) says that all animals are either predators or prey and in most cases, are both; also such interactions involved in attempting to eat and avoid being eaten have strong and wide-reaching influences across all facets of ecology, from behavioural, population, and community interactions to how we attempt to manage and conserve the natural world.

To study the association or interaction in predation, various predator-prey models exist to describe the association between various preys and predators, one of such is the fundamental ecological model called Lotka-Volterra (by Alfred Lotka and Vitto Volterra) predator model. This model primarily focuses on a predator to a prey and was described by Vitto in the mid 1920s from studying the increase and fall of sea fishing fleets. When fishing was smart, the number of fishermen increased, drawn by the success of others. After a time, the fish declined, perhaps due to over-harvest, and then the number of fishermen also declined. After some time, the cycle repeated.

In 2017, Biazar and Montazeri observed biological environment consisting of rabbits and foxes living together. Foxes eat the rabbits and rabbits eat clover. Suppose that there are enough clovers and the rabbits have enough food to eat. When there are a lot of rabbits, the foxes also grow and their population increase. When the number of foxes increases and they eat a lot of rabbits, they enter into a short period of food and their number decrease. As the range of the foxes decreases, the rabbits will be safe and their population increase. When the number of rabbits increases the number of foxes would increase and bypassing the time we can see infinite repeatability of increase and decrease in the population of these two kinds of animals(Biazar & Montazeri, 2017).This illustration shows that the prey and predator evolve together. The prey is a component of the

predator's setting, and the predator dies if it does not get food, so it evolves whatever is necessary in order to eat the prey: speed, stealth, camouflage (to hide while approaching the prey), a good sense of smell, sight, or hearing (to find the prey). Likewise, the predator is a component of the prey's setting, and the prey dies if it is eaten by the predator, so it evolves whatever is necessary to avoid being eaten: speed, camouflage (to hide from the predator), a good sense of smell, sight, or hearing (to detect the predator), thorns, poison (to spray when approached or bitten), etc. (Taleb, 2016).

Adding to the present state of knowledge, the fundamental model is then subjected to proper research findings, in attempt to alleviate significant problem of the model which is the ability of the preys population to bounce back, even at extreme low population. Solving the above, this research focused on applying a method to reduce the equations from first-order differential equation to linear equations.

### **Lotka-Volterra Predation Model**

Lotka-Volterra equations is a representation that models the population of two species. One species is a predator (an organism that eats another organism) and the other is the prey (the organism which the predator eats). The Lotka-Volterra equations is one of the oldest predator-prey models. It was proposed by the biophysicist Alfred Lotka in 1910 to model chemical reactions, and was modified by the Mathematician Vito Volterra in 1925 when he was attempting to explain the oscillating fish populations, he discovered in the Mediterranean. However, the Lotka-Volterra equations can be applied to many other species as well. The Hudson Bay Company (a famous Canadian fur trading company) for example observed a similar oscillatory behaviour in the populations of the predatory lynx and its prey, the hare, back in 1840. (Anderson & Blake, 2012).

The Lotka-Volterra Equations is a system of first-order, nonlinear ODEs. The simplest form of the system is the following model:

$$\frac{du}{d\tau} = c_1u - a_{12}uv \dots\dots\dots (1)$$

$$\frac{dv}{d\tau} = -c_2v + a_{21}uv \dots\dots (2)$$

In these equations  $u$  and  $v$  represents prey and predator populations,  $c_1$  is the specific rate of prey population growth in predator's absence (i.e the reproduction rate of the prey),  $a_{12}$  a constant, characterizing the rate of predators' consumption of prey species (death rate of the prey due to the presence of the predator. The greater  $a_{12}$  is, the greater the death rate of the prey is due to predation and the more effective the predator is killing the prey),  $c_2$  is the specific rate of predator's mortality (death rate of the predator. The greater  $c_2$  is, the greater the death rate of the predator is.),  $a_{21}$  is a constant that characterizes the rate of multiplied number of predators because of preys' death (reproduction rate of the predator). The greater  $a_{21}$  is, the more rapidly the predator reproduces and the more effectively the prey is able to nourish the predator.

Lotka-Volterra predation equation is based on the following assumptions:

Predator can eat limitless;

Supply of food resource (i.e. prey) depends on the prey population size;

The rate of change of population directly depends on its size;

Environment is constant, inconsequential genetic adaptations for both species;

All time unlimited food supply for the prey.

The equation is continuous and the cycle will continue endlessly with the rise and fall of both populations.

### **NUMERICAL SOLUTION**

The Lotka-Volterra Equations is a system of first-order, nonlinear ordinary differential equations (ODE). The fundamental ecological model is shown in equations (3) and (4) representing prey and predator respectively. Equations (3) and (4) are then solved by applying Eigen-value and Eigen-vector to provide new prey and predator equations (i.e equation 16 & 17).

$$\frac{du}{dt} = c_1u - a_{12}uv \quad . . . \quad (3)$$

$$\frac{dv}{dt} = -c_2v + a_{21}uv \quad . . . \quad (4)$$

$$u' = c_1u - a_{12}uv$$

$$v' = -c_2v + a_{21}uv$$

Let the co-efficient matrix be represented as

$$x' = \begin{pmatrix} c_1 & -a_{12} \\ -c_2 & a_{21} \end{pmatrix} x \dots (5)$$

We find the eigenvalues:

$$\begin{vmatrix} c_1 - \lambda & -a_{12} \\ -c_2 & a_{21} - \lambda \end{vmatrix} = 0$$

Therefore,

$$\lambda^2 - (c_1 + a_{21})\lambda + (c_1a_{21} - c_2a_{12}) = 0 \dots (6)$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Solving equation (6) quadratically with respect to  $\lambda$ , where

$$a = 1; \quad b = -(c_1 + a_{21}); \quad c = (c_1a_{21} - c_2a_{12})$$

Then,

$$\lambda = \frac{1}{2} [c_1 + a_{21} \pm \sqrt{c_1^2 + 2c_1a_{21} + a_{21}^2 - 4c_1a_{21} + 4c_2a_{12}}] \quad (7)$$

$$\text{let } L = \sqrt{c_1^2 + a_{21}^2 - 2c_1a_{21} + 4c_2a_{12}} \dots (8)$$

Then

$$\lambda = \frac{1}{2} [c_1 + a_{21} \pm L] \dots (9)$$

$$\lambda_1 = \frac{1}{2} [c_1 + a_{21} + L], \quad \lambda_2 = \frac{1}{2} [c_1 + a_{21} - L] \dots (10)$$

To find the eigenvector corresponding to  $\lambda_1$ , we solve:

$$\text{Let } \begin{vmatrix} c_1 - \lambda_1 & -a_{12} \\ -c_2 & a_{21} - \lambda_1 \end{vmatrix} \begin{vmatrix} k_1 \\ k_2 \end{vmatrix} = 0 \dots (11)$$

$$\text{i.e. } (c_1 - \lambda_1)k_1 - a_{12}k_2 = 0 \dots (12)$$

$$-c_2k_1 + (a_{21} - \lambda_1)k_2 = 0 \quad \dots \quad (13)$$

Solving equation (12) & (13) simultaneously to obtain  $k_1$  &  $k_2$

$$k_1 = a_{12}, k_2 = c_1 - \lambda_1$$

or

$$k_1 = a_{21} - \lambda_1, k_2 = c_2$$

Similarly the eigenvector corresponding to  $\lambda_2$  can easily be obtained:

$$\begin{vmatrix} c_1 - \lambda_2 & -a_{12} \\ -c_2 & a_{21} - \lambda_2 \end{vmatrix} \begin{vmatrix} k_1 \\ k_2 \end{vmatrix} = 0 \quad \dots \quad (14)$$

$$k_1^* = a_{12}, k_2^* = c_1 - \lambda_2$$

$$k_1^* = a_{21} - \lambda_2, k_2^* = c_2$$

$$x = \begin{bmatrix} u \\ v \end{bmatrix} = d_1 \begin{bmatrix} k_1 \\ k_2 \end{bmatrix} e^{\lambda_1 t} + d_2 \begin{bmatrix} k_1^* \\ k_2^* \end{bmatrix} e^{\lambda_2 t} \quad \dots \quad (15)$$

From the value of x above, the new equation is formulated thus:

$$u = d_1 k_1 e^{\lambda_1 t} + d_2 k_1^* e^{\lambda_2 t} \quad \dots \quad (16)$$

$$v = d_1 k_2 e^{\lambda_1 t} + d_2 k_2^* e^{\lambda_2 t} \quad \dots \quad (17)$$

Condition for the existence of Solution

Recall that,

$$L = \sqrt{c_1^2 + a_{21}^2 - 2c_1 a_{21} + 4c_2 a_{12}}$$

Hence,

$$L^2 = c_1^2 + a_{21}^2 + 4c_2 a_{12} - 2c_1 a_{21} \quad \dots \quad (18)$$

For L to be a real number, then

$$c_1^2 + a_{21}^2 + 4c_2a_{12} > 2c_1a_{21} \quad \dots \quad (19)$$

The inputs of the formulated model is summarized below, where:

$d_1$  &  $d_2$  are positive arbitrary constants;

$$k_1 = (a_{21} - \lambda_1) \text{ or } a_{12} \quad \dots \quad (20)$$

$$k_1^* = (a_{21} - \lambda_2) \text{ or } a_{12} \quad \dots \quad (21)$$

$$k_2 = (c_1 - \lambda_1) \text{ or } c_2; \dots \quad (22)$$

$$k_2^* = (c_1 - \lambda_2) \text{ or } c_2; \dots \quad (23)$$

$$\lambda_1 = \frac{1}{2}[c_1 + a_{21} + L] \quad \dots \quad (24)$$

$$\lambda_2 = \frac{1}{2}[c_1 + a_{21} - L] \quad \dots \quad (25)$$

$$L = \sqrt{c_1^2 + a_{21}^2 - 2c_1a_{21} + 4c_2a_{12}} \quad \dots \quad (26)$$

t = time interval

### Model Tested

All variables of the formulated equations are derived from the inputs of the Lotka-volterra equations such as  $c_1$ ,  $c_2$ ,  $a_{21}$ ,  $a_{12}$ . Several replications or runs of the newly formulated model were done in Microsoft Excel worksheet to show graphical representation using some tested parameters, all these are represented in tables and figures. Figure 1 shows the result gotten in graph of prey and predator with input given as:

$$c_1= 0.2, c_2= 0.5, a_{21}= 0.5, a_{12}= 0.2, t = 20 \text{ units}$$



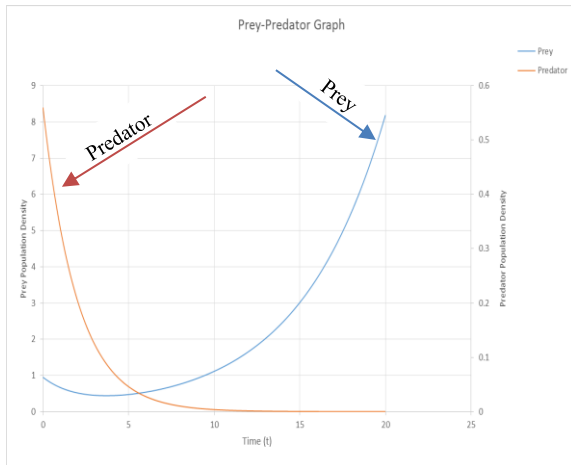


Figure 1 Prey-Predator Graphical Representation

Figure 1 illustrates the prey- predator relationship. The prey population density and predator population density are on left and right y-axis of the graph respectively and are both plotted against time on the x-axis. The graph shows the onset of the animal community, the predator-population is greatly increased against the prey-population and gradually declines as a result of insufficient food (i.e very low amount of starting prey population) which could cause death as a result of starvation, migration, chemical or biological/man control and ageing. The prey-population in turn increases gradually in response to the decrease in the predator-population and reaches its peak population as the predator population declines to zero and finds it impossible to bounce back in respect to a natural phenomenon.

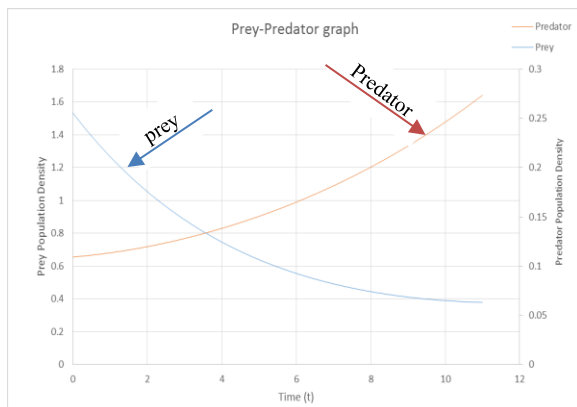


Figure 2 Prey-Predator Graphical Representation

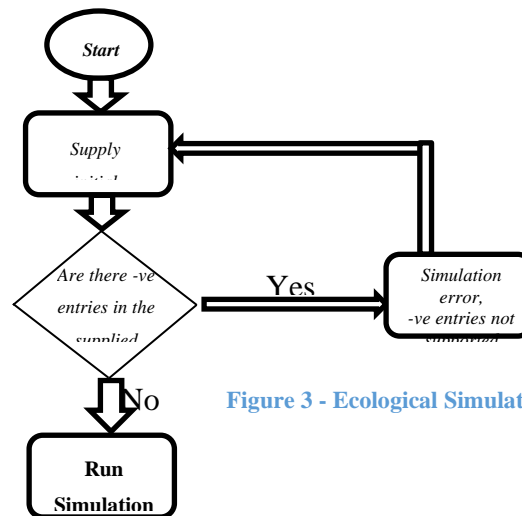


Figure 3 - Ecological Simulator Design

The graphical illustration in *Figure 2* (inputs values are  $c_1 = 0.0001$ ,  $c_2 = 0.98$ ,  $a_{21} = 0.098$ ,  $a_{12} = 0.023$ ,  $t = 11$  units) illustrates the natural phenomenon of prey-predator relationship. The influx and increase in predator population is either by migration or rapid reproduction in a prey-community pose a great threat to the prey-population.

The predator overpowers and feed on the preys which lead to a decrease in population through death. Some preys in a bid to escape the ferocious appetite of the predators relocate to safe their heads and this causes a gradual decline in prey-population. Therefore, as the predator population increases, the prey population does otherwise.

### **SYSTEM METHODOLOGY**

After an effective and efficient design of the prey-predator system as shown in *figure 3* represents appropriate experimental design and condition for simulation runs (i.e. the surveillance system is designed such that it will only take positive inputs for a successful run, this is considered because negative population number never exits), while *figure 4* shows the general activity diagram of life cycle of an animal. This will in turn lead to the production of system specification otherwise regarded as the system documentation which consists of logical steps to be taken for the actualization of the proposed system. The program written is object oriented based which immensely contributing to the attainment of the desired result design. The desired integrated development environment for the ecological surveillance will be implemented in the Netbeans (a popular IDE for Java).

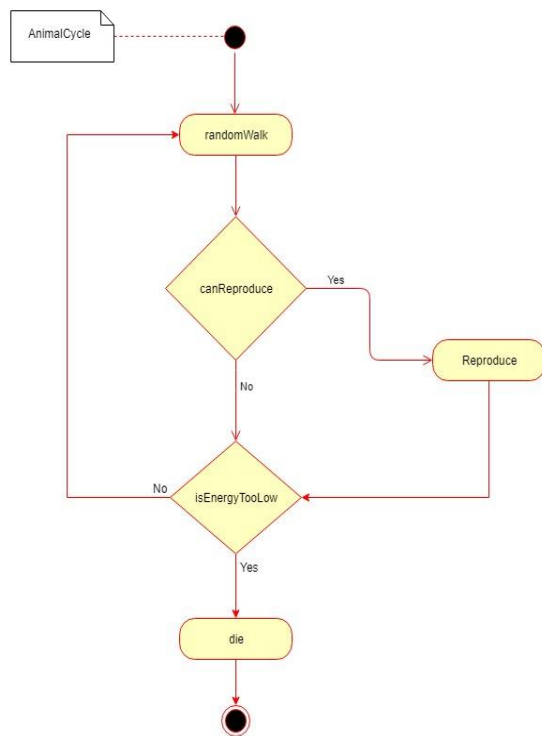


Figure Error! Use the Home tab to apply 0 to the text that you want to appear here.4 Typical design animal life-cycle

## RESULTS AND DISCUSSIONS

The first run presents simulation with an initial prey population of fifty (50) and zero (0) predator population. [Prey = 50, Predator = 0]

The first simulation run (*Figure 5*) in Java after setting up the environment, simulates a prey population in a predator free habitat (i.e preys = 50, Predator = 0). The preys without disturbance feed freely, reproduce and increase rapidly in number while a few die due to natural phenomenon (sickness, ageing) only.

The second simulation run in *figure 6* introduces an initial population 10 predators (predators are represented in red colour) in an environment consisting of population of 200 preys (preys are represented in green colour). The assumptions follow the Lotka-Volterra predation model that the predators feed limitless and feed only on one kind of prey. This introduction ten predators causes a stir in the prey habitat as the predators competes with the prey and hunts the prey for food. This

causes a significant drop in the prey population due to increase in preys' mortality. On the other hand, the predator population increases rapidly to pose more threat to the prey population.

### Ecological Surveillance: Simulation 1

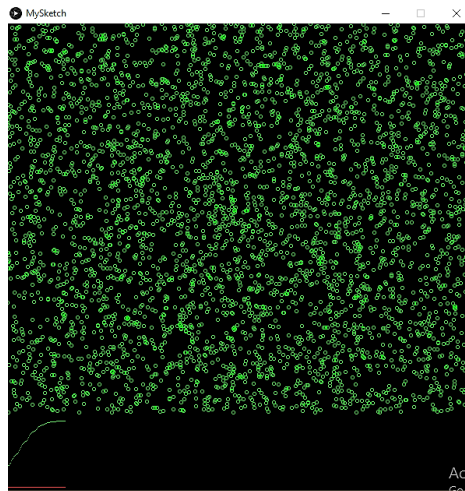


Figure 5. Simulation 1: Prey (50), Predator (0)  
Key: Prey (green); Predator (red)

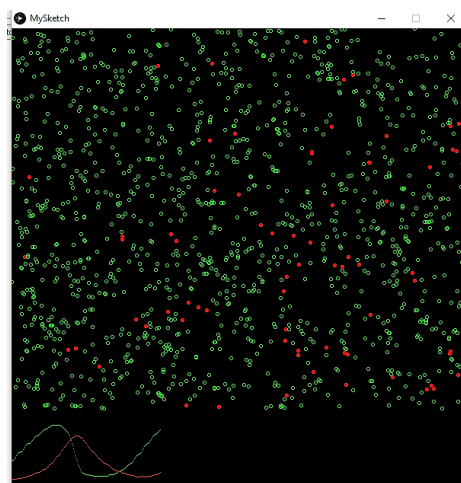


Figure.6 Simulation 2: Prey (200), Predator(10)  
Key: Prey(green); Predator(red)

At this point, the prey population decreases while the predator population increases, and the cycle continues until the ecological surveillance eventually terminates the system at the point when the

available predators pose great effect on the prey population (i.e. when prey population is likely to go into extinction), and suggests that some predator control techniques should be applied to avoid the extinction of the animal (prey).

## **CONCLUSION**

This paper presents a predator-prey model considering two species (one specie prey, the other predator). It is known that the most significant problem of the Lotka-Volterra equations as a biological model is the ability of a prey population to “bounce back” even when subjected to extremely low population numbers, being a system of first order non-linear differential equations.

Subsequent to the fundamental biological model, equations 16 & 17 in the numerical solution are the newly formulated equations which represent the prey and predator equation respectively, of which has been reformed from first order differential equations to linear equations.

From the results presented in figures 1 and 2, it is noteworthy to see that there is no likelihood that neither the predator population nor preys’ would bounce back, as the underlying equations has been resolved to linear equation, a reason for the simplicity of model’s operational behaviour. Hence, the following modelling summary was drafted for the newly formulated equations: an increase in prey population would result to an increase in predator population, an increase in predator population implies decrease in prey population, a decrease in prey population implies decrease in predator population, and finally a decrease in predator population implies increase in prey population. The total population depends on species’ mobility both of predators and preys.

This research is open to further work by looking into the proper implementation of an ecological monitoring device which may be helpful in farms to monitor infiltration of predators on crops, which in return will lead to an increase in yield of crops.

## **REFERENCES**

Anderson, W., & Blake, P. (2012). Math Modeling for Undergraduates, Unpublished B.Sc. Thesis, Department of Mathematics, Faculty of the Worcester Polytechnic Institute, Worcester, MA.

- Biazar, J., & Montazeri, R. (2017). A computational method for solution of the prey and predator problem. (S. Direct, Ed.) Applied Mathematics and Computation, 163, 841-847.
- Eugeny, P. K., Mariia, V. S., & Inna, S. F. (2016). A Predator-Prey Mathematical Model in a Limited. Global Journal of Pure and Applied Mathematics., 12, 4443-4453. Retrieved from <http://www.ripublication.com/gjpam.html>
- Robert, L. S., & Stuart, L. P. (2019). Ecology. Retrieved from Encyclopedia Britannica: <https://www.britannica.com/science/ecology#ref48753>
- Roth, T. C. (2016). Predator-Prey Interactions. Retrieved from Oxford Bibliographies: <http://www.oxfordbibliographies.com/view/document/obo-9780199830060/obo-9780199830060-0100.xml>
- Taleb, A. S. (2016). Ordinary Differential Equations. (ResearchGate, Ed.) Basrah Journal of Science, 31, 103-109. Retrieved from <https://www.researchgate.net/publication/308633701>

## **PURIFICATION AND PHYSICO-CHEMICAL ANALYSIS OF CRUDE GLYCERIN PRODUCED BY TRANSESTERIFICATION PROCESS.**

Aworanti, O.A., \*Agbede, O.O., Ogunleye, O.O., Agarry, S.E., Babatunde, K.A. and Akinwumi O.D.

Department of Chemical Engineering, Ladoke Akintola University of Technology,

P. M. B. 4000, Ogbomoso, Nigeria.

\* E-mail of Corresponding Author: ooagbede@lautech.edu.ng

### **ABSTRACT**

Glycerol is a clear, odourless and viscous liquid derived from both natural and petrochemical feed stocks. The adsorption process combined with neutralization and distillation processes to remove free fatty acid, soaps and excess methanol removal were studied. The crude glycerin was produced as a byproduct of the transesterification of oil with methanol using potassium hydroxide as the homogeneous catalyst. The crude glycerin was separated from biodiesel after 24 hours and then purified. The purification process of the crude glycerin undergoes three stages that involved neutralization, distillation and adsorption processes. The neutralization process was carried out by titrating phosphoric acid against the glycerin, while the distillation process was carried out by heating the glycerin to a temperature of 90 °C for 1 hour and the methanol was condensed and collected. The adsorption process was carried out for 48 hours to remove the odour and colour using activated parkia-biglobosa-sawdust derived carbon. The physicochemical properties of the crude and pure glycerol were determined using international standard for glycerin specifications. The volume yield of crude and pure glycerin were 114.1 ml and 82 ml, respectively. The physicochemical analysis indicated that purified glycerin had a molecular weight of 92.03 kg, boiling point of 290 °C, vapor pressure of 0.00249 mm, moisture content of 0.3, viscosity of 1478 Cp, density of 4.234 g/cm<sup>3</sup>, free fatty acid of 0%, pH of 6.3, flash point of 182 °C, and all these values were in the acceptable ranges according to international standard for glycerin specifications.

**Keywords:** Glycerin, Adsorption, Activated carbon, Neutralization and Distillation

## **INTRODUCTION**

Glycerol is widely used in many industries ranging from pharmaceutical, cosmetics and food industries (Ardi *et al.*, 2015 and Thompson *et al.*, 2006). Glycerol is also used to manufacture mono-di-glycerides that are used as emulsifiers as well as polyglycerol esters used in production of margarine (Ash *et al.*, 2004 and Ooi *et al.*, 1993). This clear, odorless, viscous liquid with naturally sweet taste is derived from both natural and petrochemical feed stock (Morrison *et al.*, 2001). The crude glycerol (glycerin) is a by-product of biodiesel production, it contains impurities such as excess catalyst, soap, methanol, free fatty acid, organic non-glycerol matter and water. It requires purification in order to be used as a raw material in the industries (Pachauri *et al.*, 2006). Purification process is required to transform it to the valuable product. The technology developed for purification of crude glycerol (glycerin) – derived from biodiesel – is mainly adapted from existing soap making industry, that utilizes various techniques such as convectional technique, chemical treatment, crystallization, microfiltration, ultrafiltration using organic polymer membrane treatment with ion exchange resin, adsorption process, electrolysis and vacuum distillation ( Yong *et al.*, 2001; Carmona *et al.*, 2009; Asher *et al.*, 1956; Shibasaki-Kitakawa *et al.*, 2013; Ardi *et al.*, 2015 and Authanit *et al.*, 2013). As a rule of thumb, a general purification of glycerin processes comprise of three steps (Ziels, 1956). The first step involves the removal of non-glycerin substances which can be achieved through precipitations during neutralization, whereby free fatty acids and some salts are removed. The next step which known as convectional process, is to concentrate the solution by evaporation in which alcohol is removed from the crude glycerol (glycerin). However, the convectional process for the purification of crude glycerol (glycerin) is energy intensive, complex and expensive (Van-Gerpen *et al.*, 2004). The final step is the purification and refining step which can be achieved to the desired degree with a combination of these methods which are vacuum distillation, ion exchange, membrane separation and adsorption. The classical ion-exchange method is uneconomical because the salt content of crude glycerol (glycerin) produced from biodiesel production is high which leads to high cost of chemical regeneration of resins (Van-Gerpen *et al.*, 2004).

The above problems prompted us to search out for other methods to purify crude glycerol (glycerin). Adsorption process with combination of neutralization and distillation process is a well-



known method which can be used for smaller batches, it increases the percentage purification to 99.5%, and also the cost of the process is low and is not time consuming (Ardi *et al.*, 2015; Yong *et al.*, 2001 and Authanit *et al.*, 2013). Adsorption process can also remove the acid salts and micro size particles in the crude glycerol (glycerin) (Ardi *et al.*, 2015). In this study, adsorption process with combination of both neutralization and distillation processes was applied in the purification of crude glycerol (glycerin) obtained from biodiesel production using homogeneous catalyst.

## **MATERIALS AND METHODS**

### **Materials**

Soybean oil was purchased from a local market in Ogbomosho. Methanol and potassium oxide were obtained from a chemical store in Ibadan, both in Oyo state, Nigeria. *Parkia biglobosa* (Locust bean) tree wood was obtained from a local farm in Ogbomosho, Nigeria. A round bottom - flask was used as a reactor and magnetic stirrer (with hot plate) was used as a stirring and heating medium. 100 ml burette, condenser, 250 ml conical flask, heating mantle and thermometer were other materials used in this experiment.

### **Methods**

#### **Preparation of Activated Carbon from *parkia biglobosa* Tree Wood Sawdust**

The activated carbon was prepared according to the method of Aworanti *et al.* (2017). Sawdust was obtained from *Parkia biglobosa* tree wood and then sorted out as to remove unwanted particles. The *Parkia biglobosa* sawdust (PBS) was severally washed with distilled water to remove impurities. The washed sawdust was then dried at 105°C for 24 h in an oven dryer. About 200 g of the dried sawdust (which is the precursor for the activated carbon to be produced) was then immersed in 200 ml of 0.2 M phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) solution and thoroughly stirred to ensure good mixing with acid. The mixture was left for 24 h and then kept on water bath for 30 min at 70°C, after which it was allowed to cool and then neutralized with 500 ml of 1M sodium hydroxide (NaOH) solution. The mixture was then washed several times with double-distilled water until the washing solution pH became neutral. After this, the chemically treated sawdust was dried in an oven at 105°C for 4 – 5 h. The activated sawdust was then pyrolysed in a furnace in the presence of steam flow. A two-step procedure was carried out. Sample was carbonized at 500°C

for 3 h and then followed by a physical activation. Steam generated from double-distilled water using a steam generator was allowed to flow through a glass tube (introduced into the furnace through the inspection hole in the furnace door) into the furnace at a rate of 3 cm<sup>3</sup>/min for 3 h. The resulting PBS-derived acid-steam activated carbons were ground in a mill and finally sieved in the particle size range of 0.15 – 0.42 mm.

### **Transesterification of Soybean Oil**

The transesterification reaction for the production of biodiesel from soybean oil was carried out in accordance with the procedure of Aworanti *et al.* (2019). 240 ml of methanol and 9 % of catalyst were weighed and mixed vigorously with magnetic stirrer in order for the catalyst to be dissolved and form potassium methoxide solution. 900 ml of soybean oil was weighed into a round bottom flask and heated to 60°C, then the potassium methoxide solution was poured gently into the heated waste frying oil. The entire mixture was stirred with hot plate magnetic stirrer at 300 rpm and the temperature was maintained at 60°C. After the process, the mixture was poured into a separating funnel and kept for 24 hours so as to separate the glycerin from the biodiesel. The separation segments were as follow; crude glycerol (glycerin) layer at the bottom and biodiesel layer at the top. Thereafter, the physicochemical properties of glycerin derived from the transesterification of soybean oil was determined and compared with EN 14214.

### **Neutralization Process**

The neutralization process was used to remove soaps and excess catalyst in the crude glycerol (glycerin) and this is done according to the method of Isahak *et al.* (2016) and Ardi *et al.* (2015). According to the method 13.5 ml of phosphoric acid was titrate against 114.1 ml crude glycerol. The reaction of phosphoric acid with soaps in the glycerol gives free fatty acid and its reaction with homogeneous catalyst produces inorganic salts, water and other fatty acid salts. The three layers were formed during the reaction, the insoluble free fatty acid and some salts formed the top layer, neutralized glycerol and methanol formed the middle layer while inorganic salts formed the bottom layer. The insoluble free fatty acid and some salts at the top layer of the reaction were skimmed off.

### **Precipitation Process**

Precipitation process was used to remove the solubilized inorganic salts from the pre-purified crude glycerol (glycerin) and this is done according to the method of Isahak *et al.* (2015). According to the method lime ( $\text{Ca}(\text{OH})_2$ ) and phosphoric acid were added to the pre-purified glycerol and this reaction forms calcium apatite ( $\text{Ca}_5(\text{PO}_4)_3(\text{OH})$ ). This chemical reaction removed the solubilized inorganic salts (Chuang-Wei *et al.*, 2006). Removal of calcium apatite was by centrifugation which removed all the inorganic salts in the pre-purified glycerol. The process was driven by calcium ion and hydroxide-ion attraction.

### **Distillation Process**

Distillation process was used to remove the excess methanol in the pre-purified crude glycerol (glycerin) and this is done according to the procedure of Yong *et al.* (2001). A distillation column which consisted of condenser, 250 ml conical flask, heating mantle and thermometer was used for the distillation process. The 114.1 ml of crude glycerin was weighed into a 250 ml conical flask and heated up to a temperature of  $90^\circ\text{C}$  for 1 hour with a heating mantle, the excess methanol in the crude oil was condensed in a condenser and collected.

### **Adsorption Process**

The adsorption process was used to remove the colour, odour, some fatty acids and other components from the pre-purified crude glycerol (glycerin). Adsorption column which was made of 100 ml burette containing 10 g of activated carbon powder of 0.15 mm particle size was set up and the glycerin was introduced into the adsorption column, pure glycerol was produced after 48 hours.

### **Result and Discussion**

#### **Characterization of Crude Glycerin and Purified Glycerol and the Comparison with a Commercially Refined Glycerol**

The results of characterization test done on both crude glycerol (glycerin) and purified glycerol as well as the properties of refined glycerol are presented in Table 1. The test results of purified glycerol fall within the specification range of the ASTM D-1093-98 standard. The pH value of crude glycerol (glycerin) and purified glycerol were 11.120 and 6.740 respectively, this is similar to the pH value of refined glycerol. It could also be observed from the results that the pH value of

crude glycerol (glycerin) is higher than the pH value of refined glycerol, this is due to neutralization process of basic excess or leaches catalyst in the sample. The free fatty acids of crude glycerol (glycerin) and purified glycerol were 0.84 % and 0 % respectively, while the commercial glycerol has free fatty acid of 0.050 %. The purified glycerol is however free of free fatty acids, this showed that combined neutralization and adsorption processes removed the free fatty acids in the crude glycerin. It could be observed from the results of the analysis that the moisture content level of 3.24 % in the crude glycerol (glycerin) was reduced to 0.3 % in the purified glycerol. The results of moisture content level meets the ASTM D4377-00E01 standard. It was observed from the result that the physical properties obtained from the purified glycerol fall within the standard range. It can also be deduced from the physical properties of refined glycerol that both the purified and refined glycerol have the same physical properties, this shows that the crude glycerin was well purified.

**Table 1: Properties of crude glycerin, purified and refined glycerol**

Parameters	Crude Glycerin	Purified Glycerol	Refined Glycerol	Standard value of glycerol
Molecular weight (kg)	92.09	92.03	92	92.09
Boiling point (°C)	135	290	290	290
Vapour pressure (mm)		0.00247	0.003	0.0025
Moisture content	2.50	0.3	0.150	0.5 max
Viscosity (cp)	5050	1478	1055	1499
Density (g/cm <sup>3</sup> )	1.230	1.450	1.260	1.261
Free fatty acid	0.840	N/A	0.050	0.05
pH	11.120	6.3	6.70	4.0-9.1
Flash point (°C)	130	182		160-200

## 5 Conclusion

It can be concluded from the result of the analysis that the crude glycerol (glycerin) obtained from by-product of a transesterification reaction can be purified and used as refined glycerol. The crude glycerol (glycerin) can be purified without using both the convectional and ion exchange methods, as these processes are energy intensive, complex and expensive and involve high cost of chemical generation of resins. The techniques used for the purification of crude glycerol (glycerin) obtained from by-product of a transesterification reaction were more economical and operationally feasible. Additionally, it was found that the molecular weight, boiling point, vapour pressure, density, viscosity, pH value, free fatty acid value, moisture content and flash point of the purified glycerol were the same with the refined glycerol properties and this indicates that combination of the purification techniques used in this research work were very efficient. Also the physio-chemical values of the purified glycerol were in the acceptable ranges according to international standard for glycerin specifications.

## REFERENCES

1. Ardi, M.S., Aroua, M.K. and Awanis Hashimn, N. (2015). Progress, prospect and challenges in glycerol purification process: A review Renewable and Sustainable Energy Reviews, 42:1164–1173
2. Ash, M. and Ash, I. (2004) Handbook of Preservatives. Synapse Info. Resources: New York.
3. Asher, D. R. and Simpson, D. W. (1956). Glycerol purification by ion exclusion. J Phys Chem., 60: 518–21.
4. Autthanit, C. and Hunsom, M. (2013). Crude glycerol purification by adsorption via Activated carbon derived from sewage sludge. Chemical Engineering Journal 2:29 334-343.
5. Aworanti O. A. and Agarry S. E. (2017). Kinetics, isothermal and thermodynamic modelling studies of hexavalent chromium ions adsorption from simulated wastewater onto *Parkia biglobosa*-Sawdust derived acid-steam activated carbon. Applied Journal Environmental Engineering Science 3 N°158-76.
6. Aworanti O. A., Ajani A. O., Agarry S. E., Babatunde K. A. and Akinwumi O. D. (2019). Evaluation of process parameters for biodiesel production from vegetable and palm waste frying oils using a homogeneous catalyst. International Journal of Energy Engineering, 9(2): 25-35

7. Carmona, M, Valverde, J L, Pérez, A, Warchol, J. and Rodriguez, J F.( 2009). Purification of glycerol/water solutions from biodiesel synthesis by ion exchange: sodium removal Part I. *J. Chem Technol Biotechnol.*, 84: 738–44.
8. Chuang-Wei, C., Dasari, M.A., Sutterlin, W.R., and Suppes, G.J. (2006) Removal of residual catalyst from simulated biodiesel's crude glycerol for glycerol hydrogenolysis to propylene glycol. *Ind. Eng. Chem. Res.*, 45: 791–795
9. Isahak, W.N.R.W., Jahim J. M., Ismail, M., Nasir, N. F., Ba-Abbadm, M. M. and Yarmo, M.A. (2016). Purification of crude glycerol from industrial waste: Experimental and simulations studies *Journal of Engineering Science and Technology* 11(8):1056 - 1072
10. Isahak, W.N.R.W., Ramli, Z.A.C., Ismail, M., Jahim, J.M., and Yarmo, M.A. (2015). Recovery and purification of crude glycerol from vegetable oil transesterification. *Separation and Purification Reviews*, 44(3): 250-267.
11. Morrison, L.R. (2001). *Kirk-Othmer Encyclopedia of Chemical Technology*. Glycerol; John Wiley & Sons, Inc.: New York.
12. Ooi, T.L., Leong, W.L., and Radzuan, J. (1993) Potential source of sterols from a palm kernel oil methyl ester residue of an oleo chemical plant. *PORIM Bulletin*, 27: 25–37.
13. Pachauri, N, and He, B. (2006). Value-added utilization of crude glycerol from biodiesel production: a survey of current research activities. *American society of agricultural and biological engineers*, 1-16
14. Shibasaki-Kitakawa, N, Kanagawa, K, Nakashima, K, and Yonemoto, T. (2013). Simultaneous production of high quality biodiesel and glycerin from *Jatropha* oil using ion- exchange resins as catalysts and adsorbent. *Bioresour Technol.*, 142: 732–6.
15. Thompson, J.C. and He, B.B. (2006). Characterization of crude glycerol from biodiesel production from multiple feedstocks. *Applied Engineering in Agriculture*, 22, 261-265.
16. Van Gerpen, J, Shanks, B., Pruszko, R., Clements, D. and Knothe, G. (2002-2004). Sub-contractor report. *Biodiesel Prod Technol.*, 1- 52.
17. Yong, K. C, Ooi, T. L, Dzulkefly, K, WanYunus, W. M .Z. and Hazimah, A. H. (2001). Refining of crude glycerine recovered from glycerol residue by simple vacuum distillation. *J Oil Palm Res.*, 13:39–44.
- 18.** Ziels, N. W. (1956). Recovery and purification of glycerol. *J Am. Oil Chem Soc.*, 33: 556– 565.

## **LABORATORY INVESTIGATION OF SEDIMENT TRANSPORT IN OPEN CHANNEL FLOWS**

Eya, S. A.; Saleh, J. Y.; Ekwo, J. E.; Nubiya, R. N. and Busari, O. A.

Department of Civil Engineering, Federal University of Technology Minna, Niger State,  
Nigeria.

Email: sundayeya123@gmail.com

### **ABSTRACT**

The model is made up of rectangular channel and a dam structure, the rectangular channel was calibrated in order to record the depth of the water and the level of the discharge as it moves towards the dam body. The combination of fine and coarse grains was used to investigate the movement of sediment particles. Transport of grains occurs when instantaneous vertical component of flow exceeds the settling velocity of the particles. Fall velocity in still water is influenced by two sets of forces: Submerged weight of the particle, and viscous fluid resistance and inertia effects. Small and big particles behave differently: for small particles, viscous resistance dominates; inertia is negligible. for large particles that fall quickly, inertial forces dominate. Coarser-grained sediment (typically sand and gravel) transported on the bottom of the channel bed by rolling and sliding. Fine-grained sediment (typically clay and silt) transported in suspension due to turbulence. The deposition of the incoming sediment reduces the storage capacity of a reservoir over time, and affects the effective management of the structure. Good management of sediment in dams will have economic benefits and reduce environmental impacts.

**Keywords:** Model, Sediment transport, Deposition, Fine and Coarse grains, and Storage capacity.

### **1. Introduction**

Reservoir water storage capacity is lost through the deposition of sediment. The life of a reservoir is usually limited by sediment accumulation. The ability of the channel to entrain and transport sediment depends on the balance between gravitational forces acting to settle particles on the bed and drag forces that act to either suspend them in the flow or shove them along downstream. The management of sediment in river basins and waterways has been an important issue for water managers throughout history, from the ancient Egyptians managing

deposition of sediment on floodplains to provide their crops with nutrients, to today's problems with siltation in large reservoirs and maintaining river systems as transport arteries. The changing nature of sediment issues due to the increasing human population (and the resulting changes in land use and increased water use), the increasing numbers of manmade structures such as dams, weirs and barrages - as well as the increasing recognition of the importance of sediment in the transport and fate of both nutrients and contaminants within river systems - has meant that water managers today face many complex technical and environmental challenges in relation to sediment management UNESCO, (2017). The International Sediment Initiative (ISI) was launched by UNESCO's International Hydrological Programmed (IHP) in 2002. It addresses the wide-ranging social, economic and environmental impacts of erosion, sediment transport and sedimentation processes, and aims to support the global agenda for sustainable integrated land and water resources management by promoting sound sediment management.

The most significant physiographic factors include the climate, topography, soil type, and land use of the river basin and its sub-basins. The major components of climate that can affect soil erosion are rainfall and wind and were reported to originate from major storm events occurring during the wet season IRTCES, (2005) and Wang *et al.*, (2015). Land use has a very important impact on erosion and sediment transport by rivers- because it influences the vegetative cover of a catchment. Plants and associated residues protect the soil from the impacts of rainfall, increase infiltration and reduce the volume and velocity of surface runoff. The rates of soil erosion and sediment yield have varied over time in the Volga River Basin, often following changes in land use; greater rates of soil erosion and increased sediment yields were associated with the cultivation of steep hillslopes due to the reduction of arable land during wars or other historical events Sidorchuk and Golosov, (2003). The social demands on water management, including water supply, flood control, sediment control, navigation, environmental health and recreational use, are increasing with the growth of human populations around the world. In this context, the study is expected to provide a better understanding of the characteristics of flood modelling represents the basis for effectively transported sediment may pass through a reach of channel with the flow and their impacts on the land. The objective is to provide the best means for assessing and subsequently, reducing the vulnerability of bed load transport areas, determine flow discharge, using models and discharge and weigh data were recorded for different gate openings.



## 2. Methodology

The model is made up of rectangular channel and a dam structure, the rectangular channel was calibrated in other to record the depth of the water ( $h$ ) and the level of discharge as it moves towards the dam body. The model consisting of: 2400mm long, 240mm wide and 200mm deep rectangular and horizontal channel; An upstream reservoir with one lateral face that is a 300mm long weir; 100mm wide and 50mm high downstream dam provided with a gate; and 600mm long (after V-notch) and 400mm long (before V-notch) as shown in figure (2) below. The Parameters: Discharge Flow over V-notch weir; Wave speed or Celerity ( $C$ ) and Velocity of water at the gate; Depth of flow water or reservoir ( $h$ ) and Measure the weight of sediments that passed through the gate and deposited at the downstream.

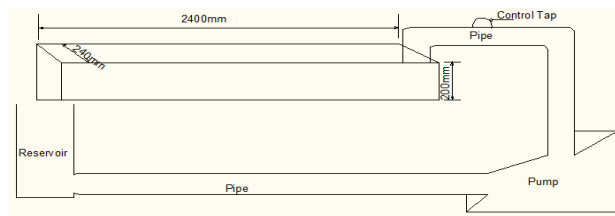


Fig. 1: plan view of the model

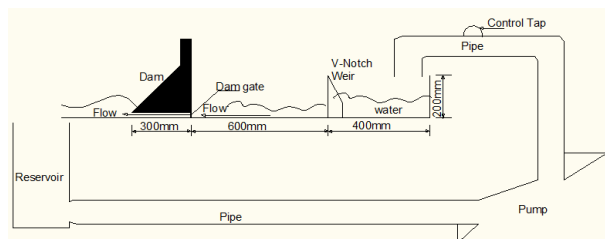


Fig. 2: Longitudinal cross-section of the experimental set-up.

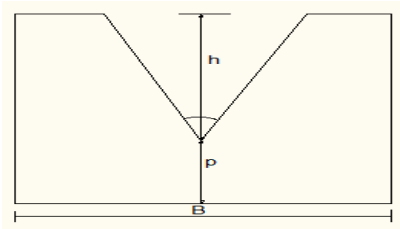


Fig. 3: V-Notch Weir

Where:  $h$  = Depth of water (head above the vertex of the weir);  $p$  = the height of the notch vertex with respect to the floor of approach channel;  $B$  = width of approach channel; and  $\Theta$  = angle of V-notch.

## **2.1 Flow Over a V-notch Weir**

$$Q = \left(\frac{8}{15}\right)C[\tan\left(\frac{\Theta}{2}\right)](2g)^{1/2}h^{5/2}$$

$$V = \frac{Q}{A}$$

$$A = BH$$

$$H = h + p$$

Where:

Q = flow Discharge; C = Discharge Coefficient;  $\Theta$  = angle of the V-notch; and h = head above the vertex of the weir and p = the height of the notch vertex.

According to Strickland equation (1910);

$$C = 0.566 + \left[\frac{0.0157}{h^{1/2}}\right].$$

## **2.2 International Standards for Sediment**

### **Monitoring (ISO 4365:2005)**

The standards for sediment monitoring are developed in more details for the suspended sediments than for the bed-load sediments. The standards provide methods for determining the concentration, particle-size distribution, relative density of sediment, etc. Specifies methods for determining the concentration, particle-size distribution and relative density of sediment in streams and canals. The detailed methods of analysis are given for the following: determination of the suspended sediment concentration by evaporation and filtration, particle-size analysis of suspended sediment, determination of the bed-load and bed material sediment, determination of the relative density of sediment Dijana *et la.*, (2015).

## **2.3 Techniques**

The technique for managing the sedimentation of reservoirs is to prevent or reduce the settling and deposition of fine sediments by increasing turbidity currents. Sediment flushing is a technique whereby sediment previously accumulated and deposited in a reservoir is hydraulically eroded and removed by accelerated flows created when the bottom outlets of a reservoir are opened De Cesare *et al.*, (2008). The entraining forces involve at least three groups

of applied forces: impact force; shear stress (drag force) and lift forces (buoyancy, hydrodynamic lift, turbulence).

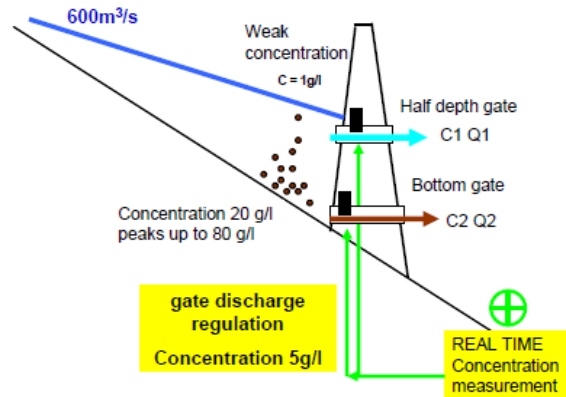


Fig. 4: Flushing (Send downstream only the concentration of sediment) White, (2000).



Fig. 5: observation of water level above the vertex of the v-notch weir.



Fig. 6: Observation at the control gate

### 3. Results and Discussion

The combination of fine and coarse grains was used to investigate the movement of sediment particles. Transport of grains occurs when the instantaneous vertical component of flow exceeds the settling velocity of the particles. Fall velocity in still water is influenced by two sets of forces: Submerged weight of particle, and viscous fluid resistance and inertia effects. Small and big particles behave differently: for small particles, viscous resistance dominates; inertia is negligible. for large particles that fall quickly, inertial forces dominate. The measuring weight of sediments passed through the gate and deposited at the downstream (Table 1). The result showed that the small the space at the control gate the lesser the particles of sediment passing through, and the larger the space at the control gate the more the particles passing through the gate.

Table 1: Weight of sediment deposited at the downstream

S/No	Time (s)	Height of the gate opening (mm)	Weight of sediment passed through the bottom outlet (g)
1	30	10	99.2
2	30	20	119.7
3	30	30	133.5
4	30	40	148.6
5	30	50	161.2

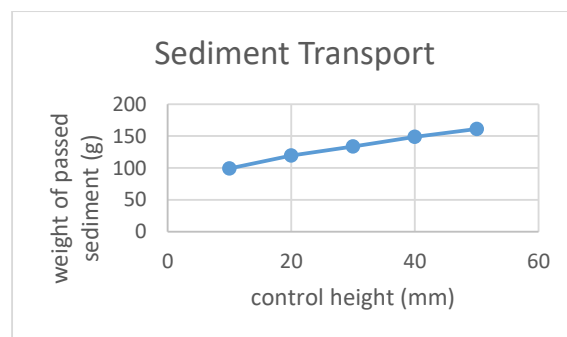


Fig. 8: Graph of measured sediment grains passed through the bottom outlet.

### **3.1 Entraining Forces**

The impact force is the result of direct momentum transfer to the grain as the water impacts on the upstream-projected surface area. Shear stress is the tangential force exerted by the fluid as it flows over and around the grain on the bed. The lift forces include the buoyant force, the hydrodynamic lift force, and the upward turbulence flux. The buoyant force is the hydrostatic force resulting from the particle/fluid density differences and is easily accounted for in the usual way as the buoyancy-discounted or submerged weight of the particle. The hydrodynamic lift force occurs because a grain on the bed is in the zone of steepest velocity gradient and the velocity at the base of the grain is considerably less than that at the top. In accordance with Bernoulli (which specifies an inverse relationship between velocity and pressure), there is an upward declining pressure gradient which tends to lift the grain off the bed. The role of turbulence is not independent of the pressure-gradient force because excursions of velocity above the mean flow velocity obviously intensify that gradient temporarily and increase the lift at those times.

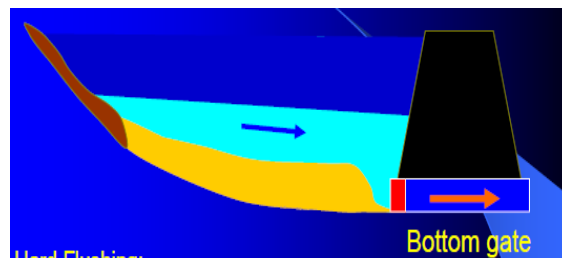


Fig. 7: Hard Flushing

### **3.2 Principles of Sediment Transport**

Fine-grained sediment (typically clay and silt) transported in suspension due to turbulence. the suspended-sediment load consists largely of the finer fraction, the fine sand, silt and clay, of the sediment available to the channel. Because turbulence is generated at the channel boundary and is most intense there, suspended sediment tends to have higher concentrations and involve coarser material near the boundary and both sediment size and concentration decline as we move up through the water column towards the surface of the flow (figure 9 and 10).

Coarser-grained sediment (typically sand and gravel) transported on the bottom of the channel bed by rolling and sliding. Bed load is bed material which moves by sliding and rolling, largely as a result of the shear stress exerted on the boundary by the flowing water. Bed load consists of largely of the coarser fraction, the sand and gravel, of the sediment available to the channel. As flow increases, the shear stress at the boundary eventually threshold or critical conditions for bed particle movement and bed load transport become active (figure 10).

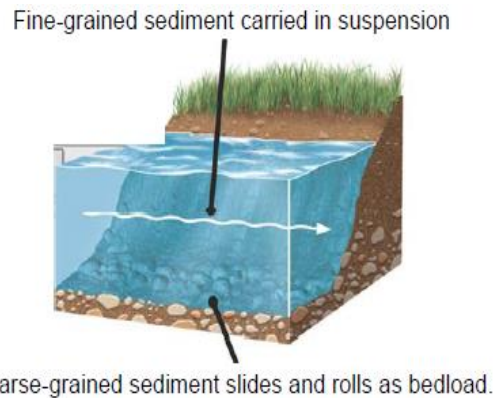


Fig. 9: Movement between Fine and Coarse Grains.

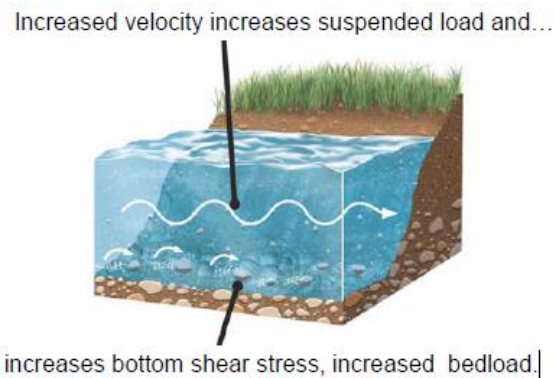


Fig. 10: Increasing in Velocity and Shear Stress.

Sediment (typically sand) transported by intermittent jumps - a transitional state between bed load and suspended load. Bed load transport typically moves a small amount of sediment relative to the total sediment load and generally is less important than the suspended-load component in the context of sediment budgets (figure 11).

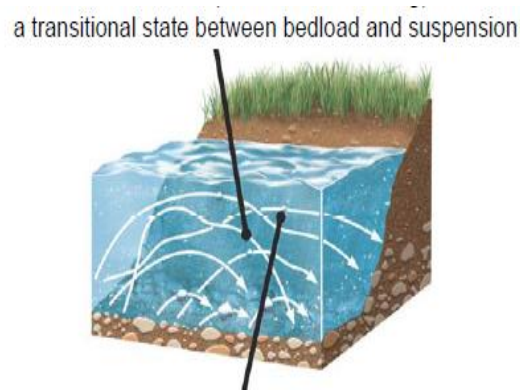


Fig. 11: Saltation (Intermittent Bouncing) source: Bill and Peter (2004).

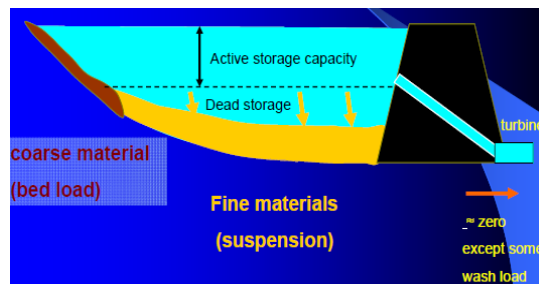


Fig. 12: Sediment trapping by dams

As particles settle, a concentration gradient develops, with more sediment deeper in the flow, a reservoir suffers from sediment problems. The deposition of the incoming sediment reduces the storage capacity of a reservoir over time and affects the effective management of the structure (figure 12). The downstream impacts associated with the trapping of sediment by reservoirs are quite different from the effects upstream. The problems generally result from a shortage of sediment and the resulting impacts on the equilibrium of the environment.

#### 4. Conclusion

Coarser-grained sediment (typically sand and gravel) transported on the bottom of the channel bed by rolling and sliding. Fine-grained sediment (typically clay and silt) transported in suspension due to turbulence. the submerged weight of the grain acts to hold it on the bed; and fluid lift and drag forces act to lift, roll, and slide the grain along the bed. All of these forces are highly variable in nature and the general problem of sediment transport. The deposition of the incoming sediment reduces the storage capacity of a reservoir over time and affects the

effective management of the structure. Good management of sediment in dams will have economic benefits and reduce environmental impacts.

## **REFERENCES**

Bill, D. and Peter, C., (2004). Understanding Earth. Streams: Transport to the Oceans. Lecture slides.

De Cesare, G., *et al.*, (2008). Reservoir Sedimentation. Overview on the problematic of sedimentation and sediment management in Alpine reservoirs, Rapport No 2. Lausanne.

Dijana, O., Damir, B., Matjaž, M., Marina, B. and Tarik, K., (2015). Review of technical international standards and techniques for sediment monitoring. Sediment monitoring workshop September 3-4, 2015, Zagreb.

IRTCES., (2005). Case Study on the Yellow River [online]. UNESCO-ISI report. Available from <http://www.irtces.org/isi/>.

Julien, P.Y. and Vensel, C.W., (2005). Review of Sedimentation Issues on the Mississippi River [online]. UNESCO-ISI report. Available fr <http://www.irtces.org/isi/>.

Kolkman, P. A. and Jongeling, T.H.G., (2007). Dynamic Behaviour of Hydraulic Structures. Delft University of Technology, Delft, The Netherlands.

Sidorchuk, A.Y., and Golosov, V.N., (2003). The history of erosion and sedimentation on the russian plain during the period of intensive agriculture. *Hydrological Processes*, 17: 3347-3358.

UNESCO., (2017). Sediment Problems and Strategies for their Management. Experience from several large river basins.

Wang, Z.Y., *et al.*, (2015). River Dynamics and Integrated River Management. Tsinghua University Press, Beijing and Springer- Verlag Berlin Heidelberg.

White., (2000). Flushing of Sediments from Reservoirs. World Commission on Dams. Thematic Review IV.5. <http://www.dams.org/kbase/thematic/tr45.htm>.



# **CONVERGENCE BETWEEN THE MARXIST AND INFORMATION THEORY IN RELATION TO MOTIVE-BASED OCCLUSION-INVARIANT FACIAL DISPARITY: AN ANALYSIS OF CONFLICT RESOLUTION**

Alabi, A.

Department of Computer Science and Engineering, Oduduwa University, Ipetumodu, Ile-Ife

[newalabikompurer@gmail.com](mailto:newalabikompurer@gmail.com)

## **ABSTRACT**

One trending issue in Face Recognition has to do with the term ‘disparity’ which relates to parameters such as *occlusion* which in this area of research has to do with the blockage or covering of a portion of the face using items such as eye glasses, nose cover and so on. Occlusion could either be *ordinary* if the act responsible for it is *nature-induced*; in which case, the individual in question has no ulterior motive for doing so or *motive-based* where, an individual stages such an act with a view to compromise his own identity. This form of disparity tends to be largely responsible for security issues such as change in the status of a set of images of the same face and thus brings up contradiction against the identity of such an individual; a situation that could better be referred to as “*conflict*”. Theories such as Marxist (*Karl Marx Theory*) and Information theory seem to share some form of similarity in terms of their resolution strategies as regards to conflict-related issues; hence, the need to examine their convergence in relation to face recognition. Key aspects such as the exact scenario of conflict in relation to motive-based occlusion were highlighted and analyzed with the *possible players* as well as *respective goals* as key parameters of interest. It was finally concluded that the resolution strategies employed in both Marxist and Information theory present similar dimension as regards to the analysis of motive-based occlusion disparity as a form of conflict resolution.

**Keywords** Face Recognition, Disparity, Facial Occlusion, Conflict, Marxist, Information Theory

## INTRODUCTION

The human face is considered as the most important part of the body that is crucial for identity. It hosts a highly sensitive region of the body with the forms and positions of its constituent elements varying with respect to the brain's stimulation in response to emotions. One trending issue in Face Recognition has to do with the term '*disparity*' which in simple terms means *difference* or *dissimilarity*. This relates to parameters such as expression and occlusion. While scenarios relating to motions or positions of the muscles beneath the face skin in response to emotions are grouped under '*expression*', aspects such as feature availability, pose etc. come under '*occlusion*'. *Occlusion* in this area of research has to do with the blockage or covering of a portion of the face using items such as eye glasses, nose cover and so on. This could either be ordinary or motive-based. It could be regarded as *ordinary* if the act responsible for it is nature-induced; in which case, the individual in question has no ulterior motive for doing so (e.g. covering the mouth, nose while sneezing, coughing, laughing or crying). On the other hand, an individual could stage such an act with a view to compromise his own identity; this could be termed *motive-based*. However, what first comes to mind during facial analysis has to do with the status any possible-numeric form a facial image can take especially when dealing with facial images with one form of disparity or the other. The point here is that, *occlusion invariant* disparity tends to be largely responsible for security issues when it comes to human identity owing to an unavoidable change in status of the affected face images. This difference in the status of a set of images of the same face may bring up issues of contradiction against the recognition of such a face; a situation that could better be referred to as "*conflict*" for proper analysis. For instance, two facial images of an individual (say  $f_1$  &  $f_2$ ) are said to be in conflict with each other if the correlation existing between them is negative in value. Although, 'conflict' has never been a popular term in face recognition, treating disparity as explained earlier is in a way tantamount to treating conflict as regards to the logic required. Researches have shown that theories such as Marxist (*Karl Marx Theory*), Game theory and Lanchester Theory have greatly been employed in the pursuance of providing answers to conflicting subjects in relation to human endeavours (e.g. wars, protest, truce etc.), while others such as Information theory, Set theory etc. play their roles in the analysis of conflict in data items. Marxist and Information Theory seem to agree to some extent in some aspects of resolution even though their areas of applicability differ. This paper is therefore aimed at examining the various strategies and resolution scenarios employed in both the Marxist and Information

theory with a view to identifying their possible areas of convergence in relation to face recognition.

## **RELATED WORKS**

Conflict generally derives its meaning from any form of opposing or contradicting scenarios with its resolution demanding a form of negotiations of a solution for managing it (Katz & McNulty, 1994). Issues of conflict in relation to recognition systems are a direct link to some aspects of disparity which brought about contradiction of opinions in the detection and identification of faces and so, several areas of research have been introduced in that direction. Yen-Yu *et al* (2007), earlier proposed a framework on rapid object detection using a boosted cascade of simple features where they formulated the detection task as a series of non-face rejection problems; in addition, they calculated an integral image to speed up rectangle feature computation and came up with a stage-wise face classifiers. This represents a generalized form of some previous works in efficiently detecting objects with occlusion and also creating a more robust system by dealing with the problem of over-fitting in training boosted cascades. Also included was cascading-with-evidence scheme to handle occlusions. An attempt was also made by Al-Osaimi *et al* (2009) to address the issues related to expression deformation and interpersonal deformation using three-dimensional faces. Patterns of expression were first learnt with the aid of Principal Component Analysis (PCA) and employed to morph out deformation as it relates to disparity. The outcome proved effective on Face Recognition Grand Challenge Version 2.0 (FRGC V2.0) database with superior recognition performance. Jorstad *et al* (2011), introduced a novel framework over the deformation and lighting insensitive metric to determine the dense correspondence between image and Neire Bayes' Classifier is applied to improve recognition. The goal was to solve the problem of lighting and expression variations and the result obtained proved promising. Raajan *et al* (2012), dealt with the estimation of the level of disparity resulting from camera resolution in selected images. The methodology involves the capturing of some images in full form and the determination of their depth information warped into image position as a form of disparity followed by the application of some required steps. The result showed correctness as regards to the determination of disparity and texture map of used images. There was also the need to improve on the eigenvector selection employed for image representation as used in PCA for better recognizing the features of African bust being art work of the face. An approach by Alabi (2013), known as variable-size eigenvectors selection for image representation was employed with a view to addressing

the disparity between a typical human face image and that of an African bust. The technique represents an improvement of the existing Principal Components Analysis and thus, proved efficient in the analysis and recognition of African bust images. Problems associated with two-dimensional images were addressed by Kandlikar *et al* (2014). The idea was to analyze the possible challenges of two 2D-images captured from two different cameras and resolve the disparities between them. The images in question were first converted into their three-dimensional format with the aid of 3D binocular disparity technique and the recognition scenario in both cases were said to be positive with a given range of viewing angles. Also, the extension in error rates as regards to the problems of variable lighting, pose, facial expression, aging and inaccurate alignment were looked into by Arpit *et al* (2014). The study brought about many benefits such as the use of geometric depth information rather than color and texture (i.e. invariant to lighting conditions), ability to rotate face model in three-dimensional spaces (invariant to head angles), 3D modules captured to scale (absolute measurement invariant to camera distance). This was as a result of the newly used 3D cameras which allow sub-second generations of 3D face model. An example was an attempt to test the efficiency of the Eigenface algorithm on images with plain features in comparison with those with distinct features by Alabi *et al* (2015). The result showed that recognition of faces with distinct features took the lead compared to those images with plain features. Li *et al* (2015), also introduced an aspect of disparity related to hyper-spectra image classification due to the complexity and non-linearity of the data involved. The resulting output surpassed both Principal Components Analysis Technique (PCA) and Linear Discriminant Analysis (LDA) performance-wise. Kumari *et al* (2015), came up with a brief survey of facial expression approaches with Local Binary Pattern (LBP), Local Gradient Code (LGC) and Local Directional Pattern (LDP) as areas of interest. The LBP only exhibits a comparison mechanism of the central pixel value within the neighboring value while the relationship among the pixel values within the neighbors was the case in the LGC. The results showed that the LGC performed better than the LBP and LDP with LBP outweighing LDP performance-wise. One non-verbal communication strategy of understanding someone's mood or mutual state is through his/her facial expression (Kumari *et al*, 2015). Alabi *et al* (2015) demonstrated the effect of the presence of distinct features on the performance of the PCA technique using faces with distinct features in comparison with those of plain features. The results showed that recognition is faster and more efficient on faces with distinct features than those with plain features. A combination of Convolutionary Neural Network and specific image pre-processing steps were employed by (TeixeiraLopes *et al*,

2017) to demonstrate the variance in features in the way people show expression with better results obtained. Jain *et al* (2018), made use of hybrid guided images filter coupled with the Bayesian non-local means with edge aware constraint as the method. The result was able to address disparity related to issue of location. Iloh and BongKang (2018) also developed issues on utilization of a disgusting image data set to understand and predict visual disgust with positive results obtained.

Popular concepts in conflict resolution include Karl Marx Theory and others such as Game Theory (e.g. *Prisoner's Dilemma, Penny Matching Problem, Chicken Problem* etc.) and the Lanchester Theory.

### **Karl Marx theoretical concept**

Generally speaking, a society is said to be composed of people or individuals of different status with different means of livelihood, hence, posing some form of differences in the area of resources sharing. The implication of this is that people in possession of resources will protect and keep away what they either have or is/are available to them while those in need will surely try to have those resources or share from those in control of such resources. This often brings about a constant struggle between the rich and the poor (Barker *et al*, 2013). This theory introduced by Marx isn't about whether or not conflict is bad or not but to understand its scenarios and provide measures towards addressing it with a view to having stable situation or condition of living for people within a given society. This in a way provides answers to questions about avoidable situations such as wars, violence, unrests, revolutions and the likes. One great application of this theory is in the handling of conflict issues in finance or related aspects. Strategies involved in this resolution include resources re-allocation between the rich and the poor, mediating in other manner between these two parties and so on. This usually brings about the introduction of progressive taxes, minimum wages, incentives, social assistance and the likes. The idea is to narrow the gap between affected parties in order to prevent uncontrollable occurrences which might eventually lead to unrest or war.

### **Prisoner's Dilemma**

The concept in the analysis of the Prisoner's Dilemma remains one of the most famous problem solving strategies employed in addressing issues related to conflict. Prisoner's Dilemma is an example of a non-zero sum game; in other words, the "win" status of a player doesn't necessarily amount to the "lose" status of the other player. This has been presented in diverse

form of research applications. As stressed by Jameson (2014), two suspects arrested for a certain crime were put to a game tactic with a view to ensuring that they get prosecuted even though the evidence available against them wasn't enough. Meanwhile, the police had to create a work around hence came up with the following conditional possibilities; defect and cooperate. To cooperate in this case means "keep quiet" and therefore both suspects are expected not to say anything. On the other hand, "defect" has to do with "talking to the police" at least in a manner to incriminate one another. The established rules against each of the suspects (in his separate location) are as follows;

Rule 1; If both suspects cooperate (i.e. remain silent), then they will both serve short sentences.

Rule 2: if one of the suspects defects (i.e. betrays the other), he gains his freedom and the other serves a long term in jail.

Rule 3: If both defect (i.e. betray one another), each one gets a lesser sentence.

### The Penny Matching Problem

The term "penny" shares meaning with the token-like material (just as in a dice form) with two directly opposite side outcomes Head and Tail. In the concept of game theory, penny matching (Fig.1) involves two players placing pennies simultaneously on a table with outcomes (payoff) depending on whether or not the pennies match. If the pennies match, the first player wins and takes the other's penny. On the other hand, the second player takes the first player's penny when the pennies don't match (Chappello, 2019). The scenario in the penny matching problem is considered zero-sum since one player's loss is tantamount to the other player's gain. Also, the game requires that each player is entitled to only one choice of the penny status (i.e. either Head or Tail).

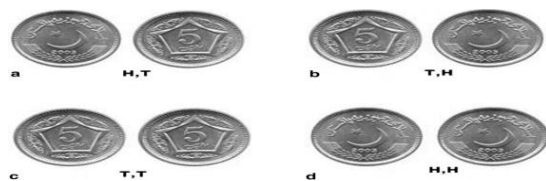


Figure 1: Diagram illustrating Penny Matching

Table 1: Payoff matrix for penny matching

P1/P2	Heads	Tails
Heads	+1, -1	-1, +1
Tails	-1, +1	+1, -1

Hence, there is not any room for uniformity of results. In other words, one of the players

must surely lose or win i.e. No win-win or lose-lose situations. Penny matching game is a way of demonstrating how rational decision-makers seek to maximize their pay-offs. The scenario in Table 2 shows two players (P1 and P2) with their possible payoffs in matrix form. The first of the four sets of numbers shown in the given cells represented belong to P1 while the second belongs to P2. Also, a “win” is denoted by “+1” while “-1” represents “loss”. The outcome +1, -1 in cell1 is about Head-Head (i.e. P1 wins). This is simply because the two pennies match making player 1 the winner hence, P1 takes P2’s penny while P2 loses the penny. The instances in cell 2 (i.e. -1, +1) bring about the reverse situation. In this case the Head-Tail outcome portrays player 2 as the winner since the pennies do not match; hence, P1 loses his penny to P2. The whole table only consists of those two outcomes i.e. P1 wins while P2 loses (as shown in cells 1 and 4) and P2 wins while P1 loses (as shown in cells 2 and 3). However, outcomes such as “win-win” i.e. (+1, +1) or “lose-lose” i.e. (-1, -1) are never obtainable in the penny matching game theory.

### **Chicken Problem**

The Chicken Problem (sometimes written as Chicken’s Problem) consists of players with interactions covered by the Game Theory Concepts. The scenario in this concept (Fig.2) presents a special form of game with unique payoffs from the actors involved. Unlike in most games whereby two players exhibit their strategies in a manner that eventually leads to one player winning, the conflict here is about one player directly opposing the other leading to either bigger conflict or cancellation of the existing conflict. As Illustrated by (Jameson, 2014), two conflicting players tend to be moving towards each other until they either crash or one of the players surrenders and so moves out of the way. In game terminologies, whenever both players move away, the winner (i.e. the opposing party) gets the pride/glory while the loser (i.e. the opposed) gets the embarrassment. Technically, situation like this simply brings about difficulties in quantifying of the possible payoffs needed to proceed with required analysis. In other words, ascribing or assigning value(s) to results such as “gain” and “loss” might not really be feasible enough to make deductions. However, negative payoff emerged whenever none of the opposing parties moves; a situation that usually leads to the term known as “crash”. The term crash in this context is tantamount to severe situation of conflict and so, negative outcome(s) are expected as payoffs. A real-life example of this was the confrontation involving the United States of America (USA) and the then USSR on the USA’s rejection of USSR military presence in environs close to them by forming blockage against the USSR troops on

the way to such places which eventually ended by the discontinuation of the journey by the USSR to avoid escalation.



Figure 2: The Chicken Problem

### **Lanchester theory**

As stressed by Kress *et al* (2017), The Lanchester theory applies to a set of two linear ordinary differential equations in a way to establish and comprehend the dynamics of a conflict between two opposing parties. In this case, two opponents fight each other with sizes or number of resources considered as state variables. However, there is dependence between the size of the forces and their per capita effectiveness measured by individual attrition rates and the decrease of the said forces over time. The theory was modeled in different forms namely the Lanchester Linear Law for ancient war and his Square Law for the modern war. Meanwhile, progressive analysis taking into consideration issues related to implications of information superiority for ground combat brought about a third law known as mixed law. One way of explaining the difference between the ancient warfare and that of the modern is about the possibility of one party having an advantage over the other due to its larger committed force. For instance, there could be invariably unidentical engagement between a party 1 with minimal force and another say “party 2” with larger force (probably with higher number of fighters) in the ancient warfare. In this, victory or success is really a function of the number of people in a particular fighting party. This isn’t the case in the modern warfare in which case, a party with larger fighters might not enjoy some form of advantage over the other thus determining who wins in the end may not be a function of size or number of fighters. However, merging these two scenarios earlier mentioned brought about the Lanchester third law also known as The New Lanchester Law. According to Perry (2009), one of the simplest mathematical models proposed by Lanchester involving two sides of strength  $x(t)$  and  $y(t)$  are described as follows;



$$\frac{dx}{dt} = -ay(t), x(0) = x_0 \quad \dots 1$$

$$\frac{dy}{dt} = -bx(t), y(0) = y_0 \quad \dots 2$$

$$\frac{x_0 - x(t)}{y_0 - y(t)} = \frac{a_x}{b_y} \quad \dots 3$$

Where 1 and 2 represent individual combat on the other hand with 3 as the equation of state.

### Information Theory (IT)

Generally speaking, Information theory is about neutralizing the effect of the noise against a sent message passing through a channel with a view to reconstructing the said image in a form

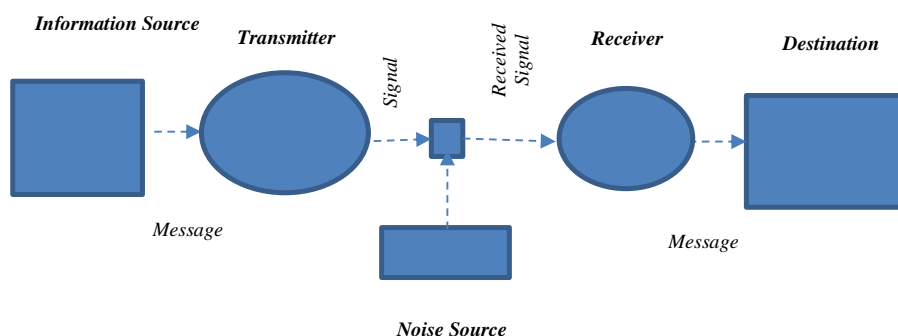


Figure 3: Diagram showing Information Theory (Aftab *et al*, 2001)

optimal for the receiver to understand (Aftab *et al*, 2001). As shown in figure 3 above, the theory gives us an idea of devising strategies towards reconstructing the message in a sent image irrespective of the nature of distortion emanating from or within the channel. This distortion in relation to face images could be as a result of pose, illumination, defect, missing features and the likes. One major aspect of this that directly centers on issues related to conflict is the issue of disparity due to missing features or appearance of unknown features. In other words, information theory could broadly be applied to diverse issues in conjunction with conflict. There is need to find ways of encoding the information that would allow us set up the desired limit without any errors regardless of the amount of distinction.

## **DISCUSSIONS**

The analysis in the review above has shown that the two theories of interest (Marxist and Information Theory) seem to share some form of relationships in their resolution strategies. even though their areas of application differ. While marxist infers more on issues related to human social life, the information theory basically addresses areas such as data conflict, Information flow, Error coding and the likes. One way to explain this as regards *to motive-based occlusion* is to clearly discuss *the possible players* with their individual stances in this conflict scenario and highlight the suggested resolution strategies required to address it in this aspect of face recognition.

### **Possible players and respective stances**

In reality, the act of hiding/covering one's eye or another feature of the face undertaken by ill-minded people while perpetrating evils is in a way to create an identity different from the actual being; in a form of game. Therefore, resolving such an issue demands a tool that could possibly provide a measure of correlation between any two set of images of the same individual (considered as players) with a view to clarifying the identity of the individual in question vis-a-vis the effect of the occlusion. These include *the unaffected* (which serves as the *trained*) and the other *with occluded portion*( referred to as *test*). This issimply because every feature of the face has a complimentary role (Information) played in the identity of an individual. Therefore, the absence of a feature is tantaumount to the loss of certain information which is likely responsible for some level of mis-representation of the individual in question. In terms of stance, the occluded image which has to be processed in relation to an already trained and stored image of the same person poses a form of compromise in relation to the identity of the person. That is, while the trained image portrays the individual as someone (say *A*), the test image speaks about someone else (say *A'*). This is evident owing to the motive associated with the effect of occlusion.

### **Expected Impact of The Resolution**

The possible contradiction (feature-wise) is a function of the factor responsible for it. Since the conflict here is a result of *motive-based occlusion*, a condition referred to as *false identity* is likely to come up. As a measure towards addressing this, the required resolution is expected to create a form of *balance inbetween any inconsistency emanating from this conflict* by bringing up a template which is capable of harnessing features of a given test image of a face in relation to those of a trained image with a view to identifying the person irrespective of the occlusion.

### **Juxtaposition of Marxist and IT**

Although, the facial conflict scenarios under motive-based occlusion present patterns that follow the same as those of a game, the resolution strategies applied in most of the existing game theory concepts do not conform with what is expected as result of

the facial analysis. This owes to the fact that virtually all concepts in game theory explain the need to have a winner in any form of conflict between the parties involved. However, not all conflicting issues are expected to end up in a form of “win” or “lose” outcome solution-wise. The case in face recognition isn't about whether an affected image to be put to test gets rejected or accepted as resolution; but requires the mechanism (figure 4) that could present a unifying platform capable of mediating between the face images in question irrespective of their differences since they emanate from the same person.

As stated in Karl Marx theory (*Marxist theory*), resolving conflicts sometimes requires an approach that could bring about a *balance (i.e. a form of justice)* between parties involved and not necessarily proclaiming a party as *winner* or *loser*.

This is evident in the case of the *rich* (people with enough resources) and the *poor* (those with limited resources) where part of the resolution is to obtain a form of consensus inbetween the two parties with a view to maintaining the stability of the region or society. Logically speaking, the resolution parameters in this case ( figure 5) are expected to be a function of some inputs from both the rich as well as the poor. This concept employed in Marxist also coincides with what says the Information theory (IT) The Information theory which is considered ‘the pioneer theory in this regard’ also gives credence to the resolution concept proposed in the Marxist theory. For instance, one important question to provide answer to vis-à-vis the strategies in IT is; “By what formalism should *prior knowledge* and *proposed mechanism* be combined with *incoming data* to draw formally *justifiable inferences* in resolving conflict?”. The idea here is to devise a measure to process the elements of occluded image with respect to those of trained images with a view to resolving any possible differences thus recognising the said individual. This showcases how the Marxist and IT coincide in terms of strategies as well as expected results in the analysis of any conflict scenario in face images. The result of the system in question is to give room for analyzing the features of the affected image in a way thus ensuring that the gap between the test and training images doesn't affect the recognition of the individual they represent.

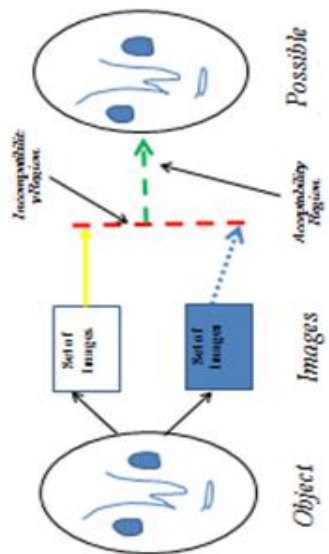


Figure 4: Conflict Scenario in Face Recognition

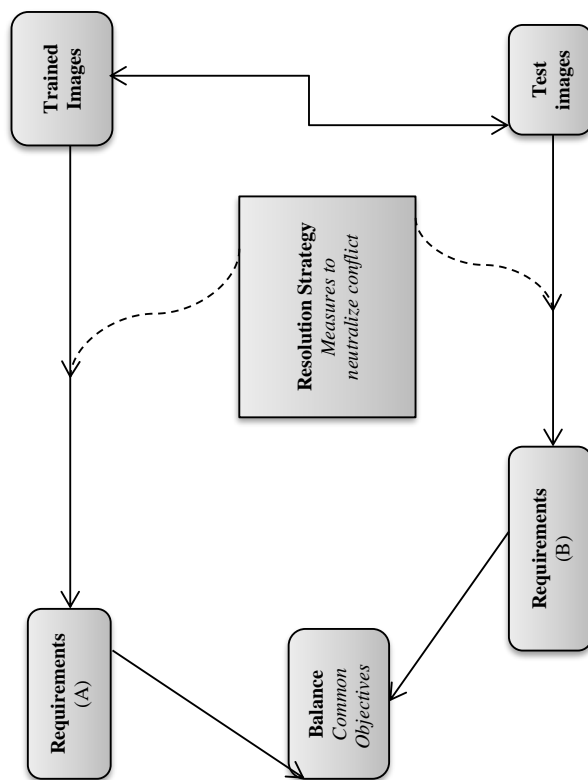


Figure 5: Diagram imitating common resolution strategy in Marxist and Information Theory

For instance, with some form of disparities existing between the set of trained images and those of the test images, it is obvious that *requirement (A)* may not be as exact as those of *(B)*, the resolution strategy is to create the needed mapping function by harnessing the differences in the available requirements of the images in play thus making possible for achieving uniform status with a view to achieving the desire balance.

## **CONCLUSION**

Resolving conflict in relation to *motive-based occlusion* invariant disparity has been proposed with various strategies discussed with a view to highlighting and justifying the relationships existing between Marxist and Information theory especially in their resolution strategies and goals. Aspects such as the key features of a face together with the inter-dependence existing among them were discussed in relation to how they contribute to the conflicting scenarios emanating from motive-based facialocclusion. The study observed that both theories (Marxist and IT) provide parallel background information on how occlusion-invariant issue can better be addressed in face recognition. This could be a useful tool in the development of more robust recognition systems as regards to security and related matters.

## **REFERENCES**

- Aftab O., Cheung P., Kim A., Thakkar S. and Yeddanapudi N., (2001). Information Theory and the Digital Age. 6.933—Final Paper, The Structure of Engineering Revolutions, Massachusetts Institute of Technology, Cambridge.
- Alabi A. A. (2013). A Modified Principal Component Analysis Technique For Recognizing African Bust. *International Journal Of Engineering And Science (IJES)*; ||Volume||2 ||Issue|| 9||Pages|| 116-129||2013|| ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805.
- Alabi A. A., Akanbi L. A., Ibrahim A. A. (2015). Performance Evaluation of the Eigenface Algorithm on Plain-Feature Images in Comparison with Those of Distinct Features. *American Journal of Signal Processing*, 5(2): 32-39 DOI: 10.5923/j.ajsp.20150502.02.
- Al-Osaimi F., Bennamoun M. and Mian A. (2009). An Expression Deformation Approach To Non- Rigid 3d-Face Recognition. *International Journal of Computer Vision*. 81: 302–316. DOI 10.1007/s11263-008-0174-0.

Arpit, A., Abhishek, K. and Leena A. (2014). Study on Advancement In Face Recognition Technology. *Proceedings of National Conference on Recent Advances in Electronics and Communication Engineering (RACE-2014)*. (Accessed: 18/10/2018)

Barker, C., Cox, L., Krinsky, J. and Nilsen, G. (2013). *Marxism and Social Movements*. Koninklijke Brill NV. ISBN 978-90-04-21175-9

Chappello, J. (2019) Matching Pennies. <https://www.investopedia.com/terms/m/matching-pennies.asp>.

Iloh S. and BongKang H. (2018). Development And Utilization Of A Disgusting Image Dataset to Understand and Predict Visual Disgust. *Image and Vision Computing, Volume 72*, Pages 24-38.

Jain K., Pannu H., Singh K. and Malhi A. (2018). Efficient disparity estimation from stereo images using hybrid-guided image filter. *The Imaging Science Journal* Vol. 66 (3).

Jameson, Kristal, "Game Theory and its Applications" (2014). Sr. Seraphim Gibbons Undergraduate Symposium. 30. [https://sophia.stkate.edu/undergraduate\\_research\\_symposium/2014/natural\\_sciences/30](https://sophia.stkate.edu/undergraduate_research_symposium/2014/natural_sciences/30).

Jorstad A., Jacobs D. and Trouve A. (2011). [A. Jorstad , D. Jacobs , A. Trouve, A deformation and lighting insensitive metric for face recognition based on dense correspondences, Proceedings of the 2011 IEEE Conference on Computer Vision and Pattern Recognition, p.2353-2360, June 20-25, 2011 \[doi>10.1109/CVPR.2011.5995431\]](#)

Kandlikar W., Laxman T. and Jagannath D. (2014). Conversion of 2D image into 3D and Facial Recognition- Based Attendance System. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization)*. Vol. 3, Issue 6.

Katz, N. and McNulty. K. (1994). *Conflict Resolution*. [http:// www.academia.edu.com](http://www.academia.edu.com).

Kress, M., Caulkins, J., Feichtinger, G., Grass, D. and Seidl, A. (2017). Lanchester Model for Three-way Combat. Operations Research Department, Naval Postgraduate School, Monterey, California. (Accessed:05/07/2018)

Kumari J., Rajesh R. and Pooja K. (2015). Facial Expression Recognition: A survey. (*Elsevier*) *Procedia Computer Science*, 58 ( 2015 ) 486 – 491. [www.sciencedirect.com](http://www.sciencedirect.com).

Li F., Xu L., David A. And Clausi, S. (2015). Feature Extraction for Hyperspectral Imagery Via Ensemble Localized Manifold Learning. *IEEE Geoscience And Remote Sensing Letters*, Vol.12, No.12.

Perry, N. (2009). Fractal Effects in Lanchester Models of Combat. Department of Defense, Australia. (Accessed: 17/12/2018)

Raajan N., Ramkumar M., Monisha B. Jaiseeli C. and Prasanna S. (2012). Disparity Estimation From Stereo Images. *International Conference on Modeling and Computing*. (*Elsevier*) *Procedia Engineering*. 38 ( 2012 ) 462 – 472. [www.sciencedirect.com](http://www.sciencedirect.com).

[TeixeiraLopes A.](#), [Aguiar E.](#), [De Souza A.](#) and [Santos T.](#) (2017). Facial Expression Recognition with Convolutional Neural Network Coping With Few Data and Training Sample Order. *Pattern Recognition*, Volume 61, Pages 610-628.

Yen-Yu, L., Tyng-Luh, L., and Chiou-Shan, F. (2007). Face Detection with Occlusions. Inst. Of Information Science, Academia Sinica, Taiwan Department of CSIE, National Taiwan University. Vol 13 No.1.

Yixin S. and Liu J. and Du L. (2018). Wrong Matching Point Elimination after Scale Invariant Transformation and Its Application in Image Machinery. *Pattern Recognition and Image Analysis*. Volume 28, Issue 1, pp. 87–96.

## **DISTRIBUTION SYSTEM POWER LOSS MINIMIZATION BASED ON NETWORK STRUCTURAL CHARACTERISTICS**

Ayanlade, S.O.<sup>1\*</sup>, Komolafe, O. A<sup>1</sup>, Adejumobi, I. O.<sup>2</sup> and Jimoh, A.<sup>3</sup>

<sup>1</sup> Electronic and Electrical Engineering Department, Obafemi Awolowo University, Ile-Ife, Nigeria.

<sup>2</sup> Electronic and Electrical Engineering Department Ladoko Akintola University of Technology, Ogbomosho, Nigeria.

<sup>3</sup> Technical Operations Department, Ibadan Electricity Distribution Company, Molete Business Hub, Ibadan, Nigeria

\*Email of Corresponding Author: [ayanladeoladayo@gmail.com](mailto:ayanladeoladayo@gmail.com)

### **ABSTRACT**

The major problems associated with distribution systems are voltage control and power losses. The placement of reactive power compensator (RPC) is one of the methods used in distribution systems to solve these problems. Minimization of power loss requires that RPC should be appropriately located. Inherent structural characteristic theory (ISCT) which is based on the circuit law can be used to determine the location of RPC without running repetitive and time-consuming load flow solution. The objective of this paper is to present the ISCT method to determine the appropriate location of RPC. The method was implemented on Matlab and applied to Imalefalafia 32-bus radial distribution network. The results obtained were compared with the voltage stability index (VSI) and QV sensitivity methods. The result showed that the appropriate location was bus 24 and when appropriate size of RPC was injected at this bus, real and reactive power losses were reduced by 38.84 and 41.12%, respectively. The appropriate location selected by the VSI and QV sensitivity methods were buses 22 and 23. The real and reactive power losses were reduced by 33.06 and 34.52%, for the VSI method and 31.19 and 39.09%, for QV sensitivity method, respectively when appropriate sizes of RPC were injected at these buses. The computational time for ISCT was 0.002766 s as compared with VSI and QV which were 0.12973 and 0.009257 s, respectively. In each case, the ISCT method was faster and reduced real and reactive power losses much better.



**Keywords:** ISCT, VSI, QV sensitivity, RPC, real power, reactive power.

## **INTRODUCTION**

The distribution system is an important component of the power system because it serves as a link between the transmission system and the consumers. The main aim of constructing distribution system is to deliver electric power to the end users (Ighalo and Williams, 2012). Distribution systems are considered as ill-conditioned because of their high resistance to reactance ratio, large number of nodes and radial structure. Due to these aforementioned structural natures of distribution network, there exists real and reactive power losses in the network and consequently the efficiency of the power system is reduced.

In power systems, it is required that the real and reactive power losses be minimized so as to improve the efficiency of the system. ***One of the methods of minimizing real and reactive power losses in distribution systems is by the injection of reactive power into the network.*** For optimal benefit, it is required that compensators be properly sized and located. Studies indicate that poor selection of location of reactive power compensators does not lead to effective power loss minimization (Kim, 2001a, b; Acharya *et al.*, 2006; Atwa *et al.*, 2010).

Many researches have been carried out in this area of research. Different methods have been proposed by many researchers to determine the appropriate locations of reactive power compensators. Some of these methods are particle swarm optimization method (Reddy *et al.*, 2012), genetic algorithm method (Kotb *et al.*, 2010; Yadav and Srivastava, 2015), voltage stability index method (Arvindhababu and Mohan, 2009; Thishya and Balamurugan, 2017; Eminoglu and Hocaoglu, 2007; Naik *et al.*, 2012), QV sensitivity method (Wang and Nehrir, 2004; Mithulananthan and Hien, 2013), fuzzy logic method (Injeti and Kumar, 2011) etc.

However, the problem associated with these existing methods is that repetitive and time-consuming power-flow solutions have to be carried out before the optimal location of RPC could be determined. This paper therefore, presents the ISCT method which is less time-consuming computational method and based on circuit theory to determine the optimal location of RPC in distribution system in order to minimize real and reactive power losses.

## METHODOLOGY

### Inherent Structural Characteristic Theory

The theory of inherent structural characteristics argues that, it is possible to solve some of power system problems by considering the interconnections of the network components and their impedance values (Sikiru *et al.*, 2013). This inherent structural behaviour of the network is based on the structural relationship between the voltages at the network nodes and the currents flowing through the links of the network (Carpinelli *et al.*, 1998).

The inherent structural characteristics of a power system network is defined by their primitive admittance and can easily be captured by the network structural impedance or admittance matrix according to the fundamental circuit theory law given as (Sikiru *et al.*, 2012 and Sikiru *et al.*, 2013).

$$V = IZ \quad (1)$$

or

$$I = YV \quad (2)$$

where,

$V$  = bus voltage vector.

$I$  = injection current vector.

$Z$  = impedance matrix of the network.

$Y$  = admittance matrix of the network

Equation (2) can be expanded to yield

$$\begin{bmatrix} I_G \\ I_L \end{bmatrix} = \begin{bmatrix} Y_{GG} & Y_{GL} \\ Y_{LG} & Y_{LL} \end{bmatrix} \begin{bmatrix} V_G \\ V_L \end{bmatrix} \quad (3)$$

where,

$Y_{GG}$  = connectivity between generator buses.

$Y_{GL}$  = generator to load buses matrix.

$Y_{LG}$  = transpose of  $Y_{GL}$ .

$Y_{LL}$  = connectivity between load buses.

$I_G$  = injected generator bus currents.

$I_L$  = injected load bus currents.

$V_G$  = generator complex voltage.

$V_L$  = load bus complex voltages.

For a distribution system, there is usually only one input source hence,  $G = 1$ .

Making  $V_G$  and  $I_L$  the subject of Equation (3) gives

$$\begin{bmatrix} V_G \\ I_L \end{bmatrix} = \begin{bmatrix} Z_{GG} & H_{GL} \\ W_{LG} & C_{LL} \end{bmatrix} \begin{bmatrix} I_G \\ V_L \end{bmatrix} \quad (4)$$

where,

$Z_{GG} = Y_{GG}^{-1}$ , represents the total generator impedances and accounts for the total generator losses.

$H_{GL} = -Y_{GG}^{-1}Y_{GL}$ , represents the influence of generators over load buses. The generator's electrical attraction to these load buses is termed "generator affinity".

$W_{LG} = Y_{LG}Y_{GG}^{-1}$  is the negative transpose of matrix  $H_{GL}$ , it contains the same information.

$$C_{LL} = Y_{LL} - Y_{LG}Y_{GG}^{-1}Y_{GL} \quad (5)$$

Equation (5) is referred to as the Schur complement of  $Y_{GG}$  in  $Y$  (Sikiru *et al.*, 2013) and defines the electrical property of the load-load electrical attraction region.

The matrix in Equation (4) captures the structural interconnections of the transmission or distribution lines and buses within the network. The matrix  $C_{LL}$  represents the total load buses equivalent admittance with the influence of all generator buses eliminated.

The structural impact of load-load electrical attraction region on power flow is the essential information contained in this matrix. The association of a unique eigenvalue per bus for this matrix is termed the "Structural Impact of Load Electrical Attraction Region matrix" (Sikiru *et al.*, 2013).

Expanding Equation (4) and applying eigenvalue decomposition on matrix  $C_{LL}$  yields Equation (6).

$$V_L = \sum_{i=1}^n \frac{m_i m_i^*}{\mu_i} [I_L - W_{LG} I_G] \quad (6)$$

where,

$m_i$  = eigenvectors.

$\mu_i$  = eigenvalues.

The bus associated with the smallest eigenvalue is the critical load bus due to its reciprocal relationship with the load voltages. This implies that the bus is positioned at a considerable distance from the other buses in the electrical attraction region formed by the load buses.

These buses are the most suitable locations for siting RPC. Sikiru *et al.* (2012) demonstrated that weak nodes within a network could be easily identified using the eigenvalue decomposition analysis of matrix  $C_{LL}$ . It is shown by Sikiru *et al.* (2012) that ISCT can be effectively used to determine the strength of the buses.

### Determination of appropriate location

The bus admittance matrix of the distribution network was developed and partitioned into four sub-matrices according to Equation (3). The partitioned bus admittance matrix was restructured to obtain structural impact of load electrical attraction region matrix ( $C_{LL}$ ) according to Equation (5).

The eigenvalues of this sub-matrix were computed and used to determine the strength of the nodes and consequently the appropriate location of reactive power compensators.

### Determination of optimal size

The optimal size of the reactive power compensator was determined using exact loss formula stated in Equation (7) for bus  $i$ , for the loss to be minimized (Rani and Devi, 2002; Reddy, 2014).

$$Q_{RPCi} = Q_{Di} + \frac{1}{\alpha_{ii}} \left[ \beta_{ii} P_i - \sum_{\substack{j=1 \\ j \neq i}}^n (\alpha_{ij} Q_j - \beta_{ij} P_j) \right] \quad (7)$$

$$\alpha_{ij} = \frac{r_{ij}}{V_i V_j} \cos(\delta_i - \delta_j)$$

$$\beta_{ij} = \frac{r_{ij}}{V_i V_j} \sin(\delta_i - \delta_j)$$

$r_{ij}$  = resistive part of bus impedance matrix

$P_i$  = sending end real power

$Q_i$  = sending end reactive power

$P_j$  = receiving end real power

$Q_j$  = receiving end reactive power

$V_i$  = sending end voltage

$V_j$  = receiving end voltage

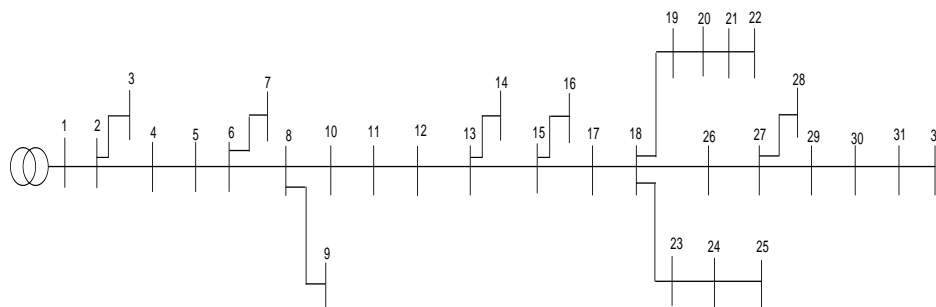
## Implementation

A Matlab program was developed to implement the method and applied to Imalefalafia 32-bus network. Existing power flow solution technique was applied to solve the power flow problem with and without reactive power injection. The result was compared with the VSI and QV sensitivity methods for determining the appropriate location of reactive power compensators in power systems.

### Imalefalafia 32-bus

The Imalefalafia 32-bus radial distribution system is extracted from 33/11 kV Oluyole Injection sub-station of Ibadan Electricity Distribution Company (IBEDC), situated at Ibadan, Oyo state Nigeria. This radial distribution system consists of one main line and seven laterals. It has thirty-two buses and thirty-one branches.

The total magnitudes of real and reactive power load on this distribution system are 3.174 MW and 1.941 MVar, respectively. The single line diagram of this distribution system is shown in Figure 1. The bus data and the line data of this distribution network is shown in Appendix 1. The distribution system is fed by a source at the substation connected to bus 1. The rest of buses are load buses.



**Figure 1:** Single line diagram of Imalefalafia 32-bus distribution system

## RESULTS AND DISCUSSION

Results obtained using inherent structural characteristic theories of network have been presented in this section. The ISCT, VSI and QV sensitivity methods were implemented and programmed in Matlab 2017a. The methods were implemented on Imalefalafia 32-bus system.

The reactive power compensator was optimally sized using the exact power loss formula. Different comparisons have also been done so as to show the accuracy of ISCT method in determining the appropriate location of RPC for minimizing real and reactive power losses in relation to VSI and QV sensitivity methods.

### Imalefalafia 32-Bus

The buses were ranked in ascending order of magnitude of eigenvalues associated with the buses. Table 1 shows the ranking of the first 10 buses of Imalefalafia distribution network arranged in ascending order of magnitude of eigenvalues. Bus 24 has the lowest eigenvalue and was ranked first. Hence, it was selected as the appropriate location for injecting reactive power to minimize real and reactive power losses.

The appropriate size of reactive power compensator to be injected at bus 24 was determined to be 508 kVar. The total real and reactive power losses when power flow analysis was performed were 74 kW and 116 kVar, respectively. RPC of size 508 kVar was injected at bus 24 and power flow analysis was performed. The real and reactive power losses were reduced by 38.84 and 41.12%, respectively.

**Table 1:** Ranking of Buses

Ranking	Eigenvalue	Bus Number
1	2.213637	24
2	6.398131	25
3	8.885750	26
4	16.40227	27
5	18.92398	28
6	49.42187	30
7	55.85672	31
8	58.61950	32
9	79.93344	29
10	102.6629	23

### Comparison with VSI and QV sensitivity methods

Table 2 shows the comparison of the three methods of determining the appropriate location of RPC. After ranking, as shown in Table 2, the VSI method ranked bus 22 as the appropriate location for injecting reactive power, while bus 23 was ranked as the appropriate location for injecting reactive power by QV method.

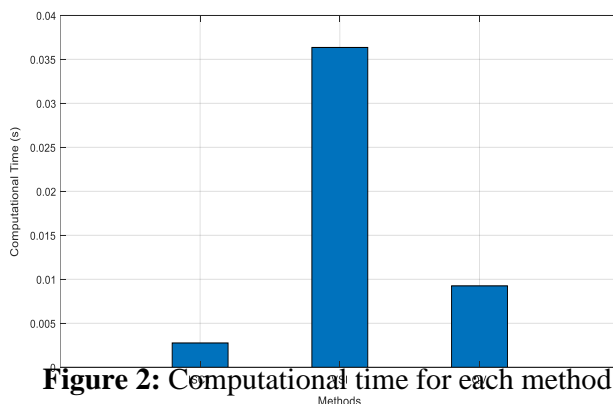
**Table 2:** Ranking of buses for Imalefalafia 32-bus distribution system

Ranking	ISCT	VSI	Q-V
1	24	22	23
2	25	32	24
3	26	21	25
4	27	31	26
5	28	30	28

Table 3 and Figure 2 show the computational time for ISCT, VSI and QV sensitivity methods. From Table 3, ISCT took 0.002766 s to determine the appropriate location of RPC while VSI method took 0.03635 s to determine the appropriate location of RPC. QV method took 0.009257 s to determine the appropriate location of RPC.

**Table 3:** Computational time for each method

Method	Computational Time (s)
ISCT	0.002766
VSI	0.036350
QV	0.009257

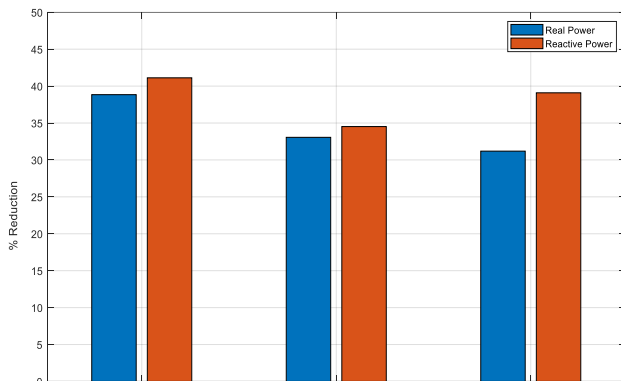


**Figure 2:** Computational time for each method

The optimal sizes of RPC were determined and injected at buses 22 and 23 also. Table 4 shows the results of the percentage real and reactive power loss reduction after reactive power were injected at buses 22 and 23. The real and reactive power losses were reduced by 33.06 and 34.52%, respectively for VSI and by 31.19 and 39.09%, respectively for QV sensitivity method.

**Table 4:** Percentage real and reactive power loss

Method	Real Power (%)	Reactive Power (%)
ISCT	38.84	41.12
VSI	33.06	34.52
QV	31.19	39.09



**Figure 3:** Percentage real and reactive power loss

As shown in Table 4, the location (i.e. bus 24) selected by the ISCT method proved to be the most appropriate location as real and reactive power losses were reduced significantly after injecting reactive power compared with buses 22 and 23, as determined as the appropriate location by the VSI and QV sensitivity analysis methods, respectively.

In each case, the ISCT method proved to be more superior in terms of computational time and accuracy in determining the location most suitable for injecting RPC for reducing real and reactive power losses.

## CONCLUSION

This paper demonstrated the capability of power loss minimization achievable using circuit theory approach applied to radial distribution system networks. The suitable locations for reactive power compensators were obtained from the application of eigenvalue decomposition of a sub-matrix of the Y-admittance matrix. The injection of real and reactive power at the bus associated with the smallest eigenvalue reduced the distribution power losses.



The ISCT method was implemented and applied to Imalefalafia 32-bus distribution system and this method proved to be very fast and accurate in determining the optimal location of reactive power compensator when compared with the VSI and classical QV sensitivity methods.

The study concluded that the ISCT method is more effective for optimal location of reactive power compensator in radial distribution networks for minimizing real and reactive power losses.

## **REFERENCE**

Acharya, N., Mahat, P., and Mithulananthan, N. 2006. An Analytical Approach for DG Allocation in Primary Distribution Network, *Int. J. Electr. Power Energy Syst.*, 28(10), pp. 669–678.

Arvindhababu, P., and Mohan, G. 2009. Optimal Capacitor Placement for Voltage Stability Enhancement in Distribution Systems, *ARPN Journal of Engineering and Applied Sciences*, 4(2), pp. 88-92.

Arvindhababu, P., and Mohan, G. 2009. Optimal Capacitor Placement for Voltage Stability Enhancement in Distribution Systems, *ARPN Journal of Engineering and Applied Sciences*, 4(2), pp. 88-92.

Atwa, Y., El-Saadany, E., Salama, M., and Seethapathy, R. 2010. Optimal Renewable Resources Mix for Distribution System Energy Loss Minimization, *IEEE Transaction on Power System*, 25(2), pp. 360–370.

Carpinelli, G., Russo, A., Russo, M., and Verde, P. 1998. Inherent Structure Theory of Networks and Power System Harmonics, **IEEE Proceedings - Generation, Transmission and Distribution**, 2(1), pp. 123-132.

Eminoglu, U., and Hocaoglu, M. H. 2007. A Voltage Stability Index for Radial Distribution Networks, *2007 42nd International Universities Power Engineering Conference*, pp. 408–413.

Ighalo, G. I., and Williams, A. A. 2012. Simulating Power Distribution Network in Nigeria – The Ikpoba-Hill District Network as A Case Study, *International Journal of Scientific & Technology Research*, 1(9), pp. 1-8.

Injeti, S. K., and Kumar, N. P. 2011. Optimal Planning of Distributed Generation for Improved Voltage Stability and Loss Reduction, *International Journal of Computer Applications*, 15(1), pp. 40-46.

Kim, T. E. 2001b. Voltage Regulation Coordination of Distributed Generation System in Distribution System, *IEEE Transaction on Power Delivery*, 6(3), pp. 1100-1117.

Kim, T. E. 2001a. A Method for Determining the Introduction Limit of Distributed Generation System in Distribution System, *IEEE Transaction on Power Delivery*, 4(2), pp. 100-117.

Kotb, M. F., Shebl, K. M., El Khazendar, M., and El Husseiny, A. 2010. Genetic Algorithm for Optimum Siting and Sizing of Distributed Generation, *Proc. 14th Int. Middle East Power Systems Conference, Cairo University, Egypt*, pp. 433-440.

Mansour, Y., Xu, W., Alvarado, F., and Rinzin, C. 1994. SVC Placement Using Critical Modes of Voltage Instability, **IEEE Transactions on Power Systems**, 9(1), pp. 757-763.

Mithulananthan, N., and Hien, N. C. 2013. Location and Sizing of Distributed Generation Units for Loadability Enhancement in Primary Feeder. *IEEE systems Journal*, 7(4), pp. 1-10.

Reddy, S. C., Prasad, P. V. N., and Laxmi, A. J. 2012. Power Quality and Reliability Improvement of Distribution System by Optimal Number, Location and Size of DGs Using Particle Swarm Optimization, *7th IEEE International Conference on Industrial and Information Systems (ICIIS), Chennai, India*, pp. 0-6.

Sikiru, T. H., Jimoh, A. A., and Agee, J. T. 2013. Inherent structural characteristic indices of power system networks, *International Journal of Electrical Power and Energy Systems*, 47(1), pp. 218–224.

Sikiru, T. H., Jimoh, A. A., Hamam Y., Agee, J. T., and Ceschi, R. 2012. Relationship Between Generator Affinity and Voltage Profile Improvement, *IEEE 10<sup>th</sup> International Power and Energy Conference (IPEC)*, pp. 451-454.

Singh, N., Ghosh, S., and Murari, K. 2015. Optimal Sizing and Placement of DG in a Radial Distribution Network using Sensitivity based Methods, *International Electrical Engineering Journal (IEEJ)*, 6(1), pp. 1727–1734.

Thishya, V. U., and Balamurugan, K. 2017. Optimal Placement of Distributed Generation with SVC for Power Loss Reduction in Distributed System, *ARPJ Journal of Engineering and Applied Sciences*, 12(17), pp. 4895-4901.

Wang, C., and Nehrir, H. 2004. Analytical Approaches for Optimal Placement of Distributed Generation Sources in Power System, *IEEE Transaction on Power Systems*, 19(4), pp. 2068-2076.

Yadav, P. S., and Srivastava, L. 2015. Optimal Location of Combined DG and Capacitor for Real Power Loss Minimization in Distribution Networks, *International Journal of Electrical and Electronics Engineers*, 7(1), pp. 222-233.

Zakaria, E., Eltigani, D., and Ramadan, K. 2015. Identification of Voltage Collapse Vulnerable Buses Using Modal Analysis, *International Conference on Computing, Control, Networking, Electronics and Embedded Systems Engineering*, pp. 0-4.

**Appendix 1: Bus and Line Data for Imalefalafia 32-Bus Feeder**

<b>From Bus</b>	<b>To Bus</b>	<b>R (p.u.)</b>	<b>X (p.u.)</b>	<b>1/2B <math>\mu</math>(p.u.)</b>	<b>Load at Receiving End</b>	
					<b>P (kW)</b>	<b>Q (kVar)</b>

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1	2	0.034690	0.059724	0.692699	0.0000	0.000
2	3	0.006033	0.010387	0.120469	176.67	57.58
2	4	0.003017	0.005193	0.060235	141.54	46.21
4	5	0.021116	0.036354	0.421643	242.15	79.06
5	6	0.001508	0.002597	0.030117	0.0000	0.000
6	7	0.000754	0.001298	0.015059	195.31	63.76
6	8	0.003017	0.005193	0.060235	0.0000	0.000
8	9	0.000754	0.001298	0.015059	71.890	23.47
8	10	0.007541	0.012983	0.150587	204.27	66.69
10	11	0.006033	0.010387	0.120469	25.870	8.440
11	12	0.001508	0.002597	0.030117	83.500	27.26
12	13	0.004525	0.007790	0.090352	0.0000	0.000
13	14	0.004525	0.007790	0.090352	87.170	28.46
13	15	0.003017	0.005193	0.060235	0.0000	0.000
15	16	0.000754	0.001298	0.015059	25.870	8.440
15	17	0.009050	0.015580	0.180704	210.38	68.68
17	18	0.018099	0.031160	0.361408	0.0000	0.000
18	27	0.001508	0.002597	0.030117	57.640	18.82
27	26	0.004525	0.007790	0.090352	0.0000	0.000
26	28	0.001508	0.002597	0.030117	45.420	14.83
26	29	0.003017	0.005193	0.060235	117.51	38.36
29	30	0.001508	0.002597	0.030117	195.11	63.70
30	24	0.004525	0.007790	0.090352	247.44	80.78
31	32	0.006033	0.010387	0.120469	229.73	75.00
18	19	0.007541	0.012983	0.150587	101.22	33.05
19	20	0.015083	0.025967	0.301174	131.16	42.82
20	21	0.012820	0.022072	0.255998	133.60	43.62
21	22	0.001508	0.002597	0.030117	79.430	25.93
18	23	0.001508	0.002597	0.030117	31.570	10.31
23	24	0.004525	0.007790	0.090352	104.07	33.98
24	25	0.001508	0.002597	0.030117	235.43	76.86

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## **SUSTAINABILITY OF IFE STEEL SLAG ON THE SPLIT AND FLEXURAL STRENGTHS OF CONCRETE**

Adedokun, S. I.<sup>1</sup>, Anifowose, M. A.<sup>2\*</sup>, Oyeleke, M. O.<sup>2</sup>, Oduoye, W. O.<sup>3</sup>, Ibiwoye, E. O.<sup>4</sup>

<sup>1</sup>Department of Civil Engineering, Ladoko Akintola University of Technology, Ogbomosho, Nigeria

<sup>2</sup>Department of Civil Engineering, Federal Polytechnic Offa, Offa, Nigeria

<sup>3</sup>Department of Civil Engineering, Osun State University, Osogbo, Nigeria

<sup>4</sup>Department of Civil Engineering, Kwara State Polytechnic, Ilorin, Nigeria

\*Corresponding author: mukaila.anifowose@fedpoffaonline.edu.ng

### **ABSTRACT**

Steel slags are by-product from steel producing company and it may be categorized base on steelmaking techniques. The sustainable use of Ife Nigeria Steel Slag (INS) as granite replacements in concrete were examined using 0, 40, 50 and 60% of steel slag by weight of granite. A mix ratio of 1:2:4 was adopted and batching was done by weight with water-cement ratio of 0.4, 0.5, 0.6 and 0.7. A total number of thirty two (32) cylindrical concrete samples (150 mm by 300 mm) and thirty two (32) beam concrete samples (100 mm x 100 mm x 500mm) were produced and cured by immersion in water for twenty (28) days. Physical properties of the aggregate used were examined while slump and compacting factor (workability tests) were determined on fresh concrete. At the end of the curing age, the split tensile and flexural strengths test were determined on the cylindrical concrete samples and concrete beam respectively. The results of the workability test showed that the concrete became more workable with increase in water cement ratio but stiffened as the INS contents increased. The study concluded that the split tensile and flexural strengths of the hardened concrete decreased with increased in water cement ratios while addition of steel slag improved concrete properties. Adoption of 40% INS would be sustainable for mix ratio 1:2:4 concrete productions thereby reducing environmental pollution.

**Keywords:** Concrete, flexural strength, split tensile strength, steel slag, water cement ratio

## **INTRODUCTION**

Concrete (formed by cement, water, fine aggregate and coarse aggregate) is one of the most widely used construction material in the world which can be cast in diverse shapes (Adedokun *et al.*, 2018). The aggregates commonly account for about 75% of concrete volume and play a significant role in properties of concrete. There is focus on the utilization of alternate aggregate materials and significant research has been made on the use of several materials as substitute for conventional aggregates in concrete (Anifowose *et al.*, 2019). Utilization of environmental friendly materials in any industry and construction industry in particular, is of major importance (Adedokun *et al.*, 2016; Raheem *et al.*, 2017a & b; Raheem *et al.*, 2018). Steel slag aggregates are already being used as aggregates in asphalt paving road mix due to their stiffness, mechanical energy, wear resistance, porosity and water absorption potential. Additionally, metallic slag could be used as a partial substitute for coarse aggregates in concrete (Padmapriya *et al.*, 2015). Steel slag have been found as a better substitute for coarse aggregate in concrete production.

Steel slag is a by-product from metal manufacturing. It may be categorized as carbon steel slag and stainless steel slag according to the kind of steel, and as casting residue, Electric Arc Furnace Slag (EAFS), Basic Oxygen Furnace Slag (BOFS), Ladle Refining Slag (LFS) and pre-remedy slag in line with the steelmaking technique (Yi *et al.*, 2012)

Steel slag are disposed around the steel company leading to environmental danger (Olanade *et al.*, 2015). This study investigated the sustainable use of Ife steel slag on the split and flexural strengths of concrete.

## **MATERIALS AND METHODS**

### ***Materials***

Dangote cement brands of 32.5R and potable water were used for production of concrete specimens while the aggregates used were fine aggregate that passes through sieve 5.0 mm and granite of maximum size 12.5 mm both of which conforms to BS 882 (1992). Steel slags were collected from Ife Iron and Steel Nig. Ltd., Ife-Ibadan Expressway, Osun State, Nigeria and were denoted as Ife Nigeria Slag (INS). The steel slags were broken down manually with hammer into required sizes that retained on British Stand sieve 5.0 mm. The physical properties of the aggregate used are shown in Table 1.

Table 1: Physical properties of aggregates

Test	Aggregate			Test Conformity
	Fine Aggregate	Granite	INS	
Water Absorption		0.5%	2.5%	BS EN 1097:6 (2013)
Specific Gravity	2.67	2.69	2.75	BS 1377:2 (1990)
Aggregate Impact Value (AIV)		12.50%	7.50%	BS 812-112 (1990)
Aggregate Crushing Value (ACV)		24.60%	22.50%	BS 812-110 (1990)

## Methods

The sustainable use of steel slag as granite replacements in concrete were examined using 0, 40, 50 and 60% of steel slag by weight of granite. A mix ratio of 1:2:4 was adopted and batching was done by weight with water-cement ratio of 0.4, 0.5, 0.6 and 0.7. A total number of thirty two (32) cylindrical concrete samples (150 mm by 300 mm) and thirty two (32) concrete beam samples (100 mm x 100 mm x 500mm) were produced and cured by immersion in water for twenty (28) days. Slump and compacting factor (workability tests) were determined on fresh concrete. At the end of the curing age, the split tensile and flexural strengths test were determined on the cylindrical concrete samples and concrete beams respectively using Haida Universal Testing Machine (UTM) of 2000 kN capacity at Materials and Structures Laboratory, Civil Engineering Department, Osun State University, Osogbo, Nigeria.

## RESULTS AND DISCUSSION

### Workability of Fresh Concrete

Slump and compacting factor test were carried out in accordance with BS EN 12350-2 (2009) and BS 1881:103 (1983) respectively.

The INS-Fresh-Concrete witnessed reduction in slump height (Figure 1) as the granite replacement with INS increases for water-cement ratio of 0.4, 0.5, 0.6 and 0.7. However, the fresh concrete becomes more workable as the water cement ratio in the fresh concrete mix increases.

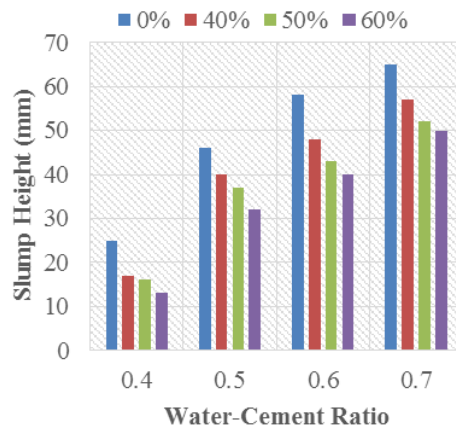


Figure 1: Concrete slump height versus w/c

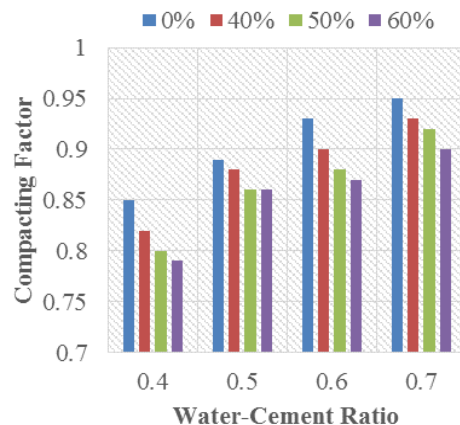


Figure 2: Concrete compacting factor versus w/c

The compacting factor result (Figure 2) shows similar trend to the slump test result in terms of water cement ratio and INS. Split Tensile Strength of INS Hardened Concrete.

This test was carried out in accordance with BS EN 12390-6 (2000). The INS-Split-Tensile strength results (Figures 3) indicated reduction in strengths as the water-cement ratio increased.



The split tensile strength increased up to 40% INS and reduced at 50% INS and 60% INS substitutes of granite for water-cement ratio of 0.4, 0.5, 0.6 and 0.7.

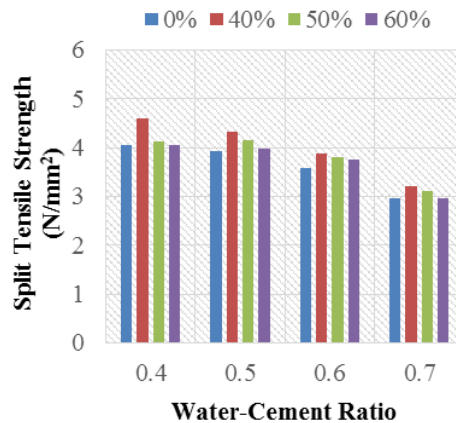


Figure 3: INS-Splitting strength versus w/c

The optimum replacement of INS-Hardened-Cylindrical-Concrete splitting strength at twenty-eight days was found to be 40% for all water-cement ratio. The result corresponds to the previous study by Kothai and Malathy (2013) and Qurishee *et al.*, (2016).

#### Flexural Strength of INS Hardened Concrete

This test was carried out in accordance with BS EN 12390-5 (2009). The INS-Flexural strength (Figures 4) also indicated reduction in flexural strengths as the water-cement ratio increased. The flexural strength increased up to 40% INS and reduced at 50% INS and 60% INS substitutes of granite for water-cement ratio of 0.5, 0.6 and 0.7. However, for water-cement ratio of 0.4, the flexural strength reduced as the granite substitute with INS increased up to 40% INS and witnessed increment in flexural strength at 50% INS but the strength further reduced at 60% INS.

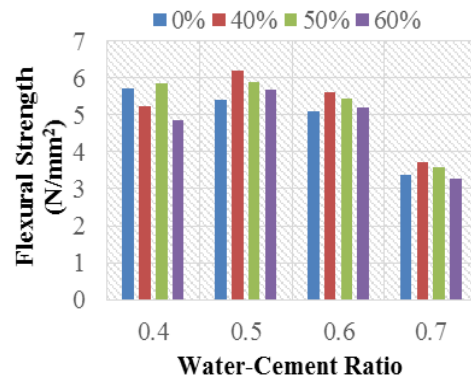


Figure 4: INS-Flexural strength versus w/c

The optimum replacement at twenty-eight days with highest flexural strength for water-cement ratio of 0.4 was 50% INS while 40% INS was found to be the optimum replacement for water-cement ratio of 0.5, 0.6 and 0.7. The maximum flexural strength with 40% INS is in agreement with the previous finding by Kothai and Malathy (2013) while 50% INS with maximum FS at W-C of 0.4 correspond to the study of Sharma *et al.*, (2015).

## CONCLUSION

The workability of the INS-Fresh-Concrete-Mix shows that the concrete became more workable with increase in water cement ratio and became stiffened as the INS contents increased. Similarly, the split tensile and flexural strengths of the hardened concrete decreased with increased in water cement ratios while addition of steel slag improved concrete properties. Utilization of 40% INS would be sustainable for mix ratio 1:2:4 concrete production thereby reducing environmental pollution.

## REFERENCES

Adedokun, S. I. Ajamu, S. O. and Aderinto, H. T., 2016. Effect of synthetic hair fibre additions on the strength characteristics of concrete, USEP: Journal of Research in Civil Engineering, 13(2), pp. 928-939.

- Adedokun, S.I. Anifowose, M.A. and Odeyemi, S.O., 2018. Assessment of steel slag as replacement for coarse aggregate in concrete: a review, ACTA TECHNICA CORVINIENSIS–Bulletin of Engineering Journal, 11(4), pp.139-146.
- Anifowose, M.A. Adeyemi, A.O. Odeyemi, S.O. Abdulwahab, R. and Mudashiru, R.B., 2019. Comparative study of ikirun and osogbo slag on concrete grade 20, Nigerian Journal of Technology (NIJOTECH), 38(2), pp. 283-288. doi:10.4314/njt.v38i2.2
- BS EN 1097-6., 2013. Tests for mechanical and physical properties of aggregates: determination of particle density and water absorption, British Standards Institutions, London.
- BS EN 12350-2., 2009. Testing fresh concrete: slump test, British Standards Institutions, London.
- BS EN 12390-5., 2009. Testing hardened concrete - flexural strength of test specimens, British Standards Institutions, London.
- BS EN 12390-6., 2000. Testing hardened concrete - tensile splitting strength of test specimens. British Standards Institutions, London.
- BS 812:110., 1990. Testing aggregate: methods for determination of aggregate crushing value (acv), British Standards Institutions, London.
- BS 812:112., 1990. Testing aggregate: methods for determination of aggregate impact value (aiv), British Standards Institutions, London.
- BS 882., 1992. Specification for aggregates from natural sources for concrete, British Standards Institutions, London.
- BS 1377-2., 1990. Methods of test for soil for civil engineering purposes, British Standards Institutions, London.
- BS 1881:103., 1983. Testing concrete: method for determination of compacting factor, British Standards Institutions, London.
- Kothai, P.S. and Malathy, R., 2013. Enhancement of concrete properties by steel slag as a partial replacement material for coarse aggregates, Australian Journal of Basic and Applied Sciences, 7(12), pp. 278-285.
- Olonade, K.A. Kadiri, M.B. and Aderemi, P.O., 2015. Performance of steel slag as fine aggregate in structural concrete, Nigerian Journal of Technology (NIJOTECH), 34(3), pp. 452-458. doi:10.4314/njt.v34i3.4

- Padmapriya, R. Bupesh Raja, V.K. Kumar, V.G. and Baalamurugan J., 2015. Study on replacement of coarse aggregate by steel slag and fine aggregate by manufacturing sand in concrete. *International Journal of ChemTech Research*, 8(4), pp. 1721-1729.
- Qurishee, M.A. Iqbal, I.T. Islam, M.S. and Islam, M.M., 2016. Use of slag as coarse aggregate and its effect on mechanical properties of concrete, *Proceedings of the 3rd International Conference on Advances in Civil Engineering*, CUET, Chittagong, Bangladesh, pp. 475-479.
- Raheem, A.A. Adedokun, S.I. Ajayi, B.R. Adedoyin, O.A. and Adegboyega, B.O., 2017a. Application of saw dust ash as partial replacement for cement in the production of interlocking paving stones, *International Journal of Sustainable Construction Engineering and Technology*, 8(1), pp. 1-11.
- Raheem, A.A. Adedokun, S.I. Adeyinka, E.A. and Adewole, B.V., 2017b. Application of corn stalk ash as partial replacement for cement in the production of interlocking paving stones, *International Journal of Engineering Research in Africa*, 30, pp. 85-93.
- Raheem, A.A. Adedokun, S.I. Uthman, Q.A. Adeyemi, A.O. and Oyeniyi, O.M., 2018. Application of corn husk ash as partial replacement for cement in the production of interlocking paving stones, *LAUTECH Journal of Civil and Environmental Studies*, 1(1), pp. 14-20.
- Sharma, G. Goyal, R. Gupta, A. and Sharma, D., 2015. Beneficial effects of steel slag on concrete. *International journal of Recent Research Aspects*, 2(2), pp. 51-57.
- Yi, H. Xu, G. Cheng, H. Wang, J. Wan, Y. and Chen, H., 2012. An Overview of utilization of steel slag, *Proceedings of the 7th International Conference on Waste Management and Technology*, *Procedia Environmental Sciences* 16, pp. 791-801.

## **FACTORS INFLUENCING TIME PERFORMANCE OF CONTRACTORS ON CONSTRUCTION PROJECTS IN OSUN STATE, NIGERIA**

Ademola, S. A.<sup>1</sup>, Akomolafe, M. A.<sup>1</sup> and Buari, T. A.<sup>2</sup>

Department of Building Technology, Osun State Polytechnic, Iree, Osun State.)<sup>1</sup>

Department of Building Technology, Federal Polytechnic, Ede, Osun State)<sup>2</sup>

Email of Corresponding Author: ([sakariyauademola@gmail.com](mailto:sakariyauademola@gmail.com))

### **ABSTRACT**

Time performance is one of the primary parameters used in measuring success of construction projects. The significance of time performance cannot be underestimated due to its effect on the cost of the construction project. This study examined the effect of time performance on construction projects execution and the perceptions of major players in the construction industry on factors influencing time performance of construction contractors in Osun State, Nigeria. Despite several studies conducted by scholars on construction performance, the construction industry has continued to grapple with the challenge of time performance. The significant contribution of the construction industry to the GDP of developed and developing nations necessitates further study to address poor time performance in construction project delivery. The study reports on the perception of the major players in the construction industry on factors influencing time performance of construction contractors and the perception of clients and users of time performance of the construction contractors in Osun State, Nigeria. A quantitative research approach was adopted through administration of questionnaire to randomly selected respondents. The data obtained from respondents were analyzed using SPSS version 23 through descriptive statistics by ranking and the use of percentages. The study found that the factors that influence time performance of contractors depends largely on Ineffective project planning and scheduling by the contractor which ranked first with a mean score of **4.08** followed by financial capability of the client with a mean score of **3.93** and poor site management with a mean score of **3.92**. Users' perception also shows that Satisfaction with quality ranked highest with a mean score of **4.02** followed by timely completion that has a mean score of **3.74** and conformity with stakeholders' expectation with a mean score of **3.72**.

**Keywords:** Time performance, Construction Projects, Project delivery and Construction Contractors.

### **Introduction**

Construction period is the period that is required to finish the work, starting from site handover until completion and the final handover of the completed project. “Duration” is the time, normally within times, instituted in accordance with perfecting the whole project besides beginning the preceding challenge after finishing the last one ( Baker and Baker 2003). Estimating the period of duties is very important. According to Chan and Kumaraswamy, (1997), projects which are completed within the stipulated time, on budget and of good quality are said to be the successful project while Rwelamilla and Hall (1995) are of the opinion that for a building project to be considered successful, the project is required to be completed within the predetermined completion period as stated in the contract document.

In the last two decades, researchers have identified enhancement strategies with respect to time performance in construction projects (Aftab, Nadizira and Noor, 2014). Improvement techniques are integral moves to limit losses. Proper planning and prompt settlement of contractor’s bill by the client are the basic enhancing measures to improve time performance of contractors. Aftab, Ismail and Ade (2012), defined time overrun as late completion of works when compared with the planned schedule or contract schedule while Ali *et al.* (2012), are of the opinion that time overrun is encountered in the construction industry all over the world. Aftab, Ismail and Ade (2012) revealed in their findings that 92% of the construction projects worked upon had time overrun and only 8% were completed within the contract duration. This can be considerably mitigated when the underlying causes are identified. It is also fundamental that contractors give more attention to adequate planning and scheduling. This further necessitated improvement techniques so as to moderate and also avert time overrun. The improvement strategies to adopt rely on the factors that contribute to delay of construction project.

Enshassi, Mohammed and Abushaban (2009) noted that the contractors should be encouraged to hire quality and skilled workers in the building industry so as to have good managerial and technical personnel on the project. They maintained that if this done it will improve the time performance of the contractors. Time performance can be better worked from regular time hours or job by using shifts. Similarly, regular site meetings in every purposeful group are

helpful to grasp the construction problems at different levels. Also, the organisation can advocate an alternative to construction method or utilize exceptional technological know-how to enhance the time performance. Numerous studies have been undertaken to improve time performance in construction project. However, clients' perceptions with regards to time performance of construction contractors have not been largely explored. Consequently, this study seeks to identify factors that influence time performance on construction projects and further provides interventions towards timely delivery of construction projects in Osun State, Nigeria

## **Literature Review**

### **Time Performance and Delay in Construction Project**

Delay in construction could be described as an action and event that extends beyond the required time in conformity with performing the construction of a contract (Sweis *et al.* 2008) and are of the opinion that delay often gives additional days of work. According to Assaf and Alhejj (2006), extension of time could be defined as the time overrun both beyond ending date designated in a contract, or beyond the date that the parties agreed to on the delivery of a project. It is a project shedding above its deliberate time table and is considered common problem in construction projects. In some cases, to the contractor, delay connotes higher overhead expenses as a result of longer duty period, high material charges through inflation, and due to labour cost increase.

Aibinu and Jagboro, (2002) described delay as a situation where the contractor and the project owner at the same time make a contribution to the non- finishing of the project within the agreed arrangement time. Delays in building project are often expensive, considering the fact that generally, construction projects are financed through foreign loans involving charges, expenses interest, administration of workers devoted to the construction whose prices are time reliant, and ceaseless inflation of salary and material costs. Construction project cost may be described as the aggregate concerning dedication in terms of cash as is required in conformity with occurrence of a construction project such as building. Construction project price represent all these items included under the headings of the expenses (Ashworth, 1997).

As indicated by Frimpong, Oluwoye and Crawford (2003), construction project everywhere in the world is dealing with delays in finishing their projects due to extraordinary reasons. Various elements are observed to have extended the required time of construction project. They further

noted that many scholars stressed the magnitude of proactive measures to identify the delays of development projects and discovered the accomplishment remedies in overcoming the delays.

Sweis *et al.* (2008) are of the view that delay occurs in all types of construction projects whether small or large, simple or complex and asserted that it is very difficult to analyse because there are large numbers of activities involved in any construction project. Such activities encompass dealing with excessive weather, scarcity of resources, financial issues faced by public corporations and contractors, bad contract management, shortages of materials, and inadequate resources. According to Sambasivan and Soon (2007) improper planning by contractor, inefficient site management and inadequate experience of the contractor are the major causes of delay. While writing about contractor related delaying factors. Odeh and Battaineh (2002) identified that the major issues related to contractors are the poor site management, sub-contractors inadequate planning approaches used for construction and insufficient experience of the main contractors. Chan and Kumaraswamy (1996) conducted a study to establish or consider the relative appreciation of the various factors causing delays in Hong Kong construction projects. They analyzed and ranked primary motives for delays or labeled them into two groups: the position on the events in the regional building project (clients, consultants or contractors) and the type of projects.

Frimpong, Oluwoye and Crawford (2003) conducted a study so as to identify and assess the relative importance regarding tremendous factors contributing to delay and cost overruns in Ghana groundwater construction projects. The result revealed that the foremost causes of delay and cost overruns in construction of groundwater projects are monthly payment difficulties from agencies; poor contractor management, material procurement, poor technical performance and material cost escalation.

Assaf and Alhejj. (2006) recognized 56 principal reasons of delay in Saudi Arabia large building construction projects and their relative importance. Based on the contractors surveyed, the major important delay factors were: preparation and approval of drawings, delays in contractor's progress, payment by the proprietors and design changes. From the view of the architects and engineers the cash issues all through construction, the alliance of subcontractors and the slow decision process concerning the owner have been the primary motives regarding delay. However, the proprietors agreed that design errors, labour shortages and insufficient action abilities have been essential delay factors.



### **Improvement Method on Time Performance**

Construction period can be defined as the duration of a project starting from the date stated in the contract or provisional finishing dates vital to phases of the work. It may also be described as the period that is required to finish the work starting from site handover until finished. “Duration” is the time, normally within times, instituted in accordance with perfecting the whole project beside beginning the preceding challenge after finishing the last one ( Baker and Baker, 2003). Estimating the period of construction work is very important. This is like trying to predict the future.

Aftab, Nadizira and Noor (2014) stated that to achieve a successful construction project, one of the fundamental conditions is that the building project needs to be completed within the stipulated contract duration. They also opined that during the last two decades, numerous researchers have suggested many enhancement strategies to tackle the problems of time performance in the construction projects. Park and Park (2012) also opined that construction time is increasingly important because it often serve as a crucial benchmarking for assessing the performance of a project and the efficiency of the project organization. It is therefore important to take necessary action to improve the estimated activity duration to be able to finish the project within the estimated time.

Improvement techniques are integral moves to limit losses. Proper planning and prompt settlement of contractors’ bill by the clients are the basic enhancing measures to enhance time performance of contractors. Abdul Rahman (1995) identified the improvement techniques to mitigate and also recover the time overrun. However, the improvement strategies to be adopted will rely on the type of problems that cause the delay of building project.

Time performance can be better worked from regular time hours or job by using shifts. Similarly, regular site meetings in every purposeful group are helpful to grasp the construction problems at different levels and the administration can advocate an alternative to construction method or utilizes exceptional technological know-how to enhance the time performance. In figuring out common improvement methods, a total of thirteen strategies had been identified by Sambavisan and Soon (2007) through review of previous works which were considered for further investigation to find the effectiveness of these improvement methods in the Malaysian construction industry. These improvement methods were also adopted in Nigeria for this study

using Osun State as a case study. The thirteen (13) recognized improvement methods are listed below:

- i. Proper Planning and scheduling on work.
- ii. Committed partnership or management.
- iii. Close power of work.
- iv. Send clear or completed news in conformity with employee so as to secure effective communication.
- v. Hire older people in order to reap honest progress, keep away from bad virtue regarding work, extra rectification and doubled handling.
- vi. Focus on the quality, longevity price and delivery regarding the project.
- vii. Training and improvement of entire party in conformity with aid delivery process.
- viii. Fully utilizes the construction team.
- ix. Use instant construction applied sciences (IBS- Industrialize Building System).
- x. Focus of clients need.
- xi. Provide knowledge/training in accordance with inexperienced employees based on their scope of work.
- xii. Adoption of equipment and strategies.
- xiii. Measure performance in opposition to other projects.

### **Methodology**

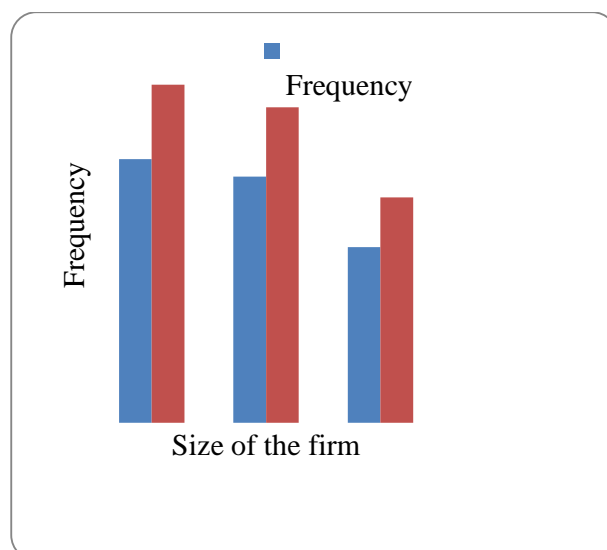
The study was undertaken in Osun State due to massive building and civil engineering construction projects that were embarked upon by the state government in the last eight years. A quantitative research technique was adopted through questionnaire to achieve the purpose of the study. The population of this research work consists of registered construction experts such as Architects, Engineers, Builders, Quantity Surveyors and other professionals in the built environment who are working with the client, contractor or the consultant. The sample was drawn from a list of registered construction contractors, clients and the consultants. These sets of population were chosen due to their huge participation in the construction process of

building and infrastructural projects. A random research design was used where samples were drawn randomly and subsequently administered questionnaire to clients or his representative, the consultants and the contractors or their representatives. A structured questionnaire was used as the principal instrument for obtaining primary data in form of responses from the respondents. One hundred (100) questionnaires were distributed while a total of seventy eight (78) were retrieved which is 78% of the questionnaires that were distributed which was considered adequate to achieve the objectives of the study. The secondary data used for this study were obtained from data that have been collected, classified, analyzed and published in textbooks, magazines, journal articles, bulletins, newspapers and other researchers. The data obtained from the study were analyzed by the use of statistical package for social sciences (SPSS) version 23. Descriptive statistics was employed for analyzing the data. The Mean Item Score was calculated and ranked from the highest to the lowest. The Ordinal Likert scale was arranged and calculated using the formula;

$$\text{Mean Item Score} = \frac{5n^5 + 4n^4 + 3n^3 + 2n^2 + 1n^1}{5N}$$

### **Results and Discussion of Findings**

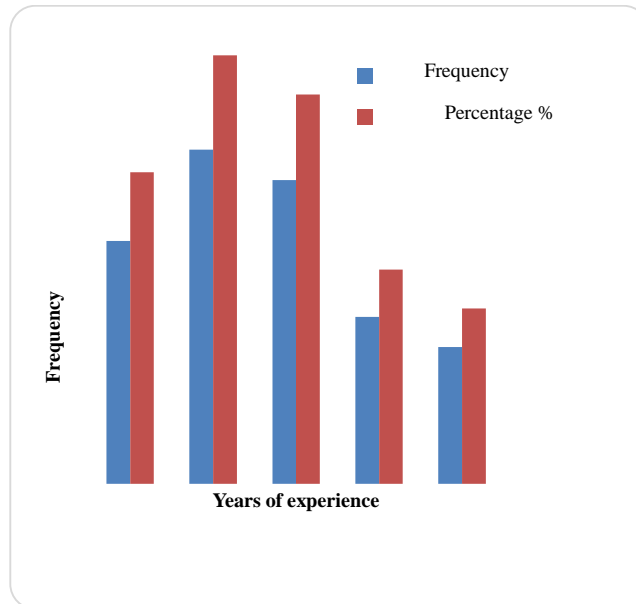
This section presents the results and discussion of findings of the study. Consequently, the result of this study, its conclusion and proposed recommendations were exclusively based on the number of seventy eight (78) questionnaires that were duly completed, retrieved and analysed.



### Figure 1: Size of Construction Firm

Source: Authors field work 2018

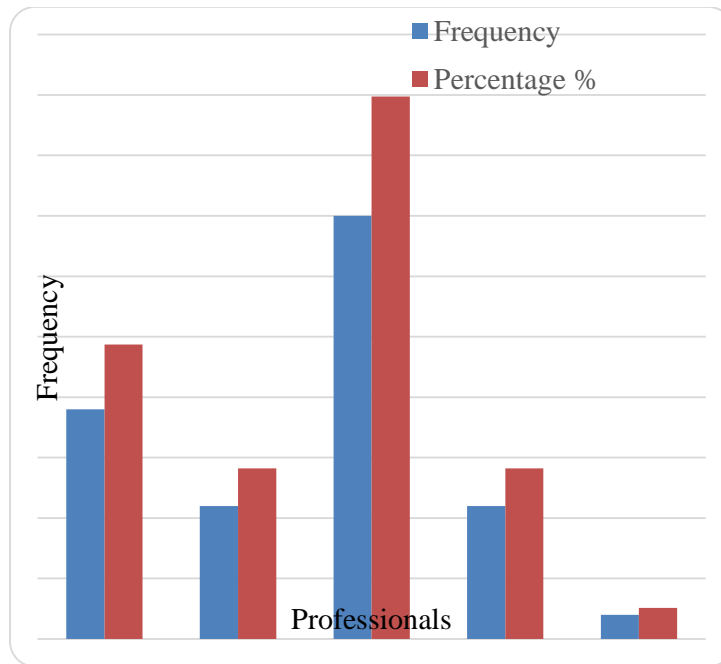
Figure 1 indicates that 38.46 of the respondents work with Large Construction Firms, 35.46 with Medium construction Firm while the remaining 25.64 work with Small Construction Firms.



### Figure 2: Year of Experience of Respondents

Source: Authors field work 2018

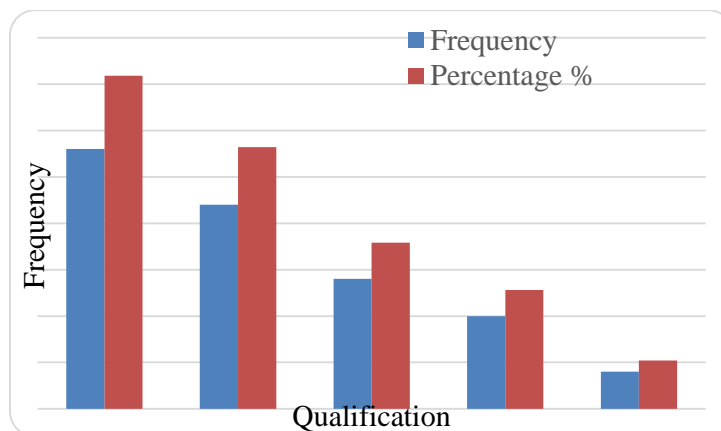
Figure 2 reveals that only 20.51% of the respondents have less than 5 years' experience in construction works, 28.21% of respondents have between 6-10 years' experience, 25.64% have 11-15 years' experience, 14.10% of respondents have between 16-20 years' experience while 11.54% of respondents have over 20 years' experience. Therefore, from the analysis, it can be deduced that the number of respondents involved in highest statistics have experience of between 6-10 years; hence, the researcher considered the data to be dependable.



**Figure 3: Designation of respondents**

*Source: Authors fieldwork 2018*

Figure 3 illustrates that 24.36% of the respondents are Builders, 14.1% are Architects, 44.88% are Engineers, while 14.1% are Quantity Surveyors and 2.56% are from other professions but also in the built environment. This shows that all the respondents were from relevant professions and highly competent and qualified to respond to the questionnaires.



**Figure 4: Qualification of Respondents**

*Source: Authors fieldwork (2018)*

Figure 4 above, 35.9% of the respondents are HND holders, 28.2% are BSc/B.Tech holders, 17.9% are PGD holders, 12.8% are M.Sc/M.Tech holders, while 5.2% are holders of other certificates. This showed that the respondents have adequate academic qualification to respond to the questionnaires.

**Table 1: Evaluation of Factors Influencing Time Performance of Contractors on Construction Projects Delivery**

<b>Factors</b>	<b>Freq.</b>	<b>Mean</b>	<b>Ranking</b>
Ineffective project planning and scheduling	78	4.08	<b>1</b>
Financial difficulties of owner	78	3.93	<b>2</b>
Poor site management and supervision	78	3.92	<b>3</b>
Delay in site delivery	78	3.90	<b>4</b>
Unqualified/inexperience workers	78	3.86	<b>5</b>
Delay in payments	78	3.79	<b>6</b>
Design changes by owner in construction	78	3.78	<b>7</b>
Unrealistic contract duration and requirement	78	3.66	<b>8</b>
Frequent design changes	78	3.64	<b>9</b>
Delay in decision making	78	3.61	<b>10</b>
Lack of experience	78	3.61	<b>11</b>

Owner interference	78	3.51	<b>12</b>
Delay in performing inspection and testing	78	3.50	<b>13</b>
Slowness in decision making	78	3.50	<b>14</b>
Mistake during construction	78	3.49	<b>15</b>
Delay preparation and approval of drawing	78	3.46	<b>16</b>
Late delivery of materials	78	3.43	<b>17</b>
Poor communication and coordination	78	3.40	<b>18</b>
Unreliable subcontractor	78	3.34	<b>19</b>
Delay in approving design documents	78	3.17	<b>20</b>
Change orders	78	3.16	<b>21</b>
Accident on site	78	4.11	<b>22</b>

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Source: *Authors fieldwork (2018)*

The result in Table 5 showed that ineffective project planning and scheduling is the predominant factor influencing time performance of construction projects in Osun State, Nigeria as it rated first with a mean score of **4.08** while financial difficulties of owner rated second with mean score of **3.93** and poor site management and supervision ranked third with a mean score of **3.92**. The result also indicated that the other factors have closely related mean scores. The assertion negates the remark of Anderson & Mc Adam (2004) which stated that performance difficulty comes up in large construction projects due to numerous reasons namely: incompetent designers/contractors, poor estimation, change in management, social and

technological issues, site related issues and improper techniques and tools. In the same vein, it also negates Cordero (1990) that earlier pointed that the main performance problem can be divided into two groups: (a) unrealistic target setting (b) causes originating from the actual construction (in many cases the causes for deviation originate from both sources). It is however concluded from the result of this study that ineffective project planning and scheduling is the predominant ranking factor influencing time performance of contractors on construction projects in Osun State, Nigeria.

**Table 2: Evaluation of Users'/client Perception of Time Performance of Construction Contractor on Project Delivery**

<b>Factors</b>	<b>Freq.</b>	<b>Mean</b>	<b>Ranking</b>
Satisfaction with the quality	78	4.02	<b>1</b>
Timely completion	78	3.74	<b>2</b>
Conform to stakeholders' expectations	78	3.72	<b>3</b>
Meet user's requirement	78	3.68	<b>4</b>
Effectiveness of performance	78	3.61	<b>5</b>
Project completed on budget	78	3.55	<b>6</b>
Availability of maintenance plan	78	3.50	<b>7</b>
Efficient use of resources	78	3.48	<b>8</b>
Minimized construction aggravations & disputes	78	3.39	<b>9</b>

Source: *Author's fieldwork (2018)*



Table 7 reveals that satisfaction with the quality is the greatest perception of client on time performance of construction contractors as it is ranked first with mean score of **4.02**, followed by timely completion which took **3.74** and ranked second, and conform to stakeholders' expectations which is also **3.72** closely related and ranked third with mean score of. As a result, it could be deduced that time performance of construction contractors lead to users'/clients satisfaction. Hence, the need for construction contractors to consider time performance as a serious tool in construction projects delivery. This result is in line with Chan and Chan (2004) result that found that client/user /customer satisfaction is an important target of all construction projects and hence should be considered when evaluating project performance.

## **Conclusion**

From the study, the following conclusions were drawn

- (i) Ineffective project planning and scheduling is the most ranking factor causing time performance of construction projects as it is rated first with a mean score of **4.08** and financial difficulties of owner is rated second with mean score of **3.93**.
- (ii) Satisfaction with the quality is the greatest perception of client on time performance of construction contractors as it is ranked first with mean score of **4.02**, followed by timely completion which took **3.74** and ranked second, and conform to stakeholders' expectations which are also closely related and ranked third with mean score of **3.72**. As a result, it could be deduced that time performance of construction contractors lead to users'/clients satisfaction.

## **Recommendations**

Within the limit of this research, the following recommendations were made:

- (i) The contractor's management should always see to the proper planning and scheduling of work so as to have effective time performance on construction project so as to facilitate timely delivery of construction project.
- (ii) Contractors should also consider Satisfaction of the users very important by making sure that users of the product of their construction works are satisfied with the quality of the work.
- (iii) Management of the construction contractors should attach utmost importance to the provision of adequate tools/equipment to the their operatives in order to stimulate

their time performance and prevent time overrun, cost overrun and also ensure good quality of the work.

## **REFERENCES**

- Abdul-Rahman, H. (1995) —The Cost of Non-conformance During a Highway Project: A Case Study. *Construction Management and Economics*, 13, 23-32
- Aftab, H. M., Nadzirah, R. and Noor, Y. Z., (2014). Improving Time Performance in Construction Projects Perspective of Contractor: *Journal of American Science* 10 (8), 45 – 50.
- Ali *et al.* (2012). Indicators for Measuring Performance of Building Construction Companies in Kingdom of Saudi Arabia. *Journal of King Saad University –Engineering Services* 25, 125-134.
- Aibinu A. A. and Jagboro G. O. (2002). The Effects of Construction Delays on Project Delivery in Nigerian Construction Industry. *International Journal of Project Management*, 20(8), 593-599.
- Anderson, K. and McAdam, R. (2004). A Critique of Benchmarking and Performance and Mitigating Measures in Practice. *Construction Management and Economics*, 28, 509-526.
- Ashworth, 1997; and Chinyio *et al.*, (1998), employee measures (Bititci, 1994; Shah and Murphy, 1995; and Abdel-Razek, 1997), Project Performance Measures (Belassi and Tukel, 1996) and Industry Measures (Latham, 1994; Egan, 1998; Construction Productivity Network, 1998; and Construction Industry Board, 1998); as cited in (Mbugua *et al.*, 1999).
- Assaf, S. A and Alhejj S. (2006). Causes of Delay in Large Construction Projects. *International Journal of Project Management*, 24 (4), 349-357.
- Chan, A. P., & Chan, D. W. (2004). Developing a Benchmark Model for Project Construction Time Performance in Hong Kong. *Building and Environment*, 39(3), 339-349.

- Chan, D. and Kumaraswamy, M. (1996). An Evaluation of Construction Time Performance in the Building Industry. *Journal of Building and Environment*, 96, 569-578.
- Cordero, R. (1990). The Measurement of Innovation Performance in the Firm: An Overview. *Research Policy*, 19(2), 185-192.
- Enshassi, A., Mohammed, S., & Abushaban, S (2009). Factors Affecting the Performance of Construction Projects in the Gaza Strip. *Journal of Civil Engineering and Management*, 15(3), 269-280.
- Frimpong, Y., Oluwoye, J., & Crawford, L. (2003). Causes of Delay and Cost Overruns in Construction of Groundwater Projects in Developing Countries; Ghana as a Case Study. *International Journal of Project Management*, 21(5), 321-326.
- Kumaraswamy, M. (1997). Conflicts, Claims and Disputes. *Engineering, Construction and Architectural Management*, 4(2), 95-111.
- Odeh, A. M. and Battaineh, H. T. (2002). Causes of construction delay: traditional contracts. *International Journal of Project Management*, 20(1), 67-73.
- Park, Y. W., and Park, H. S. (2012). Weights for Construction Performance Impact Factors of Public Construction Project. *The Journal of the Korea Contents Association*, 12(8), 373-379.
- Sambasivan, M., and Soon, Y.W. (2007). Causes and Effects of Delays in Malaysian Construction Industry. *Journal of Project Management*, 25(5), 517-526.
- Baker, S and Baker, K (2003). *On Time On Budget; A Step-by-Step Guide for Managing Any Project*. Prentice Hall, Englewood Cliffs.
- Sweis, G., Sweis, R., Hammad, A.A. and Shboul, A., (2008). Delays in construction projects: The case of Jordan. *International Journal of Project Management*, 26(6), 665-674.

## **Comparison of Physicochemical properties of two varieties of cucumber (*Cucumis sativus*)**

Lamidi, W.A.<sup>1</sup>, Oyedun, T. D.<sup>1</sup> and Adesigbin, A.J.<sup>2</sup>

<sup>1</sup>*Department of Agronomy, College of Agriculture, Ejigbo Campus, Osun State University, Osogbo.*

<sup>2</sup>*Department of Agricultural and Bio-Environmental Engineering Technology, Federal Polytechnic, Ede, Osun State.*

Correspondence e-mail: [wasiu.agunbiade@uniosun.edu.ng](mailto:wasiu.agunbiade@uniosun.edu.ng); +2348135860977

### ABSTRACT

The research focused on the physical and chemical properties of two varieties of cucumber planted under the same environment. The varieties were snake (Fanfare) and prickling (English) cucumber types. Four physical parameters of cucumber namely: fruit length, circumference, weight and their temperatures at 10.00 hrs and 14.00 hrs were measured. Chemical properties measured were phenols, tannins, flavonoids, vitamin C, titrable percent, polyphenols, phytates, oxalates. Proximate analysis of the two varieties was also investigated. Data collected were statistically analyzed using statistical software (statistical 7.1) at 95% significance, also, student t-test was performed for the comparison between both varieties. Fruits' length, circumference and weights were higher for prickling variety than for snake variety. The proximate analysis revealed that English variety had higher moisture, higher ash and fibre content than fanfare variety. Moisture and ash contents were  $95.08 \pm 2.58$  and  $0.31 \pm 0.08$  respectively. Also, English cucumber varieties were lengthy and weightier than Fanfare variety; ( $22.06 \pm 0.38$  and  $2.50 \pm 0.01$  kg) for English compared to respective  $18.02 \pm 0.01$  and  $0.82 \pm 0.00$  kg of Fanfare cucumber. English cucumber provides more protein content (0.27%) and higher reducing carbohydrates content (3.54%). The comparison shows fanfare cucumber has a lower acid traits (pH of 5.31 and titratable acid value of 0.08 mEq/100 g), English cucumber (0.90%) shows higher trait of total carbohydrate content than fanfare cucumber (0.32%). but less crude proteins (English = 3.53 > 3.47 of Fanfare) and carbohydrates. Chemically, English variety has high anti oxidant properties than fanfare variety, thus increasing the yield of cucumber by farmers and their antioxidant properties may be done through the cultivation of prickling (English) variety.

**Keywords:** *environment, fanfare, oxidant properties, proximate, snake variety*

## **1.0 Introduction**

Cucumber (*Cucumis sativus*) is a widely cultivated plant in gourd family, *cucurbitacea*. It is a creeping vine that bears cucumiform fruits that are used as vegetables. There are three main types of cucumber namely: slicing, pickling and seedless, (Hawaii Agricultural Statistical Service, 1993). Cucumber is originally from south Asia, but it now grows on most continents, many different types of cucumber are traded on the global market, (Afangideh et al., 2005; Alan, 1989). Those cucumbers intended for pickling, called picklers, grow to about 7 to 10cm (3 to 4 in) long and 2.5cm (1 in) wide. Compared to slicers, picklers tend to be shorter, thicker, less regularly shaped, and have bumpy skin with tiny white or black-dotted spines. Cucumber fruit (*Cucumis sativus*) are cultivated in subtropical and tropical environments and are therefore native to many countries of the world (Eifediyi and Remison, 2010). The worldwide production of cucumber was 65 million tonnes in 2012, grown in an area of 2,109,650 ha (FAOSTAT, 2013). Cucumber is a highly perishable crop and the environmental conditions under which cucumber is produced, transported and displayed have a noteworthy effect on its keeping quality and loss. In most Sub - Saharan countries such as Nigeria, cucumber fruits are often kept and displayed on the shelves in market places, resulting in degreening, and other physiological deterioration associated with alterations in the nutritive values and quality parameters. Cucumbers are often eaten as a vegetable but they are scientifically considered a fruit as they contain enclosed seeds and develop from a flower (Adams et al., 1992; Chartzoulakis, 1992; Cook et al., 1988).

Cucumbers, like cantaloupes, squash, pumpkins and watermelons, are members of the cucurbit family of produce. According to Eifediyi and Remison (2010), the fruit is eaten fresh in salads with other vegetables because cucumber has high nutritional value which has a lot of nutrients in it. Hence, it is of utmost importance to determine and compare the physical and chemical properties of the varieties of cucumber to know the amount of micronutrient and the anti- nutrient present in the varieties and that is the reason why the project is considered very necessary and important. The aim of this study was to determine the nutritional values physically and chemically.

## **2.0 Materials and Methods**

The research was conducted at College of Agriculture, Ejigbo campus, Osun State University, Osogbo. The investigations and research was performed on cucumber fruits, the varieties of the seed used for this research were slicing and pickling cucumber.

### **2.1 Sampling**

The fanfare cucumber samples were purchased from three (3) main markets of Osogbo, namely ‘‘Orisunmibare’’ market, ‘‘Akindeko market, and ‘‘Igbonna’’ market, all in Osogbo, Osun State, (their source according to the seller was Osun State of Nigeria). Cucumber seed samples each of 10 kg were purchased from three various sellers per market. While the English cucumber was purchased in another market in Lagos State ‘‘Mile 12’’ market, ‘‘Shoprite’’ and ‘‘Agege’’ Market (their source according to the seller was Odeda in Ogun State of Nigeria). Thus, 30 kg of each cucumber were gathered per market leading to 180 kg (***30 kg \*2 varieties \*3 markets***) for overall cucumber samples purchased. The samples were then conveyed into laboratory for further analyses.

### **2.2 Physical characterization of two varieties of Cucumber (*cucumis sativus*)**

Five (5) physical parameters were assessed on the cucumber fruits, namely; length, circumference, weight, moisture and ash. The length and the circumference of the full fruit were estimated using a meter tape, and allowed the deduction of the general fruit shape. The fruit weight was measured using *a 2 digit scale (satorius) of 0.00 sensitivity*. The determination of the moisture was done followed the method proposed by Association of Analytical Chemists (AOAC). The moisture was assessed by drying 5g of cucumber fruit in an oven at 105<sup>0</sup>C till constant weight resulted after 24hr. The ash content was measured by incinerating 5g of oven dried cucumber into a muffle furnace at 55<sup>0</sup>c for 12hrs.

### **2.3 Determination of the chemical trend of cucumber fruits (Acidity)**

The acidity traits (pH and titratable acidity) were measured using AOAC methods, 10 grams of crushed sample were slurred in 100ml of distilled water. The resulting solution was filtered on microscope filter paper. The pH was then directly measured out by immersing the previously calibrated pH meter electrode in the filtrate. However 10ml of the filtrate was taken and titrated with NaOH solution 0.1n in the presence of phenolphthalein. The NaOH volume used into the sample for resulting to a persistent pink colour allowed the deduction of the titratable acidity given in mEq/100g of dried sample.

#### **2.4 Total soluble carbohydrates and reducing carbohydrates content**

Ethanol soluble carbohydrate was extracted for 1g of dried cucumber with 20ml of 10% (m/v) zinc acetate and 2 ml of 10% (m/v) oxalic acid. The extract was centrifuged at speed of 3000rpm for 10minutes, the ethanol residue was then evaporated from the extract upon a hot sand bath. Then, the extracted soluble carbohydrates were measured out. This operation consist of adding 0.9ml of distil water, 1ml of 5% (m/v) phenol, and 5ml of 96% sulfuric acid into 100ul of extract, then the absorbance was measured at 490 nm with 1ml of distilled water and 0.5 ml of 3, 5 dinitrosalicylic acid prior to the recording of the absorbance from the final solution at 540 nm with a spectrophotometer (PG instruments). Calibrations were performed with standard solutions of glucose and sucrose for recovering the three final total carbohydrates and reducing carbohydrates contents in the studied samples.

#### **2.5 Lipids, protein and fibres content**

Lipids were quantified from 10g of ground dried cucumber sample by solvent extraction using 300ml of n-hexane reagent and a soxhlet device for 7 hrs. The hexane oil mixture resulted from the extraction was recovered and separated with a rotavapor apparatus. The difference between the sample weight before and after the experiment allowed the estimation of the lipids content. Also, crude proteins was determined as the total nitrogen using Kjeldhal method, thus 1g of cucumber mash will be mineralized at 40<sup>0</sup>c for 2hr, with addition of concentrated sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) and potassium sulphate (K<sub>2</sub>SO<sub>4</sub>) catalyst. The min realization was diluted and distilled for 10mins. Thereafter, the distillate collected into a flask containing boric acid and methylen bromoscresol reagent ion , was titrated for the total nitrogen using ammonium sulphate ((NH<sub>4</sub>)<sub>2</sub> SO<sub>4</sub>). The crude protein content of the cucumber was deduced from the nitrogen level using 6.25 as conversion coefficient.

The determination of the crude fibers consists in the treatment of 2g of ground cucumber sample with 50ml of 0.25N sulphuric acid and 50ml of 0.31 N sodium hydroxide and filtration of the resulting solution upon Whatman paper. The residue was dried for 8h at 105°C before it is then incinerated at 550°C for 3h in the ovens. The final residue was weighed as crude fibres and will be expressed in percentage.

## **2.6 Total carbohydrates content and energy value**

Total carbohydrates and energy values were determined using calculation formulas accounting the moisture, fat, protein, ash contents and the energetic coefficients for macromolecules.

$$\text{TCC (\%)} = 100 - [\text{P} + \text{M} + \text{F} + \text{A}] \%$$
 ----Eqn 1

$$\text{CEV} = \frac{\text{KCa}}{100\text{g}} = [(4\text{P}) + (9\text{F}) + (4\text{C})]$$
 ----Eqn 2

TCC is total carbohydrates content, CEV is caloric energy value, P is the protein content, M is the moisture content, F is the fat content; A is the ash content, C is total carbohydrates content.

## **2.7 Polyphenols contents**

The phenol compounds were extracted from cucumber with methanol reagent. 1g of dried cucumber sample was homogenized in 10ml of methanol solution 70% v/v. The resulting mixture was centrifuged at 1000rpm for 10min. The pellet was recovered and treated likewise. The deriving supernatants were thus gathered into a masked flask and added with distilled water at 50ml. The total polyphenols content was measured using Folin-ciocalteu reagent, sodium carbonate solution (20% w/v) and distilled water. Essays were measured for their absorbance at 745nm with a spectrophotometer against standard gallic acid solutions that was taken as polyphenols control. The tannins content was deducted from the total polyphenols using vanillin reagent. Essays were measured for their absorbance at 500nm with a spectrophotometer against standard tannic acid solutions taken as tannins control. Flavonoids content was determined from the total polyphenols using aluminum chloride (10% w/v), potassium acetate (1M) and distilled water. Essays were



measured for their absorbance at 415 nm with a spectrophotometer against standard quercetin solutions taken as flavonoids control.

## **2.8 Vitamin C content, Oxalates content and Phytates content**

The vitamin C was evaluated from the cucumber using 2, 6-dichlorophenol-indophenol (DDCPIP) reagent. 10g of ground dried cucumber sample was dissolved into 40ml of metaphosphoric acid-acetic solution (2%, w/v). The resulted mixture was then centrifuged at 3000 rpm for 20 min. Thus, the supernatant was recovered, added with boiled distilled water for 50ml, and titrated with 2, 6-DCPIP solution (0.5g/l) previously calibrated with pure vitamin C solution. The oxalate content was determined with standard AOAC method. 2g of ground dried cucumber sample were homogenized into 200ml of distilled water and added with 20ml of 6N hydrochloric acid (HCl). The mixtures were then heated in boiling bath water for 1h, cooled, and filtered. The 2<sup>nd</sup> filtrate was treated with methyl red, (0.1% w/v), concentrated ammonia, heated, and filtered. The third filtrate were boiled, treated with calcium chloride (5%, w/v) for the formation of calcium oxalate crystals, and then filtered once again. The residues deriving from the filtration steps was successively washed with distilled boiling water, dried into an oven; dissolved into ml of diluted sulphuric acid, and titrated with 0.05N potassium permanganate solution. The phytates were measured according to the method processed by Mahmoud et al., (2009), a slight ground cucumber sample 0.5g were treated with 25ml of TCA solution at 3% (w/v) and centrifuged at 3500 rpm for 15min, 5 ml of supernatant was removed, treated with 3 ml of ferric chloride 1% (w/v) reagent, were heated in a boiling bath water, cooled and also centrifuged at 3500 rpm for 10 min. thus 1 ml of the final supernatant was added with 4.5 ml of distilled water and 4.5 ml of orthophenantroline reagent and then measured for the absorbance at 470 nm with a spectrophotometer against standard mohr salt solution treated likewise and taken as phytates ferric control.

## **2.9 Determination of mineral elements**

Finely ground cucumber sample of 0.4g previously oven dried at 60c was incinerated into a muffle furnace at 550c for 3hr. The resulting gray-white ash was cooled, added with 2ml of half-diluted HCl, it was placed on a sand bath at 120c until full evaporation, it was then ovened at 105c for 1hr. The final dry extract was recovered with 2ml of half-diluted HCl, filtered, and the resulting filtrate was added with distilled water, and ianthum chloride. The

mineral elements in the solution were then measured using atomic absorption spectrometry (AAS 20 type VARIAN).

## **2.10 Statistical analyses**

All essays were performed in triplicate. The data collected was statistically analyzed using statistical software (statistical 7.1) at 95% significance. A statistical student T- test was performed for the comparison between both varieties regarding each parameter accessed.

## **3.0 Results and Discussion**

### **3.1 Moisture and Ash content**

From the results, English cucumber has a moisture content of  $95.60 \pm 0.38^b$  while  $94.57 \pm 0.20^a$  was obtained from fanfare cucumber. This shows that both cucumbers have almost the same amount of moisture content. However, English cucumber has ash content of  $0.43 \pm 0.02^b$  and  $0.19 \pm 0.15^a$  recorded in fanfare cucumber, this indicates that English cucumber has a higher ash content than fanfare cucumber which implies that English cucumber will have higher mineral elements (macro and oligo elements) than fanfare cucumber.

### **3.2 Circumference, Length and Weight**

Table 3.1 shows higher size and weight from English cucumber ( $22.06 \pm 0.38^b$  and  $2.50 \pm 0.01^b$ ) compared to the respective  $18.02 \pm 0.01^a$  length and  $0.82 \pm 0.00^a$  weight of fanfare cucumber. This implies that English cucumber will have higher value in the market than fanfare cucumber; it also implies that fanfare cucumber will be readily available and common to the people.

### **3.3 pH (acidity)**

The comparison of the two cucumbers shows that fanfare cucumber has a lower acid traits of pH 5.31 and titratable acid value of 0.08mEq/100g compared to English cucumber pH of 6.54 and titratable acid value of 0.36mEq/100g. This implies that English cucumber is slightly acidic than fanfare cucumber.

### **3.4 Total Protein content, Fat Matter content and Total Fat content**

The comparison shows that English cucumber shows a higher protein content of 0.27% while fanfare cucumber shows a protein content of 0.19%. This implies that English cucumber is richer in protein and contributes more to building body tissues in the body. The comparison shows that English cucumber shows a higher percentage of Fat matter content of 6.74% than fanfare cucumber 4.72%. This implies that English cucumber is richer in Fat matter content than Fanfare cucumber. The comparison shows that English cucumber shows a Total fat content of 0.46% while Fanfare cucumber shows a total Fat content of 0.19%. This implies that English cucumber is richer in Total fat content than Fanfare cucumber.

### **3.5 Total carbohydrate content, reducing carbohydrate content and Total Glucides content**

The comparison of the two cucumbers show that English cucumber is very rich in Total carbohydrate content with a value of 0.90% while fanfare has a lower total carbohydrate content of 0.32%. This implies that English cucumber is richer in total carbohydrate content than Fanfare cucumber. The comparison shows that English cucumber is slightly higher in reducing carbohydrate content than fanfare cucumber. They both have a value of 3.54% and 3.48% respectively. The comparison shows that the English cucumber is richer in Glucides content with a value of 0.43% while Fanfare cucumber has a value of 0.19%. This implies that English cucumber has more total Glucides content than Fanfare cucumber.

### **3.6 Total caloric energy value**

The comparison shows that English cucumber has more Total caloric energy value (19.43%) than Fanfare cucumber with Total caloric energy value of 17.62%. This implies that English cucumber has more total caloric energy than Fanfare cucumber.

### **3.7 Polyphenol Compounds**

For polyphenols, the comparison shows that English cucumber has a Total polyphenols with a value of 7.45% while fanfare has a value of 6.62%. For tannins, the comparison shows that English cucumber has tannin of 1.56% while Fanfare cucumber has a value of 1.48%. This implies that English cucumber is richer in tannins. For flavonoids, the comparison shows that English cucumber has a flavonoid of 2.70% while Fanfare cucumber has a value of 2.63%. This implies that English cucumber is richer in flavonoids.

### 3.8 Vitamins and Minerals

The comparison between both cucumbers shows that English cucumber is richer in vitamins with a value of 4.85% while fanfare cucumber has a value of 4.34%. The comparison shows that English cucumber is richer in almost all the minerals tested for in the two cucumbers with a value of 14.30% phosphorus, 63.67% potassium, 0.38% calcium, 16.77% magnesium, 2.25% sodium, 13.50% iron, 11.63% manganese, 11.57% zinc and 0.01% copper while Fanfare cucumber has a value of 13.50% phosphorus, 53.43% potassium, 0.27% calcium, 14.47% magnesium, 1.85% sodium, 11.53% iron, 11.50% manganese, 11.50% zinc, 0.01% copper.

### 3.9 Anti-nutrients content

The comparison shows that English cucumber has an oxylate value of 5.17% while fanfare cucumber has an oxylate value of 2.25%. This implies that English cucumber has more oxylates than Fanfare cucumber. The comparison shows that English cucumber has a phytates value of 2.02% while fanfare cucumber has a value of 1.98%. This implies that English cucumber is richer in phytates than Fanfare cucumber.

Table 1: Some physical parameters of English cucumber and fanfare cucumber

Parameters	English cucumber	Fanfare cucumber	F value	p value
Length (cm)	22.06±0.38 <sup>b</sup>	18.02±0.01 <sup>a</sup>	4411.24	<.0001
Circumference	18.63±0.01 <sup>b</sup>	9.99±0.00 <sup>a</sup>	2786.43	0.0004
Weight (g)	2.50±0.01 <sup>b</sup>	0.82±0.00 <sup>a</sup>	40922.6	<.0001
Moisture (%)	95.60±0.38 <sup>b</sup>	94.57±0.20 <sup>a</sup>	19.64	0.047
Ash (%)	0.43±0.02 <sup>b</sup>	0.19±0.15 <sup>a</sup>	8.60	0.099
Temperature °C	27.30±0.00 <sup>a</sup>	26.60±0.00 <sup>b</sup>	Infinity	<.0001

Mean values with different superscripts are statistically different at 5% along the rows

**Table 2: Chemical composition of English cucumber and fanfare cucumber**

Parameters	English cucumber	Fanfare cucumber	F value	p value
<b>pH</b>	6.54±0.00 <sup>a</sup>	5.31±0.00 <sup>a</sup>		<.0001
<b>TTA %</b>	0.36±0.45 <sup>a</sup>	0.08±0.00 <sup>b</sup>	1.12	0.401
<b>TPC %</b>	0.27±0.02 <sup>b</sup>	0.19±0.01 <sup>a</sup>	625.00	0.002
<b>FMC %</b>	6.74±0.04 <sup>a</sup>	4.72±0.09 <sup>b</sup>	4945.08	0.0002
<b>TFC %</b>	0.46±0.02 <sup>b</sup>	0.19±0.02 <sup>a</sup>	20.16	0.079
<b>TCC %</b>	0.90±0.36 <sup>a</sup>	0.32±0.18 <sup>b</sup>	8.47	0.101
<b>RCC %</b>	3.54±0.03 <sup>a</sup>	3.48±0.02 <sup>b</sup>	15.43	0.059
<b>TGC, %</b>	0.43±0.02 <sup>b</sup>	0.19±0.15 <sup>a</sup>	8.60	0.362
<b>TEV kg</b>	19.43±0.03 <sup>a</sup>	17.62±0.85 <sup>b</sup>	5.81	0.137

Mean values with different superscripts are statistically different at 5% along the rows.

*TTA-total titratable acidity; TPC-total proteins content; FMC-fat matter content; TFC-total fibers content; TCC-total carbohydrates content; RCC-reducing carbohydrates content; TGC-total glucides content; TEV-total caloric energy value*

Both cucumbers have higher moisture value, over 95%. The high moisture content of cucumber is disadvantageous for their preservation since the crops could be submitted to rapid post-harvest change and rotting. This phenomenon has been previously observed from ripe palm fruit by Rosenheim et al., 1990.

English cucumber is more provided with proteins (0.27%) compared to Fanfare cucumber (0.19%). English cucumber contains higher fat content compared to fanfare cucumber (0.46 and 0.19%), that is more than the 0.14% lipid content in cooked spinach. Their total glucides content are also low (0.43% and 0.19%). Thus, they are not considered as glucides products since the glucides values are more strengthened from the common starchy products such as sweet potato (28.5%) according to the FAO. In evidence, the cucumbers are vegetable crops and are not really used as source of carbohydrates, nor lipids and proteins. So, they are advisable in low-calory dietaries. The English cucumber displays

fibre content around 6.74% while Fanfare cucumber displays a lower fibre content of 4.72%, a higher value compared to the 3.92% fibre recorded with the fresh dough processed from the new shoots tuber of *Borassus aethiopum*. However, these cucumbers could be significant sources of dietary fibers that are essential for the digestive balance in the intestinal duct and the stomach, (Razmjou et al., 2011; Stall, 1993; Hanna and Adams., 1991). Indeed, dietary fibers are factors of healthy body. Many studies have shown opposite correlation between consumption of dietary fibres and the upcoming of colon cancer. Dietary fibres can complex with carcinogenic molecules, thus preventing their contact with the colon and facilitating their excretion. English cucumber displays a Vitamin C of 4.85mg while Fanfare displays 4.34mg. The consumption of these cucumbers added with other vegetables richer in vitamins would be more beneficial. Vitamin C contributes in healthy bones, cartilage, teeth, and gums. It also protects against infections, accelerates healing and promotes the absorption of iron. Significant total polyphenols contents (around 7.04 mg/100 g) are recorded from the studied cucumbers, with any statistical change per variety. Most important parts of these polyphenols run for tannins (around 1.52 mg/100 g), while flavonoids are scarcely measured (2.67 mg/100 g). Polyphenols are credited with numerous health benefits, such as reduction of cardiovascular concerns, inflammatory or neurodegenerative diseases, cancer prevention, antiplatelet effects, blood pressure regulation, etc. But, because of low amount of tannins in cucumbers, it could be easily consumed fresh From their mineral composition, the cucumbers studied are provided with the same contents in macro elements (Ca, P, Mg, Na, K) and oligo elements (Fe, Zn, Cu, Mn).

**Table 3: Micronutrients, polyphenols compounds and anti- nutrients contents in English cucumber and fanfare cucumber**

Properties	English cucumber	Fanfare cucumber	F value	p value
<b>Total Polyphenol</b>	7.45±0.05 <sup>a</sup>	6.62±0.09 <sup>b</sup>	35.15	0.603
<b>Tannins</b>	1.56±0.13 <sup>a</sup>	1.48±0.03 <sup>b</sup>	2.00	0.293
<b>Flavonoid</b>	2.70±0.02 <sup>b</sup>	2.63±0.01 <sup>a</sup>	21.00	0.045

<b>Vit.C(mg/100)</b>	4.85±0.03 <sup>a</sup>	4.34±0.08 <sup>b</sup>	81.22	0.012
<b>Phosphorus</b>	14.30±0.20 <sup>b</sup>	13.50±0.20 <sup>a</sup>	12.00	0.074
<b>Potassium</b>	63.67±1.26 <sup>a</sup>	53.43±0.21 <sup>b</sup>	274.78	0.004
<b>Calcium</b>	0.38±0.03 <sup>a</sup>	0.27±0.02 <sup>b</sup>	38.44	0.025
<b>Magnesium</b>	16.77±0.15 <sup>a</sup>	14.47±0.35 <sup>b</sup>	226.71	0.004
<b>Sodium</b>	2.25±0.02 <sup>b</sup>	1.85±0.02 <sup>a</sup>	120.00	0.001
<b>Iron</b>	13.50±0.10 <sup>a</sup>	11.53±0.25 <sup>b</sup>	217.56	0.005
<b>Manganese</b>	11.63±0.15 <sup>a</sup>	11.50±0.17 <sup>b</sup>	0.84	0.456
<b>Zinc</b>	11.57±0.15 <sup>a</sup>	11.50±0.20 <sup>b</sup>	0.13	0.754
<b>Copper</b>	0.01±0.00 <sup>a</sup>	0.01±0.00 <sup>b</sup>	400.00	0.003
<b>Anti-nutrients oxalate</b>	5.17±0.03 <sup>b</sup>	2.25±0.03 <sup>a</sup>	0.02	0.908
<b>Phytates</b>	2.02±0.03 <sup>a</sup>	1.98±0.04 <sup>b</sup>	2.75	0.239

*Mean values with different superscripts are statistically different at 5% along the rows.*

Both cucumber shows in various medium circumference ( $14.31\pm 0.005$ ) and moisture and ash contents ( $95.08\pm 2.58$  and  $0.31\pm 0.08$  respectively). Oppositely, Table 1 shows higher size and weight from English cucumber ( $22.06\pm 0.38^b$  and  $2.50\pm 0.01^b$ ) compared to the respective  $18.02\pm 0.01^a$  length and  $0.82\pm 0.00^a$  weight of Fanfare cucumber. Except for the proteins and reducing carbohydrates contents and the acid values, the main chemical traits do not show any obvious divergence between English cucumber and Fanfare cucumber (Table 2). Indeed, English cucumber provides more protein content (0.27%) and higher reducing carbohydrates content (3.54%) compared to Fanfare cucumber (0.19% and 3.48%, respectively). Both cucumber varieties are highly acidic. However, the comparison shows fanfare cucumber has a lower acid traits (pH of 5.31 and titratable acid value of 0.08 mEq/100 g) compared to English cucumber (pH of 6.54 and acid value of 0.36 mEq/100 g). English cucumber (0.90%) shows higher trait of total carbohydrate content than fanfare cucumber (0.32%). Both studied cucumber provide statistically similar means for the contents in fat matter, total fibre, and total glucides, and for the energy value. For those characteristics, the respective general contents averages are 5.73%, 0.33%, and 0.31%, providing 18.53 Kcal/100 gas energy value (Table 2). The micronutrients, secondary

metabolites (polyphenols) and anti-nutrients in the cucumbers studied are gathered in Table 3. For polyphenols, the general contents averages from 100 g cucumber dried sample are 7.04 mg total polyphenols, 1.52 mg tannins, and 5.33 mg flavonoids; while the vitamin C content is measured 4.60 mg/100 g. From the main mineral elements, macro elements are measured between 2.05 ppm (Sodium) and 58.55% DM (phosphorous), when oligo elements oscillate from 0.01 ppm (copper) to 12.52 ppm (iron) as shown in Table 3. Besides, from the anti-nutrients compounds, English cucumber provides more oxalates content (5.17 mg/100 g) and phytates content (2.02 mg/100 g) compared to Fanfare (2.25 mg/100 g and 1.98 mg/100 g, respectively).

#### **4.0 Conclusion**

English cucumber and Fanfare cucumber contain macronutrients (carbohydrates, proteins, lipids) and several micronutrients (mineral elements, polyphenols, and vitamin) that highlight their significant nutritional potential.

#### **Recommendation**

Farmers should be encouraged to cultivate and grow English cucumber because of its nutritional value.

#### **References**

- Adams, P., C. J. Graves, and G. W. Winsor. 1992. Some responses of cucumber, grown in beds of peat, to N, K and Mg. *J. Hort. Sci.* 67:877-884.
- Afangideh, U., Uyoh, E.A., Ittah, M. and Uko, A.E. 2005. Morphological characterization of some cultivars of cucumber (*Cucumis sativus* L.). *J. Sustain. Trop. Agric. Res.*, 14: 13 - 18.
- Eifediyi, E.K. and Remison, S.U. 2010. Growth and yield of cucumber (*Cucumis sativus* L.) as influenced by farmyard manure and inorganic fertilizer. *Researcher*, 2(4): 1-6.
- Mahmoud, E., Abd EL- Kader, N., Robin, P., Akkal-Corfini, N. and Abd El-Rahman, L. 2009. Effects of Different Organic and Inorganic Fertilizers on Cucumber Yield and Some Soil Properties. *World J. Agric. Sci.*, 5 (4): 408-414.
- Razmjou, J, Mohammadi, M and Hassanpour, M. 2011. Effect of Vermicompost and Cucumber Cultivar on Population Growth Attributes of the Melon Aphid (Hemiptera: Aphididae). *Journal of Economic Entomology* 104(4): 1379-1383



Alan, R. 1989. The effect of nitrogen nutrition on growth, chemical composition, and response of cucumbers to N forms in solution culture. *J. Hort. Sci.* 64:467- 474.

Chartzoulakis, K. S. 1992. Effects of NaCl salinity on germination, growth and yield of greenhouse cucumber. *J. Hort. Sci.* 67:115-119.

Cook, W. P., R. P. Griffin, and C. E. Drye. 1988. Commercial slicing cucumber production. Clemson University Cooperative Extension Service Hort. Lf. 34.

Hanna, H. Y., and A. J. Adams. 1991. Staking fresh market cucumbers for higher yields: a long term research project. *Proc. Fla. Hort. Soc.* 104:237-240.

Hawaii Agricultural Statistical Service. 1993. Statistics of Hawaiian agriculture, 1992. Honolulu, HI. Hochmuth, G. J., ed. 1988.

Rosenheim, J. A., S. C. Welter, M. W. Johnson, R. F. L. Mau, and L. R. Gusukuma-Minuto. 1990. Direct feeding damage on cucumber by mixed-species infestations of Thrips palmi and Frankliniella occidentalis. *J. Econ. Entomol.* 83:1519-1525.

Stall, W. M. 1993. Weed control update for cucurbits. *Citrus and Veg. Mag.* (March):50.

## **A PARTICLE SWARM OPTIMIZATION (PSO) BASED SMART GRID APPLICATION FOR OPTIMUM SIZING OF HYBRID RENEWABLE ENERGY SYSTEMS IN NIGERIA**

Oyelami, S.<sup>1</sup>, Azeez, N. A.<sup>2\*</sup> and Ologunye, O. B.<sup>2</sup>

<sup>1</sup>Department of Mechanical Engineering, Osun State University, Osogbo, Nigeria

<sup>2</sup>Department of Mechanical Engineering Technology, Federal Polytechnic, Ede, Nigeria

\*E-mail: [azeeznurudeen08@gmail.com](mailto:azeeznurudeen08@gmail.com)

### **ABSTRACT**

A novel intelligent algorithm based on smart grid applications to determine the optimal size of grid-independent hybrid PV/wind/battery/diesel energy systems so as to meet the load requirements with minimum cost and highest reliability was introduced. Load shifting-based load priority was presented in this research as one of smart grid applications by dividing the load into two factions, high priority load (HPL) and low priority load (LPL). Demand profile improvement was carried out by shifting the LPL from low generation to high generation time. The logic used in this algorithm was designed to follow the value of the loss of load probability (LOLP) and the dummy energy (Edummy) to satisfy the aggregate load demand with a minimum value of levelized energy cost (LEC). The main objective of this algorithm is to optimize the system size so as to meet the load requirements with the minimum cost and the highest reliability. A comparison between the results obtained from PSO algorithm and those from the iterative optimization techniques (IOT) was introduced. Moreover, parallel implementation of PSO (PIPSO) is a new proposed method utilized in this research to distribute the evaluation of the fitness function and constraints among the readymade processors or cores, and to speed up the optimization process.

Keywords: Hybrid, Grid, Renewable Energy and PSO

### **INTRODUCTION**

One of the most important issues in the recent studies is to optimally size the Hybrid Renewable Energy System (HRES) components to meet all load requirements with possible minimum cost

and highest reliability. In view of the complexity of optimization of the HRES, it was imperative to discover effective optimization methods ready to get good optimization results especially, for the complex optimization problems.

Particle swarm optimization (PSO) was recommended as a standout amongst the most valuable and promising methods for optimizing the HRES because of using the global optimum to locate the best solution. PSO algorithm is designed based on swarm intelligence and used to handle the complex optimization problems Belfkira, Zhang and Barakat (2016).

PSO is considers an effective tool for nonlinear optimization problems. However, PSO sometimes requires a lengthy computing time to find the optimal solution. Parallel implementation of particle swarm optimization (PIPSO) is a set of parallel algorithms, in which the population is divided into sub-populations that advance autonomously. Every sub-population is allocated in each processor included in parallel computing. Diaf, Notton, Belhamel, Haddadi and Louche (2018).

The smart grid has recently started receiving great interest from various government organizations globally. Therefore, the smart grid and its applications are the focus of interest in this research especially in the field of renewable energy generation. In this research work, a proposed model of a hybrid renewable energy system (HRES) integrated with the smart grid was developed.

The hybrid system includes wind turbines (WT), photovoltaic (PV) arrays, diesel generator (DG), battery bank, charge controller, bidirectional converter, and load. A model for each component of the generation and load sides is introduced.

The hourly data of the wind speed, solar radiation, and temperature for five sites in Osun State are used as a case study. The main objective of this research work is to introduce an algorithm based on smart grid applications to solve the problem of sizing the HRES so as to meet the load requirements with the minimum cost and highest reliability.

## **REVIEW OF RELATED WORKS**

Gaviano, Weber and Dirmeier (2012). surveyed and summarized the smart grid applications for renewable energy generation and its potential study in the future. The authors affirmed that the communication between the electronic devices is a key technology in order to adapt renewable energies to the future grid infrastructure.

Ayompe, Duffy, McCormack and Conlon (2017) presented real-time energy models for small scale PV grid connected systems suitable for the domestic application. The models have been used to predict the real-time output power from the PV systems in Dublin, Ireland using 30 min intervals of measured data between April 2009 and March 2010. The future renewable electric energy delivery and management system (FREEDM) was one of the smart grid applications applied on the laboratory scale and proposed by NSF at the NSF FREEDM systems center, Raleigh, NC. Crow, McMillin, Wang and Bhattacharyya (2010).

The FREEDM system is a power distribution system that interfaces with residential and industry customers. The system operation is based on the belief that the key to avoid the energy crisis is not necessarily the renewable energy itself, but the infrastructure needed to deliver and manage large-scale distributed RES and energy storage. The objective of FREEDM is to have an efficient electric power grid integrating highly stochastic, distributed and scalable alternative generation sources and energy storage with the existing power systems.

Kohsri and Plangklang (2011). Proposed an energy management and control system for smart renewable energy generation. They used LAB-View technology as a basic design for the overall system. Their proposed system is constructed as PV/wind/diesel. The system itself can forecast and make a decision for future power management.

A linear programming technique has been introduced in Chedid and Rahman (2017) for optimum sizing of hybrid PV/wind/battery power system to feed a certain load with minimum system total cost. The total system cost consists of the initial cost, the running cost, and the maintenance cost.

Belfkira, Zhang and Barakat (2016) reported the practical interest of using the sizing methodology and showed the effect of the battery storage on the total cost of the HRES. These authors presented a deterministic algorithm that minimizes the total system cost while satisfying the load requirements of a stand-alone hybrid PV/wind/diesel energy system. This algorithm uses six months' data of wind speed, solar radiation, and temperature.

The main disadvantage of this algorithm is using a short-term meteorological data of wind speed, solar radiation, and temperature which reduces the system sizing accuracy. In addition,

this algorithm did not apply the smart grid applications when determining the optimum size of the system under study.

A study was introduced in celik (2013) for optimally sizing an autonomous hybrid PV/wind energy system with battery storage on techno-economic basis. The level of autonomy and the cost of the system were the targeted objectives of this study.

The author in this study used a numerical analysis based on 1994 weather data from the TyB experimental site of the Cardiff University. The main advantage of this study is that, it considers the monthly variation in the required size of HRES to overcome the limitations of the scenarios which select the optimum size based on the worst renewable month(s). However, this study did not take the smart grid applications into account.

An iterative optimization technique was introduced in Diaf, Notton, Belhamel, Haddadi and Louche (2018) for the techno-economic optimization of a hybrid PV/wind energy system with/without an uninterruptible power supply to supply certain load. The optimum size of HRES components and the lowest LEC were the main optimization objectives.

The authors compared the performances of HRES with and without the uninterruptible power supply and reported that the type of system configuration affects LEC and the battery state of charge (SOC), especially at low windy sites. Furthermore, the authors confirmed that the hybrid system is the best option for the systems understudy. However, the authors did not use the smart grid applications while determining the optimum system size.

## **METHODOLOGY**

PSO is an evolutionary technique which is inspired by the social behavior of bird flocking, fish schooling and swarm application. Each particle in the PSO algorithm represents a potential solution; these solutions are assessed by the optimization objective function to determine their fitness. In order to move to the optimum solution, particles move around in a multidimensional search space.

The best experience for each particle is stored in the particle memory and called local best particle (pbest) and the best global obtained among all particles is called as a global best particle (gbest). During flight the current position ( $x_i$ ) and velocity ( $v_i$ ) of each particle ( $i$ ) is

adapted according to its own experience and the experience of neighboring particles as described by the following equations:

$$v_i^{(g+1)} = \omega v_i^{(g)} + c_1 a_1 (pbest_i - x_i^{(g)}) + c_2 a_2 (gbest - x_i^{(g)}) \quad (1)$$

$$x_i^{(g+1)} = x_i^{(g)} + v_i^{(g+1)} \quad (2)$$

Velocity of the particles  $c_1$  and  $c_2$  are positive acceleration constants in a range of [0, 4], designated as self-confidence factor and swarm confidence factor, respectively. These factors provide an insight from a sociological stand point.  $c_1$  has a contribution towards the self-experience of particles.  $c_2$  has contribution towards the motion of the particles in global direction.  $a_1$  and  $a_2$  are uniform randomly generated numbers in a range of [0, 1].

Swarm size, the number of particles,  $x$ ,  $c_1$  and  $c_2$  are the main parameters of the PSO algorithm, which are initialized by the users, based on the problem being optimized.

This program can determine the optimum size of the HRES components for supplying the load demand with minimum LEC and within the specified limits of LOLP and Pdummy. Likewise, the program can choose the best site out of many available sites and select the most economic WT for this site.

In this program, the value of LOLP HPindex has been considered to be 4% and PLL sum index has been taken by (8 days of average LPL, 8 \_ PLave\_ low). Edummy min and Edummy max have been considered to be 0%, 4% of LAE, respectively.

The process of the PSO algorithm is shown in Figure 1. To run NPPBPSO, the following information must be accessible:

- Initial values of PSO parameters, swarm size, the number of particles,  $x$ ,  $c_1$  and  $c_2$ .
- The optimum design values; LOLP HPindex, PLL sum index, Edummy min and Edummy max.
- The geographic data of the sites under study and meteorological data of wind speed, solar radiation, and temperature at these sites.
- Specification of WT, PV modules, inverter, batteries, and diesel generator.

- The load power data, HPL, and LPL.
- Technical and economic data of system components, lifetime, interest rate and inflation rate.

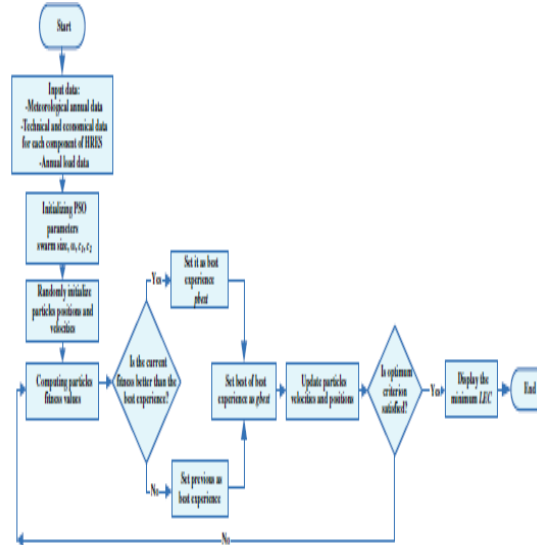


Figure 1: The process of the PSO algorithm

## RESULTS AND DISCUSSION

A PSO-based MATLAB algorithm has been created to determine the optimum size of a PV/WT/batteries/DG system in order to supply a certain load in different remote sites in Nigeria. As indicated in the literature and according to the nature of the problem under study; the suitable values for PSO parameters have been set to make the PSO faster, and exact.

The population size has been set to be 20, a maximum number of iterations has been set to be 100,  $c_1$  and  $c_2$  have been chosen as 2,  $a_1$  and  $a_2$  have been picked as 0.02, and  $x$  has been set as 0.7.

In addition, SOC of the battery bank and the DG rated power have been sized to meet the load demand in the time of deficit generation. HPL and LPL have been considered to be 75 and 25% of the aggregate load demand, respectively.

The comparison results are shown in Table 1. As seen in this table, the results obtained from the IOT and NPPBPSO are almost the same.

The PSO idea relies on imposing various particles for searching the optimum solution, every particle represents a solution. In the next iteration, the solutions number is multiplied until it gets the optimum one. Imposing more particles in each iteration encourage coming to the optimum solution, and furthermore decreases the number of optimization iterations. The solution obtained from PSO is the one that fulfills all the optimization constraints and objective function, which makes it the exact solution.

The IOT impose one solution for each iteration relying upon the experimentation strategy, which in turn may raise the number of iterations until getting the optimum solution. However, the IOT can't solve variant optimization problems attributable to poorly known objective functions and that have multi-constraints.

Table 1: Comparison with IOT and NPPBPSO

Tools	C	K	NW T	PVA	PSV	FC	OMC	RC	LEC	
IOT	5.7 8	1.97	91	3.8 X 10 <sup>4</sup>	X	1.8 X 10 <sup>6</sup>	7.18 X 10 <sup>6</sup>	1.2 X 10 <sup>8</sup>	2.9 X 10 <sup>8</sup>	0.2417
NPPB PSO	5.7 2	1.95	90	3.78 X 10 <sup>4</sup>	X	1.7 X 10 <sup>8</sup>	6.89 X 10 <sup>6</sup>	1.1 X 10 <sup>8</sup>	2.8 X 10 <sup>8</sup>	0.2334



Figure 4.1 demonstrates the convergence process of the PSO algorithm during the minimization of the LEC for 4 autonomous runs. As illustrated in this figure, the optimum solution is acquired after around 30 iterations, and the 100 iterations are considered as a reasonable end measure. In addition, it can be noted that the optimum solution almost converges to the same optimum value (global minimum) for all runs.

Figure 4.2 shows the convergence process for one run of the IOT. As shown in this figure, the optimum solution is obtained after around 215 iterations and this solution may be away from the optimum one. It is also observed that the time taken to find the optimum sizing by using PSO is lower than that taken by using IOT.

Therefore, the optimization utilizing PSO is quicker and more precise than utilizing IOT. PIPSO is a granulated approach to speed up the optimization process, to activate PIPSO, parallel choice should set to true. When this

condition is true, the NPPBPSO assesses the objective function of the optimization problem in parallel population. Figure 4.3 shows how to speed up the optimization process by utilizing the PIPSO. Intel® Core™ i5-2410 M processor with clock speed: 2.30/2.90 Turbo GHz, 3rd level cache: 3 MB and front side bus: 1333 MHz has been used to run the optimization process. The optimization process has been

carried out in a serial manner as appeared in the first part of Figure 4.3 (SIPSO) and carried out in the second part of Figure 4.3 using parpool (PIPSO). As clear from this figure, utilizing the PIPSO can save more time during the optimization process.

Figure 4.4 describes the sensitivity analysis of the proposed algorithm with the help of quadratic curve fitting. This figure shows the DG performance with relation to the rate of load shifting, at 50% penetration ratio.

As shown in this figure, there is an opposite relation between load shifting rate (LPL energy (LPLE)/annual load energy (LAE)) and the DG capacity (PDgr). In other words, as the rate of load shifting increases, it reduces the DG capacity, which in turn, reduces the whole system cost, and also, reduces the load peak value.

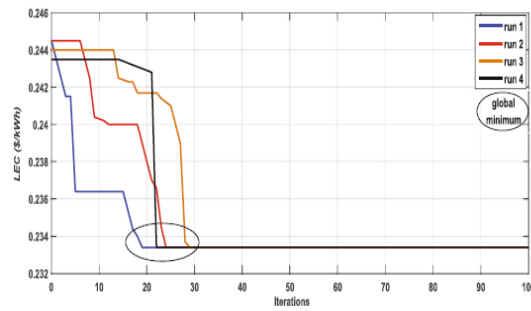


Figure 2: The convergence process of the PSO algorithm for 4 autonomous runs

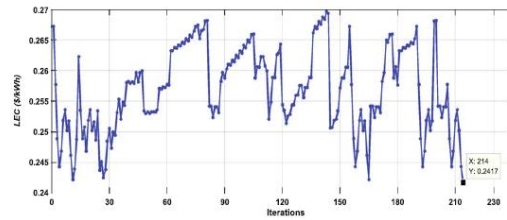


Figure 3: The convergence process of the IOT

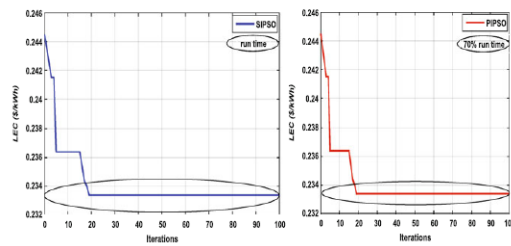


Figure 4: The comparison results of SPSO and PIPSO

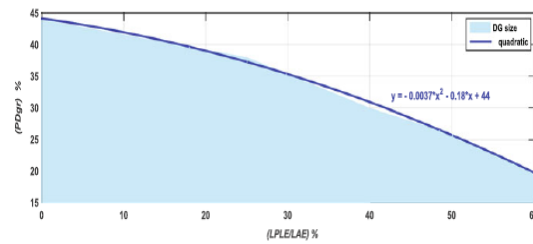


Figure 5: Sensitivity analysis for DG performance with load shifting rate

## **CONCLUSION**

A methodology for optimum sizing of stand-alone hybrid PV/wind/battery/diesel energy systems utilizing PSO has been presented in this research work. The optimization goal was to minimize the system cost with the state of ensuring the load demand and satisfying a set of optimization constraints. In addition, sensitivity analysis has been carried out in this research work to predict the system performance under varying operating conditions. The simulation results affirmed that PSO is the promising optimization techniques due to its ability to reach the global optimum with relative simplicity and computational proficiency contrasted with the customary optimization techniques. Finally, PIPSO has been utilized to speed up the optimization process, and the simulation results confirmed that it can save more time during the optimization process compared with utilizing SIPSO.

## **REFERENCE**

- Ayompe, L. M., Duffy, A., McCormack, S. J., and Conlon, M. (2017). Validated real-time energy models for small-scale grid-connected PV-systems. *Energy*, 35(10), 4086–4091.
- Belfkira, R., Zhang, L., and Barakat, G. (2016). Optimal sizing study of hybrid wind/PV/diesel power generation unit. *Solar Energy*, 85(1), 100–110.
- Celik, A. N. (2013). Techno-economic analysis of autonomous PV-wind hybrid energy systems using different sizing methods. *Energy Conversion and Management*, 44(12), 1951–1968.
- Chedid, R., and Rahman, S. (2017). Unit sizing and control of hybrid wind-solar power systems. *IEEE Transactions on Energy Conversion*, 12(1), 79–85.
- Crow, M. L., McMillin, B., Wang, W., and Bhattacharyya, S. (2010). Intelligent energy management of the FREEDM system. In *Proceedings of the IEEE PES General Meeting* (pp. 1–4).
- Diaf, S., Notton, G., Belhamel, M., Haddadi, M., and Louche, A. (2018). Design and techno-economical optimization for hybrid PV/wind system under various meteorological conditions. *Applied Energy*, 85(10), 968–987.

Gaviano, A., Weber, K., and Dirmeier, C. (2012). Challenges and integration of PV and wind energy facilities from a smart grid point of view. *Energy Procedia*, 25, 118–125.

Kohsri, S., & Plangklang, B. (2011). Energy management and control system for smart renewable energy remote power generation. *Energy Procedia*, 9, 198–206.

## **APPRAISAL OF FLOODING AND DRAINAGE CONDITIONS IN OSOGBO, OSUN STATE, NIGERIA.**

Gasu, M. B., Olaiyiwola, O. and Ezekiel, A. O.

*Department of Urban and Regional Planning, Osun State University, Osogbo, Nigeria.*

Corresponding Authors- <sup>1</sup>Gasu [M.B.-gasumart@yahoo.com](mailto:M.B.-gasumart@yahoo.com)

### **ABSTRACT**

The study appraises flooding and drainage conditions, especially channelization and dredging along major rivers, streams and drainage channels in Osogbo with a view to reducing the threats of floods on lives and property. A total of 1,953 buildings were identified using the Google earth satellite image and 10% was selected for the study. The study adopted a multistage sampling technique where in the first stage, study sites were selected purposively within 100m distance on the drainage channels and in the second stage 195 pretested questionnaires were administered systematically on the residents. Advanced Space born Thermal Emission Reflection Radiation (ASTER) Data of the study area was used to generate flood vulnerability maps using geospatial techniques. The study generated a flood vulnerability map categorizing the area into highly vulnerable (0-100 m), moderately vulnerable (100-200m), not vulnerable (200-300m) and high grounds 300 m and above. The data collected was analyzed using descriptive statistics. The study generated an ordered weighted values of significance of the causes of flooding to include; method of waste disposal (4.24), building along flood plain (4.18), lack of drainage system (4.18), poor drainage system (3.88), heavy rainfall (3.67) and topography (3.51). The result further revealed that a total 13.7 km of channels were dredged while 3.6 km of streams were channelized which significantly reduced the level of flooding in these areas. Similarly, the study identified in order of significance the impact of channelization and dredging on the people to include: livelihood (4.56), and safety (4.44), health (4.17), environment (4.11), economic activities (4.05), social security (3.94) and property value (3.81). The study recommended; resettlement, environmental awareness; flood retention and control infrastructure, proper waste management, channelization and strict implementation of urban development control measures as possible solutions to flooding in the study area.

**Keywords:** Geospatial Techniques, Flooding Control, Dredging and Channelization, Vulnerability and Urban management.

## **1. Introduction**

Drainage performs the role of collecting and conveying both storm water and waste water away from urban settlement to a disposal unit, thereby keeping the urban environment drained and free from waste. According to WHO/UNICEF 2012 and Olukanni 2014, about 2.6 billion people are living without proper sanitation, of which Africa is not exempted. The need to provide proper drainage and sanitation facilities is essential to match up with the ever increasing population growth (Banerjee and Morella, 2011). Poorly drained storm water forms stagnant pools that serves as breeding sites for disease vectors. For this reason, some diseases are common in the wet season. Poor drainage can also lead to flooding which results into loss of properties and at times lives which also influences the migration of people from areas prone to flooding. It has therefore, been reported that poor drainage systems are often associated with street flooding, and this has become critical environmental problems in Nigeria where flood disasters have occurred in Ibadan 1985, 1987, 1990, 2011; Osogbo 1992, 1996, 2002; Yobe in 2000; Akure 1978, 1996, 2000, 2002, 2004 and 2006; and Lagos 2010, 2011, 2012; Kwara State 1991, 1992, 1993, 1994, 1997, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008; Sokoto 2010; and other parts of the country, (Olajuyigbe, Rotowa and Durojaye, 2012; Justin, 2010; Jimoh 2008; Akinola et al, 2013; Olorunfemi and Raheem, 2013; Aladelokun and Ajayi, 2014; Akukwe, 2014), Similarly, poor drainage systems are often associated with street flooding in coastal cities of Nigeria such as Lagos, Port Harcourt, Ondo, Warri, Uyo, and Calabar (Eze, 2008).

Urban flooding is a condition characterized by its repetitive and systemic impacts on communities whether or not the affected communities are located within floodplains or near any body of water (CNT, 2013). The problem of flooding also emanates from poor maintenance of roads constructed without good drainages. There is also the negligence and poor attitude of people who dump waste into the drainages located along road side, which eventually blocks flow of both household sewage and storm water. Osogbo is a city built on hills (Oke) such as Oke-balee, Oke-Onitea, Oke-Ayepe just to mention but a few which means that it is well drained and is not supposed to have challenges with flooding. Before 2011 flood used to be a recurrent decimal but some channels were dredged and channelized and between 2011 and 2019 there has not been any major incidence that threatened life and property.

It was at the backdrop of all these, that the study was conceived to assess flooding, and drainage systems in Osogbo metropolis with a view to improving on the present drainage systems to reduce threats to lives and property.

The objectives of the study include: identification and characterization of the existing drainage network in Osogbo; assessment of the existing drainage system especially dredging and channelization done by Osun State Government; and assessment of the impact of dredging and channelization on the social and economic status of the residents.

## **2. Literature Review**

Researchers have been able to establish that there are different reasons for which flooding can occur in different areas but most have emphasized on the human activities which has led to flooding and its consequences on the environment lives and property loss (Berggren 2008, Yussuf et al. 2017, Olukanni et al. 2014).

In Assessing climate change and its impact on urban drainage system, Berggren (2008) stated that, changes of the climatic conditions will affect urban drainage systems, as they are closely related to the weather phenomenon and are built as to cope with the weather occurring. He further summarised the problems associated with surface flooding and basements, increased amount of combined sewer overflows (CSO), increase of the inflow to waste water treatment plants (WWTP) and increase in pollutants spreading from urban areas to the environment.

According to Yussuf et.al. (2017), the floods that occurred in Lokoja were occasioned by high rainfall intensity coupled with inadequate drainage system which was determined through the use of peak flow analysis. From his evaluation, it was concluded that the factor responsible for perennial flooding can be given to the fact that the peak flow is quite higher than the designed capacity of the drainage system within the area.

Olukanni et al. (2014) also worked on the assessment of urban drainage and sanitation challenges in Nigeria. The study established that ineffective drainage systems are basically associated with poor maintenance, indiscriminate dumping of refuse in drains, erection of building on drainage channels and poor alignments that inhibit the flow of water which leads to critical environmental hazards.

## **3. Research Methodology**

A total of 1,953 buildings were identified using the Google earth satellite image and 10% was selected for the study. The study adopted a multistage sampling technique where in the first stage, study sites prone to flooding were selected purposively within 100m distance on the drainage channels and in the second stage 195 pretested questionnaires were administered systematically on the residents. The questionnaire were administered on every 5<sup>th</sup> household after every 3<sup>rd</sup> street located within the 100m range of the flood plain and 185 questionnaires were returned for analysis.

Similarly, information was collected on the possible causes of flooding in Osogbo. This was gotten directly from areas that had experienced flood overtime such as; Rasco/Old-garage, Gbonmi, Obate-Okebaale, Ita-Olookan, Alekuwodo etc. The causes of flooding examined includes; human and climatic factors; illegal dumping of waste into drainage channels, construction of buildings along the flood plains, poor maintenance of drainage system, rainfall etc.

Advanced Spaceborn Thermal Emission Reflection Radiation (ASTER) Data of the study area was used to create flood vulnerability maps using geospatial techniques. The study generated a flood vulnerability map categorizing the area into highly vulnerable (0-100m), moderately vulnerable (100-200m), not vulnerable (200-300m) and high grounds 300m and above. This classification was done with their differences in altitude.

Likert scale was used to weigh the level of response of the respondents in order to assess the possible causes of flooding in the area. Likert scale made use of responses like; Very Significant (VS), Significant (S), Fairly Significant (FS), Less Significant (LS), and Not Significant (NS) which responses were attached with weighted value of; 5,4,3,2, and 1 respectively.

## **Results and Discussions**

### **1. Table 1: The possible causes of flooding in the area**

SN	VARIABLES	RANK					NR	WV	SWV	RANKING
		VS	S	FS	LS	NS				
		(5)	(4)	(3)	(2)	(1)				



1	Method of waste disposal	410	292	66	16	0	185	784	4.24	1 <sup>st</sup>
2	Building along flood plain	284	332	102	20	2	185	774	4.18	2 <sup>nd</sup>
3	Lack of drainage system	400	280	72	22	0	185	774	4.18	2 <sup>nd</sup>
4	Topography	135	188	312	14	0	185	649	3.51	5 <sup>th</sup>
5	Poor drainage system	325	248	87	58	0	185	718	3.88	3 <sup>rd</sup>
6	Heavy rainfall	390	148	175	62	13	184	675	3.67	4 <sup>th</sup>
	Total	1944	1488	832	192	15		4374	23.66	

**Source: Author's fieldwork, 2019.**

Mean of  $\sum MWV/N = 23.66/N = 3.94$  Where NR= number of questionnaires, n= number of responses, WV= weighted values, SWV= Sum of the mean value which is the index of possible causes of flood was arrived at by dividing the Summation of the Weighted Value (SWV) by the number of responses (N).

#### **4.1 Impact of Flooding on Communities**

The result in Table 1 shows that the possible causes of flooding in the study area are associated with their method of waste disposal which was ranked first (4.24), buildings constructed along flood plains (4.18), lack of drainage system (4.18), poor drainage system (3.88) amidst others which needs urgent attention to control the impact of flooding in the area, heavy rainfall (3.67) is also a natural phenomenon that demands the construction of adequate drainages within the urban metropolis while topography ranked the least (3.51).

Similarly, the results show that Heavy Rainfall, Poor drainage system, and topography were below the average and therefore less significant but need to be improved upon for a better managed human environment safe for human habitation.

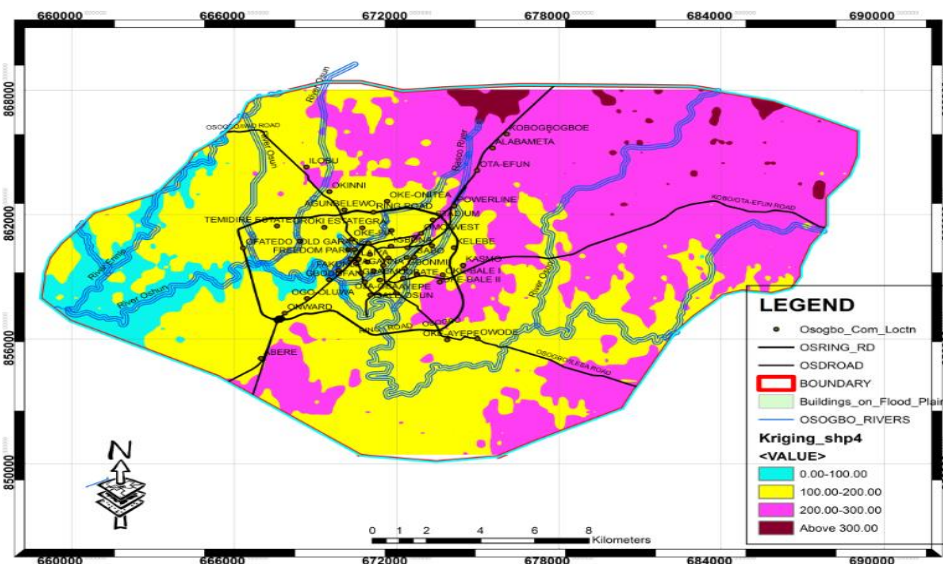
The result revealed that variables such as method of waste disposal, building on the flood plain, lack of drainage system were very significant factors that contributed to drainage challenges of the city. On the spot assessment confirmed that so many buildings have encroached on the flood plains which do not have building permits as illustrated in plate 1 and 2 at Gbodafon along Osun River and Baruwa street.

Osogbo is located on hilly topography which is not expected to face any difficulty in drainage system but due to land management problem that exists within the area, the town is experiencing high magnitude of flooding that displaces people from their homes.



**Plate 1: buildings constructed along the flood plains in Gbodofon area.**

It was observed in the study area that most of the buildings that were affected by flooding were as a result of building on the flood plain. Also, the flooding that occurred in the study area was observed to have been occasioned by intensified rainfall which was observed in an earlier studies by Yusuf *et al.*, 2017 in Kogi State.



**Fig 1: Flood Vulnerability Map of Osogbo.**

*Source: ArcGIS, 2019.*

Figure 1 reveals the rivers, streams as well as vulnerable areas in Osogbo that are prone to flooding which dredging and channelization was proffered as the mitigation measures. The areas within the range of 0.00m-100.00m are highly vulnerable to flooding, the areas within the range of 100.00m-200.00m are moderately vulnerable, areas within the range of 200.00m-300.00m are not vulnerable, while those above 300.00m are on high ground. The buildings located at Baruwa on the flood plain and Gbodofon along Osun river experienced serious flooding which was indicated in Plate 1 and 2. This area is highly vulnerable to flooding as it is within the altitudinal range of 0.00m-100.0m.



**Plate 2: Houses flooded along the flood plains along Baruwa Street behind Methodist Church.**

The occurrence of flooding in this area have displaced the residence and caused the destruction of properties, affected education and disrupted economic activities of residents. Plate 3 shows the devastating impact of flooding on Adekids school at Gbodofon completely

overwhelmed by floods.



**Plate 3: Adekids School flooded along the river Gbodofon flood plain in Osogbo.**

#### **4.2 Impact of Dredging and Channelization on the people.**

The study also collected information on drainages especially the dredging and channelization done by the state government in Osogbo. This included the

assessment of effect of dredging and channelization on peoples' life, economic activity, health, safety, property and others. These variables were backed up with pictures as a means of establishing direct observation within the area.

SN	VARIABLES	RANK					NR	WV	SWV	RANKING
		VS (5)	S (4)	FS (3)	LS (2)	NS (1)				
1	Life	630	148	63	2	0	185	843	4.56	1
2	Economic Activities	265	380	96	6	2	185	749	4.05	5
3	Social Security	300	336	69	12	12	185	729	3.94	7
4	Environment	400	248	78	34	0	185	760	4.11	4
5	Health	500	132	114	24	2	185	772	4.17	3
6	Property Value	265	320	84	18	14	184	701	3.81	8
7	Aesthetic	180	228	246	16	2	185	672	3.63	11
8	Urban Agriculture	150	212	225	22	16	185	625	3.38	12
9	Flooding	170	340	108	46	6	184	670	3.64	10
10	Residential Accommodation	180	372	120	22	5	185	699	3.78	9
11	Aquaculture	200	160	216	34	16	185	626	3.38	12
12	Mobility	210	420	84	12	4	185	730	3.95	6
13	Safety	545	208	63	6	0	185	822	4.44	2
	Total								50.84	

Mean of  $\sum MWV/n = 3.91$

Source: Author's fieldwork, 2019.

Table 2 indicates the impact of dredging and channelization of flood plains on the social and economic lives of the people. It was deduced that the impact of dredging and channelization on the “life” of the people was ranked as the highest followed by safety then health with the mean weighted value of 4.56, 4.44, and 4.17 respectively. This shows that the impact of

flooding in the area does not only put them in the state of unrest but also affects their health, safety, mobility etc. but this has been reduced through dredging and channelization of the flood plains which involved the demolition of structures built along this area and the maintenance of drainages by periodic cleaning and collection of waste especially those dumped in the drainage. The result further revealed that a total 13.7 km of channels were dredged while 3.6 km of streams were channelized which significantly reduced the level of flooding in these areas (Table 3).

**Table 3: Assumed Channelized and Dredged Flood Plains in Osogbo.**

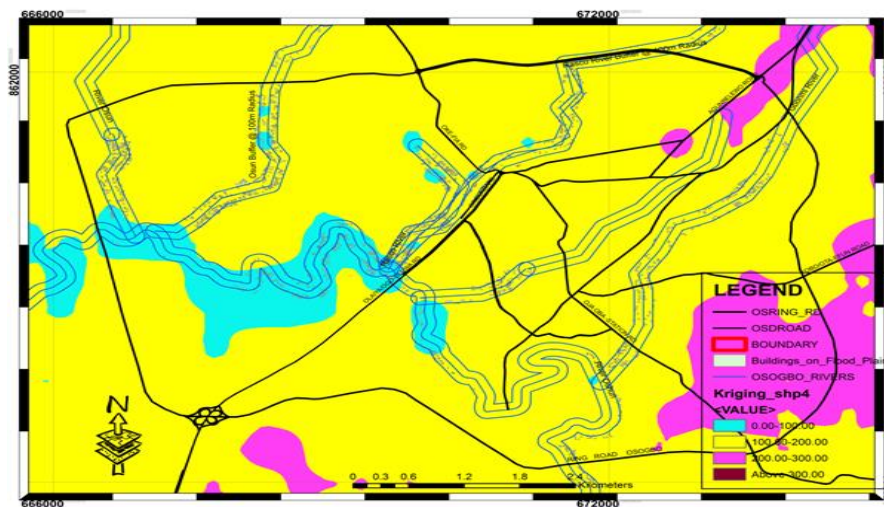
<b>Location</b>	<b>Mitigation Measure</b>	<b>Length(m)</b>	<b>Width(m)</b>
Gbonmi – Obate/Okebaale	Channelization	2,120	12
Ita-Olookan – Osun River	Dredging	148	15
Old-garage-Alekuwodo	Channelization	798	11.7
Testing Ground – Gbonmi	Dredging	1,480	15.6
Asubiaro	Dredging	123	13.7
Rasco – BCJ	Dredging	2,170	14.8
Freedom Park-Olaiya	Channelization	676	10.6
Osun River – Olaiya	Dredging	1,128	15.3
Africa – Dada Estate	Dredging	4,200	14.2
Powerline - Kobongbogboe	Dredging	2,720	15.3
Ebunoluwa – Africa	Dredging	1,640	14.2

**Source: Author's fieldwork, 2019.**



**Plate 4: Dredged area blocked with waste behind Old-garage Motor Park.**

Plate 4 denotes that flooding affects some of the areas that were dredged and this is due to high intensity of rainfall in the study area in addition to waste being disposed of along the dredged areas.



**Fig 2: River and Stream Channels, and Variation in Elevation of Osogbo**

Figure 2 indicates the buildings susceptible to high vulnerability located along the flood plains in Osogbo. However, the waste management culture of the people is very poor as most residents engage in indiscriminate dumping of refuse in drains (Olukanni, 2014). Similarly, most of the dredged areas in Osogbo have been littered with wastes which blocks the water channels and causes street flooding as is evident in Plate 4.

## **Conclusion**

The study concluded that the impact of flooding in the study area does not just affect the lives of the people but also cripples the economic viability of the communities are affected as it caused the displacement of people out of their residence and thereby increasing their rate of migration. The study showed that great impact of dredging and channelization embarked by the government on the social and economic lives of the people as those living along the dredged and channelized streams and channels attested that the impact of flooding in recent years have been minimal compared to what was in the past in terms of safety, healthy and conducive environment for economic activities to thrive.

## **REFERENCES**

- Akinola, S. R.; Ogudanhunsi, D. S.; Deborah Y. (2013). Urban degreening, erosional impact and housing quality in Osun State, Nigeria: mitigating flooding through polycentric environmental planning. In: Laryea, S.; Agyepong, S. (eds). Procs of 5th West Africa Built Environment Research (WABER) Conference, 12-14 August 2013, Accra Ghana, 1173-1190.
- Akukwe, T. I. (2014). Determinants of Flooding in Port Harcourt Metropolis, Nigeria. *Journal of Humanities and Social Science* 19(11): 64-72.
- Aladelokun, A. O.; Ajayi, C. F. (2014). An Appraisal of the Socio Economic Impacts of Urban Flood in Ado – Ekiti Metropolis in Ekiti State. *International Journal of Asian Social Science* 4(10): 1027-1034.
- Banerjee, S. G., & Morella, E. (2011). *Africa's Water and Sanitation Infrastructure: Access, Affordability and Alternatives*. Washington D.C. USA: International Bank for Reconstruction and Development/World Bank.
- Centre for Neighbourhood Technology (CNT). (2013). *The Prevalence and Cost of Urban Flooding*. Cook County, IL.
- Eze, B. E. (2008). Topography and Urban Expansion as Twin Factors of Street Flooding in Calabar Municipality. *ANG 50th annual conference*, Calabar: University of Calabar.



- Jimoh H. I. (2008): Effects of River Erosion on Houses: A Case Study of Asa River Catchment in Ilorin, Kwara State, Nigeria. *Medwell Journals on Social Sciences* Volume 3, No 2, 2008.
- Justin Uwazuruonye (2010): 2010 Flood Disaster in Kosofo – Lagos State, Nigeria. A Summarized Report on Causes and Mitigating Measures
- Olukanni, David O., Adebayo , R. A., & Imokhai, T. (2014). Assessment of Urban Drainage and Sanitation Challenges in Nigeria. *International Journal of Emerging Technology and Advanced Engineering Vol 4, 100-1005.*
- Olorunfemi, F.B and Raheem, U.A (2013): Floods and Rainstorms Impacts, Responses and Coping among Households in Ilorin, Kwara State. *Journal of Educational and Social Research Volume 3, No 4, pp. 135-148.*
- Olajuyigbe E., O.O Rotowa and E. Durojaye (2012): An Assessment of Flood Hazard in Nigeria: The Case of Mile 12, Lagos. *Mediterranean Journal of Social Sciences. Volume 3, No 2.pp. 367-375.*
- WHO/UNICEF. (2012). *Progress on Drinking Water and Sanitation. Joint Monitoring Programme for water supply and sanitation.* ISBN: 978-92-806-4632-0.
- Yussuf, M. J., Sanni, J. E., Alabi, J. O., Onyowoicho, C. O., & Amanda, U. E. (2017). Evaluation of Drainage System in Part of Lokoja Town in Kogi State, Nigeria. *International Journal of Engineering and Modern Technology, Vol. 3 No.5 39-48.*

## **DECENTRALIZED LOAD FREQUENCY CONTROL OF MULTI-AREA INTERCONNECTED POWER SYSTEMS**

Yahaya, E. H<sup>\*</sup>., Kunya, A. B., Jibril, Y., Okorie, P. U.

Department of Electrical Engineering, Ahmadu Bello University, Zaria—Nigeria.

[\\*elhasan0808@gmail.com](mailto:elhasan0808@gmail.com).

### **ABSTRACT**

In interconnected multi area power systems (MAPS), interruption in the generation-demand balance leads to undesired deviations in frequency and variations in inter Control Area (CA) tie-line power interchange. These deviations if prolonged can make generators to lose synchronism thereby leading to system collapse ultimately. To maintain zero frequency deviation and ensure tie-line exchange power on schedule at steady state, Load Frequency Control (LFC) is applied. In this paper, a decentralized LFC for interconnected MAPS is presented. A standard proportional-integral (PI) controllers are employed at the supplementary control loop, in a decentralized pattern, to regulate the CA's frequency and tie-line power interchanges. To achieve best closed loop performance, Whale Optimization Algorithm (WOA) is used to optimize the gains of the decentralized PIs by minimizing an objective function formulated based on integral squared error (ISE) subject to frequency deviation range, generation rate and controllers' gains constraints. The effectiveness of the developed control scheme is ascertained by applying it on a 3-area MAPS subjected to step load change. From the simulations studies carried out in MATLAB/Simulink environment, it is established that the Integral Squared Error (ISE) of the frequency deviation is reduced by 44.32%, 43.82% and 54.77% in the respective CAs when compared with conventional Ziegler Nichols based PI control scheme. While the reduction in the ISE of the tie-line power deviation is found to be 56.03%, 53.19% and 56.84% in the three CAs.

Keywords—Multi Area Power Systems, Control Area, Load Frequency Control, Tie-line Power, Whale Optimization Algorithm.

### **INTRODUCTION**

Among the well-known control engineering problem, power system (PS) control is proved to be one of the most challenging. This is due to the large geographical spanning of the PS, tight margin of frequency and tie-line power deviations and intermittent interruption in generation-

demand (Sujan, 2017). If these undesired deviations in frequency and inter Control Area (CA) tie-line power interchange protract, generators will be forced to lose synchronism and eventually lead to system collapse ultimately. To curtail the adverse effect of frequency deviation, load frequency control (LFC) is applied. LFC as a one of the most vital control strategies in PS is applied to adjust the load reference point against the variation of the load changes in order to keep the system frequency and tie-line power as closed to the prescribed values as possible (Kunya *et al.*, 2019).

LFC represents a very crucial ancillary services towards establishing a proper operating condition of power system. The primary and fundamental objectives of LFC are (Zhang, 2017; Stil & Mehmedovic, 2018; Saxena, 2019):-

maintaining zero steady state error for frequency and tie-line power deviations, sudden load disturbance rejection, establishing an optimal transient behavior under prescribed overshoot, settling time and error tolerance, provision of a robust performance in presence of modeling uncertainties and nonlinearities, ensuring better security margin of system in sense of stable frequency regulation, and less computing power

Therefore, LFC is generally treated as a single or multi-objective optimization and robust control problem. As a result, various LFC strategies have been developed by applying optimal, robust, adaptive and intelligent control approaches (Hirase, *et al.*, 2018; Ejegi *et al.*, July, 2015; Pappachen & Fathima, 2017; Anne Mai Ersdal, 2015; Ejegi *et al.*, 2016).

Among the approaches proposed are classical control such PI in (Guolian *et al.*, 2011) and PID controllers (Abd-Elazim, 2010; Mehta, *et al.*, 2017; Hota & Mohanty, 2016). These family of controllers have gained considerable attention due to the simplicity of the underlying concept and fast dynamic response. In the PI controller, the *P* part signifies the drop of the governor action while *I* part restores frequency to nominal value by changing load reference set point of the turbine (Machowski *et al.*, 2008). However, the effectiveness of these controllers often deteriorate considerably with increased system complexity. This is why many research works focused on improving their robustness by optimizing the gains using heuristic and meta-heuristic optimization techniques. For instance, (Abd-Elazim, 2010) employed a Bacterial Foraging Optimization Algorithm (BFOA) to optimize the PI controller parameters and shown its superiority over Genetic Algorithm (GA)-tuned in a two area non-reheat thermal system. (Saikia, 2015) proposed an LFC of a multi-area thermal power system using Grey Wolf

Optimization algorithm (GWO) based classical controllers and modified the objective function using Integral of Time Multiplied by Absolute Value of Error (ITAE), and the results are compared with BFOA and GA optimized ITAE-based PI controller to show its superiority. Similarly in (Simhadri & Mohanty, 2019), quasi-oppositional whale optimization algorithm (WOA) is employed to tune a dual-mode PI controller serving as supplementary frequency controller. The quasi-oppositional-based learning theory is incorporated with the WOA to make it faster, efficient and more reliable. The control scheme is applied on a two- and three-area interconnected system with governor dead band nonlinearity. Similar approach is presented in (Guha, *et al.*, 2016), however Quasi-oppositional differential search algorithm is applied instead of WOA.

On the other hand, optimal and robust control techniques like model predictive control (MPC) (Ejegi *et al.*, 2016; Kunya & Argin, 2018; Ersdal, *et al.*, 2015) linear quadratic regulator (LQR) (Kumari & Jha, 2014; Rahman, *et al.*, 2018), fractional-order controller via internal model control (Saxena, 2019), fuzzy-based control (Pradhan & Bhende, 2019; Azeer, *et al.*, 2017; Sahu, *et al.*, 2018) or hybrid of these schemes (Mohamed, *et al.*, 2015; Prasada, *et al.*, 2019) were proposed by various research works.

In (Prasada, *et al.*, 2019), generalized extended state observer (GESO) and non-linear sliding mode control (SMC) are hybridized together to study the frequency deviation problem in multi-area power system. In study, the GESO is used not only for state and disturbance estimation but also for disturbance rejection of the system. The said observer ensures accurate estimation of the actual states leading to convergence of estimation error to zero. The non-linear SMC is used to increase the damping ratio of the system whenever, any perturbations occurs. The proposed observer based controller is compared with an existing two-layer active disturbance rejection control (ADRC) and also validated on large power system at random load disturbance. Further, the proposed controller performance is tested on the minimum and non-minimum phase systems. In addition to fast response in terms of settling time and reduced over/undershoots, the proposed control scheme satisfactorily compensates the disturbance in the system. Among other studies is the application of Jaya optimization algorithm, due to its simplicity and speed, for on online tuning the fuzzy controller for LFC of wind integrated power system (Pradhan & Bhende, 2019). However, Jaya due to the absence of algorithm-specified parameter, its performance may degrade in terms of convergence speed and obtain

the optimal value for the real-world complex optimization problems which are usually nonlinear and non-differentiable in nature.

In this paper, a decentralized LFC for interconnected MAPS is presented. A standard PI controllers are employed at the supplementary control loop, in a decentralized pattern, to regulate the CA's frequency and tie-line power interchanges. To achieve best closed loop performance, WOA is used to optimize the gains of the decentralized PIs by minimizing an objective function formulated based on ISE subject to frequency deviation range, generation rate and controllers' gains constraints.

After this introduction section, the rest of the paper is organized with system modeling and design is presented in Section II. Section III presents the tests, results, and discussion and the paper is concluded in Section IV.

## SYSTEM MODELLING AND DESIGN

### Load Frequency Control in Multi-Area Power System

In this study, the LFC is carried on a 3-area interconnected power system. The topology of 3-area power system can be configured either in a linear or ring structure (Kunya & Argin, 2018). The linear topology of the multi area power systems (MAPS), represents the simplest configuration of interconnected power system even though is not very common in real world.

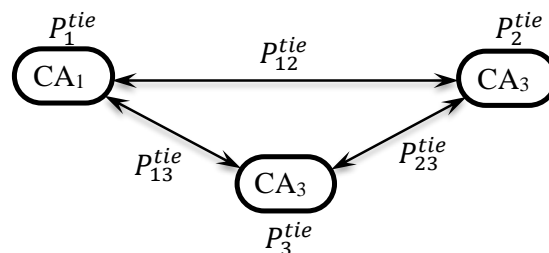


Fig. 1: Proposed 3-area MAPS with Ring Topology

While in the ring topology presented in Fig. 1 represent a more realistic configuration of MAPS and hence used in this paper. The CAs are equipped two thermal generators each.

The relationship between the system's input(s), state(s) and output(s) is non-linear, and in most cases, it is modeled as such. However, in LFC studies, linearized models are widely used. This is because LFC operation is limited to relatively small system load disturbances. Therefore,

linearized PS dynamic model in state-space is presented. The formulation includes swing equation, tie-line powers, turbine dynamics and ACE.

In this context, load disturbance is the input, frequency and tie-line power deviations, valve position and turbine mechanical output in each CA are the states. ACEs of all the CAs are the system outputs. For  $i$ th CA, frequency deviation is modelled using a linearized differential equation describing the generator's dynamics known as *swing equation*, illustrated in (1) (Ejegi *et. al.*, 2016).

$$\dot{f}_i = \frac{1}{M_i} (P_i^G - D_i f_i - P_i^{tie} - P_i^D) \quad (1)$$

Due to the coherency of generators in a given CA, single frequency is assumed for each CA. Equation (1) defined the deviation in the system frequency. Generation from individual generators summed up to give the total area generation,  $P_i^G$  as given in (2) (Kunya & Argin, 2018),

$$P_i^G = \sum_{j=1}^{\mathcal{G}} P_{i,j}^G; \quad \text{and} \quad P_{D_i} = \sum_{j=1}^{\mathcal{G}} P_{D_{i,j}}; \quad (2)$$

$P_i^D$  is the total demand of  $i$ th area obtained by adding up load demands of all the load points as shown in (2).

In MAPS, it is required for each CA to provide for its own load. However, power is often imported or exported to other neighboring CAs via tie-lines. Approximate DC power flow is used to model the tie-line power between two CAs, as in (3),

$$\dot{P}_i^{tie} = \sum_{j \in \mathcal{A}_i^{tie}} \dot{P}_{ij}; \quad \dot{P}_{ij} = 2\pi T_{ij}^0 (f_i - f_j) \quad (3)$$

Where  $T_{ij}^0$  is the synchronizing coefficient expressed as a function of the of  $i$ - $j$ th line static transmission capacity. The derivation of (3) and physical interpretation of  $T_{ij}^0$  are explained in (Yousef, 2017).

The power output of the turbine is regulated by a careful adjustment of the control valves' position, which control the flow of steam/water to the turbines. For small disturbance, the turbine dynamics of the  $k$ th generator in the  $i$ th CA is modelled as

$$\dot{P}_{i,k}^G = \text{sat}_{P_{i,k}^G}^i \left\{ \frac{1}{T_{T_{i,k}}} (P_{i,k}^{Gov} - P_{i,k}^G) \right\} \quad (4)$$

Each generator is supplied with a supplementary control signal,  $P_{i,\ell}^{SC}$ , however, valve position cannot be adjusted at infinite speed. Hence, further dynamics is introduced into the system as governor model. For  $\ell$ th generator in the  $i$ th CA, the change in governor valve position as it relates to frequency is represented as in (5) (Prasada, et al., 2019);

$$\dot{P}_{i,\ell}^{Gov} = \frac{1}{T_{Gov_{i,\ell}}} \left( P_{i,\ell}^{SC} - P_{i,\ell}^{Gov} - \frac{1}{R_{i,\ell}} f_i \right) \quad (5)$$

Area Control Error (ACE), formed by combining the deviation in frequency and tie-line power as shown in (6), is utilized in the dynamic controller as a feedback input for optimal computation of  $P_{i,\ell}^{SC}$ . Thus, for  $i$ th CA,

$$ACE_i = \beta_i f_i + P_i^{tie} \quad (6)$$

ACE is used as system output as well as performance measure in LFC. The model presented in (1) – (6) is the continuous time (CT) model of LFC in MAPS. For brevity, this model is represented in state-space as shown in (7) and (8);

$$\dot{x}_i(t) = A_{ii}x_i(t) + B_{ii}u_i(t) + D_{ii}d_i(t)$$

$$+ \sum_{j \in \mathcal{A}_i^{tie}} (A_{ij}x_j(t) + B_{ij}u_j(t)) \quad (7)$$

$$y_i(t) = C_{ii}x_i(t) \quad (8)$$

Where  $x_i = [f_i \quad P_{i,\ell}^G \quad P_{i,\ell}^{Gov} \quad P_i^{tie}]^T \in \mathbb{R}^4$  is the system state vector,  $u_i = P_{i,\ell}^{SC}$  is the optimal control input, and  $d_i = P_i^D$  is change in the load disturbance as input,  $y_i(t)$  is output for  $i$ th CA.

The respective coefficients matrices are defined as;

$$A_{ii} = \begin{bmatrix} -\frac{D_i}{H_i} & \frac{1}{H_i} & 0 & -\frac{1}{H_i} \\ 0 & -\frac{1}{T_{T_{i,\ell}}} & \frac{1}{T_{T_{i,\ell}}} & 0 \\ \frac{1}{R_{i,\ell}T_{Gov_{i,\ell}}} & 0 & -\frac{1}{T_{Gov_{i,\ell}}} & 0 \\ \frac{1}{2\pi} \sum_{j \in \mathcal{A}_i^{tie}} T_{ij}^0 & 0 & 0 & 0 \end{bmatrix}; B_{ii} = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix}$$

$$A_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -2\pi \sum_{j \in \mathcal{A}_i^{tie}} T_{ij}^0 & 0 & 0 & 0 \end{bmatrix}; D_{ii} = \begin{bmatrix} -\frac{1}{H_i} \\ 0 \\ 0 \\ 0 \end{bmatrix}; C_{ii} = \begin{bmatrix} \beta_i \\ 0 \\ 0 \\ 0 \end{bmatrix}^T \quad (9)$$

$$B_{ij} = [0]_{1 \times 4} \quad (10)$$

To generate the optimal control input, optimized PI controllers in decentralized pattern are used.

### Supplementary Controller Design

To design the LFC Supplementary Controller, a PI controller is designed. The proportional gains ( $K_{P1}$ ,  $K_{P2}$  and  $K_{P3}$ ) and integral gains ( $K_{I1}$ ,  $K_{I2}$  and  $K_{I3}$ ) of the PI controllers are simultaneously and optimally obtained using Whale Optimization Algorithm (WOA). The optimization is based on the Integral Square Error (ISE) criteria in the presence of system generation rate constraints as shown in (11).

$\min(J_i)$  Such that

$$J_i = \int_0^t (ACE_i)^2; \quad i = 1, 2, 3 \quad (11)$$

Where  $ACE_i$  is the  $i$ th CA area control error formulated by combining the area frequency deviation,  $f_i$  and its tie-line power deviation  $P_i^{tie}$  as in (6),

The minimization of (11) is subject to the following set of static and dynamic constraints: -

*i-* Load-generation balance as equality constraint as expressed in (12).

$$P_{Gi}(t) + P_i^{tie}(t) = P_{Di}(t) \quad (12)$$

*ii-* *Generation Rate Constraints:* the rate at which active power generation is changing from generator  $k$  in  $i$ th CA is constrained as in (13);

$$|\dot{P}_{Gi,k}(t)| \leq GRC_{i,k}; \quad (13)$$



In this study, a GRC of  $0.1pu/min$  is chosen for all the eight generators in the network as chosen in (Saikia, 2015).

iii- *Frequency band*: the frequency is constrained within certain upper and lower bounds as chosen in (Zhang, 2017).

$$f_i^{min} \leq f_i^{lim} \leq f_i^{max}; \quad \text{as such } f_i^{lim} = 0.2Hz \quad (14)$$

iv- *Controller gains constraints*: the controller proportional gains ( $K_{P1}$ ,  $K_{P2}$  and  $K_{P3}$ ) and integral gains ( $K_{I1}$ ,  $K_{I2}$  and  $K_{I3}$ ) are constrained within some upper and lower limits for practical considerations, as shown in (15) and (16);

$$K_{Pi}^{min} \leq K_{Pi} \leq K_{Pi}^{max}; \quad (15)$$

$$K_{Ii}^{min} \leq K_{Ii} \leq K_{Ii}^{max}; \quad (16)$$

After solving (11) subject to (12) - (16), the PIs generate their respective optimal control signal using (17),

$$u_i = K_{Pi}ACE_i(t) + K_{Ii} \int_0^t ACE_i(t) dt; \quad i = 1, 2, 3 \quad (17)$$

#### Whale Optimization Algorithm (WOA)

Whale Optimization Algorithm (WOA) is one of the biologically inspired optimization techniques mimicking the hunting behavior of humpback whales. It is the simulated hunting behavior with random or the best search agent to chase the prey and the use of a spiral to simulate bubble-net attacking mechanism of humpback whales. The WOA algorithm starts with a set of random solutions. At each iteration, search agents update their positions with respect to either a randomly chosen search agent or the best solution obtained so far. The basic steps involved in WOA are bubble-net attacking method (exploitation phase) and searching for

the prey (exploration phase). It can be applied for many other applications. In this study, it is applied to optimize the gains of the PI controllers.

## SIMULATION RESULTS AND DISCUSSION

To test the effectiveness and superiority of the proposed algorithm, the three area system developed is subjected to step load change. Integral Square Error (ISE) is used as performance metric to quantify the improvements. The developed WOA tuned PI control scheme is compared with that tuned using Ziegler Nichols method.

Area 1 of the system is perturbed with  $0.1pu$  step load change at the beginning of the simulation time, while the load demands in area 2 and 3 are left constant. The frequency, tie-line, and ACE responses all the areas with the developed control scheme and the Ziegler Nichols (ZN) tuned PI controller are analyzed.

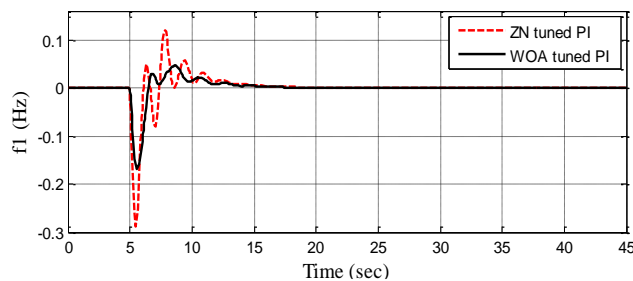


Fig. 2: Frequency Deviation of Area 1

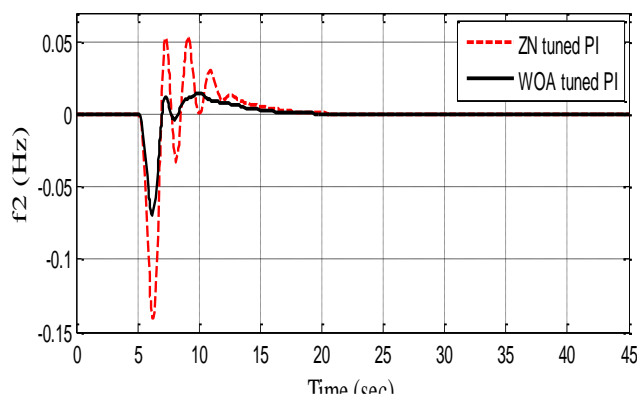


Fig. 3: Frequency Deviation of Area 2

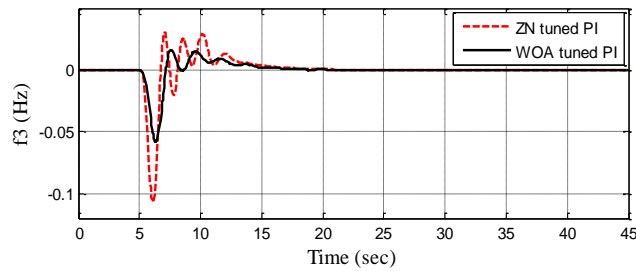


Fig. 4: Frequency Deviation of Area 3

Figs. 2 – 4 show the responses of the frequency changes in area 1 – 3 respectively. It can be seen from the dynamic responses that the frequency change in area 1 has higher undershoot compared to the other two areas. This indicates that the load disturbance occurred in area 1. From the responses of the frequency changes in all the areas, it can be observed that both control schemes have restored the system frequencies to their allowable range with approximately zero steady state error. However, the developed WOA tuned PI scheme achieved better performance with reduced overshoot and faster settling time.

Table 1: ISE and IAE of the Frequency Deviations

CA	Control Scheme	ISE ( $pu^2$ )	Improvement	IAE ( $pu$ )	Improvement
1	WOA-PI	0.0062		0.2915	
	ZN-PI	0.0136	54.32%	0.5688	48.75%
	LQR-PI	0.0036		0.2259	
2	dec-PI	0.0078	53.82%	0.4407	47.66%
	LQR-PI	0.0037		0.2276	
3	dec-PI	0.0080	54.77%	0.4441	48.89%

Table 4.1 summarizes the improvement of the developed WOA optimized PI scheme over the Ziegler Nichols tuned PI vis-à-vis integral squared error (ISE) and integral absolute error (IAE) of the frequency change responses.

By comparing the performance of the two control schemes, it can be seen a reduction of 54.32%, 53.82% and 54.77% are observed in the ISE of the frequency deviation of the three areas respectively. While the IAE is found to be reduced by 48.75%, 47.66% and 48.89%

respectively. This clearly shows that the superiority of the developed LFC scheme over conventional one.

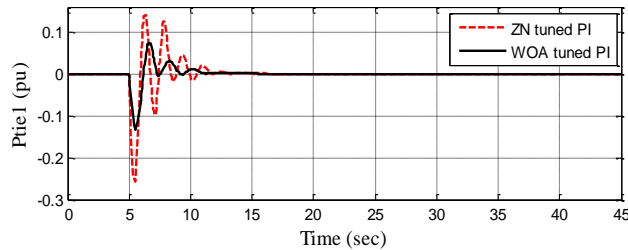


Fig. 5: Tie-Line Power Deviation of Area 1

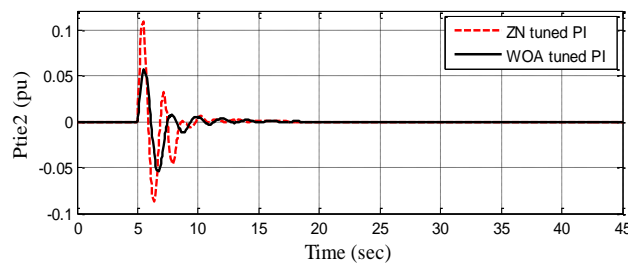


Fig. 6: Tie-Line Power Deviation of Area 2

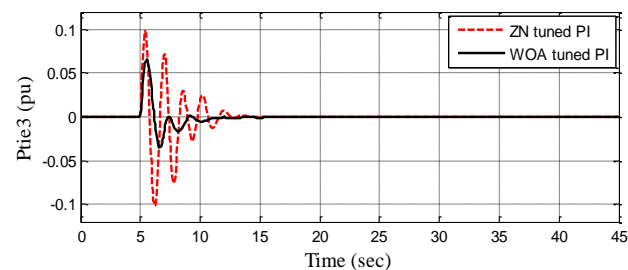


Fig. 7: Tie-Line Power Deviation of Area 3

Fig. 5 – 7 show the tie-line power flow deviations of the interconnected system for area 1 – 3. From the responses, it can be seen that the developed WOA tuned PI scheme achieved better performance with reduced overshoot and faster settling time and less oscillations compared to ZN PI control scheme. This is due to the optimized gains of the PI controllers.

It can equally be inferred from the responses that negative overshoot is observed in area 1 tie-line power deviation for the first three load disturbances and positive overshoot in area 2 and 3. This indicates that power flows into the area 1 following the step load change and out of the area 2 and 3.

By comparing the performance of the two control schemes on the tie-line power deviation, a reduction of 56.03%, 53.19% and 56.84% are observed on the ISE of the three areas respectively. While the IAEs of the tie-line power is found to have been reduced by 46.96%, 45.33% and 46.74% respectively as summarized in Table 2.

Table 4.2: ISE and IAE of the Tie-line Power Deviations

CA	Control Scheme	ISE ( $pu^2$ )	Improvement	IAE ( $pu$ )	Improvement
1	LQR-PI	0.0009		0.1112	
	lec-PI	0.0021	56.03%	0.2097	46.96%
2	LQR-PI	0.0020		0.1529	
	lec-PI	0.0045	53.19%	0.2882	45.33%
3	LQR-PI	0.0031		0.1943	
	lec-PI	0.0072	56.84%	0.3664	46.74%

Fig. 8 – 10 show the ACE deviations of the three areas with single area step load disturbance.

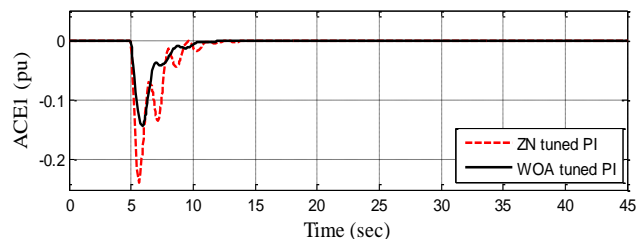


Fig. 8: ACE Deviation of Area 1

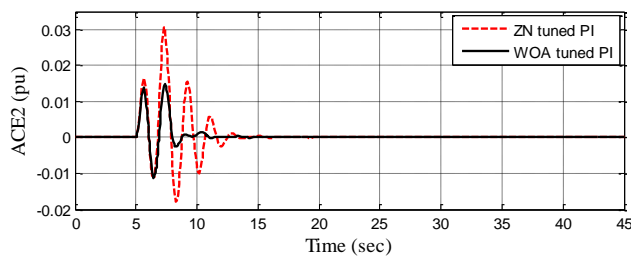


Fig. 9: ACE Deviation of Area 2

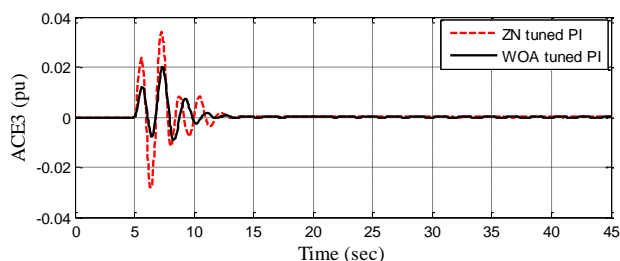


Fig. 10: ACE Deviation of Area 3

As in the other two states of the system, there is significant reduction in the ISE and IAE of the ACE of the three control areas as summarized in Table 3.

Table 3: ISE and IAE of the ACE Deviations

CA	Control Scheme	ISE ( $pu^2$ )	Improvement	IAE ( $pu$ )	Improvement
1	LQR-PI	0.0042		0.2694	
	dec-PI	0.0088	52.58%	0.5214	48.33%
2	LQR-PI	0.0002		0.0501	
	dec-PI	0.0005	51.06%	0.0969	46.55%
3	LQR-PI	0.0050		0.2893	
	dec-PI	0.0106	52.92%	0.5599	49.14%

## CONCLUSION

In this paper, a decentralized LFC for interconnected MAPS is presented. A standard proportional-integral (PI) controllers are employed at the supplementary control loop, in a decentralized pattern, to regulate the CA's frequency and tie-line power interchanges. To achieve best closed loop performance, Whale Optimization Algorithm (WOA) is used to optimize the gains of the decentralized PIs by minimizing an objective function formulated based on integral squared error (ISE) subject to frequency deviation range, generation rate and controllers' gains constraints. The effectiveness of the developed control scheme is ascertained by applying it on a 3-area MAPS subjected to step load change. From the simulations studies carried out in MATLAB/Simulink environment, it is established that the Integral Squared Error (ISE) of the frequency deviation is reduced by 44.32%, 43.82% and 54.77% in the respective

CAs when compared with conventional Ziegler Nichols based PI control scheme. While the reduction in the ISE of the tie-line power deviation is found to be 56.03%, 53.19% and 56.84% in the three CAs. These reductions indicate better performance with reduced overshoot and faster settling time and less oscillations compared to ZN PI control scheme. This is due to the optimized gains of the PI controllers. It is envisioned as future work to use a more robust controllers configured in a distributed pattern.

## REFERENCES

- Abd-Elazim, S. A., 2010. Optimal PID tuning for load frequency control using bacteria foraging optimization algorithm. Cairo, Proceedings of the 14th international Middle East power systems conference. Cairo University, Egypt;
- Azeer, S. A., Ramjug-Ballgobin, R. & Hassen, S. Z., 2017. Intelligent Controllers for Frequency Control for Two Area Power System. Réduit, Mauritius,
- Davidson, U. A., 2016. H-Infinity Loop-Shaping Controller for Load Frequency Control of an Uncertain Deregulated Power System. Kerala, India, IEEE Proceedings International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT), pp. 2185-2191.
- Ejegi, E.E., Rossiter J.A. & Trodden P. (2015), Model predictive load frequency control of a two-area deregulated Power System. Linz, Austria, s.n.
- Ejegi, E.E., Rossiter J.A. & Trodden P. (2016), Distributed model predictive load frequency control of a deregulated power system. Belfast, UK., UKACC 11th International Conference on Control (CONTROL).
- Ersdal, A. M., & Kjeti U., 2015. Model Predictive Load-Frequency Control. IEEE TRANSACTIONS ON POWER SYSTEMS, Volume 7, pp. 1-9.
- Guhaa D. P., Kumar, R., Subrata, B., Quasi-oppositional differential search algorithm applied to load frequency control. International Journal of Engineering, Science and Technology, 19(4), p. 1635-1654..
- Guolian, X. Z., 2011. Design of PSO-Based Fuzzy Gain Scheduling PI Controller for Four-Area Interconnected AGC System after Deregulation. Zhengzhou, China, , IEEE, pp. 72-76.

- Hemmati, R., Azizi, N., Khah, M. S. & Catalao, J. P. S., 2018. Decentralized frequency-voltage control and stability enhancement of standalone wind turbine-load-battery. *International Journal of Electrical Power & Energy Systems*, Volume 102, pp. 1-10.
- Hirase, Y., Abe, K. & Ise, T., 2018. A novel control approach for virtual synchronous generators to suppress frequency and voltage fluctuations in microgrids. *Applied Energy*, Volume 210, pp. 699-710.
- Hota, P. & Mohanty, B., 2016. Automatic generation control of multi source power generation under deregulated environment. *Electrical Power and Energy Systems*, Volume 75, p. 205–214.
- Khajehoddin, S. A., 2016. Robust Load Frequency Control in Islanded Microgrid Systems Using  $\mu$ -Synthesis and D-K Iteration. s.l., IEEE Proceedings.
- Kocaarslan, C., 2005. Fuzzy logic controller in interconnected electrical power systems for load-frequency control. *International Journal of Electrical Power Energy System*, 27(8), p. 542–9.
- Kumari, N. & Jha, A. N., 2014. Automatic Generation Control Using LQR based PI Controller for Multi Area Interconnected Power System. *Advance in Electronic and Electric Engineering*, 4(2), pp. 149-154.
- Kunya, A. B. & Argin, M., 2018. Model Predictive Load Frequency Control of Multi-Area Interconnected Power System. College Station, Texas, USA, s.n.
- Kunya, A. B., Jibril, Y., & Emmanuel, O., 2017. Distributed MPC-Based Load Frequency Control of Multi-Area Interconnected Power System. *Journal Electrical Engineering, Department of Electrical Engineering, A.B.U Zaria*, pp. 30-39.
- Kunya, A. B., Argin, M. & Kucuksari, S., 2019. MPC-Based Load Frequency Control of Multi-Area Power System. College Station, Texas, USA, s.n.
- Machowski, J. W., 2008. *Power System Dynamics: Stability and Control*. West Sussex, United Kingdom: John Wiley and Sons Ltd.
- Mehta, P., Bhatt, P. & Pandya, V., 2017. Optimized coordinated control of frequency and voltage for distributed generating system using Cuckoo Search Algorithm. *Ain Shams Engineering Journal*, Volume xxx, pp. 1-10.



- Mohamed, T. H., Shabib, G., Abdelhameed, E. H. & Khamies, M., 2015. Load Frequency Control in Single Area System Using Model Predictive Control and Linear Quadratic Gaussian Techniques. *International Journal of Electrical Energy*, 3(3), pp. 141 - 143.
- Mohammad M. A., 2017. Robust Decentralized Networked Control Design for Multi-Area Load Frequency Control. Iran, s.n.
- Pappachen, A. & Fathima, P., 2017. Critical research areas on load frequency control issues in a deregulated power system: A state-of-the-art-of-review. *Renewable and Sustainable Energy Reviews*, Volume 72, p. 163–177.
- Pradhan, C. & Bhende, C. N., 2019. Online load frequency control in wind integrated power systems using modified Jaya optimization. *Engineering Applications of Artificial Intelligence* 77 (2019) , Volume 77, p. 212–228.
- Prasada, S., Purwar, S. & Kishor, N., 2019. Load frequency regulation using observer based non-linear sliding mode control. *Electrical Power and Energy Systems* , Volume 104, p. 178–193.
- Rahman, M., Sarkar, S. K. & Das, S. K., 2018. Stabilization Improvement of Load Frequency Deviation for Multi-Area Interconnected Smart Grid Using Integral Linear Quadratic Gaussian Control Approach. Dhaka, Bangladesh, s.n.
- Sahu, P. C., Mishra, S., Prusty, R. C. & Panda, S., 2018. Improved -salp swarm optimized type-II fuzzy controller in load frequency control of multi area islanded AC microgrid. *Sustainable Energy, Grids and Networks*, Volume <https://doi.org/10.1016/j.segan.2018.10.003>, pp. 1-28.
- Saikia, S., 2015. Automatic generation control of a multi-area Thermal power system using Grey Wolf Optimizer algorithm based classical controllers. *Electrical Power and Energy Systems*, pp. 73 (2), 853-862.
- Saxena, S. & Hote, Y. V., 2016. Decentralized PID load frequency control for perturbed multi-area power systems. *Electrical Power and Energy Systems*, Volume 81, p. 405–415.
- Saxena, S., 2019. Load frequency control strategy via fractional-order controller and reduced order modelling. *Electrical Power and Energy Systems*, Volume 104, p. 603–614.
- Simhadri, K. S. & Mohanty, B., 2019. Performance analysis of dual-mode PI controller using quasi-oppositional whale optimization algorithm for load frequency control. *International Transaction on Electrical Energy System*, pp. 1 - 23.

- Stil, V. J. & Mehmedovic, M., 2018. Interconnection and damping assignment automatic voltage regulator for synchronous generators. *Electrical Power and Energy Systems*, Volume 101 , p. 204–212.
- Su, H.-Y. & Liu, T.-Y., 2018. WAMS-based coordinated automatic voltage regulation incorporating voltage stability constraints using sequential linear programming approximation algorithm. *Electric Power Systems Research*, Volume 163, pp. 482-490.
- Sujan, Q. X., 2017. Decentralized control of two DC microgrids interconnected with tie-line. *Journal of Modern Power System and Clean Energy*, pp. 599–608, vol. 5, no. 4.
- Yousef, H. A., 2017. *Power System Load Power System Load Classical and Adaptive Fuzzy Approaches*. Broken Sound Parkway NW: Taylor and Francis.
- Zhang, Y., & Xia. L. Q., 2017. Distributed Model Predictive Load Frequency Control of Multi-area Power System with DFIGs. *IEEE/CAA Journal of Automatica Sinica*, vol. 4, no. 1, pp. 125-135.

## **METHYLENE BLUE RECOVERY FROM SIMULATED WATER USING BENTONITE CLAY, KAOLINITE CLAY AND WORM CASTING COMPOSITE ADSORBENT**

Adeniji, A.T.<sup>1,2\*</sup>, Alade, A.O.<sup>1,2,3</sup>, Afolabi, T.J.<sup>1,2</sup>, Arinkoola, A.O.<sup>1</sup>, Araromi, D. O.<sup>1</sup>,  
Salam, K.K.<sup>1</sup>, Ajibike, M.A.<sup>1,2</sup>, Ganiyu, S.O.<sup>1</sup>

<sup>1</sup>Department of Chemical Engineering, Faculty of Engineering, Ladoke Akintola University  
of Technology, Ogbomosho, Nigeria

<sup>2</sup>Bioenvironmental, Water and Engineering Research Group (BWERG), Ladoke Akintola  
University of Technology, Ogbomosho, Nigeria

<sup>3</sup>Science and Engineering Research Group (SAERG), Ladoke Akintola University of  
Technology, Ogbomosho, Nigeria

\*Email of Corresponding Author: [atadeniji@student.lautech.edu.ng](mailto:atadeniji@student.lautech.edu.ng)

### **ABSTRACT**

Methylene Blue (MB) is an organic dye that has wide applications in the textile industries. Its presence in water stream is dangerous to aquatic animal and man. Its removal through various methods has been explored but adsorption method has attracted much attention. Thus, there is a growing effort to get the best adsorbent that can remove MB effectively from waste water. This study investigated MB recovery from simulated water using Bentonite Clay, Kaolinite Clay and Worm Casting composite adsorbent. Bentonite clay, Kaolinite Clay and Worm Castings were sourced, crushed to fine particles, washed, sun-dried and subsequently crushed to fine particles. 80g of the crushed fine particles were activated with 100 ml of 2 M of H<sub>3</sub>PO<sub>4</sub> for 24 hours, neutralized with NaOH, sundried and finally crushed. Simplex Centroid Design of the Design-Expert (7.1.6) software was employed to optimize the effective ratio mix of the mass composition (25–50%) of the three clay samples. 1 g of the clay composite/mixture was added to 100 ml of 10 mg/l of Methylene Blue solution and agitated for 24 hr. The unabsorbed amount was quantified using UV spectrophotometer. The data generated were analyzed statistically, for the Analysis of Variance (ANOVA) and model generation. Upon activation of the clay samples, the resulting suspension gave a pH of 1.2, conductivity of 10.1 S/m and Temperature of 30°C. The effective composite ratio mixed was 0.42:0.29:0.29 (w/w) (Kaolinite Clay: Bentonite Clay: Worm Casting).The maximum Adsorption Capacity (q<sub>e</sub>) of

the MB solution by the Clays composite was 976.60 mg/g while the minimum is 941.80 mg/g. The Quadratic model developed for RE gave  $R^2$  and Standard deviation of 0.9444 and 0.0576 respectively. The adjusted  $R^2$  from the model was 0.8518. The model was significant with a Prob > F of 0.0423 and F value of 10.19. The Bentonite Clay, Kaolinite Clay and Worm Casting composite adsorbent developed demonstrated satisfactory efficiency for methylene blue removal.

**Keywords:** Adsorbent, Bentonite, Clay, Kaolinite, Methylene Blue, Worm Casting

## **INTRODUCTION**

Water pollution arises when pollutants are directly or indirectly discharged into water bodies without adequate management. Water pollution is caused by marine dumping, industrial waste, domestic sewage, nuclear waste, oil pollution, underground storage leaks etc. Disposal of large amounts of wastewater that contains possibly toxic organic solutes is a challenge shared by many companies. These water contaminants are the main cause of life taking diseases like cancer, lung diseases, skin issues, allergies and many more (Aksu, 2005).

Dyes from industries such as dye synthesis, printing, paper, textile, electroplating, pulp mill, food, and cosmetic are the major cause of water pollution. The complex aromatic structures and xenobiotic properties of dyes make them more challenging to degrade (Parida, 2012). Dyes are dangerous to flora and fauna, and some of the organic dyes and their products have a mutagenic or carcinogenic effect on human beings (Aksu, 2005).

It was detected that high solubility of dyes present in water causes extensive dissemination into the environment, thus causing harmful to crops, aquatic life, and human health. The alarming level of synthetic and natural organic substances in natural water led to the value of using adsorption method as one of the most productive methods of removing impurities from wastewater since most of the dyes and its degradation byproducts are very much toxic to living organisms (Hesham & Yang, 2010). Thus, removal of dyes is one of the significant parts of wastewater treatment before release, as it is hard to expel dyes from effluent because they are not easily degradable and are generally not removed from wastewater by the conventional wastewater purification systems (Hesham and Yang, 2010).

Several methods of wastewater treatment such as coagulation (Lau *et al*, 2014), aerobic or anaerobic digestion (Kokabian *et al*, 2013), advanced oxidation process (Sakkas *et al*, 2010),

adsorption (Fernandez et al, 2014 and Rotte et al, 2014), and others have been effectively applied for the removal of various dye stuff from aqueous solutions. All these methods have advantages and disadvantages in terms of their effectiveness, cost, and environmental impact (Luo, 2010).

Adsorption has been vastly reported as the most widely used technique for the removal of toxic organic and inorganic micro-pollutants from wastewater because of its performance and ease of operation (Zhou *et al*, 2014 and Obeid *et al*, 2014). Activated carbon is an extensively used adsorbent applied for the removal of pollutants because of its high specific surface area and surface reactivity (Hassan et al, 2014). The main problem associated with activated carbon involves the costs of preparation and raw materials; however, this drawback can be alleviated by utilizing low-cost material such as bentonite clay derivatives has become important. Thus keeping the above limitation of activated carbon, clay minerals have been extensively studied because of their strong sorption and complexation ability.

## **MATERIALS AND METHODS**

### **Materials**

The Bentonite and Kaolinite Clay were obtained from Ikpoba River, Benin City, Edo State, Nigeria and the Worm Casting was sourced from LAUTECH, Ogbomosho, Nigeria premises, they were ground to a particle size that ranges from 20  $\mu\text{m}$  to 45  $\mu\text{m}$ .  $\text{H}_3\text{PO}_4$  (Phosphoric Acid), Methylene Blue (Chemical Formula:  $\text{C}_{16}\text{H}_{18}\text{N}_3\text{SCl}$ , Molecular Weight: 319.85 g/mol, Solubility in water: 40 g/L, UltraViolet (UV) Absorbance Value: 665nm), NaOH (Sodium Hydroxide) were purchased from Bond Chemicals, Ibadan, Oyo State, Nigeria.

### **Preparation of the Adsorbent**

The crushed Bentonite clay (80 g) was added to 100ml of double distill water, stirred vigorously and allowed to form a dispersion for 24 hours which was then sundried for 3 days and the resulting dried cake was subsequently crushed for acid activation. The same method was employed for the preparation of Kaolinite Clay and Worm Casting.

### **Activation of the Adsorbent**

Phosphoric acid (2 M) was prepared from the stock solution and 80 g of the water treated and crushed Bentonite clay was added to 100 ml of the prepared phosphoric acid, stirred vigorously and allowed to form a dispersion for 24 hours which was then sundried for 3 days

and the resulting dried cake was subsequently crushed for batch adsorption experiment. The same method was employed for the preparation of Kaolinite Clay and Worm Casting.

### **Preparation of the Adsorbate**

Methylene Blue (MB) dye is used for this study. The maximum wavelength of this dye is 665 nm. The stock solution of concentration 1000 mg/L for dye was prepared from the powder dye. The studied solutions are synthesized by dilution of stock solution to obtaining the desired concentrations (10 mg/L). The standard solutions of the dye are prepared from the stock solution already prepared; this preparation was used for the establishment of the standard curve thus allowing the reading of the concentrations.

### **Adsorption of Methylene-blue**

Adsorption of Methylene-blue dye was carried out according to the procedures described by (Alade *et al*, 2012), with some modifications. The prepared adsorbent composite (1 g) containing Kaolinite Clay, Bentonite Clay and Worm Casting in different ratio obtained from Design of Experiment (DOE) was soaked in 100ml methylene-blue dye solution of 10mg/L concentration, then left for 24 hours. The solution was decanted and taking for UV analysis using a UV spectrophotometer to obtain the absorbance.

The final concentration was calculated from the standard curve with known concentrations. The standard curve was constructed with the absorbance versus the known concentration of methylene blue. The analysis of variance (ANOVA) procedure was used to determine the significance of variables and to substantiate the adequacy of the quadratic regression model obtained in this study. The Adsorption Capacity ( $q_e$ ) was calculated using equation

$$q_e = \frac{C_o - C_e}{M} \times V \quad (1)$$

Where  $q_e$  is the Adsorption Capacity,  $C_o$  and  $C_e$  are the initial and equilibrium concentration (mg/L) respectively,  $V$  is the volume of the solution (ml) and  $M$  is the mass of the adsorbent composite (g).

### **Design of Experiment**

The design of the experiment is generally undertaken to minimize time, materials and, invariably cost, involve in experimental design. Design-Expert software (Version 7.1.6) was

used for the experimental design. The experimental design information is expressed in Table 1 below.

Table 1: Experimental Design Information

<b>Design Information</b>	
Study Type	Mixture
Design Type	Simplex Centroid
Design Model	Quadratic
Build Time (ms)	2.00
Subtype	Randomized
Runs	9
Blocks	No Blocks

The independent variables for this study were adsorbent dosage (1 g), concentration (10 mg/L), and time (24 hours), giving one response variable which is the adsorption capacity. The experimental values are expressed in Table 2 below.

Table 2: Response Derivatives

<b>Response</b>	<b>Run 1</b>
Name	$q_e$
Units	mg/g
Observations	9
Analysis	Polynomial
Minimum	941.80
Maximum	976.60

Mean	958.84
Std. Dev	11.05
Ratio	1.04
Transform	None
Model	Quadratic

## RESULTS AND DISCUSSION

### Adsorption capacity of the Composite

The experimental design with 9 runs for adsorption capacity (mg/g) gave the following results expressed in Table 3 for which mixture loading is L-Pseudo. Suitable models for adsorption capacity is usually selected based on the highest order polynomial where the additional terms are significant and the model is not aliased.

Two models (linear and the quadratic model) of the adsorption capacity response gave values (0.0608 and 0.3222 respectively) for the Predicted Residual Error Sum of Squares (PRESS) and the Cubic Model showed an aliased condition. This confirms the suitability of both the linear and the quadratic model.

The quadratic model for the adsorption capacity response has a higher  $R^2$  value (0.9444) than that of the Linear model (0.6437). The quadratic model has a lower standard deviation value (4.26) as compared to that of the linear model (7.62). The suitability of the quadratic model was further supported with the least value (662.42) of the Predicted Residual Error Sum of Squares (PRESS) as against that of the linear model. Table 3 shows the model summary statistics of the adsorption capacity.

Table 3: Model Summary Statistics of the Adsorption Capacity

Source	Linear	Quadratic	Special Cubic	Cubic
Std. Dev.	7.62	4.26	2.66	0.42
$R^2$	0.6437	0.9444	0.9855	0.9998



Adjusted R <sup>2</sup>	0.5250	0.8518	0.9421	0.9985
Predicted R <sup>2</sup>	0.0608	0.3222	-	-
PRESS	662.42	917.82	-	-
Comment	Suggested			

R<sup>2</sup>= Correlation Coefficient

### ANOVA of Adsorption Capacity (Quadratic model)

The significance of the model was based on the principle of the Fisher’s statistical test (F-test) and it generates the F-value, which represents the ratio of the mean square of regression to the mean error. Significance of the model terms was further tested based on lower probability (p-value) which may lie between 95 % confidence level. Lack of fit, which is usually preferred to be insignificant, was also used as the diagnostic test to determine the adequacy of any model developed. The result of the ANOVA is presented in Table 5.

The Mixture Component coding is L\_Pseudo for adsorption capacity and the Sum of squares is Type III – Partial. The Model **F-value** for adsorption capacity is 10.19. The F-value (0.0423) implies that there is a 4.23% chance that an F-value this large could occur due to noise. A **P-value** of less than 0.0500 indicates model terms are significant. In this case, Linear Mixture Components, AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model, were A, B and C represent the mass of Kaolinite Clay, Bentonite Clay and Worm Casting respectively.

Table 4: ANOVA for Response Surface model Analysis for adsorption capacity

Source	Sum of Squares	df	Mean Square	F-Value	P-Value
Model	922.96	5	184.59	10.19	0.0423*

Linear	629.11	2	314.56	17.37	0.0224*
Mixture					
AB	280.97	1	280.97	15.52	0.0292*
AC	72.27	1	72.27	3.99	0.1396
BC	11.10	1	11.10	0.61	0.4908
Residual	54.32	3	18.11		
Corr Total	977.28	8	0.18		

\*Significant

### Fit Statistics for Adsorption Capacity

The positive **Predicted R<sup>2</sup>** of 0.3222 is not as close to the **Adjusted R<sup>2</sup>** of 0.9444 as one might normally expect; i.e. the difference is more than 0.2. This may indicate a large block effect or a possible problem with the model and/or data for the adsorption capacity. **Adq Precision** measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 10.016 for adsorption capacity indicates an adequate signal. This model can be used to navigate the design space. Table 5 shows a summary of the statistics for adsorption capacity.

The plot of the predicted versus actual R<sup>2</sup> justifies the correlation coefficient R<sup>2</sup>, which shows most of the points are close to the straight line expresses in the plot in figure 1. Thus, this is the reason for the high value of R<sup>2</sup>.

Table 5: Statistics for Adsorption Capacity

Properties	Values
Std. Dev.	4.26
Mean	958.84
C.V.%*	0.44
R <sup>2</sup>	0.9444

Adjusted R <sup>2</sup>	0.8518
Predicted R <sup>2</sup>	0.3222
PRESS	662.42
Adeq Precision	10.016

\*Correlation Variance

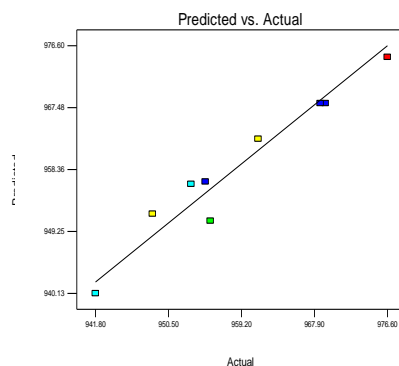


Figure 1: Plot of Predicted versus Actual values for adsorption capacity

### Final Equation for Adsorption capacity in terms of the actual component

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor and the levels should be specified in the original units for each factor. The final equation derived from the statistical analysis of the experimental runs for adsorption capacity is expressed in equation 2.

$$Adq. = 1980.96726A + 1175.19381B + 904.56726C - 2282.4212AB - 1796.13451AC + 453.57876BC \quad (2)$$

Where Adq is the Adsorption Capacity (mg/g), A is the mass (g) of Kaolinite clay and B is the mass (g) of Bentonite clay and C is the mass (g) of Worm Casting

### Model Graphs of Component Mix

Model graph (figure 2) of Kaolinite clay and Bentonite clay keeping Worm Casting composition at 33% indicated that as the mass composition of the kaolinite clay increases from 25% to 33% and that of Bentonite Clay decreases from 42% to 33%, the adsorption capacity decreases from 961.5 mg/g to 951.5 mg/g. Further increase in the mass composition of the kaolinite clay from 33% to 42% and decrease in the Bentonite Clay from 33% to 25%, the

adsorption capacity increased from 951.5 mg/g to 971.5 mg/g showed the influence of the kaolinite clay on adsorption.

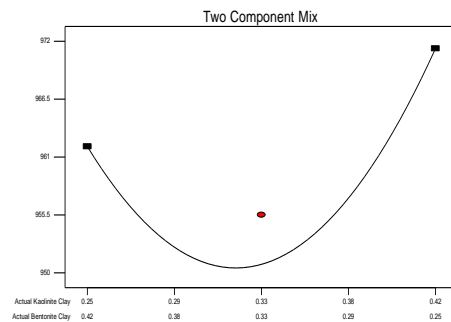


Figure 2: Model Graph of Variation of Kaolinite clay and Bentonite Clay component mix

Also, Model graph (figure 3) of Kaolinite clay and Worm Casting keeping the Bentonite clay composition at 33% indicated that as the mass composition of the Kaolinite clay increases from 25% to 33% and that of the Worm casting decreases from 42% to 33%, the adsorption capacity decreases from 950 mg/g to 947 mg/g. Further increase in the mass composition of kaolinite clay from 33% to 42% and decrease in the Bentonite Clay from 33% to 25%, the adsorption capacity increased from 947 mg/g to 977 mg/g showed the influence of the Kaolinite clay on adsorption.

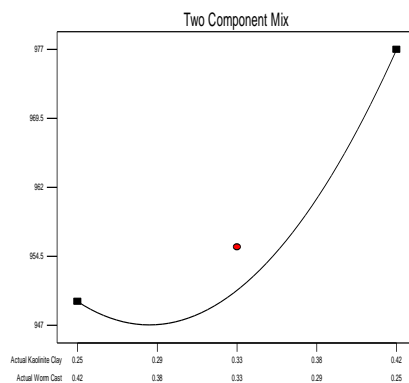


Figure 3: Model Graph of Variation of Kaolinite clay and Worm Casting component mix

Also, model graph (figure 4) of the Bentonite clay and Worm Casting keeping the Kaolinite clay composition at 33% indicated that as the mass composition of the Bentonite clay increases from 25% to 42% and that of the Worm casting decreases from 42% to 25%, the adsorption

capacity increased from 939 mg/g to 956 mg/g showed the influence of the Bentonite clay on adsorption.

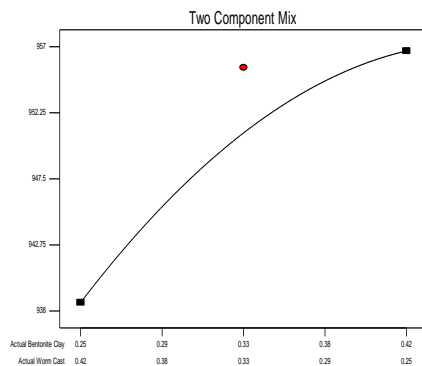


Figure 4: Model Graph of Variation of Bentonite clay and Worm Casting component mix

## CONCLUSION

Adsorption capacity conditions that best aid recovery of methylene-blue from adsorbent composite made from material A (Kaolinite Clay) and material B (Bentonite Clay) and material C (Worm Casting) has been carried out in this study. The independent variables in this study include contact time (24 hours), temperature (30 – 37°C), and adsorbent composite dosage (1g), and concentration (10mg/L).

The composition of the adsorbent composite that gave the best adsorption capacity (mg/g) values is 42% of material A (Kaolinite clay) to 29% of material B (Bentonite clay) to 29% of material C (Worm casting). Quadratic model was developed to correlate the process variables to the response of the adsorption capacity. The optimum adsorption conditions established could be useful for large-scale adsorption of methylene blue from wastewater using biocomposite developed from Banana and plantain peels.

## REFERENCES

- Aksu, Z. (2005). Application of biosorption for the removal of organic pollutants. *a review. Process Biochem*, 40, 997-1026
- Alade, O. A., Amuda, O. S., Afolabi, T. J., & Okoya, A. A. (2012, April). Adsorption of naphthalene onto activated carbons derived from milk bush kernel shell and flamboyant pod. *Journal of Environmental Chemistry and Ecotoxicology*, 4(7), 124-132

- Fernandez, M.E., Nunell G., Bonelli, P.R. & Cukierman, A.L.(2014) Activated carbon developed from orange peels: Batch and dynamic competitive adsorption of basic dyes. *Industrial Crops and Products* 62: 437–445.
- Hesham, A.&Yang, M. (2010). *Biodegradation of Petroleum Compounds and Environmental Meta-Genomics: Biotechnology*. Lambert Academic Publishing, Germany, ISBN-13: 978-3838393414
- Hassan, A.F., Abdel-Mohsen, A.M. & Fouda, M.M. (2014). Comparative study of calciumalginate, activated carbon, and their composite beads on methylene blue adsorption, *Carbohydr. Polym.*102, 192-198
- Kokabian, B., Bonakdarpour, B. & Fazel, S. (2013). The effect of salt on the performance and characteristics of a combined anaerobic–aerobic biological process for the treatment of synthetic wastewaters containing Reactive Black 5, *Chem. Eng. J.* 221, 363-372
- Lau, Y.Y., Wong, Y.S., Teng, T.T., N. Morad, N., Rafatullah, M. & Ong, S.A. (2014). Coagulation flocculation of azo dye Acid Orange 7 with green refined laterite soil, *Chem. Eng. J.* 246, 383-390.
- Luo, P., Zhao, Y., Zhang, B.,Liu, J., Yang, Y & Liu, J. (2010). Study on the adsorption of Neutral Red from aqueous solution onto halloysite nanotubes, *Water Res.* 44 1489-1497
- Obeid, L., El Kolli, N., Dali, N., Talbot, D., Abramson, S., Welschbillig, M., Cabuil, V. & Bée, A. (2014). Adsorption of a cationic surfactant by a magsorbent based on magnetic alginatebeads, *J Colloid. Interf. Sci.* 432, 182-189
- Parida, K., Mishra, K. G., & Dash, S. K. (2012). Adsorption of Copper (II) on NH<sub>2</sub>-MCM-41 and Its Application for Epoxidation of Styrene. *Industrial & Engineering Chemistry Research*, 51(5), 2235-2246. doi: 10.1021/ie200109h
- Rotte, N.K., Yerramala, S., Boniface, J. & Srikanth, V.S. (2014). Equilibrium and kinetics of Safranin O dye adsorption on MgO decked multi-layered graphene, *Chem. Eng. J.* 258, 412-419
- Sakkas, V.A., Islam, M.A., Stalikas, C. & Albanis, T.A. (2010). Photocatalytic degradation using design of experiments: A review and example of the Congo red degradation, *J. Hazard. Mater.* 175, 33-44
- Zhou, C., Wu, Q., Lei, T., &Negulescu, I.I. (2014). Adsorption kinetic and equilibrium studies formethylene blue dye by partially hydrolyzed polyacrylamide/cellulosenano crystal nanocomposite hydrogels, *Chem. Eng. J.* 251, 17-24



## **BIOSORPTION OF METHYLENE BLUE USING CHEMICALLY MODIFIED *CHRYSOPHYLLUM ALBIDIUM* SEED SHELL**

Omotayo, M. I. <sup>1,2\*</sup>, Dada, E.O. <sup>1</sup>, Alade, A.O. <sup>1,2,3</sup>, Ajani, A.O. <sup>1</sup>, Aworanti, O.A. <sup>1</sup>,  
Oyekunle, O.S. <sup>1</sup>, Adeniji, A.T. <sup>1,2</sup>, Ajibike, M.A. <sup>1,2</sup>, Adebayo, M.A. <sup>1,2</sup>

<sup>1</sup>Department of Chemical Engineering, Faculty of Engineering, Ladoke Akintola University  
of Technology, Ogbomoso, Nigeria

<sup>2</sup>Bioenvironmental, Water and Engineering Research Group (BWERG), Ladoke Akintola  
University of Technology, Ogbomoso, Nigeria

<sup>3</sup>Science and Engineering Research Group (SAERG), Ladoke Akintola University of  
Technology, Ogbomoso, Nigeria

\*Corresponding Author: [miomotayo@student.lautech.edu.ng](mailto:miomotayo@student.lautech.edu.ng) +238 160 7622 11

### ABSTRACT

Dyes are important hazardous substances found in textile, food, pharmaceutical, paper and plastics industries. Methylene blue (MB) is one the dyes that have been linked with adverse environmental impacts and there is need to reduce its effect in the water bodies. This study examined the feasibility of developing biosorbent biocomposite from *Chrysophyllum albidum* seed shell as an adsorbent for the removal of methylene-blue dye from wastewater. The African star apple (*Chrysophyllum albidum*) fruits were obtained from Oja-Oba Market, Ibadan, Oyo State. The seeds was removed and cracked to recover the shells from them. The seed shells were pretreated, oven-dried to constant weight before being milled to uniform particle sizes. Acid ( $H_3PO_4$ ), base (NaOH) and salt ( $BaCl_2$ ) was used to treat the seed shell. Suitable biocomposite mixtures were developed based on the Mixture Methodology of the Design Expert Software (7.0.1) in which the mixed ratio was varied from 5 to 100% (v/v). Fourteen (14) experimental runs were suggested by the software and the effective mixture was evaluated based on Removal Efficiency of methylene blue by the composite. The statistical tools embedded in the software were used to analyze the data obtained. Maximum Adsorption value (801.37 mg/g) of methylene blue was obtained with a mixture of chemical modified *Chrysophyllum albidum* seed shell in 20:40:40 % ( $H_3PO_4$ : NaOH:  $BaCl_2$ ). The model equation for the adsorption is quadratic given as  $MB \text{ Adsorption} = 737.09A + 790.0B + 740.69C - 37.54AB + 54.74AC + 114.31BC$ . The model gives a P value  $< 0.0001$  and the model equation is characterized with high correlation coefficient ( $R^2$ ), Adjusted  $R^2$  and predicted  $R^2$  of 0.9610,



0.9331 and 0.8756, respectively. This study has demonstrated the suitability of using optimization tools for the establishment of mixture ratio needed to make effective *Chrysophyllum Albidum* seed shell biocomposite biosorbent for the removal of common dyes in wastewater.

**Keywords:** Biosorption, *Chrysophyllum Albidum*, Methylene Blue, Mixture Methodology

## INTRODUCTION

The increasing generation of wastes from the *chrysophyllum albidium* seed shells in Nigeria is alarming and must be put to useful ends industrially. Generation of agricultural waste in the environment as a major concern has to be reduced in volume by using them for productive purpose. Methylene blue (MB) is a basic blue dyestuff with chemical formula of  $C_{16}H_{18}N_3SCl$ . Natural and Synthetic dyes are group of organic pollutants, they are extensively used in several industries such as textile, paper, printing and dye houses. The effluents of these industries are highly colored (Aksu, 2005) and discharge of dye containing effluents into the natural water bodies can pose hazardous effects on the living systems because of carcinogenic, mutagenic, allergenic and toxic nature of dyes.

The presence of very small amounts of dyes in water (less than 1 mg/dm<sup>3</sup> for some dyes) is highly visible and undesirable (Crini, 2006). Methylene blue has several harmful effects in spite of being not strongly hazardous. It is harmful when it is swallowed and it can be harmful if it is breathed and in contact with skin.

Moreover, it causes severe eye irritation (Demir *et al.*, 2008). Different biosorbent have been used for removal of dyes. Some of them include rice straw, sea-weed, wood and bark, tea-waste, maize-corn cob, sugarcane bagasse, tamarind hull, sawdust, rice husk, sunflower stem, etc. (Zahra *et al.*, 2013). In this study, the solid phase preparation technique of a cationic sorbent derived from chemically modified *Chrysophyllum albidum* seed shell was reported. This study examined the feasibility of developing biosorbent biocomposite from *Chrysophyllum albidum* seed shell as an adsorbent for the removal of methylene-blue dye from wastewater.

## MATERIALS AND METHOD

The raw materials that was used for this project work was *chrysophyllum Albidum* seed shell while the reagent was distilled water, phosphoric acid ( $H_3PO_4$ ), sodium hydroxide (NaOH) and

Barium chloride ( $\text{BaCl}_2$ ). The African star apple (*Chrysophyllum albidum*) fruits were obtained from Oja-Oba Market, Ibadan, Oyo State. It was sorted and washed with detergent and distilled water, afterwards sun dried to constant weight, then ground to smaller and uniform particle size using a blender, the grounded *chrysophyllum albidium* seed shells were soaked in phosphoric acid ( $\text{H}_3\text{PO}_4$ ), sodium hydroxide ( $\text{NaOH}$ ) and Barium chloride ( $\text{BaCl}_2$ ) respectively to decolourized and activate it for 18 hours, then added distilled water to it and neutralized the acid-base-salt materials to pH range of 6.9 - 7.0. Then it was oven dried to constant weight for 24hrs at  $110^\circ\text{C}$  and kept in plastics until further use.

### **Preparation of Adsorbate**

Methylene Blue (MB) dye is used for this study. The maximum wavelength of this dye is 665nm. The stock solution of concentration 1000mg/L for dye was prepared from the powder dye.

The studied solutions are synthesized by dilution of stock solution to obtaining the desired concentrations (10 mg/L). The standard solutions of the dye are prepared from the stock solution already prepared; this preparation was used for the establishment of the standard curve thus allowing the reading of the concentrations.

### **Adsorption of Methylene-blue**

Adsorption of Methylene-blue dye was carried out according to the procedures described by (Alade *et al*, 2012), with some modifications. 1g of prepared biocomposite mixtures were developed based on the Mixture Methodology of the Design Expert Software (7.0.1) in which the mixed ratio was varied from 5 to 100% (v/v). Fourteen (14) experimental runs were suggested by the software and containing different ratio obtained from Design of Experiment (DOE) was soaked in 100ml methylene-blue dye solution of 10mg/L concentration, then left for 24hours. The solution was decanted and taking for UV analysis using a UV spectrophotometer to obtain the absorbance. The final concentration was calculated from the standard curve with known concentrations. The standard curve was constructed with the absorbance versus known concentration of methylene blue. The analysis of variance (ANOVA) procedure was used to determine the significance of variables and to substantiate the adequacy of the Biosorption of Methylene Blue from Wastewater Using Chemically Modified *Chrysophyllum Albidium* Seed Shell. The removal efficiency and adsorption capacity was calculated using equation 1 and 2 respectively.

$$\text{Removal (\%)} = \frac{C_o - C_e}{C_o} \times 100\% \quad (1)$$

$$\text{Adsorption capacity} = \frac{C_o - C_e}{M} \times V \quad (2)$$

Where RE is the removal efficiency (%), Co and Ce are initial concentration and equilibrium concentration (mg/L) respectively, V is volume of the solution (ml) and M is the mass of the biocomposite (g).

### Design of Experiment

The design of the experiment is generally undertaken to minimize time, materials and, invariably cost, involve in Design-Expert software (Version 7.0.1).

Table 1 Experimental design information

Study Type	Mixture
Design Type	Simplex Lattice
Design Model	Quadratic
Build Time (ms)	2.00
Subtype	Cubic
Runs	13
Blocks	No block

## RESULT AND DISCUSSION

### Adsorption capacity of the Biocomposite

The experimental design with 13 runs for adsorption capacity (mg/L) and removal efficiency gives the following results expressed in Table 2 for which mixture loading is Pseudo, with transformation power of lambda,  $\lambda$  raised to the power of -3 having no constant. Suitable models for adsorption capacity and removal efficiency were usually selected based on the highest order polynomials. Run 4 have the highest response of value (801.37mg/L) with mixture ratio of 20:40:40 (H<sub>3</sub>PO<sub>4</sub>: NaOH: BaCl<sub>2</sub>).

Table 2: Runs for Adsorption Capacity Response

Run	Component (%)			Response 1
	A:H <sub>3</sub> PO <sub>4</sub> -Modified	B:NaOH-Modified	C:BaCl <sub>2</sub> -Modified	MBN (mg/L)
1	20.000	60.000	20.000	794.52
2	26.667	46.667	26.667	787.10
3	60.000	20.000	20.000	736.30
4	20.000	40.000	40.000	801.37

5	26.667	26.667	46.667	767.12
6	33.333	33.333	33.333	766.55
7	40.000	40.000	20.000	754.00
8	20.000	20.000	60.000	745.43
9	20.000	20.000	60.000	735.73
10	20.000	40.000	40.000	785.96
11	20.000	60.000	20.000	784.25
12	60.000	20.000	20.000	738.01
13	40.000	20.000	40.000	753.42

The quadratic model has a  $R^2$  value (0.9610), Adjusted  $R^2$  value (0.9331) predicted  $R^2$  value (0.8756) and standard deviation (6.04) for the adsorption capacity.

Table 3: Experimental design information

Std. Dev.	6.04	R-Squared	0.9610
Mean	765.37	Adj R-Squared	0.9331
C.V.* %	0.79	Pred R-Squared	0.8756
PRESS	813.95	Adeq Precision	13.850

C.V.\* = Correlation Variance

The "Pred R-Squared" of 0.8756 is in reasonable agreement with the "Adj R-Squared" of 0.9331. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 13.850 indicates an adequate signal. This model can be used to navigate the design space

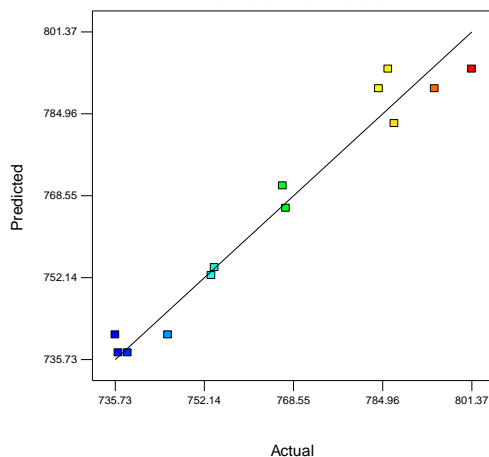


Figure 1: Plot of Predicted versus Actual values for adsorption capacity

The plot of the predicted to actual  $R^2$  justifies the correlation coefficient  $R^2$ , which shows most of the points are close to the straight line expresses in the plot in figure 1. Thus, this is the reason for the high value of  $R^2$ .

**Final Equation in Terms of Actual Components:**

$$\text{MBN} = +7.20212 * \text{H}_3\text{PO}_4\text{-Modified} + 7.78027 * \text{NaOH-Modified} + 5.39415 * \text{BaCl}_2\text{-Modified} - 0.023461 * \text{H}_3\text{PO}_4\text{-Modified} * \text{NaOH Modified} + 0.034210 * \text{H}_3\text{PO}_4\text{-Modified} * \text{BaCl}_2\text{-Modified} + 0.071441 * \text{NaOH-Modified} * \text{BaCl}_2\text{-Modified}$$

**CONCLUSION**

Adsorption capacity conditions best aid adsorption of methylene-blue using biocomposite of chemically modified *Chrysophyllum Albidum* seed shell made has been carried out in this study. The independent variables in this study include contact time (24 hours), temperature (30 – 37°C), and biocomposite dosage (1g), and concentration (10mg/L). The composition of the biocomposite that gave the best adsorption capacity (mg/g) is 20 % of  $\text{H}_3\text{PO}_4$ -Modified to 40 % of NaOH Modified to 40% of  $\text{BaCl}_2$ -Modified of *Chrysophyllum Albidum* seed shell.

**REFERENCES**

Aksu, Z. (2005). Application of biosorption for the removal of organic pollutants. *A review. Process Biochem*, 40, 997-1026.

Alade, O.A., Amuda, O.S., Afolabi, T.J., & Okoya, A.A. (2012). Adsorption of naphthalene onto activated carbons derived from milk bush kernel shell and flamboyant pod. *Journal of Environmental Chemistry and Ecotoxicology*, 4(7), 124-132.

Crini, G. (2006). Non-conventional low-cost adsorbents for dye removal. *a review. Bioresour. Technol*, 97, 1061-1085.

Demir, H., Top, A., Balköse, D., & Ülkü, S. (2008). Dye adsorption behavior of *Luffa cylindrica* fibers. *Journal of Hazardous Materials*, 153, 389-394.

Gupta, V., & Suhas, K. (2009). Application of low-cost adsorbents for dye removal. *a review, J. Environmental Management*, 90, 2313-2342.

Oboh, I., Aluyor, E., & Audu, T. (2009). Use of *Chrysophyllum Albidium* for the removal of metal ions from aqueous solution.

Zahra, A., Mohammad, A., Eshagh, R., Nezhad, Farzaneh, M., & Vahid, M. (2013). Adsorptive Removal of  $\text{Co}^{2+}$  and  $\text{Ni}^{2+}$  by Peels of Banana from Aqueous Solution. *Universal Journal of Chemistry*, 1(3), 90-9

## **DEVELOPMENT OF KIFILIDEEN (POWER OF BASE 11) AND ANTI-KIFILIDEEN (ANTIPOWER OF BASE 11) TABLES**

Osanyinpeju, K. L.

*Agricultural and Bio-Resources Engineering Department, College of Engineering, Federal  
University of Agriculture Abeokuta*

\* Corresponding Author email address: *amkifilideenosanyinpeju@gmail.com, prof\_4us@yahoo.com*

### **ABSTRACT**

Mathematics should be dynamic not static. The use of logarithm table which is based on power of base ten to solve mathematical problem has been in existence for nearly 400 years ago without any alternative which makes mathematics look static, austere and monotonous. Some real life mathematical problem encounter on daily basis in field of Engineering, Physics, Mathematics, Finance, Cosmology, Accounting, Carpentering and Medicine involve problem on other base power of number and in addition with power of base ten. There is need to find alternative way to solve mathematical problems using other means and working on the power encounter directly. This study developed and applied kifilideen (power of base 11) and Antikifilideen (Antipower of base 11) tables to solve mathematical problems which logarithm table can solve without any obstacle. The novel method also utilized the power and ability of 11 which its power can be expanded without using calculator. These methods have been tested and found simple, accurate, effective, easy and useful.

**Keywords:** Kifilideen table, Antikifilideen table, Logarithm table, Power of base 11, Mathematics problem, Indices, Combination.

### **Introduction**

The use of logarithm table which is based on power of ten to solve mathematical problem has been in existence for nearly 400 years ago (Siegried, 2014; Macrae *et al.*, 2016; Seath, 2017) without any alternative which makes mathematics look static, austere and monotonous. Cetin (2004) indicates that the way mathematics is been tutored and learned has been long overdue for more than three decades and required reform. A Scottish mathematician John Napier (1550-1617) and English mathematician Henry Briggs (1561-1630) singly published logarithms tables in 1614 and 1620 respectively (Gourdon and Sebah, 2004; Roegel, 2010; Weber, 2016).

John Napier titles his book as *Mirifici Logarithmorum Canonis Descriptio* meaning Description of the marvelous rule of logarithms (Hobson, 1914; Campbell-Kelly et al., 2007; Villareal-Calderon, 2008, Roegel, 2011; Lexa 2011; Clark and Montelle 2011; Ayoub, 2018).

Napier died in 1617 at the age 67 (Bryant and Scott, 2004). In the same year, Burgi privately published decimal or common logarithm table of base 10 to containing number from 1 to 1, 000 to 14 decimal places (Bradwardine, 1974). He gave the title of the book as Briggs's *Logarithmorum chilias prima*. There was no author's name, place or date on it. The first table of common system of logarithm of base 10 was invented as joint and vigorous attempt of Napier and Henry Briggs in 1624 (Waldvogel, 2012; Brian et al., 2017) title *Arithmetica Logarithmica* (Cajori, 1999). Their common logarithm Tables which uses base 10 contains number from 1 to 20, 000 and from 90, 000 to 100, 000 in 14 decimal points (Barnes-Svarney and Svarney, 2012).

Some real life mathematical problems encounter on daily basis such as calculating and computing the cost and amount of materials, calculation which involves multiplication of large numbers that are complex may result to problem involving power of base number other than power of ten. Many professions such as Engineering, Statistics, Finance, Chemistry, Architect, Astronomy, Mathematics, Accounting, Economic, Carpentering and Medicine confront problem of this nature mention above (Berezovski, 2004).

The power of base number of tables helps to convert multiplication and division into much easier addition and subtraction problems. The use of common logarithm table which is on base 10 has been used extensively till date without any alternative both in secondary school and various professions to solve mathematical problem. The beauty of mathematics is that is dynamic not static. Mathematics is designed and created in such a way that mathematical problem can be solved in different ways and the same answer would be established. Some of procedure in solving the mathematical problems can be short or long, simple or complex, real or ABSTRACT. What matter must in mathematics is that the method used is accurate, generally accepted by the scientific world.

Mathematics is put in place to develop the brain and improve reasoning. Along the line due to some challenge and obstacle in using some methods and in handling figure the procedure in solving mathematical problems was now narrow and streamline to one way thing which suppose not to be so and not good for mathematics. Every number in nature has its power, capabilities and potential in solving man problem. There should be a way out to solve



mathematical problem with the used of other power of other base number table directly other than logarithms table which is base on power of base 10.

The establishment of various power of number table would make the procedure in solving mathematical problem flexible and not rigid. The power table would also give room for the conversion of one power base of a number to another power base without the use of calculator rather than table. The used of power base tables other than common logarithm table which is on base 10 is not available. This study developed and applied kifilideen (power of 11) and Antikifilideen (Antipower of 11) tables to solve mathematical problem which logarithm table can solve without any obstacle.

### **Methods**

The Kifilideen (power of base 11) and AntiKifilideen (antipower of base 11) tables were invented based on manual method of computing and also with the ministration of calculator although the established tables can be used to solve present-day real life problems without the use of calculator. The root of the manual method adopted for the inception of Kifilideen (Power of base 11) and AntiKifilideen (Antipower of base 11) tables is illustrated as follows:

To refashion 7 to the power of base 11, you commence by looking for the value to be raised by 11 to give 7.  $11^{0.8} = 6.809483128$  which is less than the 7 to be obtained. Meanwhile, the power of the base 11 is increased. So, we try  $11^{0.82}$  which gives 7.144009145. The value attained is more than the value we wanted that is 7. Then, the power is decreased to 0.812. So,  $11^{0.812} = 7.008270569$ . This value realized is getting closer to the preferred value. Furthermore,  $11^{0.8115}$  is tested which gives 6.999873055 but  $11^{0.811508}$  gives 7.000007336. To drop the value you attempt  $11^{0.8115075}$  which produces 6.999998943 while  $11^{0.81150756}$  gives 6.999999995.

Then we try  $11^{0.8115075630}$  gives 7.000000001 while  $11^{0.8115075629}$  produces 6.999999999. Although the power of base 11 is put in 5 decimal places then  $11^{0.81151}$  yields 7.00004. Since the table was established base on power of 5 decimal places. Therefore, the power in which 11 must be raised to give 7 is 0.81151 stipulating Kif (7) is 0.81151 or  $7 = 11^{Kif(7)} = 11^{0.81151}$ .

In the utilization of kifilideen (power of 11) and Antikifilideen (Antipower of 11) tables effectively, the expansion of power of 11 must be understood. The power of 11 is easy to

expand compares to other power greater the 11. The expansion of power of base 11 can be done using matrix method.

**Evaluation of power of base 11**

Power of base 11 can be evaluated without using calculator. This can be done using combination or Pascal triangle involving matrix approach.

**Application of combination method in the evaluation power of base 11**

An agricultural company in collaboration with some local farmers started with 11 poultry birds. After 7 months the new stock of poultry birds in the agricultural firm increases to 11 times of the total number of previous stock of birds. If the stock of poultry birds own by the company increases 11 times every 7 months. [a] Determine the stock of the poultry birds after 70 months. [b] If the company sale each of the poultry birds 34.5 US Dollar determine the amount the company would generates from the birds after the 70 months.

**Solution**

[a] To determine the stock of the poultry birds after 70 months the formula,  $N = [11]^{\frac{T}{t_{11}}}$  is used

Where,  $N$  –the number of stock of birds for the total time duration,  $T$  –time lapses,  $t_{11}$  –time of each 11 times increase in the number of stocks of birds.

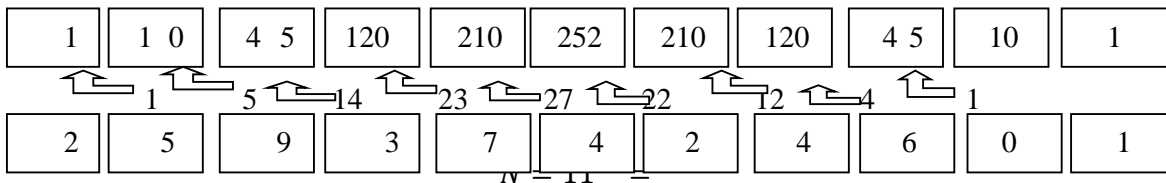
$T = 70$  months and  $t_{11} = 7$  months

$N = [11]^{\frac{70}{7}} = [11]^{10}$

To solve for  $N = [11]^{10}$  the combination approach is applied as follows:

The solution of  $11^{10}$  would has answer of (10+1) digits number i.e. 11 digits number since the 11 is in the index of 10. To determine the digits number you add the index value with one.

Using combination method we have:



25937424601 or  $2.5937424601 \times 10^{10}$  poultry birds

**Illustration of the evaluation of power of base 11 multiply by number using combination methods**

[b] To work out the amount the company would generates if the company sale each of the poultry birds 34.50 US Dollar after the 70 months

The formula  $P = p \times N$  is used

Where,  $P$  – the price generates after 70 months,  $p$  – the price of each poultry bird

$N$  – the total number of birds produce by the company after the 70 months

$$\text{So, } P = 34.50 \times [11]^{\frac{T}{t_{11}}}$$

Where,  $N$  –the number of stock of birds for the total time duration,  $T$  –time lapses,  $t_{11}$  –time of each 11 times increase in the number of stocks of birds.

$$T = 70 \text{ months and } t_{11} = 7 \text{ months}$$

$$P = 34.50 \times [11]^{\frac{70}{7}} = 34.50 \times [11]^{10} = 34.5 \times 11^{10} = 345 \times 11^{10} \times 10^{-1}$$

The solution of  $345 \times 11^{10}$  would has answer of (n+m) digits number

where n–the number of the digits of the number to be multiplied by the power of base 11.

m– the index of the power of base 11.

The solution of  $345 \times 11^{10}$  would has answer of (3+10) digits number that is 13 digits number. Since the number as 3 digits and the power of the base 11 has index 10. This makes 13 boxes

${}^{10}C_0 \times 3$ _____	3
${}^{10}C_1 \times 3 + {}^{10}C_0 \times 4$ _____	34
${}^{10}C_2 \times 3 + {}^{10}C_1 \times 4 + {}^{10}C_0 \times 5$ _____	180
${}^{10}C_3 \times 3 + {}^{10}C_2 \times 4 + {}^{10}C_1 \times 5$ _____	590
${}^{10}C_4 \times 3 + {}^{10}C_3 \times 4 + {}^{10}C_2 \times 5$ _____	1335
${}^{10}C_5 \times 3 + {}^{10}C_4 \times 4 + {}^{10}C_3 \times 5$ _____	2196
	2688

$$\begin{aligned}
 & {}^{10}C_6 \times 3 + {}^{10}C_5 \times 4 + {}^{10}C_4 \times 5 \text{ -----} \\
 & {}^{10}C_7 \times 3 + {}^{10}C_6 \times 4 + {}^{10}C_5 \times 5 \text{ -----} \boxed{2460} \\
 & {}^{10}C_8 \times 3 + {}^{10}C_7 \times 4 + {}^{10}C_6 \times 5 \text{ -----} \boxed{1665} \\
 & {}^{10}C_9 \times 3 + {}^{10}C_8 \times 4 + {}^{10}C_7 \times 5 \text{ -----} \boxed{\phantom{0000}} \\
 & {}^{10}C_{10} \times 3 + {}^{10}C_9 \times 4 + {}^{10}C_8 \times 5 \text{ -----} \boxed{\phantom{0000}} \\
 & \qquad {}^{10}C_{10} \times 4 + {}^{10}C_9 \times 5 \text{ -----} \boxed{54} \\
 & \qquad \qquad {}^{10}C_{10} \times 5 \text{ -----} \boxed{5}
 \end{aligned}$$

3	34	180	590	1335	2196	268	2460	1665		268	54	5
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5 25 74 158 249 295 363 474 633 827 1115

8	9	4	8	4	1						4	5
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$$P = 34.5 \times 11^{10} = 345 \times 11^{10} \times 10^{-1} = 8,948,411,487,143 \times 10^{-1}$$

$$P = 34.5 \times 11^{10} = 8.948 \times 10^{11} \text{ US Dollar}$$

This also gives the conversion of power base 11 to power of base 10 (that is  $34.5 \times 11^{10} \text{ US dollar} = 8.948 \times 10^{11} \text{ US Dollar}$ )

### Logarithm table

This is a table of logarithm of number in base 10 (Macrae *et al.*, 2016).

### Kifilideen table

This is a table which indicates the power in which base 11 has to be raised to proclaim a given number. The table is used to transmute ordinary number to power of base 11. It generates the power in which 11 would be raised to yield the required ordinary number. The table was established in order to carry out evaluation of power of base number, multiplication and division of numbers without using calculator.

Mathematical problems encounter on daily life involve power of bases other than power of base ten. Evaluation of compound interest and depreciation, population problem, mortgage problem, nuclear chain reaction problems, decay word problems involve powers which are not

base on the power of ten alone. The use of logarithms table which is based on base 10 has been in existence for decades in solving mathematical problem. Mathematical approach in solving mathematical problem suppose to be dynamic not static where different method should be allowed when the procedure is valid and can solve wide range of problems. The establishment of the power of 11 (Kifilideen) table would make it easy to convert from power of 11 to another power of number without using calculator.

### **AntiKifilideen table**

AntiKifilideen table is the table which is used to convert the power of base 11 of numbers to ordinary number. It is the table which shows the reverse of Kifilideen table. The Antikifilideen was developed to help in removing the power of base 11 of any number to ordinary number.

### **Ordinary number**

Ordinary number is a real number which is not in power form. It can also be defined has a real number whose power is one. Ordinary number could be in form of decimal or whole number.

### **Conversion of number to power of base 11**

Kifilideen (Power of base 11) table can be utilized to solve multiplication and division problem.

### **Display on how to solve multiplication problem using Kifilideen table**

An automobile car engine consumes average of 4211 litres of fuel for every 11 days. Determine the quantity of fuel consumes by the car after 7869 days using Kifilideen table.

### **Solution**

The quantity of fuel consumes can calculated using the formula:  $V = v \times \frac{T}{t_{11}}$

Where,  $v$  –the volume of fuel consumption for every 11 days,  $T$  –time lapses,  $t_{11}$  – time for the 4211 litres increase in the fuel consumption.

So,  $v = 4211, T = 7869$  days and  $t_{11} = 11$  days

$$V = 4211 \times \frac{7869}{11} = 11^{\text{Kif}(4211)} \times 11^{\text{Kif}(7869)} \div 11 = 11^{\text{Kif}(42.11 \times 10^2)} \times 11^{\text{Kif}(78.69 \times 10^2)} \div 11$$

$$V = 11^{\text{Kif}(42.11) + \text{Kif}(10^2)} \times 11^{\text{Kif}(78.69) + \text{Kif}(10^2)} \div 11$$

Using Kifilideen (power of base 11) table

$$\text{Kif}(42.11) = 1.55972 + 0.00010 = 1.55982$$

$$\text{Kif}(78.69) = 1.82008 + 0.00048 = 1.82056$$

From conversion of  $[10]^n$  to  $[11]^y$  table

$$\text{Kif}[10]^2 = 1.92051$$

$$V = 11^{1.55982 + 1.92051} \times 11^{1.82056 + 1.92051} \div 11$$

$$V = 11^{3.48033 + 3.74107 - 1} = 11^{6.2214} = 11^{0.2214} \times 11^6$$

$$V = \text{Antikifi}(0.2214) \times 11^6$$

From AntiKifilideen table,

$$\text{AntiKifi}(0.2214) = \text{Check } 0.22 \text{ under } 1 \text{ Difference } 4 = 1.69882 + 0.00164 = 1.70046$$

$$V = 1.70046 \times 11^6 \text{ litres}$$

### Illustration on the conversion power of base 11 to power of base 10

In a data analysis of the population growth of a new species of rabbits introduced in a country, 11 rabbits are launched in the country. After one year the population of the rabbits has attained 11 times the population of the first set of rabbits. For every other year the population increases 11 times the previous year. Assuming the average mass of each of the rabbits is 445.6 g for any particular year. Determine the total mass of the rabbits after 72 years of the inauguration of the rabbits using Kifilideen table.

### Solution

Total mass of the rabbits after 72 years is determined using the formula:  $M = m \times [11]^{\frac{T}{t_{11}}}$

Where,  $M$  – the total mass of the rabbits after 75 years,  $m$  – the average mass of the rabbits,  $T$  – time lapses,  $t_{11}$  – time of each 11 times increase in the population of the rabbits.

Therefore,  $m = 445.6$  g,  $T = 75$  years and  $t_{11} = 1$  year

$$M = 445.6 \times [11]^{\frac{72}{1}} = 445.6 \times 11^{72}$$

From Kifilideen table,  $11^{71.05869} = 10^{74}$

$$M = 445.6 \times 11^{72} = 44.56 \times 10^1 \times 11^{71.05869} \times 11^{0.94131} = 11^{\text{Kif}(44.56)} \times 10^1 \times 10^{74} \times 11^{0.94131}$$

Using Kifilideen table,  $\text{Kif}(44.56) = 1.58284 + 0.00056 = 1.58340$

$$\text{Then, } M = 11^{\text{Kif}(44.56)} \times 10^1 \times 10^{74} \times 11^{0.94131}$$

$$M = 11^{1.58340} \times 10^1 \times 10^{74} \times 11^{0.94131}$$

$$M = 11^{1.58340+0.94131} \times 10^{75} = 11^{2.52471} \times 10^{75}$$

From Kifilideen table,  $11^{1.92051} = 10^2$

$$M = 11^{1.92051+0.6042} \times 10^{75} = 11^{0.6042} \times 11^{1.92051} \times 10^{75} = 11^{0.6042} \times 10^2 \times 10^{75}$$

$$M = \text{AntiKif}(0.6042) \times 10^{77}$$

From AntiKifilideen table,

$$\text{AntiKifi}(0.6042) = 4.25600 + 0.00204 = 4.25804$$

$$M = 445.6 \times 11^{72} = \text{AntiKifi}(0.6042) \times 10^{77}$$

$$M = 445.6 \times 11^{72} g = 4.25804 \times 10^{77} g$$

### Calculations using Kifilideen table

Solve the following using kifilideen table (without using calculator)

$$[i] \quad \left[ \frac{12.06 \times 101.9}{[1.345]^2 \times 2.672} \right]^{\frac{1}{3}}$$

### Solution

$$[i] \quad \left[ \frac{12.06 \times 101.9}{[1.345]^2 \times 2.672} \right]^{\frac{1}{3}}$$

From kifilideen table

$$\text{Kif}(12.06) = 1.03629 + 0.00201 = 1.0383,$$

$$\text{Kif}(101.9) = \text{Kif}(10.19) + \text{Kif}(10^1) = 0.96440 + 0.00358 + 0.96025 = 1.92823,$$

$$\text{Kif}(1.345) = \text{Kif}(13.45) - \text{Kif}(10^1) = 1.08231 + 0.00155 - 0.96025 = 0.12361,$$

$$\text{Kif}(2.672) = \text{Kif}(26.72) - \text{Kif}(10^1) = 1.36981 + 0.00032 - 0.96025 = 0.40988$$

NO	KIF	
12.06	1.03830	
101.9	+1.92823	
Numerator (12.06 × 101.9)	2.96653	2.96653

$$\begin{array}{rcl}
 1.345 & & 0.12361 \\
 [1.345]^2 & & 0.12361 \times 2 = \\
 & & 0.24722 \\
 2.672 & & + 0.40988 \\
 \text{Denominator } ([1.345]^2 \times & 0.65710 & - 0.65710 \\
 2.672) & & \\
 \frac{12.06 \times 101.9}{[1.345]^2 \times 2.672} & & 2.30943 \\
 \left[ \frac{12.06 \times 101.9}{[1.345]^2 \times 2.672} \right]^{\frac{1}{3}} & & 2.30943 \div 3 = \\
 & & 0.76981 \\
 6.33367 & \longleftarrow & 
 \end{array}$$

Using the AntiKifilideen table

$$\text{AntiKifi } (0.76981) = (6.32166 + 0.01201) = 6.33367$$

$$\left[ \frac{12.06 \times 101.9}{[1.345]^2 \times 2.672} \right]^{\frac{1}{3}} = 6.33367$$

**Discussion**

Each row of the difference sections of Osanyinpeju (Power of base 2), Lekan (Power of base 5) and Kifilideen (Power of base 11) tables as linear progressions (Osanyinpeju, 2019). The first 10 columns of each table, each row also has an arithmetic progressions which generate a straight line graph. Furthermore, each column of the first 10 columns of each table mentioned above has the same pattern of graph.

It indicates that there is possibility to predict the value for a particular column and row of the difference section of any of the power of base table and also there is very high likelihood to foresee the value of a particular row and column of the first 10 columns of any of the power of base table.

**CONCLUSION**

The power (Kifilideen) and antipower (Antikifilideen) of base 11 tables have been developed and fully utilized for power of 11 of positive numbers. The evaluation and expansion of the



power of 11 without using calculator was carried out using combination method. The results obtained from the expansion were linked to the power of base 10. The tables developed had been tested using various mathematical problems and had been found simple, accurate, effective, easy and useful.

## **References**

- Ayoub R. (2018). What is a Napierian Logarithm? *The American Mathematical Monthly* 100 (4): 351-351.
- Berezovski T. (2004). An Inquiry into High School Students' Understanding of Logarithms. Msc. Published Project. Simon Fraser Univeristy, Burnaby, BC, Canada, USA 104 pg.
- Brian R., Gonzalez-Velasco E., Corrigan A. (2017). *The Life and Works of John Napier*. Springer Publisher, Sal, on Tower Building, New York City, United State 994 pg.
- Barnes-Svarney P. and Svarney T.E. (2012). *The Handy Answer Book Series*. Visible Ink Press, Canton Charter Township, Michigan, United State 528 Pg.
- Bryant K. and Scott P. (2004). John Napier's Life Napier's Logarithms. *AMT* 61 (1): 1-3.
- Bradwardine T. (1974). *Busbridge Lecture*. Mathematical Institute: Oxford Mathematics 9 pg.
- Cajori F. (1999). *A History of Mathematics*. American Mathematical Soc. 524 pg.
- Campbell-Kelly M., Croarken M., Flood R. and Robson E. (2007). *The History of Mathematical Tables from Sumer to Spreadsheets*. Oxford University Press, New York, United State 372 pg.
- Cetin Y. (2004). *Teaching Logarithm By Guided Discovery Learning and Real Life Applications*. Master Project. Department of Secondary Science and Mathematics Education, Middle East Technical University 147 pg.
- Clark K.M. and Montelle C. (2011). *Logarithms: The Early History of a Familiar Function- John Napier Introduces Logarithms*. Mathematical Association of America 7 pg.
- Gourdon X. and Sebah P. (2004). *The Logarithmic Constant: Log 2*. Numbers.computation.free.fr/Constants/constants.html 24 pg.
- Hobson E.W. (1614). *John Napier and the Invention of Longarithms, 1614*. Cambridge University Press, London 60 pg.

Lexa M.A. (2011). Remembering John Napier and His Logarithms Remembering John Napier and his Logarithms. Department of Electrical and Computer Engineering, Rice University, Houston 17 pg.

Macrae M.F., Chima Z.I., Garba G.U., Ademosu M.O. and Kalejaiye A.O. (2016). New General Mathematics for Senior Secondary Schools Book Pearson Education Limited, Edinburgh Gate, Harlow, Essex, England 301 pg.

Osanyinpeju K.L. (2019). Development, Conversion and Application of Osanyinpeju (Power of Base 2) And Antiosanyinpeju (Antipower of Base 2) With Lekan (Power of Base 5) and Antilekan (Antipower of Base 5) Tables. 1<sup>st</sup> International Conference on Engineering and Environmental Sciences (ICEES) Theme: Advancing Technology and Environment Burdens (Challenges and Sustainable Solution 5<sup>th</sup>- 7<sup>th</sup> November 2019.

Roegel D. (2010). Burgi's Progress Tabulen (1620): Logarithmic Tables without Logarithms. HAL Id: inria-00543936 105 pg.

Roegel D. (2011). A Reconstruction of Briggs' Logarithmorum chilias prima (1617). The Loria Collection of Mathematical Tables (LOCOMAT) Project, Digital Table Library, Nancy-University and Loria 32 pg.

Seath G. (2017). Beyond Logarithms and Bones: A short history of John Napier and His Legacy. Edinburgh Napier University 22 pg.

Siegfried T. (2014). Logarithms Celebrate their 400<sup>TH</sup> Birthday. Science News, Society for Science and the Public, Washingtons D.C. 2 pg.

Villarreal-Calderon R. (2008). Chopping Log: Alook at the History and Uses of Logarithms. The Mathematics Enthusiast 5 (2): 337- 344.

Waldvogel J. (2012). Jost Burgi and the Discovery of the Logarithms. Seminar for Applied Mathematics, SAM, Swiss Federal Institute of Technology Zurich, Switzerland 31 pg

Weber C. (2016). Making Logarithms Accessible-Operational and Structural Basic Models for Logarithms. Springer Journal Fur Mathematik-Didaktik 37 (1): 69-98.

**DEVELOPMENT, CONVERSION AND APPLICATION OF  
OSANYINPEJU (POWER OF BASE 2) AND ANTIOSANYINPEJU  
(ANTIPOWER OF BASE 2) WITH LEKAN (POWER OF BASE 5) AND  
ANTILEKAN (ANTIPOWER OF BASE 5) TABLES**

Osanyinpeju, K.L.<sup>1\*</sup>, Aderinlewo, A.A.<sup>1</sup>, Dairo, O.U.<sup>1</sup>, Adetunji, O.R.<sup>2</sup>, Ajisegiri, E.S.A.<sup>1</sup>

1. *Agricultural and Bio-Resources Engineering Department, College of Engineering,*

*Federal University of Agriculture Abeokuta*

2. *Mechanical Engineering Department, College of Engineering, Federal University of*

*Agriculture Abeokuta*

\* *Corresponding Author email address: amkifilideenosanyinpeju@gmail.com,*

*prof\_4us@yahoo.com*

**ABSTRACT**

Human day to day activities especially in the sector or area which involves reoccurrence of events always landed into mathematical problems which demands different kinds of power of different bases. Overtime the conversion of power of base of one number to another or to the power of base ten has been difficult to do except with the use of calculator. Due to this the mathematical process of evaluation of mathematical problem is slowed down when calculator is not available. The utilization of calculator has its own limitation in evaluation of large value of power of base number. Calculator cannot solve power of very large number. The study developed and applied osanyinpeju (power of base 2) and antiosanyinpeju (antipower of base 2) with lekan (power of base 5) and antilekan (antipower of base 5) tables to proffer solution to modern real life problems. The establishment of various powers of bases number of tables would make it easy to convert from one power of base of number to another power of base of number without using calculator.

**Keywords:** Osanyinpeju table, Antiosanyinpeju table, Logarithm table, Power of base 2, Mathematics problem, Indices, Lekan table, AntiLekan table, Power of base 5.

**Introduction**

The practical applications of logarithm to solve real life situation should be properly taught. This would go a long way to ensuring the enthusiasm of the students in knowing the topic. The

knowledge of logarithms helps to simplify multiplication, division and power of base numbers. Cetin (2004) stated that students would digest mathematics better if real life practical problems are used as the starting point of conceptual development of mathematics. As it is generally known, people put more interest in what would benefit them. Application and practical based learning would assist the students to see the value of what they have been taught and boost their zeal for knowing mathematics.

Erol (1989) confirmed that many students recognized mathematics as a mysterious subject where perplexing formulas, principles, rules, theorems and laws must be assimilated but origin of which are not known to them. Reimer and Reimer (1995) and Toumasis (1993) indicate that linking mathematics with its history build the learning morale, drive, stimulate and strengthen the student interest in mathematics.

Human day to day activities especially in the sector or area which involves reoccurrence of events always landed into mathematical problems which demands different kinds of power of different bases. Some physical problems which involve power of base of number are interest rate problem, population problem, radioactive decay problems, cooling rate, virus infection, compound interest, bacterial growth, growth of events like use of internet, acceptance of trends, accumulation of object, deposition of particles, storage of goods and mortgage problems. Great deal of practice in business is connected or attributed to rate of growth or decay. The power of bases number tables can be used to determine the number of neutrons produce in large generation of a nuclear chain reaction of a fission reaction. The number of neutrons that can be released per nuclear fission process ranges from 1 to 7 depending on the isotope and the bombarding or initiating neutron energy (Murray and Holbert, 2020).

The tables of power of different bases can be efficacious and relevant in the modeling of how reoccurring events grow or decline (Smith and Confrey, 1994; Kenney and Kastberg, 2013; Nicholas, 2006). The understanding and utilization of the conversion of power of base tables will help to make mathematical decision when comparing the power with dissimilar power base. For example, if a student is questioned to give a judgment of which power is greater between  $11^{25}$  and  $12^{20}$ . The student may eventually picked  $11^{25}$  has the larger value because is having a greater index while a set of students would predict correctly by selecting  $12^{20}$  for it possessing a larger base which bases of judgment may not be true always (Berezovski, 2004). To prevent such trial and error method of decision making and give better and precise judgment

the two powers need to be converted to have the same power base. The developed power tables would be handy for such conversion and would allow proper and sensible decision.

Availability of the tables of power of different base would provide ways to combine power of different bases together either when the powers to be combined divide or multiply each other. Unfortunately combining powers with different bases cannot be done or achieved using laws of indices (Bird, 2003).

Overtime the conversion of power of base of one number to another or to the power of base ten has been difficult to do except with the use of calculator. Due to this the mathematical process of evaluation of mathematical problem is slowed down when calculator is not available. Although the availability of calculators do not solve or provide solution to all the mathematical problems involving power of different base number. The utilization of calculator has limitation in evaluation of power of base. It cannot solve power of large number. The implementation of power of base of table has no limitation or so ever in evaluation power of base of which power is of large number unlike the use of calculator. The largest numbers of power of bases 2, 3, 4, 5, 6, 7, 8, 9, 10 11 and 12 that can be evaluated by casio or propo calculator are  $2^{332}$ ,  $3^{209}$ ,  $4^{166}$ ,  $5^{143}$ ,  $6^{129}$ ,  $7^{118}$ ,  $8^{110}$ ,  $9^{104}$ ,  $10^{99}$ ,  $11^{96}$  and  $12^{92}$  respectively beyond these powers the calculator would indicates math error.

Every number in the universe has their uniqueness and importance, putting more attention and focus on power of base 10 would continue to keep the hiding potential and ability of other power of bases. As the saying, you can only know more about something when you continue having interaction with it. Keeping off from it you know less from it. The study developed and applied osanyinpeju (power of base 2) and antiosanyinpeju (antipower of base 2) with lekan (power of base 5) and antilekan (antipower of base 5) tables to proffer solution to modern real life problem.

## **Methods**

The Osanyinpeju (power of base 2) and Lekan (power of base 5) tables with AntiOsanyinpeju (antipower of base 2) and AntiLekan (antipower of base 5) tables were built based on manual method of computing and also with the assistance of calculator although the developed tables can be used to solve modern real life problem without the use of calculator. The genesis of the manual method used to construct these tables mentioned above is illustrated as follows:

To convert 5 to the power of base 2, you start by looking for the value to be raised by 2 to give 5.  $2^2 = 4$  which is less than the 5 to be obtained. Then, the power of the base two is increased. So, we try  $2^{2.5}$  which gives 5.656854. The value obtained is greater than the value we needed that is 5. Then, the power is reduced to 2.3. Meanwhile,  $2^{2.3} = 4.924578$ . This value attained is getting closer to the required value. So,  $2^{2.32}$  is tried which gives 4.99332 but  $2^{2.33}$  gives 5.02805. The power is given a 3 decimal places trial. For  $2^{2.321}$  we have 4.996784 but  $2^{2.322}$  produces 5.000025. With this power 2.322 we are almost there. We go for power of 4 decimal places. Trying  $2^{2.3219}$  we obtained 4.9999026. For 5 decimal places,  $2^{2.32181}$  gives 4.999590731 while  $2^{2.32193}$  gives 5.000007. Then we try  $2^{2.321928}$  we have 4.999999671. Since the table was constructed base on power of 5 decimal places. So the power in which 2 must be raised to give 5 is 2.32193 indicating Osan (5) is 2.32193 or  $5 = 2^{Osan(5)} = 2^{2.32193}$ .

### **Osanyinpeju table**

Osanyinpeju table is the table which indicates the power in which base 2 has to be raised to express a given number. The table is used to transmogrify ordinary number to power of base 2. It offers the power in which 2 would be raised to give the required ordinary number. The table contained ordinary number ranging from 1 to 99.99 but the table can be utilized to transform any range of ordinary number to power of base two.

### **Antiosanyinpeju table**

Antiosanyinpeju table is the table that stipulates the value that would be obtained for a given power of base 2. The power of base 2 that can be estimated by the antiosanyinpeju table to ordinary number ranges from 0.0000 to 0.9999. It is used to change the power of base 2 of numbers to ordinary number. It is the table which shows the reverse of osanyinpeju table. The Antiosanyinpeju was established to help in removing the power of base 2 of any number to ordinary number.

### **Lekan table**

Lekan table is the table which point out the power in which base 5 has to be raised to proclaim a given number. The table is employed to transform ordinary number to power of base 5. It provides the power in which 5 would be raised to give the needed ordinary number. The table accommodates ordinary number ranging from 1 to 99.99 but the table can be used to convert any range of ordinary number to power of base 5.

### **Antilekan table**

Antilekan table is the table that specifies the value that would be achieved when estimating power of base 5. The power of base 5 that can be evaluated by the antilekan table to ordinary number ranges from 0.0000 to 0.9999. It is used to convert the power of base 5 of numbers to ordinary number. It is the table which demonstrates the reverse of Lekan table. The Antilekan was established to help in removing the power of base 5 of any number to ordinary number.

### **Kifilideen table**

Kifilideen table is the table which shows the power in which base 11 has to be raised to articulate a given number (Osanyinpeju, 2019). The table is used to transfigure ordinary number to power of base 11. It produces the power in which 11 would be raised to create the required ordinary number.

### **Antikifilideen table**

Antikifilideen table is the table stipulates the value that would be attained for a given power of base 11 (Osanyinpeju, 2019). The power of base 11 that can be estimated by the antikifilideen table to ordinary number ranges from 0.0000 to 0.9999. It is used to convert the power of base 11 of numbers to ordinary number. It is the table which displays the reverse of kifilideen table. The Antikifilideen was established to help in removing the power of base 11 of any number to ordinary number.

### **Ordinary number**

Ordinary number is a real number which is not in power form. It can also be defined has a real number whose power is one. Ordinary number could be in form of decimal or whole number.

### **Conversion of power of one base number to power of base 10 using power of base tables**

The power of base 10 still retain is uniqueness in every ratification of conversion process. It stands in between the power of bases to be interchanged. To convert from power of one base number to another power of another base number, the power of base number to be converted has to pass through power of base 10 before obtaining the required power of base.

### **Conversion of power of one base number to another power of base number using power of base tables**

To convert from one power of base to another power of base using power of base tables it is required to convert the initial power of base using the power of base table of that particular base to power of base 10 then the intermediate power of base 10 obtained is then transformed to the power of base required using the power of base table of the base to be obtained.

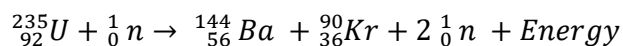
Conversion of power of base 2 to power of base 5

The conversion of power of base 2 to power of base 5 using power of base tables is achieved by first converting the power of base two to power of base 10 using the osanyinpeju and antiosanyinpeju tables and then the power of base 10 obtained is then converted to power of base 5 using Lekan and antilekan tables.

### **Demonstration on the transformation of power of base 2 to power of base 5**

[i] In nuclear chain reaction of a fission reaction, to produce the first generation one neutron collides with uranium to create two neutrons. For every generation the number of neutrons is double of the previous generation. [i] Determine the number of neutrons produce in the 1557<sup>th</sup> generation. [b] If 5 neutrons are produced in the first generation and in every generation the number of neutrons produces is 5 times the previous generation. Determine the generation that case 2 would create the same number of neutrons as produce in 1557<sup>th</sup> generation in case 1.

[a] The equation of the first generation is given has:



Number of neutrons produce in the 1557<sup>th</sup> generation =  $2^{1557}$

$2^{1557}$  cannot be estimated using propo or cacio calculator.

$$2^{1557} = (2^{15.57})^{100} = (2^{15.57})^{100}$$

The power of base 2 is first change to power of 10

$$2^{1557} = (2^{2.2823+13.2877})^{100} = (2^{2.2823})^{100} \times (2^{13.2877})^{100}$$

$$2^{1557} = (2^{22.823})^{10} \times (2^{13.2877})^{100}$$

$$2^{1557} = (2^{2.89143+19.93157})^{10} \times (2^{13.2877})^{100}$$

$$2^{1557} = 2^{28.9143} \times (2^{19.93157})^{10} \times (2^{13.2877})^{100}$$

$$2^{1557} = 2^{2.33887} \times 2^{26.57543} \times (2^{19.93157})^{10} \times (2^{13.2877})^{100}$$

$$2^{1557} = 4 \times 2^{0.33887} \times 2^{26.57543} \times (2^{19.93157})^{10} \times (2^{13.2877})^{100}$$



From conversion of  $10^n$  to  $2^y$  table

$$2^{13.2877} = 10^4, 2^{19.93157} = 10^6, 2^{26.57543} = 10^8$$

$$\text{Antiosan}(0.33887) = 1.2640 + 0.00079 = 1.26479$$

$$2^{1557} = 4 \times 1.26479 \times 10^8 \times (10^6)^{10} \times (10^4)^{100}$$

$$2^{1557} = 5.05916 \times 10^{468} \text{ neutrons}$$

[b] Let  $G_5$  be the generation that would produce the same number of neutrons as case 1

$G_2$  be the 1557<sup>th</sup> generation

$$N_5 = \text{Number in neutrons in case 2} = 5^{G_5},$$

$$N_2 = \text{Number in neutrons in case 1} = 2^{G_2}$$

From the question,  $N_5 = N_2$

$$N_5 = 5^{G_5} = 5.05916 \times 10^{468} \text{ neutrons}$$

Each of the operand is converted to power of base 5

$$5^{G_5} = 5.05916 \times 10^{468} \text{ neutrons}$$

$$5^{G_5} = 50.5916 \times 10^{67} \times (10^4)^{100}$$

$$5^{G_5} = 5^{\text{Lek}(50.5916)} \times 5^{\text{Lek}(10^{67})} \times (5^{\text{Lek}(10^4)})^{100}$$

From Lekan table,

$$\text{Lek}(50.5916) = \text{check 50 under 5 difference 9} = 2.43686 + 0.00111 = 2.43797$$

From conversion of  $10^n$  to  $5^y$  table

$$10^{67} = 5^{95.85533}, 10^4 = 5^{5.72271}$$

$$5^{G_5} = 5^{2.43797} \times 5^{95.85533} \times (5^{5.72271})^{100}$$

$$5^{G_5} = 5^{2.43797 + 95.85533 + 572.71} = 5^{671.0033}$$

$$G_5 = 671^{\text{st}} \text{ generation}$$

### Application on the conversion of power of base 2 to power of base 5

[i] Federal ministry of education opens online portal for application for unemployed youth to be absorbed into the federal civil service commission it is observed that the total number of people that apply after the first 1 hour is 2 while the total number of people increases 2 times every 1 hour. [a] Estimate the total number of people that applied after 22 hours. [b] Determine the number of hours if the total number of people started with 5 and increases 5 times every 1

hour which would have the same number of people when the number of people increases 2 times every 1 hour in 22 hours as in the first case.

### Solution

[a] the total number of people that apply is determined using the formula:  $N = [2]^{\frac{T}{t_2}}$

Where,

$N$  –the number of people for the total time duration,  $T$  –time lapses,  $t_2$  –time of each 2 times increase in the number of people

$$T = 22 \text{ hours}, \quad t_2 = 1 \text{ hour}$$

$$N = [2]^{\frac{22}{1}} = [2]^{22} = 2^{2.06843} \times 2^{19.93157}$$

$$N = 2^2 \times 2^{0.06843} \times 2^{9.96578}$$

$$2^{22} = 4 \times \text{Antiosan}(0.06843) \times 2^{19.93157}$$

From conversion of  $10^n$  to  $2^y$  table

$$2^{19.93157} = 10^6$$

From antiosanyinpeju table,

$$\text{Check } 0.06 \text{ under } 8 \text{ Difference } 4 = 1.04826 + 0.00029 = 1.04855$$

$$2^{22} = 4 \times 1.04855 \times 10^6 = 4 \times 1.04855 \times 10^3 = 4.1942 \times 10^6 \text{ people}$$

The total number of people that apply after 22 hours is  $4.1942 \times 10^6$  or 4,194,200 people

[b] case 1 for 2 times people apply for every 1 hour for 22 hours

$$N_2 = [2]^{\frac{T_2}{t_2}}$$

$$N_2 = 4.1942 \times 10^6, \quad T_2 = 22 \text{ hours}, \quad t_{11} = 1 \text{ hour}$$

Case 2 for 5 times people apply for every 1 hour we have

$$N_5 = [5]^{\frac{T_5}{t_5}},$$

$$t_5 = 1 \text{ hours}$$

For the number of people to be the same in both cases,  $N_2 = N_5$

$$N_2 = [2]_{t_2}^{T_2} = N_5 = [5]_{t_5}^{T_5}$$

$$[2]_{t_1}^{T_2} = [5]_{t_1}^{T_5}, \quad [2]^{T_2} = [5]^{T_5}, \quad [2]^2 = [5]^{T_5}$$

Converting  $[2]^{22}$  to power of base 5 we have

$$[5]^{T_5} = [2]^{22} = 4.1942 \times 10^6 = 41.942 \times 10^5$$

Each of the operand is converted to power of base 5

$$[5]^{T_5} = 5^{Lek(41.942)} \times 5^{Lek(10^5)}$$

From Lekan table,

$$Lek(41.942) = \text{Check 41 under 9 difference } 4 = 2.32086 + 0.00060 = 2.32146$$

Using conversion of  $10^n$  to  $5^y$  table

$$[10]^5 = 5^{7.15338}$$

$$[5]^{T_5} = 5^{2.32146} \times 5^{7.15338} = 5^{2.32146+7.15338}$$

$$[5]^{T_5} = 5^{9.47484}$$

So,  $T_5 = 9.47484$  hours

### Transfiguration of power of base 5 to power of base 11

The transfiguration of power of base 5 to power of base 11 is done by first converting the power of base 5 to power of base 10. The transitional power of base 10 derived is finally transfigured to the desired power of base 11.

### Illustration on the transformation of power of base 5 to power of base 11

Obtain the transformation of the power of base 5 to power of base 11  $[i] 1.2 \times 5^{535}$

#### Solution

$$[i] 1.2 \times 5^{535} = 11^{Kif(1.2)} \times (5^{53.5})^{10} = 11^{Kif(1.2)} \times (5^{0.56497+52.93503})^{10}$$

$$1.2 \times 5^{535} = 11^{Kif(1.2)} \times (5^{0.56497} \times 5^{52.93503})^{10}$$

$$= 11^{Kif(1.2)} \times (Antilek(0.56497) \times 5^{52.93503})^{10}$$

From Kifilideen table

$$Kif(1.2) = 0.07603$$

From Antilekan table

*Antilek* (0.56497) = *check* 0.56 under 5 = 2.48266

From conversion of  $10^n$  to  $5^y$  table

$$5^{52.93503} = 10^{37}$$

$$1.2 \times 5^{535} = 11^{0.07603} \times (2.48266 \times 10^{37})^{10} = 11^{0.07603} \times (24.8266 \times 10^{36})^{10}$$

Each of the operand is converted to power of base 11

$$1.2 \times 5^{535} = 11^{0.07603} \times (11^{kif(24.8266)} \times 11^{(10^{36})})^{10}$$

From Kifilideen table

$$Kif(24.8266) = 1.33903 + 0.00051 = 1.33954$$

From conversion of  $10^n$  to  $11^y$  table

$$10^{36} = 11^{34.56909}$$

$$1.2 \times 5^{535} = 11^{0.07603} \times (11^{1.33903} \times 11^{34.56909})^{10}$$

$$1.2 \times 5^{535} = 11^{0.07603} \times (11^{1.33903+34.56909})^{10}$$

$$1.2 \times 5^{535} = 11^{0.07603} \times (11^{35.90812})^{10}$$

$$= 11^{0.07603} \times 11^{359.0812} = 11^{359.15723}$$

$$1.2 \times 5^{535} = 11^{0.15723} \times 11^{359}$$

$$1.2 \times 5^{535} = Antikif(0.15723) \times 11^{359}$$

From Antikifilideen table

$$Antikif(0.15723) = 1.45713 + 0.00104 = 1.45817$$

$$1.2 \times 5^{535} = 1.45817 \times 11^{359}$$

Check using calculator

$$1.2 \times 5^{535} = 5^{Lek(1.2)} \times 5^{535} = 5^{0.11328} \times 5^{535} = 5^{535.11328} = (5^{53.511328})^{10}$$

$$1.2 \times 5^{535} = (2.528 \times 10^{37})^{10} \approx (2.53 \times 10^{37})^{10}$$

$$11^{359.15723} = (11^{35.915723})^{10} = (2.53 \times 10^{37})^{10}$$

### **Application on the conversion of power of base**

The conversion of the power of bases tables can be used extensively in the sectors where reoccurrence of event, value, quantity, deposition, decay, growth and price exist over time. It can be used to determine the growth or decay rate when the values of reoccurrence change. The areas of utilization are in warehousing, storage of goods or items, banking, saving of money, visiting on internet or site, trending on social media, deposition and accumulation of particles,

population growth, radioactive decaying, chain reaction problems and bacteria growth. In conversion of one power base to another power base, the initial power base is first converted to power of base 10 then the power of base 10 obtained is then converted to the required power of base.

**For instance**

The initial number of atoms of Uranium element before radioactive decay is  $25 \times 10^{245}$  atoms. Assuming the half life of the uranium element is 20 days. Determine the number of atoms of the uranium remaining after 10000 days without using calculator.

**Solution**

This problem cannot be solved using the common casio or propo calculator because  $2^{1000}$  and  $10^{245}$  is not recognized by the calculator.

According to the formula use for calculating radioactive decay (Duru and Ayuk, 2011) we have:

$$\frac{N}{N_o} = \left[ \frac{1}{2} \right]^{\frac{T}{t}}$$

Where,

$N_o$  –initial number of atoms of uranium,  
after the decay

$N$  –final number of atoms of the uranium

$T$  –time duration

$t$  –half life

$$\frac{N}{25 \times 10^{245}} = \left[ \frac{1}{2} \right]^{\frac{10000}{20}} = \left[ \frac{1}{2} \right]^{500} = \frac{1}{2^{500}}$$

$$N = \frac{25 \times 10^{245}}{2^{500}} = \frac{25 \times 10^{240} \times 10^5}{2^{500}}$$

$$N = \frac{25 \times (10^{24})^{10} \times 10^5}{2^{500}}$$

$$N = \frac{2^{osan(25)} \times (2^{osan(10^{24})})^{10} \times 2^{osan(10^5)}}{2^{500}}$$

Using osanyinpeju table

$$osan(25) = 4.64386$$

Using conversion of  $10^n$  to  $2^y$  table

$$10^{24} = 2^{79.7263} \quad \text{and} \quad 10^5 = 2^{7.153383}$$

$$N = \frac{2^{4.64386} \times (2^{79.7263})^{10} \times 2^{7.15338}}{2^{500}} = \frac{2^{4.64386} \times 2^{797.263} \times 2^{7.15338}}{2^{500}}$$

$$N = 2^{4.64386+797.263+7.15338-500} = 2^{309.06024}$$

$$= 2^{0.12124} \times 2^{308.939} = \text{Antiosan}(0.12124) \times 2^{308.939}$$

Using antiosanyinpeju table

$$\text{Antiosan}(0.12124) = 0.12 \text{ under 1 difference } 2 = 1.08749 + 0.00015 = 1.08764$$

Using conversion of  $10^n$  to  $2^y$  table

$$2^{308.939} = 10^{93}$$

$$N = 1.08764 \times 10^{93} \text{ atoms}$$

### Discussion

From the illustration and application of each power of base table of 2, 5 and 11 the tables are very useful in the evaluation of event which results to geometric progression, multiplication, division and power of base number. The tables are also very essential and helpful in the conversion of one power of base number to another.

### Conclusion

The study developed and applied osanyinpeju (power of base 2) and antiosanyinpeju (antipower of base 2) with lekan (power of base 5) and antilekan (antipower of base 5) tables to proffer solution to modern real life problems. The research work applies the power of base tables 2, 5 and 11 and antipower of base tables 2, 5 and 11 to carry out various conversion of power of bases in which power of base 10 was used for the intermediate converter in the conversion process. The conversion of power bases tables have been utilized to solve real life word problems in the area which involve reoccurrence of events like storage of substance, radioactive decay problem, chain reaction problems, bacteria growth, population growth, accumulation of particles.

### References

Berezovski T. (2004). An Inquiry into High School Students' Understanding of Logarithms. Unpublished Master Thesis. Simon Fraser University 104 pg.

Bird J., (2003). *Engineering Mathematics*. Newnes, Oxford, An imprint of Elsevier ScienceLinacre House, Jordan Hill, Oxford OX2 8DP 200 Wheeler Road, Burlington MA 01803 545 pgs.

Cetin Y. (2004). *Teaching Logarithm By Guided Discovery Learning and Real Life Applications*. Master Project. Department of Secondary Science and Mathematics Education, Middle East Technical University 147 pg.

Duru C.E. and Ayuk A.A. (2011). *Derivation of aa Simplified Radioactive Decay Equation*. Department of Chemistry, Federal University of Technology, P.M.B. 1526, Owerri, Imo State, Nigeria 4 pg.

Erol E. (1989). *Matematik Dersinde Bulgulama*, Istanbul: FKM Yayinlari 20 pg.

Kenney R. and Kastbery S. (2013). *Links in Learning Logarithms*. Australian Senior Mathematics Journal 27 (1): 1-9.

Murray R.L. and Holbert K.E. (2020). *Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes*. 8<sup>th</sup> Edition Science Direct, Elsevier 624 pages.

Nicholas J. and Thomas C. (1998). *Exponents and Logarithms: Applications and Calculus*. Mathematics Learning Centre, University of Sydney, NSW, Australia 44 pages.

Osanyinpeju K.L. (2019). *Development of Kifilideen (Power of Base 11) and Antikifilideen (Antipower of Base 11) Tables*. 1<sup>st</sup> International Conference on Engineering and Environmental Sciences (ICEES) Theme: Advancing Technology and Environment Burdens (Challenges and Sustainable Solution 5<sup>th</sup>- 7<sup>th</sup> November 2019).

Reimer L. and Reimer W. (1995). *Connecting Mathematics with Its History: A Powerful, Practical Linkage*. In P.A. House Ed., *Connecting Mathematics Across the Curriculum*. Reston, VA: NTCM 109 pages.

Smith, E. and Confrey J. (1994). *Multiplicative Structures and the Development of Logarithms: What was lost by the Invention of Functions?* In G. Harel and J. Confrey (Eds.), *The Development of Multiplicative Reasoning in the Learning of Mathematics*. Albany, NY: State University of New York Press pp 331-360.

Toumasis C. (1993). Teaching Logarithms via their History. *School Science and Mathematics* 93 (8): 428-434.



## **I-OPTIMAL DESIGN OPTIMIZATION OF SYNTHESIS OF SILVER-GOLD NANOPARTICLES FROM YAM, POTATO AND CASSAVA PEELS EXTRACT BIO-COMPOSITE**

Ajibike, M.A.<sup>1,2\*</sup>, Alade, A.O.<sup>1,2,3</sup>, Adeniji, A. T.<sup>1,2</sup>, Adeniyi, B.A.<sup>1,2</sup>, Omotayo, M.I.<sup>1,2</sup>,  
Asinyabi, V.O.<sup>1,2</sup> and Ajayi, K.<sup>1,2</sup>

<sup>1</sup>Department of Chemical Engineering, Ladoke Akintola University of Technology,  
Ogbomoso, Nigeria

<sup>2</sup> Bioenvironmental, Water and Engineering Research Group (BWERG), Ladoke Akintola  
University of Technology Ogbomoso, Nigeria

<sup>3</sup>Science and Engineering Research Group, Ladoke Akintola University of Technology  
Ogbomoso, Nigeria

\* Correspondence Author: moreedajib@gmail.com +234 8086425438

### **ABSTRACT**

Nanoparticles have a great potential to be produced from renewable resources such as agricultural wastes and residues. Therefore, this study was designed to biosynthesize nanoparticles involving mixture of extracts obtained from Yam, Potato and Cassava peels. The Yam peel, Potato peel and Cassava peel were hygienically processed, ground to powder and subjected to aqueous extraction. Extracts of the precursors were combined in different percentage (0-100%) compositions and mixed with standard solution of silver nitrate at various volumetric ratios (1:4-6 ml). The I-Optimal Design under the Combined Methodology of the Design Expert (11.0.4) software was used to optimize the combination of the components (extracts) and factor (silver solution). Twenty-four experimental runs were generated and Optical Density of the synthesized nanoparticle used as response were the UV, EC, TDS of the sample with highest absorbance was investigated. Statistical analysis of the data obtained was conducted to determine the suitability of the optimization tool used and models developed. The mixture of Potato/Cassava/Yam (25%/50%/25% v/v) with volumetric ratios (1:4-6ml) gave the optimum Optical Density of 0.50. The correlation coefficient ( $R^2$ ) of the data gotten was 0.7495 and the adjusted  $R^2$  was 0.5953. The results gotten from this study exhibited Yam peel, Potato

peel and Cassava peel as potential biomass for the synthesis of Silver-Gold nanoparticles and the I-Optimal design is an effective optimization tool for nanoparticle synthesis.

Keywords: Cassava peel, Potato peel, Yam peel, Biosynthesis, Nanoparticles

## **INTRODUCTION**

Water is the most essential substance whose material existence is secondarily compared to the symbolic value as it is manifested in our mind as the symbol of life. Reliable access to clean and affordable water is considered one of the most basic humanitarian goals, and remains a major global challenge for the 21st century.

Presently, water supply faces enormous challenges, both old and new. Worldwide, some 780 million people still lack access to improved drinking water sources (WHO, 2012). It is urgent to implement basic water treatment in the affected areas (mainly in developing countries) where water and wastewater infrastructure are often non-existent. In both developing and industrialized countries, human activities play an ever-greater role in exacerbating water scarcity by contaminating natural water sources. Worldwide, according to a United Nations Environment Programme (UNEP) study over 2 billion people depend on aquifers for their drinking water. 40 per cent of the world's food is produced by irrigated agriculture that relies largely on groundwater (UNEP, 2003).

Today a number of techniques are used for treatment of water i.e. chemical and physical agent such as chlorine and its derivatives, Ultraviolet light (Droste, R.L 1997), Boiling, Low frequency ultrasonic irradiation, Distillation, Reverse Osmosis, Water sediment filters (fiber and ceramic) Activated carbon, Solid block, Pitcher and faucet-mount filters, Bottled water, Ion exchange water Softener, Ozonisation, Activated alumina 'Altered' Water (Gupta, *et al* 2006).

Study is carried out to use advance nanotechnology in water purification for safe drinking. Nanotechnology is the design, characterization, production and applications of structures, devices and systems by controlling shape and size at nanometer scale(<100nm). In recent years, a great deal of attention has been focused on the applicability of nanostructured materials as adsorbents or catalysts in order to remove toxic and harmful substances from wastewater (Savage, *et al* 2005). Recent advances in nanotechnology offer leap frogging opportunities to develop next-generation water supply systems. Our current water

treatment, distribution, and discharge practices, which heavily rely on conveyance and centralized systems, are no longer sustainable. The highly efficient, modular, and multifunctional processes enabled by nanotechnology are envisaged to provide high performance, affordable water and wastewater treatment solutions that less rely on large infrastructures (Qu et al., 2013).

## **MATERIALS AND METHODS**

### **Materials and Reagent**

The main raw biomaterials used for this study include Potato (*Solanum tuberosum*) peel, Yam (*Dioscorea*) peel and Cassava (*Manihot esculenta*). Reagents that were used include silver nitrate ( $\text{AgNO}_3$ ), chloroauric acid ( $\text{HAuCl}_4$ ) and distilled water ( $\text{H}_2\text{O}$ ) all at analytical grade. The various equipment that was used included analytical weighing balance (DT-5024, Max=500g, d=0.01g), beakers, hot plate, measuring cylinder, UV-vis-spectrophotometer (DECIL, CE 7200,7000series), pH meter, stop watch, Fourier transform infrared spectroscopy, and centrifuge.

Silver nitrate ( $\text{AgNO}_3$ ) and chloroauric acid ( $\text{HAuCl}_4$ ) were procured from Scientific Laboratory Equipment (Ilorin) and Tropical Com & Scientific Chems Ltd, (Ibadan, Oyo state) respectively. *Solanum tuberosum* peel, *Dioscorea* peel and *Manihot esculenta* peel were obtained from the university environment of Ladoke Akintola University of Technology, (LAUTECH) Ogbomoso, Nigeria. The materials were deposited in L.A. Gbadamosi Laboratory of the Department of Chemical Engineering and Technology, LAUTECH, Ogbomoso. The outermost layer were carefully separated and rinsed with distilled water. They were air dried for about 4 days under ambient condition and then milled into powder form using an electric blender.



**Fig. 1a: *Solanum Tuberosum* (Potato)**



**Fig. 1b: *Dioscorea* peel (Yam)**



**Fig. 1c: Powdered *Solanum Tuberosum***



**Fig. 1d: Powdered *Manihot esculenta***



**Fig. 1e: Powdered *Dioscorea***

### Preparation of Extract

The extracts were prepared as previously described by Lateef *et al.*, (2015, 2016), which involves suspending 1 g of the respective powdery sample in 100 ml of distilled water, and heating in water bath at 60 °C for 1 h to obtain the extracts. The extracts were filtered using Whatman No. 1 filter paper and then centrifuged at 4000 rpm for 20 min. The supernatants collected were used without further purification Lateef *et al.*, (2016).

### Experimental Design

The I-Optimal Design of Combined Experimental Design in the Design Expert Software (11.0.4.0) was used to generate the number of experimental run at random for the selected factor. The selected factors used were volume of silver nitrate (Ag-Au) ranging within 4-6 ml and three mixtures components [mix ratio of *Solanum tuberosum* extract ranging within 0–100% volume, *Dioscorea* extract (0–100%) volume and *Manihot esculenta*], used for the synthesis of the biocomposite (Table 1). Optical density (absorbance) was selected as the response in order to determine the optimum biocomposite formulation ratio, volume of AgNO<sub>3</sub> and the most efficient synthesized nanoparticle.

**Table 1: Factor Levels of the Components and AgNO<sub>3</sub> used**

Input Type	Name	Unit	Level
------------	------	------	-------

			Low	High
Components	Dioscorea extract	%	0	100
	Manihot esculenta extract	%	0	100
	Solanum Tuberosum extract	%	0	100
Factor	AgNO <sub>3</sub> +HAuCl <sub>4</sub> solution	ml	4	6

### Green Syntheses of AgNO<sub>3</sub> and HAuCl<sub>4</sub>

The biocomposite was used to synthesis AgNO<sub>3</sub> and HAuCl<sub>4</sub> (Sukumran et al, 2012). The control experiments consisted of 1 mM HAuCl<sub>3</sub> solution and equal volumes of 1 mM AgNO<sub>3</sub> solutions respectively. The biocomposite was prepared by mixing various volumes ranges of the *Dioscorea*, *Manihot esculenta* and *Solanum Tuberosum* extracts, in 6 ml bottle, as suggested by the software (Table 2), and the resulting mixture was shaken vigorously for efficient mixing. This process was repeated for the twenty-four runs with the various ratio of mixing required. Green synthesis of Ag-AuNPs was carried out as illustrated by Lateef *et al.*, (2016). About 1 ml each of the biocomposite supernatant was added to the required volume of silver nitrate (Ag-Au) solution, as suggested by the software (Table 2), to reduce the silver-gold ions. This procedure was conducted at room temperature (30±2 °C) for 2 h and later under intense sunlight for 30 mins. Evidence of formation of Ag-AuNPs was supported with visual observations for colour changes before being subjected to UV-Vis Spectrophotometer (Lateef *et al.*, 2016).

### Analytical Characterization

Synthesis via biogenic reductions of Silver and gold ions in the reaction mixtures leading to the formation of nanoparticles was monitored quantitatively using UV-Vis spectrophotometer (PG Instruments, T90+ UV-visible spec. 18-1901-01-0160 UK) (Lateef, *et*

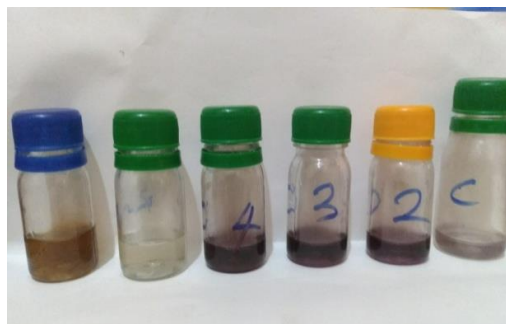
*al.*, 2016). The UV–Vis spectrophotometer was used to scan the synthesized mixture and the absorbance spectra and wavelength detected around 522 nm were taken to indicate effective synthesis of Ag-AuNPs of the composite extracts.

### **Statistical Analysis**

The data which was obtained were analyzed using the statistical tools embedded in the Design Expert (11.0.4.0) software. The adequate significance of the model developed was evaluated based on the lack of fit, coefficient of determination ( $R^2$ ) obtained from the analysis of variance (ANOVA) generated by the software. The mean squares were obtained in the ANOVA by dividing the sum of the squares of each the variation sources, the model and the error variance, by the respective degrees of freedom. Statistical significance was set at the 95 % confidence level ( $p < 0.05$ ) (Alde, *et al* 2012). If the value of Prob>F is less than 0.05 then model terms are considered to be significant. The significance of the model was based on the principle of the Fisher's statistical test (F-test) and it generates the F-value, which represents the ratio of the mean square of regression to the mean error. Significance of the model terms were further tested based on lower probability (p-value) which may lie between 90 % confidence levels (Hegazi, 2012). Lack of fit, which is usually preferred to be insignificant, was also used as diagnostic test to determine the adequacy of any model developed.

### **RESULTS AND DISCUSSION**

The Twenty-four (24) experimental run generated was conducted carefully, and the optimum biocomposite formulation ratio of 25.0% of *Dioscorea*, 50.0% of *Manihot esculenta* and 25.0 % of *Solanum Tuberosum* extract, with 6 ml of AgNO<sub>3</sub> and HAuCl<sub>4</sub> with optical density of 1.274, was obtained for the synthesis of Ag-AuNPs at 518 nm, while composite 37.5% of *Dioscorea*, 37.5 of *Manihot esculenta* and 25.0 % of *Solanum Tuberosum* extract as well as 5ml AgNO<sub>3</sub> and HAuCl<sub>4</sub> gave the least optical density of 0.908, at 516 nm (Table 2). The optimum synthesized Ag-AuNPs materials showed a contrasting colour difference from the colour displayed by the composite extracts of the (Plate 1). The mean of all the values obtained was 0.7495 with standard deviation of 0.5953 and this suggests that all the combinations synthesized relative to the average performance of the *Solanum Tuberosum*, *Manihot esculenta* and *Dioscorea* extracts. The colour changes are illustrated in the Plates 2a-b for all the Runs.



**Plate 1a.** Synthesized Ag-AuNPs containing 4ml of Silver and Gold and 2ml, 1.5ml, 1ml and 0.5ml extract of *Manihot esculenta* respectively.



**Plate 1b.** Synthesized Ag-AuNPs containing 4ml of Silver and Gold and 0.5ml, 1ml, 1.5ml and 2ml extract of *Dioscorea* respectively

Extract	Ag- Au	2ml	1.5ml	1 ml	0.5ml



**Plate 1c.** Synthesized Ag-AuNPs containing 4ml of Silver and Gold and 0.5ml, 1ml, 1.5ml and 2ml extract of *Solenum Tuberosum* respectively

Extract	Ag-Au	0.5ml	1ml	1.5ml	2ml





**Plate 2.** Colour Changes Observation For The Synthesized Nanoparticles, Ag-Au 0.5ml  
1ml 1.5ml 2ml Extract

## Characterization of Ag-AuNPs Synthesized

### UV-Vis spectrophotometer

The green synthesized particles showed maximum optical density (Run9) of 1.274, at 518 nm wavelength, while Run 14 gave the minimum optical density of 0.908 at 516 nm. All these signify the formation of Ag-AuNPs, and the values obtained are within the ranges reported for Ag-AuNPs synthesis (Thirumurugan, *et al.*, (2011); Zaki, *et al.*, (2011); Lateef *et al.*, (2015), (2018).

The results obtained from the UV-Vis spectrophotometric scan carried out are illustrated in Figure 2.

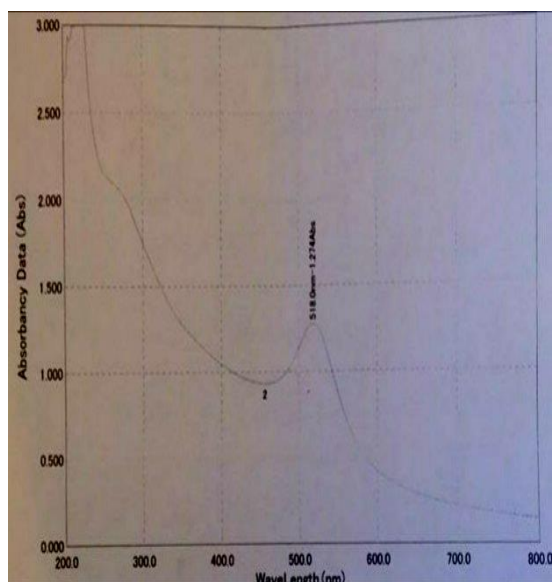


Fig. 2: UV-Vis spectrophotometric scan

Table 2: Component, Factor and of the Responses of the Ag-AuNPs Synthesis of Solanum Tuberosum, Manihot esculenta and Dioscorea Extract

<b>4</b>	<b>Dioscorea</b>	<b>Manihot esculenta</b>	<b>Solanum tuberosum</b>	<b>Factor</b>	<b>Response</b>
<b>Run</b>	<b>A:M1</b>		<b>B:M2</b>	<b>C:M3</b>	
<b>D:Sol</b>	<b>vol</b>			<b>Optical</b>	<b>Density</b>
	<b>%</b>	<b>%</b>	<b>%</b>	<b>ml</b>	<b>Abs</b>
<b>1</b>	<b>37.500</b>	<b>25.000</b>	<b>37.500</b>	<b>5.00</b>	<b>1.182</b>
<b>2</b>	<b>29.167</b>	<b>41.667</b>	<b>29.167</b>	<b>4.50</b>	<b>0.934</b>
<b>3</b>	<b>25.000</b>	<b>37.500</b>	<b>37.500</b>	<b>6.00</b>	<b>1.050</b>
<b>4</b>	<b>25.000</b>	<b>50.000</b>	<b>25.000</b>	<b>6.00</b>	<b>1.009</b>
<b>5</b>	<b>25.000</b>	<b>37.500</b>	<b>37.500</b>	<b>4.00</b>	<b>1.005</b>

<b>6</b>	<b>50.000</b>	<b>25.000</b>	<b>25.000</b>	<b>6.00</b>	<b>1.150</b>
<b>7</b>	<b>25.000</b>	<b>37.500</b>	<b>37.500</b>	<b>5.00</b>	<b>1.158</b>
<b>8</b>	<b>37.500</b>	<b>25.000</b>	<b>37.500</b>	<b>6.00</b>	<b>0.942</b>
<b>9</b>	<b>25.000</b>	<b>50.000</b>	<b>25.000</b>	<b>6.00</b>	<b>1.274</b>
<b>10</b>	<b>37.500</b>	<b>37.500</b>	<b>25.000</b>	<b>6.00</b>	<b>1.202</b>
<b>11</b>	<b>37.500</b>	<b>37.500</b>	<b>25.000</b>	<b>4.00</b>	<b>1.027</b>
<b>12</b>	<b>37.500</b>	<b>25.000</b>	<b>37.500</b>	<b>4.00</b>	<b>1.113</b>
<b>13</b>	<b>25.000</b>	<b>50.000</b>	<b>25.000</b>	<b>5.00</b>	<b>1.011</b>
<b>14</b>	<b>25.000</b>	<b>25.000</b>	<b>50.000</b>	<b>6.00</b>	<b>1.054</b>
<b>15</b>	<b>29.167</b>	<b>29.167</b>	<b>41.667</b>	<b>5.50</b>	<b>1.029</b>
<b>16</b>	<b>29.167</b>	<b>29.167</b>	<b>41.667</b>	<b>4.50</b>	<b>1.047</b>
<b>17</b>	<b>50.000</b>	<b>25.000</b>	<b>25.000</b>	<b>4.00</b>	<b>0.984</b>
<b>18</b>	<b>25.000</b>	<b>25.000</b>	<b>50.000</b>	<b>4.00</b>	<b>1.127</b>
<b>19</b>	<b>41.667</b>	<b>29.167</b>	<b>29.167</b>	<b>4.50</b>	<b>1.031</b>
<b>20</b>	<b>25.000</b>	<b>25.000</b>	<b>50.000</b>	<b>5.00</b>	<b>1.199</b>
<b>21</b>	<b>50.000</b>	<b>25.000</b>	<b>25.000</b>	<b>5.00</b>	<b>1.046</b>

<b>22</b>	<b>25.000</b>	<b>50.000</b>	<b>25.000</b>	<b>4.00</b>	<b>1.054</b>
<b>23</b>	<b>37.500</b>	<b>37.500</b>	<b>25.000</b>	<b>5.00</b>	
<b>0.908</b>					
<b>24</b>	<b>41.667</b>	<b>29.167</b>	<b>29.167</b>	<b>5.50</b>	
<b>1.026</b>					

## CONCLUSION

The green synthesis produced Ag-AuNPs of biocomposite of *Dioscorea*, *Manihot esculenta* and *Solanum Tuberosum* extracts. using the experimental runs generated by the Design of Experiment (DOE) software. The inputs and selected factors were the formulation ratio of biocomposite and volume of AgNO<sub>3</sub> and HAuCl<sub>3</sub> ratio. An optimum run indicated that the mixtures of the extracts *Dioscorea*, *Manihot esculenta* and *Solanum Tuberosum* can best synthesized AgNO<sub>3</sub> and HAuCl<sub>3</sub> when mixed in the best ratio of 25.0:50.0:25.0% of *Dioscorea*: *Manihot esculenta*: *Solanum Tuberosum* extract to 6 ml of AgNO<sub>3</sub> and HAuCl<sub>3</sub>. The optimisation tools has facilitated the development of biocomposite without wasting too much reagents and other resources. It can thus be deduced that biocomposite of *Dioscorea*, *Manihot esculenta* and *Solanum Tuberosum* extracts is a good starting material in the synthesis of silver and gold nanoparticles.

## REFERENCES

Alade, O.A., Amuda, O.S., Ogunleye, O.O., and Okoya, A.A. (2012).Evaluation of interaction of carbonization temperatures and concentrations on the adsorption capacities and removal efficiencies of activated carbons using Response Surface Methodology (RSM). *Journal of Bioremediation and Biodegradation*. 3:14

Droste, R.L., (1997). Theory and practice of water and wastewater treatment. New York: Wiley.

Gupta, S., J. Behari and K. Kesari, 2006. Low frequency ultrasonic treatment of sludge. Asian J. Wat, Envi and Pollu., 3-2: 101-105.

Lateef, A., Ojo, S. A. Akinwale, A. S. Azeez, L. treatment and reuse. Accounts of Chemical Research 46 (3), 834-843

Gueguim-Kana, E.B. and Beukes, L.S. (tttt). "Biogenic synthesis of silver nanoparticles using cellfree extract of *Bacillus safensis* LAU 13: Antimicrobial, free radical scavenging

Lateef, A., Adelere, I., Gueguim-Kana, E., Asafa, T., and Beukes, L. (2015). Green synthesis of silver nanoparticles using keratinase obtained from a strain of *Bacillus safensis* LAU 13. *International Nano Letters* 5:, 29-35.

Lateef, A., Azeez, M. A., Asafa, T. B., Yekeen, T. A., Akinboro, A., and Oladipo, I. C., *et al.*, (2016). Cobweb as novel biomaterial for the green and eco-friendly synthesis of silver nanoparticles. *J. Taibah Univ. Sci.* doi:10.1016/j. jtusci.2015.10.010, 868-870.

Manish, H., Shreeram, J., Mayor, D., and Kisam, K., (2012). Green Synthesis of TiO<sub>2</sub> Nanoparticles by using Aqueous Extract of *Jatropha carcus* L. latex. *Material Letters*.75:196-199

Qu, X.L., Brame, J., Li, Q., Alvarez, J.J.P., 2013. Nanotechnology for a safe and sustainable water supply: enabling integrated water

Savage, N., Diallo, M.S. 2005. Nanomaterials and water purification: Opportunities and challenges. *Journal of Nanoparticle Research* 7: 331–342

Sukumaran, P. and K. P. Eldho, "Silver nanoparticles: Mechanism of antimicrobial action, synthesis, medical applications and toxicity effects," *Int.Nano Lett.*, vol. 2, pp. 32– 40, 2012. and larvicidal activities," *Biologia*, vol. 70, pp. 1295–1306, 2015.

Thirumurugan, A., Tomy, N. A., Kumar, H. P., and Prakash, P. (2011). Biological synthesis of silver nanoparticles by *Lantana camara* leaf extracts. *International Journal of Nanomaterials and Biostructure*,, 1(2):22–24.

United Nations Environment Programme (UNEP) (2003). Groundwater and its susceptibility to degradation: A global assessment of the problem and options for management. UNDP Report, Nairobi, Kenya.

WHO, (2012). Progress on Drinking Water and Sanitation. 2012 Update

Zaki, S., El-Kady, M. F., and Abd-El-Haleem, D. (2011). Biosynthesis and structural characterization of silver nanoparticles from bacterial isolates. *Material Research Bulletin.*, 46, 1571–1576.

## OPTIMIZATION OF SILVER-GOLD NANOPARTICLE SYNTHESIS FROM BANANA SPECIES PEELS EXTRACT BIOCOMPOSITE

Adeniyi, B.A.<sup>1,2\*</sup>, Alade, A.O.<sup>1,2,3</sup>, Afolabi, T.J.<sup>1,2</sup>, Agarry, S.E.<sup>1</sup>, Ajibike, M.A.<sup>1,2</sup>, and  
Adeniji, A.T.<sup>1,2</sup>

<sup>1</sup>Department of Chemical Engineering, Ladoke Akintola University of Technology,  
Ogbomoso, Nigeria

<sup>2</sup>Bioenvironmental, Water and Engineering Research Group (BWERG), Ladoke Akintola  
University of Technology Ogbomoso, Nigeria

<sup>3</sup>Science and Engineering Research Group, Ladoke Akintola University of Technology  
Ogbomoso, Nigeria

Corresponding Author: adeniyibukunmiadetunji@gmail.com

### ABSTRACT

This study investigated green synthesis of silver-gold nanoparticle using biocomposite of extracts obtained from the peels of banana species (*Musa paradisiaca*, *Musa acuminata*, and *Musa balbisiana*). The peels were air-dried under hygienic conditions before being ground to powder. Aqueous extraction was carried out by adding 1 g of the ground peel to 100 ml distilled water and heated at 60 °C for 1 hr. The extracts of the precursors were combined in different percentage (0-100%) compositions and mixed with standard solution of Ag-Au (1:1 mol) at various volumetric ratios (4-6 ml), based on I-Optimal Design under the Combined Methodology of the Design Expert (7.1.6) software. Twenty-four experimental runs were generated and Optical Density of the synthesized nanoparticle was used as response. Statistical analysis of the data obtained was conducted to determine the suitability of the optimization tool used and models developed. The mixture *M. paradisiaca*, *M. acuminata* and *M. balbisiana* extracts (29.16:29.17:41.67 % v/v) with volumetric ratios (5.5 ml) gave the optimum Optical Density of 0.936 at 523nm wavelength. The correlation coefficient ( $R^2$ ) of the data gotten was 0.6173, and the Model Equation developed is Special Cubic given as  $Optical\ Density = 0.60A + 0.64B + 0.73C - 0.28AB - 0.83AC - 1.13BC + 15.24ABC$ . This study has demonstrated the suitability of I-Optimal design as an effective optimization tool for nanoparticle synthesis and the valorization of waste peel obtainable from *M. paradisiaca*, *M. acuminata* and *M. balbisiana*.

Keywords: *Musa paradisiaca*, Biosynthesis, Optimization, *Musa balbisiana*, *Musa Acuminata*, Nanoparticle

## **INTRODUCTION**

Nanoparticles (NPs) are particles with a size varying from 1 to 100 nanometers and, due to their large area to volume ratio and smaller size, they exhibit different physical and chemical properties. These NPs earned particular attention because of their useful effect in the improvement of many economic areas such as agriculture, cosmetics, pharmaceuticals, transport and since Output is increasing rapidly with the application of these NPs (Roco, 2003; Novack & Bucheli, 2007). Physical, chemical and biological approaches are the three main methods for synthesizing nanoparticles.

Green nanoparticle synthesis has attracted a lot of attention in recent years. In this regard, in the synthesis of nanoparticles, plant extracts and natural resources, such as microorganisms and enzymes, were found to be good alternatives. Green synthesis of nanoparticles using plants and their extracts has several advantages over chemical and physical methods like low energy consumption, low cost, biocompatibility, cost efficiency (Dhuper *et al.*, 2012). Several studies have examined the applications of silver nanoparticles (AgNPs) and AuNPs in health sciences; therefore, we reviewed the biosynthesis process and potential applications of silver nanoparticles (AgNPs) and AuNPs and their biocomposites in this article.

A lot of attention has been drawn to the green synthesis of nanoparticles in recent years like green synthesis and antibacterial activities of silver nanoparticles using extracellular laccase of *lentinus edodes* (Lateef *et al.*, 2016). In this regard, plant extracts and natural resources such as microorganisms and enzymes in nanoparticles synthesis have been found to be a good alternative reagent. Green synthesis of nanoparticles using plants and its extracts has several advantages over chemical and physical methods which includes low energy consumption, cheapness, biocompatibility, cost effectiveness (Dhuper *et al.*, 2012).

The extracts obtained from these materials possess various phytochemicals and biochemical capable of reducing the metal ion and stabilizing the resulting nanoparticles to expected morphology (Husen *et al.*, 2014; Khan *et al.*, 2015).

Banana is a common fruit in Southeast Asia that has quality as well as being a food source and is one of the world's most important crops grown by small and large farmers alike,



with production occurring in more than 130 countries (Edward and Fredy, 2012). Agricultural and crop processing industries in the form of banana peel generate huge amounts of waste. Banana peel is renewed to have several types of biomass tools (such as starch or sugar crops, weeds, and plants of oils, etc.) that can be used in chemical synthesis to minimize agent. This work is therefore aimed at synthesizing Silver and Gold nanoparticles using an extract from cultivated banana peel waste.

## **MATERIALS AND METHODS**

### **Preparation of banana peel extract (BPE) powder**

Banana peels were gathered and washed thoroughly with distilled water, separated and left air-dried for approximately 7 days and then grinded into powdery form using an electric blender. The powdered samples were stored until further use in an airtight container. The extracts were prepared by measuring 1 g of the respective powdery material and adding 100 ml of distilled water, the extracts were obtained by heating to 60 ° C in the water bath for 1 h. The extracts were filtered with filter paper, then centrifuged for 20 minutes at 4000 rpm (Lateef *et al.*, 2016).

### Experimental design

The I-Optimal Design of Combined Experimental Design in the design expert software (7.1.6) was used to generate the number of experimental run at random for the selected factors. The selected factors used were volume of silver nitrate ( $\text{AgNO}_3$ ) and Gold chloride ( $\text{AuCl}_3$ ) ranging between 4-6 ml and two mixture components [mix ratio of the three extracts ranging within 25–50% volume], used for the synthesis of the biocomposite (Table 1).

### **Selection of factors**

The selected factors that were input are; mix ratio of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* extracts, ranging within (0 – 100%) and Silver and Gold solution are (29.16 : 29.17 : 41.67 % v/v) with volumetric ratios (5.5ml) respectively. The compositions of material A, B, C and D are expressed in Table 2, where ‘A’, ‘B’, C and D are *M. paradisiaca*, *M. acuminata* and *M. balbisiana* and Silver and Gold solution respectively.

### Preparation of biocomposite

*M. paradisiaca*, *M. acuminata* and *M. balbisiana* extracts biocomposite was prepared by measuring various volumes ranges of each extract as illustrated in Table 2 above, poured into 10ml bottle and the resulting mixture vigorously shaking for efficient mixing. This process was repeated for twenty-four runs with the various ratio of mixing required.

#### Green Synthesis of AgNPS-AuNPS

About 1 ml each of the biocomposite supernatant was added to a reaction vessel containing 40ml of silver nitrate ( $\text{AgNO}_3$ ) gold chloride ( $\text{AuCl}_3$ ) The reaction was carried out under static conditions at room temperature ( $30 \pm 2^\circ\text{C}$ ) for 2h. The formation of AgNPs and AuNPs was observed as a change in colour was monitored both visually and through absorbance measurement of each sample (Lateef *et al.*, 2016).

Table 1: Factor Levels of the Components and  $\text{AgNO}_3$  and  $\text{AuCl}_3$  used

Input Type	Name	Unit	Level	
			Low	High
Components	<i>M. paradisiaca</i> extract	%	25	50
	<i>M. acuminata</i> extract	%	25	50
	<i>M. balbisiana</i> extract	%	25	50
Factor	$\text{AgNO}_3$ - $\text{AuCl}_3$ Solution	ml	4.0	6.0

## RESULT AND DISCUSSION

Design summary for the production of silver-gold nanoparticles from *M. paradisiaca*, *M. acuminata* and *M. balbisiana*

The I-Optimal Design under the Combined Methodology of the Design Expert 7.1.6 was the software employed in this study and twenty-four experimental runs were generated at random. There was no selection of block for the design and the experimental design model is Specific Cubic as shown in Table 2. The percentage composition of the extracts ranged from 0-100% and the ratio of extract to silver –gold solution, which is the factor ranged from 4-6. The optimum blend composition which is the fifth experimental run, 29.167% *M. paradisiaca*, 29.167% *M. acuminata* and 41.667% *M. balbisiana* and gave the highest optical density of 0.936 as shown in Table 2. The optimum synthesized AuNPs-AgNPs materials showed a contrasting colour different from the colour displayed by the composite extracts of the banana extract. The correlation coefficient (R<sup>2</sup>) of the data gotten was 0.6173, and the Model Equation developed is Special Cubic given as  $\text{Optical Density} = 0.60A + 0.64B + 0.73C - 0.28AB - 0.83AC - 1.13BC + 15.24ABC$  and this suggests that all the combinations synthesized relative to the average performance of the *M. paradisiaca*, *M. acuminata* and *M. balbisiana* biocomposite extract with colour changes.

#### Characterization of AgNPs –AuCl<sub>3</sub>

The characterization of AgNPs and AuNPs was done using UV–Vis Spectrophotometer which is done by synthesizing via biogenic reductions of Silver and gold ions in the reaction mixtures leading to the formation of nanoparticles was monitored quantitatively using UV–Vis spectrophotometer (PG Instruments, T90+ UV-visible spec. 18-1901-01-0160 UK) (Lateef, *et al.*, 2016).

#### UV–Vis Spectrophotometer

The UV of the silver-gold nanoparticles developed from the 24 runs of the mixture of *M. paradisiaca*, *M. acuminata* and *M. balbisiana*. Peel extract are shown in Figure 1. The UV–Vis spectrophotometer was used to scan the synthesized mixture and the absorbance spectra and wavelength detected around 528 nm were taken to indicate effective synthesis of AgNPs and AuCl<sub>3</sub> of the composite extracts. The highest absorbance of 0.936 was gotten from Run 15 with wavelength of 526 from Table 2

Table 2: Component, Factor and of the Responses of the AgNPs Synthesis of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* Biocomposite Extract

Run	<i>M. paradisiaca</i>	<i>M. acuminata</i>	<i>M. balbisiana</i>	Factor 4	Optical
	A:M1	B:M2	C:M3	D:Sol	Density vol
	%	%	%	ml	Abs
1	37.500	25.000	37.500	5.000	0.313
2	29.167	41.667	29.167	4.500	0.700
3	25.000	37.500	37.500	6.000	0.342
4	25.000	50.000	25.000	6.000	0.586
5	25.000	37.500	37.500	4.000	0.408
6	50.000	25.000	25.000	6.000	0.684
7	25.000	37.500	37.500	5.000	0.914
8	37.500	25.000	37.500	6.000	0.608
9	25.000	50.000	25.000	6.000	0.576
10	37.500	37.500	25.000	6.000	0.371
11	37.500	37.500	25.000	4.000	0.667
12	37.500	25.000	37.500	4.000	0.424
13	25.000	50.000	25.000	5.000	0.747
14	25.000	25.000	50.000	6.000	0.763
15	29.167	29.167	41.667	5.500	0.936
16	29.167	29.167	41.667	4.500	0.758
17	50.000	25.000	25.000	4.000	0.572
18	25.000	25.000	50.000	4.000	0.668

19	41.667	29.167	29.167	4.500	0.678
20	25.000	25.000	50.000	5.000	0.677
21	50.000	25.000	25.000	5.000	0.592
22	25.000	50.000	25.000	4.000	0.675
23	37.500	37.500	25.000	5.000	0.677
24	41.667	29.167	29.167	5.500	0.678



Figure 1: Colour changes of synthesized nanoparticles

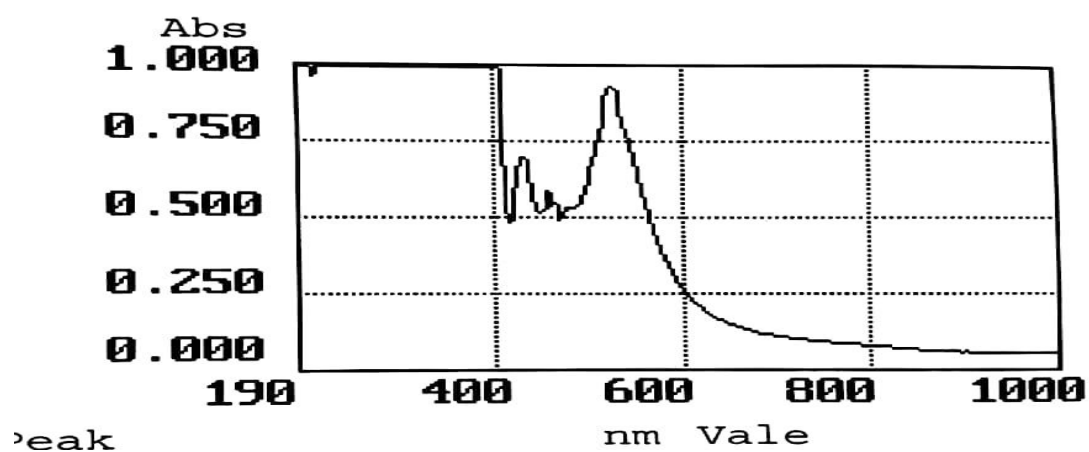


Figure 2: UV of silver-gold nanoparticles Run 15

## **CONCLUSION**

The AgNPs-AuNPs was produced from the green synthesis of biocomposite of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* extract using the experimental runs generated by the Design of Experiment (DOE) software. The inputs and selected factors were the formulation ratio of biocomposite and volume of AgNO<sub>3</sub> and AuCl<sub>3</sub> ratio. An optimum run indicated that the mixtures of the extracts *M. paradisiaca*, *M. acuminata* and *M. balbisiana* can best synthesized AgNO<sub>3</sub> and AuCl<sub>3</sub> when mixed in the best ratio of (29.16:29.17:41.67% v/v) of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* extracts to 5.5 ml of AgNO<sub>3</sub> and AuCl<sub>3</sub>. The optimization tools have facilitated the development of biocomposite without wasting too much reagents and other resources. It can thus be deduced that biocomposite of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* extract is a good starting material in the synthesis of silver- gold nanoparticles.

## **REFERENCES**

- Adelere, I. A., & Lateef, A. (2016). A novel approach to the green synthesis of metallic nanoparticles: the use of agro-wastes, enzymes, and pigments. *Nanotechnol Rev* ,2, 567–587.
- Adelere, I. A., Lateef, A., Aboyeji, D. O., Abdulsalam, R., Adabara, N. U., & Bala, J. D. (2017). Biosynthesis of silver nanoparticles using aqueous extract of buchholzia coriacea(wonderful kola) seeds and their antimicrobial activities. *Annals, Food Science and Technology* , 3, 671-679.
- Ahmad, A., Senapati, S., Khan, M. I., Kumar, R., & Sastry, M. (2005). Extra-/intracellular, biosynthesis of gold nanoparticles by an alkalo tolerant fungus, *Trichothecium* sp. *J. Biomedicine Nanotechnology*, 1, 47-53.
- Ankamwar, B. D., C. Ahmad, A., & Sastry, M. (2005). "Biosynthesis of gold and silver nanoparticles using *Emblica officinalis* fruit extract, their phase transfer and transmetallation in an organic solution". *J Nanosci Nanotechnol*, 5, 1665-1671.

Dhuper, S., Panda, D., & Nayak, P. L. (2012). Green synthesis and characterization of zero valent iron nanoparticles from leaf extract of mangifera indicis. *Nano Trends : J Nanotech App*14, 16-22.

Lateef, A., Ojo, S., Folarin, B., Gueguim-Kana, E., & Beukes, L. (2016). Kolanut (Cola nitida) Mediated Synthesis of Silver–Gold Alloy Nanoparticles: Antifungal, Catalytic, Larvicidal and Thrombolytic Applications. *J Clust Sci* , 27 , 1561–1577.

Novack, B., & Bucheli, T. (2007). Occurrence, behaviour and effects of nanoparticles in the environment. *Environ. Pollut.* , 5-22.

Roco, M. C. (2003). Broader societal issue of nanotechnology. *J. Nanopar. Res.* , 181-189

## **URBAN CRIME AND INSECURITY: A STUDY OF OLODI APAPA LOCAL GOVERNMENT AREA, LAGOS, NIGERIA**

Asiyanbola, R. A.\* and Ayeolowo, S. D.

Department of Geography, Faculty of Social Sciences, Osun State University, Nigeria

\*Email of Corresponding Author: [rasiyanbola@gmail.com](mailto:rasiyanbola@gmail.com)

### **ABSTRACT**

The literature reveals that there has been increasing frequency, scope and sophistication of crime and insecurity in cities of the world generally and Nigerian urban centers in particular. The insurmountable problems associated with its seemingly uncontrollable tendencies makes it a universal phenomenon that is threatening the security of various countries in varying degrees. Every society across the globe has its peculiar problems and challenges of crime and insecurity. Nigeria is not an exception. This study is an addition to the literature and it examined the state and severity of crime and insecurity in the major urban land use areas in Olodi-Apapa Local Government Area in Lagos State and the form of protective measure employed by residents in crime prevention and control. Both primary and secondary sources of data were used in the study. A total of 120 questionnaire forms were administered at major land use types which comprises of; commercial land use, residential land use, transport land use and educational land use. The choice of selected area for questionnaire administration were based on hotspot of crime in Olodi-Apapa LGA. Records of different types of crimes from 2014 to 2018 were obtained from The Nigerian Police MSD Section, Oduduwa, Ikeja, Lagos. Simple frequencies and percentage were used to analyze the data. The result of the analysis show that theft and other stealing were the greatest crimes committed, and majority of the various crimes were committed by male adult persons. Urban dwellers perceived crime and insecurity as a huge threat to life and property. In order to prevent and control crime, the security agencies should be adequately equipped and motivated, poverty eradication policies and employment generation policies among others should be pursued.



**Keywords:** Urban crime, insecurity, Lagos, Nigeria

## **INTRODUCTION**

The literature reveals that crime is one of the human security problems confronting humanity across the world and there has been increasing frequency, scope and sophistication of crime and insecurity in cities of the world generally and Nigerian urban centers in particular (Adebayo, 2013; Abolurin, 2010; Usman et al, 2012; Aremu and Ahmed, 2011; Ewetan and Urhie, 2014; Asiyabola, 2003). As observed in the literature, nations have grappled to contain the rising incidence of homicide, armed robbery, and kidnap, drug trafficking, sex trafficking, illegal gun running and host of others. United Nations 2011 reported that homicides globally were estimated at 468,000 and more than a third (36%) was estimated to have occurred in Africa, 31% in the Americas, 27% in Asia, 5% in Europe and 1% in the tropical Pacific region. According to the United Nations 2011 report, economic crisis; food insecurity; inflation; and weak or limited rule of law are factors that drive crime. However, the drivers of crime are not restricted to the aforementioned causative factors. There are other several factors including the inability of the country to control her population ratio which has led to an increase in the rate of crime and insecurity. This is because no proper plan has been designed or executed in prospect of the country.

Observation from the literature reveals that the efforts of government and related agencies in combating crime and insecurity in the country has been a subject of controversy over the past years. To some extent though, the Nigerian government has been aiming at their possible best to curb crime and issues of insecurity within the shores of the country; one thing however is the fight against crime but another is adequate and commensurate developmental planning for the citizenry (Ewetan and Urhie, 2014; Achumba et al, 2013). The argument in the literature is that while combating crime using The Nigeria Police Force and other security agencies, Government should likewise develop the population through means such as youth empowerment schemes, consistent employment opportunities, provision of standard educational facilities and improved socio-economic activities etc. These factors however may not completely eliminate crime and issues of

insecurity in the country but will reduce it to the barest minimum. As argued in the literature, these factors are important because if government should focus on combating crime and insecurity with no proper alternative for building adequate developmental planning systems for the citizenry, the situation would keep on festering because the frustration of many citizens are owing to lack of employment, abject poverty compels them to become aggressive and to engage in all sorts of organized and unorganized crimes. Despite the rate of conviction in the country, many citizens still view crime as an alternative to survival.

The literature reveals that crimes are not just increasing but have heinous implications on the lives of individuals and the community at large. Apart from being a socio-economic menace, crime is a serious impediment to development, an undeniable stigma to national image and a significant source of threat to people's safety and wellbeing (Omisakin, 1998). Peaceful and safe existence is becoming a tale of the past in many Nigerian urban centers. Lives are on constant threat at home, on the streets even at places of worship, which supposed to be safe haven. Criminals attack people of diverse social status, destroying lives and looting valuables. Different types of crimes are due to different types of people and at different time and circumstances (Dambazau, 2007).

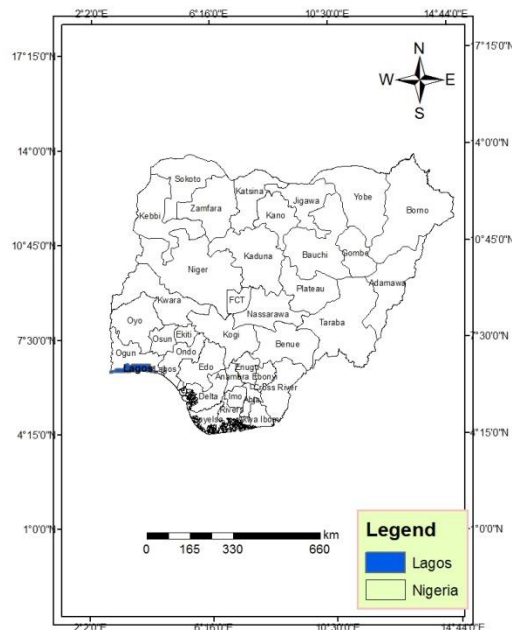
As observed in the literature, the effects of these devilish operations on the society and its institutions is evident in a new wave of social behaviour featuring isolation, anxiety, individualism, hostility, mistrust, aggressiveness, feelings of hopelessness and helplessness etc. (Madden, 1996). Consequent upon all these crime-associated problems, coupled with residents' realization of how vulnerable their lives are, and the apparent inability of the criminal justice system to cope with the current crime wave, there have emerged various individual and community efforts at safeguarding their lives and properties. These include the formation of Odua People Congress and/or the use of security guards at community level and the inclusion of various safety gadgets in their buildings.

As observed in the literature (Ayeni-Akeke, 2001) we can perhaps not find a city where there are no appreciable number of people who are frustrated, impoverished or dissatisfied and ready to vent off their grievances through organized criminality, individually or collectively. Suffice it to say then, that no city is totally rid of crime and insecurity problem, though the level may differ.

Against the background of increasing frequency, diversity and sophistication of crime in cities of the world generally, and the insurmountable problems associated with it seemingly uncontrollable tendencies, the study seeks to examine the state of urban crime and insecurity in Olodi Apapa Local Government. Specifically, the study examines the following: socio economic characteristic of resident in the study area, crime and insecurity types in the study area, the residents' perception of the severity of the different crime and insecurity in the study area, various ways or various method resident use in controlling crime in the study area and residents' perception of government impact on the issue of insecurity.

## **MATERIALS AND METHODS**

The study is carried out at Olodi Apapa Local Government Area in Lagos State. Figure 1 shows map of Nigeria showing Lagos, while Fig. 2 shows map of Lagos showing Olodi Apapa



**Fig. 1: Map of Nigeria showing Lagos**

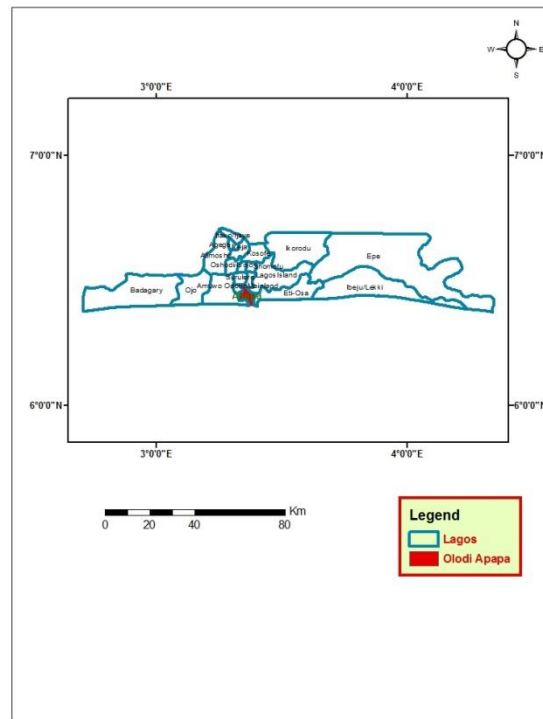


Fig. 2: Map of Lagos showing Olodi Apapa LGA

Local Government Area. Both primary and secondary data were used in the study. The data were collected between March 2019 and August 2019. The primary data obtained using structured questionnaire include: socio-economic and demographic characteristics of the respondents; types of crime, preventive /controlling measures employed in the area. Based on constrain of time as well as resource availability 120 questionnaires were administered at four major land use in the study area which are residential land use, commercial land use, transport land use and educational land use. Purposive sampling technique was used to administer the questionnaire to the residents at the following selected areas of hotspot for crime in the four major land use in the study area: residential area (Ojoku Street, Wilmer Crescent, Maracana, Tolu and Idowu street), Commercial area (Boundary market, Alakoto market), Transport land use area (Coconut Park, Boundary Park), and Educational land use area (Tolu Complex Olodi). Out of the total number of questionnaire distributed, 102 copies were completed and suitable for the analysis (Table 1). Secondary data

used in the study include records of different types of crimes from 2014 to 2018 which were obtained from the Nigerian Police MSD Section, Oduduwa, Ikeja, Lagos.

Table 1: Showing number of returned completed questionnaires

S/N	Land use type	Number of returned questionnaires	%
1	Residential land use	24	23.5
2	Transport land use	26	25.5
3	Commercial land use	26	25.5
4	Educational land use	26	25.5
	Total number	102	100.0

## **RESULTS AND DISCUSSION**

### **Findings from the secondary data collected**

Records of different types of crimes from 2014 to 2018 in Lagos State were collected from The Nigerian Police MSD Section, Oduduwa, Ikeja, Lagos. In 2014 the records show that theft and other stealing were the greatest reported cases of crime committed (2893), followed by assaults (2136), breach of public peace (1644), false pretense and cheating (1311), and grievous harm and wounding (1300). In 2015, theft and other stealing were the greatest reported cases of crime committed (10,013), followed by assaults (7434), false pretense and cheating (4496), grievous

harm and wounding (4471), breach of public peace (2822), unlawful possession (1169) and burglary (1090). In 2016, theft and other stealing were the greatest reported cases (10,162), followed by assaults (8274), breach of public peace (5910), false pretense and cheating (4997), grievous harm and wounding (4814), burglary (1373), unlawful possession (936), and house breaking (702). In 2017, theft and other stealing were the greatest reported cases (11,741), followed by assaults (7428), grievous harm and wounding (5866), breach of public peace (5456), false pretense and cheating (5236), burglary (1142), unlawful possession (715), and house breaking (618). In 2018, theft and other stealing were the greatest reported cases (10,895), followed by assaults (6933), breach of public peace (4608), grievous harm and wounding (4461), false pretense and cheating (4016), burglary (1099), unlawful possession (791), house breaking (646) and rape and indecent assaults (588). These records of different types of crimes cases reported in Lagos State shows that theft and other stealing were the greatest crimes committed in Lagos State. The records also show that majority of the various crimes were committed by male adult persons.

## **Findings from the primary data collected**

### ***Socio-economic characteristics of the respondents***

The sex distribution of the respondents shows that 52.9% were male while 47.1% were female, 37.3% of them were married, 43.1% of them were secondary school certificate holders while 56.9% of them have post-secondary education. Most (50.0%) of the people interviewed were landlords while 49.0% of them were tenants. Majority (64.8%) of the respondents have been staying in the study area for more than 11 years.

### ***Urban crime and insecurity in the study area as reported by the respondents***

The following crimes were identified in the study area: armed robbery, burglary, house breaking, store breaking, stealing/theft, murder, rape, assaults, kidnapping, and fraud. Analysis of the data shows that the common crimes in the area is stealing/theft (67.6%), followed by armed robbery (51.0%), burglary (49.0%), house breaking (40.2), store breaking (37.3%), fraud (22.5%) and kidnapping (13.7%) (Table 2). Majority (86.3%) of the respondents said that they have witnessed

those crimes before in the study area. While some of them (35.3%) said that they reported the crime to the police, most of the respondents (43.1%) were afraid to report the crime.

When asked about the cause of crime, the rate of crime and the effects of crime in the area.

Table 2: Showing the common crimes in the study area

S/N	Common crime in the study area	Percentage
1	Stealing/theft (n = 102)	67.6
2	Armed robbery (n = 102)	51.0
3	Kidnapping (n = 102)	13.7
4	House breaking (n = 102)	40.2
5	Store breaking (n = 102)	37.3
6	Fraud (n = 102)	22.5
7	Burglary (n = 102)	49.0

8	Rape (n = 102)	4.9
9	Murder (n = 102)	2.9
10	Assault (n = 102)	3.9
11	Suicide (n = 102)	0.0

Source: Field survey 2019

Majority (50.0%) of the respondents said that unemployment was the cause of crime in the area. Majority (54.0%) of the respondents said that the rate of crime in the study area is high. Most (46.1%) of the respondents said that the effects of crime and insecurity in the study area on economic growth is worsening.

When asked about the crime committed most in the study area, majority of the respondents said house breaking (65.7%) and store breaking (65.7%), followed by armed robbery (61.8%), and burglary (55.9%). When asked which season of the year, time and festival period of the year crime occur most, majority of the respondents said that crime occur most during dry season (58.8%), at night time (84.3%) and during Christmas period (74.5%).

When asked about the form of protective measures respondents used, the analysis shows that they use burglary roofing materials (73.5%), special windows and door locked (71.6%), high fence/wall (52.0%), security dog (41.2%), axe/club/stick (15.7%), traditional method (15.7%), local security guard (13.7%), vigilante (5.9%), and private security guard (5.9%).

When asked whether they know police number in case of distress, majority (73.5%) of them said they did not. Most (48.0%) of the respondents said that police are doing fairly well in controlling crime in the study area. When asked whether they report crime to police when it occur, majority (59.8%) of the respondents said they did not. When asked why, most (45.1%) said that



police would not respond. When asked how they will rate the impact of government on the issue of insecurity in the past five years, majority (68.6%) said poorly, only few of the respondents said good and very good.

## **CONCLUSION AND POLICY ISSUES**

The paper examined the state and severity of crime and insecurity in the major urban land use areas in Olodi-Apapa Local Government Area in Lagos State and the form of protective measures employed by residents in crime prevention and control. From the study it is evident that crime and insecurity is a huge threat to life and property of urban dwellers, and the security agencies are inadequately equipped and motivated, coupled with poverty and unemployment among others have made crime prevention and control a difficult task. There is therefore the need to enforce creative poverty alleviation schemes that promote rapid enterprise development in both urban and rural areas. This will help to reduce drastically the rate of unemployment in the country. Formation of local or grassroots associations such as landlords/tenants in the residential areas and formation of similar associations in other major land use areas should be encouraged while residents should be more security conscious and the local government should rise to support these groups by providing needed equipment, fund and periodic training programmes in collaboration with the Nigerian Police. There is need for public enlightenment on the values of crime reporting and the values of crime reporting should be integrated into all levels of the nation's educational system. There is the need for government to increase its funding for the police so that modern and adequate equipment to combat crime could be acquired.

## **REFERENCES**

- Abolurin A. (2010). *Crime control in Nigeria, 1999-2010*, Ibadan: John Archers Publishers Ltd.
- Adebayo A.A. (2013). Social factors affecting effective crime prevention and control in Nigeria. *International Journal of Applied Sociology*, 3(4): 71-75

Achumba I.C., Ighomereho O.S., and Akpan-Robaro M.O. (2013). Security challenges in and implications for business activities and sustainable development. *Journal of Economic and Sustainable Development*, 4(2): 79-99

Aremu M.A. and Ahmed Y.A. (2011). An investigation of security and crime management in developing society: the implications for Nigeria democratic set-up. *International Journal of Academic Research in Business and Social Sciences*, 1(3): 390-399.

Asiyanbola R.A. (2003); "Gender, residential segregation, psychological well-being and involvement in sustainable urban safety and security management in Ibadan city, Nigeria: a preliminary survey," in E. Beriatos, C.A. Brebbia, H. Coccossis and A. Kungolos (eds.) *Sustainable Planning and Development*, WIT Press: Southampton, UK, pp. 403-413.

Ayeni – Akeke, A (2001) 'Collective Violence and Insecurity in Nigeria Cities: Some Theoretical Consideration'. Paper Presented at the International Conference on Security Segregation and Social Network in West Africa Cities, 19th – 20th centuries held at the International Centre for African Studies (IFRA) University of Ibadan Oct 29th - 31st, 2001.

Danbazau, A.B. (2007). *Criminology and Criminal Justice*. 2<sup>nd</sup> edition. Ibadan: Spectrum Books Limited.

Ewetan O.O. and Urhie E. (2014), Insecurity and socio-economic development in Nigeria. *Journal of Sustainable Development Studies*, 5(1): 40-63.

Madden (1996) Violence and its Effects on Women's Access to Social Services. *The Urban Age*. Vol. 4, No. 2 pp. 16

Omisakin I.S. (1998) Crime Trends and Prevention Strategies in Nigeria. A study of Old Oyo State. Ibadan : NISER Monograph pp1-7.

United Nations Office on Drugs and Crime (2011). "United Nations 2011 Global Study on Homicide"

Usman U. Yakubu M. and Bello A.Z. (2012). An investigation on the rate of crime in Sokoto State Using Principal Components Analysis. *Nigerian Journal of Basic and Applied Sciences*, 20(2): 152-160.

## **EVALUATION OF RANDOM MUTAGENESIS ON BIOFLOCCULANT-PRODUCING ACTIVITY AND CASSAVA WASTEWATER PURIFICATION OF *Enterococcus* sp. OBTAINED FROM YAM PEEL**

Fagbohunbe, M. E.<sup>1</sup>, Oyedara, O. O.<sup>1</sup>, Jimoh, S. O.<sup>2</sup>, Akinde, S. B.<sup>1</sup> and Olaitan, J. O.<sup>1</sup>

<sup>1</sup>Department of Microbiology, Faculty of Basic and Applied Sciences, Osun State University, Osogbo, Nigeria

<sup>2</sup>Department of Biological Sciences, College of Natural and Applied Sciences, Fountain University, Osogbo, Nigeria

\*Email of Corresponding Author: omotayo.oyedara@uniosun.edu.ng

### **ABSTRACT**

A bacterium with excellent bioflocculating activity (81%) based on kaolin clay suspension assay was isolated from yam peel. The bacterium possessed 85% 16S rRNA gene sequence identity with *Enterococcus canis* and was designated *Enterococcus* sp. YP-A3 (wild-type strain). To determine the effects of random mutagenesis on the bioflocculating activity, the wild-type strain YP-A3 was exposed to UV radiation (420 nm) for 1, 5, and 10 min, and cultured with 10 mg/L nitrous acid for 30, 45 and 60 min. Mutant strain E<sub>5M</sub> with high flocculating activity (88%) was obtained upon wild-type exposure to UV radiation for 5 min. Meanwhile, mutant strain E<sub>60M</sub> had the highest flocculating activity (75%) when cultured with nitrous acid for 60 min. The percentage lethality increased exponentially with time upon wild-type strain exposure to both UV radiation (6 – 94%) and nitrous acid (14 – 96%). The bioflocculants obtained from the mutant strains E<sub>5M</sub> and E<sub>60M</sub> reduced the turbidity of cassava wastewater collected from local cassava processing factory in Osogbo, southwest Nigeria with the removal efficiency of 72% each after 24 h. However, turbidity removal was higher when whole-cells of the wild-type (77%), mutant strains E<sub>5M</sub> (74%), and E<sub>60M</sub> (77%) were applied to treat the cassava wastewater compared to when bioflocculants only were used. Unlike when exposed to nitrous acid, exposure of the *Enterococcus* sp. strain YP-A3 to UV radiation for 5 min enhanced its bioflocculant production though with high lethality rate of 78 %, and this potential has biotechnological application for the treatment of wastewater discharged from cassava-processing factories.

**Keywords:** bioflocculant, flocculating activity, random mutagenesis, wastewater.

## **INTRODUCTION**

Bioflocculation involves the precipitation of suspended solids, colloids, and debris by living cells (Xia *et al.*, 2008). It is considered as an alternative to the use of chemical or inorganic flocculants such as polyaluminium chloride and aluminum sulfate, which are not environmentally friendly. Moreover, they are neurotoxic and carcinogenic to humans (Nwodo *et al.*, 2014). Microorganisms such as *Enterococcus spp* (Xu *et al.*, 2017) *Citrobacter sp.* TKF04 (Fujita *et al.*, 2000), *Brachybacterium sp.* (Nwodo *et al.*, 2013), *Cellulomonas sp.* Okoh (Nwodo and Okoh, 2013), *Klebsiella pneumoniae* (Luo *et al.*, 2010), and *Bacillus subtilis* (Giri *et al.*, 2015) are known to produce bioflocculants. Microorganisms can produce bioflocculants in low quantity thereby making its application in industrial processes less competitive economically when compared to chemical or synthetic flocculating agents. As a result, most industrial processes require hyper-producing microbial strains for flocculation. However, microorganisms can be improved to produce bioflocculants insufficient amount for industrial processes. Microbial strain improvement can be achieved by manipulating the nutritional and environmental factors to favour high yield of bioflocculants (Tahzibi *et al.*, 2004). Random or site-directed alteration of genetic make-up (mutation) of a bioflocculant-producing bacteria with physical or chemical agents such as Ultraviolet radiation (UV) and nitrous acid respectively can damage DNA. Consequently, this can affect numerous pathways of the cell machinery (Mukherje *et al.*, 2006), leading to genetic instability and eventually potentially improved strain (Ghribi *et al.*, 2004) that can produce large quantity of bioflocculants.

Nigeria is one of the world-leading producers of cassava (Martin *et al.*, 2017). Cassava waste products contain almost 70% water and 30% dry weight. It also contains nitrogenous compounds and cyanoglycosides which can be hydrolysed into toxic hydrogen cyanide (Abiona *et al.*, 2005). The improper discharge of untreated waste from cassava processing industries not only pose health hazards to humans but also aesthetic nuisance to the environment. Hence the need to apply efficient means to treat cassava wastewater. The physicochemical treatment of wastewater from local cassava processing factories is essential to remove suspended solids, which are mostly responsible for turbidity, colour, taste, and odour of cassava wastewater.

Worldwide, researches on bioflocculants in different areas such as pharmaceutical, agriculture, and food industries (Tahzibi *et al.*, 2004) has increased immensely. However, there is a paucity of information on strain improvement by mutagenesis for efficient production of bioflocculants and their applications in the treatment of industrial wastes in Nigeria.

In this study, a strain of bioflocculant-producing *Enterococcus* sp. isolated from yam peel was subjected to random mutagenesis using ultraviolet radiation and nitrous acid as a mutagen to improve its capacity to produce a high yield of bioflocculant. We further tested the bioflocculating potential of the bioflocculating agent derived from the *Enterococcus* sp. and its whole cell for the clarification of cassava wastewater.

## **MATERIALS AND METHODS**

### ***Bacterial Strain***

A bacterium with bioflocculating activity was isolated from yam peel samples collected from domestic waste. The bacterium was identified as *Enterococcus* sp. by the amplification and sequencing of the 16S rRNA gene using the Polymerase Chain Reaction (PCR) technique and 5'-GTGCCAGCAGCCGCGCTAA-3' and 5'-AGACCCGGGAACGTATTCAC-3' (Taiwo *et al.*, 2017) as forward and reverse primer, respectively. The obtained sequences were subjected to similarity searches against 16S rRNA gene sequences in NCBI databases (<http://www.ncbi.nlm.nih.gov/>). The bacterial isolate was designated *Enterococcus* sp. YP-A3.

### ***Random Mutation of YP-A3 by Exposure to UltraViolet (UV) Radiation and Nitrous Acid***

For treatment with UV radiation, a 24 h old culture of wild type strain YPA-3 on nutrient agar was exposed to UV radiation for variable periods of 1, 5 and 10 min at a wavelength of 240 nm and the UV source fixed at 20 cm (Vahed *et al.*, 2013). From the exposed plates, colonies of mutants of mutant strains were randomly selected and cultured in sterile nutrient broth overnight (OV) at 37 °C. For nitrous acid treatment, bacterial isolate was cultured in nutrient broth to an optical density (OD) of 0.1 at wavelength of 600 nm. The bacterial culture was harvested by centrifugation, and 10 ml nitrous acid (10 mg/L) and phosphate buffer (PBS) was added to the resultant pellets. The bacterial cell suspension was incubated in a rotary shaker incubator (Stuart S1600, United Kingdom) at 150 rpm and 37 °C for a period of 15, 30, 45, and 60 min (Ghribi *et*

*al.*, 2004). A ten-fold serial dilution of the OV culture and bacterial suspension obtained from the UV and nitrous acid treatment, respectively, was done in sterile PBS buffer and 0.1 ml dilution factors of the stock suspension,  $10^{-2}$  and  $10^{-4}$  were cultured on nutrient agar and incubated OV at 37°C. After incubation, colony forming units per ml (CFU/ml) of the bacterial isolates was determined. The lethality rate of mutants was calculated as follows:

$100 \times (1 - (\text{CFU of treated suspension}/\text{CFU of non-treated suspension}))$  (Bouassida *et al.*, 2018).

#### ***Selection and Determination of Bioflocculating Activity of Mutant Strains***

The bioflocculating activity of the mutant strains obtained from exposure of wild-type YP-A3 was determined using a suspension of kaolin clay (5 g/l) according to the method described by Zheng *et al.* (2008). The percentage flocculating activity was calculated as follows:

Flocculating activity (%) =  $[(A - B)/A] \times 100$

Where A and B were the absorbance at 550 nm for Control and sample, respectively.

#### ***Cassava Wastewater Purification with Bioflocculant extract and Whole-cells of Wild-type and Mutant Strains of YP-A3***

Cassava wastewater was collected from a cassava factory site in Kola Balogun, Osogbo metropolis, Osun State (7° 48' 0''N and 4° 13' 0''E). Four litres of the cassava wastewater was collected aseptically into sterile kegs. Samples were transported to the laboratory in an ice pack and store at 4 °C. The purification process was done using the method described by Zhang *et al.* (2007) and Cosa and Okoh, (2014). Briefly, two millilitres of bioflocculant solution was added to 100 ml of cassava wastewater. The suspension was stirred at 200 rpm for 2 min and 40 rpm for 10 min at room temperature (25 °C). The samples were left unshaken on the bench for 20 min. The purified cassava wastewater was subjected to physicochemical analysis including measurement of pH, flocculating activity, temperature, conductivity, and turbidity.

## **RESULT AND DISCUSSION**

The mutant strains obtained after the exposure of wildtype YP-3A to UV-radiation have different percentage flocculating activity (Table 1) with mutants (E<sub>5M</sub> 0) generated after exposure for 5 min exhibiting the highest flocculating activity (88 %). The high flocculating activity observed for this strain was associated with high lethality rate (78 %). In a similar experiment, Ghribi *et al.* (2004)

observed high lethality rate but improved the production of biopesticide when *Bacillus thuringiensis* was exposed to UV radiation and nitrous acid, indicating that few bacteria might survive exposure to UV radiation, but they produced high bioflocculants compared to the wild-type. Contrarily, the lethality rate for mutant strain E<sub>10M</sub> 4 (95 %) obtained after 10 min exposure to UV was the highest with low flocculating activity (32 %). The increase in lethality rate (78-94 %) with a decrease in percentage flocculating activity (88-32%) after 5 min of exposing wild-type YP-A3 (Table 1) to UV might be an indication of gross damaging effects of the UV on the DNA of the wild-type strain suggesting that strain improvement might not be achieved when bacterial isolates were exposed to UV for a long duration of time. Therefore, for *Enterococcus* sp. YP-A3, exposure to UV for more 5 min can affect its bioflocculant-production capabilities

Table 1. Flocculating Activity and Lethality Rate of *Enterococcus* sp. YP-A3 When Exposed to Ultraviolet Radiation

S/N	Isolate code	R1	R2	R3	Mean±SD	% Flocculating Activity	% Lethality
1	E <sub>1M</sub> 0	0.668	0.669	0.671	0.669±0.002	66	6
2	E <sub>1M</sub> 2	0.657	0.655	0.655	0.656±0.001	67	18
3	E <sub>1M</sub> 4	0.676	0.676	0.676	0.676±0.000	66	3
4	E <sub>5M</sub> 0*	0.242	0.243	0.24	0.242±0.002	88	78
5	E <sub>5M</sub> 2	0.264	0.265	0.265	0.265±0.001	87	80
6	E <sub>5M</sub> 4	0.256	0.256	0.257	0.256±0.001	87	75
7	E <sub>10M</sub> 0	1.322	1.323	1.323	1.323±0.001	33	93
8	E <sub>10M</sub> 2**	1.354	1.353	1.353	1.353±0.001	32	95
9	E <sub>10M</sub> 4	1.357	1.356	1.356	1.356±0.002	32	94
10	Control 0	1.982	1.986	1.985	1.984±0.002	0	0
	Control 2	1.982	1.986	1.985	1.984±0.002	0	0
	Control 4	1.982	1.986	1.985	1.984±0.002	0	0

Keys: SD: Standard deviation; \*Mutant strain E<sub>5M</sub> 0 has the highest bioflocculating activity; \*\*Mutant strain E<sub>10M</sub> 2 with the highest lethality rate; A bacterial culture that was not exposed to UV light served as control; 0, 2 and 4 in the isolate code column represented the dilution factor of stock, 10<sup>-2</sup> and 10<sup>-4</sup> respectively plated out on nutrient agar plate.

For treatment with nitrous acid (Table 2), all the mutants generated showed stable bioflocculant production by having 50% activity for number of generations studied, suggesting the stability of



these mutants for bioflocculant production. The mutant strain E<sub>60M0</sub> obtained after treatment of YP-A3 for 60 min exhibited the highest flocculating activity (75 %). The flocculating activity recorded was high but lower when compared with 81 % (result not shown) obtained for the wild-type YP-A3 strain in our previous work. Similar to the result of UV exposure, the lethality increased with an increase in the time of exposure to nitrous acid. Contrary to the observation of Ghribi *et al.* (2004), the UV may be more effective in generating mutant strains of *Enterococcus* sp. YP-A3 with improved bioflocculant production. The increase in percentage lethality for both UV and nitrous acid treatments indicated that YP-A3 is sensitive to the two mutagens. However, the morphological properties of the mutant strains including colour and shape were not altered. The colony morphology of the isolated mutants was circular and opaque, as observed in the wild-type strain.

Table 2. Flocculating Activity and Lethality Rate of *Enterococcus* sp. YP-A3 When Treated with Nitrous acid

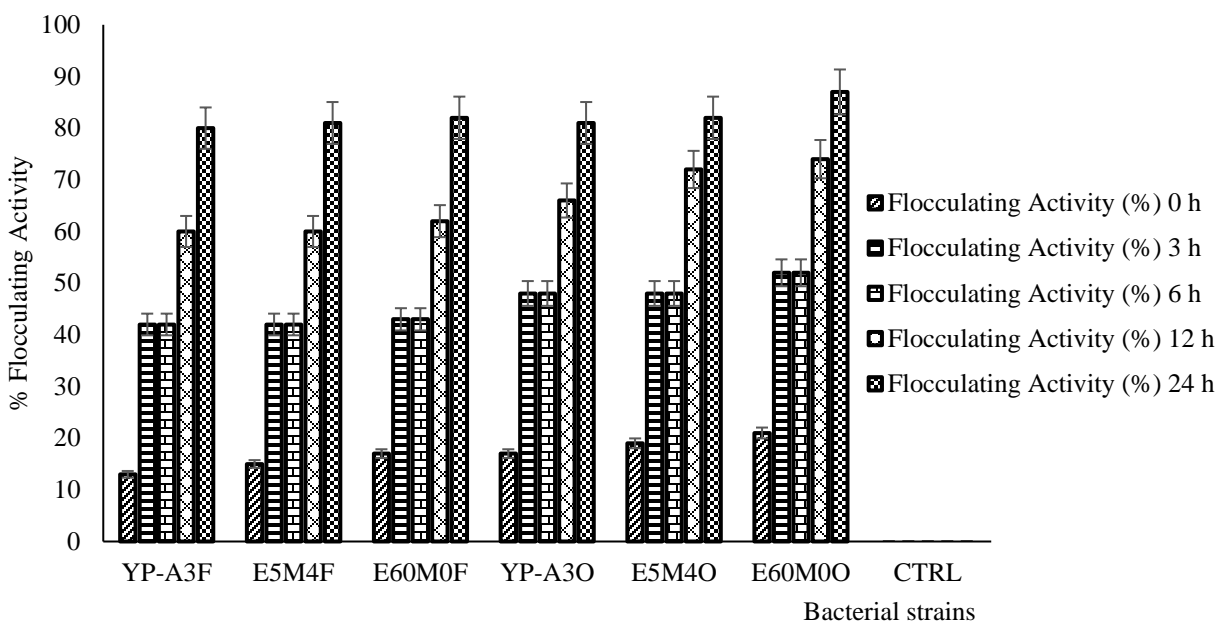
S/N	Isolate code	R1	R2	R3	Mean±SD	% Flocculating activity	% Lethality
1	E <sub>15M0</sub>	0.737	0.737	0.738	0.737±0.001	62	14
2	E <sub>15M2</sub>	0.791	0.791	0.79	0.791±0.001	59	58
3	E <sub>15M4</sub>	0.833	0.838	0.835	0.835±0.003	57	76
4	E <sub>30M0</sub>	0.663	0.662	0.665	0.663±0.002	67	78
5	E <sub>30M2</sub>	0.682	0.684	0.683	0.683±0.001	65	85
6	E <sub>30M4</sub>	0.701	0.702	0.703	0.702±0.001	64	85
7	E <sub>45M0</sub>	0.653	0.653	0.652	0.653±0.001	67	87
8	E <sub>45M2</sub>	0.662	0.664	0.663	0.663±0.001	66	90
9	E <sub>45M4</sub>	0.673	0.674	0.673	0.673±0.001	65	94
10	E <sub>60M0</sub> *	0.491	0.49	0.492	0.491±0.001	75	91
11	E <sub>60M2</sub>	0.565	0.565	0.566	0.565±0.001	71	94
12	E <sub>60M4</sub>	0.57	0.57	0.571	0.57±0.001	71	96
13	Control 0	1.932	1.93	1.931	1.931±0.001	0	0
	Control 2	1.932	1.93	1.931	1.931±0.001	0	0
	Control 4	1.932	1.93	1.931	1.931±0.001	0	0

Keys: SD:Standard deviation; \*Mutant strain E<sub>60M0</sub> has the highest bioflocculating activity and lethality rate; 0,2 and 4 in the isolate code column represented the dilution factor of stock, 10<sup>-2</sup> and 10<sup>-4</sup> respectively plated out on nutrient agar plate

The bioflocculating activity of extracts from wild-type and mutant strains of YP-A3, and whole cells increased with time when used to treat cassava wastewater for 24 h. The highest flocculating activity (87 %) was recorded when whole-cells of mutant strain E<sub>60M00</sub> was used to treat cassava wastewater (Figure 1). In application, mutant strain E<sub>60M00</sub> showed better capabilities to treat cassava wastewater compared to mutant strain E<sub>5M0</sub> with higher flocculating ability when flocculating activity was determined using Kaolin suspension assay. However, several factors such the effects of complex substances in the cassava wastewater, and physiological state of the mutant bacterial isolates during the process of cassava wastewater treatment may influence the ability of the mutants to produce floc from the cassava wastewater.

The bioflocculant extracts obtained from the mutant strains E<sub>5M</sub> and E<sub>60M</sub> reduced the turbidity of cassava wastewater collected from local cassava processing factory in Osogbo, southwest Nigeria with the removal efficiency of 72% each after 24 h (Table 3). The result is similar to the findings of Gong *et al.* (2008), who reported turbidity removal of 64.1-80.7% and 91.8-93.7%, respectively, in agricultural wastewater using the bioflocculant produced by *Serratia ficaria*. However, turbidity removal was higher when whole-cells of the wild-type (77%), mutant strains E<sub>5M</sub> (74%), and E<sub>60M</sub> (77%) were applied to treat the cassava wastewater compared to when bioflocculants only were used. This implies that whole-cell of YP-A3 or its mutants may prove to be better candidate in cassava wastewater treatment than its extracts. However, several factors need to be considered when applying the whole-cell for wastewater treatment. These include the ability of the component of cassava wastewater or metabolites generated to limit the growth of the bioflocculant-producing bacteria. The pathogenicity of YP-A3 needs to be studied before recommending its application as a bioflocculation agent.

The pH and temperature at different time interval ranged between 3.5-4.6 (Table 4) and 25.1-27.1 °C (Table 5), respectively. The low pH observed during the cassava wastewater treatment could be due to the presence of hydrogen cyanide.



Keys: YP-A3F: Bioflocculant extract from wild-type *Enterococcus* sp YP-A3  
 E5M4F: Bioflocculant extract from mutant strain obtained after exposing YP-A3 to UV for 5 min  
 E60M0F: Bioflocculant extract from mutant strain obtained after treating YP-A3 with nitrous acid for 60 min  
 YP-A3O: Whole cell of bioflocculant-producing YP-A3  
 E5M4O: Whole cell of mutant strain obtained after exposing YP-A3 to UV for 5 min  
 E60M0O: Whole cell of mutant strain obtained after treating YP-A3 with nitrous acid for 60 min  
 CTRL: Control

Figure 1: Percentage flocculating activity of bioflocculants extracts and whole-cell of bacterial isolates after treatment of cassava wastewater for 0, 3, 6, 12 and 24 hours

Table 3. Percentage clarity of Cassava Wastewater When Treated with bioflocculants extracts and whole-cell of bacterial isolates measured by reduction in turbidity at different time interval

Bacterial Type	Treatment Code	% Removal Efficiency				
		0 h	3 h	6 h	12 h	24 h
Bioflocculant Extract	YP-A3F	63	70	71	71	72
	E <sub>5M</sub> 4F	64	65	67	71	72
	E <sub>60M</sub> 0F	65	66	68	72	72
Bacterial Strains	YP-A3O	66	72	74	75	77
	E <sub>5M</sub> 4O	66	72	73	74	74
	E <sub>60M</sub> 0O	67	67	68	77	77
Control	CTRL	0	0	0	0	0

Moreover, bioflocculant is applied to remove the suspended solids in the cassava wastewater and not the other toxic substances like hydrogen cyanide. The optimum pH reported by Buthelezi *et al.* (2010) for efficient bioflocculating activity for *Bacillus subtilis*, and *Klebsiella terrigena* is 8. However, the wild-type and mutant strains in this study were able reduce the turbidity of the cassava wastewater at acidic pH range of 3.8-4.6. This also indicated the possible ability of YA-P3 and the mutant strains to tolerate low acidic pH of the cassava wastewater. The temperature range for bioflocculating activity observed in this study agrees with the report of Buthelezi *et al.* (2010) and it is within the optimum temperature needed for flocculant activity.

Table 4. The Change in the pH of Cassava Wastewater When Treated with bioflocculants extracts and whole-cell of bacterial isolates at different time intervals

Bacterial Type	Treatment Code	pH Measurement				
		0 h	3 h	6 h	12 h	24 h
Bioflocculant Extract	YP-A3F	4.1	4.0	4.1	3.9	3.9
	E <sub>5M</sub> 4F	3.9	4.1	3.9	3.9	3.9
	E <sub>60M</sub> 0F	4.6	4.1	3.9	3.9	3.5
Bacterial Strains	YP-A3O	4.6	4.1	3.9	3.9	3.9
	E <sub>5M</sub> 4O	4.0	3.9	3.9	3.8	3.8
	E <sub>60M</sub> 0O	4.2	4.4	3.9	3.9	3.8
Controls	Positive Ctrl	5.6	5.3	5.4	5.4	5.4
	Negative Ctrl	7.1	7.1	7.1	7.1	7.1

Table 5. The change in the temperature of Cassava Wastewater When Treated with bioflocculants extracts and whole-cell of bacterial isolates at different time intervals

Bacterial Type	Treatment Code	Temperature Measurement (°C)				
		0 h	3 h	6 h	12 h	24 h
Bioflocculant Extract	YP-A3F	25.1	25.5	26.4	26.5	25.5
	E <sub>5M</sub> 4F	25.4	26.2	26.2	26.8	26.1
	E <sub>60M</sub> 0F	25.8	26.4	26.6	26.6	26.1
Bacterial Strains	YP-A3O	27.1	25.5	26.5	26.4	25.4
	E <sub>5M</sub> 4O	25.8	26.5	26.5	26.0	24.5
	E <sub>60M</sub> 0O	26.0	26.6	26.9	25.5	25.2
Control	Positive Ctrl	25.0	24.93	25.0	24.99	25.0
	Negative Ctrl	26.0	26.0	26.0	26.0	26.0

## **CONCLUSION**

Random mutation by exposing *Enterococcus* sp. YP-A3 isolated from yam peel to UV radiation for 5 minutes generated mutant strains that have increased flocculating activity. Meanwhile treatment of YP-A3 with nitrous acid generated mutant strains with flocculating activity >50 % but less than observed in wild-type strain. The ability of wild-type YP-A3 and the mutant strains to reduce the turbidity of cassava wastewater effectively at low pH make them a good choice for biotechnological application for the treatment of wastewater discharged from cassava-processing factories.

## **REFERENCES**

1. Abiona, O. O., Sanni, L. O., & Bamgbose, O. (2005): "An evaluation of microbial load, heavy metals and cyanide contents of water sources, effluents and peels from three cassava processing locations", *Journal of Food Agriculture and Environment*, 3(1), 207-208.
2. Bouassida, M., Ghazala, I., Ellouze-Chaabouni, S., & Ghribi, D. (2018): "Improved biosurfactant production by *Bacillus subtilis* SPB1 mutant obtained by random mutagenesis and its application in enhanced oil recovery in a sand system", *Journal of microbiology and biotechnology*, 28(1), 95-104.
3. Buthelezi, S. P., Olaniran, A. O., & Pillay, B. (2010): "Production and characterization of bioflocculants from bacteria isolated from wastewater treatment plant in South Africa", *Biotechnology and Bioprocess Engineering*, 15(5), 874-881.
4. Cosa, S., & Okoh, A. (2014): "Bioflocculant Production by a Consortium of Two Bacterial Species and Its Potential Application in Industrial Wastewater and River Water Treatment", *Polish Journal of Environmental Studies*, 23(3).
- Fujita, M., Ike, M., Tachibana, S., Kitada, G., Kim, S. M., & Inoue, Z. (2000): "Characterization of a bioflocculant produced by *Citrobacter* sp. TKF04 from acetic and propionic acids", *Journal of bioscience and bioengineering*, 89(1), 40-46.
6. Ghribi, D., Zouari, N., & Jaoua, S. (2004): "Improvement of bioinsecticides production through mutagenesis of *Bacillus thuringiensis* by uv and nitrous acid affecting metabolic pathways and/or delta-endotoxin synthesis", *Journal of applied microbiology*, 97(2), 338-346.

7. Giri, S. S., Harshiny, M., Sen, S. S., Sukumaran, V., & Park, S. C. (2015): "Production and characterization of a thermostable bioflocculant from *Bacillus subtilis* F9, isolated from wastewater sludge", *Ecotoxicology and environmental safety*, 121, 45-50.
8. Gong, W. X., Wang, S. G., Sun, X. F., Liu, X. W., Yue, Q. Y., & Gao, B. Y. (2008): "Bioflocculant production by culture of *Serratia ficaria* and its application in wastewater treatment", *Bioresource technology*, 99(11), 4668-4674.
9. Luo, Z., Chen, L., Chen, C., Zhang, W., Liu, M., Han, Y., & Zhou, J. (2014): "Production and characteristics of a bioflocculant by *Klebsiella pneumoniae* YZ-6 isolated from human saliva", *Applied biochemistry and biotechnology*, 172(3), 1282-1292.
10. Martín, C., Wei, M., Xiong, S., & Jönsson, L. J. (2017): "Enhancing saccharification of cassava stems by starch hydrolysis prior to pretreatment", *Industrial crops and products*, 97, 21-31.
11. Mukherjee, S., Das, P., & Sen, R. (2006): "Towards commercial production of microbial surfactants", *TRENDS in Biotechnology*, 24(11), 509-515.
12. Nwodo, U. U., & Okoh, A. I. (2013): "Characterization and flocculation properties of biopolymeric flocculant (glycosaminoglycan) produced by *Cellulomonas* sp. O koh", *Journal of applied microbiology*, 114(5), 1325-1337.
13. Nwodo, U. U., Green, E., Mabinya, L. V., Okaiyeto, K., Rumbold, K., Obi, L. C., & Okoh, A. I. (2014): "Bioflocculant production by a consortium of *Streptomyces* and *Cellulomonas* species and media optimization via surface response model", *Colloids and Surfaces B: Biointerfaces*, 116, 257-264.
14. Nwodo, U., Agunbiade, M., Green, E., Nwamadi, M., Rumbold, K., & Okoh, A. (2013): "Characterization of an Exopolymeric Flocculant Produced by a *Brachybacterium* sp." *Materials*, 6(4), 1237-1254.
15. Tahzibi, A., Kamal, F., & Mazaheri Assadi, M. (2004): "Improved production of rhamnolipids by a *Pseudomonas aeruginosa* mutant", *Iranian Biomedical Journal*, 8(1), 25-31.
16. Taiwo, L., Ailenokhuoria, V., & Oyedele, A. (2017): Profiling rhizosphere microbes on the root of maize (*Zea mays*) planted in an Alfisol for selection as Plant Growth Promoting Rhizobacteria (PGPR). *Microbiology Research Journal International*, 1-10.

17. Vahed, M., Motalebi, E., Rigi, G., Akbari Noghabi, K., Souidi, M. R., Sadeghi, M., & Ahmadian, G. (2013): "Improving the chitinolytic activity of *Bacillus pumilus* SG2 by random mutagenesis", *J Microbiol Biotechnol*, 23(11), 1519-1528.
18. Xia, S., Zhang, Z., Wang, X., Yang, A., Chen, L., Zhao, J., Leonard, D. and Jaffrezic-Renault, N. (2008): "Production and characterization of a bioflocculant by *Proteus mirabilis* TJ-1", *Bioresource technology*, 99(14), 6520-6527.
19. Xu, L., Ma, R., Sun, C., & Sun, D. (2018): "*Enterococcus faecalis* Bioflocculant Enhances Recovery of Graphene Oxide from Water", *Polish Journal of Environmental Studies*, 27(6).
20. Zhang Z, Lin B, Xia S, Wang X, & Yang A (2007): "Production and application of a novel bioflocculant by multiple-microorganism consortia using brewery wastewater as carbon source", *Journal of Environmental Sciences*, 19(6), 667-673.
21. Zheng, Y., Ye, Z. L., Fang, X. L., Li, Y. H., & Cai, W. M. (2008): "Production and characteristics of a bioflocculant produced by *Bacillus* sp. F19", *Bioresource Technology*, 99(16), 7686-7691.

## **SOURCING RIGHT ERGONOMIC EXECUTIVE OFFICE CHAIR**

Oddiah, A.O.<sup>1</sup>, Ismaila, S.O.<sup>2</sup>, Orintunsi, K.T.<sup>3</sup>, Kolo, J.G.<sup>3</sup>, Musilim, A.A.<sup>4</sup>, Ali, I.A.<sup>3</sup>, &  
Oloko, G.A.<sup>4</sup>

<sup>1</sup>*Industrial Maintenance Engineering Department, Yaba College of Technology, Yaba, Nigeria*

<sup>2</sup>*Mechanical Engineering Department, Federal University of Agriculture, Abeokuta, Nigeria*

<sup>3</sup>*Mechanical Engineering Department, Yaba College of Technology, Yaba, Nigeria*

<sup>4</sup>*Welding and Fabrication Engineering Department, Yaba College of Technology, Yaba, Nigeria.*

**CORRESPONDING AUTHOR:** kolojohn62@gmail.com

### **ABSTRACT**

Working in an office especially as an executive typically involves a sedentary action which requires expending much more time resting in an office chair thus causing additional strain to the arrangements in the spine. In order to prevent evolving back problems from being developed or compounded, it is paramount to utilize an office chair that has ergonomic features that can support the lower back and promotes good pose Rodney (2004). Relevant anthropometric measurements such as sitting eye height, forearm hand length, elbow rest height, seat width, buttock-popliteal height, buttock-knee length, sitting height, Angle of projection and popliteal height were taken from 50 participating executives in Lagos, Nigeria. These measurements were analyzed statistically using SPSS version 16.0. The result showed that elbow rest height, buttock popliteal length, popliteal height, were 31.70 cm, 47.80 cm, and 55.70cm (i.e 95<sup>th</sup> percentile + clearance allowance) respectively and the data were used for the selection of a chair with ergonomic characteristics that best fits the operations of the executives. Since the aim of ergonomics is to fit the task to the individual and not the individual to the task, it is expected that making use of the ergonomic executive office chair will help to achieve higher productivity, improve well-being and safety of officer and promote higher job satisfaction. All these improvement were considered to ensure that work-related musculoskeletal ailments are prevented among executives.

**Keywords:** Ergonomics, sedentary, anthropometry, executive, office chair



## **Introduction**

The study of human efficiency in work environment based on chair design has become more important in the last two decade. The word ergonomics is mostly misconstrued by layman to be associated with only office and chair ergonomics Sanders and McCormick (1992). Ergonomic design for office chair in European and United States has a set international standard and this makes the ergonomic chair industry becoming an enterprise of multi-billion dollars.

Research has shown two most important studies on ergonomic chair design in scientific parlance that points the way to a new development: Muscle tensions in erector spines and intra-disc pressure measurement by Nachemson (1996). This convincingly shows that as chair user sit down; there will be a decimal increase of between 40-50% of disc increase pressure when compared to upright position. The users of most chairs do not notice any increase in pressure due to the absence of nerves at the disc.

It was observed that moving from upright to the sitting position, there is a decrease in hip joint angle from  $180^{\circ}$  to  $90^{\circ}$ . However, at  $60^{\circ}$  bending is observed in the hip joint and the rest  $30^{\circ}$  are taking up by the forward rotation of the pelvic that flat up the lumbar curve. The development causes distance leverage arm to become shorter between the erector spine muscle and the spine, resulting to increased pressure so as to maintain forced equilibrium. A lumbar support is required by the chair designers to restore the lumbar curve in order to reduce the disc pressure or alternatively increasing the back rest angle by opening up the hip angle to  $110^{\circ}$ - $120^{\circ}$  Michel and Helander (1994). As a standard, chairs are designed with lumbar support and back rest angle which are adjustable between  $110^{\circ}$ - $120^{\circ}$ .

Other design criteria's are;

- (i) Chair must fit the user's size, and
- (ii) Chair having a waterfall front, to allow blood circulation to the legs to avoid cut off Helander and Zhang (1997). The above criteria's are common for users who experience changes in disc pressure; hence evaluation of office chairs can be used for potential customers. Researchers have carried out evaluation studies to identify chairs or designs feature that may reduce the extent of discomfort experienced by users in order to select the best and unique chair model out of several. Many companies/ organizations have pursued with vigor to have an ideal line of chairs for use in offices as a standard. Igbinedion (2010) investigated on ergonomics

features of chairs for comfort/discomfort and evaluation of ten conducted. There was only a slight significant differences found in their comfort/discomfort which makes it very difficult to establish ranking order between the chairs. To further establish additional findings on comfort//discomfort, 3 tilt-able and inclined office chair seat using 12 subjects were used, also there is no significant discomfort differences observed Lee and Ferraiuolo (1993). Generally a measured local discomfort in sixteen motor vehicle seats using 100 sample subjects were undertaking and there was no significant difference in the disc pressure and local comfort/discomfort. Wilder and Pope (1994) took a comparative test on two truck seats and recorded no significant difference in comfort between the seats made of steel spring and gas spring using six test subjects.

From various research activities, it is obvious that there is no significant difference even with new developed measurement methodologies having greater sensitivity. Further studies by Shackel et al. (1996) selected 4 assessment methodologies to be used for the best ergonomic chairs within sample of ten. A chair is used for a day taking measurement in the morning, before lunch and at the close of work. Evaluation checklist was conducted for each day, results analyzed using variance approach. Only little significant findings were obtained, as users could not express perceived difficulties on account of comfort and discomfort that were the subject of initial method Shackel et al. (1996); Lee (2000). Since every individual crave for relief in their workplace, this paper therefore, aim at sourcing for and select chair that best fit executives in an organization in order to ensure that work-related musculoskeletal ailments are prevented and optimum performance is achieved.

## **Materials and Method**

### ***Methods of sampling and samples***

The research focused on congested areas of Lagos where there are top executives in densely areas of the metropolis. The samples in this study were fifty (50) selected executives in a middle scale organization in Lagos metropolis whose activities are almost daily done in a sedentary position.

### ***Materials***

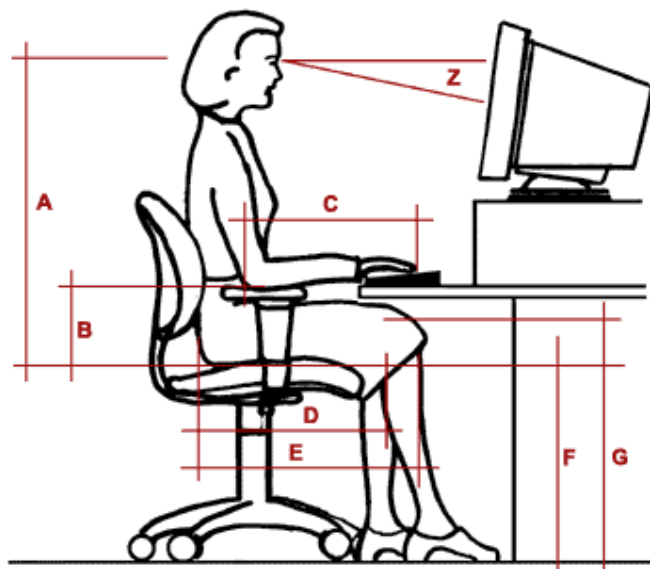
Dimensioning instruments used for this research work are: Measuring tape, Steel tape, Bevel-Protractor, Pencil, Measurement form, Eraser, Digital Camera, Pen and leaflets

### ***Anthropometry Measurements***

Anthropometric data is a collection of the dimensions of the human body and is useful for apparel sizing, forensics, physical anthropology and ergonomic design of the workplace Ismaila et al (2013). Anthropometric variables of office executive as well as their workstations (desks or tables and chairs) were measured by above mentioned instruments. Anthropometry refers to the dimensions of the human body and how these are measured. It covers the size of people; their height and circumference; their weight and percentage body fat; the length and range of movement of their limbs, head and trunk; and their muscle strength. Measurements of large numbers of people were considered and needed in any given population to determine ranges, averages and percentiles.

Each of the executive anthropometry measurements was taken pertaining to their daily activities, physical workstation characteristics, ergonomics injury-related symptoms, perceptions towards the current working environment and ergonomics knowledge. The measurements taken are meant for finding the criteria to quantify the actual working posture of the top executives by maintaining his/her usual keying position by using the measuring instruments.

While sitting in front of computer on a workstation. Dimensions were taken such as the distance of the monitor to the eye with fingers on the key board, as well as angle of viewing by the operator and appropriate measurements taken (details in plate1)



**Plate 1: A Typical Workstation of an executive (Source: en.m.wikipedia.org)**

**Keys:**

*A: Eye height sitting. B: Elbow rest height. C: Forearm-hand length*

*D: Buttock-popliteal length. E: Buttock-knee length. F: Popliteal height - no shoes*

*G: Knee height sitting – without wearing the shoes. Z: Angle of projection*

**Ergonomics Furniture**

Furniture is an item used by all and must accommodate wide range of sizes for individual end users. The average person is a mythical creature and when measurements are taken for a particular design from a target population, a mid-point is reached (termed the 50<sup>th</sup> "percentile"). This splits users into two groups; one above and one below the average. From logical point of reasoning, the mid-point/average number can be used to determine the height of chair seat, but not the height of shelf top in a storage cabinet. In the latter case, it is a standard practice to use dimension that can accommodate 90% to 95% of users who can reach an object on the top shelf. The ideal design consideration is to provide for adjustability and the use of anthropometric data for the determination of the upper and lower limits for a range of adjustments, for example, case of work station chairs Shikdar and Das (1995).

**Seat Design Criteria**

**Traditional Criterion:** The height of the seat can be adjusted in order to avoid swelling of the leg with knee angle support of 90<sup>0</sup> to avert swelling of the leg. However 75% of leg swelling may be as a result of leg muscle lower part activities peculiar to chair position.

**Minimum Height:** This can be 39.62cm designed to 5th percentile of women having 30.48cm heels, while seat may adjust to 27.43cm.

**Fixed Height:** The fixed height may be about 45.72cm, this may be a compromise. Higher chair promote increase pressure around the popliteal fold under the knees, causing a rise in nerve pressure with reduced blood circulation.

**Seat Depth:** The recommended seat depth is 44.19cm for a fixed seat and 36.58cm to 50.29cm for seats that are adjustable. A seat depth that is greater than the buttock-popliteal length, 5<sup>th</sup> percentile woman will be at 45.72cm, user cannot use the backrest Resnick and Zanotti (1997).

**Seat Pan Contours:** Nearly half of the body weight is supported by 8% area under the "seat structure". A hard and flat surface may give pressures of about 85-100 p.s.i. Cushioning and contours in seats can distribute pressure over a wide area by moving the pelvis forward for a better pelvic posture.

**Seat Cushioning:** The proposed thickness is put 4.57cm to 6.10cm. The cushioning effect can be made firmer at the back and thicker, while at the front it can be firm and thinner. Heavy cushioning has the tendency to sink the body into the chair thereby causing movement constraints. Chairs that are soft may have been in the first instance considered comfortable, but while the body sinks, a reduction in blood circulation occurs, compression under thighs region increases with increase skin temperature and consequently, discomfort sets in.

**Cushion Compressibility:** This may be regarded as indentation deflection load or indentation deflection force. A better blend is a soft top layer (25%) over a sturdy bottom layer of (65%). An increase ratio greater than 2.6 in between the two, will promote good quality support.

**Seat Width:** A clothed person can ideally be accommodated between 54.86cm to 60.96cm. An ideal seat will be the one with armrests and elbow to elbow breadth.

**Seat Angle:** A backrest of between  $5^0$  to  $10^0$  positive seat angle will help users to maintain good contact.

**Armrests:** This aids postural support in rising and sitting down. Padding is ideal to aid the fleshy part of the forearm. A gap of approximately 12.19cm between the armrest and seat back is recommended when the sensitive ulnar nerve is close to the surface in order not to engage the bony part of the elbow. Above the seat surface height cantilevered elbow rests should be 24.38cm to 30.48cm. There may be at least 46.33cm armrest difference to exceed thigh breadth of 95th percentile females Resnick and Zanotti (1997).

## **Backrests Design Criteria**

**Height:** There are three categories for higher backrests to promote better weight support:

**Low-level backrest:** This is for only the lumbar region. The lumbar curve depth for the backrest can be 1.82cm to 6.10cm. A backrest height of 15.24cm, 21.34cm, and 27.43cm seems also operative.

**Medium-level backrest:** This is for shoulder support in car seat and chair use in the office and may be about 67.06cm high to take the 95th percentile man.

**High-level backrest:** Enhance full head and neck support (in the case of plane seats) and can be about 91.44cm for a 95<sup>th</sup> percentile man Resnick and Zanotti (1997).

## **Results and discussions**

### ***Anthropometric Percentiles***

Table 1 shows the analysis of anthropometric percentiles for the fifty executive with highest value of 95<sup>th</sup>, mid value of 50<sup>th</sup> and the lowest value of 5<sup>th</sup>. The analysis showed that the highest and lowest values that can accommodate any executive within the studied area for eye height sitting and elbow rest height are 76.45 & 66.00 cm and 31.45 & 24.00 cm respectively.

**Table 1: Anthropometric Percentiles**

Parameters	F	Min	Max	Percentiles		
				5 <sup>th</sup>	50 <sup>th</sup>	95 <sup>th</sup>
Eye height sitting (cm)	50	66	77	66.0	70.0	76.5
Elbow rest height (cm)	50	23	33	24.0	27.5	31.5
Fore arm hand length (cm)	50	36	46	37.0	40.5	44.5
Buttock popliteal length (cm)	50	46	60	47.6	55.5	58.0
Buttock knee length (cm)	50	48	62	51.0	56.5	60.0
Popliteal height (cm)	50	44	56	45.0	51.0	55.5
Knee height sitting (cm)	50	54	66	54.6	60.0	64.5
Seat Buttock width (cm)	50	38	48	40	42.5	47.5
Angle of projection (°)	50	20	25	20.00	22.00	24.00

### **Designed Calculations**

The design of the proposed chair is based on the following parameters derived from 5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentiles of the analysis with 25% (0.25) clearance. However, anthropometric data differs between races, and changes with time. People whose height falls on the 50<sup>th</sup> percentile line are often said to have average height. People whose height falls on the 5<sup>th</sup> percentile can be said to be small people, while people whose height falls on the 95<sup>th</sup> percentile can be said to be tall people.

- i. Position Eye height sitting measurement is the 50% percentile = 70.00 + 0.25 = 70.25 cm
- ii. Position of Elbow rest height measurement is the 95% percentile = 31.45 + 0.25 = 31.70 cm

- iii. Measurement for Fore arm hand length is 95% percentile  
 $= 44.45 + 0.25 = 44.70 \text{ cm}$
- iv. Measurement for Buttock popliteal length is 5% percentile  $= 47.55 + 0.25 = 47.80 \text{ cm}$
- v. Measurement for Buttock knee length is the 5% percentile  
 $= 51.00 + 0.25 = 51.25 \text{ cm}$
- vi. Measurement for Popliteal height is 95% percentile  
 $= 55.45 + 0.25 = 55.70 \text{ cm}$
- vii. Measurement for Kneel height sitting is 95% percentile  
 $= 64.45 + 0.25 = 64.70 \text{ cm}$
- viii. Measurement for Seat (Buttock) width is 95% percentile  
 $= 47.45 + 0.25 = 47.70 \text{ cm}$
- ix. Measurement for Angle of projection is 95% percentile  
 $= 24.00 + 0.25 = 24.25$

## **Discussions**

The analysis of anthropometric percentiles for the fifty executive staff had the highest value of 95<sup>th</sup>, mid value of 50<sup>th</sup> and the lowest value of 5<sup>th</sup>. It was shown that the highest values that can be accommodated by any executive for buttock popliteal length and be accommodated are 47.55 and 51.00 cm in that order. It was shown that fore arm hand length and popliteal height had highest values of 44.45 and 55.45 cm respectively while their lowest values are 37.00 and 45.00 cm and mid values were 40.50 and 51.00 cm. The knee height sitting values buttock knee lengths are 58.00 and 60.00 cm respectively. For lowest, mid and highest are 54.55, 60.00 and 64.45 cm respectively and angle of projection for the executive staff in degrees are 20.00, 22.00 and 24.00 in that order.

The designed calculations for the new workstation is stated as; the position eye height sitting measurement is the 50% percentile is 70.25 cm, Position of Elbow rest height measurement is the 95% percentile is designed to be 31.70 cm, measurement for fore arm hand length is 95% percentile is 44.70 mm, measurement for buttock popliteal length is 5% percentile is 47.80 cm, measurement for buttock knee length is the 5% percentile is 51.25 cm, measurement for seat (buttock) width is 47.70 cm and measurement for popliteal height is 95% percentile in degree is stated to be 6.25°.

## **Conclusions**

It could be concluded that some of the anthropometric data of the executive staff taken fell out of lowest and highest percentiles. Finally, the research work has been enabled to propose selection criteria for sourcing for an ergonomic chair that will abrogate the Work-related Musculoskeletal Disorders for an effective productivity. It can therefore be concluded that the work-related musculoskeletal disorders of executive shall persist with lack or substandard ergonomic workstation.

## **Recommendations**

It is hereby recommended that top executives in our respected organizations should be enlightened (that is, through training or workshop) on relevance/importance of ergonomic chairs. Also the redesigned of workstation with ergonomic characteristics should be espoused which falls between the limits of 5<sup>th</sup> percentile and 95<sup>th</sup> percentile.

## **References**

- Goonetilleke, R. S. and Feizhou, S. (2001). A Methodology to Determine the Optimum Seat Depth. *Industrial Ergonomics* 27: 207-217.
- Helander, M.G. and Zhang K.T. (1997). A Field Study of Productivity Improvements in the Manufacturing of Circuit Boards. *Int. J. of Industrial Ergonomics*, 7:207-215.
- Igbinedion, V.I. (2010). Knowing the Graduate Office Secretary. *Ozean Journal of Social Sciences*, Ozean Publication, 3 (1).
- Ismaila, S. O., Musa, A. I., Adejuyigbe, S. B., Akinyemi, O. D. (2013). Anthropometric design of furniture for use in tertiary institutions in Abeokuta, south-western Nigeria
- Lee, K. (2000). Occupational health and safety in the third world—a simple case of neglect. In: *Human Space Time—en.m.wikipedia.org Environment*, ed. By Sohn JY, Proc. of the 5th International Congress on Physiological Anthropology, Seoul: pp. 247-252.
- Michel, D., Helander, M. (1994). Effects of Two Types of Chairs on Stature Change and Comfort for Individuals with Healthy Herniated Discs. *Ergonomics* 37:1231-1244.



- Nag, P. K., Pal. S., Kotadiya, S. M., Nag, A., and Gosa, K., (2008). Human-seat interface analysis of upper and lower body weight distribution, *International Journal of Industrial Ergonomics*, 38(6):539-545.
- Nachemson, A. (1996). The load on lumbar disks in different positions of the body. *Clinical Orthopaedics and Related Research*, 45:107-122.
- Resnick, M. L., and Zanotti, A. (1997). Using ergonomics to target productivity improvements. *Computers and Industrial Engineering*, 33 (2): 185-188.
- Rodney K. Lefler, 2004. Choosing the Right Ergonomic Office Chair, peer review article
- Sanders, M. S. and McCormick, E. J. (1992). *Human factors in engineering and design* (7th Ed.). New York: McGraw-Hill.
- Shackel, B., Chidsey, K.D. and Shipley, P. (1996). The assessment of chair comfort. *Ergonomics*, 4:269-306.
- Shikdar, A.A. and Das, B. (1995). Participative Versus Assigned Production Standard Setting in a Repetitive Industrial Task: A Strategy for Improving Worker Productivity, *Int. J. of Occupational Safety and Ergonomics*, 5(3):417-430.
- Vos, G. A. (2001). Evaluation and Analysis of Buttock-Thigh Pressures amongst Contemporary Ergonomic Chairs, with Regards to the Effects of 3-D Fabric and Memory Foam. Doctoral Dissertation, Texas A and M University, Department of Interdisciplinary Engineering.
- Wilder, D. G. and Pope, M. H. (1994). How the lumbar motion segment responds to sustained sitting. *Advances in Bioengineering*, (pp. 8-9). Rockville, MD: National Institute for Occupational Safety and Health.

## **CONDITION ASSESSMENT OF OJUTU BRIDGE IN ILOBU OSUN STATE, NIGERIA USING RELIABILITY AND NON-DESTRUCTIVE TESTING ON SELECTED STRUCTURAL ELEMENTS.**

Olawale, S.O. A., Adebajo, A.U., Thanni, M. O., and Fatokun, A. A.

Department of Civil Engineering Osun State University Osun State, Nigeria.

Corresponding Author: [abdulfatai1234@gmail.com](mailto:abdulfatai1234@gmail.com)

### **ABSTRACT**

The assessment of structural integrity of in-service structural elements during its lifetime is vital to predicting the present, future and required maintenance needs of such structures. Structural components of a bridge are not an exemption, most in-service Reinforced Concrete (RC) bridges in Nigeria are suffering from aging and deterioration due to harsh environmental exposure conditions and are damaged by natural (hydrologic forces) or man-made hazards.

In this project's some of the structural elements of a 107 years RC bridge (Ojutu Bridge) located in Ilobu, Osun State, Nigeria, were assessed. The methods of assessment include visual inspection, Non-Destructive Test (NDT) on selected members using Schmidt Hammer and reliability assessment based on limit state functions in accordance to BS 5400.

From this study, the result of the visual inspection shows that most of the elements assessed are showing signs of distress as this can be seen from the various defects observed during the study. Compressive strength values obtained from NDT carried out on the deck, abutment and beams were between  $26\text{N/mm}^2$ - $30\text{N/mm}^2$  which is below the minimum required compressive strength stipulated by BS5400 part 4 cl 5.1.4 for in Service Bridge structures, the probability of failures obtained from the reliability assessment were extremely high suggesting that the elements were in critical condition.

It was therefore concluded that the structural integrity of the bridge should be subjected to further structural integrity test. In addition to this, there is a need for urgent maintenance and provision of crossbar to restrict activities of heavy- duty trucks thereby preventing the bridge from total collapse as a result of excess load on the bridge due to current concrete strength.

**Keywords:** Non-Destructive Test (NDT), Reliability Analysis, Bridge Structural members

## **1.0 INTRODUCTION**

The assessment of structural integrity of existing structures has become a more frequent task for engineers in recent times, this is largely due to the increasing age of existing infrastructure and the lack of maintenance over a long period of time. Jansen (1996) stated other reasons that could impair the usability of structural elements are; change in intended use of the structure, new regulations with higher load requirements for the structure, indications of ongoing deterioration in the structure, unusual incidents during use (e.g. vehicle impact, fire, earthquakes), inadequate serviceability, discovery of design or construction errors.

In the same vein, the assessment of a bridge is important in predicting the present and future required maintenance needs. For bridges to operate at optimum capacity there is a need to carry out frequent checks to help understand the structural integrity of the bridge per time. Richard (2004) explained that to assess the integrity of an in-service bridge one must take the following into consideration; the extent of creep, shrinkage, volumetric changes, rebar corrosion, honeycombing, chemical attacks and the inherent concrete strength amongst others.

In ascertaining the condition and the capacity of in service concrete structures especially when the concrete strength is of importance a combination of any of the following Non-Destructive Test (NDT) methods as stated by Richard (2004) can be used; Visual Inspection (VI), Acoustic Emissions Methods (AEM), Impact Echo (IE), Spectral Analysis of Surface Waves (SASW), Galvanostatic Pulse Technique (GPT), Impulse Response (IR) , Radiography, Intrusive Visual Examination (IVE) and Rebound Hammer Test (RHT).

Reliability analysis is a powerful tool that can improve and nuance the understanding of a structure and increases the utilization of both load -carrying capacities and service life for existing structures.

This study is limited to the assessment of the condition of the selected bridge based on the inherent Compressive Strength using a Non-Destructive Test and developing a reliability function based on limit state functions in accordance to BS 5400 using Java. The Bridge to be assessed is Ojutu Bridge, Ilobu. The assessment was carried out using visual inspection and the use of Schmidt Hammer.

## **2.0 METHODOLOGY**

### **Study Area**

Ojutu Bridge is situated along Ogbomosho -Osogbo road in Osun State. It is a continuous bridge constructed in 1912 with three abutment supports spanning 27m, the bridge has a width of 5.8m. It is a major route from Osogbo to Ogbomosho with high volume traffic.

### **2.1 Primary Assessment**

#### **Visual Inspection**

This refers to a physical assessment technique amongst the non-destructive methods. It was used to detect the orientation of cracks, surface dampness, wear and tear due to temperature and traffic, material flaws and structural serviceability. Visual features may be related to workmanship, structural serviceability, and material deterioration. This was carried out in accordance to NDT guide for concrete structures series 17 (2002).

#### **Non-Destructive Test (Rebound Hammer Test)**

Equipment for Schmidt/ The hammer weighs about 1.8 kg and is suitable for use both in a laboratory and in the field. A schematic cutaway view of the rebound hammer is shown in Fig. 2.1 The main components include the outer body, the plunger, the hammer mass, and the main spring. Other features include a latching mechanism that locks the hammer mass to the plunger rod and a sliding rider to measure the rebound of the hammer mass. The rebound distance is measured on an arbitrary scale marked from 10 to 100. The rebound distance is recorded as a “rebound number” corresponding to the position of the rider on the scale.

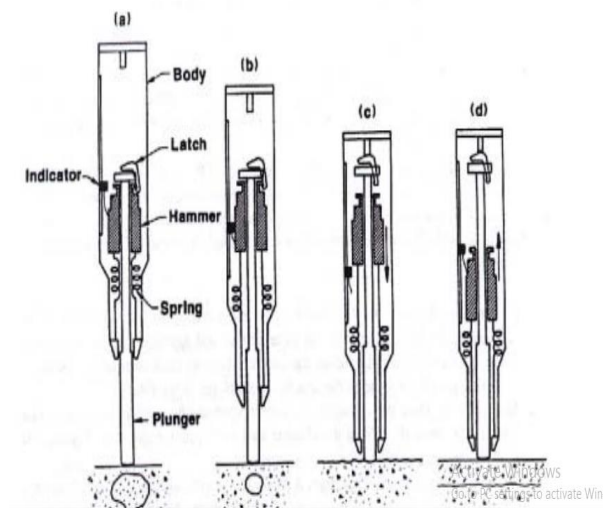


Figure 2.1 A cutaway schematic view of the Schmidt rebound hammer.

This was done in 2 stages, the Calibration test and Field test

#### Stage 1: Calibration Test

A total number of (15) 100 mm × 100 mm concrete cubes (or 100 mm<sup>3</sup> cube specimens) were cast of different grades, cured the cubes under standard moist-curing room conditions. Conducted 12 hammer rebound readings, 3 on each side of the cube. Average the readings and call this the rebound number for the cube under test. Repeat this procedure for all the cubes. Tested the cubes to failure in compression with the aid of a compressive machine and plotted the rebound numbers against the compressive strengths on a graph and after which line of best fit was drawn. To produce equivalent compressive strength.

$$C_s = m (RN) + C \quad \dots\dots\dots \text{Eq 2.1}$$

Where  $C_s$  = compressive strength,  $m$  = gradient of the line  $RN$  = rebound number and  $C$  is the intercept on  $C_s$  axis. The Test was carried out in accordance with BS 1881 (Part 202) – 1986.

#### Stage 2 Field test

Each structural member was segmented using grid lines which were drawn on surfaces of the members at regular intervals and the compressive strength obtained from the rebound number using equation 2.1 above.

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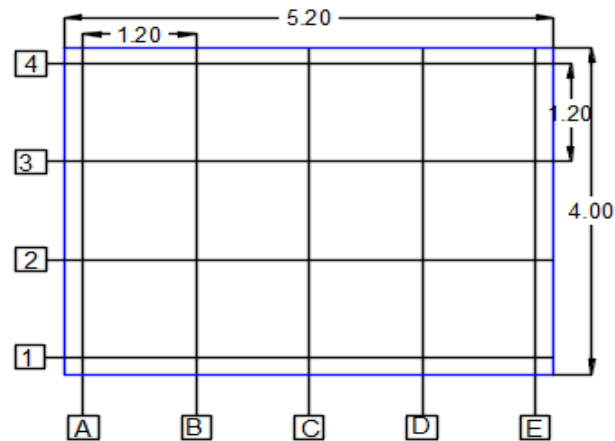


Figure 2.2 Abutment grid lines

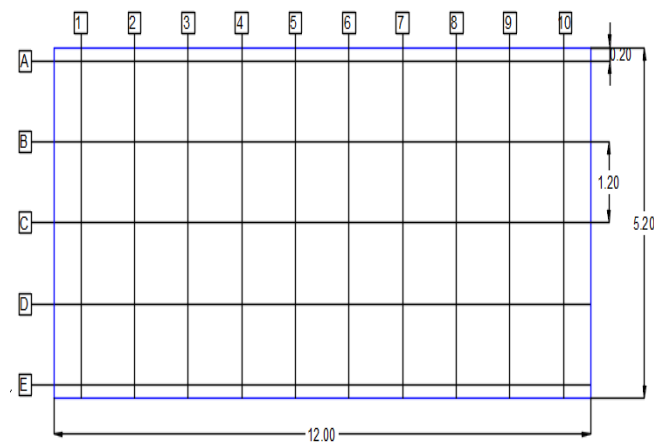


Figure 2.3 Grid lines on the bridge deck

## 2.2 Secondary Assessment (Parametric Studies)

Reliability method has been used to establish the uncertainties involved in the analysis of selected members of the bridge. The failure probability and the reliability index are used to quantify risks and therefore evaluate the consequences of failure.

### The development for the reliability for Flexure

**2.2.1 For sections without compression reinforcement for both beam and deck in accordance to BS5400 Part 4 (1990)**

The ultimate moment capacity in accordance with BS 5400-4 (1990) is:

$$M_{ult} = 0.15f_{cu}bd^2 \dots \dots \dots (2.1)$$

Equation 1 can be express as:

$$M_{ult} = 0.158f_{cu}bhZ \dots \dots \dots (2.2)$$

Where,

$f_{cu}$  = Characteristics strength of concrete

B = Breadth of the deck/beam

H = Height of the deck/beam

Z = lever arm

$M_a$  = The moment capacity applied

$M_{ult}$  = The ultimate moment capacity

The Limit State Equation is given by:

$$.g(b, d, h, f_{cu}, M_a) = 0.158f_{cu}bhZ - M_a \dots (2.3)$$

Let  $b = X_1$  ,  $h = X_2$  ,  $f_{cu} = X_3$  ,  $z = X_4$ ,  $M_a = X_5$

Hence the Limit State Equation then becomes:

$$g(X_1, X_2, X_3, X_4, X_5) = 0.158X_3X_1X_2X_4 - X_5 \dots (2.4)$$

At  $g(X) = 0$

$$X_5 = 0.158X_3X_1X_2X_4 \dots \dots \dots (2.5)$$

Determining the partial derivatives with respect to the variables, we obtain:

$$\frac{\partial g}{\partial X_1} = 0.158X_3X_2X_4 \dots \dots \dots (2.6)$$

$$\frac{\partial g}{\partial X_2} = 0.158X_3X_1X_4 \dots \dots \dots (2.7)$$

$$\frac{\partial g}{\partial X_3} = 0.158X_1X_2X_4 \dots \dots \dots (2.8)$$

$$\frac{\partial g}{\partial X_4} = 0.158X_3X_1X_2 \dots \dots \dots (2.9)$$

$$\frac{\partial g}{\partial X_5} = -1 \dots \dots \dots (2.10)$$

If the original vector space is given as  $\{X\} = \{X_1, X_2, X_3, X_4, X_5\}$  then the transformed reduced vector space  $\{X'\} = \{X_1', X_2', X_3', X_4', X_5'\}$  is given by:

$$X' = (X_i - \mu) / \sigma \quad i = 1, 2, 3, 4, 5 \quad \dots \dots \dots (2.11)$$

2.2.2 For a flanged beam in accordance to BS5400 Part 4 (1990)

$$M_u = 0.4f_{cu}bh_f(d - \frac{h_f}{2}) \dots \dots \dots (2.12)$$

Where  $h_f$  is the thickness of the flange

The Limit State Equation is given by:

$$g(b, d, f_{cu}, h_f, M_u) = 0.4f_{cu}bh_f(d - \frac{h_f}{2}) - M_u \dots \dots (2.13)$$

Let  $b = X_1$ ,  $d = X_2$ ,  $f_{cu} = X_3$ ,  $h_f = X_4$ ,  $M = X_5$

Hence the Limit State Equation then becomes:

$$g(X_1, X_2, X_3, X_4, X_5) = 0.4X_3X_1X_4 \left( X_2 - \frac{X_4}{2} \right) - X_5 \dots (2.14)$$

At  $g(X) = 0$

$$X_5 = 0.4X_3X_1X_4 \left( X_2 - \frac{X_4}{2} \right) \dots \dots (2.15)$$

Determining the partial derivatives with respect to the variables, we obtain:



$$\frac{\partial g}{\partial X_1} = 0.4X_3X_4 \left( X_2 - \frac{X_4}{2} \right) \dots\dots\dots(2.16)$$

$$\frac{\partial g}{\partial X_2} = 0.4X_3X_1X_4 \dots\dots\dots(2.17)$$

$$\frac{\partial g}{\partial X_3} = 0.4X_1X_4 \left( X_2 - \frac{X_4}{2} \right) \dots\dots\dots(2.18)$$

$$\frac{\partial g}{\partial X_4} = 0.4X_1X_3(X_2 - X_4) \dots\dots\dots(2.19)$$

$$\frac{\partial g}{\partial X_5} = -1 \dots\dots\dots(2.20)$$

### **3.0 RESULTS AND DISCUSSION**

#### *3.1 Visual Inspection Observations*

From the visual inspection carried out the following observation were made during the inspection. Plates 3.1 to 3.3 provides a pictorial view of some of the distresses experienced on site.

1. There was a high presence of potholes on the bridge deck.
2. The deck surface is characterized by pitting and spalling.
3. The bridge experiences high vibration whenever heavy moving loads or heavy trucks move on the bridge.
4. The soffit of the bridge deck is characterized by surface bleeding and wide cracks
5. Reinforcement bars viewed from the soffit are corroded
6. The surface of the abutment shows that large presence of honeycombs
7. Rails provided along the walkway has been detached thereby exposing pedestrians to danger



Plate 3.1 Distress under the bridge deck and corrode reinforcement as a result of concrete cover spilled off.



Plate 3.2 Walkway without rails to prevent from falling into the river.



Plate 3.3 Top of the bridge deck with superimpose deteriorated layer

### 3.2 Results from Calibration of Rebound Hammer

Based on the rebound hammer readings and the characteristic compressive strength of concrete cubes a linear equation relating the Rebound Number(x) to the Compressive Strength of concrete (y) was obtained as equation 3.1. The plot of compressive strength against rebound number is represented as figure 3.1 below

$$y = 0.6435 (x) + 5.9913 \dots \dots \dots 3.1$$

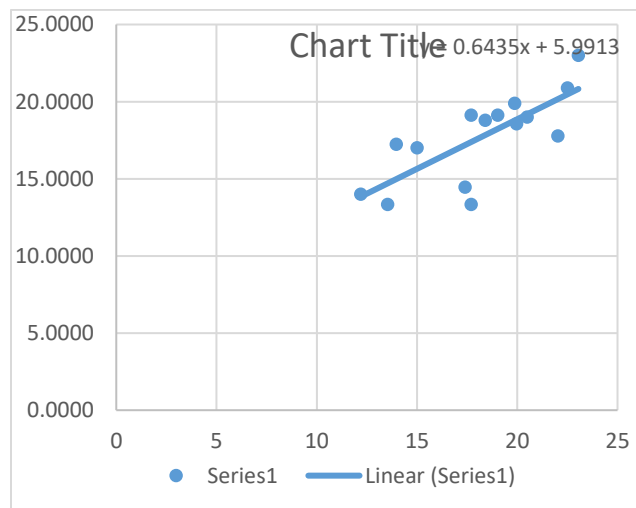


Figure 3.1 Showing Calibration curve result from Rebound Number and Compressive Strength

### 3.3 Compressive strength obtained from selected bridge members

The inherent compressive strength of the structural elements obtained from RBT is represented as Table 3.1, the structural elements tested include the bridge deck, beams and abutment. From the values obtained it was discovered that the bridge abutment had the lowest compressive strength of 26.04 MPa which is lesser than the minimum design compressive strength as specified by BS 5400 Part 4 (1990). Figure 3.1 and 3.2 show the stress pattern for the bridge deck and abutment respectively, from the stress pattern obtained for the deck it was observed that the lowest values of compressive strength were obtained at the middle area of the deck which suggests that the slab is experiencing distress around that area.

Table 3.1 Compressive Strength of Structural Elements

Bridge Components	Average Rebound Value	Average Compressive strength
Bridge Deck N-S	38.53	30.79MPa
Bridge Deck S-W	42.13	33.10MPa
Bridge Beam	35.39	28.76MPa
Bridge Abutment	31.15	26.04MPa

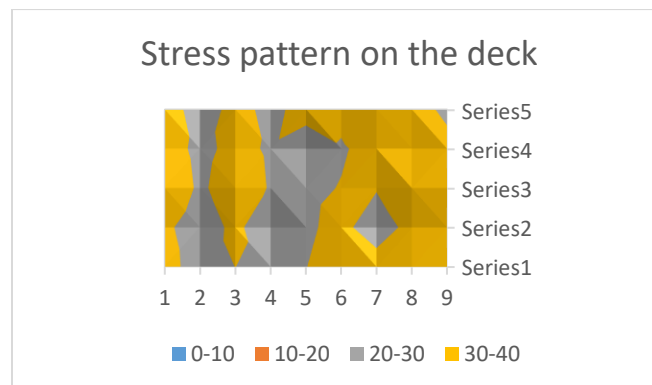


Figure 3.2 Stress Pattern on the bridge deck

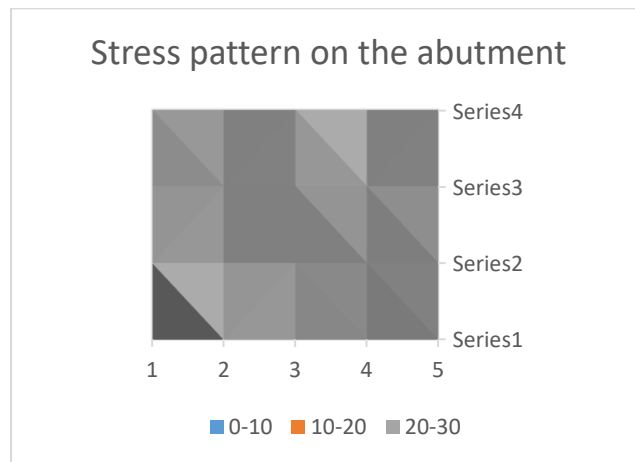


Figure 3.2 Stress pattern on the abutment.

### 3.4 Reliability of the Compressive strength Results

The variation of Compressive Strength from 10- 60N/mm<sup>2</sup>, whose deck height is 350mm, spanning 12m having an applied moment of 384.35x10<sup>6</sup> according to BS 5400 Part 4 (1990) was carried out using JAVA program and the reliability indices for the Compressive Strength variation were obtained and thus represented in the graphs as Figures 3.3 to 3.5

#### 3.4.1 Effect of Compressive Strength Variation with Reliability Index in Slab Deck.

For the plot of the variation of Reliability indices against Compressive Strength due to varying moments. It was noted that as the compressive strength increases the Reliability Index increases, and result from the plot indicated that values of compressive strength of 45N/mm<sup>2</sup> and above are well sufficient in accordance with Joint Committee on Structural Safety (JCSS) recommendation of 3.7 for bridges. This showed that the average compressive strength of 31N/mm<sup>2</sup> obtained from NDT carried out on the deck is tending towards failure.

#### 3.4.2 Effect of Compressive Strength Variation with Probability of failure in Slab Deck

The Probability of Failure for the Compressive Strength variation were obtained and thus represented as Figure 3.3 It can be observed that the Probability of Failure (POF) increases with increasing concrete strength from 25 N/mm<sup>2</sup> to 60 N/mm<sup>2</sup>. Comparing these results with that

obtained from the RBT indicates that the elements with compressive strengths lower than 30 N/mm<sup>2</sup> are not as safe as the probability of failure is high.

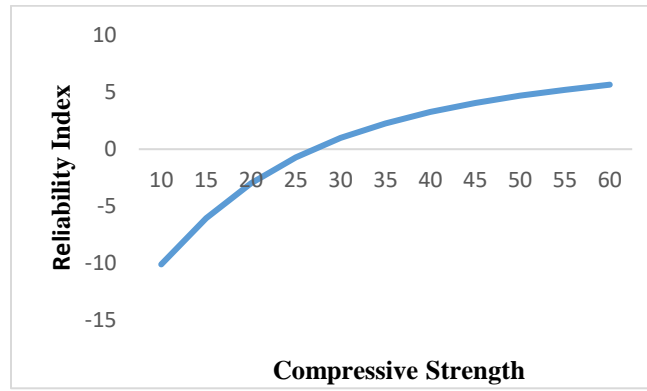


Figure 3.3 Reliability Index against Compressive Strength in Slab

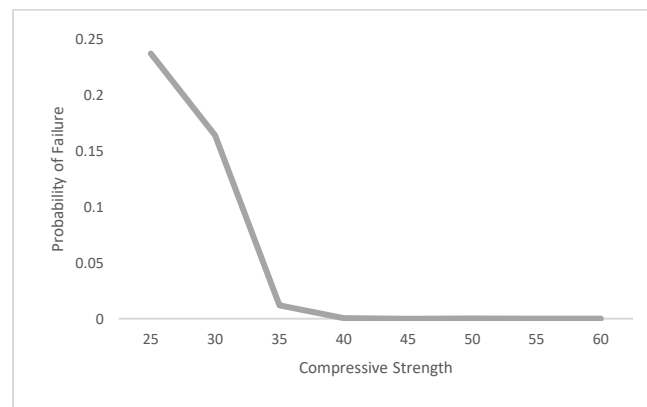
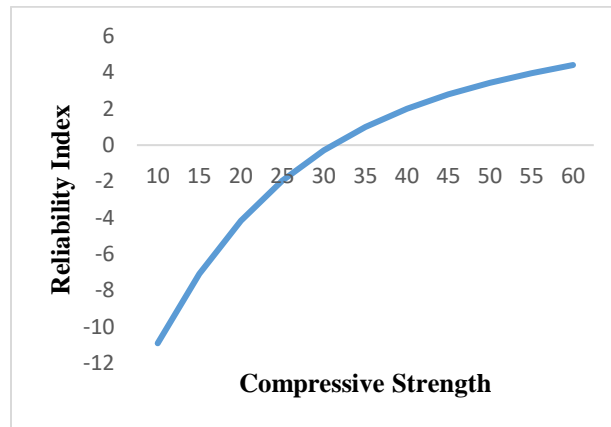


Figure 3.4 Probability of failure against Compressive Strength

For the plot of the variation of Reliability indices against Compressive Strength due to flexure. It was noted that as the compressive strength increases the Reliability Index increases when compared with the benchmark of 3.7 as provided by the Joint Committee on Structural Safety (JCSS), result from the plot indicated that values of compressive strength of 50 N/mm<sup>2</sup> and above exceeds minimum provision and are well satisfied. This showed that the average compressive strength gotten from field is trending towards failure with an average compressive strength of 29 N/mm<sup>2</sup>.

### 3.4.3 Effect of Compressive Strength Variation with Reliability Index in Beam

The variation of Compressive Strength from 10- 60 N/mm<sup>2</sup>, whose beam height is 600mm, breadth is 450mm, with an applied moment of 707.963x10<sup>6</sup> according to BS 5400 Part 4, was carried out using JAVA program and the reliability indices for the Compressive Strength variations were obtained and thus represented in the graphs



Figures 3.5 Reliability Index against Compressive Strength in beam

### 3.4.4 Effect of Compressive Strength Variation with Probability of failure in Beam

A similar trend was observed as was experienced in the bridge deck as the compressive strength increased. These findings agree with the opinion of Marco et al. 2005 which concludes that, most beams lose their design strength and durability as the load exceeds its design capacity. The fatigue failure zone was initiated by the cracks from tension zone and extended to the compression zone before reaching its ultimate fatigue life. These cracks usually start from the bottom of the applied load which indicates flexural failure.

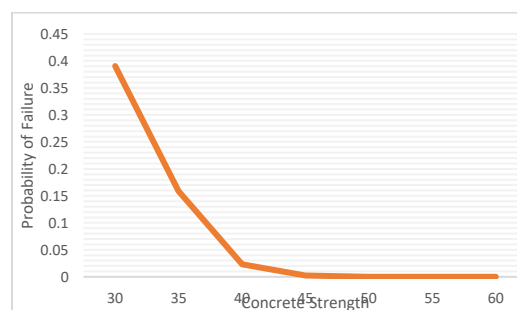


Figure 3.6 Probability Index against Compressive Strength in beam

#### **4.0 CONCLUSION**

The Bridge at Ojutu, Ilobu, Osun State Nigeria was found to be in the state of Structural deterioration.

- i. Visual Inspection shows the heavy presence of various physical distress on all the structural elements.
- ii. The non-destructive test carried out on the structural members' shows that structural members of the Bridge are weak with the average strength of the concrete for all structural members was lower than the design specification, this may be due to the aging of the bridge.
- iii. The reliability analysis shows that increasing concrete strength increases the reliability indices of the structural elements in flexure. It was also discovered that the probability of failure became less significant as the concrete strength increase above 40 N/mm<sup>2</sup>

#### **Recommendation**

From the structural assessment and reliability analysis of the bridge at Ilobu, Osun State, it is recommended that the bridge should be subjected to further structural integrity tests. In addition to this, there is a need for urgent maintenance and provision of the cross bar to restrict activities of the trucks, thereby preventing the bridge from total collapse as a result of excess load on the bridge due to current concrete strength.

#### **REFERENCES**

- Abejide O. S (2014). Reliability analysis of bending, shear and deflection criteria of reinforced concrete slabs, Nigerian journal of technology (nijotech) vol. 33. no.3, page 394-400  
University of Nigeria, Nsukka, ISSN: 1115 8443



Ajitesh Y.V.S. (2015) Condition Assessment Of Existing Structures Using NDT Techniques. Published thesis Department of Civil Engineering Gitam Institute of Technology Gitam University

Ayaz Mahmood, (2008) “Structural Health Monitoring Using Non Destructive Testing Of Concrete”, National Institute of Technology Rourkela.

Ayswarya K.S ,Ann Maria Johnson, Chaithanya, Devika Prasad, DhanyaKrishnan R, Radhika Nair N J. (2016). Evaluation of bridge performance using nondestructive testing, international advance journal in science, engineering and technology. Vol. 5 doi:10.17148/IARJSET.

Bastidas E.A. and Soubra A.H. (2014) Reliability Analysis Methods University of Nantes – GeM Laboratory – UMR CNRS 6183 – Nantes – France DOI: 10.13140/RG.2.1.2746.2880

BS 5400 Part 2 Code of Practice for Loading Bridge

BS 5400 Part 4 Code of Practice for designing Reinforced Concrete Bridge

Fico, R. Parretti, R. Campanella, G., Nanni, A., and Manfredi, G., (2006) Mechanical Characterization of Large-Diameter GFRP bars, 2nd International fib Congress, Naples;

Galati N, Boschetto G., Rizzo A., Parretti R and Nanni A.,(2004)“Pre-Construction Investigation for the Rehabilitation of a Bridge Using Internal FRP Technologies,” 4th International Conference on Advanced Composite Materials in Bridges and Structures - ACMBS-IV,,July 20-23, , Calgary, Alberta, Canada.

Guidebook on non-destructive testing of concrete structures (2002) Training Course Series No. 17

Heckrodt Renier Oelof (2002) Guide to Deterioration and Failure of Building Materials, Thomas Telford Books, London, UK.

Jansen A.( 1996) Research to fatigue behaviour of topping on prefabricated concrete girders. Master thesis, Delft University of Technology, Netherlands., p.128.

- Jepsson and Joakim (2003) Reliability-Based Assessment Procedures For Existing Concrete Structures, published doctoral thesis Lund University ISSN: 0349-4969
- Letoureur, R. (2001) "Bacteriogenic Corrosion of Concrete", conference paper, Biarritz Colloque 2001, Biarritz, France.
- Mibey Shiphram Chepkogei, (2014) 'Use of Non- destructive methods to assess the structural integrity of an existing concrete element' Thesis, Department of civil engineering, University of Nairobi.
- NRMCA (1998) "What, Why & How? Cracking Concrete Surfaces", National Ready Mixed Concrete Association, Silver Spring, MD.
- Piyush K. B, Ayan S. and Bhimaji D. K (2016). Advanced NDT methods for evaluation of bridges, International journal of advance research in science and engineering. Vol 5
- Qindan H. (2010) "Adaptive reliability analysis of reinforced concrete brodges using nondestructive testing," Ph.D. Dissertation, Department of Civil and Environmental Engineering, Texas A&M University.
- Richard C. U. (2004). The Use of Nondestructive Testing Methods for the Condition Assessment of Concrete Bridge Girders. Published thesis Department of Civil and Environmental Engineering Massachusetts Institute of Technology
- Ritesh, S and Sharma D.K. (2015). A review on bridge construction technology, international journal of computer technology and electronics engineering (IJCTEE). Vol 5.
- Sanayei, J. E. Phelps, J. D. Sipple, E. S. Bell, and B. R. Brenner, "Instrumentation, nondestructive testing, and finite element model updating for bridge evaluation using strain measurements," Journal of Bridge Engineering, vol. 17, no. 1, pp. 130–138, 2012
- Sangwook, L. and Nikolas, K. (2015). Bridge inspection practices using nondestructive testing methods, journal of civil engineering and management. 21(5): 654-665. Doi:10.3846/13923730.2014.890665

Sanjeev k. v, Sudhir S. B and Saleem A. (2013). Review of nondestructive testing methods for condition monitoring of concrete structures, Hindawi Publishing Corporation journal of construction Engineering.

Thomas, U. O. (2016) “Reliability analysis of reinforced concrete bridge decks subjected to fatigue”, published Msc. Thesis, Department of civil engineering Ahmadu bello university Zaria, Nigeria.

Wellison J. S. Gomes (2017). Reliability Analysis of Reinforced Concrete Beams Using Finite Element Models Conference Paper · January 2017 DOI: 10.20906/CPS/CILAMCE2017-0145

Workman, G., & O. Moore, P. (2012). Nondestructive Testing Handbook 10: Overview. Columbus: American Society of Nondestructive Testing.

# **PROSPECTING FOR IDEAL BUILT ENVIRONMENT FOR THE MUSLIM FAITHFUL THROUGH THE INTEGRATION OF ISLAMIC DESIGN PRINCIPLES IN CONTEMPORARY HOUSING NEIGHBORHOODS**

Babangida, H. M.

<sup>1</sup> Department of Architecture, Ahmadu Bello University, Zaria, Kaduna State, Nigeria  
Email of Corresponding Author: [babanhamza@gmail.com](mailto:babanhamza@gmail.com) +2348136586970

## **ABSTRACT**

The form and character of built environments are known in many respects to reflect among other factors the community's cultural belief system and building practices. The orthodox Muslim for example considered faith as way of life, and therefore influences their physical environments through the application of principles derived from the Islamic value systems. This paper attempt to test these principles in contemporary buildings. The methodology adopted in the preparation of the paper include literature search and case study approach. The literature search was carried out to identify IDP's that were specifically applied as guides in building the early and later periods of the prophet (pbuh) while the case study was used to demonstrate how these IDP's could be applied in the redesign of contemporary housing neighborhood using the Sardauna housing estate in Katsina as a case study. From the architectural perspective, the "'before and after scenarios"' of the housing estate which later were developed using the IDP's were compared. The redesign undertaking focused on three IDP's. These include a representation of the concepts of 'worship of Allah alone', '*Ummah*' among Muslim residents and 'equality of man before Allah' within the context of the neighborhood design. In the final redesign outcome of the housing neighborhood, the first IDP applied in the redesign results in the introduction of the Friday mosque, daily prayer mosques and educational institutions. The second IDP also resulted in the overall redesign of the initial layout from gridiron to cluster concept. To symbolically represent the last IDP of 'equality of man before Allah' houses of residents of different socioeconomic statuses were located within a cluster by providing different plot sizes to address their socioeconomic differences. In conclusion, it has been shown that contemporary residential neighborhoods could be designed in

line with Islamic principles which addresses their spirituality values and, yet, in line with universal design standards.

**Keywords:** Housing, Built Environment, Islamic Principles, Sardauna housing neighborhood, Katsina

## **INTRODUCTION**

The built environment according to Mohit (2013) comprises of the ‘‘human-made space in which people live, work, and recreate on a day-to-day basis’’. Three key features of the built environment were identified by Nwanodi (1989 cited in Hamza, 2011) as; extensive, creation of human intelligence and meant to protect humanity. In the physical realm however, Matthews, (2007) went further to classify building types available within the built environment: the vernacular building type which responds to the needs of the ordinary people, the traditional dwellings, the high-style built to distinguish the rich from people of the lower economic status, the speculative type, i.e. building types concerned with profiteering and lastly, the participatory type in which designers are trained to respond to human needs and give priority for the environment. Similarly, the built environment was also conceived as everything made, arranged or maintained by man to fulfill human purposes, needs, wants and values Bartuska (2007). The scholar went further to classify the built environment as consisting of Products, Interiors, Structures, Landscapes, Cities, Regions and the Earth. He contextually defined ‘‘products’’ elements created to extend the human capacity, while the Interiors are spaces enclosed within a structure such as workrooms. ‘Structures and landscapes however, are considered as planned groupings of spaces and exterior areas and/or settings for planned groupings of spaces and structures such respectively. Moreover, Cities and Regions consists of groupings of structures and landscapes as well as groupings of cities and landscapes and lastly, the Earth includes all of the above. Moreover, the physical settings and elements of built environments were greatly influenced by factors such as the faith of the people which they consider as way of life. As a result, some studies (please see seminal work of Ozkan, 1996) argued that faith was among other factors a key determinant of the form and character of housing neighborhoods in Islamic built environments.

In general, the Islamic design principles (IDP) could be referred to as principles which Islam has set up in time series which were applied by the prophet of Islam (pbuh) to achieve a Muslim urban environment that promotes spirituality values of the Muslim faithful’s. Hakim (1986)

operationalized these principles as the outcomes of mechanisms used in interpreting and applying the value system of Islamic legal system referred to as *Fiqh*, in Islamic buildings and urban development processes. Historically, these principles came to the fore after the prophet's emigration (*Hejra*) from Mecca to Medina (formerly *Yathrib*) over one thousand four hundred and forty years ago. The *Hejra* provides physical settings for the first ever prophetic building process when the prophet had cause to partake in the construction of his mosque (*Masjid al-nabawi*) to serve as spiritual and administrative center of new Islamic state (Spahic 2005). In the context of this paper, therefore, the principles shall refer to the prophetic building practices with the aim of promoting spiritual, social and economic values of Muslim residents. Majority of such buildings which serve as examples include community mosques, markets (*Suq*) educational institutions (*Medrasas*) and residential quarters they also include how and where to locate shared communal facilities such as open spaces; a trend that was later replicated all over Muslim city states (Hakim, 1986; AlSayyad1991; Hillenbrand, 1994: Hillenbrand,1999. Examples of cities in which many of such principles were applied and which was responsible for the uniformity in form and character of such cities include Damascus, in Syria, Cordoba in Spain, Basra, Kufa and Baghdad in Iraq and Tunis on the African continent (Van Grunebaum, 1969; Akeel, 2009).

Based upon the experiences drawn from the application of the IDP in the traditional Islamic cities and housing neighborhoods, practitioners concerned with Islamic built environment later tested these principles on new projects as well as in the redevelopment of existing ones. Examples where the principles were tested include the experimental housing project in Lima, in South America designed by Peter Land and at a later time, the Algouna village, Egypt designed by Hassan Fathi. The *Hafsia* housing neighborhoods in Tunis, Tunisia served as an example of a redevelopment undertaking in which the designers seek to integrate Islamic principles in the physical environment (Mortada, 2003). In view of the foregoing therefore, this paper seeks to contextually bridge the gap of what a 'before and after scenarios' could have been on recycling the IDP.

### **The Case Study; Locational and Design Contexts**

The Sardauna housing neighborhood which served as the case study in this paper lies on Latitude 12°56'33.53"N and longitude 7°36'27.84"E in Katsina, the capital of Katsina State, Nigeria. As

shown in Figure 1 , the housing neighborhood is located along Dutsinma- Batsari road and sandwiched between two public institutions, Katsina University to the west, and a public library to the south. It was designed based on the grid iron planning concept system and provided with facilities such as shopping areas, schools, daily prayer mosques (*Khamsu Salawat*), children's playground, green areas and earmarked spaces for proposed police station and a clinic. The neighborhood consists of five hundred and ten built up houses of two and three bedrooms and one hundred and four undeveloped plots allocated to individuals and corporate bodies for private development interventions. In the site layout, four plots of various sizes were provided; 450m<sup>2</sup>, 600m<sup>2</sup>, 750m<sup>2</sup> and 1600m<sup>2</sup>. The space allocated for children play ground had the highest footprint area followed by plots for secondary, primary and nursery schools and shopping in that order. The shopping area was located at the centre of the site layout. However, three plots were provided for mosques located at different locations on the site layout. The Sardauna housing neighborhood was selected for this study among four extant housing neighborhoods in the city of Katsina due to very low level considerations of IDP on its site layout design.



Figure 1. Showing the extent of the Sardauna housing neighborhood Katsina, with its characteristic grid Iron concept. This concept aims to maximize space rather than the well being and promotion of the welfare of urban man as exemplified in Islamic housing site layout designs. (Source; Housing Authority, Katsina State; 2018)

### **Objectives of the Paper**

The aim of this paper is not to produce a strict design formula for the design of Islamic housing neighborhoods, but rather to demonstrate how the IDP could be recycled to achieve a residential

neighborhood which respects Islamic value systems of residents. To achieve this aim, three objectives have become necessary;

1. To identify the IDP which were applied within the site layouts of Islamic housing neighborhood which gave them their unique form and character
2. Explain how the use of IDP affected the form and character of the Islamic housing neighborhoods
3. To demonstrate through a redesign of Sardauna housing neighborhood how IDP could be applied to achieve an Islamically responsive housing neighborhood to promote resident's spirituality values and yet in line with universal design requirements.

### **THEORETICAL FRAMEWORK: AN OVERVIEW OF ISLAMIC DESIGN PRINCIPLES AND HOW THEY AFFECTED THE FORM AND CHARACTER OF ISLAMIC RESIDENTIAL NEIGHBORHOODS**

The Muslim faithfuls believed that all actions of the prophet were a result of Gods command (see the basis for this in al- Quran 48: 8-10; al- Quran 4: 80) including building precedencies. Many scholars have thus, over the years explained the unique urban forms and housing characteristics in the Islamic built environments as outcomes of the application of IDP (Hakim & Zubairu, 2006; Ahmed, 1971; Samuel, 1980; Belhaj, 1984; Grabar, 1994). For example, the mosque and *medrasas* served as centers of spiritual and educational advancement aimed at achieving Muslims spiritual, social, economic and technological advancement in this world and in the here-after (*Din* and *Dunya*). Whilst, shopping areas, children playgrounds provided a cohesive force in attracting all classes of residents in one place (Abdelrahman, 2010; Ismawi 2009), and promote the concept of *Ummah* among Muslims (Moustapha, 2007).

The first IDP which provided the most distinct Islamic characteristic and which was considered in this paper is the mosque institution. As a way of justifying this claim, many scholars cited verses of al-Quran for example, (3: 96) and *Hadiths* (Sahih Muslim *Hadith* 3 Book 5; Sahih Muslim *Hadith* 1058, Book 4) amongst others, for the significant roles of the mosque as center of worship and spiritual development. Scholars such as AbulQaraya (2015) and AbulQaraya (1994) were of the opinion that this principle was in response to the Gods command to facilitate the 'Worship Allah alone' as referenced in al- Quran (51:56). While many *Hadiths* relates mosque and the built environment in many aspects, a particular *Hadith* according to Mortada (2003) mosques should be made accessible to all residents and at walking distances to facilitate the attendance of all residents to observe prayers. In compliance with this *Hadith* and other related ones, the Arab Urban



Development Institute developed distances of between 150m-200m as walkable distances from any reference house to daily prayer mosque (*Masjid al-jami*) and 250m-300m to Friday mosque (*Masjid al-Jumma*). Due to the significant roles it plays, therefore in the site layout of residential neighborhoods, the al-*Jumaa* mosque must be centrally located to achieve equal distances to all residents.

The second IDP considered in the paper is aimed at promoting the concept of ‘*Ummah*’ among residents. The key objective of manifestation of the concept of *Ummah* according to Akeel (2009) and Abdurrahim (2009) is to promote brotherliness, communality and participation among Muslim residents living together. Extant *Hadiths* among which include Sahih Bukhari (6011) further elaborated the benefits of the concept of *Ummah* among Muslim faithful’s living together. In the physical framework of Islamic built environment, this concept was variously manifested as provision of equal access to educational institutions (Nashabi,1980) achieving compactness in residential houses (which can be achieved using cluster instead of grid iron) and achieving human scale in the design (encouragement of walking, low rise developments characterized with single or two storey’s houses with high population density).The application of this principle similarly, preserve landscape and ensure ease of access to land for recreation (Asabere, 2012).

The last of the IDPs considered here aims to promote ‘*Equality of Muslims before Allah*’ irrespective of their socio-economic statuses. In the site layout design this IDP was clearly demonstrated through non segregation of residents based on either social or economic statuses, provision of houses of different sizes together in a cluster and around open spaces (*afniyah*) or cul-de sac, provision of simple yet similar elevations that were devoid of ornamentations, locating markets (*Suq*), shopping centers and shops close to the central mosque among others. Similarly, it includes the provision of different plot/houses size, which ultimately ensures that the poor can take small lots and live close to those of higher income on larger lots (Fathy, 1988), facilitate interactions between different classes of residents; and hence, such that an Islamic society was achieved, which Moustapha (2007) referred to socially, economically and racially ‘classless community’.

In view of the above, the three IDP considered in the redesign of Sardauna housing neighborhood include the role of mosque as the focal point of site layout, housing compactness and the promotion

of classless community/residents Figure 2, shows the Islamic design principles and the basis from *Quran* upon which they were built. For example, centrality of the mosque institution was based upon numerous Quranic verses among which include the concepts of worship of Allah alone, Concept of *Ummah* among residents, Equality of Muslims before Allah and Role of Man as Vicegerent of Allah.

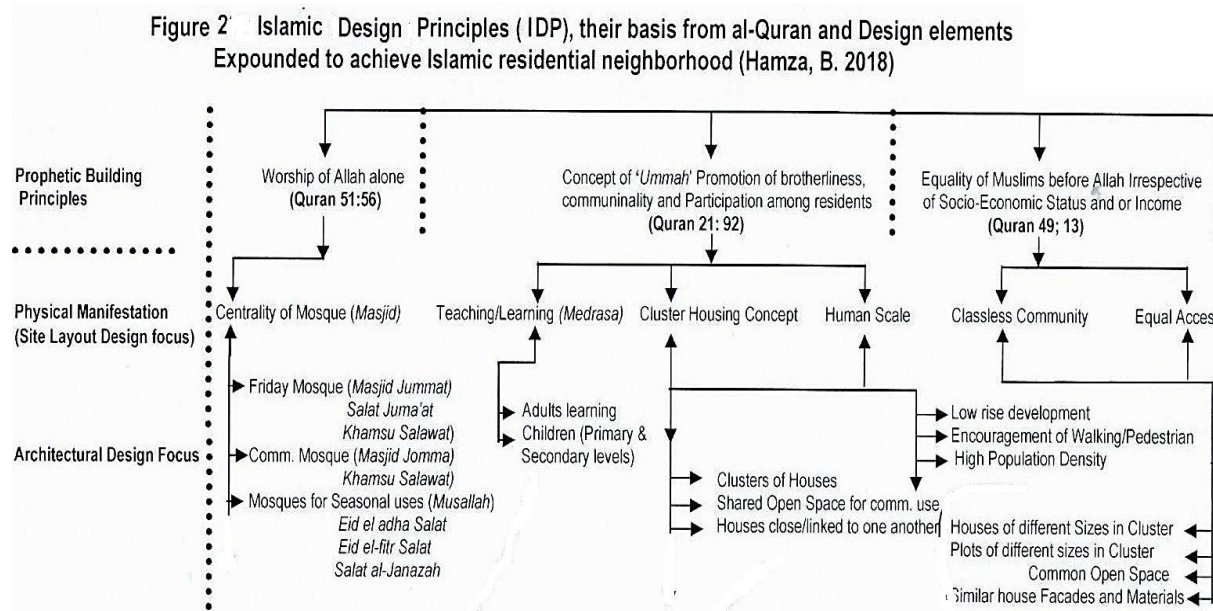


Figure 2: Islamic Design Principles (IDP), their basis from al-Quran and Design elements Expounded to achieve Islamic residential neighborhood (Source: Hamza, 2018)

### METHODOLOGY ADOPTED IN THE PAPER

In this paper, a triangulation of literature searches and case study approaches were adopted. The literature search was carried out to identify and establish the IDP which were applied in the traditional Islamic cities and residential neighborhoods and which informed their distinct forms and characteristics. During the literature search, and in particular the site layouts and architectural elements and their characteristics of extant traditional Islamic housing neighborhoods were reviewed in order to understand the contexts in which the principles were applied as they relate to *Quran* and *Hadith*. In line with the objective of this paper of recycling these principles in redesigning existing housing neighborhood, the Sardauna housing neighborhood in Katsina was selected among four other existing neighborhoods, to serve as a case study due to low level compliance of IDP on its site layout. The outcome of redesign undertaking demonstrated ‘before’

and ‘after’ scenarios, showing the existing site layout and the final redesign site layout in which the IDP were expounded. Thus, the four IDP which were earlier identified from literature were applied in the redesign of Sardauna housing neighborhood; the concept of ‘Worship of Allah alone’, concept of ‘*Ummah* among Muslims, ‘Equality of Man before Allah’ and ‘Roles of Man as Vicegerent of Allah’. In the final redesign outcome of initial site layout design, first IDP was achieved by providing equal accessibility to mosque and educational institutions. The second and third IDPs, were, however, achieved in the redesign of the overall site layout from grid iron to cluster system in which open spaces were created at intervals as well as the provision of plots of different sizes within the same cluster so that socioeconomic status could live together. The last IDP was as well achieved through effective management of natural and built environment in terms of conservation of water, protection of wild life, plants and promotion of quality air and access to natural light to residents.

### **HOUSING NEIGHBORHOOD REDESIGN OUTCOME BASED ON ISLAMIC DESIGN PRINCIPLES**

In the existing site layout design as shown in the preceding pages, three daily prayer mosques (*Masjid Jomaa*) were provided. There was however, the absence of a centralized mosque that could serve as Friday mosque (*Masjid Jumaa*), hence, the first design task of testing the principle of “Worship of *Allah* alone’ on the initial housing site layout design was the recognition of the need for a centralized mosque that could serve as Friday prayer mosque. And because it needs to be accessible to all residents, it was located at approximately centralized location and was allocated the largest space area. Hence, as shown in Figure 3, the Friday mosque (A) was introduced and located at the centre. In response to IDP which suggested equal access to the mosque, it was strategically located at a distance of 270m to the East, 300m (West), 17m (North) and 150m (South) of the site layout. Moreover, the locations of the other daily prayer mosques (B&C) (*masjid jomma*) were changed to new distances of 230m (East) and 181m (West) from the Friday prayer mosque and at distance of 225m and 218m for masjid (B) and 251m and 186m for masjid (C), so that walkable distances could be achieved. In terms of the new perimeter area provided for the mosques, however, the initial design provided an approximate perimeter area of 3,910m<sup>2</sup> for the two daily prayer mosques/medrasa/Islamiyya schools. In the new design however, the Friday mosque alone was allocated a space area of 27,846m<sup>2</sup>, in addition to a combined space area of

5,120m<sup>2</sup> provided for the two daily prayer mosques making a total perimeter area of 32,966m<sup>2</sup> for all three mosques. Similarly, the educational institutions were placed side by side with mosques; primary and secondary schools attached to *Masjid al-Jumma* and other mosques to *masjid jomaa* to achieve equal access to all residents. As shown in the same Figure 3, the spaces occupied by mosques and schools in the redesigned site layout affected thirty plots at the center (A & D) and six plots (E) while space provided for nursery and primary schools (F) on the initial site layout were maintained. In the redesigned site layout, the allocated perimeter areas for formal schools were increased from 23,309.25m<sup>2</sup> to 27,861.98m<sup>2</sup> indicating an increase of 16.34 percent. However, the plot initially provided for masjid/Isلاميyya (H) has been redesigned to residential plots.

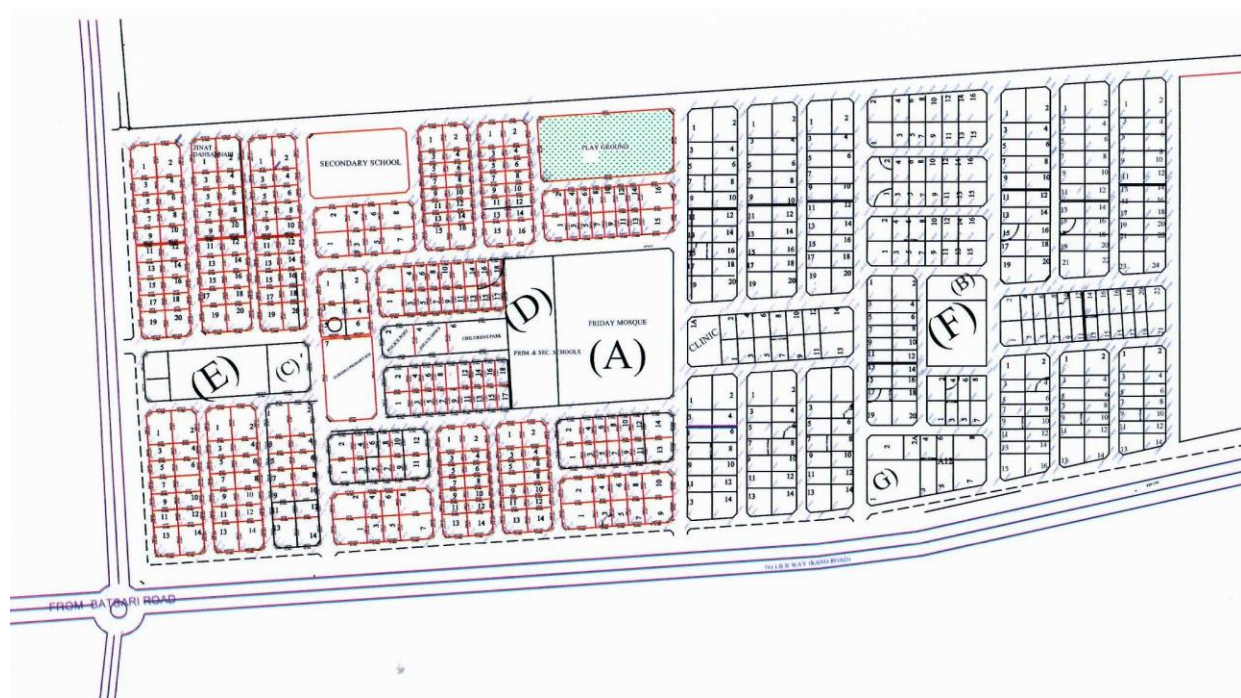


Figure 3: Showing the introduced Friday mosque (A) (*Masjid al-Jumma*) at the center. It also shows two other daily prayer mosques (B&C) (*Masjid Jomaa*) one each on East and West at approximately equal distances from the Friday mosque. Notice also educational institutions (D, E & F) attached to the mosques to provide equal accessibility to all residents. This arrangement establishes the Friday mosque as the focal point in the design of Islamic housing neighborhoods.

(Source: Redesigned by Author, 2018)

The second IDP tested on the initial site layout redesign is the ‘concept of *‘Ummah’*. Contextually, this concept aims to promote brotherliness, communality and participation among residents in Islamic housing neighborhoods; Hence, in the redesign task, it was achieved through a complete redesign of the overall initial site layout design from gridiron to cluster layout concept. This involves the conversion of all ‘grids of houses’ to ‘clusters of houses’. And in the process, open spaces and links were created with other clusters. To achieve this, plot areas for secondary school (S), playground (PG), Nursery /primary school (N/P) and masjid/Islamiyah (MI) in the initial site layout were redesigned to residential plots. However, a reduction of forty-three plots (43) or 8.6% was achieved from the plots allocated for private intervention. As shown in Figure 4, recycling this IDP on the initial site layout results in achieving between four to seven houses put together in a cluster with a centralized open space to facilitate interaction among residents. On the initial site layout, a total number of five hundred buildable plots were provided while a total of five hundred and sixty-one (561) of such plots were achieved using this concept on the final site layout indicating an increase of 12.2%. This increase in the number of buildable plots is expected to result in population increase by at least ten percent (10%). Furthermore, a total number of one hundred and one (101) open spaces (shaded black in Figure 4) in form of clusters were achieved indicating an average of one cluster for the use of between four to seven houses. Similarly, the ‘human scale aspect’ as part of the second IDP, was achieved in three ways; low rise development, reduced number of tarred roads and increase in the number and lengths of walkways in the new site layout. For example, there were forty-three (43) roads (shaded blue in Figure 4) of different hierarchies having a total length of 8,943.39m, or 9.0 Km within the initial site layout while in the redesigned site layout, this number was reduced to twenty-six (26) with total length of 5,872.4m or about 6.0 Km indicating a reduction of 16 roads or 37% and a decrease of 3,070.99m or 34.3% in lengths of the roads respectively. Moreover, the walkways distances (shaded red in Figure 4) were also increased from total length of 660 meters on the initial site layout to 1,464m achieving an increase of more than twice as provided in the initial site layout. Additionally, the walkways provided were strategically located along horizontal routes of between 250m to 300m and linked to clusters to encourage walking among residents.



Figure 4. Showing of redesigned Site layout from Gridiron to Cluster housing pattern to achieve the concept of 'Ummah'. The concept of *Ummah* aims to promote social cohesion, brotherliness, communality and participation among residents; a requisite requirement on Islamic housing neighborhoods.  
(Source: Redesign by Author, 2018)

The last IDP seeks to promote 'Equality of the Muslim before *Allah*' irrespective of their socio-economic statuses and or income level. In general, this involves the creation of a physical framework in which a community devoid of social or economic advertisement is created; a concept referred to as 'classless community'. In the new site layout, commercial areas were located close to schools and the mosques as shown in Figure 5. While only three shopping areas were initially provided, in the new redesigned site layout however, a total of five commercial areas were provided indicating an increase of 40% in the number of shopping to enhance accessibility to residents. These include two shopping areas at the center of site layout (SH1 & SH2) and one each to the west (SH3), east (SH4) and south (SH5) of the Friday mosque and primary/secondary school respectively. The other shop (SH5) was located to the south of the Friday mosque to achieve walkable distance of between 250m to 300 meters as in the case of SH3 & SH4. In terms of the total perimeter areas for shopping, however, in the new site layout, all five shopping areas have a total of 20,403.72m<sup>2</sup>. This is approximately a threefold (300%) increase when compared with the provided shopping area of 7,758.34m<sup>2</sup> on the initial site layout. Additionally, unlike in the grid iron concept which puts together similar plot sizes together across the grid, achieving a 'classless

community’ involves putting together plots/houses of different sizes together within the same cluster. In the initial site layout, the smallest plot size had a perimeter area of 450m<sup>2</sup> (15M X30M) and the biggest having 1248m<sup>2</sup> (26m X48M). In between these, two other plots of between 625m<sup>2</sup> (25m X 25m) and 600m<sup>2</sup> (20m X 30m) were provided. In the redesigned site layout as shown in Figure 5, however, the smallest plot size was reduced from 450m<sup>2</sup> (15mX30m) to 225m<sup>2</sup> (15mX15m in green color) and the biggest plot 1200m<sup>2</sup> (30Mx40m in brown color in Figure 5 ). In between these two, three other plot sizes were proposed which include 450m<sup>2</sup> (15Mx30m), 600m<sup>2</sup> (20Mx30m) and 900m<sup>2</sup> (30mX30m). In the redesign site layout, therefore, residents of different income groups would have access to the different plots sizes based on their income levels. This also applies to the houses, whereby residents with bigger houses live side by side with those who could afford smaller ones.

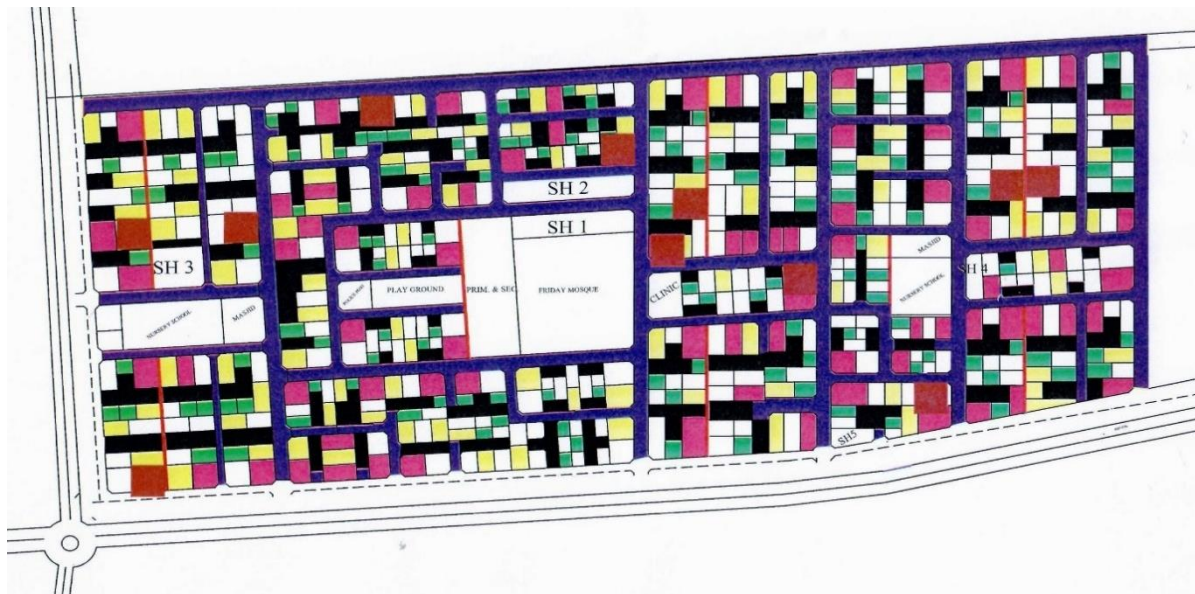


Figure 5: Showing redesigned site layout in which plots/houses of different sizes were put together within the same cluster and equal access to infrastructure was achieved. The concept of ‘Equality of Muslims before Allah’ aims to create a ‘classless community’ in which residents live side by side to each other irrespective of their socio-economic statuses

(Source: Redesign by Author, 2018)

## **THE DESIGN SUMMARY: INITIAL SITE LAYOUT DESIGN VERSUS THE FINAL REDESIGN OUTCOMES**

The contents of the initial and the final site layout design were compared in Figure 6(a&b). As shown in 6(a) the initial site layout design was based on grid iron concept while the new redesign (6b) was based on cluster concept. In the initial site layout design, plots of similar sizes were placed on the same grids; shopping area was centralized while the three mosques provided and educational institutions which include primary and secondary were spread across the layout without any known Islamic design criteria. In the redesigned site layout however, the Friday mosque was recognized as the main focus of the site layout, while the cluster housing concept as used here was adopted to achieve social cohesion, brotherliness, communality and participation among residents; a key ingredient of the Islamic housing neighborhood design. Furthermore, the last IDP was tested in the final site layout design by creating a ‘classless community’ in which the rich and his poorer neighbor live together with equal access to common facilities.

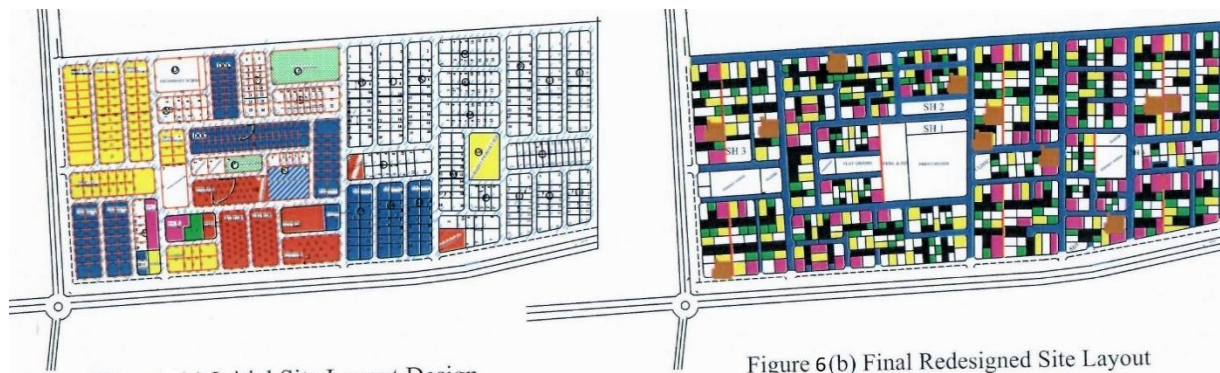


Figure 6 (a & b). Showing the ‘before’ and ‘after’ scenarios of use of Islamic design principles. Key differences between the two scenarios include consideration of the mosque (*Masjid Jummah*) as the focus of the housing neighborhood, use of cluster concept, putting up of plots of different sizes in the same cluster instead of shopping area which was used as the focus of the housing neighborhood in (b), in place of the use of grid iron concept, placement of similar plot sizes on the same grid as shown in (a). (Source: Redesign; Author, 2018)



## **CONCLUSIONS**

It has been shown in the preceding pages that possibilities exist to develop a built environment that responds to the aspirations of the Muslim faithful through the application of IDP in the site layout design of contemporary housing neighborhoods, yet without negating universal design concerns. While a strict land use determinism and maximization was the main aim of the initial site layout, the final site layout design however, centered more on promoting the wellbeing and welfare of the urban man. More so, many benefits were derivable from the new redesigned site layout. Firstly, the Friday mosque for example, which was located at the centre of the site layout provides avenues for all residents to meet atleast once a week (during *Salatul Jummah*), while the community mosques facilitate meetings among neighbors atleast twice a day (during *Subh* and *Ishaa* prayers). These meetings, thus informal in nature provides opportunities for delivering new information and knowledge on the social, economic and health status of individual residents. Similarly, the distribution of community mosques in the site layout based on the walking distances helps to avoid overcrowding of worshippers on a particular mosque at the expense of the others. Consequently, resident's health status will be enhanced pursuant to daily physical exercise as a result of walking to and from the mosque. Likewise, the location of formal schools (primary and secondary schools) close, to, or attached to mosques further enhances spiritual upbringing of school children as they will be participating in prayers sessions during school hours. It also eases the tasks of parents to streamline tasks of picking children from school and prayer in the mosque respectively. Streamlining activities together helps residents to focus more on other daily routines by freeing up their time and hence, lower their stress levels. The proposed use of all or part of the formal schools in the site layout as *medrasas* further saves resources by eliminating the need for additional buildings. The use of cluster housing concept in the new site layout gave rise to compact houses within a cluster. This particular housing form provides basis for neighbors to mutually monitor their health statuses, social and economic condition which in turn prompts participation in form of assistance among residents themselves. It also encourages residents to share common design elements and facilities in the cluster together such as open space, shades from green areas and temporary parking spaces. Similarly, the classless community achieved in the new site layout, whereby residents of different socioeconomic status were put in the same cluster with equal access to facilities promote mutual respect among residents and hence, removes the bad feelings between the rich and the poor.

## **REFERENCES:**

- Abdelrahman, E., (2010). The influence of Ḥadīth on the architecture of early congregational mosques. A PhD Thesis submitted in accordance with the requirements for the degree of PhD, University of Leeds, Institute for Medieval Studies.
- Abdurrahim, A. (2009). Home and the Neighborhood. In an Anthology of Essays on Integrating Islamic Values in the Theory and Practice of Architecture and The Built Environment. In Ismawi Zen, Shireen Jahn Kassim & Norwina
- AbulQaraya, B. S. M., (1994). The political role of the Mosque. (Unpublished MA thesis) Cairo: Faculty of Economics and Political Science at Cairo University.
- AbulQaraya, B.S.M., (2015). The Civic and Cultural Role of the Sheikh Zayed Grand Mosque. 2nd Global Conference on Business and Social Science-2015, GCBSS-2015, 17-18 September 2015, Bali, Indonesia.
- Ahmad al-Dardir A. M. (1989). *Al-Sharh al-Sogir*, Vol. 4, Wizarah al-Adl wa al-Islamiyya al-Awqaf, Dawlah al-Imarah al-Arabiyya al-Muttahidah
- Ahmed, M., (1971). Cities of Islam. Beirut; B.A.U Press
- Akeel, N. A., (2009). Urban Design and the Islamic City in the Light of Islamic Values. In An Anthology of Essays on Integrating Islamic Values in the Theory and Practice of Architecture and The Built Environment. In Ismawi Zen, Shireen Jahn Kassim & Norwina Mohd Nawawi (Eds) Pp. 79-93. MPH Group Publishing, Malaysia
- Al- Quran 4: 80
- Al- Quran 48: 8-10
- Al- Quran 51:56.
- Al- Quran 53: 3-4
- Al-Quran 3: 96
- AlSyyad, N, (1991). Cities and Caliphs: On the genesis of the Arab Muslim Urbanism. Contributions to the study of world history no. 26. Greenwood Press
- Asabere, P. K., (2012)., The Value of Homes in Cluster Development Residential Districts: The Relative Significance of the Permanent Open Spaces Associated with Clusters. [The Journal of Real Neighborhood Finance and Economics. https://www.researchgate.net/publication/234052253](https://www.researchgate.net/publication/234052253)
- Bartuska, T.J. (2007). The Built Environment: Definition and Scope. In The Built Environment; A Collaborative Inquiry into Design and Planning, Eds Wendy R.M & Bartuska T.J, John Wiley & Sons, Inc.
- Belhaj, L., (1984). Planning New Towns using Traditional Prototypes. In Abdelbaki & Hazem (Eds). Housing in Islamic City. Proceedings of a Symposium held in Ankara, Turkey. Pp. 241.

- Fathy, H.A (1988). The Social Approach to Planning: an application to Islam, Unpublished PhD Dissertation, University of South California.
- Grabar, O., (1994). Cities and Citizens, in Bernard Lewis (Eds), The world of Islam; Faith, People, Culture Thames and Hudson, London.
- Hakim, B. S. & Zubairu, A. (2006). Rules for the built environment in 19th century Northern Nigeria. *Journal of Architectural and Planning research*. 23 (1) 1-25
- Hakim, B. S. (1986). Arabic-Islamic cities: Building and planning principles. London: KPI Ltd.
- Hamza, B., (2011)., Islamic aspects of the Katsina built environment: a qualitative survey of planning and architectural attributes. *Katsina Journal of Natural and Applied Sciences (KJST)*, Umaru Musa University, (UMYU) Katsina.
- Hillenbrand, R., (1994). Islamic architecture: Form, Function and Meaning, ed. by Case Bound (New York: Columbia University Press)
- Hillenbrand, R., (1999). Islamic Art and Architecture (London: Thames & Hudson)
- Ismawi Z., (2009)., Tawhid and Al-Imarah: A Philosophical framework of Architectural and Environmental Design Education, in *An Anthology of Essays on Integrating Islamic Values in the Theory and Practice of Architectural and the Built Environment*; Eds; Ismawi Hj Zen, Shireen Jahn Kassim and Norwina Mohd Nawawi. MPH Group Publishing, Malaysia

## **COAL BOTTOM ASH AS PARTIAL REPLACEMENT OF FINE AGGREGATE IN ASPHALTIC CONCRETE**

Adebunmi, F.A.<sup>1</sup>, Mohammed, H.\*<sup>1</sup> and Adewole, B. Z.<sup>2</sup>

<sup>\*1</sup>Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

<sup>2</sup>Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife,  
Nigeria

Corresponding e-mail: [hmesteem@yahoo.com](mailto:hmesteem@yahoo.com).

### **ABSTRACT**

This paper presents the study of the effect of coal bottom ash (CBA) on the characteristics of asphaltic concrete with a view to assess its suitability as a partial replacement of fine aggregate (granite dust). The bottom ash was obtained by incinerating the coal obtained from lafia-obi coal mines until a sand size residual was produced. The properties of constituent's materials required in asphaltic concrete production and coal bottom ash were characterized using standard procedures. The coal bottom ash was introduced in the asphalt mix at an increasing rate of 10, 15, 20 and 25% content by weight of the fine aggregate (granite dust) and test samples of asphaltic concrete were prepared. The samples were subjected to Marshall stability test. The stability, flow, density, voids filled with bitumen (VFB), air voids (AV) and voids in mineral aggregate (VMA) were determined. Results showed that the specific gravity and adsorption test for granite dust were 2.45 and 0.25%, respectively, while those for coal bottom ash were 2.86 and 0.58% respectively. The result of stability, flow, bulk density, voids filled in bitumen (VFB), air voids (VA) and voids in mineral aggregate (VMA) of the asphaltic concrete at 0% bottom ash (control mix) were 12.02kN, 3.04mm, 2.491g/cm<sup>3</sup>, 66.0%, 4.3%, 12.7% respectively; while the values at 20% coal bottom ash content were 16.97kN, 3.51mm, 2.514g/cm<sup>3</sup>, 71.2%, 3.4%, 11.9% respectively. The result showed that coal bottom ash in asphaltic mixes improved its properties.

**Keywords:** Bottom Ash, Asphaltic Concrete, Asphaltic Concrete Properties

### **INTRODUCTION**

Flexible road pavements get easily damaged due to various distresses caused by daily increased of traffic loads. This increase means that they are exposed to higher stresses; therefore, maximum maintenance is necessary. Higher density of traffic in terms of commercial vehicles,

over-burdening of trucks, and noteworthy variation in day by day and occasional temperature rise of the pavements have been responsible for the development of distresses such as ravelling, rutting, and fatigue failures of bituminous surfaces (Tomar et al., 2013). For pavement to serve under these severe conditions for both present and future purposes there must be a continuous search for improvement in construction practices and more intelligent use of better construction materials (Roberts et al., 1996).

In pavement construction, asphaltic concrete is a material that is very important in its construction. Asphalt blends are generally utilized in the outmost layer of road and runway pavements. The blend is made normally out of asphalt cements and aggregate. The design of standard mix for asphalt surfaced pavement, similarly as with the structure of some other construction/engineering materials is to a great extent a matter of choosing and allocating constituent materials to acquire the ideal attributes in the completed asphalt structure (Nathem, 2013).

The rising cost of natural resources used in various highway construction prompted researchers to conduct researches on how waste products, such as coal ash and others can be utilized as engineering materials in road construction in place of conventional ones.

Bottom ash is considered a waste item with couple of commercial uses. It is a byproduct of coal combustion and researches have proven that it may be considered as a reasonable swap for a bit of the aggregate generally utilized in asphaltic pavement. According to research by Pandeline et al. (1997), bottom ash can be used in transportation related works such as dike fill, roadway fill, sub-base, and base courses. Realizing the capability of coal bottom ash to be utilized in civil engineering particularly in roadway building, numerous researchers have considered approaches to change over these waste materials into wealth.

Recently, studies conducted indicated that bottom ash has desirable properties which enable it to be classified as a good construction material. This gave justification to further research on possible uses of bottom ash (Huang, 1990).

The use of asphaltic concrete for construction of new roadway requires a great deal of resources. Substitute waste products which reduce cost is desirable, hence this study.

## **MATERIALS AND METHODS**

The materials used in this study were bitumen, coarse aggregate, fine aggregate and coal bottom ash. The bitumen used was 60/70 penetration grade. It was obtained from Slyvabogu asphalt plant along Ede-Osogbo road, Osun state. The coarse aggregate consisted of granite

aggregate of sizes ranging from 19-4.75mm. The fine aggregate consisted of granite particles passing 4.75mm and retained on 75  $\mu$ m BS sieves. The coal bottom ash used was produced by incinerating the coal obtained from Lafia-Obi coal mines, Nassarawa state, Nigeria, till sand sized residual was obtained. The ash was sieved through 4.75mm-75  $\mu$ m BS sieves and the ash retained on 75  $\mu$ m was used. The properties of the bitumen, aggregates and the coal bottom ash were determined using standard procedures. The mix design proportion consisted of coarse aggregates of 19mm (24%), 12.5mm (18%) and 9.5mm (18%); fine aggregates of 4.75mm (5%), 2.36mm (5%) and 0.075mm (30%).

### **Specimen Preparation**

The asphaltic concrete samples were prepared in accordance with ASTM D1559 standard at different bitumen contents to obtain the optimum bitumen content (OBC) of 4.93%. This was used to prepare the control mix. Samples were thereafter prepared by replacing portions of granite with coal bottom ash at 10, 15, 20 and 25 % by weight of granite dust.

### **Marshal Stability Test**

Marshal test was carried out and the values of stability, flow, bulk density, voids filled with bitumen (VFB), air voids (VA), and voids in mineral aggregate (VMA) were determined.

## **RESULTS AND DISCUSSIONS**

### **Physical Properties of Bitumen**

Table 1 shows the results of the penetration, specific gravity and softening point of bitumen. The values for the penetration, specific gravity and softening point obtained were, 63.03 mm, 1.03 g/cm<sup>3</sup> and 49.5 °C respectively. The results show that the bitumen conforms to all the requirements for asphaltic concrete production (FMWH, 1997).

Table 1: Physical Properties of Bitumen

Property	Test Result	Specification	Test Method
Penetration test(0.1mm)	63.03	60-70	ASTM D-5
Specific Gravity(g/cm <sup>3</sup> )	1.033	1.01-1.06	ASTM D-70
Softening point (°C)	49.5	48-56	ASTM D-36

### **Physical Properties of Aggregates**

Table 2 shows the results of the aggregate and crushing value, flakiness index and water absorption tests. The values obtained are all within allowable limits by FMWH specification, 1997. Similar results were also presented by Brennan and O’Flaherty (2002).

Furthermore, the aggregate crushing value, flakiness index and water absorption factor of 23.6, 24.4 and 0.25 % respectively, do not exceed the corresponding values of 30, 35 and 0.5 % respectively, provided for in the FMWH, 1997, specification. The aggregates are therefore of the quality required.

Table 2: Physical Properties of Granite Aggregate and Bottom Ash

Properties	Granite Aggregate	Coal Bottom Ash
Aggregate crushing value (%)	23.6	0
Flakiness index (%)	24.4	0
Water absorption (%)	0.25	0.58
Specific gravity	2.45	2.86

### **Chemical Properties of Bottom Ash**

Table 3 shows the chemical composition of the coal bottom ash obtained from particle induced X-ray emission (pixe). Based on

ASTM standards, the major constituents of coal ash are silica ( $\text{SiO}_2$ ), ferric oxide ( $\text{Fe}_2\text{O}_3$ ) and calcium oxide ( $\text{CaO}$ ). These oxides are typical constituents of fine aggregates.

Table 3: Chemical Composition of Coal Bottom Ash

Chemical composition	Percentage oxides
$\text{SiO}_2$	35.09
$\text{Fe}_2\text{O}_3$	22.00
$\text{Al}_2\text{O}_3$	1.63
$\text{CaO}$	5.59
$\text{MgO}$	4.09
$\text{TiO}_2$	1.12
$\text{K}_2\text{O}$	0.10
$\text{Na}_2\text{O}$	0.14

### Aggregate gradation

Figure 1 shows the aggregate gradation curve. The curve shows that the blended mix of all selected aggregates fall within the standard specified by the Federal Ministry of Works and Housing (FMWH, 1997) for hot asphalt mix design for binder course.

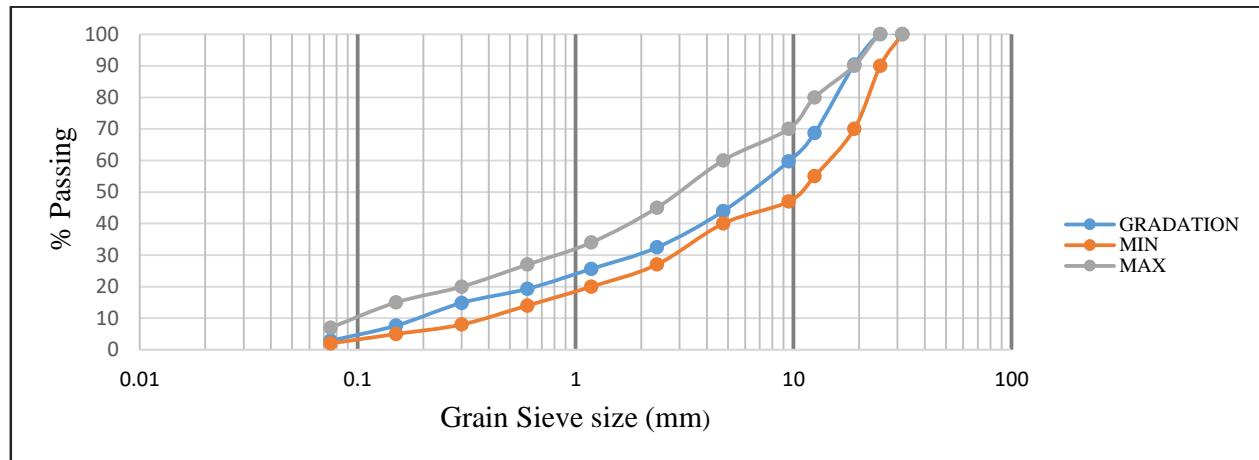


Figure1: Aggregate gradation

### Effects of Coal Bottom Ash on Marshal Properties of Asphaltic Concrete

#### Stability

Figure 2 shows the graph of the stability of the samples versus the percentage of CBA. All stability values from 10-25% showed that they were above the control mix. The higher value of specific gravity of the coal bottom ash caused an increase in weight which contributed to the increase in stability. The increase in stability could also be attributed to the increase in internal friction established within the aggregate which is as a result of strong bonding properties caused by coal bottom ash particles (Gunalaan, 2013).



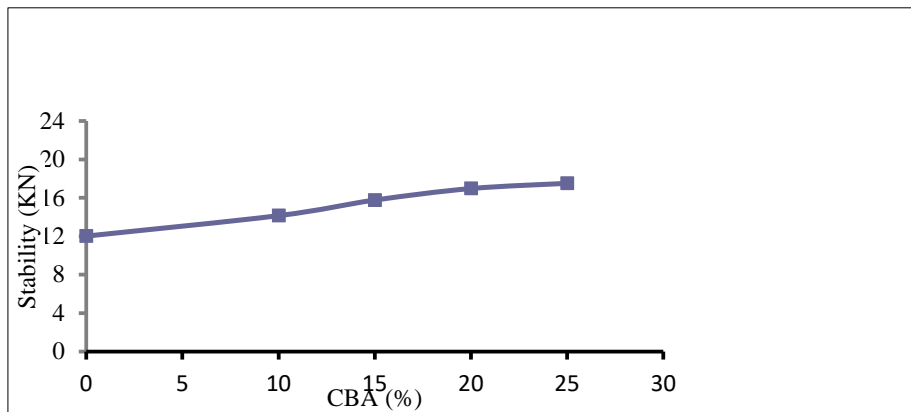


Figure 2: Stability Against CBA

### Flow

Figure 3 shows the graph of flow against coal bottom ash. The flow increases with increased CBA content. This increase could be attributed to the stiffness of the mix when coal bottom ash is added. This makes the mix to be stiffer, thereby leading to increase in flow hence, better flexibility of the asphaltic concrete asphaltic concrete (Gunalaan, 2013).

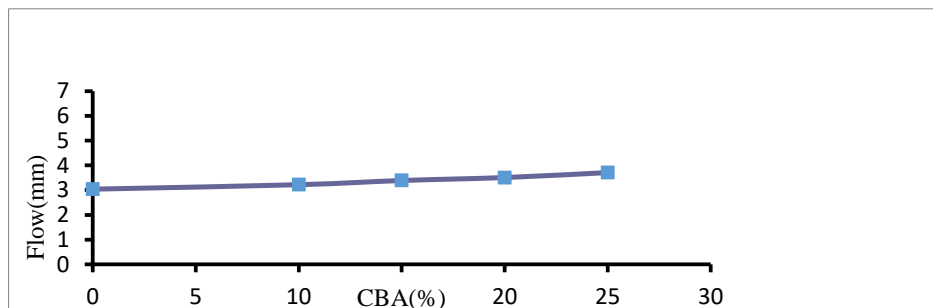


Figure 3: Flow Against CBA

### Voids filled with bitumen (VFB)

Figure 4 shows the graph of voids filled with bitumen against CBA percentage. Gunalaan (2017), described VFB as the pores that exist within aggregate particles in a compacted specimen containing air voids and the amount of bitumen that could not be absorbed by the aggregate. The relationship between VFB and air voids is inversely proportional and hence as

air voids decreases, the VFB gradually increases. The curve shown on figure 4 indicates that there is more bitumen in the mix as the coal bottom ash is added. This is expected because the mix containing coal bottom ash contains less voids. This shows that as the percentage of coal bottom ash increases, the volume of bitumen that is not absorbed by the aggregate due to lesser voids in the aggregate mix caused by coal bottom ash increases. This could be attributed to the high specific gravity of the coal bottom ash. Higher specific gravity indicates increased in density. The higher the density, the lower the air voids (Gunalaan, 2017).

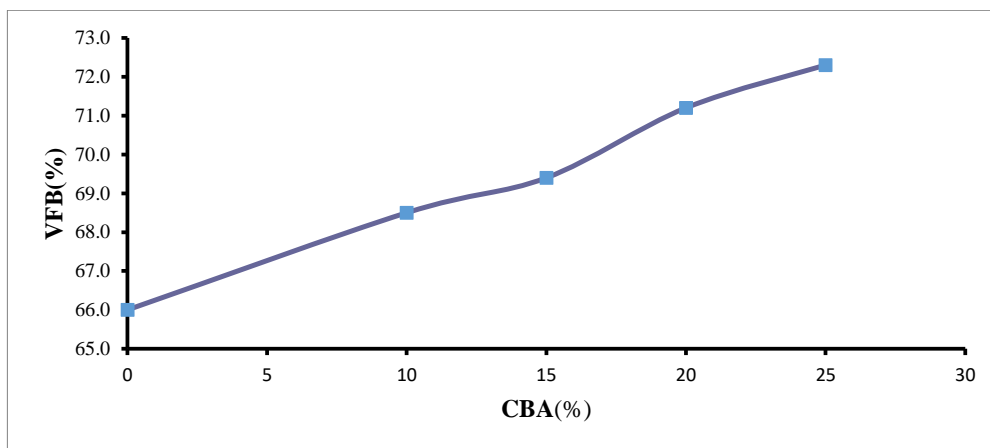


Figure 4: VFB Against CBA

### **VOIDS IN MINERAL AGGREGATE (VMA)**

Figure 5 shows the graph of voids in mineral aggregate against CBA replacement. It can be observed that there is a decrease in VMA as CBA increases from 0% to 25%. This shows that addition of CBA in the asphalt mix causes the pores in the aggregate particles to reduce thereby creating less space within the aggregates to be accommodated by bitumen.

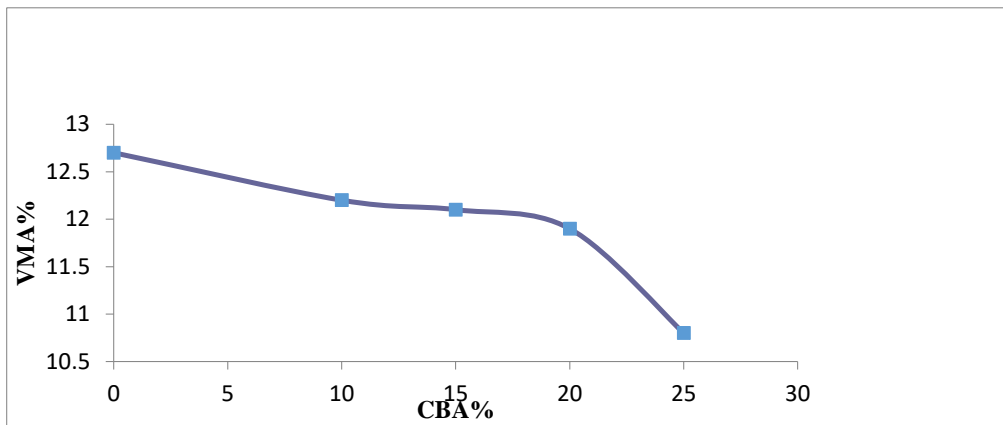


Figure 5: VMA Against CBA

### AIR VOID (AV)

Figure 6 shows the graph of air void against CBA percentage. It can be seen that there is a decrease in air void as CBA increase from 0% to 25%. The introduction of coal bottom ash has reduced the air voids because the coal bottom ash is denser due to its high specific gravity. Air voids and density are inversely proportional, the lower air voids, the higher the density (Gunalaan, 2017.).

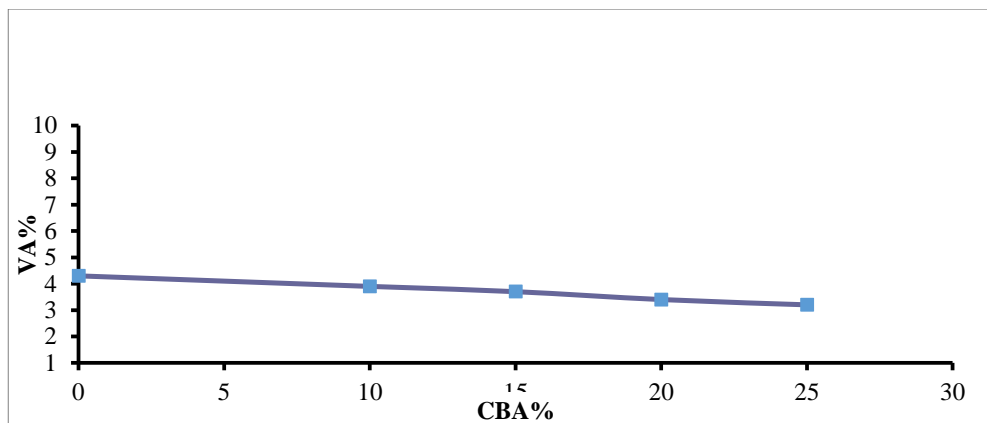


Figure 6: Air Void Against CBA

## DENSITY

Figure 7 shows the graph of density against CBA percentage. It can be observed that the density increases as the coal bottom ash content increases. This is as a result of the coal bottom ash having a higher specific gravity than the granite dust.

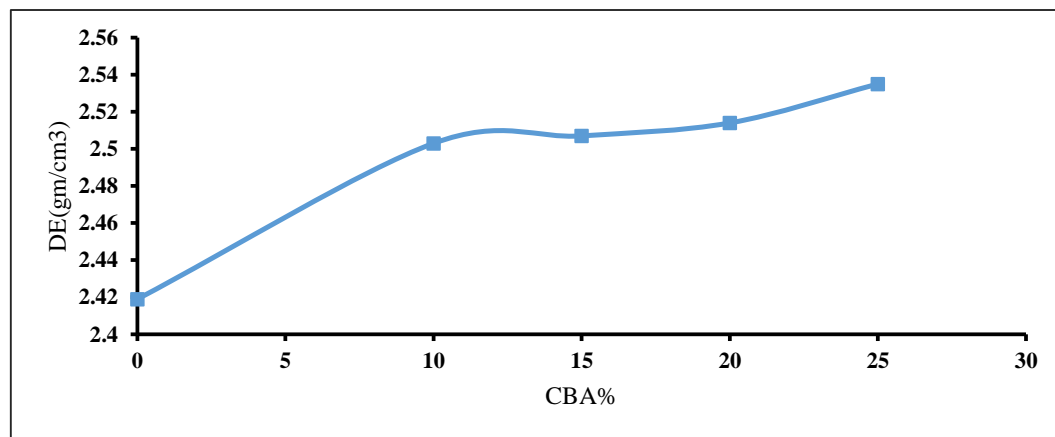


Figure 7: Density Against CBA

## CONCLUSION

The application of coal bottom ash as a partial replacement of fine aggregate in asphaltic concrete binder course showed improvement in its marshal properties.

Based on the result of marshal analysis, the proportion of asphalt mixes with bottom ash shows that all samples containing coal bottom ash display values within specification for all marshal stability parameters in the mix.

The result further showed that coal bottom ash can be used as a partial replacement of the fine aggregate in asphaltic concrete to improve its stability parameters.

## **REFERENCES**

American Society for Testing and Materials, ASTM D1559 (1997). Standard Test Method for Penetration of Bituminous Materials. ASTM International, West Conshohocken, PA.

Brennan, M. J. and O'Flaherty, C. A. (2002). Highway materials used in Road Pavement. Fourth Edition, Butterworth and Heinemann, 118-162.

Federal Ministry of Works (1997). General Specifications for Roads and Bridges, Vol. 11, Federal Highway Department, Lagos, Nigeria.

Gunalaan, V. (2013). A study on the Performance on Coal Bottom Ash in Hot Mix Asphalt. Faculty of Engineering and Built Environment, Tunku Abdul Rahman University College, Malaysia

Gunalaan, V. (2017). A study on the effect of coal bottom ash in hot mix asphalt as binder course. Proceedings of International Multiconference of Engineers and Computer Scientists, vol.ii, IMECS, Hong Kong.

Huang, W. (1990). The use of bottom ash in highway embankments, subgrade and subbases. Joint research project, Indiana Department of Transportation and Purdue University, Indiana.

Nathem, A. H. (2013). A study on the effect of filler type and content on hot asphalt concrete mixtures properties. College of engineering/civil engineering department, Mosul University.

Pandeline, D. A., Cosentino, P. J., Kalajian, E. H., and Chavez, M. F. (1997). A study on the shear and deformation character of municipal waste combustor bottom ash for highway applications. Transport Research Record, 1577(1), 101-108.

Roberts, F.L.; Kandhal, P.S, Brown, E.R, Lee, D.Y. and Kennedy, T.W. (1996). Hot Mix Asphalt Materials, Mixture Design, and Construction. National Asphalt Pavement Association Education Foundation. Lanham, MD. Transportation Research Board, Washington, DC, 1976.

Tomar, R., Jain, R. K. and Kostha, M. K. (2013). Effects of Filler of Fillers on Bituminous Paving Mixes. *International Journal of Engineering Research, Science and Technology*, 2(4): 2319-5991.

# **MODELING A WIRELESS ALARM RESPONSE CENTER—A SCIENTIFIC APPROACH TO SOLVE FARMERS AND HERDSMEN CONFLICT IN NIGERIA**

Awofolaju, T. T.<sup>1</sup> and Yahaya, J. A.<sup>2\*</sup>

<sup>1</sup>Department of Electrical and Electronic Engineering, Osun State University, Osogbo,  
Nigeria

<sup>2</sup>Department of Electronic and Electrical Engineering, Obafemi Awolowo University Ile-Ife,  
Osun state Nigeria

\*Email of Corresponding Author: [yahayajamiu92@gmail.com](mailto:yahayajamiu92@gmail.com)

## **ABSTRACT**

Many developing countries have agriculture as one of the primary source of income for its low income population which constitutes the majority, most of which are still peasant farmers with little or no education and exposure. Modern agriculture requires various types of technologies for improved harvest and larger livestock. The attack of animals in farm lands without restrictions cause a heavy loss to farmers. In Nigeria today, one of the most serious security challenge is the incitement of farmers-herdsmen violent conflicts which have led to the loss of many lives and properties. This work focuses on farm monitoring and security as proper monitoring and quick response to prevent intruders is eminent. A scientific approach to this is the deployment of sensing equipment and gadgets that will monitor the activities of both the farmer and the herdsman, thereby controlling their interaction and limiting the boundary between farm lands and grazing areas. This work presents the modeling of an alarm response center (ARC) with wireless sensor networks (WSNs) for farm monitoring and security. The architecture of the WSNs system comprises of a set of sensor nodes, surveillance facilities and a base station that communicate with each other and gather information to the ARC wirelessly.

**Keywords:** Farmers, Herdsman, Conflict, Alarm response center, Wireless sensor network, Modeling

## **INTRODUCTION**

This work focused on the modeling of a wireless alarm response center and effective wireless sensor network transmission over a large farm area and through very long distance. It also

focuses on how to employ the use of wireless photoelectric beam for perimeter fencing of a large farm area thereby eliminating the use of humans as onsite guards and offering a completely automated and remote control monitoring thereby increasing security by reducing risk and prompt response to security challenges on farm lands. This work is motivated by various previous researches in agriculture safety. Many have looked at safety in agriculture according to regional challenges, for example in South Africa, cattle rustling is a major challenge and many researchers have looked into how to suspect the act and protecting the Cattles (Kibambeet *al.*, 2014). A research into human elephant conflict in Asia led to the development of a wireless sensor network based intrusion alert prototype for Human Elephant Conflict (HEC) which is a serious socio-economic problem in Asia and some African countries (Ruwini and Dileeka, 2013). In Nigeria, there is the presence of many environmental challenges to the agricultural sector but the scope of this research is on the violent crisis between herdsmen and farmers and offering a lasting solution to it. Many of the affected farmers and herdsmen are not elites and can hardly interpret the data being sent to them (Williams, 2017), hence my proposed model of developing a wireless alarm response center. This will be achieved by deployment of wireless sensors (nodes) such a passive infrared motion detectors (PIR), photo electric infrared beams, cameras, sirens and site warnings through an onsite speaker within and around the farm land and establish a direct link with the Alarm response center as the first responder, local police authority and other emergency responders to sanction a response. The method of achieving this is by hosting a private base transceiver station to ensure the secured transmission of data wirelessly.

## **PROPOSED MECHANISM**

This would be divided into three parts. The first part discusses wireless sensor network (WSN), the second part discusses alarm response center (ARC) and the third part incorporates the two as a model.

## **WIRELESS SENSOR NETWORK**

Wireless sensor network is a very popular service utilized in industrial and commercial applications, because of its technical advancement in processor, communication, and usage of low power embedded computing devices. A wireless sensor network is a self-configuring network of small sensor nodes communicating among themselves using radio signals and it is deployed in quantity to sense, monitor, and understand environmental conditions like pressure, sound, vibration, position etc (Ben-Haddouand Al-Fuqaha, 2015). In many real time



applications the sensor nodes are performing different tasks like close node discovery, smart sensing, data storage and processing. It serves as a link between the physical and virtual worlds by allowing the ability to observe unobservable events at a good resolution over large spatial-temporal scales such as a typical farm land. Two standards used by WSN are the 802.15.4 and Zigbee. For the purpose of this work, Zigbee is considered. This defines communication layer at level 3 in the OSI model with a main purpose of creating a network topology (hierarchy) to let a number of devices communicate amongst them and set extra communication features such as authentication, encryption and association. A large number of well distributed, self-directed, small and low powered devices are called sensor nodes or motes (Ben-Haddouand Al-Fuqaha, 2015). The necessity for motes in this model is to collect the information from the environment to accomplish the application objective of remote monitoring of a farm land and relay gathered information to the ARC. WSN has an edge over existing ad hoc networks some of which are illustrated in the Table 1. In comparison with sensor networks, Ad Hoc networks will have less number of nodes without any infrastructure.

Table 1: Comparison of WSN and Ad Hoc networks

<b>Parameters</b>	<b>Wireless Sensor Networks</b>	<b>Ad Hoc Networks</b>
Number of sensor nodes	Large	Medium
Deployment	Densely deployed	Scattered
Failure rates	Prone to failure	Very rare
Topology	Changes frequently	Very rare
Communication paradigm	Broadcast communication	Point-point communication
Fusion /aggregation	Possible	Not possible

Redundancy	High	Low
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A brief insight to the two sensor nodes for the model is explained below:

- a) **Passive infrared motion sensor:** Infrared radiation is the section of the electromagnetic spectrum that has wavelengths smaller than microwaves and longer than the visible light wavelengths. The term PIR is the short form of passive infrared. The ‘passive’ means that the sensor is not actively taking place in the process, in other word, it does not emit IR itself but passively detects infrared radiation coming from the human body in the surrounding area. The detected radiation is converted into an electric charge which is directly proportional to the detected level of radiation. The PIR range is up to 10 meters at an angle of  $\pm 150^\circ$ . A PIR is quite complicated than other sensors as it consists of two slots. These slots are made up of materials sensitive to infrared. A Fresnel lens is used to see that the slots can see out past some distance. When the sensor is inactive, the two slots sense the same amount of IR which is the ambient radiated from the surrounding. When a human body or any animal passes by, it intercepts the first slot of the PIR sensor and causes a positive differential charge between the two bisects and when the body leaves, a negative differential charge. Due to the fact that the area of deployment is on a farm land, the IR sensor is housed in a hermetically sealed metal to shield from humidity, temperature, noise and immunity (Yuvaraj and Ramesh 2012). It can work day and night without the need for visible light, as it senses just radiation.

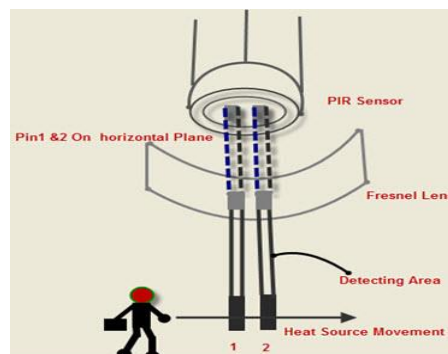


Figure 1: Working principle of PIR (source: elprocus.com)

- b) **Photoelectric beam sensor:** A photoelectric sensor emits a light beam (visible or infrared) from its light-emitting element. A reflective-type of photoelectric sensor is used to detect the light beam reflected from the target. A thru beam type sensor is used to measure the change in light quantity caused by the target/intruder crossing the optical axis. Figure 2

shows the illustration of the thru beam sensor. Separate emitter and receiver units are required for a thru-beam sensor. The units are aligned in a way that the greatest possible amount of pulsed light from the transmitter reaches the receiver. An intruder (target) placed in the path of the light

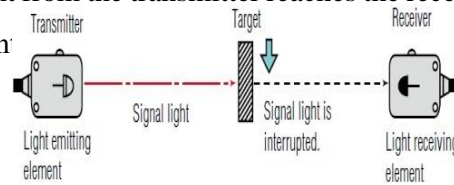


Figure 2: Thru beam sensor

When the target no longer blocks the light path the receiver's output returns to its normal state. Thru-beam is suitable for detection of opaque or reflective objects. It cannot be used to detect transparent objects. In addition, vibration can cause alignment problems. The high excess gain of thru-beam sensors make them suitable for environments such as the farm lands.

#### ALARM RESPONSE CENTER

This is also called Alarm receiving center. The function of an alarm in a monitoring and detection system is "to indicate that an anomalous signal has been detected" (Smith *et al.*, 2013) and that a response is required to investigate this. The response might be to shut the alarm down if a false alarm is discovered, or for the incident to be referred for further investigation by stake holders, first responders or the police.

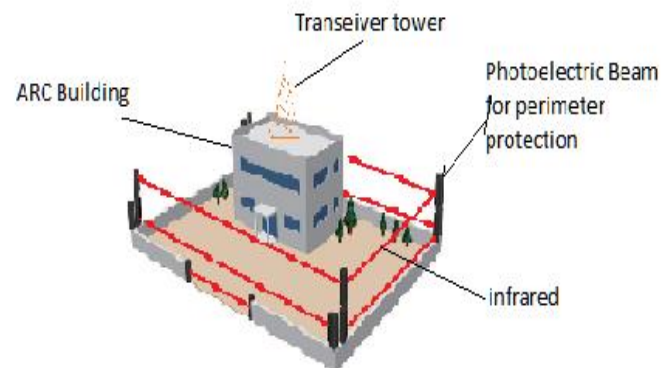
Three basic elements make up an alarm system, typically detection devices such as the PIR and Photoelectric beam sensors; control equipment; and signaling equipment. These latter two can be categorized as alarm panel. Detection devices identify an intruder or intrusion attempts via a sensor through recognizing changes in motions, sound, vibration or other disturbances, in areas where these are not expected. Detection devices may also include hold-up alarms such as panic button and key fobs, which are activated discretely by a person requesting emergency assistance. At first, the intrusion alert is received by the 'panel', or control equipment which acts as the main 'nerve center' of the system. Often the signaling equipment is incorporated into the panel. However, the purpose of this is to transmit a signal that an alarm has been activated. This may be locally via a siren or light, or remotely to an alarm monitoring/receiving center (Medhat *et al.*, 2015). In Nigeria, as of the time of writing this paper, no ARC exists,

adaptation of this model by the government will be a meaningful and welcome development. This initiative is consistent with the Federal government's intervention into the lingering Farmers and herdsmen crisis in Nigeria. With the adoption of this model, some of the benefits include:

- Consistent and continuous delivery, response and stable functions
- Reduction in response time to crisis
- Decrease in labor costs and optimization in effort/input
- Increase in accuracy and reduction of human error
- Ability to Undertake tasks beyond human capacity
- Reduction in the number of false alarms through proper filtering.
- Ease of maintenance with simple quality checks, many of which can be inbuilt into system.
- Provision of a platform for integration with other monitoring systems
- Can produce better quality of data – including pictures, CCTV, video.
- Capture System transparency to avoid fake news by media houses.
- Potential reduction in insurance premium.

Some of the notable limitations include:

- The cost of the initial capital outlay
- High development costs
- Loss of versatility
- Software and other technical glitches



## ARC LOCATION

The ARC will be contained within a building such that all areas of the building from which access to the response center's normal entrance can be gained and are occupied by the state farm guards who operates the center and are the sole occupant. Such areas shall not be accessible to any other occupant of that building (Witte *et al.*, 2012).The center will be in isolation within the farm premises or far away from it such that there will not be any entrances to such areas from any part of an adjoining premises except where those parts of such adjoining premises are also occupied by the farm guards. No part of such adjoining premises shall be accessible to any other occupant of that building. The area of the building will be protected by an intruder alarm system installed in accordance with the applicable Standard(s) for intruder

alarm systems. An illustration of the ARC is shown in Figure 3 this was done by using autocad software.



Figure3: Autocad Illustration of an ARC

## **OVERALL SYSTEM ARCHITECTURE**

The sensor nodes will be mounted at strategic locations within the farmland. The photoelectric beam replaces the use of bricks and wires for perimeter fencing and the PIR will be mounted at some distance from the perimeter. The aim of the model is to prevent an intrusion and not to tackle one if it occurs, hence, the limitation in use of gadgets and thereby increasing system efficiency with a 24/7 real time monitoring and response center whenever an intrusion abounds.

The base station located in a safe place within the farmland will be responsible for receiving signals from the sensors, process these signals and relay them to the ARC. The farmer is not involved in the process at all as the model is aimed at local farmlands of which most of the farmers are not technology inclined. The duty of the ARC will be to monitor these farmlands and ensure safe relation between farmers and herdsmen who serve as the major intruder to farmlands. Below is a brief guide on how the system can be implemented in Nigeria.

1. Each farm land will be assigned a unique reference number (URN)
2. The State government can initiate a state owned independent first responder to farm alarms and crisis, such can be termed “Farm guards”
3. The farm location will be checked to ensure it is in the relevant district, if not the application of URN is rejected.
4. Checks are made to ensure there is no existing farm with a URN to prevent duplication and interference.
5. The data will be collected by state owned ARC
6. The performance of the system will be checked and review daily

7. Policy sanctions will be made against false calls and alarms, should it exceed the stipulated level by the government, warnings, withdrawal or deletion will be issued to the subscriber.
8. Registered URN will be subjected to an annual audit process and overall system performance check.

In summary, ARC model for farmlands provide reassurance that intruders are monitored and kept away 24 hours a day, 365 days a year. Activation signals from the sensors are received at the base station and to the ARC, where they are filtered for false activations that are neither crime related or caused by genuine intrusions. In the event of a confirmed signal the Farm guards (first responders) or other relevant emergency services will be contacted on behalf of the farmer.

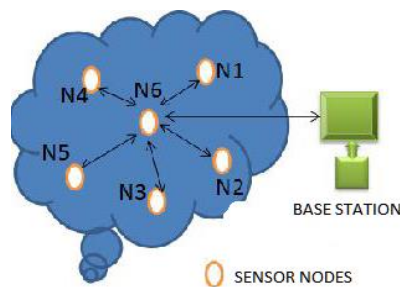


Figure 4: Sensor nodes connectivity

Figure 4 shows the interaction of nodes with the base station and interconnectivity between themselves

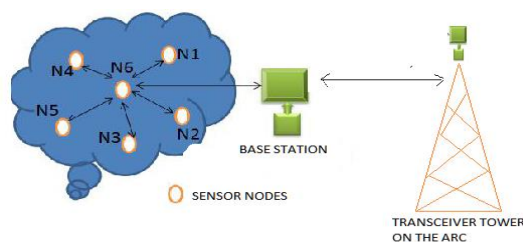


Figure 5: Nodes interconnectivity with ARC



Figure 6: A farmland illustration

Figure 5 shows the interaction of sensor nodes with the base station and transceiver tower at the ARC, all connections are wireless.

Figure 6 shows an illustration of a farmland. The photoelectric beams are placed around the farm perimeter with the transmitting beam and receiving beam aligned. The red lines show the infrared link but in ideal case this is not visible to the human eye. Once an intruder crosses the infrared beam, a signal is sent to the base station on the farm and transmitted wirelessly to the ARC. PIR motion sensors are placed on the surrounding land at few meters to the farm, this is to be aware of normal activities around the farm and effective monitoring and awareness can begin at this point.

## CONCLUSION AND RECOMMENDATIONS

In perspective of future developments, farm security will change, owing to technological advances and system integration. The lingering crisis between farmers and herdsmen which have claimed many lives and properties in Nigeria is a socio-economic challenge. Many social approaches have been made to solve the crisis, here is taking a scientific approach, an approach that will be transparent with little human intervention. Very prompt response to any bias interaction between the two parties' thereby preventing intrusion and loss of lives and properties. A step by step guide on how to establish an ARC was discussed also stating some of its limitations. The scope of this study is to introduce a scientific approach into solving the socio-economic challenge in the country. Further study will be in implementation of the proposed model, incorporating more sensors such as metallic sensors and visual representation of the data using CCTV cameras. Also the cost analysis of implementation and design was not discussed as this is a broad area of study as well. Some recommendations include:

- The need to raise awareness of the ARC, not limited to farm lands alone
- The need for clarity on costs of implementation
- The engagement between ARCs and the police

- Science and technology should be an integral part of socio-economic decisions
- A look into an assessment of the capability to manage and maintain the system when implemented.

## REFERENCES

- Ben-Haddou, A; Al-Fuqaha (Eds.) (2015):“Wireless Sensor and Mobile Ad-Hoc Networks: Vehicular and Space Applications” Springer, New York, 2015
- Kibambe P; Rimer S; Paul B.S (2014): “Cattle monitoring system using wireless sensor network in order to prevent cattle rustling”. IEEE International conference on communications
- Medhat, Karen, Rabie A. Ramadan, and IhabTalkhan (2015). "Distributed Intrusion Detection System for Wireless Sensor Networks in Next Generation Mobile Applications, Services and Technologies." 2015 9th International Conference on, pp. 234-239. IEEE, 2015.
- Ruwini E., Dileeka D. (2013): “ Wi-Alert: A Wireless Sensor Network Based Intrusion Alert Prototype for Hec”, International Journal of Distributed and Parallel Systems (IJDPS) Vol.4, No.4.
- Williams A. Ahmed-Gamgum (PhD) (2017): “Herdsman and Farmers Conflict in Nigeria: Another Dimension of Insecurity”, Journal of Public Administration and Social Welfare Research Vol. 3 No. 1 2018 ISSN 2504-3597www.iiardpub.org
- Witte, G., Cook, M., Kerr, M., Shaffer, S. (2012): Security Automation Essentials: “Streamlined Enterprise Security Management & Monitoring with SCAP”. McGraw Hill Professional.
- Smith, C. L., Brooks, D. J. (2013): Security science: “The theory and practice of security. Amsterdam”: Elsevier.
- S. Yuvaraj and Ramesh S., “Improved Response Time on safety Mechanism Based on PIR sensor,” International journal of emerging Technology and Advanced Engineering, vol. 2, no. 4, April 2012.



## **DESIGN AND CONSTRUCTION OF A STAND-ALONE ATTENDANCE SYSTEM**

Awofolaju, T.T., Orolugbagbe, D. O., Oladoye, S.O. and Obiyemi, O.O.

Department of Electrical and Electronic Engineering, Osun State University, Osogbo, Nigeria

Corresponding author: D.O Orolugbagbe

\*Email of Corresponding Author: danwizy96@gmail.com

### **ABSTRACT**

In recent years, there have been rise in the number of applications based on radio frequency identification (RFID) systems and have been successfully functional to different areas as diverse as transportation, health-care, agriculture, and hospitality industry to name a few. Iot technology facilitates automatic wireless identification using electronic passive and active tags with suitable readers. In this study, the design and implementation of a stand-alone attendance system using RFID module is made to solve regular lecture attendance monitoring problem in developing countries using RFID technology. The application of RFID to student attendance monitoring will be capable of eliminating time wasted during manual collection of attendance and an opportunity for the educational administrators to capture face-to -face classroom data for allocation of proper attendance scores and for further managerial decisions. This study also helps to increase the monitoring of student activities by keeping the time record. In comparison with other studies on RFID, this study has the advantage over them because it is handy and easy to access. It is a standalone attendance system with powers itself and store data into its own database. Also, this study comes along with a software which is used to access the device database to keep records.

**Keywords:** RFID reader, RFID module, Microcontroller, attendance software

### **INTRODUCTION**

RFID devices are wireless microchips used for tagging objects for automated identification. RFID systems consist of a reading device called a reader, and one or many tags the reader is a powerful device with ample memory and computational resources. RFID can identify objects wirelessly without line-of-sight. Attendance system will produces an automatic system which give better routine and efficiency than the traditional method of observing student. Furthermore, RFID technology can help to identify and to monitor items (products, people, student etc.) wirelessly within a specified distance. In this system, the RFID tags will

enable the school/college management people to supervise the student movement in and out of the campus. When RFID tags pass through the RFID reader in read range zone, then system will record the data from the RFID tags to the database systems (microcontroller). Due to limited supervision of students, this has caused students to be less motivated to come to the lecture rooms than ever before. Laziness on the part of students, nonchalance to school work, extra social activities that have no importance in aiding the objectives of the institution and a lot more, may prevent students from attending lectures. Sequel to these, lecturers and administrators in most developing countries have had to come up with ways to ensure a healthy participation from students, and make sure that the student-lecturer interactive relationship is kept intact. This in some cases have come in simple forms like roll calls, while in more interesting cases, can be formats like surprise quizzes, extra credit in class, etc. These strategies are however time consuming, stressful and laborious because the valuable lecture time that could otherwise been used for lectures is dedicated to student attendance taking and sometimes not accurate.

The main concept behind Radio Frequency Identification (RFID) based attendance system is to take the attendance of students or employees in any college or university or company. RFID card has to be shown in front of the RFID reader, then the attendance of the respective person is noted down in the microcontroller memory. The data is then accessed using a software to keep the record in its database.

Most educational institutions' administrators are concerned about student security. The conventional method allowing access to students inside a college/educational campus is by showing photo ID cards to security guard is very time consuming and insecure, hence inefficient. With the Automated Attendance system, the security level increases, the time consumed reduced and monitoring of students become more efficient.

This device has the ability to keep track of student record and time with less stress and less time consuming.

Using Osun State University lecture room as a case study. This device will help in monitoring the student attending a particular course at a specific time. This device will restrict students from taking attendance for those that are absent in class for the particular course.

## **LITERRATURE REVIEW**

Time and attendance has being the greatest interest of the administrators of an institution or organization. The time and attendance of students/staffs has been taken into record by the use of paper and pencil. As time goes by, technology advances has had impacts in the attendance systems. The automation of attendance system has been put in place of the paper and pencil.

The use of RFID technology in automated electronic environment and for tracking objects has been studied widely with deployed by various organizations as part of their automation system (Daniel & Steven, 2010). Charles Walton, received a patent for a passive transponder used to unlock a door without a key. The U.S. government was also working on RFID systems. Typically, RFID system has three basic tasks: RFID tags, RFID readers and the application management system. RFID tags have two categories, such as Passive model and Active model. As well as the system is must specified by tag and reader with the same frequency. When RFID has HF reader it only can read the HF tags and cannot read other frequency tags. Many universities use HF or UHF RFID cards as student's ID card. RFID card integrate many functions into the card as security card, library entrance card, car and motorcycle parking card, payment car, etc (Wikipedia, 1998).

#### Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) technology is one of the key technologies to realize the Internet of Things (IoT). The typical RFID systems consists of tags, readers and back-end computer system. There are two types of tag: active and passive tag, where active tag has battery and can send the information at hundreds of meters, and passive tag depends on the emitted energy of reader's antenna instead of using battery to transmit information (Oyeyemi, 2017). Patel et al. designed an online students' attendance monitoring system in classroom using UHF RFID, which can automatically record students' attendance at lectures or laboratories. However, the UHF are not widely used in universities and colleges. In fact, HF RFID cards are widely used as IDs of students in campus management (Daniel & Steven, 2010). Arbain et al. implemented a web-based laboratory attendance system by integrating RFID with Arduino platform, which is a cable network and not convenient to be used by IoT environment.

With the passage of time and development of society, smart attendance system has been processed by different designers. This study introduce a modified approach in the attendance

automation in school and organizations for security and monitoring reasons. RFID reader and RFID card are deployed differently than in the typical security applications and different results are expected by the user from the reader. In the security application, it is required to inform the security system as soon as possible about any movement in the observed, while in the attendance application and at the end, the user are interested in the intensity of the movement of student in a given time frame. In addition, the RFID reader node demonstrating the approach provides extended feature such as time, name and the card number of the particular student or staff in the organization.

Automatic attendance system using RFID reader and RFID cards is designed as a standalone automatic attendance system. In the approach, the attendance system operate as an independent device. The data is stored in the device. In the assessment of the previous studies on smart attendance system, the previous device designed needs a computer software before operation. This creates a limit to the accessibility of the design. Therefore this study produce a devices that has no limit in it application and mode of operation. The mode of operation of the device is dependent of the computer interfacing which house the data base.

In a basic RFID system setup, there are sets of devices that makes up of a complete RFID system and this system is not functional if any of these devices are missing. The devices include:

1. An RFID reader
2. An RFID card/tag
3. RFID antennas

A computer is often needed to make the system complete and extensible by integrating the RFID reader with a software for customized use.

The components and software used in the design and construction of this study are chosen based on some key factors which are:

1. Power requirement of the system
2. Proposed form factor of the device
3. The range of the RFID module to be used
4. Communication requirement for data transmission
5. Software implementation and storage mechanism

## 6. Passive and active components.

### Description of the equipment used

These key factors were used in the selection of components used for this study and the components and software used are:

1. RC522 RFID reader
2. RFID card
3. ATmega328P microcontroller
4. Printed circuit Board
5. Liquid Crystal Display
6. Arduino (embedded software platform)

**1. RFID reader:** - The full meaning of RFID is “radio frequency identification”. Wireless communication is used between the RFID reader and the RFID card. RFID reader does not require line of sight communication with the cards. It means that the reader detects the RFID card even if there is some object between the RFID card and the RFID reader. Thus, it is a non-contact type of reader. RFID reader interfacing with microcontroller is done using serial port.

**2. RFID Cards:** - there are two main type of RFID cards. We have the passive and the active RFID tags. In this study, we are using a passive RFID cards. As given in the introduction, we are using a RFID card with are of the size of a credit card. These are rectangular in shape and white in color and can be attached with the ID card.

**3. ATmega328P Microcontroller:-** this is the main component of this study. It is the heart of the system. Microcontroller communicates with all input and output devices using its pins. Various function of the microcontroller includes

- Display clock on LCD
- Reading input from RFID reader
- Comparing the RFID card number with the initial programed RFID numbers stored in it database
- Turning on buzzer if the card does not march
- Storing time into database if card marches
- Sending data to computer software

**4. Liquid Crystal Display:** - it is used to show current time and various messages. These messages are invalid card, valid card, attendance of students, etc. we have used 16 by 2 alphanumeric display.

## METHODOLOGY

This study is divided into parts; the hardware and the attendance software part.

### The hard ware:

This is the physical device that users interacts with directly to take attendance for an event while the software part receives, processes and store the attendance data gotten from the developed hardware.

The first and most important parameter in any electronic system is the power supply requirement for such system. If the power supply system fails, then such system will surely fail too. Other parameters that served as a guide to the complete design of this system includes control unit, inter-circuit communication, and display and data management. The hardware units are divided into subsections as listed below.

1. **Power supply:** - the power supply requirements for the study are 5v at 500mA and 3.3 at 3000mA.

The power requirement is indeed a tangible and useful guide for choosing power supply components like transformers, rectifiers and voltage regulators. The power supply unit consist of the voltage - circuit, rectifier circuit, filtering circuit, and the voltage regulator circuit. The power supply circuit is shown in Figure 1.

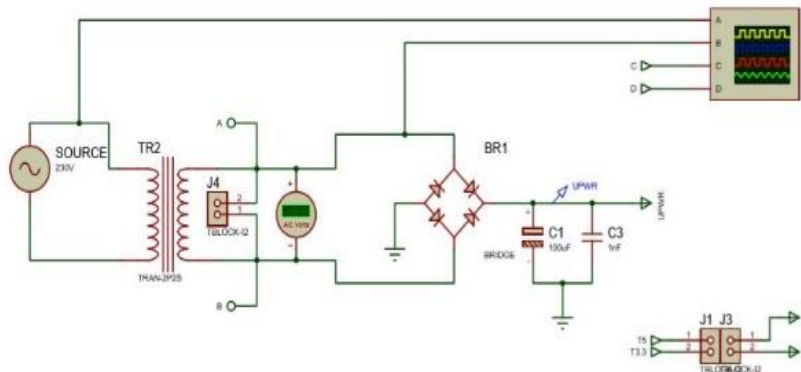


Figure 1: Power supply circuit

2. **Battery management system:** - this is the system that helps the device to a standalone smart attendance system. This system deals with the charging of the device and helps the device to operate on its own.
3. **ATmega328P:** - this is used as the controller for the device in the design. This IC is known for its high reliability, ease of use and Arduino compatibility. The microcontroller powered from the 5v supply rail was used to interface with the LCD, the RFID module and other output peripheral as shown in Figure 2.

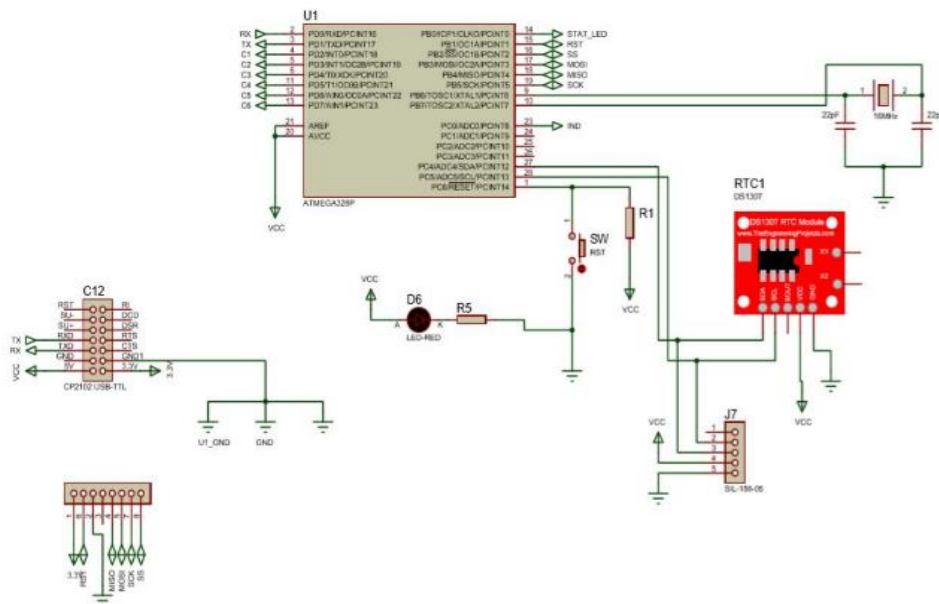


Figure 2: Atmega328p interface circuit

4. **Inter-Circuit Communication:** The ATmega328p microcontroller has two hardware communication interfaces which it uses to communicate with other circuit and modules.
5. **Display:** - the attendance system uses a 20 by 4 character alphanumeric liquid crystal display. The LCD is controlled by the microcontroller.

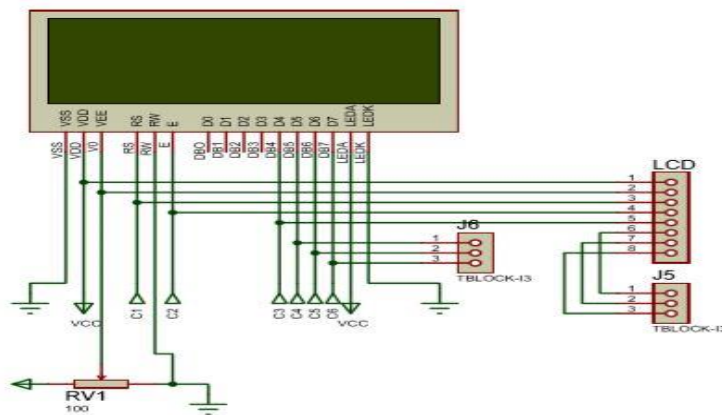


Figure 3: The Display Circuit

The LCD displays the attendance number, date and time, registered and unregistered cards. Figure 3 shows the display circuit.

**6. PCB Development:** - The printed circuit Board used for this study is a kinsten positive pre-sensitized printed Circuit Board.

**The Attendance Management Software:**

The other part of this design is the system software. The Arduino software is used. The software serves as the database of the device. The software keeps the record of the students. It stores the registered numbers and keeps track of the attendance system.

Figure 4 contains the registration and the class attendance part.

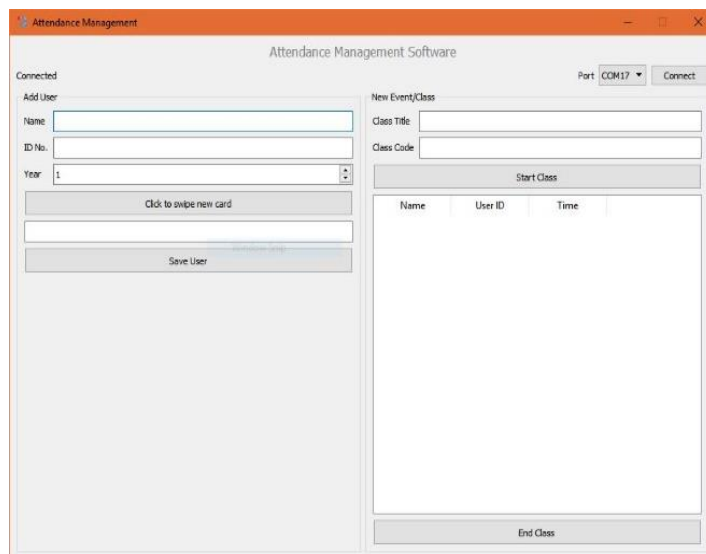




Figure 4: The Attendance Software

Under the registration aspect, the information to be assigned to a RFID card is entered and 'click to swipe new card' button is clicked to swipe the RFID card to be assigned to. After then, save user is clicked to finish the registration.

The class attendance part contain the information about the class that the device will be used for. The part includes: class title and class code. After the information about the class has been entered, then the 'start class' button is clicked. After all the attendance has been collected, then the 'end class' button is clicked.

Immediately after clicking the 'end class' button, the software prompt the user to save the data in an excel format in a preferred location as shown in Figure 5.

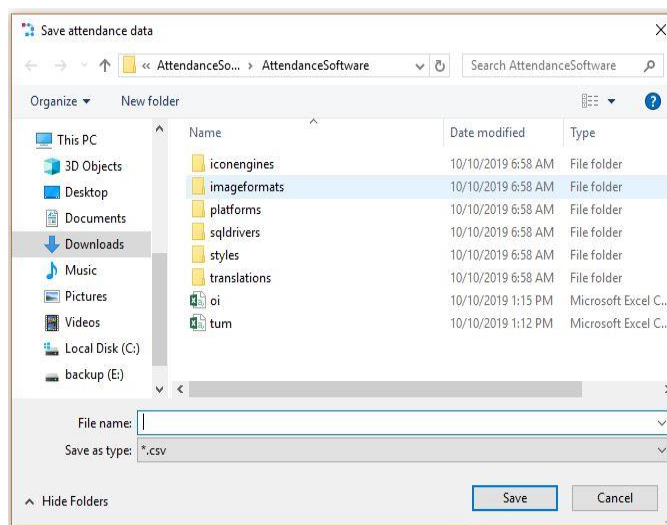


Figure 5: The Software Saving Platform

## MODE OF OPERATION

The standalone attendance system is the device that takes the record of the students in accordance to the time which they are being taken. The following are the steps in using the device:

1. The device must be powered ON using the power button.
2. The device LCD displays 'swipe card'.
3. The RFID module is ready to be used

4. After the RFID card has been swiped, RFID reader reads the card and note the card number and then send the data to the Microcontroller.
5. The Microcontroller compares the card number that is being swiped with the already programed card numbers.
6. After then, the microcontroller stores the data
7. After the class attendance has all been made, the information is then collected using the software.
8. The software is a database for the device. It helps to keep the record of the attendance in accordance with time.

This study's basic flow diagram is shown in Figure 6.

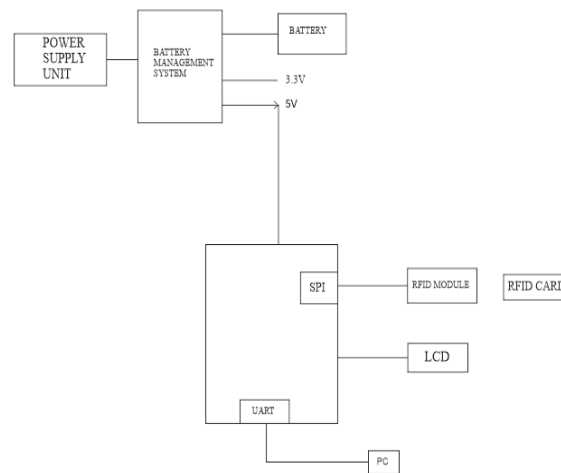


Figure 6: The block diagram of the device

## **RESULTS AND DISCUSSION**

The attendance taking device was placed at a remote location, then a registered card was swiped. The attendance management software was able to receive the information and display the unique identity number (UID) of such tag been swiped as shown in Figure 7.

New Event/Class

Class Title TEST

Class Code TEST 502

Start Class

	Name	User ID	Time
1	NOT REGISTERED	166 242 127 31	10:25:28
2	Oyetunde Oluw...	EEE/2014/0039	10:25:33
3	Raji Mubarak	EEE/2014/0040	10:25:39
4	Oladoye Sunday	EEE/2014/0056	10:25:42
5	Orolugbagbe O...	EEE/2014/0038	10:25:45
6	NOT REGISTERED	198 186 104 213	10:26:12
7	Oyetunde Oluw...	EEE/2014/0039	10:29:01
8	Oyetunde Oluw...	EEE/2014/0039	10:29:11
9	Adepoju Abolaji	CSC/2012/0012	10:29:21

End Class

Activat  
Go to End

Figure 7: Class attendance Demo

The final and packaged device is shown in Figure 8.



Figure 8: The device after construction

## CONCLUSION

At the end of this study, the device was able to perform the speculated task. It was able to take attendance and able to transfer the attendance taken in the classroom to the attendance software on the system

## REFERENCES

- Burrunner, H. (1984). An introduction to theory and application. *Volterra integral equations*, 95-109.
- Daniel, M. D., & Steven, M. W. (2010). Environment Effects in RFID card. *California: Bulis Press*.
- Dennison, A. (2016). Retrieved September 26, 2019, from Atlasrfid Store: <http://www.atlasrfidstore.com>
- google. (n.d.). Retrieved from Google: google.com
- Madbouly, N., McGhee, D., & Roach, G. (2001). Adomian's method for Hammerstein integral. *Appl. Math. Comput*, 241–249.
- Olashile, B. I. (2015). *Tau method for solution of linear and nonlinear integro differential equation*.
- Oyeyemi, F. (2017). *Design and Implementation of an electronic attendance management system using Osun State as a case study*.
- Razzaghi, M., & Ordokhani, Y. (2001). Solution of nonlinear Volterra-Hammerstein integral equations. *Math. Probl. Eng*, 205–219.
- Robomart. (2018). Retrieved September 26, 2019, from Robomart: <http://www.robomart.com>
- S. Suresha, G. T. (2019). Initial Value Problem for Nonlocal Impulsive Integro-Differential Equation Involving Fractional Derivation of order. *American Journal of Engineering Research (AJER)*, 193-199.
- s.shahmorad. (2007). Numerical solution of the non-linear Volterra integro-differential equation by Tau method. *Applied Mathematics and computation* , 1580-1586.
- Technologies, M. (2017). *Microtronics*. Retrieved from <http://www.projects8051.com/rfid-based-attendance-management-system/>: www.projects8051.com
- Wikipedia. (1998). *Institute for Employment Studies*. Retrieved September 20, 2017, from Wikipedia: <https://en.m.wikipedia.org/wiki/Rfid>

Y.Mahmoudi. (2017). Taylor polynomial solution of non-linear Volterra-fredholm integral equation . 881-887.

## **STUDIES OF CLIMATE CHANGE ON RAIN RATE PREDICTION OVER SOUTHWESTERN NIGERIA**

Semire, F.A.\*, Adekunle, A.J. and Adegbola, O.A.

Department of Electronic and Electrical Engineering, Ladoke Akintola University of  
Technology,

P.M.B. Ogbomosho, Oyo State, Nigeria

\*Corresponding author's Email: [fasemire@lautech.edu.ng](mailto:fasemire@lautech.edu.ng)

### **ABSTRACT**

The issue of climatic change and its adversative effect on mankind as well as communication links has become a global concern. This paper examines effect of climate change on the yearly trend of rainfall in three locations in Nigeria. Rainfall volume data for three locations in the south-western Nigeria were obtained for rain rate computation using Semire and Rosmiwati model and then analyzed for possible trend and variability through two variation metrics. Result shows rise in total rainfall invariably corresponding to increase in the rain rate distribution. This rising trend as a result of climate change therefore needs to be taken into cognizant consideration towards future microwave communication link design.

### **INTRODUCTION**

The variation of climatic condition in deserts, heavy rain regions and areas affected by oceanic winds results in diversity in geographical parameters. Rain, as opposed to other kinds of precipitation such as snow, hail and sleet, is liquid precipitation formed by the condensation of atmospheric water vapor into drops of water (of up to 0.5mm), often large enough to fall from clouds in the sky to the earth surface (Wikipedia, 2017; Perez-Garcia and Silva-Mello, 2004). Rainfall rate distribution is a function of how rainfall occurrence changes in time and space, in terms of daily, monthly, yearly and seasonal variability (Ajayi *et.al.*, 1996). The availability of spatial rain rate statistics, and the drop-size distribution of any climatic zone is essential for the accurate prediction of attenuation characteristic due to rain. Hence, the seasonal variability of rain rate distribution is one of the important factors to link engineer for calculating rainfall attenuation when providing adequate link budget estimate for communication link (Mandeep and Allnut, 2007).

The rain rate statistics can either be in the form of point rain rate data or cumulative distributions, so that rain rate exceeded at different percentages of time can be

determined. The long-term behavior of rainfall rate is expressed by a cumulative probability distribution usually referred to as Cumulative Distribution Function (CDF). This rain rate CDF, commonly referred to as an exceedance curve is the percentage of time that rainfall rate exceeds a given value (Pratt, Bostian and Allnut, 2006). According to ITU-R, the estimation of induced attenuation due to rain requires the knowledge of rain rate exceeded 0.01% of the time with one minute integration time in predicting induced rain attenuation (ITU-R, 2005).

The characteristic difference between rain in tropical and temperate climate is that rainfalls in the tropics are largely convective and characterized by higher rates of precipitation which occur within short duration over limited extensions while that of temperate climate are from stratiform cloud and characterized with lower rain rates being widespread, and as such, extend over a longer propagation path. Hence, the empirical relationships adaptable for propagation predictions in the temperate regions are not suitable in the tropical climates and this critically affects countries located in equatorial regions that experience a high rainfall rate of up to 120 mm/h throughout the year.

Nigeria lies between latitude  $4^{\circ}\text{N}$  and  $14^{\circ}\text{N}$ , and between longitude  $2^{\circ}\text{E}$  and  $15^{\circ}\text{E}$ . It has a total area of  $923.77\text{km}^2$  and land mass coverage of  $910.77\text{km}^2$ . Climate is the average state of the lower atmosphere, and the associated characteristics of the underlying land or water, in a particular region, usually spanning at least several years (World Health Organization, 2003). The Nigerian climate is dominated by the influence of the Tropical Maritime (TM) air mass and the Tropical Continental (TC) air mass. The TM air mass originates from the southern high-pressure belt located off the coast, which picks up moisture from over the Atlantic Ocean, thus becoming a moisture-laden air mass which is characterized by high humidity and heavy rainfall (Odjugo, 2005). According to the CHIRPS rainfall dataset, FEWS NET/USGS (2016) explored trends in rainfall over Nigeria during a period of 1981-2015, suggesting that rainfall has increased across much of the country since the 1980s, highlighting that the large amount of rainfall are typically received in the central and southern parts of the country. Total rainfall is highest in the south where more than 1,400mm are received; the central band of Nigeria receives 800-1,200mm while the Northern areas receive less than 800mm, with some northeastern areas bordering Niger and Chad receiving less than 400mm.

The locations under study were drawn from two states of the Southwest region of Nigeria which are Lagos State (Itoikin), and Oyo State (Sepeteri and Iseyin). Lying within the rain forest climatic zone and having a rugged and undulating topography with rivers of many tributaries, annual mean temperature during the day varies from  $20^{\circ}$  to  $34^{\circ}$  and rainfall from

928mm to 3240mm per year with its relative humidity ranges between 65% and 75%. Basically having two seasons which are dry season (majorly November between February) and wet season (within the rest of the calendar year), rainfall of the locations of study usually falls during the wet season and during this period, the Intertropical Convergence Zone (ITCZ) moves across the country. The average monthly rainfall depends on the effects of movement of the ITCZ. The rainy season is interrupted by short breaks which usually occur in August, but heavy rain in September, hence having tropical rainfall pattern with seasonal distribution (Semire and Raji, 2011; Omotosho and Oluwafemi, 2009).

Rainfall data of over twenty years were obtained from Weather Stations as provided by the Nigerian Meteorological Agency (NIMET), a Federal Government Agency in charge of Weather parameters and atmospheric conditions in Nigeria, and also from the Ogun-Osun River Basin Development Authority (OORBDA). Obtained data are of monthly integration time which according to Ajayi *et.al.* (1996) and Semire *et.al.* (2012) may be adequate for providing enough information for rainfall estimation for the purpose of attenuation prediction along terrestrial or satellite communications link. The rain gauge has a bucket size of 0.1mm to 0.5 mm per tip. The locations and their geographical parameters are as presented in Table 1.

**Table 1 Geographical parameters of locations under study**

	Itoikin	Sepeteri	Iseyin
Longitude (degrees)	3.79	3.65	3.60
Latitude (degrees)	6.65	8.63	7.37
Height above sea level (m)	43	348	308.22
Mean annual accumulated rainfall (mm)	1245.69	1257.95	1193.78
Observation period (Years)	27	21	21



## **METHODOLOGY**

Owing to lack of measured one-minute data for the locations under study, measurement data of annual accumulated rainfall volume obtained were used to generate rain rate Cumulative Distributions Functions (CDFs) over the locations. Since obtained data are in millimeter (mm), then it is necessary to convert the available rainfall volume data into rainfall rate of one minute integration time at 1%, 0.1%, 0.01% and 0.001% of time exceedances and Semire and Rosmiwati model (2011) which was generated from Ogbomoso in Oyo state was adopted. Their equations are as shown below:

$$R_{1.0} = 1.496M^{0.332} \quad (1)$$

$$R_{0.1} = 0.627M^{0.6} \quad (2)$$

$$R_{0.01} = 4.866 M^{0.431} \quad (3)$$

$$R_{0.001} = 21.338 M^{0.3372} \quad (4)$$

where **M** is the accumulated annual volume and **R<sub>1.0</sub>**, **R<sub>0.1</sub>**, **R<sub>0.01</sub>**, **R<sub>0.001</sub>** are one-minute rain rates at 1%, 0.1%, 0.01% and 0.001% exceedances respectively.

The coefficient of variation (CV) is given as;

$$CV = \frac{\sigma}{\bar{R}} \times 100\% \quad (5)$$

where  $\bar{R}$  is the mean of the entire rain rate series and  $\sigma$  is the standard deviation from the mean of the series.

Also the correlation coefficient (r) used is defined as;

$$r = \frac{\frac{\sum(Y \cdot R)}{N} - (\bar{Y} \cdot \bar{R})}{\sigma_Y \cdot \sigma_R} \quad (6)$$

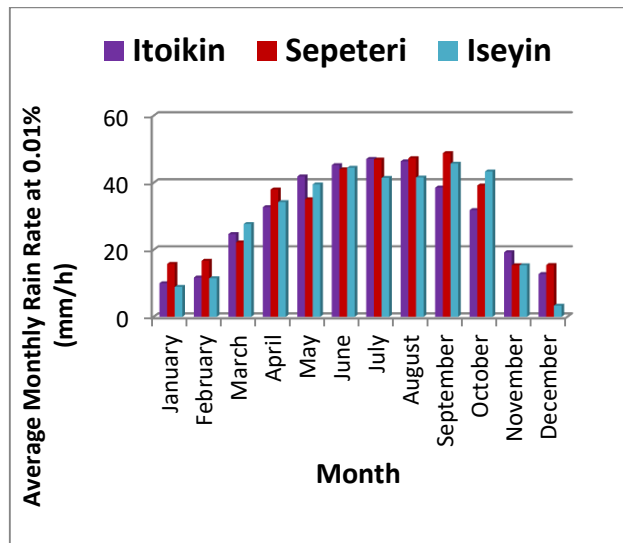
where r is correlation coefficient, N is total number of observations in the series, R is the observation in the series, Y is the time in years,  $\sigma_Y$  is the standard deviation of Y and  $\sigma_R$  is the standard deviation of R.

## **RESULTS AND DISCUSSION**

The peak rain rates of Itoikin, Sepeteri and Iseyin within the observation periods were 126.30mm/h, 140.52mm/h and 117.32mm/h in the years 1996, 2008, 2014 and 2006 respectively. The mean rain rates at 0.01% time unavailability over various months of the year for the locations within the observation period is shown in Figure 1. On the average, Sepeteri had the highest mean rain rate of 109.32mm/h while Iseyin with 101.87mm/h ranks the lowest.

The statistical distribution of the annual one-minute cumulative rainfall rates derived at 0.01% time ordinate (corresponding to 52.56 minutes in a year) unavailability for the locations is represented in the scatter plots as revealed in Figure 2.

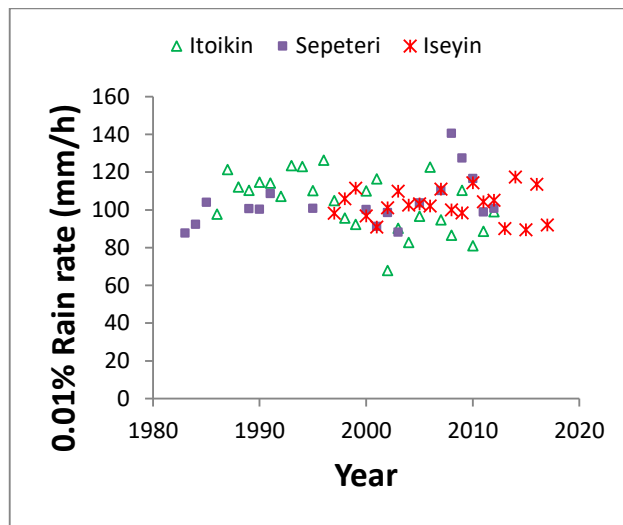
The fluctuation errors of the annual rain rate trend follow a normal distribution with standard deviation, coefficient of variation and correlation coefficient as obtained from simple linear regression are summarized in Table 2.



**Figure 1: Chart of average monthly rain rate for the locations**

Plots of trend lines of rain rate for the locations presented in the Figure 3 with the respective trend equations, shows that gradient of location Sepeteri out of the three considered is positive i.e.,  $a > 0$ . This indicates increase in the rain rate tendency.

The result overview through standard deviation and coefficient of variation (CV) indicates that the modeled rain rate deviates from the actual value. The occasional overshoot of the rain rate trend is largely due to variability caused by climate change.

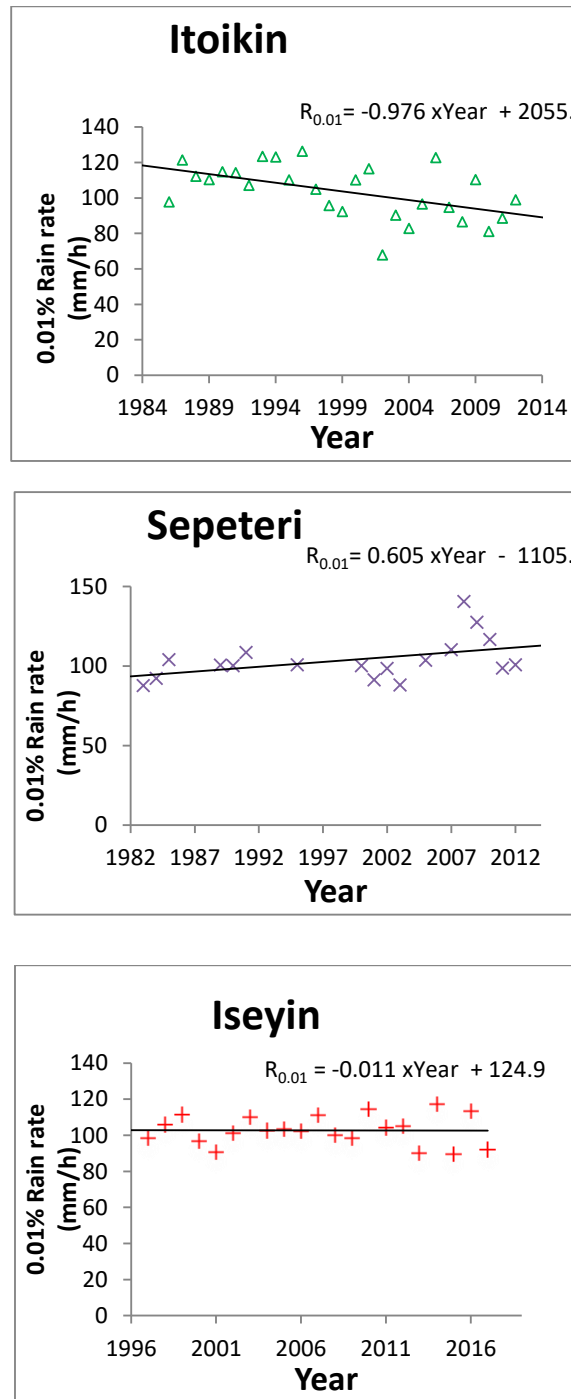


**Figure 2 Scatter plot of annual rain rate at 0.01% for the locations**

The coefficient of variation (CV) fluctuates, being higher as the modeled rain rate deviates from the actual value, showing variability with the yearly trend. However, analysis of the rain rate distributions using correlation coefficient of rain rate for the two remaining locations (Itoikin and Iseyin and) yielded a negative value which infers that their trend direction is actually the reverse of what was implied on the rain rate trend plots.

**Table 2. Trend Line regression coefficients of annual one-minute rain rate at 0.01% exceedance**

		Itoikin	Sepeteri	Iseyin
Coefficients of Annual Rain Rate Trend Regression	a	-0.976	0.605	-0.011
	b	2055	-1105	124.9
Variation Performances	Standard Deviation ( $\sigma$ )	15.089	13.816	8.229
	Coefficient of Variation (CV)	14.553	13.440	8.013
	Correlation Coefficient ( $r$ )	-0.495	0.424	-0.008



**Figure 3 Plot showing trend lines of rain rate for the locations**

**CONCLUSION**

This research has provided information on the intensity of rain as it relates to rain rate in six locations in the southwest of Nigeria. It was found that the months of June, July, August, September and October experienced heavy and more intense rain, thereby implying high

probabilities of the fade occurrence for these months. Also, the locations under study are experiencing progressive rise in rainfall intensity. This increase in total rainfall suggests a change in the corresponding rainfall rate distribution. Hence, there is likelihood that rain rate will be more severe since observed rainfall trend depicts reasonable rise as a result of climate change and therefore needs to be taken into cognizant consideration towards future planning.

### **REFERENCES**

- Ajayi, G. O., Feng, S., Radicella, S. M., and Reddy, B. M. (1996). *Hand book on Radio Propagation Related to Satellite Communications in Tropical and Subtropical Countries*. U.R.S. I Standing Committee on Developing Countries, UNESCO and ICTP.
- FEWS NET/USGS CHIRPS. (2016). *NIGERIA special Report: Famine Early Warning Systems Network*. Retrieved 2017, from FEWS NET: <https://earlywarning.usgs.gov/fews>
- International Telecommunication Union Radio communication, ITU-R, (2005). Specific attenuation model for rain for use in prediction methods. *Recommendation ITU-R P.838-3*.
- Mandeep, J. S. and Allnut, J. E. (2007). Comparison of rainfall properties on VHF & UHF bands in Krojak 2. *Progress in Electromagnetic Research*, 76, 65 – 74.
- Odjugo, P. A. (2005). An analysis of rainfall pattern in Nigeria. *Global J. Environ. Sci.*, 4 (2), 139-145.
- Omotosho, T. V. and Oluwafemi, C. O. (2009). One-minute rain rate distribution in Nigeria derived from TRMM satellite data. *Journal of Atmospheric and Solar-Terrestrial Physics* 71, 625–633.
- Perez-Garcia, N. and Silva-Mello, L. A. R. (2004). Improved method for prediction of rain attenuation in terrestrial links. *ResearchGate*, 40 (11), 683-684.
- Pratt, T., Bostian, C. and Allnut, J. (2006). *Satellite communication, Second edition*. Wiley India Pvt. Ltd. 536.
- Semire, F. A., Rosmiwati, M-M., Omotosho, T. V., Ismail, W., Mohamad, N. and Mandeep, J. S. (2012). Analysis of Cumulative Distribution Function of 2-year Rainfall Measurements in Ogbomoso, Nigeria. *International Journal of Applied Science and Engineering.*, 10 (3), 171-179.

Semire, F. A. and Raji, T. I. (2011). Characteristics of Measured Rainfall Rate at Ogbomoso, Nigeria for Microwave Applications. *Journal of Telecommunication and Information Technology*, 2, 85-89.

Semire F. A., and Rosmiwati M-M., (2011). Development of Rain Rate Prediction Model for Nigeria. *Canadian Journal of Pure and Applied Sciences* , 5 (. 3), 1721-1728.

Wikipedia, (2017), Rain Fade. Available from [https://simple.m. HYPERLINK "wikipedia.org/wiki/Rain" wikipedia.org/wiki/Rain](https://simple.m.wikipedia.org/wiki/Rain) , accessed on May 2017.

World Health Organization, WHO. (2003). *Climate Change and human health – risks and responses*. Geneva: World Health Organization.

## **DEVELOPMENT AND PERFORMANCE EVALUATION OF A PV-BASED SOLAR TRAINER**

Lawal, M. O., Olanrewaju, M. D. and Afolabi, O. O.

Department of Electrical and Electronic Engineering,  
Osun State University, Osogbo, Osun State, Nigeria.

[muyideen.lawal@uniosun.edu.ng](mailto:muyideen.lawal@uniosun.edu.ng)

### **ABSTRACT**

The objective of this work is to construct a simple and affordable pv-based solar training kit for laboratory study of solar panel electrical characteristics. The major motivation for this work is the expensiveness of the imported trainer that is mostly available. The trainer has been developed with incandescent lamp to simulate the sun, light dimmer to vary the intensity of the lamp, cooling fan to consume the energy from the panel and a multimeter to measure the electrical parameters of the kit. A lux meter has also been used to monitor the light intensity of the lamp as the dimmer varies the light brightness. The trainer has been used to perform various experiments to evaluate its performance. The results of the evaluation are presented and discussed.

**Keywords:** Solar Energy, Solar Panel, Light Radiation, Training Kit, Meter

### **INTRODUCTION**

Energy from sunlight also called solar energy can be converted into electricity through the combination of many photovoltaic (PV) solar cells which forms the solar panel (Lund, 2010). It can also be harnessed through solar collectors which are used to concentrate the heat from the sun to heat water to steam which could be used to drive a turbine in order to generate electrical energy (Fardo and Patrick, 2009; Cossent et al., 2011). The sun is a major source of unlimited free energy (i.e., solar energy). Advantages of solar energy are that it is available almost everywhere on earth, it is non-polluting and requires little maintenance. The major disadvantages associated with this energy system are that; the initial cost is expensive, it is weather dependent, hence requires storage and it requires lots of space (Liang et al., 2007; Patel, 1999).

The PV system is the most widely adopted. To make best use of the solar PV systems, the output is maximized either by mechanically tracking the sun and orienting the panel in such a

direction so as to receive the maximum solar irradiance or by electrically tracking the maximum power point under changing condition of insolation and temperature. The overall performance of solar cell varies with varying irradiance and temperature. With the change in the time of the day, the power received from the sun by the PV panel changes (Ranjit *et al.*, 2012).

Simulating how the conversion of light into electricity using PV cells in the laboratory is essential so as to make student have a first-hand experience on parameters that affect the operation of PV-based solar power systems. Tools developed for such purpose are usually referred to as solar training kit or solar energy trainer. This kit usually makes student to understand the relationship that exists between;

- (i) the light radiation and energy deliverable,
- (ii) the angle of light incidence and energy deliverable,
- (iii) the height of light source and energy deliverable and so on.

The relationship between the light radiation and the energy output will allow the student to appreciate the effect of varying irradiance on the panel's output. The relationship between the angle of light incidence and energy deliverable will make student to appreciate the importance of tracking the sunlight for maximum output. Varying the height of the light source will show the effect of different height of installation.

The trainers usually used in the laboratories of developing countries are usually imported from abroad, hence, the price of such trainers are usually high as a result of high exchange rate, import and other duties. To avoid spending much on trainer, it is essential to look inward and develop some of the trainers used in the laboratories of such countries. In view of this, this work develops a PV-based solar training kit that will make student to understand various factors that contributes to solar power energy through solar panel.

## **MATERIALS AND METHODS**

The materials used for this training kits are; 10W PV panel, digital multimeter, lux-meter (multipurpose), adjustable frame, lamp holder, 2-200W tungsten filament lamp, light dimmer, connecting leads, DC fan, DC power supply unit and 13A plug. These materials have been sourced both locally and abroad. The multimeter and the lux meter have been sourced abroad while all other materials are sourced locally. It has been discovered that sourcing the two meters locally is expensive when compared to sourcing from abroad.



The panel receives light energy from the tungsten lamp and convert the energy into electrical energy that powers the DC fan which serves as the load. In between the panels and the fan is a multimeter which measures the voltage, current and the power delivered to the load. The light dimmer which is connected to the two lamps has been used to simulate the varying nature of the sunlight. The 200W lamps are supplied from an alternating current (AC source). The lux meter is to monitor the luminance level at the panel for every brightness of the light. The multimeter needs a 7-12VDC, hence the need for a power supply unit. A protractor has been attached to one side of the connecting arm to the panel to monitor the angle of incidence. A blind is being developed to reduce the effect of the surrounding light on the trainer. All the metal parts are made of aluminium material. The completed trainer is shown in Figure 1. The total cost of producing this trainer is approximately thirty thousand naira (84 dollars).

Various experiments have been carried out on this trainer to test its performance. The experiments carried out are to study the;

- (i) effect of luminance on solar panel outputs.
- (ii) effect of incident angle of illumination on solar panel outputs.
- (iii) effect of distance of light source on solar panel

To study the effects of luminance level on the solar panel outputs, the light dimmer is adjusted to give an illumination level that varies from 8000 to 40000 Lux in a step of 8000 Lux. The procedure in carrying this is itemized below;

- (i) Switch on the AC source to power the Lamps and the multimeter.
- (ii) Adjust the height of the lamp to 15cm from the panel and make the angle of light incidence to be  $90^\circ$  to the panel.
- (iii) Place the lux meter at the center of the panel.
- (iv) Adjust the illumination level of the lamp until the reading on the lux meter is 8000 Lux.
- (v) Record the readings on the multimeter
- (vi) Repeat (iii) to (v) for illumination of 16000, 24000, 32000 and 40000.
- (vii) Tabulate your results.

To study the effect of the light angle of incidence on the solar panel outputs, the angle of incidence has been varied between  $90^\circ$  and  $30^\circ$  in step of  $15^\circ$ . The procedure used in carrying out this experiment is given below;

- (i) Switch on the AC source to power the Lamps and the multimeter
- (ii) Adjust the height of the lamp to 15cm from the panel and make the illumination at the center of the panel to be 40000 Lux using the luxmeter.

- (iii) Adjust the arm attached to panel and lamp until the mark on the arm is at  $90^\circ$  to the panel.
- (iv) Record the readings on the multimeter.
- (v) Repeat (iii) to (iv) for angles of  $75^\circ$ ,  $60^\circ$ ,  $45^\circ$  and  $30^\circ$ .
- (vi) Tabulate your results.



**Figure 1. The Completed kit**

To study the effect of the distance of light source on solar panel outputs, the height of the lamp is moved between 20cm to 45cm in step of 5cm. The procedure used in carrying out this experiment is given below;

- (i) Switch on the AC source to power the Lamps and the multimeter.
- (ii) Adjust the light angle of incidence to  $90^\circ$  and make the illumination at the center of the panel to be 40000 Lux using the lux meter.
- (iii) Adjust the height of the lamp to 20cm.
- (iv) Record the readings on the multimeter.
- (v) Repeat (iii) to (iv) for heights of 25cm, 30cm, 35cm, 40cm and 45cm.
- (vi) Tabulate your results.

## **RESULTS AND DISCUSSION**

After carrying out the experiment outlined in the previous section, the results of the experiments will be presented and discussed.

### **Effect of luminance on solar panel outputs**

Table 1 shows the implication of varying the illumination level of the lamp on the solar panel. It can be observed from this table that the higher the illumination level of the lamp, the higher the voltage, current and the power. The implication of this in real life is that, the more

the solar radiation, the more the power that will be delivered to the load connected to the solar panel.

Table 1: Effect of illumination level on solar panel output

Illumination (Lux)	Voltage (V)	Current (A)	Power (W)
8000	5.9	0.04	0.21
16000	11.9	0.10	1.19
24000	15.1	0.14	1.98
32000	17.8	0.16	2.78
40000	18.4	0.17	3.00

#### **Effect of incident angle of illumination on solar panel outputs**

Table 2 shows the influence the angle of incidence has on the solar panel output. It can be observed that, as the angle of incidence reduces, the electrical outputs from the panel reduce. The implication of this is that, the movement of sun from the point it rises to the point it sets affects the electrical outputs of a fixed solar panel. This is the major reason why the sun is being tracked for maximum output. If the solar panel can be made to always be at 90° to the sunlight, it will be able to deliver more energy.

#### **Effect of distance of light source on solar panel**

Table 3 shows the effect of distance of light source to the solar panel. It is clear that, the higher the light source, the lesser the electrical output of the panel. This shows that, the farther the sunlight, the lesser the output deliverable from the solar panel.

Table 2: Effect of angle of incidence on solar panel output

Angle (Degree)	Voltage (V)	Current (A)	Power (W)
90°	18.4	0.17	2.99
75°	18.3	0.16	2.87

60°	17	0.15	2.50
45°	12.2	0.11	1.29
30°	8.0	0.06	0.45

Table 3: Effect of height of light source on solar panel output

Height (cm)	Voltage (V)	Current (A)	Power (W)
20	18.1	0.17	2.92
25	17.2	0.16	2.68
30	16.8	0.15	2.41
35	15.8	0.14	2.17
40	13.7	0.14	1.88
45	13.4	0.14	1.78

## CONCLUSION

A PV-based solar trainer that is simple and affordable has been developed in this work. The performance of the developed trainer has been shown by conducting three different experiments. The results of the experiments have shown that the trainer can be effectively used to study the electrical characteristics of the solar panel, hence, educate students on PV based solar technology. The total cost of producing this trainer is a pointer to its affordability.

## REFERENCES

- Cossent, R., Gomez, T. and Olmos, L. 2011. Large-Scale Integration of Renewable and Distributed Generation of Electricity in Spain: Current Situation and Future Needs. *Energy Policy*, 39, pp. 8078–8087.
- Fardo, S.W. and Patrick, D.R. 2009. *Electrical Power Systems Technology*, The Fairmont Press, Indian.

- Liang, R. H. and Liao, J. H. 2007. A Fuzzy-Optimisation Approach for Generation Scheduling with Wind and Solar Energy Systems. *IEEE Transaction on Power Systems*, 22(4), 1665-1674.
- Lund, H. 2010. *Renewable Energy Systems: The Choice and Modeling of 100% Renewable Solutions*. Academic Press, New York.
- Patel, M. R. 1999. *Wind and Solar Power Systems*. CRC Press LLC, Boca Raton, Florida.
- Ranjit, S.S., Anas, S.A., Subramaniam, S.K, Tan, C.F. and Chuah, S.H 2012. “Development of Solar Educational Training Kit, *International Journal of Engineering and Innovative Technology*, 2(3), pp. 25-29.

## **POWER FLOW ANALYSIS OF OSOGBO 33-KV DISTRIBUTION NETWORK**

Lawal, M.O.<sup>1\*</sup> and Olasupo, B.I.<sup>2</sup>

<sup>1</sup>Department of Electrical and Electronic Engineering,  
Osun State University, Osogbo, Osun State, Nigeria.

<sup>2</sup>Operations Department,  
National Identity Management Commission,  
Oyo State Headquarters, Ibadan, Oyo State, Nigeria.

\*[muyideen.lawal@uniosun.edu.ng](mailto:muyideen.lawal@uniosun.edu.ng)

### **ABSTRACT**

This work studies the power flow analysis of the Osogbo distribution network. The power flow solution has been achieved using existing software. The system parameters required as input data for the software have been calculated from raw data obtained from the distribution company. The base MVA and kV have been selected to be 100-MVA and 33-kV, respectively. The analysis has been carried out with and without reactive support. The results have shown that the inclusion of reactive support has reduced the systems' real and reactive power loss, total real power required at main substation and the overall voltage profile has been significantly improved.

**Keywords:** Power Flow, Reactive Support, Voltage Profile, Power Loss, Distribution Network

### **INTRODUCTION**

The three major stages of electric power systems are generation, transmission and distribution. Out of these three stages, the distribution network is the closest to the end users of electricity (Wadhwa, 2005). Irrespective of how efficient are the generation and transmission stages, if the distribution network is not well planned, the quality of power supply to the consumers may be greatly affected (Grainger and Stevenson, 1994). The efficiency of the distribution network is a key pointer to the efficiency of the other two stages, since most loads are connected to the distribution network. For example, if the distribution network is not efficient, the generation stage will be affected, since the principle of power balance requires the usage of electrical energy as it is being generated (Weedy, 1972). If the power consumed at the distribution level is more or less than the generated, the generators at the generating plants may go out of synchronism and this may cause total system collapse. One way to ensure

system security and balance is through power flow analysis (PFA) (Gonnen, 1988). PFA has the ability to reveal the total amount of power needed, amount of reactive injection required to maintain voltage within a tolerance level, the suitable bus for the injection and appropriate expansion needed in the entire network.

Power flow (PF) study ensures that at any given period, generation must track both the customers' demands and line losses. PF is used to determine the magnitude and phase angle of voltage at each bus and power flow in each line (Sadaat, 2002). In solving PF problem, the system is assumed to be operating under a steady-state condition. A power flow study can be carried out on transmission, sub-transmission and distribution networks. What differentiates these three networks is the voltage level of operation. In Nigeria, the transmission and sub-transmission voltage level are, respectively, 330-kV and 132-kV. The distribution network operates at 33-kV, 11-kV and 0.415-kV. Most industrial premises are always supplied with 33-kV and 11-kV while residential premises are supplied with 0.415-kV three-phase or 0.24-kV single-phase.

Various researchers have used PFA as the basics for their various works on the distribution network of some locations in Nigeria. These works have investigated the harmonics, voltage profile and power loss in the system. The usage of distributed generation and reactive power support to improve the system have also been investigated. In the work of (Adesina and Fakolujo, 2015), the distribution network harmonics of the Eko Electricity Distribution Company's 33-kV network was investigated and presented. Abdulkareem et al. (2014) performed a PFA on some part of the Abule-Egba distribution network to study the impact of reactive power injection on the improvement of the voltage profile of the network. Idoniboyeobu and Ibeni- (2017) also used PFA to identify buses with low voltages and subsequently injected reactive power to improve the voltage profile of the 33-kV distribution network in a town in Portharcort city. (Okereafor et al., 2017) used the PFA to analyse the 33/11-kV River State University, Portharcort Injection Substation for Improved performance using DG units. These units have been used to improve power losses and low voltage profile. The analysis also ensured optimal placement and size of DG.

There are situations where PFA reveals some lapses in the system. One of such lapses is the violation of voltage magnitude limits, which can be corrected with appropriate reactive supports (Komolafe and Lawal, 2015). Examples of devices that are used for reactive supports

are shunt reactors, shunt capacitors, static var compensators and static synchronous compensators STATCOM's. Shunt reactors are designed to regulate high voltage magnitude while shunt capacitors are designed for low voltage magnitude. Unlike these two devices, the SVC's and STATCOM's can conveniently and flexibly perform the functions of these two devices depending on the operating condition of the network (Acha et al., 2004). The main objectives of this work are to show the effect of reactive power injection on an existing network; to determine the suitable bus for reactive power injection in the network and to study the performance of the network. All these objectives have been carried out with the aid of the PFA.

### POWER SYSTEM FORMULATION FOR POWER FLOW ANALYSIS

A popular approach to mathematically represent the steady-state operation of a power system is to write equations stipulating that at a given bus, the generation, load, and power exchanged through the transmission elements connecting to the bus must add up to zero. This applies to both active power and reactive power. These equations are termed 'mismatch power equations' and at bus  $i$  they take the following forms (Acha *et al.*, 2004):

$$P = P_i + P_{di} - P_{gi} = 0 \quad (1) \quad Q = Q_i + Q_{di} - Q_{gi} = 0 \quad (2)$$

where

$$P_i = V_i \sum_{k=1}^{nb} V_k Y_{ik} \cos(\delta_k - \delta_i + \theta_{ik}) \quad (3) \quad Q_i = -V_i \sum_{k=1}^{nb} V_k Y_{ik} \sin(\delta_k - \delta_i + \theta_{ik}) \quad (4)$$

where

$V_i$  and  $V_k$  are the voltage magnitudes at buses  $i$  and  $k$ , respectively.

$\delta_i$  and  $\delta_k$  are the voltage phase angles at buses  $i$  and  $k$ , respectively.

$Y_{ik}$  and  $\theta_{ik}$  are, respectively, the magnitude and angle of the admittance of the line connecting buses  $i$  and  $k$  together.

$P_{di}$  and  $Q_{di}$  are, respectively, the active and reactive power load at bus  $i$ .

$P_{gi}$  and  $Q_{gi}$  are, respectively, the scheduled active and reactive power generations at bus  $i$ .

Solving Equations (1) and (2) gives the PF solution.

In PFA solution procedure, the nodes or buses are classified based on the known and the unknown variables. For example, the bus where the real and reactive powers are known and the voltage magnitude and angle are unknown is referred to as load bus. The bus where the real power and the voltage magnitude are known while the reactive power and the voltage angle



are unknown is referred to as generator bus. Lastly, the bus where the voltage magnitude and angle are known while the real and reactive powers are unknown is the slack bus. During the solution procedure, the bus with known real and/or reactive power forms the basis for the number of equations that are to be solved. For example, a load bus will have two equations (i.e. for  $P$  and  $Q$ ) to be solved while a generator bus will have just one equation (i.e. for  $P$ ) to be solved. So, if a power system contains two generator buses and four load buses, the equations to be solved will be ten (i.e. two for the generator buses and eight for the load buses). In summary, the known  $P$  and  $Q$  will be used to determine the unknown  $\delta$  and  $V$  after which the known and the determined  $\delta$  and  $V$  will be used to determine the unknown  $P$  and  $Q$  in the system.

Since Equations (1) and (2) are non-linear, the PF problem is often solved with iterative methods of solving non-linear equations. The two most popular methods used for PF problem are Gauss Seidel and Newton-Raphson. From the literature, the Newton-Raphson method is commonly applied because of its rapid convergence characteristics (Sun *et al.*, 1984). This paper has adopted the N-R method to solve the PF problem of the Osogbo Distribution network.

#### **POWER FLOW SOLUTION USING NEWTON-RAPHSON**

The N-R iterative method of solving PF problem has been extensively discussed in the past. The N-R method of solving PF problem requires the linearization of Equations (1) and (2). Linearizing these equations yields Equation (5).

$$[J] \begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix} = \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \quad (5)$$

where

$$J = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{bmatrix} \quad (6)$$

$\Delta P$  and  $\Delta Q$  are the calculated power mismatch for

every iteration.

$\delta$  and  $V$ , respectively, represent all the voltage angle and magnitude relating to the equation being solved.

$\Delta\delta$  and  $\Delta V$  are, respectively, the increment or decrement in  $\delta$  and  $V$ .

At the end of each iteration, the variables are updated as follows:

$$\left. \begin{aligned} \delta^{new} &= \delta^{old} - \Delta\delta \\ V^{new} &= V^{old} - \Delta V \end{aligned} \right\} \quad (7)$$

In PF solution procedure, the unknown  $\delta$  and  $V$  are initialized at zero and one, respectively. Equation (7) is used to adjust these two values at every iteration until the power mismatch in Equation (5) is within a tolerance margin of approximately zero.

The software program developed by (Sadaat, 2002) is used for this work. For any PF program, some data are needed. Some of such data are the power demand (real and reactive) at load buses, real power at the generator buses, known and initialized voltage magnitudes and angles, line parameters and the reactive power injection.

### DETERMINATION OF NEEDED SYSTEM PARAMETERS

In the distribution network of Osogbo 33-kV undertaking, overhead lines are used to convey the electric power from the 132/33-kV transmission substation to the various 33/0.415-kV distribution substations in the town. The transformers at the substations are 33/0.415-kV step down transformers and the size of the conductor used is 100 mm<sup>2</sup>. Tables 1 and 2, respectively shows the equivalent resistance and reactance for different conductor sizes.

Table 1: 33-kV line Resistance (R)

<b>Nominal Conductor Size (mm<sup>2</sup>)</b>	<b>Copper (Ohmkm<sup>-1</sup>)</b>	<b>Aluminum (Ohmkm<sup>-1</sup>)</b>
<b>25</b>	0.930	1.54
<b>35</b>	0.671	1.11
<b>50</b>	0.495	0.82
<b>70</b>	0.343	0.567
<b>95</b>	0.247	0.410
<b>120</b>	0.196	0.324
<b>150</b>	0.159	0.264

(Source: Olasupo, 2012)

It is observed that the data for 100mm<sup>2</sup> conductor size is missing in the tables. Therefore, interpolation has been used to find the resistance and reactance for the used conductor size to be 0.3928 Ωkm<sup>-1</sup> and 0.126 Ωkm<sup>-1</sup>, respectively.

Table 2: 33-kV line Reactance (X)

<b>Nominal Conductor Size (mm<sup>2</sup>)</b>	<b>Armored Cable (Ohm km<sup>-1</sup>)</b>	<b>Un-Armored Cable (Ohm km<sup>-1</sup>)</b>
<b>50</b>	0.147	0.140
<b>70</b>	0.141	0.133
<b>95</b>	0.135	0.127
<b>120</b>	0.130	0.122
<b>150</b>	0.126	0.118

(Source: Olasupo, 2012)

The impedance of the transmission line per kilometer has been determined to be;

$$z = 0.3928 + j0.126 \Omega km^{-1}$$

and in per unit with a MVA base of 100 and kV base of 33,

$$z = 0.0361 + j0.0116 pu km^{-1}$$

The length of each line will dictate its total impedance.

The bus powers at the buses (except the slack bus) are calculated from the transformer ratings at the substations. For example, if a 300 kVA transformer is used in a substation, at a power factor of 0.85, the complex power is calculated as

$$\begin{aligned} S &= 0.3(0.85 + j0.5268) \\ &= 0.255 + j0.1580 \text{ MVA} \end{aligned}$$

Assuming a 95% loading,

$$S = 0.2423 \text{ MW} + 0.1501 \text{ MVar}$$

The only generator bus is assumed to be the incoming power from the 132/33-kV transmission line supplying the distribution system. Since one generator bus exists, the generator bus is considered the slack bus and the voltage magnitude and angle at this bus are 1.05pu and 0°, respectively.

Since one of the objectives of this work is to study the effect of reactive injection in the system, a 20-MVar reactive power has been used.

## **RESULTS AND DISCUSSION**

This section presents and discusses the results of the case study. The results of the PFA without the injection of any reactive power are first presented. After this is done, the effect of reactive injection on various systems' parameters is presented.

### **Description of Test System**

The 33-kV network of Osogbo town feeder consists of 31 buses and 30 interconnected transmission lines. The data used for this study together with the one-line diagram are contained in (Olasupo, 2012).

### **Power Flow Results**

The PF solution converged in the fourth iteration. The maximum and minimum voltage magnitudes at all buses are 1.05 pu and 0.878 pu, respectively. It is obvious that the minimum voltage magnitude is below the tolerable limit of 0.9 pu, hence, the need to improve the systems voltage profile. Reactive power injection is needed to achieve this. Therefore, a reactive power injection test has been simulated on each bus to determine the most suitable bus to incorporate a capacitor bank. Reactive power of 10-Mvar and 20-Mvar are injected into individual buses and 20-Mvar performed better. The result has shown that Odiolowo 2 has the best performance out of the 31 buses tested with reactive power injection. Two cases are considered in this work; case 1: PF solution without reactive support and case 2: PF solution with reactive support.

Table 3 compares various parameters of the system. This table has shown that the injection of reactive power has reduced the total real power at the main substation by 5.08%, real and reactive power loss by 30.7%. The minimum voltage magnitude is now within the tolerable limit. The improvement in voltage profile for case 2 is shown in Figure 1. The value of capacitor bank required for 20-MVar of reactive support is calculated as:

Table 3: Effect of Capacitor Bank on Power Generation and Loss

<b>Case No.</b>		<b>Case1</b>	<b>Case2</b>
<b>Total</b>	<b>Active</b>	37.021	35.141
<b>Power</b>			
<b>Generated</b>			
<b>(MW)</b>			
<b>Total</b>	<b>Reactive</b>	21.104	0.501
<b>Power</b>			

<b>Generated</b>			
<b>(Mvar)</b>			
<b>Total</b>	<b>Active</b>	6.121	4.241
<b>Loss (MW)</b>			
<b>Total</b>	<b>Reactive</b>	1.964	1.361
<b>Loss (Mvar)</b>			
<b>Minimum</b>			
<b>Voltage</b>		0.8780	0.9077
<b>Magnitude (pu)</b>			

$$c = \frac{Q}{V^2 2\pi f} \quad (8)$$

Where  $Q$  is the reactive injection;  $f$  is the operating frequency;  $V$  is the voltage magnitude at Odiolowo 2.

$$c = \frac{20 \times 10^6}{(33000 \times 0.9307)^2 \times 2\pi \times 50}$$

$$c = 6.74889 \times 10^{-5} F$$

$$c \approx 0.7 \mu F$$

The value of the capacitor that has the ability to provide 20 MVar is 0.7  $\mu F$ .

## CONCLUSION

A Newton-based method for PF solution with and without the incorporation of a capacitor bank was investigated and discussed in this work. The main objective considered for this work is to study the effect of reactive power injection on real and reactive power generations and nodal voltage magnitudes. The results have shown that some system parameters have been improved with the incorporation of a capacitor bank of 0.7  $\mu F$  at Odiolowo 2. Some of the parameters improved are active and reactive loss, voltage profile. The reduction in the system loss has caused the reduction in the active power requirement at the injection station. As part of further work, the capacitor bank should be replaced with a DG to study the improvement this will achieve.

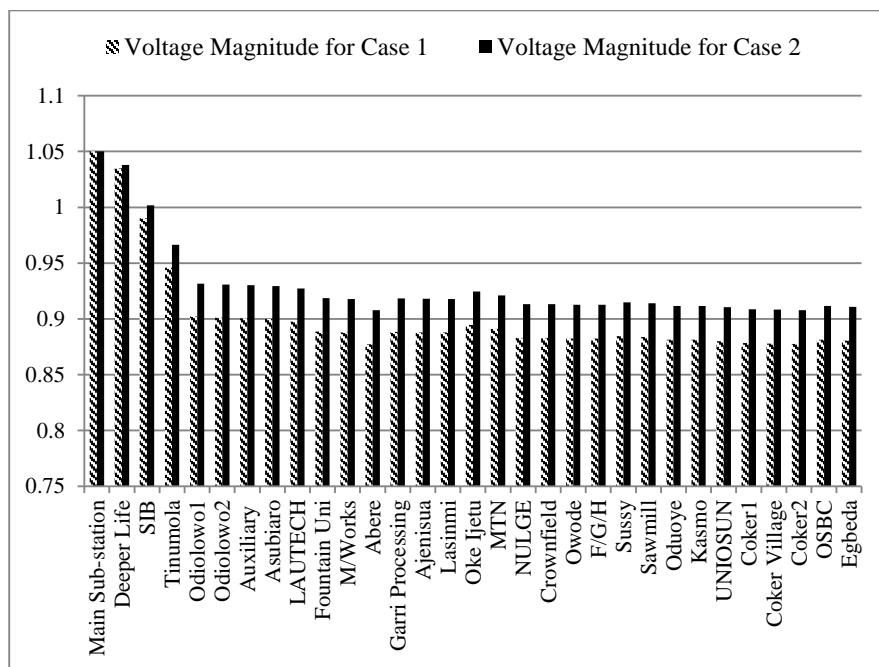


Figure 1: Voltage magnitude for different cases

#### REFERENCES

- Abdulkareem, A. Awosope, C.O.A. Orovwode, H.E. and Adetakun, A.A. 2014. Power Flow Analysis of Abule-Egba 33-kV Distribution Grid System with real network Simulations, *IOSR Journal of Electrical and Electronics Engineering*, Vol. 9(2), pp. 67-80.
- Acha, E., Fuerte-Esquivel, C. R., Ambriz Perez, H. and Angelas-Camacho, C., 2004. *FACTS Modeling and Simulation in Power Networks*, John Wiley and Sons Limited, England.
- Adesina, L.M. and Fakolujo, O.A. 2015. Harmonic Analysis in a 33kV Distribution Network: A Case Study of Island Business District. *African Journal. of Computing & ICT*. 8(2), pp 183-192.
- Gonnen, T., 1988. *Electric Power Transmission System Engineering Analysis and Design*, John Wiley and Sons Limited, New York.
- Grainger, J and Stevenson, W. 1994. *Power System Analysis*, McGraw-Hill, New York.
- Idoniboyeobu, D.C. and Ibeni C. 2017. Analysis for Electrical Load Flow Studies in Port Harcourt, Nigeria, Using Newton Raphson Fast Decoupled Techniques, *American Journal of Engineering Research*, 6(12), pp. 230-240.
- Komolafe, O. A. and Lawal, M. O. 2015. Optimal Power Flow Analysis of Nigerian Power Network Including FACTS Devices, *NSE Technical Transactions*, 49(1), 71-82.

- Okereafor, F.C.1, Idoniboyeobu, D.C., and Bala, T. K. 2017. Analysis of 33/11KV RSU Injection Substation for Improved Performance with Distributed Generation (DG) Units, *American Journal of Engineering Research*, 6(9), pp. 301-316.
- Olasupo, B. I. 2012. *A Power Flow Study of 33-kV Network of Osogbo Undertaking, Osogbo Distribution Station, Osogbo, Osun state, Nigeria*, B. Eng. Thesis at the Department of Electrical and Electronic Engineering, Osun State University, Osogbo, Osun State.
- Sadaat, H., 2002. *Power System Analysis*, Tata McGraw-Hill, New Dheli.
- Sun, D. I., Ashley, B., Brewer, B., Hughes, A. and Tinney, W. F. 1984. Optimal Power Flow by Newton Approach. *IEEE Transactions on Power Apparatus and Systems*, 103, 2864-2880.
- Wadhwa, C.L., 2005. *Electrical Power Systems*, Fourth edition, John Wiley and Sons, New York.
- Weedy B. M. 1972, *Electric Power Systems Second Edition*, John Wiley and Sons, London.

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## **DEVELOPMENT OF A DYNAMIC DEMAND FORECAST MODEL FOR JOB SHOP**

Idris, M. O.<sup>1\*</sup>, Enwerem, G. C.<sup>2</sup> and Kareem, B.<sup>3</sup>

<sup>1</sup>Mechanical Engineering Department, Osun State University, Osogbo

<sup>2</sup>Mechanical Engineering Department, The Federal Polytechnic, Ede.

<sup>3</sup>Mechanical Engineering Department, The Federal University of Technology, Akure.

\*Email of Corresponding Author: [musibaudeen.idris@uniosun.edu.ng](mailto:musibaudeen.idris@uniosun.edu.ng)

### **ABSTRACT**

Job shop is a manufacturing system that favours a low-to-medium volume production and schedules its work by jobs or batches. They do not have linear flow of the work. Instead, requirements and specifications determine the job routine. Since the unpredictability is so high, determination of quality and quantity of job to be performed at any time is not only vague but characterized with socio-techno economic factors from within and outside the premise of shop floor. Prior-knowledge of the demand is not only a sine qua non for effective planning and control of production system but also a condition for sustainability of any manufacturing company in this current competitive global market. Many traditional forecast models such as moving average, exponential smoothing, causal or econometric models being applied for short- and long- term demand/job predictions in job shops have not yielded a better result. In this work, a tractable dynamic demand forecast model was developed and tested using real demand data collected from a job shop located in Osogbo, Osun State, Nigeria. The model developed was an integration of Moving Average (MA) and Exponential Smoothing Approach (ESA). The dynamism feature of MA combined with the maneuverability inherent in ESA makes the model developed stands out, most especially for job shop environment. The accuracy of the model was evaluated using most popular forecast accuracy metrics; Mean Absolute Deviation (MAD), Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE). It was discovered that the model's performance was consistently better than the traditional models like, naïve, moving average, exponential smoothing approach in terms of error reduction in most of the test cases.

**Keywords:** Job shop, demand, forecast, dynamism, competition, and developing nations



## **INTRODUCTION**

Basically, there are two types of environments in manufacturing system. These are; flow shop and job shop. The flow shop uses continuous flow processes. These are commonly found in medium-to-high-volume production and all the jobs normally follow a similar pattern. In this method of production, the production capacity and resources are easily predictable and tractable because in flow shop, the demands are majorly make-to-stock (MTS) which make the production planning and control to be relatively independent of the customers' demands. On the other hand, demands in job shop are mostly make-to-order (MTO) system. Job shop is characterised with a low-to-medium volume production in which there is no definite work flow. The issues of market uncertainties, demand inequalities and resource limitations make the planning for job shop operation very dynamic and involving (Schaer et al., 2019). The complexity of the jobs in terms of the different operational requirements for its manufacture or processing and the infrastructural limitations in developing nations make the solution to job shop scheduling a dynamic one.

Appropriate job shop scheduling starts with the forecasting of the demand-supply chain (Kocaoglu et al., 2014). Demand forecasting, which is applicable in inventory management (Prak&Teunter, 2019), shipping, distribution routes, product manufacturing and equipment maintenance situations, enables product managers to plan future needs and to consequently make pertinent decisions. A very good demand forecast will accelerate the flow of raw materials, and services from the supplier, through the transformation stages in the shops to the final delivery to the customer, thereby optimising the use of man-hours and machine-hours while meeting the due date requirements, a condition that, not only woo new customers but also retain and sustain the existing customers (Idris, 2018). Forecasting is not only determines which product to produce, the quantity the consumers will demand for, but in some cases, it predicts when these products will be demanded (Kocaoglu, Acar & Yilmaz, 2014).

In literature, methods of forecasting are broadly grouped into; subjective methods, methods on average of past data, regression models on historical data, causal or econometric models and time-series analysis. Prak and Tunter (2019) submitted that despite the considerable amount of research that have been devoted to the optimal forecasting of various types of demands, no single method has successfully and consistently proved to be the best among the existing methods. Hence, current researches have focused on the combination of methods of predictions as a means of improving the forecasting accuracy. Such efforts are well documented in Clemen

(1989), De Menezes, Bunn, & Taylor (2000), Armstrong (2001), Timmerman (2006), Soll & Larrick, (2009), Wallis (2011) and Thomson et al. (2019).

The accuracy of a forecasting method not only depends on the methods used to determine the errors (Teunter and Duncan (2009), reliability and availability of data used (Schaeret al., 2019), but mostly on the pattern of the data (Boylan, Syntetos & Karakostas, 2008; Teunter and Duncan, 2009). Common classifications of demand patterns include; Smooth, irregular, slow-moving, erratic, highly erratic, mildly intermittent and highly intermittent (Eavesi&Kingsman, 2004 and Syntetosi, Boylan&Croston, 2005). In literature, there are scanty works that specifically study the job shop demands pattern; hence most early works arbitrarily used forecasting methods based on assumptions that are inappropriate when considering the effects of demand pattern on the accuracy of forecast method. (Eavesi and Kingsman, 2004).

In most of the job shops in the developing nations, there are scanty records from the previous jobs and the nature of each job which hardly like others necessitate the use of forecast methods that will rely on few past data and the one that will permit judgmental or experts' opinion. (Idris, 2010). Exponential Smoothing Approach (ESA) was considered as appropriate forecast method for job shops considering its features (Aderoba, 2000; Kareem & Aderoba, 2003) but Willemain et al. (1994) has early considered ESA for estimating demand which exhibit an intermittent pattern to be inadequate. In the works of Hsu et al.(2006) and Shakeel et al, (2016) data from job shops were employed to test the performance of various forecasting methods and their results show that ESA outperforms Moving Average and Simple Weighted Average (SWA). However, the former limited the data used to the indirect consumables needed in job shops while the latter considered the aggregate demand in job shop. Forecasting demand in a job shop based on these criteria could not be relied upon because one of the peculiarities of job shops is the discrete nature of the production system that is, each section of the job shop is independence and its demands may not necessarily affect the demand of other sections like in the case of flow shops.

Other researchers have shown that, ESA when combined with other forecasting methods produces more accurate results (Hsu, et al., 2006; Shakeelet al, 2016 and Thomson et al., 2019). However, these works assumed that activities in job shops could be treated like a flow shop activities where aggregate demands could be used. To the best knowledge of the researchers, there is no work that specifically forecast for each of the major activity centres in job shops. In

this study, moving average and exponential smoothing were integrated to evolve a new technique, Dynamic Exponential Smoothing Approach (DESA). This method is dynamic in nature because of the effects of moving average on the results of the ESA.

The study used this new method, DESA to forecast for demand hours for five major activity centres (turning, milling, welding, electrical and carpentry section) of a particular job shop situated in Osogbo. The results were compared with the actual demand hours from the shop for the period of twelve (12) months. Mean Absolute Error/Deviation (MAE or MAD), Mean Square Error/ Deviation (MSE or MSD) and Mean Absolute Percentage Error (MAPE) were used to evaluate the method's degree of accuracy.

### **DEVELOPMENT AND EVALUATION OF THE PROPOSED FORECAST MODEL**

Exponential smoothing and moving average were integrated to develop the new forecast model that aimed to reduce the error due to limited data analysis in job shop and to address its various peculiarities.

#### **Exponential Smoothing Approach (ESA)**

In using exponential smoothing approach only three pieces of data are needed (eqn. 1). These are; the most recent forecast ( $f_{t-1}$ ), the actual demand that occurred for that forecast period ( $a_{t-1}$ ) and a smoothing constant ( $\alpha$ ). This smoothing constant (ranges between 0 and 1) determines the level of smoothing and the speed of reaction to differences between forecasts and actual occurrences. The value for this constant is arbitrary and is determined both by the nature of the product and the feelings of the managers as to what constitute a good response rate. Stevenson and Hojati (2007) and Karmaker (2017) opine that defining the value of smoothing constant is a matter of judgment or trial and error.

ESA places most weight on the more recent data, giving estimates that are highest just after a demand and lowest just before a demand (Eavesi&Kingsman, 2004). This method is suitable for forecasting data with no clear trend or seasonal pattern. (Ostertagova and Ostertag, 2012) consider it to be the most widely used of all forecasting techniques that requires little computation and mostly used when data pattern is approximately horizontal (i.e., there is no neither cyclic variation nor pronounced trend in the historical data). The idea of exponential smoothing is to smooth the original series the way the moving average does and to use the smoothed series in forecasting future values of the variable of interest.

The Exponential Smoothing equation is shown in eqn. (1)

$$f_t = f_{t-1} + \alpha(a_{t-1} - f_{t-1}) \dots \text{eqn. 1}$$

(Source: Karmaker (2017))

### **Moving Average (MA)**

Moving Average is a time series constructed by taking averages of several sequential values of other times series. Moving average is used to describe this procedure because each average is computed by dropping the oldest observation and including the next observation. Variations on moving averages allow the number of points in each average to change. While moving averages are very simple methods, they are often building blocks for more complicated methods of time series smoothing, decomposition and forecasting. (Hyndman, 2009). A moving average is obtained by calculating the mean for a specified set of values and then using it to forecast the next period. That is, for n period moving average, the moving average forecast at time t ( $MA_t$ ) is

$$MA_t = (a_{t-1} + a_{t-2} + \dots + a_{t-n})/n \dots \text{eqn. 2}$$

(Source: Hyndman, 2009)

Eqn. 2 can as well be written as

$$MA_t = \left( \sum_{i=t-n}^{t-1} a_i \right) / n \dots \text{eqn. 3}$$

Where

$$t > 2 \text{ and } n \geq 2 \dots \text{eqn. 4}$$

Moving average can become *naïve* method of forecast if “n”, period of forecasting is set to be 1. In this situation, the next forecast will always be equal to the previous actual demand. That is;

$$MA_t = a_{t-1} \dots \text{eqn. 5}$$

The user of any naïve forecasting method is not concerned with causal factors, those factors that result in a change in actual demand. For this reason, the naïve forecasting method is mostly used to create a forecast to check the results of more sophisticated forecasting methods (Nordmeyer, 2018).

### **Proposed Forecast Method: Dynamic Exponential Smoothing Approach (DESA)**

Since the activities and demand pattern in job shop is dynamic, the authors considered the dynamic nature of moving average as important when forecasting for demands in job shops. They also considered the exponential smoothing approach which was preferred for data with

no clear trend or seasonal pattern and the flexibility in determine its smoothing constant, the major component in exponential smoothing approach that determines its accuracy (Karmaker, 2017), in producing *Dynamic Exponential Smoothing Approach (DESA)*.

Dynamic Exponential Smoothing Approach (DESA) is produce by integrating moving average into the exponential smoothing approach as shown in eqn. 6.

$$f_t = MA_t + \alpha(MA_t - f_{t-1}) \dots \text{eqn. 6}$$

Substituting eqn. 3 in eqn. 6 gives

$$f_t = [1+\alpha] \left[ \left( \sum_{i=t-n}^{t-1} a_i \right) / n \right] - \alpha f_{t-1} \dots \text{eqn. 7}$$

To get started the algorithm, an immediate past forecast, n-actual values and a smoothing constant are needed.

### Forecast Errors

Forecast evaluation involves comparing a set of predictions with their corresponding ex-post actual values. There are a variety of error measures that can be used for assessing forecast performances, including the mean squared error (MSE), the mean absolute error (MAE), the mean absolute percentage error (MAPE), and a range of related measures (Thomson et al., 2019).

Despite that there are various methods for determine the most appropriate forecast methods; there is no agreement among the researchers as to which method gives the best result. (Ostertagova & Ostertag, 2012, and Thomson et al., 2019). The accuracy is the major criterion to validate the best forecast method, and the method that gives the least error is considered as the best method. Forecast error (e) is the difference between the forecast values with their corresponding ex-post actual values (eqn. 8). There are a variety of error measures that can be used for assessing forecast performances, including the mean squared error (MSE), the mean absolute error (MAE), and the mean absolute percentage error (MAPE). These are mathematically described in equations 9, 10 and 11 respectively.

$$e_t = (a_t - f_t) \dots \text{eqn. 8}$$

$$MAE = \left( \sum_{t=1}^n |e_t| \right) / n \dots \text{eqn. 9}$$

$$MSE = \left( \sum_{t=1}^n e_t^2 \right) / n \dots \text{eqn. 10}$$

$$MAPE = \left( \sum_{t=1}^n \frac{|e_t|}{a_t} \right) / n \dots \text{eqn. 11}$$

Considering all these common indicators for measuring forecast accuracy, Ostertagova and Ostertag (2012) noted that *MAPE* is the most useful measure to compare the accuracy of forecasts since it measures relative performance. Also, it has advantages of scale-independency and interpretability. However, MAPE has the significant disadvantage that it produces infinite or undefined values for zero or close-to-zero actual values. (Kim & Kim, 2016). Thus, using MAPE, when two or more forecasting methods are compared, the one with the minimum MAPE can be selected as the most accurate.

### Evaluation of Dynamic Exponential Smoothing Approach

The model developed was evaluated by comparing it with the other widely used forecast models, such as naïve, moving average and exponential smoothing approach. Twelve months demand hours from the major activity centres of a job shop was collected. The data is presented in table 1. The data collected shows a random demand pattern as shown in fig. 1.

**Table 1:** Actual Demand Hours for Various Centres in a Job shop

Months	Turning Centre	Welding Section	Milling Section	Electric al	Carpent rv
1st	267	212	203	167	111
2nd	299	49	78	12	60
3rd	106	264	41	99	299
4th	116	257	41	211	180
5th	223	139	89	65	49
6th	159	279	25	251	194
7th	273	274	61	184	110
8th	235	198	71	92	107
9th	87	148	294	224	235
10th	213	49	227	138	215
11th	127	169	274	233	98
12th	90	147	156	299	120

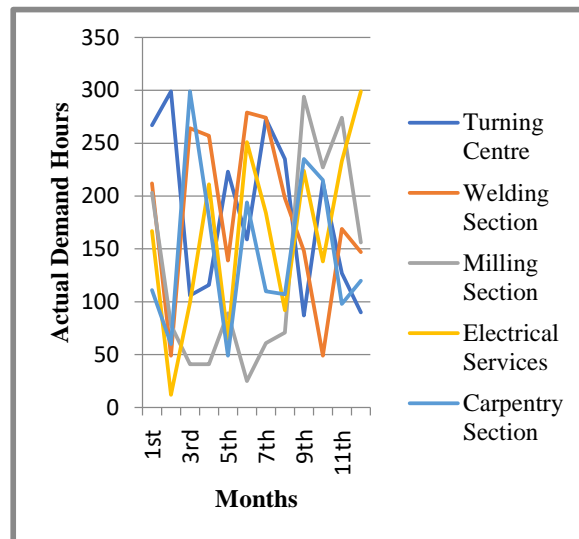


Fig. 1: 12 months Demand Hours for Various Centres in a Job shop

### Determination of forecasts using Naïve Approach

Naïve approach is simply a forecast method that considers the immediate past actual demand to be the current forecast. That is

$$f_t = a_{t-1} \dots \text{eqn. 12}$$

Where  $t > 1$

This approach is mostly used for comparison with the forecasts generated by the other sophisticated methods. Dhakal (2017). In computing this method, the first period cannot be determined since there is no prior value or data for the immediate past value. That is, the forecasts only exist from the second month.

### Determination of forecasts using Moving Average Approach

In using moving average approach, the forecast for the next period is the average of a specified number of the most recent past observations, with each observation receiving the same weight. Hence, the forecast for the period less than the specified period cannot exist. That is  $t \geq n + 1$ . In this work, three (3) months moving average was used, for this reason, forecasts only exist from the fourth months.

### Determination of forecasts using Exponential Smoothing Approach

In this work, 0.6 was used as the smoothing constant ( $\alpha$ ), a value favoured by many researchers (Karmaker, 2017). Since, in using ESA, the current forecast can only be determined if there is available immediate past forecast and its corresponding actual demand. Hence

forecasts could not be established for the first and second months. However, naïve method was used to forecast for the second month.

**Determination of forecasts using Dynamic Exponential Smoothing Approach**

This approach is the new model developed, which is the integration of the moving average and exponential smoothing approach, hence, it shared the same features with the moving average approach which invariably makes it impossible to generate forecasts for the first three months.

Tables 2 to 6 show the forecasts generated by using the above four approaches (naïve, moving average, exponential smoothing and dynamic exponential smoothing) for the five-job shop centres used for this work.

**Table 2:**Forecasts for Turning Centre

Months	Actual Sales	NAÏVE	ESA	Moving Average	DESA
1st	267				
2nd	299	267	267		
3rd	106	299	286		
4th	116	106	178	224	106
5th	223	116	141	174	214
6th	159	223	190	148	109
7th	273	159	171	166	200
8th	235	273	232	218	229
9th	87	235	234	222	218
10th	213	87	146	198	186
11th	127	213	186	178	174
12th	90	127	151	142	124

**Table 3:** Forecasts for Welding Section

Months	Actual Demand	NAÏVE	ESA	Moving Average	DESA
1 <sup>st</sup>	212				



2 <sup>nd</sup>	49	212	212		
3 <sup>rd</sup>	264	49	114		
4 <sup>th</sup>	257	264	204	175	264
5 <sup>th</sup>	139	257	236	190	146
6 <sup>th</sup>	279	139	178	220	265
7 <sup>th</sup>	274	279	238	225	201
8 <sup>th</sup>	198	274	260	231	248
9 <sup>th</sup>	148	198	223	250	252
10 <sup>th</sup>	49	148	178	207	180
11 <sup>th</sup>	169	49	101	132	103
12 <sup>th</sup>	147	169	142	122	134

**Table 4:**Forecasts for Milling Section

Months	Actual Demand	NAïVE	ESA	Moving Average	DESA
1st	203				
2nd	78	203	203		
3rd	41	78	128		
4th	41	41	76	107	41
5th	89	41	55	53	61
6th	25	89	75	57	55
7th	61	25	45	52	50
8th	71	61	55	58	63
9th	294	71	64	52	46
10th	227	294	202	142	200
11th	274	227	217	197	196
12th	156	274	251	265	306

**Table 5:** Forecasts for Electrical Services Centre

Months	Actual Demand	NAïVE	ESA	Moving Average	DESA
1 <sup>st</sup>	167				
2 <sup>nd</sup>	12	167	167		
3 <sup>rd</sup>	99	12	74		
4 <sup>th</sup>	211	99	89	93	99
5 <sup>th</sup>	65	211	162	107	112
6 <sup>th</sup>	251	65	104	125	133
7 <sup>th</sup>	184	251	192	176	202
8 <sup>th</sup>	92	184	187	167	146

9 <sup>th</sup>	224	92	130	176	194
10 <sup>th</sup>	138	224	186	167	151
11 <sup>th</sup>	233	138	157	151	152
12 <sup>th</sup>	299	233	203	198	226

**Table 6:** Forecasts for Carpentry Section

Months	Actual Demand	NAÏVE	ESA	Moving Average	DESA
1 <sup>st</sup>	111				
2 <sup>nd</sup>	60	111	111		
3 <sup>rd</sup>	299	60	80		
4 <sup>th</sup>	180	299	212	157	299
5 <sup>th</sup>	49	180	193	180	108
6 <sup>th</sup>	194	49	106	176	217
7 <sup>th</sup>	110	194	159	141	96
8 <sup>th</sup>	107	110	130	118	131
9 <sup>th</sup>	235	107	116	137	141
10 <sup>th</sup>	215	235	187	151	157
11 <sup>th</sup>	98	215	204	186	203
12 <sup>th</sup>	120	98	140	183	170

## RESULTS AND DISCUSSION

### Results

The outcomes of accuracy evaluation of the new model (*DESA*) on the bases of *MAE*, *MSE* and *MAPE* errors statistics as compared with selected traditional models are shown in Figures 3, 4 and 5 for *MAE*, *MSE* and *MAPE* respectively.

**Table 7:** *MAE* for different forecast methods

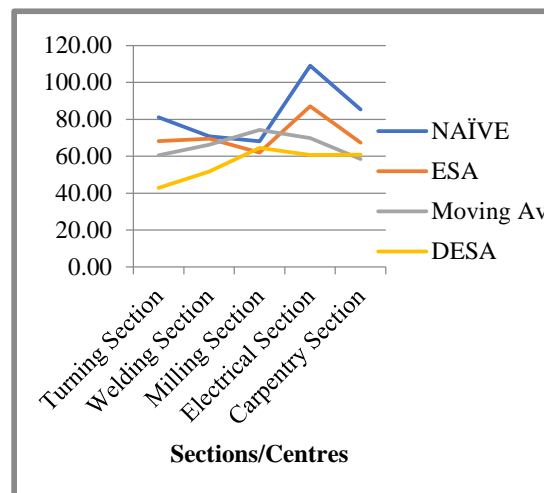
Section/ Centre	NAÏVE	ESA	Moving Average	DESA
Turning Section	81.11	68.16	60.59	42.83
Welding Section	70.78	69.53	66.22	51.67
Milling Section	68.11	61.99	74.26	64.55
Electrical Section	109.11	87.10	69.89	60.65
Carpentry Section	85.44	67.47	58.48	60.82

**Table 8: MSE for different forecast methods**

	NAÏVE	ESA	Moving Average	DESA
Turning Section	8514	6131	5538	3249
Welding Section	7395	6047	5958	4501
Milling Section	8683	7893	10037	10337
Electrical Section	13290	9029	6364	4996
Carpentry Section	10041	6528	4930	4982

**Table 9: MAPE for different forecast methods**

	NAÏVE	ESA	Moving Average	DESA
Turning Section	54.76	51.41	47.69	34.51
Welding Section	55.53	58.71	61.57	49.97
Milling Section	64.58	60.50	64.50	44.58
Electrical Section	74.70	57.29	40.91	35.87
Carpentry Section	76.54	67.78	60.04	50.05



**Fig. 2: Result of Mean Absolute Error**

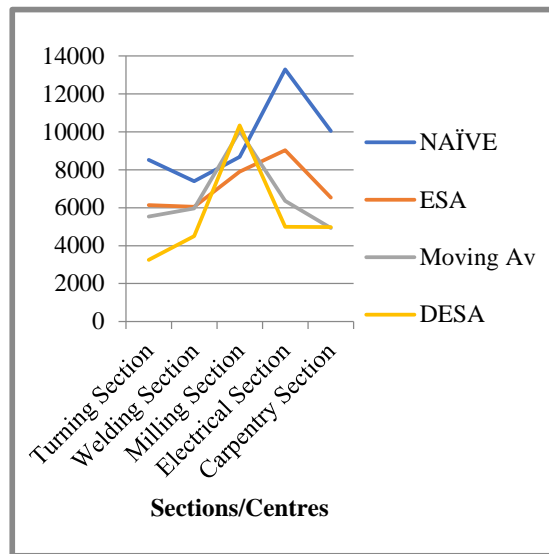


Fig. 3: Result of Mean Square Error

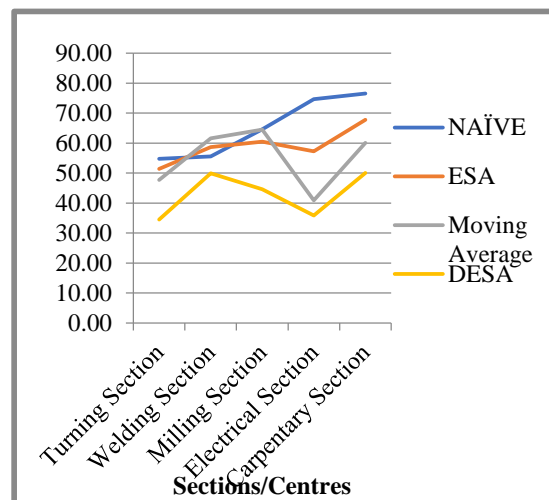


Fig 4: Result of Mean Absolute Percentage Error

### Discussion

Table 7 shows the values of Mean Absolute Error (*MAE*) for the four methods used. It is clearly shown that *MAE* for the new method *DESA* would have consistently performed better than the other methods in all sections of the job shop, if not for the carpentry section where moving average has a better *MAE* (58.48) when compared with the *MAE* for *DESA* (60.82). *MAE* results also revealed that after *DESA*, moving average approach is better than the remaining two methods (naïve and *ESA*) for having 60.59, 66.22, 74.26, 69.89 and 58.48 for turning, welding, milling, electrical and carpentry section respectively. However, in milling section, *ESA* and naïve methods ranked 2<sup>nd</sup> and third after *DESA* while moving average gives the worst

*MAE*. This result supported the position of Hyndman (2006) that *MAE* or *MAD* cannot be compared across series because it is scale dependent.

Table 8 reveals the performances of all the four methods for each of the centres on a using *MSE*. The result is also similar to the results got when using *MAE*, using this measure of accuracy, DESA was overall best method for all the centres. In table 9, the *MAPE* results obviously shows that DESA is more accurate when compared with other methods with *MAPE* values of 34.51%, 49.97%, 44.58%, 35.87% and 50.05% for turning, welding milling electrical and carpentry sections respectively. While moving average method followed with 47.69%, 40.91% and 60.04% in turning, electrical and carpentry sections respectively. In the other two sections, naïve and ESA are second to the best in welding and milling, respectively with 55.53% and 60.50%.

This result not only shows that DESA is proved to be the best among the other methods but also collaborate the fact that *MAPE* is the best forecast accuracy metric that could be employed where there is random demand pattern. The argument that planning and control in job shop cannot be treated on aggregate basis but on independent level is also shown by the result of this work.

## **CONCLUSION**

Need to have a least-error forecast method is highly important for planning and control of manufacturing system, most especially in job shop where the demand pattern is not only intractable but complex. Many of researchers have rated Exponential Smoothing Approach to be the best and others have proposed integration of ESA with other methods to have a better result. Strictly speaking, job shops environment had suffered negligence with regards the development of workable and specific model that will cater for its peculiarities. This study has developed a method by integrating moving average and ESA to evolve a dynamic forecast method called *Dynamic Exponential Smoothing Approach*. The approach, even though it is a derivative of ESA and moving average, when tested using different forecast accuracy metrics, such as *MAE* or *MAD*, *MSE* and *MAPE* gives better result than ESA, and moving average. Hence, using this model, for predicting job demands in job shops will not only solve one of the problems facing planning and control in job shops but also facilitate its sustainability.

## **REFERENCES**

- Aderoba A. A. (2000). Manpower Planning for New Job Shops. *Nigeria Journal of Engineering Management*. Vol.1 (4), pp. 1-4.
- Armstrong, J. S. (2001). Combining forecasts. In J. S. Armstrong (Ed.), *Principles of forecasting: a handbook for researchers and practitioners* (pp. 417–439). Norwell, MA: Kluwer Academic Publishers.
- Boylan, J. E.; Syntetos, A. A. and Karakostas, G. C. (2008). Classification for forecasting and stock control: A case study. *Journal of the Operational Research Society*. Vol. 5, pp. 473-481.
- Clemen, R. T. (1989). Combining forecasts: A review and annotated bibliography. *International Journal of Forecasting*, 5, 559–583.
- De Menezes, L. M., Bunn, D. W., and Taylor, J. W. (2000). Review of guidelines for the use of combined forecasts. *European Journal of Operational Research*, 120, 190–204.
- Dhakal, C. P. (2017). Naïve Approach for Comparing a Forecast Model. *International Journal of Thesis Projects and Dissertations (IJTPD)*. Vol.5(1), pp. 1-3.
- Eavesi, A. H. C. and Kingsman, B. G. (2004). Forecasting for the Ordering and Stock-Holding of Spare Parts. *Journal of the Operational Research Society* (2004) 55, 431–437.
- Hsu, M. X.; Pennington, P. B. and Olorunniwo, F. (2006). Sales Forecasting: A “Job Shop” Case Study Revisited. Retrieved on 23<sup>rd</sup> September, 2019 from <https://pdfs.semanticscholar.org/20bf/046bde9ec04e7d8b62afba8ff90d01d92b24.pdf>
- Hyndman, R. J. (2006). Another look at forecast accuracy metrics for intermittent demand. *Foresight: The International Journal of Applied Forecasting*, 4, 43–46.
- Hyndman, R. J. (2009). Moving Average. Retrieved from <https://robjhyndman.com/papers/movingaverage.pdf> on 27th September, 2019
- Idris, M. O. (2010). Review of Selected Models for Optimal Decision Making in Jobshops. *Journal of Engineering and Applied Sciences*. Vol.5(2), pp.138-145.
- Idris, M. O. (2018): “Evaluation of Effects of External Factors on Due Dates Prediction”, *Journal of Engineering and Engineering Technology*, Vol. 12 (2), pp. 250-260.

Kareem B. and Aderoba A.A. (2003). Assessment of Constraints affecting Maintenance Job Shop Operations in Nigeria. *Nigeria Journal of Engineering Management*. Vol. 4 (2), pp 29- 32.

Karmaker, C. L. (2017). Determination of Optimum Smoothing Constant of Single Exponential Smoothing Method: A Case Study. *International Journal of Research in Industrial Engineering* Vol. 6(3), pp. 184-192.

Kim, S and Kim, H. (2016). A New Metric of Absolute Percentage Error for Intermittent Demand Forecasts. *International Journal of forecasting*. Vol. 32, pp. 669-679.

Kocaoglu, B., Acar, A. Z., and Yilmaz, B. (2014): "Demand Forecast, Up-To-Date Models, and Suggestions for Improvement an Example of a Business." *Journal of Global Strategic Management*, Vol. 8 (1), pp. 26-37.

Nordmeyer, B. (2018). Types of forecasting. Retrieved from <https://bizfluent.com/info-8195437-types-forecasting-methods.html> on 17th September, 2019.

Prak , D and Teunter, R. (2019). A General Method for Addressing Forecasting Uncertainty In Inventory Models. *International Journal of Forecasting*. Vol.35, pp. 224–238

Ostertagova, E. and Ostertag, O. (2012). Forecasting Using Simple Exponential Smoothing Method. *Acta Electrotechnica et Informatica*. Vol. 12(3), pp. 62-66.

Schaer O., Kourentzes N. and Fildes R. (2019). Demand forecasting with user-generated online information. *International Journal of Forecasting*, 35, pp. 197–212.

Shakeel, M.; Khan, S. and Khan, W. A. (2016). Forecasting of Indirect Consumables for a Job Shop. Proceeding of the 14<sup>th</sup> International Symposium on Advanced Materials: Materials Science and Engineering 146.

Soll, J. B., & Larrick, R. P. (2009). Strategies for revising judgment: How (and how well) people use others' opinions. *Journal of Experimental Psychology – Learning Memory and Cognition*, 35(3), 780–805.

Stevenson, W. J., and Hojati, M. (2007). Operations Management. Boston: McGraw-Hill/Irwin

Syntetosi, A. A.; Boylan, J. E. and Croston, J. D. (2005). On the Categorization of Demand Patterns. *Journal of the Operational Research Society*. Vol. 56, pp. 495-503.

Teunter, R. H. and Duncan, L. (2009). Forecasting Intermittent Demand: A Comparative Study. *Journal of the Operational Research Society*. Vol. 60, pp. 321-329.

Timmerman, A. (2006). Forecast combinations. In G. Elliot, C. W. J. Granger, & A. Timmerman (Eds.), *Handbook of economic forecasting, vol. 1*. Amsterdam: North Holland.

Thomson, M. E.; Pollock, A. C.; Onkal, D. Gonul, M. S. (2019). Combining Forecasts: Performance and Coherence. *International Journal of Forecasting*. Vol. 35, pp. 474-484.

Wallis, K. F. (2011). Combining forecasts – forty years on. *Applied Financial Economics*, 21, 33–41.

Willemain, T. R.; Smart, C. N.; Shockor, J. H. and DeSautels, P. A. (1994). Forecasting Intermittent Demand in Manufacturing: A Comparative Evaluation of Croston's Method. *International Journal of Forecasting*. Vol. 10: 529–538.



## **A STUDY OF RESIDENTS' ROAD TRANSPORT SAFETY PERCEPTION AND AWARENESS IN OSOGBO, NIGERIA**

Fadare, S.O. and Olasupo, B.O.

Department of Urban and Regional Planning

Obafemi Awolowo University Ile-Ife

*e-mail: sfadare23@gmail.com*

### **ABSTRACT**

The study assessed residents' road transport safety in Osogbo. It examined socioeconomic and trip characteristics of residents; and assessed the residents' perception of the road transport infrastructure and safety facilities. The study employed cross-sectional analyses of data collected via questionnaire and analysed using descriptive statistics and five-point Likert scale. Primary data were obtained from residents in the three residential density zones: the high, medium and low-density areas in Osogbo and Olorunda local government areas, in Osogbo city. The residential areas were selected from the existing political wards in each density in the two local government areas. A simple random sampling technique was used for the selection of the wards. One ward in each of six zones were selected in the two local government areas. Systematic sampling technique was used to sample one out of every 10 residential buildings. A total of 213 questionnaires were administered in the residential zones of the study area. Findings revealed that majority (81.7%) of the respondents were male adult residents in the study area, 54% of the respondents had tertiary education and 39.4% earned between ₦21,000 to ₦70,000. Work and religious trips were the highest type of daily trips among the residents. On the awareness of transport infrastructure, 96.2% are aware of streetlights followed by road signs (98.6%), speed bump (86.9%), traffic light (83.1%) and street markings (73.7%). Personal car was considered the safest (RSI = 4.07). Other modes of transport were considered only safe, but commercial motorcycle is considered not safe with its relative safety index value of 2.01. The study revealed average RII of 3.13, 3.12 and 3.07 regarding the residents' awareness, compliance and satisfaction of road safety infrastructure and facilities respectively in the study area. The study concluded that the residents' safety awareness, compliance and satisfaction levels are above average but calls for Government intervention to provide policies

that will enhance the transport safety and security of the people and to provide facilities that will ensure same.

**Keywords:** *road transport; transport safety; perception; awareness; compliance*

## **1.0 INTRODUCTION**

Increase in population and the need to satisfy inevitable human activity systems have resulted to people, goods and services to move from one place to another. This movement is inevitably achieved through air, rail, water and road transport modes. However, of all these modes, road transportation is the most prominent and dominant in Nigeria particularly due to its flexibility and availability. It offers relative freedom to road users from one place to another according to their relative needs and conveniences (Okoko, 2006). There has been an increase in the number of vehicles registered in Nigeria according to the National Bureau of Statistics. It is therefore not surprising that road transportation in Nigeria faces critical problems such as poor road infrastructure, poor road networks and poor control of the transport system resulting in serious but preventable traffic crashes, injuries and death (Johnson, 2017). Concern for road transport safety has led to efforts to develop road infrastructure to the extent possible as there is still much more to do in this regard, to ensure safe, convenient and adequate mobility for all in Nigerians generally (Otegbulu, 2011).

Road transport safety refers to the situation whereby methods and measures are put in place to protect people from the risk directly or indirectly related to and arising from road transport (Safety and Security, 2014). It also connotes the application of methods and measures to prevent road users from being killed or seriously injured in the utilisation of road transport corridors. Road transport safety aims to reduce the harm (deaths, injuries, and property damage) resulting from crashes of road vehicles travelling on public roads. This is because, fatal and long-term crash injury is hugely predictable, mostly avoidable and a problem amenable to rational analysis and remedy.

Safety issues in urban transportation is an area of interest in urban planning as they have implications for the various aspects of the lives of urban dwellers, and for urban transportation planning and engineering, especially in urban areas where human activity system is relatively high. Osogbo is an important urban area in Nigeria considering the rate of its physical development and its economic and political significance. Its transportation system and characteristics have played a vital role in this development. However, for the development to

be sustainable, the safety of the road users is essential. Any upgrading in road transport safety requires an adequate study of the situation as a basis for reliable policy responses. For this to happen, it will be necessary for the urban residents who by default are road users to be aware and have a clear perception of the nature and characteristics of the available road safety infrastructure. It is against this background that this study looked into the situation of road transport safety in Osogbo, the Osun State capital in Nigeria.

The study therefore examined the level of perception and awareness of road traffic safety infrastructure open to the road users residents in Osogbo, with a view to providing information that could engender safe urban mobility. The study implicitly examined the socioeconomic characteristics of residents, the intra-urban trip characteristics of residents in the study area; the road transport safety infrastructure available and their condition in the study area. It also assessed residents' perception, awareness and level of satisfaction of road transport infrastructure and safety facilities in the study area.

## 2.0 LITERATURE BACKGROUND

Road transport infrastructure development has been perceived as one of the most important in ensuring road user's safety (Owusu-Bio, Frimpong and Duah, 2016). It has been seen to be the basic physical and institutional structures needed for the transportation services of vehicles such as cars, bus etc. and even pedestrians for the purposes of effective and safe urban mobility (Grubber, 1990). Oni and Okanlawon, (2006) noted that road transport infrastructure is a major component part of the transport system offering the provision of transport service and operation.

Road transport infrastructure is critical for the overall growth of the nation, as well, a major tool of the economic and strategic development. Road transport infrastructure has a bearing on the sustainability of growth and development of a country as it benefits the country by improving its connectivity (Tripathi, 2015). The adequacy of road transport infrastructure therefore tends to determine a country's success; as good road transport infrastructure has the capacity to raise productivity especially in most sectors of the economy Safer Road partnership (2015). Quality road transport infrastructure is very important to ensure road transport safety for all road users (Owusu-Bio, Frimpong and Duah, 2016). This study is designed to look at

the availability and the condition of road transport safety infrastructure as perceived by the residents in Osogbo.

### Urban Road Transport Safety

Safety is a basic human need (Uittenbogaard, 2014). Transport safety can be defined in terms of vulnerability to accidental injury (usually involving at least one vehicle as the instrument causing the injury) and measures put in place to prevent them. Traffic safety has three primary dimensions they are: exposure (to risk), risk (of having a crash given a certain amount of exposure), and consequences (e.g. injury given a crash) (Wegman, Zhang; Dijkstra (2012). Risk in a transport trip includes risk faced in access trip, often as pedestrians, risk to the occupants inside the vehicle, and risk that vehicle poses to the other road users. Risk itself can be defined as exposure to undesirable event. Internal risks are those imposed on same mode users while external risks are those from other mode users (Litman, 2014). This is summarized as transportation risk categories in table 1

**Table 1: Transportation Risk Categories**

<b>Perspectives</b>	<b>Accidents</b>
<b>Internal</b> (impacts on a mode's user)	Crash damages to vehicle occupants. Falls (e.g. in stations). Worker injuries.
<b>External</b> (impacts on non-users)	Crash risk to other people

Source: Litman (2014)

According to World Health Organisation (2004), road traffic injury is one of the most significant global public health issues of the 21<sup>st</sup> century. Presently, globally, over a million persons die annually while up to 50 million more are injured or maimed in road crashes. Accordingly, a leading cause of disease, injury and death in the world is road trauma (WHO, 2004).

### 3. METHOD OF DATA COLLECTION AND ANALYSES

The study utilised primary data obtained through questionnaire administration in the three residential areas of Osogbo.

The study employed cross-sectional analyses of data collected via questionnaire and analysed using descriptive statistics and five-point Likert scale. Multistage sampling technique was employed. Osogbo was first stratified into three different residential areas which are low, medium and high-density areas respectively. The next stage involved the stratification of the residential zones into electoral wards as recognized by the Independent National Electoral Commission (INEC). Information obtained from INEC showed that there are 24 electoral wards in the study area (Osogbo).

The next stage is the selection of a political ward in each residential zone of the two local government areas. Through this method, six (6) wards from the three different residential zones were randomly selected. This selection represents 25% of the study population. The study was based on the information from household members in the political wards selected.

For the purpose of questionnaire administration, the study area has been grouped into homogeneous residential density zones, in which one ward was randomly selected without replacement in three residential zones. In all, six wards were selected for the study, and they include Akogun, Otun Jagun B, Balogun, Are Ago, Ayetoro and Baba Kekere in high, medium and low residential densities respectively.

Following this is the identification of roads in each selected political ward. Reconnaissance survey, coupled with information obtained from Google earth revealed that there were 433 streets in the selected political wards in the three residential zones. The distribution showed that there were 109, 145 and 179 streets in the high, medium and low residential zones respectively. One of every 10 (10%) of the total number of streets were selected. Thus, 44 streets were selected in all residential zones.

The next stage is the identification of residential buildings along the selected streets. Information obtained from Google earth and author's field survey showed that there were 715, 720, and 701 buildings in the high, medium and low residential zone respectively. Systematic sampling technique was adopted in the selection of every 10th building (10%) in the selected streets. Random sampling was adopted to pick the first house where household heads were selected. Using this procedure, a total of two hundred and thirteen (213) sample questionnaires were administered.

#### **4. RESEARCH FINDINGS**

The study revealed that most of the respondents were young male adults (31-60 years), accounting for 81.7% of the household heads, and were married (64.3%). Majority (54.0%) of the residents were educated with tertiary/postgraduate education. This showed that the literacy level of the respondents was high and agrees with Fadare and Olawuni (2007). In addition, the major mode of employment was the public sector, although there were a reasonable percentage (30.5%) in the informal sector

Information obtained on average monthly income showed that most of the respondents earn between ₦21,000- ₦70,000. In the high, medium and low residential density of Osogbo, with average monthly income of ₦21, 206, ₦56,761 and ₦123,333 respectively. These findings show, as may be expected, that there is variation in the average income in the three residential densities of Osogbo, with the low density earning more than the other density areas. Ownership of private vehicle was found to follow the same trend with the highest (63.8%) proportion of respondents in the low residential density who mostly males.

Private car was the most popular mode (50.7%) used for daily travel, following this, (16.95%) of the residents use of motorcycle for public transport purposes, locally known as Okada daily, followed by taxi (14.1% and walking 12.2%. The next mode according to the level of usage is the use of 5 Passenger minibus (5.9%) and cycling (0.3%).

Findings on the purpose of the trip made revealed that work and School (83.1%) trips are the trips mostly made in Osogbo. This finding agrees with Solanke (2005) which observed that school and work places account for the majority of trips made in urban areas especially in Ogun State. Information obtained on transport modes used in association with trip types shows that private car/motorcycle was the most commonly used transport mode for work trip (34.7%) and religious trip (30.5%). Public minibuses/taxis were mostly used for social trips (27.2%), medical trip (29.6%), shopping trip (39.9), leisure/recreational trip (19.7) and school trip (13.1) There is an evidence of double entry by the respondents.

Findings from the perception of residents on the availability of road transport infrastructure in Osogbo showed that streetlights (96.2%), road signs (98.6%), street markings (73.7%), speed bumps (86.9%), and traffic light (83.1%) are the most available road infrastructure. Walkway (59.2%) and Bus stops (52.1%) are also available road infrastructure. Based on the foregoing it is evident that the residents are aware of the available road safety infrastructure. Bollards are not are not captured by the sample residents in the study area. Further study was carried out on

the condition of the available road transport infrastructure in Osogbo. It was revealed that traffic light has the best condition with an index value of 4.48 RII, Road signs 4.04, Bus stops 3.92, speed bumps 3.85 and street markings 3.78. The Relative Importance Index RII for the selected transport infrastructure are above the average index 3.76, suggesting that the condition of the facilities are at least good.

Residents' perception of transport modal safety in Osogbo was assessed. It was measured on a five-point Likert scale and tagged 'Relative Safety Index (RSI)'. As presented in Table 2. It was found that personal car as expected, was perceived the safest (RSI = 4.07). Other modes of transport were considered to be averagely safe. In any case, commercial motorcycle was considered not safe with its relative safety index value of 2.01. This finding is in accordance to the study of European Transport Safety Council (2003) that observed that car travel is safer compared to other modes. It is therefore less worrying that private car ownership and usage is high in Osogbo.

Residents' awareness, compliance and satisfaction regarding road transport safety facilities in Osogbo are as shown in Tables 3, 4 and 5 respectively based on the five-point Likert scale. It was observed (table 3) that the respondents are more aware of road safety officials (3.83), seat belt usage (3.7), child car seat (3.69) and driving license (3.55). This not surprising since the Road safety personnel are ever so watchful on those safety items. The other safety items considered in this study which are higher than the general awareness mean of 3.22, in order of importance are Driving licence, use of helmet, Zebra crossing and Traffic Warden, are respondents that are also aware of the above listed road safety facilities. Others, that are below the mean are Valid insurance certificate, Traffic wardens, and Vehicle Inspection officers' services. It is important to note that mobile phone usage restrictions while driving, tinted glass authorisation and pedestrian bridges in that order are rated and perceived to be less noticed. This perhaps is understandable as surveillance on mobile phone use while driving has not been effectively carried out and vehicle tinted glass inspection is limited to those who have the facility on their vehicles. The pedestrian bridges are not available anywhere in the study area. The overall awareness index of 3.22 depicts that the respondents are aware of those road safety facilities in Osogbo.

The compliance level of road transport safety facilities, information on Table 4 showed that the respondents complied the most with the use of walkway (3.92 RII), seat belt (3.78) and

road safety (3.57) regulations. The other facilities that the resident comply with in that order are Driving licence, Traffic lights, Road signs, Child care seat, Traffic warden, and traffic road signs that are 3.12 RII mean calculation. The others below the mean barely comply with other road transport safety facilities according to the information in Table 4.

**Table 2: Safety level of transport modes in Osogbo**

Item	TWV	RII	Rank
Personal car	867	4.07	1
Personal motorcycle	670	3.15	2
Taxi/Tricycle	665	3.12	3
Commercial mini bus	655	3.08	4
Foot	644	3.02	5
Commercial motorcycle	428	2.01	6

Average RII<sub>Osogbo</sub> = 3.07

**Table 3: Residents' Awareness of Road Safety Facilities in Osogbo**

Road safety facilities	TWV	RII	Rank
Road Safety Officers	816	3.83	1
Seat belt	788	3.70	2
Child car seat	785	3.69	3
Driving license	757	3.55	4
Helmets	734	3.45	5
Zebra crossing	707	3.32	6
Lines and lane marking	705	3.31	7
Traffic Wardens	693	3.25	8
Speed limits	683	3.21	9
Vehicle Inspection Officers	678	3.18	10
Valid Insurance Certificate	644	3.02	11
Signal and Stopping	590	2.77	12
Mobile Phone Restrictions	545	2.56	13



Tinted glass authorization	504	2.37	14
Pedestrian Bridges	360	1.69	15

Average  $RII_{OSOGBO} = 3.22$

The facilities that are barely complied with particularly, use of helmets, speed limits, mobile phone use restriction while driving have grave implications on occurrence of accidents in any city or region. In any case the general compliance index is relatively high to suggest that the traffic safety level is generally not excellent.

Further analyses were carried out (reported on table 5), on the satisfaction level of the respondents regarding road transport safety facilities in Osogbo. It was revealed that the respondents are satisfied with the use of walkways, seat belt regulations (3.73), road safety regulations as carried out by Road Safety Corps (3.59) followed by walk ways (3.55), driving licence (3.47), helmets regulations for motor cycle riders (3.43), speed limits (3.41) and road signs (3.18) that are within the RII 3.11 mean. The overall satisfaction index which is 3.11 implies that the respondents are barely satisfied with road transport safety facilities in Osogbo

**Table 4: Residents' compliance level**

Road safety facilities	TWV	RI	Rank
Walk way	835	3.92	1
Seat belt	806	3.78	2
Road Safety Officers	760	3.57	3
Driving license	740	3.47	4
Traffic light	732	3.44	5
Road signs	726	3.41	6
Child car seat	679	3.19	7
Traffic Wardens	678	3.18	8
Lines and lane marking	663	3.11	9

Valid Insurance Certificate	651	3.06	10
Zebra crossing	638	3.00	11
Helmets	626	2.94	12
Speed limits	6.23	2.92	13
Vehicle Inspection Officers	6.23	2.92	13
Tinted glass authorization	551	2.59	15
Mobile Phone Restrictions	555	2.61	16
Pedestrian Bridges	414	1.94	17

AVERAGE RII<sub>OSGBO</sub>= 3.12

**Table 5: Residents' satisfaction level**

Road safety facilities	TWV	RII	Rank
Seatbelt	795	3.73	1
Road Safety Officers	764	3.59	2
Walkway	756	3.55	3
Driving license	739	3.47	4
Helmets	730	3.43	5
Speed limits	726	3.41	6
Road signs	678	3.18	7
Zebra crossing	661	3.10	8
Valid Insurance Certificate	650	3.05	9
Traffic Wardens	638	3.00	10
Vehicle Inspection Officers	635	2.98	11
Lines and lane marking	631	2.96	12
Police Traffic Control	624	2.93	13

Signal and Stopping	610	2.86	14
Mobile Phone Restrictions	609	2.86	14
Tinted glass authorisation	539	2.53	15
<u>Pedestrian bridges</u>	<u>388</u>	<u>1.82</u>	<u>16</u>

AVERAGE  $RII_{OSOGBO} = 3.11$

## **5. CONCLUSION**

This study examined road transport safety in Osogbo with a view to providing information that could engender a safer urban mobility. As shown in this study, the rate of private vehicle ownership is on the average, and most trips were made with the use of personal car or motorcycle. The para-transit motorcycle operation is considered dangerous by the residents of Osogbo. The users are vulnerable to accidents and all sorts of urban insecurity. In order to prevent crash, certain road infrastructure would have to be put in place to improve road transport safety in Osogbo. Some are adequately available; some are inadequate while some are absent.

From this study the road transport safety, awareness, compliance and satisfaction level of road transport facilities indicated that the residents of Osogbo are barely aware of available facilities, and the level of compliance and satisfaction are not excellent hence suggests necessary Government interventions. It is important to note that the results obtained in this study have implications for other similar cities outside Osogbo Nigeria.

## **6. RECOMMENDATIONS**

There should be adequate provision of road transport infrastructure such that all road users whether motorists and pedestrians will be safe. This should include provision of walkways along major roads in the core city centres, overhead bridges, bus stops, bollards where they are not available or inadequately maintained. There is need for capacity building for traffic control and management officers, enlightening and educating drivers and passengers and general populace on transport safety and other related issues. Citizen Awareness and strict compliance and enforcement of traffic laws must be maintained. Rules and regulations especially mobile phone restrictions while driving, use of pedestrian facilities must be encouraged. Road safety activities should be viewed as a shared responsibility of the government and the people for effective service delivery. The activities of Federal Road Safety Corps (FRSC) must be

expanded to ensure stricter enforcement to achieve compliance of road users to road transport safety facilities and control.

## **REFERENCES**

- Campbell, J.L.; Litchy, M.G.; Brown J.L.; Richard, C.M.; Graving, J.S.; Graham, J.; O’laughlin M.; Topic, D.; and Harwood, D. (2012) NCCHRP Report 600; *Human factor guidelines for Road systems*, [http://onlinepubs.trb.org//onlinepubs/nctrp/nchrp\\_rpt\\_600secondpdf](http://onlinepubs.trb.org//onlinepubs/nctrp/nchrp_rpt_600secondpdf)
- Eiksund, S. (2009) A geographical perspective on driving attitudes and behaviours among adults in urban and rural Norway, *Safety Science* 47 (4) 529-536
- European Transport Safety Council [ETSC], (2003). *Transport Safety Performance in the European Union. A Statistical Overview*. <http://www.info@etsc.be>
- Evans, L. (1991) *Traffic Safety and the driver*, New York: Van Nostrand Reinhold
- Fadare, S. and Olawuni, P. (2007). Domestic Water Supply and Health of Households in the Three Residential zones in Osogbo, Osun State, Nigeria. *Ethopian Journal of Environmental Studies*, 1(2): 35-43.
- Litman, T. (2014). *Safer Than You Think! Revising the Transit Safety Narrative*. Victoria Transport Policy Institute, [www.vtpi.org](http://www.vtpi.org)
- Okoko (2006). *Transportation and urban modelling*. Millennium Publishers: Akure. Pp 79.
- Oni, S. and Okanlawon, K. (2006): Nigeria Transport Infrastructure Development: An integral Part of National Economic Empowerment and Development strategy (NEEDS). *Journal of Social and Policy Issues*, 3(2):7-13.
- Otegbulu, A. (2011). Economic Valuation of Poor Road Infrastructure in Lagos: A Focus on Urban Neighbourhood. *Global Journal of Human Social Sciences*, 11(10): 1-9.
- Owusu-Bio, M., Frimpong, J. and Duah G. (2016). The State of Road Transport Infrastructure and Ensuring Passenger Safety for all Road Users. *European Journal of Logistics, Purchasing and Supply Chain Management*, 4(2): 79-85.

Peter S., Rita, E. and Edith, M. (2015). The Impact of Road Transport Infrastructure on Economic Growth in Nigeria. *International Journal of Management and Commerce Innovations*, 3(1): 673-680.

Safer Road Patnership (2015) *Embrace life Campaign* Cox/Alexander/Hopkins  
<http://www.Sussexsaferroads.gov.uk/page/embrace-life>

Safety and security, (2014). *Transport Research and Innovations Portal*. Available at:  
<http://www.transport-research.info/web/publications/thematic.cfm> (access date: 27-10-2014).

Tripathi, S. (2015). Road Transport Infrastructure and Economic Growth in Indian: 135-151.

Uittenbogaard, C. (2014). *Crime Clusters and Safety in Underground Stations*. Doctoral Thesis Submitted to the Department of Real Estate and Construction, School of Architecture and the Built Environment, KTH Royal Institute of Technology.

Wegman, F., Aarts, L. and Bax, C. (2008). Advancing Sustainable Safety, National Road Safety Outlook for the Netherlands for 2005-2020: *Journal of Safety Science*, 46: 323-343.  
[www.sciencedirect.com](http://www.sciencedirect.com)

World Health Organization (WHO) (2004): *World Report on Road Traffic Injury Prevention*. Geneva: World Health Organization.

## **DESIGN, CONSTRUCTION AND ANALYSIS OF 1 KVA INVERTER POWERED BY SOLAR PANEL VIA A 12V INDUSTRIAL BATTERY**

Olatona, G.I., Akinloye, I.A.\*, Ogunbiyi, D. M., Sulaiman, F. A. and Adegbola. F.

\*Department of Physics, Osun State University, Osogbo

\*\* Email: [akinloyeidrisabidemi92@gmail.com](mailto:akinloyeidrisabidemi92@gmail.com)

### **ABSTRACT**

The need for an uninterrupted power supply cannot be over emphasized. Solar energy is one of the cleanest and renewable sources of energy available. However, it comes in form of direct current while most of the electric devices are designed to operate on alternating current. Hence this work concerns the design, construction and analysis of 1KVA inverter powered by a solar panel via a 12 V industrial battery. The solar panel is made to charge the battery using a solar charge controller as a regulator. The 12 V DC from the battery is converted to 12 V AC at a frequency of 50Hz using integrated circuits, semiconductors and a power MOSFETs as a switching component. This voltage is then stepped up to a 220 V AC via the windings of a transformer. A progressive load was applied to the inverter and stability determined. It was stable to 500 W after which it shows signs of stress. Hence it was concluded that the inverter must not be loaded beyond 50% of its rated power.

**Key Words:** Solar energy, inverter, direct current, alternating current, conversion.

### **1. INTRODUCTION**

The erratic nature of power supply is a thing of major concern to all Nigerians. The cost of acquiring a generator set to supplement the irregular power supply by the various Distribution Companies otherwise called DISCOS makes it essential for the introduction of alternative source(s) to improve energy mix in Nigeria. Olatona and Adeleke (2015); Adegoke Olatona (2015) and Olatona (2018) have advocated for the inclusion of solar energy in the Nigeria's energy mix. However, most electrical appliances are designed to be powered from an alternating voltage source, hence the need for the design and construction of a DC/AC power inverter which serves as a complete automatic switchover function for conversion of direct currents to alternating current.

## **1.1 INVERTER**

An inverter is used to provide uninterrupted 220V AC supply to the load connected to its output socket. It is a combination of inverter circuit, charger circuit and a battery. The inverter circuit converts the DC 12V power stored from the battery charged by a solar panel to 220V/50Hz AC, which can be used to power any common electronic equipment or devices. It performs the reverse role of a rectifier where the AC power is converted to DC coupled with some smoothing circuits. The solar panel traps the solar radiation which is utilized to charge the battery and the power inverter in turn transforms the DC output from the battery to an alternating current for which the electric devices were designed to operate on.

Primarily, the inverter converts DC voltage to AC voltage at a desirable output voltage, current and frequency. The conversion may be achieved with such devices like the ICs, MOSFETs, capacitors, resistors, diodes, and bipolar or unipolar transistors when properly arranged and combined [Nwoye and Ezeonu, 2005].

For alternating current energy sources, inverters are the essential step between a battery's DC power and the AC power needed by standard household electrical systems. Batteries produce power in direct current (DC) form, which can run at very low voltages but cannot be used to run most modern household appliances designed to be powered by alternating current. Mains supply from utility companies and generators produce sine wave alternating current (AC) power, which is used by most commonly available appliances. Inverter takes the DC power supplied by a storage battery bank and electronically converts it to AC power.

## **1.2 Basic Principle of an Inverter**

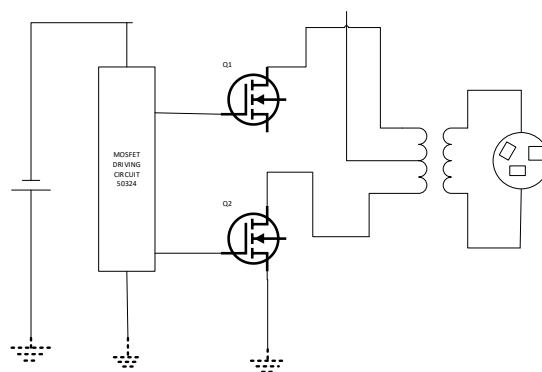


Figure 1: Circuit diagram for the working principles of an inverter. J.C. Osuwa and C.F. Peter (2014).

The use of semiconductor power devices such as bipolar transistors, thyristors for voltage amplification, particularly the MOSFET as the power switches, makes the inverter a better additional power supply (Ekwuribe and Uchegbu, 2016). The inverter is less noisy, provides complete automatic switchover function, poses no environmental threats, less bulky and less expensive to maintain.

The basic working principles of an inverter are explained with the aid of Figure 1; the inverter operates by performing two functions. Firstly, it converts DC voltage (12V) from the battery to AC voltage (12V) using a pair of powerful MOSFETs (Q1 and Q2) serving as switches. Secondly, it steps up the resulting 12V AC into equivalent mains voltage (220v) with corresponding frequency (50Hz) and phase, using appropriate step up transformer. As shown in Fig1 above, the positive 12V from the battery is connected to the centre tap of the transformer primary, while each MOSFET is connected between one end of the primary and earth. So by switching on Q<sub>1</sub>, the battery current can be made to flow through the top half of the transformer primary and to earth through Q<sub>1</sub>. Conversely, by switching on Q<sub>2</sub> instead, the current is made to flow in the opposite direction via the lower half of the primary and to earth. Thus, by switching on the two MOSFETs alternately, through an oscillator at a frequency of 50Hz and AC voltage is applied across the primary windings, which induces an AC voltage in the secondary windings.

### **1.3 Components Used in Designing the Inverter**

The following components are used in the design of the inverter:

Integrated Circuit(IC) SG 3524 PWM, Transistor,

Metal Oxide Semiconductor Field Effect Transistor (MOSFET),

Transformer

Relay Switch,

Rectifier,

Capacitor,

Diode,



Light-Emitting Diode (LED)

Resistor

Breakers

Opto-Isolator

Operational Amplifier

## **2.0 CALCULATION ANALYSIS**

This section deals with the actual calculation used to obtain parameter for the design. All components used in the construction were sourced locally and adequate adjustments were made on all available substitute components in order to achieve the best result of the device under construction.

### **2.1 Oscillating Frequency**

By supplying a constant 12 Volt DC through a voltage regulator to the IC SG 3524 PWM, the frequency of the oscillating signal was determined using a 10 K $\Omega$  variable resistor connected in series with another 56 K $\Omega$  resistor and both connected in parallel with 0.22  $\mu$ F to form the RC time constant network.

Frequency,

$$f = 1.18 \times RC \times CT$$

Where:

Time Capacitor (CT) = 0.22  $\mu$ F

Fixed Resistor (RF) = 56 K $\Omega$

Variable Resistor (VR) = 10 K $\Omega$

Time Resistor (RT) = 56 K $\Omega$  + 10 K $\Omega$  = 66 K $\Omega$

Therefore,

$$f = \frac{1}{1.1 * 0.22 * 10^{-6} * 66 * 10^3} = 62.6Hz$$

It should be noted that the variable resistor was varied until the frequency of the signal was 50Hz

## **2.2. Transformer unit**

The transformer used for this project has a center-tapping which divides the primary into two equal sections. This center-tap is connected to the positive terminal of the battery. Two ends of the primary are connected to the negative terminal of the battery through switches S1 and S2. These switches S1 and S2 are turned ON/OFF alternately to generate current in the primary coil. When the switch S1 is closed and S2 is opened, the current flows in the first part of the primary winding and the EMF is induced in the secondary winding. When the switch S2 is closed and S1 is opened, the current flows in the second part of the primary winding and the EMF of opposite polarity is induced in the secondary winding. Thus if the switches S1 and S2 are alternately opened and closed at constant rate, then the output from the secondary winding is a square wave of the frequency at which the switches S1 and S2 are opened and closed. A single transformer was used for this construction. The number of secondary winding is obtained from the approximate design equation for 50Hz transformer;

Laminated E-coreas: Secondary turns = 48 x output voltage core area leading to a calculated value of secondary winding of 429 turns. The primary winding was obtained from the voltage Transformation ratio of a transformer as follows:

$$\frac{E_2}{E_1} = \frac{N_1}{N_2}$$

Hence, 
$$N_1 = \frac{E_1 N_2}{E_2} = \frac{12 * 429}{220} = 23.4 \text{ turns}$$

## **2.3 Charge controller**

This inverter has an inbuilt controller that regulates the battery from being either over charged by the solar panel or use below the manufacturer's specification. The controller will be able to handle the specifications below:

Max.Current = 20A and Max PV voltage = 50V.

The charged controller is designed to work for both 12V and 24V panel(s).

## 2.2 Transistor (MOSFET) Switching Current

The MOSFET used is the IRF 150 in the power switching circuit due to high switching speed. By using 3.67 volts supplied by the two NPN and the two PNP transistors, the switching time (T) as well as the gate switching current  $I_g$  is determined from the oscillating frequency.

$$T = \frac{1}{f} = \frac{1}{50} = 0.02s$$

$$I_g = C \frac{\nabla V}{\nabla t} = \frac{1 \times 10^{-3} * 3.67}{0.02} = 183.5 \mu A$$

## 2.3 The Drain Current of the MOSFET

From the Inverter, total power is 1000 Watts. The battery Voltage is = 12V

$$\text{Therefore, the drain current: } I_d = \frac{1000}{12} = 83.3A$$

Where the voltage output of the inverter is;  $V_{\text{output}} = 220 \text{ V}$

$$\text{Load output current: } I_o = \frac{1000}{220} = 4.5A$$

## 2.4 Analysis of Power Switch Circuit

Inverter power output (P) = 1000 Watts

Output voltage, V = 220 V

Inverter Input = battery output voltage = 12 V

Frequency = 50 Hz

Power factor = 0.8

Real power of inverter = Apparent power  $\times$  power factor

$$= 1000 \times 0.8$$

$$= 800VA$$

Therefore, the load current flowing at the transformer primary

; Real power = current (I)  $\times$  voltage

$$1000 = I \times 12$$



- 5. Razor blade
- 6. Pliers
- 7. Digital Multimeter
- 8. Ferro and bread boards

### **3.3.1 ESTIMATION OF LOADS TO BE POWERED BY THIS PROJECT;**

The table below shows the load estimates of various appliances and their power ratings:

Table 1: Power rating of the appliances connected to the Inverter

<b>Appliances</b>	<b>Quantity</b>	<b>Power rating</b>	<b>Voltage rating</b>
Electric Fan 1	1	50 W	227.5
Electric Fan 2	1	135 W	221.5
Refrigerator	1	110 W	228.5
Fan 1 + Fan 2	2	185 W	226.5
Fan 1+ Fan 2+ Refrigerator	3	295 W	226.6

The circuit was coupled using the circuit diagram above as a guide and a progressive load was applied to the inverter to determine its stability determine. The appliances added as load to the inverter are shown in Table 1.

The results show that the inverter was stable with no sign of electrical stress. However, when a printer of 660 W rating was loaded, the transformer of the inverter starts to vibrate indicating an overload. Hence it was concluded that the inverter should not connected to a load above 50% of the rated power output.

### **3.3.2 The Casing**



**Figure 4a:** Front view of the inverter casing



**Figure 4b:** Back view of the inverter casing

Packaging of the constructed project was done to achieve a good looking and presentable device. During the packaging, some factors were considered; these include:

The durability of the material to be used in the packaging, materials like wood, plastic or metal could be used but for this project work, metal sheet was used; this is to ensure easy dissipation of heat to the environment.

Cautionary measure was taken to avoid short-circuiting of any part of the design. The portability of the package was taken into consideration to limit the space it will occupy as well as to ease the burden associated with the movement of the device.

The ventilation of the package was also considered; this is to help in temperature control of the device since most of the components in the construction are heat-generating components.

#### **4.0 CONCLUSION**

The epileptic generation of power supply in the country calls for an alternative power supply to be used as an emergency.<sup>1172</sup>This project has met the objective and purpose for which it was designed and constructed. It could be used in homes, offices and industries to serve as an alternative power supply because of the following advantages: -

- Low maintenance cost
- No moving parts
- No noise pollution

- Easy installation.
- No environmental pollution.

Hence it was concluded that the inverter should not be connected to a load above 50% of the rated power output.

## **5.0 RECOMMENDATION**

One of the limitations of this project is that the 12V DC battery backup cannot withstand a large load applied on it for a long period; the overload cut-off is triggered when the load on the Inverter is larger than the designed capacity. Hence, for a more reliable and stable power supply, it is recommended that a larger battery backup should be provided to enable this project withstand larger loads for a long period. The department should develop a cottage workshop where young interested students will be engaged in mass-production, customization and commercialization of this equipment (Inverter); thereby encouraging entrepreneurship and product localization.

## **References**

- [1] **Olatona Gbadebo I.** and Adeleke Ademola E. (2015): Estimation of solar Radiation over Ibadan from Routine Meteorological Parameters. *The International Journal of Engineering and Science* (The IJES) ISSN (e) 2319 – 1813 ISSN (p): 2319 – 1805 4(3) 44-51. **India.**
- [2] Adegoke, C. W. and **Olatona, G. I.** (2015): Assessment of solar and wind power resources in Osogbo (SW Nigeria- 7°47′N, 4°29′E) for viability of hybrid power applications. *Int J. Renewable Energy Technology* (IJRET). Vol. 6. No. 4. Pp. 353-363. **Inderscience, Switzerland.**
- [3] **Olatona G. I.** (2018): Estimating global solar radiation from routine meteorological parameters over a tropical city (7.23°N; 3.52°E) using quadratic models. *Annals of West University of Timisoara - Physics*. Vol. LX Sciendo, DOI: 10.2478/awutp-2018-0005 pg. 45-55.
- [4]. **Nwokoye, A. O. C. & Ezeonu, S.O** (2005). *Intermediate Electronics and Circuit Theory*, Rex Charles Publishers, Nimo

[5] **Ekwuribe J. Michael and Uchegbu E. Chinenye** (2016): Design and Construction of a 2.5Kva Photovoltaic Inverter

[6]. **J.C. Osuwa and C.F. Peter** (2014): Construction and implementation of 1Kva inverter. **IOSR Journal of Applied Physics.**

[7] [www.Wikipedia.com](http://www.Wikipedia.com). Circuit diagram of 1kva solar power inverter. [www.edaboard.com](http://www.edaboard.com), 16th, march 2011



## **A REVIEW OF COMPUTATIONAL TECHNIQUES USED IN LOAD MODELING**

Mohammed, M. \*, Abdulkarim, A., Abubakar, A. S., Kunya, A.B. and Jibril, Y.

Department of Electrical Engineering Ahmadu Bello University, Zaria

\*Email of corresponding author: [musam@abu.edu.ng](mailto:musam@abu.edu.ng)

### **ABSTRACT**

In power system stability studies, planning and control load modeling plays a significant role. If the load model is not accurate, the stability studies may contain a substantial error. To determine the actual generation and transmission lines capacities, knowledge of system potential load is required. Also, to decrease power system operational uncertainties load modeling is central. Perfect models of different complexity for generators, lines and transformers are available today, whereas load models are still challenging. Penetration of renewable energy and wide application of power electronic devices as well as participation of active customers in distribution systems make traditional methods of load modeling inadequate. This paper presents a review of computational techniques used in measurement – based load modeling. In addition, gaps in the literature as well as research directions are also pointed out.

### **Keywords:**

Computational techniques, Load modeling, Static models, Dynamic models, Composite models.

### **I. INTRODUCTION**

The process of estimating a load curve, load profile, load shape, or load pattern of a given consumer is known as load model (Chang et al., 2002; Dong et al., 2012; Shafiei et al., 2017; Yamashita et al., 2012). Load modeling and identification is an important aspect in the area of power system stability analysis, planning, monitoring, control and protection (Braunstein *et al.*, 2015; Choi *et al.*, 2006; Collin *et al.*, 2014). Accurate load model is required in design and adjustment of transmission and distribution networks, design for protective devices such as circuit breakers, relays and also for the control, monitoring and analysis of the system (Chassin *et al.*, 2011; Jahromi & Ameli, 2018; Zhang *et al.*, 2019). Electric loads are nonlinear and

extremely dynamic in nature, they are therefore difficult to be optimally modelled. There are fundamentally two approaches in load modeling reported in literatures, the component based modeling approach and measurement based modeling approach (Arif *et al.*, 2017; Dong *et al.*, 2012; Jahromi & Ameli, 2018; Eleftherios O Kontis *et al.*, 2017; Zheng *et al.*, 2019).

Component based load modeling approach need the physical individual loads information to form an analytical mathematical function that represents the relationship between the system voltages, frequency, active and reactive power consumed by the load (Espinoza *et al.*, 2005; Stephen & Galloway, 2012; Tasić, 1996). This approach however, cannot give the actual time-variant behavior of the load composition. The advantages of this method are that it does not require field measurements, it is easier to adapt to different systems and conditions. Another advantage is that once it is developed it can be used for the entire system life, only the load class mix data need to be updated (Kazmi *et al.*, 2017; Price *et al.*, 1988). On the other hand, measurement based approach make use of field data, obtainable at the load bus for which the model is developed. loads are well known to be time-variant and nonlinear; for these reasons therefore, the measurement based model overtakes the component based approach (Hou *et al.*, 2012). Detail of load models can be found in (Arif *et al.*, 2017).The remainder of this paper is organized as follows: Section II describes details of composite load models. In section III, computational techniques used in load modelling were reviewed while areas of future research works are highlighted in section IV. Finally, the conclusions are contained in section V.

## **II. COMPOSITE LOAD MODELS**

Composite load model consists of group of both static and dynamic load components to formulate a model. Literatures have shown that composite load models provide more accurate response than the statics or dynamic models alone (Jahromi & Ameli, 2018; Kosterev *et al.*, 2008). The most common composite load model is the combine ZIP model and Induction Motor (IM), figure 1 shows an equivalent circuit of composite load model.

The static part is represented by equations (1) to (3) while the dynamic part is represented by equations (4) to (7). Any typical load center of a power system comprises both static and dynamic combinations of loads and that is the reason why composite load model give more accurate representation of the loads in distribution systems.

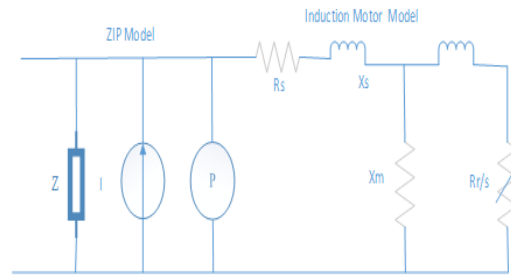


Figure 1: Equivalent Circuit of Composite Load Model

A static load model is not dependent on time, and it describes the relation of the active and reactive power at any time with the voltage and frequency at the same instant of time (Miranian & Rouzbehi, 2013; Rouhani & Abur, 2015). The static characteristics of the load can be classified into constant power, constant current and constant impedance load (ZIP model), depending on the power relation to the voltage. For a constant impedance load, the power dependence on voltage is quadratic, for a constant current it is linear, and for a constant power, the power is independent of changes in voltage (Chassin *et al.*, 2011; García *et al.*, 2013). ZIP model is the most common used and can be described by the equations (1) and (2). Another static model is exponential model and sometimes these models are modified to incorporate frequency dependent term. The frequency dependent term is given by equation (3)

$$P_A = P_n \left( \alpha_z \left[ \frac{V_A}{V_n} \right]^2 + \alpha_i \left[ \frac{V_A}{V_n} \right] + \alpha_p \right) \quad (1)$$

$$Q_A = Q_n \left( \beta_z \left[ \frac{V_A}{V_n} \right]^2 + \beta_i \left[ \frac{V_A}{V_n} \right] + \beta_p \right) \quad (2)$$

where:  $P_A, Q_A$  are respective real and reactive powers of a given phase,  $P_n, Q_n$  are real and reactive power of the load at the nominal voltage  $V_n$ ;  $V_A$  is a phase voltage;  $\alpha_z, \alpha_i, \alpha_p$  and  $\beta_z, \beta_i, \beta_p$  are proportions of constant impedance, current, and power components of real and reactive power of the total static load respectively (Mousavi & Abyaneh, 2010; Vignesh *et al.*, 2015).

$$f_{factor} = (1 + \alpha \Delta f) \quad (3)$$

where:  $\Delta f$  is the frequency deviation from nominal value, and  $\alpha$  is the frequency sensitivity parameter (Arif *et al.*, 2017).

A dynamic load model expresses the relationship of voltage, frequency, active and reactive power at any instant of time, as a function of voltage and frequency time history, including normally the present moment. Dynamic model is particularly important in voltage and angular

stability studies (Arif *et al.*, 2017; Rouhani & Abur, 2015). Induction Motor (IM) model is the most common dynamic load model used (almost 70% of the total energy supply by utilities are consume by electric motors and large portion of this are IMs); the model is derived from the equivalent circuit of the motor and represents the active and reactive power as a function of the past and present voltage magnitude and frequency of the load bus. The model is generally used to represent loads that slowly recover over time period and are developed as nonlinear first order differential equations as depicted in equations (4) to (7).

$$T_p \frac{dx_p}{dt} = -x_p + p_o \left(\frac{v}{v_o}\right)^{N_{ps}} - p_o \left(\frac{v}{v_o}\right)^{N_{pt}} \quad (4)$$

$$p_d = x_p + p_o \left(\frac{v}{v_o}\right)^{N_{pt}} \quad (5)$$

$$T_q \frac{dx_q}{dt} = -x_q + Q_o \left(\frac{v}{v_o}\right)^{N_{qs}} - Q_o \left(\frac{v}{v_o}\right)^{N_{qt}} \quad (6)$$

$$Q_d = x_q + Q_o \left(\frac{v}{v_o}\right)^{N_{qt}} \quad (7)$$

where  $x_p$  and  $x_q$  are state variables related to active and reactive power dynamics,  $T_p$  and  $T_q$  are time constants of the exponential recovery response,  $N_{ps}$  and  $N_{qs}$  are exponents related to the steady-state load response,  $N_{pt}$  and  $N_{qt}$  are exponents related to the transient load response (Arif *et al.*, 2017).

### III. COMPUTATIONAL TECHNIQUES USED IN LOAD MODELLING

Generally, parameter identification of load in measurement based modeling is a curve fitting/estimation problem, that used the actual measurement and try to compare with the simulated. This approach makes use of historical measurement data obtainable from different measurement devices usually installed at load bus substations. Devices such as Smart Meters (SM), Digital Fault Recorder (DFR), Power Quality Monitors (PQM) and Phasor Measurement Unit (PMU) are used to capture network data in real time at both low and medium voltage levels (Zhang *et al.*, 2018). The advantages of this method are that; the model is developed based on actual real time scenario, and there is no need of having deep knowledge of individual loads. Basically there are two techniques reported for parameter identification in measurement based load modeling: the statistical and the metaheuristics methods as seen in figure 2 (Chassin *et al.*, 2011; Collin *et al.*, 2014). The statistical method is actually an analytical approach which is characterized with computational error. Although it is more preferred when compared with component based methods in terms of both accuracy and simplicity. These techniques include; Least Square (LS) method, Vector Fitting (VF) technique, Weighted LS (WLS), Kalman's filter among others. The evolutions of metaheuristics techniques opens another window for

load modeling techniques as they perform better in terms of both accuracy and reduction of computational time (Jahromi & Ameli, 2018). Techniques such as Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and Artificial Neural Network (ANN) are used in recent load modeling problem among others. All these methods of solutions have their peculiarities in terms of accuracy and speed of convergence, Table 1 give summary of the review and respective shortcomings associated with each technique.

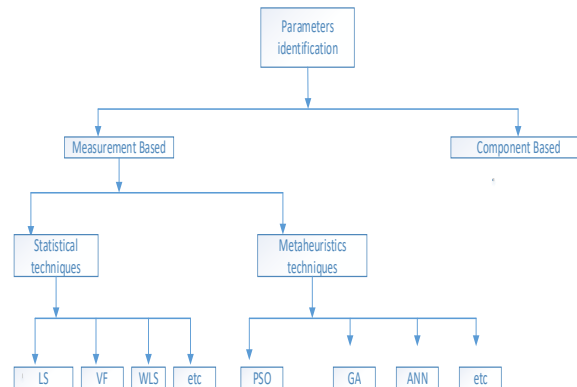


Figure 2: Parameters Identification Techniques

The whole process of measurement based load modeling can be summarized as follows:

- a. identification of model structure (i.e. Load Bus)
- b. data accusation accomplished with a measurement device
- c. formulate a load model
- d. provide an optimization technique that will minimize a cost function and thereby identifying the load parameter
- e. Evaluations of the cost function by testing the results
- f. Model validation

The process above is also described in Figure 3. Measured voltage ( $v$ ) and if necessary with corresponding frequency ( $f$ ) values are uses as input to the model, the model use this information to estimate active and reactive powers  $P_e$  and  $Q_e$  respectively. The estimated powers (active and reactive) are then compared with the real load measurement  $P_m$  and  $Q_m$  with the aim of minimizing the error function of equation (8). This is where the computational techniques play a role.

$$f(e) = \frac{1}{N} \sum (P_m - P_e)^2 + (Q_m - Q_e)^2 \quad (8)$$

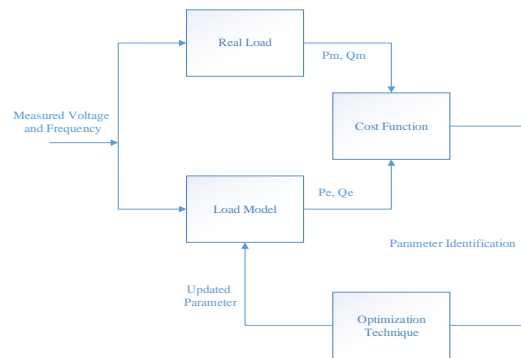


Figure 3: Block Diagram of Load Parameter Estimation

Table 1: Summary of Review

Author (s)	Identification technique	Shortcomings
(Hou <i>et al.</i> , 2012)	Nonlinear Least Square Error	sensitive to outliers, unreliable when data is not normally distributed.
García <i>et al.</i> (2013)	PSO	low convergence rate in iterative process
Regulski <i>et al.</i> (2014)	Improve PSO	Easy to fall into local optimal in dimensional space
(Hua <i>et al.</i> , 2015)	Transfer Function (TF)	TF does not take account of initial conditions of the system
(Rouhani & Abur, 2015)	Kalman's Filter (KF)	Small steady state error associated with KF

(Eleftherios O Kontis <i>et al.</i> , 2017)	Vector Fitting	Computational intensive requirement in addition to Multiple local optimums,
(Eleftherios O Kontis <i>et al.</i> , 2017)	TF	TF does not take account of initial conditions of the system
(Wang, 2017)	Dynamic equations	Exhibits high amount of error with small convergence speed
(Jahromi & Ameli, 2018)	GA	Slow convergence characteristic
(Saviozzi <i>et al.</i> , 2019)	ANNs	Absent of temporal connection in ANNs
(Zheng <i>et al.</i> , 2019)	RNNs	Fail when Operating Condition are change far from the original

## VI. FUTURE RESEARCH WORK

More research is required to develop advanced algorithms that perform online modeling using real time data, so that it can accurately capture the seasonal and geographical variations of the loads. In order to overcome the shortcoming associated with RNNs when the operating conditions are change far from the original operating condition an effective method is required for searching the threshold distance for good performance. A hybridized method that will address the problem of convergence speed and at the same time accuracy is not tampered with is required, other machine learning techniques should be tested especially Support Vector

Machine (SVM) as it performs excellently and demonstrates higher accuracy than any other machine learning in other areas of research.

## **V. CONCLUSION**

In this paper, computational techniques for load modeling are reviewed and finally new approaches to the problems are pointed out. Metaheuristics optimization methods are considered superior over statistical methods in terms of accuracy.

## **REFERENCES**

- Arif, A., Wang, Z., Wang, J., Mather, B., Bashualdo, H., & Zhao, G. (2017). Load modeling— A review. *9*(6), 5986-5999.
- Braunstein, S. H., Bretas, N. G., Rossoni, A., & Bretas, A. (2015). *Bad data analysis in distribution state estimation considering load models*. Paper presented at the 2015 IEEE Power & Energy Society General Meeting.
- Chang, R.-F., Leou, R.-C., & Lu, C. (2002). Distribution transformer load modeling using load research data IEEE Power & Energy Society General Meeting. *17*(2), 655-661.
- Chassin, F. S., Mayhorn, E. T., Elizondo, M. A., & Lu, S. (2011). *Load modeling and calibration techniques for power system studies*. Paper presented at the 2011 North American Power Symposium.
- Choi, B.-K., Chiang, H.-D., Li, Y., Li, H., Chen, Y.-T., Huang, D.-H., & Lauby, M (2006). Measurement-based dynamic load models: derivation, comparison, and validation. IEEE Power & Energy Society General Meeting. *21*(3), 1276-1283.
- Collin, A. J., Tsagarakis, G., Kiprakis, A. E., & McLaughlin, S. (2014). Development of low-voltage load models for the residential load sector. 5th International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET). *29*(5), 2180-2188.
- Dong, Z., Borghetti, A., Yamashita, K., Gaikwad, A., Pourbeik, P., & Milanovic, J. (2012). CIGRE WG C4. 605 recommendations on measurement based and component based load modelling practice. *4*, 2012.
- Espinoza, M., Joye, C., Belmans, R., & De Moor, B. (2005). Short-term load forecasting, profile identification, and customer segmentation: a methodology based on periodic time series. *20*(3), 1622-1630.



- García, L. F. R., Londoño, S. M. P., & Flórez, J. (2013). *Dynamic load modeling for small disturbances using measurement-based parameter estimation method*. Paper presented at the Simposio Internacional sobre la Calidad de la Energía Eléctrica-SICEL.
- Hou, J., Xu, Z., & Dong, Z. Y. (2012). *Measurement-based load modeling at distribution level with complete model structure*. Paper presented at the 2012 IEEE Power and Energy Society General Meeting.
- Hua, K. Q., Vahidnia, A., Mishra, Y., & Ledwich, G. (2015). *PMU measurement based dynamic load modeling using SVC devices in online environment*. Paper presented at the 2015 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC).
- Jahromi, M. E.-N., & Ameli, M. (2018). Measurement-based modelling of composite load using genetic algorithm. *3rd International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET)*.  
. 158, 82-91.
- Kazmi, S. A. A., Shahzad, M. K., Khan, A. Z., & Shin, D. (2017). Smart distribution networks: A review of modern distribution concepts from a planning perspective. *10(4)*, 501.
- Kontis, E. O., Papadopoulos, T. A., Chrysochos, A. I., & Papagiannis, G (2017). Measurement-based dynamic load modeling using the vector fitting technique. *33(1)*, 338-351.
- Kontis, E. O., Papagiannis, G. K., Syed, M. H., Guillo-Sansano, E., Burt, G. M., Papadopoulos, T. A., & Chrysochos, A. I. (2017). *Development of measurement-based load models for the dynamic simulation of distribution grids*. Paper presented at the 2017 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe).
- Kosterev, D., Meklin, A., Undrill, J., Lesieutre, B., Price, W., Chassin, D., . . . Yang, S. (2008). *Load modeling in power system studies: WECC progress update*. Paper presented at the 2008 IEEE Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century.
- Miranian, A., & Rouzbehi, K. (2013). Nonlinear power system load identification using local model networks. *28(3)*, 2872-2881.
- Mousavi, S. M., & Abyaneh, H.(2010). Effect of load models on probabilistic characterization of aggregated load patterns. *26(2)*, 811-819.
- Price, W. W., Wirgau, K. A., Murdoch, A., Mitsche, J. V., Vaahedi, E., & El-Kady, M. J. (1988). Load modeling for power flow and transient stability computer studies. *3(1)*, 180-187.

- Rouhani, A., & Abur, A. J. (2015). Real-time dynamic parameter estimation for an exponential dynamic load model. *IEEE Power & Energy Society General Meeting*. 7(3), 1530-1536.
- Saviozzi, M., Massucco, S., & Silvestro, F.. (2019). Implementation of advanced functionalities for Distribution Management Systems: Load forecasting and modeling through Artificial Neural Networks ensembles. *IEEE Power & Energy Society General Meeting*. 167, 230-239.
- Shafiei, M., Nourbakhsh, G., Ledwich, G., Femando, T., Iu, H., & Arefi, A. (2017). *Dynamic load modelling using measured data in distribution networks*. Paper presented at the 2017 3rd International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET).
- Stephen, B., & Galloway, S. (2012). Domestic load characterization through smart meter advance stratification. *3rd International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET)*. 3(3), 1571-1572.
- Tasić, D. J. U. o. N. (1996). The Influence of Static and Dynamic Load Characteristic on Voltage Collapse in Electrical Power System.
- Vignesh, V., Chakrabarti, S., & Srivastava, S. (2015). Load modeling under unbalanced disturbances. *31(2)*, 1661-1662.
- Wang, X. (2017). *Estimating dynamic load parameters from ambient PMU measurements*. Paper presented at the 2017 IEEE Power & Energy Society General Meeting.
- Yamashita, K., Djokic, S., Matevosyan, J., Resende, F., Korunovic, L., Dong, Z., & Milanovic, J. (2012). Modelling and aggregation of loads in flexible power networks—scope and status of the work of CIGRE WG C4. 605. *45(21)*, 405-410.
- Zhang, L., Wang, G., & Giannakis, G. B. J. a. p. a. (2018). Real-time power system state estimation and forecasting via deep neural networks. *5<sup>th</sup> International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET)*.
- Zhang, L., Wang, G., & Giannakis, G. B. (2019). Real-Time Power System State Estimation and Forecasting via Deep Unrolled Neural Networks. *67(15)*, 4069-4077.

Zheng, C., Wang, S., Liu, Y., & Liu, C. (2019). A novel RNN based load modelling method with measurement data in active distribution system. 3rd International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET).

## **HARMONIC REDUCTION IN THREE PHASE INVERTER USING SVPWM AND SHUNT ACTIVE FILTER**

Mohammed, M. <sup>\*1</sup> and Abdullahi, M. <sup>2</sup>

<sup>1</sup>Department of Electrical Engineering Ahmadu Bello University, Zaria

<sup>2</sup>Department of Electrical Engineering Technology Federal Polytechnic, Kaura- Namoda

\*Emails of corresponding author: [musam@abu.edu.ng](mailto:musam@abu.edu.ng), [musamtzaria1981@gmail.com](mailto:musamtzaria1981@gmail.com)

### **ABSTRACT**

General use of power electronics devices such as rectifier, inverter and regulators. in power system causes serious problems of power quality. One of such problems is generation of current and voltage harmonics causing distortion of load waveform, voltage fluctuation, voltage dip, heating of equipment etc. origination of non-linear loads such as Compact Florescent Lamp (CFL) Uninterrupted Power Supply (UPS), Switch Mode Power Supply (SMPS), Speed drives etc. causes the generation of current harmonics in power system. They draw reactive power components of current from the AC mains, hence causing disturbance in supply current waveform. Therefore, to avoid the penalties of harmonics we have to mitigate the harmonic component in power utility system. There are a number of techniques used in harmonic reduction among which are Space Vector Pulse Width Modulation (SVPWM) and Shunt Active Power Filter (SAPF). This work described detail performance analysis of SVPWM and SAPF under current control strategy namely, instantaneous active and reactive power theory (p-q) and their comparative analysis to justify the performance of each in comparison with IEEE bench mark of less than 5% THD and less than 3% for individual harmonic. Simulation results indicate that SVPWM is more efficient in mitigating current harmonics than SAPF with a Total Harmonic Distortion (THD) of 3.40% and 7.43% respectively.

Keywords: Harmonics, Inverter, SVPWM, SAPF, THD.

### **INTRODUCTION**

Power quality is a major concern in power system operation. Regrettably, its faces a lot of disturbances among which is Harmonic distortion. A harmonic is a voltage or current at multiple of fundamental frequency created by the action of nonlinear loads. Generally, converters are considered as major source of harmonics in power systems, A device that converts DC power into AC power at desired output voltage and frequency is called an Inverter

(Kushwah & Walke, 2018). The fact that inverters are built from power electronics components (which are highly nonlinear) they generate currents harmonics which result in low power factor, low output power and voltage fluctuation (VANAJAKSHI & RAO, 2015). Traditionally, passive filters are used to mitigate harmonics current in power systems but due to resonance, large size and non-variable character exhibited by the passive filters, active power filters are recently gaining more attention (Campanhol et al., 2014). On the other hand SVPWM is one of the active area of development is in the reduction of THD created by the rapid switching characteristic of the SVPWM procedures. These distortions of harmonics are set to be within a limit of less than 5% THD and less than 3% individual harmonics by IEEE 519 standard for voltage harmonic level (Hoevenaars et al., 2003). In order to ensure good system operations. Recently (Shankar & Kumar, 2017) presented SAPF based technique for harmonic reduction in four wire distribution network controlled by PI controller. In Mukherjee *et al.* (2014), method of improving the power quality using shunt active power filter was proposed comprises of PI controller, filter hysteresis current control loop, dc link capacitor with the all these element shunt active power filter reduce the total harmonic distortion significantly. This paper presents the simulation and analysis of SVPWM and SAPF in MATLAB/ Simulink. The remainder of the paper is organized as follows: section two provides a brief of the SVPWM technique and SAPF, while section three presents the simulation setup and section four contains the results and discussion. Conclusions are presented in section five.

## **I. HARMONIC REDUCTION BY SVPWM AND SAPF TECHNIQUES**

Three phase time varying quantities can be sum up to zero and displaced  $120^\circ$  apart this expression is known as space vector. When time increases the angle of space vector also increases resulting the vector to rotate with equal frequency of the sinusoids (Nisha et al., 2012). Three phase balance system can be define by  $V_a(t)$ ,  $V_b(t)$ , and  $V_c(t)$  these can be represented by rotating vector as:

$$V = V_a(t) + V_b(t)\angle 180 + V_c(t)\angle 180 \quad (1)$$

Where;

$$V_a(t) = v_m \sin \omega t$$

$$V_b(t) = v_m \sin (\omega t + 180)$$

$$V_c(t) = v_m \sin(\omega t - 180)$$

In SVPWM three phase stationary reference frame voltages for each inverter switching state are mapped to the complex two phase orthogonal q and d plane as shown in figure 1. The mathematical transformation for converting the three phase parameters is given in equation (2).

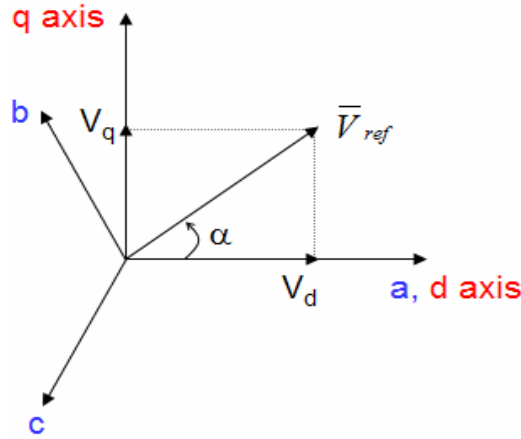


Figure 1: Space Vector Reference (Ryu et al., 2005)

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{an} \\ v_{bn} \\ v_{cn} \end{bmatrix} \quad (2)$$

The reference voltage and the space voltage can be obtained from equation (3) and (4) respectively

$$|v_{ref}| = \sqrt{v_d^2 + v_q^2} \quad (3)$$

$$\alpha = \tan^{-1} \left( \frac{v_q}{v_d} \right) = \omega t = 2\pi f t \quad (4)$$

where  $f$  is the fundamental frequency while  $v_d$  and  $v_q$  are forming an orthogonal two phase system.

The required pulses of the SVPWM can be generated by comparing the modulating functions with triangular waveform. symmetric seven segment technique is to alternate the null vector in each cycle and to reverse the sequence after each null vector. The switching pulse pattern for the three phases in the six sectors can be generated. switching sequence for generating reference vector in sector. To select harmonic to eliminate, the firing command are programed such that they provide three phase balance wave form. The fundamental component can be controlled

and select any other harmonic component for elimination by proper choice of switching angle (Nisha et al., 2012).

SAPF is connected to a harmonic-polluted power component at the point of common coupling (PCC), between the voltage supply and a harmonic producing load. The shunt active filter approach is based on the principle of injection of harmonic currents in to the ac system, of the same amplitude but opposite in phase to that of the load harmonic currents or mainly aims at generating compensating currents and feed as inverter output in order to cancel out the current harmonics present (Ryu et al., 2005).

## II. SIMULATION SETUP

To demonstrate the effectiveness of the two techniques, a simulation of three phase inverter was carried out in MATLAB/Simulink as seen in Figure 4.

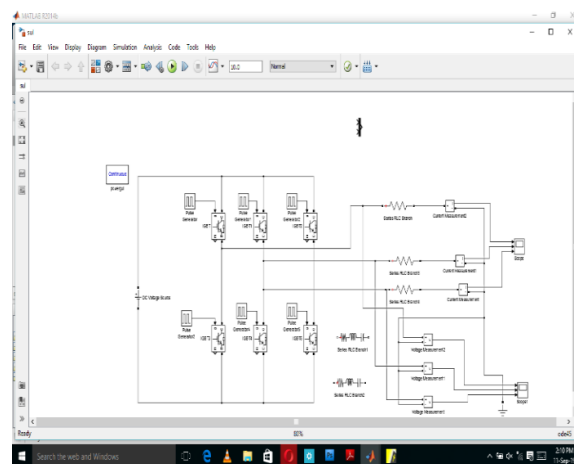


Figure 2: Model of SVPWM Inverter on Matlab version

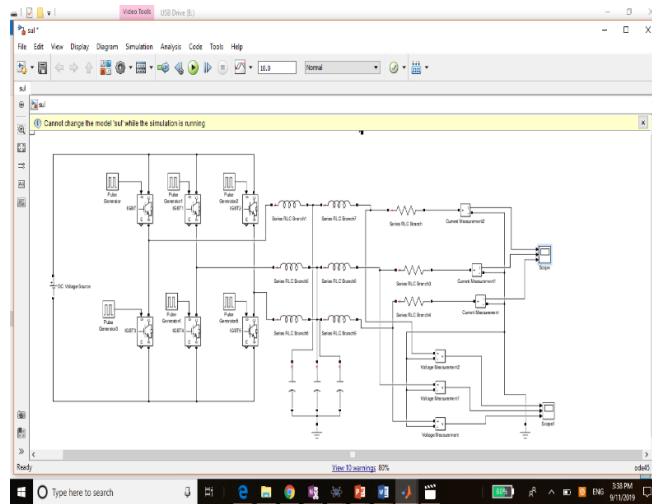


Figure 3: Simulation model of the System with SAPF using Control Strategy

The inverter was connected with RL load in each case and obtain the harmonic with and without the mitigation techniques. Later, SVPWM and SAPF was connected to controlled the harmonic components. The MATLAB models are shown in figure 2 and figure 3 for SVPWM and SAPF respectively.

### III. RESULTS AND DISCUSSION

The result of the work is limited to simulation studies as follows:

#### Without Mitigation Techniques

When the inverter was simulated without mitigation techniques the output voltage and current waveform were obtained as shown Figure 4 and Figure 5 respectively.

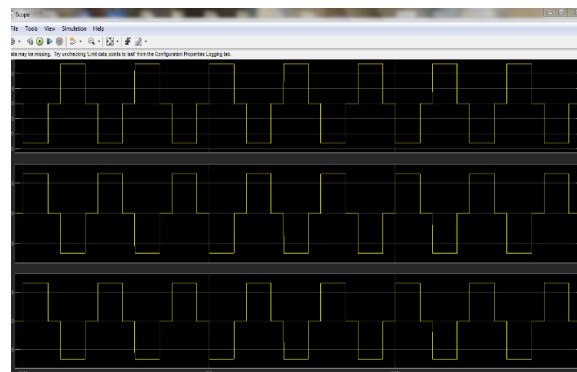


Figure 4: Output Voltage Waveform for the Three Phase Inverter Without Technique



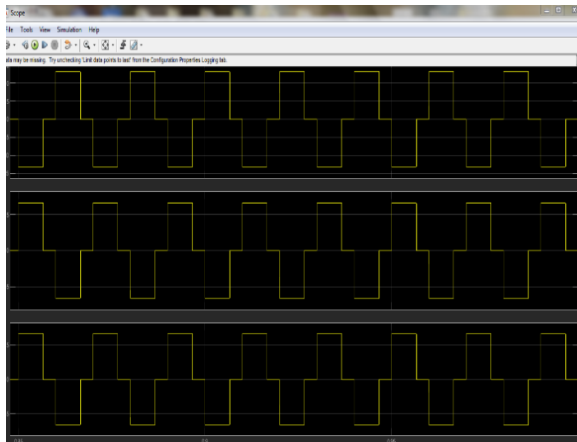


Figure 5: Output Current Waveform for the three Phase Inverter Without Technique.

It can be seen that the output of the inverter is not pure AC for both current and voltage and contain reasonable harmonic components. It is also evident from Figure 6 that the THD when FFT analysis was carried out was 31.41% which is far away from the acceptable limit

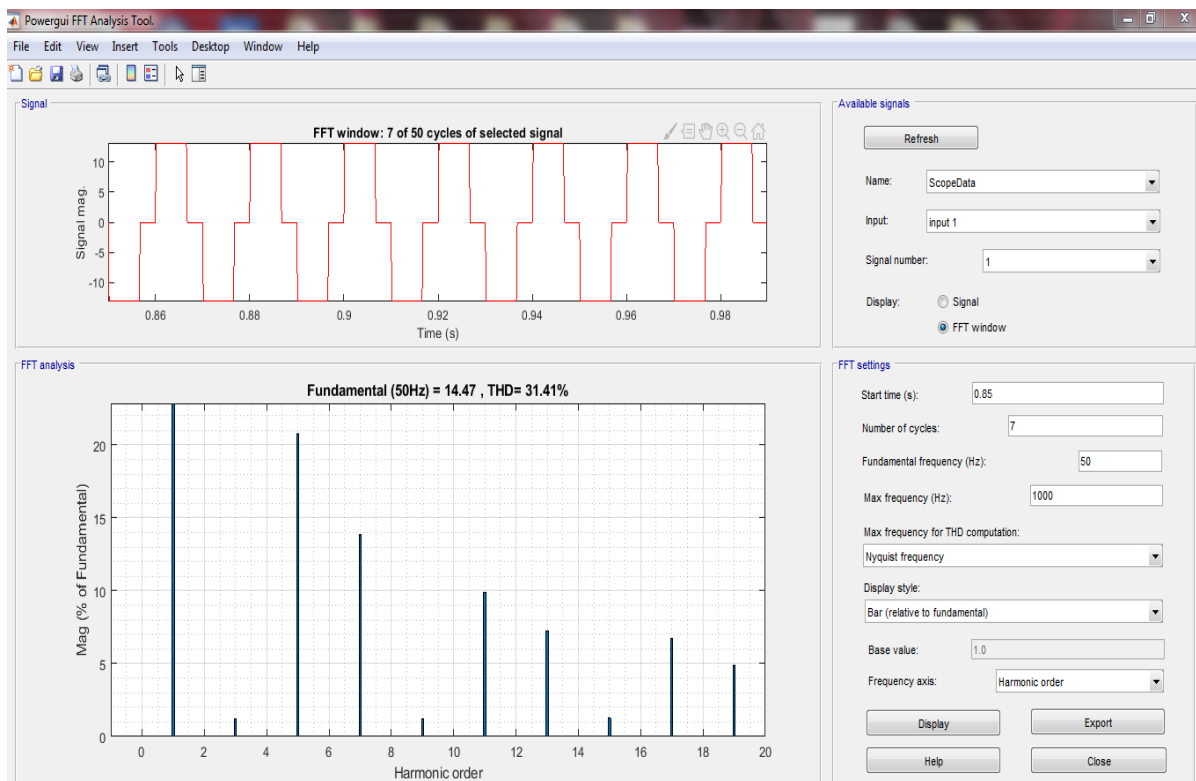


Figure 6: FFT Analysis for THD Produce by the Inverter

The FFT analysis shows that the harmonic spectrum contains odd multiple low order voltage harmonics (i.e. 150 Hz, 250 Hz and 350 Hz).

### SVPWM Results

The controlled signal and reference voltage signal were generated and applied to the inverter following application of the gate pulse to three phase inverter, there was reduction in the harmonic content of which the FFT analysis calculated up to 3.40% yielding 89.17% reduction of THD present in the system, this is shown in Figure 7.

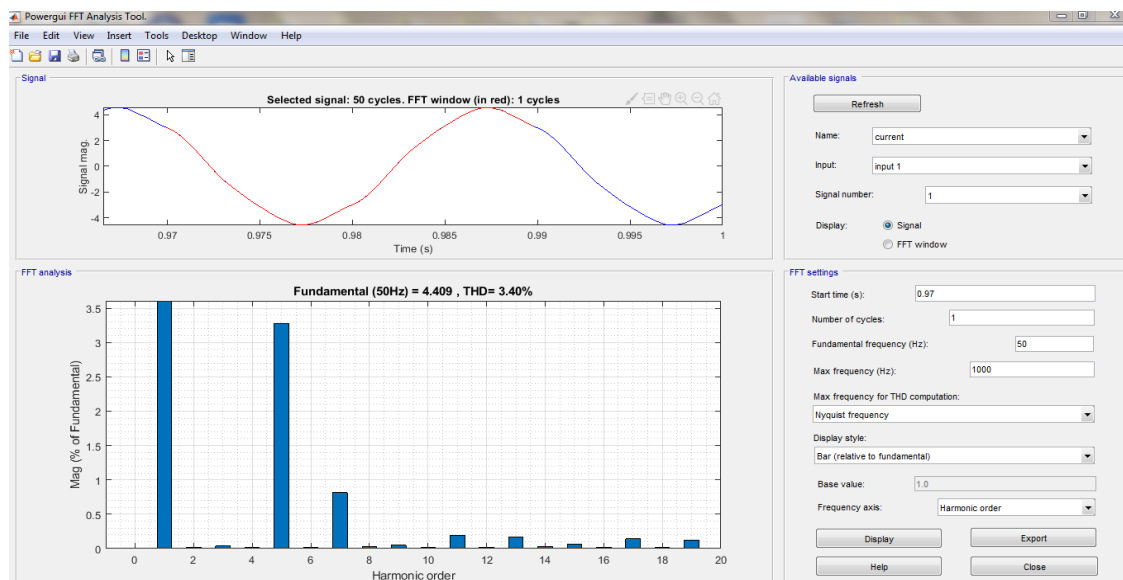


Figure 7: THD with SVPWM

### SAPF Results

Following incorporation of SAPF in the inverter model, a significant reduction of THD was obtained from FFT analysis. This can be seen in figure 8.

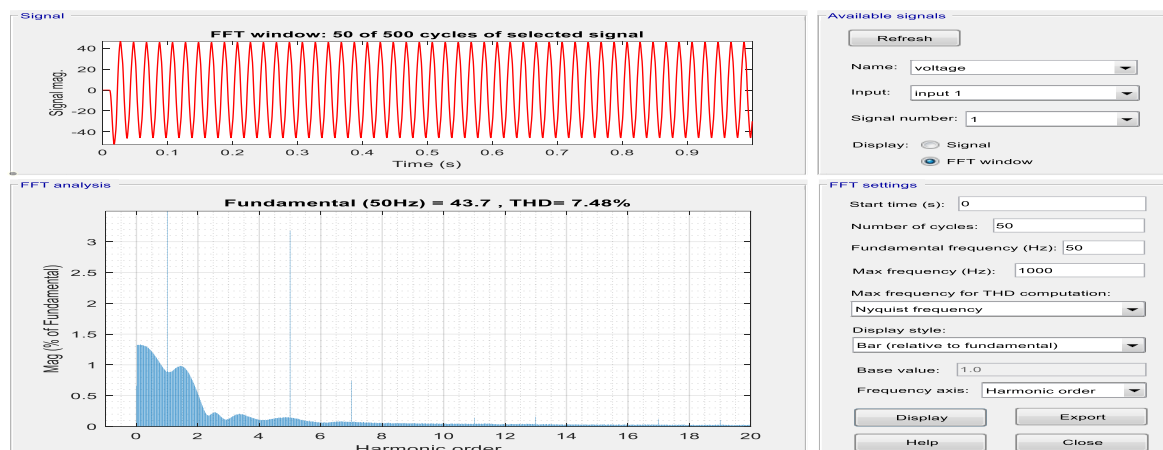


Figure 8: THD with SAPF

Although the THD is not up to the requirement of IEEE possibly because of our inability to locate the PCC correctly, but reduces the harmonic from 31.4 % to 7.43% accounting for 76.34% of the output without SAPF.

#### IV. CONCLUSION

In this work, the performances of SVPWM and SAPF were analyzed, from simulation result and comparative merits of IEEE Standard. It was observed that SVPWM technique is very good control technique of harmonic reduction. A reduction from 31.41% THD to 3.40 % accounting for 89.17% reduction hence, it can be concluded that the SVPWM meets the requirement of the IEEE benchmark. Also, SAPF performs good for reducing THD 76.34%. Therefore, SVPWM Technique is efficient in eliminating harmonics. In the future, we plan to implement a hardware of the simulation and to optimally search for a better PCC for SAPF so that it can meet the IEEE requirement.

#### REFERENCES

- Campanhol, L. B. G., da Silva, S. A. O., & Goedel, A. (2014). Application of shunt active power filter for harmonic reduction and reactive power compensation in three-phase four-wire systems. *IET Power Electronics*, 7(11), 2825-2836.
- Hoevenaars, T., LeDoux, K., & Colosino, M. (2003). *Interpreting IEEE STD 519 and meeting its harmonic limits in VFD applications*. Paper presented at the IEEE Industry Applications Society 50th Annual Petroleum and Chemical Industry Conference, 2003. Record of Conference Papers.

- Kushwah, R. S., & Walke, G. (2018). *Parallel Operation of Inverters With Droop Control of Voltage and Frequency*. Paper presented at the 2018 International Conference on Smart City and Emerging Technology (ICSCET).
- Mukherjee, S., Saxena, N., & Sharma, A. (2014). Power System Harmonic Reduction using Shunt Active Filter. *International Journal of Research in Engineering and Technology*, 3(04).
- Nisha, G., Ushakumari, S., & Lakapampil, Z. (2012). *Harmonic elimination of space vector modulated three phase inverter*. Paper presented at the Proceedings of the International Multi conference of Engineer and Computer Scientists.
- Ryu, H.-M., Kim, J.-H., & Sul, S.-K. (2005). Analysis of multiphase space vector pulse-width modulation based on multiple dq spaces concept. *IEEE Transactions on power electronics*, 20(6), 1364-1371.
- Shankar, V. A., & Kumar, N. S. (2017). Implementation of shunt active filter for harmonic compensation in a 3 phase 3 wire distribution network. *Energy Procedia*, 117, 172-179.
- VANAJAKSHI, N., & RAO, G. N. (2015). A three phase Shunt Active power Filter for harmonics reduction. *International Research Journal of Engineering and Technology*, 2.

## **DELAY OF CATASTROPHIC BOUNDARY LAYER SEPARATION OVER NACA 23012 AIRFOIL; A NUMERICAL STUDY**

Julius, M.O.<sup>1\*</sup> and Alonge, O. I.<sup>2</sup>

<sup>1</sup>Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

<sup>2</sup>Department of Mechanical Engineering, Elizade University, Ilaramokin, Ondo State, Nigeria.

\*Email of Corresponding Author: [mosesjulius41@gmail.com](mailto:mosesjulius41@gmail.com)

### **ABSTRACT**

Flow separation is caused by the action of the combined effect of the adverse pressure gradient and viscous force on the surface of the aeroplane wing and these lead to enormous loss of energy. Consequently, the aerodynamic performance is adversely affected (i.e. there is lift reduction and drag enhancement) and may lead to a catastrophe which put the safety of the aeroplane and the lives on it in danger. The introduction of suction slots, flaps, sophisticated high lifting devices to control the flow through separation delay can mitigate the aerodynamic losses. Therefore, this paper focuses on using a perpendicular suction to control the boundary layer separation of flow over the NACA 23012 aerofoil in order to stem the stalling effect that may lead to fatality. This was achieved by careful design and optimisation of the suction positions, suction jet amplitudes and other geometric parameters. The Reynolds Average Navier-Stokes (RANS) equations were employed together with the Menter's shear stress turbulent model. The jet width of 2.5% of the chord length was placed at different position varied from 10% to 70% of the chord length; the jet velocity was varied from 0.1 to 0.3 of the free stream velocity. The result of this study demonstrated that when the jet position is moved towards the trailing edge the lift to drag ratio decreases. Also, as the jet amplitude was increased, the lift to drag ratio increased commensurately. The jet position of 0.2c and jet amplitude of 0.3 is the most effective to improve the lift to drag ratio when compared to the NACA 23012 without suction. So the point of separation is delayed and the lift is increased significantly.

**Keywords:** flow control, jet width, lift to drag ratio, suction, boundary layer separation, turbulent flow.

## **INTRODUCTION**

In recent times and decade's age, most of the catastrophes on aeroplanes are caused by flow separation. The flow separation leads to loss of streamwise momentum which affects the aerodynamic performance of an aeroplane (lift enhancement, drag reduction and stall improvement) causing enormous loss of energy. At a low angle of attack, the flow over the streamline body (such as airfoil) is close to that of the inviscid theory prediction flow pattern (Snorri, 2013). However, at a high angle of attack or low Reynolds numbers, the combined action of viscous force (skin friction) and adverse pressure gradient enhances the formation of flow separation around the trailing edge which advances towards the leading edge as the angle of attack increase (Schlichting, 1955). The investigations into the boundary layer have produced numerous solutions to many design problems in areas of fluid mechanics through flow or boundary layer control. Flow control is the process of manipulating flow around a smooth straight surface to behave differently from its normal norms. The control of boundary layer separation can be grouped into two: passive method and active method. The active methods require energy expenditure while passive methods do not require energy expenditure (Gad-el\_Hak, 2000). Various works of literature have considered works of literature different technique to control flow in order to delay the transition, postpone separation, enhance lift, reduce drag, suppress noise, and augment turbulence. Prandtl (Schlichting, 1955) was the first scientist to experimentally investigate flow control through the application of suction on a cylindrical surface and he revealed that boundary layer separation would be eliminated almost entirely via suction through a slot on the back of the cylinder. Jacobs and Clay (1936) experimentally studied the aerodynamic characteristics of NACA 23012 wing under various aerodynamic conditions as compared to Clark Y and other NACA's airfoils. They concluded that NACA 23012 has the best aerodynamic characteristics. The development of sophisticated computation facilities in the past few decades has resulted in an increase in the use of computational fluid dynamics to investigate boundary layer control. Various numerical works have been done on most common NACA airfoils and other streamline bodies to measure and enhance the aerodynamic characteristics under several flow conditions [Firooz and Gadami (2006) to Manoha et al. (2001)]. Huang et al. (2004) applied suction and blowing techniques on NACA 0012 to control flow separation. They revealed that perpendicular suction located at the leading edge increased lift coefficient better than other suction conditions and the location of tangential blowing at the trailing edge produced the maximum increase in the lift coefficient

value. Yousefi et al. (2014) worked on the numerical optimization of suction jet parameters on the characteristics of NACA 0012. They concluded that suction located between 0.0175 and 0.125 of the chord length from the leading edge with 0.5 amplitude improved the aerodynamic characteristics of the airfoil; maximum increases in the lift, reduction in drag and stall improvement. Akcayoz and Tuncer (2009) worked on the maximization of lift to drag ratio through optimization of synthetic jet parameters on NACA 0015 airfoil in various angles of attack. Their results showed that the optimum jet location moved towards the leading edge, and as the angle of attack increased the optimum jet angle increased. Azim et al. (2015) delayed boundary layer separation through suction on NACA 4412 and optimized the suction parameter. They revealed that suction located 0.68 of the chord length, the suction pressure of 65kpa delay separation and the application of suction improved the lift to drag ratio approximately 2.24 times higher than that of without suction. The investigations have illustrated that suction located at an appropriate position modifies pressure distribution over an airfoil surface as such produce a satisfactory effect on lift and drag coefficients, hence mitigating the streamwise momentum loss in the growth of the separation thickness. In the current study, suction and length of the suction jet on aerodynamic characteristics of the NACA 23012 airfoil is numerically analysed at Reynolds number  $3.4 \times 10^6$ .

## **GOVERNING EQUATIONS**

The fluid was modelled as a two dimensional, steady, turbulent and viscous incompressible flow with constant properties. The classical physics equations that governed the fluid dynamics for this study are the continuity and the momentum equations which are as follows.

$$\frac{\partial \bar{u}_i}{\partial x_i} = 0 \quad (1)$$

$$\frac{\partial (\bar{u}_i \bar{u}_j)}{\partial x_j} = -\frac{1}{\rho} \frac{\partial \bar{P}}{\partial x_i} + \frac{\partial}{\partial x_j} \left[ \nu \frac{\partial \bar{u}_i}{\partial x_j} - \overline{u_i u_j} \right] \quad (2)$$

where  $\overline{u_i u_j}$  is the Reynolds stress tensor that incorporates the effects of turbulent fluctuations (Alfonsi, 2009).

## **THE TURBULENT MODEL**

The turbulent model used to predict the mechanics of fluid and the behaviour of fluids around the airfoil is Menter shear stress transport two-equation model. The Menter shear stress two-equation model provides a great and excellent predictive capability for flow with separation. This model (k $\omega$ -SST) includes k- $\omega$  and k- $\epsilon$  standard models as such it improves the calculation

of the flow of the boundary layer with separation and removes the k- $\omega$  model sensitivity to external flow. The Menter shear stress model is presented as:

$$\frac{\partial}{\partial x_i} (\rho U_i k) = \tilde{P}_k - \beta^* \rho k \omega + \frac{\partial}{\partial x_i} \left[ (\mu + \sigma_k \mu_t) \frac{\partial k}{\partial x_i} \right] \quad (3)$$

$$\frac{\partial}{\partial x_i} (\rho U_i \omega) = \alpha \rho S^2 - \beta \rho \omega^2 + \frac{\partial}{\partial x_i} \left[ (\mu + \sigma_\omega \mu_t) \frac{\partial \omega}{\partial x_i} \right] + 2(1 - F_1) \rho \sigma_{\omega 2} \frac{1}{\omega} \frac{\partial k}{\partial x_i} \frac{\partial \omega}{\partial x_i}$$

(4)

where  $\beta^*$  is 0.09 and  $\sigma_{\omega 2}$  is 0.856. Away from the surface, the blending function is zero (k-e model). Inside the boundary layer, the blending function switches to unity (k-w model).  $\tilde{P}_k$ , a production limiter was used in the SST model to prevent the buildup of turbulence in the stagnation regions (Menter, 1992) (Menter et al., 2003).

### THE GEOMETRIC MODEL SELECTION OF PARAMETER

In this study, ANSYS FLUENT was used for the modelling and numerical simulation. Values for the Reynolds number and the free stream velocity was  $3.4 \times 10^6$  and 49.66 m/s respectively. The geometry of NACA 23012 airfoil, suction jet location, suction jet angle and the jet length are shown in Figure 1. The chord length of the airfoil was 1 m; the suction jet length for this investigation was 2.5% of the chord length; the suction jet amplitude (i.e. the ratio of the suction jet velocity to free stream velocity) was between 0 and 0.3. Therefore, the following three parameters which are suction amplitude (A), dimensionless suction jet width ( $H = \frac{h}{c}$ ), suction jet location ( $L_j$ ) were investigated for optimum performance of the NACA23012 wing. Since stall occurs on NACA 23012 at around  $16^\circ$  AOA, the above investigations were carried out between  $0^\circ - 18^\circ$  angles of attack. The jet entrance velocity components are defined as follows:

$$v = u_{jet} \sin(\theta + \beta) \quad (5)$$

$$u = u_{jet} \cos(\theta + \beta) \quad (6)$$

where  $\beta$  is the angle between the free-stream velocity direction and the local jet surface, and  $\theta$  is the angle between the local jet surface and the jet output velocity direction. suction condition is represented with negative  $\theta$

### NUMERICAL PROCEDURES

The second-order upwind scheme was employed to discretize the governing equations. In the simulations, second-order upwind discretization in space was used and then, the resulting system of equations was solved through Semi-Implicit Method For Pressure Linked Equations

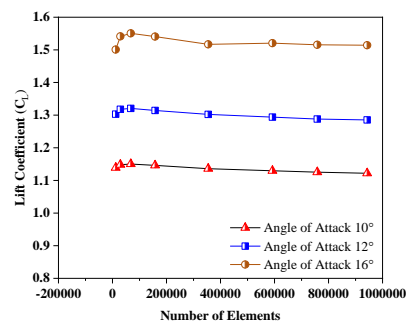


(SIMPLE) procedure until a convergence criterion of  $O(5)$  reduction in all dependent residuals is satisfied. A C-type structured grid with multi-zone blocks was generated as a computational domain. The computational area was large enough to prevent the outer boundary from affecting the near flow field around the airfoil. The inlet and lower boundaries were fixed with a uniform inlet velocity value. The upper and outer boundary conditions were the free-stream boundaries that satisfy the Neumann condition. No-slip boundary condition was used on the aerofoil surface. A low free-stream turbulence intensity less than 0.15% was used to match the wind tunnel characteristics and the mesh of  $y^+ < 1$  around the airfoil/ wing was ensured.

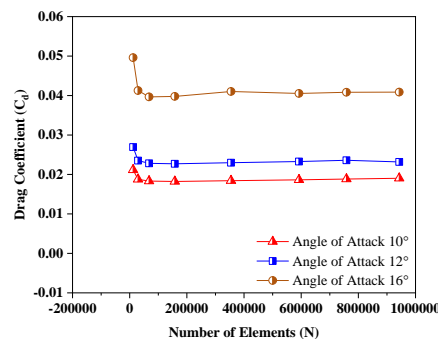
## RESULTS AND DISCUSSION

### Mesh Independent Study

The computations of the different sized grid were performed for NACA 23012 airfoil at Reynolds number  $3.4 \times 10^6$  to ensure grid independency test to the calculated results through the study of lift and drag coefficients at the angle of attack  $10^\circ$ ,  $12^\circ$  and  $16^\circ$  for the fundamental conditions without the application of jet on the airfoil surface. Figure 1 presented the lift and drag independency for lift and drag coefficient. The grid size with the fine mesh following a grid-independent result that produces a reasonable accuracy was selected to be 758410 cells.



(a)



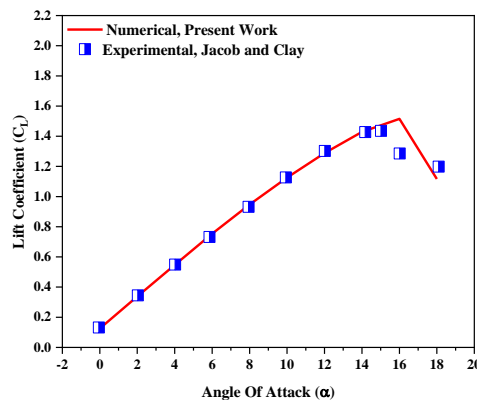
(b)

**Figure 2: Mesh Indecency For (a) Lift Coefficient (b) Drag Coefficient**

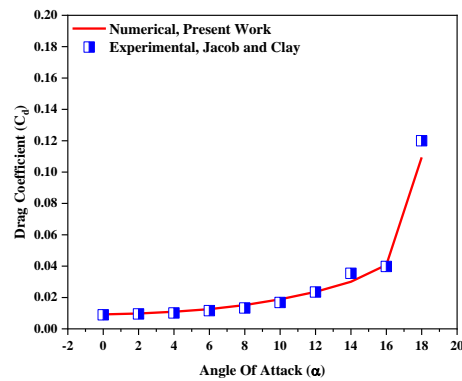
This mesh has a difference less than 0.001 from the preceding mesh as such the lift and drag ceased to have significant change as the number of quadrilateral elements increased as shown in details in Figure 1.

**VALIDATION**

For the validation of the data, the residuals in all simulations were continuing until the lift and drag coefficient reach a full convergence. The lift and drag coefficient were studied and compared with the experimental values of .Jacobs and Clay (1936). They investigated the Characteristics of the NACA 23012 airfoil under a Reynolds number of 3400000. The variation of the present work to the Jacob et al. experimental data started at the angle of attack of about  $14^{\circ}$  as shown in Figure 2. Thus, the percentage change between the present work and, Jacobs and Clay (1936) at an angle of attack  $16^{\circ}$  was 15.2%. The present computational results of lift coefficients show better agreement with Jacob et al. The significant variation is as a result of some uncertainty and the uncertainty could be attributed to several factors, such as different flow regimes, angles of attack, airfoil geometries, and turbulence model. Turbulence model selection has a significant effect on stall prediction and lift-to-drag ratio accuracy. The k- $\omega$  ST model has better stall prediction capability. For suction, the exact experimental data were not available.



(a)



(b)

**Figure 3: The comparison at Reynolds number  $3.4 \times 10^6$  for (a) lift Coefficient (b) drag coefficient**

#### Slot Selection

In enhancing the aerodynamic performance of suction, it is thereby necessary to place the suction in the appropriate position. The dependency of suction position on a various parameter such as Reynolds number, angle of attack (AOA), amplitude etc. makes the decision of choosing the best suction position complex because the parameters affect the position of suction. In other to ease the enormous complexities, the aerodynamic performance is measured at the various suction position on the upper surface of the aerofoil at amplitude 0.1 making Reynolds number and AOA constant at  $3.4 \times 10^6$  and  $10^\circ$ ,  $14^\circ$ ,  $18^\circ$  respectively as shown in detail in Figure 3. According to the velocity contour shown in detail in Figure 4, the trailing edge separation point is found around  $0.148c$  from the leading edge of the aerofoil for aerofoil without suction at AOA  $18^\circ$ . Suction slot close to the leading edge i.e. suction slot at  $0.2c$ , moves the separation point more in the vicinity of the trailing edge, about  $0.860c$  from the leading edge of the airfoil. On the contrary, the earlier suction slot such as  $0.05c$  and suction slot towards the trailing edge such as  $0.4c$ ,  $0.5c$ ,  $0.7c$  decreases the performance drastically as shown in detail in Figure 3 and Figure. 4. Therefore, the suction slot at  $0.05c$  and  $0.7c$  decreases the lift increases the turbulence and gives fully the adverse effect. This suggests that moving the slot downstream and upstream from  $0.2c$  will produce a catastrophic separation as such the increase in turbulence causes the skin friction to contributes to the increase in drag coefficient than that of without suction and the lift also decreases slightly, hence, lift to drag ratio falls off drastically. But suction slot at  $0.2c$  for AOA  $14^\circ$  decreases the drag coefficient by 44.4% from 0.030 to 0.016 which results in 78.3% increase in the lift to drag ratio from that of without suction. So, therefore, for better aerodynamic performance, suction is done at slot  $0.2c$ .

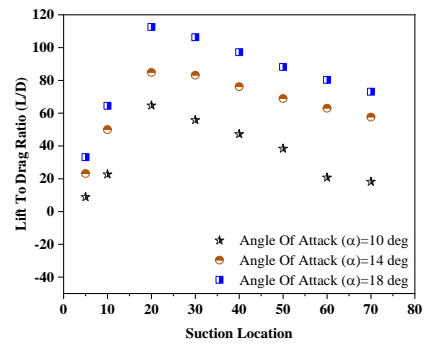
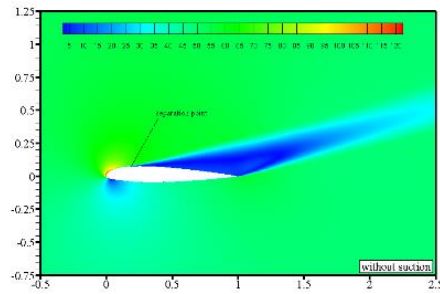
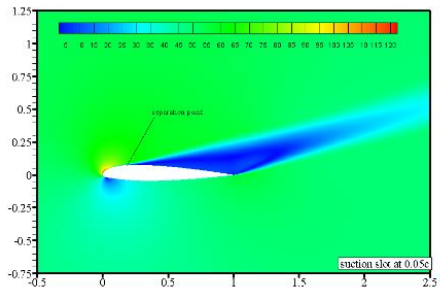


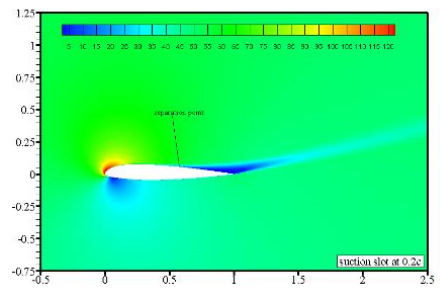
Figure 3: comparison between lift to drag ratio and suction location



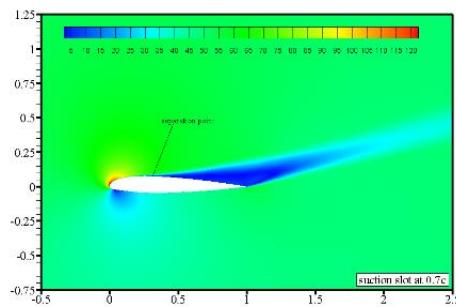
(a)



(b)



(c)

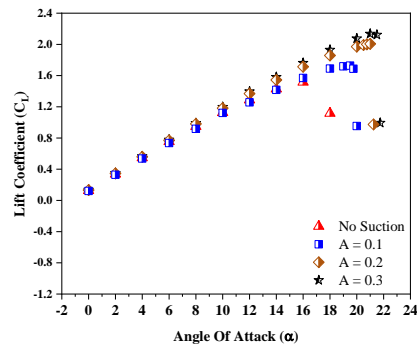


(d)

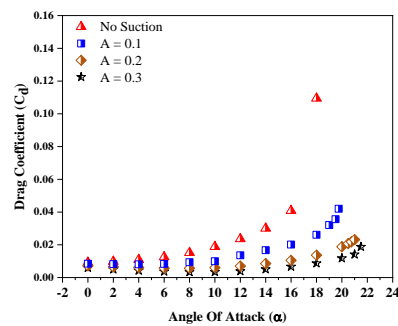
**Figure 4: velocity contour for AOA= 18° (a) without suction; (b) with suction at slot 0.05c; (c) with suction at slot 0.2c and (d) with suction at slot 0.7c of the aerofoil at suction amplitude 0.1.**

#### Effect of Suction Amplitude On Lift and Drag Coefficient

In Figure 5(a, and b) and Figure 6, the impact caused by the changes in suction amplitude was investigated. The location and width of the jet were fixed at 2.5% and 20% of the chord length, respectively. As suction amplitude was increased from 0.1 to 0.3 there was an improvement in the lift coefficient and reduction in the drag coefficient. However, the increase in the lift coefficient and reduction in drag coefficient are negligible for the angle of attack less than 10° for lift coefficient and angle of attack less than 4° for the drag coefficient. At an angle of attack of 18° with an amplitude of 0.3, the lift coefficient increased by 72.7%, and the drag coefficient decreased by 92.1%. However, increasing suction jet amplitude leads to improvement in the stall angle, which increased from 16° to 21.5° for jet amplitudes of 0 and 0.3, respectively. No suction conditions mean a jet amplitude of 0. Therefore, not only did the lift-to-drag ratio increases dramatically when suction was applied but also the stall angle was delayed effectively.

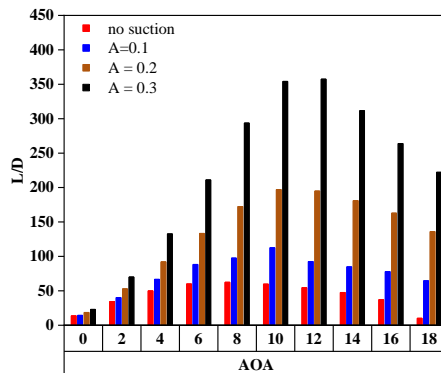


(a)



(b)

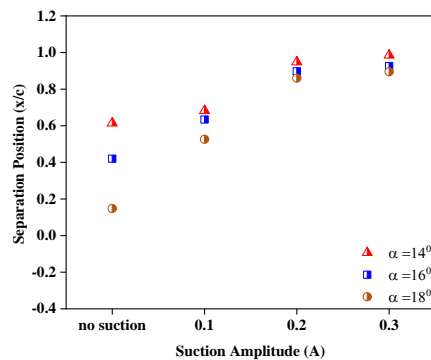
**Figure 5: Comparison of (a)lift coefficient and (b)drag coefficient between suctioned aerofoil and un-suction aerofoil at a different angle of attack.**



**Figure 6: comparison of lift to drag ratio between suctioned and un-suction aerofoil at a different angle of attack**

Trailing-Edge Separation for Different Suction Amplitude

The separation position moves towards the vicinity of the trailing edge of the aerofoil as the suction amplitude increase from 0.1 to 0.3. Initially, the introduction of the suction slot with an amplitude of 0.1 on the aerofoil moves the separation position towards the trailing edge in a great extent but later on; increase in suction amplitude moves the separation position slightly towards the trailing edge as shown in detail in Figure 7. For instance, at AOA=18°, separation position moves from 0.148c to 0.526c of the airfoil when the suction amplitude of 0.1 was introduced on plain aerofoil and later on, when suction amplitude changes from 0.1 to 0.2 and from 0.2 to 0.3 the separation point moves from 0.526c to 0.860c and 0.860c to 0.895c respectively on the aerofoil. Changes in separation point from leading-edge with the increase in suction amplitude is shown in Figure. 7.



**Figure 7: Change in trailing edge separation position with different suction amplitude.**

## CONCLUSION

In conclusion, the numerical investigation on the delay of catastrophic boundary layer separation over NACA 23012 airfoil has led to these remarks. The effects of suction parameters on a NACA 23012 airfoil for flow separation control were analyzed. Thus, employing numerical simulation, the results showed that the lift to drag ratio increased when suction amplitude was enhanced and the separation point moved to the vicinity of the trailing edge. The maximum lift to drag ratio value was obtained when suction amplitude reached 0.3. At the angle of attack 18° and same suction amplitude, vortex behind the airfoil was eliminated entirely. Another significant point, as it has been described is that the flow separation control using suction had no significant influence on aerodynamic characteristics at low angles of attack. In addition, the use of suction on airfoil could raise the airfoil stall angle. In this investigation, the stall angle changed from 16 to 21.5° when suction amplitude reached 0.3.

Finally, the airfoil lifts to drag ratio boost 75% and stall angle reached to  $21.5^\circ$  at the suction amplitude of 0.3, the angle of attack  $18^\circ$ , and 2.5 percent of the chord length as suction jet length.

## **REFERENCES**

- Akcayoz, E., and Tuncer, I. H. (2009). Numerical investigation of flow control over an airfoil using synthetic jets and its optimization. AIAC Paper 2009-043.
- Alfonsi, G. (2009). Reynolds-Averaged Navier–Stokes Equations for Turbulence Modeling. *Applied Mechanics Reviews*, 62(4), 040802.
- Azim, R., Hasan, M. M., and Ali, M. (2015). Numerical investigation on the delay of boundary layer separation by suction for NACA 4412. *Procedia Engineering*, 105(2014), pp. 329–334.
- Bahatmaka, A., Kim, D.-J., Chrismianto, D., Setiawan, J. D., and Prabowo, A. R. (2017). Numerical investigation on the performance of ducted propeller. MATEC Web of Conferences. Reykjavík University.
- Broeren, A. P., Addy, H. E., Bragg, M. B., and Busch, G. T. (2019). Aerodynamic Simulation of Ice Accretion on Airfoils.
- Firooz, A., and Gadami, M. (2006). Turbulence Flow for NACA 4412 in Unbounded Flow and Ground Effect with Different Turbulence Models and Two Ground Conditions : Fixed and Moving Ground Conditions. *Int. Conference on Boundary and Interior Layers (2006)*, pp. 1–11.
- Gad -el\_Hak, M. (2000). *Passive*. Cambridge University Press.
- Geissler, W., and van der Wall, B. G. (2017). Dynamic stall control on flapping wing airfoils. *Aerospace Science and Technology*, 62, pp. 1–10.
- Hand, B., Kelly, G., and Cashman, A. (2017). Numerical simulation of a vertical axis wind turbine airfoil experiencing dynamic stall at high Reynolds numbers. *Computers and Fluids*, 149, 12–30.
- Huang, L., Huang, P. G., LeBeau, R. P., and Hauser, T. (2004). Numerical Study of Blowing and Suction Control Mechanism on NACA0012 Airfoil. *Journal of Aircraft*, 41(5), pp. 1005–1013.
- Jacobs, E., and Clay, W. (1936). Characteristics of the NACA 23012 airfoil from tests in the full-scale and variable-density tunnels. Langley Field.



- Jones, K., Dohring, C., and Platzler, M. (1996). Wake structures behind plunging airfoils - A comparison of numerical and experimental results. 34th Aerospace Sciences Meeting and Exhibit, (96), pp. 1–11.
- Jones, L. E. (2008). Numerical studies of the flow around an airfoil at low Reynolds number. University of Southampton Faculty.
- Kroll, N., Rossow, C., and Schwaborn, D. (2002). MEGAFLOW-a numerical flow simulation tool for transport aircraft design. ICAS Congress. Braunschweig.
- Lee, S., and Bragg, M. B. (1999). Experimental Investigation of Simulated Large-Droplet Ice Shapes on Airfoil Aerodynamics Introduction. *Journal of Aircraft*, 36(5), pp. 844–850.
- Lehmkuhl, O., Rodríguez, I., Baez, A., Oliva, A., (2013). On the large-eddy simulations for the flow around aerodynamic profiles using unstructured grids. *Computers and Fluids*, 84, pp. 176–189.
- Lei, J., Zhao, S., and Wang, S. (2016). Numerical study of aerodynamic characteristics of FSW aircraft with different wing positions under supersonic condition. *Chinese Journal of Aeronautics*, 29(4), pp. 914–923.
- Lu, L., Liu, M. ming, Teng, B., Cui, Z. dong, Tang, G. qiang, Zhao, M., and Cheng, L. (2014). Numerical investigation of fluid flow past circular cylinder with multiple control rods at low Reynolds number. *Journal of Fluids and Structures*, 48, pp. 235–259.
- Manoha, E., Redonnet, S., Delahay, C., Sagaut, P., Mary, I., Ben Khelil, S., and Guillen, P. (2001). Numerical prediction of the unsteady flow and radiated noise from a 3D lifting airfoil. RTO AVT Symposium on “Ageing Mechanisms and Control: Part A - Developments in Computational Aero- and Hydro-Acoustics” (Vol. 079). Mancheste.
- Menter, F. R. (1992). Improved Two-Equation Turbulence Models for Aerodynamic Flows. Moffett Field.
- Menter, F. R., Kuntz, M., and Langtry, R. (2003). Ten Years of Industrial Experience with the SST Turbulence Model. In *Turbulence Heat and Mass Transfer*. Turkey: Heat and Mass Transfer, 4 (4), pp. 625–632.
- Moriche, M., Flores, O., and García-Villalba, M. (2016). Three-dimensional instabilities in the wake of a flapping wing at low Reynolds number. *International Journal of Heat and Fluid Flow*, 62, pp. 44–55.
- P. B. Makwana1. (2014). Numerical Simulation of Laminar Flow over Slotted Airfoil . *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 11(4), pp. 64–71.
- Resendiz, C., and Cizmas, P. (2006). Control of flow separation by oscillatory fluid injection -

- a numerical investigation. AandM University, Texas.
- Schlichting, H. (1955). Free turbulent flows; jets and wakes. In *Boundary Layer Theory* (4th Edition, pp. 590–596). McGraw-Hill Book Company Inc.
- Snorri Gudmundsson. (2013). *General Aviation Aircraft Design: Applied Methods* (1st Edition). Oxford: Butterworth-Heinemann.
- Spentzos, A., Barakos, G. N., Badcock, K. J., Richards, B. E., Wernert, P., Schreck, S., and Raffel, M. (2005). Investigation of Three-Dimensional Dynamic Stall Using Computational Fluid Dynamics. *AIAA Journal*, 43(5), pp. 1023–1033.
- Sunnyvale, C. and W. J. M. and P. K. (1984). Numerical Simulation of the Interaction of a Vortex with Stationary Airfoil in Transonic Flow. In *AIAA 22nd Aerospace Sciences Meeting*, pp. 1–27.
- Yousefi, K., Saleh, R., and Zahedi, P. (2014). Numerical study of blowing and suction slot geometry optimization on NACA 0012 airfoil. *Journal of Mechanical Science and Technology*, 28(4), pp. 1297–1310.

## NOMENCLATURE

$\alpha$	airfoil angle of attack
$\alpha_{stall}$	stalling angle of attack, coincident with the maximum lift coefficient
$c$	airfoil chord length
$C_d$	drag coefficient
$C_L$	lift coefficient
AOA	angle of attack
$x/c$	separation position
Re	Reynolds number based on chord surface length along with airfoil profile
$L_j$	suction width
A	suction jet amplitude
$L_p$	suction position
$\rho$	the density of the fluid
N	number of element
$\bar{P}$	the mean pressure
$\nu$	the kinematic viscosity
$u_{jet}$	the suction jet velocity

$u_\infty$	the free stream velocity
$\bar{u}$	the mean velocity
$\overline{u_i u_j}$	the Reynolds stress tensor
$F_1$	the blending function
$S$	the invariant measure of the strain rate

## **COMPARATIVE ASSESSMENT OF PROPERTIES OF LOCAL AND IMPORTED STEEL REINFORCING BARS IN SELECTED AREAS IN OSUN STATE**

Kareem, M.A.<sup>1\*</sup>, Adesiyan, T.O.<sup>1</sup> and Oduoye, W.O.<sup>1</sup>

<sup>1</sup> Department of Civil Engineering, Osun State University, Osogbo, Nigeria.

\*Email of Corresponding Author: [mutiu.kareem@uniosun.edu.ng](mailto:mutiu.kareem@uniosun.edu.ng)

### **ABSTRACT**

This study examines the properties of local and imported reinforcing bars used in building construction industries in Osun State. Imported and locally available steel reinforcing bars of 10, 12, 16 and 20 mm sizes were sourced from building construction sites within Osun State, Nigeria. Physical (percentage deviation in terms of actual bar sizes and weight) and mechanical properties (yield stress, ultimate stress, strain hardening ratio and percentage elongation) of the steel specimens were determined. The results showed that the percentage deviation in terms of actual bar sizes were 3% for 10 and 12 mm imported and local steels while it was 5 and 3% for 16 and 20 mm local steel against their imported counterpart. The percentage deviation in terms of weight were 12.8, 6.3, 2.3 and 11.5% for 10, 12, 16 and 20 mm sizes of local steels as against 5.2, 6.1, 22.8 and 16.8% obtained for the respective imported steels. The lowest yield stress and ultimate values of 467.19 and 580.37 N/mm<sup>2</sup> were obtained for 16 and 20 mm imported steels respectively. The lowest strain hardening ratio and percentage elongation values of 1.11 and 6.03% were obtained for 12 mm local and 10 mm imported steel bars. All local and imported steel products met the minimum yield and ultimate stresses requirement as specified by BS 4449 (1997), ASTM A706 (1996) and Nst 65-Mn (1994) respectively. However, the imported 10 and 12 mm steel rebars are brittle than their local counterparts.

**Keywords:** Percentage elongation, Reinforcing bars, Strain hardening ratio, Ultimate stress, Yield stress.

### **INTRODUCTION**

The properties of the materials used in construction need to be critically assessed before they are being used for construction works. This would enable the incorporation of these

properties relating to each material in the design of structures such as; building, dam, bridge, intake structures among others. This is particularly important in avoiding premature failure of the structures under service conditions. Several studies (Ayinnuola and Olalusi, 2004; Olusola and Opawole, 2009; Ede, 2010; Oleyede *et al.*, 2010; Olagunju *et al.*, 2013) have investigated the causes of building collapse in Nigeria. The use of substandard materials, foundation failure, faulty construction, poor design and improper site investigations are some of the factors responsible for these collapse of structures (Folagbade, 2002; Akintoye *et al.*, 2013; Chukwudi and Onyeka, 2010).

Steel reinforcing bars are used in conjunction with concrete, the commonly used construction materials (Nwakonobi *et al.*, 2015). The result of the combination of steel and concrete is referred to as reinforced concrete (Agbayere and Limbrunner, 2014). Thus, when they are combined, the steel provides the tensile strength and probably some of the shear strength while the concrete, strong in compression, protects the steel to give durability and fire resistance (Mosley and Bungey, 2007). Among the choices of fibres, glass, bamboo, polypropylene and so on being used as reinforcements in concrete. The choice of steel as a reinforcing material in concrete has gotten to the peak of preference. In most cases, the design of the structures become inadequate when the outcome of structural design is set aside when procuring the materials or when the properties of the material procured fail to meet up with the specifications which were put into considerations in the design and results of the design of such structures Arum (2008).

Steel reinforcing bars used by the indigenous construction industries in Nigeria are procured without the specification on their actual properties. Thus, this breathes gap in the performance of steel in reinforced concrete under applied loads without failure during its intended life. Also, the steels are used in buildings without being subjected to any test to confirm their adequacy and compliance with the actual specifications (Nwakonobi and Umar, 2015). The major sources of the available steel reinforcing bars in Nigeria's Construction Industry are both local and international (Akintoye *et al.*, 2013; Mohammed, 2012). The local ones are sourced from major indigenous steel plants such as Ikirun, Katsina, Delta and so on or the foreign-owned mini-mills located in different parts of the country. The international sources are the ones imported to the country from Russia and Ukraine and others procured by multinational companies for specific uses (Mohammed, 2012).

Mohammad (2012) stated that the steel produced by the rolling mills in Nigeria as well as the imported steel should have their quality testing certificate and the regulatory agencies

should carry out periodic inspection to ensure compliance with the standard specification. Ede *et al.* (2015) investigated the quality of steel reinforcing bars used in building construction sites in Lagos state and the study concluded that an average of 70% of the samples considered satisfied BS 8110 code specification. Ejeh and Jibrin (2012) carried out the tensile tests on steel reinforcing bars produced by different companies in Nigeria and recommended that a constant check and re-evaluation of the steel reinforcing bars produced in Nigeria must be carried out on regular by the government agency so as to proactively avert the occurrence of building collapse in construction industries. Thus, this current work investigated the physical and mechanical properties of local and imported steel reinforcing bars in selected areas in Osun State, Nigeria.

## **MATERIALS AND METHODS**

### **Materials**

The steel reinforcing bars used in this study were imported and locally reinforcing steel bars of 10, 12, 16 and 20 mm sizes. These steel were sourced from building construction sites across 5 Local Government Areas in Osun State, Nigeria. Each bar size was randomly selected from each source.

### **Specimens Preparation**

Three specimens were prepared for each bar size collected from different building construction sites in the study area and a total of 24 specimens were prepared for the test. Each specimen consist of a length of a bar of 460 mm.

### **Testing of Specimens**

The physical properties of the steel reinforcing bars determined were the diameter and weight. The bar diameter and weight were measured for 3 specimens of each bar size and the average was obtained as bar diameter and weight, respectively. The percentage deviation in terms of actual bar size and weight were evaluated from the average bar diameter and weight respectively.

The mechanical properties of steel reinforcing bars were determined by carrying out tensile strength test on the steel reinforcing bar specimens using a Universal Testing Machine (UTM) of 2000 kN capacity (Figure 1) at the Structural and Materials Laboratory, Osun State University, Osogbo, Nigeria. Three specimens of each bar size and were tested and the average

of tensile parameters were recorded. The test was carried according to BS 4449 (1997) and ASTM 370 (2016).



**Figure 1: Tensile test specimen in the UTM**

The tensile parameters measured on the computer monitor attached to the UTM are yield load, maximum load and elongation. The yield stress, ultimate stress, strain hardening ratio and percentage elongation were evaluated using the expressions In Equations 1-4, respectively (Ejeh and Jibrin, 2012; Ede *et al.*, 2015).

$$\text{Yield Stress} = \frac{\text{Yield Load}}{\text{original cross – sectional area}} \quad (1)$$

$$\text{Ultimate Stress} = \frac{\text{Maximum Load}}{\text{original cross–sectional area}} \quad (2)$$

$$\text{Strain hardening ratio} = \frac{\text{Ultimate stress}}{\text{Yield stres}} \quad (3)$$

$$\text{Percentage elongation} = \frac{\text{elongation}}{\text{Original length}} \times 100 \quad (4)$$

## **RESULTS AND DISCUSSION**

Physical properties of reinforcing steel bars

**Table 1: Comparison of the diameter of reinforcing bars with standard**

\* BS 4449 (1997)

SOURCE	Nominal Bar dia. (mm)	Measured Bar dia. (mm)	Percentage Deviation (%)	*Percentage Deviation (%)	Remarks
LOCAL	10	9.7	3	8	Satisfactory
	12	11.7	3	8	Satisfactory
	16	15.2	5	8	Satisfactory
	20	19.7	3	8	Satisfactory
IMPORTE D	10	9.7	3	8	Satisfactory
	12	11.7	3	8	Satisfactory
	16	14.5	9.4	8	Not Satisfactory
	20	18.7	6.5	8	Satisfactory

The results of the physical properties of steel reinforcing bars; diameter, weight and their percentage deviation in terms of actual bar sizes and weight are presented in Table 1 and 2.

#### Bar diameter

Table 1 shows the bar diameters measured for the local and imported steel reinforcing bars. The results revealed that the 10 and 12 mm local and imported steel reinforcing bars had the same cross-sectional percentage deviation of 3% as compared to their nominal diameters and satisfied BS 4449 (1997) requirements of the maximum 8% both local and imported steel reinforcing bars. The 16 mm local reinforcing bars had 5% deviation as against 9.4% deviation for imported 16 mm, thus, the 16 mm reinforcing bars exceeded the BS 4449 (1997) requirements maximum value. Besides, the 20 mm local had 3% as against 6.5% deviation for 20 mm imported however, both are still within the specification range of BS 4449 (1997) requirements.

#### Bar weight

Table 2 shows the bar weight measured for the local and imported steel reinforcing bars. The results showed the percentage deviation of 10 mm local reinforcing bars of 12.8% as against 5.2% by imported reinforcing bars. Thus the 10 mm local reinforcing bar exceeded the maximum



**Table 2: Comparison of the weight of reinforcing bars with standard**

SOURCE	Bar dia. (mm)	Standard Bar Weight (kg/m)	Measured Bar Weight (kg/m)	Deviation (%)	*Deviation (%)	Remarks
LOCAL	10	0.617	0.538	12.8	6.5	Not Satisfactory
	12	0.888	0.832	6.3	4.5	Not Satisfactory
	16	1.580	1.544	2.3	4.5	Satisfactory
	20	2.470	2.187	11.5	4.5	Not Satisfactory
IMPORTED	10	0.617	0.585	5.2	6.5	Satisfactory
	12	0.888	0.834	6.1	4.5	Not Satisfactory
	16	1.580	1.219	22.8	4.5	Not Satisfactory
	20	2.470	2.054	16.8	4.5	Not Satisfactory

\* BS 4449 (1997)

tolerance on the mass of 6.5% specified by BS 4449 (1997) as shown in table 2. The 12 reinforcing bars exceeded the BS 4449 (1997) requirements maximum value. Besides, the 20 mm local had 3% as against 6.5% deviation for 20 mm imported however, both are still within the specification range of BS 4449 (1997) requirements.

The 16 mm local reinforcing bars had the deviation of 2.3% as against the local 16 mm reinforcing bars which had the deviation of 22.8%. This indicates that the local 16 mm reinforcing bars satisfied the maximum

tolerance on the mass limit of 4.5% specified by BS 4449 (1997) whereas its imported counterpart fails to meet up with the specifications. The local and imported 20 mm reinforcing bars had a deviation of 11.5% and 16.8% which are far above the tolerance on the mass of 4.5% specified by BS 4449 (1997).

## Mechanical Characteristics of the Steel Bars

The mechanical properties of the local and imported steel reinforcing bars determined from tensile strength tests specimens; yield stress, ultimate stress, strain hardening ratio and percentage elongation are presented in Figures 2 to 5.

### Yield stress

Figure 2 shows the results of yield stress for the local and imported reinforcing steel bars specimens. It can be observed that all the imported reinforcing bars recorded the highest yield stress compared to their local counterpart and the highest yield stress value of 693.38 N/mm<sup>2</sup> was obtained for 10 mm imported steels while the lowest yield stress value of 467.19 N/mm<sup>2</sup> was obtained for 16 mm imported steels, respectively. The results also indicated that 10, 12, 16 and 20 mm local and imported reinforcing bars met minimum yield stress value of 460 N/mm<sup>2</sup> specified by BS 4449 (1997), 415 N/mm<sup>2</sup> by ASTM A706 (1996) and Nst 65-Mn (1994), respectively which is in line with the findings of Awofadeju *et al.* (2014).

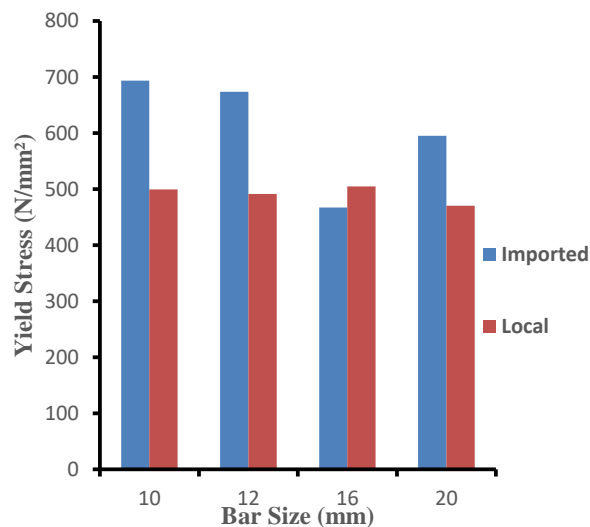


Figure 2: Yield Stress for Local and Imported Steel

### Ultimate stress

Figure 3 shows the ultimate stress results for local and imported steel reinforcing bar specimens. It can be observed that all the imported reinforcing bars recorded the highest ultimate stress compared to their local counterpart except the 16 mm local. Also, the highest

ultimate stress value of 775.02 N/mm<sup>2</sup> was obtained for 10 mm imported steels while the lowest yield stress value of 596.97 N/mm<sup>2</sup> was obtained for 16 mm imported steels, respectively. Thus, the outstanding performances of 10, 12 and 20 mm imported steel rebars in both yield and ultimate strength may be an indication that those imported bars contain more carbon contents than the locally produced bars as high per cent carbon contributes to high strength in steel products (Alabi and Oyeji, 2010). The results also indicated that 10, 12, 16 and 20 mm local and imported reinforcing bars met minimum yield stress value of 600 N/mm<sup>2</sup> specified by BS 4449 (1997), 580 N/mm<sup>2</sup> by ASTM A706 (1996) and 600 N/mm<sup>2</sup> Nst 65-Mn (1994), respectively which is in line with the findings of Nwakonobi and Umar (2015).

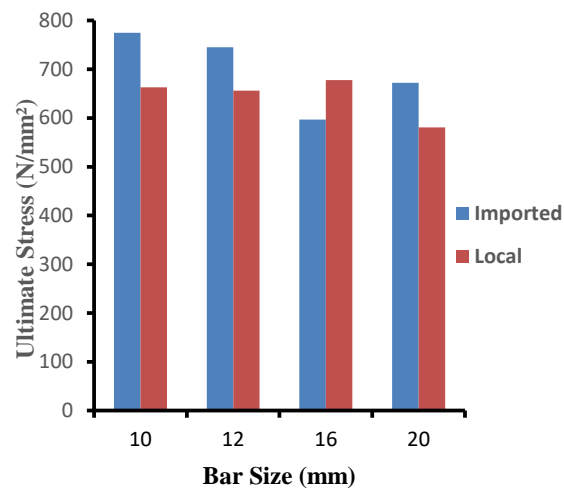


Figure 3: Ultimate Stress for Local and Imported steel

#### Percentage elongation

The results of the percentage elongation of the local and imported steel reinforcing bars specimens are shown in Figure 4. The results indicated that the 12 and 20 mm local reinforcing bars satisfied the minimum percentage elongation value of 12% recommended by BS 4449 (1997) and 10% by Nst 65-Mn (1994), respectively but failed to satisfy 14% by ASTM A706 (1996) while the 10 and 16 mm local reinforcing bars satisfied the 10% recommended by Nst 65-Mn (1994) but failed to satisfy 12% recommended by BS 4449 (1997) and 14% by ASTM A706 (1996). All the imported steel reinforcing bars failed to satisfy 12% recommended by BS 4449 (1997), 14% by ASTM A706(1996) and 10% recommended by Nst 65-Mn (1994) with the exception of 16 mm imported reinforcing bars which satisfied 10% recommended by Nst 65-Mn (1994). These results indicate that none of the imported products comports to these

requirements. This is in agreement with the findings from previous studies (Ejeh and Jibrin, 2012). This could be attributed to higher percentages of manganese in the imported bars as higher manganese reduces percentage elongation of steel reinforcements (Nwakonobi *et al.*, 2015). However, the percentage elongations of 10 and 12mm local bars are relatively more than the imported ones, which indicates that the imported 10 and 12mm bar products are brittle than local bar products (Apeh, 2013).

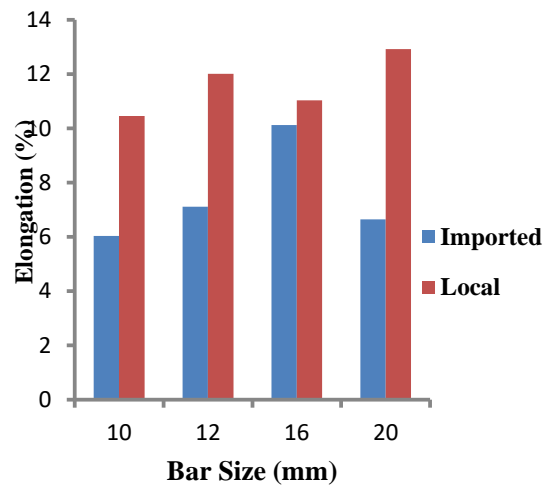


Figure 4: Percentage Elongation for Local and Imported steel rebars

#### Strain hardening ratio

Figure 5 shows the Strain hardening ratio results for the local and imported reinforcing steel bars specimens. It can be observed that all the imported and local reinforcing bars satisfied the minimum strain hardening ratio value of 1.15 recommended by BS 4449 (1997) except for the 10 and 12 and 20 mm of the imported bars. The Strain hardening ratio values obtained for the local reinforcing steel bars are generally higher compared to their imported counterparts which are closer to the minimum requirements. This result is in agreement with the finding of Ejeh and Jibrin (2012). However, about 75% of the conformed local products surpassed the code value by more than 15% which is not true for the imported products.

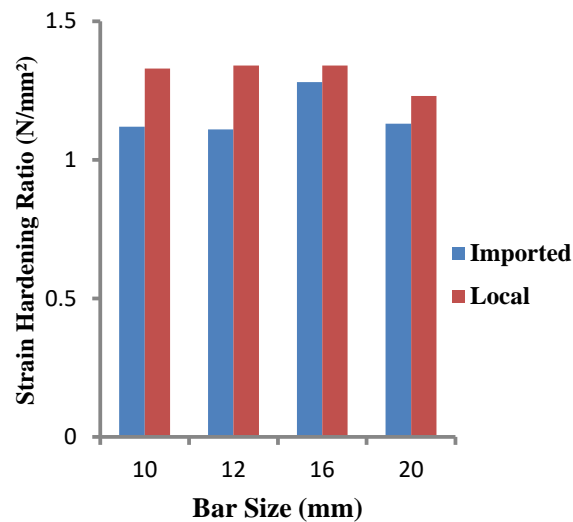


Figure 5: Strain Hardening Ratio for Local and Imported Steel rebars

## CONCLUSION

The following conclusions were drawn based on the findings from this study:

1. It is well understood from the study that product sources affect significantly the characteristics of steel reinforcing bars.
2. Both local and imported steel products met the minimum yield stress requirement of 460 N/mm<sup>2</sup> as specified by BS 4449 (1997).
3. The 10, 12 and 20 mm imported steel reinforcing bars performed outstandingly better in both yield and ultimate strength.
4. The imported 10 and 12 mm steel reinforcing bars are brittle than their local counterparts.

## REFERENCES

- Agbayere, A.O. and Limbrunner, G.F., 2014. Reinforced concrete design Pearson Education Inc. New Jersey.
- Akintoye, O., Chris, F. and Oladimeji, D., 2013. Effects of source of reinforcement on microstructure and Strength characteristics of reinforced concrete beams, *Civil and Environment Research*, 3(9), pp. 26-35.
- Alabi, A. and Onyeji, L., 2010. Analysis and comparative assessment of locally produced reinforcing steel bars for structural purposes, *Journal of Research Information in Civil Engineering*, 7(2), pp. 49-60.

- Apeh, A.J., 2013. Assessment of mechanical properties of reinforcing steel used in construction works at F.C.T, Abuja, *International Journal of Engineering Research and Technology (IJERT)*, 2(6), pp. 2346-2358.
- Arum, C., 2008. Verification of properties of concrete reinforcement bars: Nigeria as case study, *Journal of Indoor and Built Environment SAGE*, pp. 370-376.
- ASTM A706, 1996. Standard specification for deformed and plain low-alloy steel bars for concrete reinforcement: Grade reinforcing bars. America Standard for Testing Materials.
- Awofadejo, A.S. Adekiigbe, A., Akanni, A.O. and Adeyemo, B.G., 2014. Evaluation of locally produced and imported reinforced steel rods for structural purposes in Nigeria, *International Journal of Recent Development in Engineering and Technology*, 3(8). pp. 81-84.
- Ayinuola, G.M. and Olalusi, O.O., 2004. Assessment of building failures in Nigeria: Lagos and Ibadan case study”, *African Journal of Science and Technology AJST*, 5(1), pp. 73-78.
- BS 4449, 1997. Carbon steel bars for the reinforcement of Concrete, British Standard Institutions, London. pp. 1-48.
- Chukwudi, B. C. and Onyeka, J. O., 2010. Assessment of the quality of a steel rods available in onitsha market: In view of the role of poor quality rods in building failures in Nigeria, *The Pacific Journal of Science and Technology*, pp. 73-78.
- Ede, A.N., Egunjobi, E.O., Bamigboye, G.O. and Ogundeji, J., 2015. Assessment of quality of steel reinforcing bars used in Lagos, Nigeria, *International Research Journal of Innovative Engineering*, 1(3), pp. 1-8.
- Ede, A. N., 2010. Structural stability in Nigeria and worsening environmental disorder: The way forward. The West African Built Environment Conference Research”, Accra, Ghana, July, 76-78, pp. 489-498.
- Ejeh, S. P. and Jibrin, M.U., 2012. Tensile tests on reinforcing steel bars in the Nigerian Construction Industry, *IOSI Journal of Mechanical and Civil Engineering*, 4(2), pp. 06-12.
- Folagbade, S.O., 2002. Case studies of building collapse in Nigeria, D.R Ogunseemi, eds., proc. of Nigeria Institute of Building Conference held at Ondo State, Nigeria on Building Collapse: Causes, Prevention, and Remedies, pp.110-121, 2002

- Mohammad, U.J., 2012. Characterization of reinforcing steel bars in the Nigerian Construction Industry, Unpublished Ph.D. thesis, Department of Civil Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria.
- Mosley, W. H., Bungey, J.H. and Hulse. R. 2007. Reinforced concrete design to Eurocode 2”, 6<sup>th</sup> Revised Ed., Great Britain, Antony Rowe
- Nwakonobi, T.U. and Mohammad, S.M., 2015. Comparative study on the strength characteristics of reinforcement bars from Local Industries and Imported sources, *International Journal of Scientific & Engineering Research*, 6(5), pp. 1011-1012.
- Nst 65-Mn, 1994. Raw materials and specifications for Federal Government Steel Companies”, 1<sup>st</sup> Edition: Nigeria Standard.
- Olagunju, R.E., Aremu, S.C. and Ogundele, J., 2013. Incessant collapse of buildings in Nigeria: An Architect’s view, *Journal of Civil and Environmental Research*, 3(4), pp. 49-59.
- Oloyede, S.A., Omogun, C.B. and Akinjare, O.A., 2010, Tracking causes of building collapse in Nigeria”, *Journal of sustainable Development*, 3(3), pp. 127-132.
- Olusola, B.S. and Akintayo, O., 2009. An assessment of failure of building components in Nigeria, *Journal of Building Appraisal*, 4. pp 279-286.
- Oloyode, S.A. Omogun, C.B. and Akinjare, O.A., 2010. Tracking Causes of Building Collapse in Nigeria, *Journal of sustainable Development*, 3(3) pp. 127-132.

## **APPLICATION OF TAU METHOD TO LINEAR AND NON-LINEAR INTEGRO-DIFFERENTIAL EQUATIONS.**

Olayiwola, M.O. <sup>1</sup>, Adedeji, J.A. <sup>1\*</sup>and Aregbesola, Y.A.S.<sup>2</sup>.

<sup>1</sup>Department of Mathematical Sciences, Faculty of Basic and Applied Sciences, Osun State University, osogbo, Nigeria.

<sup>2</sup>Department of Mathematics, Obafemi Awolowo University, Ile-ife, Nigeria.

**\*Corresponding author e-mail: [adedejijoseph001@gmail.com](mailto:adedejijoseph001@gmail.com)**

### **ABSTRACT**

The present study employed Tau method to obtain an approximate solution of integro differential equations both linear and non-linear. An assumed approximate solution using basic polynomial are substituted into the problem considered. After simplifications, which resulted into system of linear algebraic equations which are then solved to obtain the unknown constants involved in assumed approximate solutions. We consider the solution of integro-differential equation of the type Fredholm, Voltterra and the combination of Volterra-Fredholm equation. We also used the method of Taylor's expression approach to integro-differential Volterra equations. We compared the solutions of Volterra equation using the Taylor's series expression with Tau method, the result percentage error of  $0 \leq x \leq 1$  is 0 to 0.001631% which compared to be favourably well.

We formulate mathematical algorithm for the computation of all the problems considered with the help of Maple software and we also observed that the more terms in the assumed solution the less the error.

**KEYWORDS:** Tau method, Integral equation, differential equation, Integro-differetial equation, Taylor's Series.

### **1. Introduction**

Integral and integro-differential equations play an important role in characterizing many social, biological, physical and engineering problems; for more details see (S. Suresha, 2019).

Nonlinear Volterra integral equations:



$$u(t) = f(t) + \int_0^t k(t,s)G(s,u(s))ds, \quad 0 \leq t \leq a \quad (1)$$

Where  $f$ ,  $k$  and  $G$  are smooth given functions with  $G(s,u)$  nonlinear in  $u$ , and  $u(t)$  is a solution to be determined. These types of equations arise as a reformulation of some initial value problems for ordinary differential equations where the kernel is of convolution type and the free term is a polynomial whose coefficients are essentially given by the initial values. Detailed description and analysis of these models may be found in Madbouly, McGhee and Roach, 2001.

The numerical solvability of the (1) and other related equations has been pursued by several authors. Brunner (Brunner, 1984) applied the implicitly linear collocation method for (1) and discussed its connection with the iterated collocation method. In (Razzaghi & Ordokhani, 2001), the rationalized Haar functions are developed to approximate solution of (1). Yalcinbas (Y.Mahmoudi, 2017) has been concerned with the Taylor polynomials of certain nonlinear Volterra-Fredholm integral equations with algebraic nonlinearity. Recently, (s.shahmorad, 2007) have been concerned with the numerical solution of integro-differential equations and some linear classes of (1) via the Tau method with the arbitrary bases especially Chebyshev and Legendre bases.

Spectral methods have been studied intensively in the last two decades because of their good approximation properties.

The Tau method first introduced by Lanczos in 1938 has over time been developed into different variants and Tau method does not require a stage of discretization of the given differential operator, as discrete-variable methods do (Olashile, 2015). Using the Taylor series, this method differentiates the integro-differential equation as many times as the number of constants introduced.

## **2. Tau Method**

Assuming one wishes to solve by means of a power series expansion the simple linear differential equation  $Dy(x) := y'(x) + y(x) = 0, 0 \leq x \leq 1, y(0) = 1$  (2)

Which defines  $y(x) = \exp(-x)$ . To find the coefficients of a formal series expansion of  $y(x)$ , one substitutes the series in the equation and generates a system of algebraic equations for the coefficients:  $a_j$  for  $j = 1, 2, \dots$ , solving it in terms of  $a_0$ . The value of  $a_0$  is fixed using the initial

condition. To find a finite expansion, say of order  $n$ , one needs to make all coefficients  $a_j$  with  $j > n$  equal to zero. This is achieved by adding a term of the form  $\tau x^n$  to the right-hand side of the differential equation. One has  $(n+1)a_n + 1 + a_n = \tau$ , so that  $a_n + 1$  and all the coefficients following it, will be equal to zero if one chooses  $a_n = 1$ . The same condition follows by substituting a segment of degree  $n$  of the series expansion of  $y(x) = \exp(-x)$  into the equation. If the solution of the perturbed differential equation is regarded as an approximation to that of the original equation with, say, a right-hand side equal to zero, it seems natural to replace it by the best uniform approximation of zero over the same interval  $j$ , which is a Chebyshev polynomial  $T_n^*(x)$  of degree  $n$ , defined over  $j$ .

Therefore, to find an accurate polynomial approximation of  $y(x)$ , Lanczos proposed solving exactly the more complex perturbed problem (the Tau problem),

$$Dy_n^*(x) = \tau T_n^*(x) \quad (3)$$

With the same initial conditions as before. The polynomial  $y_n^*(x)$  is called the Tau method approximation of  $y(x)$  over the given interval  $j$ .

### 3. Taylor's Method

One of the oldest methods for the approximate solution of ordinary differential equations is their expansion into a Taylor series. In this method the solution of an equation

$$y = f(x, y) \quad (4)$$

with the initial condition

$$y(x_0) = y_0 \quad (5)$$

is approximated by a partial sum of the Taylor series

$$\sum_{n=0}^{\infty} \frac{f^{(n)}(a)}{n!} (x-a)^n. \quad (6)$$

The method of expansion into a Taylor series as well as methods based on the expansion in series of a more general nature are commonly used to find an approximate solution in the form of an analytical expression.

#### 4. Integral Differential Equation

We consider the integro-differential equation with variable co-efficient of the form:

$$y(x) = f(x) + \lambda \int_a^b k(x, t)y(t) dt \quad (7)$$

Equation above is referred to as Fredholm integro-differential equation with variable co-efficient, where  $f(x)$  are given continuous smooth functions defined on  $a \leq x \leq b$  and Volterra integro-differential equation where  $f(x)$  is defined on  $(0, x)$ .

In order to solve equation (7) using the Tau method, we used an approximate solution of the form:

$$Y_N(x) = \sum_{n=0}^N a_n x^n \quad (8)$$

Where  $N$  is the degree of our approximation,  $a_n$  are constants to be determined and  $Y_N(x)$  are the basic functions defined in equation (8). Thus, differentiating equation (8) with respect to  $x$ , determine by the order of differential equation involve, we obtain;

$$Y'(x) = \sum_{n=0}^N n a_n x^{n-1} \quad (9)$$

$$Y''(x) = \sum_{n=0}^N n(n-1) a_n x^{n-2} \quad (10)$$

And so on:

Then substituting equation (8) and its derivate in equation (9) and (10) into equation (7), we obtain.

$$y(x) = f(x) + \lambda \int_a^b k(x, t)y(t) dt \quad (11)$$

Evaluating the integral part of equation (7) which will provide a constant in form of

$$A(a_0, a_1, \dots, a_n) = \int_a^b g(x, t)y(t) dt \quad (12)$$

Putting the expression  $y(t)$  into the equation above to have;

$$Y(x) = f(x) + \lambda A \quad (13)$$

After simplifications, we collect the like terms of power of x to get some equations, after making the assumed solutions to satisfy the given initial conditions which is used in the equation gotten, to obtain the computed solution.

## 5. Numerical Examples:

### Problem 1:

$$y''(x) = y(x) + \frac{1}{e} - 1 + \int_0^1 y(x) dx \quad (14)$$

With initial conditions  $y(0) = 1$ ,  $y'(0) = -1$  the exact solution is  $y(x) = e^{-x}$ .

$$y''(x) = y(x) + \frac{1}{e} - 1 + \int_0^1 y(x) dx \quad (15)$$

The solution can be express in form of power series; considering a finite series with six constant

$$y(x) = \sum_{n=0}^5 a_n x^n = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5 \quad (16)$$

$$y'(x) = \sum_{n=0}^5 n a_n x^{n-1} = a_1 + 2a_2 x + 3a_3 x^2 + 4a_4 x^3 + 5a_5 x^4 \quad (17)$$

$$y''(x) = \sum_{n=0}^5 n(n-1) a_n x^{n-2} = 2a_2 + 6a_3 x + 12a_4 x^2 + 20a_5 x^3 \quad (18)$$

$$\text{Let } A = \frac{1}{e} - 1 \quad \text{and } B = \int_0^1 y(x) dx \quad (19)$$

Putting the expression of equation (16) in the integral we have;

$$B = a_0 + \frac{a_1}{2} + \frac{a_2}{3} + \frac{a_3}{4} + \frac{a_4}{5} + \frac{a_5}{6} \quad (20)$$

Note that B is in form of constants from (15)

$$y''(x) = y(x) + A + B \quad (21)$$

In putting the equation (16), (18), (20) and (21) above, we have;

$$\begin{aligned}
 2a_2 + 6a_3x + 12a_4x^2 + 20a_5x^3 = & a_0 + \frac{a_1}{2} + \frac{a_2}{3} + \frac{a_3}{4} + \frac{a_4}{5} + \frac{a_5}{6} \\
 a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4 & \\
 + a_5x^5 - 0.6321205588 + a_0 + & 
 \end{aligned} \tag{22}$$

Collecting terms involving like powers of x and applying initial condition, we have;

$$y(0) = 1 = a_0, y'(0) = -1 = a_1$$

$$x^0 : \frac{5a_2}{3} - 0.8678794412 - \frac{a_3}{4} - \frac{a_4}{5} - \frac{a_5}{6}$$

$$x^1 : 6a_3 + 1$$

$$x^2 : 12a_4 - a_2$$

$$x^3 : 20a_5 - a_3 \tag{23}$$

After computation, the constant is;

$$a_0 = 1, a_1 = -1, a_2 = 0.4998932640,$$

$a_3 = -0.1666666667, a_4 = 0.0416577200$ , Substituting these co-efficient into (16), which is

$$a_5 = -0.0083333333$$

called computed solution

$$\begin{aligned}
 y_c(x) = & 1 - x + 0.4998932640 x^2 \\
 & - 0.1666666667 x^3 + 0.0416577200 x^4 \\
 & - 0.0083333333 x^5
 \end{aligned}$$

$$y_e(x) = 1 - x + \frac{x^2}{2} - \frac{x^3}{6} + \frac{x^4}{24} - \frac{x^5}{120} + 0(x^6)$$

(24)

Substituting these co-efficient into (20);

$$B = 0.63190070868.$$

Table 1.0 comparison of the computed solution with the exact solution.

x	$Y_e$	$Y_c$	abs( $y_e - y_c$ )
0	1	1	0
0.1	0.904837	0.904836	1.07E-06
0.2	0.818731	0.818726	4.37E-06
0.3	0.740818	0.740808	1.06E-05
0.4	0.67032	0.670297	2.27E-05
0.5	0.606531	0.606483	4.75E-05
0.6	0.548812	0.548712	9.92E-05
0.7	0.496585	0.496382	0.000203
0.8	0.449329	0.448931	0.000398
0.9	0.40657	0.405824	0.000745
1	0.367879	0.366551	0.001328

We note that as the value of the value of increase from 0.0 to 1.0 the absolute error with increases from 0.0 to 0.013284052 .This is expected since the series is convergent [radius of convergent]  $0 \leq x \leq 1$  .

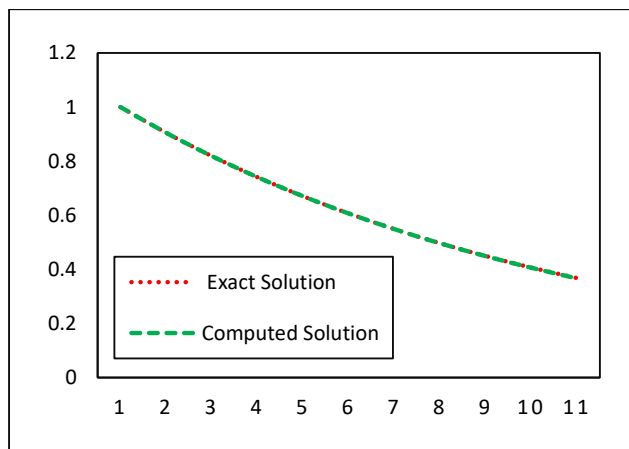


Figure 1. Comparison of the exact solution and the approximate solutions for Problem 1

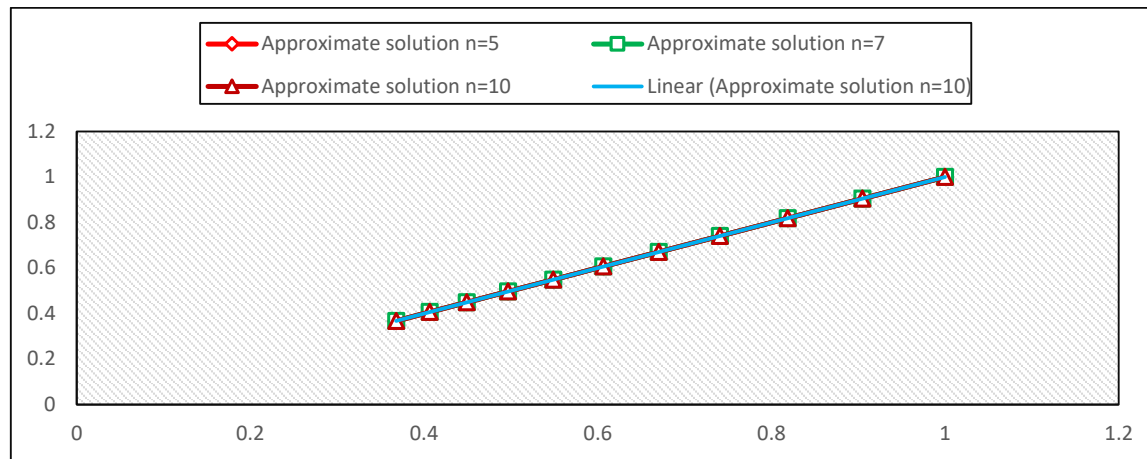


Figure 2. Comparison of the exact solution and the approximate solutions for Problem 1.

**Problem 2:**

$y'(x) + \int_0^x y(x)dx = 1$ , with initial conditions  $y(0) = 0$ , the exact solution is

$$y(x) = \sin(x).$$

$$y'(x) + \int_0^x y(x)dx = 1 \quad (25)$$

The solution can be expressed in form of power series; considering a finite series with six constant

$$y(x) = \sum_{n=0}^5 a_n x^n = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5 \quad (26)$$

$$y'(x) = \sum_{n=0}^5 n a_n x^{n-1} = a_1 + 2a_2 x + 3a_3 x^2 + 4a_4 x^3 + 5a_5 x^4 \quad (27)$$

$$\text{Let } A = \int_0^x y(x)dx \quad (28)$$

Putting the expression  $y(x)$  in the integral, we have;

$$A = a_0 x + \frac{a_1 x^2}{2} + \frac{a_2 x^3}{3} + \frac{a_3 x^4}{4} + \frac{a_4 x^5}{5} + \frac{a_5 x^6}{6} \quad (29)$$

Note that  $A$  is a function of  $x$ , from (24);

$$y'(x) + A = 1 \quad (30)$$

Inputting the equation (26) and (28) above, we have;

$$a_1 + 2a_2x + 3a_3x^2 + 4a_4x^3 + 5a_5x^4 + a_0x + \frac{a_1x^2}{2} + \frac{a_2x^3}{3} + \frac{a_3x^4}{4} + \frac{a_4x^5}{5} + \frac{a_5x^6}{6} = 1 \quad (31)$$

Collecting terms involving like powers of x and applying initial condition, we have;

$$y(0) = 0 = a_0$$

$$x^0 : a_1 - 1$$

$$x^1 : 2a_2$$

$$x^2 : 3a_3 + \frac{a_1}{2}$$

$$x^3 : 4a_4 + \frac{a_2}{3}$$

$$x^4 : 5a_5 + \frac{a_3}{4}$$

(32)

After computation the constant are;

$$a_0 = 0, a_1 = 1, a_2 = 0, a_3 = \frac{-1}{6}, a_4 = 0, a_5 = \frac{1}{120}$$

Substituting these co-efficient into (26) which is called computed solution;

$$y_c(x) = x - \frac{x^3}{6} + \frac{x^5}{120} \quad (33)$$

$$y_e(x) = x - \frac{x^3}{6} + \frac{x^5}{120} - 0(x^6) \quad (34)$$

Substituting these co-efficient into (29);

$$A = \frac{x^2}{2} - \frac{x^4}{24} + \frac{x^6}{720} \quad (35)$$

Table 2.0 compare the computed solution with the exact solution.

<b>x</b>	<b>Y<sub>e</sub></b>	<b>Y<sub>c</sub></b>	<b>abs(y<sub>e</sub>-y<sub>c</sub>)</b>
0	0	0	0
0.1	0.099833	0.099833	2E-11



0.2	0.198669	0.198669	2.5E-09
0.3	0.29552	0.29552	4.3E-08
0.4	0.389418	0.389419	3.2E-07
0.5	0.479426	0.479427	1.5E-06
0.6	0.564642	0.564648	5.5E-06
0.7	0.644218	0.644234	1.6E-05
0.8	0.717356	0.717397	4.1E-05
0.9	0.783327	0.783421	9.4E-05
1	0.841471	0.841667	0.0002

We note that as the value of the value of increase from 0.0 to 1.0 the absolute error with increases from 0.0 to 0.0001956818. This is expected since the series is convergent [radius of convergent]  $0 \leq x \leq 1$

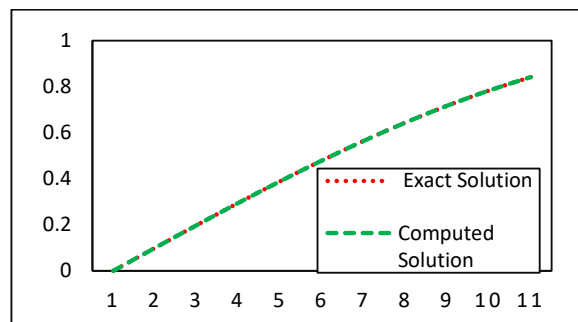


Figure 3. Comparison of the exact solution and the approximate solutions for Problem 2

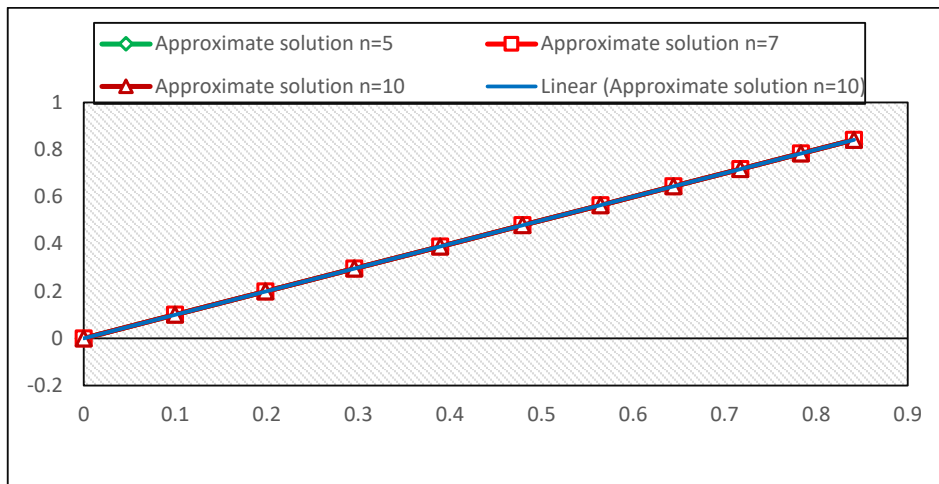


Figure 4. Comparison of the exact solution and the approximate solutions for Problem 2

## 5.1 APPLICATION OF TAYLOR SERIES TO THE SOLUTION OF INTERO-DIFFERENTIAL

### VOLTERRA EQUATION

We also use Taylor series application to obtain the result of constant, this is done by differentiating as many time as the number of constant introduce.

General Formula:

$$G(x) = \int_{\alpha(x)}^{\beta(x)} f(t) dt \quad (36)$$

$$\frac{dG(x)}{dx} = \frac{d\beta(x)}{dx} (f(\beta(x))) - \frac{d\alpha(x)}{dx} (f(\alpha(x)))$$

(\*)

$$\text{When } \alpha(x) = 1; \frac{d\alpha(x)}{dx} = \frac{d(1)}{dx} = 0$$

(37)

$$\text{When } \beta(x) = x; \frac{d\beta(x)}{dx} = \frac{dx}{dx} = 1$$

(38)

**Problem 3:** Consider the following non-linear system of Volterra – Integro differential equations

$$y_1''(x) = 1 - \frac{x^3}{3} - \frac{y_2'(x)}{2} + \frac{1}{2} \int_0^x (y_1^2(t) + y_2^2(t)) dt, y_1'(0) = 2, y_1(0) = 1$$

$$y_2''(x) = -1 + x^2 - xy_1(x) + \frac{1}{4} \int_0^x (y_1^2(t) - y_2^2(t)) dt, y_2'(0) = 0, y_2(0) = -1$$

The exact solution is  $y_1(x) = x + e^x$  and  $y_2(x) = x - e^x$

$$y_1''(x) = 1 - \frac{x^3}{3} - \frac{y_2'(x)}{2} + \frac{1}{2} \int_0^x (y_1^2(t) + y_2^2(t)) dt, y_1'(0) = 2, y_1(0) = 1 \tag{39}$$

$$y_2''(x) = -1 + x^2 - xy_1(x) + \frac{1}{4} \int_0^x (y_1^2(t) - y_2^2(t)) dt, y_2'(0) = 0, y_2(0) = -1 \tag{40}$$

In this particular problem, evaluating the integrals part each will provide a function of x, say;

$$A = f_1(x) = \int_0^x (y_1^2(t) + y_2^2(t)) dt \text{ and } B = f_2(x) = \int_0^x (y_1^2(t) - y_2^2(t)) dt \tag{41}$$

Now we consider a finite series with eight constant

$$y_1(t) = \sum_0^7 a_n t^n = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5 + a_6 t^6 + a_7 t^7 \tag{42}$$

$$y_1'(t) = \sum_0^7 n a_n t^{n-1} = a_1 + 2a_2 t + 3a_3 t^2 + 4a_4 t^3 + 5a_5 t^4 + 6a_6 t^5 + 7a_7 t^6 \tag{43}$$

$$y_1''(t) = \sum_0^7 n(n-1) a_n t^{n-2} = 2a_2 + 6a_3 t + 12a_4 t^2 + 20a_5 t^3 + 35a_6 t^4 + 42a_7 t^5 \tag{44}$$

$$y_2(t) = \sum_0^7 c_n t^n = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 + c_5 t^5 + c_6 t^6 + c_7 t^7 \tag{45}$$

$$y_2'(t) = \sum_0^7 n c_n t^{n-1} = c_1 + 2c_2 t + 3c_3 t^2 + 4c_4 t^3 + 5c_5 t^4 + 6c_6 t^5 + 7c_7 t^6 \tag{46}$$

$$y_2''(t) = \sum_0^7 n(n-1) c_n t^{n-2} = 2c_2 + 6c_3 t + 12c_4 t^2 + 20c_5 t^3 + 35c_6 t^4 + 42c_7 t^5 \tag{47}$$

Putting  $y_1^2(t)$ ,  $y_2^2(t)$  into  $f_1(x)$ ,  $f_2(x)$  equation (39) and (40) becomes :

$$y_1''(x) = 1 - \frac{x^3}{3} - \frac{y_2'(x)}{2} + \frac{1}{2} A \tag{48}$$

$$y_2''(x) = -1 + x^2 - xy_1(x) + \frac{1}{4} B \dots \dots \dots (49)$$

Inputting (42), (43), (44), (45), (46), (47) into equation (48) and after much computation, we have some equation in terms of  $a_0, a_1, a_2, a_3, \dots, a_7$  and  $c_0, c_1, \dots, c_7$ .

$$x^0 : 2a_2 + \frac{c_2}{2} = 1 \dots\dots\dots(50)$$

$$x^1 : 6a_3 + 2c_1c_3 - \frac{a_0^2}{2} - \frac{c_0^2}{2} = 0 \dots\dots\dots(51)$$

$$x^2 : 12a_4 + 3c_1c_3 + 2c_2^2 - \frac{a_0a_1}{2} - \frac{c_0c_1}{2} = 0 \dots\dots\dots(52)$$

$$x^3 : 20a_5 + 4c_1c_4 + 6c_2c_3 - \frac{a_0a_2}{3} - \frac{a_1^2}{6} - \frac{c_0c_2}{3} - \frac{c_1^2}{6} = \frac{-1}{3} \dots\dots\dots(53)$$

$$x^4 : 30a_6 + 5c_1c_5 + 8c_2c_4 - \frac{a_0a_3}{4} - \frac{a_1a_2}{4} - \frac{c_0c_3}{4} - \frac{c_1c_2}{4} - \frac{9c_3^2}{2} = 0 \dots\dots\dots(54)$$

$$x^5 : 42a_7 + 6c_1c_6 + 10c_2c_5 + 12c_3c_4 - \frac{a_0a_4}{5} - \frac{a_1a_3}{5} - \frac{2a_2^2}{5} - \frac{2c_2^2}{5} - \frac{c_0c_4}{5} - \frac{c_1c_3}{5} = 0 \dots\dots\dots(55)$$

Also putting above series into equation (49) and after much computation, we have some equation in terms of  $a_0, a_1, a_2, a_3, \dots, a_7$  and  $c_0, c_1, \dots, c_7$ .

$$x^0 : 2c_2 = -1 \dots\dots\dots(56)$$

$$x^1 : a_0 + 6c_3 - \frac{a_0^2}{4} + \frac{c_0^2}{4} = 0 \dots\dots\dots(57)$$

$$x^2 : a_1 + 12c_4 - \frac{a_0a_1}{4} + \frac{c_0c_1}{4} = 1 \dots\dots\dots(58)$$

$$x^3 : a_2 + 20c_5 - \frac{a_0a_2}{6} - \frac{a_1^2}{12} + \frac{c_0c_2}{6} + \frac{c_1^2}{12} = 0 \dots\dots\dots(59)$$

$$x^4 : a_3 + 30c_6 - \frac{a_0a_3}{8} - \frac{a_1a_2}{8} - \frac{c_0c_3}{8} - \frac{c_1c_2}{8} = 0 \dots\dots\dots(60)$$

$$x^5 : a_4 + 42c_7 - \frac{a_0a_4}{10} - \frac{a_1a_3}{10} - \frac{2a_2^2}{10} + \frac{c_0c_4}{10} + \frac{c_1c_3}{10} + \frac{c_2^2}{20} = 0 \dots\dots\dots(61)$$

Applying boundary condition to equation above and simplifying these equation, we have:

$$y_1(0) = 1 = a_0, y_1'(0) = 2 = a_1 = 2,$$

$$y_2(0) = -1 = c_0, y_2'(0) = 0 = c_1 = 0$$

$$a_0 = 1, a_1 = 2, a_2 = \frac{1}{2}, a_3 = \frac{1}{6}, a_4 = \frac{1}{24}, a_5 = \frac{1}{120}, a_6 = \frac{1}{720}, a_7 = \frac{1}{5040}$$

$$\text{and } c_0 = -1, c_1 = 0, c_2 = -\frac{1}{2}, c_3 = -\frac{1}{6}, c_4 = -\frac{1}{24}, c_5 = -\frac{1}{120}, c_6 = -\frac{1}{720}, c_7 = -\frac{1}{5040}.$$

These are substitute in the series which are called the computed solution: which are:

$$y_1(x) = 1 + 2x + \frac{x^2}{2} + \frac{x^3}{6} + \frac{x^4}{24} + \frac{x^5}{120} + \frac{x^6}{720} + \frac{x^7}{5040} \dots\dots\dots(62)$$

$$y_2(x) = -1 - \frac{x^2}{2} - \frac{x^3}{6} - \frac{x^4}{24} - \frac{x^5}{120} - \frac{x^6}{720} - \frac{x^7}{5040} \dots\dots\dots(63)$$

**5.1.1 TAYLOR APPLICATION:**

$$y_1''(x) = 1 - \frac{x^3}{3} - \frac{y_2'(x)}{2} + \frac{1}{2} \int_0^x (y_1^2(t) + y_2^2(t)) dt, y_1'(0) = 2, y_1(0) = 1$$

$$y_2''(x) = -1 + x^2 - xy_1(x) + \frac{1}{4} \int_0^x (y_1^2(t) - y_2^2(t)) dt, y_2'(0) = 0, y_2(0) = -1$$

The solution can be express inform of Taylor series; considering a finite series with seven constant;

$$y(x) = y(0) + \frac{xy'(0)}{1!} + \frac{x^2y''(0)}{2!} + \frac{x^3y'''(0)}{3!} + \frac{x^4y^{(4)}(0)}{4!} + \frac{x^5y^{(5)}(0)}{5!} + \frac{x^6y^{(6)}(0)}{6!} + \frac{x^7y^{(7)}(0)}{7!} \tag{64}$$

Given  $y_1(0) = 1, y_1'(0) = 2, y_1''(0) = 1, y_1'''(0) = 1, y_1^{(4)}(0) = 1, y_1^{(5)}(0) = 1, y_1^{(6)}(0) = 1, y_1^{(7)}(0) = 1$  (from equation \*)

$$y_2''(x) = 2x - y_1(x) - xy_1'(x) + \frac{1}{4} \left[ \frac{dx}{dx} (y_1^2(x) - y_2^2(x)) \right] \Rightarrow y_2''(0) = -1 \tag{65}$$

$$y_2^{(3)}(x) = 2 - y_1'(x) - xy_1''(x) - y_1' + \frac{1}{4} [2y_1y_1' - 2y_2y_2'] \Rightarrow y_2^{(3)}(0) = -1 \tag{66}$$

$$y_2^{(4)}(x) = -2y_1''(x) - xy_1'''(x) - y_1''(x) + \frac{1}{4} [2(y_1')^2 + 2y_1y_1'' - 2(y_2')^2 - 2y_2y_2''] \Rightarrow y_2^{(4)}(0) = -1 \tag{67}$$

$$y_2^{(6)}(x) = -3y_1^{(4)}(x) - xy_1^{(5)}(x) - y_1^{(5)} + \frac{1}{4} (6y_1'y_1'' + 2y_1y_1''' - 6y_2'y_2'' - 2y_2y_2^{(3)}) \rightarrow y_2^{(6)}(0) = -1 \tag{68}$$

$$y_2^{(7)}(x) = -4y_1^{(5)}(x) - xy_1^{(6)}(x) - y_1^{(6)} + \frac{1}{4} (6(y_1')^2 + 8y_1'y_1'' + 2y_1y_1^{(3)} - 6(y_2')^2 - 8y_2'y_2'' - 2y_2y_2^{(3)}) \rightarrow y_2^{(7)}(0) = -1 \tag{69}$$

$$y_1'''(x) = x^2 - y_2y_2'' + \frac{1}{2} \left( \frac{dx}{dx} (y_1^2(x) + y_2^2(x)) \right) \rightarrow y_1'''(0) = 1 \tag{70}$$

$$y_1^{(4)}(x) = -2x - (y_2'')^2 - y_2'y_2''' + \frac{1}{2} (2y_1y_1' + 2y_2y_2') \rightarrow y_1^{(4)}(0) = 1 \tag{71}$$

$$y_1^{(5)}(x) = -2 - 3y_2''y_2'''(x) - y_2'y_2^{(4)} + \frac{1}{4} (2(y_1')^2 + 2y_1y_1'' + 2(y_2')^2 + 2y_2y_2'') \rightarrow y_1^{(5)}(0) = 1 \tag{72}$$

$$y_1^{(6)}(x) = -3(y_2''')^2 - 4y_2''y_2^{(4)}(x) - y_2'y_2^{(5)} + \frac{1}{2} (6y_1'y_1'' + 2y_1y_1^{(3)} + 6y_2'y_2'' + 2y_2y_2^{(3)}) \rightarrow y_1^{(6)}(0) = 1 \tag{73}$$

$$y_1^{(7)}(x) = -12y_2''y_2^{(4)} - 5y_2''y_2^{(5)} - y_2'y_2^{(6)} + \frac{1}{2} (6(y_1')^2 - 8y_2'y_2'' + 2y_2y_2^{(3)}) \rightarrow y_1^{(7)}(0) = 1 \tag{74}$$

After computation the Constant are:

$$\begin{aligned} y_1(0) &= 1, y_1'(0) = 2, y_1''(0) = 1, y_1'''(0) = 1, y_1^{(4)}(0) = 1, \\ y_1^{(5)}(0) &= 1, y_1^{(6)}(0) = 1, y_1^{(7)}(0) = 1, y_2(0) = -1, y_2'(0) = 0, \\ y_2''(0) &= -1, y_2'''(0) = -1, y_2^{(4)}(0) = -1, y_2^{(5)}(0) = -1, \\ y_2^{(6)}(0) &= -1, y_2^{(7)}(0) = -1 \end{aligned}$$

Substituting these constants into (64) which is called computed solution;

$$y_1(x) = 1 + 2x + \frac{x^2}{2} + \frac{x^3}{6} + \frac{x^4}{24} + \frac{x^5}{120} + \frac{x^6}{720} + \frac{x^7}{5040} \tag{75}$$

$$y_2(x) = -1 - \frac{x^2}{2} - \frac{x^3}{6} - \frac{x^4}{24} - \frac{x^5}{120} - \frac{x^6}{720} - \frac{x^7}{5040} \tag{76}$$

The exact solution is;

$$y_2(x) = -1 - \frac{x^2}{2} - \frac{x^3}{6} - \frac{x^4}{24} - \frac{x^5}{120} - \frac{x^6}{720} - \frac{x^7}{5040} \dots\dots\dots(78)$$

**Table 3.0** compare the computed solution with the exact solution.

$x_i$	$Y_{1e}$	$Y_{1c}$	Abs	$Y_{2e}$	$Y_{2c}$	abs
0	1	1	0	-1	-1	0
0.1	1.205171	1.205171	2.51E-13	-1.00517	-1.00517	2.5E-13
0.2	1.421403	1.421403	6.49E-11	-1.0214	-1.0214	6.5E-11
0.3	1.649859	1.649859	1.68E-09	-1.04986	-1.04986	1.7E-09
0.4	1.891825	1.891825	1.7E-08	-1.09182	-1.09182	1.7E-08
0.5	2.148721	2.148721	1.03E-07	-1.14872	-1.14872	1E-07
0.6	2.422119	2.422118	4.46E-07	-1.22212	-1.22212	4.5E-07
0.7	2.713753	2.713751	1.55E-06	-1.31375	-1.31375	1.5E-06
0.8	3.025541	3.025536	4.56E-06	-1.42554	-1.42554	4.6E-06
0.9	3.359603	3.359591	1.18E-05	-1.5596	-1.55959	1.2E-05
1	3.718282	3.718254	2.79E-05	-1.71828	-1.71825	2.8E-05

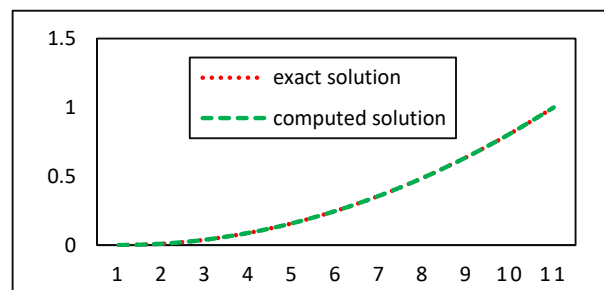


Figure 5. Comparison of the exact solution and the approximate solutions for Problem

We observe from the results that the terms obtained are exact with the series given, showing that the leading error is  $O(x^8)$ .

It is clearly seen from the above table that the result is quite reasonable and moderate because as the value of  $x$  increases, the absolute error  $y_1(x)$  increases from 0.00000000 to 0.008333333 and absolute error of  $y_2(x)$  also increases from 0.00000000 to 0.000024802.

We observed in this chapter that the more terms in the assumed solution the better the accuracy of the solutions.

The result compared with the exact solution in tabular and graphical shows that the approximation becomes more accurate when the terms is increased.

## **6. CONCLUSION**

In this research, we have proposed a numerical solution to solve integro-differential equations of the type Fredholm, Volterra and the combination of Volterra-Fredholm equations with initial conditions by Tau method and Taylor's series approach. We use formula for numerical examples and it is obvious that the numerical solution coincides with the exact solution even with a few basic polynomials used in the approximation.

Finally, Errors and Graphs show that the approximation becomes more accurate when the terms is increased. Therefore, for better results, it is recommended to use a larger number of terms in the assumed solution.

## **7. REFERENCES**

Burrunner, H. (1984). An introduction to theory and application. Volterra integral equations, 95-109.

Madbouly, N., McGhee, D., & Roach, G. (2001). Adomian's method for Hammerstein integral. Appl. Math. Comput, 241–249.

Olashile, B. I. (2015). Tau method for solution of linear and nonlinear integro differential equation.

Razzaghi, M., & Ordokhani, Y. (2001). Solution of nonlinear Volterra-Hammerstein integral equations. Math. Probl. Eng, 205–219.

S. Suresha, G. T. (2019). Initial Value Problem for Nonlocal Impulsive Integro-Differential Equation Involving Fractional Derivation of order. American Journal of Engineering Research (AJER), 193-199.

s.shahmorad. (2007). Numerical solution of the non-linear Volterra integro-differential equation by Tau method. Applied Mathematics and computation , 1580-1586.

Y.Mahmoudi. (2017). Taylor polynomial solution of non-linear Volterra-fredholm integral equation . 881-887.



## **SENTIMENT ANALYSIS ON SOCIAL MEDIA PRODUCT REVIEWS USING MACHINE LEARNING TECHNIQUES**

Jamiu, S.A<sup>1</sup> and Akanbi, C.O<sup>2</sup>

Department of Information, Communication and Technology, Osun State University,  
Osogbo, Nigeria

E-mail: [suviatsoffy@gmail.com](mailto:suviatsoffy@gmail.com)

### **ABSTRACT**

Social media has now emerged as one of the most common means of communication of media for numerous number of people. When a product or service is being advertised, it is the concern of the product or service company to know what their customers feel about their products and services. Meanwhile, manually reading and sorting of voluminous text data would be unsurmountable to a human. Hence, this study hereby adopts Data scraping method in which dataset were gathered using a scrapper written in python programming. Machine learning models were being developed using Random Forest and Naïve Bayes algorithms which are being trained with extracted data for text classification. At the end of the experiments, the product reviews are being classified into positive, negative, slightly negative, slightly positive or neutral polarities of sentiments using the classifiers, in which the experimental results show that the Random Forest classifier performs better in terms of accuracy with 76.5% over the Naïve Bayes with 70.01%.

### **Terms/keywords**

Social Media (OSN), web scrapping, Naïve Bayes (NB), Random Forest (RF), Product Reviews, Sentiment Analysis.

### **1. NTRODUCTION**

There is absolutely no doubt that the emergence of technology especially social media comes along with so many advantages over the conventional methods of communication such as time and stress required to procure airtime from radio and television stations, thereby made business owners, politicians and other professionals take maximum advantages provided by social media to promote their careers and businesses. Social media is one of the most widely used

source of data about customer's opinion towards companies, when a product or service is being advertised, it is the concern of the organization to know what their customers feel about their products and services (Marta, 2014).

Meanwhile, social media data are usually unstructured and contains a lot of irrelevant information, therefore it is impossible for individuals to read and analyze all of the data manually as it tends to be stressful and time consuming. Therefore, a way to efficiently classify text data is required. Hence, the need for this study which adopts machine learning techniques.

Machine learning is a field in Computer science that focuses on the study of algorithms, in which this study adopts Naïve Bayes and Random Forest for its classification.

Sentiment analysis is therefore done using natural language processing and information extraction with the goal of obtaining the writer's feeling about the product as positive, negative or neutral ( Subhabrata, 2012). Sentiment analysis is often used as component in opinion mining when the goal is to is to analyze sentiment and attitudes (Bing, 2012).

## **2. RELATED WORKS**

Pablo, et al. (2012), proposed sentiment analysis on Spanish tweets. Authors focused on stressed the microblogging service Twitter. As Twitter may be seen as an outsized supply of short texts (tweets) containing user opinions. The task of constructing sentiment analysis from tweets may be an exhausting challenge. Authors used approach, Naive- Bayes classifier for detecting the polarity of Spanish tweets. Experimental results shown a performance of the system regarding 67% accuracy.

Fattah, (2012), sentimentally classifies movie reviews. Authors used Gaussian Mixture Model (GMM) and Feed Forward Neural Network (FFNN) for sentiment classification. GMM has been exploited since it's typically been found to supply smart classification results. The achieved result using GMM is eighty 81.5% based on accuracy measurement. A set of highest score sentences area unit chronologically such that as a document outline supported half-hour compression rate by using feed forward neural network.

Lina, et al. (2014), in their own work, Created models to perform sentiment analysis on movie reviews on twitter using Naive Bayes Classifier with accuracy of 62.35% and Neural Network Classifier with accuracy of 49.95%

Humera, et al. (2015), classified movie reviews for sentiment analysis using WEKA Tool. They enhanced the earlier work done in sentiment categorization which analyzes opinions which express either positive or negative sentiment. In this paper, they also considered the fact that reviews that have opinions from more than one person and a single review may express both the positive and negative sentiment. They conducted their experiment on WEKA and concluded that Naïve Bayes performs much better than SVM for movie reviews as well as text. Naive Bayes has an accuracy of 80.65% accuracy.

In the work of Michael and Kang (2016), the authors used machine learning and social media to predict how successful a movie will be. In order to measure success of a movie the authors used return on investment (ROI) which is a profitability metric, and they applied binary and multi-class classification algorithms such as support vector machines (SVM), multilayer perception (MLP), decision trees (J48), random forest and logitBoost algorithm to predict the success.

In the view of Sepehr, (2016), Predicted financial performance of a company using social media and machine learning based on what people write about the company on Twitter. He created model using Naïve Bayes, Random Forest and Ada Boost.

In the study of Palak, et al., (2017), they Created models to perform sentiment analysis of Movie Reviews using Naïve Bayes, Random Forest and K-Nearest neighbor in WEKA. They concluded that K-Nearest neighbor has an accuracy of 55.30 %, Naïve Bayes has an accuracy of 81.4% and Random Forest has an accuracy of 78.65%.

Niketani (2018), created models to perform twitter sentiment analysis of movie reviews using Naïve Bayes and SVM.

Most existing work focused on Movie reviews using binary classification while this work is based on product review which further classified text into 5 categories using multi-class text classification.

### **3. METHODOLOGY**

#### **3.1 ARCHITECTURE**

The proposed architecture in fig1.0, dataset is being gathered through web scrapping procedure (explained in fig1.2), which is later being pre-processed (text transformation) and important features are being extracted. Dataset is then segmented into train and test set. The train set is being fed into the Machine learning algorithm to build the models.

The test set is then fed into the trained model to predict its' output. The results from both models are then analyzed to measure their performances.

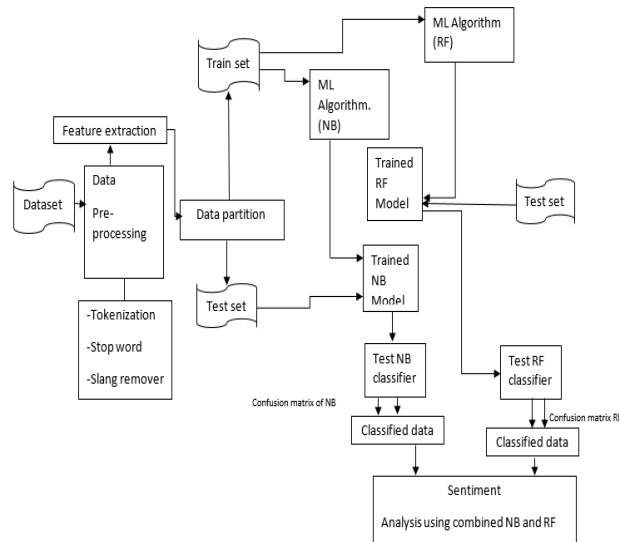


Fig 1.0: System Architecture

### 3.1.1 Data Collection

This research work adopts the web scrapping methods for data collection; using a scrapper developed in python programming language. Because the conventional method of copy and paste is slow in nature as it tends to be tedious and time consuming. Web Scrapping automates this process in such a way that the Web Scrapping algorithm performs the same task within a fraction of the time instead of copying data from web-sites manually.

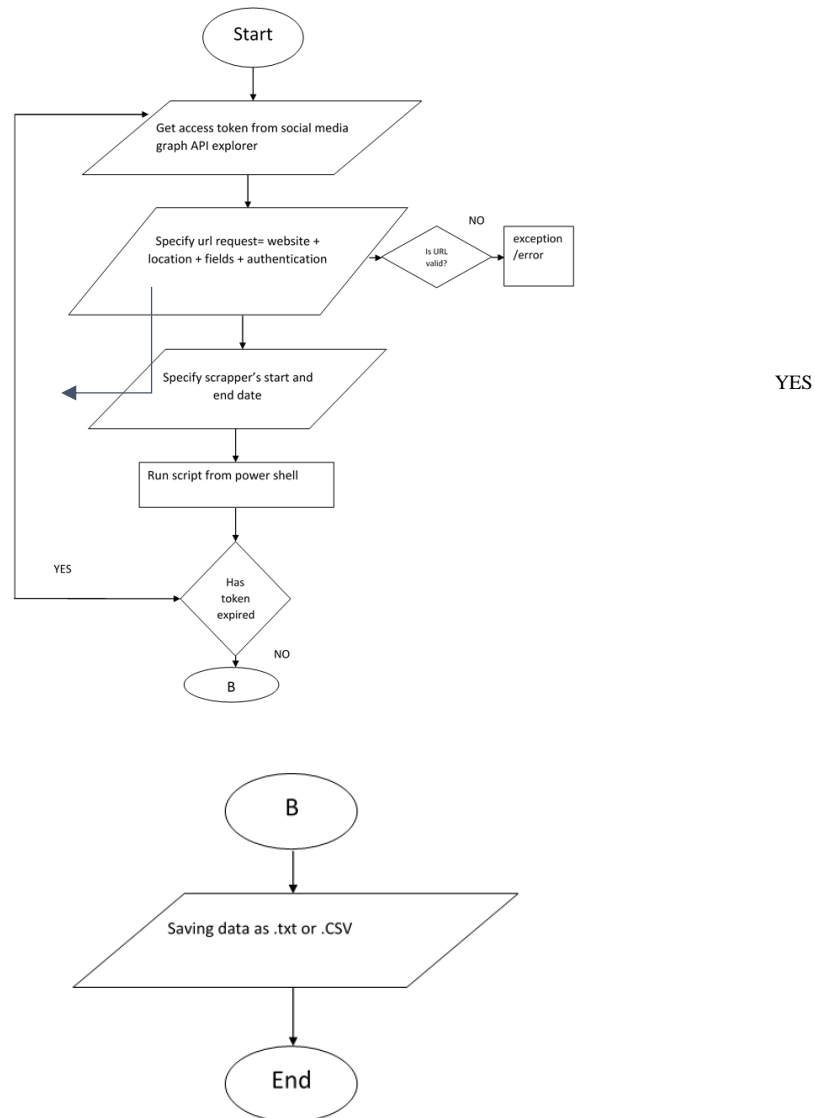


Fig 1.2: flowchart depicting process of web scrapping

### 3.2 Random Forest Classifier

Are the learning method for classification and regression. It construct variety of call trees at coaching time. To classify new case it sends the new case to every of the trees. Each tree perform classification and output on a class. The output category is chosen supported majority ballot that's the most variety of comparable category generated by varied trees is taken into account because the output of the Random Forest. Random Forests are easy to learn and use for both professionals and laypeople with little research and programming required. It will simply be employed by persons that don't have a robust applied mathematics background.

### 3.3 Naïve Bayes Classifier

#### Naïve Bayes Classifier

It is a technique based on Bayes' Theorem. Naive Bayes classifier assumes that the presence of a selected feature during a class is unrelated to the presence of the other feature. This model is simple to make and significantly helpful for terribly giant datasets. Along with simplicity, A Naive Bayes classifier is a technique that applies to a certain class of problems, namely those that phrased as associating an object with a discrete category. From numerical based approach group,

Naive Bayes has many benefits like easy, fast and high accuracy. Leung, (2013) describes the Bayes rule:

$$\gamma(\beta) = (\gamma(\alpha | \beta)) / (\gamma(\alpha) * \gamma(\beta | \alpha)) \quad (1)$$

Where  $\alpha$ : Specific class.

$\beta$ : Document wants to classify.

$\gamma(\alpha)$  and  $\gamma(\beta)$  : Prior probabilities.

$\gamma(\alpha | \beta)$  and  $\gamma(\beta | \alpha)$  : Posterior probabilities.

The value of class  $\alpha$  might be positive, slightly negative, negative or neutral. Document is a review of food product.

According to Shimodaira (2013), the multinomial model of Naive Bayes captures word frequency information in documents. The Maximum probability Estimate (MLE) is just the ratio and corresponds to the foremost doubtless price of every parameter given the coaching knowledge. For the previous likelihood this estimate is shown in Equation one.

$$\gamma(\alpha) = (N_c) / N \quad (2)$$

Where  $N_c$  : The number of documents in class  $\alpha$ .

$N$  : Total number of documents.

In Multinomial model, assumes attribute values are independent of each other given for the particular class :

$$\gamma(\beta | \alpha) = \gamma(\omega_1 \dots \omega_{nd} | \alpha) \quad (3)$$

In the multinomial model, a document is an ordered sequence of word events, drawn from the same vocabulary  $V$ . Assume that the lengths of documents square measure freelance of sophistication. Thus, every document  $\beta_i$  is drawn from a multinomial distribution of words with as several freelance trials because the length of  $\beta_i$ . This yields the familiar bag-of-words representation for documents. The BOW model is usually employed in ways of document

classification, where the (frequency of) occurrence of each word is used as a feature for training a classifier.

A unigram feature marks the presence or absence of one word at intervals a text. Estimate the conditional probability  $\gamma(\omega | \alpha)$  as the relative frequency of term  $\omega$  in documents belonging to class  $\alpha$  including multiple occurrences of a term in a document.

$$\gamma(\omega | \alpha) = (\text{count}(\omega, \alpha) + 1) / (\text{count}(\alpha) + |V|) \quad (4)$$

Where  $\text{count}(\omega, \alpha)$  : Number of occurrences of  $\omega$  in training documents from class  $\alpha$ .

$\text{count}(\alpha)$  : Number of words in that class.

$|V|$ : Number of terms in the vocabulary in test set

To eliminate zero probability problem, use add-one or Laplace smoothing, this simply adds one to each count.

Then, the likelihood of a document given its category is just the multinomial distribution presents in Equation two. Finally classify new document using posterior probability.

Let  $\alpha_{NB}$  is the posterior probability,  $\alpha_j$  is one of the class from class  $\alpha$  and  $\beta_i$  is ith document.

$$\alpha_{NB} = \arg \max_{\alpha_j \in \alpha} \prod_i [\gamma(\beta_i | \alpha_j)] \quad (5)$$

Table 3.1 take as the example of product review. Using Naïve Bayes classifier classifies product review in positive or negative category. Calculate prior probability of positive and negative by using Equation 2

$$\gamma(\text{positive}) = 1/3 \quad (i)$$

$$\gamma(\text{negative}) = 2/3 \quad (ii)$$

Table 3.1 dataset Example

	Id		Review	Sentiment
Train set	1		Sweet food	Positive
	2		Not good as advertised	Negative
	3		Bad food	Negative
Test set	4		bad bad food	?

Calculate conditional probabilities/maximum likelihood smoothing (Laplace) Naive Bayes Estimate by using Equation 2

$$\gamma(\text{bad} | \text{positive}) = (0 + 1) / (2 + 7) = 0.01235 \quad (\text{iii})$$

$$\gamma(\text{bad} | \text{negative}) = (1 + 1) / (6 + 7) = 0.15385 \quad (\text{iv})$$

$$\gamma(\text{food} | \text{positive}) = (1 + 1) / (2 + 7) = 0.2222 \quad (\text{v})$$

$$\gamma(\text{food} | \text{negative}) = (0 + 1) / (6 + 7) = 0.0769 \quad (\text{vi})$$

Calculate posterior probability

$$\gamma(\text{positive} | \text{Id4}) = 1/3 * 0.01235 * 0.2222 = 0.0009139 \quad (\text{vii})$$

$$\gamma(\text{negative} | \text{Id4}) = 2/3 * 0.222 * 0.0769 = 0.0113812 \quad (\text{viii})$$

$$\gamma(\text{negative} | \text{Id4}) > \gamma(\text{positive} | \text{Id4})$$

$\gamma(\text{negative} | \text{Id4})$  is maximum means probability of negative words in document 4 is maximum so document 4 is negative.

## 4.0 RESULT AND DISCUSSION

In this section the experimental results are described.

### 4.1 Dataset

Table 4.1: Dataset

	Id	Review	Sentiment
0	1	Good Quality Dog Food	Positive
1	2	Not as Advertised	Negative
2	3	"Delight" says it all	Slightly Positive
3	4	Cough Medicine	Neutral
4	5	Great taffy	Positive
5	6	Nice Taffy	Slightly Positive
6	7	Great! Just as good as the expensive brands!	Positive
7	8	Wonderful, tasty taffy	Positive
8	9	Yay Barley	Positive
9	10	Healthy Dog Food	Positive
10	11	The Best Hot Sauce in the World	Positive
11	12	My cats LOVE this "diet" food better than thei...	Positive
12	13	My Cats Are Not Fans of the New Food	Negative
13	14	fresh and greasy!	Slightly Positive
14	15	Strawberry Twizzlers - Yummy	Positive



Dataset used for the experiments contains amazon food reviews with labels (Positive/Negative/SlightlyPos/Slightly Neg/Neutral).

During the experiment the dataset was later segmented into train (80%) and test (20%) set.

Sample dataset is shown in Table 4.1.

#### 4.1.1 Dataset Description

Name	Variable type	Variable Description
Id	Input	unique id of each review
Review	Input	Comments about food product from Social media page.
Sentiment	Output	label associated with each reviews

## 4.2 Experimental Result

The results for the two classifiers are described as confusion matrices in which it is presented as the number of true positives, false negatives, true negatives, and false positives as illustrated in Fig 4.1 and Fig 4.3 below.

Table 4.2 Structure of Confusion Matrix

Actual class	Predicted class	
	True Neg. (TN)	False Pos. (FP)

	False Neg. (FN)	True Pos. (TP)
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True Positives (TP): tested for Positive & Review is actually positive.

True Negatives (TN): tested for Negative & Review is actually negative.

False Positives (FP): tested for Positive & Review is not (known as a “Type I error.”)

False Negatives (FN): tested for Negative & Review is not. (Also known as a “Type II error.”)

#### 4.2.1 Naïve Bayes’ Classifier

Was used for classifying the polarity of the documents on the Data set, in which test one of the review from dataset and checks that review is positive, slightly negative, slightly positive, neutral or negative polarity.

Table 4.2 shows result after experiments in which 79658 correct samples were found from 113683 review using Naive Bayes classifier as derived from confusion matrix.

Where correct samples = Summation of all TP values *and*

Incorrect samples = Summation of all FN and FP

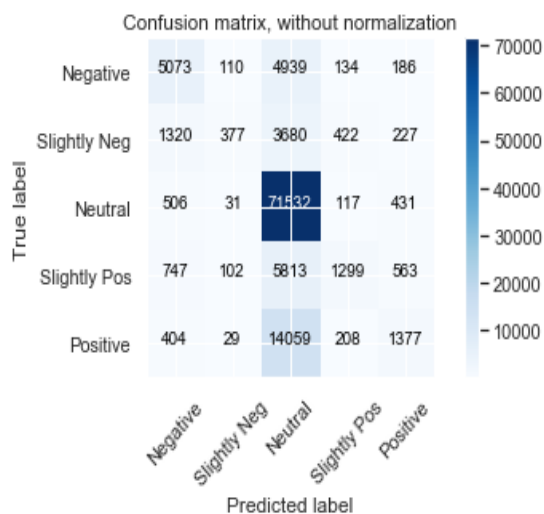


Fig 4.1: Confusion Matrix of Naïve Bayes.

Table 4.3: Result of Experiment of Naïve Bayes’ Classifier

Total Reviews	Classifier	Correct sample	Incorrect Sample
113,683	Naïve Bayes	79,658	34,025

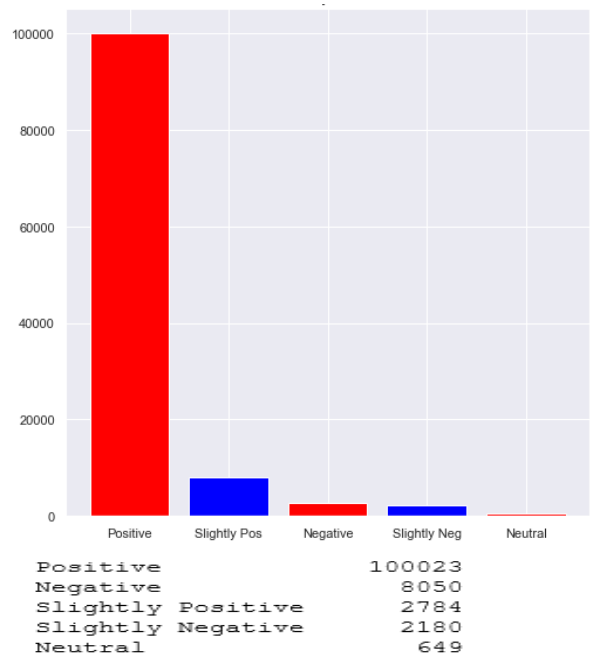


Fig 4.2: bar chart depicting output from Naïve Bayes’ classifier.

#### 4.2.2 Random Forest Classifier

Was used for classifying the polarity of the documents on the Data set, in which test one of the review from dataset and checks that review is positive, slightly negative, slightly positive, neutral or negative polarity.

Table 4.3 shows result after experimented system which found 86898 correct samples from 113683 review using Random Forest classifier as derived from confusion matrix.

Where correct samples = Summation of all TP values *and*

Incorrect samples = Summation of all FN and FP

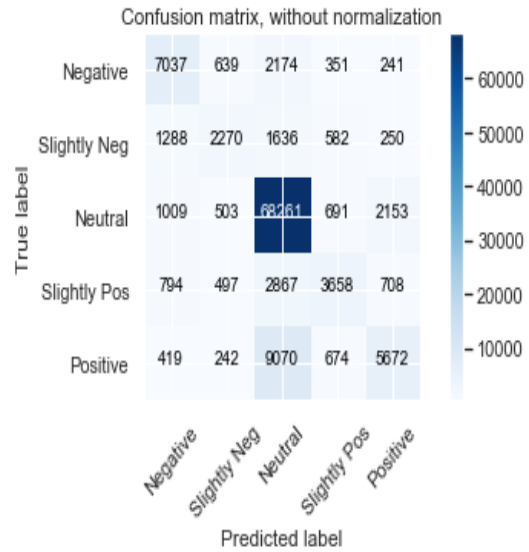
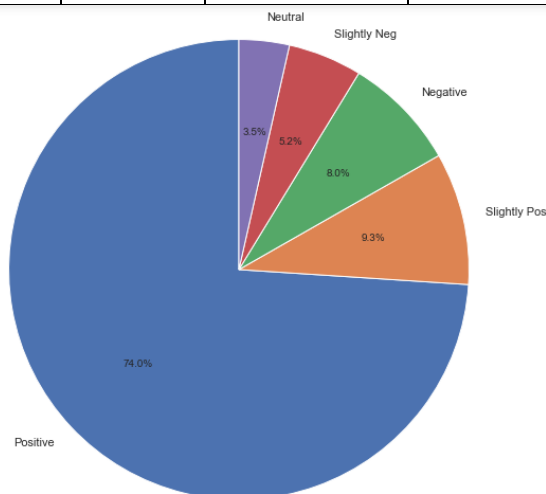


Fig 4.3: Confusion Matrix of Random Forest.

Table 4.2: Result of Experiment of Random Forest Classifier

Total Reviews	Classifier	Correct sample	Incorrect Sample
113,683	Random Forest	86,898	26,788



Positive	84085
Negative	10560
Slightly Positive	9120
Slightly Negative	5906
Neutral	4015

Fig 4.4: pie chart depicting output from Random Forest classifier.

### 4.3 Performance Metrics

In this experiment, performance metrics are used for the analysis of classifier accuracy. The proposed system is evaluated using various accuracy parameters which includes: precision, Recall and F1-score.

Where:

1. **Precision:** ability of classifier not to label a positive sample as negative. When it predict, how often is the classifier correct, defined as:  $TP/(TP + FP)$
- Recall:** is the ability of a classifier to find all positive instances. For each class it is defined as the ratio of true positives to the sum of true positives and false negatives.  $TP/(TP + FN)$
2. **F1-score:** It is the Harmonic mean of the two values which we have i.e. Precision and Recall. (To measure accuracy of classifier for each classes over others) as:  
 $(2 * precision * recall) / (precision + recall)$ .

Table 4.5 Naïve Bayes Classification Report

Naïve Bayes classification Report			
	Precision	Recall	Fi-score
Negative	0.63	0.48	0.55
Neutral	0.58	0.06	0.11
Positive	0.72	0.99	0.83
Slightly Neg.	0.59	0.15	0.24

Slightly Pos.	0.51	0.09	0.15
Avg/Total	0.66	0.70	0.63

Table 4.6 Random Forest Classification Report

Random Forest classification Report			
	Precision	Recall	Fi-score
Negative	0.67	0.66	0.66
Neutral	0.55	0.37	0.44
Positive	0.81	0.94	0.87
Slightly Neg.	0.61	0.43	0.51
Slightly Pos.	0.63	0.36	0.45
Avg/Total	0.74	0.77	0.74

After experiment, the result of sentiment analysis using Naive Bayes classifier is obtained 70.01% accuracy on test data. And Random Forest with the accuracy of 76.5%; therefore, Best accuracy was given by the Random Forest classifier.

Table 4.7 : Percentage Accuracy of Various Classifiers.

Dataset	Classifier	Performance Accuracy of Classifier
Product Review	Naïve Bayes	70.01%
	Random Forest	76.5%

In Table 4.7, shows the accuracy results of classifier. Accuracy is calculated by:

No of correct Samples/total no of samples \* 100 (6)

## **5.0 CONCLUSION**

Customer's opinion about products and services is always a concern for most large-and middle sized companies because it has effects on the company's financial performance.

In this study, an experiment is conducted on Product Review dataset. Naive Bayes classifier and Random Forest classifier are used to train dataset. It is concluded at the end of the day that the RF performed better over the NB classifier.

## **5.1 RECOMMENDATION**

For future work, development of a mobile application or a GUI interface design should be considered to allow people without programming skills to be able to determine what their customers feel about their product.

Also, further Research can be considered on African languages.

## **REFERENCES**

Marta Zembik (2014) Social media as a source of knowledge for customers and enterprises Online Journal of Applied Knowledge Management, Volume 2, Issue 2

Subhabrata M. (2012). Sentiment analysis. Indian Institute of Technology, Bombay Department of Computer Science and Engineering.

Lina L. Dhande L. and Girish K. (2014), "Analyzing Sentiment of Movie Review Data using Naive Bayes Neural Classifier" International Journal of Emerging Trends & Technology in Computer Science (IJETTCS)

Palak B., Apoorva G. and Neelam C. (2017). "Sentiment Analysis of Movie Reviews using Machine Learning Techniques " International Journal of Computer Applications (0975 – 8887) Volume 179 – No.7, December 2017 45

Niketani J. (2018). "Twitter sentiment Analysis of movie Reviews using Machine Learning Techniques"

Humera S., Kavitha G., and Raniah Z., 2015, Text Categorization of Movie Reviews for Sentiment.

Shimodaira H., (2013) "Text classification using naïve bayes," pp. 1-5, <http://www.inf.ed.ac.uk/teaching/courses/inf2b/learnnotes/inf2blearn-note07-2up.pdf>, Accessed: December 2013].

Michael T. and Kang Z. (2016). Early Predictions of Movie Success: the Who, What, and When of Portability Artificial Intelligence (cs.AI); Social and Information Networks (cs.SI).

Sepehr F. (2016), Using social media and machine learning to predict financial performance of a company: uppsala universitet

Pablo G., Garcia M., and Santiago T. (2012): A naivebayes strategy for sentiment analysis on spanish tweets," in International Conference on Social Informatics, pp. 215-221, 2012.

Fattah M.A, (2012) "Gaussian mixture model and feed forward neural network based models for sentiment classification," In International Conference on Computer Science and Information Technology, pp. 45-49, 2012.

Leung, K.M (2013) "Naive Bayesian classifier," [Online]. Available: <http://www.sharepdf.com/81fb247fa7c54680a94dc0f3a253fd85/naiveBayesianClassifier.pdf>, [Accessed: September 2013].

Bing L. (2012). Sentiment analysis and opinion mining. Claypool Publishers.

Shelke, N. M., Deshpande, S. V. and Thakre, (2012) "Survey of techniques for opinion mining," International Journal of Computer Applications, vol.57, no.13, pp. 30-35, November 2012.

Sheng Yu and Subhash Kak (2012) A Survey of Prediction Using Social Media Department of Computer Science, Oklahoma State University.



## **PARTIAL REPLACEMENT OF CEMENT WITH PALM KERNEL SHELL ASH IN CONCRETE**

Adeyanju, D.O. <sup>1\*</sup>, Awogboro, S.O. <sup>1</sup>, Kareem, M.A. <sup>1</sup>

<sup>1</sup>Dept. of Civil Engineering, Osun State University, Nigeria

\*Email of corresponding Author: [strikerdconcept@gmail.com](mailto:strikerdconcept@gmail.com)

### **ABSTRACT**

This study investigates the properties of the concrete produced with partial replacement of cement with Palm Kernel Shell Ash (PKSA). The palm kernel shell was burnt to ashes at a temperature of 700 °C and sieved using 150 µm sieve. The chemical compositions of the ash were examined using X-ray fluorescence analysis. A mix proportion of 1:2:4 with water-cement ratio 0.5 was used for the preparation of concrete mix. The percentages of PKSA used as replacement for ordinary Portland cement (OPC) were 0%, 5%, 10% and 20% by weight. Sixty (60) Concrete cubes of 150mm × 150mm × 150mm size were cast and cured of the curing age of 7, 14, 21, and 28 days, respectively. At the end of each hydration period, three concrete cubes were crushed and the average compressive strength recorded. Slump and compacting factor tests were carried out on the fresh concrete while density and compressive strength tests were carried out on hardened concrete. The result of the slump of control test was 59 mm while the results for 5 – 20 % of PKSA in cement decrease from 57 – 49 mm. The density of concrete increased with increase in PKSA contents and curing ages. The compressive strength of 5-20% PKSA/cement mixtures decrease from 26.00 - 19.10 N/mm<sup>2</sup> as against 27.8 N/mm<sup>2</sup> for the control test. The results of this study indicated that PKSA is a good partial replacement of cement and also decreases the cement content in concretes thereby reducing the production cost as well as minimizing the environmental menace with agricultural wastes.

**Keywords:** Compacting Factor, Compressive strength, Density, Palm kernel shell ash, Slump, Water absorption.

### **INTRODUCTION**

There is need for affordable building materials in providing adequate housing for the teeming populace of the world. The cost of conventional building materials continues to increase as the majority of the population continues to fall below the poverty line. Thus, there is the need to

search for local materials as alternatives for the construction of functional but low-cost buildings in both the rural and urban areas. Some of the local materials that have been used are earthen plaster (Svoboda and Prochazka, 2012), lateritic interlocking blocks (Raheem *et al.*, 2012) and Palm kernel shell (Raheem *et al.*, 2008). Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal.

Construction industry has been identified as the one that absorbs the majority of such materials as filler in concrete (Antiohos *et al.*, 2005). If these fillers have pozzolanic properties, they impart technical advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved (Hossain, 2013). Appropriate utilization of these materials brings ecological and economic benefits. Concrete is the most versatile heterogeneous construction material and the impetus of infrastructural development of any nation (Olafusi and Olutoge, 2012). Concrete is a composite inert material comprising of a binder course (e.g. cement), mineral filler (body) or aggregates and water (Oyenuga, 2001). Concrete is one of the oldest manufactured construction materials used in construction of various structures around the world.

The cost of concrete and other construction materials in Nigeria is currently so high that the majority of individuals find it difficult to afford, with the exception of Government, Industrial and Business Corporations. Thus, the reduction in the cost of Civil Engineering construction works can be achieved by adopting cheap locally available engineering materials (Raheem and Kareem, 2017a, b). The Nigerian Building and Road Research Institute (NBRRI) was established in order to fulfil this mandate (Olutoge *et al.*, 2012). PKSA has pozzolanic qualities which make it to be used as a partial replacement for ordinary Portland cement (OPC) (Olutoge *et al.*, 2012; Fadele and Ata, 2016). Pozzolana is defined as a siliceous or alumino-siliceous material, which in itself possesses little cementitious value, but will in finely divided form and in the presence of water chemically reacts with free lime from cement at ordinary temperature to form compounds possessing cementitious properties (Malhotra and Hemmings, 1995).

In other words, the physical characteristic of PKSA is very much influenced by the operating system in the palm oil factory. Utilization of PKSA is minimal and unmanageable while its quantity increases annually and most of the PKSA are disposed as waste in landfills causing environmental problems (Tanqchirapatet *et al.*, 2007). As a solution to the disposal problem of the wastes derived from palm oil production, research studies have been carried out to examine

the feasibility of using the oil palm waste incineration ash as cement replacement materials (Tay and Show, 1995).

The aim of this research is to investigate the engineering properties of concrete produced with partial replacement of cement with PKSA.

## **Materials and Method**

### **Material**

The materials used for this research include Dangote brand of ordinary Portland cement, palm kernel shells obtained from local Palm Oil Mill Industry at Egbeda, Osogbo, Nigeria, granite and dry mining sand from borrow pit within Osun State and water from tap at the Structural and Material laboratory of Department of Civil Engineering, Osun State University, Osogbo, Nigeria. Grading test was carried out on sand and granite as specified in BS 812: 103.1 (1985).

### **Sample Preparation**

The palm kernel shell was burnt using furnace at about 700<sup>0</sup>C and then grinded properly to ashes. The ashes were sieved through a 150µm sieve in order to remove bigger size of ash particles and if any alien materials exist. The chemical analysis of the PKSA sample was carried out to examine the chemical compositions of the ash at Jawura Environmental Services Limited, Lagos Sate, Nigeria.

### **Mix Design of Concrete**

The proportioning by weight was used in this research as shown in Table 1. The cement-aggregates ratio used in this work was 1:2:4. PKSA were used to replace OPC at replacement levels of 5%, 10% and 20% by weight of cement.

**TABLE 1:** Mix Design of Concrete Specimen

Constituent Materials	Control	PKS A 5%	PKSA 10%	PKSA 20%
Cement (kg)	21	19.9	18.9	16.8

PKSA (kg)	-	1.1	2.1	4.2
Sand (kg)	42	42	42	42
Granite (kg)	84	84	84	84
Water/Cement Ratio (kg)	0.5	0.5	0.5	0.5
Total Water	10.5	10.5	10.5	10.5

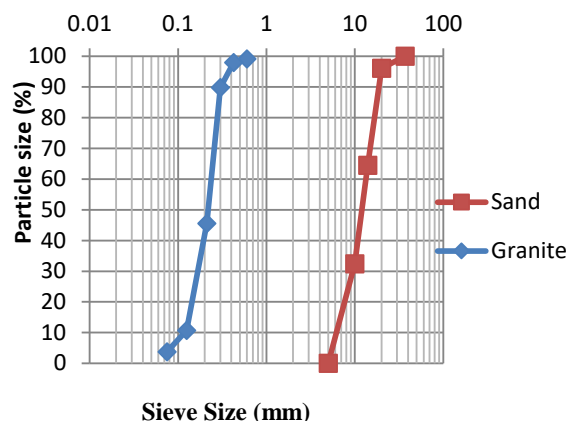
### **Test Procedure**

A total of sixty (60) concrete cubes of 150mm × 150 mm × 150 mm size of OPC/PKSA were cast and cured for 7, 14, 21 and 28 days, respectively. Slump and compacting factor tests were carried out on fresh concrete. At the end of each hydration period, three concrete cubes for each hydration period were weighed prior to crushing to determine the densities, water absorption and then average compressive strength was recorded.

### **Results and Discussion**

#### **Particle size distribution of Aggregates**

The particle size distribution curves for natural sand and granite are shown in Figure 1. The particle size of sand conformed to zone II with the maximum particle size of 4.75mm. The coarse aggregates ranged between 12mm and 20mm nominal size. The particle size of granite conforms to BS 882-1970. The grain particle of granite is uniformly well-graded which improve the strength of the concrete.



**Figure 1:** Particle Size Distribution of Fine and Coarse Aggregate

### Chemical Composition of PKSA

The PKSA collected were grayish black in color. The main constituents of the PKSA are Silicon Dioxide ( $\text{SiO}_2$ ), Aluminum Trioxide ( $\text{Al}_2\text{O}_3$ ), and Ferric Oxide ( $\text{Fe}_2\text{O}_3$ ). The total amount of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$  present in PKSA is 62.16% which is more than the minimum required (50% Min.) specified by ASTM Designation: C 618 for Type C Ash; while its Calcium oxide (CaO) content is about 7.96%; as shown in Table 2.

**Table 2:** Chemical Properties of PKSA

Chemical composition (%)	PKSA	Dangote Cement
Silicon Dioxide ( $\text{SiO}_2$ )	49.63	22.13
Aluminium Trioxide ( $\text{Al}_2\text{O}_3$ )	12.12	3.74
Ferric Oxide ( $\text{Fe}_2\text{O}_3$ )	0.41	2.97
Calcium Oxide (CaO)	7.96	63.36
Magnesium Oxide (MgO)	5.68	2.58
$\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	62.16	28.84
True Density ( $\text{g/cm}^3$ )	1.29	2.97

### **Specific Gravity (Gs) of Sand, Granite and PKSA**

The higher the specific gravity of a material the higher the density of concrete made with and the higher will be the corresponding strength of the concrete (Salem and Pandey, 2015). The palm kernel shell ash (PKSA) has average G<sub>s</sub> of 2.60 as shown below in Table 3, this makes the density of concrete made with PKSA has higher density than the control mix made with OPC.

**Table 3:** Specific Gravity of Samples

<b>Sample</b>	<b>Specific Gravity (Gs)</b>
<b>Sand</b>	<b>2.55</b>
Granite	2.65
<b>PKSA</b>	<b>2.60</b>

### **Slump of Fresh Concrete**

Table 4 shows the result of the slump test of concrete produced with 0-20 % replacement of cement with PKSA. The result of the slump test of the control test is 59 mm while 5-20 % replacements of OPC with PKSA decrease from 57 – 49 mm. The results show that the slump of concrete produced as the percentage replacement of cement with PKSA increases. This implies that concrete becomes less workable as the PKSA increases meaning that more water is needed to make the concrete workable (Adesanya and Raheem, 2009). The 0%, 5%, and 10% have true slump and medium workability of 59, 57, and 53 mm respectively while 20% has Shear slump and low workability of 49 mm. According to Neville and Brook (2010), 0 – 25 mm is very low workability, 25 – 50 mm is low workability, 50 – 100 mm is medium workability and 100 – 175 mm is high workability.

**Table 4:** Slump of Fresh Concrete

<b>% Cement Replacement</b>	<b>Slump (mm)</b>

0	59
5	57
10	53
20	49

### Compacting Factor of Fresh Concrete

The compacting factor of concrete is presented in Table 5. The result of the compacting factor of control test is 0.92 while 5-20% replacements of OPC with PKSA decrease from 0.89 to 0.82, and the volume of Portland cement in the concrete determines the porosity and the degree of compaction of the concrete. The compacting factor for concrete of normal range lies between 0.08 and 0.92. The workability of the control and concrete with replacement are all satisfied.

**Table 5:** Compacting Factor of Fresh Concrete

% Cement Replacement	Compacting Factor
0	0.92
5	0.89
10	0.85
20	0.82

### Water Absorption of Hardened Concrete

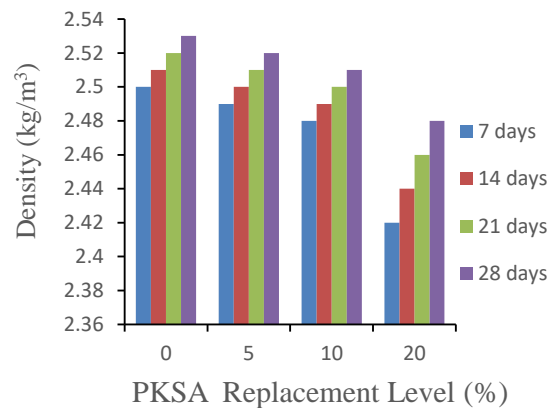
The water absorption of concrete produced is illustrated in Table 6. The result of the water absorption of the control specimen is 2.5% while 5-20% replacements of OPC with PKSA decline from 1.7-0.82%. The result also shows a decrease in the water absorption of concrete produced as the percentage replacement of cement with PKSA increases. Initial and final setting time of the PKSA concrete took longer time than OPC concrete as observed during the concrete cast. The higher the PKSA content in concrete, the longer the water absorption and setting time. However, PKSA concretes do not absorb water as fast as OPC concretes; thereby retarding hydration processes in the PKSA concrete which causes slow development of the compressive strength of PKSA concrete.

**Table 6:** Water Absorption of Hardened Concrete

% Cement Replacement	Water Absorption ratio
0	2.5
5	1.7
10	1.3
20	0.82

### Density of Hardened Concrete

Figure 2 revealed that the density decreased with increasing percentage of PKSA and increased with curing age. These results indicate that PKSA concretes are lighter than OPC concretes due to the low specific gravity of the ash, low surface area of the ash and the Ordinary Portland cement is finer than the ashes. This is in agreement with the findings from previous studies (Olutoge *et al.*, 2012; Fadele and Ata, 2016). The higher the density of the concrete, the higher the corresponding compressive strength. This is because density is a reflection of weight; as concretes gain strength and weight with curing age due to hydration process, the weight is also increasing.



**Figure 2:** Density of the Concrete Cubes



### Compressive Strength of Hardened Concrete

Figure 3 showed the compressive strength of concrete at different curing ages. It can be observed that up to 10% replacement of cement with PKSA, a compressive strength of 20 N/mm<sup>2</sup> can be obtained. With more than 10% PKSA replacement level, the compressive strength goes below the targeted strength of 20 N/mm<sup>2</sup> specified characteristic compressive strength of 150 mm cube at 28 days for a M20 grade concrete in IS 456 (2000). The slow

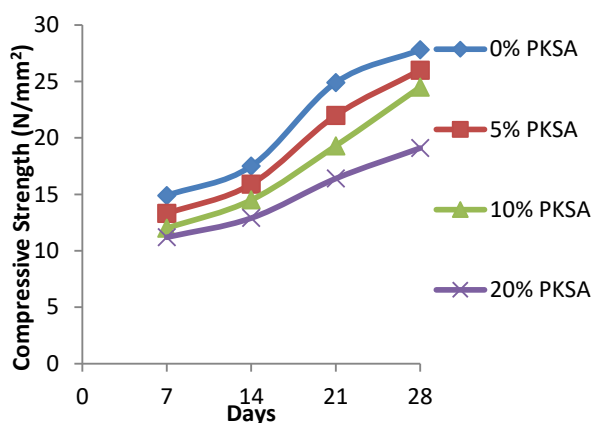


Figure 3: Compressive Strength of the Cubes

development of strength which is an important characteristic of pozzolanas (Antiohos *et al.*, 2005) could be responsible for low 28 days strength of 20% PKSA concrete which was 19.1N/mm<sup>2</sup>.

### Conclusion

Based on the findings from the study, it can be concluded as follows:

- PKSA is a pozzolana material which has main chemical composition of cement but in varying proportions as compare to that of OPC, if the right quantity is used, it means it will be a good partial replacement of cement.
- Results suggest that 10% replacement of cement with PKSA which will satisfy with no compromise in compressive strength requirement for the concrete production.
- Concrete strength increases with curing age and decreases with increasing percentage of PKSA replacement in concrete.

(d) The presence of PKSA in concrete exhibits a lower water absorption rate and slower setting time of concrete.

(e) The workability decreases with the increase in the percentage replacement of cement with PKSA.

(f) PKSA used as cement replacement enables the large utilization of waste product thereby reduces the environmental menace.

### **Recommendations**

(a) The PKSA should be treated with additive to enhance the strength and durability of the concrete containing PKSA.

(b) Long term studies on the development of strength as well as durability aspect of concrete containing PKSA have been recommended for further investigation.

### **REFERENCES**

Antiohos, S., Maganari, K. and Tsimas S., 2005. Evaluation of blends of high and low calcium fly Ashes for use as Supplementary cementing materials, *Cement and Concrete Composites*, 27, pp. 349-356.

Fadele, O.A. and Ata, O., 2016. Compressive strength of concrete containing Palm Kernel Shell Ash, *American Journal of Engineering Research (AJER)*, 5(12), pp. 32-36.

Hossain, K.M.A., 2003. Blended Cement using Volcanic Ash and Pumice, *Cement and Concrete Research*, 33, pp. 1601-1605.

Malhotra, V.M. and Hemmings, R. T., 1995. Blended Cement in North America - A Review, *Cement and Concrete Composites*, 17(1), pp. 23-35.

Neville, A.M. and Brook, J.J. (2010). *Concrete Technology*, 2<sup>nd</sup> ed. Prentice Hall, Pearson Education Limited, Edinburg Gate Harlow, Essex CM20 2JE, England.

Olafusi, O.S. and Olutoge, F.A., 2012. Strength properties of corn cob ash concrete, *Journal of Emerging Trends in Engineering and Applied Sciences*, 3(2), pp. 297-301.

- Olutoge, F.A., Quadri, H.A. and Olafusi, O.S., 2012. Investigation of the Strength Properties of Palm Kernel Shell Ash Concrete”, *ETASR - Engineering, Technology and Applied Science Research*, 2(6), pp. 315-319.
- Oyenuga, V.O. 2001. Simplified reinforced concrete design, ASTROS Limited, Lagos, Nigeria.
- Raheem, A.A., Nwakanma, E.O. and Ogunleye, K.O., 2008. Engineering properties of concrete with palm kernel shell as fine and coarse aggregates, *USEP, Journal of Research Information in Civil Engineering (RICE)*, 5(1), pp. 58-70.
- Raheem, A. A., Falola, O. O. and Adeyeye, K. J. (2012). Production and testing of lateritic interlocking blocks, *Journal of Construction in Developing Countries*, Malaysia, 17(1), pp. 35-50.
- Raheem, A. A. and Kareem, M. A. 2017a. Optimal raw material mix for the production of rice husk ash blended cement, *International Journal of Sustainable Construction Engineering and Technology*, 7(2), 77-93.
- Raheem, A.A. and Kareem, M.A., 2017b. Chemical composition and physical characteristics of rice husk ash blended cement, *International Journal of Engineering in Africa*, pp 25-35. DOI: 10.4028/www.scientific.net/JERA.32.25.
- Salem, M.A.A. and Pandey, R.K., 2015. Influence of specific gravity on weight of proportion of concrete, *International Journal of Engineering Research and Technology (IJERT)*, 4(2), pp. 318-320.
- Svoboda P. and Prochazka M., 2012. Outdoor earthen plasters, *Organisation, Technology and Management in Construction: an International Journal*, 4(1), pp.420-423.
- Tanqchirapat W., Saeting, T., Jaturapitakkul, C., Kiattikomol, K and Siripanichgorn, A., 2007. Use of waste ash from palm oil industry in concrete, *Waste Management*, 27(1), pp. 81-88.
- Tay J.H. and Show, K.Y. 1995. Use of ash derived from oil-palm waste incineration as a cement replacement material, *Journal of Resources, Conservation and Recycling*, 13(1), pp.27-36.
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