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Title: New insights into the antimicrobial properties of copper alloy surfaces

Abstract:

The ability of copper to fight wound infections and keep water safe has been known since Antiquity. More recently, we have shown that copper surfaces significantly reduce the presence of the waterborne pathogens, *Legionella pneumophila* and verocytotoxic *Escherichia coli* O157, in biofilms inside copper plumbing tube supplying potable water at different temperatures. Copper and its alloys also kill important foodborne pathogens, such as *E. coli* O157, *Listeria monocytogenes* and *Salmonella*, when present on dry surfaces that could be used as work surface materials in various food and healthcare industries. Indeed, several of the alloys are able to kill important pathogens responsible for hospital acquired infections, including methicillin resistant *Staphylococcus aureus* (MRSA), vancomycin resistant enterococci (VRE), *Acinetobacter baumanni*, *Clostridium difficile* spores, fungal spores and influenza A virus. We are now elucidating the mechanisms of copper's potent antimicrobial effects and a clear distinction can be made between the different actions of copper solutions and copper surfaces, the latter involving Cu(I)/Cu(II) redox cycling phenomena for the generation of reactive oxygen species (ROS) in Fenton-like reactions:

(i) $H_2O_2 + O_2^- \rightarrow O_2 + OH^- + OH^\cdot$

(ii) $Cu\ (II) + O_2^- \rightarrow Cu\ (I) + O_2$

(iii) $Cu\ (I) + H_2O_2 \rightarrow Cu\ (II) + O_2 + OH^- + OH^\cdot$

For example, DNA is rapidly degraded by ROS in enterococci exposed to copper surfaces, meaning that there is little chance of high level copper or antibiotic resistance developing. Consequently, this disintegration of the bacterial nucleic acid supports the use of copper alloys as contact surfaces in clinical environments to actively kill bacterial cells without the occurrence of DNA mutation and transfer of genetic material carrying antibiotic resistant genes. These studies suggest the future potential for using copper and selected alloys in various industries, especially healthcare, to prevent dissemination of traditional and emergent pathogens, including control of fungi in heating, ventilating, and air conditioning (HVAC) systems.