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PERFORMANCE EVALUATION OF A CLAY CERAMIC FILTER FOR IMPROVING THE SURFACE WATER QUALITY

Anindha Ghosh[1], Mohammad Shafiul Azam[*1], Md Shafiquzzaman[2]

[1]Department of Environmental, Water Resources and Coastal Engineering, Military Institute of Science and Technology (MIST), Mirpur Cantonment, Dhaka-1216, Bangladesh.
[2]Department of Civil Engineering, College of Engineering, Qassim University, Buraydah, 51452, Saudi Arabia

Corresponding Author

ABSTRACT

In this study a Ceramic Filter (CF) was used to remove pathogenic bacteria and other contaminants from surface water. CF core was made by combining clay particles (80%) with rice husk (20%). It was burned at 900^0C in a muffle furnace and then fixed in a clay pot. To evaluate the efficacy of CF with that of a commercial filter, one was assembled from the local market. Three surface (lake) water samples were filtered for five days each and both filters were operated for 15 days. Both filters' flow rates were measured. Filtration rate of CF dropped from 809 mL/h to 647 mL/h (20% reduction). In case of commercial filter it dropped from 12,000 mL/h to 10,009 mL/h (17% reduction). The commercial filter had a much higher flow rate due to its larger pore size. Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Color, Hardness, Iron (Fe), Manganese (Mn), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform (TC), and Fecal Coliform (FC) were all measured in the filtered water samples. For water quality parameters, CF performed better than commercial filter in removing: Metals (Fe, Mn), Turbidity-related parameters (TSS, Color), Microbial contaminants (TC, FC) and Organic pollutants (BOD, COD). Commercial filter performed better in pH, EC, TDS and Hardness (likely due to differences in filter media). CF is cheaper and reusable after cleaning. Despite a slower flow rate, CF was highly effective at removing pathogens, metals, and organic pollutants, making it a low-cost, sustainable option for water purification in resource-limited settings. While the commercial filter has a higher flow rate, it is less effective at critical contaminant removal.

Key words: Ceramic Filter, Surface Water, Rice Husk, Water Quality, Commercial Filter

1. INTRODUCTION

The basic need of humans, water is as important as air and is tied to every type of life on the planet. Directly or indirectly, water is involved in every facet of daily life. Everyone, on a fundamental level, requires access to clean, sufficient, and safe water for drinking, cooking, personal hygiene, and sanitation facilities that do not compromise health. Pure, healthy, potable, and safe drinking water must be given. At the point of supply to the customers, the water must meet the necessary quality requirements in terms of its (chemical, biological, and physical) components.

According to (Hutton & Haller, 2004) and (Clasen et al., 2005), the water filtration process at the household scale offers a higher level and more affordable way to improve drinking water quality and lessen water-borne disease. Different low cost water treatment systems are frequently utilized in poor nations. For instance, water-related diseases can be eliminated by the use of bio-sand filtration, solar water disinfection, natural coagulation, and boiling. Unfavorable health impacts can result from some water treatment techniques. People in developing nations suffer the most since they have many surface water resources like rivers, lakes, and ponds that are tainted as a result of various human activities (Wiesner et al., 1987). Different environmental stressors and natural calamities might have an impact on Bangladesh (Chowdhury, 2010). The challenges in obtaining potable water may be made worse by these pressures (Abedin et al., 2014). The treatment of surface water has been the subject of numerous studies, but due to high costs, adequate upkeep, and lack of background information, very few of these studies are viable. In developing nations where chemical disinfection or boiling may not always be feasible or efficient, filtering technologies are becoming more and more prevalent (Colwell et al., 2003). The safe treatment of drinking water in poor nations is ceramic filters (CF), which are produced from materials that are readily available locally.

S.I. Akosile et al. looked into how well CF performed when clay and sawdust were mixed in different proportions. All of them demonstrated increased germ elimination effectiveness, but the best mixture was 50% clay to 50% sawdust blend. Clay-sawdust composite filters have been investigated for performance, and (Nnaji et al., 2016) reported that they removed SS, BOD, and TC with satisfactory results. Using clay, sand, wood sawdust, and silver nitrate as filters, (Fahriza et al., 2020) examined their effectiveness. Turbidity, hardness, E-coli, and TC were all reduced by the filter with good results. The effectiveness of the CF, which is formed from various percentages of clay to sawdust and is fired at various temperatures, was the subject of research by Bulta and Michael. As compared to the WHO criteria, the majority of the CF efficiently eliminated microorganisms from the contaminated river water. (Zereffa & Bekalo, 2017) determined the CF with 15% sawdust, 80% clay, and 5% grog burnt at 950°C or 1000°C demonstrated the best removal effectiveness of microbes, hardness, nitrite, and turbidity. Different ratios of clay granules and rice husk were used to create three different forms of CF by (Das et al., 2018). It was discovered that surface water effectively removed turbidity, TC, and FC. The major goal of this study was to manufacture a CF at a laboratory scale using clay and rice husk and to evaluate how effective it is at enhancing the quality of the surface water. Also to check CF's effectiveness compared to a locally available commercial filter.

2. METHODOLOGY

Manufacturing of Ceramic Filter Core

The manufacturing of the CF followed the procedure mentioned in Shafiquzzaman et al. (2011, JWET) and Hasan et al. (2012, WST). The clay soil was collected and filtered through a 0.420 mm sieve after being dried in an oven at 120^0C for 24 hours. Rice husk was collected from rice mill, which was then screened through a 1 mm sieve. For instance, to make dough, 720 g of soil and 80 g of rice husk were mixed with water. The dough was formed into a cylindrical CF core using a wooden dice bar which had hollow cores with an opening on one side. The finished CF was 10 cm in height and 2 cm in thickness. The filter was burned in a muffle furnace between 900°C and 1000°C.

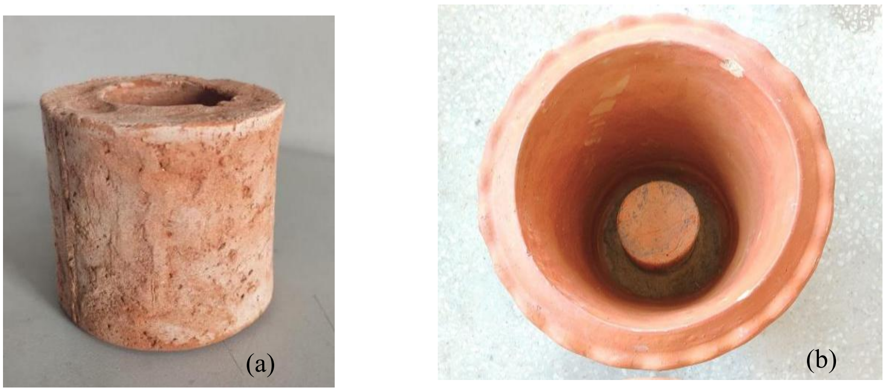


Figure 1: (a) Clay Ceramic Filter Core and (b) Filtration Unit

Ceramic Filtration Unit Setup

In the earthen clay pot (10 liter), the filtering system was fixed. Using cement paste, the opening side of the CF was affixed to the clay pot's base (Fig. 1) and left there for one day to dry. After drying, a hole with a diameter of 2 cm was drilled through the center of the clay pot's bottom to create the path that filtrated water would take as the filter unit ran. The earthenware pot was then set on the steel stand.

Commercial Filtration Unit Setup

People use typical commercial filter for guaranteed safe, clean drinking water, eliminating harmful bacteria and heavy metals. Filter core was collected from local stores. The filter core is made with activated carbon and circular in shape. Filter core was fixed at the bottom of earthen clay pot (10 liter) (Fig. 2) using glue paste and was kept for10 minutes for drying.

Water Sample Collection

From Mirpur Cantonment and Defense Officer’s Housing Society (DOHS) area, three separate surface water samples (10 liters each) were collected (Fig. 3) from 3 locations. There is one sampling point per lake where the local people has easy accessibility and use this water for their daily life. We have collected water sample from surface depth and fully filtered all the water samples. In order to prevent any contamination, the bottles were adequately pre-washed and rinsed with sample water throughout the sample collection. Water samples were taken immediately to Environmental Engineering Laboratory of Military Institute of Science and Technology (MIST) for analysis.

Analytical Procedure

A microcomputer pH meter from HANNA instruments (HI9024) was used to monitor pH. The following parameters were examined using a UV-Vis laboratory spectrophotometer (HACH DR-6000, USA): TSS, color and COD (after digesting the sample in a digester). Utilizing the typical DO meter and incubator, BOD was measured. The membrane filter method was used to measure both TC and FC.

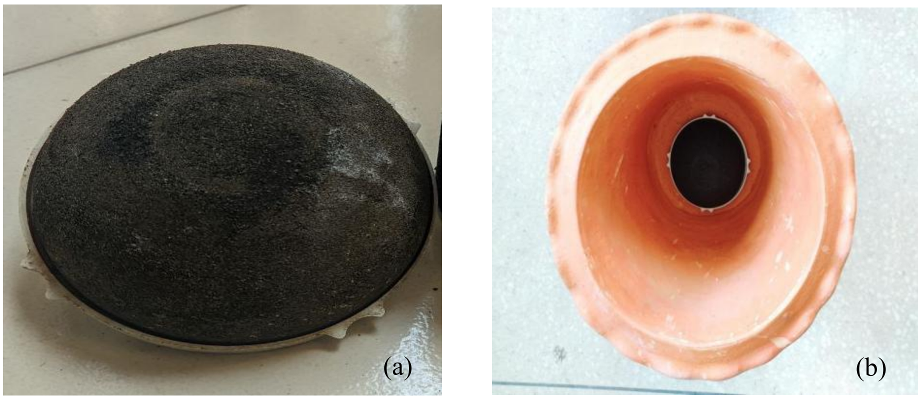


Figure 2: (a) Commercial Filter Core and (b) Filtration Unit

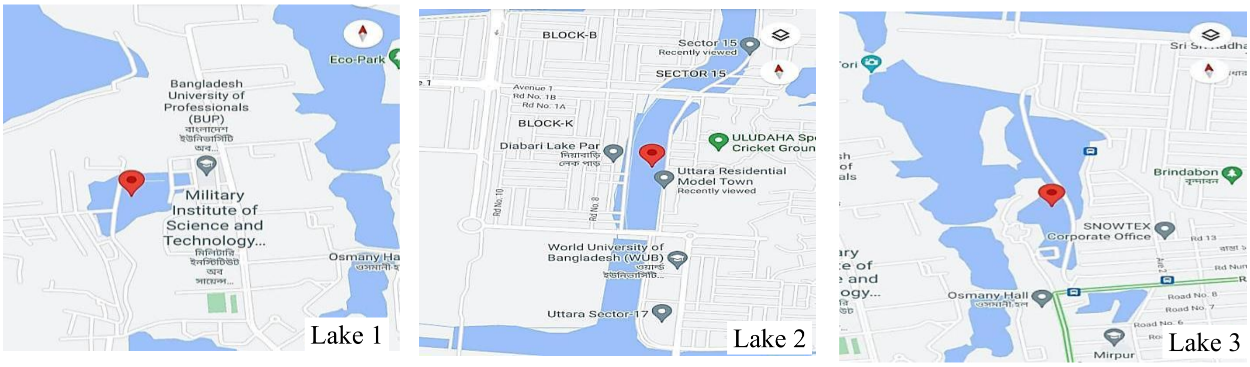


Figure 3: Location map of water sample collection points

RESULT AND DISCUSSION

Characteristics of Raw Water Samples

The raw water quality of the three lake water samples is shown in Table 1. Twelve quality criteria were determined for both the pre- and post-filtration values. Lake 1 has the most balanced profile of the three, with moderate levels of most contaminants. Its main concern is the presence of fecal coliforms. Lake 2 is the most contaminated, with high levels of manganese, electrical conductivity, TDS, and TSS, in addition to fecal contamination. Its EC and TDS are roughly double those of Lake 1. Lake 3 is notable for having the highest hardness and color, along with detectable fecal contamination.

Table 1: Quality parameters of raw water used in the study

Parameter	Lake 1	Lake 2	Lake 3
pH	8.15	7.49	7.12
EC (µS/cm)	342	654	512
TDS (mg/l)	164	319	248
Hardness (mg/l as $CaCO_3$)	112	59	136
Fe (mg/l)	0.41	0.37	0.35
Mn (mg/l)	0.04	0.91	0.14
TSS (mg/l)	28	42	23
Color (Pt-Co)	184	211	241
DO (mg/l)	6.5	7.1	6.8
BOD (mg/l)	1.74	2.03	1.90
COD (mg/l)	36	53	34
TC (cfu/100ml)	44	35	38
FC (cfu/100 ml)	12	8.0	10

Flow rate

The CF was used to filter water from three different surface sources for a total of fifteen days. In figure 4, the flow rates are displayed. For every sample of surface water, the flow rate was decreased. The flow rate was 809 ml/h on the first day and 647 ml/h on the fifteenth. One significant element that could affect the flow rate is the filter's pore size. As the filter was run continuously, the suspended solids (SS) and bacteria from the water samples might eventually clog the filter pores and flow rate of the filter reduces with operational time (Jackson and Smith, 2018).

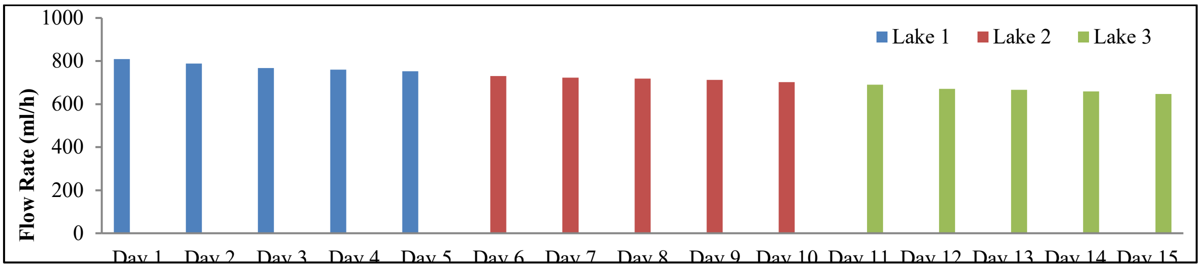


Figure 4: Flow rate of three surface water samples through CF

Ceramic Filter efficiency

The percentage of water quality parameters removed following filtration through the CF is displayed in Table 2.

Metals (Fe and Mn): The removal of iron (Fe) was consistently high (83% to 91%). Manganese (Mn) removal was also strong, with 86% in Lake 1 and 93% in Lake 3, and an impressive 100% removal in Lake 2.

Color and Total Suspended Solids (TSS): The filter showed excellent performance in removing substances that cause color and turbidity. Color removal ranged from 91% to 99%, while TSS removal was consistently high, ranging from 86% to 91%.

Biochemical Oxygen Demand (BOD): The filter's performance for BOD was less consistent, ranging from a moderate 66% in Lake 1 to a lower 50% and 52% in Lake 2 and Lake 3, respectively. This suggests the filter is less effective at removing certain biodegradable organic matter compared to other contaminants.

Chemical Oxygen Demand (COD): The filter was very effective at reducing COD, with removal rates between 93% and 97%.

Total Coliforms (TC) and Fecal Coliforms (FC): The filter achieved a perfect 100% removal of TC and FC in all three lakes, indicating its strong capability as a barrier against bacteria and other biological contaminants.

Table 2: Filtration results for three surface water samples through CF

Parameter	(%) of Removal		
	Lake 1	Lake 2	Lake 3
Fe	83	86	91
Mn	25	100	93
TSS	89	86	91
Color	99	94	91
BOD	66	50	52
COD	96	93	97
TC	100	100	100
FC	100	100	100

Comparison with Commercial Filter Unit

The comparative analysis of water quality parameters removal through CF and commercial filter are shown in figure 5.

Color: The CF is far more effective than the commercial filter at removing color from the lake water. Since the pore size of the commercial filter is larger than the CF, the commercial filter cannot remove much color.

Total Suspended Solids (TSS): TSS in surface water indicates the presence of particles that are larger than 2 microns. As the pore size of the CF is around 1-5 micro meters, TSS has been removed so well by CF.

Iron (Fe): Dissolved ferrous iron (Fe^{2+}) is oxidized to insoluble ferric iron (Fe^{3+}) particles, often by aeration and then the CF's microspores physically trap these particles, removing them from the water.

Manganese (Mn): Certain bacteria naturally oxidize Mn, and their growth can be encouraged on the filter's surface to create a biologically active layer that oxidizes Mn into solid MnO_2. CF physically traps the solid particles.

Biochemical Oxygen Demand (BOD): CF removes BOD primarily through physical filtration and biological degradation. As the pore size of the CF is smaller than the commercial filter, the CF removed much amount of organic materials from the surface water.

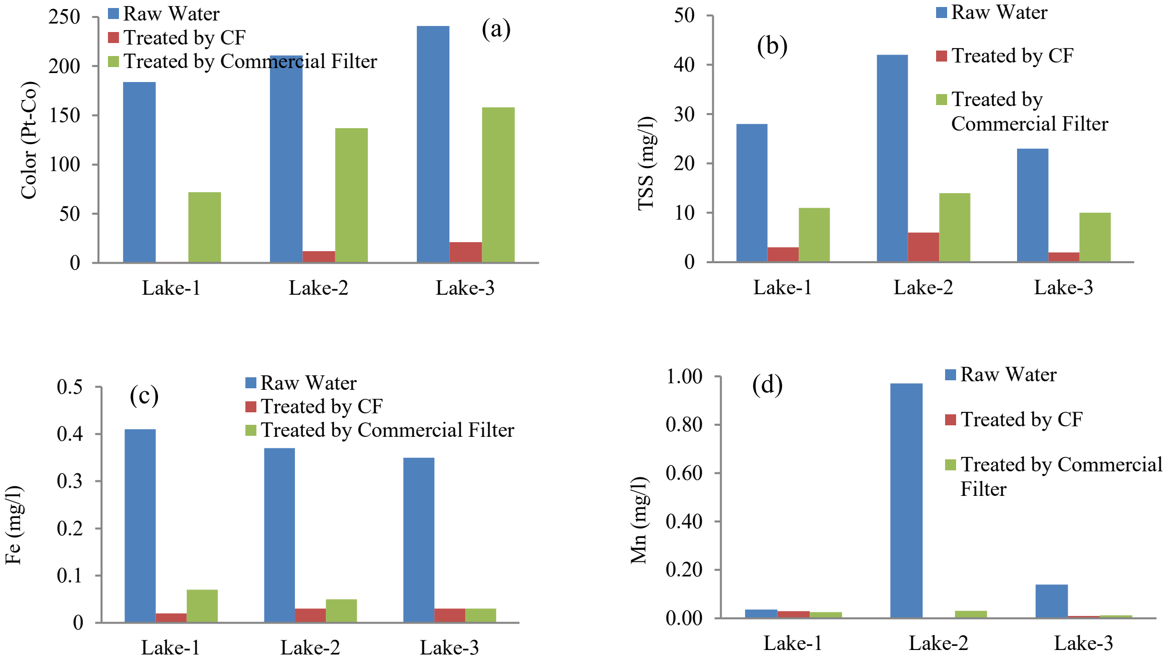
Chemical Oxygen Demand (COD): COD removal efficiency of both filters was 100%. CF primarily removes COD through the physical trapping of solids and the adsorption of organic compounds.

Total Coliform (TC): CF performed better than commercial filter for TC removal, due to physically trapping bacteria in their microscopic pores.

Fecal Coliform (FC): CF removes fecal coliforms by physically trapping them through a fine pore structure, a process known as size exclusion. The small pores in the ceramic material act as a physical barrier, blocking bacteria like fecal coliforms from passing through.

***pH*:** pH of the filtered water from commercial filter was decreased than raw water while it increased in CF due to the introduction of minerals from the CF itself.

***Electrical Conductivity (EC)*:** When filtration through a CF increases EC, because the filter is leaching minerals into the water. A higher concentration of dissolved ions and minerals results in higher EC. In all three samples, the commercial filter successfully reduced the EC, indicating that it effectively removed a portion of the dissolved charged particles, such as salts and minerals, from the water.



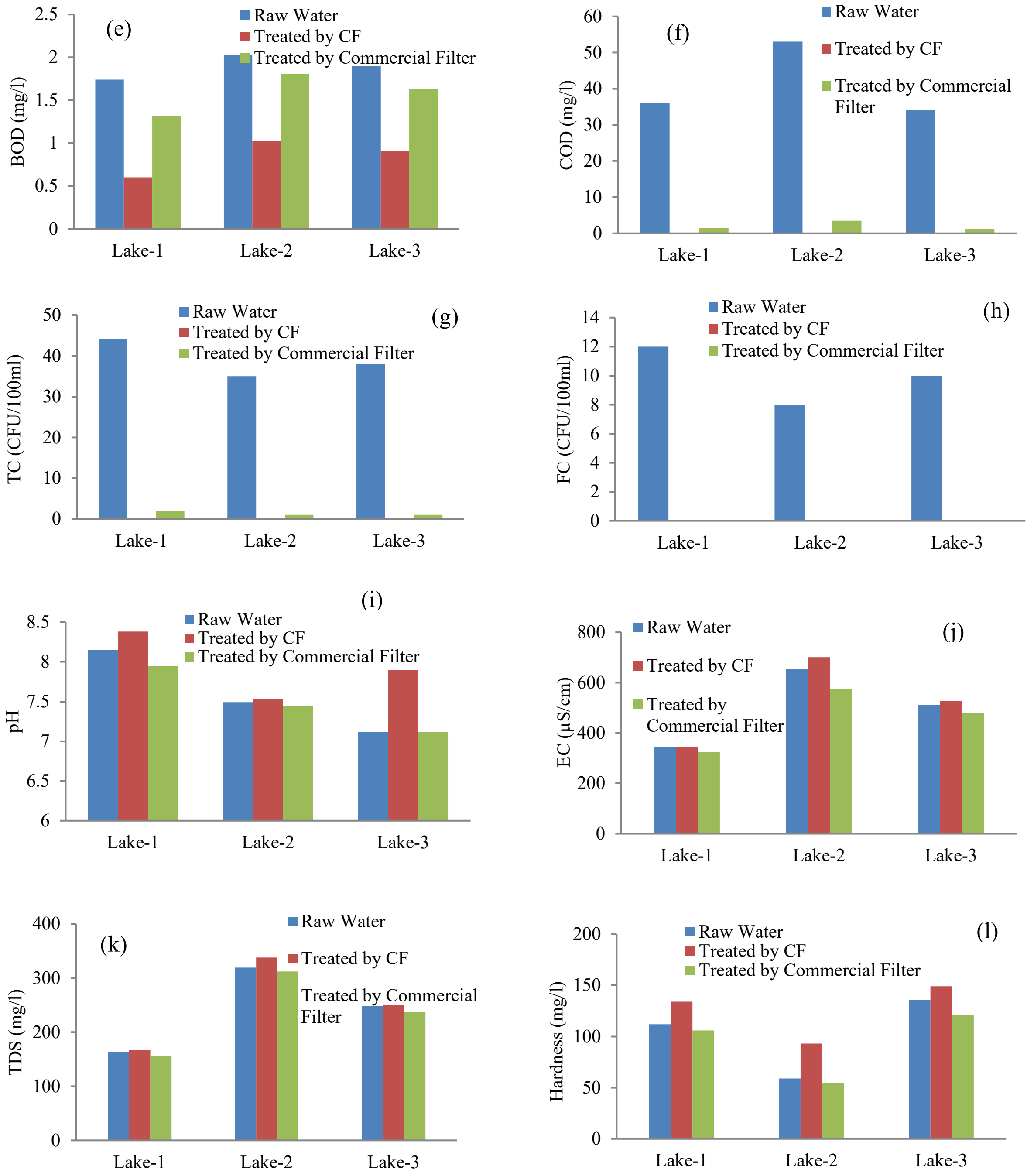


Figure 5: Comparison of water quality parameter removal between CF and Commercial Filter (a) Color (b) TSS (c) Fe (d) Mn (e) BOD (f) COD (g) TC (h) FC (i) pH (j) EC (k) TDS and (l) Hardness

Total Dissolved Solids (TDS): The clay used to make a CF naturally contains minerals like feldspar and mica, which contain sodium, calcium, and magnesium. During filtration, these minerals can leach out of the ceramic body and dissolve into the water, increasing its TDS level.

Hardness**:** Hardness of filtered water in CF increased than raw water primarily due to the filter's composition or the presence of additional mineralizing media.

CONCLUSION

The flow rate of both filters reduces with operational time due to clogging by bacteria and suspended solids of inlet water. Flow rate reduction of CF was 20.02% and the commercial filter was 16.59% in total 15 days. Though the value of some water parameters (pH, Electrical Conductivity, Total Dissolved Solids, Hardness) was more than commercial filter but they were within the acceptable limits. Continuous use of ceramic filter could reduce it. Efficiency of CF was better than commercial filter (Color, TC, FC, BOD, COD, TSS, Fe and Mn). Based on the overall performance, the CF could be used to improve SW quality.

Declaration of Use of AI

During the preparation of this work, the author(s) did not use any AI tools and used Google for sentence structure and language refinement. The author(s) take full responsibility for the content and accuracy of this published article.

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