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A study of chemical composition of some clay deposits in Borno state for refractory production

A.O. Inegbenebor, A. Bamgbadeand A. I. Inegbenebor
Department of Chemistry
University of Maiduguri.

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ABSTRACT

The chemical composition of some clay deposits from Shuwari, Pulka and Ngala in Borno State were studied for refractory production. This is to indicate their classification as refractory material and their places of use in industrial set up. The result showed that the Shuwari clay has 36% and 47% of alumina and silica respectively, this placed the clay in the group of siliceous fire-clay refractory. The Pulka clay has 41.3% and 51.0% of alumina and silica respectively. This placed the clay under the medium duty and low-melting semi-acid fire clay; while Ngala clay has 38.0% and 46.8% of alumina and silica respectively. However, this was placed under the group of low-duty and low-melting fire clay refractory due to high lime (CaO + MgO) counted. The possible areas of applications of the studied clay have also been indicated in this paper.

INTRODUCTION

Clay mineral is a high industrial raw material used in the manufacturing of a wide variety of products such as pottery and ceramic wares, porcelain stoves, bricks, roofing and floor tiles etc. The mineral is distinctive in at least two properties that renders them technologically useful. These are plasticity, and composition of extremely fine crystals or particles (Michael, 1989). The very fine particles of this material yield very large specific surface areas that are physically absorptive and chemically surface reactive.

The use of clay in structural and engineering products depends on its physical and chemical properties. Clays have found use as refractory in many industries. Refractory industry is very important in any country which is aspiring to be technologically advanced. The refractories are absolutely essential for the lining of any thermal unit such as kilns and furnaces. The commonly used refractories include fire-clay, silica, high alumina, magnesia, dolomite and carbon (Ibhadode, 1997, Oiks, 1977).

Refractories are classified by their properties and characteristics as follows (Krivandin and Morkov, 1980).

1. By refractoriness:
   a. Common refractoriness (up to 1580 – 1770 °C)
   b. High refractoriness (1770 – 2000 °C)
   b. Highest refractoriness (above 2000 °C)

2. By their chemical and mineral composition:

   a. Siliceous, in which the refractory base is SiO_2 (silica quartzite). Silica bricks have a fusion point of 1700 °C (Ibhadode,1997).

   b. Aluminium – Siliceous, where the refractory components are Al_2O_3

corundum grade (Krivandin and Morkov, 1980).

Abundance of fire clay has been reported to exist in Gwoza, Bama, Ngala, Biu, Damboa and New-Marte, all in Borno State (Borno State Handbook, 1990).

Objectives

The aim of this work is to study the chemical composition of the clay deposits in Shuwari, Pulka and Ngala areas of Borno State. This would entail the determination of the percentage chemical composition of clay samples taken from these areas. From the results of the chemical analysis, the clay will be classified into various refractories groups which will assist in determination of their probable uses in refractory production in the state. Also, the data information of the chemical compositions of the clays in the state will help future prospective investors, who want to invest in this area.

MATERIALS AND METHODS

Three areas in Borno State were chosen for this study, they are Shuwari, Pulka and Ngala. The soil of Shuwari is lateritic of a fine and medium sedimentary type which gives rise to Kaolin of the sedimentary formation (Brindley and Nkahira, 1977). Shuwari clay is used locally for the production of clay pots.

The Pulka area is 500m above sea level and the soil is tropical mountainous ferrallatic type resulting from the weathering of granitic rocks which forms soil, rich in silica (Barthlomew, 1976). Pulka clay is used locally for building bricks. Ngala is located in the Lake Chad depression where large deposits of silica sand is reported.

Enough quantities of various clay samples were dug with shovel from the deposits and sun-dried for a day to reduce the moisture content and enhance grinding. Some quantity of each sample clay was crushed using a jaw crusher. They were further ground and passed through a fine sieve of 0.053µm. The sample clays were labeled as indicated in Table 1.

Determination of Loss-On-Ignition (LOI)

The finely powdered particles of each clay sample was weighed (5g) into a clean platinum crucible (20 cm^3). The crucible was partially covered with lid and placed in muffle furnace and the temperature raised slowly to 1000 °C for 30 minutes. The crucibles were removed from the furnace and cooled in a dessicator. The samples were reweighed and the weights recorded. The values obtained were used to calculate the Loss-On-Ignition using Leford (1975) equation. LOI = 100 – OT. Here OT is the total percentage of oxides in the clay.

Extraction of the Samples

Finely powdered particles (5g) of each of the clay samples was placed into volumetric flasks (100 cm^3) containing a solution of NH_4OAl (1M, 30 cm^3) to which a tetfon covered magnetic follower had been added. The flasks were sealed and thermostated for 1hr at 25.20 °C in a water bath and stirring was effected by a magnetic stirrer. This was followed by further addition of NH_4OAl (1M, 100 cm^3) while the stirring continued for another 30 minutes. The content of the flasks were filtered using filter paper (0.45µ Millipore) and the volumes were made up to 100 cm^3 with distilled water. These flasks were labeled A,B,C,D,E,F according to their localities. Each of these solutions were labeled stock solution and used for the various measurements.

Calcium Oxide

The stock solution (10 cm^3) was pipetted into conical flask (250 cm^3) then distilled water (50 cm^3) was added, NH_4OH (15 cm^3), KCN, $K_4Fe(CN)_6$ (1:1, 50 cm^3) and EDTA (0.1M, 10 drops) were added in that order. Sodium hydroxide (10%) was then added until the pH became 12 on meter reading. The mixture was then titrated against

Table 1. Composition, colour change at firing temperature and possible areas of usage of clay samples from different localities in Borno State.

SAMPLE CODE	LOCATION	%CONSTITUENT						LOI%	A	B	C
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Other Oxides				
SSA	Shuwari Maiduguri Damboa Road	47.01	36.00	0.02	0.22	0.06	8.00	8.82	Grey	Reddish	Regenerators and ladles lining. Laying the lower parts of hearth: cement factory, burnt brick and other ceramic applications.
PSB	Pulka, Gwoza	51.00	41.30	1.95	0.28	0.09	1.37	4.01	Brown	Reddish	Earth dam: canals and bricks.
NSC	Gamboru Ngala	46.80	38.00	0.50	0.89	0.27	2.91	11.63	Black	Reddish Brown	Binder: foundry sand and as drilling muds

LOI = Loss-On-Ignition
A = Appearance before firing
B = Colour at firing temperature (1000 °C - 1200 °C)
C = Possible areas of usage

EDTA to a reddish violet colour using murexide powder as indicator. The ensuring solution was analysed for calcium oxide using Direct Reading Spectrophotometer (DR200). Silica, Al_2O_3 and Fe_2O_3 were analysed using the Direct Reading. The results are presented in Table 1.

Magnesium Oxide

The stock solution (10 cm^3) was pipetted into conical flask (250 cm^3) then distilled water (50 cm^3) was added, NH_4OH (15 cm^3) KCN, $K_4Fe(CN)_6$ (1:1), 50 cm^3) and EDTA (0.1M 10 drops) were added in that order. This mixture was allowed to stand for about 10 minutes and titrated to permanent blue colour with EDTA (0.1M) using Erochrome black T indicator (EBT). The magnesium oxide of the final solution was determined by Direct Reading Spectrophotometer (DR 200) and the results are presented in Table 1.

RESULTS AND DISCUSSION

The results of the chemical analysis of the clay samples from Shuwari (SSA), Pulka (PSB) and Gamboru-Ngala (NSC) are presented in Table 1. The colour change at firing temperature (1000 – 1200 °C) together with Loss-On-Ignition and possible areas of usage of the clay samples studied are also listed.

All the clay samples that is PSB, NSC, and SSA contain reasonably high amounts of alumina, 41.30, 38.00 and 36.00% respectively. This high value of aluminum (III) oxide in consonant with the works of Leford (1975) and Michael (1989) is a major determinant for refractoriness in clay.

Iron (III) oxide in sample SSA is rather low (0.02%). This suggests that Shuwari, Maiduguri Damboa Road clay can withstand very high temperature as required in fire-clay (George, 1969, Leford, 1975, Oiks, 1977).

Samples PSB from Pulka, Gwoza contain moderate amounts of alumina and silica and the highest amount of iron (III) oxide of 1.95% when compared with SSA and NSC. This clay may give high plasticity (Brady and Clauser, 1991, Michael, 1989). The oxide impurities present in the clay promote the formation of low melting glasses, which tend to reduce the refractoriness.

According to Aneke (1981) and Brady and Clauser (1991), samples NSC can be said to have a good chemical composition suitable for its use as binder clay in foundry sand and drilling muds. With the composition of the alumina of 38.0% and silica 46.8% high refractoriness should be expected. However, this is negated by the high lime (CaO + MgO) content, 1.16% and low-firing temperature of 1000 °C.

The reddish brown colouration of the NSC at firing temperature is indicative of the presence of decayed vegetation, which burns out upon firing yielding the LOI value obtained (Aneke, 1981 Brady and Clauser 1991, Nnuka *et al*, 1992). This reddish brown colour could also be as a result of Fe_2O_3 but the amount is small (0.5%).

CONCLUSION

It may be concluded that Al_2O_3, SiO_2, Fe_2O_3, CaO and MgO form the major and minor constituents of the clay samples from the arid zones of Nigeria. The suitability of the clays for high temperature application has been determined. The values in the clay act as pointer to high refractoriness.

These contents also can serve as a useful guide to the usage of the clays. The Shuwari clay belongs to medium duty acidic siliceous fire-clay. Pulka was classified as moderate duty low melting fire-clay while Ngala clay has high percentage of alkali impurities and LOI of 11.63%, which give the clay an excellent plasticity suitable for use as binder and drilling muds.

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