

A Review on Antiseptic and Disinfectant

Mr. Anuj Sanjay Khairnar¹, Mr. Dhammadip Malhari Ingole², Mr. Sumit Bhimrao Jadhav³, Ms. Priya K. Javare⁴, Ms. Trupti D. Shetane⁵, Ms. Ashwini Sukhdev Pundkar⁶, Dr. Santosh A. Payghan⁷
^{1,2,3,4,5,6,7}Rajesh Bhaiyya Tope College of B. Pharmacy, Nipani Bhalgaon, Chh. Sambhajinagar, 431007

Abstract—This review thoroughly examines the chemical diversity, mechanisms of action, and potential resistance mechanisms associated with antiseptics, highlighting their clinical relevance and the difficulties posed by microbial adaptation. Antiseptics are chemical agents used on living tissues to inhibit or destroy microorganisms, serving as an essential tool in infection prevention across healthcare, food safety, and public hygiene. Their broad-spectrum activity and versatility have established them as a cornerstone of antiseptics in clinical and community settings.

Protein denaturation, membrane rupture, and interruption of vital bacteria functions including nucleic acid synthesis are the main ways that antiseptics work. By damaging membranes and triggering protein coagulation, alcohol-based antiseptics like ethanol and isopropanol have quick bactericidal effects on a variety of pathogens, including bacteria, fungi, and some viruses. However, their use in sterilization is limited due to their lack of sporicidal activity. Although their effectiveness decreases against mycobacteria and non-enveloped viruses, biguanides such as chlorhexidine have long-lasting antibacterial effects and are effective against both gram-positive and gram-negative bacteria. Although discomfort and discoloration can occasionally make it difficult to use, iodine-based antiseptics, such as povidone-iodine, exhibit quick and strong antibacterial activity by targeting microbial proteins and nucleotides. Despite their extensive use, attention is required due to the growing concern about antiseptic resistance. The effectiveness of antiseptics is threatened by microbial resistance mechanisms, including enzymatic degradation, decreased permeability barriers, and adaptive resistance during sporulation. Gram-negative bacteria, for instance, can withstand some antiseptics thanks to the protective qualities of their outer membranes, but bacterial spores are less vulnerable to many biocidal agents because they have developed strong structural defenses like spore coats and a highly resistant cortex. This review emphasizes the vital role that antiseptics play in contemporary infection control procedures, but it also stresses the need for their prudent use in order to strike a balance between the risks of developing resistance and the elimination of microorganisms. Maintaining their effectiveness and

tackling the difficulties posed by changing microbial pathogens will require an understanding of their resistance and methods of action.

Index Terms—Antiseptics, infection prevention, biocides, microbial resistance, alcohol-based antiseptics, chlorhexidine, iodine-based antiseptics, membrane disruption, protein denaturation, nucleic acid interference, gram-negative bacteria, bacterial spores, sporulation, antiseptic efficacy, antimicrobial resistance.

I. INTRODUCTION

In hospitals and other healthcare facilities, antiseptics and disinfectants are widely utilized for a range of topical and hard-surface applications. Specifically, they help prevent nosocomial infections and are a crucial component of infection control procedures. The public's usage of antiseptics and disinfectants has also increased as a result of growing worries about the possibility of microbial contamination and infection hazards in the food and general consumer markets. These products contain a wide range of active chemical agents, also known as "biocides," many of which have been used for centuries to prevent infections, disinfect, and preserve food. However, compared to antibiotics, little is known about how these active drugs work. Generally speaking, biocides are more active than antibiotics, and they may have more than one intracellular target, whereas antibiotics typically have just one. There has been some conjecture regarding the emergence of microbial resistance, namely antibiotic cross-resistance, due to the extensive usage of antiseptic and disinfection products. The mechanisms of microbial resistance to antiseptics and disinfectants, as well as their mode of action, are examined in this review, which makes every effort to connect the most recent findings to the clinical setting. Table 1 provides an overview of the several kinds of biocides used in disinfectants and antiseptics, together with information

on their chemical makeup and therapeutic use. It is crucial to remember that a lot of these biocides can be used separately or in combination to create a range of solutions with varying levels of antimicrobial activity. Numerous factors, including formulation effects, the presence of an organic load, synergy, temperature, dilution, and test method, might affect antimicrobial effectiveness. These topics are covered elsewhere and are outside the purview of this review. The term "biocide" refers to a broad-spectrum chemical agent that inactivates microorganisms. Other terms may be more specific, such as "-static," which refers to agents that inhibit growth (e.g., bacteriostatic, fungistatic, and sporistatic) and agents that kill the target organism (e.g., sporicidal, virucidal, and bactericidal), because biocides vary in their antimicrobial activity. For the purposes of this review, antibiotics are defined as naturally occurring or synthetic organic substances that, usually at low concentrations, inhibit the growth of bacteria or other microorganisms; antiseptics are biocides or products that do the same (e.g., surgical scrubs and hand washes for healthcare personnel); and disinfectants are similar but typically are products or biocides that are used on inanimate objects or surfaces. Although they are not always sporicidal, disinfectants can be sporicidal. A physical or chemical procedure known as sterilization eliminates or totally destroys all microbiological life, including spores. Preservation is the process of stopping germs from growing in prepared goods, such as meals and medications. Cleaning in these contexts refers to the physical removal of foreign material from a surface, and certain biocides are also employed for this purpose.

II. CLASSIFICATION OF ANTISEPTICS AND DISINFECTANTS

1. Alcohols:

Ethyl alcohol (ethanol, alcohol), isopropyl alcohol (isopropanol, propan-2-ol), and n-propanol (especially in Europe) are the most commonly utilized alcohols, despite the fact that several others have been demonstrated to be efficient antimicrobials. Although they are not sporicidal, alcohols have quick broad-spectrum antibacterial effect against viruses, fungi, and vegetative bacteria, including mycobacteria. Though this effect is reversible, they are known to prevent sporulation and spore germination. Alcohols are frequently used for skin antiseptics and hard surface

disinfection; however, they are not advised for sterilization due to their lack of sporicidal activity. It is also possible to employ lower quantities as preservatives and to increase the potency of other biocides. Low amounts of other biocides, like chlorhexidine, which stay on the skin after the alcohol evaporates, or excipients, such as emollients, which shorten the time it takes for the alcohol to evaporate and can greatly boost product efficacy, are found in many alcohol products. Phenol causes progressive intracellular component leakage, which includes the release of radioactivity from ¹⁴C-labeled *E. coli* and K1, the initial sign of membrane disruption. According to Lumb and Pulvertaft, low doses of phenols (0.032%, 320 mg/ml) and other (nonphenolic) substances lysed rapidly growing cultures of *E. coli*, staphylococci, and streptococci, and it was found that autolytic enzymes were not involved. Younger bacterial cells are more vulnerable to phenol than older cells, and phenol only functions where pairs of daughter cells split apart

2. Aldehydes:

Glutaraldehyde. Glutaraldehyde is a significant dialdehyde that has been used as a fixative in electronics and as a disinfectant and sterilant, especially for low-temperature sterilization and disinfection of endoscopes and surgical instruments.

- Glutaraldehyde action:

More than with mature spores, but still less than with vegetative cells, during germination and outgrowth. low level of focus. Spores of bacteria High quantities are sporicidal, most likely due to a strong contact with outer cell layers, while low concentrations prevent germination.

Although the exact mechanism of action of mycobacteria is unknown, it most likely involves their cell walls. Other bacteria that don't sporulate Strong attachment to gram-positive and gram-negative bacteria's outer layers; protein cross-linking of amino groups; and suppression of cell transport mechanisms fungi. The main target location seems to be the fungal cell wall.

- Chlorhexidine action:

pH 8.3 inactivates it. To put it another way, poliovirus RNA is far less sensitive than the entire poliovirus particle. This has led to the conclusion that capsid

alterations are linked to glutaraldehyde-induced loss of infectivity. The poliovirus and echovirus capsid proteins interact with glutaraldehyde at low concentrations of 0.05 and 0.005%, respectively. The two viruses' significant structural differences are most likely the cause of the sensitivity disparities. In order to learn more about the mechanisms of virucidal activity, bacteriophages were recently examined. The empty heads of many glutaraldehyde-treated dP aeruginos an F116 phage particles suggested that the phage genome had been expelled. The double-chlorhexidine action of F116 may have bound the aldehyde.

3. Anilides:

Although they are infrequently employed in clinical settings, the anilides have mostly been studied for their potential as antiseptics. The most researched member of this series, triclo carban (TCC; 3,4,4'-trichlorocarbanilide), is primarily found in consumer soaps and deodorants. TCC lacks noticeable substantivity (persistence) for the skin and is especially effective against gram-positive bacteria, but it is much less effective against gram-negative bacteria and fungus. It is believed that the anilides cause cell death by attaching themselves to the cytoplasmic membrane and damaging its semi-permeable nature.

4. Biguanides:

As a disinfectant and preservative, chlorhexidine is arguably the most commonly used biocide in antiseptic products, especially in oral and hand washing products. This is especially because of its low irritation, substantivity for the skin, and broad-spectrum efficacy. Notably, irritability has been reported and is frequently product-specific. Despite its benefits, chlorhexidine's activity is pH dependant and significantly diminished when organic matter is present. Most of the focus has been on how this significant bisbiguanide stimulates non-sporulating bacteria, although a significant amount of study has been done on the mechanism of its antimicrobial effect. However, enough information is now available to investigate its antiviral activity, effects on yeasts and protozoa, and sporostatic and mycobacteriostatic action. Harold et al. reported that chlorhexidine inhibited net K1 absorption in *Enterococcus faecalis* and both membrane-bound and soluble ATPase. But only membrane-bound ATPase is inhibited by high

biguanide concentrations, indicating that the enzyme is not the main target of chlorhexidine activity. Chlorhexidine compresses the membrane potential; however, its fatal effects are linked to it's unclear why it has no effect on the former process yet significantly interferes with the latter. However, the relative absorption of chlorhexidine may indicate this, as bisbiguanide is absorbed by germination cells far less than by outgrowing forms. Therefore, binding sites in germinating cells may be fewer or hidden.

5. Phenols:

Depending on the substance, phenolic type antimicrobial agents have long been utilized for their antiseptic, disinfecting, or preserving qualities. For many years, people have been aware of it. that despite their frequent designation as "general protoplasmic poisons," they also possess membrane- active characteristics that add to their overall activity. K+, the initial sign of membrane disruption, and radioactivity from 14C-labeled *E. coli* are among the intracellular components that gradually leak out when exposed to phenol. Lumb and Pulvert showed that autolytic enzymes were not involved in the lysis of rapidly growing cultures of *E. coli*, staphylococci, and streptococci at low concentrations of phenols (0.032%, 320µg/ml) and other (non-phenolic) agents. Younger bacterial cells are more sensitive to phenol than older ones, according to Srivastava and Thompson's theory, which states that phenol only acts at the point where pairs of daughter cells separate. Progressive intracellular component leakage is caused by phenol, including the release of radioactivity from 14C-labeled *E. coli* and K1, the first indicator of membrane breakdown. Lumb and Pulvertaft showed that low. Rapidly growing cultures of *E. coli*, staphylococci, and streptococci were lysed by doses of phenols (0.032%, 320 mg/ml) and other (nonphenolic) chemicals, and it was determined that autolytic enzymes were not involved. According to Srivastava and Thompson, phenol only operates where pairs of daughter cells separate, and younger bacterial cells are more susceptible to phenol than older cells. Using the chlorinated bisphenol fenticlor, Hugo and Bloomfield demonstrated a strong correlation between bactericidal activity and 260-nm-absorbing material leakage, with the latter being triggered solely by bactericidal concentrations. Fenticlor impacted *S. aureus* and *E. coli* metabolic processes and resulted in a specific rise

in permeability to protons, which causes the proton motive force (PMF) to dissipate and oxidative phosphorylation to uncouple. The activity of chlorocresol is similar. Hugo has described the coagulation of cytoplasmic contents at higher phenol concentrations, which results in irreversible cellular damage.

6. Diamidines:

Table 1 provides a chemical description of the diamidines. Propamidine (4,4-diaminodiphenoxypropane) and dibromo propamidine (2,2-dibromo-4,4-diamidinodiphenoxypropane) are two chemicals that have been employed as antibacterial agents in their ethionate salt form. Hugo and Russell studied their antibacterial qualities and application. Diamidines are applied topically to wounds in clinical settings.

Although diamidines' precise mode of action is uncertain, it has been demonstrated that they prevent oxygen uptake and cause amino acid leakage, which is consistent with their classification as cationic surface-active agents. There have been reports of *P. aeruginosa* and *Enterobacter cloacae* cell surface damage.

7. Peroxygens:

Peroxide of hydrogen. One common biocide for antiseptics, sterilization, and disinfection is hydrogen peroxide (H₂O₂). Commercially available in a range of concentrations from 3 to 90%, it is a transparent, colorless liquid. H₂O₂ is regarded as environmentally benign due to its quick breakdown into the harmless byproducts of oxygen and water. The majority of solutions contain stabilizers to stop decomposition, even though pure solutions are usually stable. H₂O₂ exhibits broad-spectrum effectiveness against bacteria, yeasts, viruses, and bacterial spores.

At low concentrations (0.3%), peracetic acid (PAA) (CH₃COOOH) exhibits sporicidal, bactericidal, virucidal, and fungicidal properties, making it a more powerful biocide than hydrogen peroxide. Although PAA likewise breaks down into harmless byproducts like oxygen and acetic acid, it has the extra benefits of not being broken down by peroxidases like H₂O₂ and continuing to function even when organic loads are present.

8. Bis-Phenols:

Two phenolic groups joined by different bridges form the hydroxy halogenated derivatives known as bis-phenols. They have broad-spectrum efficacy overall, although they are not very active against molds or *P. aeruginosa*, and they are a resporostatic against bacterial spores. The most popular biocides in this category are triclosan and hexa chlorophane, particularly in hand rinses and antiseptic soaps. It has been demonstrated that both substances have long-lasting and cumulative effects on the skin (Triclosan). 2,4,4'-trichloro-2'-hydroxydiphenyl triclosan. Particular efficacy against gram-positive bacteria is demonstrated by ether; Irgasan DP300. Formulation effects can greatly increase its effectiveness against gram-negative bacteria and yeasts. For instance, triclosan and EDTA together increased the outer membrane's permeability. Additionally, reports have indicated that triclosan may have anti-inflammatory effect in addition to its antibacterial qualities.

9. Halogen-Releasing Agents:

The most important microbicidal halogens utilized in clinical settings are compounds based on chlorine and iodine, which have long been employed for both antiseptic and disinfection applications. Agents that release chlorine. There are excellent studies available that address the physical, chemical, and microbiological characteristics of chlorine-releasing agents (CRAs).

Sodium hypochlorite, chlorine dioxide, and N-chloro compounds like sodium dichloro isocyanurate (NaDCC) are the most significant kinds of CRAs, however chloramine-T is also utilized to a lesser degree. Human immunodeficiency virus, or HIV, -containing blood spills can be cleaned with sodium hypochlorite solutions, which are commonly used for hard surface cleaning (household bleach). NaDCC offers the benefits of having a larger concentration of accessible chlorine and being less vulnerable to inactivation by organic matter, making it suitable for this use as well. Na⁺ and the hypochlorite ion OCl⁻ are produced when sodium hypochlorite ionizes in water, creating an equilibrium with the hypochlorous acid HOCl. The active moiety of chlorine is primarily HClO between pH 4 and pH 7, although OCl⁻ predominates above pH 9. Novel acidified sodium chlorite, a two-component system of sodium chlorite

and mandelic acid, has employed CRAs primarily as hard surface disinfectants.

10. Quaternary Ammonium Compounds:

The molecular architectures of surface-active agents, or surfactants, contain two regions: a hydrocarbon group that repels water (hydro-drophobic) and another group that attracts water (hydro-philic or polar). Surfactants are categorized as cationic, ionic, non-ionic, and ampholytic (amphoteric) chemicals based on the charge or lack of ionization of the hydrophilic group. The most effective antiseptics and disinfectants among them are cationic agents, such as quaternary ammonium compounds (QACs). They are occasionally referred to as cationic detergents. QACs have been used to mucosal membranes, disinfect noncritical surfaces, and disinfect unbroken skin prior to surgery, among other clinical uses. QACs are great for cleaning and deodorizing hard surfaces in addition to their antibacterial qualities. The fact that QACs are membrane active agents that is, with a target site primarily at the cytoplasmic (inner) membrane in bacteria or the plasma membrane in yeasts—has long been known. According to Salton, bacteria exposed to cationic agents can cause the following effects: (i) adsorption and penetration into the cell wall; (ii) reaction with the cytoplasmic membrane (protein or lipid) followed by membrane disarray; (iii) intracellular low-molecular-weight material leakage; (iv) protein and nucleic acid degradation; and (v) wall lysis brought on by autolytic enzymes. Thus, in addition to other detrimental effects on the bacterial cell, bacteria experience a loss of structural order and integrity of the cytoplasmic membrane.

11. Silver Compounds:

Silver and its compounds have long been employed as antimicrobials in one form or another. Although silver metal, silver acetate, silver nitrate, and silver protein—all of which have antibacterial qualities—are listed in Martindale, The Extra Pharmacopoeia, silver sulfadiazine (AgSD) is currently the most significant silver compound in use. Silver compounds have been employed in recent years to eradicate warts and prevent the spread of burns and certain eye infections.

12. Polyhexamethylene biguanides (PHMB):

an approximate molecular weight of 3,000. In the food business, polymeric biguanides are used as general

disinfectants. They have also been used to disinfect swimming pools with great success. Although *P. aeruginosa* and *Proteus vulgaris* are less susceptible, vantocil is effective against both gram-positive and gram-negative bacteria. It is not sporicidal, vantocil. Although the outer membrane of gram-negative bacteria may potentially function as a permeability barrier, PHMB, a membrane-active substance, also compromises the integrity of the membrane. With increasing levels of polymerization, which has been connected to improved dinner membrane perturbation, the activity of PHMB rises on a weight basis.

III. NEW AND EMERGING ANTISEPTIC AGENTS

1. Hypochlorous Acid (HOCl):

White blood cells naturally create this potent antimicrobial, which oxidizes the proteins and membranes of microorganisms.

Used as a nasal and oral hygiene spray, for wound care, and for surface disinfection.

2. Octenidine Dihydrochloride:

A contemporary antiseptic agent that works by rupturing microbial cell membranes and preventing replication, it has broad-spectrum effectiveness against bacteria, fungi, and certain viruses. utilized for surgical preparation, mucosal antiseptics, and wound care. Compared to previous medicines like iodine, it is thought to be less cytotoxic.

3. Cetylpyridinium Chloride (CPC):

- Uses: Oral care items, throat sprays, mouthwashes, and certain dermatological formulations.
- Advantages: Antibacterial and antiviral qualities, lowers tooth plaque, and stops bacteria from adhering to surfaces.
- Mechanism: CPC is a cationic surfactant that disrupts bacterial and viral membranes, leading to leakage of cellular contents and cell death.
- Applications in Oral Care: CPC is widely used in mouthwashes for preventing dental plaque, gingivitis, and bad breath. It has also shown efficacy against SARS-CoV-2 in recent studies.
- Safety and Considerations: While CPC is generally well-tolerated, excessive use may lead to mild

staining of teeth and taste alterations in some individuals

4. Iron Oxide Nanoparticles (Fe_2O_3 , Fe_3O_4 - Magnetite):

- Used in antimicrobial coatings, wound dressings, and drug delivery systems.
- Works by generating ROS and disrupting bacterial cell walls.

5. Applications of Iron Nanoparticles in Antiseptics:

- Medical Wound Dressings: Improves healing by preventing infections.
- Hospital Surfaces and Instruments: Antimicrobial coatings on surgical tools and equipment.
- Water Purification: Removes bacteria from drinking water.
- Food Packaging: Prevents microbial contamination.

IV. CHITOSAN-BASED ANTISEPTICS:

Introduction:

The natural biopolymer chitosan is made from chitin, which is present in the shells of crustaceans, such as shrimp and crabs. Because of its broad-spectrum antibacterial qualities, non-toxicity, and biodegradability, it has drawn interest as an antiseptic.

Uses of DBSA-Based Antiseptics:

- Surface Disinfectants: Used in hospitals and industries for cleaning medical equipment.
- Hand Wash & Sanitizers: Found in alcohol-free antiseptic hand washes.
- Oral Hygiene Products: Present in some mouthwashes for its antiplaque effects.
- Skin Antiseptics: Used in medicated soaps and anti-acne treatments.

Advantages:

- Strong antibacterial, antifungal, and antiviral properties
- Stable over a wide pH range, making it effective in different conditions
- Long-lasting antimicrobial activity compared to traditional surfactants

Dodecyl benzenesulfonic Acid (DBSA) – A Newer Surfactant-Based Antiseptic:

Introduction:

An anionic surfactant with potent antibacterial and detergent qualities is dodecyl benzenesulfonic acid (DBSA). Because of its capacity to degrade microbial membranes and eliminate impurities, it is frequently found in medications, industrial disinfectants, and personal care products.

DBSA is commonly found in:

- Household disinfectants
- Hand washes and body washes
- Pharmaceutical antiseptic formulations
- Oral care products
- Surface cleaners in hospitals

Advantages of DBSA as an Antiseptic:

- Broad-spectrum antimicrobial activity (bacteria, fungi, viruses)
- Stable across different pH levels (remains effective in various conditions)
- Long-lasting antimicrobial effect compared to traditional detergents
- Non-volatile, meaning it does not easily evaporate, ensuring prolonged action

V. CHLOROXYLENOL (PCMX) – A BROAD-SPECTRUM ANTISEPTIC:

Introduction:

PCMX (Para-chloro-meta-xylenol), another name for chloroxylenol, is a phenolic antiseptic that is frequently found in personal hygiene, household, and medical products. Numerous well-known antiseptic solutions, including Dettol, contain it as their active ingredient.

PCMX is known for its broad-spectrum antimicrobial activity, particularly against:

- Gram-positive and Gram-negative bacteria
- Fungi and yeasts
- Some viruses

It is commonly used in hand washes, antiseptic soaps, wound disinfectants, and surgical scrubs.

- Uses of PCMX-Based Antiseptics:

Wound Disinfectants:

Used in first aid solutions to clean cuts, wounds, and burns.

Helps prevent bacterial infections in minor injuries.

Surgical Scrubs & Hospital Disinfectants:

- Found in preoperative surgical scrubs to sterilize hands before surgery.
- Used in hospital surface disinfectants to prevent cross-contamination.

Hand Washes & Soaps:

- PCMX is widely used in antiseptic hand washes to prevent infections.
- It provides long-lasting protection against bacteria, fungi, and some viruses.

Personal Hygiene & Skin Care:

- Present in medicated soaps, body washes, and feminine hygiene products.
- Used to treat skin conditions like acne, eczema, and dermatitis

VI. RATIONAL OF THE STUDY

Public Health Importance:

- Infection Control:

Globally, nosocomial infections—hospital-acquired infections— are a major source of illness and mortality. General wound infections, catheter-associated infections, and surgical site infections can all be decreased with the use of effective antiseptics.

- Pandemics:

The necessity of efficient antiseptics for preserving hygiene and stopping viral transmission was highlighted by the COVID-19 pandemic.

Antimicrobial Resistance (AMR):

- Microorganisms develop resistance as a result of the overuse and abuse of antiseptics. It's crucial to comprehend resistance mechanisms and identify substitutes.
- To fight AMR, research into new antiseptics is crucial, such as solutions based on natural compounds or nanoparticles.

Advances in Technology:

- New opportunities for efficacy and patient compliance are presented by the development of antiseptics that incorporate hydrogels, sustained-release formulations, and nanotechnology.
- The drawbacks of the antiseptics used today, such as their toxicity, irritation, and environmental impact, can also be addressed by technological developments.

Global Health Needs:

- The prevalence of avoidable infections can be considerably decreased in low-resource environments with the provision of safe and affordable antiseptics, especially for the health of mothers and new-borns.
- Reducing infection-related fatalities requires addressing worldwide inequalities in access to potent antiseptics.

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