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Microstructural Characterisation of Nanka Clay Deposit for Use in Domestic and Industrial Appliances

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Abstract: In the present investigation, we report on the microstructural characterisation of Nanka Clay deposit in Nanka, Orumba North Local Government Area in Anambra State of Nigeria, with emphasis on their possible applications. The clay sample used for the analysis were collected at a depth of 0.8 m, dispersed in excess water in a pre-treated plastic container and stirred vigorously to ensure proper dissolution. The porosity, water of absorption and density of the sample were determined using standard procedures and the compositional characterisation was done using the Atomic Absorption Spectrophotometry techniques. The results show that the apparent density of the sample was in the range 2.33-2.49 gcm^{-3}, water of absorption was in the range 14.33-19.59%, while the apparent porosity was between 25.07-32.76%, with all the parameters decreasing with an increase in temperature. However the bulk density increased with an increase in temperature. From the compositional analysis, the results show that Nanka Clay sample consists of 46.26% of silica (SiO_2), 28.64% of aluminum (Al_2O_3), Na_2O at 2.18% and CaO at a composition of 0.62%. In particular, the value for loss on ignition at 1200 °C was 17.35%. These values strongly suggest the use of Nanka Clay for various domestic and industrial applications.

Key words: Characterization · Density · Microstructural · Nanka Clay · Porosity · Inhibitor

INTRODUCTION

Until recently, very little was known about the fundamental nature of most clay minerals. With the development of x-ray diffraction analyses, it was found that soil materials are composed of crystalline particles and that a limited number of different crystalline minerals are likely to be found in it.

According to the literature [1-2], clay soils constitute important group of minerals in that they are mostly one of the offsprings of chemical weathering and thus are the dominant constituents of the fine-grained sedimentary rocks generally referred to as mudrocks (including mudstones, claystones and shales). Clay minerals are the main constituent of soils and in sedimentary rocks, clay minerals constitutes up to 40% of the total composition. In the tropical regions, Clay are mostly formed either as a product of the chemical weathering of pre-existing granitic rocks and feldspar minerals, because of the hydrothermal alteration of granitic rocks or other related phenomena. According to Grim [3] "clays are hydrous aluminum silicates, ordinarily containing impurities, for example potassium, or iron, in small amounts and are characterized by sheet silicate structures of composite layers staked along the c-axis".

Clay minerals have been investigated because of their importance in domestic applications, agriculture, ceramics, engineering, construction and other fields including paleoclimate determination amongst others. With the development of standard chemical analyses, it was determined that the finest clay fractions were composed of silica and one or more of the following: alumina, iron oxide, magnesium oxide, potassium oxide and various other oxides.

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The term "clay" is applied both to materials having a particle size of less than 2 micro-meters and to the family of minerals that has similar chemical compositions of minerals that has similar chemical compositions and common crystal structural characteristics [4-5]. Without clay to act as a carrier, it would be difficult to evenly mix the paint base and color pigment. A mixture of a lot of clay and a little water results in a mud that can be shaped and dried to form a relatively rigid solid. This property is exploited by potters and the ceramics industry to produce plates, cups, bowls, pipes and items of importance to man. Environmental industries use these properties to produce homogenous liners for absorption of metal ions.

The process by which some clay minerals swell when they take up water is reversible. Swelling clay expands or contracts in response to changes in environmental factor (wet and dry conditions and temperature). Hydration and dehydration can vary the thickness of a single clay particle by almost 100 percent (for example, a 10Å – thick clay mineral can expand up to 19.5Å in water) [4].

It has been established that soil containing clay could have the same colour, texture and general appearance yet differ widely in other characteristics [6]. The various characteristics properties of most clay products are believed to be effect of impurity additions, sintering and manufacturing processes. Clay deposits are typically associated with very depositional low energy. Primary clays are also known as kaolin and generally undergo a series of phase transformations upon thermal treatment in air at atmospheric pressure while secondary clay deposits are those that have been moved by erosion and water from their primary location [7]. In the southern part of Nigeria, most regions are richly blessed with natural resources like clay. These clays based materials occur both in the plain and riverine areas [8]. The use of these material resources was made possible by the application of heat in transforming the soft clay deposit into something malleable, hard and durable [9-10].

Nanka is an Igbo town with geographic coordinates 6" 03' 00 North, 7" 05' 00 East, located in Orumba North Local Government Area of Anambra State in south eastern Nigeria[11]. The geology/geophysical characteristics of Nanka areas have been reported by other authors [12-15]. In this study, the major aim is to investigate the potentials of Nanka Clay for utilization in domestic and industrial applications. In the literature, the viability of exploiting Nanka Clay is rarely reported, hence this research forms a fundamental step towards further research in establishing the optimised conditions needed for maximal utilization of this natural resource.

MATERIALS AND METHODS

Clay sample was collected from Nanka in Anambra State, Nigeria, at a depth of 0.8m. The collected sample was dispersed in excess water in a pre-treated plastic container and stirred vigorously to ensure proper dissolution. The dissolved clay was then filtered through a 0.425 mm mash sieve to get rid of unwanted particles and plant materials. The sample was then sundried and over dried at 100 °C for 3 hours, pulverized and passed through a mesh sieve of size 0.18 mm.

The porosity and density of the sample were determined using a simple weighing method. The apparent porosity, apparent density and bulk density were calculated using the formula:

Apparent Porosity (%) = $\frac{100\ [M_2 - M_1]}{M_1 - M_3}$

Apparent Density = $\frac{M_1}{[M_2 - M_3]}$

Where M_1 = Dry weight, M_2 = socked weight and M_3 = suspended weight.

In order to determine the chemical analysis of the sample, 0.2g of the clay was weighted into a beaker and 10ml of aqua rega (HCl + HNO_3) in the ration 3: 1 respectively) was added and digested in a hot plate in a fume cupboard. 10ml of Hydrofluoric acid was also added to aid the digestion process. After digestion, 30ml of de-ionized water was added and the mixture filtered through a filter paper into a 250ml volumetric flask and made up to the meniscus mark with de-ionized water. The sample was then analyzed for the elemental composition by the use of the Atomic Absorption Spectrophotometer (Buck Scientific Model 201 VGP). The concentration of metal oxide in the clay was expressed in mg/L. Thereafter the weight of an empty porcelain crucible was determined. 2g of the dried pulverized clay was added and the weight of crucible + clay determined. The sample was then ignited in the laboratory kiln at 1200 °C. After, the cooling of the sample the weight of the crucible + sample after ignition was determined. Hence, the loss on ignition was then calculated as

Loss on ignition (LOI) = $\frac{W_3 - W_1}{W_2 - W}$

Where
W_1 = weight empty porcelain
W_2 = weight of crucible + clay
W_3 = weight of crucible + clay after ignition

RESULTS AND DISCUSSION

Table 1 gives the composition of the clay from the analysis of the characterisation done using the Atomic Absorption Spectrophotometer (Buck Scientific Model 201 VGP). From the chemical analysis, the chemical composition of the sample is presented in Table (2). The sample consists of 46.26% of silica (SiO_2) which is high and 28.64% of aluminium (Al_2O_3), while Na_2O, CaO have 2.18% and 0.62% respectively. Their presence is often due to contamination by lime mortars or salt. Fe_2O_3 has 1.26% meaning that the sample has little of iron oxide. The result indicates that the value for loss on ignition at 1200 °C is 17.35%. The absence of quartz composites is an indication the absence of grittiness of the clay sample. From the result obtained above, it could be infered that the clay sample collected from Nanka consists of kaolinite, illite and smectite. This observation is close to that reported by the other research groups in the literature [6, 13].

Fig. 1 gives the variation of the apparent density with the temperature while Fig. 2 show the variation of the apparent porosity with the temperature. The result show that the apparent density increased uniformly with increasing temperatures. Research done by Odo *et al*., [16] noted that a decreased mean resistivity and an increase in porosity indicate the location of the fracture zone, hence in this case, it is strongly suggested that the decreased porosity with increasing temperature is an indication of reduced/zero fracturing in the clay sample.

The result of bulk density, porosity and water absorption by immersion in cold water for the sample clay are Figs 2-4. It was observed that the apparent porosity decreases as the temperature increases Fig. 2. This means that the clay has high porosity and the maximum temperature service is 900°C. Also the results obtained from Fig. 3, shows that the bulk density increases with increase in temperature.

Table 1: Chemical Composition of the Clay Sample

Metal Oxides	Conc. (mg/l)	Composition (%)
SiO_2	370.08	46.26
Al_2O_3	229.12	28.64
Fe_2O_3	10.08	1.26
Na_2O	17.44	2.18
K_2O	16.24	2.03
MgO	11.28	1.41
CaO	4.96	0.62
MnO	1.68	0.21
LOI at 1200°C	-	17.35

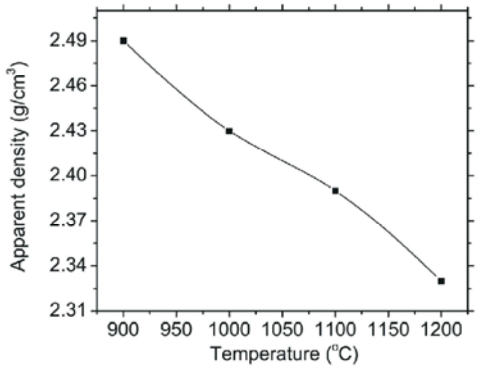

Fig. 1: Variation of apparent density with temperature.

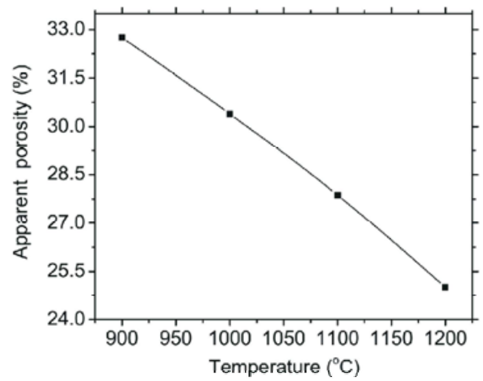

Fig. 2: Variation of apparent porosity with temperature.

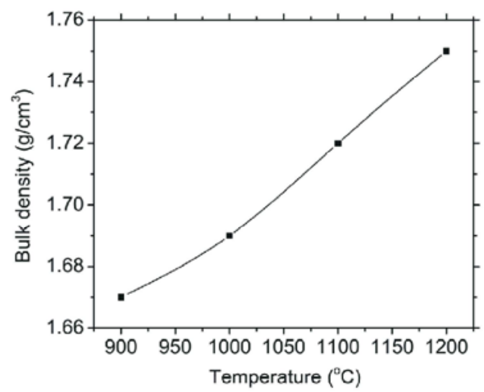

Fig. 3: Variation of bulk density with temperature.

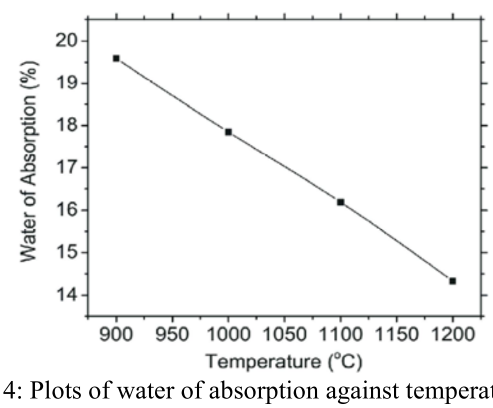

Fig. 4: Plots of water of absorption against temperature.

Whereas apparent density decreases with increase in temperature. It can be observed that the sample has porosity values about 25 – 35%, which is rather large and indicates a considerably reduced scatter.

CONCLUSION

In the present investigations, the Microstructural and compositional studies of Nanka Clay has been undertaken. From the results, it was observed that the clay from Nanka has high content of silica (S_iO_2) with little content of iron which makes the clay a very good candidate for the fabrication ceramic wares. The sample has a high porosity and with reasonable density. The increased silica content also points to the use of such clay in semiconductor materials for applications electrical and electronic devices.

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