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Review Article

A REVIEW ON COPPER AS A DISINFECTANT IN WATER PURIFICATION

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ABSTRACT

The basic element of all living things and vital for all kind of activities is water.Today getting pure drinking water is big calamity in developing counties. Availability of water resources is very less and also contaminated by various habits of human and animals. Recently lot of water purifiers are available in market which is constructed with chemical and physical disinfectants. These are having some disadvantages such as odour, affordability and cause some side effect to the consumers. The present study is focussed to replace the chemical and physical agent by metal disinfectants. During ancient period, people used copper and brass pots to store drinking water. Lot of studies are carried out to prove that metals such as Brass and Copper have disinfectant properties. This article reviews the antimicrobial activity of copper against water borne pathogens, mechanism and concentration.

INTRODUCTION

Copper occur in nature as the metal and in minerals, most commonly as cuprite (Cu_2O) and malachite [$Cu_2CO_3 (OH)_2$]. More than 5000 years, Copper has been used by human and it is probably the second metal in its usefulness to human. One of the important trace element is Copper in most living organisms, and more than 30 types of copper-containing proteins are known today. Prominent examples are lysyl oxidase, which is involved in the cross-linking of collagen, tyrosinase, required for melanin synthesis, dopamine β-hydroxylase, which functions in the catecholamine pathway, cytochrome *c* oxidase, the terminal electron acceptor of the respiratory chain, and super oxide dismutase, required for defense against oxidative damage. On the other hand, the redox properties of copper can also cause cellular damage. A number or mechanisms have been suggested. Reactive hydroxyl radicals can be generated in a Fentontype reaction:

$$Cu^{+} + H_2O_2 \longrightarrow Cu^{2+} + OH^{+} + OH^{+} \quad (1)$$

The extremely reactive hydroxyl radical can participate in a number of reactions detrimental to cellular molecules, such as the oxidation of proteins and lipids[1].

Copper ions can also lead to depletion of sulfhydryls, such as in cysteines or glutathione, in a cycle between reactions 2 and 3:

$$2\,Cu^{2+} + 2\,RSH \longrightarrow 2\,Cu^{+} + RSSR + 2H^{+} \quad (2)$$

$$2\,Cu^{+} + 2\,H^{+} + O_2 \longrightarrow 2\,Cu^{2+} + H_2O_2 \quad (3)$$

The hydrogen peroxide thus generated can in turn participate in reaction 1 and lead to further generation of toxic hydroxyl radicals. It is still not clear to what extent reactions 1 to 3 cause copper toxicity. Cells try to keep H_2O_2 at very low levels, and reaction 1 may not be the chief toxic mechanism, although this has been frequently claimed. An alternative route of copper ion toxicity has been shown to be the displacement of iron from iron-sulfur clusters[2].

Role of Copper in Human Health

Copper is used extensively in pesticide formulations as a fungicide and antimicrobial agent, particularly for the treatment of wood and water supplies for drinking water and recreational use. Copper is an essential element in human metabolism, and it is well-known that deficiency results in a variety of clinical disorders, including nutritional anaemia in infants.

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Table1 Dietary Copper Intakes for Females and Males per Age Group[3]

Age Group	Sex	Dietary Copper Intake (mg/day)
6-11 months	F/M	0.47
2 years	F/M	0.58
14 to 16 years	F M	0.77 1.18
25 to 30 years	F M	0.93 1.24
60 to 65 years	F M	0.86 1.17

Data collected from the U.S. National Health and Nutrition Examination Survey (NHANES, 1988-1994) and from the Continuing Survey of Food Intakes by Individuals (1994-1996) indicated that the median intake of copper.

The World Health Organization has recommended a daily intake of 30 µg/kg body weight per day (or 2.1 mg/day) for an adult male and 80 µg /kg body weight per day for infants[4]. These recommendations were based on balance studies in children and adults, including studies on intakes required to equal the daily copper loss through metabolism and excretion.

Bactericidal Property of Copper

Based on this observation, Kuhn[5] (1983) investigated bacterial growth on metals. Small strips of stainless steel, brass, aluminium, and copper were inoculated with broths of *Escherichia coli, Staphylococcus aureus, Streptococcus group* D, and *Pseudomonas* species. The broths contained a very heavy inoculum (~10^7bacteria/ml). The strips were then air-dried for 24 hours at room temperature, inoculated onto blood agar plates, and incubated for 24 hours at 37°C. The results were striking. The copper and brass strips showed little or no growth, while the aluminium and stainless steel strips produced a heavy growth of all the different types of microbes. The test was repeated at varying intervals of 15 minutes, 1, 5, 7, 20 and 24 hours. Brass disinfected itself in seven hours or less, depending on the inoculum size and the condition of the surface of the metal. Freshly scoured brass disinfected itself in one hour. Copper disinfected itself of some types of microbes within 15 minutes. Aluminium and stainless steel produced heavy growths of all isolates after eight days and growths of most isolates after three weeks.

Table 2 Contact killing of microbes by copper surfaces

Species	Application method	Killing time, RT*a*	Reference
Salmonella enteric	Wet, 4.5× 10^6 CFU	4 h	6
Campylobacter jejuni	Wet, 4.5× 10^6 CFU	8 h	
Escherichia coli O157	Wet, (3-4) ×10^7 CFU	65 min	7
Escherichia coli O157	Wet, 2.7 × 10^7 CFU	75 min	8
MRSA*d* (NCTC10442)	Wet, (1-1.9) × 10^7 CFU	45 min	9
EMRSA-1*e* (NCTC11939)	Wet, (1-1.9) × 10^7 CFU	60 min	
EMRSA-16*e* (NCTC13143)	Wet, (1-1.9) × 10^5 CFU	90 min	
Listeria monocytogenes Scott A	Wet, 10^7 CFU	60 min	8
Mycobacterium tuberculosis	Wet, 2.5 × 10^7 CFU	5-15 days	10
Candida albicans	Wet, >10^5 CFU	60 min	
Klebsiella pneumonia	Wet, >10^7 CFU	60 min	
Pseudomonas aeruginosa	Wet, >10^7 CFU	180 min	
Acinetobacter baumannii	Wet, >10^7 CFU	180 min	
MRSA	Wet, >10^7 CFU	180 min	
Influenza A virus (H1N1)	Wet, 5 × 10^5 viruses	6 h 4-log decrease	9
C. difficile (ATCC 9689)vegetative cells and spores	Wet, 2.2 × 10^5 CFU	24-48 h	11
C.difficile NCTC11204/R20291 vegetative cells	Wet, (1-5) × 10^6 CFU	30 min	12
C. difficile dormant spores	Wet, 8 × 10^6 CFU	Unaffected in 3 h	
C. difficile germinating spores	Wet, 8 × 10^6 CFU	3 h	
Pseudomonas aeruginosa PAO1	Wet, 2.2 × 10^7 CFU	120 min	13
MRSA NCTC 10442	Wet, 2 ×10^7 CFU	75 min	
Escherichia coli W3110	Dry, 10^9 CFU	1 min	14
Acinetobacter johnsonii DSM6963	Dry, 10^9 CFU	few minutes	
Pantoea stewartii DSM30176	Dry, 10^9 CFU	1 min	
Pseudomonas oleovorans DSM 1045	Dry, 10^9 CFU	1 min	
Staphylococcus warnerii DSM20316	Dry, 10^9 CFU	few minutes	
Brachybacterium conglomeratum DSM 10241	Dry, 10^9 CFU	A few minutes	
Aspergillus flavus	Wet, (2-300)×10^5spores	120 h	15
Aspergillus fumigatus	Wet,(2-300)×10^5 spores	>120 h	
Aspergillus niger	Wet, (2-300)×10^5 spores	>576 h	
Fusarium culmonium	Wet, (2-300)×10^5 spores	24 h	
Fusarium oxysporum	Wet, (2-300)×10^5 spores	24 h	
Fusarium solani	Wet, (2-300)×10^5 spores	24 h	
Penicillium crysogenum	Wet, (2-300)×10^5 spores	24 h	
Candida albicans	Wet, (2-300)×10^5 spores	24 h	

Role of Copper in Water Treatment

Recognition of the bacteriostatic properties of copper has led to testing its capacity as a water purifier. Copper was found to be one of the most toxic metals to heterotrophic bacteria in aquatic environments. Some authors[16] found that sensitivity to heavy metals of microflora in water was (in order of decreasing sensitivity): Ag, Cu, Ni, Ba, Cr, Hg, Zn, Na, Cd. Also it was found that cupric chloride inactivated 9 of the 13 bacteria strains that they tested by more than 5 logs within 30 minutes[17]. The other four strains were inactivated to a lesser extent. Consequently, the antibacterial potential of copper has been exploited since these ancient times. In contrast to the low sensitivity of human tissue to copper, microorganisms generally are extremely susceptible to copper, making it suitable for water disinfection[18].

In another study[19], water with a suspension of *E. coli* was introduced into 50 foot coils of different plumbing materials and changes in bacteria viability were periodically determined. While in different types of plumbing material, including glass, the level of bacteria remained the same or even increased, in the copper loop only 1% of the *E. coli* bacteria remained viable after five hours.

Similarly, it was found that water distribution systems made of copper have a greater potential for suppressing growth and for decreasing persistance of *Legionella pneumophila* cells in potable water than distribution systems constructed of plastic materials or galvanized steel[19]. The use of a continuous culture model system for the growth of *L. pneumophila* on copper and other plumbing materials was also examined. It was found that bacteria levels were reduced on copper surfaces compared with a glass control and other plumbing materials at the various temperatures tested and in the three different waters used[20].

Copper can help preserve the purity of drinking water. The confirmed antimicrobial effects of copper can inhibit water-borne microorganisms, such as viruses, bacteria, infectious parasites or algae. These microorganisms can create a variety of health risks to humans, including Legionnaire's Disease, deadly *E. coli* infections (Copper Development Association, 2004). The Center for Applied Microbiology and Research (CAMR) found that the highly toxic *E. coli* O157:H7 strain of bacteria survives for shorter periods of time on copper and brass surfaces than on stainless steel. This finding has wide-ranging implications for reducing outbreaks from cross contamination of *E. coli* O157:H7 in the food processing industry (Center for Applied Microbiology and Research, 2000). The World Health Organization[4] recommended that any water intended for drinking should contain fecal and total coliform counts of 0, in any 100-mL sample. When either of these groups of bacteria is encountered in a sample, immediate investigative action should be taken.

Some works[21] were designed to investigate not only the dynamics of inactivation of *S. typhi, S. typhimurium* and *V. cholerae* in water stored in copper vessels but also to quantify the extent of any sub-lethal injury caused to these bacteria during storage in the vessels. Such sublethal injury is manifest in terms of ROS-sensitivity and counteracted using ROS-n enumeration conditions[22]. It was also demonstrated[21] the value of using traditional copper storage vessels to inactivate the water-borne pathogens responsible for typhoid fever and cholera, while also highlighting the occurrence of sub-lethal injury during storage for periods of less than 24 h. The application of improved methods for water storage at the household level is likely to have a significant impact on the overall health of the community[23,24]. It was reported that micro sized copper particles have antimicrobial activity to against E.*coli, Salmonella* and minimum on *Shigella* at the incubation time of 6hrs and the above[25].

Also was studied and substantiated the ancient claim by Ayurvedic texts that water stored in copper vessels can promote health[26]. This is the first time that an antimicrobial effect of copper pots and a copper device on *V. cholerae* and *S. typhi* has been reported. Dhanalakshmi & Rajendran reported that that the copper has killed the *Salmonella sp*. especially *Salmonella typhi.* bacterial colonies 100% at 2, 4, 6, 10 hrs of incubation time in 2% concentration and 98.4% at 2 hrs of incubation in 1% of concentration[27]. The inexpensive copper device developed by us has immense potential as a point-of-use intervention at household level for improving the quality of drinking water by removing enteric pathogens. The cost of our copper device is one-tenth the cost of a copper pot and can be used in a regular plastic pot. Copper and silver ions have demonstrated *in vitro* efficacy against the waterborne pathogens[28]. Shish reported that the copper-silver ionization is efficacious for control of biofilms and plankton-associated waterborne pathogens[29]. Dankovich showed strong antibacterial activity of the CuNP papers[30], which supports the idea that bacterial inactivation is due to the direct contact with CuNPs during filtration through the CuNP paper.

CONCLUSION

The presence review article reported that the copper metal has antimicrobial activity to kill the bacteria, Fungi and Virus. Copper metals are using in all fields such as hospitals, paint and purifiers as a disinfectant. An ancient period itself used the copper vessels to store the drinking water and the people called as holly water which have no microbes and purified. Although many studies have shown the antimicrobial effects of copper surfaces in hospitals, the use of copper in drinking water treatment, has been limited to silver-copper ionization systems for the control of Legionnaire's disease. Hence the present review article reviewed the copper has antimicrobial activity and it is used in Hospital, water purifier and paints.

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