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# ANTIMICROBIAL MATERIALS 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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## Introduction

Healthcare facilities use different materials to limit microbial contamination. Some act at the surface, some release an active agent, and others make microbial attachment more difficult. The choice depends on the application and the intended function.

An antiseptic is used on living tissue, for example during skin preparation. A disinfectant is intended for inanimate objects and surfaces. Metals, polymers, textiles and coatings are usually described as antimicrobial materials. A wound dressing may carry an antiseptic or another active agent, but the finished dressing must be assessed for its intended use.

Table 1. Key terms used to describe antimicrobial activity and products in healthcare

| Term | Meaning |
|---|---|
| **Antimicrobial** | A general term for activity against microorganisms. The target organisms and level of activity need to be specified. |
| **Antibacterial** | Active against bacteria. |
| **Antifungal** | Active against fungi, including yeasts or molds where tested. |
| **Antiviral** | Able to inactivate specified viruses under stated conditions. |
| **Antiseptic** | An agent intended for use on living tissue, for example during skin preparation. |
| **Disinfectant** | An agent intended to inactivate microorganisms on inanimate objects or surfaces. |

A material's antimicrobial activity must be established for the organisms of interest. Activity against bacteria, for example, does not by itself establish activity against fungi or viruses. These materials can supplement routine cleaning, disinfection and hand hygiene, but do not replace them.

## 1. Types of antimicrobial materials

The active component may be part of the material, attached to a surface, incorporated into a coating or released from a dressing. This affects its duration of activity and how the product should be maintained. A silver containing polymer combines a metal based active agent with a polymer carrier, so a single product may fit more than one category.

Table 2. Typical antimicrobial materials: modes of action and uses

| Material approach | How it acts | Typical use and main limitation |
|---|---|---|
| **Copper alloys** | Exposed copper bearing alloy and its surface reactions can reduce the viability of some microorganisms. | Used for selected high touch hardware. Activity depends on alloy composition, surface condition, contamination and contact time. |
| **Silver and silver compounds** | Silver ions interact with microbial membranes and proteins. | Used in selected wound dressings and medical devices. Activity depends on ion release, surrounding fluid and exposure. |
| **Antimicrobial polymers and coatings** | Some release an active agent; others have contact active or antiadhesive surfaces. | Used on selected touch surfaces and devices. Soil, wear, cleaning and release affect performance. |
| **Photocatalytic and other metal oxides** | Titanium dioxide can form reactive species under suitable light. Zinc oxide and related oxides are also being studied. | Considered for surface coatings and biomedical products. Light, formulation, particle release and compatibility affect performance. |
| **Wound care materials** | Silver, iodine and selected other agents are delivered at the wound interface. | Chosen for a specific wound and clinical purpose. Release, tissue tolerance and wound conditions matter. |
| **Treated textiles** | Antimicrobial agent is incorporated into or applied to the fibers. | Used for selected clinical textiles. Laundering, disinfection and wear can change activity. |

## 2. Chemistry and biochemical mechanisms

Antimicrobial materials do not all work in the same way. Some release ions, some damage cell envelopes on contact, and others create reactive chemicals when activated by light.

Metal ions and cellular components

Silver, copper and zinc containing materials may release metal ions when moisture is present. The ions can bind to proteins, including sulfur containing sites, interfere with enzymes and membrane proteins, and disturb the balance of ions inside a cell. The chemistry depends on the metal, its form, concentration and surrounding fluid. Enough release to affect microorganisms can also harm human cells, so performance and biological compatibility have to be considered together.

Membrane damage and active agents

Quaternary ammonium groups have a positive charge and can interact with negatively charged microbial envelopes. Depending on the formulation, this interaction may disrupt membrane function. Chlorhexidine and polyhexamethylene biguanide also act mainly through interactions with microbial cell envelopes, although their behavior differs with concentration and product design. Iodine released by some dressings reacts with proteins and other cell components. These agents are not interchangeable, and their activity depends on how they are delivered.

Reactive oxygen species

Reactive oxygen species (ROS) can damage microbial membranes, proteins and nucleic acids. Their role depends on the material. ROS are central to the photocatalytic activity of titanium dioxide under suitable illumination and may also contribute to the action of copper surfaces. In copper and silver materials, interactions of metal ions with proteins, membranes and other cellular components also matter. Quaternary ammonium compounds act mainly through disruption of microbial membranes, rather than through the same light driven process.

Titanium dioxide provides a clear example of light driven activity. Under suitable ultraviolet illumination, the material forms electron and hole pairs. Surface reactions can then produce ROS, which damage nearby microorganisms and oxidize organic compounds. Without enough suitable light, this reaction is much weaker. This is why results from a laboratory test under ultraviolet light may not predict what a coating will do in a normally lit room.

## 3. Silver and silver containing materials

Silver activity is mainly associated with silver ions, which interact with microbial membranes and proteins. How much silver becomes available depends on the formulation and the surrounding fluid. A silver salt in a moist dressing, a catheter coating and a metallic silver surface do not release silver in the same way.

Silver is used in selected wound dressings, where wound fluid helps make the active ions available. A silver dressing is not needed for every wound, and clinical benefit varies with the product and wound type. The decision depends on the wound condition and the purpose of treatment.

Silver is also used with other agents in certain medical device coatings. For example, some central venous catheters combine silver sulfadiazine with chlorhexidine. Such products are considered in selected situations when infection rates remain high despite proper insertion, care and other prevention measures. They are not substitutes for aseptic technique or a catheter care program.

Silver release needs to be controlled. The same chemistry that damages microorganisms can affect mammalian cells at sufficiently high local concentrations. Release rate, coating adhesion, the condition of the substrate and the duration of exposure therefore belong in the product assessment. Nanoparticles, ionic silver and metallic silver should not be treated as equivalent simply because all contain the same element.

## 4. Antimicrobial polymers and coatings

Polymer based antimicrobial products can work in two broad ways. A coating may release an active substance into the immediate environment, or its surface may be modified so that microbial cells are affected on contact. The distinction matters during use. A releasing coating can lose activity as its available agent is depleted, while a contact active surface depends on the active groups remaining exposed and accessible.

Quaternary ammonium compounds are familiar disinfectant ingredients, and related chemical groups have also been incorporated into coatings and polymer surfaces. Their positive charge helps them interact with microbial envelopes. Some experimental coatings are designed to retain these

groups at the surface rather than release them. Others depend on controlled release of the active compound.

Organic soil can separate microorganisms from the active surface. Repeated wiping may wear a coating, remove it or leave residues. The substrate, surface coverage and cleaning method all affect performance, so general results for quaternary ammonium compounds cannot establish how a particular product will perform in service.

Some surfaces are designed to reduce microbial attachment rather than kill organisms directly. Hydrophilic layers or selected surface textures can make initial attachment less likely. In practice, proteins and other deposits can cover the surface, and wear can change its properties. Reduced attachment should not be confused with demonstrated microbial killing.

Chlorhexidine and polyhexamethylene biguanide (PHMB) are used in selected medical products, including some dressings and device coatings. Their release profiles and intended uses differ. For devices that contact the body, antimicrobial activity must be considered alongside tissue compatibility, release, sterilization and the possibility that the active agent will be depleted during service.

## 5. Photocatalytic and other metal oxide materials

Titanium dioxide is widely used as a white pigment and is also studied for photocatalytic coatings. Its practical value depends on whether the required light reaches the surface and whether the finished coating remains active after cleaning.

Light is a practical limitation. Conventional titanium dioxide often needs ultraviolet radiation, which is limited under ordinary indoor lighting. Modified formulations that respond to visible light are being investigated, but performance must be shown under the conditions where the coating will be used.

Zinc oxide and other metal oxides have been studied for coatings and biomedical products. Depending on the formulation, their effects may involve zinc ion release, surface interactions or oxidative processes. Particle size, surface treatment and the surrounding polymer or binder can change both activity and release. A result obtained with a powder does not establish the performance of a finished coating.

For a photocatalytic surface, check whether it receives suitable light, survives routine cleaning and has been tested against relevant organisms. Deposits still need to be removed.

## 6. Wound care materials and treated textiles

Wound dressings are chosen according to the wound, the amount of exudate and the purpose of treatment. Options include silver dressings, products containing PHMB, and dressings containing iodopovidone, which releases iodine at the wound interface. Iodine reacts with proteins and other cellular components, but the amount available at the wound surface depends on the formulation and wound fluid. Not every wound requires an antimicrobial dressing.

An antimicrobial dressing does not make a wound sterile. Its effect depends on the active ingredient, release rate and wound conditions. Product choice should follow the intended clinical use and the manufacturer's instructions.

Antimicrobial finishes are also used or investigated for bedding, curtains and staff garments. The active agent may be silver, copper or an organic compound, depending on the product. Repeated washing, drying, disinfection and abrasion can alter the finish or reduce the amount of active agent available. Results from a new fabric do not establish activity after repeated laundering, and a reduction in textile contamination does not by itself show that infections are reduced.

## 7. Antimicrobial materials on healthcare surfaces

Door handles, bed rails, overbed tables, call buttons and shared equipment can become contaminated between cleaning events. Proposed treatments include silver containing coatings, antimicrobial polymers and photocatalytic finishes. What matters is the surface that people actually touch, not just the coating label.

The surface must be easy to clean and tolerate the facility's cleaning products. Joints, edges and texture can retain soil. Paint or lacquer may block contact with an active surface, while a releasing coating needs evaluation of both remaining activity and exposure to the released agent.

Lower microbial counts on a treated surface show that the material has activity under the conditions tested, but they do not by themselves demonstrate fewer infections in patients.

## 8. Comparison of antimicrobial materials

Copper alloys provide a useful comparison because the exposed metal itself contributes to antimicrobial activity. Copper ions and surface reactions can damage microorganisms, but performance still depends on alloy composition, surface condition, moisture and contamination.

Table 3. Comparison of antimicrobial material approaches and their practical limitations

| Approach | Where the activity comes from | Main consideration |
|---|---|---|
| **Copper alloys** | Exposed bulk alloy and its surface reactions. | No separate antimicrobial coating is required, but alloy choice, tarnish, deposits and cleaning remain important. |
| **Silver coatings** | Silver ions released from a coating or composite. | Useful in selected devices and dressings. Release rate, tissue exposure and coating durability need attention. |
| **Antimicrobial polymers** | Active groups at the surface or an agent released from the polymer. Some surfaces are designed to reduce attachment. | Performance depends on chemistry, surface accessibility, aging and cleaning. |
| **Photocatalytic oxides** | Surface reactions triggered by suitable light. | The required light and actual use environment can limit activity. |
| **Treated textiles** | An antimicrobial agent is incorporated into or applied to the textile fibers. | Activity can change with laundering, disinfection and abrasion. Suitability depends on the intended use and any contact with skin. |

## 9. Selection, maintenance and evidence

Start by defining the intended outcome: lower surface contamination, management of microbial burden in a wound, reduced catheter colonization or less biofilm in a fluid path.

For a treated surface, check which organisms were tested, the contact time, whether organic soil was present and whether the product was tested after routine cleaning. For a device or dressing, also consider active agent release, exposure, biological compatibility and the requirements for the intended product.

Follow the product's maintenance instructions. Do not polish or coat an antimicrobial surface, or change a validated cleaning process, without checking compatibility. For a ward wide installation, decide how damage, repair, replacement and performance will be checked.

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