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Sterilization with steam

Effective, environmental and personal safe

The process of steam sterilization has proven itself for years, and it is the safest method of sterilization to date. Hot steam destroys all living micro-organisms and thus ensures efficient and reliable results without the use of toxic substances. Accordingly, contributes to protecting the environment from additional noxious contaminants and above all minimizes personnel contact with harmful chemicals.

What exactly happens during steam sterilization?

Under normal conditions, at atmospheric pressure, the water vapour does not exceed 100° Celsius, and consequently it would take a long time to eliminate all germs on these conditions. Steam sterilizers operate at much higher temperatures (and pressures), which allows to drastically shorten sterilization times while increasing process efficiency and reliability. First, it is essential that the water steam comes into direct contact with the processed items. Thus, steam will be able to deliver all its stored energy, in the form of heat, by condensing onto the surfaces of the instruments. This thermal energy, released within a certain time period, will kill all different types of germs. When instruments with lumens of any kind are being sterilized, residual air pockets can form and remain inside the cavities, thus preventing steam to penetrate into these spaces. The consequences are unsterile patches within the instrument lumens. At this moment one of the features of steam sterilizers comes into play: By applying vacuum technique, air is suctioned out of the sterilization chamber to allow steam to fill the chamber completely. This process is repeated for several times to ensure that as much air as necessary is removed from the chamber. As a result, a vacuum is built up and the steam generated can flow unhindered within the chamber and reach all inner and outer surfaces, including the now air free, unobstructed small lumens of the instruments. By continuously releasing steam into the chamber, the pressure inside increases. Consequently, so-called strained steam forms, which is accompanied by a rise in temperature up to 134°C.
With increased temperature and pressure the time needed to kill germs changes effectively, as it shortens considerably.

Good to know: **Sterilizers with vacuum technology** enable quicker automatic safe drying of the sterile goods within the autoclave chamber, as the drying process is also performed under vacuum. During the cool down process, steam and condensed water droplets are removed from the autoclave repeatedly, so drying happens fast and gentle.

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Thermal reduction

Destruction of microorganisms

Key facts

- Heat is the most reliable means of inactivating/ killing microorganisms
- Microorganisms show high variability in heat tolerance
- Thermal reduction is mathematically described as a logarithmic process

Heat as a means of inactivation or rather destruction of **microorganisms** can either be applied as moist or dry heat. Both methods are reliable but when applicable moist heat is more effective as steam is a better heat conductor than air and thus exposure times shorten significantly because proteins lose their functionality more readily in moist conditions [1].

Microbial heat resistance

Each microbial species has its own particular heat tolerance. Important variants in microbial resistance are the composition of the outer membrane, metabolism and developmental stage of the microbial organism. Outer membranes vary in their chemical composition not only across species but also during developmental stages e.g. spores and resting stages which are encased in special hulls to protect the organism from external influences. Viruses have no metabolism of their own and are dependent on their host's cells to replicate, so there is no metabolic activity to be targeted. Furthermore, contrary to other microorganisms viruses without an outer protein hull are more resistant than enveloped ones [2, 3].

The principle of heat destruction

Heat targets proteins. These essential biomolecules are sensitive to temperature and start losing their functionality at 55°C, dependent on composition and intermolecular binding. This process is called **denaturation** and is based on breaking and rebonding on a molecular structural level. Once the native structure of a protein is destroyed through the process of denaturation it cannot be reassembled to regain its biological activity [1].

The thermal death time curve and the D-value

Killing microorganisms is a time and temperature dependent process which results in a thermal death time curve for each organism. The process of microbial elimination by means of heat follows a logarithmic procession (see also **logarithm, exponentiation**). Meaning that during each passing time unit at a certain temperature the number of viable bacteria will be reduced by the same percentage, regardless of the number of bacteria. Also, by altering the applied temperature, holding times shorten or lengthen respectively. Consequently, anywhere along a death time curve represents the same degree of lethality [2].

Based on this dependence the **D-value** (decimal reduction time) has been defined as the necessary holding time, at a certain temperature, to eliminate 90% of a microbial population, thus can be determined for different microbial species and temperatures [2, 3]. Hence the D-value serves as parameter in evaluating and monitoring sterilisation procedures.

Bacteria species	Temperature (°C)	D-value (time)
Salmonella thyphi	65	1 s
Vibrio cholerae	65	3 s
Mycobacterium tuberculosis	75	5 s
Staphylococcus aureus	80	2 s
Bacillus anthracis	100	15 min
Bacillus stearothermophilus (endospores)	121 (121/134)	2-5 min (15/3 min)
Clostridium botulinum A and B	121	10-20 s
Endospores C. botulinum	120	20 min
Endospores C. tetani	134	3 min

The table shows selected bacteria species or developmental stages and their respective D-values at defined temperatures e.g. when a temperature of 65°C is applied to a population of Vibrio cholerae 90% of the present population will be killed off after 3s.

Bibliography:

[1] ÖSGV Fachkundelehrgang: Weiterbildung Sterilgutversorgung – Grundlagen der Aufbereitung von Medizinprodukten
[2] Thermal destruction of microorganisms, Article by Goff D. University of Guelph
[3] ÖSGV Fachkundelehrgang: Weiterbildung Sterilgutversorgung – Grundlagen der Sterilisation
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What role does water quality play **in reprocessing?**

In the reprocessing procedure for instruments, rinsing with water is often required to prevent the formation of stains, spots, marks and **corrosion**. If conventional tap water instead of de-mineralized water is used during the final phases (rinsing and disinfection) of the thermal washer-disinfector process, this can result in deposits on the load, thereby possibly impairing functionality of instruments. If contact is made with these deposits and left-over protein residues, this can impair the health of both the user and the patient. The use of **de-mineralized,** purified water provides a high degree of protection from deposits of mineral origin, as well as from the associated reductions in functionality of instruments and devices.

Water quality in steam sterilization
In steam sterilization, saturated steam is used for the sterilization of medical instruments.

All products in the autoclave must be fully in contact with the saturated steam. This is the only way to guarantee sterilization. This also applies to wrapped instruments; here, too, the steam penetrates the packaging and comes into contact with the instruments. In order to achieve sterile conditions it is important that the water is free from contamination (like e.g. chemicals, mineralization, etc.).

The use of poor-quality (e.g. hardness of water) of water can also substantially impair the lifespan of the autoclave or the sterilized instrument. Regular cleaning of the water container and the autoclave's chamber also provides protection from additional contamination and possible corrosion of the steam-producing parts of the autoclave. Some standards (EN 13060/EN 285; ANSI/AAMI ST55, ...) provide information regarding the desired optimized water quality through the respective water treatment.

The table below provides examples of the possible effects of several contaminants:

Contamination	Effect
Metals	Stains or blemishes on instruments; reduction of heat transfer (steam will not get in direct contact)
Bacteria and their products	Endotoxins can be deposited; can result in adverse effects for the patient (e.g. impaired wound healing)
Chlorides	Reduce the efficiency of the steam generation by corroding the steam providing parts of the steam generator
Ions	Calcium and magnesium salts; because of their low solubility in warm water, precipitation of the salts occurs. Result in coatings in chamber/on instruments. Compromise the lifespan of instruments/autoclaves. Reduce the efficiency of the steam
Deposits like lime scale or proteins	Deposits – exposure to contamination – reduction of lifespan of instruments and steam sterilizer

Several manufacturers offer **water treatment systems** that filter out the relevant contaminants and thereby produce demineralised water. The quality of the water vapour is thereby also heavily dependent on the quality of the water in terms of the hardness of water. Water reservoirs in autoclaves should be cleaned regularly, at least once per week, to avoid possible accumulations of particles and germs.

Bibliography:
The European standard EN 285:2006 (please check for updated version)
United States standard ANSI/AAMI ST79:2006 (please check for updated version)