Stainless Steel in Hygienic Applications

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1 Background

There has been a discussion amongst experts and consumers about antimicrobial properties of materials. It has long been known that copper [1] and silver are metals which can inhibit the growth of bacteria, viruses and fungi. Stainless steel, in contrast, is an inert material and, although its easy cleanability makes it a proven solution whenever sanitization is essential, it is not in itself bioactive.

In some applications (e.g. touch surfaces in hospitals), active, antimicrobial materials have been proposed as a substitute for stainless steels [2]. Extensions of the idea into professional kitchens and handrails in public transport have also been discussed. It is the purpose of this paper to put the discussion about active, antimicrobial materials into perspective. A summary is provided of the reasons why stainless steel is often the only viable option when the highest levels of hygiene or sterile surfaces are required.

Active antimicrobial surfaces vs. standard stainless steels: Summary of arguments

Comparisons between countries show that the occurrence of healthcare-related infections with multiple-resistant micro-organisms is determined by factors other than material selection in touch surfaces.

Active antimicrobial surfaces in general

- are not effective against all micro-organisms. There are many pathogenic micro-organisms and some of them are less sensitive than others to active surfaces. Only proper cleaning and disinfection can remove all relevant germs
- are often overestimated in terms of antibacterial efficiency because some current assessment methods are unable to identify dormant cells

Silver-containing coatings in particular

- wear off easily
- provide no visible indicators to show when the antimicrobial effect starts to fail
- are expensive

Copper and its alloys

- owe their antibacterial effect to the release of metal ions; however, there are indications of detrimental effects of copper on the environment
- have become associated with resistance forming in bacteria such as E. coli
- may be softer and less wear-resistant than stainless steel
- are expensive

Stainless steel

- has a long history of successful use in the most demanding medical applications such as implants and surgical instruments, which require sterile conditions
- does not imply the risk of micro-organisms forming new types of resistance
- does not undergo changes over time; the efficiency of cleaning and disinfection remains the same over many years
- has a harder surface than many other metallic alloys and makes fixtures less susceptible to superficial damage such as scratches and dents, in which biomass may accumulate
- is resistant to both corrosion and high temperatures. It can be sterilized by thermal process and (liquid or gaseous) chemical agents without corroding or loss of mechanical or physical properties
- is passive so there is virtually no exchange of ions with the environment
- is a cost-effective high-performance material

2 Active antimicrobial solutions

2.1 Overview

Certain metals have an oligodynamic effect: they release ions into the environment, which damage the cell walls and cell membrane. Some research also suggests that the DNA is damaged and prevented from replicating [3].

While bacteria are affected by the oligodynamic effect, viruses are generally much less sensitive to it.

For hygienic purposes, silver and copper are used. Their effects have been known for centuries – long before micro-organisms were even discovered. The downside is that their surfaces oxidise, if unprotected, requiring labour-intensive regular polishing. This is why silver in cutlery and brass in hardware were to a large extent replaced by stainless steel when this material became commonly available in the early 20th century.

Recently, the use of the oligodynamic effect of silver and copper has been re-considered in hygiene-critical applications:

- In the United States, silver-containing coatings were developed into an industrial solution [4]. They can be applied to metallic and other surfaces – among them to stainless steel. They are used in, for instance, ventilation ducts and refrigerators.
- The copper industry has launched an "Antimicrobial Copper" campaign [5]. It maintains that copper and its alloys (such as bronze, brass, cupronickel and copper-nickel-zinc alloys) can be a solution to one of the most serious problems in the medical sector: hospital (or, more generally, healthcare) acquired (nosocomial) infections. Certain bacteria have become resistant to the usual antibiotics. The best-known germ of this type is the methicillin-resistant staphylococcus aureus (MRSA). Experts hold the view that infections caused by "superbugs" (e.g. MRSA) in hospitals cost more lives than road accidents.

2.2 Silver-containing coatings

Silver-containing coatings have been applied to various materials. These include a silver/zinc-containing zeolite matrix, which is applied to stainless steel and other materials. It is reported to reduce colonies of microbes by 85.5–99.9 % after 4 hours and virtually 100 % after 24 hours. Applications can be found in ventilation systems, where the coating contributes to reducing the proliferation of germs and fungi [6].

However, for such coatings to be efficient, a relatively high concentration of 39–78 µg/ml of silver ions in the zeolite is required [6]. Nevertheless, such coatings can wear off especially if the coating is applied wet, i.e. by spray painting. Powder coating produces somewhat more durable layers.

Worn and damaged coatings have a negative effect on the surface topography of the material. They can form cracks and crevices, which make it more prone to the adhesion and retention of organic matter. They have obvious limitations on surfaces which are exposed to wear and tear [7]. Over time, the silver is depleted. The silver ion release may also be inhibited in environments that contain sulphur and chloride ions [6]. Against the background of volatile silver prices, the treatment can be expensive.

Summary: silver-containing coatings

- are expensive
- wear off easily
- show no visible indicator when their effect fades

2.3 Copper and its alloys

Copper is known to have antimicrobial effects. Copper ions can penetrate cell walls and obstructs cell metabolism [8]. Studies show that the colonization of touch surfaces in hospitals can be reduced if copper or copper containing alloys are used for touch plates, light switches, door handles, water taps and others. In some of these studies even a limited presence of copper-containing materials in the environment is reported to reduce the number of hospital-acquired infections strongly [9].

However, these results need to be interpreted carefully. Direct contact with the patient or common materials such as textiles, plastics, chinaware or glass should be more relevant for the transfer of micro-organisms than fixtures and fittings. Artefacts in an experimental setting could explain why sometimes surprisingly strong effects are shown: when medical and cleaning staff become aware that they are in an experimental situation, they may observe the cleaning and disinfection regimes more strictly than in their normal day-to-day work. The reported reduction in nosocomial infections may therefore partly be attributable to variables that are related to human behaviour rather than the surface contact material.

The surface topography of materials has a strong influence on their cleanability. Hard surfaces are less susceptible to scratches and dents which can form microscopic recesses in which deposits may accumulate and become difficult to wipe away. Stainless steel grade 1.4301 (304) has a typical hardness of 88 (Rockwell B-scale), while the equivalent value is 10 for cold-rolled copper (1/8 hard), 42 for Commercial Bronze (1/4 hard) and between 55 and 65 for various types of brass [10]. In contact with water, copper can release ions. The anti-bacterial efficiency of copper depends on the presence of humidity. Biofilms that naturally occur on frequently touched surfaces can, however, act as a barrier between the copper and the micro-organisms and strongly reduce ion migration. There are indications that copper surfaces, despite regular cleaning, have a tendency to build up layers of biomass that reduce the release of copper ions significantly over time [11].

It should also be borne in mind that the effect of copper can be detrimental. Long-term low-level exposure to copper ions can lead to micro-organisms becoming resistant to copper, as has been shown in the case of E. coli [12], [13], enterococci and Salmonella [13], [14]. It has been cited [14] that since the mid-1980s, copper-resistant bacterial pathogens have been detected repeatedly. As the antibiotic and heavy metal resistance genes are located on the same mobile genetic elements, it is possible that the natural selection pressure imposed by heavy metals indirectly co-select for antibiotic resistance [15].

In applications outside of the medical sector, copper release is often unwanted because of its environmental effects as a heavy metal [16]. The release of copper from roofs is a case in point. The release rate of copper has been found to be between 1.3 and 2.0 g/m² per year [17], [18]:

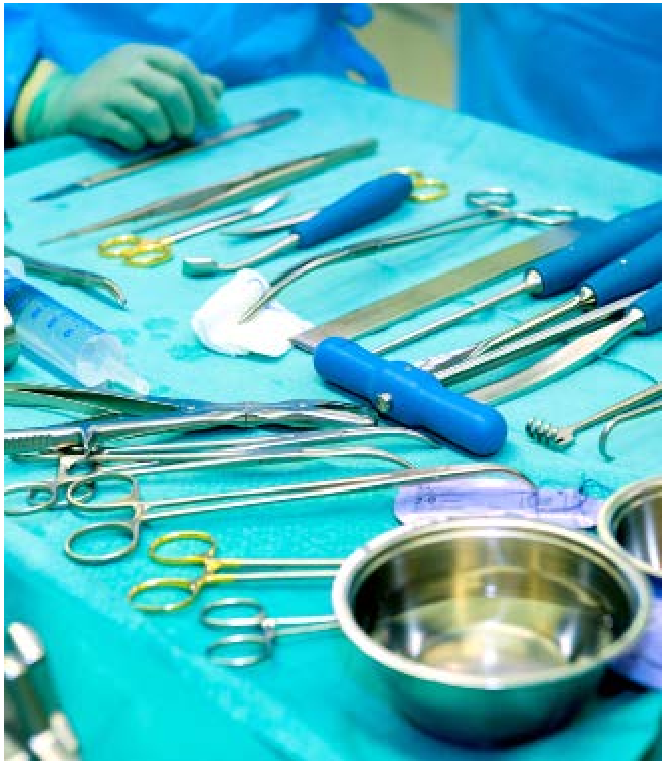
- In the Netherlands, the use of copper in roofs and rainwater systems can locally be restricted or measures can become necessary to reduce copper emissions. The maximum admissible risk level for copper in surface water is 3.8 µg/l and new installations must not add more than 10 % of this level to the pre-existing charge [19].
- In Sweden, the environmental programme of the city of Stockholm for 2012–2015 says that (PVC and) copper piping should be avoided if suitable alternatives are available. In roofs and facades, copper, zinc and their alloys should be avoided unless runoff-water is treated [20].

Therefore, there are good reasons to question solutions that work by deliberate release of copper ions into the environment – also in a healthcare environment.

In addition to the question whether or not the human body and the environment should be exposed to high concentrations of metal ions, there are also factors which may limit the practical usefulness of copper in hospital environments.

Summary:

- Release of copper ions can make pathogenic micro-organisms resistant to copper.
- The toxic or even lethal effect on certain cells is not limited to pathogen germs but can also affect other useful micro-organisms.



2.3.1 Re-contamination

The data suggest that visual assessment is a poor indicator of cleaning efficacy in hospital environments [21]. While cleaning methods can effectively remove pathogens from surfaces, studies have shown that more than half of the surfaces are not adequately cleaned and may become re-contaminated within minutes. In several comparative studies copper seems to perform particularly well because it is compared with materials such as plastics, wood or composites which tend to have rough and porous surfaces [22].

Summary:

Even if bacteria die away within two hours on a copper surface, many hands will typically touch that surface within the same time frame and recontaminate it with germs.

2.3.2 Biofilm formation

It has been known that biofilms can colonise almost any surface, including glass, steel, cellulose and silicone which are the main materials used to produce medical devices. Some of the latest results show that the antimicrobial activity of copper depends on a very close contact between the bacteria and the copper, the presence of humidity and a high concentration of released copper ions into the surrounding medium. The presence of organic matter in the solution also affects the antibacterial efficiency of copper [7], [23].

Summary:

- Micro-organisms may not be killed quickly enough to cope with levels of re-contamination experienced in a busy hospital environment.
- In practice, biofilms accumulate and reduce the effect of copper release strongly.
- Copper and its alloys become progressively more difficult to clean over time, while the cleanability of stainless steel remains the same throughout its life.

3 Why statements about antimicrobial effects should be viewed with scepticism

An often-neglected differentiation of various "antimicrobial" effects is the distinction between

- the killing of micro-organisms, as defined, for instance, in EN 14885 [24];
- their reduction; or
- the inhibition of their growth (bacteriostatic effect), as described in the Japanese standard JIS Z2801:2000, which is most commonly referred to [25].

It has been shown that antimicrobial effects may vary strongly between different strains of bacteria. Some may be more sensitive to copper, others to silver. Also different detection methods may lead to diverging results, with some of them systematically overestimating antimicrobial efficiency [26].

Based on data by the European Antimicrobial Resistance Surveillance System (EARSS), there is strong variability in the rate of nosocomial infections between countries. The prevalence (the occurrence in the total hospital population) of infections with MRSA is said to be about 1 % in the Netherlands, Denmark and other Scandinavian countries and up to nearly 50 % in others [27].

There are no indications of significant differences in the material mix used in hospital equipment between those countries. Specifically, the Netherlands and Scandinavia are not known to use more copper alloys than the rest of Europe. As a consequence, it seems that material selection in touch surfaces is not a decisive factor. Instead, the striking differences in MRSA prevalence are obviously related to hygiene management. In some countries,

- risk patients newly accepted to hospital are systematically screened for MRSA and other multiple resistant pathogens and kept in quarantine until they have been tested negative;
- when cases of MRSA infections occur, entire hospital wards may temporarily be closed;
- there has been a long history of persistent hygiene measures and their strict implementation, often implying full-time hygienists;
- since the 1990s, a policy of minimising the use of antibiotics in the healthcare system and in society as a whole has been pursued.

Against the background of these findings, the use of antimicrobial materials in touch surfaces appears to have only a negligible practical effect,

if any, on the probability of nosocomial infections. Patients, hospital staff and visitors should not be tempted to rely on "self-sanitizing" properties of antimicrobial materials. A rational approach to material selection in hospital touch surfaces should therefore be governed by criteria such as

- a surface topography that is favourable to thorough cleaning and does not deteriorate over time;
- wear resistance;
- and, provided the hygienic performance is comparable, also life-cycle cost.

Summary:

- "Antimicrobial" does not necessarily mean "killing micro-organisms" – often their growth is only inhibited.
- Inactive micro-organisms can survive, be transmitted and proliferate again when the conditions are favourable.
- There are many dangerous micro-organisms. The studies published in a promotional context usually include only a few of them – typically those for which a marked effect can easily be demonstrated. Only complete removal of micro-organisms and the biofilms harbouring them ensures the necessary level of safety.
- Antimicrobial surfaces are not a substitute for thorough and effective cleaning procedures.
- International comparison suggests that the prevalence of nosocomial infections is strongly dependent on hygiene management, irrespective of the materials used for touch surfaces.

4 Why stainless steel is a preferred option

While stainless steel does not have an active antimicrobial effect, it is the predominant material in medical and other hygiene-critical applications [28] for a number of reasons:

- Stainless steel is easy to clean and sanitize – even after decades of service. In contrast, the performance of copper-containing alloys and silver-containing coatings will change over time.
- Stainless steel is inert. It does not lead to resistance-forming in micro-organisms. Active surfaces, in contrast, release large amounts of metal ions into the environment, the effects of which are not fully known.
- Stainless steel can be sterilized in multiple ways (chemically, thermally). For copper and silver containing coatings the reactive nature of the surface limits the options.

5 Conclusions

Good cleaning and disinfection practices are key factors for the prevention of nosocomial infections. Active surfaces cannot replace proper sanitisation. If disinfection is performed according to the commonly accepted standards, active surfaces provide at best only a marginal benefit. The disadvantages of active surfaces typically include:

- weakening efficiency over time;
- lower mechanical resistance against wear and damage;
- higher investment cost.

Knowing that touch-surfaces are to a certain extent "self-sanitizing" may also induce personnel to believe that they can be more lenient in terms of cleaning and hand disinfection.

If all of these factors are taken into account, stainless steel continues to be a preferable option for touch surfaces in hospitals and in the public sector, especially in old age homes, in schools and in public transport.

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About ISSF

The International Stainless Steel Forum (ISSF) is a non-profit research and development organisation which was founded in 1996 and which serves as the focal point for the international stainless steel industry.

Who are the members?

ISSF has two categories of membership: company members and affiliated members. Company members are producers of stainless steel (integrated mills and rerollers). Affiliated members are national or regional stainless steel industry associations. ISSF now has 65 members in 25 countries. Collectively they produce 80% of all stainless steel.

Vision

Stainless steel provides sustainable solutions for everyday life.

More information

For more information about ISSF, please consult our website worldstainless.org.

For more information about stainless steel and sustainability, please consult the sustainablestainless.org website.

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Acknowledgement

The present brochure is adapted from "Inert vs. antimicrobial – A position paper concerning stainless steel and competing materials in hygiene-critical applications", unpublished paper, Euro Inox 2013.

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