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Performance Evaluation of a Simple Ceramic Filter (SCF) Combined with Roughing Filter for Pond Water Treatment

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Abstract

The pond water was used for many non-productive purposes, such as cooking, bathing, ablution, and washing clothes and kitchen utensils. About 11% of people in rural areas use pond water for drinking purposes, and 77.14% of households use sweet pond water as a secondary source for drinking and cooking purposes in southern Bangladesh. Filtration is one of the easy options for pond water treatment. However, most filtration systems are either expensive or performance not so good. Ceramic filters are reported to be one of the best treatment options for reducing turbidity and bacteria. A low-cost, simple ceramic filter (SCF) was successfully applied for arsenic removal from groundwater, which was expected to be useful for pond water treatment to obtain drinkable water quality. The purpose of this study is to evaluate the effectiveness of color, turbidity, iron, and bacteria (total coliforms (TC) and Escherichia coli (E. coli)) removal by filtration units using SCF combined with roughing filter from pond water. The results showed that the filtration system was highly effective in reducing the turbidity, iron, total coliforms, and total suspended solids in the pond water, making it safe for drinking purposes. The percentage removal of TC by filtration unit was found to be 98% and *E. coli* by 99%. The filter unit also had good removal efficiency for turbidity (100%), color (98%), and iron (98%) from the raw pond water.

Keywords: *Filtration; pond water; ceramic filter, low cost, bacteria*

1 Introduction

Access to drinking water is essential for human well-being. Also, safe drinking water is a critical concern worldwide, particularly in developing countries. However, as a developing country, Bangladesh lacks safe drinking water access. Surface water sources, such as ponds, are often contaminated with microorganisms that can be accused of waterborne diseases in Bangladesh. About 11% of people in rural areas use pond water for drinking purposes, and 77.14% of households use sweet pond water as a secondary source for drinking and cooking purposes in the southern part of Bangladesh (Munnaf & Hassan, 2016). Moreover, most of the pond water is contaminated with various impurities, such as algae and pathogenic bacteria, which cause serious health effects (Knappett *et al.*, 2011). There are several types of filters commonly used in pond water treatment. Like, Simple Ceramic Filter (SCF), Roughing Filter (RF), Slow Sand Filter (SSF), Rapid Sand Filter (RSF), Pond Sand Filter (PSF), etc. SCF is a porous ceramic pot or cylinder that filters out larger particles and sediments from the water. It allows water to pass through the small pores in the ceramic material while trapping larger impurities. The SCF can successfully remove arsenic (Shafiquzzaman et al., 2011) and be applied to pond water treatment for the short term (Rahman & Nakajima, 2015). A Roughing Filter (RF) is a type of water treatment filter that is designed to remove larger particles and sediment from water before it undergoes further treatment. It was reported that natural materials such as stone, gravel, sand, soil, carbon, diatomaceous earth, agricultural byproducts, etc., are incorporated into the filtration system (Nkwonta & Ochieng, 2009). RF can be considered a major pre-treatment process for wastewater since they efficiently separate fine solids particles over prolonged periods without adding chemicals (Nkwonta & Ochieng, 2009). As pond water has fine solids, particle RF could be a good option for reducing fine solid particle load. The slow sand filter operates by allowing water to pass slowly through the sand bed, where physical, biological, and chemical processes take place to remove impurities. The filtration rate is 0.1-0.2 m^3 per m^3 per hour; bacteria can remove 95-99.9%, and turbidity and color remove 80-85% (Ahmed & Rahman, 2000). Rapid sand filters (RSF) include high filtration rates, compact design, and efficient removal of suspended solids. The filtration rate is 5-15 m^3 per m^3 per hour; bacteria can remove 8596%, and turbidity and color remove 80-85% (Ahmed & Rahman, 2000), which is unsuitable for bacteria removal. The average efficiency of RSF in removing microplastics was 50.48% (using bentonite) and 47.78% (without bentonite) (Sembiring *et al.*, 2021). Pond sand filter (PSF) is widely used in Bangladesh for pond water treatment. The performance of the pond sand filter (PSF) in laboratory analysis shows that the odor, color, pH, dissolved oxygen, hardness, calcium, magnesium, nitrate, sulfate, and phosphate of the PSFs water meet Bangladesh standards. The efficiency of PSF in reducing total dissolved solids (TDS) (15 %) and potassium (8.2 %) is not enough to meet the standard of 20 % PSFs for TDS and one-third PSFs for potassium. The study proves that PSF cannot remove coliform bacteria by 100 % from highly contaminated water. Hence, disinfection should be adopted before distribution to ensure safe drinking water (Harun and Kabir, 2013). This study aims to assess the filtration performance of SCF combined with RF for pond water treatment in the long term.

2 Methodology

The SCF was manufactured in a hollow cylindrical shape (one side closed), according to (Shafiquzzaman et al., 2011). One SCF was attached at the bottom of the 10-liter clay flowerpot for filter setup. The process of SCF setting is shown in Figure 1. In a single-compartment down-flow RF, three layers of stone of different sizes were placed, one above the other in the same compartment, with gravel size decreasing in the direction of flow. A 10 L flower clay pot was used for the RF compartment. The flower clay pot diameter was 32.5 inches at the top and 15.5 inches at the bottom. The sizes of stone used in the first, second, and third layers were 6.3 mm, 9.5 mm, and 14 mm, respectively (Nkwonta & Ochieng, 2009), and the volume of the first layer was 1.5 cft and the second and third layers were one cft. The layout configurations of the down-flow roughing filter are shown in Figure 2. For this study, SCF and RF were combined, as shown in Figure 3(a). First, the pond water pours into the roughing filter and then through the simple ceramic filter. Finally, the filtrate water is collected in a bucket. The detailed filtration processes are shown in Figure 3(b). The roughing filter helps remove larger particles, sediment, and debris, improving the efficiency of the subsequent filtration stages. After passing through the roughing filter, the water should flow into the simple ceramic filter. The simple ceramic filter effectively captures smaller suspended particles, pathogens, and other contaminants with its porous structure. Data collected from laboratory tests were analyzed using Microsoft Office Excel 2019. All of the data were analyzed by graphical analysis.

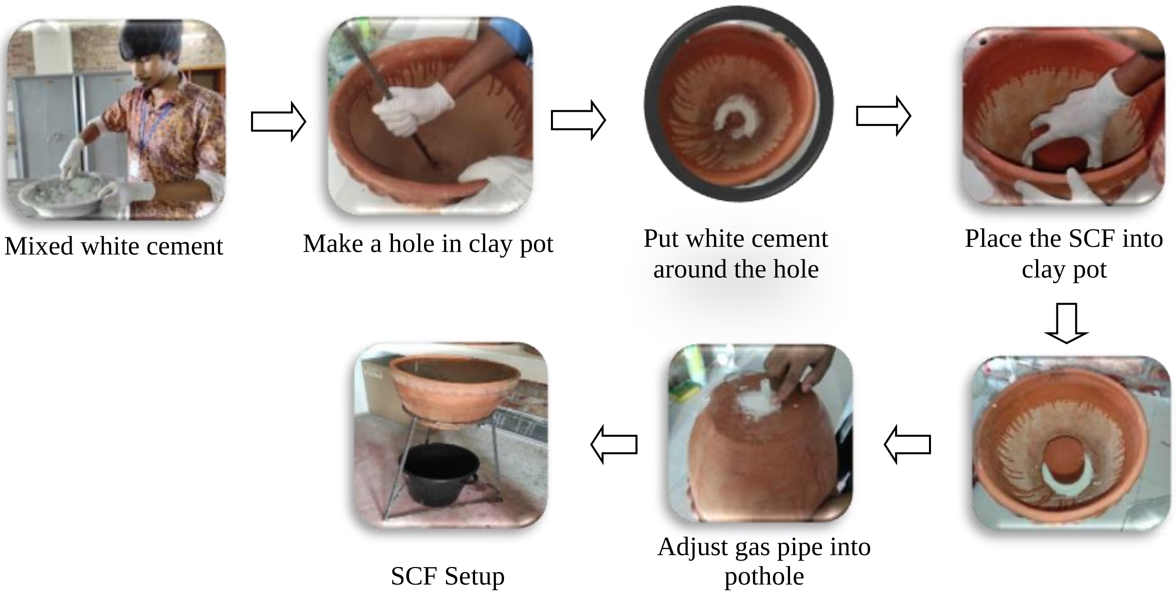


Figure 1: Simple Ceramic Filter Setup

Placing Stone layer   Three-layer stone placed   RF Setup

Figure 2: Roughing Filter Setup

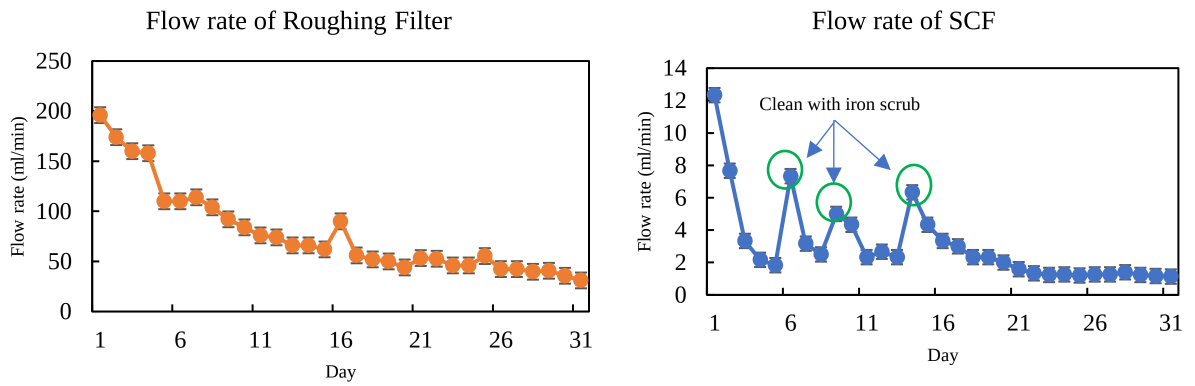
(a)   (b)

Figure 3: (a) SCF and RF Combined Filter Setup, (b) Filtration process of SCF combined RF

3 Result and Discussion

3.1 Physical Characteristics

The physical parameter of laboratory tests includes flow rate, pH, turbidity, and color. These physical parameters provide important information about the water's physical properties, aesthetic qualities, and suitability for various purposes. They serve as indicators of potential issues or contaminants in the water and help guide water treatment and management decisions. The flow rate of an SCF depends on factors like the ceramic material's pore size, the filter's surface area, and the pressure applied during filtration. Typically, SCF has relatively lower flow rates compared to roughing filters. The flow rates can range from a few liters per hour to several hundred liters per hour; roughing filters can have significantly higher flow rates than SCF, ranging from tens to hundreds of liters per hour. Figure 4 (a) shows that the flow rate of RF gradually decreases as there are different types of sediments present in pond water which reduce the flow rate. The average flow rate of RF is 78.24 (ml/min). In SCF, the flow rate also continuously decreased, but on days 6, 9, and 14, it was raised due to cleaning the SCF's body with iron scrub. However, the flow rate on the 7, 10, and 15 suddenly decreased due to high turbidity in the water. The average flow rate of SCF is 3.06 (ml/min). Figure 5 shows that the RF and SCF water pH slightly increased. Rahman and Nakajima (2015) also found the same results and concluded that an increase in pH depends on an increase in DO. Evaluating the performance of an SCF combined with an RF in treating the turbidity and color of pond water involves comparing the untreated water to the filtered water. In RF, turbidity and color were removed in seven days, 20-22% (turbidity) and 5-20%(color), and the rest of the days, no turbidity and color were removed because the pond water sediment accumulated into the RF stone. The turbidity and color increased after RF filtration after seven days as water passes into the RF, sediment is also transported along with the pond water. And in SCF, average turbidity and color were removed at 100% and 98%, as shown in Figure 6. Rahman and Nakajima (2015) found that turbidity removes more than 99% of the B-type filter (SCF).



(a) (b)

Figure 4: (a) Flow rate of RF, (b) Flow rate of SCF

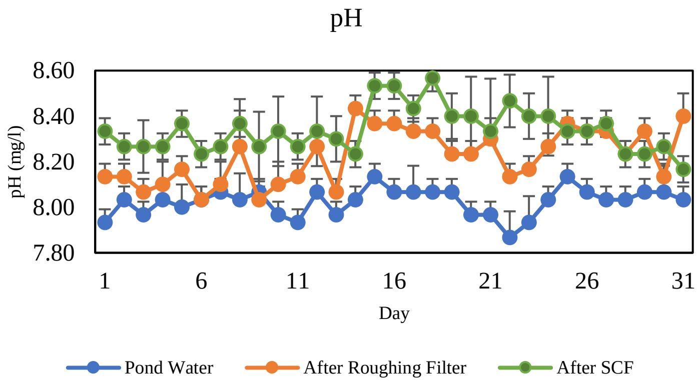


Figure 5: pH of pond water, RF and SCF

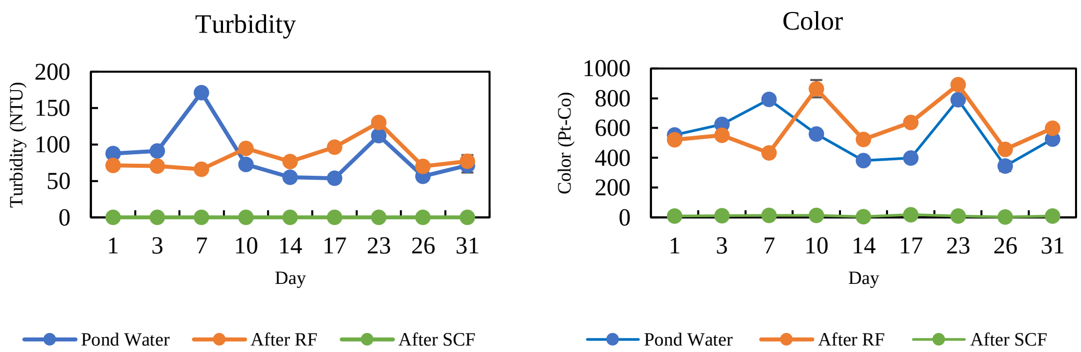


Figure 6: Turbidity and Color removal of pond water in RF and SCF

3.2 Chemical Characteristics

Various chemical parameters are measured in a laboratory test for water to assess its quality and composition. These parameters provide information about the presence and concentration of different chemical substances in the water. The chemical parameter of laboratory tests includes dissolved nitrite and iron test. These chemical parameters provide important information about the water's composition, potential contaminants, and suitability for various uses. Iron levels in water are an important parameter to consider when evaluating the performance of a simple ceramic filter (SCF) combined with a roughing filter in treating pond water. High iron concentrations can affect the taste, odor, and appearance of water, and it's desirable to reduce iron levels for better water quality. The iron test result increased the iron in the roughing filter, and after SCF, iron removes by 98%, as shown in Figure 7. Using a simple ceramic filter (SCF) for treating pond water, the alkalinity of the filtered water is generally expected to be similar to the pond water's alkalinity before filtration. This is because ceramic filters primarily function as physical barriers, removing suspended solids and larger particles from the water while preserving the water's chemical composition. And the roughing filter carries the same alkalinity as the water, as shown in Figure 8(a). The hardness of pond water and the filtered water after using a roughing filter and simple ceramic filter should generally exhibit little change, and their hardness levels are expected to be approximately the same unless other factors influence the water hardness, as shown in Figure 8(b).

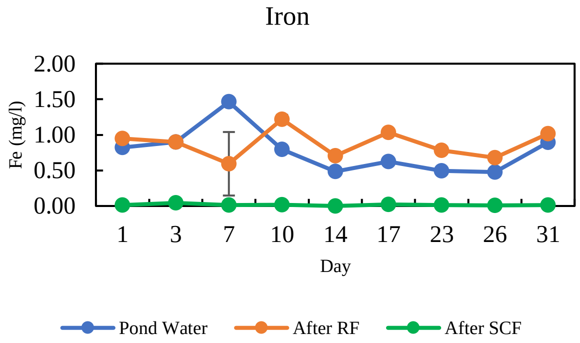


Figure 7: Iron removal of pond water in RF and SCF

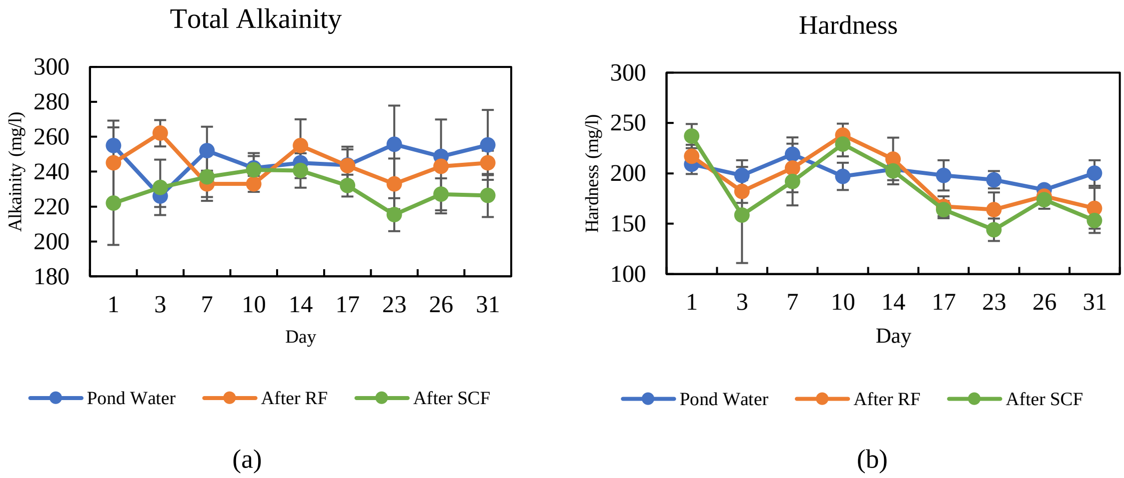


Figure 8: (a) Total Alkalinity and (b) hardness removal of pond water in RF and SCF

3.3 Biological Characteristics

In a laboratory test for pond water, various biological parameters are measured to assess the presence and abundance of microorganisms, as well as the overall biological health of the water. The biological parameters of laboratory tests include Total Coliforms and E-coli. These biological parameters help assess the biological health, ecological condition, and potential risks associated with water sources. They provide insights into the presence of microbial contaminants, fecal pollution, and overall water quality. Monitoring these parameters helps ensure the safety of water for human consumption, recreational activities, and ecosystem health. To assess the effectiveness of an SCF and RF in removing Total Coliforms (TC) and E-Coli from pond water, it is essential to conduct microbiological testing before and after filtration. In RF, as shown in Figure 9, TC was removed in the first seven days at 6-45%, and in the rest of the days, TC couldn’t remove, and the E-Coli removal in RF averaged 20%. In SCF, TC was removed, averaging 98%, and E- coli at 99%, as shown in Figure 9. The combined filter can not remove 100% TC and EC. So, the water that has been treated is not entirely safe. However, it can be utilized for domestic purposes and, in some circumstances, for drinking purposes, like in rural areas where people use pond water and flooding-affected areas.

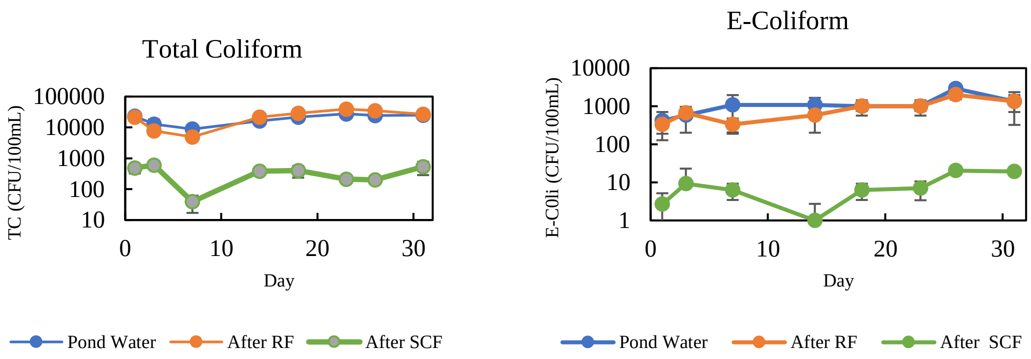


Figure 9: TC and E-Coli removal of pond water in RF and SCF

4 Conclusion

The study provides a simple ceramic filter (SCF) for treating pond water, which can yield positive results regarding water quality improvement. However, Roughing Filter (RF) is less effective for treating pond water. Evaluating an SCF combined with an RF using pond water revealed several important research findings. The research aimed to assess the effectiveness of the filtration system in improving water quality by evaluating various parameters:

- The combined use of the SCF and RF significantly reduced turbidity levels in the pond water. The filters effectively removed suspended particles, resulting in clearer water. The SCF can remove turbidity 100%.
- The filtration system showed a notable reduction in coliform bacteria, including total coliforms and E. coli. The overall filtration process removes TC at 98% and E-coli at 99%.
- The pH of the filtered water remained relatively stable and comparable to the original pond water.
- The color and iron are successfully removed in SCF, but the RF is useless for color removal. The overall filtration process removes color 98% and iron 98%.

The overall effectiveness of the filtration system depends on various factors, including the design and condition of the filters, the characteristics of the water source, and the specific parameters being evaluated.

5 References

Sembiring, E., Fajar, M., & Handajani, M. (2021). Performance of rapid sand filter – single media to remove microplastics. *Water Supply*, 21(5), 2273-2284. https://doi.org/10.2166/ws.2021.060

Harun, M. A., & Kabir, G. M. (2012). Evaluating pond sand filter as sustainable drinking water supplier in the Southwest coastal region of Bangladesh. *Applied Water Science*, 3(1), 161-166. https://doi.org/10.1007/s13201-012-0069-7

Knappett, P. S., Escamilla, V., Layton, A., McKay, L. D., Emch, M., Williams, D. E., Huq, R., Alam, J., Farhana, L., Mailloux, B. J., Ferguson, A., Sayler, G. S., Ahmed, K. M., & Van Geen, A. (2011). Impact of population and latrines on fecal contamination of ponds in rural Bangladesh. *Science of The Total Environment*, 409(17), 3174-3182. https://doi.org/10.1016/j.scitotenv.2011.04.043

Ahmed, M.F. & Rahman, M.M. (2000) Water Supply and Sanitation—Rural and Low Income Urban Communities. ITN—Bangladesh, Center for Water Supply and Waste Management, BUET, Dhaka, Bangladesh with Contribution from IRC, International Water and Sanitation Center, Delft, The Netherlands

Munnaf, M. F., & Hassan, K. M. (2016). *Installation of a simple water treatment unit at Kaligonj region and assessment of dalys lost due to diarrheoa*. In Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development (ICCESD 2016), 12~14 February 2016, KUET, Khulna, Bangladesh (ISBN: 978-984-34-0265-3), Paper ID: E449

Nkwonta, O. & Ochieng, G. (2009). Roughing filter for water pre-treatment technology in developing countries: A review. *International Journal of Physical Sciences*, 4(9), 455-463. https://academicjournals.org/ijps

Rahman, M. & Nakajima, J. (2015). Development and application of a pond water filtration unit using a simple ceramic filter in a rural area of Bangladesh. *Japanese Journal of Water Treatment Biology*, 51(4), 127140. https://doi.org/10.2521/jswtb.51.127

Shafiquzzaman, M., Hasan, M. M., Nakajima, J., & Mishima, I. (2011). Development of a simple, effective ceramic filter for arsenic removal. Journal of Water and Environment Technology, 9(3), 333-347. https://doi.org/10.2965/jwet.2011.333