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Suitability of Selected Nigeria Clay Deposit for Production of Clay Based Ceramic Water Filters

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Authors' contributions

This work was carried out in collaboration of all authors. Author SAO collected and performed all analyses, characterization and wrote the first draft of the work. Authors OSA, EOD and OTO managed the literature searches, designed the study and managed the analyses of the work. Authors OSA and OTO interpreted the results, corrected and prepared the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study is designed to investigate the suitability of selected Nigeria clay deposit for Clay based ceramic water filters (CWFs). Clay samples were collected from five randomly selected locations within Nigeria Namely: Ibafo in Lagos state, Ondo in Ondo state, Ilesha in Osun state, Ajebo in Ogun state and Kumbuso in Kano state to determine their suitability for Clay based ceramic water filters (CWFs). Experimental analysis for Liner shrinkage, water absorption, bulk density, compressive strength X-ray diffraction (XRD) and X-ray Fluorescence (EDXRF) were carried out on each of the clay samples. Test results reveals that all the clays were kaolinite in nature, containing high contents of alumina (Al_2O_3) and silica (SiO_2) with minor contents of P_2O_5, Fe_2O_3, MgO, K_2O, MnO and TiO_2. The average crystal sizes of the clay were between 8.96 nm and 19.68 nm, lattice structure indicates that the sample were Monoclinic, Anorthic and Hexagonal. Ceramic water filters (CWFs) were made from a mixture of the various clay samples and sawdust at different volume

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ratios, and processed into test samples. Water absorption, linear shrinkage, flow rate and compressive strength of the clay based ceramic filters (CWFs) reveals that as the volume ratio of sawdust increases these properties decreases. The research indicated that Lagos clay has highest strength and flow rate and thus lagos and Ogun clay can be recommended for use in Clay based ceramic water filters production.

Keywords: Clay; ceramic water filters (CWFs); X-ray diffraction; X-ray fluorescence.

1. INTRODUCTION

Clays (and clay minerals) are products of *in situ* alteration or alternatively deposited as sediment during erosional cycle or developed *in situ* as antigenic clay deposit [1]. The uses of clay are ubiquitous and diverse. On a global scale, clays are of major economic significance. They are applied in virtually every aspect of our daily lives. The applications range from medicines to cosmetics, from drilling fluids to paint, and from paper to cups and saucers. It is very difficult to over-estimate their use and importance [1,2].

The complex nature of clay makes its study and findings an ever fresh area of interest especially to the world of science. Clay bodies are widely distributed on the Precambrian basement complex of Nigeria [3,4]. Clays occur in deposits of greatly varying nature. No two deposits have exactly the same clay and frequently different samples of clay from the same deposit differ [5].

Clay based ceramic water filters (CWFs) are usually produced by mixing of clay, sawdust (woodchips) and water [6]. Although porous CWFs have been used successfully in the field [7-10] for over a decade, the suitability and utilization of the vest Nigeria clay deposit cannot be over emphasized. Thus, the present study is designed to investigate the suitability of selected Nigeria clay deposit for Clay based ceramic water filters (CWFs)

2. MATERIALS AND METHODS

2.1 Sample Preparation

Samples were collected from five randomly selected locations within Nigeria Namely: Ibafo in Lagos state, Ondo in Ondo state, Ilesha in Osun state, Ajebo in Ogun state and Kumbuso in Kano state.

The collected samples were dried in open air, after which, the samples were manually crushed into thin particles using a mortar and pestle, and then levitated using the water extraction method. The clay samples were mixed with distilled water and thoroughly stirred and allowed to hydrate for several hours and latter decanted this process is repeated until purer clay is obtained. The samples were sun dried and subsequently dried in a laboratory oven at 110℃ for 24 hours. The resulting dried clay samples were pulverised and sieve with a digital octagon sieve shaker BS/ISO 3310 to an average particle size of 150 µm, and label as processed clay (PC), and sent for analysis.

2.2 Clay Based Ceramic Filters Formation

Each of the clay samples were mixed with sawdust in five (5) different ratios into homogenous paste using an electronic mill, with water as the binding agent. The resulting mixture (clay, sawdust and water) was form into cylindrical, flat and cubes slabs; it was there after dried in laboratory air (temperature of 105℃, humidity of 40%) for 24 hours. After drying, the samples were sintered in a muffle furnace. The firing involved pre-heating of the sample to 450-500℃ (to burn off the sawdust), followed by heating to the sintering temperature of 850℃ for six hours in the same muffle furnace.

2.3 Materials Characterization

2.3.1 Determination of linear shrinkage

The Clay samples were made into flat bars of 12 cm x 3 cm x 1 cm was dried at room temperature for 14 days, after which the final length was measured. Total percentage shrinkage was determined using the formula;

$$\%\ \text{linear shrinkage} = \frac{\text{initial length} - \text{final length}}{\text{Initial length}} \times 100\% \quad (1)$$

2.3.2 Water absorption

Flat bar of clay samples were first weighed using an electronic weighing balance, soaked in a bowl of water for 24 hours. Each was then removed from water, allowed to drip and the remaining was gently wiped to ensure that no water was attached to the surface and was re-weighed again. The difference in weight was then used in computing the percentage water absorption applying the formula below:

$$\% \text{ Water Absorption} = \frac{\text{soaked weigth} - \text{dry weigth}}{\text{Dry weigth}} \times 100\% \quad (2)$$

2.3.3 Compressive strength

The compressive strength was determined using the Instron Universal Tester Model No: 3069, with a compressive load rate of 70 N/min.

2.3.4 X-ray diffraction analysis

The X-ray diffraction (XRD) was monitored using X-ray diffractometer GBC EMMA, CuKα radiation using an acceleration voltage of 25 kV and current of 400 µA. The diffraction angle was scanned from 10° to 65° 2 θ, at a rate of 4.00°/min.

2.3.5 Elemental characterization

The quantitative analysis of chemical components of both processed and unprocessed clay was done using EDX 3600B Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer.

2.3.6 Flow rate analysis

Prior to the water flow experiments, the CWFs were saturated by complete submersion in a vat containing distilled water. The ceramic pot was first placed into a plastic receptacle that was fitted with a large plastic funnel. The filter and receptacle-funnel were suspended above an empty collection bucket. A known volume of distilled water was poured into the CWF, and the volume of the water that flowed into the collection bucket was measured. The flow rates were obtained by measuring the volume of water discharged from the CWFs as a function of time.

3. RESULTS AND DISCUSSION

3.1 X-Ray Diffraction Analysis

X-Ray Diffraction Analysis, showing the average crystal size and lattice structure parameter of the clay samples are shown in Table 1, while the X-raw diffraction spectral are shown in Fig. 1 below.

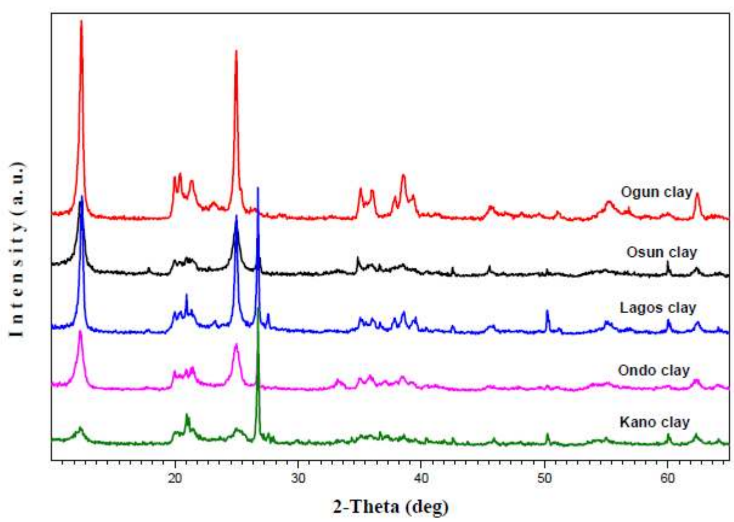

Fig. 1. X-Ray diffraction of selected clays

Table 1. Average crystal size and lattice structure parameter of clay XRD

Property	Lagos	Ondo	Osun	Ogun	Kano
Average crystal size (nm)	19.68	14.88	8.96	19.65	19.03
Lattice structure	Monoclinc	Monoclinic	Anorthic	Anorthic	Hexagonal

3.2 Elemental Analysis

From Table 3, the observed large amount of silica, alumina and iron contents suggests that the clays could be used for a variety of purposes. The results as showed in Table 3 indicated that the presence of Aluminum oxide of the order of between 40-45% makes them to fall under the class of Alumino-Silicate refractories (Hassan et al. 1993). These values are comparable to those obtained for residual and secondary clays from other parts of Nigeria, on the other hand CaO concentrations were less than 0.4%, and are lower than those of other Nigerian Clay [11]. The high Potassium oxide shows that there is high Mica content and this is good for casting.

3.3 Physical Parameters of Raw and Blended Clay

The ratio of clay-sawdust are shown in Table 3 below, while Table 4 shows test result of Bulk density, linear shrinkage, water absorption and compressive strength of both raw and blended clay are shown in Table 3.

Water absorption shown in Fig. 2, indicate that as the volume ratio of sawdust increases the water absorption of blended clay increases, this might be due to the hydophillic nature of sawdust. However, Kano clay has the highest water absorption at 60% sawdust content, followed by Ogun, while Lagos clay has the lowest water absorption rate.

Liner shrinkage results shown in Fig. 3, indicate that Clay from osun has the highest percentage shrinkage value, followed by clay from ondo, while Lagos clay shows a relative low Liner shrinkage rate as sawdust volume fraction increases.

Compressive strengths are generally attributed to stress concentration phenomena [12,13]. As shown in Fig. 4, compressive strength was observed to decrease linearly (R^2 = 0.8803) with increasing porosity caused by the addition of different volume ratio of sawdust, Similar trends have been observed by other researchers [14-16]. Clay samples from lagos shows superior strength compare to other clay sample used for this research.

Table 2. Elemental characteristics of clay sample

Element	Lagos	Ondo	Osun	Ogun	Kano
Al_2O_3	51.468	40.637	45.596	47.424	36.070
SiO_2	30.663	45.637	39.911	39.954	49.117
P_2O_5	0.162	0.117	0.175	0.128	0.183
SO_3	0.573	0.432	0.705	0.508	0.374
K_2O	1.118	0.406	1.098	1.299	1.770
CaO	0.051	0.060	0.056	0.084	0.166
TiO_2	0.948	0.859	1.057	0.141	1.458
MnO	0.003	0.128	0.032	0.183	0.023
FeO	0.850	5.956	3.594	0.866	4.631
Ni_2O	0.080	0.054	0.046	0.066	0.061
CuO	0.063	0.035	0.056	0.061	0.034
ZnO	0.121	0.063	0.087	0.069	0.089
Mo	0.150	0.149	0.187	0.231	0.195
**LOI*	13.75	5.467	7.400	8.986	5.829

**LOI: Loss on Ignation*

Table 3. Ratio of clay-sawdust from different location

Locations					Clay: Sawdust
Lagos	Ondo	Osun	Ogun	Kano	100:0
La(a)	Od(a)	IL(a)	Aj(a)	Kn(a)	70:30
La(b)	Od (b)	IL (b)	Aj (b)	Kn(b)	65:35
La(c)	Od (c)	IL (c)	Aj (c)	Kn(c)	55:45
La(d)	Od (d)	IL (d)	Aj (d)	Kn(d)	50:50
La(e)	Od (e)	IL (e)	Aj (e)	Kn(e)	40:60

Table 4. Physical parameters of blended clay

Locations	Lagos	La(a)	La(b)	La(c)	La(d)	La(e)
Water absorption (%)	25.22	28.51	31.2	36.86	45.10	48.15
Liner shrinkage (%)	7.31	7.26	7.17	7.03	6.970	6.11
Flow rate (L/hr)	0.00	0.047	0.054	0.072	0.098	0.131
Compressive strength (Mpa)	14.66	12.58	10.56	7.58	5.49	3.99
Locations	**Osun**	**IL(a)**	**IL(b)**	**IL(c)**	**IL(d)**	**IL(e)**
Water absorption (%)	22.77	40.92	45.47	48.3	49.66	60.36
Liner shrinkage (%)	12.50	10.97	10.06	9.95	8.88	8.72
Flow rate (L/hr)	0.00	0.017	0.037	0.064	0.078	0.09
Compressive strength (Mpa)	13.74	11.71	9.37	6.84	4.78	2.09
Locations	**Kano**	**Kn(a)**	**Kn(b)**	**Kn(c)**	**Kn(d)**	**Kn(e)**
Water absorption (%)	15.77	38.9	40.35	42.57	52.09	76.52
Liner shrinkage (%)	0.00	0.048	0.052	0.066	0.087	0.091
Flow rate (L/hr)	0.017	0.037	0.064	0.078	0.090	0.017
Compressive strength (Mpa)	13.65	11.51	9.89	6.69	4.73	3.09
Locations	**Ondo**	**Od(a)**	**Od(b)**	**Od(c)**	**Od(d)**	**Od(e)**
Water absorption (%)	27.41	41.38	44.19	56.12	60.83	61.6
Liner shrinkage (%)	13.70	10.07	10.02	9.18	8.77	7.77
Flow rate (L/hr)	0.00	0.025	0.034	0.065	0.085	0.091
Compressive strength (Mpa)	12.26	11.16	9.90	6.53	4.85	2.19
Locations	**Ogun**	**Aj(a)**	**Aj(b)**	**Aj(c)**	**Aj(d)**	**Aj(e)**
Water absorption (%)	31.22	44.37	48.41	49.86	55.59	71.84
Liner shrinkage (%)	9.47	9.21	8.90	8.72	8.60	8.40
Flow rate (L/hr)	0.00	0.016	0.043	0.052	0.062	0.087
Compressive strength (Mpa)	12.21	11.07	9.02	6.14	4.44	3.26

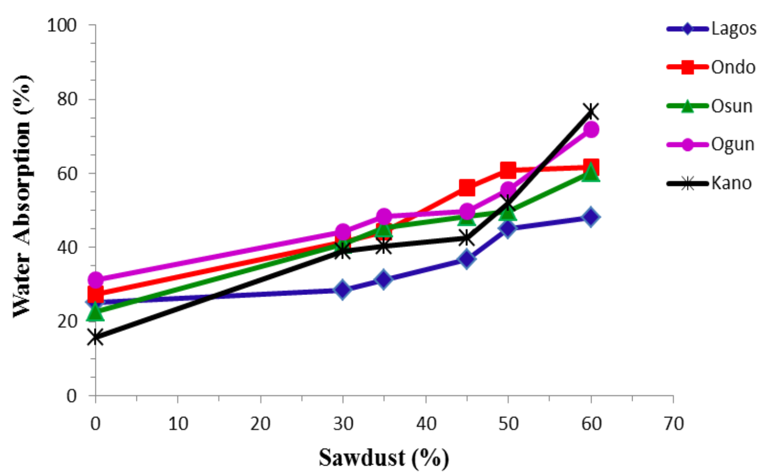

Fig. 2. Variation of water absorption with sawdust volume ratio

From Fig. 5, it was observed that, the flow rate of the clays samples increase as sawdust volume fraction increase, with clay from lagos having the highest flow rate. However clay from ogun has the lowest flow rate of 0.087 liters per hour.

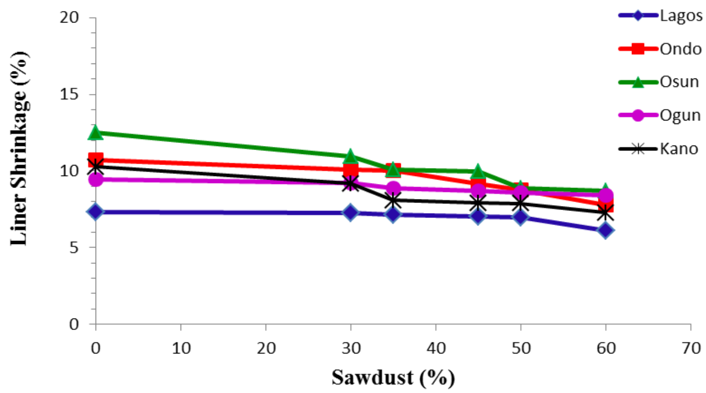

Fig. 3. Variation of Liner shrinkage with sawdust volume ratio

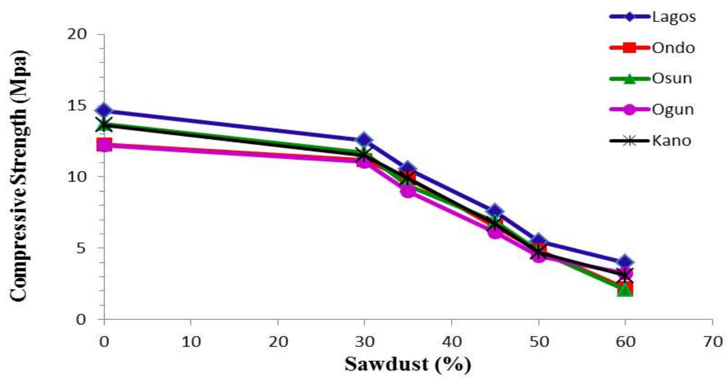

Fig. 4. Variation of Compressive strength with sawdust volume ratio

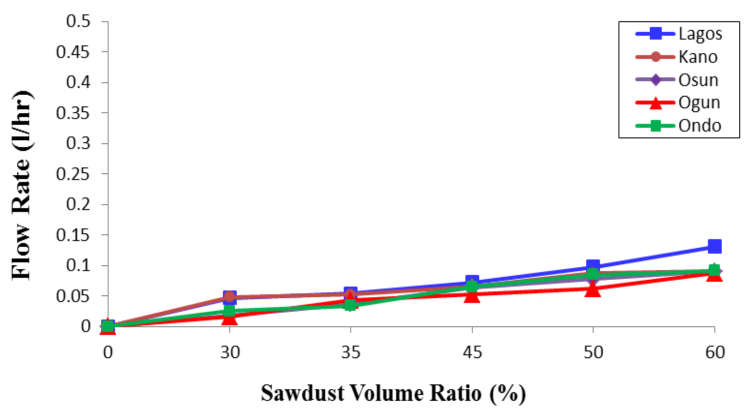

Fig. 5. Variation of flow rate with sawdust volume ratio

4. CONCLUSION

Clays from Ibafo in lagos State, Ondo in Ondo State, Ilesha in Osun state, Ajebo in Ogun State and Kumbuso in Kano State all from Nigeria has been characterized in view of its physical and chemical properties. The clay samples were blended with sawdust Results obtain suggest that the sample contain high contents of alumina (Al_2O_3) and silica (SiO_2) with minor contents of P_2O_5, Fe_2O_3, MgO, K_2O,MnO and TiO_2. The average crystal sizes of the clay were between 8.96 nm and 19.68 nm. Compressive strength varies from 12.21 Mpa to 14.66 Mpa. flow rate for bledded clays sugest that the flow rate increases as the volume ratio of sawdust increases.

A comparison of all clays used in the research indicated that clay from lagos with specification of some industrial clays can be recommended for use in ceramic filter production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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