

Economical solution to remove microbes from harvested roof water

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(Received 10 June 2014; accepted 21 July, 2014)

ABSTRACT

Scarcity of potable water is being experienced throughout the world due to increasing population (demand) and environmental pollution. These shortages are experienced more by poor rather than the rich, who can afford costly modern technologies for survival. Roof water harvesting is an ideal technique to collect and store water for drinking purposes. However, with time, in spite of all the precautions, there is a possibility of development of microbes in stored water that makes it unsafe for drinking. Moreover, microbe infected water is one of the major concern in most parts of developing countries. There are many water purification methods, although, most of them are expensive and beyond the reach of many people, especially in rural areas. In India, since ancient times, Ayurveda recommends use of copper pots / vessels for storing drinking-water, but, in last few decades, copper is replaced by steel, plastic and earthen pots. In conventional water distribution system chlorine is used to disinfect drinking water, but, it has several detrimental effects, so replacement of chlorine is essential. In this study an attempt was made to study the best method among the Copper, Silver treatment, earthen pot or Plastic jugs for removal of biological contamination from drinking water for domestic use. The result revealed that copper vessel showed maximum inhibitory effect on coliform as well as total bacterial count at 12 hrs and 24 hrs. There was a slight increase in pH and Copper concentration but it remains within the permissible limits laid by World Health Organization. The findings indicate that vessel or pot made up of copper could be used for antimicrobial treatment for purification of drinking water. It would be very economical solution to disinfect potable water, without any energy requirements, which could be adopted in urban / rural areas of the developing countries.

Key words: Harvested roof water, Water purification, Copper vessel, Drinking water

Introduction

Water is the vital component of all living organisms, besides it is the primary source to cause the disease like diarrhea, typhoid and various other diseases to the human being. The major danger associated with drinking water is its possibility of contamination by sewage, decay of plant, animal and human waste. Microbial decay of organic material leads to multiplication of host of pathogens that mix with water which acts as a carrier of bacteria causing infectious

disease as enteric fever or dysentery. Potable use of such water leads to infections and disease. Providing safe drinking water to the majority of the world's population especially to those in developing countries, is still a major problem. According to the World Health Organization, an estimated 4.1% of the total global burden of disease is contributed by diarrhea illness: around 88% of that burden is due to unsafe water supply, sanitation and hygiene, with children in developing countries being the most common victims (WHO, Burden of disease and cost

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effectiveness estimates, 2004). *Escherichia coli* (ETEC), rotavirus, *Vibrio cholera*, and species of *Shigella*, spreads through contaminated water and food or from person to person (Qadri *et al.*, 2005). In India, many states still have outbreaks of cholera. During 1996-2007, at least 2,22,038 individuals were affected by cholera (Kanugo *et al.*, 2010). In developing countries the public water distribution system are often poorly maintained. moreover, treated water is also often observed to be re-contaminated because of unsafe storage and handling practices within household (Mintz *et al.*, 2001); thus, it is important to explore effective strategies and approaches that are affordable, simple, maintenance free and that which can be implemented at home and are acceptable to the population. Storing water in gold, silver and copper pots finds mention in ancient texts of Ayurveda for purification of water (Sharma, 2004). In recent years, this practice has been replaced by the use of earthen pot, steel and plastic containers as gold, silver and copper are expensive.

The antimicrobial effect of copper and copper alloys on pathogens such as *Escherichia coli* (Sharan *et al.*, 2010, Dhanalakshmi and Rajendran, 2013), *Salmonella*, *Shigella* (Dhanalakshmi and Rajendran, 2013), *Methicillin-resistant Staphylococcus aureus* (MRSA) (Niiyama *et al.* 2013), *Mycobacterium tuberculosis* (Copper Development Center, 2004; Godbole, 1971), *Influenza A virus* (Noyce, 2007) and *Salmonella typhi* and *Vibrio cholera* (Kanugo *et al.* 2010) has been reported. Copper's antimicrobial properties have been recognized and applied by many ancient cultures for disease control and water treatment. (Borkow and Gabbay, 2005; Gorman and Humphreys, 2012). Copper is an essential micronutrient for plant, animal and human health (International Copper Association, 2012. Copper Development Association, 1988) but rarely occurs naturally in drinking water. Human body requires copper in very small amount, its higher concentration in drinking water can cause health hazard. Elevated levels of copper for 14 days or more can cause permanent kidney and liver damage in infants under the age of one year and can cause nausea, vomiting and diarrhea and stomach cramps in people of all ages (David, 2003). Very high level copper can cause a bitter metallic taste in water and result in blue-green stains on water surface (Healthy drinking waters for rhode islanders, 2003).

Materials and Method

Due to shortage of good quality drinking water in Navsari Agricultural University campus, roof water harvesting was taken up in several buildings of the University. Storage tank were designed to meet the demands of the people using the building. Though, chemical water quality of all storage tanks was found to be below 50 TDS during four year of monitoring. However, it was found that in spite of adopting all precautions; there remains the possibility of development of microbes in stored water, so this study was planned to remove microbes before consuming the water.

Collection of sample for treatment

The harvested roof water during monsoon was collected from a building where the residents did not follow the recommended measures of storage, making it vulnerable for development of microbes. Water was collected in a big sterilized 50 liter capacity plastic container. Initial water sample showed 50 to 130 total coliform (MPN/100 mL) and 3.5×10^3 to 5.3×10^3 total bacterial count, that tank was kept for 24 hrs at room temperature, later, five replications were prepared.

Treatment and control

Five liter water was kept in five different vessels / pots, the treatments consisted of: T1= water stored in a Copper vessel, T2 = Silver Treatment (Silver strip of 30 cm x 10 cm x 0.03 cm size immersed in container), T3= water passed through commercially available cloth filter, T4= water stored in an Earthen pot and T5= Control. These storage vessels were thoroughly cleaned each time before use with 70 % alcohol, sterile distilled water and surface sterilized with UV light.

Microbiological analysis

Enumeration of bacterial growth

All pots were incubated at room temperature (20-25 °C) up to 24 hrs. Samples were collected after every 0 hrs, 6 hrs, 12 hrs, 24 hrs in sterilized glass bottle and analyzed immediately or at times stored in refrigerator to avoid multiplication during holding time. The whole experiment was replicated four times.

Samples were analyzed for total bacterial count

(CFU/mL) and total coliform (MPN/100 mL). Total bacterial count were determined by plating on Nutrient agar (Standard Plate Count) and incubated at 37°C for 24 hrs while multiple tube technique was used for the enumeration of Most Probable Number of total coliform bacteria by using standard method i.e. presumptive coliform test, confirmatory test and complete confirmation test (Bureau of Indian Standards 2012) Nutrient agar (NA) as a basal medium and MacConkey agar as a differential medium were used to determine enteric bacteria.

Detection of pH and Copper

pH was analyzed at 0 hr, 6 hrs, 12 hr and 24 hr by using pH meter (Systronics make, µ pH system 362) and Copper concentration was analyzed after every 2 hrs interval in T1 water samples till 60 hr by using Atomic Absorption Spectrophotometer

Results

Laboratory study was conducted to find the copper residue in water at different time's periods of storage. The collected water samples were tested before and after different treatment at 6 hrs, 12 hrs and 24 hrs time intervals for reduction of total coliform count by MPN test (Fig. 1) in lactose broth and on the nutrient plate to measure the total bacterial count (Fig. 2) as the colony forming unit. Table 1 and Table 2 show statistical analysis regarding reduction in total coliform (MPN/100 mL) and total bacterial count (CFU/ml) in different treatment with time, i.e. 6 hr, 12 hr and 24 hr. According to the results, the treatment trend was found consistent with the duration as interaction is Non Significant.

The pH in all treatment sample and level of copper in T1 (Figure 3) leached in to the test sample, but it remained within the WHO permissible limit set by WHO [pH<8.5 and 1.3 mg/L of copper] the

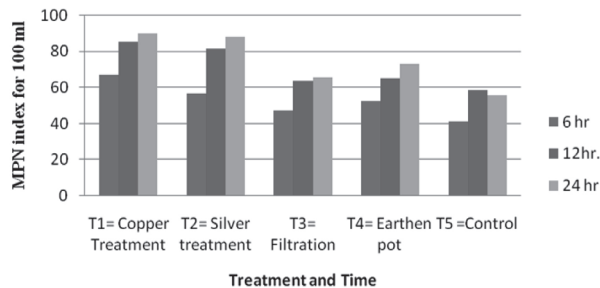


Fig. 1. %Reduction in MPN with time in different Treatment

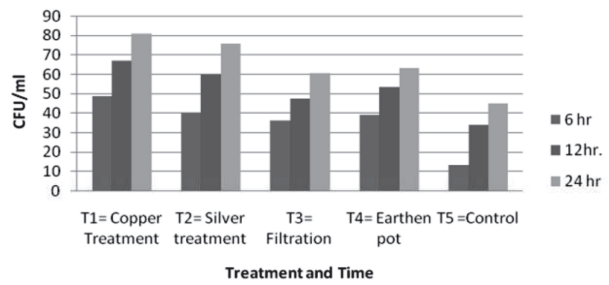


Fig. 2. %Reduction in CFU with time in different Treatment

(WHO. Guideline for Drinking water Quality, 1993), even when drinking water is stored till 4 to 5 days.

Discussion

The major public health problems in many developing countries are the enteric fever and cholera by the global initiatives in water and sanitation (Ochiai *et al.*, 2005; Gaffga *et al.*, 2007), prior most due to lack of adequate sanitation facilities and awareness for safe drinking water, alongside issues related to personal hygiene (Araya *et al.*, 2004). The contamination occurs during the transport and /or storage at the household level (Espirito Santo *et al.*, 2011). As it's a known fact that during ancient time copper pots were used for storage of drinking water and many experiments proved the copper has antimicrobial activity mainly on the water borne pathogens (Noyce *et al.*, 2007; Preethi Sudhaa *et al.*, 2009, Sharan *et al.*, 2011).

The oligodynamic effect a toxic effect of metal ions on living cells, algae, molds, spores, fungi, viruses, prokaryotic and eukaryotic microorganisms, even in relatively low concentrations. Several metal ions, especially heavy metals, show this effect

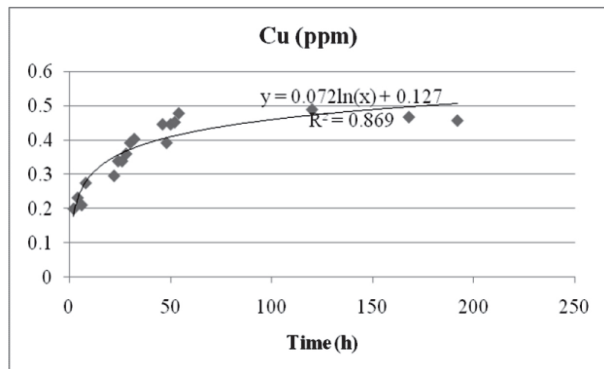


Fig. 3. Copper residue in water stored in copper pot for eight days

Table 1. ANOVA RBD-% reduction in MPN with time

Treatment	6 hr	12hr.	24 hr	pooled
T1=Copper Treatment	66.86	85.18	89.57	80.54
T2=Silver treatment	56.44	81.54	87.64	75.21
T3= Filtration	47.18	63.36	65.64	58.73
T4=Earthen pot	52.35	64.94	72.94	63.41
T5=Control	41.23	58.36	55.84	51.81
SEM	2.12	2.7	1.76	2.04
CD	6.53	8.32	5.44	3.96
Time				52.81
h1	-	-	-	
h2	-	-	-	70.68
h3	-	-	-	74.33
SEM	-	-	-	6.24
CD	-	-	-	17.64
Interaction(T x H)				
SEM	-	-	-	2.22
CD	-	-	-	6.39
CV%	8.04	7.64	4.75	6.76

Table 2. ANOVA RBD- % reduction in Total Bacterial Count with time

Treatment	6 hr	12hr.	24 hr	pooled
T1= Copper Treatment	48.64	66.94	80.74	65.44
T2= Silver treatment	40.51	60.05	75.69	58.75
T3= Filtration	36.08	47.5	60.65	48.08
T4= Earthen pot	39.28	53.25	63.16	51.9
T5 =Control	13.49	34.09	44.8	30.79
SEM	3.12	1.63	1.95	1.39
CD	9.61	5.03	6.03	3.96
Time				
h1 (6 hr)	-	-	-	35.6
h2 (12 hr)	-	-	-	52.37
h3 (24hr)	-	-	-	65.01
SEM	-	-	-	6.24
CD	-	-	-	17.64
Interaction(T x H)				
SEM	-	-	-	2.32
CD	-	-	-	NS
CV%	17.54	6.24	6.02	9.13

to various degrees. Bacteria are in general affected by the oligodynamic effect. Viruses in general are not very sensitive to this effect, since viruses are not considered to be metabolically active outside their host range. Certain metals, such as silver, copper and copper alloys, are known to be far more poisonous to bacteria than others, such as stainless steel and aluminum. Silver is capable of rendering stored drinking water potable for several months.

Water of Low pH or acid rain water when collected in Copper vessel for domestic consumption can cause poisoning in humans. The U.S. Environ-

mental Protection Agency's Maximum Contaminant Level (MCL) in drinking water is 1.3 milligrams per liter. The MCL for copper is based on the expectation that a lifetime of consuming copper in water at this level is without adverse effect (gastrointestinal). Copper poisoning can occur from eating acid foods cooked in uncoated copper cookware or from exposure to excess copper in drinking water or other environmental sources.

Copper treatment was best followed by water treated with silver strip, while cloth filtration and earthen pot are less effective for reduction of bio-

logical contamination (total coliform and total bacterial count).

The result of copper treatment at 6 hr, 12 hr and 24 shows reduction in total coliform by 67%, 85% and 90% as well as total bacterial count by 49%, 67% and 81%, respectively. While, in Silver treatment, reduction in total coliform was 56%, 82% and 88% and total bacterial count by 41%, 60% and 76% respectively. In Filtration treatment, reduction in total coliform 47%, 63% and 65% and total bacterial count by 36%, 48% and 61% respectively. In Earthen pot reduction in total coliform 52%, 65% and 73% and reduction in total bacterial count by 39%, 53% and 63% respectively.

As per the statistical analysis after 6 hr incubation Copper treatment (T1) was best treatment flowed by Silver Treatment (T2) and Earthen pot (T4), T4 was at par, but better than Filtration (T3) and Control (T5). Whereas, after 12 hrs of incubation, Copper treatment (T1) and Silver Treatment (T2) are at par, but better than Filtration (T3), Earthen pot (T4) and Control (T5). After 24 hr incubation, Copper treatment (T1) was the best method than Silver Treatment (T2) and Filtration (T3), Earthen pot (T4) and Control (T5) were at par for removal of bacterial contamination from drinking water. Filtration (T3) Earthen pot (T4) and Control (T5) were found to be less effective in removal of bacterial contamination from water. Silver Treatment (T2) was also effective but use of silver become too costly so among all of these treatment the best as well as cost effective method was the Copper treatment (T1)

Studies have shown the merits of copper surfaces for their use in improving public hygiene in healthcare facilities, the potential use of copper for the purification of drinking-water, especially in developing countries, has not been widely studied. Therefore, results of our study indicate that copper holds potential to provide microbial-safe drinking-water to the rural areas in developing countries. The use of copper pots in Indian households is common therefore, likely to be socially accepted by the people. Its functioning is not dependent on fuel, electricity, replaceable filters, intensity of sunlight, etc. to operate or maintain it; it is simply a passive storage of water. This takes into account the conditions prevailing in rural villages and the urban slums of developing countries. The health benefit that can be achieved by using copper pot as water-purification device will far outweigh the cost of the pot, if divided over the members in a rural family,

especially when it will be a one-time investment with no recurring costs.

Conclusion

To disinfect harvested rain water for drinking purpose, against any microbial activity, water could be safely stored in a copper vessel for 12 hr and 24 h to reduce Coli-form by 85% and 90% and total bacterial count by 67% and 81 % respectively.

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