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Unveiling the Power of Sanitizers: From Disinfection to Sterilization

Prasad M. G.

Introdution:

In an era where health and hygiene are of paramount importance, the role of sanitizers in safeguarding our well-being cannot be overstated. Sanitizers, which include a diverse range of chemical and physical agents, play a crucial role in disinfection and sterilization, keeping harmful microorganisms at bay. In this comprehensive article, we delve into the world of sanitizers, exploring their various types, mechanisms of action, and their applications in different industries.

Disinfection and Sterilization: Understanding the Terminologies

Germ: Microorganisms known to cause diseases;

Germicide: Agents capable of killing; athogenic microorganisms.;

Disinfection: The process of destroying pathogenic organisms capable of causing infections;

Disinfectant: Agents used to prevent infections;

Bactericidal: Agents that can kill bacteria; **Bacteriostat:** Agents that inhibit bacterial growth;

Antisepsis: The prevention of infection by inhibiting bacterial growth;

Sterilization: The complete elimination of microorganisms from surfaces or substances;

Sanitizers: A Powerful Tool in Microbial Control

A sanitizer is an agent that reduces the microbial population on a surface or substance to safe levels as defined by public health standards. These agents typically kill 99.99% of growing bacteria, making them essential tools in maintaining cleanliness and preventing the spread of infections. The primary aim of disinfection is to reduce the number of microbes that remain on surfaces, preventing their proliferation and potential to cause harm.

Classification of Disinfectants

1. Physical disinfectants
2. Chemical disinfectants
3. Gaseous disinfectants

1. Physical disinfectants:

a) Heat: Wet Heat and Dry Heat:

- Wet heat: Includes steam, autoclaving, boiling, pasteurization, and tyndallization.

Prasad M. G.

Department of Livestock Products Technology, ICAR - Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India

- Dry heat: Involves flaming, incineration, and hot air ovens.
- Desiccation: Drying up of microorganisms.
- Osmotic Pressure: Using high concentrations of solute to cause plasmolysis.
- Filtration: Passes liquid or gas through a filter to remove microorganisms.
- Radiation: Ultraviolet (UV) and ionizing radiation.

Factors Influencing Sterilization by Heat

- Nature of Heat: Different effects of dry heat and moist heat.
- Temperature and Time: The combination of temperature and duration of heat exposure.
- Number of Microorganisms Present: More microorganisms require longer exposure.
- Characteristics of Organisms: Heat resistance varies between organisms.
- Type of Material: Different materials have different heat susceptibility.
- Heat Resistance of Microorganisms

pH: Microorganisms are more heat-resistant at their optimal pH.

- Age of Cells: Young cells are more susceptible to thermal destruction.
- Growth Temperature: Organisms are more heat-resistant at their optimal growth temperature.
- Composition of Media: Bacterial cells are killed faster when heating media.
- Initial Microbial Number: Heat treatment's effectiveness depends on initial microbial load.
- Presence of Free Water (aw): Desiccation increases heat resistance.

Moist Heat: Kills microorganisms by coagulating their proteins. Example: Spores of Clostridium botulinum can be killed by moist heat treatment at 120°C for 4 to 20 minutes. Dry heat treatment at 120°C for 2 hours can also achieve the same effect.

Effect of Heat on Microorganisms:

- Thermal Death Point (TDP): The lowest temperature at which all microorganisms in a liquid suspension are killed in 10 minutes.
- Thermal Death Time (TDT): The time required to kill all microorganisms in a liquid suspension at a specific temperature.
- D-Value: The time required to kill 90% of microorganisms in a sample at a specific temperature.
- Z-Value: The temperature increase required to reduce the D-value by one log cycle.

- F-Value: The time at a specific temperature needed to kill a population of cells or spores.
- Q10-Value: The temperature coefficient, indicating the rate of change of microbial death with a 10°C change in temperature.

Wet Heat Treatment

1. **Steam:** Generated by boiling water and used to sterilize equipment. It can decrease in temperature and efficiency over time.
2. **Boiling:** Effective for destroying pathogens and saprophytic organisms. Used for sterilizing plastic cups, muslin cloth, etc.
3. **Pasteurization:** Wet heat treatment to make products safe for consumption by reducing pathogens. Variation based on nutrient and solids content.
4. **Autoclave**: Wet Heat Sterilization

Used to sterilize substances at 121°C for 15 minutes at 15 lbs pressure. Suitable for media, diluents, and liquid materials. Sterilization occurs through steam under pressure.

Dry Heat

1. **Hot Air Oven:** Sterilization at 145-160°C for 1.5 to 2 hours or 180°C for 1 hour. Used for glassware sterilization.
2. **Flaming/Incineration:** Direct heating over a flame for sterilizing tools like needles, scalpels, culture tube mouths, etc.
3. **Incinerators:** Operate at 400-600°C for disposing of contaminated materials, carcasses, bandages, etc.

Filtration

1. Membrane Filters: Used to sterilize solutions sensitive to heat, with pore sizes of 0.22 to 0.45 µm.
2. HEPA (High-Efficiency Particulate Air) Filters: Used for air filtration in aseptic environments.

UV Radiation

- Bactericidal at 254-265 nm wavelengths.
- Absorbed by nucleic acids, causing the formation of pyrimidine dimers in DNA, disrupting replication and growth.
- Used for sterilizing packaging materials, water purification, and more.

Microwave Radiation: Industrial (925 MHz) and domestic (2450 MHz) frequencies used.

Acts on polar molecules, generating thermal energy through coagulation of cell proteins.

Effective for food and medical applications.

2. Chemical Disinfectants

Chlorine-Related Compounds

- **Inorganic Chlorine Compounds:** Hypochlorites (bleaching powder, sodium hypochlorite), chlorine gas, chloramines (chloramine T, B, dichloramine T), chlorine dioxide, chlorinated trisodium phosphate.
- **Organic Chlorine Compounds:** Chloramines (chloramine T, B, dichloramine T), sodium dichloroisocyanurate, dichlorodimethyl hydantoin.
- **Mode of Action:** Hypochlorous acid is formed in water, causing damage to microbial cell components.
- Contact Time: Depends on chlorine compound and water quality.
- Organic Matter: Presence decreases chlorine action.

Quaternary Ammonium Compounds (QACs)

- They are more active against Gram-positive bacteria than Gram-negative ones.
- The growth of bacterial spores can be prevented by treating with QACs.
- The addition of non-ionic surfactants to the disinfectant can enhance the rinsability of QACs.

Advantages of Hypochlorites	Disadvantages of Hypochlorites
Inexpensive	Unstable during storage
Quick action	Inactivated by organic matter
Not affected by hard water	Corrosive and irritating
Harmless residue	Undesirable odor
Effective at low dilutions	Decreased effectiveness at higher pH
Active against various microorganisms	May remove carbon from rubber parts
Effective against spores	

Factors Affecting Chlorine Action

- pH: Optimal at pH 6-8; acidic conditions have stronger bactericidal action but can be corrosive.
- Concentration: Depends on substrate; e.g., utensils (200 ppm), floor (250-300 ppm), skin (50 ppm).
- Temperature: More effective at lower temperatures (30-40°C).

- QACs retain their activity over a broader pH range, with optimal effectiveness in alkaline conditions.
- They remain stable in dilute solutions, allowing for long-term storage.
- QACs are unaffected by organic debris, making them effective even in the presence of contaminants.
- These compounds are non-corrosive and non-irritating to the skin.

- QACs are stable in the presence of hard water salts, but their activity can be reduced by these salts.
- However, incompatible sequestering agents can cause the precipitation of QACs.
- They tend to foam vigorously, which can render them unsuitable for certain applications, such as in Clean-in-Place (CIP) or spray systems.
- Effective concentrations of QACs typically range from 50 to 500 ppm at a temperature of 40°C.

The mechanism of action of QACs involves several aspects:

Quaternary Ammonium Compounds (QACs) exert their disinfecting action through several mechanisms. Firstly, they target the microbial cell membrane, leading to its disintegration and compromising the integrity of the microorganisms. Additionally, QACs induce the denaturation of crucial cell proteins that play essential roles in growth and metabolism processes. Furthermore, these compounds have the capability to deactivate specific enzyme systems that are vital for the respiration of cells. In this way, QACs effectively disrupt various aspects of microbial function and survival. The advantages of utilizing QACs in disinfection strategies encompass their stability, extended shelf life, resistance to temperature variations, efficacy under alkaline conditions, and the ability to leave a residual bacteriostatic effect.

Iodophores: Iodophores, consisting of

Advantages of QACs	Disadvantages of QACs
• Stable with a long shelf life	• Incompatible with anionic agents in detergents
• Maintains efficacy despite temperature changes	• Relatively expensive
• Effective in alkaline conditions	• Lower activity in hard water
• Non-corrosive, odorless, and resistant to organic matter	• Less effective against spores, phages, and Gram-negative bacteria
• Leaves a residual bacteriostatic effect	• Residual film removal needed after application
• Non-irritating to the skin, nontoxic, and easy to handle	• Excessive foaming during mechanical application
• Easily dispensed and controlled in various applications	
• Can control off-flavors	
• Active against thermoduric organisms	
• Good penetration power, often combined with non-ionic for detergent-sterilizer formulations	

soluble polyvinyl pyrrolidone, surfactants, and iodine, offer unique characteristics and mechanisms:

- Iodophores are less affected by pH changes and remain active at pH levels of 3 to 5.
- They can be expensive and are not widely used.
- Iodophores are non-corrosive, non-irritating, nontoxic, and have a mild scent.
- Some plastic materials or rubber can absorb iodine and cause discoloration.
- Iodophores are stable in concentrated form, suitable for long-term storage at ambient temperatures.
- They exhibit reasonable activity even in the presence of organic wastes.
- Incorporating a low-foaming surfactant improves the performance of iodophores.
- Operating temperatures of up to 50°C are suitable for iodophores, depending on the concentration of iodine.

Mechanism of Action of Iodophores:

The mechanism of action of iodophores involves the dissociation of iodine from surfactants, leading to their bactericidal activity. They achieve this through the halogenation of cellular proteins and oxidation of protein groups, affecting the metabolism of cells. However, iodophores are generally less effective against spores and phages compared to chlorine-based compounds.

3. Gaseous disinfectants: These are applied in their vapor state, offering potent disinfection and deodorization capabilities. They are utilized for surface disinfection in various settings, particularly in rooms and enclosed spaces. Alkylating agents like formaldehyde, ethylene oxide, and propylene oxide are the active constituents of these disinfectants. Among these, ethylene and propylene oxides stand out as reactive gaseous fumigants that exhibit noncorrosive properties. Ethylene oxide, in particular, boasts superior penetrability compared to propylene oxide and is often blended with substances like chlorofluorocarbons or carbon dioxide to enhance its efficacy. It's worth noting that other gaseous disinfectants are infrequently used due to their corrosive nature, making them less suitable for widespread applications.

Conclusion

In a world where health concerns are a top priority, the significance of sanitizers cannot be underestimated. From physical to chemical and gaseous agents, sanitizers come in various forms, each with its distinct mechanism of action and applications. These powerful tools help us keep harmful microorganisms at bay, ensuring our safety and well-being across various industries and environments. Whether it's in the medical field, food processing, or everyday hygiene, sanitizers play a crucial role in maintaining a clean and healthy environment. So, the next time you reach for that sanitizer, remember the intricate science behind its effectiveness in safeguarding your health.