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Research Paper

Development and Assessment of Low-Cost, Point-of-Use Prototypes For Drinking Water Purification At Household Level in Rural Area

Environmental Science

KEYWORDS : Waterborne diseases, Rural population, Potable water, Purification Prototype

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ABSTRACT

Waterborne diseases are one of the common causes of mortality in developing nations. The potable water status is very poor in case of rural areas, where there is an urgent need of adequate and safe drinking water. Though many water purifying gadgets are available in market, the rural population is deprived of these treatment options, either due to unawareness or poor economic conditions. This study was aimed to evaluate the performance of two different types of low cost water purifying prototypes made of locally available materials. Performance of these prototypes was determined by analysing physicochemical and microbial parameters from pre-treated and treated water. The percentage removal efficiency of contaminants for Prototype I and II when compared, it was Turbidity (57 % and 60%), TS (53% and 61%), TDS (64% and 67%), TSS (60% and 76%), Total Hardness (22% and 51%), Calcium (73% and 82%), Magnesium (33% and 41%), Most Probable Number (76% and 79%), Fecal Coliforms (56% and 62%), Salmonella (24% and 40%) and E.coli (42% and 57%) respectively.Though both the prototypes work on same principle of filtration, Prototype II, which is low cost, simpler and efficient device of water purification on many counts, can be an effective option for purification of potable water at household level in rural area.

Introduction:

Waterborne diseases are the leading cause of mortality in developing countries. The problem of water pollution is more pronounced in underdeveloped as well as in many developing countries. (Ezzati et al., 2002; Pruss et al., 2002; WHO, 2002). The major victims of these diseases are children under age of five years, significantly contributing to high mortality rates (Corteguera,1993, Bern et al., 1992). In India, the problem of potable water is enhancing day by day. To some extent urban population can afford diverse types of drinking water purifiers. However, this is certainly not possible for rural people who lack basic sanitation and modern water treatment facilities due to lack of infrastructure and poor economical conditions.

Studies have shown that Point of Use (PoU) treatment can become a better option for improving the quality of household drinking water, particularly among rural poor (Agarwal and Bhalwar, 2009). A variety of low-cost PoU household treatment methods have shown reduction in the diarrheal illness in developing countries, including Chlorination, Flocculation plus Chlorination, Solar Disinfection (SODIS), Filtration with commercial ceramic filters, and Boiling or Heating of water to 70°C (Lantagne et. al. 2006; Sobsey 2002). Terafil, a burnt red clay porous media, is a device developed for supply of potable water in rural sector of Orissa, India (Khuntia et.al. 2002).Acceptability regarding locally made Janata water filter was also studied in slum areas of India (Karwasra and Sangwan, 2005). Design and application of nano silver based PoU appliances for disinfection of drinking water was studied by researchers (Nagarajan and Jaiprakashnarain, 2009).

This paper outlines attempt made by the workers to design modifications in the existing ceramic filters and evaluation of their advantages and disadvantages in water purification capacities suitable for rural population.

Material and Methods:

After thorough observation of the standard candle water filters available in the market the prototype -I was developed. Its development and post development tests encouraged development of more suitable Prototype-II by basically modifying prototype -I

1. Development of Prototype - I design

Material: *Materials used in fabrication of this prototype I were locally made Terracotta clay containers (2), Ceramic Candle (1) , Assembly lid to fit the container (1) and plastic tap (1).*

ii) Prototype - I design

Prototype-I was prepared by combining two terracotta clay earthen containers on each other with water storage capacity of 4 litres each (Figure 1.1). The diameter of upper and lower container was 25 cm and height 40 cm. The candle filter of white kaolin clay was 14 cm in height and 7 cm in diameter. The filter with pore size of 1 um was screwed into the upper earthen container by drilling a hole at the bottom. A plastic tap was attached to the lower apparatus to dispense water. The whole assembly was covered at the top with an earthen lid.

2. Development of Prototype - II design

The first prototype, though cheaper, was often developed a problem of rupturing the upper container while refitting the candle filter. Therefore, the second prototype was developed.

i) Materials

Materials used in fabrication of this prototype II were food grade transparent plastic containers of 4 liters capacity each (2), Ceramic candle (1), Assembly lid to fit the container opening (1) and Plastic tap (1).

ii)Prototype - II design

Prototype- II (Figure No.1.2) was prepared by combining two food grade plastic containers, upper and lower containers (4 liters capacity). The diameter of upper and lower container was 20 cm and height 40 cm respectively. The candle filter of white kaolin clay with 14 cm height and 7 cm in diameter was fitted at the bottom of the food grade plastic container. A tap was attached to the lower apparatus to dispense water. The whole assembly was covered at the top with plastic containers.

Fig. No. 1.1 Prototype- I made up of Terracotta Clay for water purification

Fig. No. 1.2 Prototype- II working assembly made up of Food grade plastic

3. Cost

The complete set of prototype- I and prototype- II required approximately Rs. 235/- and Rs. 205/- respectively when assembled at home.

Table No. 1.1 Developmental Cost of the Prototype-I and Prototype II

Prototype I	Unit	₹	Prototype II	Unit	₹
Terracotta clay containers	2	150	Food Grade plastic containers	2	120
Candle Filter	1	60	Candle Filter	1	60
Tap	1	15	Tap	1	15
drilling	1	10	drilling	1	10
	Total	235		Total	205

4. Test Procedure

Four litre of raw untreated water with different possible impurities was poured into the upper container with filter element and percolated water in lower container was withdrawn through a tap attached to it for laboratory analysis. The physicochemical parameters tested were odour, Turbidity, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Calcium and Magnesium. The microbial parameters studied were Most Probable Number (MPN), Fecal Coliform, *E.coli*, and *Salmonella species*. For detection and isolation of pathogens, Membrane Filter Technique (MFT) was used.

Table No.1.2 the differential media used for isolation of pathogens from the Untreated and treated water samples

Sr. no.	Name of the microorganism	Media	Temperature (°C)
1.	Coliform bacteria	Mac Conkeys Broth	37 °C
2.	Faecal Coliform	Mac Conkeys Broth	41 °C
3.	Salmonella species	Bismuth Sulphate Agar	37 °C
4.	E.coli	Endo Agar	37 °C

Result and Discussion

The Table No.1.3 shows the comparison of physicochemical and microbial parameters in the untreated and treated water samples analysed through Prototype- I and Prototype- II. The turbidity is one of the important parameter which gives cloudy appearance to liquids due to suspended particulate matter in it. It has special importance because suspended solids interfere with effective chlorination and disinfection by shielding the bacteria (Asano, 2007). Additionally, suspended solids also serve as a place of attachment for bacteria (Hurst, 1996). As per the WHO standards, Turbidity >5 NTU is considered unhealthy. It was observed that the prototype - I had 56% while prototype- II had 60% reduction in turbidity than the raw water.

For effective chlorination of water, pH should be less than 8.0 and this must be controlled to minimize corrosion of pipes, when the supply is through piped water. According to Medera *et al.* (1982), the pH of most natural waters range from 6.5 - 8.5 while deviation from the neutral 7.0 is as a result of the CO_2/bicarbonate/carbonate equilibrium. According to WHO, the pH range of drinking water should fall between 6.5 and 8.0. The fluctuations in optimum pH value may lead to an increase or decrease in the toxicity of poisons in water bodies (Ali, 1991). During the present study the untreated and the treated water through Prototype-I and Prototype-II, showed pH 7.2 (± 0.1), 7.35 (±0.5) and 7.32 (±**0.8) respectively**, i.e. the original pH values did not change much even after the treatment through both the prototypes, however it was initially suitable for potable purpose.

Table No. 1.3. Physicochemical and microbial parameters, on untreated water and water treated through purifiers Prototype I and II, and WHO standard for the parameter and % efficiency of the parameter through purifier.

Sr.No.	Parameters	Untreated water	Treated water		WHO Standard	(+) Removal %	
			Prototype I	Prototype II		Prototype I	Prototype II
1	Odour	Some odour	No odour	No odour	Unobjectionable	Unobjectionable	Unobjectionable
2	Turbidity (NTU)	12 ±***0.6***	5.2 ±***0.5***	4.8 ±***0.58***	5	57 %	60%
3	pH	7.2 ± ***0.1***	7.35 ±***0.5***	7.32 ±***0.8***	6.5- 8.5	20%	20%
4	TS (mg/lit)	2100 ± ***0.5***	785 ±***0.75***	615 ±***0.65***	1000	53%	61%
5	TDS (mg/lit)	1340 ± ***0.2***	480 ±***0.54***	429 ±***0.34***	600	64%	67%
6	TSS (mg/lit)	760 ± ***0.4***	305 ±***0.6***	186 ± ***0.5***	-----	60%	76%
7	Total Hardness (mg/lit)	485 ± ***2.3***	380 ±***0.55***	243 ± ***0.58***	300	22%	51%
8	Ca (mg/lit)	320 ± ***0.3***	85 ± ***0.25***	56 ± ***0.38***	75	73%	82%
9	Mg (mg/lit)	165 ± ***1.5***	110 ± ***0.54***	96 ±***0.68***	30	33%	41%
10	MPN per 100 ml	580	56	48	0/ 100 ml	76%	79%

11	Fecal Coliform (per 100 ml)	140	52	61	0/ 100 ml	56%	62%
12	*Salmonella* (CFU/100 ml)	37	30	28	----------	24%	40%
13	*E.Coli* (CFU/ 100 ml)	65	28	38	----------	42%	57%

Total Hardness (TH) is usually characterized by Calcium and Magnesium. The high level of TH in water is often due to mixing of sewage into the water source but the permanent hardness is mainly caused by Chlorides and Sulphates (Roy and Kumar, 2002). High levels of TH leads to formation of kidney stones and heart diseases in human beings (Freeda *et. al.*,2003, Sastry and Rathee, 1998). During the study it was observed that TH values of untreated water was 485 (± 2.3) mg/lit, whereas in treated water through prototype-I it was 380 (±0.55) mg/lit and in prototype-II, 243 (±0.58) mg/lit respectively. It was noticed that for reduction in the values of TH, Calcium and Magnesium, the prototype-II showed 51%, 42% and 82% reduction respectively which was more than prototype- I, satisfactorily treating the untreated water for TH as per the WHO.

Calcium and Magnesium content in drinking water should be, 75 mg/l and 30 mg/l respectively according to APHA, (2005). The Calcium content of untreated water, and treated water samples through prototypes- I and II were found to be 320 (±0.3) mg/lit, 85 (±0.25 mg/lit) and 56 (±0.38) mg/lit respectively. The prototype- I showed 73% reduction while prototype- II showed 82% reduction in the initial value. It was found that prototype- II gave more satisfactory results for filtration of Calcium from the untreated water.

Generally, the Total Dissolved Solids (TDS) in water show the nature of water quality or salinity (Olajire and Imeokperia, 2001). Figure No. 1.3. indicates, the TS, TDS and TSS removal efficiency of prototype- I is less than prototype- II. The prototype-II showed maximum reduction efficiency in case of TS (mg/lit) i.e.61% and TDS (mg/lit) i.e. 67% as compared to prototype-I. Also, Prototype- II showed significant decrease in Total Suspended Solids i.e. 76%.However**,** TDS contents of water filtered through prototype- I and II was within permissible limits, and would not cause any harmful effect to its consumers.

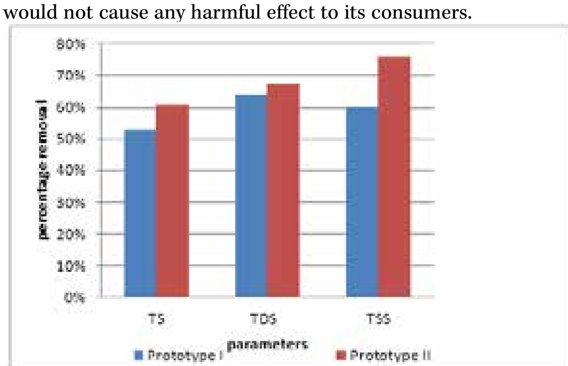

Fig. No. 1.3 TS ,TDS and TSS measurement of Untreated water and water filtered through Prototype I and II.

Coliforms are present in large numbers among intestinal flora of humans and other warm-blooded animals, and are thus found in fecal wastes (Dorothy, 1998). Coliforms, detected in higher concentrations, are used as an index of the potential presence of entero-pathogens in water environments (Rompré, 2002). The presence of coliform group in the water samples generally suggests that the sample water may have been contaminated with faeces either of human or animal origin (Richman, 1997).Coliforms are also routinely found in diversified natural environments, but drinking water is not a natural environment for them. Therefore, their presence in drinking water must be considered harmful to human health. In earlier works, it was reported that the Three in One water purifier developed for drinking water purification had shown 48% MPN removal efficiency (Khandare *et al.*, 2013) which was less than results of the two prototypes developed in the present study.

The present study showed that the Most Probable Number (MPN) count in untreated water sample was very high up to

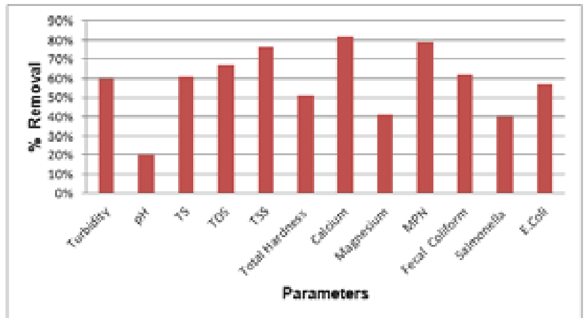

Fig. No. 1.4 Percentage reduction in physicochemical and microbial parameters treated water through prototype-II

Though both the prototypes work on the same basic principle of filtration mechanism, the percentage reduction value of physicochemical and microbiological parameters in prototypes - I and II shows that the prototype II was slightly more efficient than prototype-I. The comparison between water purification efficiency of both the prototypes is shown in Figure No.1.5 .

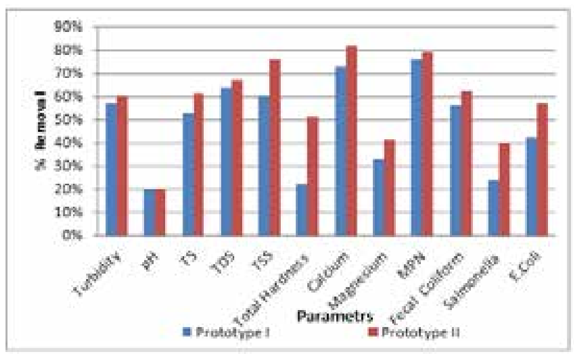

Figure No. 1.5 Percentage reduction in physicochemical and microbial parameters of treated water through prototype-I and prototype-II

The prototypes were developed with the intention that they should address the current drinking water problems of average rural household, who cannot use the high cost water purifiers in the market. Acceptance of the present purifiers in rural area depends on container design and local availability of the suitable material i.e. terracotta or food grade quality containers, maintenance and their costs. In case of prototype-II it is cheaper than prototype-I. The another advantage of Prototype- II over prototype I is, it is being transparent change in the water level in this prototype container is visible as well as it is more durable, light in weight as compared to prototype-I and thus easy to handle and clean. Due to its lighter weight, this assembly is portable. However, the water in the terracotta containers always remains cool.

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Both the prototypes are also having some shortcomings. Flow rates through both the prototypes are relatively slow as compared to modern water purifiers as well as both require periodic cleaning of ceramic filter element. While the earthen containers used in prototype- I are susceptible to breakage if handled

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