Quality Assessment Of Water Stored In Earthen & Copper Vessel – An Exploratory Study

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Abstract:

Introduction: There can be no state of positive health and wellbeing without a good quality of water. Ayurveda explains many techniques for water purification which are easy to use, economical, and can be easily applied with household resources. Methods: Vessels made of stainless steel and earthen pot were used for the purpose. The physicochemical and microbiological qualities of the drinking water were analysed for each water sample collected during an initial time ("0" hr) and after 24 hr. Results: No change in the physical parameters of the water quality is observed in both the vessels from initial "0" hr to after 24 hr. Absence of total fungal count is observed in water stored in both the vessels, i.e., copper and earthen vessel from initial "0"hr to after 24hr. The organisms Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa and Salmonella abony are seen to be absent in both the vessels in which water is stored from initial "0" hr to 24 hr. Conclusion: The results obtained in this study reveal that the quality of water stored in copper is better than others.

Introduction:

Water quality is a growing concern throughout the world. Water is considered to be potable when there are no levels of chemicals substances that would cause harm to human health. The most serious water pollutants in terms of human health worldwide are pathogenic organisms. Thus, drinking water must be free from these pathogens-viruses, protozoa, or bacteria.[1] Waterborne diseases are major causes of morbidity in developing countries.[2] Purified potable water is still not available to the majority of population. Clean drinking water is the major remedy for all.[3] In India, villages are geographically apart and inhabitants may have to walk kilometers to fetch water. Hence, it is important from a safety point of view to maintain the quality of drinking water during storage.[4] Drinking water may be contaminated at the source or during storage and contaminated after collection, either during transport or storage in the home. Drinking water may often be collected from any available source including fecally contaminated sources and stored in a vessel that may not be properly treated. This will no doubt increase the production of disease-causing pathogens and hence deteriorate the stored water further. It is well-known that a greater part of the global population consumes untreated non-piped drinking water usually consisting of small volumes collected and stored in the home by the users. Even though storage of water has been recommended as a method of water purification, contamination of treated or disinfected water can also occur during storage due to improper handling. Hence, it is important from a safety point of view to maintain the quality of drinking water during storage.[4] One such water storage method explained in Ayurveda for drinking purposes is to store water in brass, copper, earthen,[5,6] and stainless steel vessel which are easily available, very familiar to store water in rural as well as in urban India. Thus, this research study was taken with the objective to study the effect of storage of borewell water in copper and earthen vessel by comparing the water quality parameters present in the water before and after storage. The results of each parameter were compared to the guidelines and standards set by the World Health Organization (WHO).[7]

Materials and Methods:

Collection of water samples:
The drinking water sample was taken from the borewell water of Hindwadi residential area of Belagavi. This borewell water usage was open for public and private houses. The sampling was done in the morning using disposable sterile hand gloves. Both vessel (pot) having 2 l capacity to hold the water was selected for the study. The water samples kept in these two vessels [Table 1] were washed with de-ionized water before use. The collected water samples in these storage vessels were allowed to stay for 24 hr and analyses were carried out at "0" hr and 24 hr of storage. These two vessels containing water sample were covered with their respective lid and placed in a room at a constant temperature range of 20°C–23°C to avoid any contamination and the effects of light and temperature [Table 1].

Table 1: Storage of water sample in different vessels

Name of the vessel of	Water source Quantity	Water sample (l)
Copper vessel	Borewell water of Hindwadi area	2
Earthen vessel	Borewell water of Hindwadi area	2

Methodology:
Experiments were conducted in a well-sophisticated Central Research Facility (CRF) laboratory of KAHER's Shri.B.M.K Ayurveda Mahavidyalaya, Belagavi. The pH of both the water samples were measured by using a pH meter. The pH meter was calibrated, with three standard solutions (pH 4.0, 7.0, and 10.0), before taking the measurements. After the measurement of both the sample, the probe was rinsed with deionized water to avoid cross-contamination among different samples. The conductivity of both the samples were measured using a conductivity meter. The probe was submerged in the water sample and the reading was recorded after the disappearance of stability indicator. After the measurement of each sample, the probe was rinsed with de-ionized water to avoid cross-contamination among different samples. The turbidity of the water samples was measured using a turbidity meter. Each sample was poured into the sample holder and kept inside for a few minutes. After achieving the reading stability, the value was recorded.[8] The measurements of total dissolved solids (TDS) in water samples were carried out according to the standard methods of APHA[9] and Sawyer et al.[10] by the filtration process. The TDS of the water samples were determined by the gravimetric method. The filtrate which contains total suspended solids was heated in an oven at above 100°C until all the water was completely evaporated. The remaining mass of the residue represents the amount of TDS in a sample.[11]

Observation:
The standard solution for each tested element was prepared according to its concentration and used to calibrate the system before analyzing each water sample stored in both the vessels. The results were recorded accordingly after each analysis [Table 2].[12,13]

Table 2: Physico-chemical parameters of water sample from storage vessels

Parameters	At "0" hr	At "24" hr		WHO guidelines
		Copper vessel	Earthen vessel	
pH	6.52	6.98	7.4	6.5-8.5
Appearance	Colorless	Colorless	Colorless	Colorless
Odour	Odorless	Odorless	Odorless	Odorless
Taste	Tasteless	Tasteless	Tasteless	Tasteless
Turbidity (NTU)	2.4	3.6	1.9	5

Total alkalinity as CaCO3 (mg/L)	20.5	28	34	200
Conductivity (S/M)	400	430	490	<300 mg/L
Total hardness as CaCO3 (mg/L)	102.5	138	164	300 mg/L
Total dissolve solid (mg/L)	235	250	290	1000
Chloride (mg/L)	52	50	52	200 mg/L
Fluorides (mg/L)	0.3	0.4	0.6	1.5 mg/L
Sulphate (mg/L)	41.5	40	43	200 mg/L
Nitrate (mg/L)	43.5	31	30	50 mg/L

WHO: World Health Organization, NTU: Nephelometric turbidimeter unit, S/M: Siemens per meter

Physico-chemical analysis:

pH:

Increase of pH is observed in water stored in both the vessels from initial "0" h to after 24 h which is within normal limits of potable drinking water. Maximum increase in pH is observed in earthen vessel followed by copper vessel.

A sample is considered to be acidic if the pH is below 7.0 and it is alkaline if the pH is higher than 7.0. The normal drinking water pH range mentioned in the WHO guidelines is between 6.5 and 8.5. Acidic water can lead to corrosion of metal pipes and plumping systems. Meanwhile, alkaline water shows disinfection in water.

Conductivity:

Electrical conductivity is a measure of how well water can pass an electric current and is an indirect measure of inorganic dissolved solids. It helps in determining the suitability of water for irrigation and domestic uses. An increase in values of conductivity is observed in copper and earthen vessel. Maximum increase in conductivity is observed in earthen vessel followed by copper. All the values are in the normal limits of potable drinking water.

Conductivity is the ability to carry an electric current. The presence of dissolved solids such as calcium, chloride, and magnesium in water samples carries the electric current through water. According to the WHO, the maximum allowable level of conductivity is 0.005–0.05 S/m. The differences are based on various factors such as agricultural and industrial activities and land use, which affect the mineral contents and thus the electric conductivity of the water. High conductivity may lead to lowering the aesthetic value of the water by giving mineral taste to the water. APHA (2005) noted that the conductivity of water is related to its dissolved solid.

Total dissolved solids:

Increase in values of TDS is observed in copper and earthen vessel. Maximum increase in TDS is observed in earthen vessel followed by copper vessel. All the values are within the normal limits of potable drinking water. TDS helps in understanding the level of turbidity and hardness of water. The desirable TDS value of drinking water is 300 mg/L. The total solids of water sample stored in earthen vessel increased could be from the walls of the vessels.

Turbidity:

Increase in values of turbidity is observed in copper vessel, but a slight decrease in value is seen in earthen vessel. Maximum increase in TDS is observed in the copper vessel. All the values are within the normal limits of potable drinking water. Turbidity is the cloudiness of water. It is a measure of the ability of light to pass through water. It is caused by suspended material such as clay, silt, organic material, plankton, and other particulate materials in water. Higher turbidity raises water temperatures in light of the fact that suspended particles absorb more sun heat. Consequently, the concentration of the dissolved oxygen (DO) can be decreased since warm water carries less DO than cold water. Turbidity more than 5 Nephelometric Turbidity Unit (NTU) and above being visible and affecting the appearance and acceptability of drinking-water to consumers.

Chlorides:

Decrease in values of Chlorides was observed in copper vessel. In earthen vessel, the value remains unaltered.

Sulfates:
An increase in value of sulfate is observed in earthen vessel. However in copper vessel, the value has been decreased. Maximum increase in sulfate is observed in earthen vessel. All the values are within the normal limits of potable drinking water. Normal range is <250 mg/L. Sulfates are not considered toxic to plants or animals at normal concentrations. In humans, concentrations of 500–750 mg/L cause a temporary laxative effect.

Fluorides:
Slight increase in values of fluorides is observed in water stored in both the vessels from initial "0" h to after 24 h. The values are within normal limits of potable drinking water.

Nitrates:
Decrease in values of nitrates is observed in water stored in both the vessels from initial "0" h to after 24 h, which are within normal limits of potable drinking water. A maximum decrease in Nitrates is observed in copper vessel. The least decrease is seen in earthen vessel.

Total hardness as CaCO3:
Increase in values of total hardness as CaCO3 is observed in water stored in copper and earthen vessel from initial "0" hr to after 24 hr. Maximum increase in the value of total hardness is observed in earthen vessel followed by copper vessel.

Total Alkalanity as $CaCO_3$:
The alkalinity of water is its acid-neutralizing capacity comprised the total of all titrable bases. Alkalinity of water is mainly caused by the presence of hydroxide ions, bicarbonate ions, and carbonate ions or a mixture of two of these ions in water. A minimum alkalinity of 20 mg/L as CaCO3 is recommended for environmental waters and levels between 25 and 400 mg/L are generally beneficial for aquatic life. Increase in values of total alkalinity as CaCO3 is observed in water stored in copper and earthen vessel from initial "0" hr to after "24" hr. Maximum increase in total alkalinity as CaCO3 is observed in earthen vessel followed by least in copper vessel. All values are within normal limits of potable drinking water [Table 3].

Table 3: Metal analysis of water samples from different storage vessels (mg/l)

Parameters	At "0" h	At "24" h		WHO guidelines
		Copper vessel	Earthen vessel	
Calcium (mg/L)	4.25	21	13	75
Magnesium (mg/L)	2.5	13	8	30
Iron (mg/L)	0.28	0.17	0.13	0.3

WHO: World Health Organization

Metal analysis of water:
The WHO Guidelines for drinking-water quality include the following recommended limits on naturally occurring constituents that may have direct adverse health impact: arsenic: 10 µg/l, barium: 10 µg/l, boron: 2400 µg/l, chromium: 50 µg/l, fluoride: 1500 µg/l, selenium: 40 µg/l, and uranium: 30 µg/l.

Calcium:
Increase in values of calcium is observed in water stored in copper and earthen vessel from initial "0" hr to after "24" hr. Maximum increase in calcium is observed in copper vessel followed by earthen vessel.

Magnesium:

Increase in values of magnesium is observed in water stored in copper and earthen vessel from initial "0" hr to after "24" hr. Maximum increase in magnesium is observed in copper followed by earthen vessel.

Iron:
Decrease in values of iron is observed in water stored in both the vessels from initial "0" hr to after 24 hr, which is within normal limits of potable drinking water. Maximum decrease in Iron is observed in earthen vessel followed by copper vessel. For instance, a high concentration of heavy metals could be found if corrosion is imminent in a metal storage vessel.

In addition, some galvanized storage metal vessels could contain some levels of lead, iron, manganese, nickel, zinc, etc. This could contribute significantly to increased levels of heavy metals in water stored in such vessels. Calcium, magnesium and iron were not affected in the water samples stored in these two vessels.

Microbiological analysis of stored water:
Microbiological analysis was mainly done to check whether the potable drinking water contains bacteria, fungi, and other bacteria. Total heterotrophic bacterial count is a method which determines colony formation in culture media of heterotrophic bacteria in drinking water. Determination of bacterial growth was done using most probable number (MPN) method. The experiment was conducted in Microbiological Lab, CRF of KAHER's Shri. B. M. Kankanawadi Ayurveda Mahavidyalaya, Belagavi [Table 4].

Table 4: Microbes identified and their succession during storage in different vessels

Parameters	At "0" hr	At "24" hr		WHO guidelines
		Copper vessel	Earthen vessel	
Total bacterial count (cfu/ml)	32	16	26	30-300 cfu/ml
Total fungal count (cfu/ml)	33	25	23	10-100 cfu/ml
Most probable number	Absent	Absent	Absent	Absent
Escherichia coli	Absent	Absent	Absent	Absent
Staphylococcus aureus	Absent	Absent	Absent	Absent
Pseudomonas aeruginosa	Absent	Absent	Absent	Absent
Salmonella abony	Absent	Absent	Absent	Absent

WHO: World Health Organization

Total bacterial count:
Decrease in values of total Bacterial count is observed in water stored in both the vessels from initial "0" hr to after 24 hr.

Total fungal count:
Decrease in values of total fungal count is observed in water stored in copper and earthen vessels from initial "0" hr to after 24 hr.

Most probable number:
The organisms Escherichia Coli, Staphylococcus aureus, Pseudomonas aeruginosa, and Salmonella abony are seen to be absent in both the vessels in which water stored from initial "0" hr to 24 hr. Total bacterial count, total fungal count, and all the organisms mentioned above in these two vessels were absent because of inhibited action on these organisms by metals. All the values are within normal limits of potable drinking water.

Discussion:
In Ancient India, swarna (gold), rajata (silver), tamra (copper), kamsya (brass), and mrita paatra (earthen vessels) were used to store water. Ayurveda also highlights that drinking water stored in different types of container has different effects and medicinal properties to achieve good effects on overall health.[14]

The water stored in kamsya paatra (Brass vessel) is katu rasa and katu vipaka, guru guna, increases kapha and pitta dosha, also increases strength and immunity when used for a longer period of time.[15] Brass is different from copper and is an alloy of copper and zinc. Water stored in brass vessel helps to combat many waterborne diseases alternative to plastic containers. Copper in the brass is likely to thrive bacteria in the water than in the earthenware. Along with copper, zinc is also required for many biological activities which we get from brass vessels.[16,17] The water stored in the tamra paatra (copper vessel) exhibits katu rasa, ushna veerya, increases pitta and vata dosha.[18] Copper is an essential mineral, which is required every day for healthy individuals at a level of about 1 mg/day. It is essentially required for the body to manufacture red blood cells, thus helping in the formation of hemoglobin. Studies have shown that copper surfaces completely kill bacteria. Although studies have shown the merits of copper surfaces for their use in improving public hygiene in health-care facilities, the potential use of copper for the purification of drinking water, especially in developing countries, has not been widely studied.

Therefore, the results of our study indicate that copper holds the potential to provide microbially safe drinking water to the rural masses in developing countries. The use of copper pots in Indian households is common and is, 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.[19] A regular diet contains a variable amount of copper but drinking water from the copper vessel will fulfil the daily requirements of copper. Copper deficiency can manifest in parallel with vitamin B_{12} and other nutritional deficiencies resulting in anemia. Radha et al demonstrated that MPN of coliform organisms present in lake water stored in four different vessels showed decreasing order of bacterial load viz. copper vessels followed by clay vessels, stainless steel vessels, and plastic bottles.[20] Copper has anti-inflammatory properties which helps in arthritis, slows down aging, as a brain stimulant, helps in curing skin ailments, helps in iron absorption, and normalizes thyroid function. Two litres of water can supply 40% of our daily requirement of copper. Preethi Sudha et al.[21] reported that water stored overnight in copper pot gave less counts of E. coil, Salmonella typhi, and Vibrio cholerae demonstrating inactivation of these bacteria.

The water stored in mrit paatra (earthen pot) is said to have dhatu-samyakara property, improves bala, ojas and veerya in the person. Mrita paatra has the property to keep water cool and they can reduce the water temperature by a few degrees lower than the room temperature. Mrita paatra is porous in nature as water passes through its body process of evaporation occurs and it takes away some heat from the contents of this vessel, thus causing cooling. Conventionally, earthen pot water is believed to be gentle on the throat and better than drinking chilled water from the fridge. It is a better alternative to steel, glass, and plastic bottles for drinking water and healthier too.

Conclusion:

No change in physical parameters is observed in water stored in both the vessels from initial "0" hr to after 24 hr. The parameters are found to be within the recommended limits of the WHO. The concentrations of Ca, Mg, and Fe were also measured and found to be well below the standard maximum concentrations. Copper vessel is more effective than earthen vessel in killing the bacteria during water storage. The Ayurveda describes storing water in a copper vessel overnight and drinking it in the morning for many health benefits. Storing water in copper pots finds mention in ancient texts of Ayurveda for purification of water. Therefore, results of our study stated that storing water in copper vessel is being simple, practicable cheap, and better, so it is therefore recommended for use.

Conflict of interest: There are no conflicts of interest.

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