SHEng
SMART HEALTHCARE ENGINEERING
2023-1-RO01-KA220-HED-000159985

Co-funded by
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COPPER ALLOYS IN HEALTHCARE FACILITIES

Class content material

This document is part of a training materials collection developed within the Erasmus+ project “Smart healthcare engineering”, SHEng, project No. 2023-1-RO01-KA220-HED-000159985.

The collection is intended for engineering students and professionals working in the healthcare sector. It covers technical subjects relevant to hospital infrastructure, equipment, materials and support services, helping readers understand how engineering contributes to safe patient care and the reliable operation of healthcare facilities.

These materials support classroom teaching and independent study. They should be used alongside the project handbook and the presentations, courses and other learning resources available on the project website. Each document addresses a specific subject, while the collection provides a broader understanding of the responsibilities and practical challenges of healthcare engineering.

The content is educational. Its application in practice requires consideration of the conditions of each healthcare facility, the applicable standards and the instructions provided by equipment manufacturers.

Project website: www.smarthealtheng.com

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SMART HEALTHCARE ENGINEERING

Transilvania University of Brasov
ULPGC Universidad de Las Palmas de Gran Canaria
MANİSA CELAL BAYAR ÜNİVERSİTESİ
Servicio Canario de Salud
SPITALUL MUNICIPAL SĂCELE
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COPPER ALLOYS IN HEALTHCARE FACILITIES

Materials, applications and maintenance

Introduction

Copper serves several different purposes in a healthcare facility. It is used in electrical conductors and heat exchangers, and copper tube is common in plumbing and medical gas installations. Copper alloys are also considered for frequently touched parts such as door hardware and bed rails. In that case the interest is different: exposed copper can reduce the viability of microorganisms left on the surface. The reason for choosing copper for a cable or a pipe should not be confused with the reason for choosing it for a touch surface.

The label copper is not a complete material specification. It may refer to high purity metal, brass, bronze, a copper nickel alloy, or a finished component with a coating. A cast fitting and a drawn tube made from related compositions can differ in strength, residual stress, finish and corrosion behavior. Where these features affect safety, cleaning or service life, the specification should identify the actual grade and product condition.

1. Copper and copper alloys

Copper is ductile and can be drawn into wire or formed into sheet and tube. Its electrical and thermal conductivity are high, but unalloyed copper is not particularly strong. Alloying shifts that balance. Zinc produces brass, tin is used in many bronzes, nickel is useful in some water environments, and aluminium is the main addition in aluminium bronze. Bronze itself covers several compositions, so the name alone says little about a particular grade.

Table 1. Copper alloys and their uses in healthcare facilities

Material	General composition	Properties and examples of use
High purity copper	Copper with only small amounts of other elements	Very high electrical and thermal conductivity. Common in conductors, connectors and bonding components.
Brass	Copper and zinc	Many grades form and machine well. Used in fittings and hardware. Selected products use brass for antimicrobial touch surfaces.
Phosphor bronze	Copper, tin and phosphorus	Useful spring behavior, wear resistance or fatigue performance, depending on grade and temper.
Copper nickel alloy	Copper and nickel	Corrosion resistance in many aqueous environments. Used in selected heat transfer and water service equipment.
Aluminium bronze	Copper and aluminium, sometimes with iron or nickel	Higher strength and useful wear and corrosion resistance in specialized engineering components.

Cartridge brass, designated C26000, contains nominally about 70 percent copper and 30 percent zinc. Copper nickel alloy C70600 contains roughly 90 percent copper and 10 percent nickel, with small additions of other elements. These are typical composition figures, not purchasing limits. The applicable product standard gives the actual limits. Where strength, corrosion resistance or hygiene matters, specify the grade, product form and condition rather than relying on a general alloy name.

These alloys serve different purposes. Brass is widely used in fittings because many grades machine and form well. Copper nickel alloys are used in water service and heat transfer where their corrosion behavior suits the environment. Aluminium bronze is chosen for some components where strength and wear resistance matter, while silicon bronze is used for selected fittings. Those are engineering reasons for choosing an alloy; they do not confirm that its finished surface meets an antimicrobial claim.

Cold working usually increases strength and hardness but reduces ductility. Annealing restores some ductility while reducing the strength gained through working. This matters when comparing tubing, sheet and fittings made from related alloys. High electrical and thermal conductivity are particular advantages of high purity copper. Alloying can improve mechanical properties, but it usually reduces conductivity, sometimes by a substantial amount.

2. Antimicrobial behavior of copper

Copper and many copper alloys can inactivate bacteria and other microorganisms that remain in contact with the surface. The process is often called contact killing, although ion release and surface reactions are part of what happens at the interface. Copper ions can disrupt membrane integrity and ion balance and interfere with proteins and enzymes. Redox reactions and oxidative damage are also involved. No single mechanism explains every result, and the relative contribution of each process varies with the organism and test conditions.

For a healthcare surface, the relevant measure is a reduction in viable organisms over a defined period. The surface does not become sterile immediately after contact, and contamination does not disappear as soon as someone touches a handle. Organisms dried into organic material or trapped beneath deposits may survive differently from cells placed directly on a clean metal specimen.

Test conditions explain some of the variation between published results. Humidity, contact time, surface finish, the number of organisms applied and the method used to recover surviving cells all affect the measured reduction. Blood, protein residues and other organic soil can shield microorganisms or alter their contact with the metal. Results from studies using different organisms, inoculates and recovery methods should not be compared as though they were produced by one standard procedure.

Copper content is one part of the picture, not a reliable performance ranking on its own. Alloying elements, oxide films, coatings and wear can all change the surface that a microorganism encounters. When a supplier makes an antimicrobial claim, it is worth asking which finished product was tested, against which organisms and for how long. A result for one brass grade cannot automatically be applied to another composition or to a plated handle.

Antimicrobial effects have also been reported for some fungi and viruses, but the response is not uniform. Results depend on the organism, surface finish, humidity, organic soil and the recovery method. Evidence obtained with ordinary bacterial cells does not establish the same killing time for bacterial spores or every type of virus.

3. Copper alloy surfaces in healthcare

Door hardware, push plates, bed rails, overbed tables and some IV pole components are plausible places to consider copper alloy surfaces because they are handled repeatedly. Their usefulness depends on the exact surface people touch and whether the copper remains exposed. Paint, lacquer or a plastic sleeve changes the contact surface. The component must also remain mechanically sound, be easy to clean and tolerate the disinfectants used by the facility.

Studies in healthcare settings have found that copper alloy surfaces can carry lower numbers of viable microorganisms than conventional materials such as stainless steel and plastics. Some hospital studies have also reported fewer healthcare associated infections in rooms fitted with copper alloy components, including bed rails, door hardware and other frequently touched items.

The evidence for reducing microbial contamination on surfaces is more consistent than the evidence for reducing infections in patients. Copper alloy components should therefore be considered an additional measure that may help limit the survival of microorganisms between cleaning cycles. They do not replace routine cleaning, disinfection or hand hygiene.

4. Surface condition, corrosion and cleaning

Tarnish and corrosion

Copper may darken during service, and green corrosion products can form in moist conditions. Color alone does not prove failure; pitting, flaking or material loss warrants inspection.

Water chemistry and cleaning agents influence both the rate and form of corrosion. Acidity, dissolved salts, temperature and exposure time all matter. Ammonia can be a problem for some copper alloys. In certain waters, brass can undergo dezincification: zinc is removed preferentially

and a porous copper rich layer remains, weakening the part. Some brasses can also crack under tensile stress in ammoniacal environments. These are known risks under particular conditions, not evidence that all brass fittings are unsuitable.

Galvanic corrosion may occur when copper or brass is electrically connected to a different metal in the presence of moisture or another electrolyte. The outcome depends on the metal pair, the exposed areas and the conditions at the joint. Contact between dry metals is not enough. If corrosion repeatedly appears near a connection, inspect the whole assembly and the path taken by water before blaming the bulk alloy.

Cleaning and inspection

Follow the cleaning and disinfection instructions supplied for the product. A disinfectant or finish that works well with one alloy may be unsuitable for another, and increasing concentration is not automatically helpful. Abrasive pads, polishing compounds and repeated refinishing can change the surface. Do not apply lacquer, paint or wax to a product sold for its antimicrobial surface unless the manufacturer permits it; a coating may keep microorganisms from contacting the copper.

When a surface changes, note the location and the cleaning product in use before polishing it or removing deposits. Marks around fasteners and joints, or in places that stay wet, suggest different causes from uniform darkening. Inspection can help locate a problem, but visual appearance cannot confirm that an antimicrobial claim is still being met. For a specified product, follow the manufacturer's maintenance instructions.

5. Applications in healthcare facilities

High touch surfaces

Frequently touched surfaces can contribute to the spread of healthcare associated pathogens. Microorganisms deposited on door handles, bed rails, faucet handles and other shared equipment may survive long enough to be transferred to healthcare workers and patients. Other possible applications for copper alloy components include push plates, handrails, over bed tables, IV poles, nurse call buttons, light switches and wheelchair handles.

Figure 1. Collection of antimicrobial copper hardware products

These components are practical candidates for copper alloys because they are touched repeatedly, often have relatively simple shapes and can remain in service for many years. Field studies have generally found lower microbial loads on copper alloy touch surfaces than on comparable conventional surfaces. The size of the reduction varies with the type of surface and the conditions in which it is used.

Copper alloy hardware can therefore help reduce the microbial burden between cleaning cycles. It remains a supplementary infection prevention measure, however, and does not replace routine environmental cleaning, disinfection or hand hygiene.

Hospital water systems

Copper tube and fittings are common in building water services. Copper released from the internal surface can affect microorganisms in water and biofilm, but both the amount released and its biological effect vary with pH, alkalinity, disinfectant, temperature, flow, water age and the condition of the pipe. A newly installed or recently disturbed surface may behave differently from one that has been in service for years, as surface films develop.

The way a water sample is collected changes what it tells you. A first draw sample after stagnation and a sample taken after flushing answer different questions. Copper levels can also vary across a building, so one result may not represent the entire installation. Interpretation needs the sampling

point, water chemistry and recent operating history as well as the applicable drinking water requirements.

Copper pipework should not be relied on as a standalone control for Legionella. Temperature, dead legs, low flow sections, disinfectant residuals and biofilm remain important. Copper can enter drinking water, so antimicrobial activity is not a reason to accept excessive metal release or relax the building water management program. Material selection and microbiological control need to be considered together.

For wetted fittings, there is also a product compliance question. A brass grade that works well on a dry door handle is not automatically suitable for drinking water contact. Composition and release of constituents must meet the relevant requirements, including limits that apply to lead or other elements that may be present in a particular alloy or product.

Medical gas pipeline systems

Medical gas tubing is a well established use of copper. Here the reasons for specifying it are tube quality, internal cleanliness, sound joints and compatibility with the service, not antimicrobial action. EN 13348 covers seamless copper tubes for medical gases or vacuum. ISO 7396 Part 1 covers the complete pipeline system, including design, installation, testing and commissioning. The standards have different scopes. A tube that meets its specification is only one part of a compliant installation, and the required edition and national adoption should be confirmed for the project.

Tubes and fittings must be kept free of oil, grease, dirt and particles during storage and installation. Brazing is widely used, but the approved procedure still controls joint preparation, filler material, heating and protection against internal oxidation. Commissioning includes the checks specified for the system; a pressure test alone is not enough. Oxygen service needs particular care because contamination can contribute to ignition and fire in oxygen rich conditions.

Electrical and thermal applications

Copper is common in hospital electrical systems because it conducts electricity well. Cable size and connection quality still matter; a poor joint can overheat even when the conductor is correctly specified. Installation and inspection are part of safe operation.

Copper is also used in heat exchangers. Its high conductivity is useful, but water chemistry, fouling, pressure and access for cleaning can decide whether it suits a particular circuit.

Copper tubing and fins are also used in HVAC heat exchangers, where heat transfer is a major reason for choosing the material. A full scale comparison published in 2012 recovered about 3 colony forming units per square centimeter from copper exchanger surfaces. Counts from the aluminium comparison surfaces ranged from roughly 11,000 to 47,000, and fungal counts were also much lower on copper during the observation period. That is a substantial difference in surface contamination under the conditions of the study. It did not measure hospital infection rates or show that copper coils will improve indoor air quality in every building. Condensate drainage, clean pans, sound filters and routine maintenance still matter.

6. Medical devices and material selection

Copper containing coatings and materials are being investigated for medical devices, but performance on a door handle says little about suitability for contact with tissue or blood. For an implant or another device that contacts the body, copper release and biological response have to be assessed alongside corrosion, mechanical performance, sterilization and the relevant regulatory requirements. Copper is an essential trace element, but that does not establish the safety of a particular local dose or exposure route.

Brass and bronze should not be presented as standard materials for reusable surgical instruments. Hardness, edge retention, corrosion resistance and repeated sterilization help explain why specified stainless steel grades remain common. Copper containing surfaces may be worth investigating for particular instruments or accessory components, but the finished device needs its own validation. Copper treated textiles and wound dressings raise separate questions too. Evidence from a solid metal handle cannot simply be transferred to a wet textile that is laundered repeatedly or sits against skin.

There is an important difference between a material that inactivates organisms on an exposed surface and one intended to release ions inside the body. The latter raises questions about dose, local concentration, corrosion products and the response of surrounding tissue. A surface contamination test cannot answer them. The complete device has to be evaluated for its intended type and duration of contact.

Researchers have also studied titanium alloys containing copper, often called titanium copper alloys. The aim is to preserve the structural role of titanium while adding antibacterial activity, so

these materials are quite different from brass or bronze fittings. Laboratory results against selected bacteria are promising, but they do not establish clinical readiness. Copper release, corrosion, tissue compatibility, bone integration, fatigue performance and sterilization stability all depend on the exact composition and manufacturing route.

The difference between two practical choices is instructive. For a bed rail, the supplier's antimicrobial evidence, the exposed finish, resistance to repeated cleaning and the geometry around joints all matter. For medical gas tubing, internal cleanliness, the tube specification, the approved brazing procedure and system commissioning are central. Both may contain copper, but the criteria that determine whether each is suitable are quite different.

Acknowledgments

The content was supported by the project “Smart Healthcare Engineering (SHEng)”, Grant Agreement No. 2023-1-RO01-KA220-HED-000159985, co-funded by the Erasmus+ programme of the European Union. Results, views and opinions expressed are however those of the project team and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor the granting authority can be held responsible for them.