*International Journal of Innovative Environmental Studies Research 5(2):1-9, April-June, 2017*

 www.seahipaj.org ISSN: 2354-2918

# Geophysical Characterization of Bende Clay Deposit for Industrial Applications

**[*1]Chukwu G.U,** [1]Nwachukwu U.H and [2]Azunna D.E**
***Email: chukwu.godwill@mouau.edu.ng, +2348025691478**
****ukawhyte@yahoo.com, +2348063966614**

**[1]Department of Physics, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267, Umuahia, Abia State, Nigeria**
**[2]Department of Physics, Clifford Unversity, Owerrinta, Abia State Nigeria**

**ABSTRACT**
This study evaluates the geophysical characterization of Bende clay for industrial applicability. The clay is obtained from Bende Local Government Area of Abia State, Nigeria. The chemical analysis of the clay showed silica (53.65%) and alumina (26.42) as the major constituents while other metal oxides such as $Fe_2O_3$ (2.50%), $Na_2O$ (0.45%), $K_2O$ (2.7%), MgO (1.52), CaO(0.28) and LOI (12.2) are present in appreciable amounts. The physical analysis showed the firing volume shrinkage of the clay bodies to be (34.40%) at $1250^0$C. The Apparent porosity (12.54%), Bulk density (1.51g/cm$^3$), Water absorption capacity (7.66%) and modulus of rupture (33.05kgF/cm$^2$). The result of this study showed that Bende clay has good industrial potentials and can be utilized in the manufacture of ceramics and fired bricks. However, addition of additives such as feldspar and quartz has a tremendous effect on the properties of the clay body in improving its strength and reduce the amount of warping, cracking and bloating after sintering. Moreso, if well utilized, it will reduce the bulk of clay minerals and materials imported from foreign countries into Nigeria.
**Keywords**: Bende clay, ceramics, Industrial potentials, physico-chemical properties, minerals.

## 1.0 INTRODUCTION

Clay mineral is, without doubt one of the most natural and oldest earth raw materials which is recognized by certain properties. It is an earth which when mixed with water forms a coherent that is readily mouldable. However, if dried it becomes hard and brittle, but can again be made soft by the addition of water. Finally, if baked to red heat, it becomes still harder and then is no longer susceptible to the action of water (Frome, 1994). Clay minerals are layers of silicates that are formed as a result of weathering at the earth's surface. In cool, dry or different climate change, clay minerals are fairly stable and formed an important component of soil as water retention. Chemically, clays are hydrous aluminium silicates, usually containing minor amounts of impurities such as potassium, sodium, calcium, magnesium or iron. However, application of clay are so many, ranging from oil aborbants, ceramics, animal feeds, pottery, pharmaceutical, drilling fluids, water treatment, paint and lots of more uses.

However, over the years many researchers have carried out studies on characterization and properties of clays found in different parts of Nigeria in order to provide useful information on their applicability. Knowing of the characterization of the clay available in any region helps in its applicability in the area and give a general information on the usage either in ceramic, drilling mud, plastics, paints, textiles and adhesives, paper, pharmaceuticals and rubbers, etc. Consequently, the local demands for ceramic products are very high considering the population yet most of the products are imported. Presently, Nigeria imports more than 50 containers of ceramics product daily which amount to about five billion naira annually in the importation of ceramics products (Etukudoh, 2016). This is a discouragement notwithstanding the huge availability of clay materials in our country and intellectual researchers in our high institutions and research centers. Therefore, in response to this challenge, the industrial potentials and characteristics of most clay deposits in Nigeria needs to be investigated and channel to an industrial use.

In Abia State of Nigeria, there is abundance of clay deposits which have not been characterized which may be useful in the manufacture of ceramics and other industrial products. This Bende clay is one of such clay which is present in abundant amount in Uzuakoli village in Bende L.G.A of Abia State, Nigeria. Despite the discovering of huge deposit of this clay, there has been scarcity of information of its properties for industrial applications. This study therefore investigates the characterization and potentials of Bende clay for its industrial uses to help reduce the high rate of importation of clay products in Nigeria. The chemical and physical properties of Bende clay were determined and related to the application in the manufacture of useful industrial products.

### 1.2 Location and Geology of the Study Area

This research is carried out with clay mineral samples from Agbozu-Uzuakoli in Bende L.G.A of Abia State, Nigeria. Its location is between latitude $5^0$ $34^1$ and $5^0$ $38^1$N and Longitude $7^0$ $32^1$ and $7^0$ $34^1$E. Abia State is located in the South-East Geopolitical zone of the country. The geology of Abia State as a whole is in a sedimentary terrain underlain by the Benin Formation (Iloeje, 1992). This Benin Formation is made up of coastal plain sands of Pleistocene age (Thomas, 2009). It is composed of fine-coarse grained sands and sandstone which are seldomly punctuated by thin layers of dense shale clays with about 80% of quartz content and a little feldspar content (Akpokodje and Etu-Efeotor, 2007). The Benin Formation is of the Tertiary Niger Delta which occupies approximately 6400 $km^2$ of the sedimentary basin of southern Nigeria (Allen, 1996). The climate of Abia State is of the humid tropics, with fairly even temperatures throughout the two season (dry and rainy) of the year. The rainy season which usually starts from April/May and ends in October/November is characterized by clouds driven by light winds, relatively constant temperatures ($30.2^0$C – $22.3^0$C), frequent rains and high humidity. From early November, when the dry season sets in, the weather clears rapidly as the northeast trade wind shifts to become the dusty 'Harmattan' bringing in the drier air from the Sahara desert. This season is notably dry with little or no rainfall, hotter days, cooler nights and lower humidity and this ends in March/April.

## 2.0 RESEARCH METHODOLOGY AND PROCEDURES

Bende clay sample was obtained by random sampling at different points in Agbozu-Uzuakoli in Bende L.G.A. Methods employed in locating the sites were through interviews and interrogations. Identifications of the samples were through observations; the samples were felt in the palms before the actual collections were made. Machetes, shovel and hoe remained the major tools for excavation, while sac bags were used for conveyance. These clay mineral samples were taken at a surface deposit, not more than 1m beneath the earth surface. This research study is designed to investigate the chemical and geophysical properties of Bende clay mineral, to find out its suitability in order to determine its economic value and industrial potentials. It is also designed to serve as a reference material to industrialists who may wish to site a ceramics production industry in Abia State. The process flow chart for the research is given below.

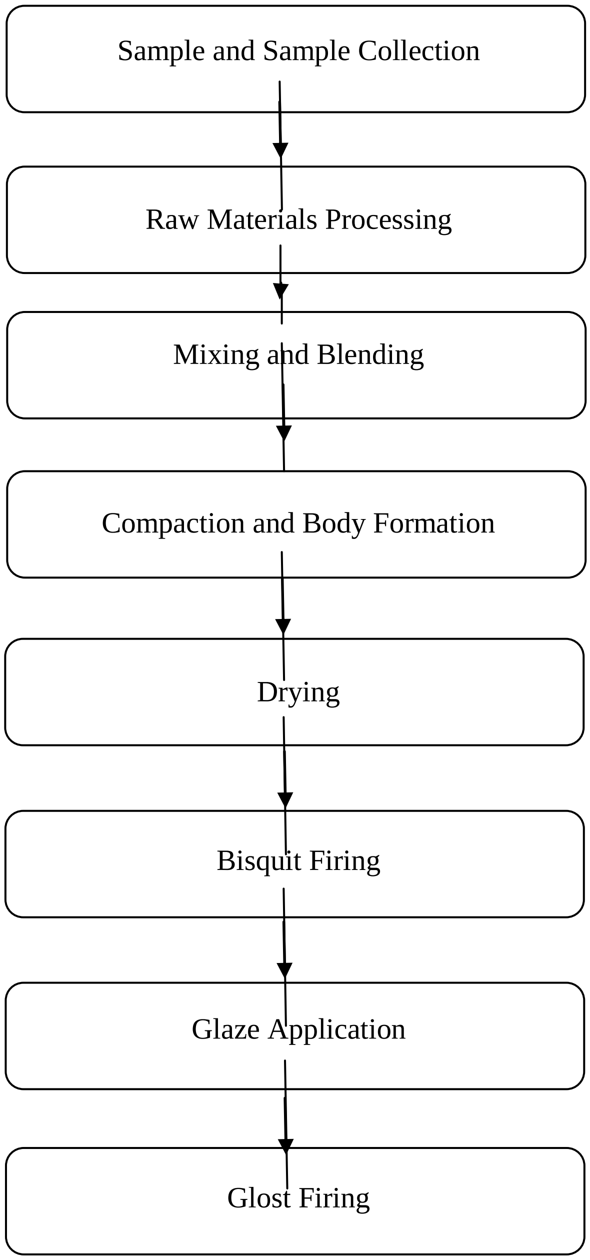



**Figure 1 Experimental steps in the production of ceramics products**

The clay sample was collected and was then molded into shapes using metallic moulds and lubricants were applied to the surface of the moulds to prevent the test pieces from sticking to the surface. The test pieces were air-dried for seven(7) days after which they were oven-dried at $105^0$C to obtain a constant weight and the sample was finally fired to a temperature of $1250^0$C in a laboratory kiln.

## 3.0 RESULTS AND CALCULATION

Each test and analyses are presented in a different table, graph or a chart which show either the percentage compositions of elements/compound present in a given sample or the degree/levels of reactions of the sample to show a clear presentation of analysis of test results. Appropriate calculations and discussions were also carried out.

**Table 1: Chemical composition of Bende clay**

| Parameter(s) | Value |
|---|---|
| $SiO_2$ | 53.65 |
| $Al_2O_3$ | 26.42 |
| $Fe_20_3$ | 2.50 |
| $Na_2O$ | 0.45 |
| $K_2O$ | 2.78 |
| MgO | 1.52 |
| CaO | 0.28 |
| LOI | 12.2 |

The result for the chemical analysis of Bende clay is shown in Table 1. It is observed that silica ($SiO_2$) and alumina ($Al_2O_3$) form the major composition of the clay while other metal oxides are present in small amounts. The silica content of Bende clay was found to satisfy the clay requirement for refractory bricks (>51.7%) and high melting clays (53-73%) (Chester, 1973). However, the silica level was also found to be lower than the requirement for glass (80-90%) but higher than that for paper (45.0 – 45%) and paint (45.3 -47.9%) (Grimshow, 1971). The alumina composition of Bende clay however, satisfies the requirement for the manufacture of ceramics (26%), Recfractory bricks (25 – 44%), paper (33.5 – 36.1%), paint (37.9 – 38.4%) but fell short of the standard required for production of glass (12 – 17%) (Grimshow, 1971). The $Fe_20_3$ content of Bende clay was found to be high and above the standard required for ceramics (0.5 – 1.2%), refractory bricks (0.5 – 2.4%), glass (2-3%) and paper (0.3 – 0.6%) but below the requirement for paper production (13.4 – 13.7%). Furthermore, such high levels of iron oxide usually give a reddish colour to the clay body when fired.

The presence of alkali oxides (CaO, $K_2O$ and $Na_2O$) in reasonable amounts in Bende clay as shown in Table 1, indicates a good ability during firing at low temperatures, thereby reducing the vitrification temperature and refractoriness of the clay (Maiti, 1992). This suggests that Bende clay is likely to have low or moderate refractory properties. The Loss on ignition (LOI) of Bende clay was within the standard for manufacture of ceramics (>8.18%), refractory bricks ( 8 – 18%) and high melting clays (5 -14%) (Grimshow, 1971).

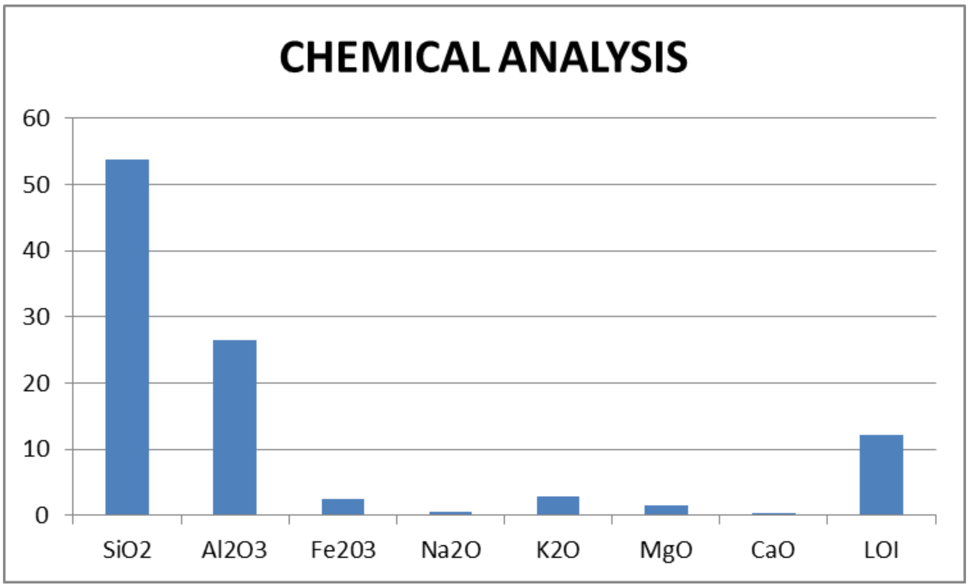



**Figure 1. A chart showing the Chemical Component of the Clay Sample**

**3.1 Moisture Contents, Liquid Limits and Plastic Index Result.**

The clay mineral sample had three trial weighing and an average was obtained.

**Table 2. The Liquid Limits of Bende Clay**

| Description | Bende Clay | | |
|---|---|---|---|
| Test Number | 1 | 2 | 3 |
| Can Identification | $B_1$ | $B_2$ | $B_3$ |
| Number of Blows | 7 | 24 | 56 |
| Can(g) = $m_1$ | 8.3 | 8.3 | 8.1 |
| Can + Wet Clay(g) = $m_2$ | 22 | 22.1 | 19.7 |
| Can + Dry Clay(g) = $m_3$ | 16.8 | 16.9 | 15.5 |
| Dry Clay(g) = $m_3 - m_1$ | 8.5 | 8.6 | 7.4 |
| Moisture loss = $m_2 - m_3$ | 5.2 | 5.2 | 4.2 |
| $Mosture\ Content\ (w) = \frac{m_2 - m_3}{m_3 - m_1}\ x\ \frac{100}{1}$ | 61.2 | 60.5 | 56.8 |

The moisture content was calculated in percentage using the following formula:

$$Mosture\ Content(w) = \frac{Loss\ of\ moisture}{Dry\ Weight}\ x\ \frac{100}{1} \quad . \quad . \quad . \qquad (1)$$

$$i.e \quad w = \frac{m_2 - m_3}{m_3 - m_1}\ x\ \frac{100}{1} \quad . \quad . \quad . \qquad (2)$$

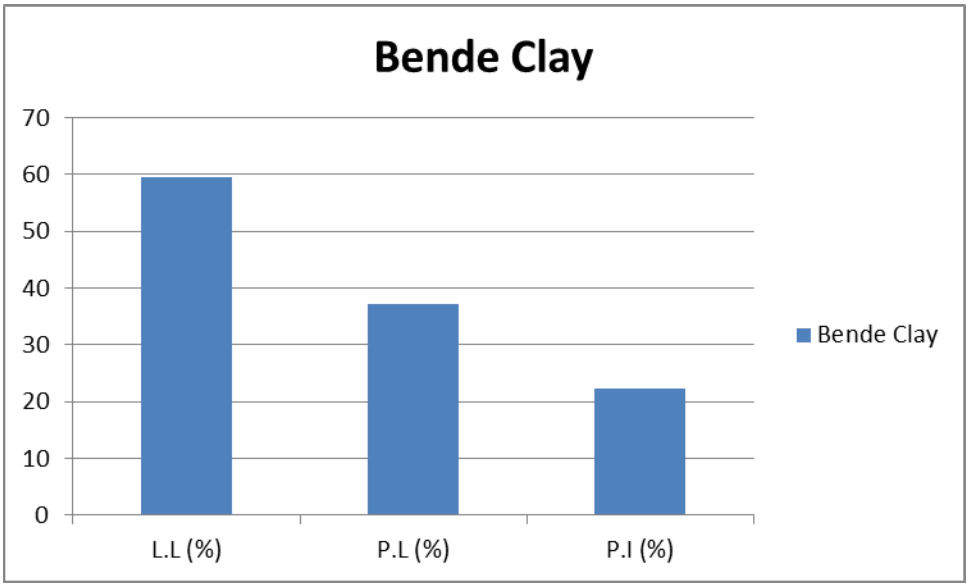
Let w = moisture content, $m_1$ = Mass of Container, $m_2$ = Mass of container and wet clays, $m_3$ = mass of container and dry clay.

**Table 3. The Plastic Limit of the Clay Samples**

| Description | Bende Clay | |
|---|---|---|
| Test Number | 1 | 2 |
| Can Identification | $B_1$ | $B_2$ |
| Can(g) = $m_1$ | 8.1 | 8.4 |
| Can + Wet Clay(g) = $m_2$ | 16.5 | 15.9 |
| Can + Dry Clay(g) = $m_3$ | 14.2 | 13.9 |
| Dry Clay(g) = $m_3 - m_1$ | 6.1 | 5.5 |
| Moisture loss = $m_2 - m_3$ | 2.3 | 2 |
| $Mosture\ Content\ (w) = \frac{m_2 - m_3}{m_3 - m_1}\ x\ \frac{100}{1}$ | 37.7 | 36.4 |
| Plastic Limit = Average (w) | 37.1 | |

**Table 4: Atterberg Limit Results**

| SAMPLE | Bende Clay |
|---|---|
| L.L (%) | 59.5 |
| P.L (%) | 37.1 |
| P.I (%) | 22.4 |




**A Bar Chart Showing the L.L, P.L and P.I of Bende Clay**

**Table 5: FIRING (VOLUME) SHRINKAGE OF THE CLAY BODIES**

| Samples | $L_i$ (mm) | $W_i$ (mm) | $H_i$ (mm) | $L_f$ (mm) | $W_f$ (mm) | $H_f$ (mm) | $V_i$ ($mm^3$) | $V_f$ ($mm^3$) | $V_s$ ($mm^3$) | $V_s$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Bende Clay | 80.0 | 60.0 | 7.0 | 76.0 | 58.0 | 5.0 | 33600 | 22040 | 11560 | 34.40 |

The $L_i$, $W_i$, $H_i$ and $V_i$ represent the clay body samples original length, width, height (thickness) and volume respectively. While $L_f$, $W_f$, $H_f$ and $V_f$ represent the length, width, height (thickness) and the volume of the clay body samples after firing. $V_s$ is the shrinkage in percentage, and it is calculated thus:

$$V_s = \frac{V_i - V_f}{V_i} x \frac{100}{1} \quad . \quad . \quad . \quad (3)$$

### 3.4 Bulk Density, Apparent Porosity and Water Absorption Capacity

The fired clay body samples were used for the apparent porosity, bulk density and water absorption capacity test. The samples were weighed in air and its weight noted as $W_d$. Each of the samples were attached to a string and suspended in water in a beaker. The water was allowed to boil for 10 minutes. The boiled water was allowed to cool and the weight soaked and suspended in water was taken as $W_n$. The weight soaked in water and suspended in air was also taken and noted as $W_s$. The following formulae were used to calculate the apparent porosity and bulk density respectively.

**Table 6: Apparent Porosity, Bulk Density and Water Absorption Capacity Test**

| Samples | $W_d$(g) | $W_n$(g) | $W_s$(g) | AP(%) | BD(g/cm3) | $W_{ac}$(%) |
|---|---|---|---|---|---|---|
| Bende | 43.4 | 18.20 | 47.00 | 12.54 | 1.51 | 7.66 |

$$\% AP = \frac{W_s - W_d}{W_s - W_n} \; x \; \frac{100}{1} \quad . \quad . \quad . \quad (4)$$

$$BD\ (cm^{-3}) = \frac{W_d}{W_s - W_n} \; x \; D \quad . \quad . \quad . \quad (5)$$

$$W_{ac} = \frac{W_s - W_d}{W_s} \; x \; \frac{100}{1} \quad . \quad . \quad . \quad (6)$$

Where; AP is apparent porosity
BD is the bulk density
D is the density of water
Water absorption capacity

### 3.5 Modulus of rupture of the fired clay sample

The clay dust was mixed with water until enough plasticity was achieved. The extruded samples were allowed to air dry and then fire at a temperature of $1250^0$C and the modulus of rupture (MOR) was obtain with its results.

**Procedure**

Each of the test bar of length of 100mm and approximate diameter of 8.75mm was loaded with span of 5mm. The modulus of rupture was computed using the formula:

$$MOR = \frac{8PL}{\pi D^3} \quad . \quad . \quad . \quad (7)$$

Where;
P is the fracture load of the specimen
L is the span
D is the diameter of specimen

**Table 7: Modulus of Rupture for Bende Clay**

| Sample | D(mm) | P(N) | MOR |
|---|---|---|---|
| 1 | 4.30 | 20.0 | 32.05 |
| 2 | 4.10 | 15.0 | 27.73 |
| 3 | 4.15 | 18.0 | 32.00 |
| 4 | 4.30 | 23.0 | 38.80 |
| 5 | 4.20 | 20.0 | 34.69 |
| Average | | | 33.05 |

## CONCLUSION

The results of this research study shows that the local clay samples (Bende Clay) has almost moderate requirements for manufacture of ceramics. The results obtain from its analysis of Silica ($SiO_2$) was 53.65%and Alumina ($Al_2O_3$) was 26.42, which formed the basic/major composition of the chemical component of the clay body sample and this implies that the clay sample will be very good for ceramics products. The loss on Ignition(LOI) of this clay sample also falls within the standard for manufacture of ceramics which is greater than 8.18% (>8.18%). In the other test such as the shrinkage volume, apparent porosity, the bulk density, water absorption and modulus of rupture, the clay sample comes out to meets the requirement for manufacture of ceramics. ( see table 2, 3, 4, 5, 6 and 7). However, this research shows that it is possible to produce tiles with local clays that can compete with imported tile products. Tiles made of Bende clay has good surface finishing to compared with those imported commercial products. production of paint.

During this research also, it is found that other ingredient such as quartz and feldspar are added to the clay sample to obtain a highly homogenous clay body after mixing. The addition of quartz and feldspar in a clay body sample has a tremendous effect on the properties of clay bodies used in production of tiles. They improve the strength of the clay samples and reduce the amount of warping, cracking and bloating after sintering.

## REFERENCES

Abia-Bassey N, Ewurum M.A, and Ume J.I. (2006).The characterization of new clays for the promotion of local ceramics industries. Ceramics Association of Nigeria, National Conference, Akure, Nigeria.

Abubakar I, Birnin-Yauri U.A, Faruq U.Z, NomaS.S and Sharif N. (2014).Characterization Of Dabagi clay deposit for its ceramics potential. African J. Environ. Sci. Technol. 14(1): 48-56.

Alege E.K, Alege T.S. (2013). Selected clays of Bida and Anambra basins of Nigeria: Their characteristics, fired properties and ceramic suitability. Inter.J.Sci. Tecnol. 2(7): 560-567.

Carter, C.B and Norton, M.G (2007). Ceramic materials: Science and Engineering. Springer. Pp. 3 & 4.

Chester J.H. (1973).Refractory, Production and properties, iron and steel institute, London. Pp 4

Chukwu GU and Ajuamiwe CF (2013) Investigation of mechanical/physico-chemical properties of kaolinite ore (clay) from Umuariaga-Umudike, Abia State of Nigeria, International Research Journal of Geology and Mining.

Etukudoh A.B, Akpomie K.G, Okereke O.C.B (2016), Characterization of Ezzodo clay deposit for its industrial potentials. Ceramics research and production department (CRPD), Projects Development Institute (PRODA), Emene, Enugu State, Nigeria.

Frome, R.M. (1994). "Basic Notes on Clay and Clay Bodies" Robbert Fromme/ for educational purpose only. (1994).

Grimshow R.W. (1971). The chemistry and physics of clay and Alhed ceramics materials, 4$^{th}$ Edition, Revised, New York: wiley in conscience. Pp 15.

Grin, R.E. (1983).Clays: Uses. "Encyclopedia of Composite Materials and Components. Gray M (Ed) John Willey and Sons, New York. Pp 321-344.

Maiti K.N and Kumar, S (1992), Microstructure and properties of a new porcelain composition containing crystallizing glasses as replacement for feldspar. British Ceramic Trans. J.91(1): 19-34.

Nuka E. E and Enejor C. (2001). Characterization of Nahuta clay for industrial and commercial applications. Nigerian J. Eng. Mater. 2(3): 9-12.

Nwajugu C. O and Aneke L. E. (2001).Characterization of Ukpor clay deposit. Journal Nigerian Society of Chemical Engineers. 5(1): 1-3.

Nwobodo, C.S. (1999). A Study of the formidability of Nitrogen Clay" Indian Journal of Chemical Tech. Vol. 6 Pp 79-84.

Omotoyinbo J. A and Oluwole O. O. (2008). Working properties of some selected refractory clay deposits in south western Nigeria. J. Miner. Mater Characterization. Eng. 11:1050-1054

Omowunmi O. J. (2000). Characterization of some Nigerian clay as refractory materials for furnace lining Nigeria Found. Eng. Manag. 12: 1-4.

Onwuachi-Iheagwara P. N. (2012). Investigations into the use of local clays in drilling operations. J. Eng. Appl. Sci. 4: 21-29.

Reeves, G.M. (2006).Clay material Used in Construction Geological Society, Engineering Geology Special Publication.No.21, London.Pp 1-2

Rhodes, D. (1982). Clay and Glazes for Potter (Revised Edition0 John Willey and Sons, New York. Pp. 96-130.

Richie, T.(2006).Querry Tile and Other Ceramic Floor Tile Canadian Building Digest CBD. www. Nrc.org.

Ryan W. (1962). Properties of ceramics raw materials, 4th ed, Pergamon Publishers Ltd, Oxford, UK.

Singer, F and Singer, S.S.(1963).Industrial Ceramics" Charpman and Hall, London. Pp 9 and 75.

Woodhouse, C.P. (1997). A History of Poultry Groiler.

www. Google.com: London's Geology Fieldwork 2016

Zubeiru S. E. (1997). Investigation on refractory clays for application in Nigerian industries. B.Eng Thesis, Department of Mechanical Engineering, Federal University of Technology Minna, Nigeria.12-34.