ORIGINAL ARTICLE

REMOVAL OF PHYSICOCHEMICAL AND MICROBIAL IMPURITIES OF WATER USING MODIFIED HOMEMADE FILTER

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ABSTRACT

Background*: There are many different methods, which are used to purify water. Some are conventional and expensive, while others are traditional and small scale, still having interesting results in killing pathogenic organisms and reducing the concentration of some chemicals and other impurities, especially for rural communities of developing countries who are suffering from water borne diseases. But because conventional water treatment methods are not affordable in rural communities of developing countries, other small-scale methods are needed. An experimental study was conducted to test the effect of modified homemade filter in reduction of turbidity, fecal coliform, fluoride and its effect on pH and temperature.*

Method And Materials*: Representative water samples were taken from' kochi' stream and laboratory analysis was done both for the raw water samples and the filtrates in school of environmental health laboratory, Jimma University.*

Filter tanks fitted with half-inch pipe were constructed and filled with stone (10 cm), gravel (9 cm), sand (40 cm) and crushed brick (10 cm) for fluoride test and local charcoal (10 cm), instead of the crushed brick for physical and biological test. Filter tanks without crushed brick, and without local charcoal were used as control. For the determination of fecal coliform, pH and temperature, turbidity and fluoride, MPN technique, pH meter, turbidimeter and Alizarin spectrophotometry method were used, respectively.

Results: *With a flow rate adjusted initially to 0.35 L/min the test resulted an average concentration of fluoride 1.42 mg/l (71.6%) from 5mg/l after filtered in a Modified Homemade Filter ($MHMF_1$) with crushed brick. After a month operation the $MHMF_2$ (with local charcoal) reduced the faecal coliform to 1 /100ml (99.95%) and turbidity to 0.13 FTU (99.83%), which was improved as the time of filter run increased and the flow rate decreased.*

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CONCLUSION: *The study showed that filtration of raw, fluoridated water with the study media could remove physical, chemical and biological impurities up to significant values for developing countries. The filter unit is very light in weight for easy transportation and costs 210 Ethiopian Birras of March 2004. Communities who have no access for treated water supplies can have this method as alternative, appropriate and cost effective technology with careful handling and timely cleaning*

KEY WORDS*: Defluoridation, crushed brick, local charcoal, modified homemade filter.*

INTRODUCTION

In the history of Public health, communicable disease is the leading problem, which calls every ones attentions. About 80% of all infectious diseases in the world are waterborne. Therefore the need for provision of potable water for all citizens in the world becomes one of the thirteen essential components of primary health care Program (1,2).

Water intended for human consumption must be free from pathogenic organisms, substances that affect the aesthetic quality and concentration of chemical substances that may be hazardous to health. Water intended for drinking purpose should also be pleasant to drink. (3,4).

Among the various naturally occurring chemicals, fluoride is one of the constituents of water that cause serious health problems in most rift valley water sources and some other highland areas. In Ethiopia, by 1990, from 150 communities and natural water sources tested for fluoride levels by the Ethiopian Water Supply and Sewerage Authority (WSSA), 47 sources from rift valley sources out of the 85 and 11 sources out of the rift valley system in the Ethiopian highlands from the 65, had fluoride levels above 1.5 PPM which has a negative impact on human health (3). Fluoride, if present in excess amount from the recommended value, may cause dental fluorosis, skeletal fluorosis and crippling skeletal fluorosis. Depending on the concentration of fluoride taken and length of time of exposure. It may also be associated with high prevalence of cancer, kidney diseases cardiovascular diseases and neurological disorders (5,6).

To reduce the incidence of water borne diseases and make the water suitable for human consumption, removal of pathogenic organisms, fecal matter, suspended solids, algae, organic matter and harmful chemicals is absolutely necessary. Several small-scale water treatment techniques are practiced to alleviate these problems especially for rural communities of developing countries who have potential problem to use the conventional water treatment methods. Homemade slow sand filter is one of the options, which have been practiced for longer time and economical for those communities to construct, operate and maintain. But the filtrate of homemade slow sand filter doesn't fulfill the recommended guideline value in removing pathogens and also it has a problem in removing some chemical like fluoride (5,7,8).

Therefore, the aim of this study is to modify home made slow sand filter so that it could remove most of the impurities; physical, biological and chemicals like fluoride.

METHODS AND MATERIALS

An experimental study was conducted to assess the efficiency of modified homemade filter in reducing physical, biological and chemical impurities in environmental health laboratory unit, Jimma University.

Materials and Construction

Two empty tanks were constructed from metal sheets, with 30 cm diameter and one meter height. Then the tanks were fitted with a half-inch outlet pipe, drain value and out let tap.

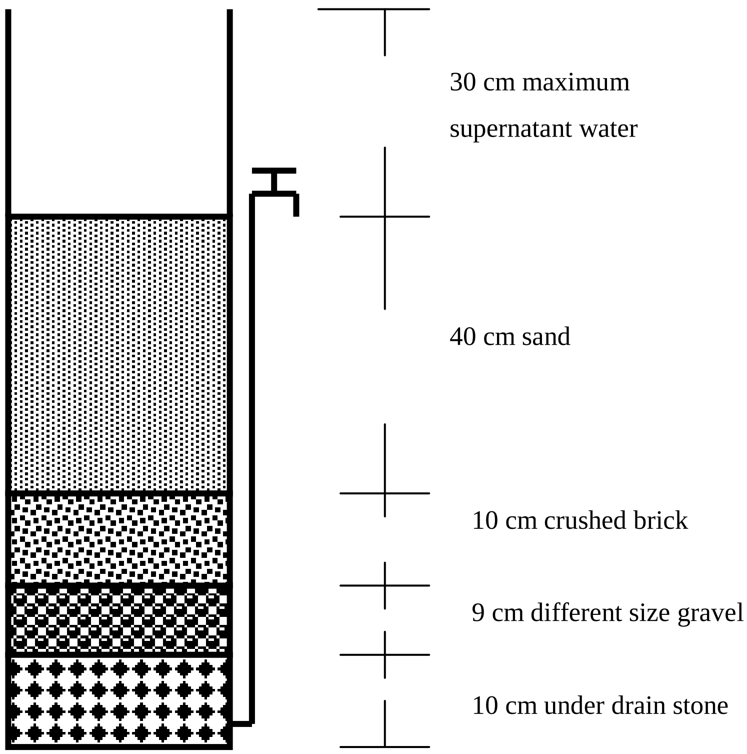

Fig.1 Components of $MHMF_2$ (with crushed brick). Note to the scale

Filter components for fluoride test

One of the tanks was filled with 10 cm stone under drain at bottom, 9 cm filter gravel provided in three layers of different sizes (3 cm deep each) and 40 cm deep filter sand (Es= 0.2 - 0.8 mm; and Uc 1.5-3); total 59 cm. This tank was used as control for the experiment (HMF_1).

The other tank was also been filled in the same way with the previous filter components of the control tank with the same arrangement, but 10 cm crushed brick with a grain size of from 0.25 to 0.5 inches was added in the filter component below the sand bed (above the gravel bed); total 69 cm. These dimensions except for the crushed brick media are the appropriate dimensions of homemade sand filter by WHO for removal of physical and biological impurities (1). This tank was used as experimental tank ($MHMF_1$).

Filter components for biological and physical tests

The two tanks used for fluoride filtration test were emptied and reassembled in the following manner.

The control tank was assembled as in the first experiment without any change either in arrangement or material type (HMF_2). The experimental tank also was reassembled in the same manner as the experimental tank of the first experiment by replacing the 10 cm crushed brick by 10 cm local charcoal with grain size of 0.25-0.5 inches ($MHMF_2$) for adsorption of physical and biological impurities.

Filter operation: To protect the top layer filter skin (*schmuzdecke*) from erosion while the addition of water to the filter tank a flat stone raised above the sand by means of three stones beneath it was prepared. Water was added to the filter tank continuously for several days. The filter media was kept from drying by fitting the outlet pipe in such away that the height of the out let tap was 5cm above the top layer of the filter sand bed. The filtration rate was controlled by fitting a gate valve on the out let line as shown in the figure. The maximum filtration rate at the beginning of the operation was adjusted at 0.35 l/min. The rate was adjusted to this value by slowly increasing for several hours. By opening the control valve to the maximum filtration rate, 0.35 l/min the head loss can be recovered as the day of the filter run increased. This rate approximately can yield 20 l/hr. (9,10).

Preparation of fluoride containing water: Samples for fluoride filtration test were prepared in the laboratory by using tap water and sodium fluoride (NaF). 0.4420gm of NaF was added into 40l tap water to get a result of 5mg/l fluoride concentration. The fluoridated water was passed through the filter beds of both the control unit (HMF_1) and the experimental filter unit, containing crushed brick ($MHMF_1$). Then the raw water (the samples) and filtrates from both of the filter units was analyzed for fluoride concentration on the first, fifth and tenth days of the filter run. The fluoride concentration was analyzed by Alizarin spectrophotometery method. Standard laboratory procedures were used during the analysis (11).

Water samples from a stream named 'kochi' found near by Jimma University main campus, was collected using a thoroughly washed plastic container having a capacity of 30 liter, by the principal investigator and research assistants for biological and physical tests. Laboratory analysis was done starting from the first day of the filter run (ten days after the installation of the unit), then every 10^{th} day up to the 50^{th} day. In each days water samples were collected from the source for filtration, then laboratory analysis for selected physical and bacteriological parameters were done for the raw water as soon as the sample reach the laboratory from the plastic container used to transport the water to the laboratory and the same parameters were analyzed for the filtrate of both the control (HMF_2) and the experimental unit ($MHMF_2$). Fecal coliforms were analyzed by using multiple tube fermentation technique for the easy availability of chemicals. Samples were taken aseptically from the 'Jerycan' (raw water) and from the out let tap of the filter units using sterile bottle. Standard laboratory procedures were used during the analysis (15). Turbidity of the samples was measured using HANA microprocessor Turbidimeter, HI-93703. Wagtech International HI-8314 portable pH meter was used to measure the temperature and pH of water samples.

RESULT

1. CHEMICAL TESTS

Filtration of the fluoridated water through a homemade filter containing crushed brick media ($MHMF_1$) reduced the Fluoride concentration to 1.18mg/l, 1.4 mg/l and 1.68 mg/l in the first, fifth and tenth days of the filter run, respectively with an average of 1.42mg/l (71.6%). The result also revealed that filtration of water with the same, 5 mg/l fluoride concentration through the homemade filter without crushed brick media (HMF_1) showed a reduction to 3.90 mg/l, 4.02 mg/l, and 4.38 mg/l on the first, fifth and tenth days of filter run respectively, with an average reduction of 4.10 mg/l (18.0%) (Fig.3)

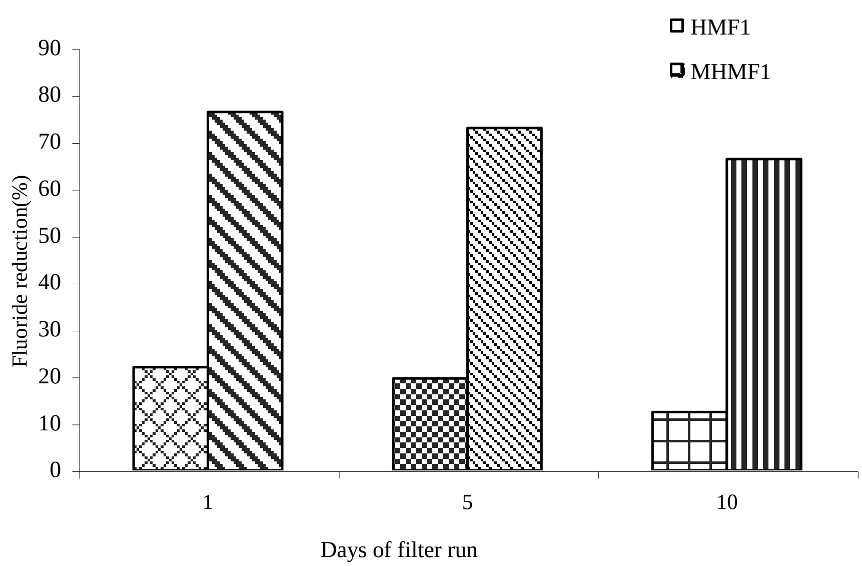

Fig.2 Effect of crushed brick on fluoride reduction

2. PHYSICAL TEST

Raw water from a stream named 'kochi' found near Jimma University main campus was filtered through the filter unit with local charcoal ($MHMF_2$) and with out local charcoal (HMF_2). The result showed that filtration of the raw water with a turbidity of 64 FTU (Formazine Turbidity Unit) was reduced on average to 94.25% and 99.34% before and after a month, respectively for HMF_2 while the $MHMF_2$ average reduction rate was 96.22% and 99.85% before and after a month respectively (Table – 1).

Table 1. Result of selected physical parameters on different days of filter run

Days of filter run	Temperature	PH			Turbidity (FTU)		
		Raw water	Filtrate		Raw water	Filtrate	
			HMF_2	$MHMF_2$		HMF_2	$MHMF_2$
1	22.4	6.8	6.9	6.9	64.0	7.8(87.8%)	6.3(90.16%)
10	20.3	6.7	7.0	7.2	70.0	6.7(90.48%)	4.2(94.0%)
20	19.6	6.9	7.1	6.9	94.6	2.1(97.8%)	0.8(99.15%)
30	21.4	7.1	7.2	7.3	81.2	1.2(98.5%)	0.4(99.5%)
40	21.8	6.7	6.8	6.9	69.3	0.51(99.25%)	0.14(99.6%)
50	19.2	7.2	7.2	7.2	71.1	0.42(99.4%)	0.13(99.83%)

The average pH of the raw water from the stream was 6.9 (ranging from 6.7-7.2). The filtrate of the HMF_2 was with average pH of 7.0 (ranging from 6.9 – 7.2) while the filtrate from the $MHMF_2$ had an average pH of 7.1 (6.9 – 7.3). The average temperature of the raw water from the stream during the study time was 20.7^0C (ranging from 19.2^0C to 22.4^0C).

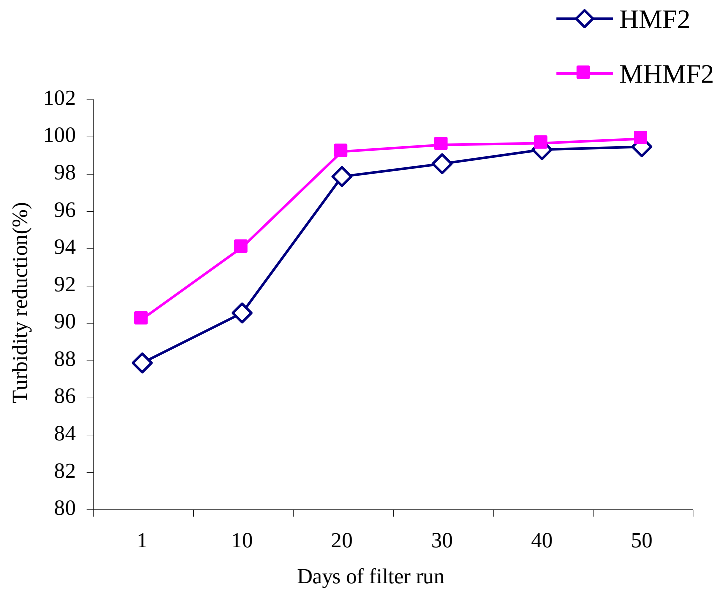

Fig.3 . Effect of local charcoal on turbidity reduction on different days of filter run

3. BIOLOGICAL TESTS

Raw water from the stream with an average turbidity of 75 FTU (64 FTU- 94.6 FTU) and an average pH of 6.9 (6.7 – 7.2) was filtered through both the control tank without local charcoal (HMF_2) and the modified tank with local charcoal ($MHMF_2$). At the beginning the flow rate was adjusted to be 0.35 l/min by rotating the control value fitted for this purpose. According to the study finding the load of fecal coliform bacteria was reduced from 1800 /100ml to 1010 /100ml (43.9%) and 980 /100ml (45.56%) after filtered through HMF_2 and $MHMF_2$ respectively, on the first day of the filter run (ten days after installation). On the 30th day the flow rate decreased to 0.21 l/min and then it is adjusted to 0.33 l/min by carefully rotating the control valve one round ahead. On the 30th day the fecal coliform load reduced form 1,900 /100ml to 3 /100 ml (99.84%) and 1 /100 ml (99.4%) for the HMF_2 and $MHMF_2$ respectively. On the last day of the experiment (50th day) flow rate was decreased again to 0.18 l/min. On this day the fecal coliform bacteria reduced from 2000 /100ml to 2 /100ml (99.90%) and 1 /100ml (99.95%) for the HMF_2 and $MHMF_2$ respectively (Table 2).

Table 2. Bacteria removal on different days of filter run

Days of filter run	Raw water (sample) MPN/100ml	Result (fecal coliform)			
		HMF_2		$MHMF_2$	
		MPN/100ml	% Reduction	MPN/100ml	% Reduction
1	1,800	1010	43.90	980	45.56
10	2,010	26	98.71	24	98.8
20	1,100	3	99.73	3	99.73
30	1,900	3	99.84	1	99.94
40	1,910	2	99.89	1	99.92
50	2,000	2	99.9	1	99.95

DISCUSSION

It is known that provision of safe water has had an important role in reducing the incidence of many water born diseases and effect of hazardous chemicals. However, the conventional water treatment methods for the provision of safe water are unaffordable in urban and rural areas of developing countries. Many studies have been accomplished to alleviate this problem with locally available materials, simple and economically affordable technologies (10, 11, 12). This study also was accomplished by considering these to remove more physical, chemical and biological impurities.

Filtration of fluoridated water through a home made filter containing a 10 cm depth (0.25 – 0.5 inch) crushed brick media removed much of the fluoride with an average reduction of 71.6% in ten days of the filter run while the control media with out crushed brick reduced only to an average of 18.0%. As the time of filter run increased, the filtration capacity of the media decreased from 76.4% to 73.0% and to 66.4% on the first, fifth and tenth days, respectively. The result is probably due to the adsorption of fluoride ion from the water on the crushed brick media. Studies showed that water with fluoride concentration more than 1.5 mg/l could be defluoridated up to 100% by using ion exchange method (8). An other study also showed that clay pots and crushed bricks fired at optimum temperature are sufficient to remove fluoride up to the value recommended by WHO (11). The flow rate during the study was 0.35 l/min. Increasing the residence time of the water by decreasing the flow rate would increase the efficiency. A study done by storing fluoridated water in clay pot from one to three days resulted in a reduction from 28.5% to 76.7% (11). This study also showed that the efficiency of the medium decreased as the day of filter run increased. This is probably due to the saturation of the media for the adsorption mechanism. Therefore exhaustion of the media will happen at some time on the filter run which needs a mechanism to de-ionize or replace the media.

Filtration of water through both the homemade filter (HMF_2) and the modified homemade filter ($MHMF_2$) with local charcoal resulted in a significant reduction of turbidity. On the first day of filter run (ten days after installation) the turbidity reduced to 7.8 FTU (87.8%) and 6.3 FTU (90.16%) for the HMF_2 and

$MHMF_2$, respectively. On this day the flow rate was 0.35l/min. The result is probably due to physical straining, sedimentation, adsorption and other chemical actions (4). As the day of filter run continued the flow rate dropped day to day and quality of the filtrate increased to 1.2 FTU (98.5%) and 0.4 FTU (99.5%) on the 30th day for the HMF_2 and $MHMF_2$ respectively. This result is almost the same with the results of the studies by Adam (16) and Esayas (12), and it fulfills the permissible limits of the WHO recommended guideline values. After a month the turbidity decreased to an average of 0.465 FTU and 0.13 FTU for the HMF_2 and $MHMF_2$ respectively. This might be because of the resulting accumulation of sediment and organic growth forming a thin layer (*schmutzdecke*) on the sand surface. The result also showed that the $MHMF_2$ (with local charcoal) has had a slightly different result to the HMF_2, which mighty be due to the adsorption of particles on the surface of the charcoal (13).

The average pH of the sample; 6.9 (6.7 – 7.2) was slightly increased after filtration to an average of 7.06 and 7.05 for HMF_2 and $MHMF_2$ respectively. This increase in pH is probably due to the removal of some impurities that cause acidity and the carbon dioxide-bicarbonate- carbonate equilibrium system which happen in most natural water treatment processes (12). The result met the WHO recommended value of pH for drinking water (5).

At the beginning with sand effective size (0.20-0.80mm) diameter and local charcoal (0.25-0.5 inch), the flow rate was adjusted to 0.2 m/h (0.35 l/min). On the first day (ten days after installation) fecal coliform bacterial reduced from 1800 MPN/100 to 1010 MPN/100 ml (43.90%) for the HMF_2 and to 980 MPN/100 ml (45.56%) for the $MHMF_2$. This might be due to the processes of sedimentation, straining, adsorption, chemical and bacteriological action (9,2). As the time of filter run continued, load of bacteria in the filtrate decrease as the flow rate decreased from day to day. On the 30th day the flow rate dropped to 0.21 l/min, and the bacteria load reduced to 3 /100ml and 1 /100 ml for the HMF_2 and $MHMF_2$ respectively. Then the flow rate was adjusted to 0.33 l/min by rotating the control value one round ahead. This amount of flow rate can yield about 20 l/hr, which is enough for an average family size of 7(seven). If the filter operates full day, it can satisfy the average per capita consumption for sub Saharan countries, which is below 15 liter per day (1, 14). On the last day of the experiment (50th day) the fecal coliform load was 2 /100ml and 1 /100ml for the HMF_2 and $MHMF_2$ respectively. The improvement in efficiency of bacterial removal and decreasement in flow rate is probably due to the formation of thin layer on the sand bed as a result of accumulation of sediment and organic growths, which remains permeable but retains particles even smaller than the space between the sand grains. Most impurities including bacteria and virus are removed from the water as it passes through the filter skin and the layer of the filter bed just below the filter skin. This result is almost similar with the study done by Esayas (12), and slightly better than the study done by Adam (16) which resulted 99.25% and 99.7% reduction rate respectively. In the present study the $MHMF_2$ with local charcoal was slightly efficient than the HMF with out local charcoal. This is probably because of adsorption of microorganisms on the surface of the local charcoal. Quality of the local charcoal, fired at optimum temperature, should be carefully selected which may otherwise affect the turbidity of the filtrate as observed in this study.

As a conclusion, according to the findings both homemade filter with and with out local charcoal can yield quality of water which has an encouraging result for developing countries interms of bacteria, turbidity and pH reduction. In addition, homemade sand filter with crushed brick media can reduce fluoride concentration of water to an optimum value for drinking and other domestic uses, which is a good alternative for area in the rift valley. The filter unit with out its contents is very light in weight for easy transportation. It costs 210 Eth.br. as of March 2004, and it is also so easy to install and operate that any layman can do it after 1-2 days training. 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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