Development of Ceramic Filter Candle from NSU (*Kaolinite* Clay) for Household Water Treatment

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Abstract– **This work was aimed at developing an effective ceramic water filter candle that is inexpensive and affordable by all and sundry. The ceramic bodies were formulated from Nsu-clay and combustible materials which act as pore-creating agent. The formulated bodies were subjected to physical analysis to determine some parameters which showed that the compounded ceramic bodies were effective in treatment of water. The Casting method of production was used to form candle shape and subjected to atmospheric drying and fired to temperature of 900^{0}C. The Nsu-clay filter-treated water samples were compared with that of raw water. The results indicate that Nsu-clay filter is very effective in removing suspended particles, coloured dissolved substances, unsavory odours and taste. Nsu-clay filter candle is mechanically strong, permeable and cheap, providing quality water drinking while the technology is accessible to all class of people and also the high abundance of raw materials make production of Nsu-clay filter economically viable.**

Keywords– **Water, Ceramics, Filter, Particles and Analysis**

I. INTRODUCTION

Water is the most important compound for the existence of man. Although we have many sources of water in Nigeria, but safe drinking water is one of the challenges of people of Nigeria as the cost of water treatment is extremely high and consequently has led to continuous increase in water borne diseases as majority of Nigerians cannot afford safe drinking water (Krishnamurthy et.al. 2009).

Drinking water conditions have great impacts on people's everyday life, especially in developing countries where access to safe drinking water is very limited. Surface water often is the only source, thus water contaminations are hard to avoid (WHO, 2004) .Unsafe drinking water causes diarrheal and other water borne diseases. According to world Health Organization (WHO), these diseases cause ninety percent of all deaths of children under five years old in developing countries, where children's resistance to infections is low (WHO, 2004). Although municipal water in developed countries already fall into the World Health Organization (WHO) safe drinking water standards, water filters are still commonly used to improve taste or to eliminate any undesired matters. Various types of filters have been designed to be more suitable in the third world countries, but the cost is still not satisfactory and many products are imported which further add to the cost (WHO, 2004).

Ceramics filter has shown to be a veritable tool in water treatment as materials are locally available while the method of production is simple to all.

The work was aimed at investigating the efficiency of Nsu-clay with sawdust as ceramic water filters as well as to design a low-cost and easily manufactured water filtration system for use in third world countries. This water filtration system will include a water filtering component, a lidded container to hold clean water and a valve for easy access of water. The water filtration system is designed to provide safe drinking water for households of four to eight people. In order to achieve the low cost, use of simple technology and readily available materials are the prime consideration needed to insure production of the filters in the local areas.

Sawdust that was used as a burnout material was obtained from New Market timber workshop in Enugu. Hard wood sawdust is preferred to soft wood sawdust because according to (Mcallister, 2005); hardwood sawdust will not bloat as much as sawdust from other woods resulting in more uniform pores and fewer defects in the filters.

II. MATERIALS AND METHODS

A) Collection of Materials

The clay samples used in this study were collected from Nsu at Ehime Mba-ano in Imo State. (The plasticity, mechanical, thermal, properties of the clays were studied under physical analysis before. Plasticity, mechanical and thermal properties of clay are very important in the manufacturing and the use of ceramic water filters.

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PVC adhesive was used for bonding the ceramic filter. The adhesive was purchased from a plumber shop. It was used because according to the specifications of this adhesive it was suitable for household and industries repair and welds, bonds to all metals, plastic, rubber, wood, ceramic, glass and concrete. In this study, the adhesive was used to bind a ceramic and plastic percolator. The adhesive was also not shrinking, waterproof and hardened in less than 3 minutes.

These properties were very important for the use of the adhesive in the study.

Fig. 1. Sample of unprocessed clay

Fig. 2. Sample of sawdust

B) Preparation of samples

Sieve

A 70 mesh-screen which is equivalent to 210 µm sieve was used to sieve the clay and sawdust powders. This would give powder particles of diameter less than or equal to 210 µm.

Sawdust powder

The sawdust from the workshop was dried in the sun and the fine powder was then sieved through the 70 mesh sieve.

Plaster of Paris mould

The plaster of Paris mould used in the study was produced from the master mould constructed at Ceramic Section PRODA Enugu.

C) Production of filter candle

Materials Processing

The organic and coarse materials in the clay were removed by hand. The clay was mixed with water until continuous homogeneous colloidal slurry was obtained. The slurry was sieved through a 200µm sieve. Successive decanting was done to obtain a silt of clay. The silt was then poured into a plaster of Paris mould to remove the excess water. The semi-dry cast was left to dry in air. The dried cast was ground by pestle and mortar to fine powder which was then sieved through the 70 mesh sieve, ready for compounding.

Body Formulation

The clay and sawdust were weighed in the proportion of 95:5, 90:10, 85:15 and 80:20 labeled A, B, C and D respectively. Each sample was poured into basin with 500mls of water to dissolve; the solution was immediately deflocculated with 5mls of sodium silicate which is the one of most vital requirements of a casting –slip, (Slip is the solution of the compounded bodies) It is expected that when the slip is its state of maximum deflocculation, the slip will have its maximum fluidity that possesses a high ratio of water to clay.

Physical analysis of the compounded bodies

Before the production of the water filter candles the physical analysis of the already compounded bodies and the Nsu-clay were done to ascertain if the bodies would be feasible in the water filter candle production as well as the strength and the durability of the products. The physical analysis was performed by the method described by Abuh et al, (2014).

Slip casting

The shaping of articles by casting is extensively used for pottery. Especially for complicated shapes just as molten metal can be cast into the required shape by pouring into mould precisely a plaster mould. Such a mould, being porous, absorbs water is stiffened. After some time, excess slip can be poured away and after a further period, the article in the mould can be removed from the mould.

Casting

Binding the candle plaster of Paris mould with a rubber band, the slip was stirred with an electrical stirrer so as to make the materials in the slip to be in a uniform state. The slip was then poured into the POP moulds and excess water was absorbed by the mould. When there is a satisfied thickness of the cast the excess slip was poured out to form an orifice. The body was removed from the mould after about thirty minutes.

Atmospheric and electrical drying of water filter candles

The water filter candles were allowed to undergo atmospheric drying that is to remove the water content which the mould cannot absorb. This process took about seven days. The candles were parked in an electrical dryer and set to a temperature of about 150^{o}C so as to remove moisture content that could not be absorbed by the atmosphere. This took up to three (3) to five (5) hours.

Firing of water candles

The candles were fettled to remove the outline of the mould that appeared on the candle. They were packed into the kiln and fired to temperature 900^{o}C-950^o.

Fig. 3. The filtration set-up (1)

III. RESULTS AND DISCUSSION

The samples of the filters were light golden brown after firing as shown in Fig. 4 This could be as a result of the presence of Fe_2O_3 in the clay samples as reported by Akpomie et al., (2012). According to them, Iron III compounds are brown in colour.

Filter candles also undergo firing in the kiln. When clay bodies are fired in the kiln, they lose moisture, organic matter, sulphur and carbon IV oxide. As the temperature rises, some of the clay particles begin to fuse destroying the original clay structure and binding the mass together.

In Table 1, water of absorption and apparent porosity are increasing with increase in combustible materials, which is more pronounced at 900^{o}C while the shrinkage, bulk density, apparent density and modulus of rupture decrease with the increase in combustible materials (sawdust).

From Fig. 7, there is general increase in shrinkage value as result of increase in content of combustible materials while the change is more profound at higher temperature.

In the Fig. 9; the increase in sawdust brings corresponding increase in apparent porosity and water of absorption, the bulk density which is how the samples are compact decreases.

Table 2 shows the pH before and after filtration. It is a measure of the hydrogen ion concentration of the water, which indicates whether the water is acidic or alkaline. The result of pH obtained before and after filtration 6.30 and 6.96 respectively, which is close to the value of the WHO standard for drinking water (6.50 to 8.50).

Table 3 shows the values of total dissolved solid (TDS) contained in both the raw and the filtered water samples. High levels of TDS in water may cause objectionable taste and have laxative effect. From the Table 3, it can be seen that the initial value of TDS in the raw water is 62 mg/L and the value of TDS dropped to the value of 15 mg/L after passing through the ceramic filter. The average removal efficiency obtained for TDS with this formula:

(untreated-treated/Untreated) × 100 gave 76%

The porosity of the filter increased linearly with increase in the amount of sawdust in the filters. Fig. 9 shows the variation of average porosity of the filters with the proportion of Nsu-clay with sawdust. But, the best result of apparent porosity and water absorption is at lower temperature; 900^{0}C. This shows that ceramics water filter candle can be best produced at this temperature. At lower temperature, the porosity and the absorption was increased with decrease in strength (modulus of rupture).

This is generally acceptable for water filter candles. The results in Table 1 show that recipe D1 at 900^{0}C is splendid for ceramic water filter candles. The filter candles improved pH in the treated water and gave reduction in Total Solids, Total Dissolved and Suspended Solid values present in the water. The developed filters proved to substantially improve the quality of treated water within the scope of the project. It was found that increase in porosity due to increase in sawdust leads to decrease in the bulk density and thus maintains the apparent density.

Fig. 4. Water filter candles that have been fired

Table 1: Result of Physical Analysis for Water Filter Candle

TEMPERATURE	900^0C				1000^0C			
CODE NO	A1	B1	C1	D1	A2	B2	C2	D2
SHRINKAGE %	2.0	2.2	4.3	5.6	6.6	6.2	9.8	11.6
WATER ABSORPTION %	50.58	53.71	58.84	82.89	39.40	41.36	52.28	74.84
BULK DENSITY g/cm^3	1.98	1.89	1.70	1.20	1.34	1.91	2.42	2.54
APPARENT DENSITY g/cm^3	1.33	1.30	1.26	1.10	1.44	1.42	1.32	1.14
APPARENT POROSITY (%)	69.88	74.10	87.18	90.64	56.53	58.52	68.66	85.61
MODULUS OF RUPTURE kg/m^2	25.43	22.92	5.32	5.63	49.24	35.29	38.18	22.74

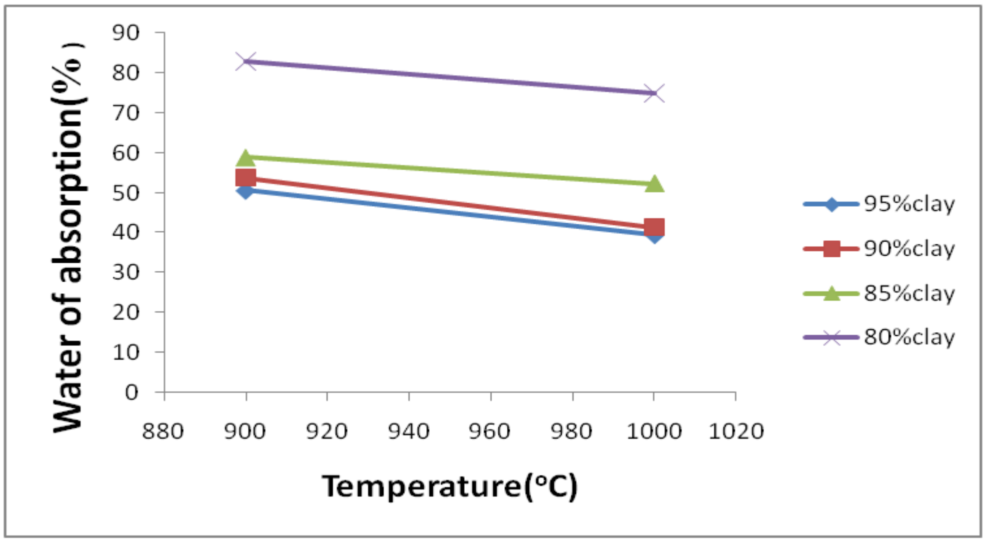

Fig. 5: Water of absorption at different temperatures

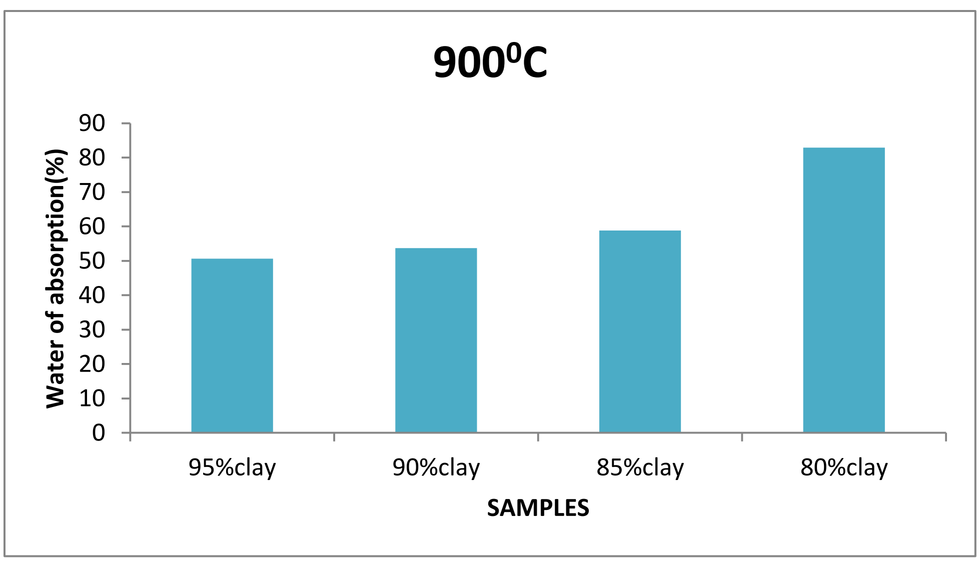

Fig. 6. Water of absorption at various proportions of Sawdust

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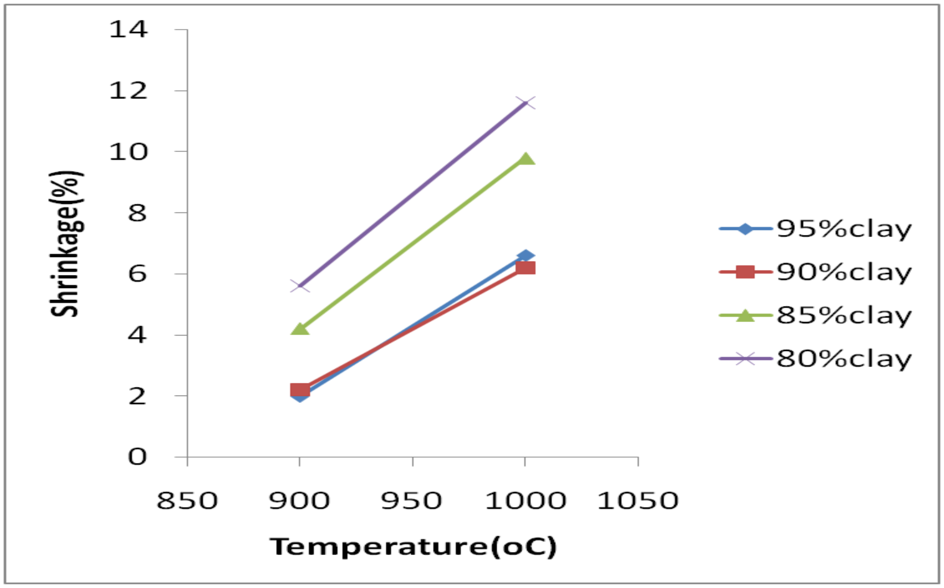

Fig. 7. Shrinkage at different Temperatures of samples

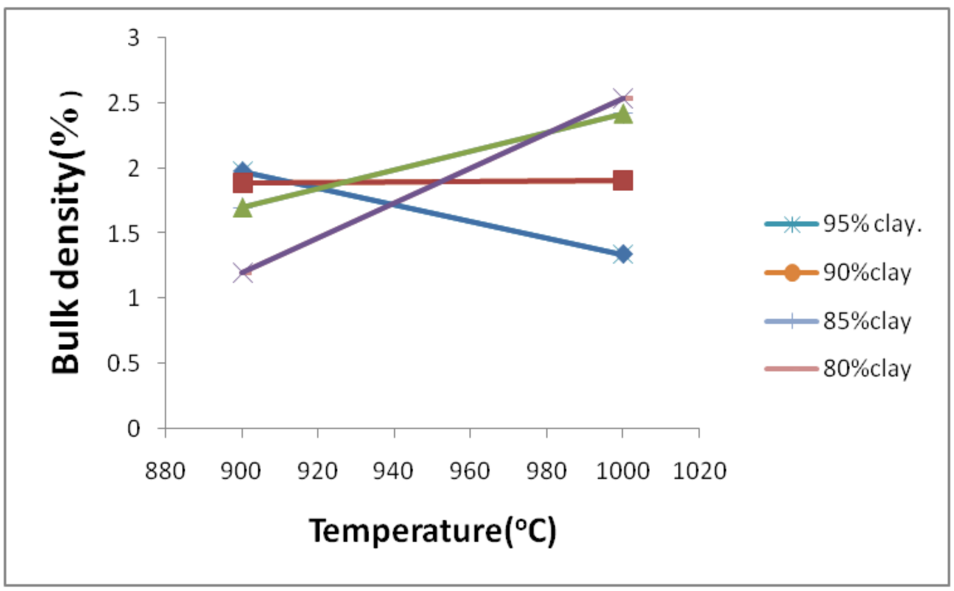

Fig. 8: Bulk density at different temperatures

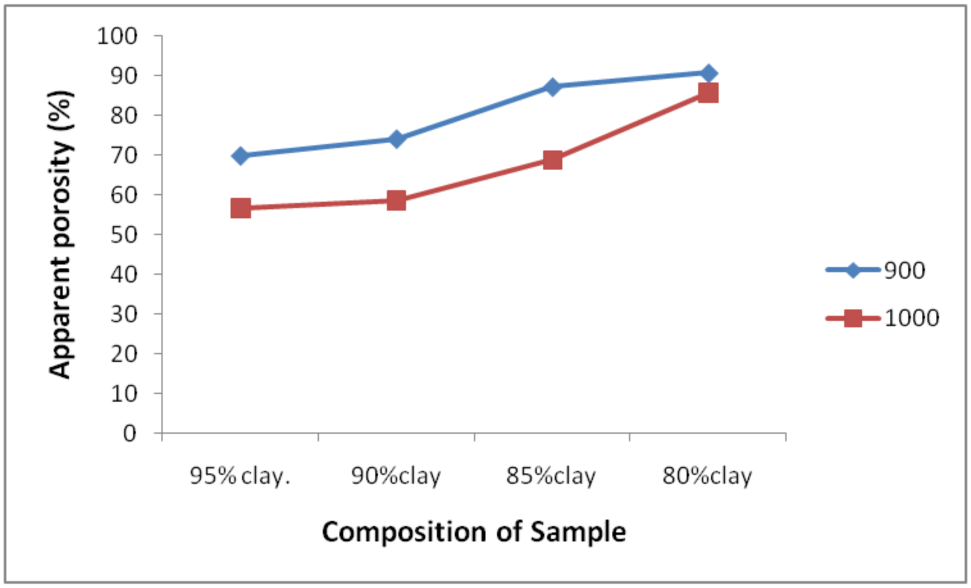

Fig. 9: Apparent porosity at different Temperatures

Table 2: The pH of water samples

Water Resource	Before filtration	After filtration
Ekulu River	6.30	6.96

Table 3: The total dissolved solid (TDS) of water samples

Water Resource	Before filtration	After filtration
Ekulu River	62	15

Table 4: The total suspended solid (TSS) of water samples

Water Resource	Before filtration	After filtration
Ekulu River	1.15	0.34

IV. CONCLUSION AND RECOMMENDATION

In this study, development of ceramic filter candle from Nsu clay for effective Household Water treatment was designed, constructed with locally sourced.

Materials (Nsu-clay) and tested to evaluate its performance. The system comprises the ceramic filter element and plastic receptacle. The plastic receptacle body housed both the filtered water and the filter element in its different compartments. Raw water sample from Ekulu River in Enugu was subjected to a series of tests before and after filtration. The result of pH of water samples obtained after filtration was 6.69, which is within the range of the WHO standard for drinking water.

The values obtained after filtration for total dissolved solid (TDS) and total suspended solid (TSS) from water samples were 15 mg/L and 0.34 mg/L, respectively, while the filter average removal efficiencies for these parameters were76%and 70% respectively. Flow rate test, the result showed that the flow rate increases with increase in ratio of sawdust to clay.

Slip casting method produced good filter samples with even thickness all-round the filter. There was minimal shrinkage and sufficient dried and strength in the body. The technique is the cheapest method of production when compared with pressing which involves hydraulic press that is capital intensive.

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