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INVESTIGATION OF GROUNDWATER AQUIFER USING ELECTRICAL RESISTIVITY METHOD AT MULERUWA VILLAGE, SOUTH WEST, NIGERIA.

Kamilu M.A, Mathew S, Ogun C., and Olapade T.S

Corresponding Author: kamiladeshina@gmail.com, +2347062778906

ABSTRACT

Groundwater is an important natural resource and constitutes our environment. Groundwater can be found in geological formations which exist below the ground surface. Differences exist in groundwater systems all over the world due to differences in their geological make up and climate.Groundwater resource assessment has been carried out using hydro-geophysical techniques (Vertical electrical maximum spread of 350m sounding and 2-D Wenner profile (a=10m) ,maximum spread of 230 m was modelled with the corresponding depth of 30 to 50 m was investigated) in Muleruwa Ogun State, Southwestern Nigeria. The 2D data was interpreted with WinPRO while VES data curve matched and interpreted results of the VES data were presented as Geo-electric sections. Six geo-electric layers were delineated which correspond to the Topsoil, Clayey sand, Lateritic clay sand, clay and sand. The Topsoil has layer thickness of 0.5m - 0.8m and Resistivity values within the range of 69.3Ωm-423.6Ωm. The Clay has a layer thickness of 1.2m - 29.9m and resistivity values within the range of 17.7Ωm - 35.0Ωm. The lateritic clayey sand has a layer thickness of 5.5m - 74.2m and resistivity value within the range of 1054.5Ωm - 9319.2Ωm.The Clayey sand has a layer thickness of 1.7m - 13.3m and resistivity value within the range 63.9Ωm - 824.9Ωm. The sand has a layer thickness of 2.2m - 58.6m and resistivity values within the range of 118.2Ωm - 940.3Ωm, this layer is not a Groundwater reservoir. Groundwater reservoirs are found between the depths 67.2m -115.8m, thickness of 23.0m – 54.5m and above in saturated sand.The physical properties of the water in this community was also seen to contradict the normal properties of water. The water was seen to be slightly coloured in appearance, had a particular taste and an unpleasant odour.

KEYWORDS: Resistivity, Aquifer, Groundwater, physical properties, Geo-electric section.

INTRODUCTION

Muleruwa village is located after Ogijo community, Sagamu local Government, Ogun state. It is an industrialized area with a large concentration of industrial wastes from different companies such as the Nigeria National Petroleum Corporation (NNPC), Iron and Steel companies and the Metal Recycling Industry. Huge masses of wastes are produced daily from the companies as a result of industrial and commercial activities, when not properly disposed could affect the groundwater aquifer present in the study area. Groundwater is an important natural resource and constitutes our environment. Groundwater can be found in geological formations which exist below the ground surface. Differences exist in groundwater systems all over the world due to differences in their geological make up and climate

The contamination of groundwater with Industrial pollution is of great concern in many countries globally due to its potential impact on health and environmental quality. (Olayinka, 2019).

Leachate generated from industrial and domestic landfill during the rain may eventually percolate and contaminate groundwater. Consequently, pollution from landfills leads to potentially communicable diseases. Groundwater is the subsurface transporting agent for dissolved chemicals

including contaminants. Materials dissolved from the wastes areas are contaminated, they commonly remain so for decades or longer. (Ofomala, 2015). Groundwater resources poses a greater risk to the domestic user and also the natural environment. The site is located at Muleruwa Community, Ogijo, Ogun State. The area is accessible via major road from Maryland Bus stop to Ikorodu Garage, from Ikorodu - Garage, board a bus going to Ogijo. Then from Ogijo Bus stop, take to Igbaga and stop at Muleruwa Community.

Site Description, Geology and Hydrogeology of the study area

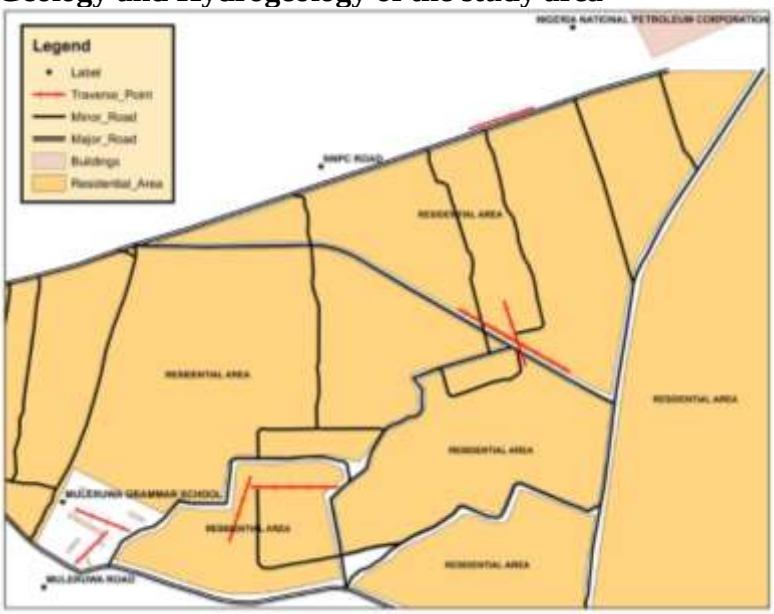

Fig 1: Base Map of the study area

The study area is located in Muleruwa and Igbaga village, Ogijo community, Sagamu local government area within Ogun state, Southwestern Nigeria. The study area is located along Ikorodu - Sagamu Expressway. It is situated along geographic coordinates of Latitude 6.6994°N and Longitude 3.5155°E. It falls within the eastern dahomey basin of Southwestern Nigeria. The study area possesses Savanna vegetations which are described with crystalline basement complex rocks. The dominant rocks are gneisses and quartzite. (Abdulaziz, 2003).

The major climatic seasons of the area are rainy and dry seasons. The rainy season rus from April to October which is characterized by heavy downpours in June/July while the remaining months constitute the dry season with little rainfall or none at all. The mean annual rainfall which is about 1270mm makes up the major source of groundwater recharge in the area with a mean annual temperature of about 27°C - 28°C. (Ojo, 1997).

The vegetation which exists within the study area is largely influenced by climate and relief though the present day vegetation cover can be said to be scarce owing to residential and commercial activities within the town.

The geological setting of the study area is that of a sedimentary terrain Easstern Dahomey basin which include; Abeokuta, Ewekoro, Ilaro, Akinbo, Oshosun and Benin formations. The local geology of the study area was observed to be one which comprises of sedimentary rocks with Shale and Clayey lithology being predominant belonging to the

Akinbo formation. (Oyeyemi and Aizbeokhai, 2015).

The major aquifer zones delineated in the study area are the shale and clay. The shale and clayey deposits are the major aquifers in the study area. Boreholes in residential buildings around the area serve as a major source of portable water for the inhabitants. With the increasing activities of industries such as Petroleum Industry, Iron and Steel Industry and Metal Recycling Industry, the groundwater may be rendered unsuitable for domestic and agricultural purposes.

The occurrence of groundwater in crystalline rocks majorly depends on the fracturing and weathering of rocks. The groundwater is primarily contained in the fractured and weathered formations which is basically recharged through surface precipitation.

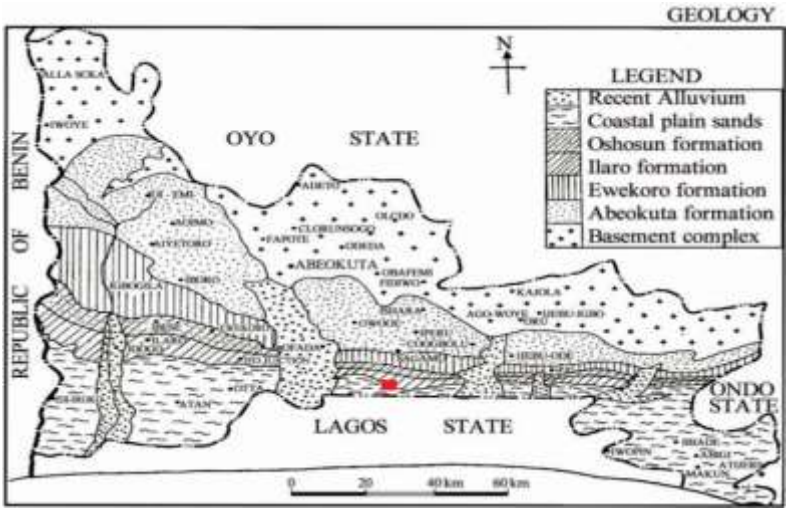

Fig 2 : Geological Map of study area. Oladunjoye,et al. (2013)

MATERIALS AND METHODS

FIELD WORK PROCEDURE

In 1D resistivity survey Fig 3, the Centre point of the electrode remains fixed and unchanged but the spacing between the electrodes are varied to obtain more information about the depth of the subsurface. (Loke, 2001). These surveys assume that the geological layers are horizontal and homogenous.

The measured apparent resistivity values are normally plotted on a log-log graph paper. To interpret the data from such a survey, it is normally assumed that the subsurface consists of horizontal layers. In this case, the subsurface resistivity changes only with depth, but does not change in the horizontal direction. This method has given useful results for geological situations (such the water-table) where the one-dimensional model is approximately true. (Loke, 2001).

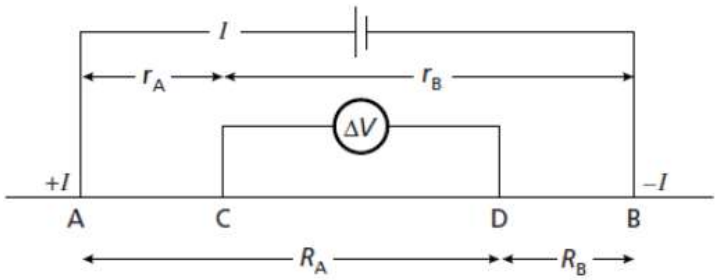

Fig 3: The generalized form of the electrode configuration used in resistivity measurements (Keary et al., 2002).

Considering the case where the current sink is a finite distance from the source. The potential VC at an internal electrode C is the From equation above

$$V_C = \frac{\rho I}{2\pi}\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$$

1

Thus

$$\rho = \frac{2\pi\Delta V}{I\left\{\left(\frac{1}{r_A} - \frac{1}{r_B}\right) - \left(\frac{1}{R_A} - \frac{1}{R_B}\right)\right\}}$$

sum of the potential contributions VA and VB from the current source at A and the sink at B: VC = VA + VB

2D is one of the most recent technique in electrical resistivity method to map out areas with moderately complex geology. The surveys are usually carried out using a large number of electrodes and connected to a multi core cable. At present, field techniques and equipment to carry out 2-D resistivity surveys are well developed. Normally, a constant spacing between the adjacent electrodes is used. The multi core cable is then attached to the electronics switching unit which is then connected to the instrument. In a typical survey, most of the field work is in laying out cables and the electrodes. After that, the survey time is spent waiting for the resistivity meter to complete the set of measurements. For a good 2-D picture of the subsurface to be obtained, the coverage of the measurement must be 2-D as well.

For instance, the figure below shows the possible sequence of measurements for a zenner electrode array for a system with 20 electrodes.

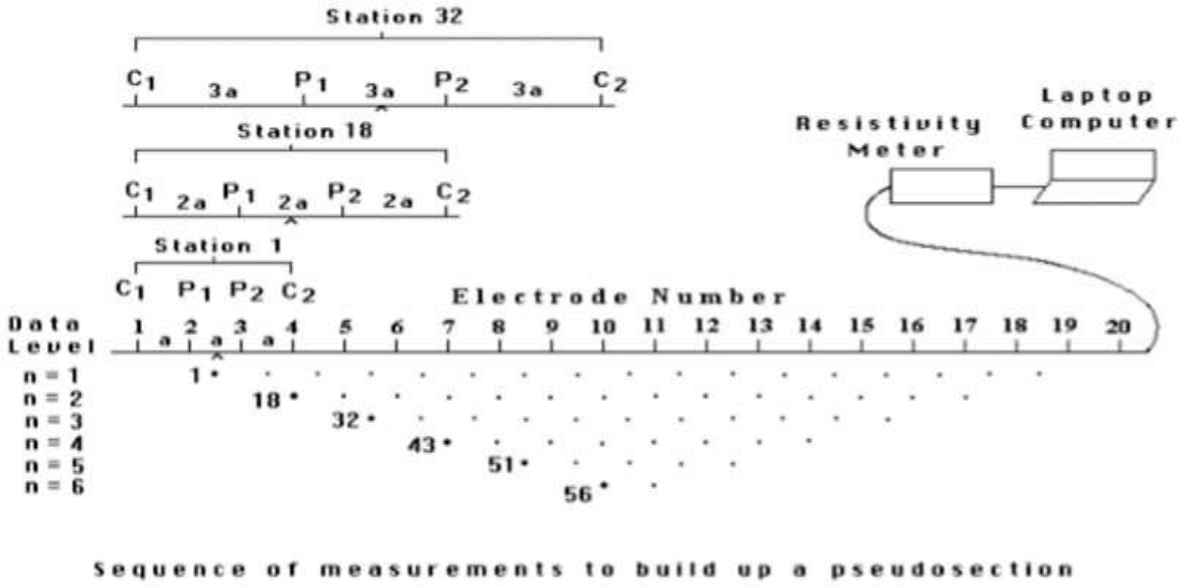

Fig 4: The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudo section (Loke, 2001).

Both Vertical Electrical Sounding (VES) and the 2-D geoelectrical survey were carried out using both Schlumberger and Wenner array configurations respectively. The basic field equipment for this survey is the PASI Earth Resistivity metre which is accompanied by other instruments such as; metal electrodes, conducting cables, hammers e.t.c. in the VES, the Schlumberger electrode configuration was adopted with four electrodes being positioned symmetrically along a straight line with the current electrode on the outside and the potential electrodes on the inside. To change the depth, the range of measurements of the current electrodes are displaced outwards while the potential electrodes are left fixed. Measurement of current and potential electrodes position are marked such that $AB/2 \geq MN/2$.

Where:
AB/2 = Current electrode spacing
MN/2 = Potential electrode spacing

One of the major advantages this method has is that only the current electrodes need to be shifted to a new position for most readings.
The Wenner arrays were used on seven traverse lines, Traverse AA - Traverse GG with a maximum length spread of 230m and minimum electrode spacing of 10m. The data were generated along the traverses. Two people manned each current electrode, marked out the required length with the tapes and hammered the electrodes connected to the cables into the ground and rewound them when each traverse was completed. Communication between the field crew and the operator were made possible with the aid of a GSM phone. By the end of the field work, a total number of seven traverses were run.
The Wenner array was used for 2-D resistivity imaging acquisition. These electrode configuration are well suited for constant separation data acquisition systems so that many data points can be recorded simultaneously for each current injection. A third party software package, Surfer 12 and RES2DINV were used for the resistivity data processing. Before processing with the RES2DINV software, the data was converted into CSV -file extension with Surfer 12 software. This conversion was done to enable the RES2DINV software to read the Wenner data. In the RES2DINV software program, each of the apparent resistivity data files was read and inverted with the user model. The inverted data was printed and saved in word file format. The result is an inverse model resistivity section which is referred to as pseudo section. The data obtained and results of interpretation from the Wenner array survey are presented below as inverse model resistivity section.

The Schlumberger configuration was used in carrying out vertical electrical soundings for the delineation of possible subsurface layers of the earth. The electrodes were moved in steps further out from a fixed center in order to achieve greater current penetration into the ground.
This method involves the use of a geophysical software called WinResist Field data are input and then modeled. Curve matching gets cumbersome where there are many layers, hence the computer iteration makes the interpretation of such problems easier. A fast observation is allowed based on the iteration intense of the program. The layer parameter are altered until a good fit is achieved between the observed and the calculated values. The iteration process of a curve can go as far as 30 times of achieving an effect match, after which the computer displays the final result of the iteration and the layer parameters. This method is the most effective method of all the interpretation method in terms of speed and accuracy

RESULTS AND DISCUSSION

Some typical resistivity curves are shown in Figure 5(a - c). A summary of the interpreted VES results with inferred lithology is presented as Table 1. The geo-electric sections are displayed in Figures 6(a – b). The 2D Electrical Resistivity models are shown in Figures 7

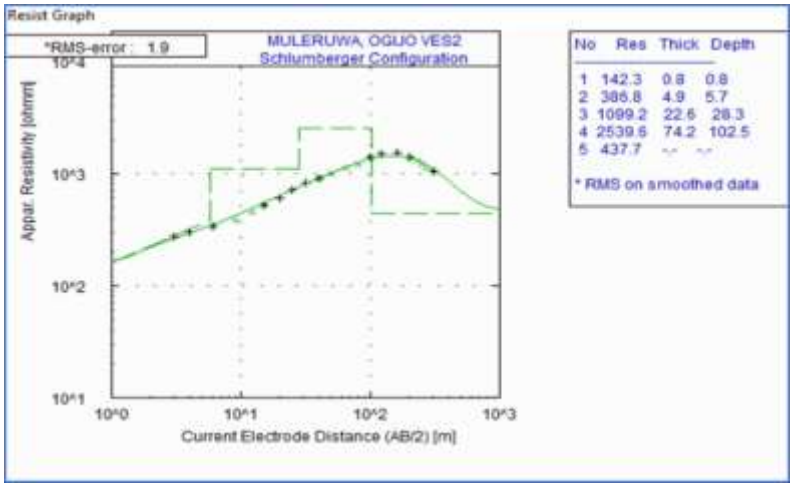

Figure 5: Resistivity Curve of VES 2 (AA)

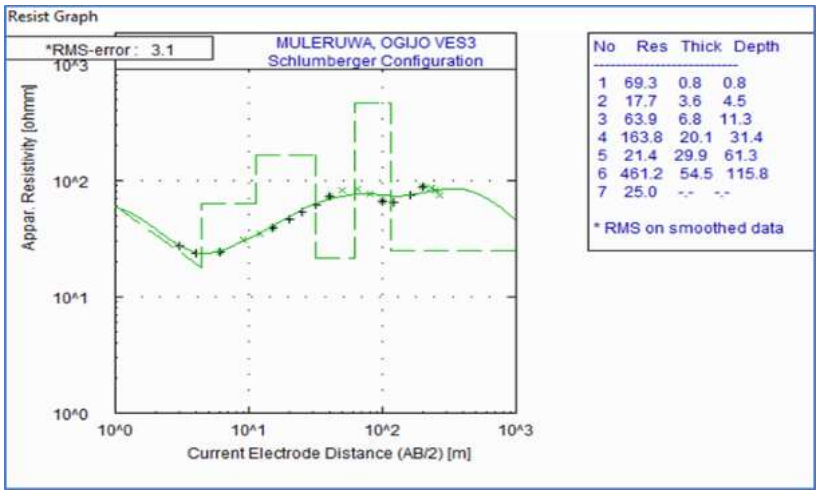

Figure 5b: Resistivity Curve of VES 3 (AAK)

Figure 5: Resistivity Curve of VES 3 (HAKHK)

Table 1: Lithology of the study area

VES Number	Possible Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Lithology
VES 1	1	71.3	0.7	0.7		Topsoil
	2	491.8	3.7	4.3		Clayey Sand
	3	738.4	13.3	17.3	**AAK**	Clayey Sand
	4	1674.1	41	58.6		Lateritic Clayey Sand
	5	277.5	---	---		Sand
VES 2	1	142.3	0.8	0.8		Topsoil
	2	386.8	4.9	5.7		Clayey Sand
	3	1099.2	22.6	28.3	**AAK**	Lateritic Clayey Sand
	4	2539.6	74.2	102.5		Lateritic Clayey Sand
	5	437.7	---	---		Sand
VES 3	1	69.3	0.8	0.8		Topsoil
	2	17.7	3.6	4.5		Clay
	3	63.9	6.8	11.3	**HAKHK**	Clayey Sand
	4	163.8	20.1	31.4		Sand
	5	21.4	29.9	61.3		Clay
	6	461.2	54.5	115.8		Sand
	7	25	---	---		Clay
VES 4	1	123.3	0.7	0.7		Topsoil
	2	1174.2	3.8	4.5		Lateritic Clayey Sand
	3	171.2	11.9	16.4	**KHK**	Sand
	4	2866.6	56.2	72.7		Lateritic Clayey Sand
	5	193.9	---	---		Sand
VES 5	1	150.1	0.7	0.7		Topsoil
	2	1275.7	5.2	5.9		Lateritic Clayey Sand
	3	259.4	7.9	13.8	**KHK**	Sand
	4	1428	57.1	70.9		Lateritic Clayey Sand
	5	281	---	---		Sand
VES 6	1	316.4	0.7	0.7		Topsoil
	2	705.2	3.3	4		Clayey Sand
	3	1340.5	3.1	7.1	**AKHK**	Lateritic Clayey Sand
	4	283.9	7.6	14.7		Sand
	5	2307	54.9	69.8		Lateritic Clayey Sand
	6	362.9	---	---		Sand
VES 7	1	423.6	0.6	0.6		Topsoil
	2	527.8	1.7	2.3		Clayey Sand
	3	97.8	1	3.4	**KHAKH**	Sandy Clay
	4	543.1	7.7	11		Clayey Sand
	5	2831.1	28.3	39.4		Lateritic Clayey Sand
	6	163.6	50.5	89.9		Sand
	7	1938.4	---	---		Lateritic Clayey Sand

VES 8	1	213.1	0.8	0.8		Topsoil
	2	774	4.4	5.2		Clayey Sand
	3	8261.5	10.8	16	**AKH**	Lateritic Clayey Sand
	4	940.3	54.7	70.7		Sand
	5	9319.2	---	---		Lateritic Clayey Sand

Geoelectric Section along BB'

Figure 6b consist of VES 3 to 7. The section reveals five to seven geoelectric layers which varies from topsoil, clay, clayey sand, lateritic clayey sand, sandy clay and sand. The topsoil is characterized by resistivity values ranging from 69.3 to 150.1 Ohm-m and layer thickness of 0.7 to 0.8 m. The second identified layer in VES 3 is representative of clay having resistivity value of 17.7 Ohm-m and layer thickness of 3.6 m while the clay is replaced with lateritic clayey sand in VES (4 and 5) with resistivity and layer thickness values ranging from 1174.2 to 1275.7 Ohm-m and 3.8 to 5.2 m respectively. However, the second layer in VES (6 and 7) denotes clayey sand with resistivity values ranging from 527.8 to 705.2 Ohm-m and layer thickness of 1.7 to 3.3 m. The third geoelectric unit in VES 3 depicts clayey sand with resistivity and layer thickness value of 63.9 Ohm-m and 6.8 m respectively. While the clayey sand is replaced with sand in VES (4 and 5) having resistivity values ranging from 171.2 to 259.4 Ohm-m and layer thickness of 7.9 to 11.9 m. However, the third layer in VES 6 is representative of lateritic clayey sand with resistivity value of 1340.5 Ohm-m and layer thickness of 3.1 m. More so, the third geoelectric layer in VES 7 represent sandy clay having resistivity and layer thickness value of 97.8 Ohm-m and 1.0 m respectively. The fourth horizon beneath VES (3 and 6) is indicative of sand with resistivity values ranging from 163.8 to 283.9 Ohm-m and layer thickness of 7.6 to 20.1 m while the sand is replaced with lateritic clayey sand in VES (4 and 5) with resistivity values ranging from 1428.0 to 2866.6 Ohm-m and layer thickness of 56.2 to 57.1 m. However, the fourth layer in VES 7 revealed clayey sand with resistivity and layer thickness of 543.1 Ohm-m and 7.7 m respectively. The fifth substratum layer beneath VES 3 is diagnostic clay with resistivity value of 21.4 Ohm-m and layer thickness of 29.9 m while the clay is replaced with sand in VES (4 and 5) with resistivity values ranging from 193.9 to 281.0 Ohm-m but their layer thickness could not be determined due to current terminated within this region. The sand in this zone represents an aquifer unit where groundwater could be tapped. However, the fifth geoelectric layer in VES (6 and 7) signify lateritic clayey sand with resistivity values ranging from 2307.0 to 2831.1 Ohm-m and layer thickness of 50.5 to 54.9 m. The sixth geologic units in VES (3, 6 and 7) is symptomatic of sand with resistivity values ranging from 163.6 to 461.2 Ohm-m. The layer thickness in VES (3 and 7) ranges from 50.5 to 54.5 m but the layer thickness in VES 6 could not be determined due to current terminated within this zone. The sand in this region represents an aquifer unit where groundwater could be tapped. The seventh geoelectric layer in VES 3 connotes clay with resistivity value of 25.0 Ohm-m but the layer

thickness could not be determined due to current terminated within this region. While the clay is replaced with lateritic clayey sand in VES 7 with resistivity value of 1938.4 Ohm-m but the layer thickness could not be determined due to current terminated within this horizon.

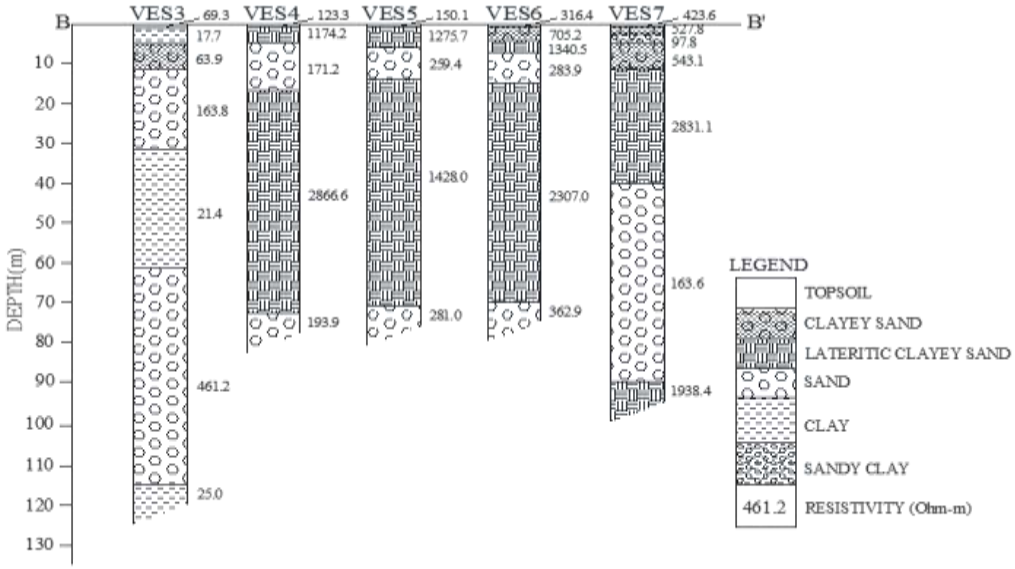

Figure 6a:Geo-electric section of traverse BB'

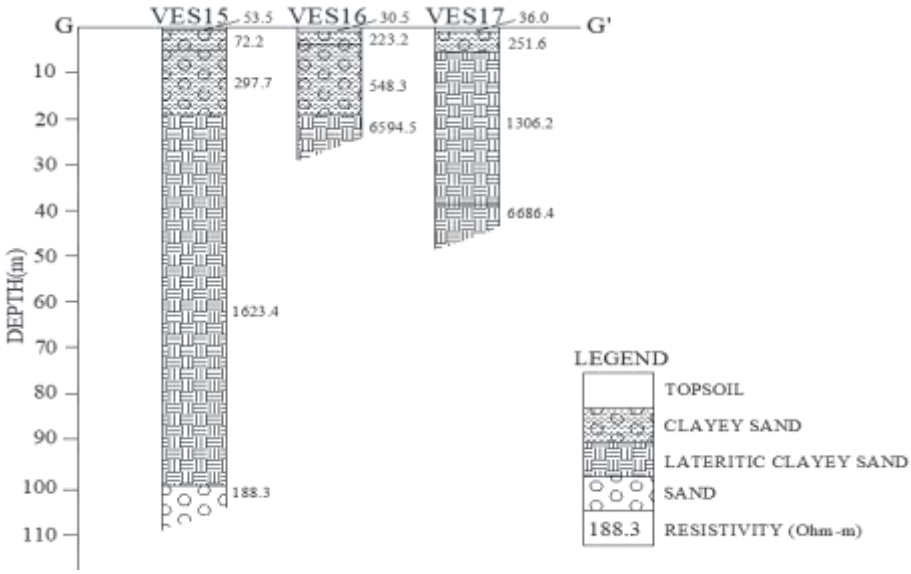

Figure 6b:Geo-electric section of traverse EE'

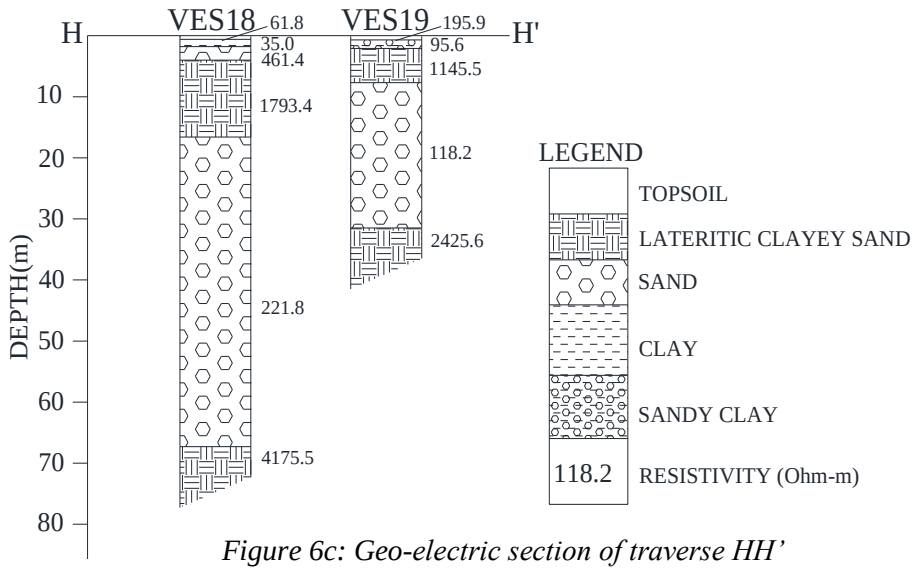

Figure 6c: Geo-electric section of traverse HH'

2-D ELECTRICAL IMAGING

In this model, the results are presented in a colour coded format Fig 7.0(a-f) consisting of the Inverted 2-D Resistivity structure. The horizontal scale on the section is the lateral distance while the vertical scale is the depths which are both in meters. A minimum and maximum spread of 130 to 230 m was modelled with the corresponding depth of 30 to 50 m investigated on all the profiles Fig 6.0 (a - f).

2-D Resistivity Section along Traverse One

A total spread of 200 m was surveyed and a depth of 50 m was probed with resistivity values ranging from 188 to 848 Ohm-m as shown in Figure 7(a-d). The VES 1 and 2 were along the 2-D profile in Figure 7(a) at lateral distance of 40 m and 120 m respectively. At depth below 20 m is indicative of clayey sand and lateritic clayey sand having a resistivity values ranging from 223 to 848 Ohm-m across the profile. The depth above 20 m to the subsurface signifies lateritic clayey sand with resistivity in the range of 718 to 848 Ohm-m across the profile in Figure (7a) at VES 2.

CONCLUSION AND RECOMMENDATIONS

The potential of groundwater at Muleruwa area was approached by establishing both 2-D Wenner array and 1- D Schlumbeger technique. The analysis of the data in 2D and 1D revealed that the water-bearing formation exist below the third and fourth layers with thickness ranging from 40.0m – 110.5m.The 2-D revealed lateral variations with depth though sand could not be delineated while 1D only shows vertical depth at which ground water could be tapped .

Further Geophysical techniques should be employed like induced polarization and Electromagnetic method to determine the level of pollution of the groundwater in the study area.It is also recommended that Physicochemical Techniques should also be employed to determine the Total Dissolved Solids (TDS), heavy metals and organic compounds present in the boreholes in the study area

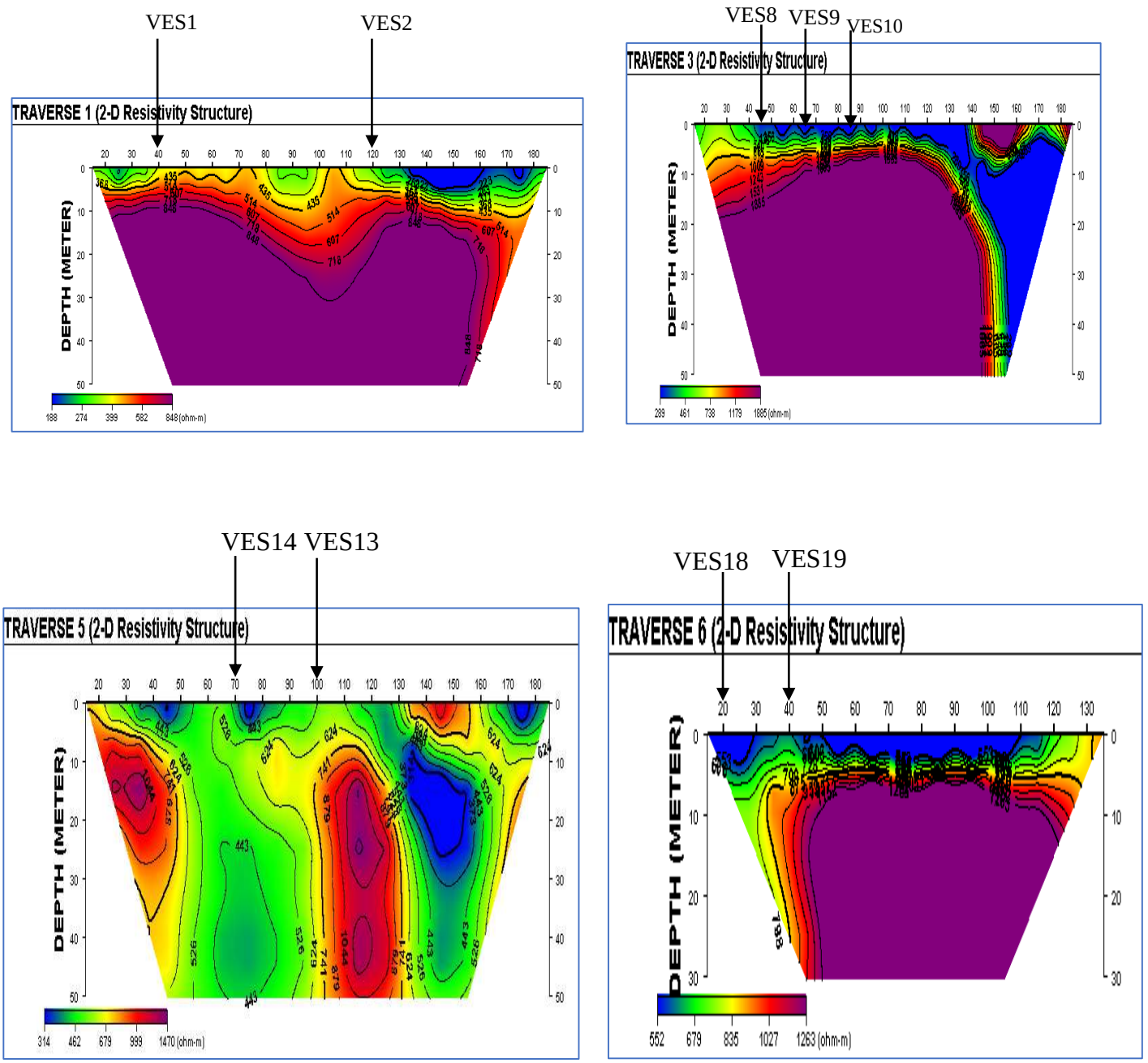

Figure 7 (a-d) ; 2D Geoelectric structure of the study area.

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THE ASSESSMENT OF THE PHYSICO-CHEMICAL PARAMETERS AND HEAVY METAL CONTENT OF TOTO-OWU RIVER OGUN STATE NIGERIA

*** Kuteyi T. R., Akinsanya A. N., Ganiyu M., and Ado P. H.**

**Department of Chemical Sciences Yaba College of Technology PMB 2011, Lagos, Nigeria.*

*Corresponding Author: temitayo.kuteyi@yabatech.edu.ng. Phone: +234-08023267743

ABSTRACT

Toto-owu River in Ado-Odo LCDA of Ogun state, South West, Nigeria has in recent times become the "unchartered smugglers' route" for vehicles and other banned items. The attendant likely pollution of the water body was investigated by determining the physico-chemical parameters and heavy metals load. Samples were collected from three sections of the river: the smuggling route, 100 m up-field and 100m down-field and analysed for twelve physico-chemical parameters and heavy metals using standard methods. The results show that the temperature, conductivity and pH of the water have mean values of 26.03^{o}C, 123.33 µS/cm and 6.34 respectively. The result also revealed a total dissolved solid of mean value of 533.33 mg/l while total suspended solid has a mean value of 233.33 mg/l. The mean total hardness of the samples was 57.50 mg/l while that of biological oxygen demand, chemical oxygen demand were 3.95 mg/l and 7.88mg/l respectively. Nitrate and chloride were present in the samples at mean values of 0.32 mg/l and 55.54 mg/l respectively. The sulphate content of the samples was below detectable limit. The mean concentration of zinc, nickel, cadmium, lead and chromium were 0.708 mg/l, 0.005 mg/l, 0.011 mg/l, 0.381 mg/l and 0.065 mg/l respectively. The result showed that most of the parameters were within the maximum permissible limit of W.H.O except for total suspended solid, biological oxygen demand, cadmium, lead and chromium.

KEYWORDS: Toto-owu River, Pollution, Smuggling, Heavy metals.

INTRODUCTION

Water is the principal need of life on planet earth and is an essential component of all forms of lives ranging from plants to animal. The entire fabric of man is woven around it. Sources of water available to mankind are; atmospheric water (precipitate), surface water (including rivers, streams, ponds etc) and ground water (including well water).

The accumulation of water that is characterised by unidirectional current with a relatively high average velocity gives rise to the water body known as river. Rivers are among the oldest water bodies in the world (Higler, 2012). Rivers have important multi-usage components such as; source of drinking water, irrigation, fishing, and energy production (Iscen *et al.*, 2008). In most urban-rural communities in the developing countries (especially the sub Saharan Africa), surface water such as rivers have been the most available source of water for domestic purposes (Dimowo, 2013). Rivers that are situated in rural areas are in addition used for washing/laundry, refuse disposal, car/motorbike washing, municipal and human waste disposal and sometimes for religious activities. Despite the multi-usage nature of rivers, expanding human population, urbanization, industrialization and discharges of wastes into them have resulted in the deterioration of their water quality (which is the chemical, physical, biological and radiological characteristics of water). The impacts of these anthropogenic activities have been so extensive that the water bodies (e.g. rivers) have lost their self-purification capacity to a large extent (Sood *et al.*, 2012) and has resulted in a kind of crises situation that has made getting clean water a serious problem (Anjum *et al.*, 2013).

Water pollution is the contamination of water bodies such as lakes, rivers, oceans, aquifers and ground water. It is a global problem which requires ongoing evaluation and revision of water resource policies at all levels (Okonko, 2008). This form of environmental degradation occurs when pollutants from various sources are directly or indirectly discharged into water bodies without adequate treatment to remove the harmful compounds. Rivers are usually polluted by pollutants such as industrial effluents, domestic wastes, oil spillage etc. When these pollutants of various types find their way into these rivers, they change the physical, chemical, and biological properties of such river (Asubiojo, 2016). It is a known fact that when pure water is polluted, its normal functioning and properties are affected (Anjum *et al.*, 2013). Adefemi & Awokunmi (2010) reported that faucal pollution of drinking water causes water borne diseases which have led to the death of millions of people.

Recently, great concern has been universally voiced regarding environmental pollution and degradation which is arising as a side effect of rapid industrialization and urbanization (Jaspal *et al.*, 2012). Today, the main concern of bodies such as the World Health Organisation (WHO), Third World Academy of Science (TWAS) and the United Nation Educational, Scientific and Cultural Organisation (UNESCO) with water pollution is with its impact or effect on the health of the present generation and the future ones. Their concern is based on the fact that water pollution affects water quality which is a critical factor that affects human health and welfare. The quality of any water is a measure of the condition of the water relative to the requirements of one or more biotic species and to any human needs. Majority of world's population does not have access to safe drinking water. This is certainly true in most part of Africa and Asia (TWAS, 2002). In the same year, WHO (2002) reported that over 2.6 billion people were still suffering from the effect of poor water around the world. In addition, the World Health Organization estimates that 3.4 million people, mostly children, die every year from water-related disease (WHO, 2004). Most people in the world do not have access to safe drinking water and this has led to increase in water borne diseases such as diarrhoea, cholera, tuberculosis etc. Globally, 4 billion cases of diarrhoea are reported every year causing 1.8 million deaths, out of which 90% are children under age 5 (UNESCO, 2007). Estimate of annual total mortality from diarrheal diseases range from 2.5 - 3.5 million and more than 80% are among children under 5 years (Kosek *et al.*, 2003). The quality of any water body is governed by its physico-chemical and heavy metal factors. Therefore, the monitoring of the physico-chemical characteristics of rivers is vital for both long term and short evaluation of its quality. It is generally accepted that water bodies with good water quality produce healthier humans than one with poor water quality. Lack of access to safe drinking water is strongly correlated with poverty and the provision of safe drinking water is considered to be a fundamental step in a community's transition out of poverty (Sachs *et al.*, 2005).

In Nigeria, availability of quality water has become a significant and imperative challenge posing a great concern to families, communities and the government (Okonko *et al.*, 2008). For this reason, several studies and reports have been directed towards the assessment of the quality of rivers in the country.

The monitoring of the physico-chemical parameters of Ogun river within two locations (Akin Olugbade and Lafenwa) in Ogun State, Nigeria by Osunkiyesi, (2012) revealed that parameters such as alkalinity, pH, chloride, and magnesium were in the normal permissible range set by WHO (2003), SON (2003) while heavy metals such as chromium, lead, zinc, cadmium were below detection limit. Parameters such as nitrate, TDS, TSS, iron, potassium were found to be out of the permissible level of WHO (2003), SON (2003). The water samples collected were organoleptically observed to be brown in

colour. This was attributed to the high level of particle suspension in the river.

The high nitrate level of the river was attributed to the wastes that are being added to the river as these wastes are used by bacteria for metabolism which give out nitrite as by-product.

Dimowo (2013) studied the physico-chemical parameters of River Ogun, Abeokuta, Ogun state, Nigeria in comparison to national and international standards. Water samples were collected on monthly basis from 4 different sampling locations along the river course between the December 2011-June, 2012. A majority of water samples collected exceeded the maximum permissible limit set by SON, FEPA, USEPA, EU, WHO, NSDW for hydrogen ion concentration, total hardness and nitrate content. The dissolved oxygen level was very low during the first four months. This was attributed to the amount of effluents discharge into the river. Parameters such as the total dissolved solids and alkalinity were within the permissible limit of all the standards aforementioned while temperature which was reported to range between 26.9-32.0 ° C exceeded the maximum permissible limits of FEPA but was within the permissible limit of WHO. This is similar to the result reported by Fafioye *et al.*, (2005) in which the water temperature of Omi River, at Ago- Iwoye, Ogun State was reported to range between 26.5- 31.5˚c. The pH of the river was reported to be between 7.7± 0.15 in March, 2012 and 9.1±0.13 in December, 2011. This value also exceeded the maximum permissible limit of all the standards excluding NSDW. This value shows that the river contains soft water. Generally, the water was reported to be unfit for domestic uses, drinking, and aquaculture purposes because most of the parameters were above the maximum permissible limits of both national and international standards.

Ogun river of South-west Nigeria has been studied extensively for water quality parameters. Jaji *et al.*, (2007) studied the physico-chemical parameters of Ogun River during the rainy and dry season. He reported that deterioration in river water quality could be attributed to urban run-off, discharge of untreated sewage, industrial effluents and runoffs from agricultural field. In his study, the most important factor determining water quality of Ogun River was found to be rainfall which was responsible for the high variation in water quality parameters during rainy season and dry periods of the year. The aim of this present research is to determine the Physico-chemical parameters and heavy metals content of Toto-owu river with a view to ascertain its level of pollution.

MATERIALS AND METHODS

Study Area and Sampling Stations

Water samples were collected from Toto-owu River in Ado-Odo LCDA of Ogun state, South West, Nigeria. Ado-Odo LCDA has an estimated population of 528,242 people (Male 262,523 & Female 265,719) (2006 Census) with about four hundred and fifty (450) towns, villages and settlements (Olukayode *et al.*, 2012). Totowu River is geographically located between latitude 6°33'0.04"N and longitude 3°11'44.7"E. It links Ogun state to Igando-Isuti area of Lagos state. The river is about 350m long and takes its source from Ogun River. It is a known site for smuggling activities. It was described by the Nation newspaper of June 29, 2004 as the "unchartered smugglers' route". Three sampling stations were chosen for the study; station A is about 100m up-field from the bank of the river at the Lagos axis while station B is about 150m from station A (i.e. the middle of the river). Station C is also about 100m down-field from the Ogun state axis of the river.

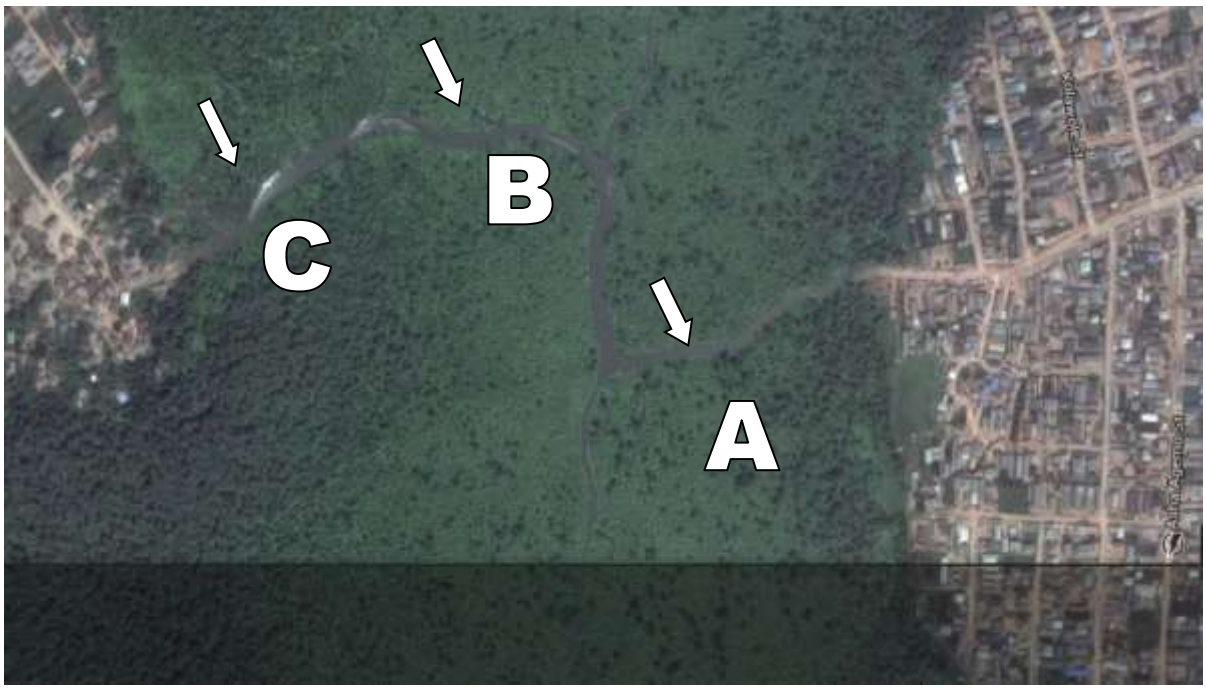

Fig1: Satellite Map showing Toto-owu River and sampling stations A, B and C in Ado-Odo LCDA, Ogun State, Nigeria.

Sampling Methods and Analytical Procedures

Water sampling was carried out in the early mornings and late evenings between 22nd and 26th of October, 2015. Ten water samples composite were collected from each station close to the right and left banks and in the middle of the river. Water samples were collected in 1.5 L Polyethylene bottles previously washed with 10% nitric acid and subsequently demineralised with water. The containers were pre-rinsed three times with the sample water before final collection according (APHA, 2003). Samples were transported to the laboratory in the Chemical Sciences Department of Yaba College of Technology and processed within 6 h of collection. Temperature, dissolved oxygen (DO), conductivity, and pH were measured insitu as field parameters by Hannar meter (model .

1945), while BOD5, COD, TSS, SO4, NO3, total hardness (TH) were analyzed in the laboratory. BOD5 was analyzed as described by 5-day test, and COD was assayed by means of the open reflux method (APHA, 2003). Additionally, total suspended solids (TSS) was determined by total solids dried at 103–105 °C. Moreover, sulfate and nitrate, were assayed by Acid Ascorbic, Sulfa Ver 4, and Nessler methods, respectively (APHA, 2003). Furthermore, total hardness was determined by titremetry with EDTA. The equipments were calibrated prior to use based on the manufacturer's directions.

Statistical analysis of data was fulfilled using SPSS version 20. Analysis of variance (ANOVA) was carried out to determine the significant differences between sampling stations

RESULTS AND DISCUSSION

Physico-chemical and heavy metal composition of the samples

The tables below show the physico-chemical and heavy metal composition of the three water samples collected from Toto-owu River.

Table *1.* Physicochemical parameters of the water samples.

Parameter	Sample A	Sample B	Sample C	Mean ± SD Values	WHO Standard
Colour	Brown	Brown	Brown		-
Temperature (˚C)	28.58	23.00	26.50	26.03 ± 2.30	30
pH	6.54	6.16	6.31	6.34± 0.16	6.5-8.5
Conductivity(µS/cm	140.00	130.00	100.00	123.33±17.00	8-10000
TDS(mg/l)	800.00	500.00	300.00	533.33±205.48	1,000
TSS (mg/l)	400.00	200.00	100.00	233.33±124.72	150
Total hardness(mg/l)	85.00	45.00	42.50	57.50± 19.47	500
BOD (mg/l)	4.21	3.51	4.14	3.95± 0.32	3
COD (mg/l)	9.02	6.49	8.18	7.88± 1.05	10
Sulphate (mg/l)	ND	ND	ND	ND	400
Nitrate (mg/l)	0.39	0.25	0.33	0.32± 0.06	5
Chloride(mg/l)	49.63	60.27	56.72	55.54± 4.42	250

Key:
SD: *Standard deviation.*
WHO: *World Health Organization;*
TDS: *Total Dissolved Solids*
BOD: *Biochemical Oxygen Demand;*
COD: *Chemical Oxygen Demand*
TSS: *Total Suspended Solids*

Table 2. Heavy metal composition of the water Samples

Heavy metal	Sample A	Sample B	Sample C	Mean ±SD Value	WHO Standard
Zinc (mg/l)	0.141	0.050	0.134	0.108± 0.040	5.000
Cadmium (mg/l)	0.021	0.000	0.012	0.011± 0.006	0.005
Lead (mg/l)	0.621	-0.089	0.610	0.381± 0.570	0.050
Chromium (mg/l	0.105	-0.005	0.094	0.065± 0.050	0.050
Nickel (mg/l)	0.012	-0.005	0.009	0.005± 0.007	---

DISCUSSION

The result obtained from the physico-chemical analysis shows the colour of all the water samples to be brown. The brownish colour of the water samples can be attributed to the presence of particle suspensions in the river. The temperature of the water samples has a mean value of 26.03 ºC. This value is below the maximum permissible limit of WHO (2006), with sample A having the highest value. This result is similar to that reported for Omi

water body in Ago-Iwoye, Ogun State by Fafioye *et al.*, (2005). The mean pH value of the water samples is 6.34 which indicate that the water is weakly acidic.

The result also show TDS, TSS to be present in water samples at mean values of 533.33 mg/l and 233.33 mg/l respectively. The TDS value is within the permissible limit of WHO but TSS is above the maximum permissible limit of WHO. The high TSS can be attributed to the dumping of municipal wastes into the river and urban run-off (Jaji *et al.*, 2007). This level of TSS is capable of causing laxative or constipation in human (Adhena *et al.*, 2015). Water hardness has a mean value of 57.50 mg/l, which is below the 500 mg/l maximum limit of WHO (2006). Based on the classification of water hardness by UNICEF (2008) & Kumar *et al.*, (2010), the water sample can be said to be soft.

The result also shows BOD and COD to have mean values of 3.95 mg/l and 7.88 mg/l respectively. The COD value is within the limit of WHO but BOD value exceeded the limit of WHO. This can be related to the reduce volume of water during the dry season and the presence of hydrophytes on the river. The sulphate content of the water samples is below detectable limit while nitrate and chloride content have mean values of 0.32 mg/l and 55.54 mg/l respectively. These values are within the standards of WHO.

The heavy metals analysis show that zinc is present in the water samples at mean value of 0.108 mg/l while nickel has mean value of 0.005 mg/l. Pb, Cr, Cd were all found to be slightly above the recommended standards of WHO with mean values of 0.381 mg/l, 0.065 mg/l and 0.011 mg/l respectively. The high level of Pb can be attributed to the corrosion of plumbing materials that pass through the river (Nor, 2007) while the Cd level can be related to the corrosion of Zn-coated galvanised pipes and machineries (such as cars, motorbikes) that are smuggled through the river. This level of Cd and Pb is capable of causing kidney diseases and delay in the physical or mental development of infants respectively.

CONCLUSION

This work presented the level of some physico-chemical parameters of Toto-owu River.

The result obtained showed that most of the parameters determined did not exceed the permissible limit of WHO except for parameters such as BOD, TSS, Cd, Cr, & Pb. Moreover, statistically significant differences were not found among sampling stations (ANOVA P>0.05,).

Due to the serious health implications of Cr, Cd and Pb it can be concluded that the water is unfit for human consumption and aqua cultural purposes.

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RE-ASSESSMENT OF THE EFFECTS OF LEACHATES ON THE PHYSICO-CHEMICAL PARAMETERS OF GROUND WATER AROUND OLUSOSUN AND SOLOUS DUMP-SITES IN LAGOS, NIGERIA.

*** Kuteyi, T. R., Akinfenwa F., Ogbe D.A. and Jesse A. W.**

[1]Department of Chemical Sciences, Yaba College of Technology PMB 2011, Lagos, Nigeria.
Corresponding Author: temitayo.kuteyi@yabatech.edu.ng, +234-08023267743

ABSTRACT

Leachate is any contaminated liquid that is generated from water percolating through a solid waste disposal site, accumulating contaminants, and moving into subsurface areas. Physico-chemical parameters and heavy metals concentration of leachate and groundwater from three bore holes located near landfills at Igando and Olusosun dumpsites in Lagos were re-assessed to ascertain the level of contamination on the groundwater quality. The bore holes location were at radial distances of 50m, 80m and 100m respectively away from the two landfill sites. The parameters determined are pH, Total Dissolved Solid (TDS), Total Hardness (TH), Sulphates (SO_4^{2-}), Nitrates (NO_3^-), Chlorides (Cl^-) and heavy metals, include Pb, Ni, Cd and Cr. Most of these parameters indicate traceable contamination but some were below the World Health Organization and the Nigeria Standard for drinking water quality (NSDWQ) limits for consumption. The concentration of Pb and Cd were found to be in considerable high levels in the groundwater samples particularly near the landfill site and absent in the control, likely indicating that groundwater quality are being significantly affected by leachate percolation. All parameters and heavy metals content were measured based on standard methods. It was found that the groundwaters were contaminated due to leachate from the landfills to a large extent and are not suitable for drinking, domestic and irrigation purposes unless treated. The extent of contamination decreased as the distances to the landfill increased.

KEYWORD*:* Leachate, Landfill, Groundwater, Heavy metals.

INTRODUCTION

Industrialization and urbanization have contributed greatly to groundwater pollution over the years without any regards to environmental consequences (Longe and Balogun, 2010). Access to safe clean water and adequate sanitation is a fundamental right and a condition for basic health (EPA, 2007). There has been an increasing concern about the environment in which man lives. Solid waste, mount of rubbish, garbage and sewage are being produced everyday by our urban society. In an attempt to dispose of these materials, man has carelessly polluted the environment. Some components of these waste including food, paper, metals, zinc and lead polythene bags, containing materials etc consume oxygen thereby changing the redox potential of the liquid present (Ugwu and Nwosu, 2009).

The solid waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation or any other possibility of infiltration of water. During rainfall, the dumped solid waste receives water and the by-products of its decomposition move into the water through the waste deposition. The liquid containing innumerable organic and inorganic compounds are called leachate. This leachate accumulates at the bottom of the landfill and percolates through the solid and reaches the ground water (Mor *et al*, 2006). Leachate varies widely in composition depending on many interacting factors such as composition and depth of waste, availability of moisture and oxygen, landfill design, operation and age. The composition is primarily a function of the age of the landfill and the degree of waste stabilization. The stabilization of waste

is suggested to proceed in five sequential or distinct phases (Al-Hashimi and Hussain, 2013) and the rate of progress through these stages is dependent on the physical (availability of free oxygen), chemical and microbiological conditions developed with the landfill and time (Al-Hashimi and Hussain, 2013).

Area near landfills and municipal disposal sites have a greater possibility of groundwater pollution because of the potential pollution source of leachate that originate from the decomposition of the organic wastes disposed at these site and finally percolate into local aquifer. Such contamination of the groundwater resources has a substantial risk to the natural environment and to the health of local residents who use the water resource for drinking and other domestic purposes (Thammani and Singh, 2009; Butt & Igbal, 2007). Several studies have been conducted in order to examine the health and environmental effects arising from waste dumps. Such studies showed that a link exist between the two (Nwanta and Ezenduka, 2010; Nguyen, 2011).

Leachate formation and concentration is a function of the type of waste, season, climate, time and management strategies (Afolayan *et al*., 2012). The concentration of a pollutant at any point removed (away) from its source vary throughout the year due to seasonal influences on recharge and release of the contamination. (Afolaya *et al*., 2012) therefore, continuous re-evaluation of the physico-chemical parameter of the leachates and the level of contamination of ground water sources are needful.

In the present study, the impact of leachate migration on groundwater quality was estimated from Igando solous and Olusosun landfill sites, Lagos, Nigeria. Various physico-chemical parameters and heavy metals were analyzed in leachate and groundwater samples to understand the possible link of ground water contamination.

MATERIALS AND METHODS

Study Area

The Olusosun dumpsite is a 42 hectares dumpsite in Ojota Lagos, Nigeria on latitude $6^0 20^0$ N and Longitude 3^0 20^d E. The site receives up to 10,000 tons of rubbish each day (LAWMA, 2011). Olusosun landfill is located on the outskirts of Lagos but is surrounded by commercial and residential areas. Around 1,000 homes exist at the site in shanty towns, occupied by residents who work at the dump.

The Solous landfill is situated at Igando in Alimosho Local Govt. Area of Lagos state Nigeria. It lies approximately between longitude $3^0$13'30"E to 3^0 17^0 15"E and latitude 6^0 28^0N to 6' 42^0N. As a result of urbanization, the landfill is now surrounded by residential, commercial and industrial activities (LAWMA, 2011).

The studies were carried out on the landfills at Igando and Olusosun dumpsite located between latitude 6'28 ^{0}N to 6' 42 ^{0}N and longitude and respectively. Three existing boreholes with average depth of 60 metres located within the distance 50 m, 80 m and 100 m radically away from the centre of the two landfill were used as sampling points for groundwater quality testing for each borehole, a control sample was taken from a bore hole about 200 m away from the landfills. 5 litres of the groundwater samples were collected into plastic container. The containers were cleaned using 1 mol/L of nitric acid. They were then left to dry for 2 days followed by thorough rinsing with distilled water before use. Since the landfills are not equipped with a leachate collection system, the leachate accumulating at the base of the landfill were sampled randomly from four different locations within the landfills and were mixed prior to analysis.

The leachate and groundwater samples were immediately transferred to the department of Chemical Science Laboratory, Yaba College of Technology and were stored in the refrigerator at 4 ^{o}C. The analyses were carried out using the standard procedure prescribed

by the American Public health Association APHA (APHA, 1994).

All the samples were analysed for some selected relevant physico-chemical parameters and heavy metals. The physico-chemical parameters examined in the leachate and groundwater samples include total dissolved solid (TDS), Total hardness (TH), Chloride and sulphate. Estimation of COD for leachate was done by reflux titrimetry, while BOD was calculated using oxygen determination by Winkler titration. Sulphate was determined using UV/Vis spectrophotometer. Concentration of cadmium (Cd), Lead (Pb), Chromium (Cr) and Zinc (Zn) were determined using atomic absorption spectrometer (AAS). The results obtained for the two landfills dumpsite are presented in Tables 1 and 2 respectively.

RESULTS AND DISCUSSION

The result of physiochemical and heavy metals analyses of the leachate and the neighourhood groundwater of Solous and Olusosun Landfills are presented in Tables 1 and 2 respectively. The pH values obtained at the two sites studied were in agreement with WHO standard showing that the samples were slightly alkaline. These results are in conformity with the work of Bozkurt and Kurtulus,(2008).

The electrical conductivity (EC) is an indication of the amount of ionic materials dissolved in the water. It was discovered that the EC are within the acceptable limits of NSDWQ standard at the sites with the exception of GW1 and GW2 which are slightly higher. Total dissolved solids are higher than the acceptable limit for potable water at the two sites. The highest values were obtained at GW1 of both sites; these may be due to their location close to the dumpsite yard. The groundwater pollution from garbage in the vicinity of the dump site is detectable through increased TDS concentration of the water. The BOD and COD indicate the organic content in the leachate and the groundwater. The BOD values at Solous dump site are lower than standard values while that of Olusosun dump site are higher: an indication that the groundwater is polluted by the landfill leachate. The results show that the groundwater is more polluted with more of non-biodegradable chemical pollutant. This is in agreement with the report of Raju, (2012). These shows that there is higher contamination of the groundwater by the leachate, similar results have been reported by Longe and Balogun, (2009). The Nitrate values of the samples were found to be above the stipulated limit of 50 mgl^{-1} by WHO and NSDWQ except at GW3 of both sites. Nitrate is the end product of the aerobic decomposition of organic nitrogenous matter. This result is also supported with the literature of John, (2014). The concentrations of the sulphate were within the recommended values of 400$mgl^{-1.}$ Thus it will not adversely affect the use of these groundwater for domestic purposes.

The results of heavy metals analysis shows that most of these metals were detected and indicate the presence of toxic waste perhaps from disposal of battery cells, used aerosol can and other materials with certain degree of toxicity. These agreed with the report of other authors (Dissanayake *et al*, 2010; Akinbile and Alatise, 2011).

CONCLUSION

The effect of the concentration of pH, EC, TDS and heavy metals tested in groundwater near the studied landfills deteriorate the quality of drinking and other domestic purposes of the water. The extent of deterioration decreased with increase in the distance from the landfills. The observed elevation of Pb, Cd, Cr and Ni in leachate and the presence of some conventional contaminants above WHO and NSDWQ permissible limits in the groundwater sampled and absence in the control is an indication that the uncontrolled accumulating of leachates over time at the landfill base will represent a significant threat to the groundwater quality.

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TABLE 1: Physico-chemical composition of Solous Landfill Leachate.

Parameter	NSDWQ	WHO	Leachate	GW_1 (50m)	GW_2 (80m)	GW_3 (100m)	Control
pH	6.5 – 8.5	6.5– 8.5	8.97	7.92	8.10	7.58	7.20
TDSmgl^{-1}	500	500	750	630	520	580	210
Temp ^0C	25-28	25-28	29.3	26.6	26.4	26.5	26.4
TH mgl^{-1}	500	500	2275	180.3	151.6	130	100
Cl^- mgl^{-1}	250	250	480	220	209	163	75
EC us/cm		300	580	410	320	225	150
SO_4^{2-} mgl^{-1}	400	400	415	380	330	310	100
NO_3^- mgl^{-1}	50	50	255.1	84.8	54	42	10
BOD mgl^{-1}	100	100	360.0	75	34	32	10
COD mgl^{-1}	250	250	700.0	133	65	62	20
Fe mgl^{-1}	0.2	0.1	6.5	0.2	0.1	0.1	ND
Pb mgl^{-1}	0.01	0.01	5.10	0.09	0.08	0.09	ND
Ni mgl^{-1}	0.1	0.1	0.012	0.012	0.008	0.007	ND
Cd mgl^{-1}	0.05	0.01	3.33	0.07	0.06	0.03	ND
Cr mgl^{-1}	0.05	0.05	0.05	0.05	ND	ND	ND

KEY:
BOD: Biochemical oxygen demand **COD:** Chemical Oxygen Demand
TH: Total Hardness **EC:** Electrical conductivity
TDS: Total Dissolved Solid **NSDWQ:** Nigerian Standard for Drinking Water Quality

TABLE 2: Physico-chemical composition of Olusosun Landfill Leachate

Parameter	NSDWQ	WHO	Leachate	GW_1 (50m)	GW_2 (80m)	GW_3 (100m)	Control
pH	6.5 – 8.5	6.5– 8.5	7.89	7.46	7.79	7.93	7.55
TDS mgl^{-1}	500	500	990	550	680	510	110
Temp ^0C	25-28	25-28	28.5	26.2	26.0	25.I	26.0
TH mgl^{-1}	500	500	2538	160	120	110	50
Cl^- mgl^{-1}	250	250	410	119	103	95.5	50
EC us/cm		300	480	320	311	250	100
SO_4^{2-} mgl^{-1}	400	400	843	305	282	260	70
NO_3^- mgl^{-1}	50	50	98	72	60	38	10
BOD mgl^{-1}	100	100	220.2	216.0	117.1	111.3	10
COD mgl^{-1}	250	250	279.3	234.0	133.2	125.5	20
Fe mgl^{-1}	0.2	0.1	5.5	0.2	0.1	0.1	0.1
Pb mgl^{-1}	0.01	0.01	6.01	0.027	0.19	0.05	0.01
Ni mgl^{-1}	0.2	0.1	0.5	ND	ND	ND	ND
Cd mgl^{-1}	0.05	0.01	1.15	0.130	0.105	0.11	0.01
Cr mgl^{-1}	0.05	0.05	0.5	ND	ND	ND	ND

KEY:
BOD: Biochemical oxygen demand **COD:** Chemical Oxygen Demand
TH: Total Hardness **EC:** Electrical conductivity
TDS: Total Dissolved Solid **NSDWQ:** Nigerian Standard for Drinking Water Quality

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EVALUATION OF MODELS FOR GLOBAL SOLAR RADIATION PREDICTION IN THE SIX GEOGRAPHICAL ZONES OF NIGERIA

Oba, M. O. and Akande, M. O.

Department of Physical Science, Yaba College of Technology, Yaba, Lagos

Corresponding Author: obamichael300@gmail.com, +234-08034228420

ABSTRACT

Estimation of solar radiation is considered as the most important parameter for the design and development of various solar energy systems. However, the availability of the required data is very scarce and often not readily accessible. The limited availability of solar radiation data makes it vital to develop models to estimate these data. This study assessed the performance of different solar radiation models namely: Angstrom-Prescott, Badescu, Pandey and Katiyar, Okundamiya and Nzeako, Fagbenle's and lastly Glover-McCulloch's model. The aim of this study was to determine the most accurate model, for evaluating models to predict global solar radiation in the six geographical zones of Nigeria. The data used in the analysis consist of monthly global solar radiation, sunshine hours, relative humidity and temperature collected from the Nigerian Meteorological Agency (NIMET) over a period of five years (2014-2018). The performances of the models were compared on the basis of statistical error tests, namely: mean percentage error (MPE), root mean square error (RMSE), mean bias error (MBE), and regression coefficient (R). Regression constants are determined for each of the model for each month of the year. This study reveals that the Okundamiya-Nzeako model gives the best estimation of the global solar radiation in North East, South South, North West, North Central and South West zones since it has the least value of RMSE and MPE. The values of RMSE and MPE for Bauchi, Delta, Kano, Kwara and Lagos states are: (0.704, -0.129); (0.722, -0.139); (0.923, -0.262); (0.629, -0.110) and (0.755, -0.148) respectively.

KEYWORDS: Solar radiation, sunshine hours, relative humidity, temperature

INTRODUCTION

Solar radiation is the most abundant and evenly distributed energy resource on earth. The amount of energy released by the sun (captured by earth) during one hour may be sufficient to cover the world's energy needs for one year. Part of this radiation can be used directly to produce heat (solar thermal) or electricity called photovoltaic solar energy. This mode of production does not require network distribution, because it can generate electricity and can be consumed in places such as villages, detached houses (one third of the world's population lacks access to electricity), water pumping, and refuges (Gronewold, 2009). The sun discharges continuously an enormous amount of energy radiant in the solar system. Earth intercepts a small portion of this energy radiated into space. An average of 1367 watts per square meter reaches the edge outside of the terrestrial atmosphere (for an average distance Earth sun 150 million kilometers), this quantity is called the solar constant. The energy received by Earth's surface depends on the thickness of the atmospheric crossing, which is the function of air mass (Abedelak *et al.,* 2013).

The usage of renewable energy resources has risen largely in the last years owing to the ever increasing need for electrical energy, the limited fossil fuel resources needed for generation of conventional electrical power, and the global environmental concerns over the use of fossil fuels. (Gielen and Gorini, 2019). Solar energy is one of the most

promising renewable sources. It is environmentally friendly, plentiful and easy to utilize. A detailed and accurate knowledge of the local solar radiation is essential for the optimum design and study of solar energy conversion system. The global solar radiation can be divided into two components: diffuse solar radiation, which results from scattering caused by gases in the Earth's atmosphere, dispersed water droplets and particulates; and direct solar radiation, which have not been scattered. Global solar radiation is the algebraic sum of the two components used measurements of global and diffuses solar radiations (Oliveira *et al.*, 2002).

The use of solar energy, like any other natural resources, requires detailed information on availability of the amount of total solar radiation striking the earth surface. This total amount of solar radiation incidents on the earth surface is called global solar radiation. Global solar radiation data are necessary at various steps of the design, engineering, simulation and performance evaluation of any project involving solar energy. Solar radiation provides the energy for photosynthesis and transpiration of crops and is one of the meteorological factors determining potential yields. Crop growth models, which have been developed since the 1960s, have been regarded as important tools of interdisciplinary research and have since been used in a number of areas such as the assessment of agriculture potential of a given region in the field of crop yield forecasting or as a climate change impact assessment tool. (Falayi *et al.*, 2019). Actually, the mapping of the solar radiant energy on the Earth's surface is a requirement not only in the studies of climate change, environmental pollution but also in agriculture, hydrology, food industry and non-conventional energy development programs (Iqbal 1983).

In developing countries namely Ghana, India, Nigeria etc, the facility for global radiation measurement is available at a few places while bright sunshine hours are measured at many locations. Some cannot even afford the equipment's and techniques involved. For such countries it is essential that correlations be developed so as to predict global solar radiation from readily measured data (Augustine *et al.*, 2010).

The best way of knowing the amount of global solar radiation at a site is to install pyranometer at different locations in the given region and look after their day-to-day maintenance and recording but this method is very expensive. An alternative approach is to correlate the global solar radiation with the meteorological parameters at the place where the data is collected. The resultant correlation may then be used for locations of similar meteorological and geographical characteristics at which solar data are not available.

This work, apart from predicting the best model for global solar radiation especially, for regions that encounter difficulties in harnessing solar radiation data due to lack of good equipment's, it will help the energy strategists and planners to utilize the solar potentials to solve the energy crises of this area of abundant sunshine.

The best way of knowing the amount of global solar radiation at a site is to install pyranometers at different locations in the given region and look after their day-to-day maintenance and recording but this method is very expensive. An alternative approach is to correlate the global solar radiation with the meteorological parameters at the place where the data is collected. The resultant correlation may then be used for locations of similar meteorological and geographical characteristics at which solar data are not available.

The aim of this study is to identify suitable models for global solar radiation in the six geographical zones in Nigeria.

MATERIALS AND METHODS

Data Acquisition

The data for this study was acquired from Nigeria Meteorological Agency (NIMET), Abuja, Nigeria. The data obtained were from the six geographical zones in Nigeria: North East (Bauchi), South South (Delta), South East (Enugu), North West (Kano), North Central (Kwara) and South West (Lagos) for the period of five years (2014-2018)

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Fig 3.1: Nigeria map showing the six geopolitical zones

The datasets includes:

1. Solar radiation (2014-2018)
2. Temperature (2014-2018)
3. Relative humidity (2014-2018)
4. Sunshine hours. (2014-2018)

Data Processing

Working with Meteorological Data

The data obtained from NIMET, were monthly data of solar radiation, temperature, relative humidity and sunshine hours for six different stations over a period of 5 years (2014-2018).

For the various stations, the local data from NIMET was compared with the global solar radiation and an analysis was carried out using statistical method.

The linear regression model used in correlating the measured global solar radiation data (H) data with relative sunshine duration (S/S_o) was given after Angstrom (1924) and later modified by Prescott (1960):

$$\frac{H}{H_o} = \left[a + b\left(\frac{S}{S_O}\right)\right] \quad (1)$$

Where: a and b are regression constants,
H is the measured monthly mean daily global solar radiation,
H_o is the monthly mean horizontal daily total extraterrestrial solar radiation.

Extraterrestrial solar radiation is the maximum amount of solar radiation available to the earth at the top of the atmosphere. The monthly average daily extraterrestrial radiation on a horizontal surface (H_o) can be calculated for days giving average of each month:

$$H_o = \left(\frac{24}{\pi}\right) I_{SC} \left[1 + 0.033 Cos\left(\frac{360n}{365}\right)\right] \left[Cos\varphi Cos\delta SinW_s + \left(\frac{2\pi W_s}{360}\right) Sin\varphi Sin\delta\right] \quad (2)$$

Where:

I_{sc} is the solar constant (=1367 Wm^{-2}),

φ is the latitude of the site,

δ is the solar declination and

W_s is the mean sunrise hour angle for the given month and

n is the number of days of the year starting from January to December.

The solar declination δ and the mean sunrise hour angle W_s can be calculated using the following equation (Iqbal, 1983; Zekai, 2008):

$$\delta = 23.45 \sin\left[360\left(\frac{284+n}{365}\right)\right] \quad (3)$$

$$W_s = Cos^{-1}(-\tan\varphi \tan\delta) \quad (4)$$

For a given month, the maximum possible sunshine duration (monthly average day length) S_o in hours can be computed (Iqbal, 1983; Zekai, 2008) by

$$S_o = \frac{2}{15} W_s \quad (5)$$

The clearness index (K_T) is defined as the ratio of the observed/measured horizontal terrestrial solar radiation H, to the calculated horizontal extraterrestrial solar radiation H_o. The clearness index (K_T) gives the percentage deflection by the sky of the incoming global solar radiation and therefore indicates both the level of availability of solar radiation and changes in atmospheric conditions in a given locality (Falayi *et al.*, 2011).

$$K_T = \frac{H}{H_o} \quad (6)$$

In this study, H_o and S_o will be computed for each month using equations (1) and (5) respectively. The correctness among the models will be determined using the data measured between the periods of 2014-2018. After analysis, the regression constants a, b, c and d for the stations will be determined by correlating the global solar radiation with the meteorological data. (Muzathik, 2011). The accuracy of the estimated values will be tested by calculating the expression forr MBE, Mean Bias Error ($MJm^{-2}day^{-1}$) Root Mean Square Error RMSE, Root Mean Square Error ($MJm^{-2}day^{-1}$) ; and MPE, Mean Percentage Error (%) as stated by El – Sebaii and Trabea (2005) as follows:

Statistical Analysis:

$$MBE = \sum(H_{cal} - H_{meas})/n \quad (7)$$

$$RMSE = [\sum(H_{cal} - H_{meas})^2/n]^{1/2} \quad (8)$$

$$MPE = \left[\sum\left(H_{meas} - \frac{H_{cal}}{H_{meas}} \times 100\right)\right]/n \quad (9)$$

RESULTS

The regression constants a, b, c and d for the six geographical zones in Nigeria were determined by correlating the global solar radiation with the meteorological data.

The proposed models for this study are shown below:

1. **Angstrom – Prescott (1940):** $\frac{H}{H_o} = a + b\frac{S}{S_o}$
2. **Badescu (1999):** $\frac{H}{H_o} = a + bT_{max}$
3. **Pandey &Katiyar (2010):** $\frac{H}{H_o} = a + b\frac{S}{S_o} + c\,T_{max}$
4. **Okundamiya&Nzeako (2010) :** $\frac{H}{H_o} = a + b\frac{S}{S_o} + c\,T_{max} + dRH$
5. **Fagbenle (1992):** $\frac{H}{H_o} = a + b\frac{S}{S_o} + c\left(\frac{S}{S_o}\right)^2$
6. **Glover & McCulloch's (1958):** $\frac{H}{H_o} = a\cos\varphi + b\frac{S}{S_o}$

RMSE and MBE statistical indicators are commonly used in comparing the models of solar radiation predictions. Low values of RMSE are desirable (*Slavica and Blanka, 2018*), but few errors in the sum can produce a significant increase in the indicator. Low values of MBE are desirable (*Slavica and Blanka, 2018*), but overestimation of an individual data element will cancel underestimation in a separate observation. It is also possible to have large RMSE values at the same time a small MBE or vice versa. The use of RMSE and MBE statistical indicator is not adequate for the evaluation of models performance and we concluded that MPE is used in addition to RMSE and MBE to give more reliable result. MPE gives long term performance of the examined regression equations, a positive MPE values provides the averages amount of overestimation in the calculated values, while the negatives value gives underestimation. A low value of MPE is desirable. (*Slavica and Blanka, 2018*)

Measured solar radiation and the calculated solar radiation from all the five models were compared using graphical representations as presented in figure 1 to figure 5

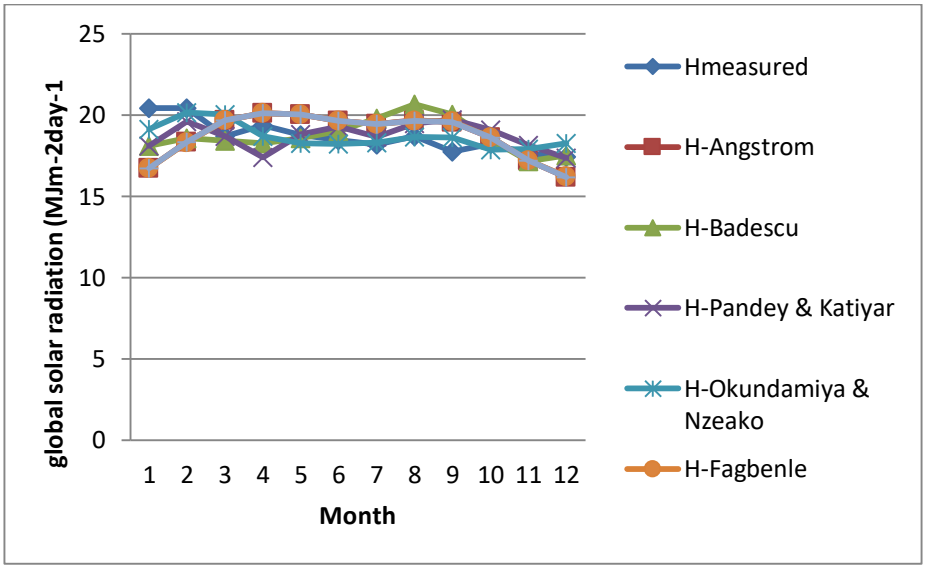

Fig 1: Comparison between the measured and calculated global solar radiation for Bauchi

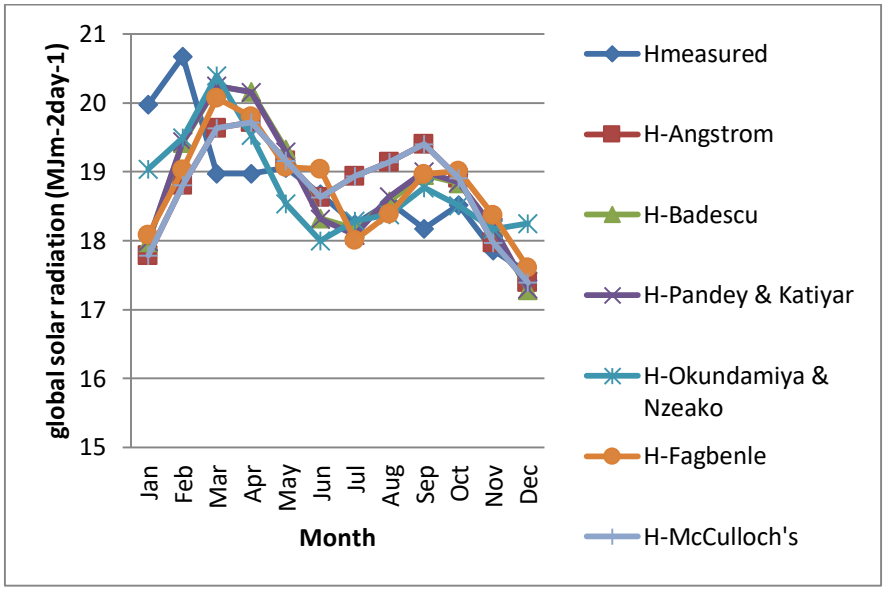

Fig 2: Comparison between the measured and calculated global solar radiation for Delta

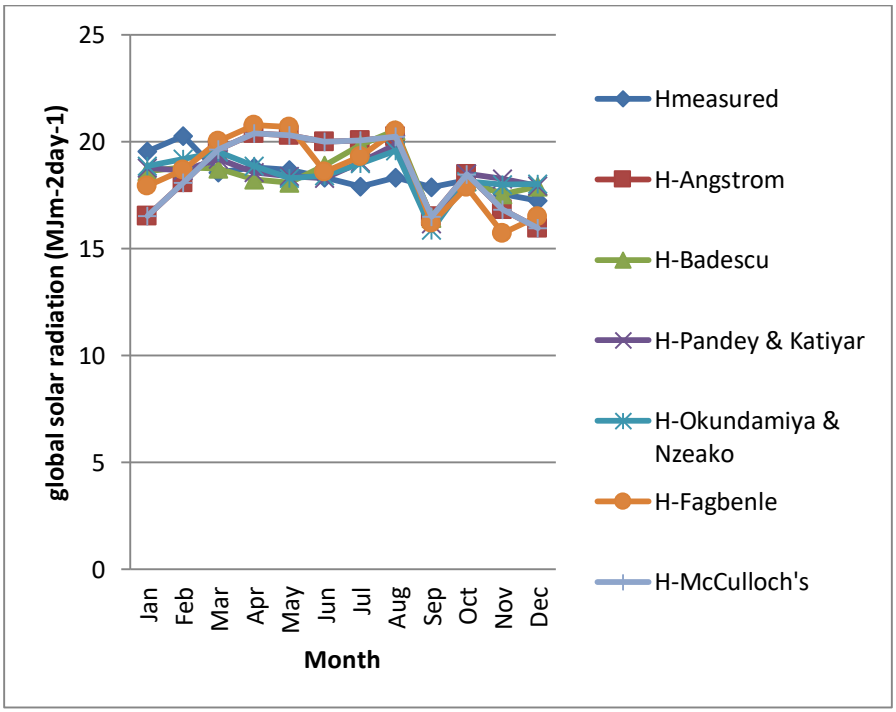

Fig 3: Comparison between the measured and calculated global solar radiation for Kano

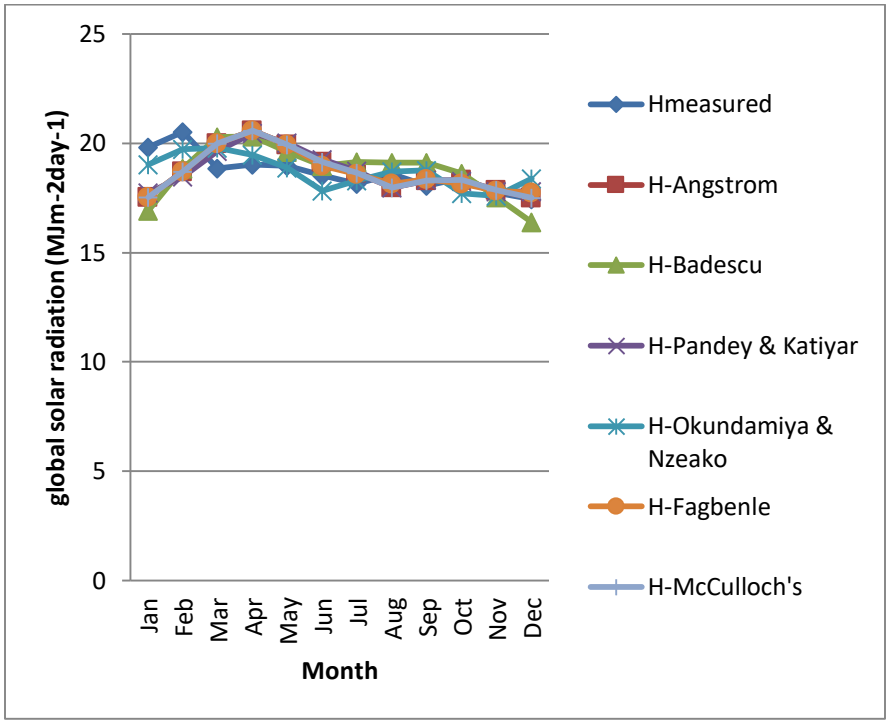

Fig 4: Comparison between the measured and calculated global solar radiation for Kwara

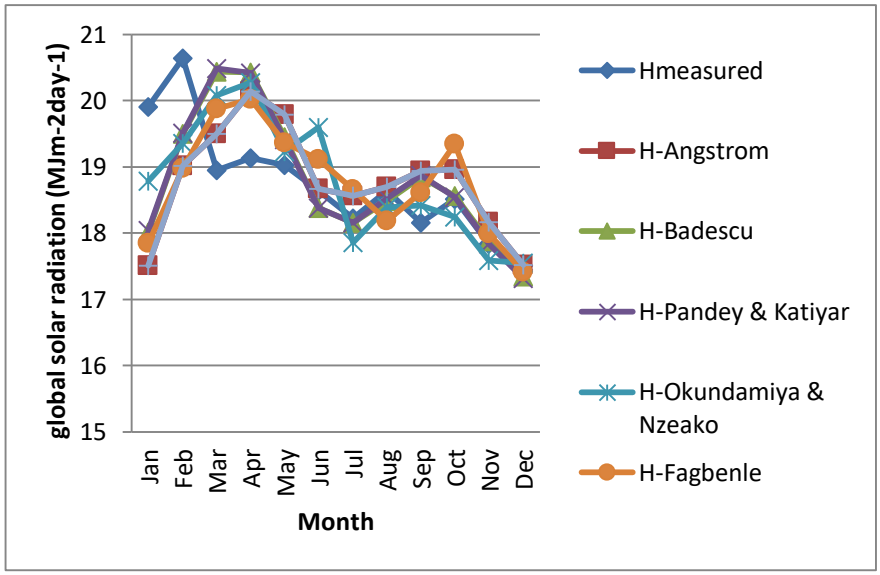

Fig 5: Comparison between the measured and calculated global solar radiation for Lagos

Table 1: Regression equation and statistical indicators for Bauchi State (2014-2018)

Model	a	B	C	d	R	R^2	MBE	RMSE	MPE
Angstrom-Prescott	0.495	0.062			0.079	0.006	0.093	1.584	-0.720
Badescu	0.831	-0.011			0.566	0.321	0.047	1.369	-0.500
Pandey &Katiyar	0.733	0.379	-0.016		0.704	0.500	0.025	1.170	-0.362
Okundamiya&Nzeako	0.886	0.045	-0.011	-0.152	0.901	0.811	0.001	0.704	-0.129
Fagbenle	0.442	0.244	-0.154		0.080	0.006	0.093	1.585	-0.720
Glover & McCulloch's	0.503	0.062			0.996	0.992	0.093	1.584	-0.720

Table 2: Regression equation and statistical indicators for Delta State (2014-2018)

Model	a	b	c	d	R	R^2	MBE	RMSE	MPE
Angstrom-Prescott	0.514	0.028			0.082	0.007	0.020	0.990	-0.269
Badescu	0.203	0.011			0.438	0.191	0.021	0.898	-0.218
Pandey &Katiyar	0.201	-0.015	0.012		0.439	0.193	0.021	0.898	-0.218
Okundamiya&Nzeako	0.969	0.033	-0.007	-0.329	0.699	0.488	0.007	0.722	-0.139
Fagbenle	0.368	0.824	-1.031		0.443	0.197	0.015	0.893	-0.215
Glover & McCulloch's	0.516	0.029			0.999	0.997	0.020	0.990	-0.269

Table 3: Regression equation and statistical indicators for Kano State (2014-2018)

Model	a	b	C	d	R	R^2	MBE	RMSE	MPE
Angstrom-Prescott	0.536	0.004			0.004	1.72E-05	0.138	1.709	-0.847
Badescu	0.855	-0.011			0.771	0.594	0.042	1.124	-0.349
Pandey &Katiyar	0.703	0.305	-0.013		0.816	0.665	0.010	0.975	-0.282
Okundamiya&Nzeako	0.799	0.110	-0.011	-0.059	0.831	0.691	0.033	0.923	-0.262
Fagbenle	-3.542	12.897	-10.110		0.464	0.216	0.124	1.543	-0.677
Glover & McCulloch's	0.548	0.004			0.996	0.991	0.138	1.709	-0.847

Table 4: Regression equation and statistical indicators for Kwara State (2014-2018)

Model	a	b	c	d	R	R^2	MBE	RMSE	MPE
Angstrom-Prescott	0.418	0.205			0.585	0.342	0.037	1.087	-0.321
Badescu	0.281	0.009			0.287	0.083	0.063	1.262	-0.457
Pandey &Katiyar	0.545	0.245	-0.005		0.599	0.359	0.032	1.073	-0.313
Okundamiya&Nzeako	0.834	-0.049	-0.003	-0.310	-0.003	-0.310	0.006	0.629	-0.110
Fagbenle	0.505	-0.169	0.382		0.592	0.350	0.035	1.077	-0.317
Glover & McCulloch's	0.423	0.205			0.998	0.996	0.037	1.087	-0.321

Table 5: Regression equation and statistical indicators for Lagos State (2014-2018)

Model	a	b	c	d	R	R^2	MBE	RMSE	MPE
Angstrom-Prescott	0.479	0.111			0.365	0.134	0.023	0.971	-0.261
Badescu	0.142	0.014			0.547	0.300	0.025	0.795	-0.212
Pandey &Katiyar	0.129	-0.011	0.014		0.548	0.300	0.025	0.892	-0.212
Okundamiya&Nzeako	0.777	0.016	0.003	-0.409	0.713	0.507	0.017	0.755	-0.148
Fagbenle	0.308	1.001	-1.094		0.470	0.221	0.021	0.928	-0.234
Glover & McCulloch's	0.482	0.111			0.999	0.997	0.023	0.971	-0.261

Table 6 to 10 shows how the measured and calculated solar radiation relatively agreed in values for Bauchi, Delta Kano, Kwara, and Lagos state.

Table 6: Monthly mean daily measured and calculated values of global solar radiation for Bauchi state

Month	H_M	H_1	H_2	H_3	H_4	H_5	H_6
Jan	20.43	16.73	18.09	18.09	19.15	16.75	16.73
Feb	20.45	18.35	18.6	19.61	20.15	18.32	18.35
Mar	18.71	19.68	18.42	18.70	20.02	19.69	19.68
Apr	19.37	20.11	18.27	17.41	18.70	20.11	20.11
May	18.78	20.02	18.58	18.81	18.28	20.03	20.02
Jun	18.47	19.65	19.03	19.29	18.21	19.64	19.65
Jul	18.2	19.46	19.8	18.68	18.3	19.44	19.46
Aug	18.7	19.67	20.66	19.49	18.66	19.63	19.66
Sep	17.76	19.57	20.05	19.74	18.64	19.6	19.57
Oct	18.23	18.62	18.5	19.09	17.86	18.62	18.62
Nov	17.62	17.21	17.18	18.14	17.9	17.19	17.21
Dec	17.42	16.19	17.51	17.38	18.28	16.21	16.19

Table 7: Monthly mean daily measured and calculated values of global solar radiation for Delta state

Month	H_M	H_1	H_2	H_3	H_4	H_5	H_6
Jan	19.98	17.79	17.98	17.99	19.04	18.08	17.79
Feb	20.68	18.81	19.42	19.44	19.50	19.03	18.81
Mar	18.98	19.64	20.24	20.25	20.4	20.07	19.64
Apr	18.98	19.72	20.17	20.16	19.53	19.8	19.72
May	19.06	19.16	19.33	19.29	18.54	19.07	19.16
Jun	18.68	18.63	18.33	18.32	18.00	19.04	18.63
Jul	18.24	18.94	18.18	18.08	18.29	18.01	18.94
Aug	18.56	19.14	18.58	18.64	18.38	18.39	19.14
Sep	18.18	19.40	18.96	19.00	18.77	18.97	19.4
Oct	18.52	18.91	18.84	18.85	18.51	19.01	18.91
Nov	17.86	17.97	18.2-	18.20	18.17	18.37	17.97
Dec	17.54	17.40	17.29	17.3	18.25	17.61	17.40

Table 8: Monthly mean daily measured and calculated values of global solar radiation for Kano state

Month	H_M	H_1	H_2	H_3	H_4	H_5	H_6
Jan	19.54	16.53	18.62	18.76	18.86	17.94	16.53
Feb	20.26	18.08	18.80	18.67	19.20	18.68	18.08
Mar	18.58	19.64	18.75	19.19	19.53	20.02	19.64
Apr	18.80	20.40	18.24	18.56	18.86	20.79	20.40
May	18.70	20.29	18.09	18.40	18.29	20.68	20.29
Jun	18.34	20.00	18.89	18.30	18.41	18.60	20.00
Jul	17.90	20.06	19.86	19.03	18.98	19.31	20.06
Aug	18.34	20.23	20.54	19.88	19.57	20.52	20.23
Sep	17.88	16.51	16.45	16.16	15.86	16.20	16.51
Oct	18.22	18.47	18.15	18.52	18.15	17.87	18.47
Nov	17.54	16.83	17.54	18.28	17.99	15.73	16.83
Dec	17.24	15.96	17.90	17.94	18.02	16.49	15.96

Table 9: Monthly mean daily measured and calculated values of global solar radiation for Kwara state

Month	H_M	H_1	H_2	H_3	H_4	H_5	H_6
Jan	19.82	17.55	16.92	17.73	19.02	17.54	17.55
Feb	20.52	18.72	18.85	18.49	19.74	18.71	18.72
Mar	18.86	20.01	20.3	19.64	19.78	20	20.01
Apr	19.04	20.59	20.32	20.48	19.47	20.58	20.59
May	18.96	19.95	19.61	20.02	18.88	19.93	19.95
Jun	18.54	19.14	18.98	19.28	17.83	18.97	19.14
Jul	18.14	18.66	19.15	18.74	18.3	18.59	18.66
Aug	18.58	17.97	19.12	17.97	18.71	18.15	17.97
Sep	18.08	18.3	19.12	18.32	18.78	18.36	18.3
Oct	18.42	18.34	18.61	18.28	17.71	18.16	18.34
Nov	17.74	17.85	17.55	17.79	17.6	17.84	17.85
Dec	17.44	17.50	16.39	17.79	18.39	17.75	17.5

Table 10: Monthly mean daily measured and calculated values of global solar radiation for Lagos state

Month	H_M	H_1	H_2	H_3	H_4	H_5	H_6
Jan	19.91	17.51	18.01	18.04	18.79	17.85	17.51
Feb	20.64	19.02	19.5	19.51	19.36	18.98	19.02
Mar	18.95	19.5	20.44	20.49	20.08	19.88	19.5
Apr	19.13	20.14	20.43	20.42	20.27	20.02	20.14
May	19.03	19.79	19.45	19.41	19.23	19.37	19.79
Jun	18.64	18.67	18.38	18.38	19.6	19.11	18.67
Jul	18.22	18.56	18.16	18.16	17.86	18.66	18.56
Aug	18.64	18.7	18.49	18.52	18.39	18.19	18.7
Sep	18.16	18.94	18.84	18.87	18.42	18.61	18.94
Oct	18.51	18.96	18.56	18.54	18.24	19.35	18.96
Nov	17.84	18.17	17.88	17.84	17.59	17.99	18.17
Dec	17.51	17.52	17.34	17.32	17.55	17.41	17.52

DISCUSSION

From the previous tables it was found that Okundamiya and Nzeako model is the most appropriate, to predict index clearance in Bauchi, Delta Kano, Kwara and Lagos states since it has the smallest value of RMSE and MPE. Figures.1-.5 show the input parameters of the models for Bauchi, Delta, Kano, Kwara state between 2014-2018. From figure 1 it was observed that the highest and lowest temperatures occurred in April and January respectively in Bauchi state, from figure 2 it was observed that the highest and lowest temperatures occurred in February and August for Delta state, from figure 3 it was observed that the highest and lowest temperatures occurred in May and January respectively for Kano state. From figure 4 it was observed that the highest and lowest temperatures occurred in March and August respectively for Kwara, from figure 5 it was observed that highest and lowest temperatures occurred in February and August for Lagos state. This is expected,

since the months February and August are characterized by heavy sunshine and dry atmosphere respectively, the month of July is characterized by heavy rainfall while the month of December is characterized by harmattan haze which greatly reduces the intensity of solar radiation (Ekpe and Nnabuchi, 2012). It is also observed that the global solar radiation has highest values in the month of February for all states while the lowest values were recorded in the month of December for all states also.

Tables 1 to 5 show the regression equation and statistical indicators for Bauchi, Delta, Kano, Kwara and Lagos states between 2014-2018 revealing that the Okundamiya-Nzeako model shows the best estimation of the global solar radiation in the states, since it has the least value of RMSE and MPE. The values of RMSE and MPE for Bauchi, Delta, Kano, Kwara and Lagos states are: (0.704, -0.129); (0.722, -0.139); (0.923, -0.262); (0.629, -0.110) and (0.755, -0.148) respectively.Hence, Okundamiya &Nzeako model with regression coefficients a, b, c and d as (0.886, 0.045, -0.011, -0.152), (0.969, 0.033, -0.007, -0.329), (0.799, 0.110, -0.011, -0.059), (0.834, -0.049, -0.003, -0.310) and (0.777, 0.016, 0.003, -0.409) is recommended to estimate monthly average global solar radiation for Bauchi, Delta, Kano, Kwara and Lagos respectively.

Tables 6 to 10 show how the measured and calculated solar radiation relatively agreed in values for Bauchi, Delta, Kano, Kwara and Lagos states. Figures 1 to 5 shows the graphical representations between measured solar radiation and the calculated solar radiation by comparing the five models for Bauchi, Delta, Kano, Kwara and Lagos states from January to December (2014-2018).

As noticed the calculated values of error indices of studied models (shown in Tables 1 – 5) vary from one place to another. The difference is perhaps due to seasonal variations of the solar radiation caused apparently by the degree of cloud cover, presence of water vapour and ozone, and atmospheric dust in the atmosphere that differs from one place to another. The highest RMSE values (0.971, 0.990, 1.262, 1.585, and 1.709 $MJm^{-2}day^{-1}$) are produced respectively by Angstrom-Prescott, Glover & McCulloch's, Badescu, Fagbenle and Angstrom-Prescott models for the geographical zones but Okundamiya & Nzeako model provides the lowest range (0.629 – 0.923 $MJm^{-2}day^{-1}$) throughout the studied locations. The MBE values vary between under-estimation and over-estimation. The MBE achieved in this study are in the acceptable range.

The results have been compared with those obtained by Ogolo (2010) who investigated the performance of some predictive models for estimating global solar radiation across the varying climatic conditions in Nigeria. Ogolo (2010) carried out model evaluation to determine which model(s) is/are more suitable for a given climatic condition. His results revealed that temperature and sunshine hour dependent models are more suitable for the simulation of global solar radiation in Sahelian Guinea Savannah climatic conditions, respectively; while all the models exihibited the tendency to perform suitably well in the Midland and Coastal areas.

According to this study, Okundamiya and Nzeako model which is temperature and sunshine hours dependent shows the best evaluation of the global solar radiation for all sites in agreement with the findings of Ogolo (2010). Also, Olomiyesan *et al* (2017) carried out evaluation of some global solar radiation models in selected locations in Northwest, Nigeria. They discovered that Angstrom-Prescott model is not suitable for estimating global solar radiation in the study area in agreement with our study that shows Angstrom—Prescott with highest RMSE which indicates less suitability for the study area.

CONCLUSION

Model calculations were carried out using a few models (sunshine hour, temperature, relative humidity and latitude dependent) for the estimation of monthly mean global solar radiation for various geographical zones in Nigeria. The study assessed the performance of different solar radiation models namely: Angstrom-Prescott model, Badescu model, Pandey and Katiyar model, Okundamiya and Nzeako model, Fagbenle model and lastly Glover-McCulloch's model. The performances of the models were compared on the basis of statistical error tests, namely: mean percentage error (MPE), root mean square error (RMSE), mean bias error (MBE), and regression coefficient (R). The study reveals that the Okundamiya-Nzeako model gives the best estimation of the global solar radiation in the study areas. The results of this work show clearly the importance of developing empirical approaches for formulating the global solar radiation field reaching the earth at different locations. Based on the statistical results, a new simple linear model $H/H_o = 0.886 + 0.045(S/S_o) - 0.011(T_{max}) - 0.152(RH)$, $H/H_o = 0.969 + 0.033(S/S_o) - 0.007(T_{max}) - 0.329(RH)$, $H/H_o = 0.799 + 0.110(S/S_o) - 0.011(T_{max}) - 0.059(RH)$, $H/H_o = 0.834 - 0.049(S/S_o) - 0.003(T_{max}) - 0.310(RH)$, $H/H_o = 0.777 + 0.016(S/S_o) + 0.003(T_{max}) - 0.409(RH)$ based on Okundamiya and Nzeako model are highly recommended to estimate global solar radiation for all the geographical zones in Nigeria and elsewhere with similar climatic conditions, and also some areas if the radiation data is missing or unavailable.

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DETERMINATION OF PHYSICAL, CHEMICAL, FUNCTIONAL AND MECHANICAL PROPERTIES OF FIVE NEW CULTIVARS OF SOYBEAN SEEDS

[*1]Ogunbisi M. A., [2]Odetunde M.T., [2]Olayiwola E.O., and [2]Ogundipe O. O.

[1]*Department of Chemical Sciences, Yaba College of Technology, Lagos, Nigeria*
[2]*Department of Food Technology, Yaba College of Technology, Lagos, Nigeria*
***Corresponding Authors:** mercy.ogunbisi@yabatech.edu.ng; +2348023631389

ABSTRACT

Soybean is an economically important bean, because it is a rich source of various vitamins, minerals, and beneficial plant compounds. The knowledge of the physical, chemical, functional and mechanical properties of soybean is important for postharvest operations. Five different cultivars of soybean seeds (TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1988-5F and TGX 1987-62F) were evaluated using standard procedures. The results of the physical parameters are: Mean length (6.13 – 7.57mm), width (5.45 – 6.41mm) and thickness (4.56 –5.26mm). Other calculated physical parameters such as arithmetic mean diameter (5.38 –6.42mm), geometric mean diameter (5.33 – 5.94 mm), sphericity (0.83 – 0.88), aspect ratio (0.82 – 0.90), surface area (80.99 – 111.96 mm^2), volume (13.48 – 18.66 mm^3) were significantly different from one another. Also, true density (0.25 – 0.26), kernel density (1.04 – 1.26 g/cm^3), bulk density (0.76 – 0.8039 g/cm^3), porosity (22.85 – 39.2), angle of repose (13.67 – 16), 100 seed kernel weight (9.11 – 16.54 g), elongation ratio (1.41 – 1.57 mm) varied with cultivar. The functional properties (Hydration capacity, Hydration index, swelling capacity, Swelling Index, Foam capacity and stability, Oil absorption capacity, Water absorption capacity) were significantly ($P \leq 0.05$) different in between treatments in this study. Significant ($P \leq 0.05$) differences were observed in mean scores of proximate compositions of the soybean cultivars. The results of this study is useful in predicting potential uses of these five new cultivars of Soybean grains in food processing preservation, food handling, storage and distribution.

KEYWORDS: Physical, Chemical, Mechanical, Soybean

INTRODUCTION

Soybean is a leguminous plant usually found in tropical, subtropical, and temperate climates. It is believed that it might have been introduced to Africa in the 19th century by Chinese traders along the east coast of Africa (IITA, 2009). Proximate composition of soybean is approximately 40% protein, 35% total carbohydrate and 20% cholesterol-free oil, 1.7% potassium, 0.3% for magnesium, 110ppm iron, 50ppm zinc and 20ppm copper (Manuwa, 2011). Improved varieties of Soybean were developed in Nigeria at the International Institute of Tropical Agriculture, Ibadan. Such major improvements include but are not limited to increase grain yield by about 20%, improve resistance to pod shattering and to maintain the level of all other traits constant. (Manuwa, 2011). The soybean plant has lately been increasingly important for resource in agriculture, because it is one of the main food sources in human and animal nutrition. It is reputed to have, high quality protein and is free of cholesterol and saturated fatty acids. In the food industry it is used primarily for manufacture of soybean protein products (Kibar and Ozturk, 2008). Despite the importance of soybean, there is not much information about its physical, chemical and mechanical properties hence, this study is aimed to determine the physical, chemical, mechanical and functional properties of five new cultivars of soybeans (TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1988-5F and TGX 1987-62F) developed by International Institute of Tropical Agriculture (I.I.T.A.)

MATERIALS AND METHODS

Preparation of soybean seeds

The soybean seed cultivars obtained from IITA were cleaned manually to remove unwanted materials, damaged and unhealthy seeds. The initial moisture content of the soybean seeds was determined using the oven-dry method as described by (AOAC, 2005) at 105 ^{0}C for 6 hrs in the oven.

One Hundred Mass Seed Weight

One hundred seed weight was determined by weighing 100 randomly selected raw seeds of each variety as recommended by AOAC, 2000.

Determination of Physical Properties of Soybean

The following physical characteristics: Length, width and thickness of randomly selected soybean seeds were determined by measuring the three major perpendicular dimensions with the aid of a digital Vernier calliper (12″ Digital Calliper, Carrera Precision, Nanjing Sulang Co., Ltd., Jiangsu, China) to an accuracy of 0.01 mm (Falade & Adebiyi, 2015).

Arithmetic Mean Diameter

The arithmetic mean diameter (D_a), was calculated using the equation below (Ozturk *et al*., 2009).

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

Geometric Mean Diameter

The geometric mean diameter (D_g) of the soybean was calculated by using the following relationship (Ozturk *et al*., 2009).

$$D_g = LWT^{1/3}$$

Where, L is the length; W is the width and T is the thickness in mm.

Sphericity

Samples were randomly chosen from each soybean cultivar. The experimental design to be used is randomized complete block design (RCBD). The sphericity (Φ) was calculated using the formula (Nwakonobi and Idike, 2003).

$$\Phi = (LWT)^{1/3}/L$$

Where, L is the length; W is the width and T is the thickness in mm.

True Density

The toluene displacement method was used to determine, the true density of the soybean. Soybean sample (about 2.5 g) was submerged in 100 ml of toluene in a measuring cylinder having an accuracy of 0.1 mL, the increase in volume due to sample was noted as true volume of sample which was used to determine the true density of the sample (Karababa, 2005).

Bulk Density

The bulk density measures the ratio of the mass sample of kernels to its total volume. It can be determined by filing a 1000 ml container with kernels from a height of about 15 cm, striking the top level and then weighing the contents. (Karababa, 2005).

Kernel Density

The kernel density is a water displacement method. It depicts the ratio of mass of the sample to its kernel volume. Five hundred millilitres of water were poured into a 1000 ml graduated measuring cylinder and 25 g seeds immersed in the water. The duration of the experiment is very so as not to allow the skin of the kernel to absorb daily, the seeds were not coated to prevent moisture adsorption. The amount of displaced water was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced water gave the kernel density (Karababa, 2005).

Porosity

Porosity (έ) helps us determine the fraction of the space in the bulk grain not occupied by the grain. The porosity of bulk seed was computed from the values of kernel density and bulk density using the relationship given by:

$$\acute{\varepsilon} = \rho_k - \rho_b \, x \, \frac{100}{\rho_k}$$

Where ρ_b is the bulk density and ρ_k is the kernel density (Karababa, 2005)

Angle of Repose

The angle of repose is the characteristics of the bulk material which indicates the cohesion among the individual grains, the higher the cohesion, the higher the angle of repose. The angle of repose is the angle from the horizontal at which the material will rest in a pile. This was determined by using an open-ended cylinder of 15 cm diameter and 30 cm height. The cylinder was placed at the centre of circular plate having a diameter of 70 cm and filled with soybean grains. The cylinder was raised slowly until it forms a cone on the circular plate. The height of the cone was recorded. The angle of repose, θ was calculated by using the following formula:

$$\theta = \tan^{-1}\frac{2h}{d}$$

Where, θ is the angle of repose; h is the height of pile and d is the diameter of cone.

Aspect ratio (Ra)

This was calculated by using the formula:

$$R_a = \frac{width}{length}$$ *(Kibar and Ozturk, 2008).*

Surface Area

The surface area as in mm^2 of soybean grains was determined by analogy with a sphere of same geometric mean diameter, using the following relationship;

$$S = \frac{\pi BL^2}{2L-B}$$ *(Kibar and Ozturk, 2008).*

Volume

The volume of the soybean sample depending on the shape of the grains was determined using Eqns. (3), (4), (5) as described by Jain and Bal (1997) as found in Kibar and Ozturk (2008).

$$V = \frac{\pi BL^2}{6(2L-B)}$$

Elongation Ratio

The initial length of 10 soybean seed of each of the five cultivars would be measured with a digital veneer calliper (12″ Digital Calliper, Carrera Precision) with an accuracy of ±0.01 mm. Seeds would be cooked in excess water (200 mL) in a 1000 mL beaker placed on an electric heater. Cooked, samples would be removed and drained dapped on tissue paper to remove excess water, then final length would be measured to determine the increase in length. Elongation ratio would then be calculated, (Falade & Adebiyi, 2015).

$$Elongation\ ratio = \frac{Length\ of\ cooked\ beans}{Length\ of\ raw\ beans}$$

Determination of Proximate Properties of Soybean

Moisture Content

Moisture content determination was carried out using the air oven method. Crucibles were washed and dried in an oven. They were allowed to cool in the desiccator and weight was noted. A known weight (3g) of samples were then transferred into the crucibles and dried at a temperature between 103 and 105^0C. The dry samples were cooled in a desiccator and the weight noted. They were later returned to the oven and the process continued until constant weights were obtained (Kashaninejad *et al*., 2003; Karababa, 2005).

$$\%\ Moisture\ conten = \frac{\text{Weight Loss X 100}}{Weight\ of\ sample}$$

Determination of Ash content

A known weight (1.5 g) of finely ground sample was weighed into clean, dried previously weighed crucible with lid (W_1). The sample was ignited over a low flame to char the organic matter with lid removed. The crucible was then placed in muffle furnace at 600 ^{0}C for 6 hours until the ashing was completed. It was then transferred directly to desiccators, cooled and weighed immediately (W_2) (Eden & Rumambarsari, 2020).

$$Percentage\ Ash = \frac{(W_2 - W_1)\ \text{x}\ 100}{Weight\ of\ Sample}$$

Determination of Crude Fat

The soxhlet extraction method (AOAC, 2005) was used. This method could only give the approximate fat content in a sample because all the substances soluble in chosen solvent (Petroleum ether, 40° C – 60 ^{0}C boiling range) were extracted from the sample.

A known weight (2 g) of sample was weighed into a weighed filter paper and folded neatly. This was put inside pre-weighed thimble (W_1).

The thimble with the sample (W_2) was inserted into the soxhlet apparatus and extraction under reflux was carried out with petroleum ether (40 ^{0}C – 60 ^{0}C) boiling range for 6 hours. At the end of extraction, the thimble was dried in the oven for about 30 minutes at 100 ^{0}C to evaporate off the solvent and thimble was cooled in a desiccator and later weighed (W_3).

The fat extracted from a given quantity of sample was then calculated:

$$\%\ \boldsymbol{Fat\ (w/w)} = \frac{\boldsymbol{Loss\ in\ Weight\ of\ sample\ x\ 100}}{\boldsymbol{Original\ Weight\ of\ sample}} = \frac{\boldsymbol{(W_2 - W_3)\ x\ 100}}{\boldsymbol{(W_2 - W_1)}}$$

Protein Determination

The crude protein content was determined using micro Kjeldahl method as described in AOAC (2005). About 0.2077g of sample was weighed into a long necked Kjeldahl flask. One tablet of Kjeldahl catalyst was added to the sample in the flask with 25cm^3 of conc. H_2SO_4. The flask was swirled, gently clamped in an inclined position and heated electricity in a fume cupboard. The heating continue until a clear solution was obtained. The clear solution was cooled, poured into a 100cm^3 volumetric flask and made up to mark with distilled water 10ml of the resulting mixture was measured into the distillation set through the funnel. 5 cm^3 of boric acid was pipetted into a 100 cm^3 conical flask and placed at the receiving end of the distillatory. The conical flask was placed such that the delivery tube dipped completely into the boric acid inside the flask. 40% NaOH was used to liberated ammonia out of the digest under alkaline condition during the distillation 2 drops of methyl orange were always added to the round bottom flask containing the digested sample before 40% NaOH was added. As soon as the contents became alkaline, the red colour changed to yellow showing NaOH to be in excess. Steam was then generated into the distillation set using a steam chest. The liberated ammonia was trapped in the boric acid solution and about 50 cm^3 of the solution collected into a conical flask. The solution in the flask was titrated against 0.1M HC1 until the first permanent colour change was observed.

A blank sample was through the sample procedure and the titre value for the blank was used to correct the titre for samples.

$$\%\ \boldsymbol{N} = \frac{\boldsymbol{Molarity\ of\ HC1\ x\ Sample\ titre - Blank\ titre)\ x\ 0.014\ x\ DF\ x\ 100}}{\textbf{Weight of sample used}}$$

% N was converted to the percentage crude protein by multiplying by 6.25

Crude Fibre

Two hundred millilitre (200ml) freshly prepared 1.25 % H_2SO_4 were added to 3g of the residue obtained from fat extraction and this was boiled for was 30 minutes.

The mixture was filtered and residue washed until it was free from acid. The residue was transferred quantitatively into a digestion flask, 1.25% NaOH was added and allowed to boil for 30 minutes. The mixture was filtered and residue washed free of alkali.

The residue was then washed with methylated spirit, thrice with petroleum ether using small quantities. It was allowed to properly drain and the residue was transferred to a silica dish (previously ignited at 600 ^{0}C and cooled).
The dish and its content were dried to constant weight at 105 ^{0}C.

The organic matter of the residue was burnt by igniting for 30 minutes in a muffle furnace at 600 ^{0}C. The residue was cooled and weighed. The loss on ignition was reported as crude Fibre (AOAC, 2005).

Carbohydrate
The carbohydrate content was calculated by difference.

$$\%\ \boldsymbol{CHO = 100 -}\ (\boldsymbol{Sum\ of\ the\ percentages\ of\ moisture, ash, fat, protein\ and\ crude\ fibre})$$

DETERMINATION OF MECHANICAL PROPERTIES OF SOYBEAN
Digital Handheld hardness tester by Electrolab (Model EH-01), made in Mumbai, India. The guard cover was slide towards the knob end to open it was ensured that the seed touched the load cell and then the axial centre of the unit closed by sliding the safety guard cover again back to the initial position to close Then the knob was turned during the test and the plunger was driven (Bamgboye and Adebayo, 2012) forward which gave a gentle movement and pressed the seed against the load cell end jaw .the process continued until the seed was fractured the rupture force was registered by the unit the readings were taken in KgF.

DETERMINATION OF FUNCTIONAL PROPERTIES OF SOYBEAN
Hydration Capacity
Twenty grams of cotyledons in triplicate were enumerated and transferred to a measuring jar containing 100mL distilled water and it was left for 24h at room temperature (29 + 2 ^{0}C). Later the water was drained; cotyledons were blotted to remove adhered water and weighed.

$$\boldsymbol{Hydration\ capacity}\left(\frac{\boldsymbol{g}}{\boldsymbol{cotyledon}}\right) = \frac{\boldsymbol{(W_2 - W_1)}}{\boldsymbol{N}}$$

Where:
W_2 is weight of cotyledon after soaking and
W_1 is weight of cotyledon before soaking and
N is number of cotyledon (Tiwari *et al.*, 2008).

Hydration Index
It is the ratio of hydration per seed/cotyledon to that of weight of one seed or cotyledon.

$$\boldsymbol{Hydration\ index} = \frac{\boldsymbol{Hydration\ capacity\ of\ cotyledon}}{\boldsymbol{Weight\ of\ one\ cotyledon}}$$ (Tiwari *et al.*, 2008)

Swelling Capacity
Twenty grams of cotyledons were enumerated in triplicate; its volume was determined and soaked overnight in distilled water. Volume of the soaked cotyledon was noted in a graduated cylinder.

$$\boldsymbol{Swelling\ capacity}\left(\frac{\boldsymbol{ml}}{\boldsymbol{cotyledon}}\right) = \frac{\boldsymbol{V_2 - V_1}}{\boldsymbol{N}}$$

Where V_2 is the volume of cotyledon after soaking and V_1 is the volume of cotyledon before soaking; N is number of cotyledon (AOAC, 2005).

Swelling Index
It is the ratio of swelling capacity of cotyledon to that of volume of one cotyledon (AOAC, 2005).

$$\textbf{Swelling index} = \frac{\textbf{Swelling capacity}}{\textbf{Weight of one cotyledon}}$$

Foam Stability
One gram of soybean flour was whipped with 100 ml distilled water for 5 min in a Kenwood blender at 500 rpm and poured into a 250ml graduated cylinder. The volume of foam at 30 sec after whipping was recorded as the foam capacity and the volume of the foam after 60 min was recorded as the stability for the duration of measurement (Appiah *et al*., 2011).

Bulk density
Using the procedure described by (Appiah *et al*., 2011), 50 g of soybean flour was put into a 100 ml measuring cylinder and tapped to a constant volume and the bulk density (gcm^3) was calculated using the formula:

$$\textbf{Bulk density} = \frac{\textbf{weight of flour } (g)}{\textbf{Flour volume } (cm^3)}$$

Water and oil absorption capacities
To one gram of soybean flour, 10 ml distilled water or refined palm oil in a pre-weighed 20 ml centrifuge tube. The slurry was agitated for 2 min, allowed to stand at 28°C for 30 min and then centrifuged at 500 rpm for 20 min. The clear supernatant was decanted and discarded. The adhering drops of water or oil in the centrifuge tube was removed with cotton wool and the tube was weighed, the weight of water or oil absorbed by 1 g of flour or protein was calculated and expressed as water or fat absorption capacity (Appiah *et al*., 2011).

Length (mm)
Length mean scores values for the length obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 6.13mm, 7.62mm, 6.77mm, 6.58mm, 7.57mm respectively with cultivar TGX 1987-10F having the minimum value and cultivar TGX 1989-19F having the maximum value. It was observed that there was a significant difference ($P< 0.05$) in all the cultivars.

DATA ANALYSIS
Samples analysis were carried out in triplicate and data analysis was done using The Statistical Package for Social Sciences (SPSS) version 21.0. The level of statistical significant difference was taken at $P<0.05$.

RESULTS AND DISCUSSION

Physical Properties Soybean Cultivars
The physical dimensions and also the mechanical properties of any grain are important in the design, fabrication and utilization of equipment especially for pre and post-harvesting technology. They are also important in a lot of food related unit operations such as transporting, storage, cleaning, separation, sorting, sizing, packaging and processing into different food products (Fathollahzadeh *et al*., 2008).
Tables 1 and 2 show the physical properties of the five varieties of soybean cultivars that were analysed which are TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1988-5F, TGX 1987-62F. The results of the analyses are given in tables and discussed below.

Table 1: Physical properties of soybean cultivars

Sample Code	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic Mean Diameter (mm)	Geometric Mean Diameter (mm)	Sphericity (%)	Aspect ratio	Surface Area $(mm)^2$
TGX1987-10F	6.13±0[a]	5.45±0[a]	4.56±0[a]	5.38±0.00[a]	5.33±0.00[a]	0.86±0.00[b]	0.90±0.00[d]	80.91±0.06[a]
TGX1989-19F	7.62±0.01[e]	6.25±0.01[d]	5.37±0.01[e]	6.42±0.00[d]	6.33±0.00[e]	0.83±0.00[a]	0.82±0.00[a]	111.98±0.10[d]
TGX1835-10E	6.77±0[c]	6.09±0.01[c]	5.11±0.01[c]	5.98±0.01[c]	5.94±0.01[c]	0.87±0.00[c]	0.89±0.00[e]	100.83±0.26[c]
TGX1987-62F	6.58±0[b]	5.73±0[b]	5±0[b]	5.77±0.01[b]	5.73±0.00[b]	0.88±0.00[c]	0.87±0.00[c]	93.31±0.06[b]
TGX1988-5F	7.57±0[d]	6.41±0[e]	5.26±0[d]	6.41±0.00[d]	6.32±0.00[d]	0.83±0.00[a]	0.84±0.00[b]	111.96±0.06[d]

Values are means ± standard deviation. Means in a column with the same superscript letters are not significantly different (P≥0.05)

Table 2. Other Physical properties of soybean cultivars

Sample Code	Volume $(mm)^3$	True density (g/cm^3)	Kernel density (g/cm^3)	Bulk Density (g/cm^3)	Porosity (%)	Angle of Repose (^{0})	100 Seed Kernel Weight(g)	Elongation Ratio (mm)
TGX1987-10F	13.48±0.01[a]	0.25±0[a]	1.04±0[a]	0.8039+0[a]	22.85±0[a]	15±1[c]	9.11±0.04[a]	1.57±0[a]
TGX 1989-19F	18.66±0.01[d]	0.26±0[a]	1.26±0[a]	0.7900+0[a]	36.8±0[a]	15±1[d]	16.54±0.24[d]	1.42±0[a]
TGX 1835-10E	16.80±0.04[c]	0.25±0[a]	1.04±0[a]	0.7810+0[a]	25.05±0[a]	13.67±0.57[a]	13.40±0.12[c]	1.51±0[a]
TGX 1987-62F	15.55±0.01[b]	0.25±0[a]	1.25±0[a]	0.7772+0[a]	37.82±0[a]	13.67±1.15[b]	11.53±0.09[b]	1.41±0[a]
TGX 1988-5F	18.65±0.01[d]	0.25±0[a]	1.25±0[a]	0.7600+0[a]	39.2±0[a]	16±1[e]	16.54±0.03[d]	1.51±0[a]

Values are means± standard deviation. Means in a column with the same superscript letters are not significantly different (P≥0.05).

Width (mm)

Width mean scores values for the width obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study ranged from 5.45mm – 6.41mm with cultivar TGX 1987-10F having the minimum value and cultivar TGX 1988-5F having the maximum value. It was observed that there was a significant difference (P≤ 0.05) in width for all the cultivars of Soybeans used in this study.

Thickness (mm)

Thickness mean scores values for the thickness obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 4.56mm, 5.37mm, 5.11mm, 5.0mm, 5.26mm respectively. Cultivar TGX 1987-10F had the least value and cultivar TGX 1989-19F had the highest value. It was observed that there

was a significant difference (P≤ 0.05) in all the cultivars of Soybeans in this study.

Arithmetic Mean Diameter (mm)

Mean scores for arithmetic mean diameter values for the arithmetic mean diameter obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 5.38mm, 6.42mm, 5.98mm, 5.77mm, 6.41mm respectively. This is a function of the length, width and thickness of the grains (mm). The results obtained ranged between 5.38 – 6.42mm with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. No significant (P> 0.05) difference was observed between TGX 1989-19F and TGX 1988-5F; however, there was a significant difference, between TGX 1987-10F, TGX 1835-10E and TGX 1987-62F.

Geometric Mean Diameter (mm)

Mean score for geometric mean values for the geometric mean diameter obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 5.33mm, 6.3mm, 5.94mm, 5.73mm, 6.32mm respectively. The geometric mean diameter like the arithmetic mean diameter is also a function of the length, width and thickness of the grain and it was calculated by using a standard equation as described in the methodology. The geometric mean of the axial dimensions is important in determining the projected area of a particle moving in the turbulent or near-turbulent air stream. Projected area of particles helps to predict behaviour in a flowing fluid such as air, as well as the ease of separating extraneous material from the particle during cleaning by pneumatic means (Asoiro *et al*., 2017). The results obtained ranged between 5.33mm – 6.33mm, with cultivar TGX 1987-10F having the minimum value and cultivar TGX 1989-19F, having the maximum value. A significant difference (P< 0.05) was observed in the cultivars.

Sphericity (%)

Sphericity mean scores values for sphericity obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.86%, 0.83%, 0.87%, 0.88%, 0.83% respectively. The sphericity of the soybean cultivars is related to the geometry. It refers to the shape of the seeds and pre - determines how a seed will roll on a surface. The flat shape of the seeds enables the seeds to slide. This property is quite important in the design of machine components, such as hoppers and dehullers for seeds. Seeds that are flat in geometry slide easier than spherical seeds, which roll on structural surfaces. The results of sphericity obtained for the five cultivars of Soybean in this study ranged from 0.83% – 0.88% with cultivar TGX 1989-19F and TGX 1988-5F having the minimum value and cultivar TGX 1987-62F having the maximum value for sphericity. No significant difference (P> 0.05) was observed between TGX 1989-19F and TGX 1988-5F and also TGX 1835-10E and TGX 1985-62F, however there was a significant difference (P< 0.05) amongst the five cultivars.

Aspect Ratio

Aspect ratio mean scores values for aspect ratio obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.90, 0.82, 0.89, 0.87, 0.84 respectively. The aspect ratio of the soybean cultivars is the ratio of width to the length; using the formula described by Omobuwajo *et al*. (1999), the values obtained ranged between 0.82 – 0.90 with TGX 1989-19F having the minimum value and TGX 1987-10F having the maximum value. A significant difference (P< 0.05) was observed between the five cultivars in this study.

Surface Area (mm^2)

Surface area mean scores values for surface area obtained for cultivars, TGX 1987-10F,

TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 80.91mm^2, 111.98mm^2, 100.83mm^2, 93.31mm^2, 111.96mm^2 respectively. The surface area is a function of the geometric mean diameter, while the geometric mean diameter is a function of the grain's length, width and thickness. The surface area of food and agricultural biomass affects the velocity of air streams. This is particularly useful in separation operations, especially when it is desirable to separate the product from an unwanted material in pneumatic separator or to convey seeds in pneumatic conveying (Asoiro *et al*., 2017). The values obtained for surface area ranged between 80.91mm^2 – 111.98mm^2 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value for surface area. A significant difference was observed among the samples however, no significant difference ($P>0.05$) was obtained between TGX 1989-19F and TGX 1988-5F.

Volume (mm^3)

Volume mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 13.48mm^3, 18.66mm^3, 16.80mm^3, 15.55mm^3, 18.65mm^3 respectively. Equal amount of each soybean cultivar were weighed, the difference in their volume is as a result of the differences in their shape and size. The values obtained ranged between 13.48mm^3 – 18.66mm^3 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. Significant difference ($P< 0.05$) were observed among the samples, however there was no significant difference in the means of samples TGX 1989-19F and TGX 1988-5F.

True density (g/cm^3)

True density means scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.25g/cm^3, 0.26g/cm^3, 0.25g/cm^3, 0.25g/cm^3, 0.25g/cm^3 respectively. True density is the density of a pure substance or a composite material calculated from its components' densities considering conservation of mass and volume (Rao *et al*., 2005). The values obtained ranged between 0.25g/cm^3 – 0.26g/cm^3 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. No significant difference was observed among the five cultivars in this study.

Kernel density (g/cm^3)

Kernel density mean scores values for kernel density obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.04g/cm^3, 1.26g/cm^3, 1.04g/cm^3, 1.25g/cm^3, 1.25g/cm^3 respectively. Kernel density refers to the density of a particle, and it includes the volume of all closed pores but not the externally connected pores. In this case, the particle is not modified structurally, as in the case of material density. The values obtained ranged between 1.04g/cm^3 – 1.26g/cm^3 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value, there was no significant difference ($P\geq 0.05$) between all cultivars in this study.

Bulk density (g/cm^3)

Bulk density mean scores values for bulk density obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.8039 g/cm^3, 0.7900 g/cm^3, 0.7810 g/cm^3, 0.7772 g/cm^3, 0.7600 g/cm^3 respectively. Bulk density of a material is the density of a material when packed or stacked in bulk.

The bulk density of packed materials has to do with the geometry, size, and surface properties of individual particles (Rao *et al*., 2005). The values obtained ranged between 0.76g/cm^3 – 0.80g/cm^3 with TGX 1988-5F having the minimum value and TGX 1987-10F having the maximum value.

No significant difference (P≥ 0.05) was however obtained between all cultivars in this study.

Porosity (%)

Porosity mean scores values for porosity obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 22.85%, 36.8%, 25.05%, 37.82%, 39.2% respectively. The Porosity of any material indicates the volume fraction of void space or air in the material. Porosity or void fraction is a measure of the void spaces or empty spaces in a material, which is between 0 to1, or as a percentage between 0 to100 percent. (Rao *et al*., 2005; Taheri *et al*., 2015), hence we can say that the porosity of the soybean grains is the volume fraction of void space or air in the grains. Also, the lower the porosity, the greater the resistance to water vapour escape during the drying process which may lead to higher power to drive the aeration fans and vice versa (Heidarbeigi *et al*., 2009). The values obtained ranged between 22.85% - 39.2% with TGX 1987-10F having the minimum value and TGX 1988-5F having the maximum value. No significant difference (P≥ 0.05) was obtained among all cultivars in this study.

Angle of repose (^{0})

Angle of repose mean scores values for angle of repose obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 15^0, 15^0, 13.67^0, 13.67^0 and 16^0 respectively. The angle of repose determines the maximum angle of a pile of grain in the horizontal plain and it is important in the filling of a flat storage facility when grain is not piled at a uniform bed depth rather is peaked (Heidarbeigi *et al*., 2009).

It is also used in design of hoppers for efficient milling in size reduction operations. This property helps to determine the minimum slope of flow in self-emptying bin and minimum slope of flow in a hopper. The results obtained ranged from 13.670 – 160, with TGX 1935-10E having the minimum and TGX 1988-5F having the maximum value. There was a significant difference in all the cultivars.

100 seed kernel weight (g)

Hundred seed kernel weight refers to the weight of hundred seeds of each cultivar as measured by a digital laboratory weighing balance. The values obtained ranged between 9.11g – 16.54g with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. Significant differences were observed between all cultivars, however no significant difference was observed in the means of sample TGX 1989 -19F and TGX 1988-5F.

Elongation ratio

Elongation ratio mean scores values for elongation ratio obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.57mm, 1.42mm, 1.51mm, 1.41mm and 1.51mm respectively. The elongation ratio of seed grains on cooking is dependent on the genetic factors as well as the degree of milling (Shamim *et al*., 2016). The values obtained ranged between 1.41 – 1.57 with TGX 1987-62F having the minimum value and TGX 1987 -10F having the maximum value, there was no significant difference between all cultivars in this study.

Table 3. Proximate composition of soybean cultivars

Parameters	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrates (%)
TGX1987-10F	8.67±0.15^{a}	39.36±0.15^{d}	19.5±0.2^{b}	4.23±0.05^{a}	1.67±0.15^{b}	26.57±0.11^{a}
TGX 1989-19F	9.13±0.15^{b}	39.67±0.15^{e}	19.57±0.15^{b}	4.33±0.15^{ab}	1.23±0.15^{a}	26.07±0.15^{a}
TGX 1835-^{10E}	9.06±0.20^{b}	37.8±0.2^{a}	18.73±0.20^{a}	4.67±0.15^{c}	1.27±0.15^{a}	28.47±0.47^{c}
TGX 1987-62F	8.6±0.2^{a}	38.8±0.1^{c}	18.63±0.15^{a}	4.77±0.15^{c}	1.6±0.1^{b}	27.6±0.36^{b}
TGX 1988-5F	8.9±0.2^{b}	38.27±0.15^{b}	19.77±0.15^{b}	4.53±0.15^{bc}	1.33±0.15^{a}	27.2±0.26^{b}

Values are means± standard deviation. Means in a column with the same superscript letters are not significantly different (P ≥0.05).

Proximate Composition of Soybean Cultivars

Table 3 shows the result for the chemical composition of the soybean seeds (TGX 1835-10E, TGX 1987-10F, TGX 1987-62F, TGX 1988-5F and TGX 1989-19F).

Moisture Content (%)

Mean scores values for moisture content obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 8.67%, 9.13%, 9.06%, 8.60% and 8.90%. The moisture content of any food is an index of its storage stability. The higher the moisture content, the more the food is predisposed to spoilage. A low level of moisture ensures good shelf life. The moisture content in seeds strongly influences the occurrence of mechanical damage, affecting elasticity and resistance in both cotyledons and the seed coat (Kuzniar *et al*., 2016). The values of mean score obtained ranged between 8.6% - 9.13% with TGX 1987-62F having the minimum value and TGX 1989 -19F having the maximum value.

No significant difference was observed between TGX 1835- 10E, TGX 1988 -5F and TGX 1989 -19F, also and there was no significant difference between the mean scores of TGX 1987 -10F and TGX 1987 - 62F.

Protein content (%)

Protein content mean scores values for protein obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 39.36%, 39.67%, 37.8%, 38.8% and 38.27% respectively. The averages protein content of the most of beans varies between 20-25% (Ogundele *et al*., 2015), In this study the protein content of soybean is about 40%. Soybean protein is low in sulphur containing amino acids, but contains sufficient lysine which is deficient in most cereals. Soybean protein is equivalent in quality to animal protein (Ogundele *et al*., 2015). The values of mean scores obtained ranged between 37.8% - 39.36% with TGX 1835 -10E having the minimum value and TGX 1987-10F having the maximum value. Significant difference ($P \leq 0.05$) was observed between cultivars of soybeans in this study. This is similar to the findings reported by Kuzniar *et al*. (2016).

Fat Content (%)

Fat content mean scores values for fat obtained for cultivars, TGX 1987-10F, TGX

1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 19.5%, 19.57%, 18.73%, 18.63% and 19.77% respectively. The values of mean score among the cultivars ranged between 18.63% - 19.77%, with TGX 1987-62F having the minimum value and TGX 1988 -5F having the maximum value, there was no significant difference between TGX 1835 -10E and TGX 1987 – 62F, and no significant difference (P<0.05) between the mean scores of TGX 1987 -10F, TGX 1989 -19F and TGX 1988 -5F. The results obtained in this study are similar to the findings of Kuzniar *et al*. (2016). Ashaye and Olusoji (2006), reported that soybean oil extracted of from its seed is fairly rich in glycerides of the unsaturated fatty acids particularly linoleic and linolenic acids with few oleic fatty acids, which do not oxidize readily because they contain natural antioxidants.

Ash content (%)

Ash content mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 4.23%, 4.33%, 4.67%, 4.77% and 4.53% respectively. The values obtained ranged between 4.23% - 4.77% with TGX 1987-10F having the minimum value and TGX 1987-62F having the maximum value, there was slight significant difference (P<0.05) between TGX 1987-10F and TGX 1989-19F, however there was no significant difference between TGX 1835-10E and TGX 1987-62F, and also a slight significance difference (P<0.05) in mean scores between TGX 1988-5F and (TGX 1835-10E and TGX 1987-62F).

Crude fibre (%)

Crude fibre mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.67%, 1.23%, 1.27%, 1.60%, 1.33% respectively. The values of mean scores obtained in this study ranged between 1.23% - 1.67% with TGX 1989-19F having the minimum value and TGX 1987 – 10F having the maximum value, there was no significant difference (P<0.05) in mean scores between TGX 1989-19F, TGX 1835-10E and TGX 1988-5F. No significant difference (P<0.05) was also observed in mean scores between TGX 1987-10F and TGX 1987-62F. Fibre is significant component of food and has a significant influence on metabolism in human digestion. Tresina *et al*. (2013), reported that legumes contained high fibre which slows down the release of glucose into the blood stream, consequently high legume diets are recommended for diabetic patients.

Carbohydrate content (%)

Carbohydrate content mean scores values for carbohydrate obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 26.57%, 26.07%, 28.47%, 27.60% and 27.20% respectively.

Table 4. Hardness properties of soybean cultivars

Samples	Transverse hardness KgF)	longitudinal hardness (KgF)
TGX1987-10F	13.81±1.73[a]	9.41±0.51[a]
TGX1989-19F	18.07±4.25[a]	8.68±1.18a
TGX1835-10E	18.49±9.30a	9.64±1.41a
TGX1987-62F	11.08±5.44[a]	8.03±1.24[a]
TGX 1988-5F	14.86±3.81[a]	10.36±2.12[a]

Results show mean ± standard deviation, means in a column with the same superscript letters are not significantly different (P ≤ 0.05).

Carbohydrates in soybean are low, also, soybean are very low in the glycemic index. Glycemic index helps us to determine how food affects, the rate of increase in blood sugar after a meal. Low glycemic index makes soybean of significant importance to diabetic patients.

The values of mean scores obtained, ranged between 26.07% - 28.47% with TGX 1989-19F having the minimum value and TGX 1835-10E having the maximum value. There was no significant difference ($P<0.05$) observed in mean scores between TGX 1987-10F band TGX 1989-19F, and there was no significant difference observed in mean scores between TGX 1987-62F and TGX 1988-5F, however there was significant difference ($P>0.05$) observed in mean scores among the various cultivars in this study.

Hardness Properties of Soybean Cultivars

Table 4 shows detail of hardness property of the five soybean cultivars analysed in terms of their Transverse and longitudinal section.

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Hardness is an important parameter used to design equipment for operations such as milling, threshing, and compression. It is very useful in analysing, optimization and control of the seed damage during storage and handling of grains for commercial purposes (Mohsen *et al.*, 2012).

Hardness properties of transverse section

For the transverse section, the value of mean scores ranged between 11.08 - 18.49KgF with TGX 1987-62F having the minimum value and TGX 1835-10E having the maximum value. No significant difference ($P<0.05$) was observed among the cultivars in this study.

Hardness properties of longitudinal section

For the longitudinal section, the values of mean scores for force applied ranged between 8.03KgF-10.36KgF with TGX 1987-62F having the minimum value and TGX 1988-5F having the maximum value, there was no significant difference in all cultivars

Table 5. Functional properties of soybean cultivars

Samples	Hydration Capacity (g/cotyledon)	Hydration Index	Swelling Capacity (ml/cotyledon)	Swelling Index	Foam capacity & Stability (cm^3)	Oil Absorption (ml/g)	Water Absorption (ml/g)	Bulk Density (g/cm^3)
TGX1987-10F	0.12 ± 0.00^{a}	1.34 ± 0.02^{d}	0.21 ± 0.00^{a}	2.25 ± 0.03^{c}	127 ± 1^{c}	5.64 ± 0.24^{ab}	3.81 ± 0.07^{b}	0.68 ± 0.00^{c}
TGX 1989-19F	0.18 ± 0.01^{d}	1.12 ± 0.02^{a}	0.32 ± 0.00^{d}	1.97 ± 0.02^{a}	117 ± 1^{a}	5.78 ± 0.54^{b}	3.82 ± 0.12^{b}	0.63 ± 0.00^{b}
TGX 1835-10E	0.16 ± 0.01^{c}	1.21 ± 0.00^{b}	0.29 ± 0.00^{c}	2.18 ± 0.03^{b}	123 ± 5^{bc}	5.79 ± 0.16^{b}	3.49 ± 0.07^{a}	0.68 ± 0.00^{c}
TGX 1987-62F	0.15 ± 0.02^{b}	1.27 ± 0.01^{c}	0.27 ± 0.01^{b}	2.31 ± 0.05^{c}	123 ± 1^{bc}	5.15 ± 0.22^{a}	3.73 ± 0.16^{b}	0.69 ± 0.00^{c}
TGX 1988-5F	0.20 ± 0.00^{e}	1.21 ± 0.01^{b}	0.36 ± 0.00^{e}	2.17 ± 0.00^{b}	120 ± 0^{ab}	5.91 ± 0.12^{b}	3.5 ± 0.01^{a}	0.61 ± 0.00^{a}

Values are means± standard deviation. Means in a column with the same superscript letters are not significantly different ($P \geq 0.05$).

Functional Properties of Soybean Cultivars

Functional properties are important in predicting the physical behaviour of food or its ingredient during biotransformation and storage thereby altering the sensory properties of the food (Tiwari *et al*., 2008). Table 5 gives a detailed result on the functional properties of the five soybean cultivars that was analyzed.

Hydration Capacity (g/cotyledon)

Hydration capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.12g/cotyledon, 0.18g/cotyledon, 0.16g/cotyledon, 0.15g/cotyledon and 0.20g/cotyledon respectively. Hydration is necessary before germination of seeds. Hydrating the reserve food material of seeds helps to initiate the metabolic activity responsible for the growth of the seed (Sibian *et al*., 2013). The values ranged between 0.12g/cotyledon – 0.20g/cotyledon with TGX 1987-10F having the minimum value and TGX 1988-5F having the maximum value, it was observed that there was significant difference in all cultivars.

Hydration Index

Hydration index mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.34, 1.12, 1.21, 1.27 and 1.21 respectively. The values ranged between 1.12 - 1.34 with TGX 1989-19F having the minimum value and TGX 1987-10F having the maximum value, it was observed that there was no significant difference ($P<0.05$) in mean scores between TGX 1835-10E and TGX 1988-5F, however there was significant difference in TGX 1987-62F, TGX 1989-19F and TGX 1987-10F.

Swelling Capacity (ml/cotyledon)

Swelling capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.21ml/cotyledon, 0.32ml/cotyledon, 0.29ml/cotyledon, 0.27ml/cotyledon, 0.36ml/cotyledon respectively. Swelling capacity and index helps to determine the absorption rate of the seed as well as some physical properties which might be due to alteration of the cell wall (Sibian *et al*., 2013). The values ranged between 0.21ml/cotyledon - 0.36ml/cotyledon with TGX 1987-10F having the minimum value and TGX 1988-5F having the maximum value, it was observed that there was no significant difference in all cultivars.

Swelling Index

Swelling index mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 2.25, 1.97, 2.18, 2.31 and 2.17 respectively. The values ranged between 1.97 - 2.31 with TGX 1989-19F having the minimum value and TGX 1987-62F having the maximum value. No significant difference in mean score was between samples TGX 1835-10E and TGX 1988-5F. No significant difference ($P<0.05$) in mean scores was also observed between TGX 1987-62F and TGX 1987-10F. The mean score of sample TGX 1989-19F was however different from that of other samples. A significant difference however occurred between samples.

Foam Capacity and Stability (cm^3)

Foam capacity and stability mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 127cm^3, 117cm^3, 123cm^3, 123cm^3 and 120cm^3 respectively. The values ranged between

117cm^3 - 127cm^3 with TGX 1989-19F having the minimum value for mean score and TGX 1987-10F having the maximum value for mean scores among the samples in this study. Significant difference ($P \leq 0.05$) in mean score was observed between samples, however no significant difference ($P \geq 0.05$) in mean score was observed between samples TGX 1835-10E and TGX 1987-62F.

Oil Absorption Capacity (ml/g)

Oil absorption capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 5.64ml/g, 5.78ml/g, 5.79ml/g, 5.15ml/g and 5.91ml/g respectively. Oil absorption capacity is significant in food industries for retention of flavour in foods and improvement of shelf life and palatability (Falade *et al*., 2015). The result of oil absorption capacity obtained ranges from 5.15ml/g - 5.91ml/g with TGX 1987-62F having the minimum value and TGX 1988-5F having the maximum value. There was no significant difference ($P > 0.05$) observed in mean scores between TGX 1988-5F, TGX 1835-10E and TGX 1989-19F, however there was a slight significant difference ($P < 0.05$) between TGX 1987 10F and the other samples.

Water Absorption Capacity (ml/g)

Water absorption capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 3.81ml/g, 3.82ml/g, 3.49ml/g, 3.73ml/g and 3.50ml/g respectively. The values ranged between 3.49ml/g - 3.82ml/g with TGX 1835-10E having the minimum value and TGX 1989-19F having the maximum value. Significant differences were obtained in mean scores for some cultivars in this study. No significant difference was however observed in mean scores between samples TGX 1987-10F, TGX 1989-19F and TGX 1987-62F. There was also no significant difference ($P > 0.05$) was obtained between the mean scores of 1988-5F and TGX 1835-10E. Water absorption capacity determines the quantity of water or oil absorbed by the flour to achieve the desired consistency. It is of significance when determining the attributes and shelf life of the products.

Bulk Density (g/cm^3)

Bulk density mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.68 g/cm^3, 0.63 g/cm^3, 0.68 g/cm^3, 0.69 g/cm^3 and 0.61 g/cm^3 respectively. The values of mean scores for bulk density ranged between 0.61g/cm^3 – 0.69g/cm^3 with TGX 1988-5F having the minimum value and TGX 1987-62F having the maximum value, it was observed that there was no significant difference ($P < 0.05$) between sample cultivars TGX 1987-62F, TGX 1835-10E and TGX 1987-10F, and there was significant difference between TGX 1989-19F and TGX 1988-5F. Bulk density is the mass of the particles that occupies a unit volume. Bulk density is relevant in food processing, when carrying out quality control in the food industry. It also determines whether a raw material can be mixed or a final product can be packed in a predetermined container. It also determines the intentional and unintentional compression that a powdery substance suffers during transport or production (Gustavo *et al*., 2005).

CONCLUSION

Soybean seeds were characterized for physical, chemical, mechanical and functional properties. The proximate composition of the Soybean cultivars studied were not significantly ($P \leq 0.05$) different in the moisture content, fat content, crude fibre and carbohydrate while significant ($P \leq 0.05$) difference was observed in protein and ash content. Mechanical and functional properties were significantly ($P \leq 0.05$)

different among cultivars. The results of this study is useful in predicting potential uses of these five cultivars of grains in food processing preservation, food handling, storage and distribution.

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SELECTED QUALITY ATTRIBUTES AND MICROBIAL EVALUATION OF KETCHUP FROM BLENDS OF HOG PLUM (*Spondias mombin*) AND TOMATOES (*Solanum lycopersicum*)

[1]Ogundipe O.O., [2]Ogunbisi M.A., [1]Amzat S., [1]Adebayo–Oyetoro A.O. and [3]Ogundipe F.O

[1]Department of Food Technology, Yaba College of Technology, P.M.B. 2011, Lagos, Nigeria
[2]Department of Chemical Sciences, Yaba College of Technology, P.M.B. 2011, Lagos, Nigeria
[3]Department of Biological Science, Yaba College of Technology, P.M.B. 2011, Lagos, Nigeria

Corresponding Author: deindeogundipe@gmail.com, +234 8056306076

ABSTRACT

Blend ratios (Tomatoes: Hog plum): HPK (0:100); TPK (100:0); THK (90:10); HTK (80:20); TKP (70:30) were studied to determine the effect of partial substitution of hog plum on the proximate, physicochemical, sensory, colour, energy value, and viscosity in ketchup blends. Significant difference ($p \leq 0.05$) was observed in the treatment for proximate composition. Mean score values for physicochemical properties: week one TTA (29.87 – 47.03 %); Ascorbic acid (9.33 – 32.67 mg/100g); pH (4.00 – 5.46); Brix (45.00 – 60.00 ^{o}B). for week two, TTA (6.40 – 14.36 %); Ascorbic acid (7.00 – 11.67 mg/100g); pH (3.46 – 4.59); Brix (44.00 – 60.00 ^{o}B). for week three, TTA 932.00 – 149.63 %); Ascorbic acid (11.67 – 23.33 mg/100 g); pH (2.78 – 4.40); Brix (45.00 – 57.00 ^{o}B) for week four TTA (25.60 – 155.33 %); Ascorbic acid (9.33 – 23.33 mg/100 g), pH (2.72 – 4.42); Brix (45.00 – 58.00 ^{o}B). The mean score value for Sensory parameters ranged between: (2.47 – 4.10); (3.23 – 4.00); (3.20 – 4.23); (3.43 – 4.97); (3.20 – 4.43) for colour, aroma, texture, taste and overall acceptability respectively. 1 represented Like Extremely and 9 represented Dislike Extremely. No significant ($p \geq 0.05$) difference was observed between treatments in samples THK, HTK and TKP respectively. Significant ($p \leq 0.05$) difference was however observed for colour, with, chroma (ΔC), colour intensity (ΔE) and hue angle ranging between: 38.22 – 42.89; 45.06 – 49.99 and 49.04 – 60.55 respectively. Mean value for energy (12.02 – 12.90 Kcal). Significant ($p \leq 0.05$) difference was observed between treatments for viscosity. By the fourth week showed that the treatment blends did not meet up with permissible limits for microbial indicators shelf life.

KEYWORDS: Ketchup, Hog plum, Tomato, Microbial evaluation

INTRODUCTION

Hog plum (*Sponidas mombin*) also known as yellow mombin, is a small drupe fruit with characteristic properties of a slightly thick skin and thin pulp encapsulating its cork-like seed (Oladunjoye *et al*., 2021). The fruit varieties are available a range of colours, including green, purple, red, orange and yellow (Ayoka *et* al., 2008). Amongst the Yoruba (Western Nigeria), it is known as "Iyeye" or "Ebo". In some parts of eastern Nigeria, it is known as *Ngulungu* and *Isada* in Hausa (Northern Nigeria). Its taste varies from sweet and sour. The fruit can be eaten raw or processed to make jams and jellies, blended to make ice cream and cold drinks. The green fruits can be pickled by fermentation to produce vinegar and consumed like olives with salt in combination with chili pepper (Kitchenbutterfly, 2016).

Hog plums are rich in dietary fiber which is important in promoting a healthy digestive system.

It is generally rich in vitamins, minerals and phytochemical properties that perform oxidation functions in the body system. It is rich in iron which helps in the production of hemoglobin and myoglobin which transfer

oxygen throughout the body systems (Oladunjoye *et al*., 2021). The juice of the fruit is said to have a cooling effect that can normalize and control a high body temperature and heart conditions. It is a fat-free, sodium-free, cholesterol-free and good source of vitamin K that helps in proper bone health. It has thiamine content which plays an important role in muscle contraction and conduction of nerve signals. It also contains polyphenols, sterols, flavonoids, quinones, tannins and saponins. Research indicates that hog plums contain copper that maintains the bone and other connective tissues in the body system and is also needed for proper assimilation of vitamin C (Ayoka *et* al., 2008; Adedokun *et al.*, 2010).

Tomato (L*ycopersicum esculentum*) is a ubiquitous vegetable, grown copiously in the tropical and temperate regions of the world (Okorie *et al.*, 2004). This fruit vegetable is widely consumed in raw and/or processed form in human diets and a products of health related food supplements (Jumah *et al.*, 2004). It is one of the most important vegetables crops grown all over Nigeria, and the world largest crop consumed after potatoes and sweet potatoes, but it tops the list of canned vegetables. In Nigeria, tomato is regarded one of the most important vegetables, with high content of antioxidant compounds that reduces oxidative damage in the body (Beecher, 1998). Tomatoes are rich in lycopene (87%) and other carotenoids, worthy of note are carotenes, phytenes, phytofluene, lutein and L-ascorbic acids (Soma, 2013). Metabolic activity in humans is enhanced as tomatoes contains water, calcium, niacin all of which are of great importance to good health, also tomato is a good source of vitamin A, C and E and also contains minerals, that are good for the body and protect the body against disease (Taylor, 1987; Khaliukova, 2016).

Tomato ketchup (catsup) is a condiment made from ripe tomato, which usually consists of sugar, vinegar, salt and some addition spicy ingredients. It is one of the commercially available sauces. People of different age ranges consumes ketchup as complement to products like hamburger, French fries and chicken wings (Intelmann *et al.*, 2005). The glucose content and high dry matter contents contributes to an increase in water activity on the level from 0.93 to 0.95. The amount of added vinegar results in 0.8 and 1.0% acetic acid in product. These products also have extensive shelf life time and with relatively heat treatments can be store for one or more years at ambient temperature (Rajchl, 2010).
The aim of this study is to produce ketchup from blends of Hog Plum and tomato and to determine the quality attributes of the resultant product.

MATERIALS AND METHODS

Materials

Tomatoes were purchased at mile 12 market, while the hog plum was picked in a garden at the University of Lagos.

Methods

The tomato and hog plum were cleaned, damaged and unwholesome ones were sorted out while the wholesome ones were steam blanched to loosen the skin. It was then cooled in cold water and the skin was removed manually exposing the pulp. The spices were tied loosely in a muslin cloth and plunged in the pulp. The pulp was boiled to below boiling point in a pan with continuous stirring until it has reduced to half the original volume. The muslin cloth was removed and sugar, salt and vinegar were added to the mixture, after which heating was continued for 10 minutes. The product was then hot filled into pre-sterilized bottles at a temperature of 80^{o}C, the lid was covered after cooling to ambient temperature.

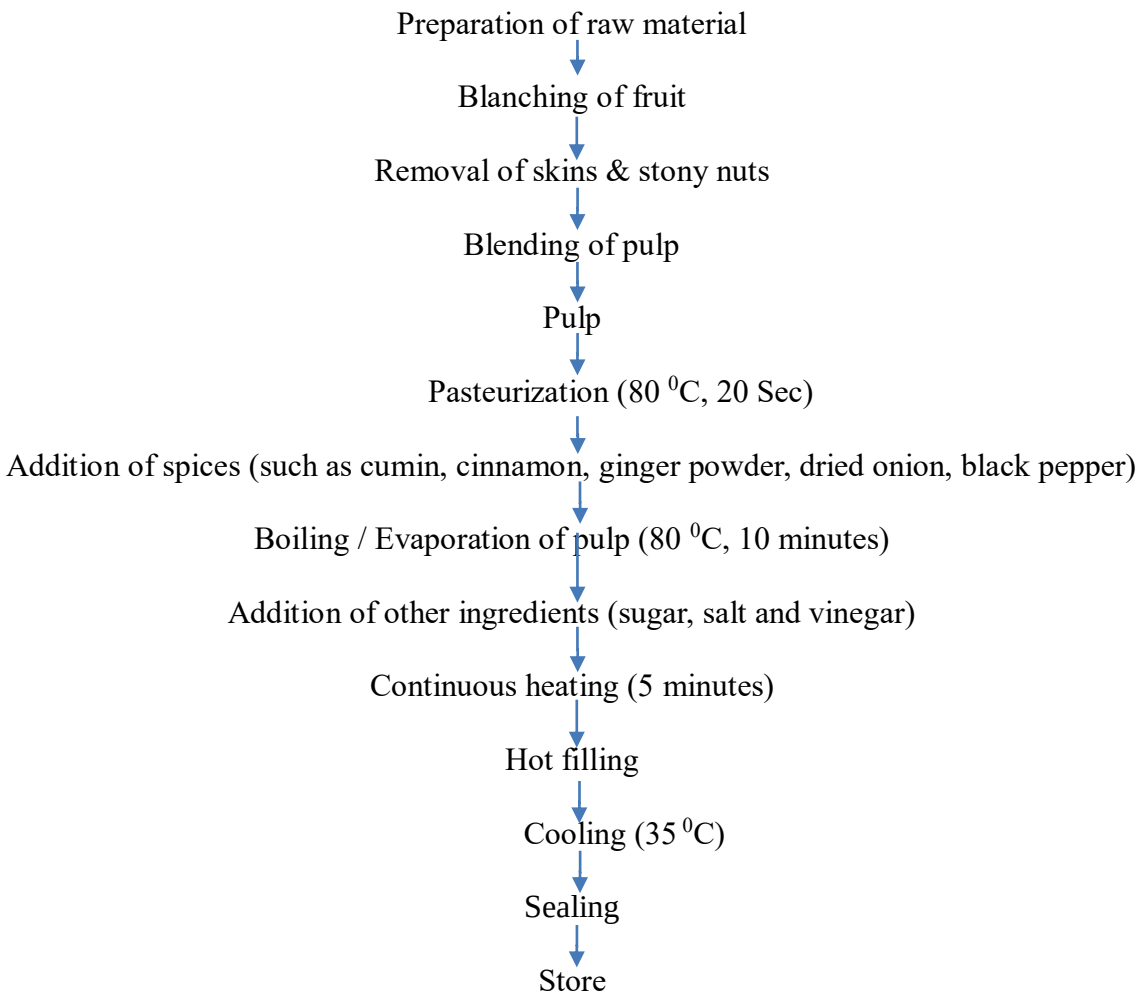

Figure 1: Flowchart for the Production of Ketchup
Source: (Modified from Azam-Ali, 2008)

Five different blend ratios were evaluated in this study:

(TPK): 100% tomato: 0 % *Spondias mombin*
(HPK): 0% tomato: 100% *Spondias mombin*
(THK): 90% tomato: 10% *Spondias mombin*
(HTK): 80% tomato: 20% *Spondias mombin*
(TKP): 70% tomato: 30% *Spondias mombin*

Determination of Physicochemical Properties

pH

The pH of the Ketchup was measured on weekly basis and readings were taken directly using a pH meter. Five grams of sample was dissolved in 50cm^3 distilled water in a beaker and vigorously mixed. The pH of the solution was then taken after the pH meter had been standardized with buffer solutions of pH 4 and 7 (Ibitoye, 2005).

Total Titratable Acidity (TTA)

The Total Titratable acidity was determined using the method described by AOAC (2002). Briefly, ten grams (10 g) of sample was weighed in a clean beaker and 25cm^3 of distilled water was added to it to make a solution. The solution was filtered using Whatman filter paper and 1ml of the filtrate was titrated with 0.1 M NaOH using 2 drops

of phenolphthalein indicator. Titratable acidity was expressed as percentage citric acid.

$$\textbf{Weight of citric acid} = \frac{\textbf{M x V x F}}{\textbf{3}}$$

Where;
V* = *volume of 0.1M NaOH used,
M* = *molarity of NaOH
F* = *factor of citric acid (192.43)

That is:

$$Weight\ of\ citric\ acid = \frac{\textbf{0.1}\boldsymbol{M\ NaOH\ x\ volume\ of\ NaOH\ (litre)\ x\ 192.43}}{\textbf{3}}$$

$$\%\ \textbf{TTA} = \frac{\textbf{Weight of citric acid x 100\%}}{\textbf{Weight of Sample}}$$

Total Soluble Solids (TSS)
The total soluble solids determination was according to Owoso, *et al.* (2000). The glass slide of the refractometer (Bellingham and Stanley Refractometer) which ranged between 0 – 40 and 40 – 85, was cleaned with water and dried with a clean napkin. The sample was smeared on the slide of the refractometer and the lid was replaced. The reading was taken on the graduated mark and recorded in degree brix (^{0}Brix)

Ascorbic Acid Content
For the determination of ascorbic acid content, ascorbic acid solution was made by weighing 50 mg of it into a 50 ml volumetric flask and made up to mark with oxalic acid solution (0.4 %). This solution was kept in a cool place for 24 hrs before use. Dye to be used as titrant was also made by dissolving 50 mg of 2, 6, Dichlorophenol indophenol dye and 42 mg sodium bicarbonate($NaHCO_4$) in a beaker using distilled water. The solution was filtered and volume made up to 250 ml, stored in a clean bottle and placed in a cool place. Five (5) mL of the prepared standard ascorbic acid solution in a conical flask was titrated against dye solution till light pink colour persisted for 15 seconds

Dye factor (f) =

$$\frac{\textbf{ml of ascorbic acid solution taken}}{\textbf{Volume of dye used}}$$

Dye factor was determined separately for each determination.
To a 100 mL volumetric flask, 0.5 ml of sample was added and volume was made up to mark with 0.4% oxalic acid solution. 10 mL of this solution was taken into a conical flask and titrated against the dye solution till light pink appeared which persisted for 15 seconds. This was repeated twice and the three readings recorded for each sample (Tariq *et al.*, 2015). Ascorbic acid content was calculated by using the following formula:
Ascorbic acid (mg/100 g) =

$$\frac{\textbf{L x F x 100 x 100}}{\textbf{D x P}}$$

L = Volume of dye (ml) used
F = dye factor
D = WL (g) of sample taken for dilution
P = Volume (ml) of sample taken for dilution.

Microbiological Analysis
Ten gram of each sample was dispersed in 90 ml sterile distilled water. Serial dilutions of 10^{-1}, 10^{-2}, 10^{-3}, and 10^{-4} was prepared by diluting 10 mL of previous dilution to 90 ml of diluent. 1ml each of the 10^{-2} diluent was then pipetted into four separate petri dishes appropriately labelled. Nutrient agar, Potato dextrose agar (PDA) and Eosin methylene blue (EMB) agar were poured into appropriate petri dishes. Sample and agar medium were immediately mixed thoroughly and uniformly and agar allowed to solidify. The nutrient agar and EMB petri dishes was inverted and incubated promptly for 24hrs at 37 ^{0}C while the PDA plates were incubated at 28 ^{0}C (FDA, 2013).

Sensory Analysis

The subjective method of quality evaluation was used to determine: colour, flavor, taste, texture. Sensory properties of the various blend ratios produced were determined after production. Parameters evaluated during the sensory evaluation were colour, taste, aroma, flavor, texture and overall acceptability. This was done by semi-trained panelists, composing of 30 members, selected amongst students and staff of Yaba College of Technology, who knows the quality attributes of ketchup. A ranking test was used to score the samples, using a scale was graduated from 1 representing like extremely and 9 representing dislike extremely. Sample was presented in 3- digits codes and panelist was arranged such that they are independent of each other, the judgements of panelist were converted to numerical values and analyzed using analysis of variances (ANOVA) Version 21(Akinjaiyeju, 2009).

Determination of Colour

The colour of Ketchup was measured objectively using a colourimeter (Model 45/0 LAV, Colour Flex, Firmware VI.32.16.014A) according to the method described by Matthew & Ojo (2013), and the values expressed in terms of L*, a*, b* values. Where L* represent lightness from 0 (black) to 100 (white); a* and b* represent redness (+a) to greenness (-a) and yellowness (+b) to blueness (-b), respectively. Twenty grams (20g) of the ketchup produced was put in clean transparent glass test cup and placed on the sensor rays of light passage of the colour flex and allowed to read through the sample and result was obtained directly from the digital display of the colour flex.

Proximate Composition of Ketchup

Moisture content determination

The determination of the moisture content was according to method described by AOAC (2005). The weights of the petri dishes were determined and recorded. To each petri dish, 5 g sample was weighed and dried in the oven at 105 ± 1 ^{0}C for 4 hours. The samples were then cooled in a desiccator and re-weighed. The moisture content was calculated as follows:

$$\text{Moisture content (\%)} = \frac{\boldsymbol{A-B\ x\ 100}}{\boldsymbol{C}} \quad \ldots\ldots (1)$$

Where:

A – B = represent change in weight

C = Initial weight of the food before drying

Protein content determination

The protein content was determined using micro-Kjedhal method AOAC (2005) by wet digestion, distillation and titration. Protein content was determined by weighing 3 g of the sample into a boiling tube that contains 25 ml concentrated sulphuric acid and one catalyst tablet containing 5 g K_2SO_4, 0.15 g $CuS0_4$ and 0.15 g TiO_2. Tubes were heated at low temperature for digestion to occur. The digest was diluted with 100 ml distilled water, 10 ml of 40 % NaOH and 5 ml $Na_2S_2O_3$, anti-bumping agent was added, and then the sample was diluted with 10 ml of boric acid. The NH_4 content in the distillate was determined by titrating with 0.1 N standard HCl using a 25 ml burette. A blank was prepared without the sample. The protein value obtained was multiplied by a conversion factor, and the result expressed as the amount of crude protein.

Calculation:

$$\textbf{\% crude protein} = \frac{\textbf{Actual titre value} - \textbf{Titre of the blank} \times \textbf{0.1N HCl} \times \textbf{0.014} \times \textbf{Cf} \times \textbf{100}}{\textbf{Weight of sample}} \quad .. (2)$$

Where:

Cf = Conversion factor (6.25)

Fat content determination

Fat content was determined using the method as described by AOAC (2005). Ten grams of the sample was wrapped in filter paper and weighed

using a chemical balance. It was then placed in an extrusion thimble that was previously clean, dried in an oven and cooled in the desiccator before weighing. Then, 25ml of petroleum ether was measured into the flask and the fat content was extracted. After extraction, the solvent was evaporated in the oven. The flask and the content were cooled in a desiccator and weighed.

Calculation:

$$\text{Percentage of Total fat content} = \frac{weight\ of\ fat\ extracted\ x\ 100}{weight\ of\ food\ sample} \quad \ldots\ldots\ldots (3)$$

Crude Fibre Determination

Crude fibre was determined using the method as described by AOAC (2005). Five grams of each sample was weighed into a 500 ml Erlenmeyer flask and 100 ml of TCA digestion reagent was added. It was then brought to boiling and reflux for exactly 40 minutes from the start of boiling. The flask was removed from the heater, cooled a little and filtered through a 15.00 cm whatman paper no.4. The residue was washed with hot water stirred once with a spatula and transferred to a porcelain dish. The sample was dried overnight 150 ^{o}C. After drying, it was a transferred to desiccator and weighed as W_1. It was then burnt in a muffle furnace at 500 ^{0}C for 6 hours, allowed to cool, and reweighed as W_2.

$$\%\ \text{crude fibre} = \frac{W_2 - W_1}{W_0} \quad \ldots\ldots (4)$$

W_1= Weight of crucible + fibre +ash
W_2 = Weight of crucible +ash
W_0 = Dry weight of food sample

Ash content determination

Ash content was determined using the method as described by AOAC (2005). Five (5 g) of each sample was weighed into crucibles in duplicate, and the samples were incinerated in a muffle furnace at 550 ^{0}C until a light grey ash and a constant weight obtained. The samples were cooled in a desiccator to avoid absorption of moisture and weighed to obtain ash content.

Calculation:

$$\textbf{\% Ash} = \frac{(\mathbf{A - B})\ \boldsymbol{x}\ \mathbf{100}}{\mathbf{C}} \ldots (5)$$

Where:

A = Weight of crucible with sample
B = Weight of crucible with ash
C = Weight of sample

Carbohydrate content determination

The carbohydrate content was calculated according to the equation below:

$$NFE = 100 - (M + P + F + A + C_f) \ldots (6)$$

Where:

M = Moisture content
P = Protein content
F = Fat content
A = Ash content
C_f = Crude fibre

Determination of Viscosity

The viscosity of the sample was determined using Rotary viscometer manufactured by NDJ-5S (2009-11) with rotor speed set at 4. The viscosity of samples was determined at a different temperature (37 ^{0}C, 70 ^{0}C, 50 ^{0}C and 30 ^{0}C) respectively, with varying temperatures achieved using water bath. Measurements on the sample were determined at a constant shear rate of 12 r.p.m. 10ml of the sample was used for all measurements. Duplicate sample was analyzed and the viscosity value was then obtained.

Determination of Energy Value

The determination of the energy value was done using a bomb calorimeter. One gram of solid sample was weighed into a crucible and placed inside a stainless steel container filled with 30bar (435 psi) of oxygen. The sample was ignited through a cotton thread connected to an ignition wire inside the decomposition vessel and combusted.

RESULTS AND DISCUSSION

Physicochemical Properties

The physicochemical properties of the ketchup blends ratios are presented in Table 1, 2, 3 & 4 respectively. Samples TPK (100% tomato: 0% Hog plum) was the control. Storage was done for four weeks (week 1, week 2, week 3 and week 4 respectively).

Table 1: Physico-chemical Properties of Ketchup blends (Week 1)

Sample	TTA %	Ascorbic Acid (mg/100 g)	pH	^{O}Brix
HPK	$47.03^{a} \pm 3.70$	$30.33^{b} \pm 10.69$	$4.00^{a} \pm 0.03$	$60.00^{c} \pm 1.00$
TPK	$29.87^{a} \pm 3.70$	$32.67^{b} \pm 4.04$	$5.46^{e} \pm 0.03$	$46.00^{a} \pm 1.00$
THK	$44.87^{a} \pm 6.45$	$16.33^{a} \pm 4.04$	$5.10^{d} \pm 0.03$	$46.00^{a} \pm 1.00$
HTK	$37.83^{a} \pm 29.05$	$9.33^{a} \pm 4.04$	$5.04^{c} \pm 0.03$	$45.00^{a} \pm 1.00$
TKP	$39.10^{a} \pm 1.21$	$30.33^{b} \pm 4.04$	$4.82^{b} \pm 0.03$	$50.00^{b} \pm 2.00$

Values are means of triplicate determinations ± standard deviation, different superscripts within the same column are significantly different at 5% level of significance

Table 2: Physico-chemical Properties of Ketchup blends (Week 2)

Samples	TTA %	Ascorbic (mg/100 g)	pH	Brix
HPK	$10.67^{ab} \pm 3.70$	$9.33^{a} \pm 4.04$	$3.46^{a} \pm 0.03$	$60.00^{c} \pm 2.00$
TPK	$14.36^{b} \pm 4.28$	$7.00^{a} \pm 0.00$	$4.59^{d} \pm 0.03$	$45.00^{a} \pm 2.00$
THK	$10.67^{ab} \pm 3.70$	$7.00^{a} \pm 0.00$	$4.10^{b} \pm 0.03$	$46.00^{a} \pm 0.50$
HTK	$6.40^{a} \pm 0.00$	$7.00^{a} \pm 0.00$	$4.16^{c} \pm 0.03$	$44.00^{a} \pm 2.00$
TKP	$10.67^{ab} \pm 3.70$	$11.67^{a} \pm 4.04$	$4.17^{c} \pm 0.03$	$50.00^{b} \pm 2.00$

Values are means of triplicate ± standard deviation, different superscripts within the same column are significantly different at 5% level of significance.

Table 3: Physico-chemical Properties of Ketchup blends (Week 3)

Samples	TTA %	Ascorbic (mg/100g)	pH	Brix
HPK	145.07^{b} ± 6.87	11.67^{a} ± 4.04	4.18^{c} ± 0.03	57.00^{c} ± 1.00
TPK	32.00^{a} ±0.00	23.33^{b} ± 4.04	2.78^{a} ± 0.03	46.00^{c} ± 1.00
THK	36.97^{a} ± 4.43	16.33^{ab} ± 4.04	4.27^{d} ± 0.03	45.00^{a} ± 2.00
HTK	44.87^{a} ± 6.45	21.00^{b} ± 0.00	4.40^{e} ± 0.03	45.33^{b} ± 2.02
TKP	149.63^{b} ± 14.78	21.00^{b} ± 7.00	3.65^{b} ± 0.03	49.00^{b} ± 1.00

Values are means of triplicate ± standard deviation, different superscripts within the same column are significantly different at 5% level of significance.

Table 4: Physico-chemical Properties of Ketchup blends (Week 4)

Samples	TTA %	Ascorbic (mg/100g)	pH	Brix
HPK	138.67^{c}±9.71	18.67^{ab}±8.08	4.03^{c}±0.03	58.00^{c}±0.50
TPK	25.60^{a}±6.40	23.33^{b}±4.04	2.72^{a}±0.03	46.00^{a}±0.00
THK	34.00^{a} ±3.46	9.33^{a}±4.04	4.17^{d}±0.03	45.00^{a}±2.00
HTK	51.07^{b}±6.50	25.67^{b}±4.04	4.42^{e}±0.03	45.00^{a}±1.00
TKP	155.33^{d}±4.04	11.67^{a}±4.04	3.62^{b}±0.03	48.00^{b}±0.50

Values are means of triplicate ± standard deviation, different superscripts within the same column are significantly different at 5% level of significance.

Total titratable acidity is an approximation of the total acidity of a solution. Titratable acidity is a better predictor of acids impact on flavour than pH (Tyl & Sadler, 2017). The total titratable acidity of samples was observed weekly. No significant ($p \geq 0.05$) difference for all the samples in week 1. The total titratable values ranged from 29.87 to 44.87 %. Sample TPK had the lowest value of total titratable acidity, while sample THK had the highest value of TTA. No significant ($p \geq 0.05$) difference was observed for TTA for all the samples in week 2. Sample HPK had an intermediate value between, sample HTK and sample TPK. Sample THK had an intermediate value between, sample HTK and sample TPK. Significant ($p \leq 0.05$) difference was observed among the samples for TTA, in week 3 with mean score values ranging between 32.00 and 149.63. Sample TPK had the lowest value of TTA, while sample TKP had the highest value of TTA. Significant ($p \leq 0.05$) difference was observed among the samples for TTA, with mean score values ranging between 25.60 and 155.33. Sample TPK had the lowest values of TTA, while sample TKP had the highest values of TTA. The result of total titratable acidity didn't comply with the standard of FDA (2013) which ranges from 0.7 – 1.2. The increases amount of titratable acidity obtained maybe as a result of the raw materials used (Hog plum) which contains high amount of acidity.

Ascorbic (vitamin C) is a natural water soluble vitamin occurring in foods and it is also consumed as dietary supplement. Its presence in food prevents scurvy, slowing down the oxidation thereby preserving colour and freshness of food (Naidu, 2003). Significant difference ($p \leq 0.05$) were observed amongst the samples for ascorbic

acid content in week 1. No significant ($p \leq 0.05$) difference was observed between sample HTK and THK. Samples HPK, TPK, and TKP also had no significant difference between the samples. In the second week (week 2), No significant ($p \geq 0.05$) difference was observed among the samples for ascorbic acid. The ascorbic acid values ranged from 7.0 % to 11.67 %. Sample TKP had the highest value of ascorbic acid while samples HTK, THK, TPK had the same least values of ascorbic acid. No significant difference ($p \geq 0.05$) was observed in week 3 among samples TPK, HTK, and TKP for ascorbic acid, however sample HTK was intermediate of samples THK, TPK, HPK and sample TKP. In the fourth week (week 4), no significant difference ($p \geq 0.05$) was observed among all samples for ascorbic acid values, however sample HPK was intermediate of samples TPK, HTK, TKP and sample HTK. The ascorbic acid values for all samples showed slight reduction except in sample HTK whose vitamin C content increased. The reduction in vitamin C content was due to temperature changes which occurred in the storage atmosphere. The result obtained in this study are similar to the findings of Famurewa *et al.* (2013) who reported that increased temperatures normally results in high percentage loss of ascorbic acid.

The soluble solid is a measure of the refractive index of the paste, depending on the concentration and temperature of solutes in solution. Product quality may attract the buyers but eating quality keeps them, the brix influences the sweetness or taste of a product according to Matthew *et al.* (2013). The soluble solid of the samples was observed weekly for a period of four weeks. No significant difference ($p \geq 0.05$) was observed for brix among samples TPK, THK, and sample HTK in week 1, week 2 and for week 4. In the third week (week 3) there was no significant difference for brix between sample HPK and sample TPK as well as between sample HTK and sample TKP. The results obtained are similar to that of Anandsynal *et al.*, (2018) who reported a brix range of 31-55 (TSS%)

The pH is a measure of active acidity or alkalinity of solution as contrasted with the titratable acidity or alkalinity. Ketchup contains pectin, pectin is more stable at pH of 3.5 therefore, the more the pH value the less viscous the gel. Significant difference ($p \leq 0.05$) was observed for pH in all samples in week 1. The mean score values for pH ranging between 4.00 to 5.46. Sample TKP had the least value of pH, while sample TPK had the highest value. In week 2, no significant difference ($p \geq 0.05$) was observed for pH between sample HTK, and sample TKP. Significant difference ($p \geq 0.05$) was observed for pH in all samples in week 3. The mean score values for pH ranging between 2.78 to 4.40 Sample TPK had the least value of pH, while sample HTK had the highest value. Significant difference ($p \leq 0.05$) was observed for pH in all samples in week 4. The mean score values for pH ranging between 2.72 to 4.42. Sample TPK had the least value of pH, while sample HTK had the highest value. The results obtained in this study are similar to the findings of Famurewa *et al.* (2013) who reported a pH range 3.76 to 4.43 as well as to the findings of Anandsynal *et al.* (2018) who reported a pH range of 3.15 to 4.14, among the parameters analyzed for the assessment of ketchup stating the significance of pH as acidity influences the thermal processing conditions required for producing a safe product.

Proximate Compositions of the Ketchup Blends

The proximate composition of five various compositions of tomatoes and hog plum are represented in Table 5.

Table 5: Proximate properties of ketchup from tomatoes and hog plum

Samples	% Ash	% Fibre	% Protein	% Fat	% CHO	% M.C.
HPK	$9.16^{e}\pm0.01$	$1.84^{e}\pm0.02$	$6.17^{e}\pm0.02$	$4.30^{c}\pm0.27$	$28.79^{e}\pm0.25$	$49.75^{a}\pm0.00$
TPK	$6.95^{b}\pm0.02$	$1.34^{b}\pm0.02$	$4.66^{b}\pm0.01$	$6.63^{d}\pm0.46$	$25.81^{b}\pm0.44$	$54.60^{c}\pm0.01$
THK	$7.48^{d}\pm0.01$	$1.49^{d}\pm0.02$	$5.00^{d}\pm0.01$	$2.83^{a}\pm0.03$	$26.66^{c}\pm0.04$	$56.53^{d}\pm0.01$
HTK	$6.76^{a}\pm0.02$	$1.31^{a}\pm0.02$	$4.44^{a}\pm0.02$	$3.48^{b}\pm0.14$	$24.79^{a}\pm0.12$	$59.20^{e}\pm54.41$
TKP	$7.29^{c}\pm0.00$	$1.42^{c}\pm0.01$	$4.89^{c}\pm0.01$	$4.33^{c}\pm0.20$	$27.65^{d}\pm0.17$	$54.40^{b}\pm0.02$

Values are means of triplicate ± standard deviation, different superscripts within the same column are significantly different at 5% level of significance.

The mean score values obtained for ash content of samples HPK, TPK, THK, HTK, TKP in this study are 9.16, 6.95, 7.48, 6.76, 7.29 respectively. Significant difference ($p\leq0.05$) was observed in all samples for ash content values, the values ranging from 6.76-9.16, sample HTK had the minimum mean score value for ash content while sample HPK had the maximum mean score value. The result obtained for ash content is not in correspondence with previous research findings such as that of Anandsynal *et al.* (2018) who reported ash content value less than 1.5 and Mohie *et al.* (2011) who reported ash content value which of 1.4 ± 0.01.

Presence of fiber in foods help to regulate blood lipids, also preventing cardiovascular diseases. The mean score values obtained for the crude fibre content of samples, HPK, TPK, THK, HTK, TKP in this study were 1.84,1.39,1.49, 1.31, 1.42 respectively. Significant difference ($p\leq0.05$) was observed in all samples for crude fibre values, the mean score values obtained ranged between 1.31-1.84. Sample HTK had the minimum mean score value for crude fibre while sample HPK had the maximum mean score value. The result obtained in this study is similar to the findings of Anandsynal *et al.* (2018) who reported a range of 0.36 – 2.71 for crude fiber content.

The mean score values obtained for the protein content of samples, HPK, TPK, THK, HTK, TKP in this study were 6.17, 4.66, 5.00, 4.44, 4.89 respectively. Significant difference ($p\leq0.05$) was observed between samples for protein content values, the values obtained ranging from 4.44-6.17. Sample HTK had the minimum mean score value for protein content while sample HPK had the maximum mean score value. High protein can be of nutritional importance in developing countries where many people cannot afford food with high protein because of cost (Adegunwa *et al*., 2014).

The mean score values for fat samples, HPK, TPK, THK, HTK, TKP in this study were 4.30, 6.63, 2.83, 3,48, 4.33 respectively. The mean score values for fat obtained ranged between 2.83 and 6.63 with the sample THK having the minimum mean score value and sample HPK having the maximum mean score value. No significant ($p\geq0.05$) difference was observed between samples HPK and TKP in this study.

Mean score values for carbohydrate obtained for samples, HPK, TPK, THK, HTK, TKP in this study were 28.79, 25.81, 26.66, 24.79, 27.65 respectively. The values obtained ranged between 24.79 and 28.79 with the sample HTK having the minimum mean score value and sample HPK having the maximum mean score value. No significant ($p\geq0.05$) difference was observed for carbohydrate between sample treatments for ketchup in this study. The result of carbohydrate obtained is slightly higher, but closely related to the findings obtained by Mohie *et al.* (2011) in who reported carbohydrate value of 22.7±0.3.

The shelf stability of a product is a function of the moisture content (Khubber *et al.*, 2020). The mean score values obtained for moisture content of samples, HPK, TPK, THK, HTK, TKP in this study were 49.75, 54.60, 56.53, 59.20, 54.40 respectively. Significant difference ($p \leq 0.05$) was observed between samples for moisture content, the values obtained ranged between 49.75 and 59.20. Sample HPK had the least mean score value, while sample HTK had the maximum mean score value. The result obtained for moisture is similar to the findings of (Petrotos & Gerasopoulos, 2022).

Viscosity

Viscosity is the property of a fluid which opposes the motion between two surfaces of the fluid that are moving at different velocity. For week 1, significant difference ($p \leq 0.05$) was observed for viscosity between samples during storage. The mean score values for viscosity ranged between 6750.0 mPa and 17957.0 mPa. Sample TKP had the least mean score value of viscosity while sample HPK had the highest mean score value for viscosity. In the second week (week 2), significant ($p \leq 0.05$) difference was observed among all the samples for viscosity, the viscosity ranged from 6050.0mP to 14100.0mP. Sample HPK had the minimum mean score value of viscosity while sample HTK had the highest mean score value. No significant ($p \geq 0.05$) difference was observed in all samples for the mean score values of viscosity in week 4, the viscosity ranged between 7250.0mP and 11250.0mP. Sample HPK had the minimum mean score value of viscosity while sample HTK had the maximum mean score value. Also for week 4, no significant ($p \geq 0.05$) difference was observed in all samples for viscosity, the values ranged between 7,000.0mP and 11,500.0mP Sample HPK had the least mean score value of viscosity while sample THK had the highest mean score value for viscosity.

The viscosity level for sample TPK varied. While for sample HPK the results showed a drastic reduction in the level of viscosity after which a little increase was observed in week 3 then a slight rise in week 4. The trend for sample THK showed a gradual increase in viscosity during the storage period. Sample HTK showed a rise in viscosity level in week 2 then a reduction in week 3 and a slight increase in week 4 while sample TKP showed a fall and rise in the level of viscosity during the storage period. The viscosity of fluid food product is a physical property as well as a textural parameter which is relevant to the quality of food product such tomato paste and ketchup (El-Desouky, 2010). Some of the parameters that contributes to flow behavior of tomato ketchup are the raw materials used and its processing conditions (Bayoda *et al.*, 2008). The results of viscosity obtained is similar to the standard of viscosity of ketchup that ranged between 50,000 – 70,000cp (Divina *et al.*, 2017).

Sensory Evaluation

The sensory evaluation scientifically analyses and measures human responses and perceptions of food and drinks e.g. appearance, touch, odour, texture, temperature and taste. The colour for sample HPK was significantly ($p \geq 0.05$) different between the samples for colour. The colour mean score values ranged between 2.47.0 and 4.10.0. Sample THK had the least mean score value for colour while sample HPK had the highest mean score value. No significant ($p \geq 0.05$) difference among all samples for mean score value of aroma. No significant ($p \geq 0.05$) difference was for Texture, for mean score values of texture in all samples as well as that of taste. There was no significant ($p \geq 0.05$) difference observed between the samples for mean score values of overall acceptability, sample TPK, however had an intermediate mean score value for overall acceptability between sample HPK and sample THK.

Table 6: Sensory Evaluation of Ketchup produced from Tomato and Hogplum

Samples	Colour	Aroma	Texture	Taste	Acceptability
HPK	4.10^{b}±2.14	4.00^{a}±1.53	4.23^{b}±2.19	4.97^{b}±2.20	4.43^{b}±1.76
TPK	3.03^{a}±1.25	3.60^{a}±1.67	3.37^{ab}±1.67	4.03^{ab}±2.34	3.80^{ab}±1.88
THK	2.47^{a}±1.20	3.33^{a}±1.56	3.27^{a}±1.34	3.50^{a}±1.53	3.43^{a}±1.74
HTK	2.67^{a}±1.35	3.23^{a}±1.55	3.40^{ab}±1.48	3.43^{a}±1.85	3.47^{a}±1.43
TKP	2.50^{a}±1.66	3.60^{a}±1.94	3.20^{a}±1.88	3.47^{a}±2.13	3.20^{a}±1.99

Values are means of triplicate ± standard deviation, different superscripts within the same column are significantly different at 5% level of significance.

Energy Value Determination

There was no significant ($p \geq 0.05$) difference between samples THK, HTK and TKP. Sample HPK had the maximum mean score value of 12.90 and sample TPK having a minimum mean score value of 12.02. The determination of energy value is important for nutritional labelling. The growing trend of obesity is major concern of the government particularly in the young. The knowledge on general calorie intake and food labelling is seen as a method for combating obesity in many national strategies (Ledikwe *et al.*, 2005).

Colour

Table 7 shows the result of the colour analysis of the tomato and Hogplum composites blends. No significant difference was recorded between the "L" values (23.88) of sample THK (90-10) and (23.90) of sample TKP (70-30). Degree of lightness is represented by 'L' values, sample HTK (80-20) was observed to be the lightest ('L' = 25.67). The result obtained above is similar to the findings of Mohie, *et al.* (2011) who reported a value of 25.26 ± 0.0552 for "L" value in his study.

The degree of redness was represented by "a" values. A significant difference ($p \leq 0.05$) was observed for all the "a" values of the samples. Sample TPK (100% tomato ketchup) recorded the highest "a" value (27.57), while sample HPK (Tomatoes Hogplum 0:100% ketchup) recorded the least "a" value (19.66). The result obtained for "a" is similar to the findings of Mohie *et al.*, (2011) who reported a value of 36.11±0.23 in his research work "Fourier Transformation Infrared Spectroscopy for Quality Assurance of Tomato products"

The "b" value represented the degree of yellowness. A significant difference ($p \leq 0.05$) was observed among all sample. The "b" value was observed to increase with corresponding increase in hog plum substitution level in tomato. A decline (30.27) was observed in "b" value for THK (90-10 Hog plum, tomato ketchup). Sample HTK (80-20 hog plum, tomato ketchup) had the highest "b" mean score value of degree of yellowness.

ΔC refers to Chroma and it represented the perceived strength of a surface colour. It also implies the colourfulness of an object relative the brightness of a white object similarly illuminated. The Chroma value range between 38.2 and 42.89. The Chroma value was observed to increase with corresponding increase in hog plum substitution level in tomato. A decrease (41.65) was however observed for sample TKP (70 – 30 Tomato, Hog plum ketchup). Sample HTK 80 – 20 has the highest Chroma value (42.89)

The total colour intensity was represented by ΔE. Colour intensity value was observed to increase with corresponding increase in hog plum substitution level. There was an increase and decrease in colour intensity value for all sample and this ranged between (45.06-49.99) with sample HTK 80-20

(Tomato, Hog plum ketchup) recording the highest mean score value of colour intensity

Hue Angle

Hue angle refers to the degree to which a stimulus can be described as similar to or different to stimuli that are described as red, green, blue and yellow.

The hue value range between 49.04 – 60.55. Hue value was observed to increase in corresponding increase in substitution level with sample TKP 70 – 30 (hogplum, tomato ketchup) having the highest mean score value of substitution for hue angle 55.24.

TABLE 7: Results colours of tomato and hog plum ketchup

CODE/ PARAMETERS	HPK	TPK	THK	HTK	TKP
L	23.48	23.79	23.88	25.67	23.90
a	19.66	27.57	23.33	24.85	23.75
b	34.81	31.75	30.27	34.96	34.22
a^2	386.52	760.10	544.29	617.52	564.06
b^2	1211.74	1008.06	916.27	1222.20	1171.0
Chroma (ΔC)	39.98	42.05	38.22	42.89	41.65
Colour intensity (ΔE)	46.36	48.31	45.06	49.99	48.02
Hue angle	60.55	49.04	52.37	54.60	55.24

Legend: "L" value represented the degree of Lightness**;** "a" value represented the degree of redness**;** "b" value represented the degree of yellowness

Microbial Population of Samples

As shown in Table 8, The total plate count for the samples immediately after pasteurization yielded no colonies. However, at week four, the total plate counts ranged between 10 – 250 colonies.

All the products except TPK fell below the maximum acceptable viable count limit of 10 colonies (DMS, 2018). It was noted that the lower the tomato proportion in the blend, the higher the level of contaminants recorded. The yeast count ranged between 0 – 500 colonies, mould count ranged between 200 – 900 and coliform count ranged below 0 – 330 count. All these fell below the acceptable level permissible in tomato sauce and ketchup (DMS, 2018).

Table 8: Microbial Analysis of Ketchup from Tomato and Hog plum

Sample	Total count 10^{-2} cfu/g	Yeast 10^{-2} cfu/g	Mould 10^{-2} cfu/g	Test for coliform 10^{-2} cfu/g
TPK	**0.1**	**0**	**2**	**1.3**
THK	**1.2**	**2**	**6**	**0.1**
TKP	**2.5**	**5**	**9**	**3.3**
HPK	**0.2**	**1**	**4**	**0.3**
HTK	**1.7**	**3**	**3**	**0**

Legend: cfu/g = colony forming unit/g

4.0 CONCLUSION

The result of this study revealed that hog plum is a good source of essential nutrient and antioxidant. It also proved that hog plum can be utilized and developed into a variety of product like ketchup. This study revealed that, ketchup made from hog plum is a rich source of vitamin C, protein, and energy but poor in taste in terms of sensory attribute. The proximate composition, sample HPK (100 % hog plum: 0 % tomato) had the least moisture content (inferring a better shelf stability), highest protein content, crude fibre (good aid for digestion) as well as highest carbohydrate (good source of energy) and ash content. The microbial shelf life study at week four showed that the tomato: hog plum blend products did not meet up with permissible limit indicating a short shelf life.

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HEAVY METALS PRESENCE IN STREET DUST OF IKEJA AREA OF LAGOS - STATE, SOUTHWESTERN - NIGERIA.

***Ojiodu C.C. , Eruola, A. O., Chinweoke, N. L., Haruna, A. D., and Jesse, W. A.**

Department of Chemical Sciences, Yaba College of Technology, Yaba- Lagos.

Corresponding Author: *Ojioduchekwube@yahoo.com*

ABSTRACT

This research reports the results of Heavy metals content of Street dust in Ikeja Area of Lagos state. The dust samples were collected randomly four times a month August - December, 2021 at ten different locations in Ikeja Area. Samples were obtained by sweeping surface dust into plastic waste packer using plastic brush and transferred into pre-labeled polythene bags. The samples collected at each location were filtered through 75 µm stainless steel sieve, weighed and digested with appropriate amount of HNO_3 and H_2O for 2 hours. The concentrations of Heavy metals were analyzed using using Atomic Absorption Spectrophotometer (AAS) PG - 990. Results of the analysis showed that the percentage contribution of each Heavy metal at Ikeja Area were: Zn - 62.12 %, Pb - 26.47 %, Cu- 8.34 %, Ni - 2.23 % and Cd - 0.84 % . The most abundant pollutant Heavy metal was Zn - 2445.53 mg/kg while the least was Cd - 33.1 mg/kg. The most polluted site is Ikeja Industrial Area (ll) - 654.48 mg/kg while the least polluted site is Ayodele Diyan Street (AL)- 150.50 mg/kg with percentage contributions 16.60 % and 3.82 % respectively. The sequence and distribution follows the pattern : Zn > Pb > Cu > Ni > Cd . There is a significant difference in the levels of each heavy metal in the dust of Ikeja (P_v < 0.05). The concentration of Heavy metal obtained exceeded the recommended limits of the Federal Ministry of Environment (FME), European communities (EC) and United Nations Environmental Programme (UNEP) permissible level for Heavy metals in the dust suggesting that the study area is polluted.

KEYWORDS: Dust, Environment; Atomic Absorption Spectrophotometer (AAS), Significant difference (SD).

INTRODUCTION

The presence of Heavy metals (Zn, Pb, Ni, Cu and Cd) in the environment beyond the acceptable limits is a serious concern to the environmentalists. Dusts are fine solid particles. It consists of particles in the atmosphere from various sources such as soil, dust lifted by wind and pollutions. Street dust is a fine powder inform of fine sand or earth which can be found in the street. Direct inhalation of the fine dust by people traversing the streets and those residing in the vicinity could be by ingestion through hand-to-mouth, eating poorly washed fruits and vegetables and dermal exposure are the routes of human exposure to road dust (Lorenzo *et al.*, 2011). Street dust being a useful indicator of environmental quality in urban area was used to determine heavy metals in street dust.(Amato *et al.*, 2009; Lu *et al.*, 2010). Street dust contamination has received much attention in recent years (Sezgin *et al.*, 2004; Jiries (2003)). The term Heavy metal may refer to any metallic substance with relatively high density and such a substance is toxic at low concentrations. Although, Heavy metals are naturally occurring elements that are found in the earth's crust, most environmental contamination and domestic and agricultural use of metals and metal-containing compounds (Herawati *et al.*, 2000 and He *et al.*,2005). Examples of heavy metals

include inc(Zn), Nickel (Ni),Copper (Cu), M*ercury* ***(Hg),*** Cadmium ***(Cd)*** **,** Chromium ***(Cr),*** Thallium ***(Tl),*** ***and*** Lead ***(Pb*)**. Heavy metals are group of non-biodegradable pollutants. They are not readily detoxified and removed by metabolic activities once they are available in the environment. This may subsequently lead to their buildup to toxic levels or bioaccumulation in the ecosystem (Lawal *et al.,* 2011). Heavy metals are natural components of the earth's crust. Reported source of heavy metals in the environment include geogenic, industrial, agricultural, pharmaceutical, domestic effluents, and atmospheric source (He *et al.,* 2005). They cannot be degraded or destroyed. Heavy metals are dangerous because they tend to bio-accumulate (Bawuro *et al.,* 2018). To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g Copper, Lead, Zinc) are essential to maintain the metabolism of the human body.

However, at higher concentrations they can lead to poisoning. Heavy metals can thus penetrate into the human body and pose a great threat to human (Aeolian *et al.,* 2008; Lu *et al.,* 2010). Anthropogenic activities release significant amount of harmful pollutants such as heavy metals, the presence of which above the threshold limits in the atmosphere poses adverse ecosystem and human health threats (Wolterbeek, 2002). For example, human exposure to heavy metals can result in a variety of negative health effects such as cancer and kidney disorder (Itoh *et al.,* 2014; Lin *et al.,* 2013**).** Heavy metals in street dust may originate from anthropogenic sources such as petroleum, diesel and coal combustion, as well as industrial activities and natural geochemical processes such as weathering (Liu *et al.*,2007; Mostafa *et al.,* 2009). Some heavy metals are nutritionally essential for a healthy life whereas large amounts of any of them may cause acute or chronic toxicity (Coen *et al.,* 2001). However, some others (like As, Cd, Pb, and methylated forms of Hg) have been reported to have no known bio - importance in human biochemistry and physiology and consumption even at very low concentrations can be toxic (Jomova and Valko, 2010). Although, there are enormous studies on the levels of Heavy metals on Street dust in the world (Kui, Cai and Chang, Li (2019), Lu *et al.,* 2010; Ahmed *et al.*,2015, Faiz *et al.*,2009; Al – Khashman (2004) & (2007); Addo *et al.,* 2012) but currently there are little or no literature on Heavy metals on Street dust in Lagos State, particularly in Ikeja Area. Therefore, the main objectives of the present study were to : (1) assess and evaluate the levels of Heavy metals on Street dust of Ikeja Area (2) determine the baseline levels of Heavy metals (3) determine whether there are significant differences in the levels of Heavy metals in each of the study areas. It is hopeful that this study will provide the percentage contributions of each Heavy metal to pollution in Ikeja.

Table 1 : Sampling sites, Characteristics and their Coordinates in Ikeja Area.

LOCATION/ SITES	CODE	LATITUDE	LONGITUDE	SITE DESCRIPTION
Ojulowo street	OS	N6.59644	E3.3412	It is a residential area with a micro finance bank, carpentry, spraying and painting workshops. Smoking of cigarette and marijuana is also prominent on this street.
Abeokuta street	AS	N6.59876	E3.33924	It is a residential Area with low human activity.
Oyelola street	OYS	N6.59793	E3.33719	It is a residential area with high commercial activities, there are Mechanic workshops.
Awolowo road	AR	N6.59607	E3.33853	It is a major road with high commercial activities such as sales of cellular phone stores, fast food joints, Car spare parts shops and high vehicular activities.
Ikeja under bridge	IUR	N6.59644	E3.3412	It is a major road with high commercial activities such as sales of cellular phone stores, fast food joints, spare part stores, hairdressing salons and vehicular activities and smoking is also prominent under bridge.
Agege Motor road	AMR	N6.59547	E3.33583	It is an major express road with high commercial and vehicular activities.
Ladipo Oluwole street	LOI	N6.61489	E3.34084	It is an industrialized area with industries such as Mouka foam, Chelsea gin, pure water production lots of ware houses.
Oba Akran road	OAI	N6.61027	E3.33603	It is an industrialized area with industries such as Dangote, Newbisco, Nigerite, textile production companies, vita foam, Guinness and lots of banks and high vehicular activities
Ayodele Diyan street	AI	N°6.6132	E°3.34174	It is an industrial area with no commercial activities
Ikeja Industrial area	II	$N^0$6.61104	$E^0$3.33761	It is an industrialized area with most industries.
YCT Botanical garden (control)	BG (CTL)	$N^0$6.51626	$E^0$3.37369	There is little or no Anthropogenic activity. A site where different agricultural crops and plant are grown.

MATERIALS AND METHOD

Selection of Sampling Sites

The eleven sites including the control site were carefully chosen based on accessibility, availability of open spaces and of course area with maximum influence from anthropogenic activities such as vehicular traffic density, human activities as well as industrial activities. The geo-referencing was carried out by using GPS MAP 76S (Garmin).

Sampling Location

The study was conducted in the following areas of Ikeja (N°6.61489 and E°3.34174 - N°6.59547 and E^0 E°3.3363) Lagos State which include the residential areas : Ojulowo street (OS), Abeokuta street (AS) and Oyelola street(OYS) ; Major roads - Agege motor road (AMR), Awolowo way (AR) and Ikeja under bridge (IUR) and Industrial Areas - Ladipo Oluwole Street
LOI), Ayodele diyan street (AI), Oba Akran Industrial Area (OAI) and Ikeja Industrial Area (II).

Sample Collection

Dust samples were collected from eleven sites within the study area, at least 100m apart, four times a month from August to December, 2021. Samples were collected in the morning while the dust has settled well throughout the night and before heavy morning traffic movement that can disrupt the dust. The samples were randomly collected from both sides of the road by sweeping surface dust into plastic waste packers using plastic brush and transferred into pre- labeled polythene bag. All irrelevant materials such as cigarette ends, papers, plastics etc. were carefully hand-picked. Thereafter, samples collected at each location were filtered through 75µm stainless steel sieve. The samples were then taken to the laboratory for further treatment and analysis.

PREPARATION AND ANALYSIS OF ROAD SIDE STREET DUSTS

Digestion of dust Samples for Heavy Metals

2.0g of sieved dust was weighed using an analytical balance and transferred into a conical flask for digestion. 30ml nitric acid and 10ml concentrated hydrochloric acid prepared in the ratio 3:1 was added. The solution was mixed thoroughly and heated on magnetic heated stirrer, then refluxed at 90ºc for 20minutes. After the disappearance of brown fumes, the digested solution was cooled and then filtered through Whatman type 589/2 filter paper. The filtrate was diluted to 50cm^3 with de-ionized water. The metal contents in the filtrate were determined using an atomic absorption spectrophotometer (AAS) PG-990.

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 20.0 Results were expressed as mean ± standard deviation. Student t-test and ANOVA was used to test for the difference in mea values between groups**.**

Table 2: Heavy metals content in street dust from Industrial Areas in Ikeja (mg/kg).

Locations	Pb Mean ± SD	Zn Mean ± SD	Cu Mean ± SD	Cd Mean ± SD	Ni Mean ± SD
IUR	50.81 ± 0.12^{c}	173.51 ± 13.18^{b}	23.94 ± 4.77^{b}	2.97 ± 0.80^{b}	6.73 ± 1.18^{b}
AMR	39.96 ± 2.48^{b}	343.59 ± 16.15^{d}	38.67 ± 2.82^{c}	2.31 ± 0.43^{b}	7.52 ± 0.84^{b}
AR	93.33 ± 2.45^{d}	214.86 ± 4.17^{c}	15.91 ± 2.05^{b}	0.07 ± 0.03^{a}	7.75 ± 0.15^{b}
C	0.95 ± 0.46^{a}	3.43 ± 0.23^{a}	0.74 ± 0.06^{a}	0.04 ± 0.00^{a}	0.04 ± 0.01^{a}
F – Statistics	$F_{3,8} = 466.132$; $p < 0.001$	$F_{3,8} = 174.487$; $p < 0.001$	$F_{3,8} = 28.737$; $p < 0.001$	$F_{3,8} = 11.205$; $p = 0.003$	$F_{3,8} = 25.473$; $p < 0.001$

NB: Industrial areas with the same superscript across heavy metals are not significantly different at 5%

Table 3: Heavy metals content in street dust from Major roads in Ikeja (mg/kg).

Locations	Pb Mean ± SD	Zn Mean ± SD	Cu Mean ± SD	Cd Mean ± SD	Ni Mean ± SD
OAI	101.36 ± 5.89^{a}	476.12 ± 5.89^{d}	44.60 ± 5.89^{c}	1.19 ± 0.01^{c}	12.39 ± 0.69^{d}
II	378.60 ± 69.40^{b}	217.32 ± 11.66^{c}	25.05 ± 1.85^{b}	22.96 ± 0.12^{d}	10.54 ± 0.69^{cd}
AI	20.99 ± 4.46^{a}	98.73 ± 0.69^{b}	19.05 ± 0.12^{b}	0.86 ± 0.01^{b}	9.12 ± 0.69^{bc}
LOI	55.63 ± 0.64^{a}	206.23 ± 5.89^{c}	37.41 ± 0.69^{c}	0.15 ± 0.01^{a}	7.61 ± 0.69^{b}
C	0.95 ± 0.46^{a}	3.43 ± 0.23^{a}	0.74 ± 0.06^{a}	0.04 ± 0.00^{a}	0.04 ± 0.01^{a}
F – Statistics	$F_{4,10} = 24.373$; $p < 0.001$	$F_{4,10} = 761.668$; $p < 0.001$	$F_{4,10} = 37.623$; $p < 0.001$	$F_{4,10} = 37087.285$; $p < 0.001$	$F_{4,10} = 58.937$; $p < 0.001$

NB: Industrial areas with the same superscript across heavy metals are not significantly different at 5%

Table 4: Heavy metals content in street dust from Residential Areas in Ikeja (mg/kg).

Locations	Pb Mean ± SD	Zn Mean ± SD	Cu Mean ± SD	Cd Mean ± SD	Ni Mean ± SD
OS	99.91 ± 1.06^{c}	221.3 ± 0.56^{c}	17.08 ± 0.19^{b}	0.59 ± 0.06^{b}	6.49 ± 0.41^{b}
OYS	39.28 ± 0.38^{b}	224.75 ± 0.84^{c}	74.41 ± 1.42^{d}	1.57 ± 0.05^{c}	9.94 ± 0.51^{c}
AS	162.03 ± 1.44^{d}	119.88 ± 43.68^{b}	32.86 ± 0.70^{c}	0.71 ± 0.31^{b}	10.00 ± 0.36^{c}
C	0.95 ± 0.46^{a}	3.43 ± 0.23^{a}	0.74 ± 0.06^{a}	0.04 ± 0.00^{a}	0.04 ± 0.01^{a}
F – Statistics	$F_{3,8} = 5605.463$; $p < 0.001$	$F_{3,8} = 22.928$; $p < 0.001$	$F_{3,8} = 1577.788$; $p < 0.001$	$F_{3,8} = 158.023$; $p = 0.001$	$F_{3,8} = 25.473$; $p < 0.001$

NB: Residential areas with the same superscript across heavy metals are not significantly different at 5%

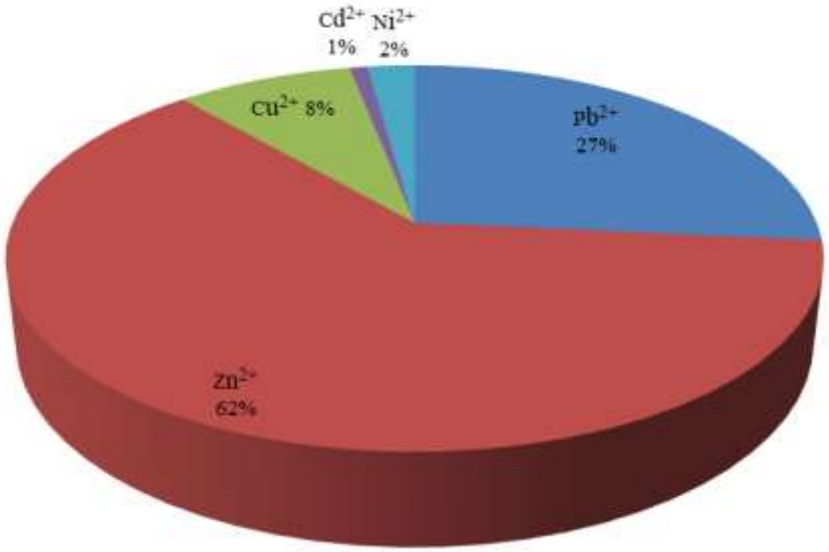

Figure 1: Percentage contribution of Heavy Metals in Ikeja Area

Table 5: *Mean concentration of Heavy metals in street dusts of Ikeja and other selected cities of the world (mg/kg).*

CITY	Pb	Zn	Cu	Cd	Ni
Ikeja (this study)	**104.37**	**244.95**	**32.90**	**3.31**	**8.81**
Ottawa (Rasmussen *et al.*, 2001)	68.00	184.00	188.00	19.00	0.60
Madrid (De Miguel *et al.*, 1997)	1927.00	476.00	188.00	144.00	-
Oslo (De Miguel *et al.*, 1997)	180.00	412.00	123.00	41.00	1.40
Mutah (Manasreh *et al.*, 2010)	143.00	132.00	69.00	1.70	1.30
London(Schwar *et al.*, 1988)	1030.00	680.00	155.00	-	3.50
Kuala Lumpur (Ramlan *et al.*, 1988)	2466.00	344.00	35.50	-	2.90
Birmingham(Charlesworth *et al.*, 2003)	48.00	534.00	466.90	41.10	1.60
Amman((Jiries (2003))	976.00	401.00	249.60	16.30	1.10
Kavala(Christoforidis *et al.*, 2009)	386.90	354.80	172.40	67.90	0.20
Tehran (Mohsen *et al.*, 2012)	257.40	873.20	225.30	10.70	34.80

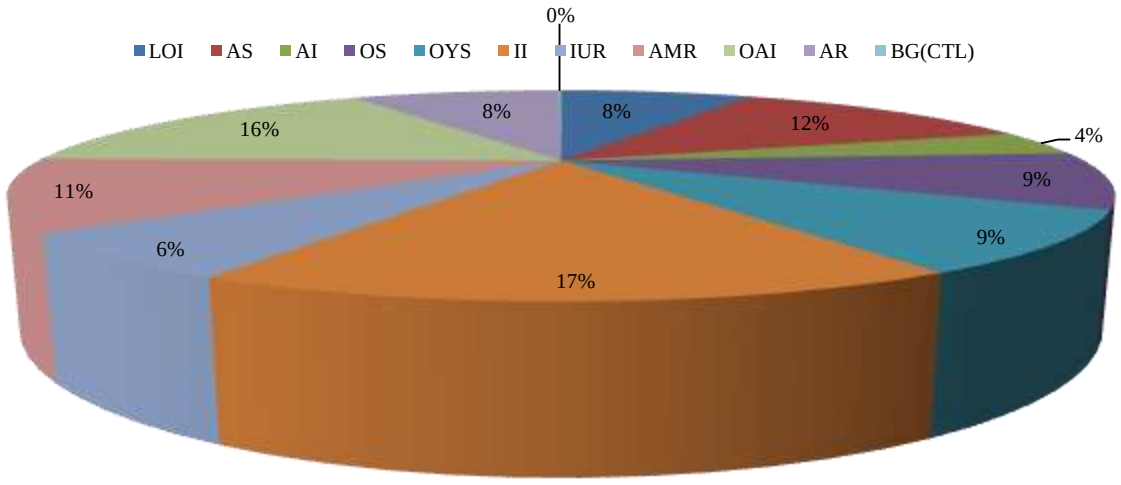

***Figure 2:** Percentage contribution of each site to pollution in the study Area.*

Figure 3: *GIS Map showing the levels of Heavy metals in Ikeja Area.*

RESULTS AND DISCUSSION

Table 6: Mean Concentration of Heavy Metals (mg/kg) of all the sites in Ikeja Area for August - December, 2019.

Sample Location/ Sites	Pb	Zn	Cu	Cd	Ni	Total	Percentage %
LOI	55.70	206.23	37.41	0.155	7.61	307.09	7.78
AS	162.03	273.11	32.86	0.44	10.00	478.43	12.13
AI	22.38	98.73	19.05	0.86	9.12	150.50	3.82
OS	99.915	221.30	17.08	0.59	6.49	345.37	8.76
OYS	39.30	224.75	74.41	1.57	9.94	349.97	8.87
II	378.60	217.32	25.05	22.96	10.54	654.48	16.60
IUR	50.81	173.51	23.94	2.97	6.73	257.95	6.54
AMR	39.96	343.59	38.66	2.31	7.52	432.05	10.96
OAI	101.36	476.12	44.60	1.196	12.39	635.66	16.12
AR	93.33	214.86	15.91	0.07	7.75	331.91	8.42
BG(CTL)	0.80	3.25	0.57	0.12	0.02	4.77	0.12
Total	1043.73	2449.53	328.97	33.10	88.09	3943.41	
Average	104.3727	244.96	32.90	3.31	8.81		
Percentage %	26.47	62.126	8.34	0.84	2.23		

The most polluted site in Ikeja is Ikeja Industrial Area- 654.48 mg/kg; 16.60 %. This is as a result of anthropogenic activities going in and around the site such as the release of gases from near by industries, fumes from generators and numerous heavy duty vehicles / traffic and commercial activities in and around the site while the least polluted site is Awolowo road 150.50 mg/kg ; 3.82 %. The most abundant heavy metals is Zinc - 2449.53 mg/kg; 62.12 % while the least abundant heavy metal is Cadmium- 33.10 mg/kg ; 0.84 % (Figure 1). This can be attributed to the versatile use of Zinc in form of Zinc oxide present in paints, rubber tyres, cosmetics, pharmaceuticals, wearing of brake lining of vehicules, lossess of oil and cooling liquids from automobile, corrosion of galvanized steels, scrap iron bars, and improper disposal of industrial waste in the area. There is a significant difference in the levels of Zinc metal in Ikeja Industial Area compared to other sites. The highest heavy metals Zn -476.12 mg/kg ; Cu- 44.60 mg/kg and Ni- 2.39 mg/kg were recorded at Oba Akran Industrial site while the highest concentration of Pb - 378.60 mg/kg and Cd - 22.93 mg/kg were recorded at Ikeja Industrial site. The highest presence of lead in Ikeja Industrial site may be due to the high Industrial, commercial, automobile and vehicular activities in the area, spillage of petroleum products, smoking of cigarettes, paint chips from the walls of industrial buildings, careless discards of lead acid batteries used in automotive as well as the use of industrial grade and non-domestic paints by the surrounding industries. The level of Lead in Ikeja Industrial site significantly different ($p < 0.05$) from all other sites. The highest concentration of Copper and Nickel at Oba Akran Industrial site may be due to the manufacturing of electrical cables, mining of metal, production of cans and the use of pesticides, combustion of fossil fuels, smelting of metals, vehicular emission, traffic congestion and industrial processes that uses these metals or their compounds fuel combustion from generators as well as frequent bush burning in that surrounding. The level of Nickel at Oba Akran Industrial site is significantly different from all other sites ($p < 0.05$). At the Industrial Areas, the highest concentration of Zn - 476.12 mg/kg; Cu- 44.60 mg/kg and Ni- 12.39 mg/kg were recorded at Ikeja Industrial Area (II) while the concentrations of Pb-378.60 mg/kg and Cd-22.96 mg/kg were recorded at Oba Akran Industrial Area (OAI) (Table 2). At the Major roads, the highest concentration of Pb - 93.33 mg/kg and Ni- 7.75 mg/kg were recorded at Awolowo road (AR). Similarly, Zn - 343.59 mg/kg and Cd- 2.97 mg/kg were recorded at Ikeja under bridge (IUR) while the highest concentration of Cu - 38.67 mg/kg were recorded at Agege motor road (AMR) (Table 3). At the Residential Areas, the highest concentration of Zn - 224.75 mg/kg; Cu- 74.41 mg/kg and Cd - 1.57 mg/kg were recorded at Oyelola street (OYS) while the concentrations of Pb-162.03 mg/kg and Ni -10.00 mg/kg were recorded at Abeokuta street (AS) (Table 4). There is a significant difference between the levels of Zn, Pb, Cu, Cd and Ni in Industrial, Major roads and Residential Areas ($P_V < 0.05$). There were progressive increase in the level of bioaccumulation of these heavy metals from August to December, 2019. The high significant levels of Zn, Pb and Cu obtained in the samples from Ikeja is an indication of their concentration in the dust while the low concentration of Cadmium Cd and Nickel Ni suggest low contributing factors to their spread and as well as dust inability to preferentially accumulate these metals (Table 6). There is significant variation in the level of heavy metals in the study area. ($P_v < 0.05$) (Table 1).

The pattern of distribution and degree of bioaccumulation of Heavy metal content of Ikeja dust is as follows: Zn > Pb > Cu > Ni > Cd, with the mean concentration of - 244.95, 104.37, 32.90, 8.81 and 3.3 mg/kg respectively (Figure 3). The trend and percentage contribution of each site to pollution of Ikeja dust is as follows: II – 16.60 % > OAI -16.12 % > AS-12.13 % > AMR -10.96 % > OYS - 8.87 % > OS- 8.76 % >AR- 8.42 % > LOI- 7.78 % > IUR- 6.54 % > AL- 3.82 % > BG(CTL) -0.13 % (Figure 2). The result of this research agrees with the results obtained in some Nigerian cities and other cities in the world.

The results also showed that concentration of Heavy metals depends on the nature of activities in the sites (Adie *et. al.* 2014 ; Ekpo *et. al.,* 2012 ; Mohsen *et al.,* 2012; Christoforidis *et al.,* 2009; Lu *et al.,* 2010; Karbassi *et al.,* 2005 ; Ojiodu *et. al.,* 2017; 2018a, 2018b).

Though, the concentrations of Zinc and Nickel in Ikeja dust is high compared to the levels in other cities of the world but Lead , Cadmium and Copper levels are Comparable (Table 5). This may be due to differences in vehicular and human activities (burning / dumping of waste), environmental management policies and technologies employed, frequency of city street cleaning and local meteorological conditions such as rains, temperature, windspeed which can affect the Heavy metals in the dust (Mohsen *et al.,* 2012). The level of heavy metals in the study area were far greater than the recommended limits of the Federal Ministry of Environment (FME), European Communities (EC) and United Nations Environmental Programme (UNEP) permissible level for heavy metals in the atmosphere (EC, 2006).

The concentration of heavy metals in all the sites was higher than the control value(Table 6). This may be due to the fact that the control environment is an area with little or no anthropogenic activity.

CONCLUSIONS

The high levels of Zn - 62.12 %, Pb - 26.47 %, Cu- 8.34 %, Ni - 2.23% and Cd - 0.84 % obtained in the dust samples from Ikeja area could be attributed to the emission originating from gases released from near by industries, wearing of brake lining, lossess of oil and cooling liquids, corrosion of galvanized steels, scrap iron bars, wearing of tyres, improper disposal of sewage, industrial waste, vehicular / commercial activities and industrial processes that uses these metals or their compounds within and around Ikeja area . The low concentration of Cadmiun Cd suggest low contributing factors to their spread and as well as the dust inability to preferentially accumulate this metal. Therefore, there is need for constant environmental Monitoring of the Ikeja due to the high concentration heavy metal pollution which could be very hazardous to human and plants existence.

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ASSESSMENT OF HEAVY- METALS (Zn, Pb, Cu, Ni, Cd) ON STREET DUST: A CASE STUDY OF OSHODI - ISOLO AREA, LAGOS - STATE, SOUTHWESTERN - NIGERIA.

***Ojiodu C.C., Eruola, A. O., Chinweoke, N. L., Haruna, A. D., and Jesse, W. A**
Department of Chemical Sciences, Yaba College of Technology, Yaba- Lagos.
Corresponding Author: *Ojioduchekwube@yahoo.com*

ABSTRACT
This research reports the results of Heavy metals content of Street dust in Oshodi - Isolo Area of Lagos state. The dust samples were collected randomly once a week August - December, 2019 at ten different locations in Oshodi - Isolo Area. Samples were obtained by sweeping surface dust into plastic waste packer using plastic brush and transferred into pre-labeled polythene bags. Samples collected at each location were filtered through 75 µm stainless steel sieve, weighed and digested with appropriate amount of HNO_3 and H_2O for 2 hours. The concentrations of Heavy metals were analyzed using using Atomic Absorption Spectrophotometer (AAS) PG - 990. Results of the analysis shows that the percentage contribution of each Heavy metals at Oshodi - Isolo Area were Zn - 51.52 %, Pb - 36.78 %, Cu- 8.65 %, Ni - 2.79 % and Cd - 0.25 % .The most abundant pollutant Heavy Metals was Zn-1445.43 mg/kg while the least was Cd - 6.99 mg/kg. The most polluted site is Agege-motor road (AGM)-1372.11 mg/kg while the least polluted site is Adewumi Ogefon (ADO)-15.41 mg/kg with percentage contributions 48.91 % and 0.55 % respectively. The sequence and distribution follows the pattern thus: Zn > Pb > Cu > Ni >Cd . There is a significant difference in the levels of each heavy metal in the dust of Oshodi-Isolo ($P < 0.05$). The concentration of heavy metals obtained exceeded the recommended limits of the Federal Ministry of Environment (FME), European communities (EC) and United Nations Environmental Programme (UNEP) permissible level for heavy metals in the atmosphere suggesting that the study area is polluted.

KEYWORDS: Dust, Environment; Heavy metals, Atomic Absorption Spectrophotometer (AAS), Significant C difference (SD)

INTRODUCTION
The quality of air in major cities around the world especially in developing city like Lagos State, Nigeria particularly Oshodi - Isolo Area is rapidly deteriorating as a result of the presence of Heavy metals arising from energy generation, vehicular traffic, combustion of fossil fuel and poor waste management policies. Dusts are fine particles of solid matter. Dust is believe to come from sources such as soil, dust lifted by wind and pollutions. Street dust can be describe as fine powder consisting of small pieces of sand or earth which can be found in the street. Direct inhalation of fine dust by people traversing the streets and those residing in the vicinity could be by ingestion through hand - to - mouth, eating poorly washed fruits and vegetables and dermal exposure are the routes of human exposure to road dust (Lorenzo *et al.*, 2011). Chemical composition of road dust can be used as an indicator for environmental pollution (Han *et al.*, 2006), dust is a valuable medium for characterizing urban environmental quality (Liu *et al.*, 2014), and exposure health risk assessment (Hussain *et al.*, 2015).

Street dust is one of the useful indicator of environmental quality in urban area, which could be used to assess heavy metals and other pollutants in the environment (Amato *et al.*, 2009, Lu *et al.*, 2010). Atmospheric aerosols and their contaminants from anthropogenic sources finally settle on the surfaces by atmospheric dry and / or wet deposition and are then transferred to the

surface of the soil or incorporated into the surface dust.

The chemical contents of the surface road dust and airborne particulates contents and their chemical composition in both road dust and air borne particulates are similar (Liu *et al*., 2007). Vehicle exhaust, tire dust, spillages and leaks from vehicles, road surface erosion material and vegetative plant fragments, garden soil and litter are the sources of deposited surface road side dust (Mostafa *et al*.,2009).

The term Heavy metals could be describe as to include any metal that is poisonous or toxic with a relatively high density. They are usually road traffic source contaminants in the local ecological environments and thus dangerous to public health (Mohsen *et al*., 2012). Heavy metals are natural components of the earth's crust. They cannot be degraded or destroyed. Heavy metals are dangerous because they tend to bio-accumulate (Bawuro *et al.*, 2018).To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g Copper, Lead, Zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metals can thus penetrate into the human body and pose a great threat to human (Aeolian *et al.*, 2008; Lu *et al.*, 2010). Automobile repair workshops release waste products such as engine oil, transmission oil, brake fluid, damaged tires, battery electrolytes, wire carbide, spent batteries and cells into their surrounding areas. Although, there are enormous studies on the levels of Heavy metals on Street dust in the world (Kui, Cai and Chang, Li (2019); Lu *et al.*, 2010; Ahmad *et al.*,2015, Faiz *et al.*,2009; Al - Khashman (2004) and (2007); Addo *et al*., 2012) but currently there are little or no literature on Heavy metals on Street dust in Lagos State, particularly in Oshodi - Isolo Area. Therefore, the main objectives of the present study were to : (1) assess and evaluate the levels of Heavy metals on Street dust of Oshodi - Isolo Area (2) determine the baseline levels of Heavy metals (3) determine whether there are significant differences in the levels of Heavy metals from each of the study area. It is hopeful that this study will provide the percentage contributions of each Heavy metals to pollution in Oshodi - Isolo Area.

Table 1 : Sampling sites, Characteristics and their Coordinates

LOCATION /SITES	CODE	LATITUDE	LONGITUDE	SITE DESCRIPTION
Oshodi road	OSR	N6^0.55609	3.334551E	This is a Major road with high vehicular and traffic emissions. Few garages with lots of abandoned vehicles.
Church street	CHS	N6^0.55609N	3.3451E	It is a Commercial area with high traffic congestion, filling station and vulcanizing activities
Brown street	BRS	N6^0.55912N	3.34877E	This is a Commercial area where traders from different ethnic groups from Nigeria sells foodstuffs and non-edibles like wears, electrical/electronic materials, the market creates lots of traffic bottleneck for motorist and commuters
Shopeju	SPS	N6^0.5680	3.3435E	It is a Residential area with little vehicular emissions, not associated with traffic congestion with fumes from generator from the residents
Adewumi Ogefon	ADO	N6^0.56774	3.34231E	Residential area with no traffic congestion, generator fumes used by all the shops in the area.
Agege motor road	AGM	N6^0.5655	3.3487E	It is a major road; there is traffic congestion in this area with lots of emissions from vehicles. There is lot of filling stations in this area, vulcanizing activities
Ariyibi oke	ARS	N6^0.5610	3.3489E	It is a commercial area with few residents, high traffic congestion especially due to the activities of buyers and sellers, a lot of vehicular emissions and mechanic workshop
Osolo Way	OSW	N6^0.539	3.33241E	Site with nylon and plastic recycling industries, abandoned cars, market and panel beater workshop
Aswani road	ASR	N6^0.54077	3.33405E	An industrial area with industry such as Emzor, there is traffic congestion, spillage of petrol and diesel.
Apapa oshodi express	APE	N6^0.53986	3.33691E	Site with industries such as Chellarams, Nylon company, vehicle emissions, due to vehicular activities.
YCT Botanical garden(control)	BG (CTL)	N6^0.51626	3.37369E	There is little or no Anthropogenic activity. A site where different agricultural crops are grown.

MATERIALS AND METHOD

Selection of Sampling Sites

The eleven sites including the control were carefully chosen based on accessibility, availability of open spaces and of course area with maximum influence from anthropogenic activities such as vehicular traffic density, human activities as well as industrial activities. The geo-referencing was carried out by using GPS MAP 76S (Garmin).

Sampling Location

The study was conducted in the following areas of Oshodi-Isolo (N^{0}6.56777 and E^{0}3.34231 - N06.5162 and E03.37369) area of Lagos state which include Shopeju street (SPS), Adewumi Ogefon (ADO), Aswani road (AWR),Osolo way (OSW), Agege-motor road (AGM), Church street (CHS), Oshodi road (OSR), Ariyibi oke (ARS), Brown street (BRS) and Apapa - Oshodi express way (APE) and the control site, Botanical garden yaba college of technology (BG).

Sample Collection

Dust samples were collected from eleven sites within the study area, at least 100m apart once a week from August to December, 2019. Samples were collected in the morning while the dust has settled well throughout the night and before heavy morning traffic movement that can disrupt the dust. The samples were randomly collected from both sides of the road by sweeping surface dust into plastic waste packers using plastic brush and transferred into pre- labeled polythene. All irrelevant materials such as cigarette ends, papers, plastics etc. were carefully hand- picked. Thereafter, samples collected at each location were filtered through 75 µm stainless steel sieve. The samples were then taken to the laboratory for further treatment and analysis.

PREPARATION AND ANALYSIS OF ROAD SIDE STREET DUSTS

Digestion of dust Samples for Heavy metals

2.0g of sieved dust was weighed using an analytical balance and transferred into a conical flask for digestion. 30ml nitric acid and 10ml concentrated hydrochloric acid prepared in the ratio 3:1 was added. The solution was mixed thoroughly and heated on magnetic heated stirrer, then refluxed at 90ºc for 20 minutes. After the disappearance of brown fumes, the digested solution was cooled and then filtered through Whatman type 589/2 filter paper. The filtrate was diluted to 50 cm3 with de-ionized water. The metal contents in the filtrate were determined using an atomic absorption spectrophotometer (AAS) PG - 990.

Statistical analysis

The analysis of variance (ANOVA) together with mean and standard deviation of each Heavy metals was carried out on the data obtained from the street dust.

Table 2: Heavy metals concentration at Oshodi - Isolo area of Lagos – State[1]

Location/ Sites	Pb (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Ni (mg/kg)
SPS	6.46 ± 0.11	26.24 ± 0.11	2.32 ± 0.11	0.075 ± 0.07	0.73 ± 0.11
ADO	2.11± 0.07	12.11 ± 0.12	0.87 ± 0.11	0.003 ± 0.01	0.32 ± 0.12
ASR	79.05± 0.11	162.08 ± 0.06	57.89 ± 0.11	-0.108 ± 0.06	12.25 ±0.21
APE	39.11 ± 0.66	88.00 ± 0.01	32.13 ± 0.12	-0.02 1± 0.10	5.25 ± 0.31
OSW	19.89 ± 0.12	136.75 ± 0.51	24.38 ± 0.67	-0.303 ± 0.07	1.51 ± 0.11
CHS	1.83 ± 0.11	24.69 ± 0.121	1.25±0.12	0.043 ± 0.01	0.03 ± 0.01
AGM	641.52 ± 0.12	651.03 ± 0.01	56.72 ± 0.08	0.79 ± 0.12	22.05 ± 0.06
OSR	57.10 ± 0.10	38.11 ± 0.10	5.12 ± 0.07	2.49 ± 0.01	16.104 ± 0.10
ARS	174.45 ± 0.11	274.77 ± 0.12	58.27 ± 0.12	2.38±0.17	18.69 ±0.04
BRS	9.41 ± 0.17	28.40 ± 0.16	3.25 ± 0.117	0.74 ± 0.045	1.241 ± 0.16
BG(CTL)	0.80 ± 0.16	3.25 ± 0.16	0.57±0.17	0.121±0.156	0.024 ± 0.01
TOTAL	**93.79 ± 182.89**	**131.40 ±185.19**	**22.07±24.26**	**0.487 ± 0.97**	**7.11 ± 8.22**

[1]Value represent mean±SD ***Mean difference is significant at P<0.05***

Table 3: Heavy metals concentration in street dusts of Oshodi - Isolo and other selected cities of the world (mg/kg)

CITY	Pb	Zn	Cu	Cd	Ni
Oshodi - Isolo (this study)	**103.17**	**144.54**	**24.28**	**0.70**	**7.85**
Ottawa (Rasmussen *et al.*, 2001)	68.00	184.00	188.00	19.00	0.60
Madrid (De Miguel *et al.*, 1997)	1927.00	476.00	188.00	144.00	-
Oslo (De Miguel *et al.*, 1997)	180.00	412.00	123.00	41.00	1.40
Mutah (Manasreh *et al.*, 2010)	143.00	132.00	69.00	1.70	1.30
London(Schwar *et al.*, 1988)	1030.00	680.00	155.00	-	3.50
Kuala Lumpur (Ramlan *et al.*, 1988)	2466.00	344.00	35.50	-	2.90
Birmingham(Charlesworth *et al.*, 2003)	48.00	534.00	466.90	41.10	1.60
Amman((Jiries (2003))	976.00	401.00	249.60	16.30	1.10
Kavala(Christoforidis *et al.*, 2009)	386.90	354.80	172.40	67.90	0.20
Tehran (Mohsen *et al.*, 2012)	257.4	873.2	225.3	10.7	34.8

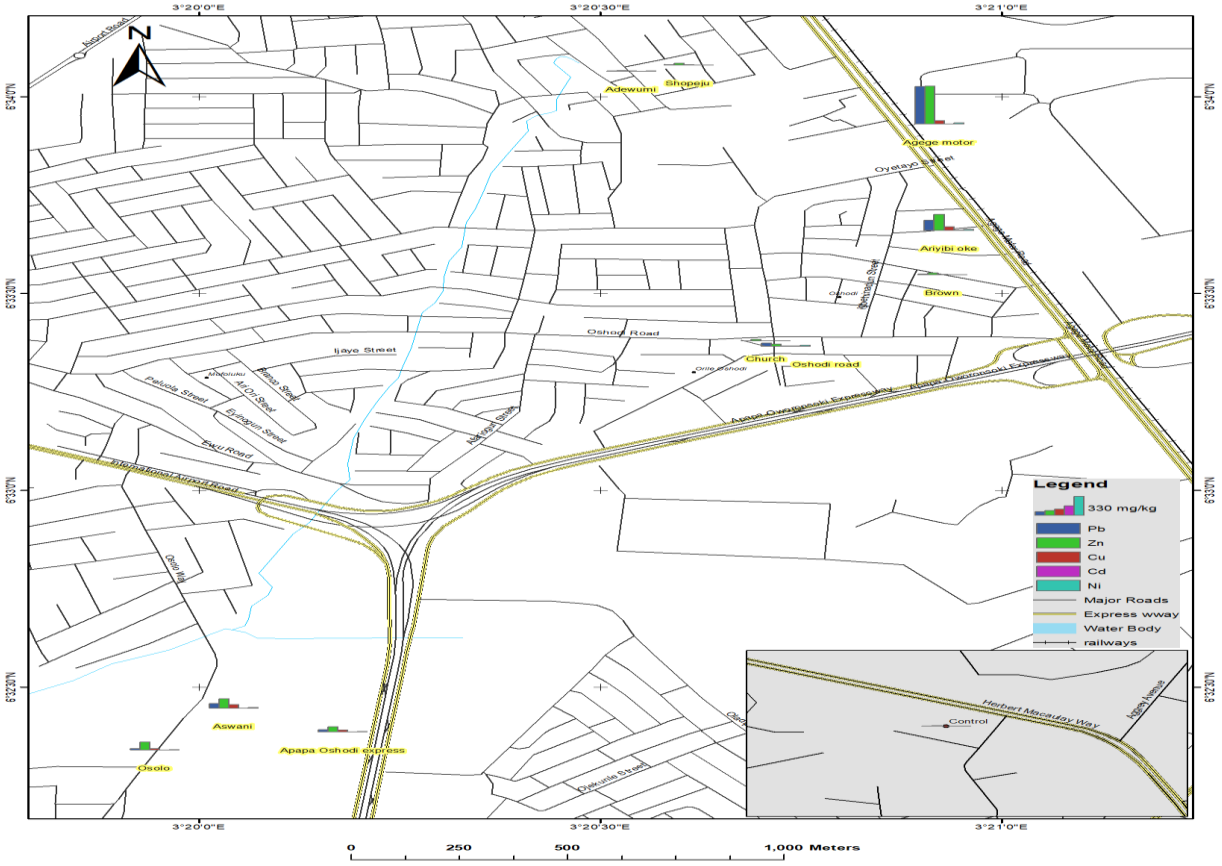

Figure 1: GPS Map of Oshodi - Isolo showing average mean concentration of Heavy metals in the study Area.

RESULTS AND DISCUSSION

Table 4: Mean Concentration of Heavy metals (mg/kg) of all the sites in Oshodi-Isolo Area for August - December, 2019.

Sample Location/ Sites	Pb (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Total
SPS	6.46	26.24	2.32	0.08	0.70	35.80
ADO	2.11	12.11	0.87	0.003	0.32	15.41
ASR	79.05	162.08	57.89	-0.11	12.25	311.38
APE	39.11	88.00	32.13	-0.01	5.25	164.51
OSW	19.89	136.75	24.38	-0.30	1.51	182.83
CHS	1.83	24.69	1.25	0.04	0.33	28.14
AGM	641.52	651.03	56.72	0.79	22.05	1372.11
OSR	57.10	38.11	5.12	2.49	16.104	118.92
ARS	174.45	274.77	58.27	2.3	18.69	528.48
BRS	9.41	28.40	3.25	0.74	1.241	43.04
BG(CTL)	0.80	3.25	0.57	0.12	0.024	4.78
Total	1031.73	1445.43	242.77	6.99	78.47	2805.39
Average	103.70	144.543	24.277	0.70	7.85	
Percentage %	36.78	51.52	8.65	0.25	2.79	100

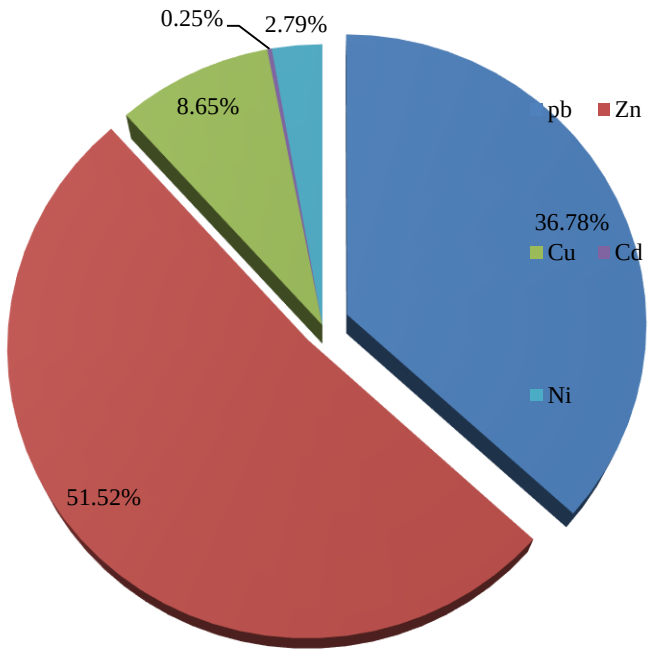

Figure 2: Percentage Contribution of Heavy metals in Oshodi- Isolo Area

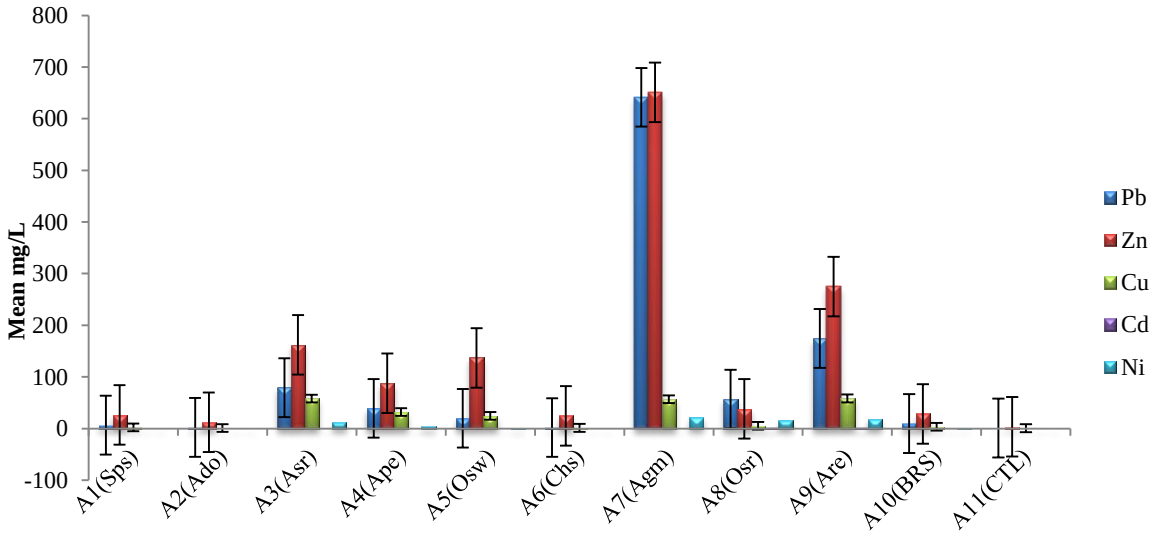

Figure 3: Average Concentration of Heavy metals in Oshodi - Isolo Area

The results of this research shows that the main contributors to the dust pollution in Oshodi- Isolo area are Zn- 51.52 %, Pb -36.78 %, Cu-8.65 % and to a lesser extent Ni -2.79% and Cd- 0.25 % (Figure 2). The most abundant Heavy metal in the dust of Oshodi- Isolo is Zn 1445.43 mg/kg followed by lead while Cd 6.99 mg/kg is the least abundant (Figure 3). The high presence of Zn may be due to emission of zinc originating from wearing of brake lining; losses of oil and cooling liquid, corrosion of galvanized steel safety fence, wearing of tyres etc; while nickel could be due to the combustion of fossil fuels, smelting of metals/steel and oil activities. Lead levels be could be attributed to emissions from vehicles which use leaded gasoline and to exhaust gas coming from fuel and from worn metal alloys which might have accumulated over times owing to its long residence time in the environment. The highest concentration of zinc was recorded at Agege motor road - 651.04 mg/kg while the least concentration was recorded at Adewumi Ogefun- 12.11 mg/kg. The highest concentration of lead was also recorded at Agege motor road - 641.63 mg/kg whereas the least concentration was recorded at Church Street - 1.94 mg/kg (Table 4). The high presence of lead at Agege motor road may be due to the high commercial, automobile and vehicular activities in the area, spillage of petroleum products, smoking of cigarettes, paint chips from the walls of industrial buildings, careless discard of lead acid batteries used in automotives as well as the use of industrial grade and non - domestic paints by the surrounding industries. The level of Lead at Agege motor road were significantly different ($p < 0.05$) from all other sites. The highest concentration of copper- 57.99 mg/kg and nickel- 22.12 mg/kg was recorded in Aswani road and Agege motor road respectively. Adewumi Ogefun has the least concentrations of copper -0.98 mg/kg and nickel- 0.43 mg/kg. The presence of copper may be due to the manufacturing of electrical cables, mining of metal, production of cans and the use of pesticides, combustion of fossil fuels, smelting of metals, vehicular emission, traffic congestion and industrial processes that uses these metals or their compounds. Furthermore, the presence of nickel in this site may be as a result of fuel combustion from generators as well as frequent bush burning in the surroundings. The highest concentration of cadmium was recorded at Oshodi road- 2.60 mg/kg while the least concentration was recorded at Osolo way - -0.39 mg/kg (Figure 2). The high significant levels of Zn, Pb and Cu obtained in the samples from Oshodi-Isolo is an indication of their concentration in the dust while the low concentration of

Cadmium Cd and Nickel Ni suggest low contributing factors to their spread and as well as dust inability to preferentially accumulate these metals (Figure 1). There is significant difference in the level of heavy metals in the study area ($P_v < 0.05$) (Table 1) . The sequence and pattern of distribution of Heavy metals content of Oshodi - Isolo dust is as follows: Zn > Pb > Cu > Ni > Cd, with the mean concentration of - 131.40, 93.79, 22.07, 7.11 and 0.48 mg/kg respectively (Table 2). The most polluted site is Agege motor road - 1372.11mgkg while the least polluted site is Adewumi Ogefun- 15.41 mg/kg. This could be as a result of both vehicular, human, commmercial and Industrial activities in the area. The trend and percentage contribution of each site to pollution of Oshodi - Isolo dust is as follows: AGM - 48.91 % > ARS- 18.84 % > ASR- 11.10 % > OSW- 6.52 % > APE- 5.86 % > OSR - 4.34 % > BRS-1.53 % > SPS- 1.28 % > CHS- 1.00 % > ADO- 0.55 % > BG(CTL)-0.17 % (Table 3). The result of this research agrees with the results obtained in some Nigerian cities and other cities in the world and also showed that concentration of heavy metals depends on the nature of activities in the sites (Adie *et. al.* 2014 ; Ekpo *et. al.*, 2012 ; Mohsen et al. 2012; Christoforidis *et al.*, 2009; Lu *et al.*, 2010; Karbassi et al. 2005 ; Ojiodu *et. al.* 2017; 2018a, 2018b). Though, the concentrations of Heavy metals (Zinc, Lead, Copper, Cadmium and Nickel) in Oshodi - Isolo dust may be high when compared with the values other cities in world (Table 3). This may be due to differences in vehicular and human activities (burning / dumping of waste), environmental management policies and technologies employed, frequency of city street cleaning and local meteorological conditions such as rains, temperature, windspeed which can affect the Heavy metals in the dust (Mohsen et al. 2012). The level of heavy metals in the study area were far greater than the recommended limits of the Federal Ministry of Environment (FME), European Communities (EC) and United Nations Environmental Programme (UNEP) permissible level for heavy metals in the atmosphere (EC, 2006). The concentration of heavy metals in all the sites was higher than the control value . This may be due to the fact that the control environment is an area with little or no anthropogenic activity.

CONCLUSION

It is evident that the dust of Oshodi - Isolo is highly polluted with the heavy metals Zinc Zn-144.54 mg/kg, Lead Pb-103.173 mg/kg, Copper Cu-24.277 mg/kg, Nickel Ni- 7.847 mg/kg and Cadmium Cd-0.699 mg/kg. The high concentration of these heavy metals could be attributed to vehicular, human, commmercial and Industrial activities in the area. Therefore, there is need for environmental Monitoring, safety and management of Oshodi - Isolo area due to the high concentration of these metal pollution which could be very hazardous to human and plants existence.

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COMPARATIVE *IN VITRO* ANTIOXIDANT POTENTIALS OF AQUEOUS AND ETHANOL EXTRACT OF *CLERODENDRUM VOLUBILE* LEAVES

***Makinde O.T., Chinweoke N.L. and Ogunyemi B.C**

Department of Chemical Science, School of Science Yaba College of Technology, Yaba- Lagos.

***Corresponding Author:** larasee@yahoo.com, +2348029287178

ABSTRACT

The leaves of *Clerodendrum volubile* are commonly consumed as a vegetable, mostly blended with other vegetables as a spice with a sweet aroma and taste among South Westerners of Nigeria. *In vitro* antioxidant potential of aqueous and ethanol extracts of *clerodendrum volubile* leaves were investigated. Fresh leaves of *Clerodendrum volubile* were obtained from Mushin herbal market Lagos State. It was identified and authenticated in department of Botany of University of Lagos. The leaves of *Clerodendrum volubile* were first chopped into small pieces, dried at room temperature for three week and reduced to powder with the aid of a mortar and pestle. Two hundred gram of the powdered samples were macerated with 600 ml 70% ethanol and water for four days. After four days the extracts were then recovered by filtration using wet wash test sieve. The crude extracts obtained were then dried in a hot air oven at 45◦C to concentrate them. Reducing power assay, DPPH inhibition and nitric oxide inhibition activities were carried out in both ethanol and aqueous extracts. Tests were carried out in triplicate and data was statiscally analyzed using SPSS version 20.0. Both extracts exhibited free radical scavenging and antioxidant potential compared to ascorbic acid. The values of reducing power, DPPH activity and nitric oxide inhibition activity was higher in ethanol extract compared to the aqueous extract. Leaf extracts showed some antioxidant potentials compared to ascorbic acids; this may be due to the presence of some phytochemical in the extract.

KEYWORDS: Antioxidant, *Clerodendrum volubile*, Nitric oxide, DPPH, inhibition

INTRODUCTION.

Oxidative stress plays a crucial role in vivo tissue damage; it is important for the pathogenesis of several life-threatening diseases, as well as in the ageing of living organisms (Ejele *et al*, 2012), with documented scientific evidence to support this. Endogenous antioxidant enzymes play a significant role in protecting the biomolecules of the living organism. Excessive production of ROS (Reactive Oxidative Species) leads to a redox imbalance between free radicals and endogenous antioxidants, thereby causing oxidative stress, leading to the destruction of proteins and the structural integrity of lipid membranes of cells, as well as DNA of organisms (Erukainure *et al.*, 2011). Over the years, synthetic antioxidant drugs have been effectively employed for the treatment of diseases mediated by free radical species. However, adverse effects associated with the usage of synthetic antioxidant drugs cannot be neglected; therefore, huge consideration has been given to natural sources of antioxidants, specifically those of plant origin. (Dembinska-kiec *et al.*, 2008)

Antioxidants are believed to play a very important role in the body defense system against ROS (Reactive Oxidative Species) (Vivex and Sunrendra, 2006). An antioxidant is “any substance that, when present at low concentrations compared with that of an oxidizable substrate, significantly delays or inhibits oxidation of that substrate (Halliwel and Gutteridge, 1995). In other terms, an antioxidant is “any substance that delays,

prevents or removes oxidative damage to a target molecule. Antioxidants are inhibitors of the process of oxidation, even at relatively small concentration and thus have diverse physiological role in the body. Antioxidants are our first line of defense against free radical damage, and are critical for maintaining optimum health and well-being. Antioxidant constituents of plant materials act as radical scavengers, and helps in converting the radicals to less reactive species. An antioxidant rich diet has a very positive health impact in the long run, reducing the risk of chronic diseases (Dembinska-kiec *et al.*, 2008).

Clerodendrum volubile (Lamiaceae) is a widely distributed vegetable in the warm temperate and tropical regions of the world. The plant is popularly known as "marugbo" or "eweta" amongst the Ikale, Ilaje, and Apoi people in the southern-senatorial district of Ondo State, Southwest Nigeria. It is, however, referred to as "obnettette" in the South-Southern part of Nigeria. The leaf of *Clerodendrum volubile* is commonly consumed as a vegetable, mostly blended with other vegetables as a spice with a sweet aroma and taste. In Nigeria and other West African countries, green leafy vegetables undergo a cooking process rather than being eaten raw. Cooking is usually carried out to increase the palatability and to improve the edibility of some food (Afolabi *et al*, 2019).

Clerodendrum volubile is a promising source of minerals and vitamins, which can be used to fight malnutrition if correctly exploited. In southwestern Nigeria, when consumed, the leaves are often noted for stimulating lost appetite as well as replenishing vitality for pregnant women and mothers of new born babies (Ogunwa *et al.*, 2016). It is also used in the management of arthritis, swellings, rheumatism, gout, dropsy, and oedema, while also possessing anti-abortifacient and sedative properties. The plant had been used in the treatment of inflammation and pain by traditional medical practitioners, but with no scientific evidence to support this (Adefegha and Oboh, 2018). Preliminary studies indicated that *clerodendrum volubile* is rich in nutrients and minerals such as carbohydrates, proteins, crude fat, ash, fibre, calcium, sodium, potassium, iron, zinc, copper, magnesium and manganese Further studies on phytochemical composition indicated that the aqueous and ethanol extracts of *clerodendrum volubile* leaves consists of phytochemicals such as tannins, phenols, alkaloids, saponins, steroids, reducing sugar, flavonoids and cardiac glycosides etc. with the ethanol extract having more phytochemicals compared to the aqueous extracts.

Phytochemicals being naturally occurring are believed to be effective in combating or preventing disease due to their antioxidant properties which produce the definite physiological actions on human body (Ejele *et al.*, 2012). The medicinal values of plants lie in their component phytochemicals; hence this study was designed to evaluate the comparative *in vitro* antioxidant potential of aqueous and ethanol extracts of *clerodendrum volubile* grown in Lagos south western Nigeria.

MATERIALS AND METHODS

COLLECTION OF PLANT MATERIAL

Fresh leaves of, *Clerodendrum volubile were* collected at Mushin market, Lagos State, Nigeria. The fresh leaves were botanically identified and authenticated at the Department of Botany, University of Lagos Nigeria with voucher specimen 8915.All reagents used were of analytical grade.

SAMPLE PREPARATION

Clerodendrum volubile leaves were dried at room temperature for three weeks and then kept dry for further use. The leaves of *Clerodendrum volubile* were first chopped into small pieces and then dried similarly.

The fresh leaves were air dried and reduced to powder with the aid of a mortar and pestle. Two hundred gram of the powdered samples was macerated with 600 ml of ethanol and water for four days. After four days the extracts were then recovered by filtration using wet wash test sieve . The crude extracts obtained were then dried in a hot air oven to concentrate the extracts by evaporating the solvents. The semi-solid material obtained was accurately weighed and then used for antioxidant activity analysis.

DETERMINATION OF ANTIOXIDANT ACTIVITIES

DETERMINATION OF TOTAL ANTIOXIDANT CAPACITY:

Solution of the sample extracts (1 ml) was mixed with 3 ml of reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The tubes were capped and incubated in a boiling water bath at 95^0 C for 90 minutes. After the samples had been cooled to room temperature, the absorbance of the aqueous solution of each was measured at 695 nm. The total antioxidant capacity was expressed as equivalent of ascorbic acid.

ASSAY OF 2,2-DIPHENYL-1-PICRYLHYDRAZY (DPPH) RADICAL SCAVENGING ACTIVITY.

An aliquot of 0.5 ml of each extract in ethanol (95%) at different concentrations (25, 50, 75, 100µg/ ml) was mixed with 2.0 ml of reagent solution (0.004 g of DPPH in 100 ml methanol). The control contained only DPPH solution in place of the sample while methanol was used as the blank. The mixture was vigorously shaken and left to stand at room temperature. After 30 minutes the decrease in absorbance of test mixture (due to quenching of DPPH free radicals) was read at 517 nm. The scavenging effect was calculated using the expression:

% inhibition = $[A^0\text{-}A^1] \times 100/A^0$

Where A^0 is the absorption of the blank sample and A^1 is the absorption of the extract

ASSAY OF NITRIC OXIDE SCAVENGING ACTIVITY

Four milliliter sample of each plant extracts or standard solution of different concentrations (25, 50, 75, 100 µg/ml) were taken in different test tubes and 1 ml of Sodium nitroprusside (5 mM in phosphate buffered saline) solution was added into the test tubes. They were incubated for 2 hours at 30 °C to complete the reaction. A 2 ml sample was withdrawn from the mixture and mixed with 1.2 ml of Griess reagent (1% Sulphanilamide, 0.1% naphthylethylene diamine dihydrochloride in 2% H_3PO_4). The absorbance of the chromophore formed during diazotization of nitrite with sulphanilamide and its subsequent coupling with napthylethylene diamine was measured at 550 nm. Ascorbic acid was used as standard. The percentage (%) inhibition activity was calculated from the following equation:

$[(A^0 - A^1)/A^0] \times 100$.

Where, A^0 is the absorbance of the control and A^1 is the absorbance of the extract or standard.

ASSAY OF REDUCING POWER ACTIVITY

Various concentrations of each extract (20 to 100 µg/ml) in 1.0 ml of deionized water were mixed with phosphate buffer (2.5 ml) and potassium ferricyanide (2.5 ml). The mixture was incubated at 5^0C for 20 min. Aliquots of trichloroacetic acid (2.5 ml) were added to the mixture, which was then centrifuged at 3000 rpm for 10 min. the upper layer of solution (2.5 ml) was mixed with distilled water (2.5 ml) and a freshly prepared ferric chloride solution (0.5 ml). The absorbance was measured at 700 nm. A blank was prepared without adding extract. Ascorbic acid at various concentrations (1 to 16µg/ml) was used as standard.

RESULTS.

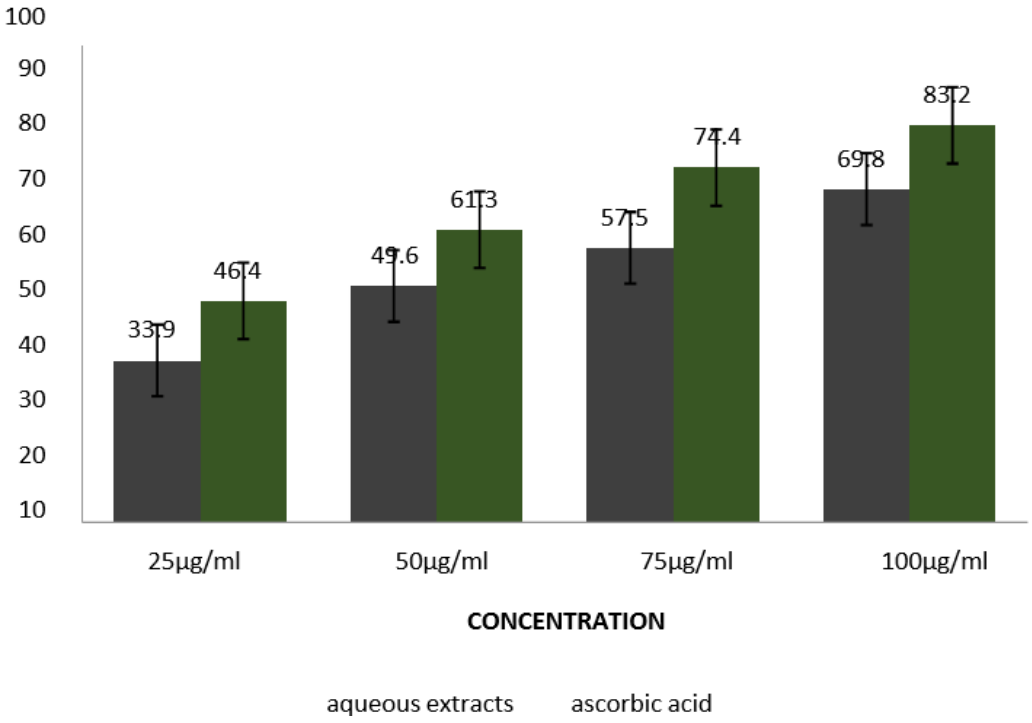

Fig 1. DPPH Scavenging activity (%Inhibition) of aqueous extract of *Clerodendrum volubile* leaves

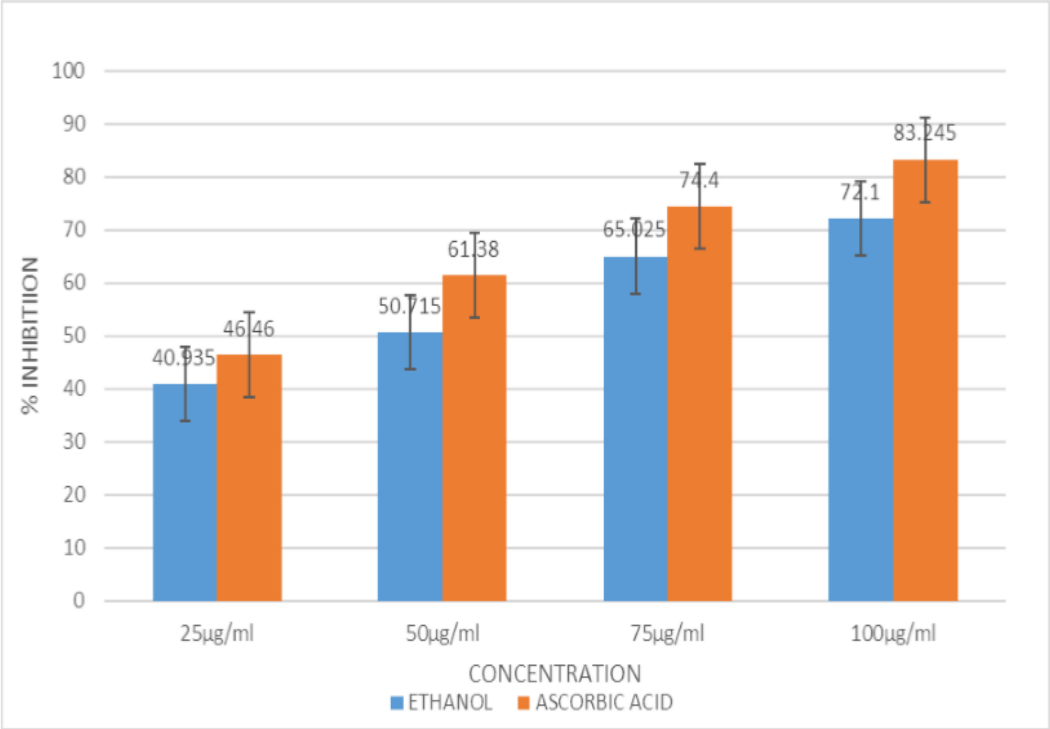

Fig. 2. DPPH Scavenging activity (%Inhibition) of ethanol extracts *Clerodendrum volubile* leaves

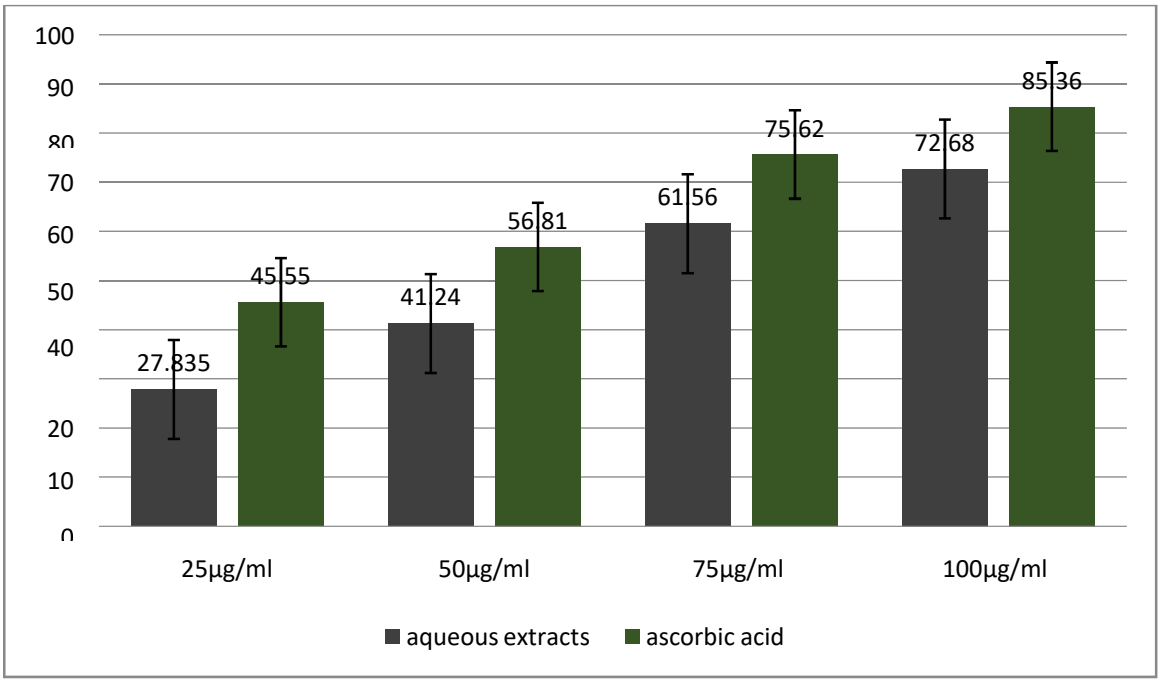

Figure 3. Nitric Oxide Scavenging activity (%Inhibition) of aqueous extracts *Clerodendrum volubile* leaves

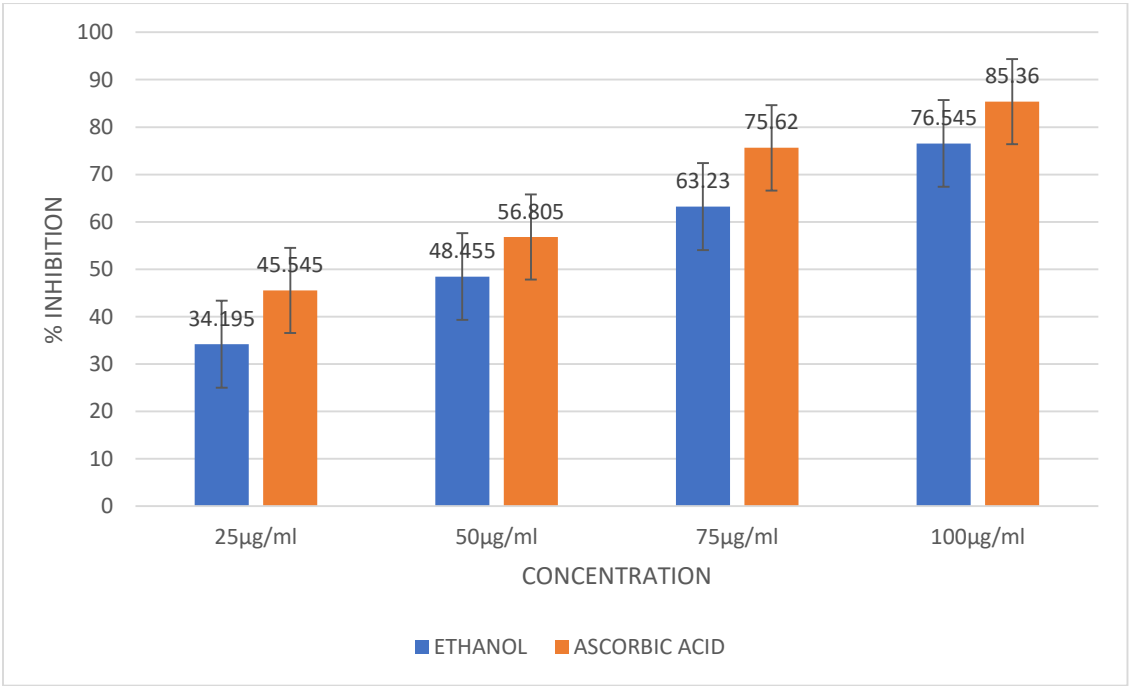

Fig 4. Nitric Oxide Scavenging activity (%I inhibition) of ethanol extracts *Clerodendrum volubile* leaves

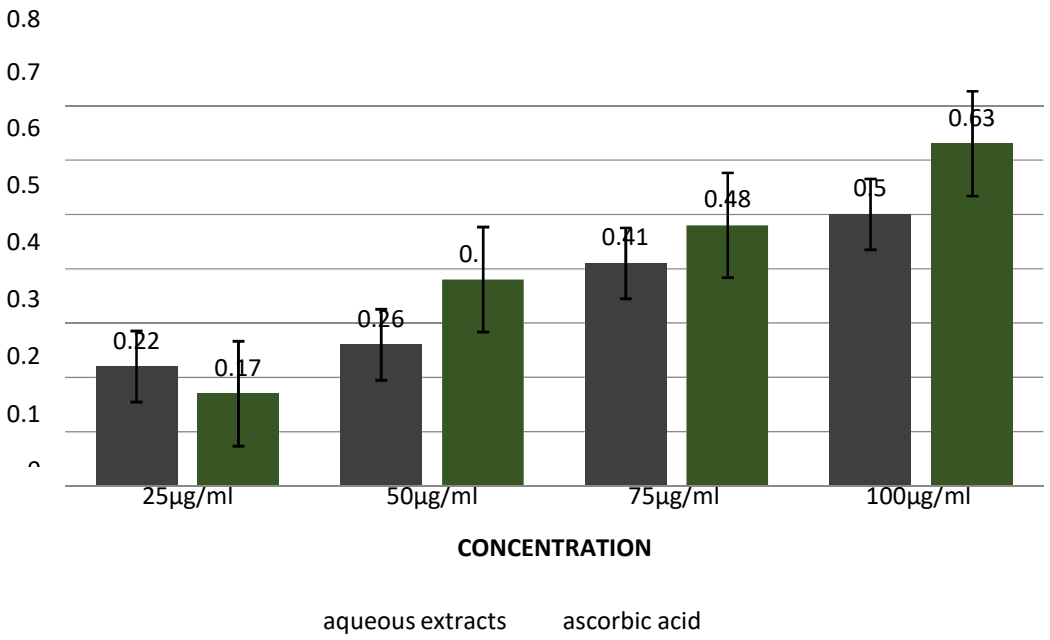

Figure 5. Reducing power of aqueous extracts *of Clerodendrum volubile* leaves

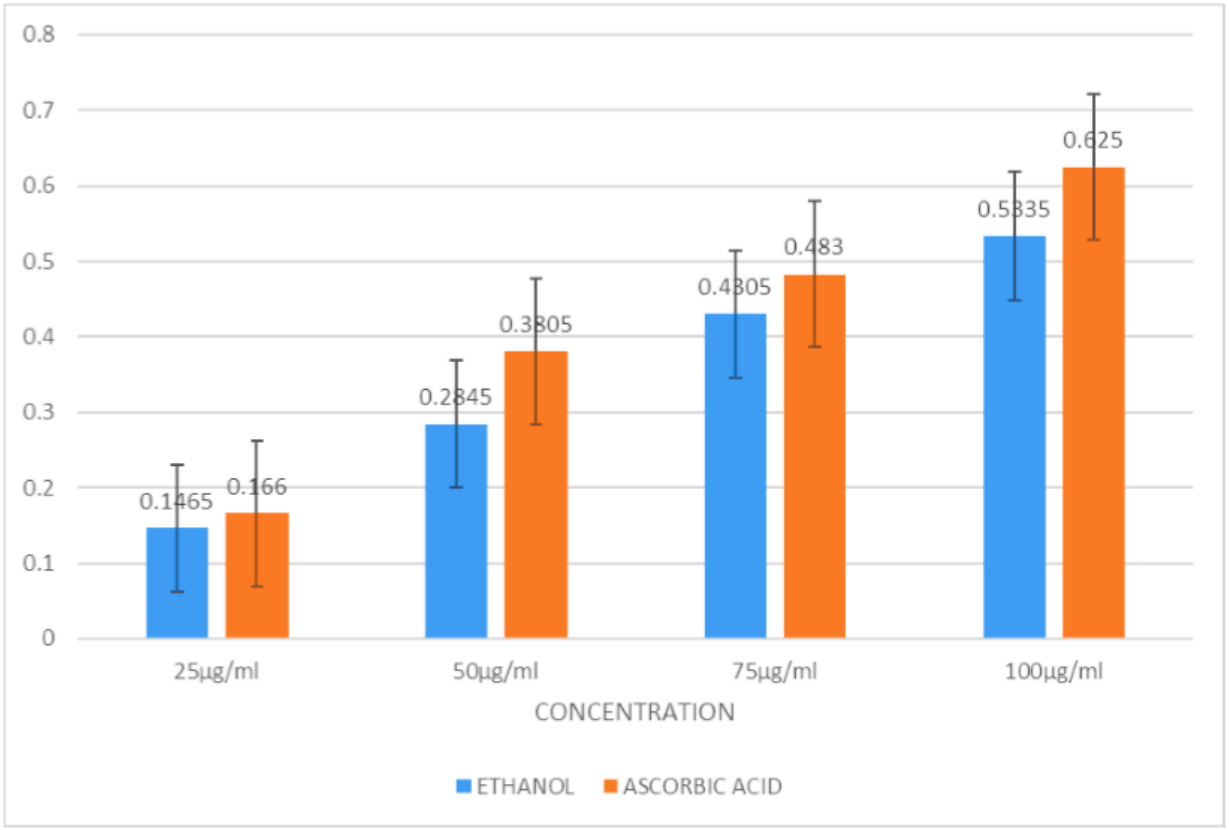

Fig. 6. Reducing power of ethanol extracts *Clerodendrum volubile* leaves

DISCUSSION

One of the important steps ever taken when it comes to the use of medicinal plants involves screening for phytochemicals for possible antioxidant activities of the plants extracts. The antioxidant activity of aqueous and ethanol extract of *clerodendrum volubile* leaves were investigated. DPPH for aqueous extract ranged from 33.94± 0.24 at 25µg/ml to 69.87 ± 1.83 at 100µg/ml while for the ethanol extract, the % inhibition of DPPH ranged from 40.94±0.78 at 25µg/ml to 72.10±0.57% at 100µg/ml. According to Ogunwa *et al.*, (2016), the DPPH model is a simple, precise, relatively quick and acceptable method which is widely used to measure free radical scavenging activity. It is a stable radical even at room temperature and becomes a stable diamagnetic molecule upon receiving an electron or hydrogen radical. It has been employed in the determination of antioxidant ability of numerous natural products.

The interaction of DPPH with antioxidants is visually noticeable because the purple color changes to yellow, demonstrating the reduction of the stable DPPH radical to its diphenyl picryl hydrazine. This reaction is used to reveal the capacity of neutral products to scavenge free radicals. It is believed that antioxidants act on DPPH via hydrogen donation or electron transfer mechanism (Zihad *et al*, 2019) and this is often measured as a decrease in absorbance taken spectrophotometrically at 517nm. This study is in agreement with the report by Ogunwa *et al*., (2016) on the antioxidant activities of *Clerodendrum volubile* showed the increasing order of 50µg/ml > 100µg/ml >200µg/ml > 500µg/ml. The nitric oxide activity for the aqueous extract ranged from 27.83±0.69 at 25µg/ml to 72.68± 0.34 at 100µg/ml compared to the ethanol extract which ranged from 34.20±0.49 at 25µg/ml to 76.55±0.36 at 100µg/ml. The reducing power followed a similar trend as observed with scavenging activities. The antioxidant activity for reducing power for the aqueous extract ranged from 0.22± 0.12 at 25µg/ml to 0.50±0.005 at 100µg/ml while for the ethanol extract it ranged from 0.15±0.0021 at 25µg/ml to 0.63±0.0014 at 100µg/ml. This study showed a lower reducing power compared to the report by Ogunwa *et al.*, (2016).

This reducing property makes them safer in administration compared to synthetic antioxidants that have been reported to be carcinogenic. Some phytochemicals have been reported to possess antioxidant activity by either acting singly or by interacting with polyphenols (Ogunwa *et al*, 2016).

From the results, we observed that the values of DPPH, Nitric oxide and reducing power activity was higher in ethanol extract compared to the aqueous extract with ascorbic acid as the positive control. This is an indication that the ethanol extract of *clerodendrum volubile* possess more antioxidant potential compared to the aqueous extract.

The antioxidant properties, as observed in this investigation, could be as a result of the phytochemicals such as phenolic compounds, flavonoids, saponins and tannins present in this plant as they have been shown to possess potent antioxidant potentials. They have high redox potentials which allow them to act as reducing agents, hydrogen donors and singlet oxygen quenchers. Previous study has indicated that the ethanol extract of *clerodendrum volubile* possess higher content of phytochemicals such as phenols, flavonoids, alkaloids, cardiac glycosides, reducing sugar, tannins etc. compared to the aqueous extract of the plant which has lower content of phytochemicals with tannins completely absent in the aqueous extract. This is an indication that ethanol is a better solvent at extracting the important constituents of this plant compared to water.

It can be said that both aqueous and ethanol extract of *clerodendrum volubile* leaves possess free radical scavenging and antioxidant activities, however, ethanol extract has comparatively more potent *in vitro* free radical scavenging activity and antioxidant capacity than aqueous extract. This capacity may be correlated with the total phenolic contents in the plant. The free radical scavenging and antioxidant potentials of this plant suggest that it could be potential natural source of antioxidants which may possess better implications at reducing oxidative stress and degenerative diseases.

CONCLUSION

Our findings revealed the potentials of *Clerodendrum volubile* leaves for treatment of many free radical-mediated life-threatening diseases and their complications, thus validating its use in folkloric and ethnomedicines. It is therefore suggested that maximum potential of these plant should be explored in pharmaceutical sciences and medicinal field for their appropriate application.

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DESIGN, CONSTRUCTION AND TESTING OF DIRECT SOLAR DRYER

[*1]Oba M. O., [1]Nzekwe N.M. [1]Ricketts M.S., [2]Fayombo D.O., [2]Simon N., [2]Nse H.J., and [2]Yusuf, A.O

[1]Department of Physical Science, Yaba College of Technology, Yaba, Lagos
[2]Department of Science Laboratory Technology, Yaba College of Technology, Yaba, Lagos

***Corresponding Author:** obamichael300@gmail.com, +2348034228420

ABSTRACT

The solar drying system utilizes solar energy to heat up air and to dry any food substance loaded, which is beneficial in reducing wastage of agricultural products and help in preservation of agricultural products. Based on the limitations of the natural sun drying for instance exposure to direct sunlight, liability to pests and rodents, lack of proper monitoring and the escalated cost of the mechanical dryer, a solar dryer is therefore developed to cater for this limitation. The dryer is composed of solar collector (air heater) and a solar drying chamber constraining rack of three cloth (net) trays both being integrated together. The air allowed in through air inlet is heated up in the solar collector and channeled through the drying chamber where it is utilized in drying. The dimension of the dryer is 90cm x 80cm x 100cm cm (length x width x height). Locally available materials were used for the construction, chiefly comprising of wood (gmelina), glass, aluminum metal sheet, copper and net cloth for the trays. The solar dryer was tested to evaluate its performance. The test results gave temperature above 44^0C in the drying chamber and the moisture content of 0.25kg of plantain reduced to about 12.5% in three days of 7 hours each day of drying. The drying rate was 0.998kg/h solar dryers produce well-dried products with reasonably long-life storage. When used, the degree of losses due to insect infestation and contamination becomes insignificant.

KEYWORDS: Construction, Moisture content, Optimum temperature, Plantain, Solar dryer

INTRODUCTION

Solar energy for drying has not been widely commercialized yet due to expensive investment, limited time and intensity of incident radiation, low skilled manpower for drying operation and poor maintenance of equipment. The main and primary reason however is that solar dryers were not designed keeping economic viability in mind. A variety of solar dryers with different types and sizes create uncertainty in the mind of users. Therefore, it is important to collect all the details of solar dryers of different types so that their usefulness for different applications may be taken into account (Hisler, 2009).

Most developing countries are unable to solve their food problems for the entire population because of the rapidly increasing number of people in their respective territories. This rapid population increase has a direct impact on food balance. The quality and quantity of food grains are deteriorating because of poor processing techniques and shortage in storage facilities. To maintain the right balance between food supply and population growth, reducing food losses during production time is mandatory. However, maximizing the food production capabilities of small farmers in rural areas is difficult. To solve the problem, drying has become one of the main processing techniques used to preserve food products in sunny areas. However, traditional open sun drying has some disadvantages. For the past few years, scientists and researchers have been trying to find the best alternative to overcome this problem. They invented various kinds of solar dryers for agricultural

products and have continuously worked to improve these dryers (Rahman *et. al.*, 2008).
The Earth has abundant solar radiation. In recent years, the use of solar energy has become more popular. Solar energy can be used in various processes such as drying, heating, cooking, and distilling. In terms of energy application, solar energy is categorized into electrical and thermal applications. In the agricultural sector, the use of solar thermal systems to conserve grains, fruits, and vegetables is feasible, economical, and ideal for farmers in many developing countries (Schneider *et. al.*, 2013).
In the two stages of the drying process, the first phase occurs when heat is applied to the surface of the drying material at a constant rate, and the second process involves decreasing the drying rate (El-Sebaii *et. al.*, 2012).
Using a solar dryer is also advantageous for drying foods, vegetables, and grains so that they can be stored for a long time. Comparing solar drying and open sun drying, the former has many advantages compared with the latter. For example, solar drying increases the quality of products. Solar dryers in different sizes and types are used to dry various agricultural materials. Therefore, dryer selection is very important in this sector as the economic aspect should also be considered (Sharma *et. al.*, 2009).
Renewable energy can play an effective role to meet energy demand. Among all, solar energy is most reliable and environmental friendly. We can use it as solar photovoltaic (PV), solar thermal for pumping and drying crops in agricultural sectors (Mekhilef *et. al.*, 2013). Drying is an essential process in the conservation of agricultural products. In the drying sector, the supply and demand of energy is an important consideration. Solar energy storage can minimize the gap between supply and demand in this case. At steady state conditions, more efficient and cost-effective dryers play a vital role in substituting for the demand for fuel in many developing countries. Solar drying has very few barriers that can be improved and is already being applied in the agricultural sector with positive results (Huda *et. al.*, 2014).
Having a solar storage system is important in energy conversion and is responsible for drying many agricultural products even when direct sunlight is not available (Bal *et al.*, 2014). In drying systems, the equilibrium theoretical model does enhance the understanding of the physics of moisture sorption. Purely empirical equations for specific conditions offer better alternatives until fairly accurate theoretical or semi-theoretical models are developed. The models have fallen short of predicting accurately the exact processes involved in drying, due to over implication of assumptions. These models for specific products and conditions offers better predictions. In this study some established moisture equilibrium models are mentioned (Haslem *et al.*, 2010).
To sustain the balance between population growth and food supply, food losses during harvesting and marketing should be minimized. The quality and quantity of agricultural produce suffer due to poor processing methods and shortage of storage facilities. Many developing countries suffer considerable losses on the agricultural front. It is mentioned that post harvesting loss of fruits and vegetables in developing countries is about 30–40% of total production (El-Sebaii *et al.*, 2012). Drying is one of the important preservation techniques for fruits and vegetables. Removing water by drying is the oldest technique used in many applications such as wood pulp drying for making paper, drying for food preservation and drying building materials Sharma 2009. The energy for drying comes from various sources, namely, fossil fuel, electricity,

natural gas, biomass and solar energy therefore, the topic of this review work comes under the application of applied energy. These thermal drying methods account for 10–20% of total industrial energy consumption in the developed world (Mekhilef *et al.*, 2013). Fossil fuels pollute the environment and the guarantee of limitless availability of such fuels is doubtful (Huda *et al.*, 2014). The aim of this study is to design a solar dryer which can be easily moved from place to place and is suitable for drying agricultural products.

MATERIALS AND METHODS

Materials

The following materials were used for the construction of the solar dryer:

Wood -as the casing of the entire system; wood was selected being a good insulator and relatively cheaper than metals.

Glass -as the solar collector cover. It permits the solar radiation into the system but resists the flow of heat energy out of the system.

Net- cloth and wooden frames for constructing the trays Hinges and handle for the dryer's door Paint (black and orange).

The solar food dryer was constructed making use of locally available and relatively cheap materials since the entire casing is made of wood and the cover is glass, the major construction work is carpentry works. The following tools were used in measuring and marking out on the wooden planks: Carpenter's pencil, Steel tapes, Steel meter rule, Vernier caliper, Steel square, Scriber, Hand saws, Jack pane, Wood chisel, Mallet, Hammer, Pinch bar and pincers. The construction was made with simple butt joints using nails as fasteners and glue where necessary. The construction was sequenced as follows for the wood work: Marking out on the planks to cut into desired shape; Cutting out the already marked out parts; planning of the cut out parts to smoothen the surfaces; Joining and fastening of the cut out parts with nails and glues. The glass used was clear glass with 4 mm thickness. The glass was cut into size of 56 x 90 cm size to act as solar collector cover. The trays were made with wooden frames and net cloth to permit free flow of air within the drying chamber. Four trays were used with average of 15 cm spacing arranged vertically one on top of another, the tray size was 35 x 50 cm. The interior of the solar food dryer was painted black with tar to allow for absorption of heat energy while the exterior was painted orange to minimize the adverse effects of weather and insect attack on the wood and also for aesthetic appeal.

DESIGN CONSIDERATION

Temperature- The design was made for the optimum temperature for the dryer to dry plantain T_0 of 60^0C and the air inlet temperature or the ambient temperature of dryer was taken as Ta = 37^0C

Efficiency- This is defined as the ratio of the useful output of a product to the input of the product.

Glass and flat plate solar collector- Solar collector glazing material was used. Collector glazing is exposed to high temperatures, long time outdoor exposure, impacts from vandals, while also requiring high light transmission and reasonable cost; 4mm thick transparent glass was used

Design of Drying Chamber- The drying chamber was made as spacious as possible with average dimension of 57 x 80 x 39 cm with air vent out of the cabinet of XX

Design of Solar Collector- The design of the solar collector was made as spacious as possible of average dimension of 88 x 49 x 15 cm. The solar collector and drying

chamber are painted black because black colour is a good absorber of heat and poor radiator of heat, so it absorbs the solar energy falling on the solar collector and converts it to heat energy required for drying plantain in the drying chamber.

Insulation- The insulating material was plywood of 2.5 cm thick, it is a good insulator as well as environmentally friendly. It is corrosion free and does not have any carcinogenic effects. Absorber Plate- GI Sheets were used as absorber plate placed inside the solar collector and painted black for better solar absorption.

Net-trays- Net type trays were selected as the dyer trays to aid air circulation within the drying chamber. Four trays were placed to keep plantain for dying purpose. The tray dimension is height of 7 cm and length of 50 cm. the gap between each tray is 15 cm.

Formulas and Calculations

1. Calculation of Angle of Tilt (β) of Solar Collector:

Angle of tilt (β) OF solar collectors is given by

$$\beta = 10^0 + \text{lat } \varphi$$

Where lat φ = latitude f the place where the solar dryer was designed, which is Yaba College of Technology, Yaba, Lagos. Here, lat φ is 6.52^0N.

Hence the suitable value of β used for the collector is given as:

$\beta = 10^0 + 6.520 = 16.52^0$ facing due South direction.

2. Calculation of Drying Rate $(\frac{dM}{dt})$

$$\frac{dM}{dt} = \left(\frac{M_i - M_f}{t}\right) X 100\%$$

M = mass
M_i = initial mass
M_f = final masst = time interval

The solar dryer is designed to help in the reduction of the moisture content preserved in it. Hence, there will be an air vent or inlet to the solar collector where air enters and it will be heated up by solar collector. The hot air will rise through the drying chamber, pass through the trays and around the farm produce reducing the moisture content and exits through the outlet near the top of the chamber

The materials for making the solar dryer are cheap and easily obtainable in the local market. The solar dryer is shown in Figure 1. The product is located on trays or shelves inside an opaque drying chamber. Solar radiation is thus not incident directly on the crop. The air is heated by a solar collector connected to a drying chamber that contains agricultural product. The product remains under shade and isolated from the ambient air. The drying process occurs by the exchange of water between the product and the flowing hot air. The testing of the solar plantain dryer was done for three days. The solar dryer was placed outside with the collector facing the direction of the Sun. The collector was positioned at an angle of 17^0 to the horizontal. About five pieces of plantain were peeled and sliced weighed 0.25 kg were arranged on the drying bed in a single layer to avoid moisture being trapped in the lower layer. The dryer chamber closed and seals placed in position. The result obtained for hourly reading of 7 hours every day is tabulated in Tables 1-3

RESULTS AND DISCUSSION

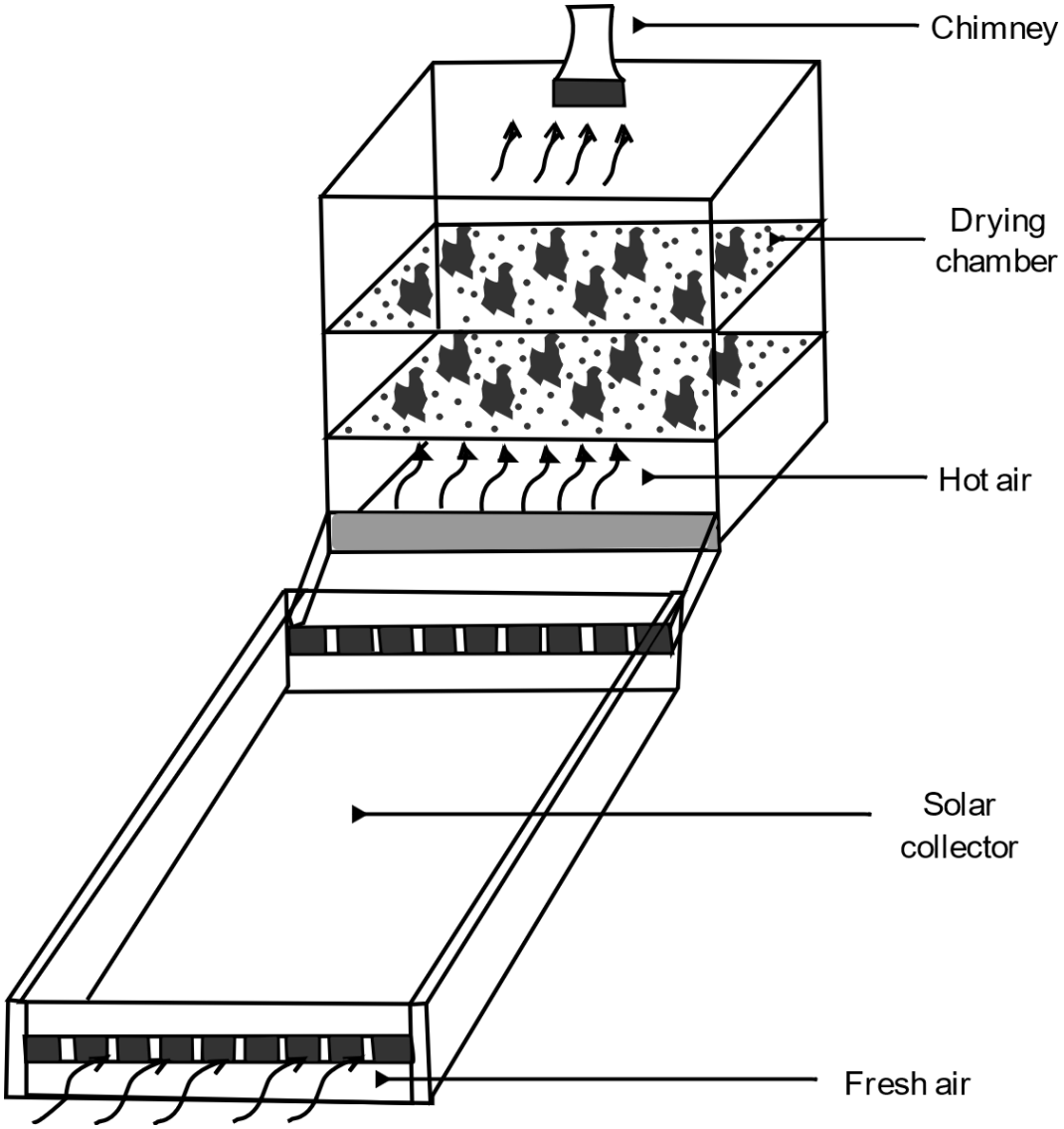

Figure 1: The constructed Solar Dryer

Table 1: Daily Hourly Measured Temperatures

Daily	Time(hrs)	Ta	Tc	T_C	T_P	M_1	M_2	M_A
DAY 1	10.00	34	35	35	34	0.25	0.25	0.25
	11.00	35	36	36	36	0.23	0.24	0.24
	12.00	39	35	36	36	0.19	0.22	0.21
	13.00	36	35	36	36	0.18	0.20	0.19
	14.00	34	35	34	34	0.16	0.18	0.17
	15.00	35	35	34	34	0.15	0.17	0.16
	16.00	36	37	34	35	0.15	0.17	0.16
	17.00	36	37	34	35	0.15	0.17	0.16
DAY 2	10.00	32	32	35	35	0.15	0.17	0.16
	11.00	34	35	36	35	0.14	0.16	0.15
	12.00	39	37	37	36	0.13	0.15	0.13
	13.00	36	37	36	36	0.11	0.14	0.13
	14.00	37	37	36	36	0.10	0.13	0.12
	15.00	36	36	35	35	0.10	0.10	0.10
	16.00	34	35	35	35	0.7	0.9	0.8
	17.00	32	32	32	32	0.6	0.7	0.7
DAY 3	10.00	32	32	34	36	0.6	0.7	0.7
	11.00	33	35	34	36	0.5	0.7	0.6
	12.00	37	43	35	38	0.4	0.7	0.55
	13.00	44	44	43	42	0.3	0.7	0.5
	14.00	42	44	39	39	0.3	0.6	0.45
	15.00	47	44	37	41	0.3	0.5	0.4
	16.00	34	35	36	37	0.2	0.4	0.3
	17.00	32	34	35	35	0	0.1	0.1

M_1- Initial Mass
M_2- Final Mass
M_A- Average Mass

Figure2: *picture of the plantain in the solar dryer after testing*

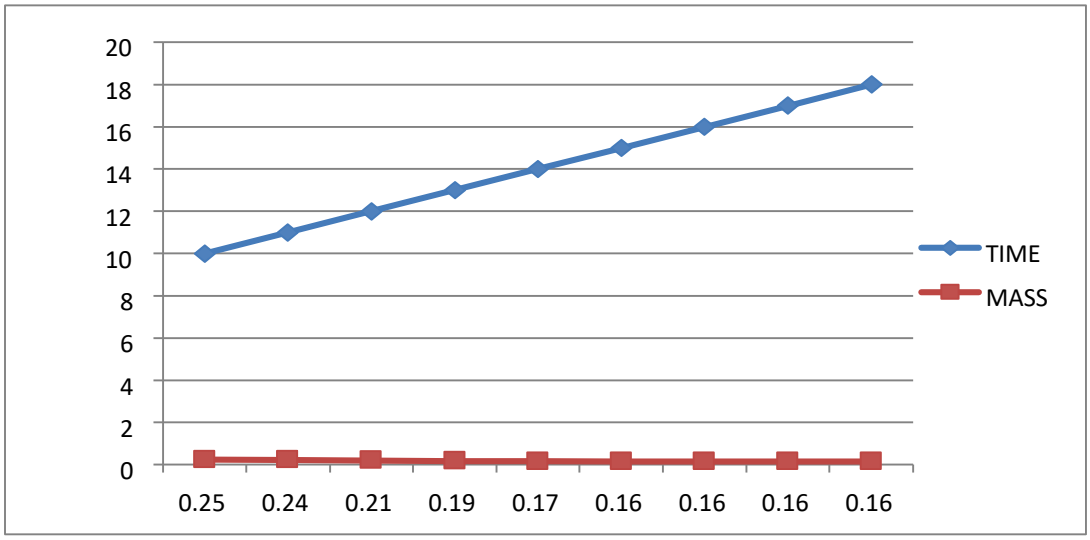

Fig. 3: *Day 1 of Drying*

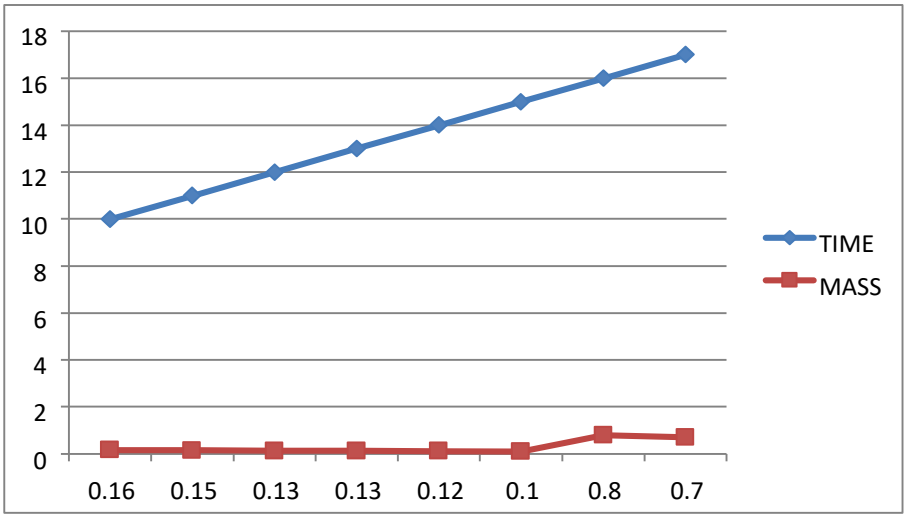

Fig 4: *Day 2 of Drying*

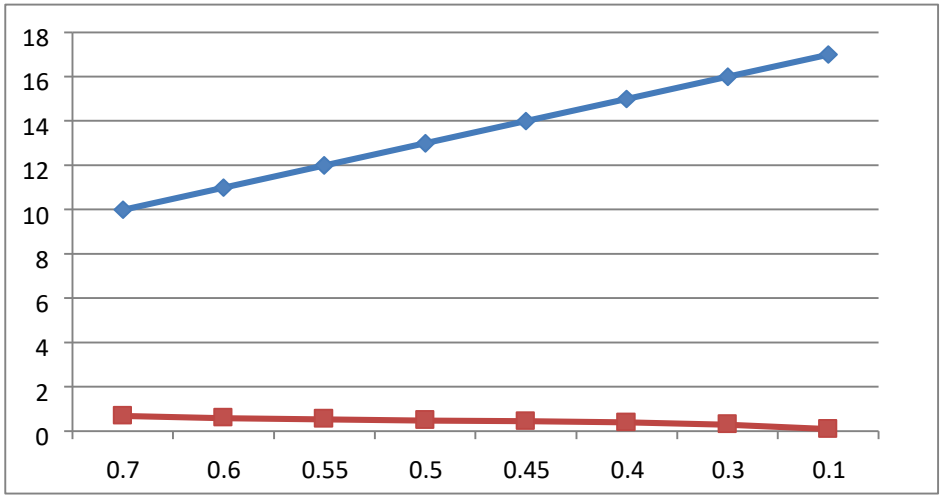

Fig 5: *Day 3 of Drying*

DISCUSSION

The solar dryer shown in Figures 1 and 2 was tested within three days to evaluate its performance. During the testing period, the air temperatures at collector inlet, collector outlet, drying chamber and ambient were measured by infrared thermometer with accuracy of +/- 0.2^0C at interval of 1 hour between 11am and 5pm each day. Table 1 shows the hourly variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The dryer is hottest about mid-day when the sun is usually overhead. The temperature inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. This agrees with the work of Chandan (2018), who constructed a solar drying system for mushroom preservation; also with the work of Phardi and Bhagoria (2013) in which a forced convention was applied in the mixed-mode dryer, yielding a temperature increase inside the drying cabinet of up to 64.5% for most of the hours in the noon time. Similarly in the work of Folaranmi (2008), an average of 45^0C was recorded inside the drying chamber against an ambient of 27^0C, which is equivalent to an increment of about 40% above ambient.

Figures 3-5 show the variation of mass with time. Figures 1 and 3 show the effect of humidity on drying capacity of the solar dryer. The mass of the agricultural produce almost remained constant when the humidity is high. There is appreciable decrease in the mass of plantain on the third day in Fig 5 when the humidity is relatively low compared with first and second day, this might be as result of large availability of solar radiation on that day. This also agrees with the work of Prakash et al. (2014) whose study was on performance analysis of Guntur red chili, where chili was dried to final moisture content of 9% wet basis from 80% wet basis. The average drying rate of the constructed solar dryer in this work was obtained to be 0.998 kg/h. In the work of Phardi and Bhagoria (2013), the performance evaluation of their mixed-mode dryer using forced convection gave a drying rate of 0.38 kg/h. Similarly, Ehiem et al. (2009), recorded a drying rate of 0.04kg/h at relative humidity of 35% using a forced convection dryer. Therefore, the performance of this dryer is quite satisfactory considering the fact that it is the natural convection type with a potential of forced convection too. This is because when the backup system is installed, it can also support a fan or a blower.

CONCLUSION

In this study, a renewable solar dryer was constructed and tested using plantain. One of the major reasons for drying food items is to reduce water content (moist content) in them so that such food items can be preserved for future use. The results gotten from this study shows that the usage of solar dryers in the preservation of agricultural product is effective. Solar dryers produce well-dried products with reasonably long-life storage. When used, the degree of losses due to insect infestation and contamination becomes insignificant.

RECOMMENDATIONS

Since solar drying has proved to be technically and economically feasible, It is therefore recommended;

- That a large scale solar dryer is developed to improve the acceptability of solar dryers among farmers.
- Further studies should be carried out of the use of solar dryers in the preservation of other agricultural products and its effects of the quality of such food items.

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DETERMINATION OF BASELINE RADIONUCLIDES CONCENTRATIONS IN FOOD SAMPLES AROUND PHOSPHATE DEPOSIT IN OSHOSUN, OGUN–STATE, NIGERIA

***[1]Ogunremi A. B, and [2]Biere P.E.,**

[1] Science Laboratoty Dept, Yaba College of Technology.Yaba, Lagos.
[2] Department of Physics, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

Corresponding Author: *ayorinde12@yahoo.com, +2348037482525

ABSTRACT:
Environmental impact assessment records are necessary before the commencement of mining operations. Deposits of phosphate mineral have been found in Oshosun, a town in Ifo Local Government Area of Ogun State, Nigeria. Radiological assessments of the matrices were carried out prior to commencement of mining. Fourteen foodstuffs samples (14) representing the major sources of dietary requirements to the villagers were collected. They were oven dried at 110 ^{0}C to constant weight, pulverized and sieved. Quantities of the sample, 150 g of each foodstuffs was sealed in cylindrical sample holders and kept for about 28 days to attain secular equilibrium between^{226}Ra and its decay products before analysis using gamma-ray spectrometry. The energy and efficiency calibrations were carried out using International Atomic Energy Agency certified materials (RGU-1, RGTh-1, and RGK-1). The mean activity concentrations of ^{40}K,^{226}Ra and ^{232}Th for the foodstuffs were 140.4±11.6,47.3±7.6, 28.4±1.9 Bq/kg respectively. The calculated mean effective dose for the foodstuff in the study area was 1.13 mSvyr^{-1}.The mean activity concentrations of naturally occurring radionuclides in the samples were below global averages. These baseline values will serve as a new set of data and references for monitoring and assessing radiological exposures after the commencement of mining operations in the area.

KEYWORDS: Environmental, Absorbed dose, spectroscopy, monitoring.

INTRODUCTION

Phosphate rock is a mineral assemblage that occurs naturally and contains an unusually high concentration of phosphate minerals (UNSCEAR,2000). It is found in igneous and metamorphic rocks as the mineral apatite, Ca5F(PO4)3, but it can also be of sedimentary origin (Koko *et al*.,2012). The most frequent source is one with a high phosphate proportion in nodular or compact masses, however, it can arise from a number of sources. It is the main resource that is extracted in order to make phosphate fertilizers, which are vital for maintaining the global agricultural output. Mineral fertilizer must be added to the soil to increase its nutritional content in order to guarantee an appropriate supply of food for human use (Olanipekun, 2017).

Naturally occurring radionuclides, such as ^{40}K and those from the uranium and thorium decay series (^{238}U and ^{232}Th), may be present in relatively high concentrations in phosphate ore (Koko *et al*.,2012). Concentrations of the ^{232}Th series and ^{40}K in phosphate rocks of all types are similar to those found in soil, whereas concentrations of ^{238}U and its decay products are elevated in sedimentary phosphate deposits. In sedimentary phosphate deposits, the typical activity concentration of ^{238}U is 1500 Bq/kg (RMRDC, 2010).

The release of emissions, such as dust from blasting and other mining operations, can have an impact on air quality. Mining waste discharge can have an impact on the environment, causing air and water pollution and environmental degradation. The

radioactive pollutants released into rivers, lakes, seas, and oceans are absorbed by aquatic plants and animals, both directly from the water and through the preceding link in the food chain. The resulting pollution contaminates all living organisms in the body of water, including the people who rely on fish as their primary source of protein and economic livelihood. In addition, the tree's photosynthetic ability to bear fruit is impaired, resulting in a decrease in production. Mining activities may cause health problems in communities near mines, including miners. (Abiye, 2005) determined that the doses in the Jos tin mining area were greater than 0.07 mSv/yr, the maximum permissible dose limit for members of the population. Therefore, the human body may experience a variety of health impacts from the consumption and inhalation of contaminants.

Ionizing radiation is harmful at high doses. Because of the potential health effects, it is imperative to understand the radiation levels in and around mining areas through the food matrix (Abiye, 2005). Certain actions, especially when there are mineral deposits, may increase chronic radiation exposure. Sadly, the general populace is not aware of the radioactive risk that could be present in the soil and food that come from these locations. As a result, mining may raise the concentration of natural radionuclides, although this must be prevented. One option is to obtain baseline data for the area prior to the start of mining. The measurement of natural radioactivity in foods and other sources is crucial because it aids in tracking changes over time in the natural background activity as a result of any radiation releases brought on by mining operations. There is possibilities that Oshosun might soon begin mining.

It is impossible to completely rule out the possibility of mining-related chemical and heavy equipment pollution of the environment's matrix-like diet, and it is always challenging to monitor the radiological and environmental effects after operations begin. Therefore, it is necessary to conduct a baseline evaluation of the area prior to the start of mining operations.

According to (Obaje *et al.*, 2013), Nigerian phosphates from the Sokoto and Ogun regions have been shown to have a very high reactivity, making them ideal as a fertilizer material, even when applied directly to the soil to increase fertility and agricultural production (Obisesan, 2004). The deposit, according to the Ministry of Solid Minerals Development (2000), is 40 million tonnes (Adebanwo *et al.*,2010). By the time operations start, phosphate mining would accelerate the development of Ogun State's and Nigeria's infrastructure.

Since mining has not yet started on the Oshosun Phosphate Deposit, there have been no industrial operations there. As a result, the levels of NORMS in the region are caused by what occurs naturally in the environment and not by human activity. Through this study, adequate data on natural and artificial radionuclide concentrations will be established. This will help in assessing any possible radiological hazard that the population could be exposed to in the future when the mining activities start. Such detailed baseline data will be made available to guide all stakeholders involved in the monitoring of the environment for environmental pollutants including radiation exposures.

MATERIALS AND METHODS

Samples Collection and Preparation

The food samples were collected randomly from various farms in and around Oshosun. Samples of each food stuffs were washed to remove dirt . Each of the samples collected were then transferred into polythene bag and labeled. The total number of representative food crop samples collected from Oshosun and its environ were fourteen . The samples

were taken to laboratory where they were cut into pieces, dried in oven at 110^0 C until a constant weight was obtained, this was followed by pulverization and then sieving of the samples. The process was followed by packaging into radon-impermeable cylindrical plastic containers. To prevent radon-222 escape, the packagings in each case were tightly sealed. The prepared samples were then stored for a period of about four weeks to attain secular equilibrium between radon (^{226}Ra) and its daughters prior to analysis using NaI(TI) gamma ray spectrometer (Khater *et al.*, 2001), (Eric, 2014).

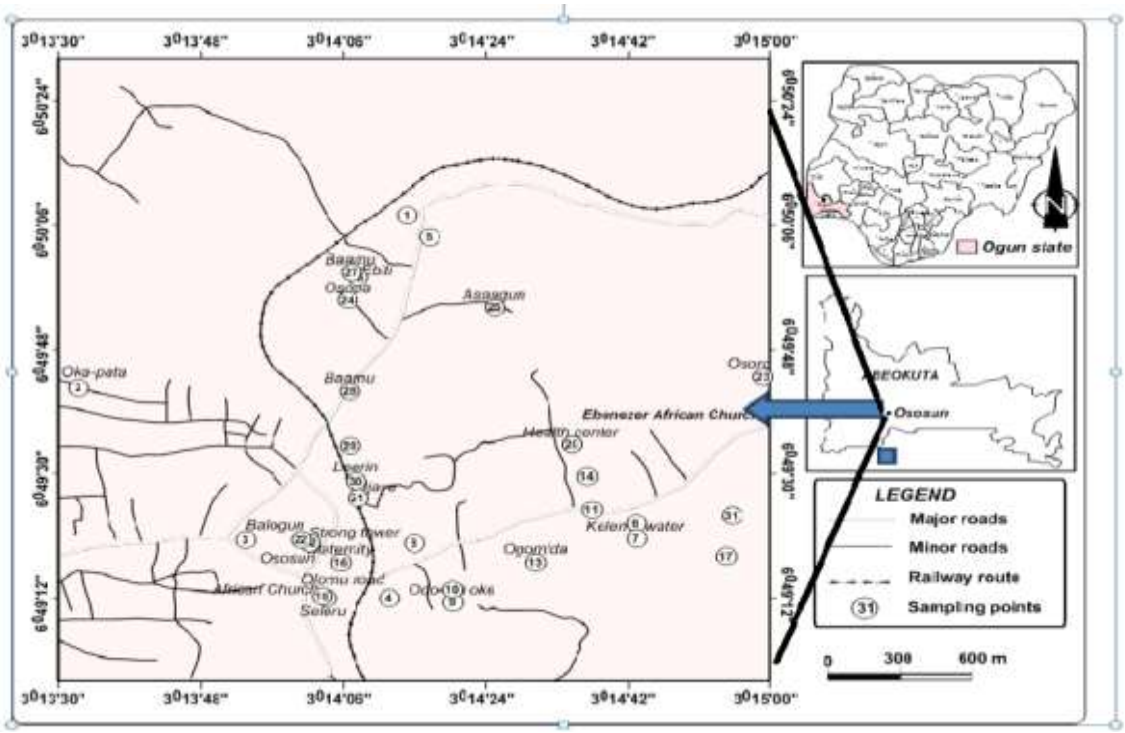

Figure 1: The map showing the locations in Oshosun where samples were collected.

Gamma-Spectrometry using Na(Tl) detector

Measurements of activity concentrations of the naturally–occurring radionuclides (^{40}K, ^{226} Ra and ^{232}Th) in the samples were performed using NaI(TI) gamma ray spectrometer. The gamma-ray spectrometry set-up consists of a 5.08 by 5.08 cm^2 NaI (Tl) detector, housed in a 6.0 cm thick lead shield which is lined with cadmium and copper sheets in order to reduce background radiation. A computer based multichannel analyser (MCA) and an Oak Ridge Technical Enterprises Corp (ORTEC) Digibase connected to a PC was used for the data acquisition and analysis of gamma spectra. The energy and efficiency calibration were performed using reference material. Both the primary reference materials and each of the samples were counted for a period of 10,800 sec, after which the net area under the corresponding gamma -ray peaks within their region of interest (ROI) in the energy spectrum, 1460 keV, 1764.5 keV and 2614 keV for ^{40}K, ^{226} Ra and ^{232}Th respectively, were computed.

Activity Concentration

The activity concentrations, C in Bqkg^{-1} are calculated from the decay and isotropic data, and the elemental concentration values provided in the reference materials preparation certificates using Equation 2.0 (Otwoma *et al.*, 2012).

$$C\left(\frac{Bq}{kg}\right) = \frac{C_o . N_A . \lambda . I}{M_W} \qquad 2.0$$

Where C_o is the Elemental concentration of the standard materials (µg g^{-1}), N_A is the Avogadro number (6.023 x 10^{23} $mole^{-1}$), λ is the decay constant ($sec.^{-1}$), I is the relative isotropic abundance, M_w is the molecular weight (g $mole^{-1}$) (IAEA,2003).

The results obtained from the samples and certified reference materials were substituted in the comparison method formula to get activity concentrations of the primordial radionuclides using Equation 2.1 (Mustapha, 1999).

$$\frac{A_{Sample}}{A_{std}} = \frac{CR_{sample} - CR_{Bgd}}{CR_{std} - CR_{Bgd}} \qquad 2.1$$

where

A_{sample} = Activity concentration of the sample, A_{std} = Activity concentration of the standard, CR_{sample} = Count rate of sample (cps), CR_{Bgd} = Count rate of Background (cps). CR_{st} = Count rate of standard (cps)

Effective dose from ingestion of radionuclides in foodstuffs

The intake of radionuclides in food is dependent on the concentration of radionuclides in the various foodstuffs and the amount consumed. The risk associated with the intake of radionuclides in the body is proportional to the total dose delivered by the radionuclides while staying in the various organs. The effective dose, E (mSv/y) to an adult individual due to intake of natural radionuclides in foodstuffs was calculated on the basis of the activity concentrations of the radionuclides. The committed effective dose owing to ingestion of ^{226}Ra, ^{232}Th and ^{40}K in foodstuffs was calculated using Equation 2.4 (Eric,2014).

E_{ing} (FS) = **Σ**(Afs × Ifs × IDCFfs) 2.4

where; Afs, is the average activity concentration of radionuclides (Bq/kg) in foodstuffs, Ifs, is the annual intake of foodstuffs, IDCFfs, is the dose conversion factors (Sv/Bq) 40 kg/y for Tubers, 45 kg/y for Vegetables, 75 kg/y for Pawpaw and 50 kg/y Plaintain (RIFE, 2004). The dose coefficients for the public were 4.5 x 10^{-5}, 7.2 x 10^{-5} and 6.2 x 10^{-6} mSvBq^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively (ICRP,1992), (Jibril and Abiodun 2012).

RESULTS AND DISCUSSION

The activity concentration oftheradionuclides in food stuff samples taken from different locations in the study are presented in Table 1. The activity concentration of ^{40}K(Bq/kg) ranged from 5.01 ±9.71 in Bitter leaf at Olomu to 138.81± 22.59 in Plantain at the same village with a mean of 68.87 ± 4.47 Bq/kg.^{226}Ra was calculated and the range was from 8.39 ± 78.17 -74.68± 33.47 Bq/kg at Asaagun with a mean of 45.35 ± 15.63Bq/kg.The range of ^{238}Th in the samples were from 13.74±12.21 at Olomu to 47.87 ±9.69 Bq/kg at Osoba with the mean of 28.37±1.90 Bq/kg.The activity concentration of vegetable was low contrary to (Awudu *et al*.2012).

It could be observed that the primordial elements are not uniformly distributed in the samples and also that the measured ^{40}K activity concentration was higher than the values of both ^{226}Ra and ^{232}Th, this attested to the probable high consumable absorption of the element from the land.Also

application of fertilizer which is a common practice in the area can enhance the availability of ^{40}K in the soil.The frequency distribution of the activity concentration in the foodstuffare presented in Figures 2,3 and 4 for ^{40}K,^{226}Ra and ^{232}Th respectively. The ^{40}K in the distribution is tri-modal (3 modes). This is not normally distributed because the modes are at both ends of the mean. Figure 2 (^{226}Ra) shows a bimodal distribution. This is somewhat normal because one of the modes is at the same level with the mean. ^{232}Th (Figure 3) in the sample is normally distributed.

The study showed a highly non-uniform distribution of primordial radionuclides in food crop samples, with activity concentrations varying significantly within the study area. ^{40}K has highest concentration when compared with other radionuclides. This may be due to the highly localized mineralization of Potassium in the soil. The calculated mean effective dose for the foodstuff in the study area was 1.13 $mSvyr^{-1}$.

Table 1: Activity Concentration and Committed Effective dose due to ^{40}K, ^{226}Ra and ^{232}Th in Food stuff Samples

Group	Sample	Botanical name	locations	Activity Concentration (Bq/kg)			Effective dose (Sv/y)
				^{40}K	^{226}Ra	^{232}Th	
Tuber	Water yam 1	Dioscorea Alata	Balogun	8.78 ± 22.00	49.89 ± 51.15	22.52 ± 13.6	0.22
	Water yam 2	Dioscorea Alata	Oshosun	94.07 ± 14.70	44.58 ± 67.76	28.37 ± 11.22	
	Yam 1	Dioscorea Rotundata	Asaagun	72.75 ± 22.87	71.78 ± 44.19	22.51 ± 12.80	
	Cassava 1	Manihot Esculanta	Olomu	58.95 ± 12.46	55.19 ± 31.73	23.49 ± 10.34	
	Cassava 2	Manihot Esculanta	Asaagun	55.19 ± 11.51	58.57 ± 39.65	19.59 ± 10.18	
	Yam 2	Dioscorea Rotundata	Osoro	28.85 ± 11.16	46.99 ± 36.83	35.19 ± 13.07	
Vegetable	Bitter leaf	Vermonia Amygdalina	Olomu	05.02 ± 9.71	57.32 ± 38.26	13.74 ± 12.21	0.19
	Jute leaf	Corchorus Olitorious	Asaagun	82.79 ± 14.65	27.69 ± 60.68	17.64 ± 10.3	
	Lagos Spinach	Celosia Argentea	Asaagun	67.73 ± 15.83	74.68 ± 33.47	26.42 ± 11.34	
	Tree Spinach	Cnidoscolus Aconitifolius	Laaran	15.05 ± 13.01	61.37 ± 61.85	30.32 ± 16.52	
	African spinach	Amaranthus Hybridus	Laaran	122.92 ± 17.87	15.15 ± 60.14	43.97 ± 9.54	
	Atetedaye	Desmodium Intortum	Asaagun	80.28 ± 11.88	8.39 ± 78.17	27.39 ± 10.49	
Plant	Pawpaw	Carica Papaya	Osoba	132.96 ± 12.19	33.96 ± 42.04	47.87 ± 9.69	0.43
	Plantain	Musa Paradisiaca	Olomu	138.81 ± 22.59	29.33 ± 74.88	38.12 ± 11.74	0.29
	Range			5.02- 138.81	8.39 -74.68	13.74-.47.87	
	Mean			68.87	45.35	28.37	

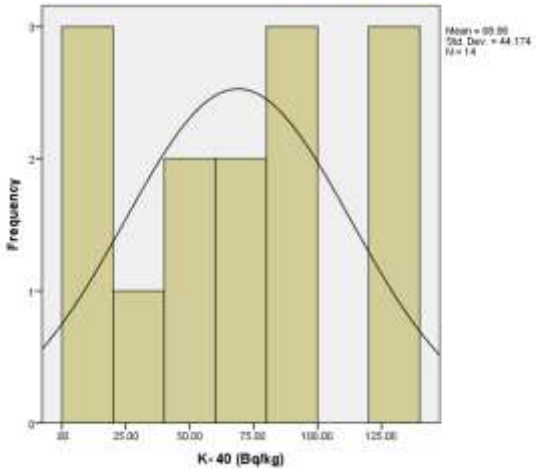

Figure 2: Frequency distribution of Activity Concentration of ^{40}K in Food samples from Oshosun.

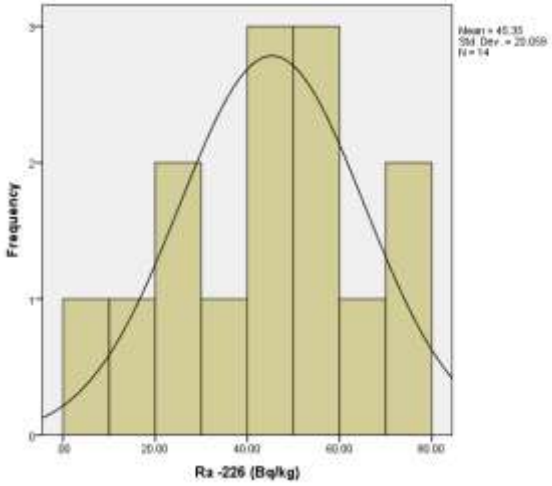

Figure 3: Frequency distribution of Activity Concentration of ^{226}Ra in Food samples from Oshosun.

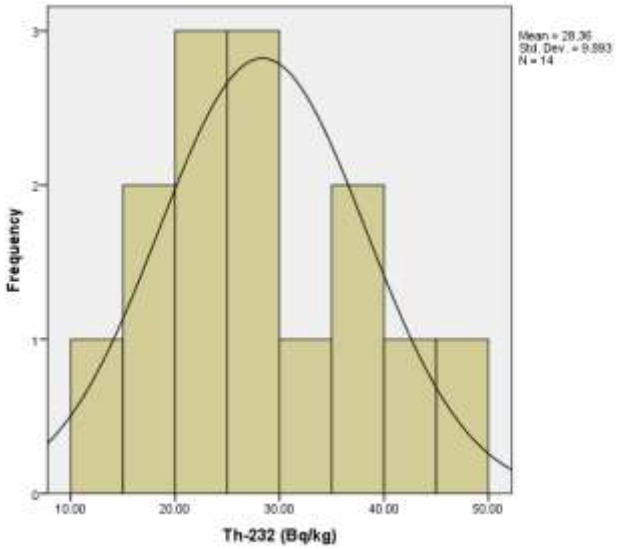

Figure4: Frequency distribution of Activity Concentration of ^{232}Th in Food samples from Oshosun.

CONCLUSION

During mining, the quality of the air can be affected due to the release of dust from blasting, drilling, loading and haulage of the earth materials as well as heavy trucks exhaust gases. This will also increase the radiation dose individual is exposed to since the release are from radionuclides of terrestrial origin.

The result revealed a highly mineralization of potassium which is an important requirement for plant growth and development in the soil. The results obtained in this work are within the tolerable values, but every effort must be made to monitor the environment in order to control the radiation dose released to man from the environment.

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$PM_{2.5}$ VARIATIONS AND AIR QUALITY ASSESSMENTS IN THREE LOCATIONS.

***[1]Nzekwe, N. M., [1]Adekoya, O.I., [2]Ovioma, G. O. and [1]Obey, B. I.**

[1]Physical Science Department, Yaba college of Technology Yaba, Lagos.
[2]Biological Science Department Yaba College of Technology Yaba, Lagos.
***Corresponding Author**: *nwachukwu.nzekwe@yabatech.edu.ng.*

ABSTRACT

Air Quality is a major concern of most civilized world; this has a serious effect on human health and the environment. Air pollution threatens the quality of air in our planet. It creates smog and acid rain, causes cancer, respiratory diseases, reduces the ozone layer atmosphere and contributes to global warming. This study aimed at assessing the level of Particulate Matters ($PM_{2.5}$) in Lagos, Abuja and Beijing for a routine measuring device at the US embassy situated in the mentioned stations. General Air Index Acquisition (GAIA) instrument uses a high-tech laser particle sensor to measure air indices in real-time. It only requires a Wi-Fi access point and a USB power supply, once connected; air quality levels of $PM_{2.5}$ are monitored continuously. Measured results showed that daily $PM_{2.5}$ values for 2021,varies from 38 to 370µg/m^3, 51-376µg/m^3 and 15-265µg/m^3 at Lagos, Abuja and Beijing respectively, while the monthly averages showed variations of 93.9 to 160.2µg/m^3, 76.0 to 179.9µg/m^3 and 74.1 to 147.03µg/m^3 respectively for Lagos, Abuja and Beijing. The implications of this monitored values in the colour ranges is a shift from "Moderate" to "Unhealthy" conditions for the three locations. Lagos had the highest in the observed values of the daily variation ranges of $PM_{2.5}$ in the air. This may be adduced to the commercial and industrial activities in Lagos.

KEYWORDS: Air pollution; Air quality index; Particulate Matter ($PM_{2.5}$), health condition and Sensitive groups.

INTRODUCTION.

The earth is enveloped by a thick blanket of gases. This gaseous cover of the earth is known as the atmosphere, and it is held to the earth by the force of gravity. It consist of 78% nitrogen and 21% oxygen, with the remaining consisting of argon, carbon (IV) Oxide (CO_2), ozone (O_3) and water vapor. Other gases such Neon, Krypton, Helium, Methane, Hydrogen etc. occur in very small proportions. The atmosphere also contains suspended liquid and particulate matters (PM), collectively called aerosols, extending several thousands of kilometers above the earth's surface. Studies have revealed that these atmospheric particles can lead to the reduction of biodiversity and the quality of goods and services offered by ecosystem. Air pollution is one of the environmental problems confronting growing cities and is currently the challenge faced by many developed and developing countries (Amos *et al*, 2015). Air pollution is defined as the presence of one or more substance in the atmospheric air at concentration and duration above the natural limits and cause damage to the natural environment (Tawari and Abowei, 2012).

Particulate matter (PM) is divided into two main categories according to type and size. Gas contaminants include PM in aerial masses. Particulate contaminants include contaminant such as Smog, Soot, Tobacco smoke, Oil smoke, Fly ash and cement dust. Life on earth is supported by layer of air, solar energy, our planet magnetic field and the quality of air is very essential to it sustenance (Adesuyi *et al*, 2016). Air Quality is a measure of how clean or polluted the air is.

Monitoring air quality is important because polluted air can be bad for our health – and the health of the environment. In addition to land and water, air is the prime resource for sustenance of life (Hiren and Jagruti, 2017). Exposure to air pollution is associated with a wide range of diseases including Chronic Obstructive Pulmonary Diseases (COPD), asthma, lung cancer, heart disease, stroke, arterial thrombosis and hypertension (Babatunde *et al*, 2020). When we breathe polluted air, pollutants get into our lungs; they can enter the bloodstream and be carried to our internal organs such as the brain. Air pollution has been common health concern not only for humans but also for animals, plants, oceans, aquatic life worldwide (Pradeep and Harne, 2018).Particulate matter is one of the most important parameter having significant contribution to increase in air pollution (Ramik, 2019). These substances are mainly concentrated in metropolitan area and their amounts are frequently higher than the threshold values imposed by local regulations. The possible causes lied in the vehicular traffic, the industrial plants emissions and heating of buildings. People are worried about the effects on human health of possible atmospheric pollution caused by the gaseous emissions of combustion plants (Sofia *et al*, 2018). Air pollution, therefore, is a serious threat to environmental health in many cities of the world today. It is very pertinent to note that this condition is not unconnected to the fact that one of the basic requirements of human health and existence is clean air (Ibe *et al*, 2017).Rapid, accurate and high-throughput sizing and quantification of particulate matter (PM) in air is crucial for monitoring and improving air quality. In fact, particles in air with a diameter of ≤2.5μm have been classified as carcinogenic by the World Health Organization (Wu *et al*, 2017).

Airborne particulate matter has a harmful impact and is estimated to cause between 3 and 7 million deaths per year, mostly due to the creation or worsening of cardio-respiratory disease (Hoek *et al*, 2013). This study is aimed at measuring and assessing the level of $PM_{2.5}$ in the atmosphere, for a routine measuring device situated in the US embassies at Lagos, Abuja and Beijing. In the process, the daily and monthly averages of $PM_{2.5}$ from the measured hourly values at Lagos were calculated. The trends of variation of $PM_{2.5}$ during 2021 were explained, and simultaneously compared with the trends at Abuja and Beijing.

MATERIALS AND METHODS

Fig1, shows picture of a routine GAIA (General Air Index Acquisition), air quality monitoring instrument with mounted sensors. Inside the metal box, the system consists of a micro controller with three sensors extending outwardly to the air, namely carbon monoxide sensor, particulate matter sensor, and smoke sensor. This system is also equipped with a data. Logger to store measured data and LCD to display the level of air quality. The air quality $PM_{2.5}$ measurements were carried out simultaneously in three geographical locations of; Lagos and Abuja in Nigeria, together with Beijing in China all at the US embassies located in the stated countries. The $PM_{2.5}$ measurement were carried out using the GAIA, air quality monitoring meters, which uses a high-tech laser particle sensor to measure in real-time $PM_{2.5}$ pollution. With the help of a WIFI access point and a USB power supply, once connected, air pollution levels are reported instantaneously and in real-time. The $PM_{2.5}$ measurements were monitored in real-time for the entire year 2021 except for December, after which the mean measurement for different months were calculated. The entire measurements in the three locations were pulled together with the help of the internet.

Fig.1: Picture of the routine GAIA Air Quality Monitoring Instrument with mounted sensors.

RESULTS AND DISCUSSION

Fig2, shows the daily trend of variation of $PM_{2.5}$ at Lagos, Abuja, and Beijing for January and February during year 2021.

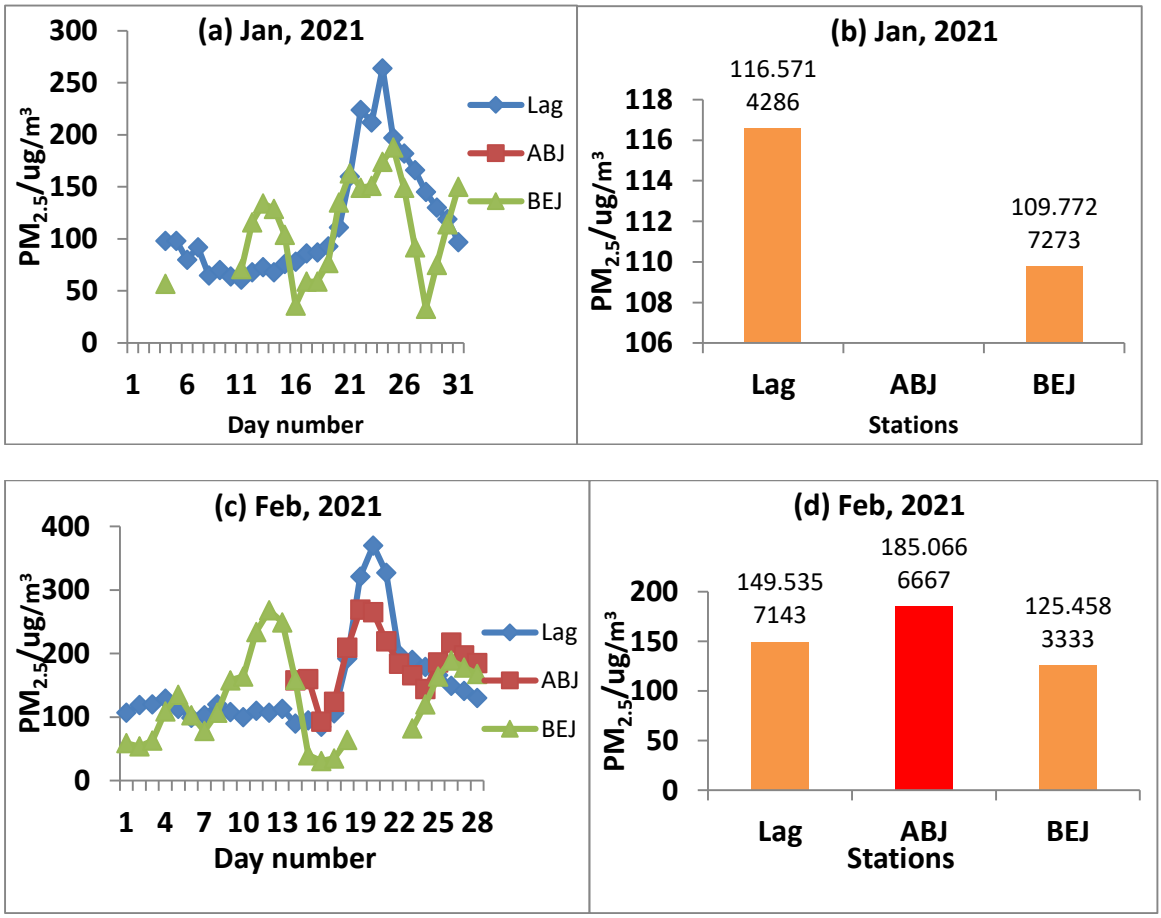

Fig 2: $PM_{2.5}$ Daily Variation (a & c) and monthly averages (b & d) at Lagos, Abuja and Beijing during January and February, 2021.

The variations of $PM_{2.5}$ depicted in Fig 2 (a & c) were 98µg/m^3 for January to 370µg/m^3 during February at Lagos, 57 to 268µg/m^3 at Abuja and 93 to 265µg/m^3 at Beijing. The monthly averages of 116.6 to 149.5µg/m^3 at Lagos, from zero record at Abuja in January to 185.1µg/m^3 in February and 109.8µg/m^3 in January to 125.5µg/m^3 in February at Beijing as indicated in Fig 2(b & d). The implications of this $PM_{2.5}$ values according to USA Environmental Protection Agency, USEPA, (2021) are for the health details of the locations which ranges from unhealthy for sensitive groups at Lagos and Beijing to unhealthy at Abuja. When is unhealthy, everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.

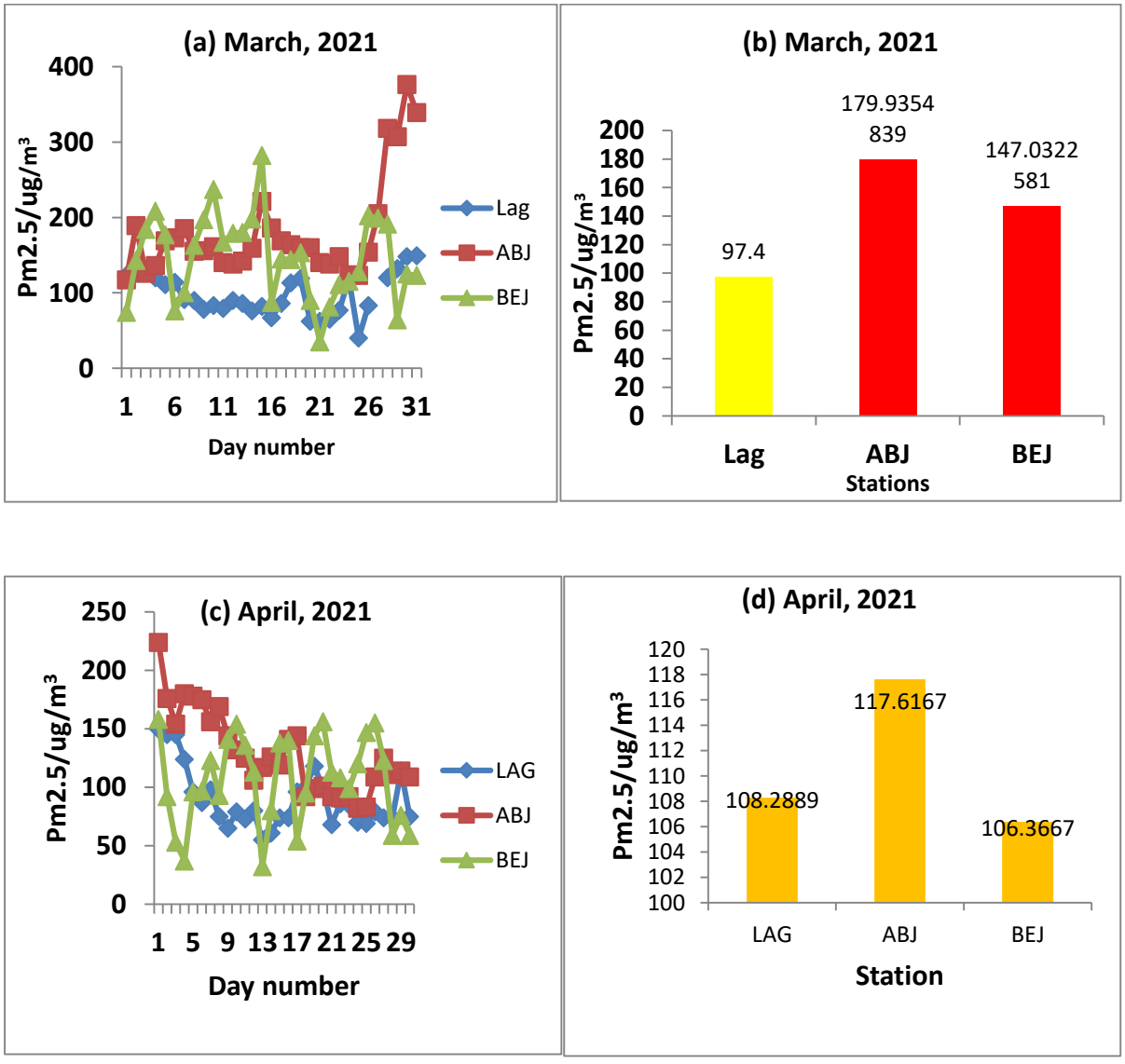

Fig 3: $PM_{2.5}$ Daily Variation (a & c) and monthly averages (b & d) at Lagos, Abuja and Beijing during March and April, 2021.

In Fig 3(a & c), the trend in the daily variation of $PM_{2.5}$ from March to April is from 40 to 145µg/m^3 at Lagos, 83 to 376µg/m^3 at Abuja and 32 to 282µg/m^3 at Beijing. The monthly averages (depicted in Fig 3(b & d)) were 97.4 (Yellow) to 108.3µg/m^3 (Orange), 179.9(Red) to 117.6µg/m^3 (Orange) and 147.03 (Red) to 106.4µg/m^3 (Orange) for Lagos, Abuja and Beijing respectively. The colours indicated

shifts from moderate to unhealthy for sensitive groups at Lagos and unhealthy to unhealthy for sensitive groups both at Abuja and Beijing. During moderate condition, air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution. Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion. (USEPA, 2021)

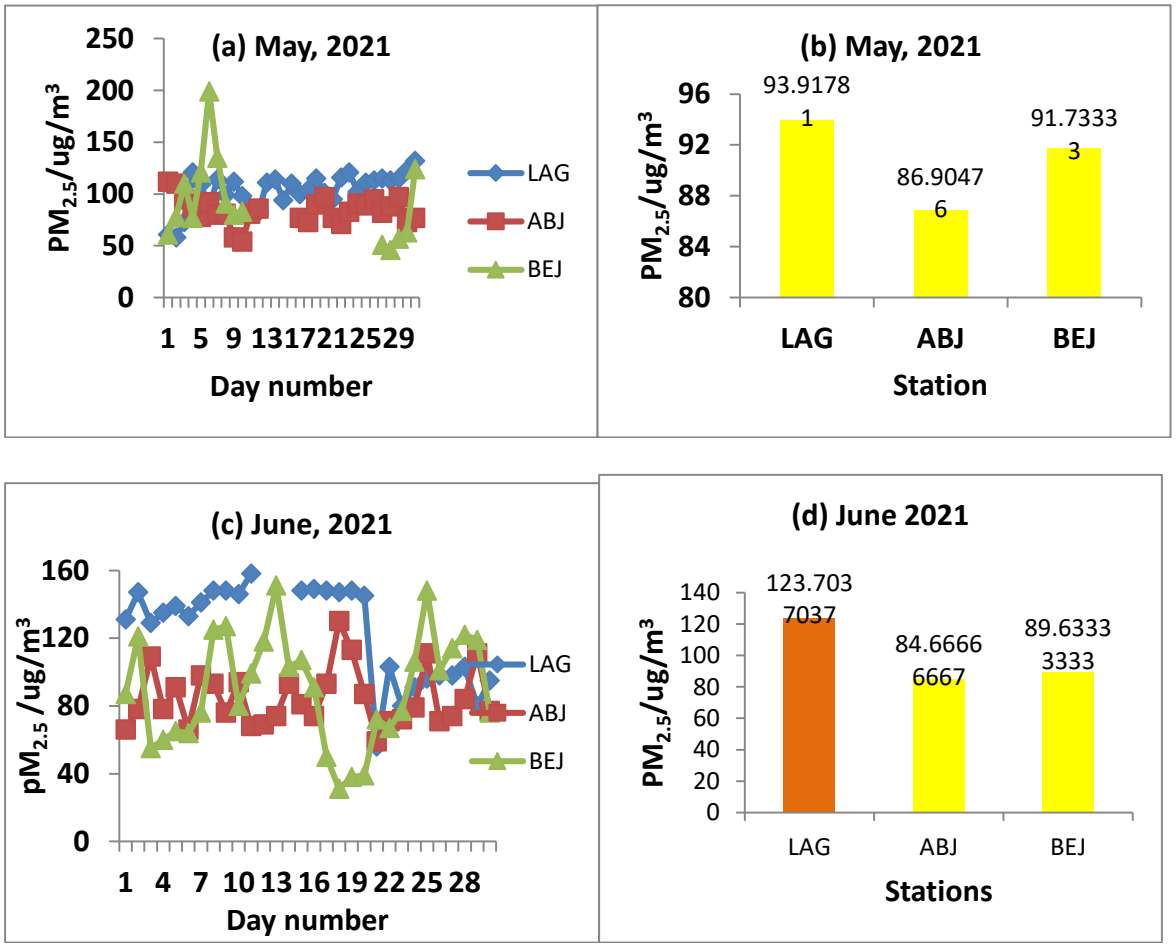

Fig 4: $PM_{2.5}$ Daily Variation (a & c) and monthly averages (b & d) at Lagos, Abuja and Beijing during May and June, 2021.

Fig 4 shows the variations and monthly averages of $PM_{2.5}$ for the months of May and June, 2021. The trend for Lagos, Abuja and Beijing, depicted in Fig 4(a & c) were 61 to 158µg//m^3, 54 to 130µg//m^3 and 51 to 151µg//m^3 respectively. The monthly averages are depicted in Fig4 (b & d) as 93.9 (Yellow) to 123.7µg/m^3 (Red), 86.9 (Yellow) to 84.7µg/m^3 (Yellow) and 91.7 (Yellow) to 89.6µg/m^3 (Yellow) for Lagos, Abuja and Beijing respectively. The variation is more at Lagos, a shift from Yellow (Moderate health condition) to Red (Unhealthy condition), while a moderate health condition were sustained at Abuja and Beijing for these two months. The result obtained in Lagos for these months could be adduced to dust entering the country, urban traffic and industries in the area (Mirhosseini *et al*, 2012).

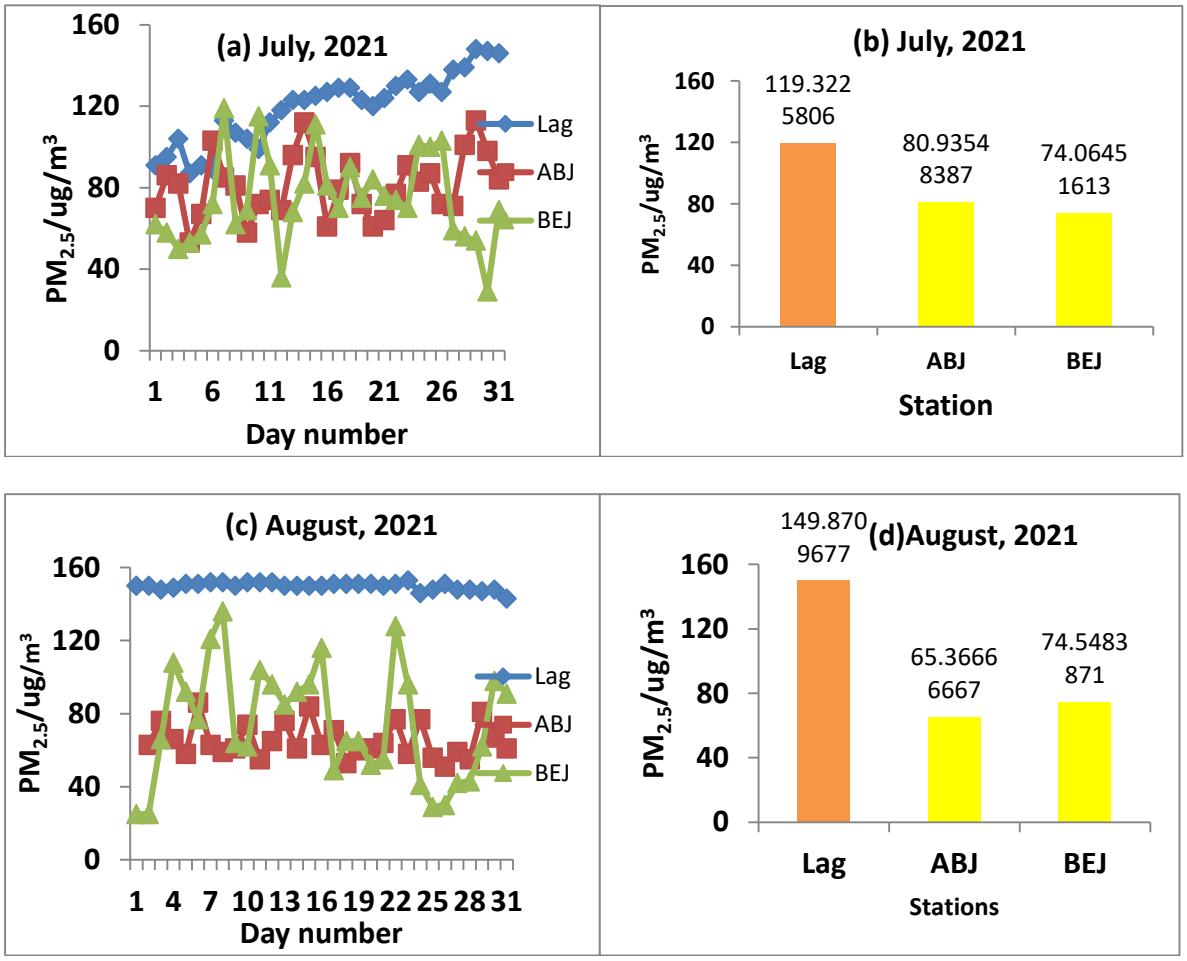

Fig 5: $PM_{2.5}$ Daily Variation (a & c) and monthly averages (b & d) at Lagos, Abuja and Beijing during July and August, 2021.

Furthermore, the trend of variations and monthly averages for July and August, 2021 are presented in Fig 5. In Fig 5(a & c), daily variation trends of 86 to 153µg/m^3, 51 to 113µg/m^3 and 29 to 136µg/m^3 are presented respectively for Lagos, Abuja and Beijing locations. The monthly averages are 119.3 (Red) to 149.8µg/m^3 (Yellow) and 74.1 (Yellow) to 74.5µg/m^3 (Yellow) for Lagos, Abuja and Beijing respectively in Fig 5(b & d). The health conditions of the locations for the two months were sustained as: Unhealthy for Lagos and Moderate for both Abuja and Beijing. The Unhealthy condition presented at Lagos for these two months in the values of $PM_{2.5}$ could not be far fetch from vehicular and industrial emissions.

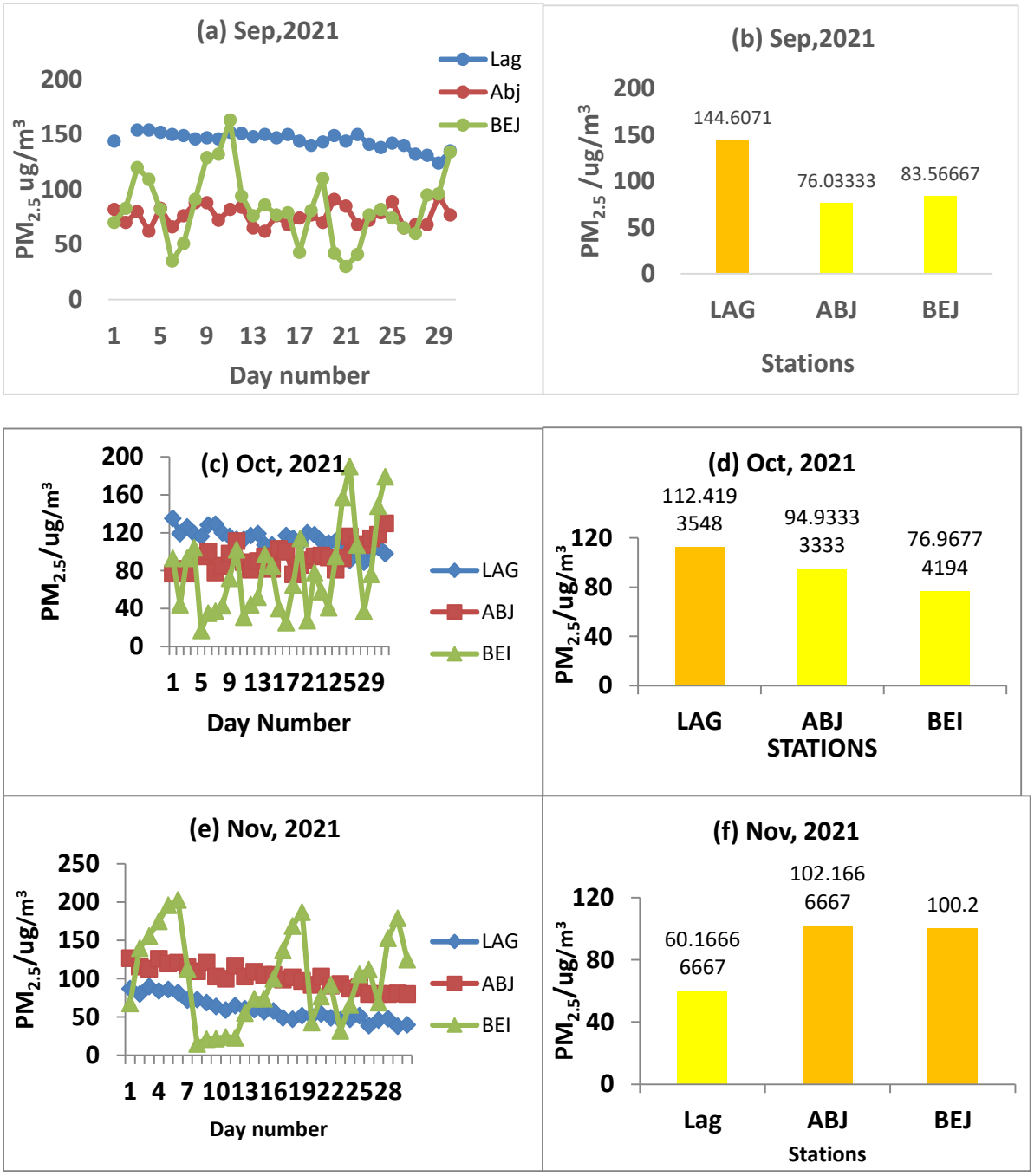

Fig 6: $PM_{2.5}$ Daily Variation (a, c & e) and monthly averages (b, d & f) at Lagos, Abuja and Beijing during Sep, Oct and Nov, 2021.

Further still, Fig 6 shows the trend in the daily variations and monthly averages of monitored $PM_{2.5}$ values for the months of September, October, and November, 2021. Considering Fig 6 (a, c & e), the observed variations are 38 to 154µg/m^3, 62 to 131µg/m^3 and 15 to 196µg/m^3 at Lagos, Abuja and Beijing respectively. The column charts in Fig 6 (b, d and f) for the three months, showed a colour shift from Orange (144.6µg/m^3) to Yellow (160.20µg/m^3), Yellow (76.0µg/m$^{3)}$ to Orange (102.2µg/m^3) and Yellow (77.0µg/m^3) to Orange (100.2µg/m^3) for Lagos, Abuja and Beijing respectively. These indicate a shift from unhealthy for sensitive groups to moderate at Lagos and Moderate health condition to Unhealthy to sensitive groups at Abuja and Beijing.

Following the daily trend depicted in the graphs, the implications of the different values are further discussed as follows:

0 – 50 (Good): Air quality is considered satisfactory, and air pollution poses little or no risk.

51 – 100 (Moderate): Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution. Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.

101 – 150 (Unhealthy for Sensitive Groups)
Members of sensitive groups may experience health effects. The general public is not likely to be affected. Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.

151 – 200 (Unhealthy)
Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.

201 – 300 (Very Unhealthy)
Health warnings of emergency conditions. The entire population is more likely to be affected.
Active children and adults, and people with respiratory disease, such as asthma, should avoid all prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.

300+ (Hazardous)
Health alert: everyone may experience more serious health effects. Everyone should avoid all outdoor exertion. (USEPA, 2021)
Overall results obtained from the study in the three stations showed some shifts in the Air quality index $PM_{2.5}$ switching from healthy, moderate, unhealthy and at some time hazardous health conditions as depicted in the daily values. Seasonal trend was depicted in the variations $PM_{2.5}$ across the various months. The Air Quality Index (AQI) values obtained from Lagos in this study was high at some times, then decreases along the line, this result depicted 'unhealthy' to 'moderate' health conditions, while that of Abuja and Beijing were increasing and decreasing i.e ranging from 'moderate' to 'unhealthy'. In the analysis, most of the $PM_{2.5}$ values were above the National Ambient Air Quality Standards, (NAAQS) limits of 35ug/m^3, (Osimobi *et al*, 2019) and the recommended air quality index of the federal ministry of environment (FMEnv) limits of .0.5ug/m^3, (Abulude *et al*, 2020).. Hence national standards to reduce the $PM_{2.5}$ in the air at these three locations are urgently required.

CONCLUSION

The findings of this work and its implications could be summarised as follows:

1. $PM_{2.5}$ daily variations at the three stations are 38-370µg/m^3, 51 - 376µg/m^3 and 15-265µg/m^3 at Lagos, Abuja and Beijing respectively. Lagos had the highest range of 332µg/m^3 in the daily variation.

2. $PM_{2.5}$ monthly averages for the entire year obtained were 93.9-160.2 µg/m^3, 76-179.9µg/$m^3$and 74.1-147.02µg/m^3 at Lagos, Abuja and Beijing respectively. Abuja depicted the highest range of 103.9µg/m^3 in the monthly averages.

3. Seasonal variations are depicted across the months. This is seen as different health conditions across months.

4. Most of the $PM_{2.5}$ values were above the National Ambient Air Quality Standards, (NAAQS) limits of 35ug/m^3. Hence national measures to reduce the $PM_{2.5}$ in the air at these three locations are urgently required.

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