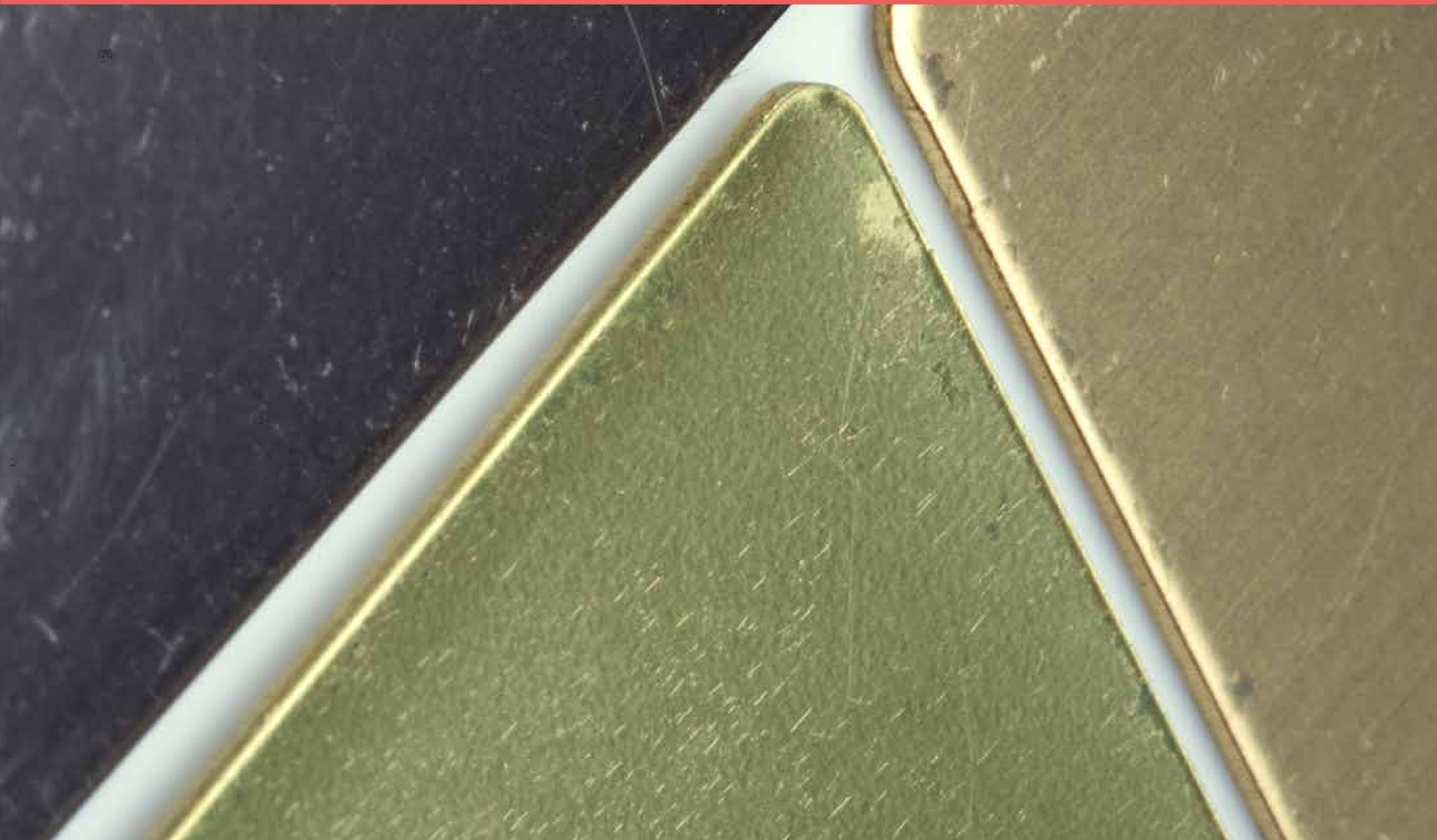
Antibacterial Surfaces

101 Material Report

Material ConneXion®
A SANDOW Company



What you need to know

Disease-carrying bacteria are present on almost every surface we encounter. Having the technology to diminish the number of harmful bacteria in our surroundings can positively impact quality of life and, in fact, has been the basis for the success of modern medicine. In our everyday lives, and for the spaces we inhabit, there are different methods by which bacteria are killed or prevented from spreading. In this report, Material ConneXion will break down everything you need to know about antibacterial surfaces – what they are, how they work, and what to consider when choosing a method or material to combat bacteria.

01

What is a Biofilm?

A biofilm is a complex structure consisting of colonies of bacteria and microorganisms that adhere to a surface and secrete a protective coating. Once formed, removing these films is very difficult, even with antibiotics or sterilizing systems. Thus, to decrease and eventually eliminate the problem, researchers have produced antibacterial surfaces.

02

Bacteria Inhibiting vs. Bactericidal Surfaces

'Bacterial Inhibiting' is the process of restricting the growth of bacteria, including the restraining of enzyme activity within the bacteria. Bactericidal surfaces refer to surfaces that kill, rather than stop the growth of, the bacteria. Though different, both processes decrease the number of bacteria present on a surface.

03

Chemical vs. Structural

Antibacterial properties on surfaces can be accomplished chemically, or through their structure. Some metals, plants, and animals are inherently 'bacteria inhibiting' or bactericidal. Through study, researchers have been able to replicate these properties and create synthetic antimicrobial surfaces, coatings, and additives.

When antibacterial surfaces are needed

As is the case with any chemical or material, an assessment must first be made as to whether its intended use is necessary. Traditionally, antibacterial properties were added to surfaces with continuous interaction with potentially harmful pathogens, such as at a healthcare facility. Increasingly, antibacterial additives, coatings, and structures are being applied to a variety of products, including countertops, textiles, masks, gloves, door handles, and phone cases.

In order to use antibacterials, chemical and product manufacturers must follow specific regulations, set by the EPA, under the general area of pesticides. These regulations apply to both synthetic and natural formulations, and are essential to ensure that the chemistries do not adversely affect living cells of humans, plants, and animals.

With the addition of antibacterial properties on a material or surface, the need for powerful cleaning agents is typically diminished, and so is the cost of cleaning labor.

The effectiveness of any antibacterial needs to be considered and taken into account with an overall need to maintain a 'clean' surface. Any surface that can be easily washed – such as a countertop, or even your hands – may not need additional treatment. An overabundance of antibacterials can end up in ground water, thus killing other organic life, and can cause the bacteria themselves to mutate and become more resistant.

Bactericidal

Direct Killing

Contact killing is a direct method for killing bacteria. The surface structure acts like a bed of nails; when the bacteria leach onto the surface, it will literally "stab bacteria to death." This phenomenon is seen in nature on both a gecko's foot pads and on a dragonfly's wings. Nanotube 'spikes' puncture the bacterial cell walls, causing cell death. Through their study of these properties in dragonfly wings, scientists have replicated the structure in products such as contact lenses, to reduce the number of bacteria present.

A highly structured material called synthetic black silicon has been created based on the structure found in dragonfly wings. With millions of 'nanopillars' that lacerate bacteria that land on the surface, this material betters the dragonfly structure in that it has twice the bactericidal rate.

A further synthetic solution that mimics this type of killing, Amosil Q, utilizes the spearing effect, but with self-assembled monolayers created by washing a surface with a water-based solution containing the chemical.

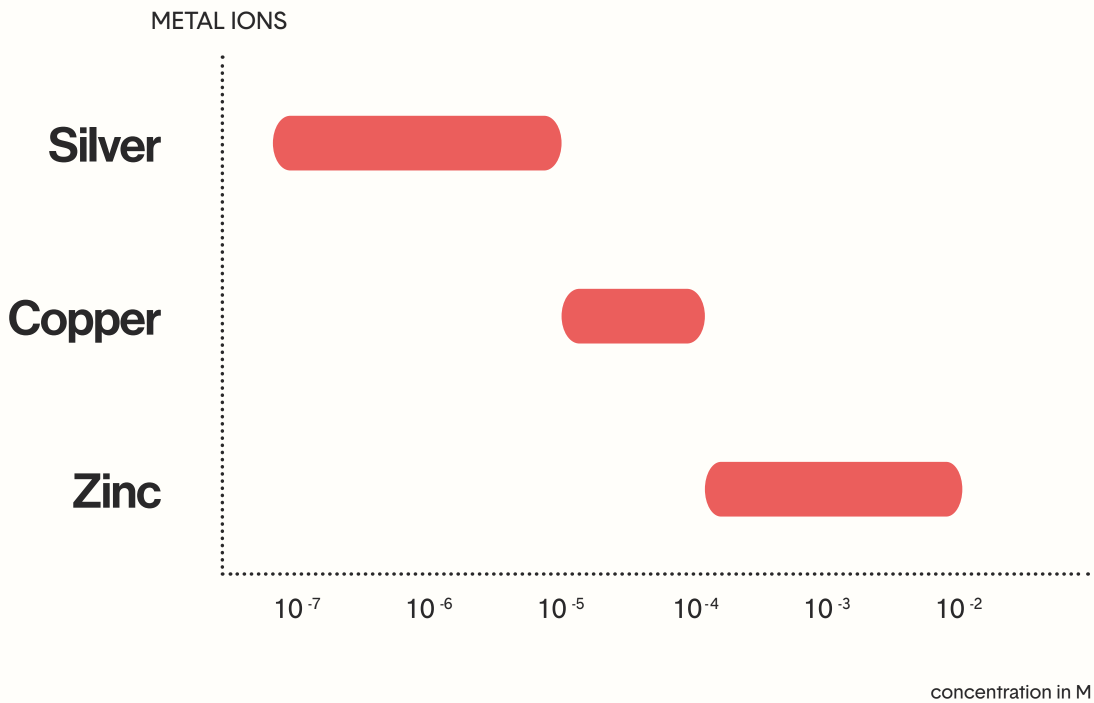
Indirect Killing

There are several ways to indirectly kill bacteria. Firstly, bacterial cells can be poisoned with metal ions. For materials to have any antimicrobial properties, the metal must be in its ionized form; the ions begin to enter the microorganisms, eventually killing them. For millennia, humans have kept water, wine and vinegar in silver and copper vessels to maintain freshness.

Another method involves 'starving it to death;' organic compounds enter the cell and alter the enzymes bacteria need to live.

Antibacterial metals

Only a handful of metals are suitably antibacterial. In order of efficacy, they are:



Silver

Silver ions are present in medical applications including bandages, ointments, surgical tools, needles, catheters, hospital gowns, etc. Other daily applications include silver additives or coatings on door handles, bathrooms, tables, etc.

Copper

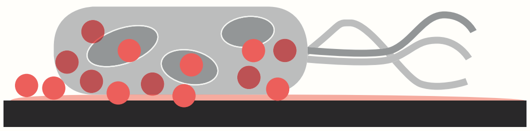
Copper is now being used on surfaces in hospitals, airports, trains, train stations, buses, restaurant kitchens, and gyms. It is typically used as a copper alloy, but with sufficient copper ions to retain efficacy.

Zinc

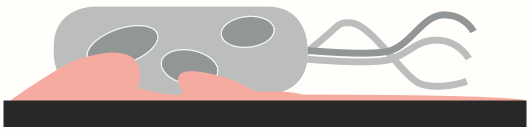
Zinc is now being used on titanium plates that will be implanted into the human body.

How copper kills

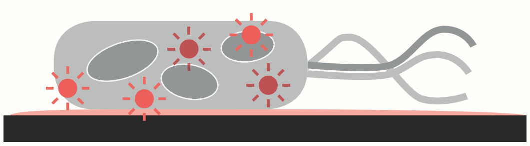
Both humans – and bacteria! – need copper as a nutrient, but, as with many things, high doses can be fatal to both. There are several processes that have been studied for determining the mechanism that causes copper to kill bacteria. None of these have been proven to be the exact method, but an approximate process that is widely held as the most likely is shown below.



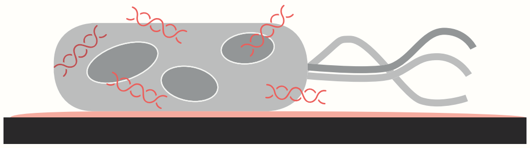
A Copper ions dissolved from the copper surface cause cell damage.



B The cell membrane ruptures, leading to loss of the cell content.



C Copper ions lead to the generation of toxic radicals that cause further damage.



D DNA becomes degraded and leaves the cell.

Reference: Copper Development Association 2018

Starved to Death

There is a long list of organic chemicals with antibacterial properties currently being tested for applications on surfaces, textiles, plants, etc. Some examples commonly used on surfaces are:

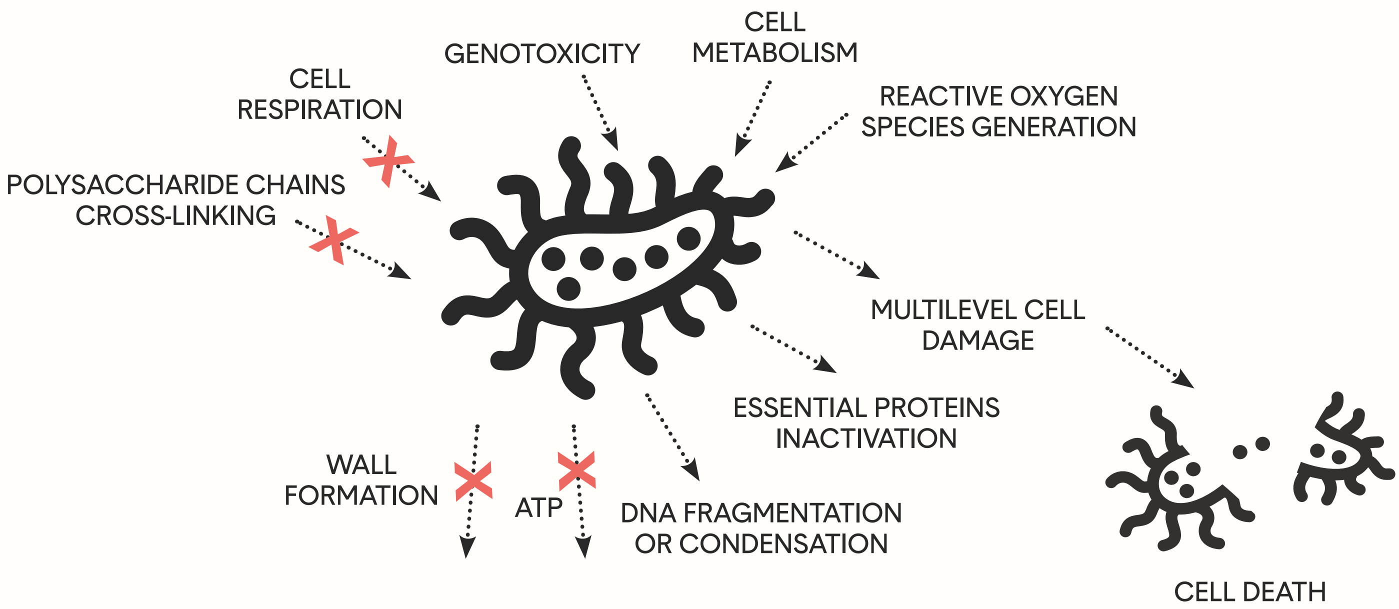
Triclosan Used in a wide range of products such as liquid soaps, chopping boards, textiles, medical applications, toys, and carpets.

Quaternary ammonium Is odorless, colorless, and non-toxic. It leave a residual antimicrobial film. It can be used in textiles, non-toxic clay, polymers, etc.

Chitosan Is a sugar that is obtained from the hard outer shell of shellfish including crab, lobster, and shrimp. Chitosan can be added into many different surfaces to become antimicrobial.

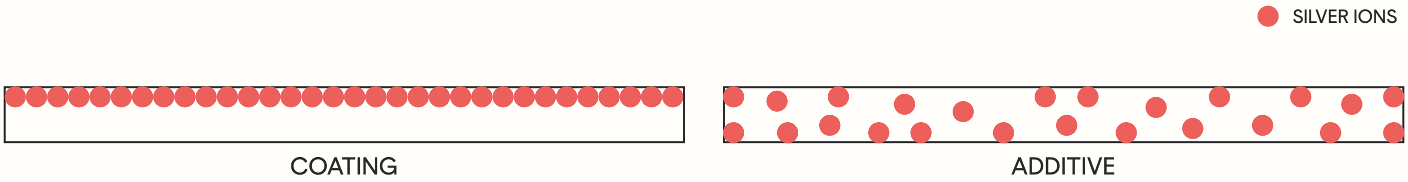
Curcumin Is the compound that gives turmeric its bright yellow color; it is considered a food-safe antimicrobial and some future applications include cutting boards, cleavers, and countertops.

Methods for bacterial cell destruction



Incorporation into products

Additives and coatings are two methods of imparting materials with antibacterial properties. Both use metal ions or organic compounds as the additives or as coatings. The concentration of these ions or compounds is the key to their efficacy.



Coating

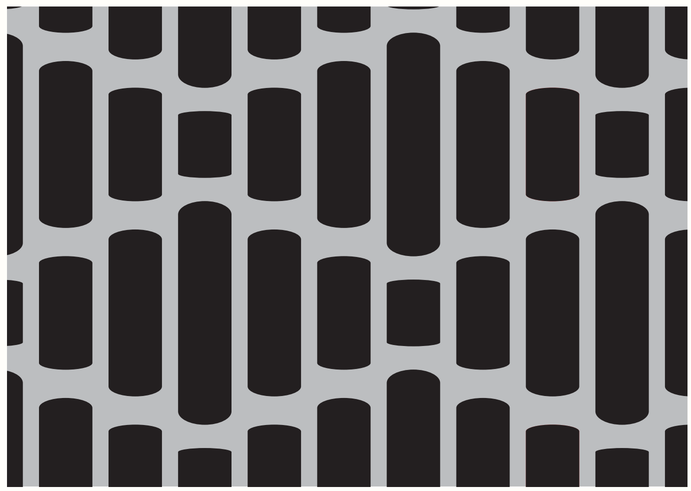
Metal ions or organic compounds can be incorporated into the coating chemistry, then deposited as part of the coating process. They can also be applied as a film onto the surface. Coatings can contain larger amounts of ions without compromising the performance of the underlying material. However, a coating will affect the appearance and feel of the product.

Additive

An additive is a chemical that is mixed into the making of a material, and becomes part of the product itself. Though additives retain the authenticity of the part, they are less effective because lower concentrations of ions need to be used to ensure part performance.

Anti-adhesion structure

SHARK SKIN



SHARKLET™ SURFACE TECHNOLOGY

Bacterial growth can also be inhibited through an 'anti-adhesion' structure. This is a structure that disrupts the ability of bacteria to hold on, colonize, and develop into biofilms. A surface in nature that exhibits this property is shark skin. With surface modification, researchers have begun to mimic the structure onto films and surfaces to impart these bacteria-inhibiting properties.

Currently the only successful commercial product that uses structural effects to reduce bacteria is Sharklet™, a biomimetic replication of shark skin. Sharklet uses a much less complex structure than is found in the original, as seen in the corresponding images (above). The product is available as a thin, disposable film, or as a mold texture to be applied to injection-molded parts. Medical applications for this product include catheters and high-touch surfaces in hospitals, such as light switches, door handles, bed rails, etc. Non-medical applications include phone cases and anti-fouling films for boats.

Log reduction

When it comes to determining actual germ kill, 'inactivation,' or removal, log reduction (or log kill) is important to understand.

The term ‘log reduction’ comes from logarithm, and it is the way that scientists measure a reduction in the number of live germs. It denotes the relative number of live microbes eliminated from a surface because of sanitizing, disinfecting, or cleaning. A ‘1’ log reduction means the number of germs on a surface is 10 times smaller than prior to cleaning. A ‘2’ log reduction means the number is 100 times smaller, a ‘3’ log reduction means the number is 1,000 times smaller, and so on up to a ‘7’ log reduction (10,000,000 times smaller).

In practical terms, a cleaning system – the techniques, equipment, and cleaning solutions – able to provide a '5' log reduction would lower the number of microorganisms on a surface 100,000-fold, i.e. after the system is employed, a surface with 100,000 microbes on it prior to cleaning would be left with 1.

The Kill Test to determine log reduction is a basic microbiology method for assessment of antimicrobial activity of an antimicrobial test material or disinfectant. The Kill Test is carried out to evaluate the microbial reduction by a disinfectant against selected bacteria or fungi. Various organisms are studied depending upon the type of analysis and test material, however, most common organisms tested include: Staphylococcus aureus, Salmonella cholerasuis, Pseudomonas aeruginosa, E.coli, Aspergillus niger, and Trichophyton mentagrophytes.

Log reduction should also embrace the concept of Soil Removal Over Time (SROT); that is, log reduction must be coupled with how long it takes forSROT to occur. A log reduction-based material assessment should provide measurable, time-factored levels of germ-reduction for objectively evaluating and comparing different systems and methodologies.

This same approach can also help provide a guide for determining the 'appropriate' levels of clean and how to achieve those goals for different surfaces and environments. Professionals, for both pragmatic and public health reasons, should neither be doing too little cleaning or sanitizing or doing too much, especially when it involves harsh chemicals.

Antibacterial surfaces

According to recent findings, humans carry more bacterial cells than actual human cells. Thus, it is clear that not all bacteria is detrimental to human health. For example, bacteria are essential for digestion. However, some bacteria do cause infections, and should be attacked with antibiotics, cleaning agents, and disinfectants.

Due to survival of the fittest, some bacteria have become resistant to antibiotics and, therefore, a lot of research has been conducted to find new methods for killing these harmful bacteria. The creation of antibacterial surfaces has been one solution for stopping the spread of bacteria.

There is growing consensus that, where possible, the use of antibacterial solutions should be eschewed in favor of simpler cleaning methods, such as soap. In many situations, basic detergents have proven to be a highly effective method for reducing the spread of harmful bacteria, reducing the spread of infection and disease. Thus, in any consideration about the potential use of an antibacterial, it is recommended that this be the position of last resort, as a way of minimizing the risk of generating bacteria that is more and more resistant.

References

Antibacterial Surfaces
1st ed. 2015 Edition
By Elena Ivanova, Russell Crawford

Silver Nanoparticles and Antibacterial Activity
By Ram Sevak Singh,
Himanshu Sharma

Learning Guide

Discussion Questions

What aspect of the report surprised you the most?

What is a biofilm?

What is the difference between bacterial inhibiting and bacteriocidal?

How does a structural antibacterial work?

Short Answer Questions

Name some metals that are inherently antibacterial.

Name some chemicals that are inherently structurally antibacterial.

Which type of cell do humans contain more of—human or bacterial?

What are the two ways antibacterials can be added into products?

Learning Guide

Long Form Essay

What are some of the reasons why, when designing a product, you might want to include antibacterial properties? Explain your reasoning and also provide some justification against claims that more antibacterial chemistry in the world causes more problems than it solves.

Team Activity

Create a comparative list of everyday objects the either should, or should not have antibacterial properties.

Try to move as many objects as possible from the should to the should not list, with justifications but also with ways in which concerns about bacterial infection can be allayed (for example, make sure that a countertop can be bleach cleaned with no damage to the surface rather than making it inherently antibacterial).

Materials relevant to this report

CHITO TECH Heather
MC 7710-04

Chitosan, a mineral sourced from crab and shrimp shells and incorporated into the fibers, is an effective natural antimicrobial.

AgPURE PET
MC 7041-01

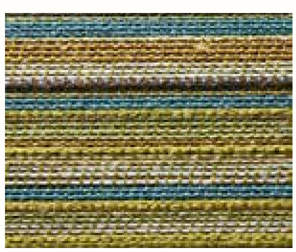
A masterbatch is a plastic concentrate that contains all the color and additives needed by a resin added into the regular virgin plastic. This one contains silver particles as an effective antimicrobial.

n9 Pure Silver
MC 6857-01

A silver particulate agent that can be incorporated into a variety of different materials, textiles, cosmetic products, and paint to give full spectrum antimicrobial properties.

Antimicrobial
MC 7409-01

Powder coatings are high durability polymer coatings that are sprayed and then heat cured onto all sorts of surfaces. This one has an addition to provide long term antimicrobial performance.



Stinson
MC 7740-01

Antimicrobial treatment using pure silver that is incorporated into an upholstery fabric to give long term bacterial resistance.