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Production of Silver Coated Ceramic Filter Candle Using Locally Sourced Materials For Household Water Treatment

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ABSTRACT

Kaolin and rice husk were utilized in the production of filter candles. The raw materials were subjected to chemical analysis using x-ray fluorescence spectrometer and x-ray diffractometer. The compounded materials were also subjected to physical analysis as follows; water absorption, apparent porosity, etc. The filter candles were produced with varying ratio of kaolin to rice husk; 50:50 (filter A), 55:45 (filter B), and 60:40(filter C) and fired at 1000°C and 1100°C. SEM analysis was carried out on the filter with best filtering properties (Filter A). Result obtained shows that flow rate increases with increase in rice husk content. Filter B (55:45) had better quality of treated water compared with other filters produced and commercial filter. The results of the pH for treated water sample were in the range of 6.95 to 7.48 which are within the WHO standard for drinking water. All other parameters compared well with WHO standard except turbidity (filtrate A-39, filtrate B-19, commercial filter-32) which were slightly higher. Filter candle A (50:50) shows optimum flow rate (0.472cm^3/s), is effective in treating water and is considerably cheap.

Keywords: Candle, ceramic, filter, solid casting, water.

INTRODUCTION

Water filters evolved out of necessity to remove materials that affect appearance, then to improve bad tastes and further to remove contaminants that can cause disease and illness [1]. Estimates suggest that 1.5 billion people out of the world over 6.8 billion lack safe drinking water [2]. Ceramic filters in recent times are produced to solve water problems at household level. Ceramic water filtration is the process that makes use of porous ceramic medium to filter microbes or other contaminants from water [3]. Ceramic filter is a promising technique for developing countries [4]. Production of filter candles for household water treatment has been x- rayed by the works of different authors on household water treatment [5,6,7,8,9]. Although these filter candles have successfully treated water, there has not been any work done to increase the flow rate of the filter candles which is usually slow in water treatment. Choosing to use kaolin from Ozanogogo community for the production of the filter candle is in a bid to bring the community to lime light because the community has a large deposit of kaolin but attempt has not been made in using it for the production of ceramic filter. The profitable use of their natural resources in harnessing clean water technology which is affordable will serve as a source of economy generation for the community. This work therefore, is aimed at producing a low cost filter candles with increased flow rate from materials sourced locally for household water treatment.

MATERIALS AND METHODS

Samples collection

The kaolin samples were collected at 8cm below land surface from a kaolin deposit at Ozanogogo community in Ika South local government area of Delta State. Ozanogogo is located at about 15km North of Agbor obi in Ika South Local Government of Delta State. It is situated around latitude N6° 05' 6°20'E and longitude 6°18' 6°20'E. The rice husk that served as a burnout material was purchased from New-market, Enugu State. The water sample was collected using 10 liter container from Amirinmaocha River in Oshimilli South, Delta State. Kaolin and rice husk were processed and sieved using a 600μm sieve to get a definite particle size. Different ratio of kaolin to rice husk (50:50, 55:45, 60:40) were mixed with appropriate amount of water until it became plastic. The formulated mixtures were placed into a metallic mould in order to take the shape of the mould. Physical analyses such as total shrinkage, wet-dry shrinkage, modulus of rupture were performed on the formulated body [10,11, 12,13]. Chemical analysis using X-ray fluorescence spectrometer and X-ray diffractometer were carried out on kaolin and the formulated body and interpreted using MATCH crystal phase version 3.4.2 Build 96. The XRD operated at Cu-Kα radiation at 40mA and 40KV and secondary monochromaton, of wavelength, 1.54Å. The diffraction angle was scanned from 5 – 70 ^{o}, 2θ with size of 0.02 ^{o} and rate of 3.57 ^{o}/min. Filter candles were then produced with the appropriate ratios and fired at 1000^{o}C and 1100 ^{o}C in a kiln. The produced filter candles were used in filtering water. Quality assessments of water before and after filtration were determined as well as the flow rate test. A further filteration test was done using filter candles coated with silver nitrate solution [14].

RESULTS AND DISCUSSION

Table 1 shows that apparent porosity and water absorption increases with increase in rice husk used while wet-dry shrinkage, dry-fired shrinkage, apparent density, bulk density and modulus of rupture decreases with increase in rice husk for all samples. This is expected as rice husk that is added to the filter element burn off, cavities are formed, hence filter with larger quantity of rice husk tend to have larger pores, higher water absorption and lower shrinkages. Also, at higher temperatures, from 1000°C to 1100°C, pore closure are experienced, hence shrinkage, bulk density and modulus of rupture increases while apparent density, water absorption and apparent density decreases. This is expected as more water is lost at increased temperature [15, 16, 17].

Table 1: Results for Physical Analysis

Parameter	**1000^{o}C**			**1100^{o}C**		
	A_1	B_1	C_1	A_2	B_2	C_2
Wet-Dry Shrinkage (%)	5.300	5.850	7.420	6.600	8.275	8.920
Dry-Fired Shrinkage (%)	1.785	2.039	2.276	2.892	3.845	4.576
Total Shrinkage (%)	7.000	7.148	8.829	9.300	10.480	11.446
Apparent Porosity (%)	46.39	39.120	22.590	46.140	30.00	20.270
Apparent Density (g/cm^3)	2.865	3.525	3.730	2.000	2.670	2.862
Bulk Density (g/cm^3)	1.536	1.549	1.588	1.539	1.585	1.598
Water Absorption (%)	30.190	30.130	27.730	29.980	28.100	25.780
Modulus of Rupture	21.100	21.590	22.000	29.090	32.760	33.600

Tables 2 and 3 show the elemental composition of the Kaolin and compounded samples respectively. From the Tables, there is no fluxing agent like Na_2O in the kaolin sample which shows that the kaolin has good porosity capability. Presence of impurities like CuO, NiO, CoO, MnO in the kaolin will make the filter candles resistant to high temperature, steam, and hetero-element compounds. These impurities also guarantee the removal of and total conversion of organic pollutant and residual components [18]. This study is in line with a work done on clay deposits in Odukpani, South Eastern, Nigeria [19]. The report concluded that Odukpani clay is kaolinite because of its high concentration of Silicon.

Table 2: Elemental Composition of Kaolin Samples using X-ray Fluorescence (XRF)

Elements	Weight (%)	Oxide form	Weight (%)
Si	24.067	SiO_2	51.480
Al	21.114	Al_2O_3	39.890
P	0.347	P_2O_5	0.790
S	0.398	SO_2	0.88
K	1.479	K_2O	1.780
Ca	0.087	CaO	0.12
Ti	0.776	TiO_2	1.290
V	0.138	V_2O_5	0.250
Cr	0.031	Cr_2O_3	0.045
Mn	0.072	MnO	0.092
Co	0.116	CoO	0.150
Fe	1.969	Fe_2O_3	2.820
Ni	0.085	NiO	0.110
Cu	0.065	CuO	0.080
Zn	0.072	ZnO	0.089

Table 3: Elemental composition of compounded sample A using XRF

Elements	Weight (%)	Oxide form	Weight (%)
Si	23.125	SiO_2	49.467
Al	15.200	Al_2O_3	28.720
P	0.595	P_2O_5	1.3635
K	7.6760	K_2O	3.223
Rb	0.0336	Rb_2O	0.036
Ti	0.7760	TiO_2	1.290
V	0.7552	V_2O_5	1.348
Cr	0.2430	Cr_2O_3	0.355
Mn	0.1029	MnO	0.133
Zn	0.1230	ZnO	0.153
Sr	0.2449	SrO	0.289
Fe	2.4448	Fe_2O_3	3.4953
Zr	4.0029	ZrO_2	5.407
Mo	0.0227	MoO_3	0.034

Tables 4 and 5, show the performance of the produced filter candles on water filtration. Filter A had highest flow rate, as seen in Table 4, lower water quality compared to filter B and commercial filter as seen in Table 5. Filter B with proportion of clay to rice husk of 55:45 had the best result after analyzing the water, reasonable flow rate, reduced turbidity, TDS and 100% Coliform and *E.coli* efficiency.

Table 4: Flow rate of the Filter Candles

Filtrate A_1(50:50)	Filtrate B_1 (55:45)	Commercial Filter
0.472cm^3/s	0.278cm^3/s	0.361cm^3/s

Table 5: Physicochemical Analysis and Microbial Efficiency Result

Parameter	**Raw Water**	**Filtrate A_1**	**Filtrate B_1**	**Filtrate C_1**	**Commercial**	**WHO Standard [20]**	**Unit**
Turbidity	84.8	39	19	-	32	5	NTU
pH	6.43	7.48	6.95	-	7.13	6.5 – 8.0	….
Alkalinity	30	70	35	-	37.5	-	mg/L $CaCO_3$
TDS	7.28	3.32	0.68	-	3.2	250	mg/L
Total Coliform	138	0	0	-	0	0	Cfu/ml
E. Coliform	52	0	0	-	6	0	Cfu/ml
Total Coliform	21.7-42.5	100	100	-	100	100	%
E.coliform	15.3-35.5	100	100	-	86.5	100	%

From Figures 1 and 2, it was observed that the crystal structure identified for the raw sample was that of kaolinite with chemical formular of Al_8 Si_8 O_{32}. It is crystalline and of monoclinic crystal system having parameters of space group C 2/m, dimensions of $\propto = \gamma = 90^o$ and $\beta = 100.2^o$ while a = 5.14 Å, b = 8.92 Å and c = 14.53 Å. The calculated volume and density are 656.90 cm^3 and 2.57 g/cm^3 respectively. The compounded sample was identified as amorphous. There was slight decrease in the value of density (2.483 g/cm^3) and increase in volume (663.959 cm^3) with system parameters showing dimensions of $\propto = \gamma = 90^o$ and $\beta = 96.770^o$ hence amorphous. The amorphous nature was attributed to the fact that the rice husk destroyed the clay crystallinity.

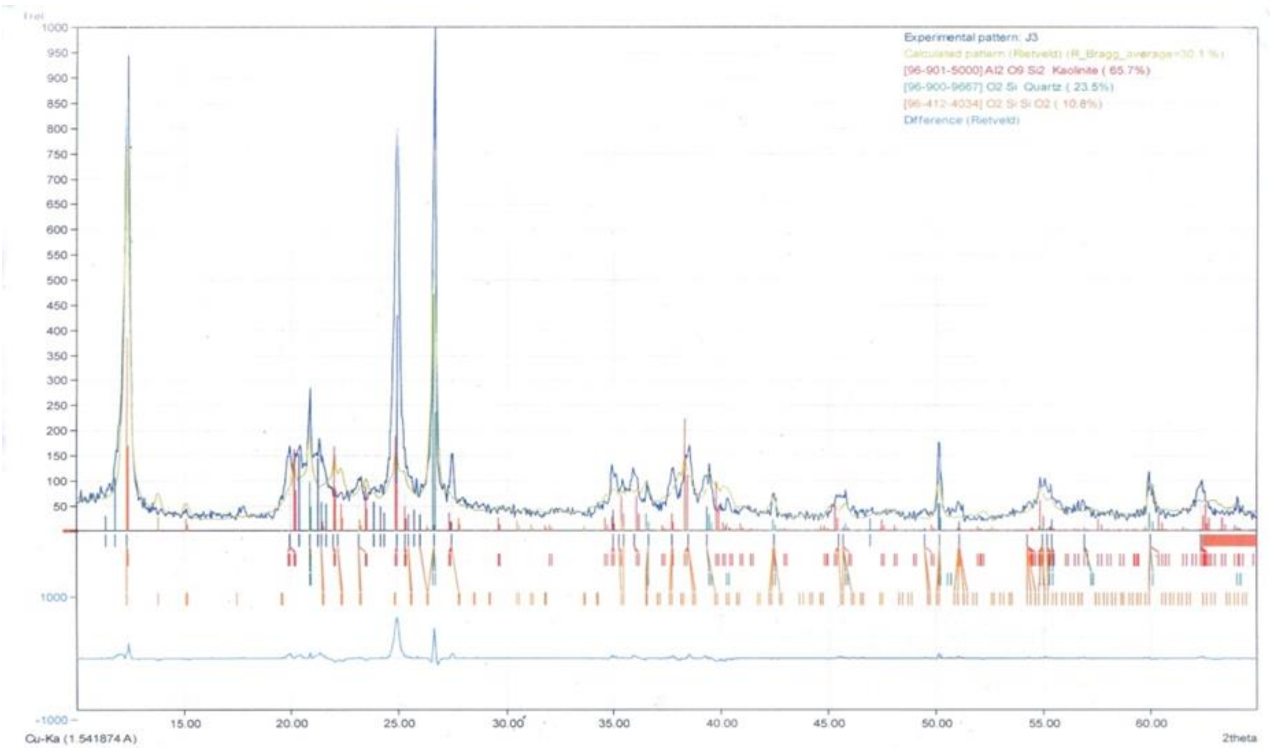


Fig. 1: X-Ray Diffractogram of Oza-Nogogo Kaolin

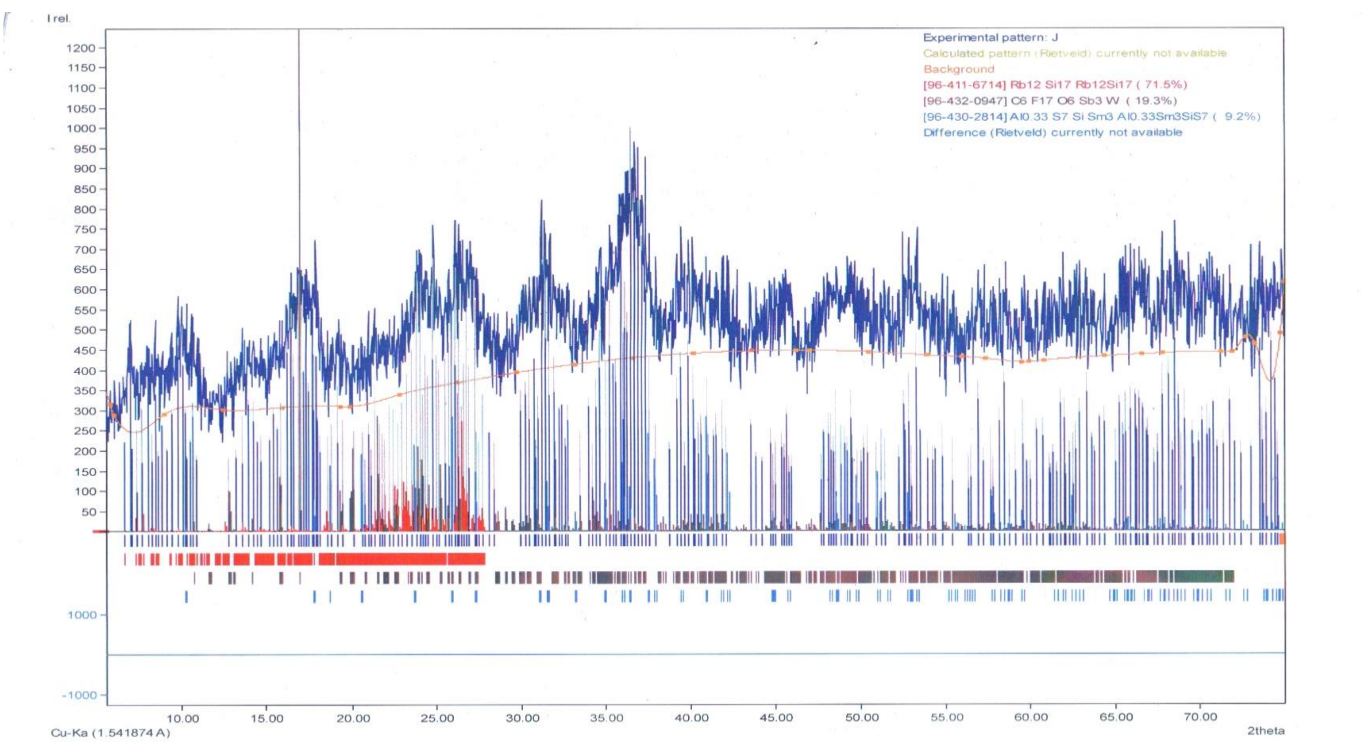
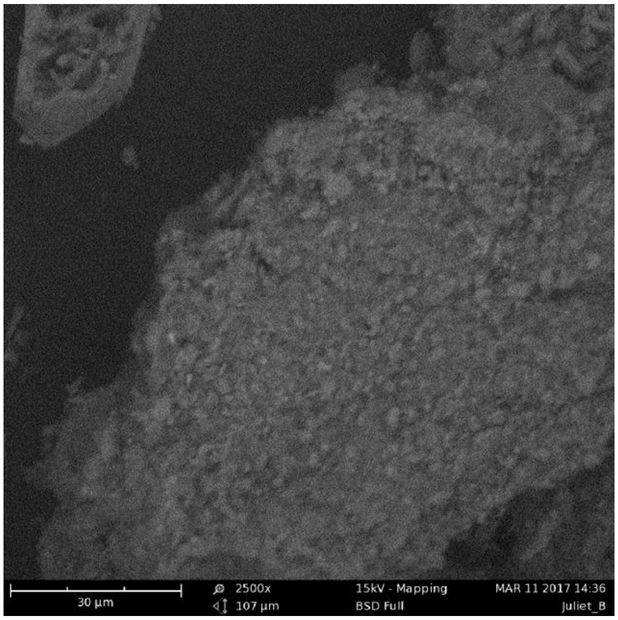


Fig. 2: X-ray diffraction pattern of Compounded Clay

SEM analysis performed on the developed filter to determine the microstructure gave a microstructure of 0.59-2.36 μm, this can only treat bacteria of size range 0.59-100 μm. Further treatment with silver gave a 100% removal for coliform and *E. coli*.



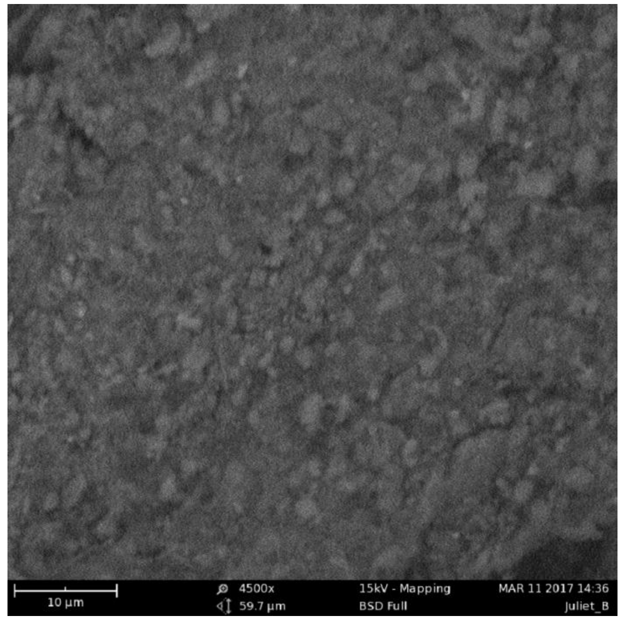


Fig. 3: Microstructure of filter sample A (Magnification size = 2500x)

CONCLUSION

Ceramic filter candles produced using kaolin sourced from Oza-Nogogo community in Delta State and rice husk which served as burnt out material to create pores in the candle during firing were able to treat water to WHO standard. Physical and chemical analysis carried out showed that increasing the quantity of rice husk, increases the flow rate hence reduces the time spent in filtering water by increasing the flow rate. It was also observed that as the temperature increased from 1000 °C to 1100 °C for each sample, the pores tend to get smaller and the candles more brittle hence 1000 ^{o}C gave the optimum temperature for firing. The qualities of the water before and after fitration show that filter B_1 with proportion of clay to rice husk content of 55:45 had the best result in terms of reasonable flow rate, reduced turbidity, TDS and 100% Coliform and *E. coli* removal efficiency

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