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Research on the antiviral and antibacterial properties of copper, as well as its possible application on surfaces for disease prevention.

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Abstract
Copper has been identified for its antimicrobial properties, killing bacteria, viruses, and yeast when in contact. Scientific evidence gathered shows that the use of copper on surfaces reduces significantly the number of bacteria in the surrounding environment. This paper reviewed the importance of copper on living organisms, applications through history revealing antimicrobial properties, as well as possible applications in the medical field.

Keywords: copper; antimicrobial; antivirus; nanotechnology; disease prevention

1 Introduction

Copper has accompanied humanity since its inception, since it is one of the metals that, in low concentrations, are essential for the metabolism of animal and plant cells; it plays a role in making red blood cells and it helps maintain healthy bones, blood vessels, nerves, and immune function, and it contributes to iron absorption (Ware, 2017)

Its properties to prevent infections were recognized since ancient times. The oldest recorded medical use of copper is mentioned in the Smith Papyrus, written between 2600 and 2200 B.C. It describes the use of copper to sterilize wounds, water, and to heal headaches, burns, infections, and intestinal worms (Grass et al., 2010, p. 1546).

In the last decade, the concept of copper as an antimicrobial has been revitalized, caused by the spread of antibiotic-resistant bacteria in hospitals, food processing plants, and animal breeding facilities. (Prado J. et al., 2012, p. 1330).

2 Evidence of the antimicrobial capacity of copper.

Research conducted in 2005 has shown that copper surfaces or their alloys are capable of eliminating 99.9% of pathogenic bacteria within hours. In said research, a copper surface eliminated *methicillin-resistant Staphylococcus aureus* (MRSA) in 90 minutes; while with stainless steel no decrease in bacterial concentration was observed after 6 hours (360 minutes). In the bronze alloy, which contains 80% copper, the MRSA was eliminated in 270 min (Wilks, Michels, & Keevil, 2005, p. 451).

Another experiment with *Pseudomonas aeruginosa* strains have shown a synergistic effect between copper cations, $Cu2+$ and quaternary ammonium disinfectants, to exert bactericidal action on this pathogen that has special ability to survive in environments with a low concentration of nutrients and a minimum of humidity.

Laboratory evidence documents the efficacy of copper in eliminating spores and vegetative forms of *Clostridium difficile*, a hospital pathogen associated with outbreaks of nosocomial infections with high mortality. These studies showed spore elimination after 24 hours of exposure to metallic copper; and another study shows that this effect occurs after 30 min for vegetative forms and at 3 h for spores, even in the presence of organic matter.

It is important to note that the bactericidal effect of copper surfaces is directly related to concentration, the maximum effect being for metallic copper (99.9%) and it is maintained in alloys that contain at least 70% copper.

Backed by accumulated scientific evidence, on March 25, 2008, the EPA registered copper as the first and only metal with antibacterial properties, authorizing the dissemination of important concepts, including that "copper surfaces eliminate 99.9% of bacterial pathogens after 2 hours of exposure" and certifying that metallic copper surfaces and their alloys are natural antimicrobials, have long-lasting antimicrobial efficacy, have a self-disinfecting effect and are superior to other coatings available on the market. This registry authorizes the use of copper surfaces in hospital environments.

3 How does copper kill bacteria?

This is a question that still has no concrete answer. Rodrigo Palma, a researcher at Navarra University developed a hypothesis on how copper acts on bacteria. He proposed that copper leaves its structure or alloys in the form of cations (Cu+), which are the positive ions that are introduced into bacteria.

"What we are guessing is that the process is similar to the corrosion of copper, in which case mass is also lost. Therefore, at first sight, we can think that as the alloy or the material itself is more prone to corrosion, the greater its bactericidal power," said Palma.

Other studies suggest that copper, in high concentrations, has a toxic effect on bacteria due to the release of hydroperoxide radicals, copper ions could potentially replace ions essential for bacterial metabolism such as iron, initially interfering with the function of the cell membrane and then at the level of the cytoplasm altering protein synthesis, either inhibiting protein formation or causing the synthesis of dysfunctional proteins, altering the activity of enzymes essential for bacterial metabolism.

4 Antiviral activity

Copper has also demonstrated the ability to destroy viruses of great medical importance, including influenza and human immune-deficiency virus, HIV, in concentrations as low as 0.16 to 1.6 mM. The development of copper oxide filters has efficiently eliminated the risk of HIV transmission through fluids (Borkow, 2008). The mechanisms involved in antiviral activity are the inactivation of a protease enzyme important for viral replication and damage at the phospholipid envelope level (Karlström, 1991).

5 Antifungal activity

Different species of fungi, among them *Candida albicans*, an important pathogen in immunosuppressed patients, are inhibited in their growth and then destroyed, in contact with copper surfaces. Recent studies indicate that antifungal activity occurs through a complex process called "contact death" in which damage to the cytoplasmic membrane occurs, which is depolarized; it is unclear whether the damage affects the proteins or lipids of the membrane. This facilitates the entry of copper ions into the cell, amplifying the damage and, secondarily, an increase in oxidative stress occurs, without appreciating apparent damage to the DNA of these cells (O157, 2005).

5 Possible applications

Lab trials have shown a reduction in bacterial counts, indicating that copper surfaces are a promising additional tool alongside other hygienic measures to curb the number and severity of hospital-acquired infections. At this point, additional studies would help determine the most cost-effective way to give maximal protection in hospitals (Grass et al., 2010, p. 1546). Highly frequented sites should be made of copper e.g., doorknobs, faucets, and bed rails.

6 Conclusion

The antimicrobial properties of copper surfaces have now been firmly established. The antimicrobial properties of copper surfaces must be integrated with other methods of disinfection and the overall hygiene concept of a health care facility. Additional measures, such as the addition of spore germinants to cleaning solutions to improve the killing of spores, also deserve further investigation.

7 References

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