Characterization of Mbaukwu Clay from Awka-South Anambra State Nigeria for Industrial Purposes

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ABSTRACT

Mbaukwu Clay from Awka South Local Government Area, Anambra State of Nigeria was characterized. The sample was analyzed for making moisture, plasticity, shrinkage, apparent porosity, apparent density, bulk density, loss on ignition, modulus of rupture, and water absorption employing standard methods. The results of the chemical analysis were as follows: SiO_2: 42.97%, Al_2O_3: 23.34%, Fe_2O_3: 4.95%, Na_2O: 2.04%, K_2O: 3.67%, MgO: 2.93%, CaO: 3.48%, MnO: 0.97%.

Physical analysis showed a mean modulus of plasticity to be 3.43kgf/cm^3, mean making moisture (26.24%), total shrinkage range from 13.5-15.4%, apparent porosity from 33.65-28.95%, bulk density of 1.66-1.71g/cm^3 over a temperature range of 900-1200^{0}C and LOI of 14.55%. The clay is moderately pure due to its alumina/silica ratio (Al_2O_3:SiO_2) of 0.54 compare to 0.84 for pure kaolinite. Comparison of this result with other research indicates that Mbaukwu clay could be useful for manufacture of some ceramic industrial products like tiles, table ware and other ceramics wares production.

(Keywords: Mbaukwu clay, refractory, industrial use)

INTRODUCTION

Clay is an unconsolidated rock matter, with very fine grain which is plastic when wet and undergoes ceramic change to become hard and stony when heated. The ceramic industries consume about 70% of all clays marketed in crude or beneficiated from and those marketed only as finished products (Fakolujo *et al*., 2012).

Natural clay minerals are well known and familiar to mankind from the earliest days of civilization. Because of their low cost, abundance in most continents of the world, high sorption potential for ion exchange, clay materials are strong candidates as adsorbents (Preeti and Singh, 2007).

Clay minerals share a basic set of structural and chemical characteristic and yet each clay mineral has its own unique set of properties that determine how it will interact with other chemical species. The variation in both chemistry and structure, among the clays leads to their applications in extremely diverse fields.

Clay is composed mainly of silica (SiO_2), alumina (Al_2O_3) and water (H_2O) frequently with appreciable concentration of oxides of iron, alkali and alkaline earth, and contains groups of crystalline substances known as clay minerals such as quartz, feldspar, and mica. These other minor oxides components (impurities) which occur in variable quantities are important as their presence impart some properties to clay which are of technical value. It is important to note that the amount of impurities allowable in clay depends on the purpose for example; when white wares are needed, coloring impurities such as Fe_2O_3 must not be in the clay and for those to be used as refractory must be free as possible from fluxes, which comprise their thermal resistance.

Knowledge of the clay available in any region helps in its applicable and general usage either in ceramic, drilling mud, refractories, plastics, paints, textiles and adhesives, paper foundry, pharmaceuticals, rubbers, etc. (Abuh *et al*., 2014). When clay body is fired, after processing, the resulting physical properties usually determine their suitability for intended use. The chemical and mineralogical composition of the samples bears enormous influence on the physical characteristics (Nnuku and Enejor, 2010).

Clay swells in water creating a thioxotropic gel (particularly benthonite) as a consequence of interlayer water adsorption. The swelling index affects green compression strength, flowability and other properties but no correlation is made between swelling index and strength properties of clay mold (RMRDC, 1999; Paul *et al*., 2006). High swelling index is reported to mean good molding properties of a clay binder but while studying the impact of swelling index on Sokoto clay a contrary result was obtained (Paul *et al*., 2012).

Porosity and fired strength are key properties. These parameters are highly affected by firing temperature, method of production, physical, chemical and mineralogical properties of raw material. Firing rate could also affect the strength, as rapid firing may cause cracks or bloating in the bodies. Prolonged firing at the finished temperature increases the proportion of fusible material therefore affecting the cold strength of the materials. Water absorption measures the available pore space and is expressed as a percentage of the dry-wet. Firing shrinkage is expected to increase with higher temperatures but few types of clay have shown a centrally result.

Due to the abundance of clay minerals in Nigeria which have not been characterized for industrial uses, this study was therefore aimed at the physicochemical characterization of *Mbuakwu* clay deposit present in abundant amount in Awka south local government area of Anambra State, Nigeria.

MATERIALS AND METHODS

Sample Collection

The clay sample used was obtained from Mbaukwu in Awka South Local Government Area, Anambra State of Nigeria. The sample was used as received without any modification. The sample after removing the contaminants, was ground to increase the surface area. Standard method according to Abuh *et al* [3] was used in the physical characterization of the clay sample prior to chemical characterization by atomic Absorption Spectrophotometer, the sample was digested.

Physical Analysis

The physical properties of Mbaukwu clay such as making moisture, pH, shrinkage, apparent porosity, apparent density, bulk density, water absorption, modulus of rupture, plasticity and loss on ignition were determined as described (Etukudoh *et al*., 2016a; Etukudoh *et al*., 2016b; Nwogwu *et al*., 2016; Ezeofor *et al*., 2017).

Digestion of Clay Sample

0.2g of the dried clay sample was weighed into a teflon crucible and moistened with Aqua regia (mixture of HCl and HNO_3 in the ratio 3:1 by volume). 10ml of hydrofluoric acid was added and the mixture covered and heated in a fumed chamber at 100^0C until the solution became clear. The solution was allowed to cool and then transferred into a 250ml volumetric flask and was made up to 250ml mark with de-ionized water. Atomic absorption spectrophotometer (AAS) (Buck scientific model 210VGP) was used to analyze the mineral.

Determination of the Oxides using Atomic Absorption Spectrophotometer (AAS)

After the digestion of the samples, the recommended standard method was used for the elemental quality analysis. The minerals were analyzed using AAS. Air acetylene flame was used for the analysis of each metal except for Si and Al which required nitrous oxides flame instead at flame temperature of 2250^0C. The machine automatically control the ratio of the fuel and oxidant gas. And de-ionized water was used as the blank. The results obtained in ppm was converted to percentage oxide.

Fourier Transformed Infrared spectroscopy (FTIR)

This was used for the identification of clay minerals and poorly crystalline mineral phases, and also for identification of possible adsorbed elements or functional groups. The samples were prepared by applying the disc techniques (mixing 1mg clay sample with 200mg KBr) and was put in a mold.

These intimate mixtures were then pressed at very high pressure (10tons per cm^2) to obtain the transparent disc, which were then placed in the sample compartment. The spectra were recorded over the range of 4000-350cm^{-1} using the Fourier

Transform Infrared Spectrophotometer (Shimadzu FT-IR 8400s).

RESULTS AND DISCUSSION

Physical Properties

Physical characterization of Mbaukwu clay deposit is shown in Table 1.

Table 1: Physical Characterization of Mbaukwu Clay.

Parameter / Temperature	900^0C	1000^0C	1100^0C	1200^0C
Wet-Dry Shrinkage (%)	6.8	7.4	7.2	7.6
Dry-Fired Shrinkage (%)	6.65	7.34	8.41	8.44
Total Shrinkage (%)	13.5	14.2	15.0	15.4
Apparent Porosity (%)	33.65	31.97	30.05	28.95
Apparent Density (g/cm^3)	2.51	2.47	2.44	2.41
Bulk Density (g/cm^3)	1.66	1.68	1.69	1.71
Water Absorption (%)	20.23	19.03	18.01	16.93
Modulus of Rupture (kg/cm^3)	16.44	21.14	24.87	27.01
Modulus of Plasticity	3.43			
Making Moisture (%)	26.24			

From the result, it had high percentage of moisture content; plasticity and strength of the clay depend on the water present. Between 1.2 to 14.26% moisture content, the clay will form an aggregate to develop strength. The high moisture content makes the clay sample suitable for molding and when combined with sodium montmorilonite, it can be used in the determination of the refractory ability of bricks. For the bulk and apparent density, at 900^0C -1200^0C, the bulk density of the sample was found to be in the range of 1.70 –1.71g/cm^3 which is within the internationally accepted range of 1.7– 2.1g/cm^3 for building and fire clays (Thring, 1962).

The apparent density of the samples was found to be in the range of 2.41 – 2.51g/cm^3 which fall within the internationally accepted standard range of 2.3 – 3.5g/cm^3 (Ryan, 1978; Manukaji, 2013).

The range of water absorption for the experimental temperature of 1000 – 1200^0C commonly used for production was within 16.9 – 18.2. When glazed, the water absorption will further drop to below 15% which is the ASTM allowable value for ceramics tile on scale. The values for the temperature range of 900 – 1200^0C were in the range of 28 – 34% which is in the internationally permissible value of 20 – 80% for fired bricks (Thring, 1962; Lawal and Abdullahi, 2010).

The decrease in apparent porosity with increasing temperature indicates the closure of the pores. For the purpose of insulation this can be enhanced by the addition of carbonaceous material such as saw dust, rice husk, corn husk, etc. (Olusola, 1998). For the modulus of rupture, the strength increased with increase in temperature.

The values for the temperature range of 900 – 1200^0C were 16.44 -27.01 which shows a very strong clay. The linear (dry – fired) shrinkage and the total (fired) shrinkage of the sample (900 – 1200^0C) is shown in the Table 1. The linear shrinkage values vary from 6.8% at 900^0C to 7.6% at 1200^0C which is within the internationally accepted standard values of 7 -10% for alumino-silicates, kaolinite and fire clays (Zubeiru, 1997; Manukaji, 2013). The slightly lower values for this sample when compared with the kaolinite and fire clays suggest a high content of non- fluxing impurities.

The total (wet – fired) shrinkage was in the range of 13 – 15%. The total shrinkage and the dry shrinkage are of little importance since their values changes with moisture content during casting (Abuh *et al*., 2014).

The pH value for the clay was found to be 5.53 shows biological transformation of ammonium to nitrate. Availability of nitrogen, phosphorus, sulphur, calcium, magnesium, molybdenum and sodium is limited under acidic conditions.

For the plasticity test, plasticity index was found to be 3.43%, which did not meet the plasticity requirement (API of 25) of refractory clays demanded in the iron making shop of iron and steel industry (Ryan, 1978).

Chemical Characterization

The result of the oxide analysis is shown in Table 2.

Table 2: Chemical Oxide Analysis of Mbaukwu Clay.

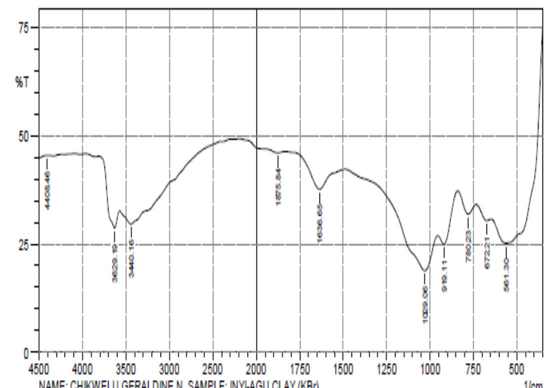
Parameter (oxide)	Clay (%)
SiO_2	42.97
Al_2O_3	23.34
Fe_2O_3	4.95
Na_2O	2.04
K_2O	3.67
MgO	2.93
CaO	3.48
MnO	
LOI	

The results shows that SiO_2 has the highest value (42.97%) followed by Al_2O_3 (23.34%), Fe_2O_3 (4.95%) and trace amount of K_2O, Na_2O, MgO, CaO and MnO. Silica may exist as clay in a free form (SiO_2) and as compounds owing to its presence in a mixture with other elements like Al_2O_3 forming kaolinite $Al_2(Si_2O_5)(OH_4)$ in the feldspar group (Johari *et al.,* 2001). The high concentration of silica (SiO_2) and Alumina (Al_2O_3) in the clay sample could indicate that it is kaolinite clay. Furthermore, clay materials that have a dominance of silica and alumina are often used for floor tile manufacture (Nwajuagu and Aneke, 2001; Bergaya *et al*., 2006).

In addition, high silica value makes such clay material potential source for brick production. This agrees with the fact that the region from which clay materials were sourced from used more of burnt bricks than cement bricks (Nweke and Egwu, 2007). The red color that clay manifests after firing is based on the presence of Fe^{3+} ions (Fe_2O_3) in its composition. The quality of Fe_2O_3 in the clay sample found to be 4.95%. The quantity in the sample though small compared to silica and alumina shows that on firing the grey color of the clay would become red. This was observed on the shrinkage test whereby the color reddened as temperature was raised from 900 – 1200^0C and giving % total shrinkage of 13.5% - 15.4%.

The lower content of K_2O (3.67%), Na_2O (2.04%), MgO (2.93%), CaO (3.48%) and MnO (0.97%) indicates that the Mbaukwu clay could be useful as refractory materials. refractory material are materials that will retain their physical and chemical nature when subjected to heat at high temperatures. It has been stated that fire clay, ball clay, kaolin and bentonites are refractory materials (Ibrahim and Biliaminu, 2010). The presence of alkali oxides have been linked to plasticity characteristics of the clay [4, 14].

The study shows modulus of plasticity to be $3.43kgf/cm^3$ on the average. The loss on ignition (Table 2) for the clay materials was determined to be 14.55%. This implies that the pores are so closely knit within the clay samples that tend to hold moisture molecules within the clay complex. The FTIR spectrum of Mbaukwu clay is shown in Figure 1. The spectrum showed absorption bands corresponding to clay minerals as reported previously (Dawodu and Akpomie, 2014).



	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	561.3	25.122	18.643	646.17	349.13	148.26	54.749
2	672.21	30.391	1.352	732.97	646.17	43.335	0.816
3	780.23	31.883	3.602	840.03	732.97	50.434	2.461
4	919.11	24.954	5.246	955.76	840.03	61.844	4.059
5	1029.06	18.873	10.158	1491.99	955.76	272.682	19.71
6	1636.65	37.647	6.375	1833.4	1491.99	127.873	7.108
7	1875.84	46.058	0.675	2191.21	1833.4	115.078	0.498
8	3440.16	29.614	4.841	3569.39	2404.35	482.706	17.516
9	3629.19	28.698	7.138	3808.57	3569.39	108.748	9.531
10	4408.46	45.426	0	4410.38	4405.56	1.653	0

Figure 1: Fourier Transform Infrared Spectrum of Mbaukwu Clay Mineral.

CONCLUSION

Clay from Mbaukwu in Awka South Local Government Area Anambra State of Nigeria was characterized physiochemically. The results obtained showed the possibility of using the clay sample for different purposes. The study has shown that the clay sample has high silica and alumina content which makes it kaolinite in nature.

Furthermore, the moderately lower content of alkali oxides (CaO, MgO, K_2O, Na_2O and MnO) in the clay qualifies it for use as refractory materials, kilns lining and for the manufacture of floor tiles and bricks making. The clay was found to be suitable in paper production, pharmaceutical, ceramic production and bricks production. These potentials therefore qualify the exploration of this Mbaukwu clay deposits for industrial applications by the Anambra State government for economic development and job creation for our teeming graduates.

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