Antimicrobial Copper FAQs

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Copper and Copper Alloys

What is copper?

Copper is an essential element required by both plants and animals to live. Copper is also an industrial metal that possesses superior electrical and thermal conductivity, is easy to process and, through the incorporation of other metals, can deliver broad technical performance. This makes it a very important material in a wide range of consumer and industrial applications.

Where does copper come from?

Copper is refined from ore that occurs naturally in many places around the world. The five largest mining countries are Chile, the United States, Peru, Australia and Russia.

Is copper recyclable?

Copper is one of the few materials that can be recycled, time and time again, without any loss in performance. In 2009, almost 34% of the world's copper demand was met through recycling and it is estimated that much of the copper ever mined is still in circulation.

Almost half of all recycled copper comes from building scrap and post-consumer waste, such as electric cables, plumbing installations, end of life vehicles and electronic and electrical equipment. The remainder is new scrap recovered from along the complex downstream value chain.

Is copper in food?

Copper is necessary in the human diet; the best sources for dietary copper include seafood, organ meats, whole grains, nuts, raisins, legumes and chocolate. An adult needs a daily intake of around 1mg per day to maintain good health.

What are copper alloys?

An alloy is created when a metal is mixed with one or more elements. This mixture allows the combined elements to take on properties that they would not have individually in their pure states. The ratios of copper and added elements vary depending on what properties are required of the resulting alloy. Brass and bronze are common alloys of copper.

Are brass and bronze different?

Yes. Brass is created by combining pure copper with zinc. Brass is strong, resistant to corrosion and easily worked without the use of heat. Bronze is created when tin and phosphorus are combined with copper. Bronze is harder than brass; it combines strength with fatigue resistance, machinability and high wear resistance. Both brass and bronze are available in a wide range of colours and finishes.

Antimicrobial Properties

What is meant by 'antimicrobial'?

'Antimicrobial' is the ability of a substance to kill or inactivate microbes, such as bacteria, fungi (including moulds) and viruses.

Does copper have antimicrobial properties?

Yes. Man has exploited the inherent antimicrobial properties of copper since the dawn of civilisation. It has been demonstrated clearly in many scientific studies conducted over several decades that copper has rapid, broad spectrum antimicrobial efficacy against some of the most toxic species of bacteria, fungi and viruses.

Which microbial pathogens can copper kill?

The scientific literature cites the efficacy of copper to kill or inactivate many different types of harmful bacteria, fungi and viruses, including:

- *Acinetobacter baumannii*
- *Aspergillus niger*
- *Campylobacter jejuni*
- *Enterobacter aerogenes*
- *Helicobacter pylori*
- *Klebsiella pneumoniae*
- *Listeria monocytogenes*
- *Mycobacterium tuberculosis*
- *Pseudomonas aeruginosa*
- *Staphylococcus aureus*
- Adenovirus
- *Candida albicans*
- *Clostridium difficile*
- *Escherichia coli* O157:H7
- Influenza A (H1N1)
- *Legionella pneumophila*
- MRSA (including E-MRSA)
- Poliovirus
- *Salmonella enteritidis*
- VRE

Is it just pure copper that has an antimicrobial effect?

No, copper alloys do too. Tests have been performed on pure copper, high coppers, brasses, bronzes, copper-nickels and copper-nickel-zincs (sometimes referred to as nickel silvers because of their shiny white colour, even though they contain no silver). Alloys with higher copper content kill organisms faster but, as a general rule, alloys with >60% copper have good efficacy. 'Antimicrobial Copper' is shorthand for these efficacious alloys. When choosing a copper alloy for a product it is important to balance the requirements for mechanical properties, manufacturing process and, of course, colour. Copper alloys provide a palette of attractive colours from silver, through the yellow of brasses, to the dark browns of bronzes.

Which variables affect the antimicrobial efficacy of copper?

Copper's rate of microbial inactivation can be affected by temperature, copper concentration and the type of microorganism with which it is in contact. Current studies demonstrate the efficacy of copper and copper alloys as hygienic, antimicrobial materials for pathogenic microbes in various environments.

Are the antimicrobial copper surfaces coated?

No, the antimicrobial property of copper is intrinsic to the metal. In order to maintain antimicrobial effectiveness, oils, waxes, glosses, paints and other coatings must NOT be applied.

Are copper platings and coatings effective too?

Yes, in limited situations, but some words of caution: coatings are susceptible to wear and tear and any surface damage may not only remove the active copper coating but may introduce scratches which can harbour germs. Surfaces made from solid copper or copper alloys are antimicrobial through and through. Careful consideration should therefore be given to the intended use and likely abuse of a product.

How are Antimicrobial Copper products specified?

As the global industry representative, the International Copper Association, Ltd. (ICA), has developed the Antimicrobial Copper name and Cu^+ mark to ensure it addresses its stewardship with regard to the deployment of copper and copper alloys in the field. The use of the Antimicrobial Copper brand and Cu^+ mark by an organisation indicates that a Copper Centre, on behalf of ICA, has granted permission to do so 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.

Antimicrobial Copper is the umbrella term for all Cu^+ approved antimicrobial copper alloys.

Clinical Trials

Has copper been tested in clinical trials?

Yes, antimicrobial copper surfaces have been proven to have over 90% less contamination than conventional touch surfaces in hospital trials around the world.

In the UK, Selly Oak Hospital, Birmingham - part of University Hospitals Birmingham NHS Trust - was selected to be the test centre for this new approach to infection prevention.

The first paper from the trial reported that copper is antimicrobial in a busy ward situation and that copper-containing surfaces had >90% less bacterial contamination than controls made from conventional materials. The results have been confirmed in a subsequent, prolonged study at Selly Oak, published in Infection Control and Hospital Epidemiology. Furthermore, in order to assess for resistance, survival of isolates of VRE, MSSA, MRSA, and coliforms was assessed by a carrier test. No resistance to copper was observed.

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

In the Department of Defense-funded US trials, carried out in ICU rooms at three hospitals, the aim was to not only determine the efficacy of antimicrobial copper in reducing the level of pathogens but whether such a reduction would translate into a lower rate of infection. Researchers at the three hospitals involved in the trial - Memorial Sloan-Kettering Cancer Center in New York, the Medical University of South Carolina and the Ralph H Johnson VA Medical Center, both in Charleston, South Carolina - replaced commonly-touched items, such as bed rails, over-bed tray tables, nurse call buttons and IV poles, with antimicrobial copper versions.

Rooms with copper surfaces demonstrated a median reduction in bioburden of 97% compared to controls, better than the level achieved by 'terminal' cleaning: the regimen conducted after each patient vacates a room.

Furthermore, the initial results demonstrated that the use of antimicrobial copper surfaces in intensive care unit rooms resulted in a greater than 40.4% reduction in the risk of acquiring a hospital infection. For patients who spent their entire stay in a 'copper room' with all six copper/copper alloy items present, the reduction in risk of acquiring an infection was 69.1%.

Because of its importance, the data has been validated by a team of independent reviewers before being submitted, as a series of papers, for publication.

Independent Verification of Copper's Antimicrobial Efficacy – US EPA Registration

Has any independent official body verified copper's antimicrobial efficacy?

Yes. On February 29, 2008, the US Environmental Protection Agency (EPA) registered 275 copper alloys with public health claims. Additional alloys have since been registered, bringing the total number of registered alloys to more than 350. Copper is the only solid material to be granted this registration, which applies to the marketing of products in the US.

What does the EPA registration mean?

Registration of copper and certain copper alloys such as brass and bronze means that the EPA recognises these solid materials' antimicrobial properties. Products made from any of the registered alloys are legally permitted to make public health claims in the US.

What is a public health claim?

Under EPA guidelines a public health claim relates to the control of organisms that pose a threat to human health. Public health claims must be supported by extensive testing under EPA protocols in an independent laboratory that adheres to OECD (Organisation for Economic Cooperation and Development) Good Laboratory Practice guidelines.

Which bacteria are covered by the EPA registration?

Laboratory studies conducted under EPA-approved protocols have proven copper's ability to kill, within 2 hours of contact time, more than 99.9% of the following disease-causing bacteria: *Staphylococcus aureus*, *Enterobacter aerogenes*, *Escherichia coli* O157:H7 (*E. coli* O157:H7), *Pseudomonas aeruginosa,* Vancomycin-resistant *Enterococcus faecalis* (VRE) and meticillin-resistant *Staphylococcus aureus* (MRSA). MRSA is sometimes referred to as a 'superbug'.

What public health claims does the EPA allow?

When cleaned regularly...

- Antimicrobial copper, brass and bronze surfaces kill greater than 99.9% of bacteria within 2 hours of exposure.
- Antimicrobial copper, brass and bronze surfaces achieve continuous antibacterial action and remain effective in killing more than 99.9% of bacteria even after repeated contamination.
- Antimicrobial copper, brass and bronze surfaces remain effective in killing greater than 99.9% of bacteria within 2 hours, even after repeated wet and dry abrasion and re-contamination.
- Antimicrobial copper, brass and bronze surfaces help inhibit the buildup and growth of bacteria within 2 hours of exposure between routine cleanings.

Note: These claims apply only to uncoated copper and copper alloys. Copper alloys are a supplement to, not a substitute for, standard infection control practices.

Applications

How can copper benefit the public?

The use of copper and copper alloys for frequently touched hospital surfaces such as door and furniture hardware, bed rails, IV poles, dispensers, taps, light switches and work stations can help reduce the amount of disease-causing microbes in hospitals. Antimicrobial copper alloy surfaces have been shown to reduce microbial contamination in between routine cleaning and disinfection, making them a useful additional measure to improve hygiene. Preliminary data from the US ICU study indicates an associated and significant reduced risk of infection.

How is copper currently used as an antimicrobial agent?

Copper is already an active ingredient in many different types of antimicrobial products, in agriculture, in marine environments, in healthcare environments and in the home. Copper is an active ingredient in antiplaque mouthwashes, toothpastes and medicines. Copper sink strainers and scourers for pots and pans can help prevent cross-contamination in the kitchen. Now, copper and copper alloy touch surfaces have also been installed in hospitals across the world.

Where can copper be used?

In addition to antimicrobial copper for frequently touched surfaces in hospitals, those materials may be used in other settings where transmission of infection could occur, such as care homes, ambulances, gyms, schools, public buildings, public transport and offices.

How can copper be used to improve indoor air quality?

In today's modern buildings, the concern about exposure to toxic microorganisms has created a priority need to improve hygienic conditions of heating ventilation and air conditioning (HVAC) systems, which are believed to be factors in over 60% of all sick building situations (e.g., aluminium fins in HVAC systems have been demonstrated to be sources of significant microbial populations).

In immuno-compromised individuals, exposure to toxic microorganisms from HVAC systems can result in severe infections, possibly leading to death. There are several papers indicating that copper kills many pathogens commonly found in HVAC systems and clinical trials are under way in the US to test the hypothesis that copper HVAC components will help improve indoor air quality.

How can antimicrobial copper be used to improve food hygiene?

The number of foodborne infections suggests that governmental hygiene programmes and industry self-monitoring are insufficient to protect the quality of the world's food supplies. Hygienic contact surfaces, such as copper and copper alloys, can be used for dry food contact and touch surfaces to help reduce the incidence of cross-contamination of dangerous foodborne pathogens, such as *E. coli* O157:H7, *Campylobacter jejuni, Listeria monocytogenes*, *Salmonella enteritidis* and MRSA, at food-processing facilities. Copper has an intrinsic ability to kill these dangerous microbes quickly at both refrigerated temperature (4°C) and room temperature (20°C).

How Does Copper Work?

How does copper kill pathogens?

Copper is an essential nutrient for humans as well as bacteria but, in high doses, copper ions can cause a series of possibly-interacting negative events in bacterial cells. These include:

- 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
- Causing degradation of bacterial DNA.

How quickly do copper alloys kill bacteria?

Laboratory tests have demonstrated that copper alloys kill 99.9% of MRSA within two hours. This test simulates a wet contamination incident. Latest research shows that in a test which simulates a dry contamination event, such as a touch, 10 million VRE are eliminated in less than 10 minutes.

Does this mean that there is a delay in the antimicrobial effect?

No, copper starts to have its antimicrobial effect immediately. The times stated are for scientific tests carried out under strictly controlled and reproducible conditions and therefore state the times for total elimination in a particular set of conditions. In these tests, an extremely high challenge of bacteria is used, many orders of magnitude higher than would be encountered in a real clinical situation. When the 'wet' tests are repeated using lower doses of contamination, total elimination of, e.g., MRSA, takes as little as 15 minutes.

Won't microorganisms develop resistance to copper?

This is highly unlikely for three reasons:

- Copper is naturally present in the earth's crust and, to date, no resistant organisms have been demonstrated. Copper-tolerant organisms do exist but even these die on contact with copper surfaces.
- Copper kills microorganisms by multiple pathways rather than by acting in a specific way on one receptor.
- Microorganisms are killed before they can replicate, thus they cannot pass on genetic material which would ultimately allow evolution and development of resistance.

Copper vs Other Antimicrobial Materials

How is copper superior to other antimicrobial surfaces?

Copper and copper alloy products are antimicrobial through and through. Even when surfaces made of these materials are scratched, their antimicrobial efficacy continues to work - they won't wear away like coatings or other treatments can. Copper alloys are the only solid surfaces with an EPA public health product registration.

Do aluminium, stainless steel and plastics have antimicrobial properties?

No. Comparative antimicrobial efficacy studies have been conducted on copper, aluminium, stainless steel, PVC and polyethylene. While it has been clearly demonstrated that copper is able to kill microbes quickly and effectively, there is no evidence that aluminium, stainless steel, PVC or polyethylene exhibit antimicrobial properties.

How does copper compare to silver in efficacy?

In Keevil's Southampton tests, polymeric coatings impregnated with silver particles behave in the same way as the stainless steel control at ambient temperature and humidity, i.e. they show no antimicrobial effect. Many silver-containing antimicrobial coatings use a Japanese Industrial Standard to test for antimicrobial efficacy. However, the test conditions of the Japanese Standard are highly unrepresentative of conditions typically found in healthcare facilities.

The Japanese Standard is a 24 hour test at 37°C and greater than 90% relative humidity. Additionally, a plastic film is pressed over the sample to retain humidity. Under these test conditions, silver-containing coatings do exhibit notable antimicrobial performance. This is largely influenced by the excess moisture available to participate in ion-exchange reactions required to release silver-ions to combat microorganisms. However, as Keevil demonstrated, when the temperature and humidity are decreased to typical indoor levels, the coatings have no antimicrobial effect and are indistinguishable from the stainless steel control. All copper alloys tested were effective under all tested conditions.

A separate study by Dr Harold Michels confirmed Professor Keevil's findings. Dr Michels tested the antimicrobial efficacy of various copper alloys and a silver-containing coating on stainless steel against MRSA under the temperature and humidity conditions prescribed by the Japanese Industrial Standard, and under temperature and humidity conditions typically found in indoor facilities (20°C and 20-24% relative humidity). At 90% relative humidity and 35°C, all the materials killed more than 99.9999% of MRSA. At 90% relative humidity and 20°C, similar results were obtained. At 20% relative humidity and 35°C, a reduction greater than 99.9999% is observed on all copper alloys; however, on the coated stainless steel no reduction of MRSA was achieved.

The results at 24% relative humidity and 20°C are very similar. A reduction greater than 99.9999% is achieved on all copper alloys, while the reduction on the stainless steel coated with a silver-containing antimicrobial coating is less than 20%. Sterling silver is an effective antimicrobial but lacks the mechanical properties and alloying capabilities for most touch surface applications and would, of course, be prohibitively expensive.

Cleaning

If copper kills pathogens, does that mean it doesn't need cleaning?

No, copper alloy products will need to be cleaned and disinfected, in the same way as other touch surfaces, to remove dirt and grime that can prevent contact with the copper surface. Prescribed hygienic practices for the cleaning of touch surfaces, along with hand-washing, are the first lines of defence and copper alloy surfaces are a supplement to, not a substitute for, standard infection control and hygienic practices. Copper alloy products are active 24/7 and help reduce microbial contamination in between cleans.

How should copper and copper alloy components and surfaces be cleaned?

The usual cleaning and disinfectant products used in hospitals are fine for use on copper and even bleach-containing solutions can be used as long as items are washed down afterwards as described in the current NHS cleaning guidelines.

Aesthetics

Will copper and copper alloy surfaces change colour over time?

Copper and copper alloy surfaces naturally oxidise and darken over time. The amount of time needed for a colour change to occur depends on the alloy and exposure conditions. In typical indoor exposure, appreciable colour changes can take many years to develop. The brass push plates on the main entrance to the Selly Oak test ward in Birmingham did not darken in 36 months. A range of colour stable copper alloys with antimicrobial efficacy is available with a palette of colours from which to select, including those with a silver appearance.

Does oxidation deter copper's antimicrobial effect?

No. In fact, studies show that as uncoated copper, brass and bronze surfaces oxidise, or darken, they become more effective at eliminating disease-causing bacteria.

Cost and Cost-benefit

Will copper products be much more expensive than the products they replace?

No. Material costs are only a small part of a product's cost. Copper and copper alloys are easy and therefore cost-effective to form into components. No coatings or platings are required and this saves costs too. Copper will be effective against microbes round the clock, 24/7. While coatings are fragile and wear out over time, the antimicrobial properties of copper, brass and bronze are integral to the metal and last the lifetime of the product. Copper products also help to deliver eco-design in that they can be fully recycled at the end of their long and useful lives, without any loss of properties.

What is the business case for copper?

Prof Tom Elliott, leader of the Selly Oak research, has stated that 'the cost of fitting out the trial ward (a 20-bed general medical ward) was equivalent to the cost of just one-and-a-half infections.'

A business case model is under development, led by the University of York, allowing calculations to be made to assess payback for installing antimicrobial copper touch surfaces in a new build or refurbishment project. Based upon preliminary data on reduction in HCAI risk from the multi-site US copper clinical trial, 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 achieves payback in less than one year.

Safety

If copper reduces microbes, is it safe?

Yes, copper, brass and bronze surfaces are safe and long lasting. The copper industry initiated a Voluntary Risk Assessment for copper. The assessment process 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. The risk assessment has now been completed and one of the main conclusions, accepted by the European Commission and EU Member State experts, is 'the use of copper products is in general safe for Europe's environment and the health of its citizens.'

Copper is also an essential micronutrient in the human diet, along with zinc and iron. An adult needs 1mg of copper every day. Foods rich in copper include chocolate, nuts and seeds. A balanced diet should provide enough copper to avoid a copper deficiency.

Resources

Is there enough copper to equip all our hospitals?

Yes. Copper extraction technology undergoes development to improve efficiency and so make even low concentration ores economic to mine. This, combined with increased recycling, will ensure there is enough copper to meet demand.

Further Information

To find out more about the properties and applications of antimicrobial copper, access the latest scientific references, see installation case studies, find products or request alloy samples and in-house presentations, visit:

www.antimicrobialcopper.org.

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