Use of disinfectants in the health care sector: Chemical hazards and preventive measures

Factsheet 1: Principles of disinfection

The prevention of hospital-acquired (nosocomial) infections is an essential role played by those responsible for hospital hygiene (infectiologists, hygienists, etc.) and has led to an increased use of disinfectants. These contain a limited number of active ingredients, but are sold under very numerous commercial names. We must admit that the safety of those using a disinfection product or procedure is not one of the priorities when choosing the product or procedure. This criterion should nevertheless be taken into account, and specialists in occupational safety and occupational health should be included in discussions when choosing disinfectants and the method to be applied, to select the best and most effective method. This factsheet aims to facilitate discussion between the various stakeholders. It would be preferable that these use a common language and be aware of their respective imperatives.

Foreword

The Chemical Risks workgroup of the Health Services Section of the International Social Security Association (ISSA) has studied the risks linked to disinfection activities in the health care sector and the preventive measures that should be applied. This workgroup has defined a position shared by all the occupational health and safety organisations represented within the group: BGW (Germany), INRS (France) and Suva (Switzerland).

This project included a collaboration with the Infectious Risks workgroup of the Section, to summarise the general principles of disinfection (Factsheet 1) for the audience targeted by the current series (see below).

For practical reasons, the results of this work will be presented as a series of technical Factsheets:

Factsheet 1: Principles of disinfection

Factsheet 2: General principles of prevention

Factsheet 3: Hazards of chemical disinfectants

Factsheet 4: Selecting safe disinfectants

Factsheet 5: Surface disinfection

Factsheet 6: Instrument disinfection

Factsheet 7: Skin and hand disinfection

Factsheet 8: Specific procedures (disinfecting premises, medical equipment, linen and clothing)

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Section on Prevention of Occupational Risks in Health Services

Each factsheet contains the essential information relating to the theme covered, and can therefore be read separately. These factsheets are destined for use by those responsible for organising and performing disinfection tasks in the health care sector, by occupational physicians and by all those involved in preventing occupational risks – in particular occupational hygienists and safety officers – as well as interested personnel and their representatives.

For questions on hospital hygiene and environmental protection, the reader is invited to consult the specialised literature

1. Introduction

Chemical disinfection uses products aiming to reduce the number of or kill microorganisms present on various surfaces (work surfaces, medico-surgical equipment or skin) or in a work area (operating theatre, ward, etc.). National and European standards define the characteristics, properties and conditions of use for these disinfectant products. Each disinfectant is studied and validated for a given use and a specific surface and can only be used to this end (an antiseptic for healthy skin cannot be used to clean medico-surgical materials).

It must be remembered that chemical disinfection is not the only method of disinfection used in the healthcare setting. Physical disinfection methods can also be used, in particular heat or steam, which are the most frequently used.

Heat: Dry heat is used particularly in laboratories, where contaminated needles or loops are flamed. Wet heat, which involves boiling for three minutes to eliminate most vegetative bacteria, can be used to disinfect glass, feeding teats, metallic instruments and some heat-resistant plastics.

Steam: At atmospheric pressure or higher pressures and a temperature of 100 °C, steam can be used like wet heat. It can also be used to disinfect linen and clothing and mattresses, in vacuum steam-based disinfection. In this procedure, the material to be disinfected is placed in a closed container where it is submitted to a low pressure to eliminate air, and then exposed to a high-pressure jet of vapour.

These heat-based or steam-based disinfection methods carry their own specific risks for the workers who use them. However, they are beyond the scope of this document and will not be dealt with here.

2. Definitions

Some important notions in the field of hygiene and disinfection are defined in this section. The definitions given are mainly those from standard EN 14885, issued in February 2007 [1].

Antisepsis: "Application of an antiseptic to living tissues, leading to an effect on the structure or metabolism of microorganisms at a level which is deemed appropriate to prevent and/or limit and/or treat an infection of these tissues" [1].

For the European committee for standardisation (CEN/TC 216) which addresses these issues, the term “antiseptic” should be reserved for cases where the intervention aims to treat a confirmed infection, while disinfection refers to a procedure aiming to prevent infection. Thus, intact/healthy skin and hands will be disinfected, but antiseptic will be applied to a wound. Only the French pharmacopoeia still uses the term “antiseptic”.

Antiseptic: "Product - excluding antibiotics - used for its antiseptic effect" [1].

For the CEN/TC 216 (European committee for standardisation), an antiseptic is "a substance or preparation which can be used to treat living tissues by killing and/or inhibiting bacteria, fungi or spores and/or by inactivating viruses with a view to preventing or limiting the severity of an infection of these tissues".

Biocides: "*Biocides* is a non-specific term which applies to products covered by the European directive relating to the commercialisation of biocidal products" [1].

Directive 98/8 [2] defines biocidal products as "Active substances and preparations containing one or more active substances, put up in the form in which they are supplied to the user, intended to destroy, deter, render harmless, prevent the action of, or otherwise exert a controlling effect on any harmful organism by chemical or biological means".

In 2012, this directive [2] was replaced by regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 [3], which provides the following definition of a biocidal product:

- "any substance or mixture, in the form in which it is supplied to the user, consisting of, containing or generating one or more active substances, with the intention of destroying, deterring, rendering harmless, preventing the action of, or otherwise exerting a controlling effect on, any harmful organism by any means other than mere physical or mechanical action,
- any substance or mixture, generated from substances or mixtures which do not themselves fall under the first indent, to be used with the intention of destroying, deterring, rendering harmless, preventing the action of, or otherwise exerting a controlling effect on, any harmful organism by any means other than mere physical or mechanical action".

Chemical disinfectant: "Product capable of causing chemical disinfection" [1]

Disinfectants are chemical substances that make it possible to destroy (bactericidal, virucidal, fungicidal, sporicidal action) or inactivate (bacteriostatic, virostatic, fungistatic action) one or more types of microorganism present on instruments, inert surfaces and living tissues, or present in the air in a work area or room (ward, operating theatre, etc.).

Chemical disinfection: "Reduction of the number of microorganisms in or on an inanimate matrix, obtained thanks to the irreversible action of a product on their structure or metabolism, at a level judged appropriate based on a given objective" [1].

Detergent: any substance or preparation containing soaps and/or other surface-treatment agents intended for washing and cleaning procedures. Detergents can be presented in any form (liquid, powder, paste, bar, block, moulded piece, stick, etc.) and be marketed or used for domestic, institutional or industrial applications [4]. They can be sold as a commercial preparation, in combination with a disinfectant. Detergents are therefore products used to remove soiling from a solid medium by detachment or solubilisation.

Detergence or cleansing: disinfection involves cleaning work surfaces, materials, linen or skin after having detached and dispersed any soiling from them. Cleaning results from the implementation of various physicochemical phenomena (wetting by surfactants, dissolution by a descaling agent, etc.) which can be completed by a mechanical action (swabbing, manual or mechanical brushing, use of ultrasound, etc.) [5].

Remanence: for a disinfectant, persistence of the anti-microbial effect after application of the product [5]. Because of its rapid evaporation, alcohol does not have a remanent effect, while a product like chlorhexidine will have a longer-lasting effect.

3. Regulatory considerations

In the European Union, directive 98/8/EC of 16 February 1998, commonly known as the "biocides directive", is the founding text for the placement on the market of products with an anti-microbial activity which are generally qualified as "biocides". This directive was replaced in May 2012 by regulation (EU) No 528/2012 [3].

According to this text, biocidal products are classed in four groups, subdivided into 22 "product -types" (PT):

- Main group 1: Disinfectants (5 PT)
- Main group 2: Preservatives (8 PT)
- Main group 3: Pest control (7 PT)
- Main group 4: Other biocidal products (2 PT)

Disinfectants are therefore all classed in group 1 Disinfectants, which is subdivided into five product-types (see box).

Main group I Biocides: The five product-types according to regulation (EU) No 528/2012 [3]

MAIN GROUP 1: Disinfectants

These product-types exclude cleaning products that are not intended to have a biocidal effect, including washing liquids, powders and similar products.

Product-type 1: Human hygiene

Products in this group are biocidal products used for human hygiene purposes, applied on or in contact with human skin or scalps for the primary purpose of disinfecting the skin or scalp for the primary purpose of disinfecting the skin or scalp.

Product-type 2: Disinfectants and algaecides not intended for direct application to humans or animals

Products used for the disinfection of surfaces, materials, equipment and furniture which are not used for direct contact with food or feeding stuffs.

Usage areas include, inter alia, swimming pools, aquariums, bathing and other waters; air conditioning systems; and walls and floors in private, public, and industrial areas and in other areas for professional activities.

Products used for disinfection of air, water not used for human or animal consumption, chemical toilets, waste water, hospital waste and soil.

Products used as algaecides for treatment of swimming pools, aquariums and other waters and for remedial treatment of construction materials.

Products used to be incorporated in textiles, tissues, masks, paints and other articles or materials with the purpose of producing treated articles with disinfecting properties.

Product-type 3: Veterinary hygiene

Products used for veterinary hygiene purposes such as disinfectants, disinfecting soaps, oral or corporal hygiene products or with anti-microbial function.

Products used to disinfect the materials and surfaces associated with the housing or transportation of animals.

Product-type 4: Food and feed area

Products used for the disinfection of equipment, containers, consumption utensils, surfaces or pipework associated with the production, transport, storage or consumption of food or feed (including drinking water) for humans and animals.

Products used to impregnate materials which may enter into contact with food.

Product-type 5: Drinking water

Products used for the disinfection of drinking water for both humans and animals.

Products are only authorised at the national level or included in lists at the community level once the hazards and risks associated with their use, and their efficacy have been assessed. Regulation (EU) No 528/2012 also stipulates that each formulation represents a separate entity, and must therefore undergo its own specific authorisation stage.

According to the regulation, only biocidal products containing duly authorised active ingredients and having received authorisation to make them available on the market can be commercialised.

It must be noted that:

- Disinfectants specifically destined for use with medical devices are not covered by the biocides directive. They must meet the criteria listed in the directive concerning medical devices.
- Antiseptics, which can be applied to broken skin, are considered to be medications and must meet the requirements of the directive relating to proprietary medicinal products.

In the European Union, the use of disinfectants must also conform to the "disinfectants" standard, EN 14885 of February 2007 [1].

4. Proper use of disinfectants

Chemical disinfection eliminates microorganisms (bacteria) or causes them irreversible damage (virus); the mechanism of action differs depending on the group of products used.

There is no universal disinfectant. Disinfectants must be tested for their planned use. There is no ideal disinfectant (*see box 1 The "ideal" disinfectant*). They are all inhibited to a greater or lesser extent by organic matter (pus, blood, keratin, mucus, etc.) and even the best tolerated ones are never absolutely safe. See factsheet 3.

Box 1: The "ideal" disinfectant (inspired by l'Antiseptoguide [6]):

The "ideal" disinfectant for use in a hospital would

1. Be an active ingredient with a broad spectrum of action against Gram+ and Gram- bacteria, as well as mycobacteria, viruses and fungi
2. Be bactericidal (destroy bacteria) and not just bacteriostatic (inhibit their growth)
3. Act rapidly, while also having a remanent effect, or even a cumulative effect when applied repeatedly
4. Have a local action (without systemic effect)
5. Be neither irritant nor toxic (particularly not mutagenic/carcinogenic/teratogenic), nor sensitising for humans and animals
6. Not have a negative effect on the environment
7. Be soluble in water and organic liquids
8. Not be excessively inhibited by organic matter (proteins).
9. Not be excessively inhibited by soaps
10. Resist contamination
11. Be stable, i.e., have a long shelf-life and be resistant to environmental factors (air, light, cold, heat)
12. Be compatible with the material to be disinfected
13. Be reasonably priced / have a good cost-benefit ratio
14. Be tolerable in terms of pain induced (e.g. alcohol) and acceptable in terms of odour

If a virucidal or fungicidal action is desired, a disinfectant displaying this property must be selected, and the manufacturer's recommendations should be strictly applied (concentration and duration).

A virucidal effect can be claimed[1] by the manufacturer after performing laboratory tests using adenoviruses as a model of enveloped viruses and polioviruses as a model of non-enveloped viruses. A disinfectant which is active against enveloped viruses may not be active against non-enveloped viruses, but any disinfectant active against non-enveloped viruses will be active against enveloped viruses. This is because enveloped viruses are surrounded by a membrane derived from the host-cell's membrane systems. This membrane makes them more sensitive to the external medium (temperature, drought, etc.) than non-enveloped viruses (which do not have this type of membrane). The lipid composition of this membrane also makes these viruses more sensitive to damage by detergents and disinfectants.

A fungicidal effect is labelled "*Candida albicans*" when the product is active against this, and all types of yeast; and "*Aspergillus niger*" when it is active against *C. albicans* and *Aspergillus*, i.e., all yeasts and fungi.

The mechanisms through which chemical disinfection is effective are, in particular:

1. Protein denaturation (aldehydes, alcohols)
2. Toxicity to the protoplasm (phenols)
3. A lesion of the cytoplasmic membrane (chlorhexidine)
4. An oxidant effect (chlorine, ozone, peroxide).

5. Mode of action and objectives

5.1 General

Disinfectants are extensively used in medicine for curative purposes (sores, etc.), but more often for prevention of human infection (bodily hygiene, hand hygiene, preoperative skin preparation, etc.) or environmental contamination (cleaning or disinfection of work areas, surfaces, materials, etc.). They are also extensively used in the food and agriculture industry and for animal health applications. The presence of proteins (in blood, pus, mucus, etc.) reduces the efficacy of disinfectants (see Table I in annex). Thus, it is essential to use detergents prior to disinfection, unless they are included in the composition of the disinfectant product. The action of disinfectants can also be hindered by the presence of a biofilm (see box 2).

Box 2: Definition of a biofilm:

A biofilm is a community of microorganisms (bacteria, fungi, etc.) covering an inert or biological surface which is in contact with water or a biological fluid. The film is maintained in place by secretion of an adhesive and protective matrix. Attachment to a surface is a "survival strategy" which allows the bacteria to settle in and colonise an environment. A biofilm is resistant to disinfectants, and must therefore be destroyed by mechanical action (brushing, rubbing, etc.) before or during disinfection.

[1] "Claimed effect": European vocabulary indicating that the producer of a product claims a specific effect for their product. After obtaining authorisation from the relevant authorities, the producer can indicate this effect on the product's label.

Detergents and disinfectants were used empirically until Pasteur demonstrated the link between micro-organisms and infectious diseases and set out the scientific foundations of disinfection. Use of these products always has the same objectives:

- To produce a clean state (cleaning with a detergent);
- To reduce or eliminate microorganisms (disinfection).

Disinfection must therefore involve three steps: cleaning, rinsing and disinfection *per se*. Cleaning ensures the "macroscopic" cleanliness of the surface or instrument, while disinfection ensures the "microscopic" cleanliness.

Cleaning (or pre-disinfection): Is performed with a detergent, a product allowing solubilisation of organic materials and fatty substances in water. Dispersion thus helps to reduce the number of micro-organisms present on the support (skin, work surface, medical device, etc.). Soap is the most commonly used, and oldest, detergent. For medical devices, this step corresponds to the pre-disinfection stage or to pre-treatment by immersion in a solution, or damp wipe, immediately after use of the device. A mechanical action can be used to detach soiling and microorganisms from their support. This mechanical action can involve rubbing, brushing, swabbing or circulation of high-pressure water [7].

Adjuvants can be added to detergents, in particular:

- anti-scaling agents and corrosion inhibitors to prevent the installation of or eliminate any biofilm;
- preservatives (biocidal agents) to limit microbial contamination of products;
- water softeners for comfort, colours and perfumes for acceptability.

These agents can have an irritant effect on the skin or airways, or even be toxic; but they are often used at such low concentrations that they are not mentioned on the material safety data sheets (MSDS).

Rinsing: the use of clean water, preferably by running it over the surface treated with the detergent, or else by wiping with damp compresses, allows elimination of soiling, mucus and flakes of skin. It thus also allows the elimination of some microorganisms. In addition, rinsing eliminates residual detergent, avoiding potential incompatibilities with the disinfectant. It should be followed by drying.

Disinfection per se: The disinfectant reduces the number of microorganisms remaining after the two previous phases. The reduction capacity is known for each individual disinfectant based on the results of various tests, it varies depending on the active ingredient. Bactericidal, virucidal, fungicidal and sporicidal activities are mentioned for disinfectants which kill bacteria, viruses, microscopic fungi and bacterial spores; a bacteriostatic, virostatic or fungistatic activity is indicated when the disinfectant only inactivates the bacteria, viruses and microscopic fungi to prevent their multiplication.

The efficacy of the detergent against microorganisms and its limitations are determined by obligatory *in vitro* tests which define the spectrum of action for a disinfectant (see Table II in annex). In real-life situations, this spectrum of action may be altered by several factors, including: concentration used, duration of contact respected or not, pH, temperature, presence of organic matter and the number of microorganisms present.

5.2 Surface disinfection (see factsheet 5)

In all cases of surface disinfection, the spectrum of action of the product used must cover bacteria and yeast. In some cases, the choice of disinfectant should take into account the proven or suspected presence of specific pathogens (*Mycobacterium tuberculosis*, fungal spores, *Clostridium difficile* spores, norovirus, adenovirus or papillomavirus, etc.). Efficacy against these pathogens should be verified.

Detergents must be used to obtain a clean state. Cleaning will be implemented based on the "SWPS" (S: nature of soiling to be removed; W: water quality used; P: procedure; S: nature of the support to be cleaned) and "TACT" parameters (T: temperature; A: mechanical action; C: chemical factor; T: time). These parameters (dilution, temperature, time, etc.) are indicated in the manufacturer's instructions, as is the recommended protective equipment (gloves, safety goggles, etc.) [5].

Disinfection, if necessary, will be performed using main group 1 products (disinfectants), product-type 2, in line with regulation (EU) No 528/2012 (see page 5).

Depending on the area to be cleaned, disinfection will involve the use of pre-impregnated wipes, wipes humidified with the disinfectant or by spraying (aerosol) or manual vaporisation. Dispersion of droplets of disinfectant (at variable distance and in varying sizes depending on the ejection pressure) can lead, over the following hours, to non-negligible respiratory exposure levels for the operator moving from room to room (when disinfecting handles, bed rails, other furniture, etc.), or from corridor to corridor (when disinfecting grab bars, etc.). After observation of practices in various hospital settings by a number of teams, and while not calling into question the quality of these hospitals, we are obliged to conclude that some of these disinfection tasks, which are repeated mechanically day after day, have become more of a disinfection ritual than a specifically justified action. It appears legitimate for an OSH professional to question the utility of these methods, particularly when they involve disinfection by spraying or manual vaporisation, which can lead to significant levels of personnel exposure.

5.3 Disinfection of medical devices (instruments) (see factsheet 6)

The solution used to disinfect instruments must effectively disinfect and clean not only surfaces, but also non-visible cavities (lumens). Disinfection products for use with instruments must be bactericidal (including, generally, action against mycobacteria and *Helicobacter pylori*), fungicidal and virucidal. They should also be non-toxic for the user and not damage the sensitive parts of instruments.

All products specifically intended for use during disinfection of medical devices must conform to the directive relating to medical devices. The level of treatment of the medical devices is determined based on the applications for which the material will be used (critical, semi-critical and non-critical). The level of infectious risk (high, medium, low) related to the use of the material will determine the required level of disinfection. This level of requirement dictates the choice of disinfectant and how it is used. This choice can be imposed by texts published by official bodies.

Three levels of disinfection are defined based on the intended use of the material and the expected level of infectious risk, which make it a critical, semi-critical or non-critical material. Thus, low-level disinfection, intermediate-level disinfection and high-level disinfection can be performed, depending on the objective to be achieved.

Low-level disinfection aims to kill vegetative microorganisms, except *Mycobacterium tuberculosis*, some microscopic fungi and some viruses.

Intermediate-level disinfection aims to kill vegetative microorganisms, including *Mycobacterium tuberculosis*, and all microscopic fungi, and to inactivate viruses.

High-level disinfection aims to kill vegetative microorganisms and inactivate viruses, but not necessarily bacterial spores present in large numbers.

There is thus a growing level of requirement depending on the objective. Some examples are given in tables 1 and 2 cross-referencing the intended use of the material, the level of infectious risk and the required disinfection level.

Table 1: The three levels of disinfection: critical, semi-critical and non-critical (as defined by D. Goullet [8])

Intended use of material	Classification of material	Level of infectious risk	Disinfection level
Introduction into the vascular system or into a sterile cavity or tissue, whatever the initial route. e.g.: surgical instruments, arthroscopes, etc.	Critical	High infectious risk	Sterilisation or single-use. If a single-use or sterilisable material does not exist: High-level disinfection
In contact with a mucous membrane or superficially damaged skin e.g.: digestive or bronchial endoscopes, spirometer mouthpieces	Semi-critical	Medium infectious risk	Intermediate-level disinfection
In contact with intact skin or no contact with the patient e.g.: blood pressure cuffs, beds	Non-critical	Low infectious risk	Low-level disinfection

Table 2: Examples of medical devices which should be reprocessed according to Spaulding's classification [9]

Definition (according to Spaulding)	Examples	Minimum requirements	Processing
Non-critical devices (only come into contact with intact skin)	Blood pressure cuffs, stethoscopes, ECG electrodes	Intermediate-level disinfection: elimination of the main pathogenic microorganisms	Appropriate cleaning followed by disinfection, e.g. with 70% alcohol
Semi-critical devices (come into contact with non-sterile mucous membranes or broken skin)	Bronchoscopes, digestive endoscopes, vaginal or nasal speculum, material for anaesthesia	High-level disinfection: elimination of all microorganisms except for some spores.	Non-fixing cleaning followed by chemical disinfection using peroxyacetic acid or aldehydes
Critical devices (coming into contact with blood or a sterile part of the body)	Catheters, acupuncture needles, biopsy forceps for endoscopes, urinary catheters	Sterilisation: elimination of all microorganisms including spores	Non-fixing cleaning and disinfection followed by sterilisation. Whenever possible, sterilisation in saturated water vapour in an appropriate wrapping

5.4 Skin disinfection (see factsheet 7)

Disinfecting the patient's skin

- Preventive disinfection / healthy skin: This includes many uses in the healthcare setting from bodily hygiene (soap, shampoo, etc.) using a disinfectant to preparation of the skin for an invasive procedure (placement of a catheter, surgical intervention, etc.). Depending on the objective of the disinfection, the products used will be classed in main group 1 (product-type 1: "Human hygiene") according to regulation (EU) No. 528/2012, or classed according to the directive on the community code relating to medicinal products for human use (antiseptics) [10].
- Curative (therapeutic) disinfection / Broken skin: Broken skin is disinfected when there is an injury. This is governed by a medical prescription. Water-based antiseptic products are used.

Hand disinfection for carers / personnel

Since the work of Semmelweis in 1847, cleaning of the hands is a routine procedure in medicine to prevent carry-over infection. Today, the use of hydroalcoholic products (HAP) on hands where no visible dirt is visible facilitates observance and allows rigorous hygiene just before an intervention, at the patient's bedside.

Depending on the act to be performed, hand disinfection can be done using one of two procedures: hygienic disinfection or surgical disinfection.

- Hygienic disinfection of the hands aims to eliminate the transitory flora and temporarily reduce the resident flora on hands free from visible soiling, preferably using a hydroalcoholic product. In all cases, products used for hygienic disinfection of the hands should cover vegetative bacteria and *Candida albicans*. It is also recommended that the product used also be effective against enveloped viruses.
- In addition to the requirements of hygienic disinfection, surgical disinfection aims to reduce the resident flora for a certain period of time (at least 3 hours). The products used can be more or less the same, but the procedures are different.

Disinfectants applied on living tissues (intact or broken skin, mucous membranes) are considered less irritant than disinfectants used to treat surfaces, instruments or the air. Nevertheless, repeated exposure of carers performing disinfection can have an impact on the state of their skin and/or their respiratory mucosa.

5.5 Aerial disinfection of work zones (see factsheet 8)

Except in very unusual circumstances, aerial disinfection of work zones is less and less used, in particular due to discussions on how formaldehyde should be classed, as it is now recognised as a carcinogen by the IARC. However, in Germany, formaldehyde-based disinfection of work zones remains the preferred procedure [11]. In France, when it is deemed absolutely necessary, aerial disinfection is performed by a chemical process using hydrogen peroxide or peroxyacetic acid, in line with the manufacturer's instructions, and after deactivating the systems treating the air in the zones to be disinfected.

Aerial disinfection is sometimes performed in departments where patients presenting a high risk of infection are treated (haematology, organ transplant, etc.), or if there is persistent contamination with *Aspergillus*-type fungi. This will require the use of a documented fungicidal disinfectant (active against *A. niger*). Aerial disinfection can also become necessary if multiple hospital-acquired infections are encountered in the same department; these are infections due to microorganisms with a very high survival potential in this environment (e.g. *Clostridium difficile*).

The product is dispersed into the air of the zone to be treated, preferably by a machine, in the absence of any personnel. It should be noted that the

disinfection system is authorised for use by the relevant health authority based on a specific product/dispersal machine combination.

Aerial disinfection does not disinfect the air of the zone to be disinfected (only ultra-violet light has been shown to be effective for this), but it can reach areas which are difficult to access during surface disinfection, thus limiting the risk of a persistent "reservoir" of pathogenic microorganisms.

It is essential to respect the time indicated by the manufacturer for the disinfection to be effective, but it is just as necessary to protect carer's health by respecting the time indicated before the disinfected zone should be re-opened, whatever the imperatives in the department where disinfection is performed.

5.6 Disinfection of linen and clothing (see factsheet 8)

The spectrum of action for disinfection of linen and clothing must cover bacteria, including any mycobacteria, dermatophytes, yeast and viruses (limited virucidal properties). If contamination with particularly resistant pathogens is suspected or known, targeted disinfection must be applied. Any clothing which cannot be washed should be disinfected with water vapour or by chemical disinfection/ cleaning.

6. Resistance to disinfectants

Resistance to disinfectants can be natural or acquired. The composition of the outer wall of microorganisms is the main element of bacterial resistance to disinfectants since most of these must penetrate the outer wall to be effective.

Natural resistance

Natural resistance is innate, specific to a species and is transmitted from generation to generation. It depends on the microorganism and the product. It results in total or partial inactivity of a product, or more often a family of products. It can be predicted for a given active ingredient and a given species of microorganism. Tthis can be used to define the spectrum of action for the disinfectant. For example, alcohol is inactive on sporulated forms of some bacteria.

Acquired resistance

Our current knowledge of acquired resistance mainly relates to bacterial resistance to antibiotics which has appeared over the last 20 to 30 years. This has led us to address the development of resistance to disinfectants.

Within a given species, acquired resistance results in the emergence of a strain with a more or less reduced sensitivity to an active ingredient. The appearance of this resistance is unpredictable and results from two different mechanisms:

- **Chromosomal acquired resistance:** One or more spontaneous, stabilised mutations of the bacterial genome, which are thus transmissible, will lead to a variable level of modification of a bacterial strain's sensitivity to an antibiotic or disinfectant. Mutations which have an impact on the composition of the cell wall are particularly significant for the sensitivity to most disinfectants which must penetrate this barrier to be active.
- **Extra-chromosomal acquired resistance:** This results from the acquisition by a bacterial strain of foreign material carried on mobile genetic elements (plasmid, transposon, etc.) which can be transmitted between different species.

Resistance to disinfectants and antibiotic resistance:

The question of a possible link between resistance to antibiotics and resistance to disinfectants is dealt with in several studies. At the European level, this complex subject is the object of a report by the Scientific Committee on Emerging and Newly Identified Health Risks at the Directorate-General for Health and Consumers dating from 2009 [12].

To avoid the appearance of these resistance phe-

nomena, disinfection should not be performed just anywhere, anytime, anyhow, but it should correspond to precise indications. If disinfection is necessary, it is recommended in the first instance to use broad-spectrum disinfectants, which have proven their efficacy on hospital-based strains in addition to their efficacy against the reference strains used in regulatory tests, and also to adhere to the manufacturer's recommendations (in terms of concentration and duration of contact to be respected).

7. Conclusion

Whatever the planned application, the general recommendations for the use of a disinfectant aim to protect the patient (respect of the duration of contact indicated, of the use-by date, of incompatibilities between disinfectants and between detergents and disinfectants, etc.), but also to preserve the health of carers (see the corresponding factsheets).

A common language should be used by physicians, chemists, hygienists and occupational health and safety specialists in the institution to facilitate sharing of imperatives between different personnel. At the end of a shared reflection, a more restricted range of disinfectants may be available, but their use may be better targeted due to optimal use in terms of patient safety and in terms of prevention of occupational risks for carers.

References

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[3] Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:167:0001:0123:EN:PDF)

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Annex

Table I excerpted from [13]: Main antiseptic and disinfectant families [14 and 15]

Families	Examples	Target and mode of action	Comments
ALCOHOLS	Ethanol, Isopropanol	Denaturation of cytoplasmic and membrane proteins, inhibition of nucleic acid and protein synthesis	Presence of water necessary for activity (use of 70% alcohol) / activity ↓ by biological matter
ALDEHYDES	Formaldehyde	Alteration of the cell wall, inhibition of nucleic acid and protein synthesis	↓ activity by biological matter
QUATERNARY AMMONIUM COMPOUNDS	Benzalkonium	Binds to fatty acids and phosphate groups in the cellular membrane → leakage of cellular constituents and cell lysis	↓ activity by biological matter, soaps and oxidants
BIGUANIDES	Chlorhexidine	Binds to fatty acids and phosphate groups in the cellular membrane → leakage of cellular constituents, coagulation of the cytosol	↓ activity by biological matter and soaps
CHLORATED AND IODATED HALOGENS	Sodium hypochlorite (Bleach, Dakin), Iodated PVP	Destruction of membrane and chromosomal proteins (halogenation)	↓ activity by biological matter and soaps / degraded by UV
OXIDANTS	Hydrogen peroxide	Production of free radicals which interact with lipids, proteins and DNA	↓ activity by biological matter

↓ = Reduction of…..

Table II: Spectrum of action of antiseptics and disinfectants (adapted from [16])

Families	Spectrum of action							
	Gram +	Gram -	Mycobacteria	Yeast	Fungi	Non-enveloped viruses	Enveloped viruses	Spores
ALCOHOLS	+	+	+	+/-	+/-	+/-	+	-
ALDEHYDES	+	+	+	+	+	+	+	+
QUATER-NARY AMMO-NIUM COM-POUNDS	+	+/-	-	+	+	+/-	+	-
BIGUANIDES	+	+	+/-	+	+/-	+/-	+	-
CHLORATED AND IODATED HALOGENS	+	+	+	+	+	+	+	+
OXIDANTS: DESINFEC-TION	+	+	+	+	+	+	+	+
OXIDANTS: ANTISEPSIS	+	+	-	+	+	+/-	+	-

+ Active products +/- Inconsistently active products - Inactive products

Comments:

- Aldehydes: used only for disinfection
- Iodated halogens: used only as antiseptics (disinfection of the skin)

Table III excerpted from [13]: Field of use of the main types of disinfectants

Group of substances	*Field of use*	*Ineffective or poor efficacy against*	*Loss of efficacy in the presence of proteins*
Alcohols	Skin, hands, small surfaces	Spores, non-enveloped viruses	high
Aldehydes	Instruments, surfaces		high
Chloride	Water, surfaces, clothing, excreta		high
Phenols	Excreta, surfaces, instruments, clothing	Spores, non-enveloped viruses	very low
Oxidants *Peroxyacetic acid / Peracetic acid*	Instruments, surfaces, thermolabile materials		moderate
Iodated PVP	Skin, mucosa, small wounds	Spores, non-enveloped viruses	high

Lists of disinfectants are available on the Internet in the following databases:

- Disinfectants listed by VAH (in English and German): www.vah-online.de.
- DesInfo (in German): information on hazardous substances (gefahrstoffe@bgw-online.de).
- Gestis (in English and German): database on the prevention of occupational risks related to chemicals, including information on many disinfectant active ingredients (http://gestis.itrust.de).
- ProdHyBase (in French): http://prodhybase.chu-lyon.fr. ProdHyBase® lists the disinfectants used in human medicine, products for the hands and related materials. The database only includes products marketed in France in the hospital and dental sectors.
- The positive list published by the SF2H (French society for hospital hygiene) (http://nosobase.chu-lyon.fr/recommandations/sfhh/2009_desinfection_sterilisation_SFHH.pdf) dates from 2009. It is no longer updated, and will not be in the future. It has been replaced by the ProdHygBase website.

Use of disinfectants in the health care sector: Chemical hazards and preventive measures

Factsheet 1: Principles of disinfection

12/2014

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