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EVALUATION OF KAOLIN CLAY DEPOSITS IN GOMBE STATE AS ADDITIVE FOR INDUSTRIAL APPLICATIONS

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ABSTRACT

The geological origin and geographical formation of kaolin coupled with the processing method influences some physical and chemical properties of the kaolin, which invariably affect its industrial application capabilities. In this study, raw kaolin clay at different point from four identified deposits around Gombe state were excavated and collected for assessment. The samples were characterized using the X-ray diffractometer (XRD) to determine the mineralogical peaks and the crystalline phases in each of the specimen. After which, the chemical composition of the samples was quantified using X-ray fluorescence (XRF) test. Firing of all specimens was conducted at varied firing temperatures of 900°C, 1000°C, 1100°C and 1200°C at the heating rate of 2.5°C/min. The result of the mineralogical analysis revealed that all the studied samples are alumino-silicate clays and were categorized under chemical classification group of 60-70% of SiO_2, 23-33% of Al_2O_3, and 6-10% of impurities, suitable for use as low duty refractories and fire bricks in accordance with ASTM C27-98 standard.

Keywords: Kaolin, Additive, Evaluation, Characterization, Alumino-silicate.

INTRODUCTION

Kaolinite clay is a versatile industrial mineral widely used as raw material for ceramic wares, paper, paints rubber, catalyst, dye, insecticide and in pharmaceutical (Muaz *et al.* 2015) Kaolin deposits in Gombe state are randomly distributed within four local government areas, which include: Akko, Dukku, Kaltungo and Nafada as illustrated in figure 1. It is obvious that differences in geological origin will translate to different geographical formation which in turn exalts strong effect on the mineralogy and composition of the kaolin (Abdullahi et al., 2019). The varieties of kaolin deposits including primary kaolin deposits of different source rock as well as the secondary kaolin deposits, this provided an impetus to examine the mineralogical variations between primary and secondary kaolin considering the variations in mineralogy among the primary kaolin deposits and the variations in source rock of these deposits.

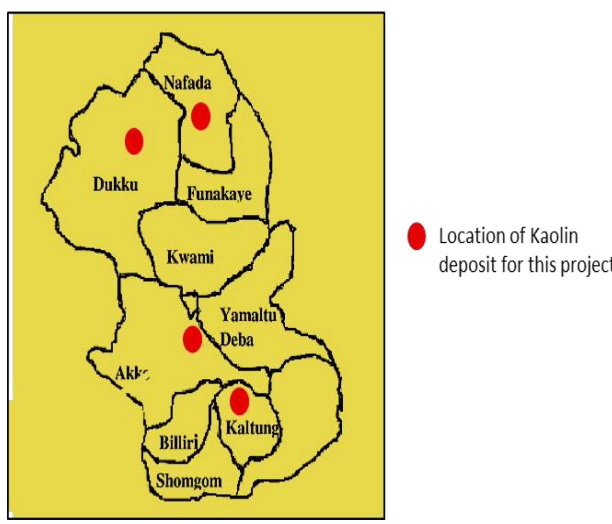

Figure 1: Map of Gombe state showing location of kaolin deposit for the study

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Kaolin has been processed in different varieties in Nigeria for local and export consumption for many years ago (Abiodun, Sadiq, Adeosun, & Oyekan, 2019). Regrettably, not all the documented clay resources (kaolin inclusive) are thoroughly studied for possible use in high value industrial product. Hence, the objective of this study is geared towards optimizing the usage of the huge kaolin resources available in Gombe state. This research became necessary because to the best of the researcher's knowledge, not all the documented clay resources in Gombe state were thoroughly studied for possible use in high value industrial application. Specifically, the study will focus on studying the mineralogical variations among some kaolin deposits from Gombe state that represent the primary deposits of different locations, with the view of having a prior information on the suitability or otherwise for further application of these kaolin deposits.

MATERIALS AND METHODS

Samples of kaolin clay were obtained at a location where local mining activities were taking place in Akko, Dukku, Kaltungo and Nafada. The kaolin lumps were ground into a fine powder, sieved according to ASTM E11-500 standard, and kept in the oven overnight before use to remove any trace of moisture in it completely. The characterization tests were conducted to evaluate the integrity of the material. The quantification of the chemical composition of the clay samples was carried out using X-ray fluorescence (XRF) test. While the mineralogical and the crystalline phases in each of the kaolin samples were analyzed using X-ray Diffractometer (XRD) and Scanning Electron Microscope (SEM).

RESULTS AND DISCUSSION

The Chemical Properties

The chemical properties of the clay samples were evaluated according to the XRD and XRF analysis. The results from the elemental composition analysis of the raw kaolin as presented in Table 1 that shows the kaolin contains exchangeable cations such as Ti, Fe3+, Na+ and K+. These were referred herein as the accompanied impurities originating from the geological history of the primary kaolinite's formation.

Table 1: Chemical property of the Clay specimens

Oxides (%)	Samples A (Akko)	 B (Dukku)	 C (Kaltungo)	 D (Nafada)
Al_2O_3	25.0	19.27	22.0	37.68
SiO_2	60.68	67.39	65	55.72
Fe_2O_3	0.56	0.39	0.77	0.66
TiO_2	0.59	0.34	0.27	1.68
MgO	0.59	0.31	0.23	0.40
K_2O	0.64	0.34	0.19	0.35
P_2O_5	0.57	0.33	0.18	0.37
SO_3	0.54	0.31	0.1	0.15
CaO	0.77	0.34	0.52	0.41
Cr_2O_3	0.54	0.29	0.26	0.26
Mn_2O_3	0.61	0.32	0.30	0.33
Cl	0.59	0.37	0.18	0.23
ZnO	-	-	-	0.16
LOI	10	10	10	1.6

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The chemical composition of the Akko kaolin (Specimen A) as presented in Table 1 has 25% Al_2O_3, 60.68% SiO_2 with 6% of impurities which indicates it belongs to alumino-silicates refractory group. The 6% of impurities, comprising Fe_2O_3, TiO_2, MgO, SO_3, K_2O, P_2O_5, CaO, Cr_2O3, Mn_2O_3 and Cl are characteristics of good refractory. The specimen has been categorized in accordance with Olalere, Yaru, & Dahunsi, (2019) under chemical classification group of 60-70% of SiO_2, 23-33% of Al_2O_3, and 6-10% of impurities, suitable for use as low duty bricks (ASTM C27-98, 2013 Standard).

Dukku kaolin (specimen B) has 67.39% SiO_2 and Al_2O_3 of 19.27% and belongs to alumino-silicate. The 3% of impurities which includes MgO, Fe_2O_3, TiO_2, CaO, P_2O_5, SO_2, K_2O, Cr_2O3, Mn_2O_3 and Cl, depicts the property of a refractory. The chemical composition of specimen B was characterized under chemical composition group of 65-80% SiO_2, 18-30% of Al_2O_3 and 3-8% of impurities, that is suitable for high duty (siliceous) bricks (UNEP, 2006; ASTM C27-98, 2013).

Kaltungo kaolin (specimen C) exhibited 22% Al_2O_3 and 65% SiO_2 with 3% impurities of Mn_2O_3, Cl, TiO_2, SO_3, MgO, Fe_2O_3, CaO, K_2O, Cr_2O_3, and P_2O_5 as shown in Table 1. The specimen exhibited chemical properties of a refractory and is in the class of alumino-silicate group (Mokwa *et al.* 2019), while Nafada kaolin (specimen D) has 37.68% Al_2O_3 and 55.72% SiO_2, 5 % impurities with Fe_2O_3, K_2O, P_2O_5, TiO_2, CaO, MgO, SO_3. The specimen was classified in the group of 50-80% SiO_2, 35-40% Al_2O_3.

Phase Analysis

The studied clay minerals were of secondary geologic origin, which means they were formed as alteration products of alumina silicate rock in an environment in which water was present. The phase analysis of the raw specimens as presented in Figure 1 reveals that the x-ray diffraction analysis shows that the specimen with ICDD 00-006-0221 composed mainly the phases of kaolinite $Al_2Si_2O_5(OH)4$, while the specimen with ICDD 00-001-0649 composed of quartz SiO_2. Kaolinite in raw specimen A, B and C had high crystallinity according to peak K (001), while quartz in raw specimen D, had high crystallinity at peak Q (101). The raw specimen exhibited crystallized kaolinite and quartz each which were seemingly attributed to the characteristics of alumino-silicate. Based on these phase analysis result, and in consistent with earlier literature (Zhu, Jiang, & Xiao, 2010). It can be concluded that all the raw materials specimens evaluated herein are of alumino-silicate group of refractory fireclays and are suitable to produce fireclay refractory bricks.

The preliminary evaluation of the kaolin clay samples indicates the potential for refractories and fire bricks. However, refractories under service conditions can experience rapid temperature changes that might develop imbalanced thermal stresses. To ascertain the suitability of the sampled clay resources, thermal tests were carried out and the following results are obtained.

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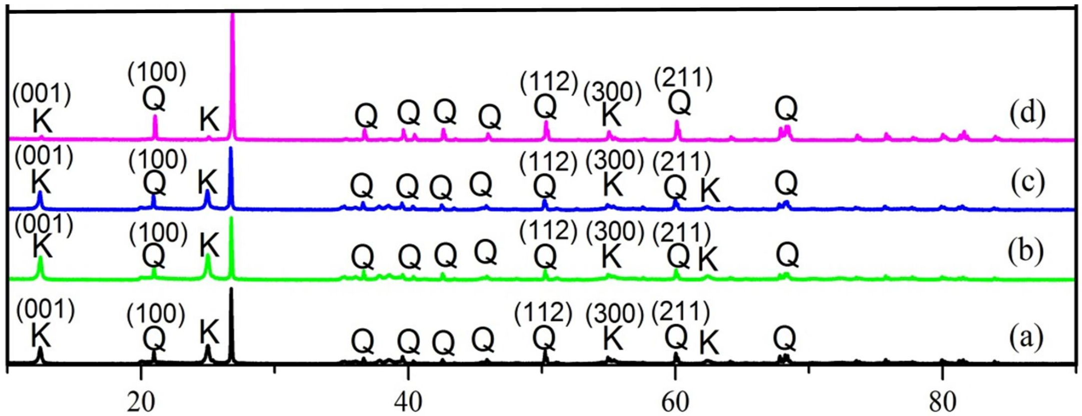

Figure 1: Phases analysis in the raw specimens (a) Akko (b) Kaltungo (c), Dukku, and (d) Nafada

Thermal shock resistance

Thermal shock failure results to the loss of fragments from the surface of a refractory brick structure through rupture and cracking of the inner portions of the refractory. The samples are subjected to alternate cycles of heating at 1200°C and the results of the clay specimen are presented in figure 2. Specimens A, B, C, and D were 24, 25, 25, and 25, cycles respectively. The thermal shock resistance results showed that the specimen fell within the standard values of 20 to 30 cycles for refractory fireclay bricks (ASTM C1100-88).

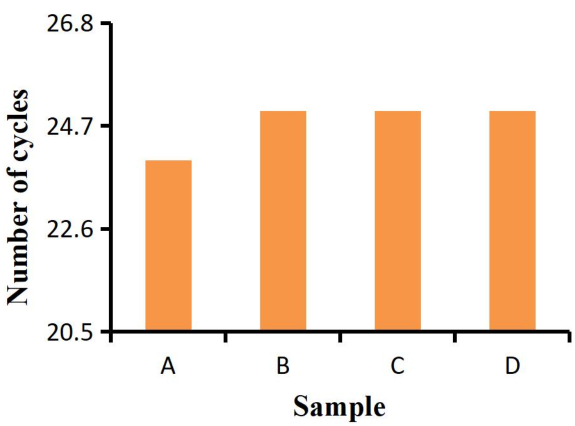

Figure 2: Thermal shock resistance of the Clay specimens

Refractoriness

The temperature of a refractory when it deformed under its specific weight is referred to as its softening temperature commonly indicated by the pyrometric cone equivalent (PCE) of the clay specimen as presented below

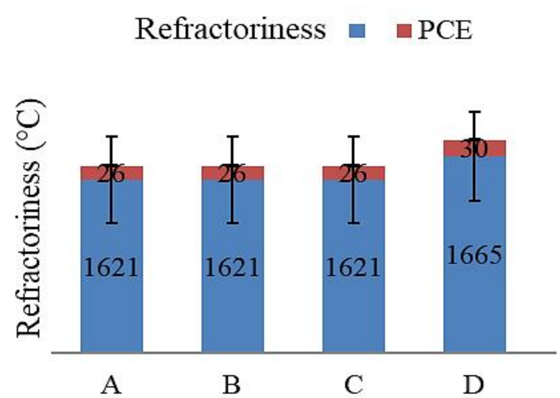

Figure 3: Refractoriness and PCE of the Clay specimens

The refractoriness of specimen A was 1621°C which corresponded to the PCE Segar cone 26. Fireclay specimen B had refractoriness value of 1621°C which was equivalent to PCE Segar cone 26. Specimen C refractoriness was 1621°C which tallies with the Segar cone 26 (PCE). Specimen D had refractoriness value of 1665°C that entails Segar cone 30 (PCE).

The results showed that specimens A, B and C had the minimum refractoriness (PCE) values of (1621°C) because of their highest content of SiO_2, this had caused the reduction of their softening temperatures as compared to specimens D which had the maximum refractoriness (PCE) values and of the lowest SiO_2 content in the chemical composition result. The refractoriness (PCE) of the clay specimen as presented in Figure 3 fell within the standard values of 1500 to 1700°C for refractory fireclay bricks (Subrata 2014).

CONCLUSION

The chemical composition of the Akko kaolin (Specimen A) has 25% Al2O3, 60.68% SiO2 with 6% of impurities which indicates it belongs to alumino-silicates group. The 6% of impurities composed of Fe_2O_3, TiO_2, MgO, SO_3, K_2O, P_2O_5, CaO, Cr_2O_3, Mn_2O_3 and Cl. Dukku kaolin (specimen B) has 67.39% SiO2 and Al2O3 of 19.27% and belongs to alumino-silicate. Similarly, the Kaltungo kaolin (specimen C) exhibited 22% Al2O3 and 65% SiO2 with 3% impurities, while Nafada kaolin (specimen D) has 37.68% Al_2O_3 and 55.72% SiO_2, 5 % impurities with Fe_2O_3, K_2O, P_2O_5, TiO_2, CaO, MgO, SO_3. The specimen was classified in the group of 50-80% SiO_2, 35-40% Al_2O_3. To ascertain the suitability of the sampled clay resources, thermal tests were carried out and the thermal shock resistance results revealed that all the specimens fell within the standard values of 20 to 30 cycles for refractory fireclay bricks in accordance with ASTM C1100-88 standard. However, specimen D was found to have the best thermal conductivity which implies a better resistance to heat escape and was considered the best in this category.

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