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Comparison of the Performance of Ceramic Filters in Drinking Water Treatment

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Abstract: - This research aimed to compare the performance of three different types of ceramic filter candles (MCC, Puro and Surya) in treating drinking water. Filter candles performance with and without colloidal silver (CS) coating was determined based on flow rate, E. coli and total coliform removal efficiency. Significant impact of CS coating in removing and/ or inactivating E. coli and total coliforms were observed for all filter candles and Puro filter candle was found to be the most efficient one. Using MCC filter candle (which was built using locally available materials) can achieve the highest filtration rate but E.Coli and total coliforms removal efficiency could not meet the standard set by World Health Organization (WHO) guideline. Further silver leaching test demonstrated that silver concentration in the filtered water through the CS coated filter was under the WHO guideline. There is a minimal difference in the flow rate before and after CS coating in the candles demonstrating the CS coating has not affected in the filtration rate. This study concludes that locally available filter candles (Puro or Surya) in Nepal after CS coating can be safely used in treating drinking water at household level.

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

I. INTRODUCTION

According to World Health Organization (WHO) over 99.8% of death caused by poor quality of drinking water in the developing countries [1] strongly suggesting a need of safe (free from physical, chemical and biological contaminations) and adequate amount of drinking water. In order to improve water quality, various water treatment techniques (bio sand filter, ceramic filters, boiling water, solar disinfection) are in common practice at household level of many developing countries where centralized water treatment systems are limited. Among many options for household water treatment methods, ceramic filter candles are one of the promising techniques for the developing countries [2]. The fact is that ceramic filter candle can be manufactured by local ceramists using locally available materials that not only make it affordable but also make it an attractive point-of-use treatment technology. Moreover, this type of filter can be used in different forms such as candle, pot and disc (as shown in Fig. 1). It physically eliminates colloidal particles (which make water turbid), odour and micro organisms including pathogens. Performance of this filter is normally evaluated based on water flow rate, removal of pathogens, reduction on chemical contaminants including turbidity and odour. Nepal. The coating of the CS on the filter candles which are built-in into the commercially available metal container have not been practiced in Nepal and it is unknown whether the CS coating on ceramic candles fitted in the metal container for controlling and/or inactivating pathogens growth is effective. Therefore, major aim of this research is to investigate the effectiveness of CS coating ceramic candle filter for controlling and/or inactivating pathogens. Further comparative study in terms of pathogens removal efficiency and flow rate between three different types of ceramic candle filters without CS coating was performed. Pathogens removal study was conducted using reverse osmosis treated water with the known number of pathogens.

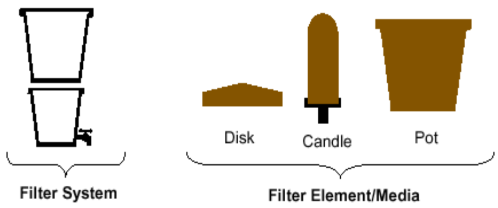

Fig. 1: Details of ceramic filter systems

In order to improve efficiency of the ceramic filter especially pathogens removal, colloidal silver (CS) coated filter has been practiced as silver is effective nano particle for inhibiting and/or controlling bacterial growth. Colloidal silver contains positively charged free ions and negatively charged particles. Free silver ions have a toxic effect on micro organisms even their presences are relatively low in concentrations. Silver reacts with the thiol groups in both functional and structural proteins of the bacterial cell and inhibits glucose, succinate, and lactate oxidation [3]. The main three mechanisms of CS are inhibiting the enzymatic activities, corroding the bacterial cell membranes and negatively interacting with nucleic acids [4]. Despite knowing the importance of CS in inhibiting and/or controlling microbial growth, ceramic filter without CS coating has been widely used in different parts of Nepal. A social organization called Solutions Benefiting Life provides the CS coated disk filters mounted in the clay containers in some districts of Nepal. The major drawback of using the clay containers is handling difficulty. Another social group called International Development Enterprise distributes the CS coated candle filters fitted in High Density Polyethylene plastic bucket but they are not in common practice in.

II. MATERIALS AND METHODS

A. Experimental Design

Three types of ceramic filter candles named Madhyapur Clay Craft (MCC) candle, Puro candle and

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Surya candle were used in this study. Three sets of experiment using nine candles for each type of filter candle were performed for flow rate and pathogens analysis. Experiment was carried out in the Environmental and Public Health Organization laboratory in Nepal.

B. Details of Ceramic Candle Filter Set

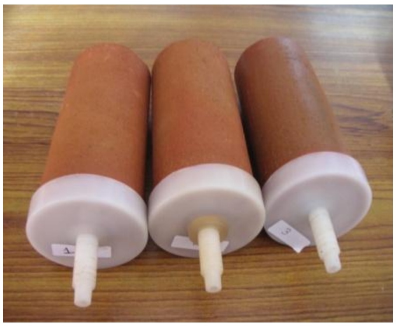
Three sets of filter containers, each capacity of 4.5 L as shown in Fig. 2A were used in this study. Three metal stands were used during the sample collection and sterilization of containers (Fig. 2B). Sterilization was carried using 70% ethanol as shown in Fig. 2B.

Fig. 2A: Filter Containers

Fig. 2B: Sterilisation of Filter Containers

C. Filter Candles

Clay collected from Bhaktapur, Nepal was used for manufacturing MCC candle. Collected clay was grinded by machine and sieved through 30 mesh to get powder form of clay. The clay and saw dust were mixed at a ratio of 70:30 by weight and then water was added 35 % (weight). The mixed material was placed into a mould and kept in 930 ^{o}C furnace. The length of candle was 13cm, external diameter was 7cm and inner diameter was 1.8cm (Fig. 3A). Plastic tube was connected at the bottom of the candle to collect the filtered water into the container. Other two filer candles (Puro and Surya) used in this study were imported from India and they are commercially available in Nepalese market. The dimensions of both types of filter were the same (Fig. 3B and 3C). Length was 11 cm, outer diameter was 7.5 cm and inner diameter was 4.5 cm. Metal tube was connected at the bottom of the candle to collect the filtered water.



(a)

(b)

(c)

Fig. 3: Details of filter candles A) MCC candles B) Puro candles C) Surya candles

D. Colloidal Silver (CS) Coating

30drops of 250 mg/L of colloidal silver was mixed with 2.5 L double distilled water in the jar and the mixture was heated to achieve 90 ^{o}C temperatures by placing the jar into the distilled water containing container. Once the temperature reached 90 ^{o}C, the current was applied for the electrolysis process and constant temperature of 90 ^{o}C was maintained by adding water. After 8 h of heating, the sample of jar was left for cooling. Silver coating was done by dipping the ceramic candle in plastic container with average volume of 300 ml of colloidal silver per candle.

E. Media Preparation

Petri dishes were dipped into 70% ethanol for half an hour and dried in the incubator at temperature 60 to 65^{o}C. Chromocult agar media for cultivating bacteria was prepared by adding 26.5 gm agar in 1L autoclaved water. The solution was then heated in water bath at 90 ^{o}C

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temperature for 1 min and cooled to temperature of 50 °C. Then about 5 ml media solution was poured in to the Petri dishes and left for 15 mins in the plane surface without disturbing.

F. Culture of Bacteria

Waste water obtained from Dhovi Khola (river) Kathmandu was used as seed water for bacterial growth. Waste water was filtered through the membrane filter (Whatman filter paper) to remove the suspended particles. Then filtered water was diluted at various ratios (1:10 to 1:200) with reverse osmosis treated water. The diluted water was spread over the agar media and a sterile loop was used for rubbing the diluted waste water. The media was then incubated for 24 h at 35 °C. Total coliforms and E. coli clones (only colonized as a single cell) were transferred to another agar media as a clone from a single streak plate may not assure purity. In order to store the cultured total coliforms and E.coli, solution was prepared by mixing 2 g peptone with 40 ml glycerol (100%) in 60 ml distilled water and was autoclaved for 15 min at pressure 15 Lb/in^2. Total coliforms (red colour) and E. coli (blue colour) clones were separately picked with cotton swab without gouging agar surface. Then, the solutions containing total coliforms and E. coli were aspirated in to the sterile glass vial with sterile transfer pipette. The stocks of both total coliforms and E. coli were stored at -20°C until they were used.

G. Water Sample Preparation for Feeding into the Filter

Water used for feeding in to the filter was reverse osmosis treated water. In order to make sure water is free from chlorine residual (that uses to inhibit or/and kill microbes), chlorine test was carried out. Then 10 L water was autoclaved for 15 mins at pressure 15 Lb/in^2 to eliminate the possible contamination of any microbial cells. Afterwards, known number of E.coli and total coliforms cells from the stock samples were added into the autoclaved water and feed into the filter tank to determine the bacterial removal efficiency.

H. Analytical Methods

Chlorine residual was measured by Iodometric method, bacterial test (E. coli and total coliforms) was performed by membrane filter method (EPA CFR141.21). Silver concentration was measured using an atomic absorption spectrophotometer (SOLAR 969 AAS). The flow rate was measured by volumetric method maintaining full volume (4.5L) in the containers. Nine samples of each type of ceramic candle were employed for the flow rate measurement.

III. RESULTS AND DISCUSSION

A. Flow Rate Measurement

Average flow rate of water through three different types of candles in both cases (with and without CS coating) are shown in Fig. 4. In both cases, average flow rate of MCC was found to be highest while compared with other types of filter candles. High flow rate of MCC candle is due to the higher surface area and high porosity which can be easily observed by breaking the candle. As a result of pore clogging after the CS coating, the average flow rate was found to be decreased in all candles. However, a marginal difference was noted before and after CS coating in Puro and Surya candles comparing to MCC (Fig. 4).

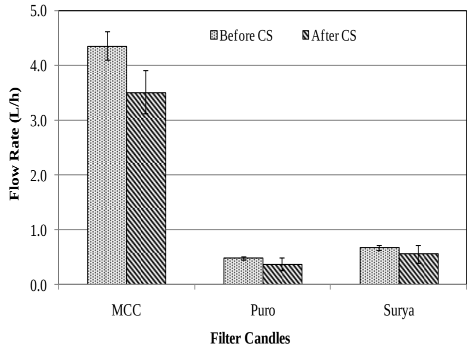

Fig. 4: Average flow rates of three filters before and after colloidal silver (CS) coating

B. Silver Concentration in the Filtered Water

In order to ensure whether the leached out silver from the CS coated candle is less than WHO guideline, silver concentration was measured in the filtered water at four different times (Table 1). However, nine candles for each type of filter candle were employed in this study; only one filter candle from each type as a representative candle was used to measure the silver concentration. The analysis as detailed in Table 1 clearly shows that silver concentration in the filtrated water from all candles is within WHO guideline limit (< 0.10 mg/L) signifying that these types of candles are safe for public health.

Table 1: Silver Concentration in the Filtrate at Different Time Interval

Frequency of test (min)	Silver concentration (mg/L)		
	MCC	Puro	Surya
0	<0.01	<0.01	<0.01
20	<0.01	0.035	0.05
90	<0.01	<0.01	<0.01
210	<0.01	<0.01	0.015

C. Comparison of Filter Candles before Colloidal Silver Coating.

In order to compare the bacterial removal efficiency of three filter candles before CS coating, E. coli concentration of 1000 cfu/100mL and total coliforms concentration of 3000 cfu/100mL were synthetically

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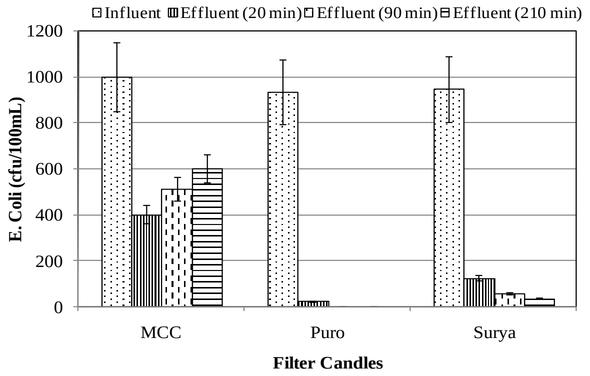
maintained in the influent water. Water samples collected from effluent at different time periods were analysed for E.coli and total coliforms number and compared with influent bacterial number to determine the removal efficiency.



5A

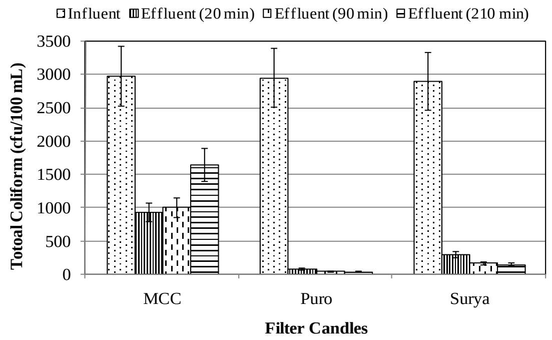
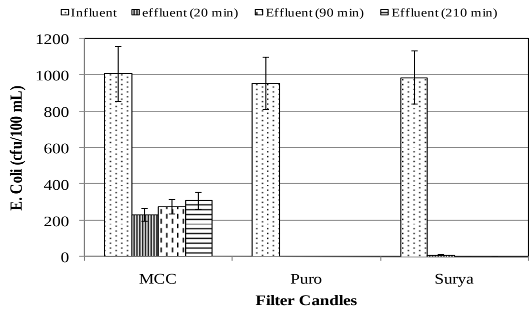


Fig. 5: Comparison of ceramic filters in terms of bacterial removal before colloidal silver (CS) coating. 5A: E. coli, 5B: Total coliforms

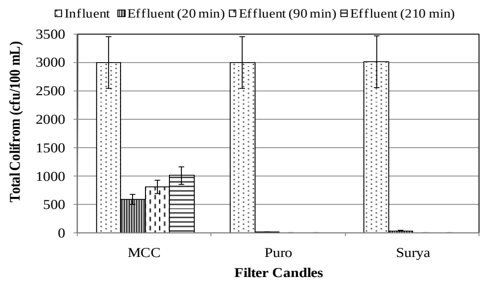
Details of E. coli and total coliforms concentration at influent and effluent (at different time periods) are shown in Fig. 5. Effluent E. coli and total coliforms concentrations were found to be increasing with time elapsing in MCC candle whereas their concentrations decreased in Puro and Surya filter candles. The clogging of filter pores with time being could be the one reason for achieving a better removal efficiency of Pure and Surya filter candles. In agreement with higher flow rate of MCC, bacterial concentration of effluent water also high, indicating a poorer performance of MCC filter candle than other two candles. Further, Fig. 5B shows that total coliforms were observed at each interval in all type of candles during the laboratory experiment and better removal performance have been increased with increasing water retention time in Puro and Surya filter candles. Among all, Puro filter was found to be effective to remove both E. coli and total coliforms numbers.

D. Comparison of Filter Candles after Colloidal Silver Coating

Significant impact of CS in removing and/or inactivating both E. coli and total coliforms for all filter candles were noted (Fig. 6). Although better bacterial removal efficiency was achieved after CS coating, E.Coli and total coliforms concentration at the effluent of MCC filter increased with time being. The E. coli removal efficiency of MCC candle was 39% to 60 % without CS coating (Fig. 5A) while it was 69% to 77 % with CS coating (Fig. 6A). Similarly, for the given influent concentration of total coliforms, removal efficiencies were 45% to 69 % (Fig. 5B) without CS coating and 65% to79 % with CS coating (Fig. 6B). The result shows that better performance of MCC filter can be achieved after CS coating but could not meet the WHO guideline. E. coli was observed at first 20 mins without CS coating in Puro candle whereas 100% E. coli removal was achieved at the same time after coating the CS (Fig. 5A and Fig. 6A). Very low number of total coliforms (12 cfu/100mL) was noted at the first 20 min of sampling time in the effluent water from Puro candle and they were completely (100%) disappeared with increasing water retention time. Better E. coli and total coliforms removal efficiency of Surya candle with the increased water retention time after CS coating was noted (Fig. 6). 100% of bacterial (both E.coli and total coliforms) removal efficiency was achieved after 20 mins of water retention time which was not achieved without CS coating in Surya candle (Fig. 5 and 6).



6A



6B

Fig. 6: Comparison of ceramic filters in terms of bacterial removal after colloidal silver (CS) coating. 6A: E. coli, 6B: Total coli firms.

There could be two possible mechanisms to get the better E.coli and total coliforms removal efficiency after silver coating in the filter candles. First one is silver particles could have reduced the pore size of the filter that have helped to block the passage of bacterial cells and second one is biocidal effect of silver ion in inactivating and/or killing bacteria. However further details investigation is needed to determine which mechanism is predominant or both of them have synergetic effect to achieve the better bacterial removal efficiency.

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IV. CONCLUSION

Three different types of filter candles (MCC, Puro and Surya) with and without CS coating were tested to determine bacterial removal efficiency using known number of bacterial cells in the reverse osmosis treated water. Conclusions made from this study are as follows:

- Significant impact of CS coating in controlling and/or inactivating E. coli and total coliforms were noted for all filter candles and among them Puro filter candle was found to be the most efficient for eliminating bacterial cells from water.
- Silver leaching test showed that silver residuals in the filtered water after CS coating is under the WHO guideline demonstrating that these candles are safe from toxic effect of silver.
- Performance of filter in terms of filtration was not affected by the CS coating as a minimal difference in the water flow rate before and after silver coating was noted.

This study concludes either Puro or Surya candle after silver coating can be safely used at household level for treating drinking waters especially eliminating microbial contamination

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