Reducing the Risk of Healthcare Associated Infections

The Role of Antimicrobial Copper Touch Surfaces

CDA Publication 196

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Antimicrobial Copper

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1. Executive Summary

Copper, as well as being man's oldest engineering metal, is now recognised as a proven, broad-spectrum antimicrobial material. Well over 60 published papers support the efficacy of copper against pathogens that cause healthcare associated infections (HCAIs) both in the laboratory and the busy clinical environment. Whilst this is a secondary function, it is intrinsic to both copper and copper alloys, like brass and bronze, and will persist throughout the lifetime of any component manufactured from them. Hundreds of alloys from this well-known family of industrial materials are now collectively referred to as 'antimicrobial copper'.

There is growing proof that contamination in the hospital environment, especially close to the patient, plays a significant role in the acquisition of HCAIs. This has been investigated with respect to antimicrobial copper and there is now evidence demonstrating a link between the installation of copper alloy touch surfaces and reduced infection rates. As the body of published scientific evidence has grown, antimicrobial copper is being increasingly recognised by the organisations advising on and developing guidelines for infection prevention and control, including in the US, Canada and the UK.

Studies on the mechanisms by which copper exerts its influence have resulted in a better understanding of the material's potential. Importantly, the combination of multiple pathways plus the rapid destruction of bacterial DNA means the development of resistance to copper on solid metal surfaces is extremely unlikely. In addition, copper's ability to destroy microbial genomic material suggests that copper alloy surfaces may also play an important role in reducing the spread of antibiotic resistant organisms.

The UK clinical trial at Selly Oak Hospital was the first in the world to publish results demonstrating copper's efficacy in reducing microbial contamination in a clinical setting by >90%. This has since been confirmed by many other trials around the world.

In the US, a seminal three-centre, three-and-a-half year study has been performed in an ICU environment, resulting in a number of papers to date. Published results show a reduction in microbial burden of >80% and an associated reduction in HCAIs of >50% following a limited copper intervention. Moreover, such an intervention requires no special training, additional cleaning or staff monitoring and causes no disruption to the hospital routine.

The University of York, well recognised as a leader in health economics research, has developed a cost-benefit model that allows the input of local data. The default data entered by York for a 20-bed ICU predicts payback in less than one year.

The increasing awareness of the antimicrobial characteristics of copper has convinced manufacturers to develop new products using copper alloys - from sink and door hardware through standard ward fittings to stretcher and hospital beds - and the number of suppliers is growing. Copper and its industrial alloys are easy to form into long-lasting products, suitable for service in the healthcare environment. Whole life costs are comparable with other materials and products are fully recyclable, so contribute to sustainable design. Alloys that look like stainless steel are available, although the distinctive golds and bronzes can provide a highly visible statement that an additional measure is being taken to reduce the risk of HCAIs.

The use of copper for touch surfaces is not a substitute for standard hygiene practices and products should be cleaned and disinfected according to standard procedures, using standard agents. Some surface oxidation (slight darkening) can take place, depending on the alloy, but this does not affect efficacy. Feedback from clinical trials shows that patients and staff found the change in appearance acceptable.

Information, training and support are available from industry trade bodies to all stakeholders, on both the supply and demand side, for the manufacture, specification and correct deployment of copper and copper alloy products. An industry stewardship scheme, comprising the Antimicrobial Copper brand and Cu^+ mark, has been established to approve efficacious alloys and applications based on the latest scientific evidence.

Adoption of antimicrobial copper touch surfaces as an additional measure to supplement current infection control practices has already started in hospitals and care homes around the world.

Antimicrobial Copper Cu+ ™

2. Introduction

Well before microorganisms were discovered, the Egyptians, Greeks, Romans and Aztecs used copper-based preparations to treat burns, sore throats and skin rashes, as well as for day-to-day hygiene. Copper was also used to ward off infection in battlefield wounds.

In the 19th century, with the discovery of the cause-and-effect relationship between germs and the development of disease, scientific evidence started to be gathered. In the last few decades, extensive research has been carried out on the antimicrobial properties of copper and its alloys against a range of microorganisms threatening public health in food processing, healthcare and air conditioning applications. A summary of the main results is presented here and key papers are listed in the Bibliography.

3. Scientific Evidence

Laboratory Studies

Research has been carried out to determine the survival of different microorganisms on copper and copper alloy surfaces. Much of this work since 1994 has been carried out by Prof Bill Keevil, Chair in Environmental Healthcare and Principal Investigator (Microbiology and Environmental Health) at the University of Southampton. The results have been verified in laboratories around the world including the UK (Aston and Kingston Universities), US, South Africa, Germany and Japan.

- *Acinetobacter baumannii*
- Adenovirus
- *Candida albicans*
- *Campylobacter jejuni*
- Carbapenem-resistant Enterobacteriaceae (CRE)
- *Clostridium difficile* (including spores)
- *Enterobacter aerogenes*
- *Escherichia coli* O157:H7
- *Helicobacter pylori*
- Influenza A (H1N1)
- *Klebsiella pneumoniae*
- *Legionella pneumophila*
- *Listeria monocytogenes*
- *Mycobacterium tuberculosis*
- Norovirus or Norwalk-like virus
- Poliovirus
- *Pseudomonas aeruginosa*
- *Salmonella enteritidis*
- *Staphylococcus aureus* (MRSA, E-MRSA and MSSA)
- Vancomycin-resistant enterococcus (VRE)

Copper has been shown to destroy microbes rather than merely prevent their growth, and efficacy has been shown against the key organisms threatening public health today, some of which are listed on this page.

Antibacterial efficacy test standards

ISO 22196, based on the Japanese standard JIS Z2801, is most commonly used in the certification of antimicrobial efficacy of hard surfaces. However this test is carried out at 35°C and >90% humidity and so is not an appropriate indicator of efficacy under typical indoor conditions for touch surface applications. This has been recognised by The Organisation for Economic Co-operation and Development (OECD) Working Party on Chemicals, Pesticides and Biotechnology, who have warned of the danger of using this test to evaluate materials that will be used under other conditions. The more appropriate US Environmental Protection Agency approved test, carried out at room temperature and humidity, is being developed into a standard by ASTM and also as a British Standard.

Test protocols

The University of Southampton uses a similar test: 1 x 1 cm^2 samples of each alloy were inoculated with high challenges (10^7) of bacteria in a soil-loaded suspension and incubated at either 20°C or 4°C for various time periods. Standard microbiological techniques were used to culture, recover and enumerate the viable bacteria and direct microscopy methods were used to assess membrane integrity and respiration. This test has also allowed comparison between copper alloys, triclosan and commercial silver-containing materials.

Results

Figures 1 to 3 show sample data for efficacy of different materials (copper, copper alloys and silver-containing materials) against MRSA. Stainless steel is used as the control.

General conclusions for all organisms tested under the 'wet' simulation protocol, simulating a sneeze or a splash, are summarised below:

- Results show that bacteria survive on stainless steel for days and are eliminated on 99% copper in less than 90 minutes (107 cfu/coupon) at room temperature (Figure 1).
- The effect is slower at 4°C but still significant.
- Greatest efficacy is seen in alloys with copper contents >60%.
- Reduced inoculum testing shows that, at levels of bacterial challenge typically encountered in the clinical environment (approx.10^3 cfu/cm^2), kill times were as rapid as 15 minutes (Figure 2).
- Silver- and triclosan-containing coatings showed no antimicrobial efficacy at room temperature and humidity and behaved the same as the stainless steel control (Figure 3).

The test has subsequently been developed to simulate a 'dry' contamination incident, such as a touch, using a lower inoculum volume but maintaining the high challenge of bacteria. In this 'dry' contamination simulation protocol, under typical indoor conditions, the speed of efficacy is even greater with 6-log reductions of VRE in less than 10 minutes (Figure 4).

Other test protocols have been developed to assess efficacy against viruses and fungi.

MRSA viability on copper alloys and stainless steel at 20˚C

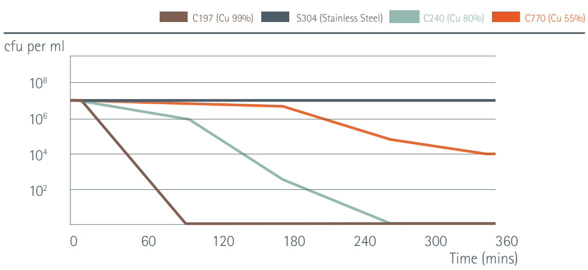

Figure 1 - Copper alloys with >60% copper have been shown to be effective at reducing exceptionally high challenges of bacteria, including antibiotic resistant strains, under typical indoor conditions (humidity and temperature).

MRSA viability on copper at 20˚C – reduced inoculum

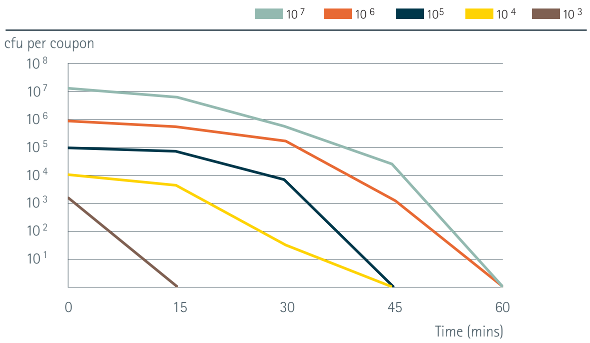

Figure 2 - At reduced inoculum challenges, more typical of clinical environments, copper rapidly eliminated MRSA e.g. 10^3 cfu in 15 minutes.

MRSA viability on copper, silver-and triclosan-coated materials and stainless steel at room temperature and humidity

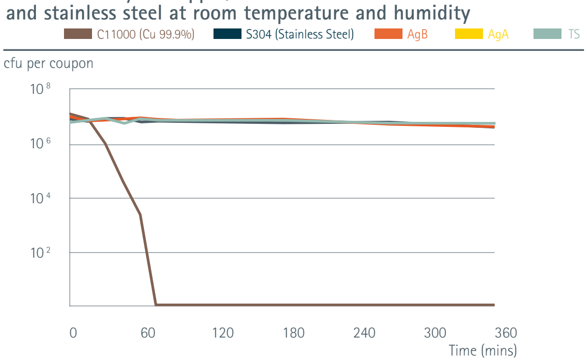

Figure 3 - Under typical indoor conditions, silver coatings (AgA, AgB) and the triclosan coating (TS) behave as the stainless steel control (S30400) - i.e. they show no antimicrobial activity.

Copper (C1100) is effective under these conditions, eliminating 10^7 MRSA in less than 90 minutes.

Rapid kill of vancomycin-resistant *Enterococcus faecalis*

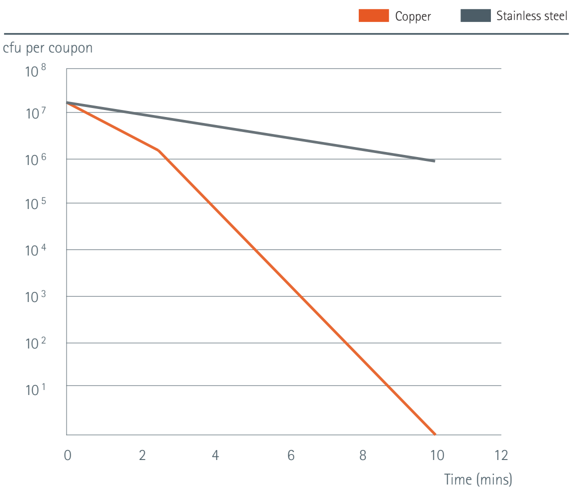

Figure 4 - With a dry inoculum, equivalent to touch contamination, there was a rapid kill with over a 6-log reduction of viable enterococci in less than 10 minutes on copper alloys.

Mode of action

These and other published test protocols have also allowed the investigation of mechanisms providing insight into how copper exerts its effect. Recent studies, showing very rapid efficacy, also go some way to explaining why the sequence of events remains unclear.

There are several probably-interacting mechanisms proposed by which copper kills bacteria, including:

- Causing leakage of potassium or glutamate through the outer membrane of bacteria
- Disturbing osmotic balance
- Binding to proteins that do not require copper
- Causing oxidative stress by generating hydrogen peroxide
- Degradation of bacterial DNA.

The combination of multiple pathways plus the rapid destruction of bacterial DNA means the development of resistance to copper is extremely unlikely. Moreover, copper has been used by man since the Bronze Age, 10,000 years ago, and no copper resistant human pathogen has been found to date.

Copper tolerance

There is a body of literature using the term 'copper resistance' but actually describing copper tolerance. Such studies have been conducted on copper compounds, such as copper chloride and copper sulphate, usually in aqueous solutions and other complex formulations. It is suggested that the copper compound kill mechanism differs from that seen on copper alloy surfaces (so-called contact killing) which provide an almost unlimited source of high concentration copper. This is not the case with compounds in solution, where the copper concentration is often low, dispersed and potentially exhaustible. Thus 'copper resistance' observed in copper compound-containing solutions is more accurately described as copper tolerance. Copper-tolerant microbes and bacteria recovered from surfaces in clinical studies, when exposed to solid copper alloy surfaces, die within minutes, confirming lack of resistance.

Preventing the spread of antibiotic resistance

A paper published in 2013 reported that the transfer of antibiotic resistance by horizontal gene transfer between two species of bacteria can take place on stainless steel but does not occur on copper and copper alloys due to the destruction of plasmid and genomic DNA. The authors suggest a role for these materials in preventing the spread of antimicrobial resistance as well as HCAIs.

Conclusions

Laboratory research on the antimicrobial efficacy of copper and copper alloys has been carried out and verified at institutions around the world and results have been peer-reviewed and published in respected journals. Results demonstrate the rapid, broad spectrum antimicrobial efficacy of copper and copper alloys against the most important pathogens - bacteria, viruses and fungi - challenging public health.

Kill times vary according to organism, strain, type and level of challenge, copper content of alloy and temperature - being more rapid at 20°C but still with a considerable effect at 4°C. Copper and its alloys exhibit efficacy under typical indoor conditions (humidity and temperature), unlike silver-containing materials and triclosan which showed no antimicrobial efficacy under these conditions.

Current theories on the mode of action make the development of copper resistance extremely unlikely.

US EPA Registration

An existing US Environmental Protection Agency (EPA) hard surface disinfectant test protocol was adapted to align with the Keevil protocol and a raft of tests (>6000 samples in total) was carried out at an EPA-approved GLP (Good Laboratory Practice) Laboratory. Results were formally submitted to the EPA to support a registration of antimicrobial efficacy in 2008, which allowed marketing of antimicrobial copper products in the US.

Key features

Three test protocols were established to assess:

- Efficacy as a sanitiser
- Residual self-sanitising activity
- Continuous reduction of bacterial contaminants.

Staphylococcus aureus, *Enterobacter aerogenes*, *Escherichia coli* O157:H7, *Pseudomonas aeruginosa*, MRSA and VRE were deposited on alloys ranging from 60% to 100% copper from two or three separately manufactured batches of each alloy.

Registered claims

Laboratory testing has shown that, when cleaned regularly (bacterial claims relate specifically to the organisms tested and to >450 specified alloys with copper content >60%):

- Antimicrobial copper alloys continuously reduce bacterial contamination, achieving 99.9% reduction within two hours of exposure.
- Antimicrobial copper alloy surfaces kill greater than 99.9% of Gram-negative and Gram-positive bacteria within two hours of exposure.
- Antimicrobial copper alloy surfaces deliver continuous and ongoing antibacterial action, remaining effective in killing greater than 99.9% of bacteria within two hours, even after repeated wet and dry abrasion and re-contamination.
- Antimicrobial copper alloy surfaces kill greater than 99.9% of bacteria within two hours, and continue to kill more than 99% of bacteria even after repeated contamination.
- Antimicrobial copper alloy surfaces help inhibit the build up and growth of bacteria within two hours of exposure between routine cleaning and sanitising steps.

The EPA registration states about the registered alloys:

These products have been rigorously tested and have demonstrated antimicrobial activity. After consulting with independent organizations – the Association for Professionals in Infection Control and Epidemiology and the American Society for Healthcare Environmental Services – as well as a leading expert in the field (Dr. William A. Rutala, Ph.D., M.P.H., University of North Carolina (UNC) Health Care System and UNC School of Medicine), the Agency has concluded that the use of these products could provide a benefit as a supplement to existing infection control measures.

The EPA requires that the following statement be included when making public health claims in the US related to the use of antimicrobial copper alloys:

The use of a Copper Alloy surface is a supplement to, and not a substitute for, standard infection control practices; users must continue to follow all current infection control practices, including those practices related to cleaning and disinfection of environmental surfaces. The Copper Alloy surface material has been shown to reduce microbial contamination, but it does not necessarily prevent cross-contamination.

Conclusions

In the US, antimicrobial products marketed with public health claims must be registered with the EPA. Copper and copper alloys were the first solid materials (i.e. not a liquid disinfectant product) to be registered. Outside the US, this registration represents an independent, official recognition of the laboratory data presented and provides the quantified efficacy claims applicable to all registered alloys for the organisms tested.

Clinical Research

In 1983, a US physician, Dr Phyllis Kuhn, published a hospital study showing copper's effectiveness in lowering the *E. coli* count on brass doorknobs. The study concluded that, if the replacement of brass with stainless steel was to continue, the frequency of cleaning and disinfection would need to be increased to control bioburden.

Dermatology and neonatal ICU study, Kitasato University Hospital study, Japan

In 2005, selected surfaces on a dermatology ward and neonatal intensive care unit at Kitasato University Hospital, Tokyo, were wrapped with copper or brass foil and levels of contamination were monitored on these and control surfaces. It was found that copper alloys had a superior sanitising effect in the hospital environment.

General medical ward study, Selly Oak Hospital, UK

On the recommendation of the UK Department of Health on reviewing the laboratory evidence of Keevil *et al*, a trial was initiated to investigate efficacy in a dynamic and challenging clinical environment. Copper Development Association (CDA) provided an education grant to University Hospitals Birmingham NHS Foundation Trust and Prof Tom Elliott developed a unique cross-over study at Selly Oak Hospital, Birmingham. CDA worked with the supply chain to provide copper products for the trial and also provided liaison with other clinical trial groups around the world.

From March 2007 onwards, surfaces identified by a multidisciplinary team as 'frequently touched' on a busy general medical ward were replaced with copper-containing items and the contamination on their surfaces compared to control items on the same ward. The domestic staff followed their standard ward-cleaning timetable.

The copper-containing items introduced included grab rails, door handles, door push plates, light switches, taps, over-bed tables, sink traps and toilet seats.

In the first phase of this study, three items were sampled - taps, door push plates and toilet seats. Sampling took place once a week for five weeks and then copper and control products were swapped over to compensate for any bias of use and sampling continued for a further five weeks. The results show that there was a reduction in contamination of between 90 and 100% on the copper-containing items compared to the controls.

In the second, extended, phase, further products were introduced (including trolleys, light pulls, flush handles, over-bed tables, dressing trolleys and commode chairs) and these were sampled for six months, with a crossover at the midway point. Results demonstrated lower levels of microorganisms on the copper compared to the standard surfaces - 8 out of the 14 copper surfaces had significantly reduced bacterial load compared to controls and the other 6 copper surfaces demonstrated a trend towards reduction without reaching statistical significance. Furthermore, copper items were less frequently colonised with VRE, MSSA, MRSA and coliform bacteria compared to control items (significance was not reached with MRSA).

In order to assess for any development of resistance to copper, isolates of VRE, MSSA, MRSA and coliforms recovered from the copper surfaces were assessed. No resistance to copper was observed.

Outpatient clinic study, US

A study in a US outpatient clinic compared the microbial contamination on phlebotomy chair arms and an associated equipment tray. Results showed the copper significantly reduced the total median bioburden by 90% on the top surface of the arms and by 88% on the trays.

ICU clinical trial, multi-site, US

The US Department of Defense funded a large-scale three-centre, intention-to-treat, randomised control trial, conducted at The Medical University of South Carolina, Charleston (MUSC), The Ralph H Johnson Veterans Administration Medical Center, Charleston, South Carolina and The Memorial Sloan-Kettering Cancer Center in New York City.

The aim of the study was to assess copper's antimicrobial efficacy in intensive care units (ICUs). The institutions replaced stainless steel, aluminium and plastic touch surfaces with antimicrobial copper alloys (hereafter referred to as 'copper' in this section) on the following frequently-touched objects within selected rooms in each of the ICUs: nurses' call devices, monitor bezels, bed rails, chairs, IV poles, data input devices (computer mice, laptop keyboard bases), arms of the patient visitor's chair and over-bed tables.

During the trial period, the level of bacterial contamination (bioburden) on matched copper and non-copper surfaces was determined weekly. No changes were made to clinical practices or cleaning regimes in the study rooms. The trial, conducted by infectious disease clinicians and led by Dr Michael Schmidt, Professor and Vice Chair of the Microbiology and Immunology Department at MUSC, was executed in three stages.

The first stage established the baseline microbial burden on the frequently-touched objects in ICU rooms before installation of the copper products. The average microbial burden of the rooms was found to be 16,885 colony forming units (cfu) per 100 cm^2. The key surfaces shown to be most contaminated and, not surprisingly, in closest proximity to patients and visitors, were replaced with copper components.

The second stage was the replacement of the most contaminated touch surfaces with copper and subsequent comparison of the microbial burden on these and non-copper equivalent surfaces over a period of 135 weeks. Eight rooms were upgraded with copper and matched with control rooms across the three sites. The first paper published reported the average bioburden observed on copper surfaces was 83% less than on the non-copper surfaces (465 vs. 2,674 cfu/100 cm^2; $P = <0.0001$, see Figure 5).

Another showed the importance of the hospital bed rails as reservoirs of contamination and that standard rails became re-contaminated significantly more rapidly than copper after disinfection (at 6.5 hours 434 vs. 5,198 cfu/100 cm^2; $P = 0.002$).

The third stage assessed the incidence of healthcare associated infections in ICU rooms with and without copper products. During the patient phase, 650 randomly assigned admissions were studied throughout 104 weeks. The number of copper components in the individual rooms was recorded throughout each patient's stay, e.g. whether or not the patient was in a bed with copper rails (bariatric patients needed special beds, which were not available with copper rails). Patients were allocated to rooms randomly and their medical condition was assessed according to APACHE II scores. A retrospective assessment of records by clinicians, blinded to patient status, assessed whether individuals contracted an HCAI.

The key paper from this phase was published in an ICHE Special Topic Issue: The Role of the Environment in Infection Prevention in May 2013: Copper Surfaces Reduce the Rate of Healthcare-Acquired Infections in the Intensive Care Unit. It reports a greater than 50% reduction in HCAIs associated with copper rooms. Statistically this reflects a reduction in HCAIs in patients cared for in copper rooms versus standard rooms 10 (3.40%) vs. 26 (8.12%); $P = 0.013$).

The paper also reports a significant association between level of contamination and HCAI risk, with 89% of HCAI occurring among patients cared for in a room with a bioburden >500 cfu/100cm^2; P =0.038 (regardless of the presence/absence of copper). See Figure 6.

Other papers from this study are in preparation and those already published have already instigated a number of discussions about larger trials in Europe and elsewhere.

In summary:

- In the test ICUs, touch surfaces were shown to serve as significant microbial reservoirs that could transfer microbes between patients, healthcare workers and visitors, despite regular cleaning.
- Objects upgraded with copper or copper alloys consistently had bacterial burdens >80% less than equivalent objects – and below the proposed safe value of 2.5 cfu/cm^2.
- During the course of the two year study, the minimal observed oxidation did not reduce the efficacy of the copper.
- Limited placement of copper surfaces significantly reduced the rates of HCAI (by greater than 50%).
- The copper surfaces were shown to work in tandem with standard infection prevention practices to significantly reduce burden and HCAIs.
- Preliminary analysis indicates that rate of infection reduction was linked to exposure frequency.
- Use of copper surfaces represents the first instance where an intervention designed to reduce burden has had a clinical impact among ICU patients.

Other trials

Trials have taken place, or are under way, in Chile, China, France, Germany, Greece, India, Japan, South Africa, Spain and the US.

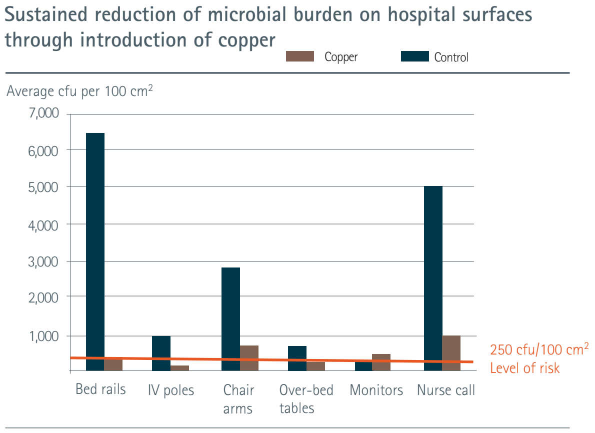

Figure 5 - Sustained reduction of microbial burden on common hospital surfaces through introduction of copper. Proposed hygiene standard level is indicated in orange. Schmidt M G *et al*, JCM. 2012.

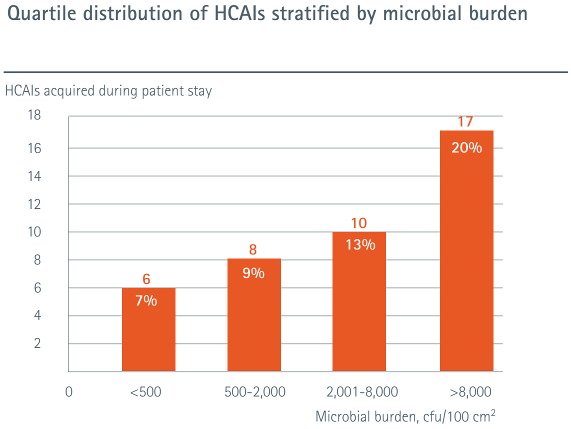

Figure 6 - Quartile distribution of HCAIs stratified by microbial burden measured in the intensive care unit room during the patient's stay. There was a significant burden association between burden and HCAI risk with 89% of HCAIs occurring among patients in rooms with a burden of more than 500 cfu/100 cm^2. Salgado *et al*, ICHE, 2013.

Evidence-based infection prevention and control guidance

Copper is now recognised as an effective antimicrobial material in the epic3 Guidelines (National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England). Copper has also been included as a 'Top 10 Technology to Watch' in the recent Horizon Scanning Reports carried out by the ECRI Institute (Emergency Care Research Institute) and the Canadian Network for Environmental Scanning in Health (CNESH).

Based upon this level of recognition, working parties within governmental and infection control organisations are actively assessing and researching the benefits of copper.

Conclusions

Teams around the world have led clinical trials to assess copper's role in reducing bioburden in the clinical environment and any associated improvement in patient outcomes.

The continuous antimicrobial activity of copper surfaces in challenging clinical environments has been confirmed. With standard cleaning and disinfection routines in both copper and control rooms, copper surfaces are reported to harbour 80% less microbial burden than controls.

Published data from the first study to assess the impact of replacing key touch surfaces in ICUs with copper, shows an associated reduction in the risk of acquiring an HCAI of >50%.

Evidence-based guidelines and recommendations now include copper as a technology to consider for reduced contamination and potential infection reduction.

4. Practical Aspects of Implementation

Touch surfaces to upgrade

In copper clinical trials conducted around the world, multi-disciplinary teams have reviewed the patient, staff and visitor use of different ward environments and prioritised high frequency touch surfaces to upgrade to copper. Based on a wider review of international research, the United States Centers for Disease Control (CDC) has published a checklist of key surfaces based upon the likelihood of touch and contamination. The factors considered include known hotspots, from microbiological testing, and likely hotspots, from experience and understanding of staff/patient/visitor dynamics.

The list below represents a summary of these surfaces but input should also be sought from the local infection control team and ward staff to ensure that all high risk touch surfaces specific to any particular area are included.

Range of Alloys

The materials chosen for clinical trials are those already in common use for other purposes and are readily available to equipment manufacturers supplying healthcare components. They represent a range of compositions based on the US EPA-registered alloys.

Fabricability, Durability and Appearance

Copper alloys, especially brass, have become an industrial standby due to their ease of use and durability. Much equipment is manufactured in these materials and subsequently lacquered or chrome or nickel plated. Brass is readily cast, is considered the 'gold standard' in terms of machining and is easy to manipulate by bending and pressing. Moreover, the alloys are very malleable, which has the potential to allow designers to provide hygienic, as well as practicable, equipment. Components are familiar, easy to install and have long service lives.

Copper forms an alloy with a number of other elements such as iron, zinc, nickel and aluminium, providing a family of alloys with material characteristics that are readily understood by engineering designers. The alloys exhibit a range of colours, again allowing expression of design as well as practicality. Because some are notably different, they can potentially provide a mark of change and innovation in healthcare.

Guidance on Cleaning and Disinfection of Antimicrobial Copper Alloys

Antimicrobial copper surfaces are a supplement to, and not a substitute for, standard infection control practices and users should continue to follow all current infection control practices, including those related to cleaning and disinfection of environmental surfaces.

Copper and copper alloys are active surfaces and may develop an oxide called a patina over the course of 2 – 4 weeks if washed and cleaned using standard healthcare agents and protocols. Once established, the patina is stable and protects the component from further oxidation unless it comes into contact with strong reagents. The developed patina does not reduce efficacy according to results from laboratory testing and clinical trials.

There are three types of cleaning products to consider – see next page. For any product specific information, it is recommended that the manufacturer is contacted.

Disinfectant products containing metal ion chelators, such as EDTA, should be avoided, as these partially and temporarily inhibit copper's efficacy.

Medical Equipment & Furniture	Fixtures & Fittings	
Bed rails*	Cabinet handles*	Light switches*
Chairs*	Counter tops	Push plates*
Dressings trolleys	Dispensers	Sinks*
Input devices/nurse call buttons*	Door handles*	Switched sockets
IV poles*	Grab rails*	Taps
Over-bed or tray tables*	Hand rails	Toilet seats and flush handles*

* Included in the CDC Environmental Checklist for Monitoring Terminal Cleaning.

1) Hospital detergents – these will clean grease and other soil from surfaces and should always be used prior to disinfection.

- Most cleaning products are proprietary and will have instructions for use – always refer to manufacturers' instructions.
- Items should be cleaned, dried (disinfected as necessary) and inspected before use.
- If applying disinfectant after normal cleaning, it is common to wash with clean water and dry between these steps to ensure optimum activity of disinfectant.
- Cleaning wipes are single-use products and should be disposed of after use.
- Some products may combine disinfectants with detergents and allow single step use.

2) Hospital disinfectants - will disinfect the surface of the copper and generally contain:

- Alcohols - not corrosive to copper alloys but not active against all microbes.
- Bleaches - containing chlorine or with the active ingredient sodium hypochlorite; the solution is not corrosive to copper alloys when used correctly.
- Quaternary ammonium – such compounds do not damage copper alloys.
- Ammonium chloride - is of little concern for copper when used in normal dilute formulations.
- Phenol and ammonia - are rarely used organic chemicals and not harmful to copper.

Other disinfection techniques:

- Hydrogen peroxide (solution or vapour - HPV) has no long-term effect on copper alloys.
- Steam may be used for cleaning or disinfection and will not harm copper alloys.
- Formaldehyde is sometimes used for laboratory disinfection and fumigation and is not deleterious to copper or copper alloys.

3) Metal polishes and cleaners - will brighten the appearance of the copper and copper alloys.

- Citric acid based cleaners are preferred as they disinfect and remove tarnish without leaving a residue.
- Proprietary polishing products, such as Brasso, will clean the copper but are not recommended as they may leave a residual film which inhibits the antimicrobial effect of copper for a period of time. Removal of waxes can be difficult but may be achieved with alcohol wipes.

Cost and Cost-benefit

A significant issue with the copper proposition is that, by its nature, it is a capital investment but one that could improve patient outcomes and therefore reduce the cost of care. This means that the costs and benefits accrue in different budgetary areas. As a world leader in health economics, the University of York's York Health Economics Consortium (YHEC) has carried out a research project, assessing relevant clinical evidence in western Europe and the US, and has developed a model illustrating the cost-benefit of a copper alloy intervention.

The YHEC model allows input of local cost data for fixtures, fittings and other medical equipment, as well as care costs. Default data entered by YHEC, based on their research and commercial costs, shows that targeted installation of antimicrobial copper will pay back in well under one year, assuming the project is part of a planned refurbishment or upgrade (see Appendix 1 for the model's assumptions and a worked example).

Copper and its alloys are sometimes perceived as expensive, however, they continue to be widely used throughout industry because they offer good value. Most of a component cost comes not from the intrinsic material value, but a combination of fabrication and fitting costs. Copper alloys are widely used for complex components, like a tap or a lock, because they are easy to fabricate, by casting, rolling, machining and then polishing. Fitting costs are broadly the same for any given component. Copper alloy components therefore represent a comparable capital cost to other widely used materials. Installation of a 'ward set' of key touch surface components is relatively easy and can be accomplished without major disruption on the ward. Prof Tom Elliott, leader of the Selly Oak research, has stated that 'the cost of fitting out the 20-bed trial ward was equivalent to the cost of just one-and-a-half infections.'

Adoption

Since the publication of the bioburden reduction results from the Selly Oak trial, hospitals and care homes in the UK and the rest of the world have started to install antimicrobial copper touch surfaces in refurbishment and new-build projects and some of these are already specifying additional installations.

Installations in Europe to date include a cystic fibrosis unit for young adults at Northern General Hospital, Sheffield, an ICU at Trafford General, Manchester, a care home in Mullingar, Ireland, a multi-generational care home in Laval, France, a children's ICU in Aghia Sophia Paediatric Hospital, Greece, a nephrology department, Poland and a geriatric ward at Evangelisches Geriatriezentrum, Berlin. These projects illustrate the variety of hospital types, ward types and different healthcare systems in Europe where antimicrobial copper has been installed.

Sustainability

Copper is 100% recyclable without loss of properties. 'Scrap' from manufacturing has value and there is a very well developed infrastructure for collecting and recycling it. In Europe, over 40% of copper needs are met through the recycling route and almost all the brass produced comes from recycled stock. According to a recent paper from the Fraunhofer Institute, two thirds of copper mined since 1900 is still in productive use today.

Design

Copper alloys are considered by many designers as traditional, and component designs often reflect a focus on a nostalgic market. In fact, they provide a great opportunity to design out infection through the use of modern manufacturing technology. The UK still plays an important part in the global industry, providing designs that can best be made using skills and equipment relevant to any country's supply chain. The clean, straight stainless steel design forms that have become so ubiquitous have arisen largely because the early steels were difficult to fabricate.

Availability

Copper alloys are widely available from both primary manufacturers and stockists. Manufacturers of components have access to a wide variety of material forms and good selection advice from these sources, as well as the support of Copper Development Association (CDA) and the global network of Copper Alliance Copper Centres. Globally, there are thousands of suppliers of both raw materials and semi-finished products.

Specifying Copper and Copper Alloy Products

As the global industry representative, the International Copper Association (ICA) has developed the Antimicrobial Copper Service Mark (logo) and Certification Mark (Cu+) to ensure it addresses its stewardship with regard to the deployment of copper and copper alloys in the field. The Antimicrobial Copper Marks are used by leading material suppliers and designers, specifiers and manufacturers of components and systems, to indicate their products and services employ Antimicrobial Copper.

The use of the Antimicrobial Copper Marks by an organisation indicates permission to do so has been granted on behalf of International Copper Association, Ltd, based upon adherence to strict usage rules. These rules guide that organisation's understanding of the underlying technology and the way they promote, advise and deploy it in line with existing research, regulatory and legislative requirements.

Conclusions

Copper and its alloys are readily available and cost-effective to form into durable equipment and fittings suitable for service in the healthcare environment. Alloys are available which look like stainless steel, as well as the distinctive golds and bronzes which can provide a highly visible statement that an additional measure is being taken to reduce the risk of HCAIs. Components are familiar, easy to install and have long service lives. They require no special training, special cleaning or ongoing maintenance and provide no disruption to the hospital routine. Products made from solid materials will remain effective in killing germs throughout their lives, even if scratched. They are fully recyclable and therefore contribute to sustainable design. An expanding range of products is available commercially and deployment of copper in hospitals is practical and viable.

Using component cost data from recent antimicrobial copper installations in European hospitals and published cost of care figures for the UK, upgrading an ICU as part of a new-build or planned refurbishment results in a payback of less than one year, according to the YHEC model.

The use of copper for touch surfaces is not a substitute for standard hygiene practices and products should be cleaned and disinfected according to standard procedures, using standard agents. Some acceptable surface oxidation (slight darkening) will take place but this does not affect efficacy.

The Antimicrobial Copper Marks form the core of a stewardship programme and have been established to provide a focus for all stakeholder needs. This includes local training and advice on both the science and practical application of antimicrobial copper.

5. Background Information

Learning More

CDA is able to offer support by providing speakers and advisors for team meetings, seminars and other events, covering the science and practical application of antimicrobial copper. All information resources are also accessible online, including the following publications, at www.antimicrobialcopper.org.

Publication 201: Antimicrobial Copper FAQs
Publication 212: Near-patient Antimicrobial Copper Touch Surfaces for Infection Control - The Business Case
Publication 213: Guidance on Cleaning and Disinfection
Publication 214: Antimicrobial Copper Alloys: Guidance on Selection
Publication 219: Antimicrobial Copper: A Hospital Manager's Guide
Publication 220: Antimicrobial Copper: A Specifier's Guide

Copper Voluntary Risk Assessment

The industry has undertaken a Voluntary Risk Assessment for Copper, the assessment process which was agreed with the Italian Government's Istituto Superiore di Sanità, acting as the review country on behalf of the European Commission and the EU Member States. One of the conclusions is that 'the use of copper products is in general safe for Europe's environment and the health of its citizens.' This statement has been accepted by the European Commission and EU Member State experts.

About Copper Development Association

CDA is a not-for-profit, membership-based organisation which supports and promotes the correct and efficient use of copper and its alloys through the provision of technical support and impartial information to professionals, end users and students. CDA is part of a global network of offices - the Copper Alliance - operating in 30 countries with a regional office in Brussels, European Copper Institute, and headquarters in New York, International Copper Association, Ltd (ICA). ICA funds the University of Southampton research on antimicrobial copper.

CDA provided an education grant to University Hospitals Birmingham NHS Foundation Trust, where Prof Tom Elliott developed a clinical trial. CDA also works with the supply chain to provide copper products, initially for the Selly Oak trial and subsequently to meet demand from the market. CDA also provides liaison with other clinical trial groups around the world.

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Appendix 1: YHEC Business Case Model Worked Example – Intensive Care Unit, UK

Parameter	Value	Note
Number of beds	20	Single room configuration.
Number of patients per annum	1,200	Based on an average stay of 6 days (Edbrooke 2011).
Infection rate (all HCAIs)	25%	27.1% in Cairns 2010. 23.4% in English National Point Prevalence Survey on Healthcare, Health Protection Agency (2012).
Cost per HCAI	£6,000	Negrini (2006) reported the average cost per patient-day over 75 UK ICUs was $1,512 (£1,000) and an HCAI results in an additional 6 days. While the model allows for costs of subsequent outpatient and GP visits to be taken into account, these are not considered here.
Items to be upgraded to copper (or antimicrobial copper alloy)	6 critical items: IV drip pole Bed rails Computer input device Nurse call button Over-bed table Visitor chair	Schmidt MG, Copper Touch Surface Initiative. Microbiology and Immunology, Medical University of South Carolina, Charleston, USA, BMC Proceedings 2011, 5(Suppl 6):O53 (Oral presentation delivered at 1st International Conference on Prevention and Infection Control, June 29-July 2, 2011, Geneva, Switzerland). Sustained Reduction of Microbial Burden on Common Hospital Surfaces through Introduction of Copper, Michael G Schmidt *et al*, Journal of Clinical Microbiology, July 2012, Vol 50, No 7. This study was conducted in single-room ICUs. Other key touch surface replacements are also available - such as door handles, push plates, taps - that comply with current hospital regulatory requirements, and have been identified as high risk touch surfaces in other clinical areas.
Cost of intervention	£30,600	This is the cost difference between copper and standard, non-antimicrobial components, using early market prices. As this example is based on a new build or planned renovation, installation costs would be similar and have therefore not been considered.
Reduction in HCAIs post intervention	20%	Copper Surfaces Reduce the Rate of Healthcare-Acquired Infections in the Intensive Care Unit, Cassandra D Salgado *et al*, Infection Control and Hospital Epidemiology, May 2013, Vol 34, No 5. This study demonstrated a 58% reduction in infections in ICU rooms equipped with copper. The example below uses a conservative figure of 20%.

5 Year Results

Using the above inputs, the model yields a return on investment of less than two months. The cost of copper components is £105,000 compared to £74,400 for standard items. There were 1,200 infections in the copper group and 1,500 in the baseline. This results in a cost per infection averted of £102. The model calculates additional benefits including bed days freed and Quality-Adjusted Life Years. To download the model visit www.antimicrobialcopper.com/uk/why-antimicrobial-copper/the-business-case.aspx or email info@copperalliance.org.uk.

	Copper	Baseline	Incremental
Total cost (excluding cost of infections)*	£105,000	£74,400	**£30,600**
Number of infections	1,200	1,500	**300**
Cost per infection averted (excluding cost of infections)			**£102.00**
Total QALYS gained			**107.40**
Cost per QALY			**£284.92**
Cost of infections*	£7,200,000	£9,000,000	**-£1,800,000**
Total cost of intervention*	£7,305,000	£9,074,400	**-£1,769,400**
Cost per infection averted			**Dominant #**

*These are direct costs to the hospital (no GP costs or societal costs have been included in the model)

Dominant means that Antimicrobial Copper is both the cheaper and the more effective option

Number of bed days saved per year	**360**
Cost per bed day day saved per year	**£85.00**

The number of bed days saved per year is 360, this would allow an increased capacity in the ICU by 63 beds with a typical length of stay of 5.7 days.

Return on investment	**< 2 months**

The cost of the copper upgrade is £105,000 compared to £74,400 for installation of non-copper items. There were 1,200 infections in the copper group over the period and 1,500 in the baseline. This results in a cost per infection averted of £102.00.

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