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The Role of Antimicrobial Copper Surfaces in Reducing Healthcare-associated Infections

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Abstract

Recent work investigating the antimicrobial characteristics of copper has led to a re-evaluation of the role of this essential metal in healthcare. While ancient civilisations used copper for its health benefits it seems its usefulness has been forgotten. The requirement for evidence-based interventions for infection control has been the driver behind recent scientific assessments of the benefits of copper. Ten years of laboratory research has led to clinical trials confirming a very significant and continuous reduction in environmental bioburden in a number of healthcare settings globally. The newest and most comprehensive clinical research has now reported an impressive 40 % reduction in healthcare-associated infections in intensive care units (ICUs) where copper was incorporated in key touch surfaces. The deployment of copper touch surfaces should be considered as an additional infection control measure to reduce care costs and improve bed availability and patient outcomes.

Keywords

Antimicrobial, copper, environment, HCAI, ICU, infection rate, nosocomial infections, public health

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Historical Context

That copper has beneficial effects for humans has been known for at least 4,000 years. The use of copper for drinking water containers to ensure potability and the application of the powdered metal to wounds for disinfection, are reported in ancient Egypt. The Aztecs used copper to treat various skin diseases. Hippocrates, the father of medicine (460–380 BCE), recommended the use of copper for leg ulcers related to varicose veins. In France, during the three cholera epidemics around 1850, it was observed that workers in copper foundries were not affected by the disease.

More recently, in 1970, the American College of Chest Physicians published on the 'antibacterial action of copper'. They showed that the use of copper in large reservoir nebulisers for respiratory therapy resulted in the contents remaining sterile.[1] More pertinently, in 1983, a hospital study in Pennsylvania showed copper's effectiveness in lowering the *Escherichia Coli* count on brass door knobs.[2]

The Healthcare-associated Infection Problem

During the subsequent decades, the major concern within the medical community has been healthcare-associated infections (HCAIs), or 'nosocomial' infections. This year's report from the World Health Organization (WHO) notes how difficult it is to gather reliable and comparable HCAI evidence globally, or even nationally. But they are able to conclude that hundreds of millions of patients are affected by them around the world.[3]

Only receiving public attention when a family member suffers or when there are outbreaks, HCAIs are a very real endemic, ongoing problem and one that no institution or country can claim to have solved, despite many efforts. The statistics are harrowing. The European Centre for Disease Prevention and Control (ECDC) indicated HCAI levels in Europe as 7.1 % in 2008.[4] This equates to over four million patients being affected each year. The estimated incidence rate in the US was 4.5 % in 2002, corresponding to 1.7 million affected patients.[5]

Infections in intensive care units (ICUs) can be as high as 51 %, most of these being healthcare associated. Furthermore, the longer patients stay in an ICU, the more at risk they become of acquiring an infection.[3]

The measures taken towards reducing microbe transportation through frequently touched surfaces started in the last decade with the WHO 'Clean Care is Safer Care' campaign. In many national healthcare systems, specific guidelines were given to healthcare professionals in order to raise awareness and help combat nosocomial infections.

In 2001 in the UK, the 'EPIC Project: Developing National Evidence-based Guidelines for Preventing Healthcare associated Infections' among other good practices, points out touch surfaces as one of the major components of microbial concentration and transfer.[6]

Table 1: Antimicrobial Copper Alloys are Effective Against These Pathogens

Acinetobacter baumannii	*Klebsiella pneumoniae*
Adenovirus	*Legionella pneumophila*
Aspergillus niger	*Listeria monocytogenes*
Candida albicans	Methicillin-resistant *Staphylococcus aureus* (MRSA, including E-MRSA and methicillin-sensitive *S. aureus* [MSSA])
Campylobacter jejuni	Poliovirus
Clostridium difficile (including spores)	*Pseudomonas aeruginosa*
Enterobacter aerogenes	*Salmonella enteritidis*
Escherichia coli O157:H7	*S. aureus*
Helicobacter pylori	*Tubercle bacillus*
Influenza A (H1N1)	Vancomycin-resistant *enterococcus* (VRE)

Copper in Laboratory Studies

In 2000, the early laboratory studies from the University of Southampton indicated that copper cast alloys (e.g. brass and bronze) were able to reduce *E.Coli* O157 cross-contamination during food-handling procedures. The research showed that although stainless steel may appear clean, bacteria can survive on these surfaces for considerable periods of time. In comparison, survival on many copper alloys is limited to just a few hours or even minutes. Due to the intrinsic characteristics of copper alloys, i.e. being homogenous and solid, wear resistant and durable, complete lifetime antimicrobial efficacy could be expected. These may then be utilised in facilities where bacterial contamination cannot be tolerated.[7]

One fundamental consideration in the early laboratory studies was which test of efficacy to employ. The only existing test for a solid material had been developed in Japan (JIS Z 2801) but stipulated conditions wholly different to a typical indoor environment, i.e. 35 ºC and in a relative humidity of 100 %. Copper alloys were shown to easily 'pass' this test, which required contact for 24 hours.

More appropriate standards were those based upon liquid disinfectants, like the current EN 1276, which used a more typical 20 ºC and allowed the inoculum to dry in sterile air. The Southampton team developed a modified version of this and was able to measure efficacy at specified times in order to obtain a kill rate curve. This test protocol has subsequently been verified in a number of other laboratories worldwide. The test is versatile and sensitive enough to allow comparison of different inoculum levels: from the disinfectant-based standard of 10 million colony-forming units (CFU) down to more typical hospital contamination levels such as 1,000 CFU or less. It has also been used to show efficacy at refrigeration temperatures. Comparative work using this test protocol (under typical indoor conditions) shows that silver-containing composites, like the stainless steel control, showed no efficacy.[8]

Subsequently, many papers have been published from numerous researchers expanding the understanding of the antimicrobial activity of copper alloys.[9,10,11] As a simple comparison, against an antibiotic, co-workers compared a copper alloy (CuZn37) with Aminoglycocide in a zone of inhibition test, showing comparable efficacy.[12]

In 2008, the US Environmental Protection Agency (EPA), following rigorous independent testing based upon the Southampton-developed protocol, permitted the registration of nearly 300 copper alloys.[13] This allows public health claims to be made for the alloys under the terms of the registration, a first for solid materials.

Most recently, further developments of the laboratory test protocols have led to published work showing that efficacy on a dry surface can be as short as two minutes.[14] The Southampton team also published work showing that even high inoculum levels of MRSA and VRE in droplet-like contamination events were eradicated in less than 10 minutes.[15,16] These have both been driven by attempts to make the laboratory tests similar to real life conditions.

Broad Spectrum Efficacy

In general, antimicrobial copper alloys are effective against bacteria, viruses, fungi and moulds, including these significant pathogens (see *Table 1*).

Mechanisms

Work is ongoing on the mechanism[14–16] by which copper exerts its effect, but it is clear that the attack is a complex interaction rather than just one process interrupter. The speed at which the reactions occur complicates the research and a number of modes of action have been identified. Theories include membrane puncture and leakage, disturbance of osmotic balance and generation of free radicals causing oxidative stress. At some stage the cell DNA is completely destroyed, indicating that transfer of antimicrobial resistance should not be a factor of concern.

Clinical Trials

The first qualitative clinical trial was performed at Kitasato University Hospital in Japan in 2005.[17] However, a fully quantitative trial was initiated in 2007 on a 20-bed medical ward at Selly Oak Hospital in Birmingham, UK.

'Hot spot' touch surfaces were identified by a team of clinicians and microbiologists. The components included dressings trolleys, light switches, taps, door and equipment handles, push plates, grab rails and over-bed tables. These were upgraded to copper or copper alloy and placed on the ward over the course of six months. Once installed, the clinical assessment ran for three months and was able to report 90–100 % reductions in contamination on copper surfaces compared with controls. Standard cleaning procedures and products were used throughout the trial.[18]

Subsequently, a clinical trial in ICU rooms at Calama Hospital in Chile reported similar reductions. Notably, this region has regular daytime humidity levels of just 6 %.[19]

In a recent out-patient study, not only was the reduction in microbial burden confirmed but a 'halo' effect was observed: reduced contamination in the immediate vicinity of the copper surfaces. The copper surfaces were calculated to reduce the risk of exposure to environmental microbes by a factor of 17.[20]

Infection Rates

In a three-centre clinical trial (see *Figure 1*) completed in June 2011, the first proof of improved patient outcomes was reported. The trial initially carried out an observational assessment of key touch surfaces and contamination levels in an ICU environment, identifying which room components to upgrade to copper alloys.

Just six key components were selected and re-engineered to take a copper or copper alloy surface. This included the bed rails, visitor chair arms and nurse call-buttons. After upgrade, reduction in contamination levels on these items was verified to be 97 % (see *Figure 2*) – confirming the results from Selly Oak. Finally, after three and a half years, the interim result reported at the 1st WHO International Conference on Prevention and Infection Control (ICPIC) indicated a reduction in HCAIs of 40 % for patients in the copper rooms compared with those in the non-copper rooms. For patients in a copper room with all six copper items present throughout their stay, the reduction was nearly 70 %.[21]

Future Activities

Up until now, all research and applications appear to show great potential regarding the effectiveness of antimicrobial copper alloys against bacteria and other pathogenic organisms.

Further to the scientific and clinical research results, manufacturers have also shown great interest in producing objects that are used frequently in high nosocomial potential areas (e.g. ICU, medical wards, etc.). However, implementation outside hospital areas, where microbial flora are at high levels, also worries public health planners.

In Laval, France, the brand new Center Inter-Generational Multi Accueil (CIGMA)[22] – a nursery for 35 infants and a 60-bed care home for dependent elderly people – has deployed copper alloys on all handrails and door handles. In Tokyo, Japan, the Mejiro Daycare Center for Children fitted copper sinks and handrails, as well as other touch surfaces.[23]

In Athens, Greece, a large private elementary school with 2,500 students changed all the handrails, door handles and push plates to those made from copper alloy (Cu 64 %, Zn 36 %). The first results showed 90–100 % less contamination than on standard, non-copper surfaces.[24]

In another application area, transport, the Santiago Metro system in Chile has installed copper alloy handrails at one new station.[25] Subsequently, the Metro has signed contracts to fit brass handrails on two new lines under construction – some 30 stations.

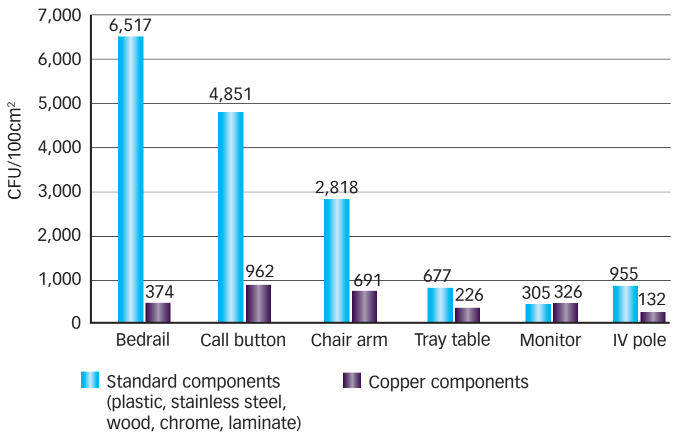
Economics

The total cost of copper or copper alloy objects is a combination of raw material and manufacturing time. Many copper alloys are still used widely in industry because they can be fabricated into complex parts easily and quickly (e.g. taps and lock mechanisms). This means that copper alloy components will become cost-effective when product volumes are economic even if prototypes carry a premium.

Furthermore, because these components are generally straightforward to install, they will be more cost-effective than many high-tech propositions. Installing during a typical refurbishment project, when such common equipment would be refitted anyway, requires few special skills and is therefore broadly cost neutral. These items will also likely have a 30-year minimum lifetime.

Figure 1: Intensive Care Unit at Sloane Kettering Memorial Hospital, One of the Three Hospitals in the Multicentre US Clinical Trial, with Copper Components Installed

Figure 2: Comparative Bacterial Load on Copper and Standard Key Touch Surfaces in US Trial[21] (for all Rooms, over 197 Weeks' Sampling)



CFU = colony-forming units, IV = intravenous.

Due to the antimicrobial efficacy, the cost of replacing and installing copper alloy components cannot be compared to the cost of objects made from other types of material (stainless steel, plastic, etc.). Rather, it is the value of the benefit of copper that should be assessed. Targeted installation of copper clearly results in a decrease in environmental bioburden. Now the link has been established between this and infection rates: Dr Schmidt's conservative assessment indicates a 40 % reduction in ICU-acquired infections, with the potential for a 70 % reduction. This should lead to a reduction in care costs, better bed availability and an improvement in patient outcomes. When, as should result, we are able to decrease antibiotics usage, we have a further a benefit of incalculable value. In times when multi-resistant bacteria are increasing and antibiotics could have run their course, the antimicrobial copper era may have dawned. ■

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