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Removal of fluoride, arsenic and coliform bacteria by modified homemade filter media from drinking water

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Abstract

An attempt was made to investigate the removal of fluoride, arsenic and coliform bacteria from drinking water using modified homemade filter media. Batch mode experimental study was conducted to test the efficiency of modified homemade filter for reduction of impurities under the operating condition of treatment time. The physico-chemical and biological analysis of water samples had been done before and after the treatment with filter media, using standard methods. Optimum operating treatment time was determined for maximum removal of these impurities by running the experiment for 2, 4, 6, 8, 10 and 12 h, respectively. The maximum reduction of fluoride, arsenic and coliform bacteria in percentage was 85.60%, 93.07% and 100% and their residual values were 0.72 mg/l, 0.009 mg/l and 0 coliform cells/100 ml, respectively after a treatment time of 10 h. These residual values were under the permissible limits prescribed by WHO. Hence this could be a cheap, easy and an efficient technique for removal of fluoride, arsenic and coliform bacteria from drinking water.
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Keywords: Arsenic; Coliform bacteria; Drinking water; Fluoride; Homemade filter media; Modified homemade filter media

1. Introduction

About 80% of communicable diseases in the world are waterborne (Shengji et al., 2004). To reduce the incidence of water-borne diseases and make the water suitable for human consumption, the removal of pathogenic organisms, fecal matter, suspended solids, algae, organic matter and harmful chemicals is absolutely necessary (Gupta and Chaudhuri, 1995). Among the various undesirable and naturally occurring pollutants in water, coliform bacteria, fluoride and arsenic are very important as these causes serious health problems (Joshi and Chaudhuri, 1996). But on the contrary the lower concentration of fluoride in water like 1 mg/l, is even found to be beneficial in preventing dental caries. However, excessive fluoride concentration in drinking water causes dental fluorosis, skeletal fluorosis and crippling skeletal fluorosis (Agarwal et al., 1999; Meenakshi and Maheshwari, 2006; WHO, 1996).

The arsenic problems are of more concerns for small communities in rural areas around the world, where groundwater comprises the main drinking source of water (Xiaoguang et al., 2001). In high concentrations, arsenic poisoning can also lead to an acute condition called arsenicosis (Hering et al., 1997; Huang and Lin, 1997; Gregor, 2001). Coliform bacteria are the indicator of contaminated water with human or animal wastes and if these are absent then only water can be considered as safe for drinking purpose. These bacteria are generally not harmful but other microbes along with these bacteria can cause short-term effects like diarrhea, cramps, nausea, headaches, or other symptoms (Jerzy et al., 1999).

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Many methods have been used to remove fluoride, arsenic and coliform bacteria from water. Most of them are conventional and expensive. Conventional methods for removal of fluoride, arsenic and coliform bacteria involve coagulation followed by separation of the produced insoluble settling or by direct filtration through sand beds (Srimurali et al., 1998). Other methods include reverse osmosis, ion exchange, lime softening, flotation and adsorption on iron oxides or activated alumina (Kartinen and Martin, 1995; Domènec et al., 1996). These conventional water treatment methods are not affordable in rural communities of developing countries (Peter, 1999). So other small-scale economical methods are needed for the decentralized communities.

Various low-cost materials like kaolinite, bentonite, charfines, lignite and pumice were investigated to assess their capacity for removal of fluoride, arsenic and coliform bacteria from water by batch adsorption studies (Lounici et al., 1997; Meng et al., 2001; Burhanettin et al., 2003). Slow sand, diatomaceous earth (DE) filtration and sand-filled glass columns having grown plants were also used for removal of Giardia muris, cryptosporidium and coliform bacteria from water (Peter et al., 1991; Esen et al., 1991; Garcia and Bécares, 1997; Jerzy et al., 1999; Wand et al., 2007).

Various technologies had been used for the removal of fluoride, arsenic and coliform bacteria from drinking water but this problem has not still been rooted out. Several small-scale water treatment techniques are practiced to alleviate these problems especially for rural communities of developing countries. Homemade slow sand filter is one of the options which had been practiced for a long time and this is also economical to construct, operate and maintain, but the filtrate of this homemade slow sand filter doesnot fulfill the recommended guideline value in removing pathogens and also it does not successfully removes some chemicals like fluoride.

Therefore, the objective of this study is to make a modified homemade slow sand filter media and to determine its efficiency for removal of impurities from drinking water to make it potable.

2. Methods

2.1. Experimental setup

Two tanks were fabricated from metal sheets, each with 30 cm diameter and 100 cm height and were fitted with a half-inch outlet pipe, a drain valve and an outlet tap. One of the tanks was filled in this manner: 10 cm stone at bottom (pebbles); 8 cm filter gravel provided in two layers of different sizes of 4 cm deep each (size ranges 0.8–1.5 mm) and a layer at the top of 40 cm deep filter sand (with a particle size of 0.2–0.8 mm). This tank was used as control tank for the experiment (HMF_1). The other tank was also filled in the same way except that a 10 cm crushed brick (grain size ranging from 0.25 to 0.5 mm) was added in the filter component between the sand bed and gravel bed and used as an experimental tank ($MHMF_1$). Six sets each of control unit and experimental unit ($MHMF_1$) were

Table 1
Physico-chemical analysis of drinking water and WHO permissible limits

S. No.	Parameters	Values	Maximum permissible limits (WHO norms)
1	pH	7.2	6.8–8.5
2	Temperature (°C)	20.5	16–32
3	Turbidity (nephalometer turbidity unit)	320	5–10
4	Fluoride (mg/l)	5	1.5
5	Arsenic (mg/l)	0.13	.01
6	MPN (coliform cells/ 100 ml)	2×10^9	Nill

Table 2
Removal of fluoride from drinking water by homemade and modified homemade filter media having an initial concentration of 5 mg/l

Treatment time	Residual fluoride concentration (mg/l)		Contribution of crushed brick in percent removal of fluoride
	HMF_1	$MHMF_2$	$[(HMF_1-MHMF_2)/5]\times 100$
2	4.91	3.89	20.4
4	4.67	3.05	38.0
6	4.05	2.08	39.4
8	3.89	1.67	44.4
10	2.99	0.72	45.5
12	2.97	0.73	44.8

Table 3
Removal of arsenic from drinking water by homemade and modified homemade filter media having an initial concentration of 0.13 mg/l

Treatment time	Residual arsenic concentration (mg/l)		Contribution of crushed brick in percent removal of arsenic
	HMF_1	$MHMF_2$	$[(HMF_1-MHMF_2)/0.13]\times 100$
2	0.12	0.11	7.69
4	0.11	0.09	15.38
6	0.08	0.03	38.46
8	0.07	0.01	46.15
10	0.07	0.009	46.92
12	0.07	0.009	46.92

Table 4
Removal of coliform bacteria from drinking water by homemade and modified homemade filter media having an initial concentration of 2×10^9 (coliform cells/100 ml)

Treatment time	Residual coliform bacteria (coliform cells/100 ml)		Contribution of crushed brick in percent removal of arsenic
	HMF_1	$MHMF_2$	$[(HMF_1- MHMF_2)/2\times 10^9]\times 100$
2	8×10^7	1×10^5	39.95
4	3×10^6	5×10^2	42.05
6	9×10^4	7×10^1	67.89
8	1×10^2	10	86.75
10	90	2	99.99
12	91	0	100

made to operate the experiments in batches under different treatment time of 2, 4, 6, 8, 10 and 12 h.

2.2. Treatment of drinking water

To protect erosion of filter's top layer during filtration of water, a layer of flat stone was raised above the sand. Water was added to the filter tank continuously for several hours. The filter media was kept away from drying by fitting the outlet pipe in such away that the height of the out-let tap was 5 cm above the top layer of the filter sand bed. The filtration rate was controlled between 0.2 l/h and 1.2 l/h and the filtration rates for the units having a treatment time of 2, 4, 6, 8, 10 and 12 h were 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 l/h, respectively for different control and experimental setups (batch). The maximum filtration rate at the beginning of the operation with each setup was adjusted at 1.2 l/h in order to recover the head loss.

The water was passed through the filter beds of all the control units and experimental filter units. Then the filtrate from all the units were analyzed separately for fluoride, arsenic and coliform bacteria concentration at a duration of 2, 4, 6, 8, 10 and 12 h of the filter run according to the standard methods (APHA, 1989). The contribution of crushed brick was also calculated for percent removal of fluoride, arsenic and coliform bacteria under all the treatment batches.

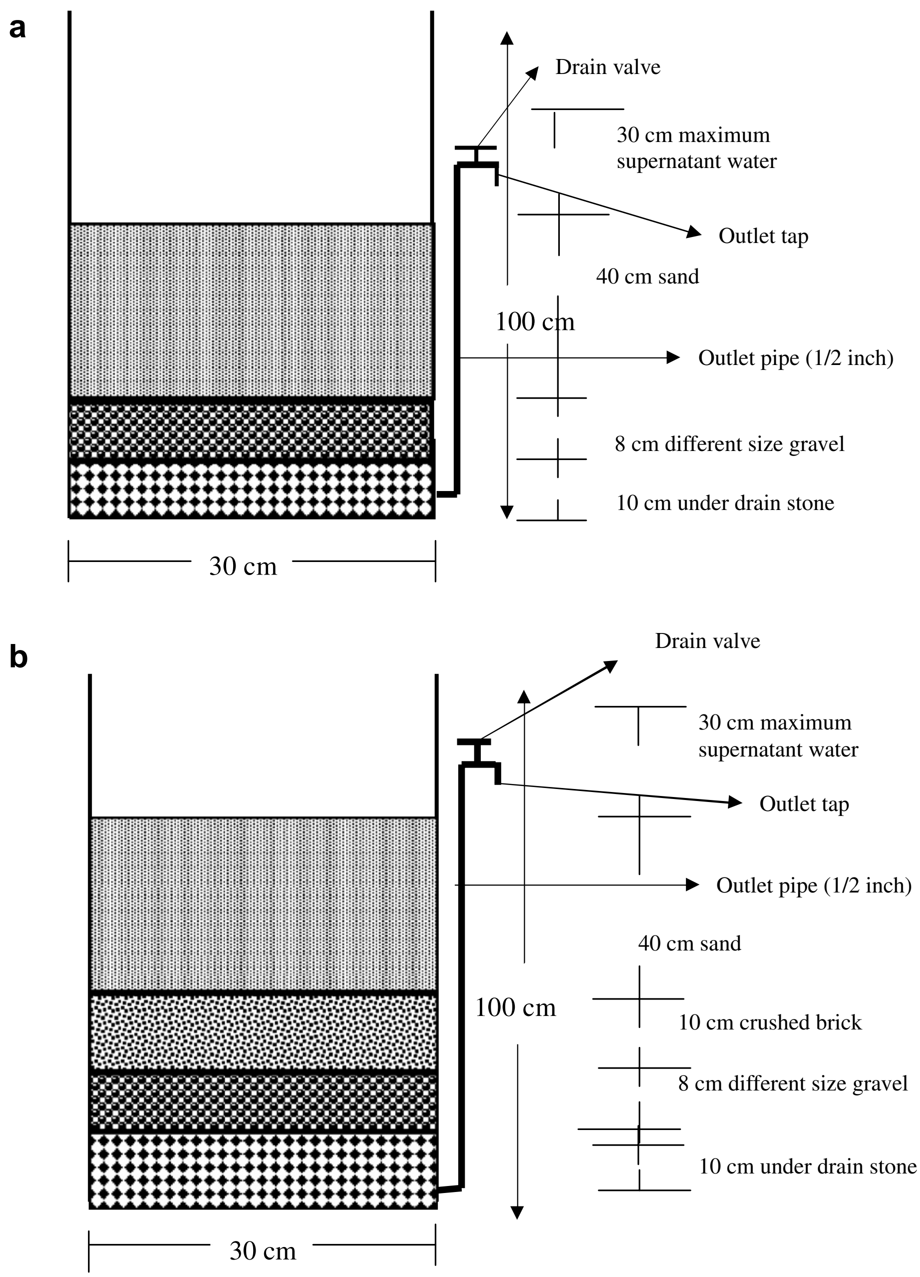

Fig. 1. Components of filter media. (a) Homemade filter media (HMF_1); (b) Modified homemade filter media ($MHMF_2$).

3. Results and discussions

The physico-chemical analysis of the drinking water sample was depicted in Table 1. It was evident that the drinking water was highly polluted with turbidity, fluoride, arsenic and coliform bacteria when compared with WHO permissible limits for these parameters as shown in Table 1. We were concerned here only for fluoride, arsenic and coliform bacteria removal using modified homemade filter media by adding crushed bricks.

The drinking water was treated under batch mode operation having different treatment times with both homemade filter media and modified homemade filter media and fluoride, arsenic and coliform bacteria concentrations were measured before and after treatment for each batch separately. The time was the important operating parameter *t* considered under the present study.

It was clear from Table 2 that the removal of fluoride with modified homemade filter media was more than homemade filter media under all the treatment times and it was maximum after a treatment time of 10 h with residual values of 2.99 mg/l and 0.72 mg/l, respectively for modified homemade filter media and homemade filter media. It was also found that the contribution of crushed bricks under different treatment time of 2, 4, 6, 8, 10 and 12 h, the percent removal of fluoride was 20.4%, 38.0%, 3339.4%, 44.4%, 4445.5% and 44.8%, respectively as depicted by Table 2. It was clear that the maximum percent removal was achieved with a treatment time of 10 h and after that the equilibrium was achieved.

From Table 3, it was clear that the modified homemade filter media was very potential for the removal of arsenic from drinking water as compared to homemade filter media under all the treatment time conditions. The maximum removal of arsenic for both the filter media was achieved with a treatment time of 10 h and the residual value of arsenic was 0.009 mg/l and 0.07 mg/l, respectively for modified homemade filter media and homemade filter media. Contribution of crushed bricks in percent removal of arsenic was also calculated and maximum value was attained with a treatment time of 10 h and it was 46.92%. For other treatment times, the values of percent arsenic removal along with treatment time were 7.69% with 2 h, 15.38% with 4 h, 38.46% with 6 h, 46.15% with 8 h and 46.92% with 12 h. It was also depicted that there was a regular trend for percent removal of arsenic under all the treatment time.

There were excellent results for the removal of coliform bacteria from drinking water with modified homemade filter media as compared to homemade filter media under all the treatment time conditions as shown in Table 4. The maximum removal was achieved under a treatment time of 10 h for both the filter media and the residual values were 91 coliform cells/100 ml and 0 coliform cells/100 ml for homemade filter media and modified homemade filter media, respectively. Crushed bricks had a great contribution in the removal of coliform bacteria from drinking water and under treatment time of 2, 4, 6, 8, 10 and 12 h and the values of percent removal of coliform bacteria were 39.95%, 42.05%, 67.89%, 86.75%, 99.99% and 100%,

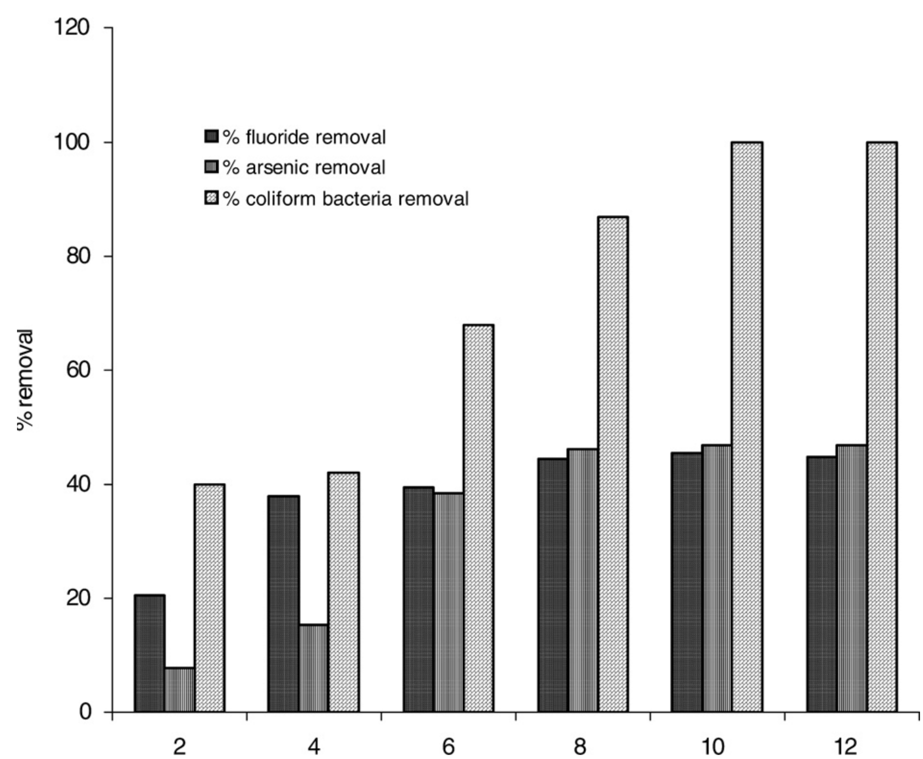

Fig. 2. Contribution of crushed brick in percent removal of fluoride, arsenic and coliform bacteria by treatment with modified homemade filter media.

Table 5
Efficiency of modified homemade filter media ($MHMF_2$) for percent removal of fluoride, arsenic and coliform bacteria from drinking water under optimum treatment time of 10 h

Pollutants	Initial concentration	Residual concentration	Permissible limits of WHO	Percent removal
Fluoride (mg/l)	5	0.72	1.5	85.60
Arsenic (mg/l)	0.13	0.009	0.01	93.07
Coliform bacteria (coliform cells/100 ml)	2×10^9	0	Nil	100

respectively with homemade filter media and modified homemade filter media (see Fig. 1).

From Fig. 2 it was clear that crushed brick used in modified homemade filter media (experimental setup) was very efficient for the percent removal of fluoride, arsenic and coliform bacteria from drinking water and it showed maximum to minimum percent removal range of 20.40–44.8%, 7.69–46.92% and 39.95–100%, respectively for fluoride, arsenic and coliform bacteria.

It was also found that there was a regular pattern of increase in percent removal of fluoride, arsenic and coliform bacteria with the increase of treatment time. Equilibrium was achieved with a treatment time of 10 h for fluoride, arsenic and coliform bacteria. From Fig. 2, it was also clear that under all treatment times, it was very efficient for the maximum percent removal of coliform bacteria as compared to fluoride and arsenic. It was also evident that initially with a treatment time of 2, 4 and 6 h it was more efficient for fluoride removal and with a treatment time of 8, 10 and 12 h for removal of arsenic.

From Table 5, it was found that percent removal of fluoride, arsenic and coliform bacteria with modified homemade filter media were 85.60%, 93.07% and 100%, respectively. The residual values of fluoride, arsenic and coliform bacteria in the treated drinking water with modified homemade filter media after a treatment time of 10 h were 0.72 mg/l, 0.009 mg/l and 0 colliform cells/100 ml, respectively. On comparing these values with the permissible limits of WHO, the values of all the parameters were under the permissible limits.

The effect of treatment time on removal of fluoride, arsenic and coliform bacteria from water with filter media could be explained that as the treatment time progressed, the adsorbent sites of the media had the tendency towards saturation. Difference of the percent fluoride, arsenic and coliform bacteria removal by filter media could be attributed due to the difference in tendency of these pollutants for adsorption towards filter media.

4. Conclusions

It is concluded from this study that modified homemade filter media is a very good option for the treatment of drinking water. It shows a good potential for the removal of fluoride, arsenic and coliform bacteria from drinking water and the residual concentrations of these parameters are well under the permissible limits of WHO standards. Thus, on the basis of the results obtained here, it can become a solution for fluoride, arsenic and coliform bacteria removal from drinking water. This technique can also overcome some of the limitations of the conventional techniques. This filter unit can be assembled easily at any site and it is cost effective also. Moreover, it is also easy to install and operate by any layman just after a training of some days. Further studies are recommended to determine the depth and exhaustion period of the crushed brick media with the appropriate method for regeneration.

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