

Original Research Article

Effect of Storage Containers on Coliforms in Household Drinking Water

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ABSTRACT

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Safe drinking water is essential to the health and well-being of the human beings. In recent years, the water is being polluted mainly due to human activities. Water pollution affects drinking water sources like ponds, lakes streams leading to shortage of clean microbial safe water for drinking purpose. In rural villages, people use pond water after filtering through a cloth for cooking and drinking purpose. They generally store it in a mud pot and in copper containers, believed to be safe for drinking purpose. The method of storage is essential in maintaining water purity and safety for drinking purposes. Based on the understanding of the literatures, we have taken efforts to study the effect of various storage vessels on the acceptable water quality where there are no bacteria especially, of faecal origin i.e. coliforms. The bore well water was collected and stored at room temperature in 10 different types of containers and evaluated for coliform bacteria at different time intervals from 0 to 25 hrs using MNP method. From the results that there was no significant reduction of coliform bacteria in the water stored in Glass. Plastic, Ceramics, Coconut shell, Aluminum and Stainless Steel container, where as significant level of reduction of coliforms bacteria was observed in the water stored in Mud pot, Brass, Copper and Silver containers suggesting that water can be stored in any one of these containers for house hold purpose free from microbes.

Introduction

Water is essential to all living beings. According to F. Batmanghelidj MD, author of “Your Body’s Many Cries for Water”, “25% of the human body is made up of solid matter while the remaining 75% is water. Safe drinking water is colourless, odourless, tasteless and free from faecal contamination (Ezeugwunne et al. 2009). Improper sanitation and fecal contamination of

drinking water sources is majorly responsible for pollution of water (Opio et al. 2011; Cabral.S.P.J. (2010). Water related diseases continued to be one the major health problems globally (Oladipo et al. 2009; Folarin et al. 2013 and Uwah et al. 2014) and people from both developed and developing countries suffer from diarrhoeal diseases due to consumption of

contaminated water (Eileen et al. 2009; UNICEF, 2013; WHO 2002a and WHO 2002b). Estimation by WHO states that about 3 million children below 5 years of age from developing countries die every year due to diarrhoeal diseases by drinking polluted water. Water often gets polluted with human and animal faeces which contain potentially highly pathogenic microorganisms that can cause diseases in human beings (Sobsey et al. 1993;; Leclerc et al. 2002; Theron and Cloete, 2002; Gerba et al. 2005 and Cabral.S.P.J. 2010). The most commonly used fecal indicator microorganisms such as total coli form bacteria, thermo tolerant bacteria and *E. coli* are both found in human and animal feces but do not differentiate between the human and animal fecal pollution (Gerba, et al. 1996; Sinton et al. 1998; Soller et al. 2010 and Odonkor et al. 2013). According to (Sarsan, 2013) coliforms are used as water quality indicators for two main reasons 1. Coliforms are mainly contaminate the drinking water 2.Determination of the coli forms in the drinking water is relatively simple and economic. Coli forms could be easily detected by its ability to ferment the lactose and produce gas within 24 to 48 hrs at 35 to 38° C.

In developing countries, people usually collect drinking water from surface sources like ponds, wells, streams, municipal pipes, stored water from tanks or storage level itself. Water may become contaminated at any point between collection, storage, serving at homes (Nala et al. 2003 and Tambekar et al. 2006 and Rufener et al. 2010). The storage water for hours or even days increases the possibility of fecal contamination of otherwise good quality water inside the household (Valerie Daw Tin Shwe, 2010 and Subbaraman et al. 2013). The Household drinking water storage containers or the point-of-use are

importance for the fecal recontamination of water (Subbaraman et al. 2013). Higher levels of microbial contamination is associated with storage vessels having wide openings (e.g., buckets and pots), by introduction of hands, cups and dippers that can carry faecal matter, and lack of a narrow opening for dispensing water (FOS, 1995 and Onigbogi and Ogunyemi, (2014). For improving and protecting the quality of water to these households, effective, affordable, functional and sustainable intervention strategies are required (CDC, 2001; Sobsey, 2002; Krieger et al. 2002; UNICEF, 2008 and Choffnes et al. 2009). The Indian ayurveda describes storing water in a copper vessel overnight and drinking it in the mornings for many health benefits. Storing water in copper and silver pots finds mention in ancient texts of Ayurveda for purification of water (Sharma et al. 2004; Preethi Sudha et al. 2012 and Radha and Susheela, 2015). Copper is known for its antimicrobial effect (Preethi Sudha et al. 2012). Sarsan, 2013 have reported that the water stored in the copper and silver vessels have antimicrobial, anti- inflammatory, antioxidant and anti carcinogenic activities.

Efforts were made to study the effect of storage of water in 10 different vessels on the storage of water by comparing the total population of coliform present in the water before and after storage for different periods. This study gives an idea about the container in water can be stored.

Materials and Methods

Sample Collection and Storage

The water sample was collected at Madippakam, Chennai, from a bore well situated nearby which is sewage water was stagnated. The water was collected in a sterilized poly propylene bottle and brought

to the laboratory and stored in the refrigerator until use. Different storage containers viz, glass, plastic, ceramics, stainless steel, aluminum, mud pot, coconut shell, brass, copper and silver containers were used in this study. The different containers were wiped with alcohol dipped cotton and then rinsed with sterile water before transferring water to it. One hundred mL of the bore well water was transferred to each container and kept the water filled containers at room temperature 32° C for 24 hrs. The water samples were analyzed for the presence of coliforms before and after storage at different time intervals from 0 to 24 hrs and physico chemical parameters.

Physiochemical Parameters

The physiochemical parameters, viz., pH, Electrical Conductivity (EC) and Total Dissolved Solid (TDS) of the water sample were analyzed using Hanan instrument portable waterproof tester (pH, EC and TDS).

Microbiological Studies of the Water Samples

Most Probable Number (MPN) technique was used for analysis of total coliform and fecal coli form bacteria in the collected water sample and the water stored in 10 different types of containers for different time periods. 3 tubes MPN method was routinely followed for the analysis of coli forms in the water.

Presumptive Test

The water samples were analyzed for the presence of coliforms in lauryl tryptose broth (g/L: Lactose, 20; Sodium chloride, 5; Dipotassium phosphate, 2.75; Mono Potassium phosphate, 2.75; Sodium Lauryl Sulphate, 0.10; pH at 25°c 6.8 ± 0.2 . by

using presumptive test specific for coli forms (Salle,1974). Ten mL of either single strength or double strength Lauryl Tryptose Broth were made in test tubes containing an inverted Durham's tube and sterilized at 121 °C, for 15 min. The broth was aseptically inoculated with 0.1 ml of bore well water to 10 mL to double strength and 1ml, 10ml of bore well water to single strength Lauryl Tryptose broth and incubated at 35° C. The results were recorded after 24 hrs. The formation of gas indicated by a bubble in Durham's tube were recorded as positive indicating the presence of coli forms and those without bubble were regarded as negative for coli forms. The negative tubes are further incubated for another 24 hrs. Tubes which exhibit positive result after 48 hr are also taken for subsequent analysis.

Confirmatory Test

Confirmatory test for the positive water samples were done in brilliant green 2% bile broth (gms/L: peptic digest of animal tissue, 10; Lactose, 10; Ox gall, 20; Brilliant green, 0.0133; pH (at 25 °C) 7.8 ± 0.2 . One loop full of the inoculums from positive tubes of Llauryl Tryptose broth was inoculated into the sterile brilliant green 2% bile broth tubes and incubated at 37 °C for 24hrs. After the incubation period, the tubes were examined for the gas production. The numbers of positive tubes were counted and the value of MPN/100 mL as computed by referring the standard MPN table (Aneja, 2003).

Completed Test

The test is aimed for the identification of coli forms through various biochemical means. Streak one loop full of the positive confirmed culture was sterile EMB agar plate and incubated at 37 °C for 24 hrs. Nucleated colonies with or without metallic sheen colonies were marked as typical

colonies and transfer to sterile Lauryl Tryptose Broth and nutrient agar slants. Observe gas production on LT broth. Gas production on LT broth indicates completed test.

Results and Discussion

Sample Collection

The site of the bore well from which water was collected for the study is represented in Fig.1. The bore well is situated near to a sewage water stagnation site. We have collected water from this well to study its physico-chemical and microbiological parameters and the effect of storage containers on the microbial safety of water also analyzed.

Physico-Chemical Parameter

The physico-chemical parameters of water before and after storage in ten different storage containers were shown in Table 1. There were no significant change in physico-chemical parameters viz., pH, EC and TDS of the sample before and after storage in different containers. A slight increase in the pH but not significant, was observed in the water stored for 25 hrs. The results were presented in the Table 1. The pH of the water stored in different containers (before and after 25 hrs storage) is as follows: mud pot (7.71 & 7.78); aluminum (7.40 & 7.65); brass (7.54 & 7.69); copper (7.55 & 7.89) and silver (7.67 & 8.02). This slight increase in pH after 25 hrs of storage might be due to some electron fluctuations as it was reported by Saran, 2011 that long period of water storage in aluminum and copper containers metals might get dissolved in water to become ionic (electrolyte) as can be ascertained by its pH measurement. The same trend was observed in EC and TDS. There was slight change in EC and TDS in stored water when compared

to fresh water.

The results of microbial analysis of water stored in ten different containers, showed very clearly the decrease in coliform bacterial population by 3 hrs of storage itself and complete removal of coliform bacteria leading to microbial free safe water within 24 hrs, in water stored in brass, copper and silver containers. The number of coli forms has significantly reduced from 1100 to 3 MPN after 2 hrs of storage. In the case of mud pots, the coli form bacteria was detected in water stored until 5 hrs and was not declined later on the storage. However, the water stored in other remaining containers viz., glass, and plastic containers A & B, ceramics, coconut shell show the presence of coliform bacteria even in the water stored for 25 hrs. The results were tabulated in tables (2-11) and Fig. (2).

The results clearly show that household water storage containers were capable of improving quality of the microbial contaminated water. The quality improvements of water by storing them in different containers were already reported and our results are in accordance to those results. (Thompson et al. 2003; Clasen et al. 2007; WHO, 2007 and Jain et al. 2008). The physico-chemical and microbial qualities of some of the bore well water show that there were frequent pollution of groundwater by household waste and sewage. The high levels of bacterial counts of water observed in this work show that most of the bore well water is not safe for human consumption (Uhuo et al. 2014; Okereke et al. 2014 and Amenu et al. 2014). The pH of water is an important factor in its quality with wide fluctuations in optimum pH ranges leading to an increase or decrease in the toxicity of poisons in water bodies (Ali, 1991; Atlas, 1995 and Okonko et al. 2008).

Table.1 Physico-Chemical Parameters of Water Before and after Storage in Different Containers

Sl.No	Name of the Containers	pH		EC (mS/cm ²)		TDS (ppt)	
		Before	After	Before	After	Before	After
1	Glass	7.67	7.68	1.29	1.27	0.75	1.5
2	Plastic (A)	7.44	7.42	1.49	1.51	0.55	0.56
3	Plastic (B)	7.41	7.38	1.66	1.69	1.00	1.1
4	Ceramics	8.00	8.06	1.72	1.74	1.00	1.1
5	Mud pot	7.71	7.78	1.82	1.86	1.50	1.43
6	Coconut shell	7.66	7.71	1.51	1.53	1.23	1.21
7	Aluminum	7.40	7.65	1.71	1.76	0.86	0.84
8	Stainless steel	8.01	8.05	1.74	1.75	0.91	0.89
9	Brass	7.54	7.69	1.81	1.89	1.28	1.25
10	Copper	7.55	7.89	1.82	1.91	1.34	1.30
11	Silver	7.67	8.02	1.65	2.06	1.32	1.28

Table.2 Result of the Analysis of Coliform in the Collected Well Water Sample Stored in Collection Container Itself at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Control		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100

Table.3 Result of the Analysis of Coliform in the well Water Sample Stored in Glass Container at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Glass		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100

Table.4 Result of the Analysis of Coliform in the Collected Well Water Sample Stored in the Plastic Container A at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Plastic A		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100
	1.0	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100
	0.1	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100	-	+	+	1100

+: gas production;-: No gas production: MPN index for 100ml

Table.5 Result of the Analysis of Coliform in the Collected well Water Sample Stored in Plastic Container B at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN

Plastic B	10	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100

Table.6 Result of the Analysis of Coliform in well Water Sample Stored in Ceramic Container at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Ceramics		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100

Table.7 Result of the Analysis of Coliform in the Collected Well Water Sample Stored in Mud Pot at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Mud pot		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10 ml	+	+	+	1100	+	+	+	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3
	1ml	+	+	+	1100	+	+	+	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3
	0.1ml	+	+	+	1100	+	+	+	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3

+: gas production; -: No gas production: MPN index for 100ml

Table.8 Result of the Analysis of Coliform in the Collected Well Water Sample Stored in Coconut Shell at Different Time Interval

Name of Vessels	Vol. of Water sample	Hours																							
		1				5				10				15				20				25			
Coconut		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN

shell	e (ml)	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100

Table.9 Result of the Analysis of Coliform in the Collected Well Water Sample Stored in Aluminium Container at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Aluminium		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100

Table.10 Result of the Analysis of Coliform in the Collected well Water Sample Stored in Stainless Steel Container at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Stainless steel		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100	+	+	+	1100

+: gas production;-: No gas production: MPN index for 100ml

Table.11 Result of the Analysis of Coliform in the Collected Well Water Sample Stored in Brass Container at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Brass		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	+	+	+	3	-	-	-	3	-	-	-	3	-	-	-	3
	1.0	+	+	+	1100	+	+	+	1100	+	+	+	3	-	-	-	3	-	-	-	3	-	-	-	3
	0.1	+	+	+	1100	+	+	+	1100	+	+	+	3	-	-	-	3	-	-	-	3	-	-	-	3

Table.12 Water Result of the Analysis of Coliform in the Collected Well Water Sample Stored in Copper Container at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Copper		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	+	+	+	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3
	1.0	+	+	+	1100	+	+	+	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3
	0.1	+	+	+	1100	+	+	+	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3

Table.13 Result of the Analysis of Coliform in the Collected Well Water Sample Stored in Silver Container at Different Time Interval

Name of Vessels	Vol. of Water sample (ml)	Hours																							
		1				5				10				15				20				25			
Silver		1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN	1	2	3	MPN
	10	+	+	+	1100	-	-	-	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3
	1.0	+	+	+	1100	-	-	-	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3

	0.1	+	+	+	1100	-	-	-	1100	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	3
--	-----	---	---	---	------	---	---	---	------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

+: gas production;-: No gas production: MPN index for 100 mL

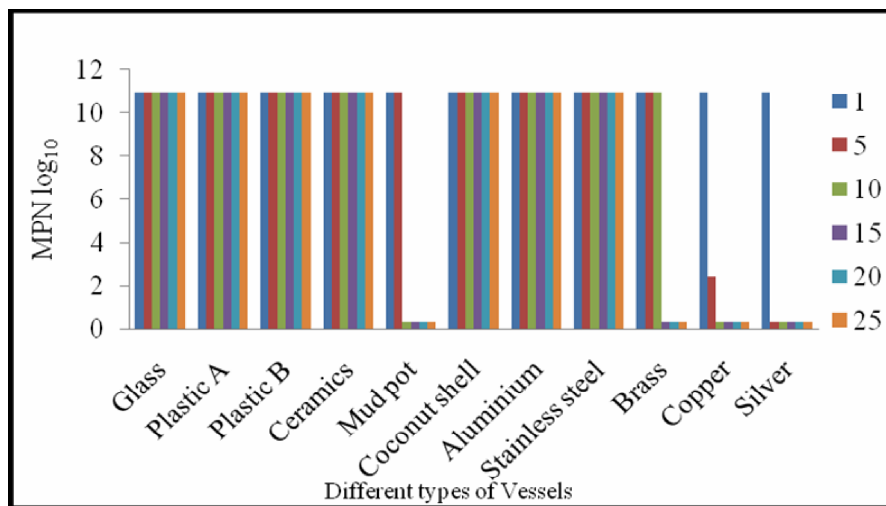
Fig.1



Fig.2



Fig.3 Total Coliform Bacteria in Water Samples Stored in Different Containers



In this research, the results showed not much change in pH, EC and TDS in all the water samples stored in different containers. Among the ten different storage containers, viz. glass, plastic A&B, coconut shell, ceramic, aluminum, stainless steel doesn't have the ability to kill the coliform bacteria as evidenced by the presence of coli form bacteria in the stored water. But there is a significant reduction in the coli forms level in water stored in mud pot, brass, copper and silver where it reduced from >1100 to <3. Mud pot gradually increased the cooling effects to the stored water and also reduced the microbial population. Because of the temperature decrease below 30 °C, which is not suitable for *E.coli* growth and it needs 30-35 °C in aerobic condition. For water kept in the earthen vessel for 12 hrs the results showed no substantial decrease compared to the initial inoculums. (Tandon et al. 2005).

It can be inferred from the published literatures that copper metal is the most effective metal in killing the coliforms (Shrestha et al. 2009; Delgado et al. 2011; Grass et al. 2011; Sarsan et al. 2012; Gorman and Humphreys, 2012; Samanovic et al., 2012; Stevenson et al. 2013; Zaman et al., 2014 and Radha and Susheela, 2015). The reduction in population of total bacteria as the day of storage increased in similar to the observation by Payment et al. (1985) and Eniola et al. (2007). The result of this study corroborates with the study of (Sarsan, 2013 and Radha and Susheela, 2015). Many researches indicate that the copper and brass is a low cost microbial safety drinking water storage container (Mehta et al. 2004; Faundez, 2004; Brick et al. 2004; Sudha et al. 2009, 2012 and Sharan et al. 2010; 2011). Brass is an alloy consisting mainly of copper (over 50%) and zinc with smaller amounts of other elements (Saran, 2011). Takes place the short-term storage of *E. coli* and *E. faecalis* for up to 48 hrs in a brass water

storage vessel caused sub-lethal injury to the bacteria (Tandon et al. 2005)

Copper has proven to kill bacteria due to what is called the oligodynamic effect, even in relatively low concentrations (Nageli, 1983). This antimicrobial effect is shown by ions of copper as well as mercury, silver, iron, lead, zinc, bismuth gold and aluminum. Copper is known to be far more poisonous to bacteria than others metals such as stainless steel or aluminum (Sarsan, 2013).

At the same time the silver has most antibacterial activity when compare to copper as evaluated by the antibacterial effects of Ag and Cu on gram-positive and gram-negative bacteria, which are resistant to nosocomial infections (Hundakova et al. 2013; Zanzen et al. 2013; Losasso et al. 2014; Paredes et al. 2014; Ben-Knaz Wakshlak et al. 2015; Franci et al. 2015 and Dugal et al. 2015). When all the containers were compared, silver and copper containers were good for storage of drinking water, having antibacterial activities within 24 hrs against *E.coli*. (Shrestha et al. 2009; Grass et al. 2011 and Saran, 2011). Effects of silver ions on normal mammalian cells are minimal (Berger et al. 1976).

Studies have shown that improving the microbiological quality of household water by on-site or point-of-use treatment and safe storage in proper containers reduces diarrhoeal and other waterborne diseases in communities and households of developing and developed countries (Thompson et al. 2003). The traditional Indian practice of storing drinking water in a copper vessel overnight is the simplest way to obtain the health benefits of copper (Radha and Susheela, 2015). The antibacterial potential of copper and brass vessels against common waterborne pathogens such as *Escherichia coli*, *Enterococcus faecalis* (Tandon et al.

2005 and 2007), *Salmonella* sp. and *Vibrio cholera* (Sudha et al. 2009) has been studied.

In conclusion, traditionally certain metal containers/pots/vessels were used to store drinking water in order to ensure safety. A study was conducted with the aim of evaluating the effect of metals such as copper, silver and brass against enteric gram negative bacteria in drinking water. Complete reduction of the tested organism was recorded within 0 to 25 hrs of holding time. This study suggested the promotion of use of water storage containers/vessels made of oligodynamic metals such as copper and brass to control the gram negative *E.coli* in drinking water as silver being expensive. Future studies need to elaborate the mechanism of interaction between Silver, Copper and Brass containers.

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References

- Agrawal, VK. and Bhalwar, BR. 2009. Household Water Purification: Low-Cost Interventions. *MJAFI*, 65(3):1-4.
- Ali J (1991), An Assessment of the Water Quality of Ogunpa River Ibadan, Nigeria. M.Sc. Dissertation. University of Ibadan, Ibadan, Nigeria.
- Aneja, K. R., 2003. Experiments in microbiology, plant pathology and Biotechnology, 4th edition, New Sage International (P) Ltd Publishers, New Delhi. Pp. 363-365.
- Applied and environmental microbiology.77 (5):1541–1547.
- Ben-Knaz Wakshlak, R., Pedahzur, R and Avnir.D (2015). Antibacterial activity of silver killed bacteria: the "zombies" effect. *Scientific Reports: Nature Publishing Group*.5:1-9.
- Berger TJ, Spadaro JA, Chapin SE, Becker RO. (1976). Electrically generated silver ions: quantitative effects on bacterial and mammalian cells. *Antimicrob Agents Chemother*. 1976 Feb; 9(2):357-8.
- Brick, T., B. Primrose, R. Chandrasekhar, S. Roy, J. Muliylil, and G.Kang. (2004). Water contamination in urban south India:household storage practices and their implications for water safety and enteric infections. *International Journal of Hygiene and Environmental Health*. 207: 473–480.
- Cabral.S.P.J. (2010). Water microbiology. Bacterial pathogens and water. *International Journal of Environmental Research and Public Health*. 7, 3657-3703.
- CDC (2001). Safe Water Systems for the Developing World: A Handbook for Implementing Household-Based Water Treatment and Safe Storage Programs. Atlanta, GA, USA: Centers for Disease Control and Prevention. (Down loaded from <http://www.cdc.gov/safewater/manual/swsmanual.pdf>)
- Clasen, F.T., Brown J., Collin.S., Suntuurf, O., and Cairncross S. 2004. Reducing diarrhea through the use of household-based ceramic Water filters: a randomized, controlled trial in rural Bolivia. *The American Society of Tropical Medicine and Hygiene*. 70(6): 651–657.

- Clasen, T., Wolf-Peter Schmidt, Tamer Rabie, T., Ian Roberts I., and Cairncross, S. 2007. Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. *BMJ Research*. 1-10.
- Delgado. K., Quijada, R., Palma R., and Palza. H. 2011. Polypropylene with embedded copper metal or copper oxide nanoparticles as a novel plastic antimicrobial agent. *Letters in Applied Microbiology*. 53, 50–54.
- Dugal, S and Mascarenhas, S. (2015). Chemical synthesis of copper nanoparticles and its antibacterial effect against gram negative pathogens. *Journal of Advanced Scientific Research*. 6(3): 1-4.
- Eileen R. Choffnes and Alison Mack, Rapporteurs; Forum on Microbia, 2009 Global Issues in Water, Sanitation, and Health: Workshop Summary.
<http://www.nap.edu/catalog/12658.html>.
- Eniola K. I. T., Obafemi, D. Y., Awe, S. F., Yusuf I. I. Falaiye, O. A. and Olowe, A.O. 2007. Effects of Containers and Storage Conditions on Bacteriological Quality of Borehole Water. *Nature and Science*, 5(4):1-6.
- Espinosa-García, C.A., Díaz-Ávalos, C., Solano-Ortiz, R., Tapia-Palacios, A.M., Vázquez-Salvador, N., Espinosa-García, S., Sarmiento-Silva, E.R and Mazari-Hiriart, M. 2014. Removal of bacteria, protozoa and viruses through a multiple-barrier household water disinfection system. *Journal of Water and Health*. 12.1: 94-104.
- Ezeugwunne IP, Agbakoba NR, Nnamah NK, Anahalu IC (2009). The Prevalence of Bacteria in Packaged Sachets Water Sold in Nnewi, South East, Nigeria. *World J. Dairy Food Sci*. 4(1):19-21.
- Faúndez, G., Troncoso, M., Navarrete, P. and Figueroa, G. (2004). Antimicrobial activity of copper surfaces against suspensions of *Salmonella enterica* and *Campylobacter jejuni*. *BMC Microbiology*. 4:19.
- Federal Office of Statistics (FOS), "Digest of Statistics Federal Office of Statistics", Lagos, 1995.
- Folarin, T.B., Olorunfoba, E.O and Ayede A.I (2013). Water Quality and Risk of Diarrhoeal Infections among Children under Five in Ibadan, Nigeria. *Afr. J. Biomed. Res*. 16; 67 – 77.
- Franci, G., Falanga, A., Galdiero, S., Palomba, L., Rai, M., Morelli, G., and Galdiero, M., (2015). Silver Nanoparticles as Potential Antibacterial Agents. *Molecules*, 20, 8856-8874;
- Franci, G., Falanga, A., Galdiero, S., Palomba, L., Rai, M., Morelli, G., and Galdiero, M. 2015. Silver Nanoparticles as Potential Antibacterial Agents. *Molecules*. 20, 8856-8874.
- Gerba, C.P., and Smith, J.E., Jr. (2005): Sources of pathogenic microorganisms and their fate during land application of wastes. *J Environ Qual* 34: 42-48.
- Gerba, C.P., Rose, J.B., Haas, C.N., 1996. Sensitive populations: who is at the greatest risk? *Int. J. Food Microbiol*. 30, 113.
- Gleick, P. H. (2002). Dirty water: Estimated deaths from water-related diseases 2000-2020. Pacific Institute of Studies in Development, Environment and Security, www.pacinst.org pp. 1-12.
- Gorman, O.J. and Humphreys, H. (2012). Application Volume 81, Issue 4, Pages 217–223 of copper to prevent

- and control infection. Where are we now?. *Journal of Hospital Infection*. 81(4): 217–223.
- Grass,G., Rensing, C and Solioz,M. 2011. Metallic Copper as an Antimicrobial Surface.
- Hundakova, M., Valaskova, M., Tomasek, V., Pazdziora, E., and Atejova, K. (2013). Silver and/or copper vermiculites and their antibacterial effect. *Acta Geodyn. Geomater.* 10, 1 (169): 97–104.
- Jain, S., Sahanon, O., Blanton, E., Schmitz, A., Imoro, T., Hoekstra, M. and Quick, R. 2008 .The Impact of Sodium Dichloroisocyanurate Treatment on Household Drinking Water Quality and Health in Peri-Urban Ghana: a Randomized Placebo Controlled, Double-Blinded trial. *International Symposium and 4th Annual Network Meeting, Accra, Ghana, 2-5.*
- Kumar.G.2014. Necessity of Bottled Water Industry in India – Some Facts. *Chemical Science Review and Letters*.3 (12):799-806.
- Leclerc, H., Schwartzbrod, and Dei-Cas, E. (2002): Microbial agents associated with waterborne diseases. *Crit Rev Microbiol* 28: 371-409.
- Leclerc, H.; Mossel, D.A.A.; Edberg, S.C.; Struijk, C.B. *Advances in the Bacteriology of the Coliform Group: their Suitability as Markers of Microbial Water Safety.* *Ann. Rev. Microbiol.*2001, 55,201–234.
- Lim, H. S., Lee, Y.L and. Bramono S. E., 2014. Community-based wastewater treatment systems and water quality of an Indonesian village. *Journal of Water and Health.* 12.1:196-208.
- Losasso,C., Belluco,S., Cibin,V., Zavagnin,P., IvanMićeti ć ., Gallochio,F., Zanella,M., LisaBregoli, Biancotto,G and Ricci.A. (2014). Antibacterial activity of silver nanoparticles: sensitivity of different *Salmonella serovars*. *Frontiers in Microbiology.* 5(227):1-9.
- Mehta, M., Dass, A. and Singh., K. J. (2004). Keeping quality of drinking water. *Human Ecology* 16: 125-128.
- Nageli, K.W. 1893. Über oligodynamische Erscheinungen in lebenden Zellen. *Neue Denkschr. Allgemein. Schweiz. Gesellsch. Ges. Naturweiss. Bd XXXIII Abt 1.*
- Nala NP, Jagals P and Jo ubert G (2003). The effect of a water-hygiene educational program on the microbiological quality of container-stored water in ho use holds. *Water SA* 29(2): 171-176.
- Nguyen, TM.2006. The effect of temperature on the growth of the bacteria *Escherichia coli* DH5 α Saint Martin’s University Biology Journal.1:87-94.
- Odonkor, T.S and Joseph K. Ampofo, K.J. (2013) *Escherichia coli* as an indicator of bacteriological quality of water: an overview. *Microbiology Research.* 4 (e2):5-11.
- Okereke, C.H., Ogbonnaya,S.Eze and Sunday O. Eze , (2014). Bacteriological and Physicochemical Qualities of Some Borehole Waters in Aba South Metropolis, Abia State Nigeria. *Asian Journal of Natural & Applied Sciences.*3 (3):83-94.
- Okereke, CH., Ogbonnaya, SE. and Eze.OS. 2014. Bacteriological and Physicochemical Qualities of Some Borehole Waters in Aba South Metropolis, Abia State Nigeria. *Asian Journal of Natural & Applied Sciences.* 3(3): 83-91.
- Oladipo C, Onyenike IC, Adebisi AO (2009) Microbiological analysis of some vended Sachet water in Ogbomoso, Nigeria. *Afr. J. Food Sci.* 3(12):406-412.

- Omezuruike, IO., Damilola, OA., Adeola, TO., Enobong, AF., and Olufunke, BS. 2008. Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. *African Journal of Biotechnology*, 7(5): 617-621.
- Onigbogi, O and Ogunyemi. O. 2014. Effect of Storage Containers on Quality of Household Drinking Water in Urban Communities in Ibadan, Nigeria. *International Journal of Public Health Science*. 3(4):253 – 258.
- Opio, A., Lukale, K.J., Masaba, S.I and Oryema, C. (2011). Socio-economic benefits and pollution levels of water resources, Pece Wetland, Gulu Municipality – Uganda. *African Journal of Environmental Science and Technology*. 5(7); 535-544.
- Paredes, D.; Ortiz, C.; Torres, R.(2014). Synthesis, characterization, and evaluation of antibacterial effect of Ag nanoparticles against *Escherichia coli* O157:H7 and methicillin-resistant *Staphylococcus aureus* (MRSA). *Int. J. Nanomedicine*. 9, 1717–1729.
- Payment, P., Trudel, M. and R. Plante. (1985). Correlation Analysis of Virus density with Bacterial Data From Seven Drinking Water Treatment Plants in Canada. *Applied and Environmental Microbiology*. 49: 1418-1427.
- Preethi Sudha, B.V., Ganesan, S., Pazhani, P.G., Ramamurthy, T., Nair, B.G and Padma Venkatasubramanian. (2012). Storing Drinking-water in Copper pots Kills Contaminating Diarrhoeagenic Bacteria. *J HEALTH POPUL NUTR*. 30(1):17-21.
- Radha, R and Susheela.P. (2015). Comparative microbiological analysis of water Stored in different storage vessels. *Int J Pharm Bio Sci*. 6(2): (B) 121 – 128.
- Raju, S.N., Roopavathi, C., Ramachandra Kini, K., and Niranjana, S.R. (2011). Assessment of coliform contamination in drinking water from source to point of use in Mysore city of Karnataka, India. 35th WEDC international Conference, Loughborough, UK. 1-6.
- Renumarn, P., Srilaong, V., Uthairatanakij, A., Kanlayanarat, S., Jitareerat, P. 2010. Effect of hot water treatments on survival of *E. coli* and *Salmonella* spp. And physical properties in fresh-cut broccoli florets. *Asian Journal of Food and Agro-Industry*. 3 (05): 516-525.
- Rufener, S., Mäusezahl, D., Joachim Mosler, H and Weingartner, R. (2010). Quality of Drinking-water at Source and Point-of-consumption—Drinking Cup as a High Potential Recontamination Risk: A Field Study in Bolivia. *International centre for diarrhoeal disease research, bangladesh j health popul nutr* ; 28(1):34-41.
- Sabino De Gisi, Luigi Petta, and Wendland, C. 2014. History and Technology of Terra Preta Sanitation. *Sustainability*. 6, 1328-1345.
- Samanovic, Marie I., Chen Ding, Thiele, Dennis. J and Heran Darwin. K. (2012). Copper in microbial pathogenesis: meddling with the metal. *Cell Host Microbe*. 11(2): 106–115. Delgado, K., Quijada R., Palma, R and Palza, H. (2011). Polypropylene with embedded copper metal or copper oxide nanoparticles as a novel plastic antimicrobial agent. *Letters in Applied Microbiology*. 53: 50–54.
- Sarsan, S (2013). Effect of storage of water in different metal vessels on coliforms.

- Int.J.Curr.Microbiol.App.Sci.* 2(11): 24-29.
- Sharan, R., Chhibber, S. and Reed, R.H. (2011). Inactivation and sub-lethal injury of *salmonella typhi*, *salmonella typhimurium* and vibrio cholera in copper water storage vessels. *BMC Infectious Diseases*.11 (204):2-6.
- Sharan, R., Chhibber, S., Attri, S., and Reed, R.H. (2010). Inactivation and sub-lethal injury of *Escherichia coli* in a copper water storage vessel: effect of inorganic and organic constituents. *Antonie Van Leeuwenhoek*. 98:103-105.
- Sharma PV, *Susruta samhita*, V. 1. Sutra Sthana 45,246 verse 13. Varanasi: Chaukamba Visva Bharati, 2004:418.
- Sharma.D. 2014. Potable Water Privation and Health Issues in Varanasi District. *Journal of Management & Public Policy*. 5(2): 35-43.
- Shrestha, R., Raj Joshi, D., Gopali, J. and Piya, S., (2009). Oligodynamic Action of Silver, Copper and Brass on Enteric Bacteria Isolated from Water of Kathmandu Valley. *Nepal Journal of Science and Technology*. 10:189-193.
- Sinton, W.L., Finlay, K.R and Hannah, J.D. (1998). Distinguishing human from animal faecal contamination in water: A review. *New Zealand Journal of Marine and Freshwater Research*. 32: 323-348.
- Sobsey MD (2002). Managing water in the home: accelerated health gains from improved water supply. Geneva: The World Health Organization (WHO/SDE/WSH/02.07)
- Sobsey MD et al. (1993). Using a conceptual framework for assessing risks to health from microbes in drinking water. *Journal of the American Water Works Association*, 85:44-48.
- Soller, A.J., Schoen, E.M., Timothy Bartrand, T., Ravenscroft, E.J and Ashbolt, J.A. (2010). Estimated human health risks from exposure to recreational waters impacted by human and non-human sources of faecal contamination. *Water Research*.44:67-4691.
- Stevenson, J., Barwinska-Sendra, A., Tarrant. E and Waldron, K. J. (2013). Mechanism of action and applications of the antimicrobial properties of copper. *FORMATX*, 468-479.
- Subbaraman, R., Shitole, S., Shitole, T., Sawant K., O'Brien., Bloom, E.D and Patil-Deshmukh, A. (2013). The social ecology of water in a Mumbai slum: failures in water quality, quantity, and reliability. *BMC Public Health*, 13(73): 1-14.
- Sudha VBP, Singh KO, Prasad SR, Venkatasubramanian P. (2009). Killing of enteric bacteria in drinking water by a copper device for use in the home: laboratory evidence. *Trans R Soc Trop Med Hyg*; 103:819-22.
- Sudha, VBP., Singh, KO., Prasad, SR., and Venkatasubramanian, P.(2009). Killing of enteric bacteria in drinking water by a copper device for use in the home: laboratory evidence. *Trans R Soc Trop Med Hyg*.103:819-22.
- Tambekar, H.D., Hirulkar, B.N., Banginwar, S.Y., Rajankar, N.P., Rajankar and Deshmukh & Rajankar.2006. Water hygiene behaviors in hotels and restaurants and their effects on its bacteriological quality. *Biotechnology* .5(4): 475-477.
- Tandon, P., Chhibber, S. & Reed, R. H.(2005). Inactivation of *Escherichia coli* and coliform bacteria in traditional brass and earthenware water storage vessels. *Ant. van Leeuwen*. 88: 35-48.
- Tandon, P., Chhibber, S., and Reed, R.H. (2007). Survival & detection of the faecal indicator bacterium *Enterococcus faecalis* in water stored

- in traditional vessels. *Indian J Med Res*, 125: 557-566.
- Theron, J. and Cloete. E.T (2002). Emerging Waterborne Infections: Contributing Factors, Agents, and Detection Tools. *Critical Reviews in Microbiology*, 28(1):1–26.
- Thompson, T., Sobsey M and Bartram J. (2003). Providing clean water, keeping water clean: an integrated approach. *International Journal on Environmental Health Research*. 1: S89-94.
- Uhuo, C.A., Uneke, B.I., Okereke, C.N., Nwele, D.E., and Ogbanshi, M.E. (2014). The bacteriological survey of borehole waters in Peri-Urban areas of Abakaliki; Ebonyi State, Nigeria. *International Journal of Bacteriology Research*. 2 (2);028-031.
- UNICEF, (2013). Children dying daily because of unsafe water supplies and poor sanitation and hygiene. http://www.unicef.org/media/media_68359.html.
- UNICEF, 2008. Promotion of household water treatment and safe storage in UNICEF wash programmes. <http://www.unicef.org/wash/files>
- Uwah, E. I., Busari, W. R., and Sayi, A. (2014). Physicochemical and Bacteriological Analyses of Sachets Water Samples in Kano Metropolis, Nigeria. *IOSR Journal of Applied Chemistry*. 6 (6): 52-56.
- Valerie Daw Tin Shwe, (2010). Thesis title “A randomized controlled trial of a household drinking water storage intervention to assess its impact on microbiological water quality and diarrhoeal diseases at mae la temporary shelter, tak province, Thailand” Submitted for the Degree of Doctor of Philosophy Program in Chulalongkorn University.
- Zakharova, V. Olga., Godymchuk, Yu. Anna., Gusev, A. Alexander., Gulchenko, I. Svyatoslav., Vasyukova, A. Inna and Kuznetsov, V. Denis. (2015). Considerable Variation of Antibacterial Activity of Cu Nanoparticles Suspensions Depending on the Storage Time, Dispersive Medium, and Particle Sizes. *BioMed Research International*. 2015:1-11.
- Zaman, S., Yeasmin, S., Yasuhiro Inatsu, Y., Ananchaipattana, C., Latiful Bari, M. (2014). Low-Cost Sustainable Technologies for the Production of Clean Drinking Water—A Review.
- Zanzen, U., Bovenkamp, G.L., Krishna, K.S., Hormes, J. and Prange, A. (2013). Antibacterial action of copper ions on food-contaminating bacteria. *Acta Biologica Szegediensis*. 7 (2):149-151.

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