Original Research Article

Evaluation of the Chemical Composition of Awgu Clay Deposit for its Industrial Potential

ABSTRACT

The chemical composition of raw clay deposit in Awgu Town in Awgu Local Government Area of Enugu State, Nigeria was evaluated. The chemical property evaluation was done using x-ray fluorescence spectrometry, in addition to the determination of the loss on ignition test (L.O.I.) using standard technique. The result of the chemical evaluation revealed that Awgu clay was composed of silica ($\mathrm{SiO_2}$), 64.26%; alumina ($\mathrm{Al_2O_3}$), 21.42%; iron oxide ($\mathrm{Fe_2O_3}$), 12.54%; potassium oxide ($\mathrm{K_2O}$), 0.19%; titanium oxide ($\mathrm{SiO_2}$), 0.78% and other oxides in traces (<0.1%), and loss on ignition test (L.O.I.) of 5.17%. The results of the chemical evaluation propose that the clay deposit is classified as kaolinite and quartz, and possesses some industrial potentials.

Keywords: Awgu clay, kaolin, quartz, silica, x-ray fluorescence

1. INTRODUCTION

Clay is in almost all inhabitable places on earth, and its easy availability and characteristic properties facilitate its diverse use in human civilization [1]. It is described as a natural, earthy, fine-grained material, mostly of a group of crystalline hydrous silicate minerals known as clay minerals – composed mainly of silica, alumina and water, but may also contain large enough quantities of iron, alkalis and alkaline earths [2]. Chemically and mineralogically, clay is a complex aluminosilicate compound composed of attached water molecules whose origin is due to the chemical and mechanical deterioration of rocks, such as granites [3]. According to the U.S. bureau of Mines as reported by [4], clays are generally classified into six groups, namely; kaolin, ball clay, fire clay, bentonite, fuller's earth, and common clay and shale clay.

[5] quoted [6] to have noted that the important property for clay classification is the basic composition and structure of clays. On the strength of this, clay minerals were classified into kaolinite group ($\mathrm{Al_2Si_2O_{10}(OH_6)}$) – containing a unit of silica and alumina each stacked in opposing fashion (1:1 lattice type). It is prominent to credit kaolin as the most valuable of the industrial clays as it is useful in many areas; paper filling and coating, paint, plastic, adhesives and ink pigment, rubber-reinforcing agent, ceramic raw materials for porcelain, dinner ware, tiles and enamels, catalyst for cosmetics base, and digestive coating remedy [7].

Ball clay has been described as a plastic and also white firing clay with applications in ceramic ware, primarily dinner ware, floor and wall tile, pottery and sanitary ware. Due to the ability of fire clays to withstand high temperatures (≥ 1500˚C), they are used for refractoriness or to raise vitrification temperatures in heavy clay products [4]. Like kaolin clay, bentonite clays are hydrated aluminosilicates composed mainly of montmorillonite ($Al_2O_3.4SiO_2.H_2O$). The chemical and physical composition of bentonite make it an important industrial mineral with wide spread applications in foundry sands, iron ore pelletizing, insulator, drilling mud, bleaching clay, clarifying and decoloring, filtering agent, treating waste water, ingredient in cosmetics, animal feed and pharmaceuticals [7].

Common clay and shale also known as quartz is the most abundant and readily available clay material. It has high percentage of silicon oxide (SiO_2), accounting for its name, silica sand. From an observatory point of view, quartz is the only clay material that posses the capacity to exist alone in pure state on account of its high content in most clays, but in many cases, may contain undesirable impurities. Silica sand is used in the production of various glass products which include, sheet glass, for windows, bottles, mirrors, optical instruments, chemical apparatus, electrical insulation and condensers, pipes, doors, crucibles, automobile and craft bodies, filters and building blocks [8].

Since the early part of 21st century, important uses have been found for clays in the rubber industry particularly those with less composition of silica [10]. The quantity/percentage and type of chemical oxides (Fe_2O_3, MgO, CaO, SiO_2, Al_2O_3, K_2O, Na_2O, etc) in clay ultimately determine the areas of applications of the clay such as in bricks, floor tiles, paper, ceramic, etc. [5] reported that clay products such as ceramic wares, burnt bricks and floor tiles, in Nigeria, are cheaper and more durable building materials than cement.

This study examined the chemical composition and loss on ignition (L.O.I.) of Awgu clay deposit in Awgu Local Government Area of Enugu State, Nigeria, in order to project its prominent versatility, and industrial and economic potentials. Furthermore, to the best of our knowledge, this study revealed that no document was found on the chemical composition of Awgu clay using x-ray fluorescence spectrometer.

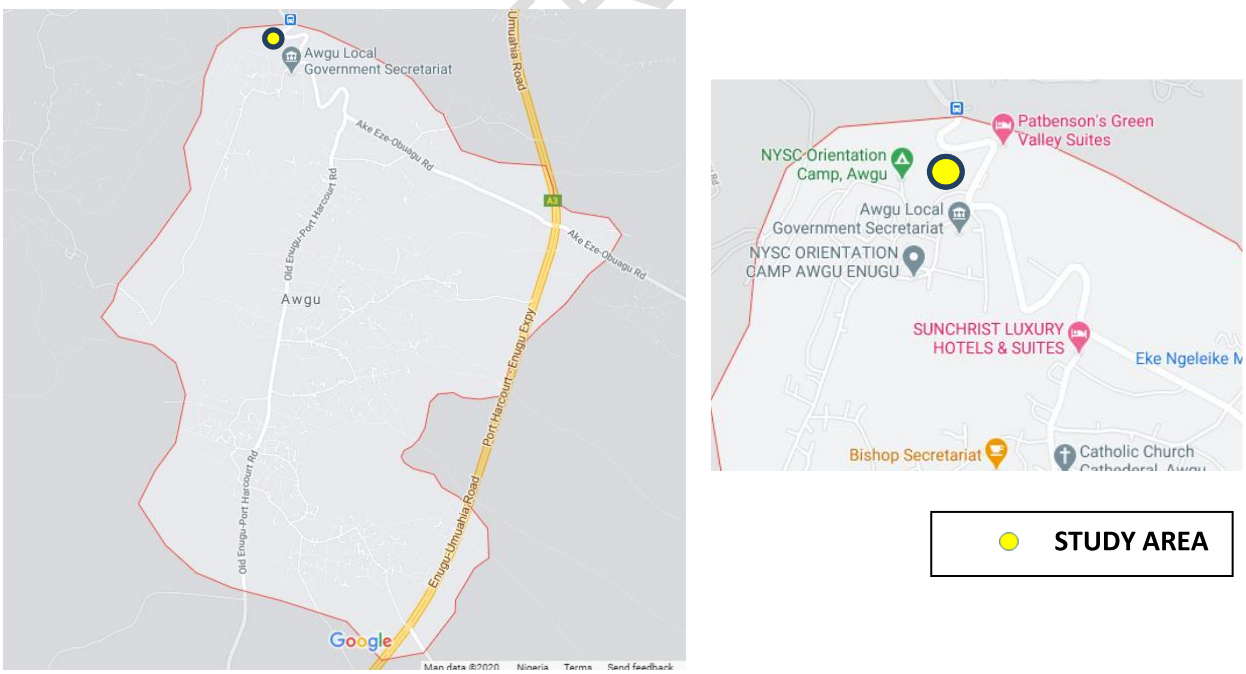

Fig. 1. Awgu map showing location of study area

2. METHODOLOGY

2.1 Sample collection and preparation

Field sampling exercise of the local clay sample was done during the dry season. Fresh samples were collected in lump form from pits dug to depths of 1.5m at a choice deposit of the clay sample. The local clay was got from Awgu region, Awgu local Government Area of Enugu State, Nigeria (Figure 1). The clay sample was dried and grounded into powder form (about 75μm) with mortar and pestle while continuously sieving.

2.2 Chemical analysis

The chemical evaluation of the clay was determined using x-ray fluorescence (XRF). The chemical composition of the clay sample is presented in Table 1.

2.3 Loss on ignition test (L.O.I.)

[10] defined L.O.I. as the quantity of chemically combined water (and sometimes organic matter content) in inorganic materials. 50g of the clay sample was dried in an oven at 105˚C and cooled in a desiccator. The dried sample was placed into a clean, dried empty crucible weighing (M_0). The crucible together with the clay sample weighed (M_1). The crucible containing the sample was heated to a temperature of 800˚C for 3 hours, cool to room temperature and then weighed (M_2). The loss on ignition was calculated from Equation 1:

$$\text{L.O.I.} = \frac{M_1 - M_0}{M_1 - M_2} \quad (1)$$

Table 1. Chemical composition of Awgu clay compared with standard clay for industrial applications: [11] and [12]

Oxide	Awgu clay	Ceramics	Refractory brick	High melting clay	Glass	Paper	Paint
Al_2O_3	21.42	26.50	25-44	16-29	12-17	33.5-45.8	37.9-38.4
SiO_2	64.26	60.50	51.70	53-73	80-95	45.0-45.8	45.3-47.9
K_2O	0.19	-	-	-	-	-	-
TiO_2	0.78	-	-	-	-	-	-
CaO	-	0.18-3	0.1-20	0.5-2.6	4.-5	0.03-0.06	0.03-0.06
MnO	0.01	-	-	-	-	-	-
Fe_2O_3	12.45	0.5-1.2	0.5-2.4	1-9	2-3	0.3-0.6	13.4-13.7
SrO	0.01	-	-	-	-	-	-
Nb_2O_5	0.01	-	-	-	-	-	-
MoO_3	0.03	-	-	-	-	-	-
Ag_2O	0.01	-	-	-	-	-	-
LOI	5.17	8.18	8-18	5-14	-	-	-

3. RESULTS AND DISCUSSION

The results of the chemical evaluation and the loss on ignition of Awgu clay are presented in Table 1. The chemical results of Awgu clay show high silica (SiO_2) content of which meets the standard for refractory bricks manufacturing, ceramics as well as high melting clay, although below the range for glass formulation. This high SiO_2 value indicates that the clay sample is more of silica (quartz) which is typical of kaolinitic clay [13]. The alumina (Al_2O_3) content of Awgu clay is 5.08% and 3.58% short of the standard required for ceramics and refractory bricks manufacturing respectively. Furthermore, the alumina content is short of the standard required for paper and paint manufacturing as reported by [12]. But it can be used in the manufacture of high melting clay and alumino silicate and fiber glasses as reported by [11]. The alumina content of the clay is a strong indicator for its refractoriness, as the higher the amount of alumina, the higher is the refractoriness of the clay. The iron oxide (Fe_2O_3) content is higher than the standard for refractory bricks, high melting clay, glass and paper. Such level of iron oxide usually imparts reddish colouration to clay when fired, hence, making it very attractive as a ceramic raw material as reported by [3]. However, it is pertinent to note that high iron oxide content also affects the high temperature characteristics of clays, such as fired strength [5]. The loss on ignition of the Awgu clay is below the range for ceramic and refractory brick production as reported by [12], but within the range for high melting clay. However, [14] noted that loss on ignition values are okay to be low due to its effects on the porosity of the material especially refractory bricks.

4. CONCLUSION

The experimental investigation on the chemical composition of Awgu clay and its subsequent suitability as an industrial raw material show that Awgu clay contains silica (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3) as major components and is classified as kaolinite and quartz. The clay is therefore found to be a source of raw material for the production of refractory bricks, ceramics of highly attractive quality on account of its high iron oxide content, and high melting clay materials. It is recommended that future researchers should use other spectroscopic tools like X- ray diffraction in the determination of the mineralogical phases of Awgu clay and how it relates to its applications.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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