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Research Article

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The Chemical Analysis of Some Local Clay Samples for the Development of Electrical Porcelain Insulators

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Abstract In this paper, the chemical analysis of some local clay samples used for the production of electrical porcelain insulator has been investigated. Test samples were made by varying the quantities of feldspar and silica required to form a mouldable plastic body with each clay sample. The investigation was carried out because some local clay have been confirmed to be poor in the production of electrical porcelain insulators. This investigation confirmed that the clay samples used are good for the production of electrical porcelain insulators with the use of an Atomic Assumption Spectrophotometre. Chemical properties such as bulk density and water absorption were determined for each test sample. Based on the results obtained, the bulk density values recorded range from 1.71g/cm^3 to 1.95g/cm^3 for Iva Valley formulations, 1.60g/cm^3 and 2.00g/cm^3 for Nawfija and 1.93g/cm^3 to 2.00g/cm^3 for Ekwulobia.. Iva Valley formulation recorded water absorption values ranging from 4.52% to 12.15%. For Nawfija formulation, water absorption values range from 5.41% to 10.84% while Ekwulobia formulations gave water absorption values ranging from 4.76% to 8.71%. The samples were found to have requisite properties that make them suitable for domestic production of porcelains insulators that can be compared with the already existing porcelain insulators in Nigeria.

Keywords clay, feldspar, porcelain, silica, translucent, vitrification

1. Introduction

Clays originated as a result of the dissolution of a given mineral or group of minerals composing rocks like granites [1]. Many benefits are derivable from local processing of minerals [2].The recognition of these benefits motivated the Nigerian government to make a shift from the import-substitution, industrialization policy to a resource-based industrialization strategy [3]. This strategy places great emphasis on the development of indigenous technology requiring the utilization of available local raw materials. Generally speaking, porcelains are vitrified and fine-grained ceramic whitewares, used either glazed or unglazed. They refer to a wide range of ceramic products that have been baked at high temperatures to achieve vitreous, or glassy, qualities such as low porosity and translucence. In the manufacture of ceramics, the 600-1000 $^{\circ 0}$C zone is of greatest importance in transforming the dried clay into a new, more rigid substance. The word "porcelain" has its origin in the Italian "porcella" literally "little pig", a

Mediterranean sea-snail whose shell is white and translucent. Marco Polo was the first to apply the name to porcelain [4]. They are used as electrical insulators in household, laboratory and industrial applications. For technical purposes, porcelain products are designated as electrical, chemical, mechanical, structural and thermal wares [5]. Electrical insulators are generally ceramic materials and they prevent the flow of electrical current through them.

Insulators are extensively used for high voltage applications [6]. They are required to be electrically inert and they isolate two conductors of different potentials [7].The primary components of electrical porcelain are clays, feldspar and silica (flint), which are all characterized by small particle size. The clay gives plasticity to ceramic mixtures, silica maintains the shape of the formed article during firing and feldspar serves as flux, which is added to decrease firing temperature in order to reduce costs by saving fuel or energy.

Electrical porcelains are widely used as insulators in electrical power transmission system due to the high stability of their electrical, mechanical and thermal properties in the presence of harsh environments. These are the reasons for their continued use over the centuries despite the emergence of new materials like plastics and composites. They are considered to be one of the most complex ceramic materials and represent the most widely studied ceramic system [8].

Bulk density depends upon the true specific gravity and the porosity [9]. By varying the proportions of the three main ingredients, it is possible to emphasize the thermal, dielectric or mechanical properties of the porcelain. In developing industrial nation like Nigeria, the porcelain need is potentially enormous, especially in improving the nation's rural electrification. Nigeria expends a lot of foreign exchange importing porcelains. Yet, a lot of clay deposits abound in the country, which can be developed to meet our local needs and also reduce cost. This state of affairs adversely affects the country's foreign exchange reverse and is inconsistent with the drive for local substitution of imported goods [10]. Fig 1 represents the chemical flow diagram.

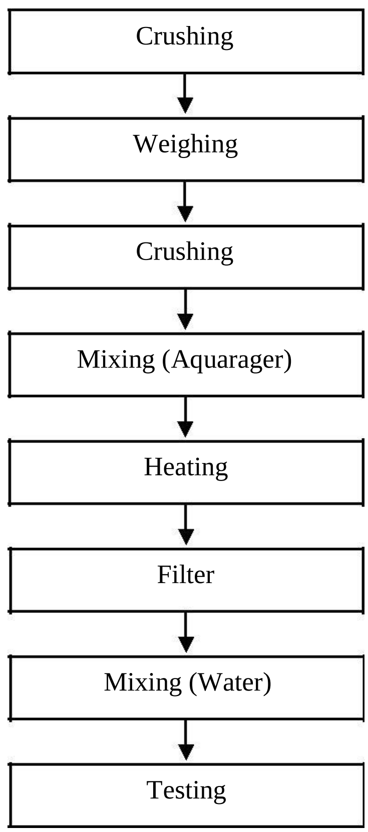

Figure 1: Flow Diagram for the Chemical Analysis

2. Materials and Methods

Representative sample of each of the five raw materials was analyzed to determine the chemical constituents [quantity of SiO_2, Al_2O_3, etc. and LOI (Loss on Ignition)].

The clay samples were crushed using a hammer to reduce it to powder form. This reduced it to the form needed for the chemical analysis. The samples were weighed at 0.2 g and poured into the Teflon Chrosible and 10ml of

Aquarager (comprising hydrochloric acid HCl^+ and Nitric acid HNO_3 in the ratio of 3:1 respectively) was added to each of the samples. Then 5 ml of Hydrofloric acid HF was also added. The Teflon Chrosible was put in an electric ovum and set at 150 °C. As soon as the temperature gets to 150^0C, the timing started until when it got to 250 °C which was in 2 hours 10 minuites. The electric ovum was turned off and waited for 30 minutes before it was opened to avoid the heat destroying any component. At that time, the samples were dissolved and turned colourless. Then the dissolved samples were poured into their respective beakers and also added 10 ml of distilled water in each. Afterwards, the filter paper was weighed. Then each of the samples was filtered into their respective 250 ml volumetric flask. The filter paper is been weighed because the initial weight will be needed to determine the silicate

$$\text{Silicate} = \frac{difference\ \ in\ filter\ \ paper}{weig\,ht\ of\ \ sample\ \ used} X\ 100 \qquad \textbf{(1.0)}$$

Distilled water was added in each of the samples to increase the volumes to 250 ml and the samples were then taken to the Atomic Assumption Spectrophotometer (AAS) for testing.

2.1. Chemical Composition

The results of Atomic Assumption Spectrophotometer AAS chemical analysis of the various constituents used for the research are presented in Table 1.

Table 1: Chemical Composition of sample clays (AAS)

		Location of Clay Samples			Additives	
s/n	**Chemical Composition (%)**	**Iva Valley**	**Nawfija**	**Ekwulobia**	**Feldspar**	**Silica**
1	**SiO_2**	53.54	51.04	59.27	63.62	97.42
2	**Al_2O_3**	27.75	24.99	29.61	17.30	0.15
3	**Fe_2O_3**	1.03	0.50	1.79	0.82	0.46
4	**MgO**	0.98	1.12	0.78	0.24	-
5	**CaO**	1.48	3.03	0.54	0.42	-
6	**Na_2O**	0.21	0.58	0.59	1.79	-
7	**K_2O**	0.64	0.67	0.23	14.86	-
8	**LOI (H_2O)**	11.20	13.62	9.95	0.51	0.42

Where, LOI is the Loss on Ignition.

The chemical composition of the samples were tested and tabulated in Table 1.

3. Results and Discussions

Bulk density and water absorption were determined in one and the same test in accordance with ASTM C 20-80a. The samples were dried over 12 hours at 105 °C in preparation for the test. They were taken directly from the oven for the test. The dry weight in air (W_{da}) was measured, after which the samples were transferred into and suspended in a vessel of boiling water for 1hr. After boiling, the specimens were left to cool to room temperature while still immersed in the water. After a day, the weight in water (W_{sw}) was measured. Each specimen was removed from the water and the surface gently cleaned with a damp cloth, and it was weighed in air to determine the saturated weight (W_{sa}).

3.1. Bulk Density

The bulk density, D_b, of each sample was also calculated using the results of the apparent porosity test, thus:

$$D_b, (g/cm)^3 = \frac{true\ \ weig\,ht}{Bulk\ \ volume} = \frac{W_{da}}{W_{sa} - W_{sw}} \quad \textbf{(2.0)}$$

Where; A_w = water absorption

W_{sa} = saturated weight

W_{da} = dry weight in air

W_{sw} = weight in water

D_w = bulk density

The results of bulk density are shown in Tables 2, 3 and 4 for Iva Valley, Nawfija and Ekwulobia formulations respectively.

Table 2: For Iva Valley clay formulations

Sample	W_{da} (g)	W_{sw}(g)	W_{sa} (g)	D_b (g/cm^3)
0	42.00	22.40	43.90	1.95
1	39.20	22.00	42.00	1.96
2	43.70	24.00	47.00	1.90
3	43.50	24.20	47.40	1.88
4	43.00	24.70	47.80	1.78
5	42.80	23.00	48.00	1.71

Where $D_b = \frac{W_{sa}}{W_{sa}} - \frac{W_{da}}{W_{sw}}$ **(3.0)**

The results in Table 2 show that Iva Valley formulation recorded bulk density of 1.71g/cm^3 to 1.95g/cm^3

Table 3: For Nawfija clay formulations

Sample	W_{da} (g)	W_{sw}(g)	W_{sa} (g)	D_b (g/cm^3)
0	37.00	20.50	39.00	2.00
1	41.00	21.00	43.60	1.81
2	40.20	20.21	43.00	1.75
3	42.00	20.50	45.50	1.68
4	41.70	20.80	45.80	1.66
5	41.50	20.00	46.00	1.60

Also, for Nawfija formulation, values of bulk density fall between 1.60g/cm^3 and 2.00g/cm^3. It is significant that variation of composition had similar effects on the above properties for all the clays.

Table 4: For Ekwulobia clay formulations

Sample	W_{da} (g)	W_{sw}(g)	W_{sa} (g)	D_b (g/cm^3)
0	42.00	23.00	44.00	2.00
1	42.50	23.20	44.70	1.98
2	42.50	23.2	45.00	1.94
3	42.00	23.50	45.20	1.93
4	42.2	24.2	46.20	1.88
5	42.5	24.2	46.20	1.93

Similarly, Ekwulobia formulations gave bulk density values ranging from 1.93g/cm^3 to 2.00g/cm^3.

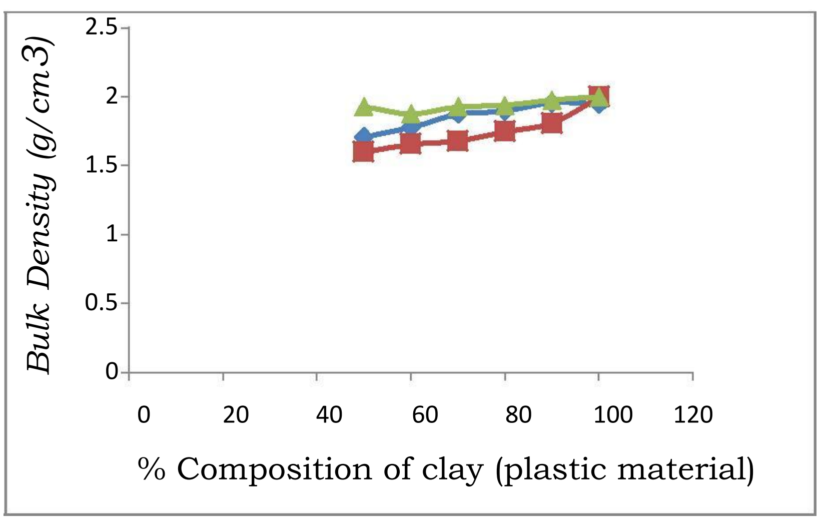

Figure 2: Bulk density as a function of clay content

3.2. Water Absorption

The water absorption, A_w, of each specimen was calculated using the results of the apparent porosity test via the relation:

$$A_w(\%) = \frac{W_{sa} - W_{da}}{W_{da}} \quad \textbf{(4.0)}$$

Where; A_w = water absorbtion

W_{sa} = saturated weight

W_{da} = dry weight in air

W_{sw} = weight in water

The results of water absorption are shown in Tables 5, 6 and 7 for Iva Valley, Nawfija and Ekwulobia formulations respectively.

Table 5: For Iva Valley clay formulations

Sample	W_{da} (g)	W_{sw}(g)	W_{sa} (g)	A_w (%)
0	42.00	22.40	43.90	4.52
1	39.20	22.00	42.00	7.14
2	43.70	24.00	47.00	7.55
3	43.50	24.20	47.40	8.97
4	43.00	24.70	47.80	11.16
5	42.80	23.00	48.00	12.15

The results in Table 5 show that Iva Valley formulation recorded water absorption values ranging from 4.52% to 12.15%. Increase in non-plastic material resulted to increase in porosity while increase in clay lowered porosity.

Table 6: For Nawfija clay formulations

Sample	W_{da} (g)	W_{sw}(g)	W_{sa} (g)	A_w (%)
0	37.00	20.50	39.00	5.41
1	41.00	21.00	43.60	6.34
2	40.20	20.21	43.00	7.00
3	42.00	20.50	45.50	8.33
4	41.70	20.80	45.80	9.83
5	41.50	20.00	46.00	10.84

Also, for Nawfija formulation, water absorption ranges from 5.41% to 10.84%. It is significant that variation of composition had similar effects on the above properties for all the clays.

Table 7: For Ekwulobia clay formulations

Sample	W_{da} (g)	W_{sw}(g)	W_{sa} (g)	A_w (%)
0	42.00	23.00	44.00	4.76
1	42.50	23.20	44.70	5.18
2	42.50	23.2	45.00	5.88
3	42.00	23.50	45.20	7.62
4	42.2	24.2	46.20	8.53
5	42.5	24.2	46.20	8.71

Similarly, Ekwulobia formulations gave water absorption values ranging from 4.76% to 8.71%.

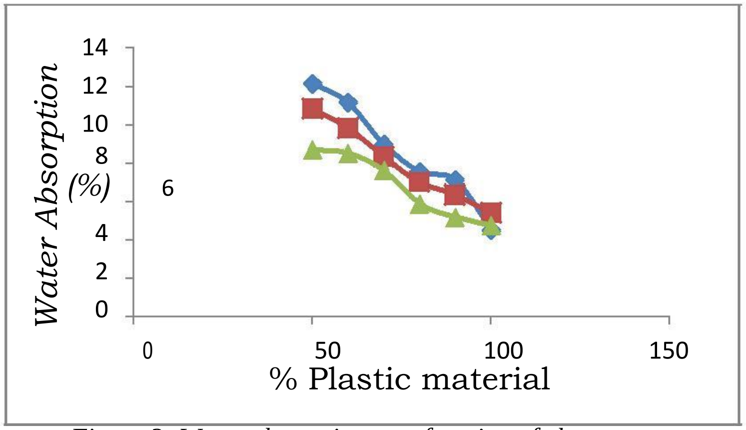

Figure 3: Water absorption as a function of clay content

4. Conclusion

Nigeria needs and consumes a lot of electrical porcelains for power distribution; most of which are imported, yet there is abundant raw materials in the country that could be utilized for porcelain production to serve both the local needs and for export.

The proportions of clay, feldspar and silica were varied in the production of porcelain test samples and properties such as the chemical compositions, bulk density and water absorption were investigated. Clays from Iva Valley, Nawfija and Ekwulobia were also researched for electrical porcelain applications.

Based on the results obtained, the bulk density values recorded range from 1.71g/cm^3 to 1.95g/cm^3 for Iva Valley formulations, 1.60g/cm^3 and 2.00g/cm^3 for Nawfija and 1.93g/cm^3 to 2.00g/cm^3 for Ekwulobia.. Iva Valley formulation recorded water absorption values ranging from 4.52% to 12.15%. For Nawfija formulation, water absorption values range from 5.41% to 10.84% while Ekwulobia formulations gave water absorption values ranging from 4.76% to 8.71%. It is therefore concluded that the three clays are suitable for the production of electrical porcelain provided the above compositional specifications are followed.

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