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Comparison Of The Effectiveness Of Various Designs Of Ceramic Filter Membranes In Domestic Water Purification

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Abstract:** This research aimed to compare the effectiveness of three different types of ceramic water filters (Disk, Candle and Frustum shaped) in treating drinking water. The ceramic water filters were made from red clay and sawdust in the volume ratio 50:50, pressed at 140kPa to the male part of the mold using a 50 ton hydraulic press and fired at an optimal temperature of 950°C. Ceramic water Filter effectiveness with and without colloidal silver (CS) coating was determined based on flow rate, E. coli and total coliform removal efficiency. Impact of Colloidal silver coating in removing and inactivating E. coli and total coliforms were observed for all ceramic water filters and frustum shaped ceramic water filter was found to be the most efficient one. There is a minimal difference in the flow rate before and after CS coating in the filters demonstrating the Colloidal Silver coating has not affected in the filtration rate. This study concludes that locally available frustum shaped ceramic water filter after CS coating can be safely used in treating drinking water at household level.

***Keywords:** Ceramic filters, Colloidal silver, E. coli, Total coliforms*

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I. INTRODUCTION

Lack of safe water supply is one of the world's major causes of preventable morbidity and mortality. World Health Organization [WHO] data on the burden of disease estimates that approximately 1.8 million of deaths per year and 61.9 million of disability adjusted life-years worldwide are attributed to unsafe water, sanitation and hygiene occur in developing countries. WHO also estimates that 884 million people (13% of the world population) live without access to an improved water source that provides 20 litres of water per person per day, within 1 km of the person's residence. The open sources of water such as rivers, springs, boreholes and many more are no longer safe due to the continued contamination at their sources. This contamination at the sources is mostly caused by various human related activities such as drainage of sewers and industrial waste. The chemicals in these wastes have resulted to endangered clean safe water for human and animal consumption.

Although Kenya has rich water resources, the failure to achieve safe water and sanitation is one of the biggest tragedies of the nation. About 31% of Kenyans depend on tap water, (household or communal tap), while 37% obtain water from an open spring, stream or river. The rest get water from wells, water vendors or other sources. WHO estimates that in 2002, 38% of Kenyans who live in urban area lacked access to safe drinking water while in rural areas the number increased to 54%. WHO also indicates that in 2012, 62% of Kenyans (82% in urban area and 55% in rural areas) had access to improved drinking water sources. About 19% of Kenyans (44% in urban areas and 13% in rural areas) are reported as having access to piped water through a house or yard connection.

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A number of researches have proposed point-of-use water purification systems. The points-of-use technologies cover microbiological and/or chemical or physical water treatment including: disinfection (chlorination, solar disinfection (SODIS), solar pasteurization, UV irradiation with lamps, and boiling); particle filtration (cloth fiber, ceramic filter, biosand and other slow sand filter technologies); adsorption media (granular activated carbon, and activated alumina, clay); combined system (combined flocculation/disinfection, filtration plus disinfection); other approaches include plain sedimentation settling, safe storage, coagulation/flocculation with iron or alum salts and membrane processes.

Even though these methods are being used in water treatment, point-of-use filtration is one of the most promising solutions available

Filtration covers a wide range of technologies from simple removal of large particles (including cloth or plastic gauze) to sophisticated membrane systems operating under high pressure capable of removal of particles down to the nanometer size. For domestic treatment, two general principles have been proposed:

- ✓ Straining: the sizes of the pores in the filter medium are smaller than the particle being removed. This can occur on the filter surface or within the depth of the filter wherever the water flow channels narrow to a size smaller than the particles.
- ✓ Depth Filtration: occurring when particles passing through channels become trapped on the surface of the channel wall by a variety of physical mechanisms. This refers to granular media filtration.

Filtration by use of ceramic filters is cheap and simple to fabricate. Anyone can make them anywhere as long as clay is available within the vicinity. The fabrication of these filters resembles that of making a simple cooking pot or flower vases. So far, about five hundred thousand people in the developing world have adopted some form of porous ceramic filter technology.

Ceramic water filters (CWFs) are usually produced by mixing of clay, sawdust (woodchips) and water. Other combustible organic materials, such as rice husk, coffee husk, or flour can also be used. The flow rate, which may depend on the water turbidity conditions, decreases gradually with increasing filter use during the 2–3 year recommended lifetime of the CWFs. This is due to the accumulation of solids on the inner surface and gradual blockage of the pores by trapped contaminants. During use, PFP recommends that the CWF be cleaned by fire heating, scrubbing and brushing to remove caked impurities that form with time. This cleaning procedure, however, is currently under debate because of the high risk of recontamination treated water.

In this study, we explore the efficiencies on the use of water Purification Systems at the point-of-use using three types of ceramic filter (Disk, Candle and Frustum shaped) membranes based on porous ceramics to filter microbes from drinking water.

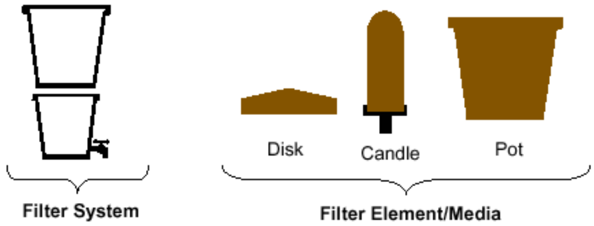

Figure 1: Details of ceramic filter systems

II. MATERIALS AND PROCESSING

Ceramic Water Filters were made by mixing red clay with sawdust in order to produce filters with optimal porosity, the proportions of clay to sawdust for an effective ceramic water filter by volume is 50:50. The sawdust was manually sieved using 50- 1000 mesh wire sieves. The blending of sieved sawdust and clay was also done manually to ensure a thorough mixing and to avoid the formation of clustered pores. The dry mixture of clay and sawdust was transferred to a mixer and thoroughly mixed again for approximately 5minutes before the addition of water. Half of the required amount of water was gradually added during mixing, and the mixture is again blended for 5 to 10 minutes. Next, half of the remaining water was added, in small increments until the mixture began to coalesce into large clumps and no longer adhered to the walls of the mixer. No more additional of water after coalescence had occurred.

The blended mixture was then manually formed into a ball, which was pressed tightly together so that no cracks were visible on its surface. This ball was compacted in a two-piece aluminum mold that was covered with a plastic bag to prevent the green ware from sticking to the walls of the mold during pressing. The blended mixture was placed into a female part of the mold before applying a pressure of approximately 140kPa to the male part of the mold using a 50 ton hydraulic press.

After pressing, the green wares were then dried in laboratory air at a temperature of about 25°C and a relative humidity of about 40%. The time required for drying the green wares varies between 5 and 8 days. After drying, the green wares were sintered in a kiln. This involves the preheating of the green wares to 450 - 550°C for 3 hours (to burn off sawdust), followed by heating to the sintering temperature of 955°C in the same kiln. The initial heating rate of 50°C per hour was increased to 100°C per hour beyond a furnace temperature of 200°C. The green wares were sintered for 5hours at a peak temperature of about 955°C. They were then furnace cooled in air to room temperatures.

Three (Disk, Candle and frustum shaped) types of ceramic water filters are designed. Different press moulds were used to produce the disk, candle and frustum shaped ceramic water filters respectively. Out of the ten green wares made from each category five of them were smeared with colloidal silver and the other five were not smeared. The fired disk shaped ceramic water filters of diameter 17cm and thickness of 2.5cm were later attached to the bottom of the top receptacle one at a time hence constant pressure controlled by height/volume of water. This was done to get the filtration rate and the filtrates. The bottom of the candle shaped ceramic

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water filters of length 13cm and thickness of 5cm was connected with a plastic tube to collect the filtered water into a bottom container. The frustum-shaped Ceramic Water Filters consisted of two sections, the base and the side. The base had a radius of 9cm and a thickness of 1.5 cm. The side had an interior slanted height of 24cm and a thickness of 1cmm. The Ceramic Water Filters had an interior depth of 24cm.

The flow rate of each filter was obtained by getting the volume of filtered water in one hour.

COMPARISON OF FILTERS BEFORE COLLOIDAL SILVER COATING

In order to compare the bacterial removal efficiency of three filter candles before and after CS coating, E. coli concentration of 1000 cfu/100mL and total coliforms concentration of 3000 cfu/100mL were synthetically maintained in the influent water. Water samples collected from effluent at different time periods were analyzed for E. coli and total coliforms number and compared with influent bacterial number to determine the removal efficiency. The efficiency of each filter was also obtained by calculating the amount of pathogens in the effluent water compared to those in the infflluent water and expressed as a percentage.

III. RESULTS AND DISCUSSION

Details of flow rate of the different designs are shown in Fig. 2. The flow rates of the filter membranes in were found to be lower when the membranes were smeared with colloidal silver. The clogging of filter pores with time is attributed to this behavior. The colloidal silver reduces the size of the pore hence reducing the amount of water flowing through it.

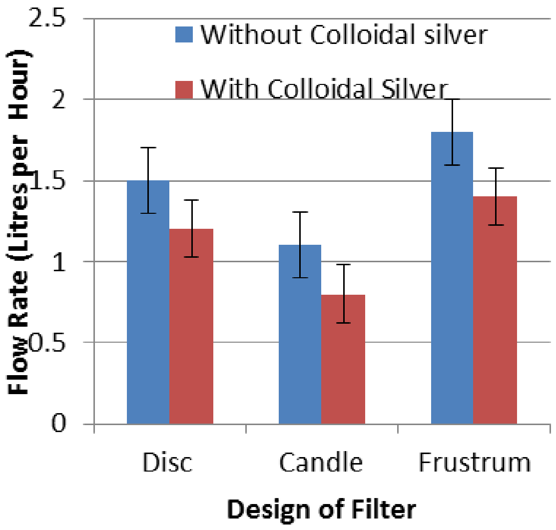

Figure 2: Average flow rates of three filters Membranes before and after colloidal silver (CS) coating

Details of E. coli and total coliforms concentration at influent and effluent (at different time periods) are shown in Fig. 3. The efficiency of the filter membranes in E. coli and total coliforms removal were found to be higher when the membranes were smeared with colloidal silver. The clogging of filter pores with time could be the one reason for achieving better removal efficiency from the filter membranes.

The E. coli removal and total coliforms efficiency of disk shaped water filter was 80% to 85 % without CS coating (Fig. 3) while it was 94% to 98 % with CS coating (Fig. 3). The result shows that better performance of disk shaped water filter and candle shaped ceramic water filter can be achieved after colloidal silver coating but could not meet the WHO guideline. Better E. coli and total coliforms removal efficiency of Frustum shaped ceramic water filter with the increased water retention time after Colloidal silver coating was noted. 99.6-100% of bacterial (both E. coli and total coliforms) removal efficiency of Frustum shaped ceramic water filter was achieved (Fig. 3).

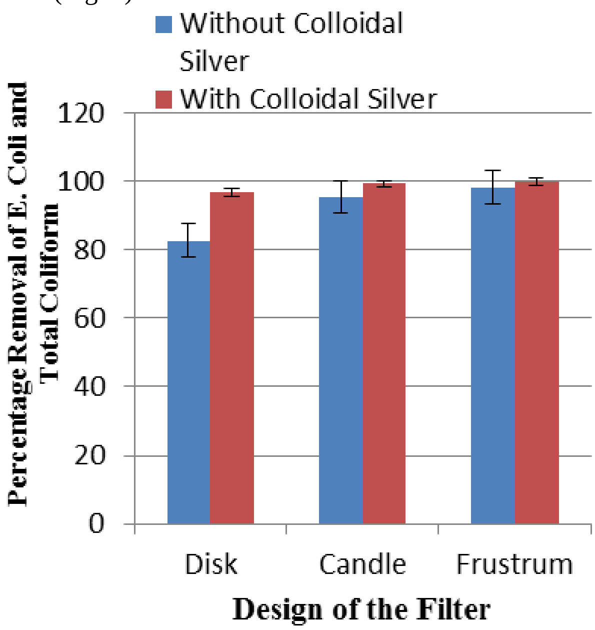

Figure 3: Comparison of ceramic filters in terms of bacterial and total Coliforms removal before and after colloidal silver (CS) coating

IV. CONCLUSION

From the three different types of filter candles (Disk, Candle and Frustum shaped water filters) with and without CS coating the following conclusions were made from this study:

Firstly, significant impact of Colloidal Silver coating in controlling and/or inactivating E. coli and total coliforms were noted for all filter candles and among them Frustum shaped water filter was found to be the most efficient for eliminating bacterial cells from water.

Secondly performance of filter in terms of filtration was not affected by the Colloidal Silver coating as a minimal difference in the water flow rate before and after silver coating was noted.

Thirdly, the flow rate of frustrum shaped filter was 1.4 litres per hour when coated colloidal silver. This amounts to 33.6 litres per day and this exceeds the WHO requirement of 20 litres per day per person.

This study concludes that the disk, Candle and Frustum shaped water filters after silver coating can be safely used at household level for treating drinking waters especially eliminating microbial contamination among them the Frustum shaped water filter is the best in bacterial removal.

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