Vol 5 Issue 7 Aug 2015

ISSN No : 2230-7850

International Multidisciplinary Research Journal

Indian Streams Research Journal

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RNI MAHMUL/2011/38595 **ISSN No.2230-7850**

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Impact Factor : 3.1560(UIF)
Volume - 5 | Issue - 7 | Aug - 2015

EVALUATION OF POINT-OF-USE (POU) DRINKING WATER TREATMENT METHODS FOR REMOVAL OF COLIFORMS IN RURAL HOUSEHOLDS

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ABSTRACT
Clean drinking water is one of the basic necessities of every human being, irrespective of his origin or socio-economic status. Water is the most abundant chemical in the human body and plays a central role in the regulation of nutrient transport, toxic waste removal, thermal regulation, and digestion, organ functioning and metabolic activities. However, if water is fecally polluted it spreads diseases into a great number of consumers. World-wide waterborne diseases account for one third of the intestinal infections (Hunter, 1997). According to UNDP (2003), it has been estimated that 1.1 billion people do not have access to improved drinking water sources. Consumption of unsafe water, mostly in children, is one of the major causes of around 2.2 million diarrheal disease deaths occurring annually (WHO, 2005).

KEYWORDS :*Point-Of-Use (PoU) ,Removal of Coliforms , Drinking Water Treatment Methods .*

INTRODUCTION

The pathogens that are transmitted through fecally polluted water are coliform bacteria, a group of enteric bacteria that includes E.coli, Klebsiella species, Enterobacter and Citrobacter species. Viruses that spread through water are Adenovirus, Enterovirus, Hepatitis A, C, D, E, Noroviruses and Rotavirus. Protozoa and Helminths that spreads through water are Acanthamoeba, Giardia, Cryptosporodium, Cyclospora, Toxoplasma, Schistosoma, and Dracunculus. For the pathogens that are transmitted by the faecal-oral route, drinking water is the only vehicle of transmission. In every household, contaminated foods, hands, utensils and clothing are responsible for entry of these pathogens in drinking water (Hunter and Syed, 2001). High levels of coliform counts indicate a contaminated source, inadequate treatment or post treatment deficiencies. Besides poor water quality in rural areas, limited information exist on the bacterial quality of water supply in these settings, since most studies are available from urban communities (Sadeghi et al, 2007).

In Urban areas cleaner and safe drinking water is provided through Water Treatment Plants (WTP's), where usually raw water is well treated through sedimentation, sand filtration and chlorination methods. Many urban households also use different types of water purifying gadgets to get better quality of drinking water. However, situation is much different in the rural areas. People do not have necessary WTP'S facility in villages and the available water, if at all treated, is only with bleaching powder. In many remote villages even this facility may not be available. Considering this grime scenario, it is need of time and a challenge to provide locally suitable Point of Use (POU) treatment methods for the deprived people to meet their basic requirements which can improve the microbial quality of drinking water (Mintz et al, 1995).Many government missions related to clean drinking water are promoting the Household Water Treatment (HWT) or Point of Use (PoU) water treatment as the solution to the problem of poor quality drinking water in deprived communities in the developing countries (Sobsey et. al., 2008). There is a great need to develop or identify alternative systems by means of which people in rural communities can obtain access to safe drinking water. These alternative systems of providing safe water need to be affordable to the poorest of the poor, easy to operate, easy to maintain, and should be socially acceptable or culturally appropriate to ensure that people will adopt them, continue to use them and thus always have access to safe water [Sobsey, 2002 and Murcott, 2006).The present study involves comparison of the performance seven Point of Use (PoU) methods for reduction of coliforms. These methods are simple, cost effective and can be used at household level.

METHODOLOGY:

Reduction of coliform bacteria was observed in 1 litre water sample with known coliform count. After PoU treatment, coliform estimation was done using Most Probable Number (MPN) method to check the coliform removal efficiency of treatment. The seven PoU methods selected for the study were water Boiling, Solar Disinfection (SODIS), Ceramic candle filtration, use of Copper Vessel, use of Medichlor, UV disinfection and Pressure Cooker. A scoring system was applied on the basis of coliform disinfection efficiency of each of the methods. The scores evaluated their coliform removal percentage i.e. 91% – 100% as score 3, 71%- 90% as score 2 and 0 %– 70 % as score 1.

RESULT AND DISCUSSION:

Boiling of water is one of the oldest means of disinfecting drinking water at the household level . Despite certain shortcomings, boiling is still the most common means of treating water in home (Sobsey, 2002 and Abadie, 2007,Clasen, 2007). If practiced correctly, boiling is one of the most effective methods for killing waterborne pathogens, including protozoan cysts (Block, 2001; Agrawal, 2006.) It removes carbonate or temporary hardness caused due to presence of bicarbonates in water. This is a household process for partial softening of hard water (Govt. of India, 2010). The study involved, water samples with known MPN value boiled for different time intervals i.e. 5 Min., 10 Min. and 15 Min. to ensure the efficiency of this method. Table No.1

Table No. 1 Coli forms disinfection of drinking water through Boiling Method in laboratory

Sr. No.	Coliform Count/100ml before treatment	Water sample boiling Time (Min)	Coliform Count/100ml after treatment	Coliform removal efficiency (%)
1.	102	5 Min.(Heating)	85	16.0
2.	102	10 Min.(Boiling)	37	63.7
3.	102	15 Min.(rolling boil)	3	90.0

It was observed during the test that rolling boil for 15 min. is very effective as it gave 90% coliform removal efficiency. Similar, results were observed in earlier studies i.e. in a 12 week study among 50 households from a rural community in Vietnam (Clasen, 2007). In a 5-week study in rural Guatemala among 45 households who claimed they almost always boiled their drinking water which was associated with 86.2% reduction (Rosa et al.,2010).

Many studies have suggested that sunlight is also one of the most important factor responsible for inactivation of fecal bacteria in fresh water (Davies and Evison, 1910, Barcina et al.,1990, Go´mez-Couso, 2009). Solar Disinfection (SODIS) is a simple, environmental friendly, sustainable and inexpensive point-of-use treatment which involves use of sunlight for drinking water disinfection (McGuigan et al., 1999).

Present study involved testing of efficiency of SODIS method by using empty cold drinks plastic bottles, which are commonly used in villages for storing drinking water. They were filled with 1 litre contaminated water sample with known number of coliforms and later exposed in sunlight. The experiment was carried out for three durations, on a sunny day in month of May in year 2011.

Table No. 2 Coliform disinfection of water through SODIS method

Sr. No.	Coliform Count / 100ml before treatment	Sunlight exposure time (hrs)	Coliform Count /100ml after treatment	Coliform Removal Efficiency (%)
1.	102	2	97	4.90
2.	102	4	76	25.50
3.	102	6	58	43.13

it is seen from Table No.2 that coliform removal efficiency increased with increase in sunlight exposure period. It was observed that the sample bottle placed in the sunlight for 6 hrs, showed the higher coliform removal efficiency of about 43.13% as compared to other two time intervals of 2 hrs and 4 hrs. But SODIS method was not much satisfactory as even after 6 hrs exposure at noon during summer, the coliform removal was barely 43 percent. The experiment could not be extended for longer duration due to decline in sunshine as well as practical limitations at household level.

Water filtration involves separation of suspended solids and impurities from water. The third PoU method tested was commonly used porous Ceramic candle filter. The water sample with known coliform count was passed through candle filter after 2 hours retention time.

Table No.3 Coliform disinfection through Ceramic Filter

Retention time (Hours)	Coliform Count /100ml before treatment	Coliform Count /100 ml after treatment	Coliform Removal Efficiency (%)
1 hr	97	52	72
2 hrs.	97	33	83

It was observed that the efficiency of this method after 2 hours was up to 83% in disinfection of coliforms. However, the water purified through this method was not completely free of coliforms, as par requirement of WHO norms. Another study shows better efficiency when the candle was impregnated with colloidal silver, which was able to inactivate E. coli and total coliforms from drinking water (Lamichhane, 2013). A study in Cambodia has shown that families who use a ceramic water filter, average 54% fewer instances of diarrheal disease when compared to families who do not use the water filter (Morrill, 2012).

The next PoU method tested was use of UV radiation for disinfection. Electromagnetic radiation in the wavelengths ranging from 240 to 280 nanometers(nm) effectively inactivates microorganisms by irreparably damaging their nucleic acid. The most potent wavelength for damaging deoxyribonucleic acid (DNA) is approximately 254 nm (Wolfe, 1990 and Sharifi et. al., 2006). In the study one liter water sample with known coliform count was placed under the UV lamp in Laminar Air Flow. The sample was exposed for for 5 min., 10 min. and 15 min. time period. The sample placed for 15 minutes showed comparatively highest coliform removal efficiency.

Table No. 4 Coliform disinfection using UV treatment

Sr. No.	Coliform Count/ 100ml before treatment	Exposure time(min)	Coliform Count/100ml after treatment	Coliform Removal Efficiency(%)
1	47	5 min	38	19
2	47	10min	13	72
3	47	15 min	8	82

As the efficacy of UV disinfection of freshwater depends on the UV exposure (Mounaouer and Abdennaceu, 2015), it was observed that coliform removal efficiency goes on increasing with increase in exposure time. Perhaps the efficiency could reach hundred percent with exposure of 20-25 minutes but such a long exposure of UV radiation in a households environment is not safe to the user in daily operation.

Chlorination is another PoU method in which Chlorine is used most widely for disinfection of drinking water because of simplicity in its use, ability to measure its effectiveness, easy availability and relatively lower cost. Usually with a chlorine concentration of 1%, liquid bleach is sold in bottles or sachets, available on a commercial basis as brand name Medichlor. During the study Medichlor, available in the local market in the form of liquid in small bottles of 40 and 100 ml bottles, was used as Chlorine source. One liter of water sample with known coliforms count was taken and 4, 6 and 8 drops of Medichlor were added in separate containers and kept for retention period of half an hour each.

Table No. 5 Coliform disinfection using chlorination

Sr. No.	Coliform Count / 100ml before treatment	Retention time (min)	Chlorine amount (ml)	Coliform Count/100ml after treatment	Coliform Removal Efficiency (%)
1	56	30 min	0.4	34	39
2	56	30 min	0.6	23	59
3	56	30 min	0.8	09	84

The disinfection of Chlorine depends on its concentration in water, contact period, water temperature, pH, the characteristics of contaminants and water supply (Dvorak, 2009). Present study shows that the sample with 8 drops of Medichlor showed the highest coliform removal efficiency of 84% in 30 minutes exposure.

Copper is one of the metals having known bacteriostatic properties. It actively acts on the waterborne pathogens as reported by some workers (Sudhaa et al, 2007; Sharan et al 2011). Copper releases copper ions that inactivate respiratory proteins in the bugs, choking them to death on a moist surface. It also degrades the DNA of a cell (Sharan, 2011). Also, treatment with Copper is reported to be effective for the removal of bacteriophages and viruses from water (Yahya et al, 1992). In present study, water with known coliform count was stored in a 2 lit copper vessel. The testing for change in presence of coliforms bacteria was carried out after an interval of 12 hrs. and 24 hr retention period .

Table No. 6 Coliform disinfection using copper vessel

Sr. No.	Coliform Count / 100ml before treatment	Retention time (hrs)	Coliform Count/100ml after treatment	Coliform Removal Efficiency (%)
1.	47	12hrs	28	40
2.	47	24 hrs	32	57

It was observed that removal of the coliforms in the copper vessel was efficient to a certain degree i.e. 40% and 57% after 12 hours and 24 hours respectively. Only two readings up to 24 hour duration were taken for the test, considering the common attitude, especially of women, against use of 'stale water' i.e. overnight stored water for drinking purpose. Change in this attitude of the users is necessary to accept due importance to the quality of stored clean drinking water for health of the family.

Use of pressure cooker, which acts as a household autoclave, is an ideal method of cooking in a sealed vessel, which does not permit air or liquids to escape below a preset pressure. In this way pressure cooker works on the same principle as an autoclave used for sterilization purposes in laboratories. Therefore, it was realized that this simple domestic gadget could be used as an effective alternative utensil to disinfect coliforms for purification of drinking water at household level.
One liter of water sample contaminated with known coliform count of bacteria was taken and heated for attaining first whistle (7-10 minutes) of cooker.

Table No. 7 Coliform disinfection using Pressure Cooker

Sr. No.	Coliform Count / 100ml before treatment	Heating time (min)	Coliform Count/100ml after treatment	Coliform Removal Efficiency (%)
1.	47	7-10	0	100

Table No.7 shows that the initial coliform count of water i.e. 47 was reduced to 0 counts after heating in pressure cooker for 10 minutes. Thus, among all the tested PoU methods, use of Pressure Cooker for water disinfection was the most efficient method where coliform bacteria were totally removed.

A rating system was applied for choosing the most efficient PoU coliform disinfection method among seven selected water purification methods. the disinfection efficiency for each tested method was grouped into coliform removal percentage i.e. 91% – 100% as score 3, 71%- 90% as score 2 and 0 %– 70 % as score 1.

Table No.8 Rating for Coliform Disinfection Efficiency of the seven Treatment methods in Terms of potability (MPN)

Sr. No.	Water Purification Method	Coliform Removal Efficiency (%)	Score
1.	Boiling	90	**2**
2.	Solar Disinfection (SODIS)	43	**1**
3.	Ceramic candle filtration	73	**2**
4.	Use of Copper Vessel	63	**1**
5.	Use of Medichlor	82	**2**
6.	UV disinfection	84	**2**
7.	Use of Pressure Cooker	100	**3**

Table No.8 gives the score values based on of MPN obtained from the sample of drinking water after purification through each PoU method for coliform disinfection.

CONCLUSION:

All the selected seven methods of drinking water purification are relatively common and used at some time in the households, particularly in urban areas. They were simple, cost effective and could be performed in rural households as well. It is observed that pressure cooker method achieved highest score of 3, due to its higher coliform disinfection efficiency. Pressure Cooker works on the principle of autoclave used in microbial laboratory where most of the microorganisms are destroyed. Now a days pressure cooker is available in many rural households and therefore it can play a great role in providing safe drinking water to rural masses. Those poor who do not have access to pressure cooker yet, government should take initiative to provide rural poor communities with free pressure cooker in each household. This besides providing PoU clean drinking water would be cost effective solution on a large scale. This initiative will not only take care of disinfection of potable water, but as bonus will save large amount of cooking firewood energy. .

ACKNOWLEDGEMENT:

The authors wish to express thanks to Department of Environmental Science, Shivaji University for providing facilities for research. Sincere thanks are also due to Development Research, Awareness & Action Institute (DEVRAAI), Kolhapur for providing valuable guidance in the rural health oriented study.
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