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APPLICATION OF CERAMIC FILTER FOR IMPROVING SURFACE WATER QUALITY

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ABSTRACT

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Ceramic filter was used to remove pathogenic bacteria and other impurities from contaminated water. Three types of ceramic filters were prepared with locally available soil and rice husk and operated for 5 days. The combinations of rice husk and clay particles were used to prepare ceramic filter core, which was burnet in potter kiln and fixed in clay pot. A total of 30 water samples were collected from inlet and outlet of filter and their flow rate was measured. The collected water samples were analyzed for turbidity (Nephelometric Turbidity Unit; NTU), total coliform (TC) and fecal coliform (FC). The filtration rate of ceramic filter was increased with increasing rice husk percentage and highest filtration rate was 702.64 ml/h in ceramic filter made up of 20% rice husk, while for 10% rice husk the value was 191.2 ml/h. The highest turbidity removal efficiency, 56%, was found in 10% rice husk mix ceramic filter but its performance reduce when rice husk percentage increase in ceramic filter core. For 15% rice husk mix filter ceramic the value was 40% and for 20% the value was 24%. In case of ceramic filter made up of 10% rice husk, the TC removal was 80% but FC removal was 90%. We found that the performance of ceramic filter reduced with increasing rice husk percentage. It was concluded that ceramic filters were able to remove turbidity and pathogenic bacteria from contaminated water which meet the drinking water demand of low income group of hard to reach saline prone coastal zone of Bangladesh.

***Key words**: ceramic filter, fecal coliform, rice husk, soil, total coliform, turbidity*

INTRODUCTION

A filter is defined as a device, instrument or material which can remove something from whatever passes through it. Ceramic water filtration is defined as the process that makes use of a porous ceramic (fire clay) medium to filter microbes or other contaminants from water. The pore size of the ceramic medium is sometimes small enough to trap anything bigger than the water molecule. From the ancient times, water filters have evolved out of necessity, first to remove materials that affect appearance, then to improve bad tastes and further to remove contaminants that can cause disease and illness (Erhuanga *et al*. 2014). The ceramic pot filter was first developed by Dr. Fernando Mazariegos of the Central American Industrial Research Institute (CAIRI) in Guatemala to make bacterially contaminated water safe for drinking purpose. Ceramic filters were popularly used for centralized water treatment but in recent times they are being manufactured for point of use applications (National Academy of Sciences, 2008). From the ancient times people are using different water treatment technologies as they understand that water borne disease is more devastating than others.

In developing countries, different low cost water treatment techniques were frequently used. For instance, boiling, chlorination, solar water disinfection, natural coagulation and bio-sand filtration are used to remove water related disease causing microorganisms. Bio-sand filter can remove protozoa up to 100% (Palmateer *et al*. 1999). Some of the water treatment technologies have some adverse effect. Chlorine in water combines with natural organic compounds to yield substances such as trihalomethanes, haloacetic acids, and chlorophenols that exhibit potentially carcinogenic, teratogenic and mutagenic activities (Yang and Shang, 2004). This is an unavoidable phenomenon for the people of developing countries as they possess plenty of surface water such as rivers, lakes, non-protected springs and ponds. Most of this surface water is contaminated because most of the people near to the water sources use the water for washing clothes, bathing, and animal watering (Wiesner *et al*. 1987). The situation is worse in Bangladesh especially in coastal areas. Bangladesh is vulnerable to water insecurity partially because of its environmental circumstances. Being a low-lying deltaic country of exceptionally dense population, Bangladesh is susceptible to a variety of environmental stresses and natural disasters (Chowdhury 2010). These stresses can exacerbate the difficulties accessing potable water (Abedin *et al*. 2014). For example, south-west Bangladesh was severely impacted by cyclone Aila in 2009, many drinking water sources were inundated with saline tidal water that made drinking water unusable (Mallick *et al*. 2011).

The drinking water sources in rural Bangladesh are varied and included shallow groundwater obtained through tube wells, small ponds with or without pond sand filters (PSF), harvested rainwater and river water. All the water sources (except tube well) are highly contaminated with pathogenic bacteria and their contamination level increase with preservation period (Ansari *et al*. 2011). The water related disease caused due to exposure of unsafe drinking water (Omole *et al*. 2015). A lot of researches have been conducted for the treatment of surface water, but a very little are sustained due to high coast, proper maintains, background knowledge and availability of python. A sustainable, but cost effective water treatment technology is urgently needed for the coastal people. Therefore, we undertook this research to purify the contaminated surface water by using locally prepared low cost ceramic filter for the coastal people of Bangladesh.

MATERIALS AND METHOD

Components of ceramic filter

For filter preparation, the soil and rice husk were collected from Churamonkhati union of Jashore district. Three distinct types of ceramic filter were prepared with soil and rice husk. The percentage of soil and rice husk in ceramic filter was represented in Table 1. The main components of ceramic filter were ceramic filter core and earthen pot which was placed over a plastic storage tank by wooden stand. The mixing ratio of soil and rice husk was fixed depending on the filtration flax and flexural strength of ceramic bar prepared with different ratios.

Table 1. The composition of soil, rice husk and their sintering temperature for ceramic filter

Filter Type	Soil wt. %	Rice husk wt. %	Sintering temperature
1	90	10	900-1000^{0}C
2	85	15	900-1000^{0}C
3	80	20	900-1000^{0}C

Manufacturing of ceramic filter

Step 1: The soil was collected from the Churamonkhati union under Jashore district of Bangladesh. The soil was dried at 120^{0}C for 24 hours and grained with martyr piston and screened through 0.5 mm sieve (Fig. 1a). While rice husk was collected from local rice mill and screened through 1 mm sieve (Fig. 1b).

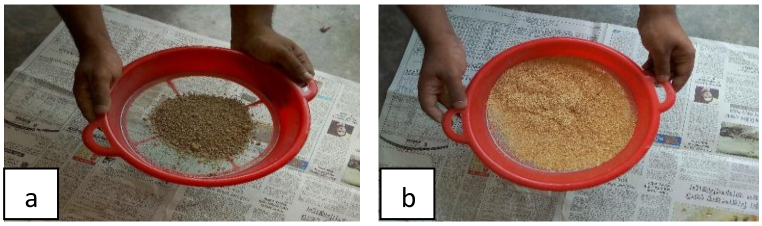

Fig. 1. Screening of (a) soil and (b) rice husk

Step 2: For one ceramic filter core 800 g of dry mixture was needed. For 10% rice husk mix ceramic filter, 90% of soil and 10% of rice husk were mixed homogeneously. For example 720 g of soil and 80 g of rice husk were combined with water to make dough.

Step 3: A wooden bar (height 9 cm and diameter 6 cm) and polyvinylchloride (PVC) pipe (height 11 cm and diameter 11 cm) was used to make ceramic filter core from the dough.

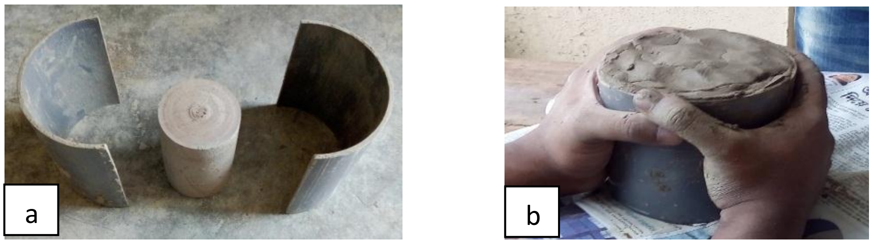

Fig. 2. The dice used for (a) ceramic filter core and (b) ceramic filter preparation

Step 4: At first the wooden bar of the dice was wrapped with newspaper. Then dough was placed around the bar of the dice and two pieces of PVC pipe were pushed by hand from both sides to make cylindrical shape. The extra soil was removed from upper side and made flat. The dice was removed and polished with water [Fig. 2 a, b].

Step 5: The resulting cylindrical ceramic filters core were hollow with one side open. The final ceramic filters had a height of 10 cm and a thickness of 2 cm. This raw filter was then dried in the sun for at least 3 days.

Step 6: Then, the air dried filters was burnt in potter kiln (Fig. 3a). The probable temperature of inside the potter kiln ranged from 900-1000^{0}C. The filter core was arranged in kiln with wood and other fuel. Then the outside of the kiln was sealed with mud and straw. The burning was continued for 6 to 8 h with wood, rice husk and the kiln was kept to cool down. The burnet filters cores were taken out (Fig. 3b) from the kiln and the quality tested.

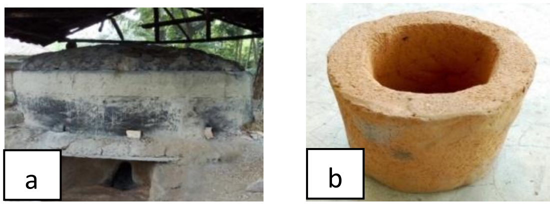

Fig. 3. The filter core burning in (a) potter kiln and (b) burnt filter core

Filtration unit setup

Step 1: The filtration unit was fixed in the earthen clay pot (Fig. 4a, b). The opening side of the ceramic filter was attached at the bottom of the clay pot using cement paste and kept for 1 day for drying.

Step 2: After drying, a 2 cm in diameter hole was made at the middle of the bottom of the clay pot to make the path of filtrated water during the running of the filter unit. Then the earthen clay pot was placed on the plastic bucket by using wooden stand (Fig. 4c) for using.

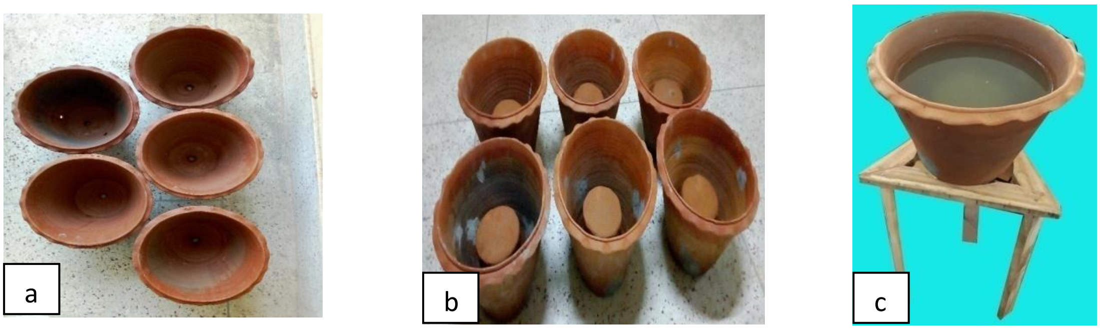

Fig. 4. Fixation of filtration unit to (a, b) clay pot and (c) placement to wooden stand

Water sample collection and analysis

Three different types of filter were prepared and each type was operated for 5 days with surface water. A total 30 water samples were collected from inlet and outlet of each types of filtration unit. The samples were collected in 250 ml plastic bottles. At first the bottle were washed with tap water and socked in 0.1 N HNO_3 for 24 h. For bacteriological analysis, the pots were sterilized by using oven. During sample collection, the bottles were prewashed and rinsed properly with sample water to avoid probable contamination. After collection of water samples, it was immediately carried to the Environmental Chemistry Laboratory, Department of Environmental Science and Technology, Jashore University of Science and Technology and analyzed. The turbidity was measured by using portable turbidity meter (HACH-2100Q; American Public Health Association; APHA, 1995). The numbers of total and fecal coliform were analyzed by membrane filtration technique (APHA 2006). The water quality data were analyzed by MS Excel 2010 and SPSS version 20.

RESULTS AND DISCUSSION

Flow rate: The filtration rate of ceramic filter significantly increases with increasing the percentage of combustible materials. The average filtration rate of 10% rice husk mix ceramic filter was 191.2 ml/h, while for 15% rice husk, the filtration rate was 424.48 ml/h. The highest filtration rate was found for 20% rice husk and the rate was 702.64 ml/h (Table 2). In first two types of filter, the filtration rate decrease with operational time but in type three it increases. Filters with larger number of pores per surface area have a greater flow rate, whereas filters with small pore number per surface area have lower flow rates (Halem 2006). The flow rate of ceramic filter reduces with operational time due to clogging by bacteria and turbidity of inlet water (Jackson and Smith, 2018). The flow rate is increased with increasing surface area in contract with water because more pore space will be utilized. For commercial purposes, it is possible to purify more water within short time by preparing large ceramic filter.

Table 2. Filtration rate of ceramic filter per hour (ml/h)

Filter code	Day 1	Day 2	Day 3	Day 4	Day 5	Average
1	229	174	193	166.2	193.8	191.20
2	418.2	394	437	415.8	457.4	424.48
3	607	764	751	687.4	703.8	702.64

Turbidity: The average turbidity of source water used for analysis was 1.47 NTU and treated water was 0.89 NTU. The average turbidity reduction performance of 10% ceramic filter was 56%, while for 15%, it was 40%. The lowest performance 24% was found in 20% rice husk mix ceramic filter (Fig. 5). In type 1 ceramic filter, turbidity removal efficiency slightly increases with operational time but in case of type 2 and 3 it increased significantly. The turbidity reduction performance of ceramic filter was increased with increasing soil percentage. Porosity of the ceramic filter is the basis for removal of particles in micro-size level resulting from physical processes such as clogging, inertia and adsorption. It is indicated that less porous ceramic filters could remove turbidity more efficiently (Sheikh and Islam, 2017). The pore sizes of ceramic water filters determine the ability to remove particles and pathogens from water (Bielefeldt *et al*. 2010).

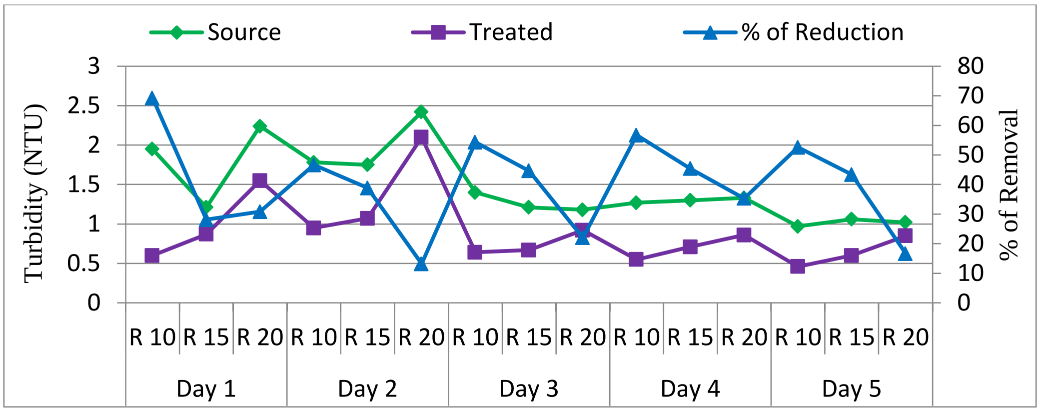

Fig. 5. Turbidity reduction efficiency of ceramic filter. R = Rice husk %; NTU: Nephelometric Turbidity Unit

Removal of total coliform (TC): The total coliform removal performance of type 1 ceramic filter in day 1 was 95%, while in day 2 it was 88% (Fig. 6). The trend continued and in day 5 it was 57% (Fig. 6). This indicates that bacterial removal performance reduced with operational time. The average performance of type 1 ceramic filter was 79.5%, while for type 2 the value was 76.1%. The performance of type 3 was relatively low (70.7%). The total coliform removal performance of type 2 filter was almost similar in its operational period but in case of type 3 it reduced gradually. The microbial removal efficiency of ceramic filters ranged from 80.00% to 97.50%. The microbial removal efficiency of the ceramic filters increased with increasing percentage of clay in the composition (Zereffa and Bekalo, 2017). The application of ceramic filter in addition with pond sand filter can remove 99% of pathogenic bacteria (Sheikh and Islam, 2017).

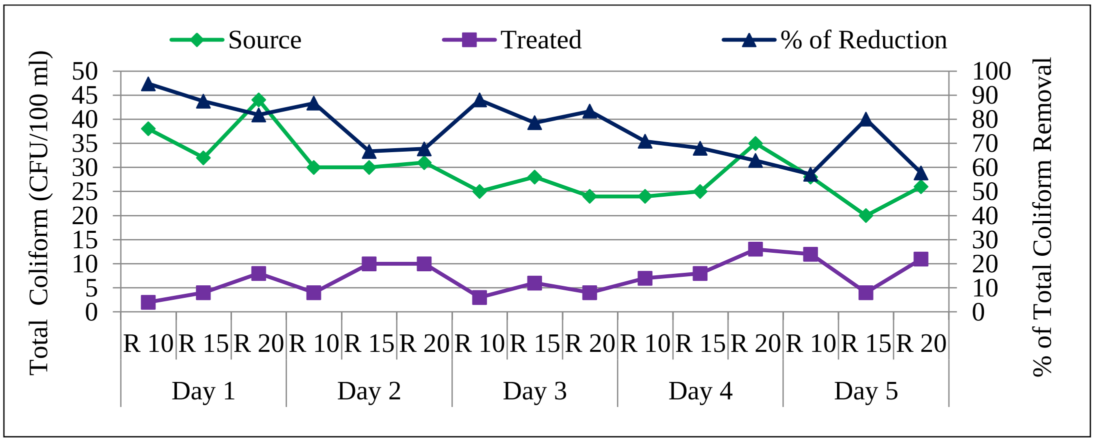

Fig. 6. Total coliform removal efficiency of ceramic filter. R = Rice husk %; CFU= Colony Forming Unit

Removal of fecal coliform (FC): The average fecal coliform removal efficiency of type 1 ceramic filter was 90.01% (Fig. 7). In day 1 it was 73% and in day 4 it was 78%, while in others 3 days it was 100%. The performance of ceramic filter reduces with increasing rice husk percentage. In the case of type 2, the average performance was 78.0%.

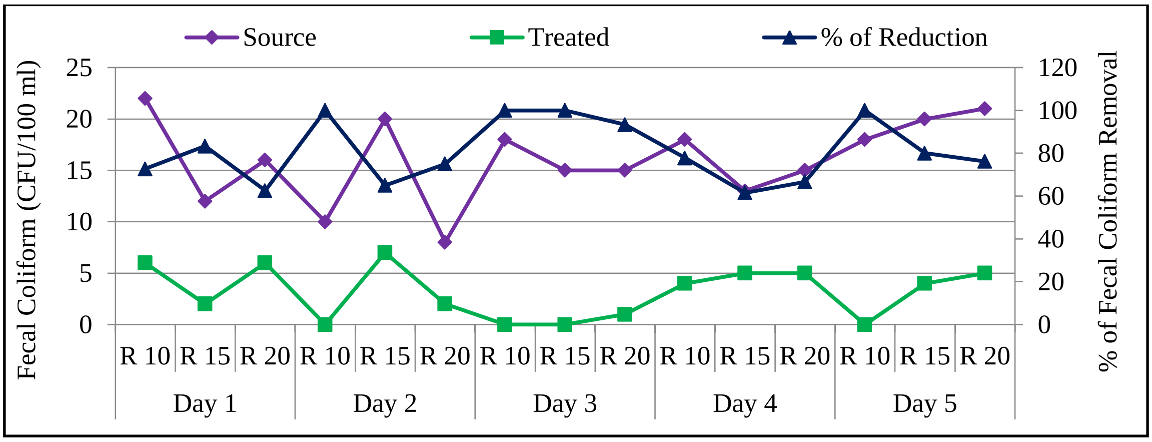

Fig. 7. Fecal coliform removal efficiency of ceramic filter. R = Rice husk %; CFU= Colony Forming Unit

The lowest performance was observed in the case of type 3 ceramic filter and the value was 74.7%. The fecal coliform removal performance in both type 2 and 3 ceramic filters was gradually increased with operational time. In all type of ceramic filter fecal coliform removal efficiency increased with operational time. A research conducted in 2014, reported that the average fecal coliform removal efficiency of ceramic filter was 78% (Erhuanga *et al*. 2014). The high performance of ceramic filter in fecal coliform removal observed in combined application with pond sand filter and the values varied from 95 to 98% (Sheikh and Islam, 2017).

ANOVA test Justification:

ANOVA is a statistical model, which is used to investigate significant mean and interaction effects of factors with respect to response. For estimating the individuals and interaction factors upon impacts strength the mean, SD (Standard Deviation), SE (Standard Error), *F*-test statistics and *P*-values are presented in ANOVA Table. 3. The results showed that, type 1 ceramic filter was the best for removing contaminants from inlet water. The filters performances gradually reduce with increasing rice husk percentage.

Table 3. Analysis of variance for filter type and contaminants removal efficiency

Removal Efficiency	Filter Code	Mean	SD	SE	F	Sig.
	1	56.00	8.12	3.63		
Turbidity (NTU)	2	40.00	7.14	3.19	19.41	0.00
	3	23.60	9.26	4.14		
	1	79.60	15.39	6.88		
Total coliform (CFU/100 ml)	2	76.40	8.85	3.96	0.67	0.52
	3	70.80	11.26	5.03		
	1	90.20	13.54	6.05		
Fecal coliform (CFU/100 ml)	2	78.00	15.31	6.85	1.79	0.20
	3	74.80	11.54	5.16		

N.B.: SD = Standard Deviation, SE = Standard Error

CONCLUSION AND FUTURE REMARKS

The highest flow rate 702.64 ml/h was found in 20% rice husk mix ceramic filter, while for 10% rice husk mix ceramic filter it was 191.2 ml/h. The flow rate of ceramic filter reduced with increasing soil percentage. The highest turbidity removal efficiency of type 1 ceramic filter was 56%. The TC removal reduction efficiency was the highest (80%) in 10% rice husk mix ceramic filter and the lowest (70%) was for 20% rice husk mix ceramic filter. The highest FC removal performance was 90% for 10% rice husk mix ceramic filter. It was concluded that, the overall performance of ceramic filter in removing contaminates from surface water was increased with increasing soil percentage or decreasing rice husk percentage. If we prepare large ceramic filter with low rice husk parentage than, it will possible to provide pathogen free available water to coastal people. The coastal people of Bangladesh face intense drinking water crisis due to groundwater salinity and ultimately they have to depend on surface water, which is highly contaminated with pathogenic bacteria. The poor coastal people are not economically solvent to use modern technique, but low coast ceramic filter would be the sustainable technology to provide pathogen free drinking water.

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