Analysis of Electrical Porcelain Insulators from Local Clays

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Abstract— *This paper focused on the chemical analysis of electrical porcelain insulators based on local clays. Test samples were made by conducting some chemical composition test using the Atomic Assumption Spectrophotometer (AAS). The clay samples were also tested for linear shrinkage and apparent porosity. Based on the results obtained, the linear shrinkage values recorded range from 7.29% to 14.29% for Iva Valley formulations, 5.14% to 14.71% for Nawfija and 7.74% to 10.29% for Ekwulobia. It was observed that linear shrinkage decreases as the content of non-plastic materials increases and increases as clay content increases. Iva Valley formulation recorded porosity values ranging from 8.84% to 20.80%. For Nawfija formulation, porosity values range from 10.81% to 17.30% while Ekwulobia formulations gave porosity values ranging from 9.52% to 16.82. Porcelain insulators that constitute the above results were found to have requisite properties that make them suitable for domestic production of porcelains insulators from the clay samples studied.*

Keywords— clay, linear, porosity, porcelain, translucent, vitrification.

I. 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 to be 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 white wares, 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^{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" meaning "little pig", a Mediterranean sea-snail whose shell is white and translucent [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 form a large base of the commonly used ceramic insulators for both low and high tension insulation. They are considered to be one of the most complex ceramic materials and represent the most widely studied ceramic system [8].

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 and is inconsistent with the drive for local substitution of imported goods [9]. Therefore the chemical analysis of electrical porcelain insulators made from some eastern Nigerian clay is the focus of this paper.

II. METHODOLOGY

The processes involved in the chemical analysis of the local clay are shown in Figure 1.0.

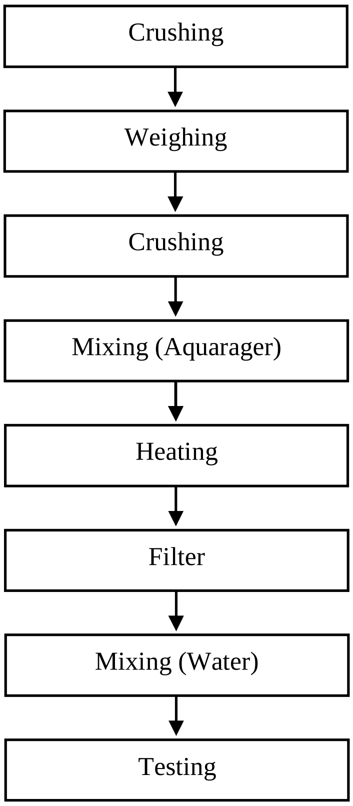

Fig. 1: Flow Diagram for the Chemical Analysis

These processes were important in the determination of 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 needed for the chemical analysis. They were weighed at 0.2g and poured into the Teflon Chrosible. 10ml of Aquarager (hydrochloric acid HCl+ and Nitric acid HNO_3 in the ratio of 3:1 respectively) was added to each of the samples. 5ml of Hydrofloric acid H_f was also added. The Teflon Chrosible was put in an electric ovum and set at temperature of 150^0C. As soon as the temperature gets to 150^0C, the timing started until when it got to 250^0C which was in 2 hours 10minutes. 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 10ml of distilled water in each. A filter paper was weighed. Then each of the samples was filtered into their respective 250ml volumetric flask. The filter paper is been weighed because the initial weight will be needed to determine the silicate using equation 1.

$$\text{Silicate} = \frac{\text{difference in filter paper}}{\text{Weight of sample used}} * 100 \quad (1.0)$$

Distilled water was added in each of the samples to increase the volumes to 250ml. Then the samples were taken to the Atomic Assumption Spectrophotometre (AAS) for testing. The chemical composition result obtained during this experiment is shown in Table 1.0.

III. RESULTS AND ANALYSIS

The results of Atomic Assumption Spectrophotometer (AAS) chemical analysis of the various constituents used for the research are presented in Table 1.0.

Table 1: Chemical Composition of sample clays (AAS)

Composition (%)	***Iva Valley***	***Nawfija***	***Ekwulobia***	***Feldspar***	***Silica***
SiO_2	*53.54*	*51.04*	*59.27*	*63.62*	*97.42*
Al_2O_3	*27.75*	*24.99*	*29.61*	*17.30*	*0.15*
Fe_2O_3	*1.03*	*0.50*	*1.79*	*0.82*	*0.46*
MgO	*0.98*	*1.12*	*0.78*	*0.24*	*-*
CaO	*1.48*	*3.03*	*0.54*	*0.42*	*-*
Na_2O	*0.21*	*0.58*	*0.59*	*1.79*	*-*
K_2O	*0.64*	*0.67*	*0.23*	*14.86*	*-*
LOI (H_2O)	*11.20*	*13.62*	*9.95*	*0.51*	*0.42*

3.1 Linear Shrinkage

To determine the linear shrinkage of the samples, the green and fired dimensions were noted using a vernier caliper. Linear shrinkage for each sample was computed as a percentage of the original green dimensions, i.e. using the equation:

$$L.S = \frac{\Delta L}{L} \quad (2.0)$$

where, ΔL is the change in length, L is the original length. The firing shrinkage values are presented in Table 2.0. The values were calculated on wet basis.

Table 2: Linear shrinkage results

Description	**Iva Valley**			**Nawfija**			**Ekwulobia**		
	L_g (mm)	**L_f (mm)**	**L.S (%)**	**L_g (mm)**	**L_f (mm)**	**L.S (%)**	**L_g (mm)**	**L_f (mm)**	**L.S (%)**
0	42.00	36.00	14.29	34.00	29.00	14.71	34.00	30.50	10.29
1	39.45	34.30	13.05	35.70	31.00	13.17	34.15	30.90	9.52
2	36.00	32.00	11.11	32.10	28.20	12.15	36.00	33.00	8.33
3	37.46	34.00	9.24	31.00	28.00	9.68	33.80	31.00	8.28
4	39.83	36.50	8.36	36.00	33.00	8.33	33.50	30.80	8.06
5	39.80	36.90	7.29	35.00	33.20	5.14	33.60	31.00	7.74

Note: L_g = green length ; L_f = fired length; L.S. = Linear Shrinkage = $\frac{L_f - L_g}{L_g}$

The linear shrinkage values recorded range from 7.29% to 14.29% for Iva Valley formulations, 5.14% to 14.71% for Nawfija and 7.74% to 10.29% for Ekwulobia. It could be observed that linear shrinkage decreases as the content of non-plastic materials increases and increases as clay content increases.

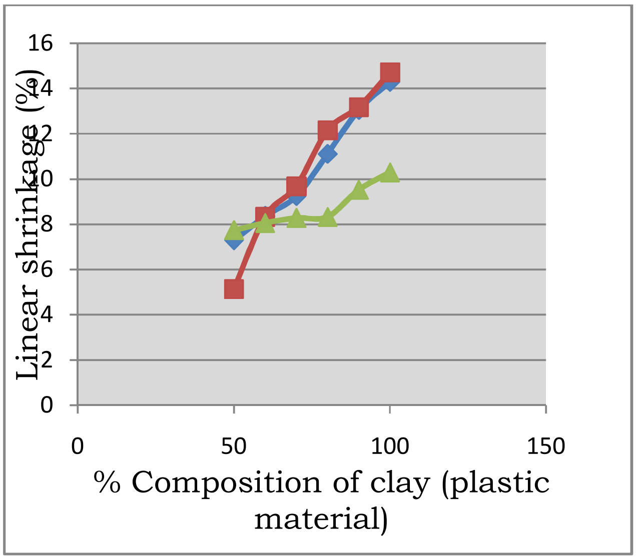

Fig.2:Linear shrinkage as a function of clay content
The graphical representation of the linear shrinkage result is shown in Figure 2.0.

3.2 Apparent Porosity

Apparent porosity, 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 105^0C 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}). The apparent porosity, P_a, of each sample was calculated using the equation 3:

$$P_a(\%) = \frac{Volumeofwaterabsorbedafterboilingx100}{Bulkvolume\ (i.e.volumebydisplacement)}$$

$$= \frac{W_{sa}}{W_{sa}} - \frac{W_{da}}{W_{sw}} \text{x } 100 \qquad (3.0)$$

The results of apparent porosity are shown in Table 3.0, 4.0 and 5.0 for Iva Valley, Nawfija and Ekwulobia formulations respectively.

Table 3: For Iva Valley clay formulations

Sample	**W_{da} (g)**	**W_{sw}(g)**	**W_{sa} (g)**	**Pa (%) -**
0	42.00	22.40	43.90	8.84
1	39.20	22.00	42.00	14.00
2	43.70	24.00	47.00	14.35
3	43.50	24.20	47.40	16.81
4	43.00	24.70	47.80	19.90
5	42.80	23.00	48.00	20.80

The results in Table 3.0 show that Iva Valley formulation recorded porosity values ranging from 8.84% to 20.80%. Increase in non-plastic material resulted to increase in porosity while increase in clay lowered porosity.

Table 4: For Nawfija clay formulations

Sample	W_{da} (g)	W_{sw}(g)	W_{sa} (g)	Pa (%) -
0	37.00	20.50	39.00	10.81
1	41.00	21.00	43.60	11.50
2	40.20	20.21	43.00	12.20
3	42.00	20.50	45.50	14.00
4	41.70	20.80	45.80	16.40
5	41.50	20.00	46.00	17.30

Also, for Nawfija formulation, porosity values range from 10.81% to 17.30%. It is significant that variation of composition had similar effects on the above properties for all the clays.

Table 5: For Ekwulobia clay formulations

Sample	*W_{da} (g)*	*W_{sw}(g)*	*W_{sa} (g)*	*Pa (%) -*
0	*42.00*	*23.00*	*44.00*	*9.52*
1	*42.50*	*23.20*	*44.70*	*10.23*
2	*42.50*	*23.2*	*45.00*	*11.93*
3	*42.00*	*23.50*	*45.20*	*14.75*
4	*42.2*	*24.2*	*46.20*	*16.07*
5	*42.5*	*24.2*	*46.20*	*16.82*

Similarly, Ekwulobia formulations gave porosity values ranging from 9.52% to 16.82%.

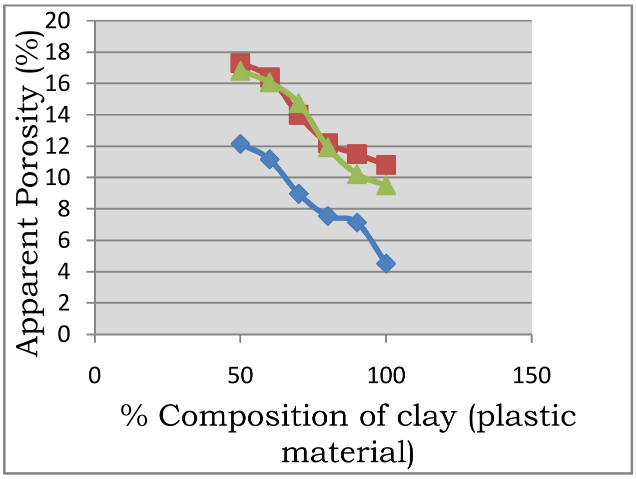

Fig 3: Apparent Porosity as a function of clay content
The graphical representation of the apparent porosity result is shown in Figure 3.0.

IV. 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, silica and also snail shell were varied in the production of porcelain test samples and properties such as the chemical compositions, linear shrinkage and apparent porosity were investigated. Clays from Iva Valley, Nawfija and Ekwulobia were researched for electrical porcelain applications.

Based on the results obtained, The linear shrinkage values rcorded range from 7.29% to 14.29% for Iva Valley formulations, 5.14% to 14.71% for Nawfija and 7.74% to 10.29% for Ekwulobia. It could be observed that linear shrinkage decreases as the content of non-plastic materials increases and increases as clay content increases. Iva Valley formulation recorded porosity values ranging from 8.84% to 20.80%. For Nawfija formulation, porosity values range from 10.81% to 17.30% while Ekwulobia formulations gave porosity values ranging from 9.52% to 16.82%. 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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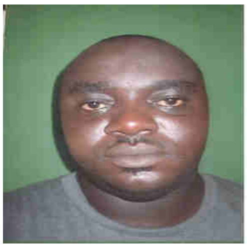
Author Detail



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