ORIGINAL ARTICLE

Raw water storage and simple fluoride filters as methods of appropriate treatment for the removal of biological, physical and chemical impurities

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Abstract: *Because of the absence of appropriate technology that addresses the sociocultural condition of the community, the majority is consuming non-potable water. Storage of raw water in local vessels and filtration of fluoridated water in crushed bricks are simple methods of treating water. Samples of water from stream, spring and fluoridated water were used to see effect of storage and appropriate home made filters in the reduction of fecal coliform, turbidity, color, and fluoride. The respective samples with initial fecal coliform 578 MPN/100ml, turbidity 61.2 NTU, color 90 TCU, and pH 6.4 at a temperature of 20 °C, have been stored for one, two and three days in clay pots, plastic (jerrycan) and metal bucket. The fluoridated water that was prepared in the laboratory was also filtered through crushed brick and porous clay pot filters. The result showed very good reduction of contaminants after three days of storage, where, fecal coliform was reduced to 0 MPN/100ml in metal bucket, 60 MPN/100ml in jerrycan and 147 MPN/100ml in clay pot. Turbidity was lowered to 29.3 NTU in metal bucket; Color to15 TCU in plastic and clay pot and to 20 TCU in metal bucket. On the other hand storage of fluoride water sample with 6 mg/l or fluoride in clay pot resulted in reduction to 4.22 mg/l, 2.43 mg/l and 1.4 mg/l after one, two and three days of storage respectively. There was no change of fluoride concentration after storage in plastic jerrycan. A sample with a fluoride content of 8.23 mg/l became 3.52 mg/l when filtered through crushed brick. Another sample with 10 mg/l fluoride concentration was reduced to 0.62 mg/l, when filtered through porous clay pot. It is found that different containers have different efficiency in the reduction of contaminants, as metal bucket is best for fecal coliform organisms, plastic jerrycan for turbidity, and clay pot and plastic jerrycan for color reduction. This study has revealed that storage of raw water and using clay filters can remove biological, physical and fluoride contaminants (fecal coliform, color and fluoride) up to a level recommended by WHO. It is believed that with further perfection communities who lack safe water source can use the method just mentioned to improve the quality of their water in their homes.*

Introduction

Pure water is a clear, colorless, tasteless and odorless fluid. It is a also a strong solvent that dissolves gas, mineral and humic substances through which it flows and carries substantial quantity of silt, microorganisms and other chemicals. Microorganisms find their way in to water and depend upon circumstances to multiply

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or die (1). Due to these properties and optimum pH, water provides a conducive habitat for many pathogenic and nonpathogenic organisms; thus water is considered unsafe for use unless treated to remove impurities. On the Other hand water that appear in public or private supplies has been exposed to pollution while falling as rain, running over the ground surface or in stream, or percolating through soil. In addition the increase in population and technological development brings about the problem of wastes which will pollute land water and air, which has direct or indirect impact in the deterioration of water quality (1).-

To make water safe for users there are different water treatment methods (1). But due to the absence of appropriate treatment methods in urban and rural areas of developing countries, including Ethiopia, water is often remote and unsafe. In areas where conventional treatment plants are available, all of the community at the vicinity may not be capable of utilizing the system. For example a study done by Wondimagegn showed that the majority (76.5%) of the people in Jimma town, in which water treatment plant is available, use unprotected sources (2). This could result from socio-cultural and economic conditions that have an influence on water use and willingness to support and pay for community water systems (3). On the other hand, in areas where municipal and public water supply or protected springs and wells are absent, consumption of raw water from any source is the major problem. So careful selection of the proper treatment unit, which will solve the particular pollution problem, in addition to cost required for maintenance and operational control, must be considered (4). The World Health Organization (WHO) also encourage the search for low cost solution of water treatment system; which is more suitable to the local socio-cultural conditions (4).

Studies show that storage of raw water can eliminate contaminants like silts and pathogenic microorganisms. Schistosome cercariae are non-infective if the water is stored for 48 hours (5). Research conducted in Somalia at Magany camp showed storage of water in a tank for 1.5 to 4 days has eliminated about 37% of the turbidity and fecal coliform reduction of 43-84% was obtained (6). Wood et al (7) have recommended the use of storage using three-pot system for the removal of harmful organisms and suspended matter. Removal of 80 to 90 percent of contaminants is achieved after 10 to 30 days of storage in reservoirs and sedimentation tanks (8). On the other hand, the study done by Hauge et al (9), showed that storing fluoridated water for 30 minutes to 20 days in ordinary clay pots and crushed brick that are fired at an optimum temperature resulted in. effective reduction of fluoride concentration.

Methodology

An experimental study was conducted in the laboratory of Environmental Health school, Jimma institute of health sciences, Jimma-Ethiopia.

<u>Sample Source:</u>

Samples of raw water were collected from unprotected spring and stream for fecal coliform, turbidity and color tests using jerrycans washed with deionized water. These sources were selected because of the need of getting considerable amount of contaminants for the laboratory test. In addition, since the majority of the Ethiopian communities are using water from such unsafe sources, it will be possible to extrapolate the result of the study to such population. For fluoride test, fluoridated water was prepared in the laboratory by adding 0.221 gm of Sodium fluoride (NaF) salt in 10 liters of tap water to get 10 mg of fluoride per liter, or adding of 0.0663 mg NaF in to 10 liters to get 3 mg fluoride per liter.

1. Storage of raw water in different containers

Storage of samples were made in ordinary clay pot (pots which are made by local potters), plastic jerrycan and metal bucket, because these containers are most commonly used vessels for transporting and storage of water by the majority of the Ethiopian communities. After initial measurement of fecal coliform, turbidity, true color (color determined after filtration through filter paper), pH and temperature, samples were stored in each vessel. To know the effect of clay pot storage on the reduction of fluoride concentration, three samples having different concentration of fluoride (10, 5, and 3 mg/l each) were stored in the three respective clay pots. Plastic jerrycan was also used to store fluoridated water as control, since clean plastic containers have no effect in changing fluoride concentration.

2. Filtration of fluoridated water through crushed brick

A conical filtration apparatus, which was made of sheet metal, was prepared for holding the filtration media. The apparatus has an internal diameter of 50 cm top, 25 cm bottom and 75 cm height. The bottom part was covered with aluminum sheet, which is perforated using 2.5 mm diameter nail for the passage of filtered sample. The filtration media was prepared by crushing bricks (those which are used for construction purpose) to a size from powdery form to 1 cm across. Generally a total of 0.046 cubic meter of crushed media was used for filtration. Different samples having different concentrations of 12.7 mg/l, 5.5 mg/l, and 6.5 mg/l fluoride were poured to the vessel to be filtered through the media. After the test of each sample the media was rinsed and washed with deionized water. The need for variation in concentration from 12.7 mg/l to 3 mg/l is to determine the effect of defluoridation at different fluoride concentrations. In addition the ground water of the Ethiopian rift valley area which has caused endemic fluorosis has an average fluoride concentrations of 10 mg/l (12); so the study may give relevant information on possible strategies to solve the problem.

3. Clay pot filtration

An ordinary clay pot, which is made by local potters around Jimma, was used to filter the sample. As is the custom, after local clay pots are bought from the market, users should glaze the pot using fire to make it strong and watertight. Otherwise there will be leakage when water is stored in them. This principle is used in this study. The clay pot bought from the market was directly used to store 5 liters of fluoridated water having fluoride concentration of 10 mg/l. The pot has started to ooze 3 ml/min through its bottom part. The filtrate was collected, analyzed and compared with the fluoride concentration of the sample before filtration.

Procedures and methods used to determine fecal coliform, turbidity, true color, and fluoride were multiple tube test [most probable number (MPN)], turbidimetric, palin test, and SPADNS respectively according to standard methods (10).

Samples for a single test of fecal coliform, turbidity, color and fluoride were 105, 25, 10 and 8 ml of water respectively. Three tests were done for each study parameter with the same step and procedure. Arithmetic mean was computed from the results of each test made for each variable. The most probable number (MPN) of fecal organisms in 100 ml of the original sample was estimated using statistical table of probability with confidence interval of 95% (11).

Data were processed using a manual calculator.

Result

The average number of fecal coliform, turbidity, and color before storage were578 MPN/100 ml, 61.18 NTU and 90 TCU respectively with average pH of 6.44 at a temperature of 20.6^{0}C.

After one day of storage contaminants has reduced at different degree except the fecal coliform count in water stored in clay pot. As shown in table 1, metal bucket has reduced the fecal coliform load to 4 MPN/100 ml (99.3% reduction) and 0(100% reduction) after two and three days of storage respectively. After three days of storage fecal coliform count became 147 MPN/100 ml (74.6% reduction) and 60 MPN/100 ml (89.6% reduction) in clay pot and plastic jerrycan respectively. Turbidity became 28.3 NTU, 24.4 NTU and 29.3 NTU in clay pot, plastic jerrycan and metal bucket containers respectively while color became 15 TCU both in clay pot and plastic jerrycan, and 20 TCU in metal bucket after three day of storage.

Clay pots have shown removal of fluoride from fluoridated water sample stored in them. Clay pot$_1$ having water sample with 10 mg/l of fluoride was reduced to 7.2 mg/l, 4.25 mg/l and 2.3 mg/l after one, two and three days of storage respectively. The other two different

Table 1.The average results of the study parameters after samples are stored in different containers for different days, JIHS, Oct. 1997.

	Study parameter	Container type	Day of storage						
			0 (initial)	1	*(% redn.*)*	2	*(% redn.)*	3	*(% redn.)*
1	Fecal	Clay pot	578	578	*(0)*	177	*(69.4)*	147	*(74.6)*
	Coliform	Plastic jerrycan	578	375	*(35.1)*	118	*(79.6)*	60	*(89.6)*
	(MPN/100ml)	Metal bucket	578	272	*(52.9)*	4	*(99.3)*	0 1	*(100)*
2	Turbidity	Clay pot	61.2	48.8	*(20.3)*	39.6	*(35.4)*	28.3	*(53.8)*
	(NTU)	Plastic jerrycan	61.2	45.5	*(25.7)*	38.5	*(37)*	24.4	*(60.2)*
		Metal bucket	61.2	46.6	*(23.8)*	41.2	*(32.6)*	29.3 29.4	*(52.1)*
3		Clay pot	90	55	*(38.9)*	40	*(55.6)*	15	*(83.3)*
	Color (TCU)	Plastic jerrycan	90	68	*(24.4)*	42	*(53.3)*	15	*(83.3)*
		Metal bucket	90	68	*(24.4)*	45	*(50)*	20	*(77.8)*

**cumulative percent reduction*

Table 2. Fluoride concentration (mg/l) and percent reduction (% reduction) of samples after storage in different containers, Jimma, Oct.1997.

Container type	Day of storage and % redn.						
	0 (initial)	1	% redn.	2	% redn.	3	% redn.
Clay pot 1	10	7.15	28.5	4.25	57.5	2.3	77.0
clay pot 2	5	3.5	30.0	1.99	60.2	1.2	76.0
clay pot 3	3	2.0	33.3	1.05	65.0	0.7	76.7
average value	6	4.22	29.7	2.4	59.5	1.4	76.7
plastic jerrycan	10	10	0	10	0	10	0

samples with fluoride concentration of 5 mg/l and 3 mg/l that are stored in clay pot_1 and pot_2 were reduced to 1.2 and 0.7 mg/l respectively. No concentration change was observed from the samples that were stored in the plastic jerrycan (Table 2).

In the filtration process, water sample with fluoride concentration of 12.7 mg/l was filtered through crushed brick media. The filtrate's fluoride concentration was found to be 5.58 mg/l (53.9% reduction). The other two samples, having fluoride concentration of 5.5 and 6.5 mg/l, filtered through the same media, have also showed considerable reduction (Table 3).

Table 3. Fluoride concentration of different water samples after filtration through crushed brick filter media, Jimma, Oct.1997.

Water sample	Initial F^-conc.* (mg/l)	F^- conc. after filtration (mg /l)	% reduction.
I	12.7	5.85	53.9
II	5.5	2.05	62.7
III	6.5	2.65	59.2
Average	8.23	3.52	57.2

**.fluoride concentration*

The three water samples with initial fluoride concentration of 10 mg/l, when filtered through the clay pot, had average fluoride concentration of 0.62 mg/l which is a 93.8% reduction (Table 4).

Table 4. Reduction in fluoride concentration (mg/l) after filtration of water samples through clay pot. Jimma, Oct 1997.

Water sample	Initial F^- conc.*	F^- conc. after filtration	% reduction.
I	10	0.65	93.5
II	10	0.62	93.8
III	10	0.60	94.0
Average	10	0.62	93.8

**fluoride concentration*

Discussion

Storage of raw water is advocated as one of the simplest method of treating water by eliminating fecal organisms, turbidity, color and fluoride (5-7, 9). On the other hand, filtration of fluoride water through clay material is also effective in removing fluoride (9). The efficiency of removing chemical, physical and biological contaminants depends on the duration of storage and type of container used to store the sample.

Among containers used in this study metal bucket was much better than clay pots and plastic jerrycan for fecal coliform removal. Plastic jerrycan was significantly better in removing fecal coliform organisms than clay pot. The complete elimination of organisms in the metal bucket could be due to the sterilizing nature of metals (12).

As indicated by Wood et al (7) the reduction in all storage vessels is achieved mainly because microorganisms are likely to settle in to the bottom together with settleable particles when water is stored in a container. The other possible explanation is that the available food for microorganisms will be diminished when storage time increases and hence bacterial growth declines.

Color and turbidity reduction was achieved in different degrees according to the duration of storage and containers used. Even though storage is said to have no significant effect on turbidity removal, in the current study 52-62% reduction was achieved after three days of storage. Higher reduction was observed in the plastic jerrycan, 24.4 NTU, after three days of storage. Generally after three days of storage the turbidity was below 30 NTU in all storage vessels. Even if this did not fulfill the WHO guideline value, in some African countries like Tanzania, the temporary drinking water quality standard states that turbidity below 30 NTU is acceptable(13). The higher reduction in plastic jerrycan could be most probably due to the sampling technique. When samples are taken by dipping, as in the case of clay pot and metal bucket, the water may get disturbed and the settled materials suspend and get into the sampled water. But sampling from plastic jerrycan was by pouring and relatively clear water sample might be found. This systematic error did not occur in the true color test, because samples were centrifuged and filtered so there was no possibility for any suspended particulate to get into test sample.

Color reduction that is recommended by WHO (15 TCU) (8), was achieved in clay pot and plastic jerrycan after three days of water storage. However, in all containers color reduction of 77.8 % to 83.3% was achieved.

Storage of fluoridated water in clay pot and filtration through crushed bricks and clay pot have shown elimination of fluoride to different degrees. As the day of storage increased from 1 to 3, fluoride concentration of different aliquots that were stored in different clay pots decreased by 28.5% to 76.7%. Higher reduction of fluoride was achieved from the aliquot with the lowest initial fluoride concentration. The fluoride concentration of samples that were stored in the plastic jerrycan was unchanged, suggesting that the fluoride concentration reduction is due to the effect of clay pots.

Filtration of fluoridated water through clay pots and crushed brick media eliminated much of the fluoride with average reduction of 57.2% and 93.8% respectively. Purdom (14) explained that water with fluoride concentration more than 1.5 mg/l can be defluoridated by 100% using ion exchange method, which is comparable with our results in filtration though, clay pot. Defluoridation of water up to the value recommended by WHO was achieved in the current study using clay pots and crushed bricks. A study done by Hauge et al has also shown that ordinary clay pots and crushed bricks fired at an optimum temperature is efficient to bind fluoride from water. Water sources that have high concentration of fluoride can best be treated using clay pot filter. This simple defluoridation method is applicable in any community whose water sources are fluoridated above the recommended limit as in Wonji Showa (15).

Selection of containers in respect to the contaminants to be removed should be made for better treatment of raw water; metal bucket for biological contaminant (fecal coliform) removal, plastic jerrycan to reduce turbidity, and clay pot and plastic jerrycan for color removal are appropriate according to this study.

Teaching institutions and rural development enterprises can develop an appropriate technology for water treatment as approached by this study. Further studies are warranted to evaluate its practical application and social acceptance.

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