DEVELOPMENT OF CERAMIC DISC WATER FILTER FOR DOMESTIC USE

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ABSTRACT:

This research aimed at to develop ceramic water filters and evaluate their performance with respect to flowrate, turbidity, hardness, and microbial removal efficiency from unclean water. The filters were developed from wood sawdust (SD) and rice husk (RH) (combustible materials) by proportionating the quantity of clay to the combustible materials. The volume ratios of the materials used were 15C:15SD, 20C:10SD, 23C:9.5SD, 25C:10RH and 30C:11.5RH. The filtered developed was pressed in a disc shaped container to the final shape, dried and fired at 850°C for six hours (6) in a furnace. The developed ceramic disc water filters were tested for their performance with respect to flowrate, turbidity reduction and bacterial removal efficiencies. The flow rates of 15C:15SD 20C:10SD, 23C:9.5SD, 25C:10RH and 30C:11.5RH filters were 12 ml/hr, 8 ml/hr, 6 ml/hr, 8.5 ml/hr and 7 ml/hr, respectively when the water level was maintained at its maximum height. These filters reduced turbidity to <5 NTU. Total coliform and fecal coliform were used to quantify bacterial removal effectiveness. The filters showed an average removal efficiency of 98.5% and 100% for total coliform and fecal coliform indicator bacteria from unclean water. Ceramic water filter development is a good House water treatment and safe storage system for Nigeria. Hence, the information collected in this study provides a basis for future work. Therefore, further study and scale – up of the ceramic water filter is needed for providing microbiologically improved household drinking water to avert and control waterborne diseases.

***Keyword**: ceramic water filters, fecal coliform, total coliform.*

Introduction

Water of good quality is required to maintain a clean environment, good health, and a healthy nation at large (Hunter *et al.* 2010, Palaniappan *et al.* 2010). But, limited access to safe drinking water, quality sanitation facilities, unhealthy hygiene practices and improper water management practices promote the spread of water-borne diseases, which causes 6.3% of the deaths recorded around the world (WHO, 2008; Emenike, *et al.* 2017). Therefore, the access to adequate potable water is highly crucial to support public social welfare and development (IPU, 1996; Joseph, 2012). It is estimated that approximately 9% of the people around the world lack access to potable water while 2.4 billion cannot adequately access quality sanitation facilities despite the harmonized global attempt to actualize the MDG target (UNICEF/WHO, 2015). In Nigeria, only 56% of households have access to improved sources of water (63 million people - 75% urban, 45% rural; NDHS, 2008). The main reason for this shortage in portable water is the cost. Often even if the water resources are available, developing countries cannot cover the expense of constructing water and waste treatment plant, distribution system and the cost of the water treatment processes for the people.

Household water treatment and safe storage (HWTS) technologies are among the method that could provide portable and safe drinking water. Household water treatment option includes bio - sand filtration, ceramic water filter, boiling, Aquatabs, solar disinfection (SODIS). (Clopeck, 2006). Many of household water treatment method have been widely known and practiced for decades and new ones continue to be developed. One such technology is ceramics water filter. Ceramic water filters transmit water by adding a fine combustible material such has rice husk, sawdust or coffee dust to the standard ceramic component of clay. This method has received significant recognition as an important intervention to address safe water drinking problems and sustainably decrease the global burden of diarrhea and contribute to millennium development goals. The advantages of locally produced ceramic filters are that they are portable, light in weight, affordable and require low-maintenance (Isikwue *et.al.* 2011 and UNICEF, 2007).

A filter is a device or mechanism, that removes something which passes through it. So, ceramic water filtration refers to as the method that use porous ceramic medium to filtrate water from contaminants or microbes. From the past to the present now, water filters have evolved out of need, firstly, to improve bad tastes and more to eliminate contaminants that can cause diseases. (Erhuanga *et.al.* 2014). The development of ceramic water filter is important especially for rural

areas where the settlements are scattered and people relay on surface water and shallow ground water as a source of drinking water which are easily subjected to contamination by pathogenic microbes. The performance of clay filters can be significantly improved by the use of burnout materials and chemicals (colloidal silver) which increase flow rate by creating a network of pores and the use of bactericidal compounds for destruction of pathogens (Nnaji *et.al.* 2016).
Thus, the purpose of this study was to develop ceramic disc water filter on laboratory scale and evaluate its performance with respect to flowrate, turbidity, water hardness, and microbial removal efficiencies using total coliform and fecal coliform indicator bacteria.

Materials and methods

Raw Materials:

1. Clay (C)
2. Combustible Material: (Sawdust, SD, Rice husk, RH)

The ceramic water filter production process follows some common steps regardless of the type of filter being manufactured. The process typically begins with material selection and processing; followed by shaping and pressing the filter element into a mold; firing; drying and then potentially treating the filter with a disinfectant.

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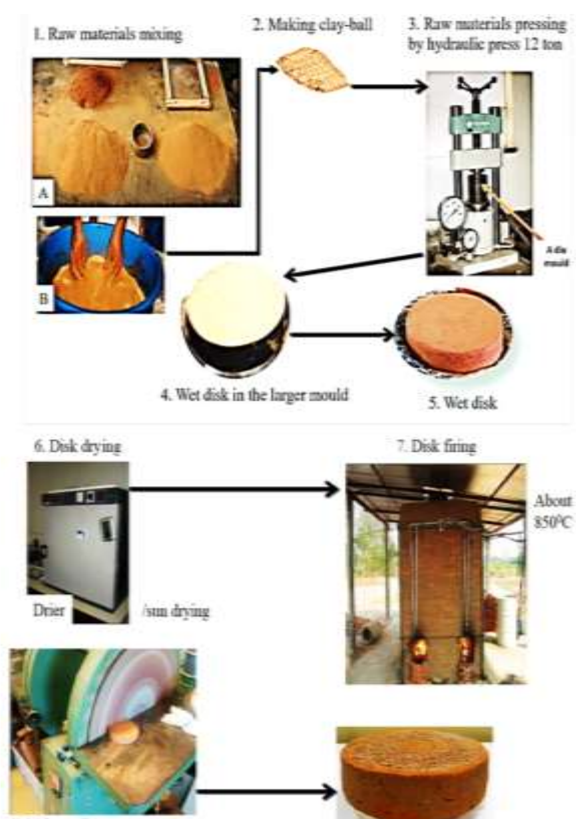
Method

The method engaged in carrying out the project are as follows:

1) The raw materials are prepared: Dry pulverized clay, screened.
2) The materials are thoroughly mixed using a clay mixer. The clay is mixed for at least ten more minutes
3) The clay is divided into blocks of approximately 10 kilograms
4) Each clay block is molded into a disc shape using a hydraulic press. The outer surface of the pressed filter is smoothed over with a plastic scraper to ensure it is even and the rim is sturdy. Each filter is labeled.
5) Filters are dried in the shade for at least three to four hours as they begin to harden.
6) Filters continue to dry on a drying rack for 7-18 days (depending on the climate) to remove excess moisture, which could cause the filter to crack during the firing process
7) Filters are fired in the furnace or kiln where the combustible material burns away forming pores and the clay becomes hard. The temperature of the kiln chamber is initially raised to 100^0C for two hours to remove any remaining moisture. The temperature is then gradually raised to around 850^0C to allow for vitrification

Figure 1: Dried ceramic disc filter

Figure 2: ceramic disc water filter mechanism



(silica and alumina molecules within the clay melt and bond and the chemical structure of the clay is altered).

8) Filters are cooled for 24 hours in the kiln.
9) Silver solution is applied to the filter as a chemical barrier to bacteria. The silver solution is painted on to both the inside and outside of the filter.

The samples were then subjected to a test for their physical properties which included shrinkage, porosity, and flow rate. Finally, the effectiveness' of the developed filters were determined by carryi ng out physio-chemical and microbial analysis on raw and the filter-treated water samples. Raw water samples were collected from water sources which were common to the study area and they included wells, boreholes, and stream. The raw water samples were passed through the filters to obtain the treated water samples (filtrate). The raw and the treated water samples were then taken to the laboratories to test for such parameters as, the microbial load counts, pH, turbidity, Total Solids (TS) and Total Dissolved Solids (TDS).

Other form of ceramic water filter
Pot shape and candle shape

Figure 4i: Ceramic Pot Filter, (Doulton, 2009)

Figure 4ii: Ceramic Candle Filter (PFP, 2008)

Result and Discussion

Table 2: Volume ratios of raw materials used for the developed filters

Clay (C) (%)	Grog	Sawdust SD, Rice husk (RH) (%)	C:SD
10	5	15 SD	**15 C:15 SD***
25	5	9.5 SD	**20 C:9.5 SD**
18	5	10.5 SD	**23 C:10.5 SD**
20	5	10.5 RH	**25 C:10.5 RH**
25	**5**	**11.5 RH**	**30 C:11.5 RH**

Note: *15C:15SD means fifteen percent clay and fifteen percent sawdust by volume.

The percentage of the materials is the average difference of the composition (30% = 100%). Actual (15:15) = 50:50 of clay and combustible material.

Physical appearance filter samples

The samples of the filters produced by both sawdust and rice husk were light golden brown after firing. The samples of the filters produced by both sawdust and rice husk were light golden brown after firing as shown in Fig. 4.0 below with clay and sawdust appear lighter in appearance.

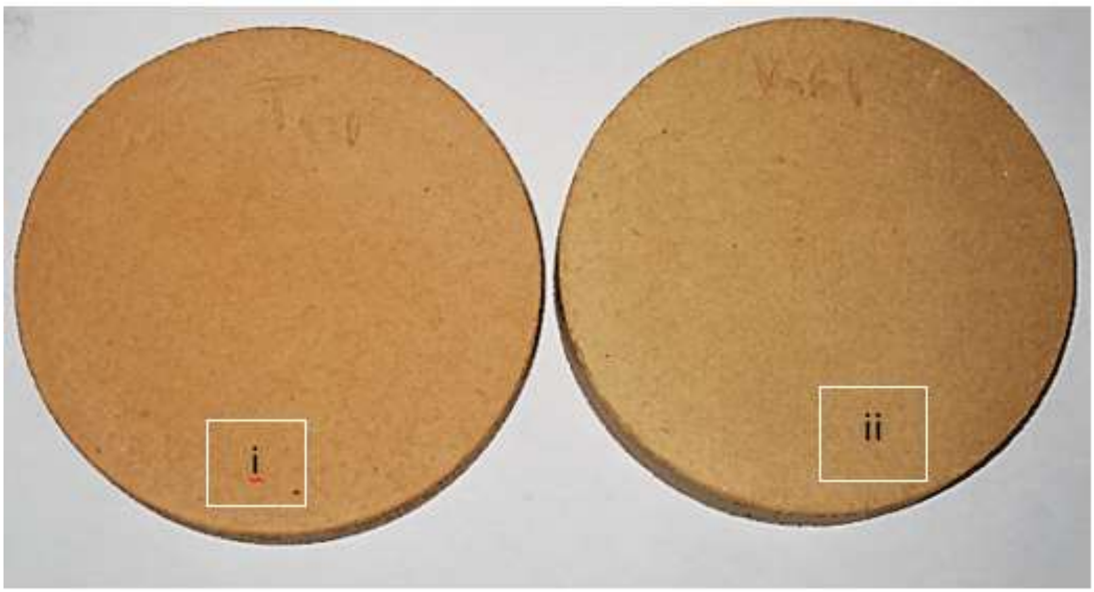


Figure 4: Filter sample; (i), C:SD and (ii) C:RH

Flow Rate

The flow rates were measured by taking the volume ratio of water measured in the plastic container to the time taken for which the volumetric measurement is taken.

$$Flow\ Rate\ = \frac{Volume\ of\ water\ measured\ at\ time\ t\ in\ mL}{elapsed\ time, t, from\ start\ of\ test\ in\ hour}$$

Table 2: Quantity of water filtered

Design Ratio	Quantity of water filtered in ml after							
	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs	7 hrs	8 hrs
15C:15SD	10	20	30	38	44	50	60	65
20C:10.5SD	7	12	16	22	28	33	39	43
23C:9.5SD	5	10	12	16	19	21	24	29
25C:10.5RH	4	6	7	8.5	10	11	12	15
30C:11.5RH	3	5	6	8	9	10	11.5	13

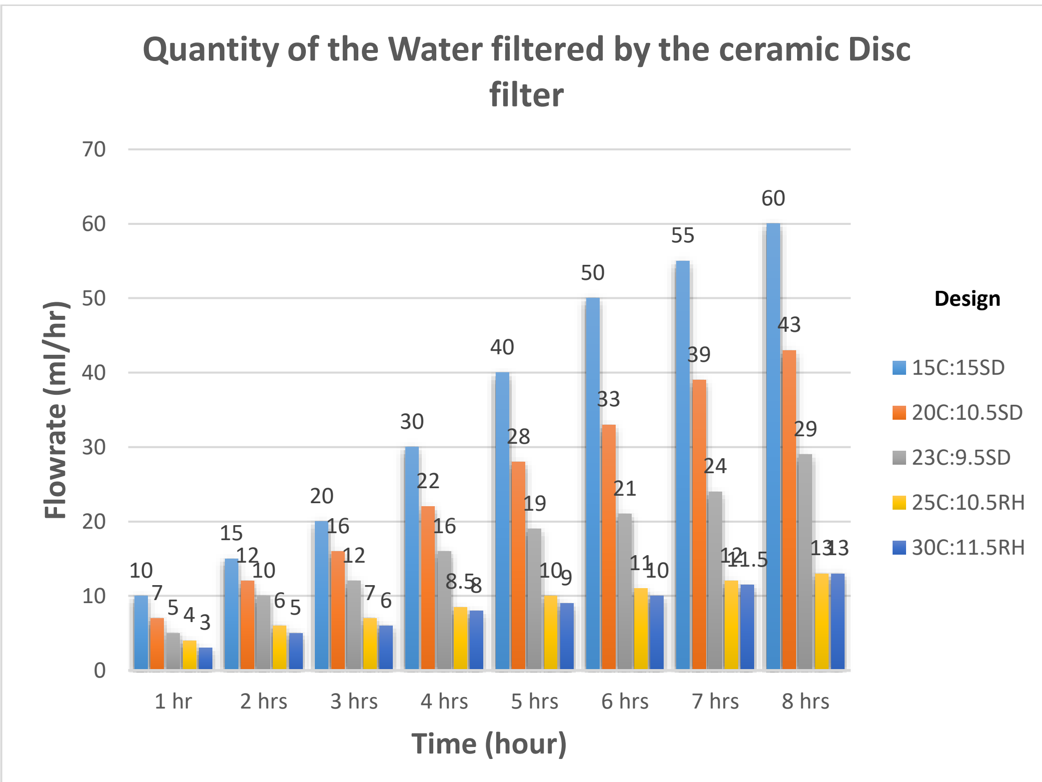


Figure 5: flowrate of various filters produced

The results of the study showed that the developed ceramic water filters have maximum flow rates of 10 ml/lhr, 7 ml/hr, 5 ml/hr, 4 mb/hr and 3 ml/hr for clay to sawdust combination ratios of 15C:15 SD, 20C:10 SD, 23C:9.5 SD, 25C:10.5 RH and 30C:11.5 RH filter respectively when the filters were filled with water. One way to increase the flow rate was to increase the number of pores in the filter by raising the proportion of combustible material (sawdust) to clay. If there are more pores in the filter, then water should flow through the filter faster. But it has effect on the microbial removal efficiency. The study results revealed that as the percentage of sawdust increased the flow rate also increased. Difference in flowrate between the filters made with 15%, 9.5% sawdust, 10.5% and 11.5% rice husk were observed.

It is difficult to make accurate estimates regarding daily water consumption because the requirement is highly dependent on body physiology, activity level, and local climate. An average estimate based on literature review for adult (male) is 2.9 L/person/day, adult (female) is 2.2 L/person/day and children is 1.0 L/person day (Howard and Bartram, 2003). If properly scaled up and manufactured, the developed ceramic disc water filters are capable of producing enough quantity of safe drinking water for an average family of 5. It assumed that filter is consistently refilled throughout the day (to maintain the maximum level of hydraulic head). Considering the above issues, it is necessary to improve the filter performance in terms of flowrate.

Turbidity Reduction Test

Table 3 Some Physical parameters in source and filtered water samples

Parameters	Source water Sample	Filtered water from				
		15C:15SD	20C:10.5SD	23C:9.5SD	25C:10.5RH	30C:11.5RH
Turbidity(NTU)	9.2	0.055	0.07	0.08	0.5	0.5
pH	7.9	7.4	7.1	7.1	6.9	6.7
Temperature(^{0}C)	22.7	22.5	22.4	21.7	21.5	21.4
Conductivity(μs)	306	164	136	131	106	101

Following filtration, turbidity of the treated water was reduced to <5 NTU for all the developed filters tested. The level is within the acceptable drinking water quality standards of < 5NTU as set by World Health Organization. The inflow water from the river water source was found to have turbidity levels from between 7 and 12 NTU with an average of 8.5 NTU. The overall removal efficiency in terms of turbidity reduction is 98%. Even when raw water with higher turbidity levels was used, the turbidity of the treated water was found to be below 5 NTU. Therefore, developed ceramic water filters have the ability of reducing turbidity to less than 5 NTU.

Table 4: Total coliform and Fecal coliform in source and filtered water samples

Design	Raw water		Filtered Water		Removal Efficiency	
Ratio	TC (cfu/100mL)	FC (cfu/100mL)	TC (cfu/100mL)	FC (cfu/100mL)	TC (Percent)	FC (Percent)
15C:15SD*	760	72	12	0	97	100
20C:10.5SD	760	72	12	0	99	100
23C:9.5SD	760	72	6	0	97	100
25C:10.5RH	760	72	2	0	99	100
30C:11.5RH	760	72	0	0	100	100

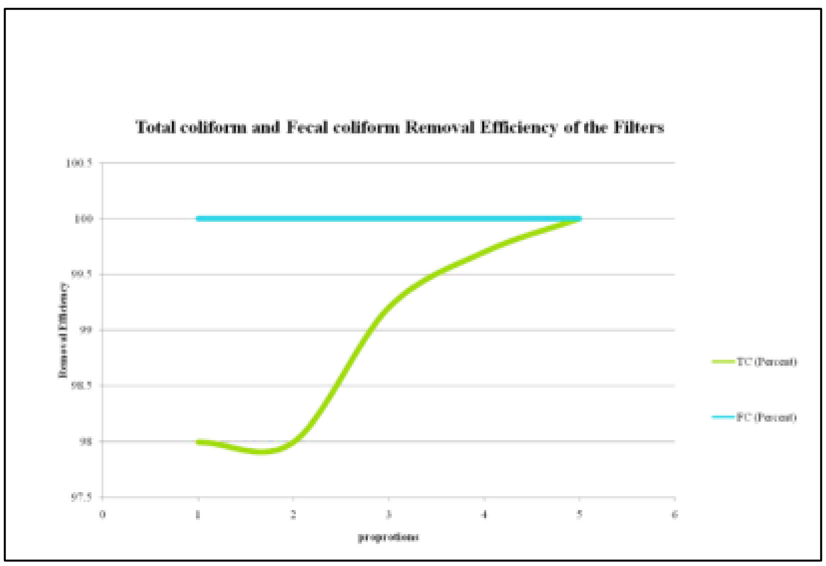


Figure 6: Ceramic water disc filter removal efficiency

The developed ceramic water filters are capable of removing more than 98% of the total coliform bacteria and 100% of the fecal coliform from influent water samples. The ceramic water filter technology should remove 99% of total coliform and *E. coli* under laboratory conditions (PFP, 2008). Some other studies revealed that the effectiveness of ceramic water filters at removing bacteria, viruses, depends on the production quality of the ceramic filter. Many studies assessing the performance of ceramic water filters have found them to be highly effective in removing total and fecal coliforms from bacterially contaminated water sources (Clasen *et al.*, 2007).

Parameters that affect filter performance

The ratio of sawdust to clay is one of the major factors that affect filter performance. If the volume ratio of sawdust is increased, more pores are created in the filter, and the water flowrate will be increased. This will affect the filter's effectiveness in removing pathogens from unclean water. The filter becomes more fragile and less solid if it is composed of a higher proportion of pores. It is important to avoid compromising the durability of the filter because breakage is a main factor of filter mismanagement (Brown *et al.* 2007). The density and size of a filter's pores are two of the factors that affect filter effectiveness (Hagan *et al*., 2009). One way of removing pathogens is to block particles and organisms that are larger in size than the pores from flowing through the outermost membrane layer (Doulton, 2009).

Pore size is important in controlling flowrate and the level of contamination removal of the filter. Small pores are efficient at turbidity and bacteria removal from contaminated water. However, flow rate increases as filter pore size increases. Thickness also affects the ceramic water filter flow rate. With a thin ceramic device, flow rate increases but the level of water microbiological and turbidity removal decrease. Increasing the thickness, the filter removes more pathogens and other particles. Surface area has a major impact on the filter performance. A larger surface area of the ceramic element allows more water to flow through the filter. Greater fluid pressure or hydraulic head is a function of height water in the filter.

Thus, increasing the above parameters with the exception of filter thickness increases the flowrate. Increasing the filter thickness lead to decrease in flowrate. Water comprising of high organic content and/or many suspended particles slowdown the flow rates of water by progressively clogging the ceramic pores. This affects the quantity of filtered water collected.

Ceramic water filters similarities (flowerpot shaped, disc and candle shape)

There are three main types of ceramic filters: disk, candle, and pot filters with many differences to each other. A disk filter, consists of a removable ceramic filter sandwiched between two containers (figure 3). Candle filters consist of one or more candle-shaped ceramic filters and two chambers (figure 4ii) while pot filter consists of only one plastic or ceramic receptacle (figure 4i). Disk and candle filters are generally effective for removing turbidity, iron, coliforms, fecal contaminants, and E. coli from contaminated water. (CDC, 2008). Disk filters with colloidal silver have exhibited a 93 to 100 percent microbial removal rate, and those without silver have shown an 80 percent removal rate. Candle filters with colloidal silver generally exhibit 100 percent bacterial removal, and those without silver average at 85 percent removal (CDC, 2008). Disk filters typically have a flow rate of 1 to 11 liters per hour and candle filters have a flow rate of 0.3 to 0.8 liters/hour while pot filters have a flow rate of 1 to 2 liters/hour. Under conditions where the filters are continuously refilled, a filter with a flow rate of 1.5 liters per hour would provide about 7 liters per day per person for a family of five. (CDC, 2008).

Ceramic water filters are easily assembled. The ceramic pot filter is assembled as one complete unit, unlike that disk and candle filters. Scrubbing the filter with a toothbrush is required as maintenance. Ceramic pot water filter is the easiest of all because it can be produced locally using local knowledge and local materials.

Recommendation

Based on the findings and discovery in the course of this study, the following observations and recommendations were made:

1) *In terms of raw materials*, Charcoal can serve as a good alternative burnout material in the body compositions, giving good binding and pore-forming qualities up to 50% volume ratio in the body and also the filter porosity.
2) *Casting techniques*: Considering the effectiveness of the slip casting method in various process it is recommended that this technique be employed in the production of ceramic filters as an alternative to pressing thereby eliminating the initial capital cost of purchasing a hydraulic press.
3) *Choice of filter type:* Pot filters yield more flowrate compare to other disk and candle filter. pot filters are better than disk and candle filters with respect to bacterial removal efficiency. Ceramic water filters are easily assembled, and no component construction is required of the user other than placing the filter into the container. The ceramic pot filter is assembled as one complete unit, unlike that disk and candle filters. scrubbing the filter with a toothbrush is required as maintenance.

4) Household should be given proper training on the Operation and Maintenance of the equipment as it performance depends solemnly on how its handling.
5) It is also recommended that further study and research be carried out on the filters to improve upon its performance in water treatment by government and private investors to bring about mass-production of these filters, making it available in most homes thereby alleviating the issue of inadequate supply of safe water in our country and the world.

Conclusion

Treating water at the point – of – use (POU) can be achieved through the use of Household water treatment technologies. The results of experiment shown that the developed ceramic water filters effectively remove microbes from unclean water which are sources of water borne diseases. But proper raw materials ratio is important in terms of filter effectiveness. And personnel must have good knowledge of O&M (operation and maintenance) of the technology for effective use.

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