Reducing UPOPs and Mercury Releases from The Health Sector in Africa

Module 27:

Basics of steam based treatment technologies

UNDP

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Content

- Little history
- The physics for steam sterilization
- Destruction of germs
- Sterilization
- Types of treatment plants

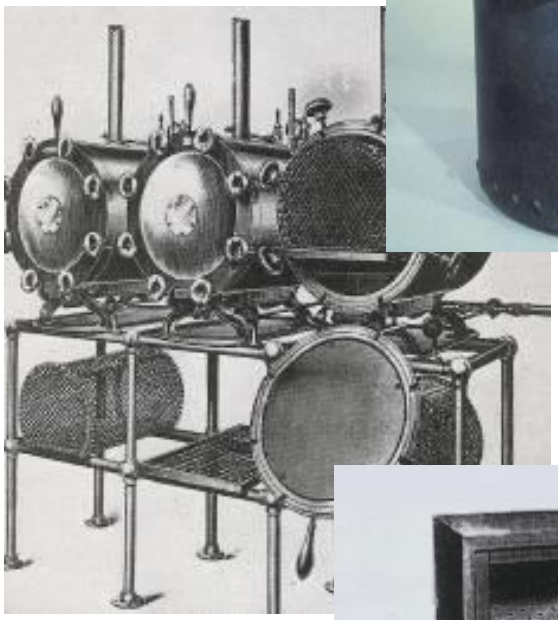
Methods of Sterilization

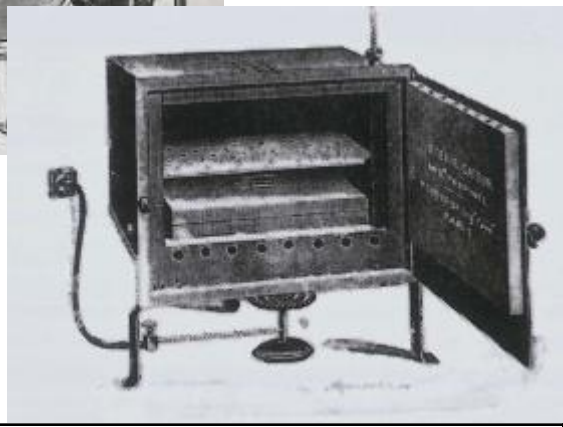
- Sterilization by heat
  - Open flame sterilization
  - Incineration
  - Steam
  - High temperature water
  - Dry heat
- Sterilization by chemicals
  - Ethylene Oxide
  - Formaldehyde and steam
  - Glutaraldehyde
- Irradiation
- Gas plasma
- Filtration

Developments in Sterilization I

In the last 150 years:

- Louis Pasteur:
  - Hot treatment of medical materials at 130°- 150°C (1878)
- Charles Chamberland
  - Build the first autoclave (1884)
- Gaston Poupinel
  - Hot air sterilizer in France (1885)
- Bigelaw and Ball
  - heat inactivation (1920)





Developments in Sterilization II

<u>In the last 50 years:</u>

- Steam sterilization improved:
  - Fractionated vacuum, systems based on EN 285 (large sterilisers) and
  - Pr EN 13060 (small sterilisers)
- Philips and Kaye
  - Ethylene oxide (1949)
- Hurrell and Line
  - Low Temperature Steam Formaldehyde - LTSF (1973).
- 1st medical version LTSF
  - WEBECO (1979)

WHY TREAT ON-SITE?

- Where possible infectious waste should be treated on-site to minimise transportation risks.
- Infectious Waste makes up about 80% of the Healthcare “Risk” Waste Stream.
- New and advanced steam treatment methods (VSV-autoclaves) allow an easy and economical treatment even of relatively small infectious waste amounts.
- Infectious waste is the waste stream with the lowest density (100 – 120 kg/m³) which results in high volumes of waste to transport = high logistics costs. (up to 50% of total cost is for packaging and transportation).
- As infectious waste is a biological “active” waste, storage times are limited.

TREATMENT OF INFECTIOUS WASTE USING STEAM

Infectious Waste treatment using a steam treatment unit is based on a thermal disinfection or sterilisation process, well known from the sterilisation of hospital equipment.

The treatment happens at high pressure (e.g. 3,2 bar) and temperature (e.g. 134°C) in a nearly 100 % saturated steam atmosphere because:

- In a wet atmosphere, germs are more heat sensitive
- Saturated steam under heat and pressure acts as a soft acid and destroys organic substances like germs
- Enthalpy energy will be set free during condensation directly on the inner- and outside surfaces of the waste – the places where germs accumulate

ADVANTAGES OF STEAM TREATMENT

Why Steam Treatment?

- Steam treatment is simple
- Steam treatment is a clean technology
- Steam is not toxic
- Steam can kill microorganisms in a short time at relatively low temperatures
- Treatment can be controlled and validated
- Steam treatment is state of the art

Note: High temperature steam is still the safest and most common agent for the sterilisation of medical supplies in health facilities. However not all Steam treatment is equal, the quality depends greatly on the process cycle, the equipment and the user

- Never forget: Steam is one of the most reliable methods for the treatment of Infectious Waste.

Some Physics I

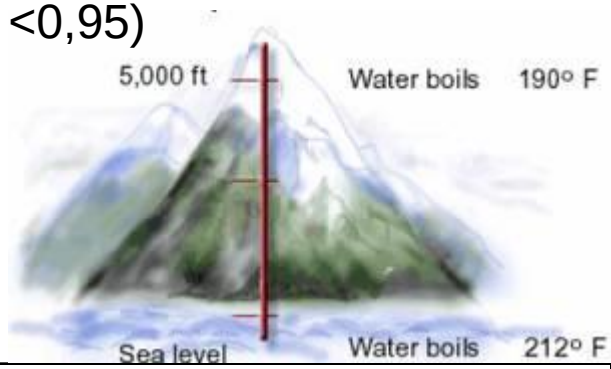
- Pressure
  - The force acting per unit of area (e.g. N/m² or Pa)
  - Atmospheric pressure: 10 N/cm² = 100,000 N/m² = 100 kPa = 1 Bar (real: 1.013 Bar)
  - Pressure in vacuum = 0 Pa = 0 Bar = 0 N/m²
  - Absolute pressure: 1.013 Bar
  - Relative pressure: pressure above atmospheric pressure (also called gauge pressure)
  - Other units:
    - PSI: 1 PSI = 0,0697 kg/cm² = 6,89 kPa (100.000 Pa = 14,22 PSI
    - Atm: 1 atmosphere (atm) = 100 kPa

Some Physics II

- Heat (energy!)
  - Temperature: Kelvin (°K) – normally used °C or F (0°C = 273°K = 32°F, 100°C = 373 °C = 212 °F, 38°C = 311°K= °F?
  - Heat content (energy) = Joule (J)
    - Heating up 1 gram water for 1°C = 4.2 J, Oil 2.1 J, Iron 0.460 J
    - Heating up 5 l water, needed energy = 21 KJ
  - Total amount of heat in a substance: enthalpy
  - Evaporation energy: Joule/kilogram (J/kg)
    - Evaporation of 1 l water: 2.257 KJ/kg (benzene 395 KJ/Kg)
  - Enthalpy energy in 1 kg of steam
    - 4.2 KJ * 100°C + 2,257 KJ/Kg = 2677 KJ/kg
  - Condensation: Transformation of a vapor back in the liquid state. The heat requirement for evaporation is equal to the heat which is released when condensing
  - Volume: 1 l water = 1,600 liter saturated steam!

Some Physics III

- Steam
  - Boiling temperature depends on the pressure of the gas above the it
    - Lower pressure (e.g. on a mountain or in a vacuum) – water boils earlier (50 KPa = 81°C, 50°C= 12,33 KPa)
    - Higher pressure (e.g. in a pressure vessel) – water boils at higher temperature (2,04 bar = 121°C; 134°C = 304 KPa)
  - Saturated steam: Pure steam at boiling temperature
    - Superheated steam: heated up steam
    - Wet steam: water is in steam
    - Quality of steam: dryness fraction (should be <0,95)
    - Note I: Wet steam can create a shield on the sterilization packs!
    - Note II: Steam can contain inert gases!



Killing !!!

- All life can be killed by heat!
  - Destruction of the cell membranes
  - Denaturation of proteins (coagulation) by moist heat.
- A microorganism is considered dead if it can not reproduce itself anymore.
- Resistance of organism against moist heat
  - Vegetative bacteria, fungi:1-5 min at 80°C
  - Spores of fungi: 1-10 minutes at 100°C
  - Low resistant bacterial spores: 1-60 minutes at 100°C
  - High resistant bacterial spores: 1-2 minutes at 134°C
- Reason why it is had to kill spores: Absence of moisture
  - Makes germination of spores difficult, difficult heat transfer to proteins in cytoplasma.
- Note: Different type of microorganism have a different resistance against heat.

Sterilization

- 5-5-5 test for decontamination
  - Within 5 minutes the number of 5 different kind of microorganism should be reduced by log 5 (1/100,000)
- Sterility Assurance Level (SAL)
  - A product is considered sterile if the chance that there are viable microorganisms on the product is equal or less than 1 to a million (of a total number of 1,000,000 sterilized products, 1 surviving microorganism is accepted)
- F-Value
  - The time in minutes required to reach sterility of a produt by exposure to a certain killing agent at a certain temperature
  - The F-value at 121°C is the F0-value
- Absolute safe sterilization: Imaginary Micro-Organism (IMO) concept
  - Combines the worst case of different microorganism
  - Standard sterilization times: 15 minutes at 121°C, 3 minutes at 134 °C
- Overkill method
  - Products are exposed to higher temperature and longer process times as needed to reach sterility

Factors affecting sterilization

- Number of organisms (bio-burden)
- Their resistance to the sterilizing agent (F-Value)
- But also:
  - Debris on the item providing protection for organisms
  - Proper loading techniques
  - Functional efficiency of the sterilizing equipment
  - Achieving required sterilization parameters
  - Human performance
  - Post sterilization handling techniques
- Sterilization is an absolute state—either something is sterile or it is not sterile!!!

Porous loads

- Number of hollow instruments is due to new surgical techniques increasing
- Problem: Air in hollow instruments and tubing which is difficult to be removed (trapped)
- Steam can penetrate fabrics good due to the suction created during condensation. But…
  - Steam comes from all sides and traps air in the textile packs.
  - Central part of a pack of dressing might not be sterilized.
  - Moisture might remain inside
- Wet package (wet wrapping or wet content is not considered sterile!

Main types of steam treatment plants

- Three different main types of steam treatment processes are used:
  - Gravity type Autoclaves (Pressure cookers), also called downward displacement sterilizers
    (Air is removed due to the density difference of air and steam)
  - Pre-vacuum autoclaves or “porous load autoclaves”
    (Air is mechanically removed and replaced by steam)
  - VSV-Autoclaves: “Vacuum-Steam-Vacuum Autoclaves” or “fractionated Autoclaves”
    (Air is several times removed and replaced by steam)