Forscher Publication

Water and Environmental Sustainability
ISSN: 2710-3404
DOI: 10.52293/WES.2.1.18
H o m e p a g e: https://www.journalwes.com/

Water & Environmental Sustainability

Research paper

The Modified Biosand Filters for Water Treatment

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A R T I C l E I N F O

Keywords:
Modified biosand filter (MBSF)
Iron oxide-coated gravel (IOCG)
Biosand filter (BSF)
Most Probable Number (MPN)
Colony forming unit (CFU)

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Received: 15 November, 2021
Accepted: 12 February, 2022
Available online: 25 March, 2022

A B S T R A C T

One of the most promising and accessible technologies for household water treatment is biosand filtration. The biosand filter is an intermittently operated slow sand filter at little scales. In this investigation, a series of laboratory scale was conducted by introducing a 10 cm thick layer of iron oxide coated gravel with three layers of underdrain were utilized to remove conductivity, turbidity, hardness, manganese, E. coli, total coliform, faecal coliform from the kabini river water and ground water. The experiments were performed to analyse the performance of the modified biosand filter with household biosand filter as far as their decrease in evacuating under various working conditions. For BSF, the removal efficiencies were found to be 83.3-81.8% for turbidity, 55.6-50.2% for hardness, 40.4-55.67% for manganese, 95-98% for Escherichia coli CFU/mL,80-75% for faecal coliforms. The removal efficiencies of MBSF were found to be 60.6-70.2% for turbidity, 40.2-50.2% for hardness, 40.5-30.3% for manganese, 98.3-99.2% for Escherichia coli CFU/mL,85.3-80.1% for faecal coliforms. The initial concentration of kabini river water for turbidity 19±1.2 NTU; hardness 430±30; manganese 0.22±0.2; Escherichia coli 3850±736 CFU/mL; faecal coliforms 380±45 MPN/100 mL; pH 7.64±0.4 and ground water for turbidity 12±4.3 NTU; hardness 360±30; manganese 0.18±0.2; Escherichia coli 3850±736 CFU/mL; faecal coliforms 240±45 MPN/100 mL; pH 7.36±0.3.

Introduction

Water normally contains many living things. Some are harmless and others can make people sick. Living things that cause infection are known as pathogens. As per the World Health Organization (WHO) 423 million individuals are use water from wells and springs and 159 million individuals are utilizing untreated surface water around the world (WHO 2017). Diarrhoea and other waterborne diseases from exposure to microbial pathogens in hazardous water comprise a major risk to health. The World Health Organization suggests point of use (POU) household water treatment as a mediation to address the need, drawing on appropriate low-cost technologies (Jeannie Darby et al., 2011). Dr. David Manz developed a household biosand filter in the 1990s at the University of Calgary, Canada. This system was developed by slow sand filter (CAWST 2009). The filter design consists of gravel, pea gravel and sand layers respectively. Physical and biological treatments are the top of the sand breaks prey on microorganism and particles are stained out by sand from water. For BSF, the removal efficiencies were found to be 83.3-81.8% for turbidity, 55.6-50.2% for hardness, 40.4-55.67% for manganese, 95-98% for Escherichia coli CFU/ml, 80-75% for faecal coliforms. The removal efficiencies of the modified biosand filter were found to be 60.6-70.2% for turbidity, 40.2-50.2% for hardness, 40.5-30.3% for manganese, 98.3-99.2% for Escherichia coli CFU/ml, 85.3-80.1% for faecal coliforms. Iron oxide amended small scale glass column biosand filters removed $5\log_{10}$ MS2 and a Full-scale biosand filter with iron particles removed $4\log_{10}$ MS2 for the duration of the experiment (Anthony Straub et al., 2011). Modified biosand filters enriched with iron oxide coated gravel to remove chemical 92.66%– 96.37% for turbidity, 99% - 98.2% for Cu, 99.12% - 99.06% for Zn, 98.17% - 94.03% for Ni, 95.27% - 92.33% for Fe(II) for influent metal concentration of 2 and 5 mg/L individually, 45.18% for COD, 48.36% for TOC, 98.07% for E. coli and 94.21% total coliforms. The removal efficiencies of contaminants in the modified biosand filter with iron oxide coated were observed to be 90.54%– 95.84 % for turbidity, 99.27% - 98.52 for Cu, 99.1 - 99% for Zn, 98.61% - 94.52% for Ni, 95.28 - 92.23% for Fe (II) for 2 and 5 mg/l influent metal focuses individually 49.29% for COD, 49.65% for TOC, 99.0% for E. coli and 95.33% for absolute coliforms (Banu Siziric et al., 2018). Bacterial, viral and turbidity removal by intermittent slow sand filtration removal of bacteria (98.5%) and mean 0.94 log removal of MS2 viruses (88.5%) were achieved (Marion Jenkins et al., 2011). Performance assessment of modified biosand filter with an extra disinfection layer removal efficiency is a 91.29% decrease (log 1.43) altogether coliform a 98.7% decrease (log 2.6) in E. coli and 88.71% decrease in turbidity were watched for the control. There was a 90.11% decrease (log 1.41) in coliform, 98.2% decrease (log 2.25) in E. coli and 88.5% decrease in turbidity for MBSF metal. A 96.93% decrease (log 1.81) altogether coliform 97.33% decrease (log 2.36) in E. coli and 91.5% decrease in turbidity (Yildiz et al., 2016) biosand filters have been used generally as a productive, reasonable, and suitable innovation for expelling particles and microbial hazards from filtered water at household level in developing countries and rural communities (Duke et al., 2006 Murphy et al., 2010; Banu sizirici yildiz et al., 2016). In the absence of access to safe drinking water sources decentralized drinking water permits allow the improvement of the quality of potable water for poor people by treating it at the domestic level. Thus, ensuring the safety of their drinking water (Sobsey et al., 2002). One such promising decentralized drinking water treatment innovation on the household scale is the biosand filter (BSF) the sand filter containing some additional biological material as filtration media (Murcott et al., 2002). A million people worldwide depend on BSF for the provision of safe drinking water. Therefore, the purpose of this study is to investigate the performance of modified biosand iron oxide enriched with iron oxide coated gravel (IOCG) to remove turbidity, hardness, manganese and reduces E. coli, total coliforms and other pollutants, thus, improving drinking water quality

Material and Method

1. Filter Set up

Two biosand filters were used in this study, a biosand filter (BSF) and a modified biosand filter (MBSF). The capacity of plastic containers 30littersis acquired from the local market were used for installing the filters. The containers were first cleaned with tap water and were filled with 5 cm deep underdrain gravel 12.5 mm in size. Locally available river sand was collected and sieved passing through a 1.18 mm sieve and retained on 0.150 mm of sand was used in the present study as filter media. The sand was washed several times using tap water until the wash water became clear. 5 cm of coarse sand was used (1.18–4.75 mm size) separation layer and 40 cm of fine sand (0.150-1.18mm size) layer in succession (Banu sizirici et al.,2018) In the case of the modified biosand filter, the 40-cm sand layer included a 10-cm iron oxide coated gravel (IOCG) layer in the middle of the sand layer. The filtration and gravel size water was present in the containers before loading the filter media to avoid any occurrence of air spaces and short circuiting. A plastic diffuser plate was placed on the top of the filter to avoid disturbance to the top layer of sand during daily charging of the filter with raw water. A Schematic diagram of the filter is presented in Figure 1. In the case of a modified biosand filter (MBSF) a 10-cm thick layer of iron oxide-coated gravel was introduced in the middle of the sand filter media (Banu sizirici et al.,2019; Komal Devra et al.,2011).

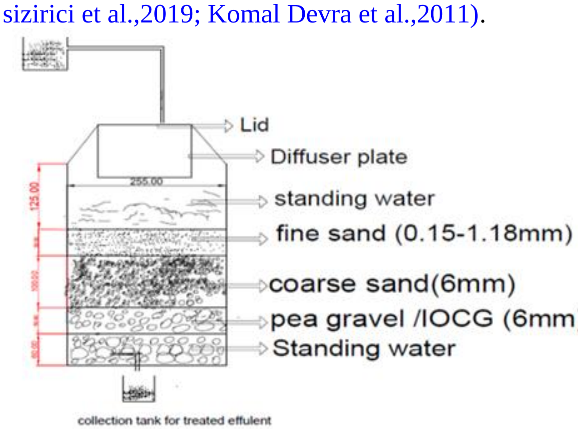


Figure 1. Schematic representation of the BSF and MBSF treatment experimental set up

2. Preparation of Iron Oxide Coated Gravel

Local pea gravel of size 4mm was used in this study. Gravel was washed thoroughly with the tap water until the runoff was clear and over dried at 90 ^{0}C. The gravel was soaked in 6 % nitric acid solution for 6 h and rinsed with deionized water (DI) pH 7.2 was maintained and dried at 105 ^{0}C. In preparation for surface coating. 5.6 M $Fecl_2$ was prepared by dissolving $Fecl6H_2O$ in DI water. Nine hundred millilitres of the gravel was mixed with 450 ml of 3.5 M $FeCl_2$ and 1 ml of 12 mole of NaOH. The sample was dried at 150 ^{0}C for 48 h and coated gravel was stored in glass sample bottles. The surface photographs and energy dispersive X-ray spectroscopy (EDX) graphs of clean gravel and iron oxide coated gravel were taken by ZEISS field emission scanning electron microscope (SEM). Fig. 2 shows the surface photographs of clean gravel (Yildiz et al., 2011).

3. Water Sample Collection

Water from two different sources was used in the study: i) Ground water collected from Vivekananda Nagar, Mysore ii) Kabini river water from an irrigation canal near Mysore.

4. Filter Operation

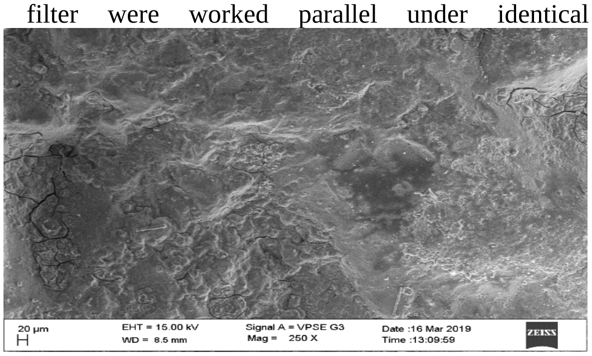
Two filtration, one with river water and the other with ground water as influent were conducted sequentially. Biosand filter and a modified biosand filter were worked parallel under identical conditions. The filters were fed with the raw water once in three days. The capacity of filter is 35 liters, since capacity of the filter could hold just around 8L. The test was conducted at room temperature. Furthermore, water temperature varied in the range of 24–32°C during the testing period.

5. Physicochemical Analysis

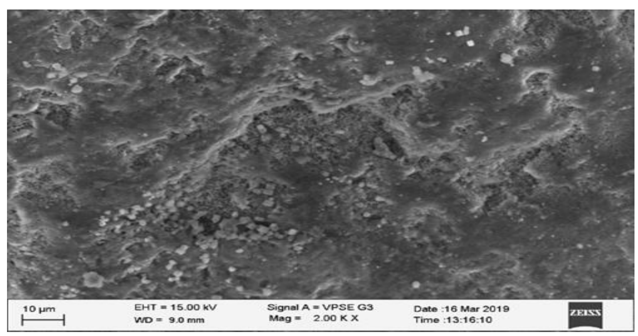
Grap samples were collected from the outlet of the tube weekly two days a week and tested immediately for pH, hardness, conductivity, manganese. The pH of the samples was measured using a digital pH meter. Hardness was measured using titration method. The instrument was standardized using the solution prepared and measure the conductivity. Manganese was measured using pyrosulphate method. Table 1 shows characteristics of the water used in different test.

6. Data Analysis

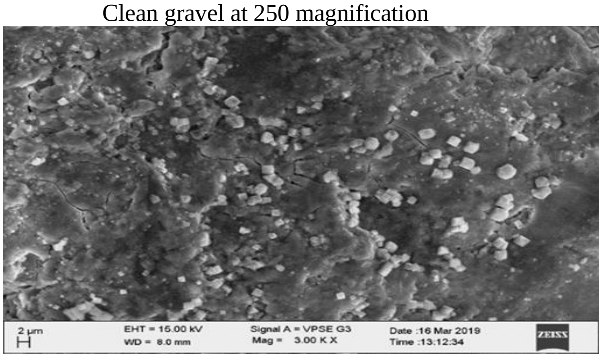
All estimations were run in duplicates and the arithmetic mean, standard deviation and least and maximum values were determined for all data sets. Percent removal values were calculated according to *(influent-effluent)/influent x100)Log*. Reduction was determined in addition to percent removal for E. Coli and total coliforms removal (Rashid Alawadi et al.,2019). Figure 2 shows the SEM images of clean and coated gravel at different magnifications.



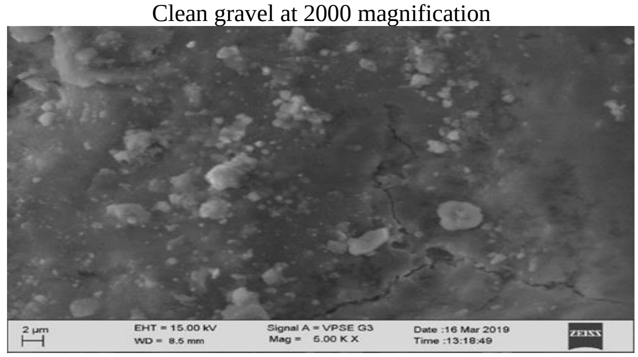
Clean gravel at 250 magnification



Clean gravel at 2000 magnification



IOCG at 3000 magnification



IOCG at 5000 magnification

Figure 2. SEM images at different magnification

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7. Bacterial Analysis

All analyses were carried for one hour after sample collection. Identification of reasonable E. coli was determined by a plate count method using macConke agar. The concentrations of total coliforms and faecal coliforms were determined by the most probable number method (MPN). Lauryl tryptose was used for the presumptive test of faecal and coliforms, broth brilliant green bile broth were used for confirmation test analyses of faecal and total coliforms. The dilutions needed for plating and most probable method test was estimated based on expected removal. Incubate for 24hr at 37^0c for developing colonies. The result is expressed as colony forming units per ml (CFU/ml) and most probable number per 100mg/l. Table shows the characteristics of water used during different tests.

Table 1. Characteristics of the water used in different tests

Parameter	Canal water	Groundwater
Turbidity(NTU)(n:9)	19±2.3	20±1.2
pH(n:9)	7.5± 0.4	7.8±0.2
Hardness(mg/Las $caco_3$)(n:9)	520±30	450±20
Manganese(mg/L)(n:9)	0.19±0.2	0.18 ±0.1
E.coli(CFU/m L)(n:9)	3615 ± 30	Not detected
Faecal coliform(MPN/mL)(n:9)	385±20	Not detected

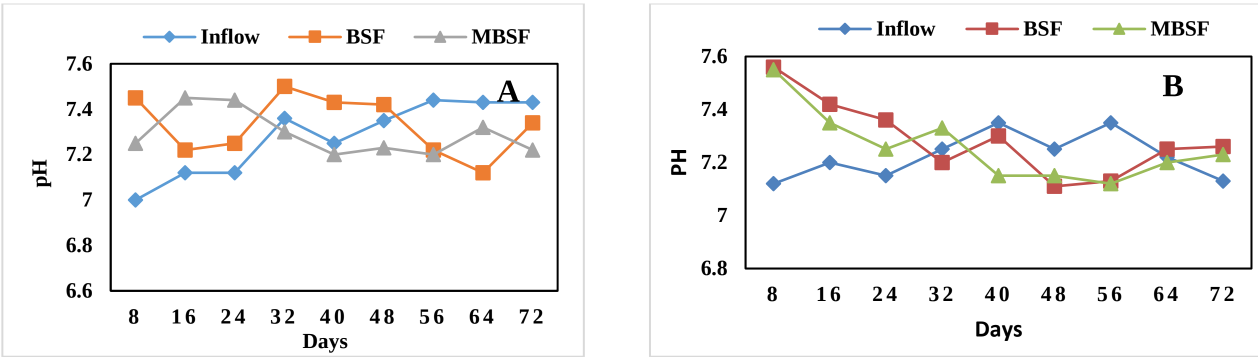
Result and Discussions

1. Flow Rate

Figure 3 shows the changes in filtration rates for the two filtration runs. The initial flow rate of about 1.2 L/min was maintained in the both filters. It was observed that the flow rate was decreased to 0.35 L/min for both the filter. A decrease in the flow rate is expected because of filter maturation and molecule accumulation. The filter charged 5-L day by day charge, it took around 6 min pass through the filter and it expanded to around 20 minutes with the most recent day of activity because of expanded head loss.

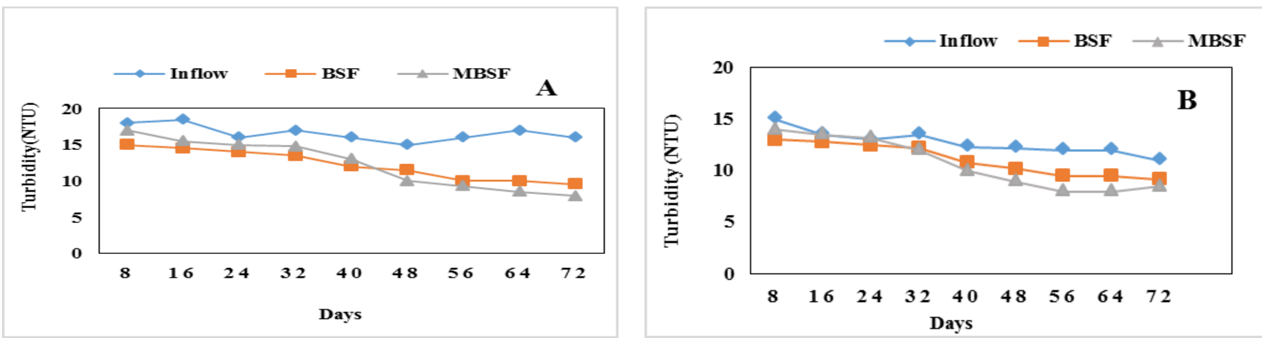
2. Turbidity Reduction

Figure 4 shows filter influent and effluent turbidity for the two filter runs. It was observed that the filters showed comparative turbidity removal in both the runs except for the initial days. The modified biosand filter demonstrated a slightly higher turbidity removal during the initial days compared with biosand filter because of leaching of iron oxide from iron oxide coated gravel, this was ruled out since the iron concentration in the effluent from modified biosand filter was not significantly higher than that from biosand filter. Influent turbidity was 18 NTU for Run A for ground water and 20 NTU for Run B for river water. Turbidity removal improved with time in both the filters as the filters developed. For filter, Run A, turbidity removal was observed to be 76% to 80% for BSF and Run B from 70% to 80% for MBSF. The introduction of iron oxide coated layer did not improve the turbidity removal. Initial concentration of turbidity was within the drinking limit so removal efficiency of turbidity is not improved.



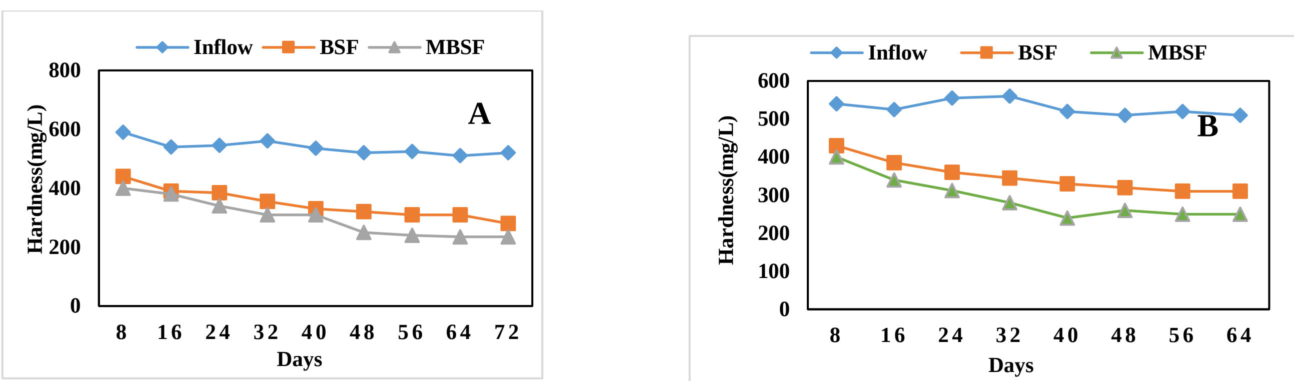
Ground water Kabini river water

Figure 3. pH rate variation over the length of the filter runs in BSF and MBSF



Ground water Kabini river water

Figure 4. Turbidity removal over the length of the filter runs in BSF and MBSF



Ground water

Kabini river water

Figure 5. Hardness removal over the length of the filter runs in BSF and MBSF

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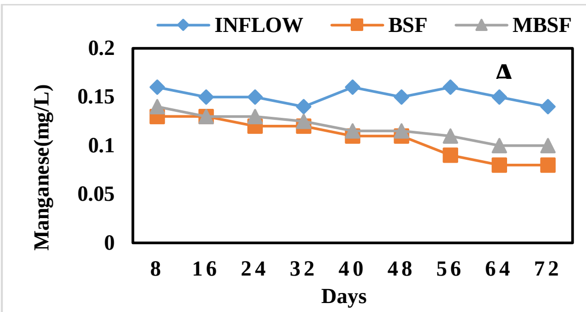
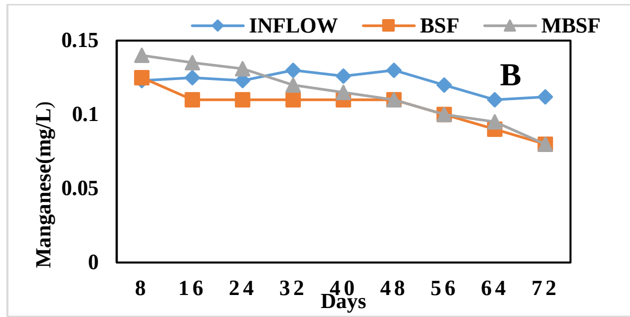
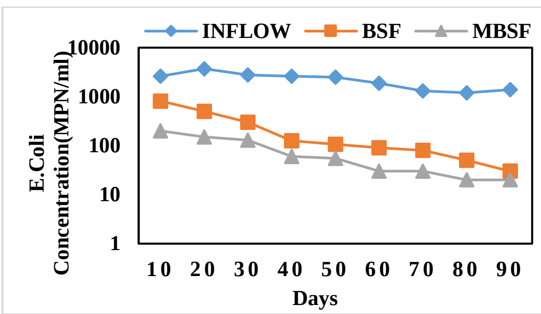


Ground water

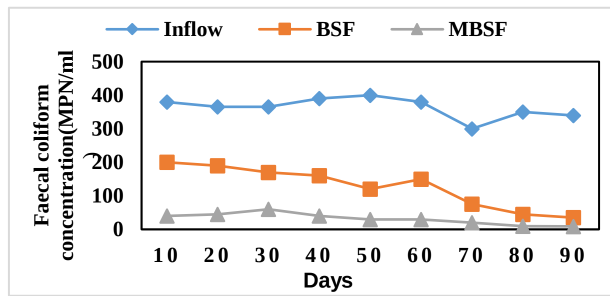


Kabini river water

Figure 6. Manganese removal over the length of the filter runs in BSF and MBSF



Ground water



Kabini river water

Figure 7. Bacterial concentration over the length of the filter runs

3. Hardness

Figure 5 shows hardness removal in BSF and MBSF. It was found that the average value of the hardness in the influent water was 560 mg/l for kabini river water and 580mg/l for ground water. Average values of 360mg/l hardness for biosand filter and 340 mg/l hardness for modified biosand filter effluent. The removal efficiency of the biosand filter is 65% and the modified biosand filter is 68% and due to the formation of biofilm in the filter increase the removal efficiency.

4. Manganese

Figure 6 shows Influent and effluent concentrations of manganese for the two runs. No significant removal differences were observed for manganese. It was found that the average value of the manganese in the influent water was 0.16 mg/L. Average values of manganese for biosand filter and modified biosand filter effluent were observed to be 0.10 and 0.09. The removal efficiency of biosand filter is 45% and modified biosand filter is 40% was observed in the filter runs. The initial concentration of manganese is very low for both filter removal efficiencies with in the drinking water limit.

5. Bacterial Removal

Figure 7 shows the influent and effluent concentration of E. Coli and faecal coliforms for the two runs. It was observed that modified biosand filter gave a better performance in terms of bacterial removal. At first, in Run A, less than the one-$\log_{10}$ decrease of E. Coli was observed for biosand filter while the modified biosand filter gave over 2$\log_{10}$ removal of bacteria. The execution of both the filters improved with time and after around one month. It is clear that maturation of the biosand filter took around one month and that point the filters performed reliably with around 2$\log_{10}$ expulsion. Expanded evacuation with time can be attributed to both filters. However, since it is known that biological activity in moderate sand filters happens mostly in the top few centimeters. Bacterial concentrations are plotted on a logarithmic-scale.

Conclusion and Significance

Based on the biosand filter and modified biosand filter studies on Kabini river water and ground water the following conclusions are drawn. The filters were operated intermittently for 90 days and the physicochemical and biological tests were conducted to compare the performances of the MBSFs for organic matter, turbidity, hardness, alkalinity and bacteria taking into account the filter media. A decrease in the flow rate over the time was seen because of the natural layer development and fouling in both types of filters. Filtration of water through biosand filters and modified biosand filter did not result in any significant changes in the physical-chemical quality of filtered water and all remained within the drinking water quality guideline values. This shows that introduction of iron oxide coated gravel is valuable, particularly during the development period and after cleaning operation when the bacterial expulsion tends to be exceptionally low. The iron oxide coated gravel filter increases the removal efficiency and achieved better E. Coli, total coliforms and faecal coliform removal percentages.

Conflict of interest

The authors declare that they have no conflict of interest.

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