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Research article

Sustainable nano-sodium silicate and silver nitrate impregnated locally made ceramic filters for point-of-use water treatments in sub-Sahara African households

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ABSTRACT

The poor access to water quality for Nigerians has pushed for the designing of new trend silver nitrate impregnated locally made Point-Of-Use (POU) ceramic filters to enhance water purification efficiency for household use. This study utilized silver nitrate-molded ceramic filters prepared with Kaolin from Owode, silt soil, sodium silicate, sawdust, and distilled water in three varying proportions to ascertain pollution removal efficiencies. Heating was carried out by firing the filters at 900 °C and further preheating at 400 °C after dipping in silver nitrate solution. Silver nanoparticle and dissociated particle discharge from filter pot painted with 0.03 mg/g casein-covered nAg or $AgNO_3$ were estimated as an element of pH (5–9), ionic strength (1–50mM), and cation species (Na+, Ca2+, Mg2+). Silver delivery was constrained by disintegration as Ag+ and resulting cation exchange measures, paying little heed to silver structure applied. Water analysis for both heavy metals (Pb and Cd) and microbial load (*E. coli*) evaluated, corroborate the maximum removal efficiency. It was observed that kaolin-sawdust with the Silver nitrate filters showed a constant and effective removal of both heavy metals and disinfection of microbial loads. The minimum flow rates observed were 4.97 mL/min for batch filter used for Iju River water sample one (AF1) and 4.98 mL/min for batch filter used for Iju River water sample two (AF2) having porosity 49.05% and 50.00%, whereas the 5 mL/min higher flow rate was used for batch filter from borehole water sample one (BF1) and batch filter used for well water sample two (CF2) with porosity of 50.00%. Significantly, the results obtained show that the filters are suitable for point-of-use application in both the urban and rural areas of developing countries such as Nigeria

1. Introduction

This study aligns with the 2030 Sustainable Development Goal number 6, according to the United Nations, which aims to “ensure availability and sustainable management of water and sanitation for all” (United Nations, 2015). Portable drinking water is an essential requirement for the safety of live. Global statistics reveal that three to ten people lack access to safely managed drinking water services; water scarcity,

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which is projected to rise, affects more than 40 per cent of the global population; and more than 80 per cent of wastewater resulting from human activities is discharged into rivers or sea without any pollution removal (United Nations, 2015). This study situates on Nigeria a developing economy located in Sub-Saharan Africa (SSA). The country has a population of about 195.8 million people, about USD$1.04 trillion in gross domestic product (GDP) and a per capita GDP of USD5′316.00/year. However, despite the abundant human and natural resources, a paltry 20% of the population have access to safe drinking water (SDG6.1.1), 27% practice safe sanitation (SDG6.2.1), and an undetermined percentage of household wastewater are safely treated (SDG6.3.1) thereby posing unprecedented health risk to the people. So far, the Nigeria's efforts towards the actualization of SDG6 have yielded fragile results. Given the challenges of safe drinking water are prevalent in developing economies, like Nigeria, and the desire to contribute to the actualisation of SDG6, this study provides a safe and alternative water treatment pollutant removal which serves as the motivation for this study.

According to World Health Organization (WHO) drinking water guideline [1], drinking water quality should be able to meet the standard reference safe level to the consumers. A 2011 report from, WHO, posits that more than one million, five hundred out of four million deaths among children annually were due to the exposure to contaminated drinking water [2]. Surface water or groundwater that did not undergo treatment processes is always contaminated with microorganisms of fecal inception. These contaminations might be during the distribution process through the pipes to the storage facilities [3, 4, 5]. Nano-enabled water treatment processes have become in recent years promising alternatives to conventional water treatment technologies [6]. However, the lack of practical applications of nanomaterials in advancing water treatment systems suggests that major barriers such as up scaling, practicality, and safety are hindering their deployment [7].

Alternatively, the World Health Organization has suggested a reorganized approach for household water treatment using point-of-use (POU) candle filter [8]. A current research funded by the World Health Organization achieved a cost-effective/low-cost household water treatment intervention using point-of-use filters for communities to enhance the microbial removal in drinking water. This has proffered solutions on the health risks of infections such as diarrheal, dehydration, and death, which was severe among children [9, 10].

The innovation of POU must be widely embraced because of its potency in the removal or potential deactivation of diseases that are waterborne. The ease of its application would guarantee its viability and reduce the risk of water contamination [11]. In this research, point-of-use water treatment method with the use of a colloidal-silver-impregnated ceramic filter was examined. The filters were designed in the shape of pots that are made from ceramics. The materials used for the filters were composed of sawdust, water, and clay, which were thoroughly mixed and shaped into a pot like shape with the aid of casts. Two different soils were tested in order to quantify the variation in their pore sizes for the removal of pollutants in different water samples. This is aimed at designing a sustainable locally made point-of-use ceramic filter for developing countries like Nigeria.

2. Material and methods

2.1. Geographical locations of the sample collection areas

In Nigeria, clay is widely distributed though not always found in sufficient quantity or suitable quality in all parts of Nigeria. The sampling area at Agbara is within the latitude 6°34.2" N and 3°7′ E and for Owode-Ketu, it lies within the Lat. 7° 8′ N and long. 3° 26' E located in the Southwestern parts of the Dahomey Basin.

2.2. Sampling and sample preparation

The prepared samples used comprise the following materials: red clay, Kaolin formed soil, sawdust, and grog. Clay soils samples were scooped from Agbara community and Kaolin soil samples were collected from Owode-Ketu in Ogun State. The scooped clay soils were carefully put into different polyethylene bags, labeled and transported to the laboratory for drying [15]. The clay soils samples were mixed in the same proportions and air-dried under the ambient temperature for 7 days, monitored by a ceramic technologist. The clay was then grounded to powdered form with wooden mortar and pestle and passed through a sieve mesh of 0.5 mm size. The sawdust, which was collected from local furniture manufacturers, was dried for 7 days and processed through wooden mortar and pestle like the clay [15]. The sawdust was then screened with 0.5 mm opening sieve. Some portion of the sawdust were burned and mixed with grog for about 40 min in dry conditions in various proportions. Water was added equally on another constituent of dry clay mixed with sawdust and grog by wedging and rolling for 40 min to get a smooth homogeneous mixture as shown in Figures 1 and 2, respectively. The filters were allowed to dry under the ambient weather condition for two days and later taken to the kiln, where they were fired so that clay would sinter in the ceramic and the sawdust would combust for stability.

Figure 1. Silt Clay preparation from Agbara Area of Ado-Odo Ota.

Figure 2. Kaolin preparation from Owode Ketu Area of Ado-Odo Ota.

This process allowed pore channels to be created in the filter for the flow of water. After the filters had been tested to ensure their quality, they were coated with silver Nano-particle solution, which is a well-studied antimicrobial agent, which would not affect the taste, color and odor of the treated water [13, 14]. The first critical and mechanical estimation of the performance of ceramic filters produced according to a designed guideline are presented in this research.

2.3. Ceramic filter production

The ceramic filters were produced by formulating a body composition with Owode kaolin soil, Agbara clay soil and sawdust as shown in Table 1. The three compositions were accurately measured with a digital weighing balance (5000 g) and properly mixed in a bowl. The mixture was done on a dry basis and 15% by weight (wt) of distilled water was added to the mixture to make the batch plastic enough for pressing. The plastic mix was then kneaded on a flat wooden bat for homogeneity. 0.5% by wt. of Sodium Silicate (Na_2SiO_3) was further added to deflocculate any lumps or undissolved particles and was used to prevent the shrinkage of ceramic filters during the processes of drying and firing, so as to improve the flow rate of water through the final filters. At this stage, the body was finally wedged and wrapped in a polythene bag for 24 h to allow for even distribution of water. After ageing, the homogeneous plastic body was pressed into a 14.5 cm diameter polyvinylchloride cylindrical mold, and compressed for 2 min at 1500 psi. The resulting cylindrical filters were approximately 2.5 cm thick after compaction. A cylindrical filter design was chosen to simplify the geometry (relative to a pot shape) and thereby facilitate one-dimensional hydraulic conductivity and bacteria transport experiments. The filters were further allowed to dry (Dried weight, DW and Dried length, DL) in an electric laboratory oven at 110 °C for 24 h. X-ray diffraction analysis was performed to determine the predominant clay mineral in each sample using the procedure developed by Ohtsubo et al [16]. The procedure employs an XDS Scintag 2000 diffractometer using monochromatic Cu KR radiation at 40 kV and 40 mA over oriented specimens. The scanning speed was 1.5° (2θ)/min. Triturated water ([3H] H_2O) was used as a conservative tracer for solute transport experiments to quantify advection velocities and coefficients of hydrodynamic dispersion for each filter. Ceramic filters were manufactured by firing the compressed dried filters of F1, F2 and F3 in a muffle furnace (Fired weight, FW and Fired Length, FL). The temperature was increased at a rate of 150 °C per hour from room temperature to 600 °C, and then increased at a rate of 300 °C per hour to 900 °C, holding this final temperature for 3 h.

At this stage, filter F1 and F2 were further impregnated with a solution of Silver Nitrate ($AgNO_3$) which was prepared by dissolving 10g of $AgNO_3$ powder in 100 mls of distilled water. A spraying method was employed to allow the $AgNO_3$ to fully saturate the body of the fired filters. After spraying, F1 and F2 samples were allowed to dry in the oven at 105 °C for 24 h. This process was done at this temperature to retain the $AgNO_3$ in the filters and also to permit kinetic reaction of the membrane during absorption. The prepared filters are presented in Figures 3 and 4, respectively.

Table 1. Ceramic filter batch formulation.

Batches	Owode kaolin	Agbara Clay soil	Saw-dust
F1	90.91%	0.00	9.09%
F2	45.45%	45.45%	9.09%
F3	0.00	90.91%	9.09%

*F1, F2 & F3: Batch filters 1, 2 & 3.
Source: Authors' Computations.

2.4. Batch filtration

Batch filtration experiments of three different water samples from Iju river, bole-hole and dug well-water were carried out using volumes of 500 and 750 mL from the water sample to produce initial pressure heads of 5.0 and 7.50 cm, respectively. 5 ml of each sample was used to determine the level of heavy metals and microbial contents before sieving through the ceramic filters using AAS. The water samples were decanted into the glass prisms from the top side of the membrane ceramic filters. The tests were conducted under dropping head conditions that started at 5.0 cm high or 7.5 cm height over the ceramic filter and decayed to zero at the end of the test. Plastic pots were placed under the ceramic membranes to receive the effluent. The preliminary flow rate through the ceramic filters was determined from the volume of the filtrate collected within the first hour of the run. This filtering process was run twice for accuracy and precision before recording the average values. At the end of each run, the ceramic filter was subjected to a backwashing process with distilled water to remove the deposited ions. Accordingly, the same ceramic filter could be reused several times. The

Figure 3. Sieving the water samples from the prepared Kaolin Ceramic Filters. Diameter: 14.5 cm, Thickness: 2.5 cm.

analysis for both heavy metals and microbial contents were crosschecked after sieving through the prepared filters.

2.5. Physical characterization

2.5.1. Determination of loss on ignition

Loss on ignition (LOI) is a physical parameter done to quantify the amount in percentage of carbonaceous volatile matters released from the filters after heating. In this research, the method used to calculate the percentage LOI is the standard method for determining soil properties. About 5 g of each batch (F1, F2 and F3) were initially weighed out inside a crucible and placed inside an oven to dry at 110 °C, fired at 900 °C in a muffle furnace and weight recorded for dried and fired (Dw & Fw). The percentage loss on ignition were calculated for batch F1, F2 and F3 by the formula specified in Eq. (1)

$$LOI(\%) = \frac{\mathrm{Dw} - \mathrm{Fw}}{Dw} X \frac{100}{1} \tag{1}$$

2.5.2. Determination of apparent porosity, bulk density and bulk volume

The apparent porosity of a material is an intrinsic property that shows the amount of open and sealed pores through which water or other solvent can penetrate. It also examines the relationship of a material to which water can absorb from the surface of to the membrane. The method used to examine the apparent porosity, bulk density and bulk volume of the filters was the 24 h soaking test, according to ASTM C303 (2003). These parameters were calculated using Eqs. (2), (3), and (4) respectively. The fired weights (FW) and soaked weights (SW) were obtained before and after soaking the three filters in clean water while the suspended weights (SSW) were obtained by immersing in water for about 5 s and weighing them on air.

Figure 4. Sieving the water samples from the prepared Silt Clay Ceramic Filters. Diameter: 14.5 cm, Thickness: 2.5 cm.

$$Apparent\ porosity(\%) = \frac{SSw - Fw}{\mathrm{Sw - Fw}} x \frac{100}{1} \tag{2}$$

$$Bulk\ density(gcm3) = \frac{Fw}{SSw - Fw} xD1 \tag{3}$$

$$Bulk\ volume(cm3) = \frac{\mathrm{SSw - Fw}}{D1} \tag{4}$$

Where;
D1 is the density of water at room temperature.

2.5.3. Filtration efficiency

The efficiency of the silver nano-ceramic filters was determined by measuring 300 mL of the waters and passing them into each filter. Initially, the filters were saturated with distilled water for 2 h to obtain constant filtration rate. The recorded filtering time was: 1 h for F1 and 1 h and 30 min for F2. The weight of filtrate was also recorded. The efficiency of the filtration from both filters was determined by the following expression in Eq. (5):

$$filtration\ efficiency\ (\%) = \frac{weight\ of\ filtrate - 1}{original\ weight\ of\ water}\ X\ \frac{100}{1} \tag{5}$$

2.5.4. Total bacterial count (TBC/Colony forming unit (mL))

Muller Hinton Agar (MHA) was prepared according to manufacturer's specification and was sterilized in an autoclave at 121 °C for 15 min. The MHA was allowed to cool to about 40 °C, and was dispensed into sterile petri-dishes and were left on the laboratory bench to set; the sterile plates were dried in the oven at 40 °C for 5 min. Three samples from Iju river, bole-hole and dug well-water were labeled in duplicates and 0.5 mL of each samples were seeded on already sterile MHA plates, using pour plate method and incubated at about 37 °C for twenty four (24) hours. After 24 h of incubation, the seeded plates were observed for bacteria growth and visible colonies were counted and equally expressed in colony forming units per 10 mL (CFU/10ml).

2.5.5. Efficiency removal of colony

The silver nano-ceramic filters efficiency in removing *E.coli* from contaminated water was determined by passing 300 mls of the samples into each filter. Initially, the filters were saturated with distilled water for 2 h to obtain constant removal rate. The *E.coli* before (*C*b) and after (*C*a) filtration was recorded and efficiency of colony removal with both filters was determined by the following expression in Eq. (6):

$$Colony\ removal\ efficiency\ (\%) = \frac{Cb - Ca}{Cb}\ X\ \frac{100}{1} \tag{6}$$

2.5.6. Permeability

It is a physical property of the material in which ability of porous media to transmit fluid through it (Bear, 1972). In 1856, Henry Philibert Gaspard Darcy, who first developed the equation to depict the fluid flow through a porous medium as shown in Eq. (7):

$$K = \frac{Q\,x\,L}{A\,x\,h} \tag{7}$$

Where: Q-is total discharge; L-length of the sample; A-cross section area; h-constant head at the ceramic filter and K- constant of proportionality which commonly known as a hydraulic conductivity.

Table 2. Physical characterization of the ceramic filters.

Batches	Loss on ignition (%)	Apparent Porosity (%)	Bulk density (g/cm^3)	Bulk volume (cm^3)	Shrinkage %
F1	17.83	49.88	2.97	421	3.45
F2	13.86	50.00	3.11	455	2.07
F3	26.47	50.11	2.48	496	0.00

*Source: Authors' Computations.

3. Results and discussion

Table 2 shows the physical characterization of the ceramic filters, loss on ignition, apparent porosity, and bulk volume increased drastically in batch F3 with no addition of Owode kaolin and Silver Nitrate ($AgNO_3$), invariably decreasing the amount of bulk density (2.48 gcm^3) and linear shrinkage (0%) as shown in Figure 5. The batch F3 shows high increase in apparent porosity (50.11%) which indicates a weak type of filter and therefore not considered good for this research.

During filtration, as indicated in Figure 6, it can be observed that a slow in flow rate through the filters give a 100 % efficiency filtration. This is, however, due to the integration of water glass (nano-sodium silicate) and silver nitrate solution. In particular, batch F2 gave relatively moderate properties with higher bulk density, which correlates to the sintering mechanism resulting in higher compaction strength and thermal stability.

Table 3 shows the result of the bacterial load in colony-forming units for Iju river water (Sample A), borehole-water (sample B) and well water (sample C). Batch sample AF1, AF2, BF1, BF2, CF1 and CF2 represents the sample batch of water with filters used in this research. Sample A1F1 (Iju water-filter 1) shows a bacterial load of 288 CFU/10ml before filtration; and gave the lowest value of 1 CFU/10ml after treatment, with colony removal efficiency of 99.65%. The batch samples prepared for analysis to identify the heavy metals and microbial contaminants present before and after sieving through the ceramic filters as shown in Figure 7.

Batch AF2 also showed (bacterial load of 296 CFU/10ml before filtering, with a resultant zero trace of *E. coli* after filtration, justifying high level of colony removal efficiency (100%). Filtration was also performed with sample water B. BF1 and BF2 showed a close range in value of the *E. coli* count before filtering and has highest bacterial load after

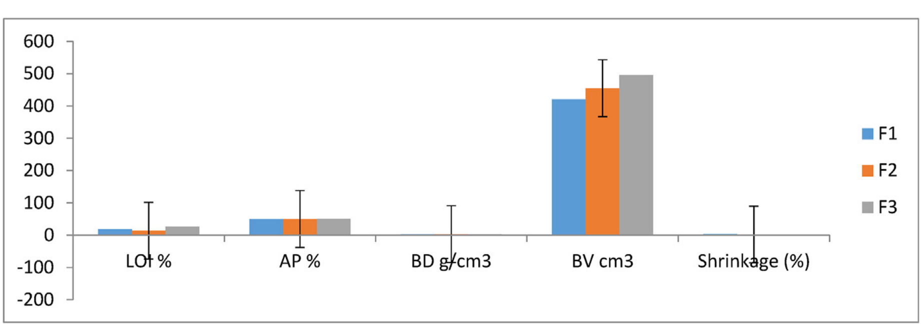

Figure 5. Comparative Chart of Physical Analysis. *LOI: Loss on Ignition, AP: Apparent porosity, BD: Bulk Density. *Source: Authors 'Computations.

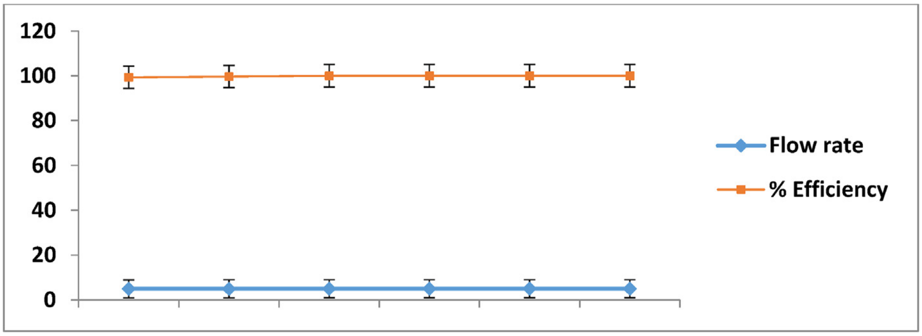

Figure 6. Effect of flow rate against efficiency. Source: Authors' computations.

filtration with Filter 1 (40 CFU/10ml) but zero trace of colony with filter 2. Batch BF1, however, indicated that colony removal efficiency was lower than other batches as shown in Table 3. Finally, Batch CF1 and CF2 with low counts of *E. coli* at 136 CFU/10ml and 48 CFU/10ml respectively resulted in no trace of colony after filtration. Batch BF2, CF1 and CF2 apparently indicate very high level of colony removal efficiency of 100%. As shown in Table 3, the efficiency of the ceramic silver nanofilters to remove coliform bacteria ranged from 99% to 100% for both filters. Efficiency in filtration for Iju-river water in AF1 and AF2 were significantly lower than other waters used in this research and ranges from 99.33% and 99.67% respectively. This lower filtration efficiency may be due to the high turbidity of surface water (River water) compared to groundwater. This value observed to be true as obtained from the result of *E. coli* unit in the water having the highest colony-forming unit as shown in Table 3. As indicated in Table 4 below, the flow rate decreased with decrease in apparent porosity.

The average flow rate observed for F1 and F2 was 5 mL/min in well water and borehole water lower from 4.97 mL/min to 4.98 mL/min in Iju-river water for F1 and F2 respectively. As shown in Figure 6, the filtration efficiency of water increases as the flow rate increases. This rate defines how less porous the filters were invariably making them valuable to treat highly contaminated waters.

High porosity implies that there are larger numbers of pores in the ceramic filters that water flows through; also the bacteria, organic

Table 3. *E-Coli* result before and after filtration.

Batch samples	Colony forming units (mls)		Colony removal efficiency %
	Before	After	
AF1	288	1	99.65
AF2	296	0	100
BF1	168	40	76.19
BF2	160	0	100
CF1	136	0	100
CF2	48	0	100

*AF1, AF2: Batch filters used for Iju River Water samples1 and 2.
*BF1, BF2: Batch filters used for Borehole Water samples 1 and 2.
*CF1, CF2: Batch filters used for Well water samples 1 and 2.
Source: Authors' Computations.

Table 4. Filtration efficiency and flow rate.

Batch samples	Weight of water before filtering (mL)	Weight of water after filtering (mL)	Flow rate (ml/min)	% Efficiency
AF1	300	298	4.97	99.33
AF2	300	299	4.98	99.67
BF1	300	300	5.00	100.00
BF2	300	300	5.00	100.00
CF1	300	300	5.00	100.00
CF2	300	300	5.00	100.00

*Source: Authors' Computations.

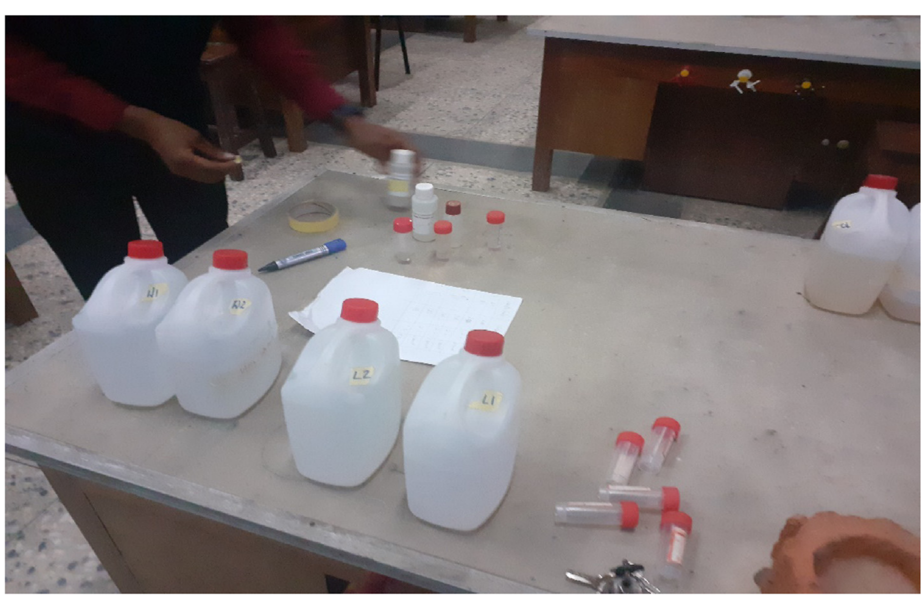

Figure 7. Prepared samples for heavy metal analysis before and after filtering through the Ceramic Filters.

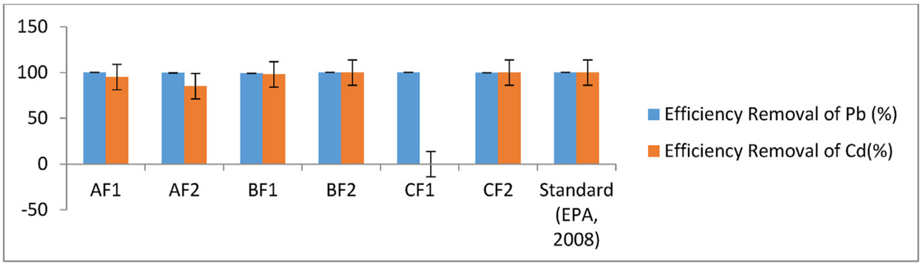

Figure 8. Removal efficiency of Pb and cd. Source: Authors' computations.

constituents and silts pass through within the filters. The results support this suggestion due to the sawdust percentage maintained at 9.09% the amount of porosity obtained closely had the same value 49.88% and 50.00% for F1 and F2 respectively. This range, however, varied in the mixing ratio with clay and silt between the two filters. F1 has 100.00%. Owode kaolin clay has more plasticity index compared to F2 with 50:50 percent of Owode kaolin and Agbara soil.

Values presented in Figure 8, indicate a trace of lead (Pb) and cadmium (Cd) in the three water samples used in this research before filtering and shows no trace of Pb for Iju River and no trace of Cd for borehole water sample in Filter 1 respectively. As shown in Figure 8, Pb and Cd have effective percentage efficiency with the two filters. Batch F2 comparatively presents 100 % efficiency removal of both Pb and Cd for well water and borehole water as seen in the standard, EPA [16, 17, 18, 19, 20, 21, 22]. This result also indicates that F2 presents highest level of filtration efficiency, filtration removal and flow rate.

3.1. Porosity effects on the efficiency of microbial removal

The level of porosity of ceramic filter determines the size of particles it removes in micro level with physical process such as clogging, adsorption and inertia. Figure 9 shows the flow rate and porosity of each filter and water sample analyzed. The result of this study agrees with the finding of Hagan et al. [14] who reported that less porous ceramic filters are able to remove microorganisms efficiently as shown in Figure 10 after microbial culture of the filtered water. The burn**outs** were leaving smaller void spaces of about 1 micron size during the period of ceramic filter firing, which can as well filter out the majority of harmful microbes.

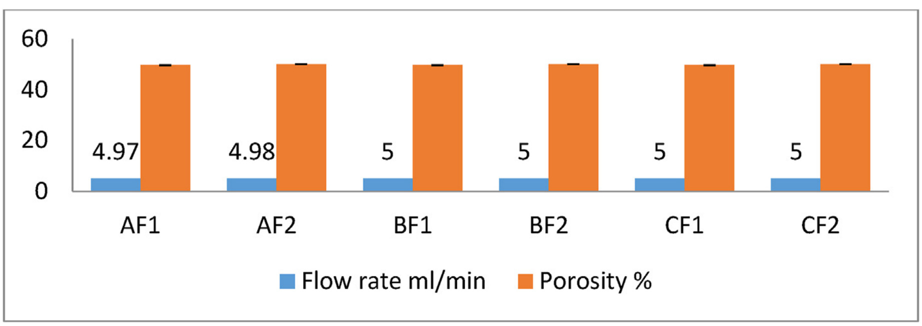

Figure 9. The flow Rate and Porosity of each Filter and Water Sample Analysed. Source: Authors' Computations.

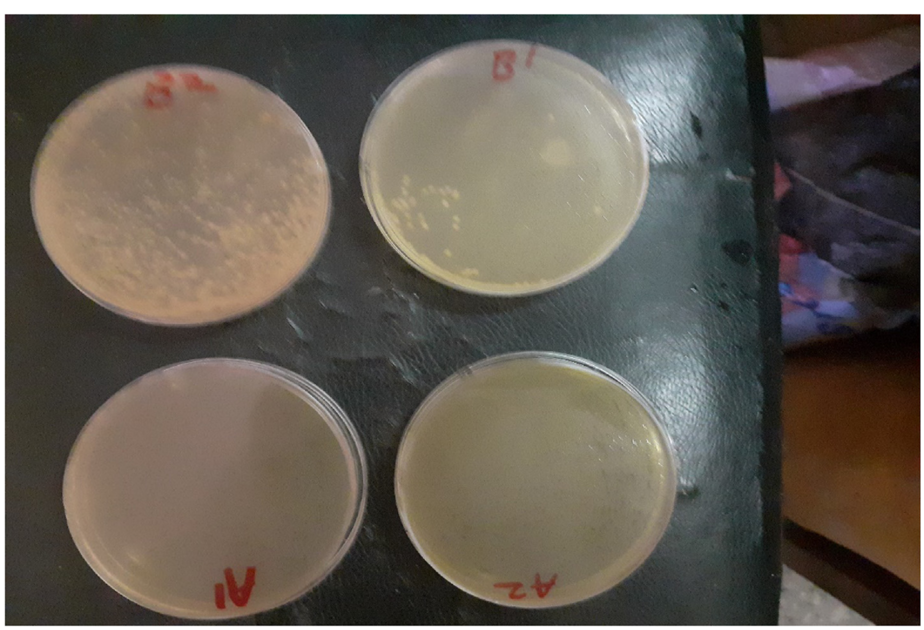

Figure 10. Microbial load culture before and after filtering through the Ceramic Filters.

Good efficiency removal was observed on the two filters fired at 900 °C with porosity range between 49.88% and 50.00%, respectively for the 3 water samples. Large sizes of microorganisms were blocked within the created pore spaces and retained from passing through the designed ceramic element according to Doulton [12].

The flow rate of the ceramic filters generally increased with increase in the porosity of the ceramic filter. The minimum flow rates observed were 4.97 mL/min for filter AF1 and 4.98 mL/min for AF2 having porosity 49.88% and 50.00%, respectively, whereas the higher flow rate was about 5 mL/min for BF1 to CF2 with porosity of 50.00%. High porosity signifies that there are larger number of pore space in the ceramic filters that water flows through the filter elements. If there are enough void spaces in the filter, the flow rate increases faster. The current results from this study in good agreement that as the percentage of sawdust maintained for each filter codes as well as the flow rate that maintained a close range in values in the filters. The porosity created in a ceramic water filter permits water to pass through the element [23].

4. Conclusion

The result of this study showed that the nano-sodium silicate and silver nitrate impregnated filters developed from the two soil samples for this study were found to be active in the removal of microorganisms from polluted water when compared to the World Health Organization guidelines (WHO, 2012). The best removal efficiency for *E. coli* filtration in both filters with value of 99%–100% indicates that integration of water glass (nano-sodium silicate) and silver nitrate solution enhanced the properties such as bulk density, bulk volume, apparent porosity and shrinkage which correlate to the sintering mechanism, resulting in higher compaction strength and thermal stability. The results obtained show that the filters are suitable for point-of-use in urban and rural areas of developing countries such as Nigeria. Given the challenges of safe drinking water which are prevalent in developing economies, like Nigeria, and the desire to contribute to the actualisation of SDG6, this study provides a safe and alternative water treatment pollutant removal which serves as the motivation for this study.

The first critical and mechanical estimation of the performance of ceramic filters produced according to a designed guideline are presented in this research. To make the current study results more appreciable, further studies need to be conducted on the social pilot program on the implementation of the ceramic policy derivative from this study. It contributes to the actualization of SDG6 agenda, by providing a solution to ensuring safe drinking water free of pollutants which can be adopted by other developing economies. It is therefore recommended that, high quality XRD and XRF will be carried out to ascertain the mineralogical conformation and compositional properties of the products.

Declarations

Author contribution statement

Omeje Maxwell: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Orere Faith Oghenerukevwe: Conceived and designed the experiments.

Adewoyin Olusegun O., Emmanuel Sunday Joel: Performed the experiments; Analyzed and interpreted the data.

Ozieme Arinze. Daniel, Ayanbisi Oluwasegun, Hassana O. Jonathan, Taiwo O. Samson: Performed the experiments.

Ngozi Adeleye, Omeje Uchechukwu A.: Analyzed and interpreted the data; Wrote the paper.

Orosun Muyiwa Michael, Akinyemi M. L., Akinwumi Oluwasayo A., Akinwumi Akinpelu, Olagoke Oladokun: Analyzed and interpreted the data.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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