Current Pain and Headache Reports (2021) 25: 21
https://doi.org/10.1007/s11916-021-00938-3

CHRONIC PAIN MEDICINE (O VISWANATH, SECTION EDITOR)

Disinfectants In Interventional Practices

Mayank Aranke[1,2] · **Roya Moheimani**[3] · **Melissa Phuphanich**[3] · **Alan D. Kaye**[4] · **Anh L. Ngo**[5,6] · **Omar Viswanath**[4,7,8,9] · **Jared Herman**[10]

Accepted: 19 January 2021 / Published online: 11 March 2021

Abstract

Purpose of Review This review aims to provide relevant, aggregate information about a variety of disinfectants and antiseptics, along with potential utility and limitations. While not exhaustive, this review's goal is to add to the body of literature available on this topic and give interventional providers and practitioners an additional resource to consider when performing procedures.

Recent Findings In the current SARS-CoV2 epidemiological environment, infection control and costs associated with healthcare-associated infections (HAIs) are of paramount importance. Even before the onset of SARS-CoV2, HAIs affected nearly 2million patients a year in the USA and resulted in nearly 90,000 deaths, all of which resulted in a cost to hospitals ranging from US$28 billion to 45 billion. The onset SARS-CoV2, though not spread by an airborne route, has heightened infection control protocols in hospitals and, as such, cast a renewed focus on disinfectants and their utility across different settings and organisms.

Summary The aim of this review is to provide a comprehensive overview of disinfectants used in the inpatient setting.

Keywords Disinfectants · SARS-COV2 · Inpatient · Healthcare-associated infections · Interventional practices

Introduction

Disinfectants can be broadly defined as chemical agents used on inanimate objects to neutralize most known pathogenic microorganisms—though not all known microbial forms (i.e., endospores) [1••]. Although often used interchangeably with antiseptics, the key difference between disinfectants and antiseptics is that the latter typically refers to substances applied to living tissues as opposed to inanimate objects—for infection control [2••, 3•]. On a more granular level, disinfectants and antiseptics can be further broken down by the mechanism of action, typical medical use, efficacy, and safety of their active chemical agents (biocides) [1••, 3•]. Antiseptics and disinfectants are used routinely in an effort to prevent nosocomial (hospital-acquired) infections, particularly so in interventional practices.

In the current SARS-CoV2 epidemiological environment, infection control and costs associated with healthcare-associated infections (HAIs) are of paramount importance. Even before the onset of SARS-CoV2, HAIs affected nearly 2 million patients a year in the USA and resulted in nearly 90,000 deaths, all of which resulted in a cost to hospitals ranging from US$28 billion to 45 billion [4•]. The onset SARS-CoV2, though not spread by an airborne route, has

---

This article is part of the Topical Collection on Chronic Pain Medicine

✉ Jared Herman
hermanajared@gmail.com

[1] Department of Anesthesiology, University of Texas Health Science Center, Houston, TX, USA

[2] Harvard T.H. Chan School of Public Health, Boston, MA, USA

[3] Department of Physical Medicine and Rehabilitation, VA Greater Los Angeles Health Care System, Los Angeles, CA, USA

[4] Department of Anesthesiology, Louisiana State University Health Sciences Center, New Orleans, LA, USA

[5] Harvard Medical School, Boston, MA, USA

[6] Pain Specialty Group, Newington, NH, USA

[7] Valley Pain Consultants, Phoenix, AZ, USA

[8] Department of Anesthesiology, University of Arizona College of Medicine-Phoenix, Phoenix, AZ, USA

[9] Department of Anesthesiology, Creighton University School of Medicine, Omaha, NE, USA

[10] Department of Anesthesiology, Mount Sinai Medical Center, Alton Road Miami Beach, FL 4300, USA

heightened infection control protocols in hospitals and, as such, cast a renewed focus on disinfectants and their utility across different settings and organisms [5•].

This review aims to provide relevant, aggregate information about a variety of disinfectants and antiseptics, along with potential utility and limitations. While not exhaustive, this review's goal is to add to the body of literature available on this topic and give interventional providers and practitioners an additional resource to consider when performing procedures.

Alcohol

Alcohol has been used as a disinfectant for several decades and possibly as early as the 1800s. In the healthcare setting, ethyl-alcohol (ethanol) or isopropyl-alcohol are considered the two most effective disinfectants, with 70% ethanol considered generally superior to isopropyl alcohol [6•]. Alcohols work as disinfectants primarily through the denaturation of microbial proteins. This mechanism of action is supported by a variety of studies, including work done with *E. Coli* dehydrogenases, *Enterobacter Aerogenes*, and the influenza virus [6•, 7•, 8•].

Alcohols, at 60–70% concentration, have several decades of data and studies accounting for their bactericidal, viricidal, tuberculocidal, and fungicidal properties. As such, they are commonly used for surface and hand disinfection, both in and out of healthcare settings [9•, 10•, 11•, 12•, 13•, 14••] However, alcohols do not contain sufficient sporicidal activity for the sterilization of surgical and procedural tools [15•]. For this reason, alcohols are not useful as disinfectants for sterile and invasive procedures, or in the intensive care unit—where alcohol-based disinfection has been associated with an increased rate of bloodstream infections [16•].

Besides its limitations in sterile procedure, alcohol is also a known corrosive material and can damage tubes, lines, lenses, and other components of medical equipment over time and prolonged exposure—rubber and plastic tubing, glass lenses, and shellac lens coatings are particularly susceptible to damage from prolonged disinfection with alcohol [14••]. Additionally, it is a known fact that alcohols are flammable, and care must be taken to ensure proper storage and ventilation while using them as disinfectants.

Chlorine and Chlorine Compounds

Sodium Hypochlorite

Sodium hypochlorite, also known as bleach, has been in use for many years. Its mechanism of action involves the ion hypochlorite, formed when dissolved into an aqueous solution. Hypochlorite works against both viruses and bacteria but is less efficacious against endospore-forming bacteria and fungi [17•]. Both the acidity of the solution, along with the concentration of the hypochlorite are important in its germicidal action and cleaning efficiency [18•]. Clinically, it is used in healthcare settings for decontaminating water systems. It can be used directly to disinfect surfaces, laundry, blood spills, and directly on equipment. It is also strong enough to decontaminate medical waste [17•]. More recently, it has been paired with UV light to turn over hospital rooms [19•]. Bleach paired with UV light has increased efficacy against Clostridium difficile and its spores. As a sole agent, sodium hypochlorite has shown effective bactericidal action against Staphylococcus aureus and Pseudomonas aeruginosa [20•]. More importantly, evidence suggests that sodium hypochlorite is able to eliminate the biofilms formed by Pseudomonas aeruginosa. Escherichia coli and Ebola virus from patient bodily fluids/feces were also found to be completely interrupted by exposure to .5% hypochlorite exposure [21•].

Safety precautions when using sodium hypochlorite include avoiding direct contact, as irritation can occur, which can range from mild dermatitis to necrosis of the skin [17•]. It can also cause severe irritation with mucus membranes, gastrointestinal tract, and conjunctiva. However, the incidence of injury secondary to sodium hypochlorite in the healthcare setting is deemed to be low [17•].

Sodium Dichloroisocyanurate

Sodium dichloroisocyanurate is another chlorine-containing compound that ionizes into an oxidizing bactericidal and cytotoxic agent [22•]. While sodium hypochlorite has been used for over two centuries as a disinfectant, sodium dichloroisocyanurate was introduced in the past 50 years as a synthetic disinfectant, similar to sodium hypochlorite in the mechanism, but heralded as more effective in bactericidal activity [23•]. Its medical uses include purifying drinking water, irrigating in endodontic procedures, and disinfecting surfaces [21•, 24•, 25•, 26•]. It can be dissolved from its tablet form into a solution or hydrolyzed into a gaseous chlorine compound [27•]. Sodium dichloroiocyanurate has shown efficacy against human immunodeficiency virus (HIV), mycobacterium tuberculosis, human corona virus 229e, Staphylococcus aureus, and Pseudomonas aeruginosa [28•, 29•, 30•].

For safety, a color additive can be added to sodium dichloroisocyanurate, which turns the solution blue, which then turns colorless as the compound evaporates to enhance safety [30•]. Much like sodium hypochlorite, sodium dichloroisocyanurate is a mild irritant to skin and mucus membranes.

Chlorine Dioxide

Chlorine dioxide works as a strong oxidant that is bactericidal and antimicrobial [31•]. In the medical field, it is used in the liquid form typically. Evidence has shown that chlorine dioxide gas solutions are strongly antiviral and even stronger than a standard sodium hypochlorite solution [32•]. It can also be used to purify hospital water systems, with bactericidal activity against non-tuberculosis mycobacterium, legionella, and gram-negative rods [33•, 34•]. Additionally, chlorine dioxide can safely be used to decontaminate medical waste, showing efficacy against human immunodeficiency virus [35•]. Chlorine dioxide has also been traditionally used to sterilize medical equipment [36•]. This sterilization process can be precluded with heating or an autoclaving process.

For safety, as a gas, chlorine dioxide can cause irritation to the respiratory tract and with direct contact as a solution, is an irritant to skin and eyes [37•]. There is also a concern when chlorine dioxide is used to purify water systems; it leaves behind carcinogenic by-products [38•].

Super-Oxidized Water

Super-oxidized water is a more novel disinfectant, produced by running sodium chloride through regular tap water while running an electric current, causing electrolysis. This produces a high concentration of chlorine and oxygen reactive species [39•]. Super-oxidized water has been utilized for its antimicrobial properties as it is both bactericidal and antiviral [40•, 41•]. Although it is not as commonly used as sodium hypochlorite, super-oxidized water is used medically as a disinfectant for simple surfaces, root canals, wounds, and reusable medical devices [39•, 42•, 43•]. In the order of minutes, super-oxidized water is proposed to be effective against human immunodeficiency virus, Myobacterium tuberculosis, Candida albicans, and Pseudomonas aeruginosa [40•].

For safety, super-oxidized water is an irritant to the skin for some [44•]. However, it is safe enough to be used in wound care, as mentioned above.

Formaldehyde

Formaldehyde is a chemical that is well known to cause direct DNA damage and hampers DNA repair, which is why formaldehyde has been implicated as a chemical that is both mutagenic and carcinogenic [45•, 46•]. For this reason, direct contact with skin is avoided, and it is used more for disinfection of spillages, heat-sensitive hospital equipment, and hemodialysis machinery [36•, 47•, 48••]. Formaldehyde is usually administered in liquid form but is known to aerosolize, as evidenced by the concern for its indoor pollution of anatomy labs [49•]. However, it is a powerful agent with efficacy against gonorrhea, HIV, hepatitis B virus, chlamydia, and mycoplasma.

For safety, there is a concern for the reproductive harm that comes with exposure with formaldehyde, including infertility, seen in animal studies [50•, 51•]. Formaldehyde is also an irritant to skin, putting users at risk for dermatitis and urticaria [52•, 53•].

Glutaraldehyde

Glutaraldehyde is widely used in the chemistry world to immobilize and fix proteins [54•]. The chemical accomplishes this by cross-linking proteins causing them to gel. In the medical world, glutaraldehyde is used to disinfect hospital instruments and dialysis systems [28•, 48•, 55•]. Typically, a 2% solution of glutaraldehyde works well to eliminate microbes, soaking for about 5–10 min. Efficacy has been shown against Mycobacterium, Pseudomonas, Staphylococcus aureus, severe acute respiratory syndrome coronavirus, human immunodeficiency virus, and hepatitis B [55•, 56•, 57•].

For safety, a barrier is recommended when handling glutaraldehyde, as contact dermatitis is a common reaction observed among healthcare workers who handle the chemical [58•, 59•]. A study found that healthcare workers tend to have eight times more allergic reactions to glutaraldehyde than their non-healthcare worker counterparts. Gluaraldehyde can also be toxic to the respiratory system, increasing the potential risk of bronchitis and nasal symptoms [60•]. However, no evidence exists of the carcinogenic or genetic toxicity of glutaraldehyde in animal studies. Caution is still recommended as small amounts of glutaraldehyde can cause adverse effects.

Hydrogen Peroxide

Hydrogen peroxide works as an oxidizing agent when used as a disinfectant [61•]. It has a strong appeal in that it eventually decomposes to non-toxic compounds, oxygen, and water. It is also popular in its lack of strong odor and reduced surface corrosiveness. Hydrogen peroxide can be used in both as a liquid, aerosolized gas, or topical wipe [62•, 63•, 64•]. In the medical field, it is used for cleaning surfaces, turning over hospital rooms, and disinfecting ambulances. Hydrogen peroxide has shown efficacy against spore and biofilm-forming bacteria and both DNA and RNA viruses, including coronavirus [20•, 24•, 65•, 66•].

For safety, gloves should be used when handling hydrogen peroxide, as it can cause allergic dermatitis [67•]. It is an irritant to human tissue and can cause a direct cytotoxic effect, especially if ingested [68•]. However, once hydrogen peroxide decomposes, with exposure to sunlight, it becomes inert.

Iodophors

Iodophors, e.g., povidone-iodine (PVP-I), are widely used as an antiseptic to prevent and treat wounds. PVP-I, or "Betadine," is an iodophor solution containing water-soluble iodine (the microbicidal element) and polyvinylprrolidone (PVP). This complex works by slowly releasing free iodine upon contact with tissues. Through the iodination of lipids and oxidation of cytoplasmic and membrane compounds, this agent effectively kills bacteria, fungi, protozoa, and viruses [69•]. The PVP component itself has no bactericidal properties, but its affinity for cell membranes allows it to deliver the iodine to the target [70•]. Then the gradual release of iodine minimizes toxicity to mammalian tissues while preserving the agent's germicidal activity [69•].

Iodophor preparations are most commonly used to disinfect skin prior to injections, invasive procedures, and surgery. It is an extremely effective broad-spectrum microbicidal agent with no known bacterial resistance, which makes it an ideal agent for broader use. Interestingly, low concentrations of PVP-I have been demonstrated to be more effective antimicrobials in chemistry literature [70•]. This paradoxical effect is likely due to the increased free-iodine available in more dilute solutions [71•]. Lower concentrations of PVP-I have a variety of alternative applications as disinfectants and as topical therapeutic agents. For example, a diluted ophthalmic formulation is used before most invasive ocular procedures [70•]. There is also an established utility of these preparations as prophylactic and therapeutic agents in neonatal and pediatric conjunctivitis [72•, 73•]. Several studies demonstrate the use of dilute PVP-I in otitis media, otitis externa, and even chronic otomycosis [74•, 75•]. Investigators have also shown iodophor preparations to safely and effectively prevent respiratory infections and treat sinusitis [76•, 77•]. A variety of studies support dilute Betadine use in chronic, non-healing wounds (e.g., diabetic foot ulcers) to reduce bacterial colonization [70•].

PVP-I is one of the rare topical microbicidal agents shown to be effective against viruses, fungi, spores, protozoa, amoebic cysts, and bacteria, including strains known to cause nosocomial infections (i.e., methicillin-resistant Staphylococcus aureus) within 20–30 seconds of exposure ([78•]. In contrast, comparators such as chlorhexidine require much longer exposure times [79•]. However, one study determined that the sequential application of povidone-iodine-alcohol (PVI) followed by chlorhexidine gluconate-alcohol reduces surgical wound contamination more effectively than PVI applied twice [80•]. There is also increasing evidence of bacterial resistance to comparable antiseptics, including chlorhexidine, quaternary ammonium salts, silver, and triclosan. Remarkably, there have been no confirmed reports of resistance to PVP-I, likely due to its multiple mechanisms of action [78•, 81•].

PVP-I is generally well-tolerated by most patients, especially when used as a topical. In contrast to chlorhexidine, PVP-I is scarcely associated with allergic contact dermatitis, with urticarial or anaphylactic reactions exceedingly rare. An EU Safety Assessment Report included data involving 6.9 g of PVP-I applied to the hands and forearms and concluded that the use of iodine for hand disinfection is suitable for human health [81•]. Although generally safe, cases of thyroid dysfunction have been reported with long-term use. For that reason, PVP-I product labeling includes general warnings against patients with thyroid disorders, very low birth weight infants, and the patient receiving radio-iodine therapy [78•].

Peracetic Acid and Hydrogen Peroxide:

Peracetic acid (PAA) is an emerging disinfectant with a low potential to form carcinogenic disinfection by-products and no persistent residues in the environment [82•, 83•]. PAA (CH_3COOOH) is a mixture of acetic acid (CH_3COOH) and hydrogen peroxide (H_2O_2) in a watery solution. PAA acts as a disinfectant by oxidizing the outer cell membranes of microorganisms [84•]. PAA preparations are registered Environmental Protection Agency disinfectants with rapid activity against bacterial, fungi, viruses, mycobacteria, and spores [85•].

This hydrogen peroxide based-liquid is mainly used as a surface disinfectant for environmental cleaning to prevent healthcare-associated infections. PAA is most commonly used in automated machines designed to sterilize medical equipment (e.g., endoscopes, dental instruments), and in a formulation with hydrogen peroxide to disinfect hemodialyzers [85•].

PAA and hydrogen peroxide are strong oxidants widely used in cleaning and disinfectant products; however, their mixture is a recognized asthmagen. Hospital cleaning staff using these products report work-related aggravation of the eye, upper airway, lower airway, and contact dermatitis symptoms. Acute eye and nasal irritation and shortness of breath are associated with increased exposure to this oxidant mixture [86•]. However, there is no evidence of any endocrine disruption potential of PAA in human health or in ecotoxicological studies [82•].

Phenolics

Phenol (carbolic acid) is the first widely used antiseptic in surgery. In 1865, British surgeon Joseph Lister used phenol to sterilize his operating field, and his mortality rate for surgical amputations dropped by about 38% [87•]. Phenolic compounds work by targeting the cell membrane.

At high concentrations, phenol acts as a gross protoplasmic poison to denature bacterial proteins and lyse the cell membrane [88•]. Low concentrations of phenol and high molecular weight phenol derivatives kill bacteria by inactivating essential enzyme systems, resulting in the leakage of key metabolites from the cell wall [89•].

Phenol is active against a wide variety of microorganisms, including some fungi and viruses, but is only slowly effective against some spores [90•]. It is bacteriostatic at concentrations of 0.1–1% and considered bactericidal, tuberculocidal, fungicidal, virucidal for enveloped viruses at their recommended use-dilution in commercial products [91•, 92•]. Many phenolic germicides are EPA-registered disinfectants for environmental surfaces (e.g., exam tables, bedrails) and noncritical medical devices. However, phenolic compounds are not approved by the Federal Drug Administration (FDA) as high-level disinfectants for use on semi-critical devices. Though, phenolics could be used to preclean or decontaminate critical and semi critical equipment prior to high-level sterilization [89•].

Phenol is an antiseptic and disinfectant with variable actions and adverse effects dependent on the concentration. Concentrations > 0.5% have a local anesthetic effect and are used in products such a Chloraseptic throat spray and lozenges to treat pharyngitis [90•]. Phenol is used to topically treat pruritis, stings, and burns because its local anesthetic and antibacterial properties relieve itching and decrease infections [91•].

Phenol penetrates organic matter effectively; however, at higher concentrations (i.e., 5% solution), phenol is strongly irritating and corrosive to tissues. Thus, it is mainly used to disinfect equipment or organic materials that will be destroyed (i.e., contaminated food or excrement). Due to its irritant and corrosive properties at higher concentrations, phenol is no longer commonly used as an antiseptic, except to cauterize infected areas—such as infected umbilicus in neonates [91•]. Phenol is also used in the surgical treatment of ingrown toenails to permanently destroy the problematic nail edge [90•].

Phenol in concentrated solutions is toxic. During World War II, the Nazis used phenol injections to execute prisoners [90•]. Oral ingestion or extensive cutaneous application can devastate the central nervous and cardiovascular systems to result in systemic toxicity and death [91•]. Phenol vapors are corrosive to the skin, eyes, and respiratory tract. Exposure to phenol and its related compounds is also associated with spontaneous abortion [90•]. Phenol disinfectants may cause skin irritation, skin depigmentation, local burns, headaches, vomiting, diarrhea, and kidney damage in severe cases [89•, 92•].

The use of phenolics is especially cautioned in nurseries due to its association with hyperbilirubinemia when infants were placed in bassinets cleaned with phenolic detergents. If phenolics are used to clean nursery floors, they must be diluted to the recommended concentration by the manufacturer. Phenolics are now contraindicated in cleaning infant bassinets and incubators while occupied. If the phenolics are used to terminally disinfect bassinets and incubators, these surfaces must be thoroughly rinsed with water and dried prior to reuse [89•].

Quaternary Ammonium Compounds

Quaternary Ammonium Compounds (QACs) are cationic surface-active agents with a permanent positive charge that allows them to readily bind to the negatively charged surface of most microbes [93•]. The bactericidal properties of quaternaries are due to the inactivation of energy-producing enzymes, denaturation of essential cell proteins, and disruption of the cell membrane [89•]. There are numerous commercially available products and formulations of QACs. Some examples of chemical names of QACs used in healthcare include alkyl dimethyl benzyl ammonium chloride, alkyl didecyl dimethyl ammonium chloride, and dialkyl dimethyl ammonium chloride [89•].

Quaternaries sold as hospital disinfectants are generally fungicidal, bactericidal, and viricidal against lipophilic (enveloped) viruses given that their primary mechanism of action is via disruption of cell membranes [89•]. Only limited formulations have claimed activity against mycobacteria, and QACs are generally not sporicidal or viricidal against hydrophilic (nonenveloped) viruses [94•]. Manufacturer data and published scientific literature indicates that QACs effectively remove an/or inactivate > 95% contaminants, including multidrug-resistant Staphylococcus *aureus*, vancomycin-resistant *Enterococcus*, Pseudomonas *aeruginosa*, from computer keyboards with a 5-s application time without any functional or cosmetic damage to the computer keyboards, even after 300 applications of the disinfectant [89•].

Nosocomial infections have resulted from using contaminated QACs to disinfect procedural medical equipment, such as cystoscopes or cardiac catheters [89•]. Additionally, cotton and gauze pads can absorb the active ingredients of quaternaries, and decrease the microbicidal properties. Case reports have recognized occupational asthma as a result of exposure to benzalkonium chloride, a QAC [89•].

Quaternaries are commonly used in the environmental sanitization of noncritical surfaces (i.e., floors, furniture, and walls). EPA-registered QACs are appropriate to use for disinfecting medical equipment that contacts intact skin (e.g., blood pressure cuffs), according to the Center for Disease Control and Prevention [89•].

Discussion and Conclusion

Acutely understanding the difference between various disinfectants is paramount for optimizing patient safety and lowering hospital infection rates. In 2020, more so than otherwise, the importance of proper disinfection technique and use has been at the forefront of the healthcare landscape. Our review of the multiple modalities used for disinfection and sanitization, particularly for invasive, inpatient procedures, aims to elucidate the mechanisms, uses, and in some cases, drawbacks of multiple chemical disinfectants. We hope that adding a comprehensive, topical ledger of disinfectants to the existing body of literature is timely, judicious, and ultimately, helpful to the healthcare community as reference resource.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance •• Of outstanding importance

1.•• Dancer SJ. Controlling hospital-acquired infection: Focus on the role of the environment and new technologies for decontamination. Clin Microbiol Rev. 2014 **Defines disinfectants for the use of neutralization of possibly pathogenic microorganisms**.

2.•• Alfa MJ, Lo E, Olson N, Macrae M, Buelow-Smith L. Use of a daily disinfectant cleaner instead of a daily cleaner reduced hospital-Acquired infection rates. Am J Infect Control. 2015; **Defines the difference between antiseptic and disinfectant techniques for the reader.**

3.• Doll M, Stevens M, Bearman G. Environmental cleaning and disinfection of patient areas. Int J Infect Diseases. 2018; **This reference provides the framework of the disinfection process by explaining the disinfection of both inanimate surfaces as well as living, human tissue.**

4.• Stone PW. Economic burden of healthcare-associated infections: an American perspective. Expert Rev Pharmacoeconomics Outcomes Res. 2009; **Outlines the $28 billion to $45 billion estimated yearly financial burden due to hospital acquired infections in the hospital.**

5.• Wong SCY, Kwong RTS, Wu TC, Chan JWM, Chu MY, Lee SY, et al. Risk of nosocomial transmission of coronavirus disease 2019: an experience in a general ward setting in Hong Kong. J Hosp Infect. 2020; **Explains the increased focus on disinfecting of patient areas in the setting of the SARS-CoV2 pandemic.**

6.• World Health Organization (WHO). Infection prevention and control of epidemic- and pandemic-prone acute respiratory infections in health care. WHO Guidel. 2014; **This article outlines the efficacy of alcohol and isopropyl alcohol in disinfecitng surfaces in relation to hospital acquired infections.**

7.• Sykes G. The Influence of Germicides on the dehydrogenases of Bact. coli. J Hyg. 1939; **Outlines the mechanism of germicides and their effect on bacterial structure and function.**

8.• Dagley S, Dawes EA, Morrison GA. Inhibition of growth of aerobacter aerogenes: the mode of action of phenols, alcohols, acetone, and ethyl acetate. J Bacteriol. 1950; **This article describes the effect of several chemicals on inhibiting growth of aerobacter aerogenes.**

9.• Kruse RH, Green TD, Chambers RC, JONES MW. Disinfection of aerosolized pathogenic fungi on laboratory surfaces. Appl Microbiol. 1964; **Outlines the role of alcohol in disinfecting surfaces containing fungal elements in the labarotory setting.**

10.• Kruse RH, Green TD, Chambers RC, Jones MW. Disinfection of aerosolized pathogenic fungi on laboratory surfaces. I. Appl Microbiol. 1963; **This article explains several ways to disinfect laboratory surfaces possibly contanimated with fungal elements spread through an aersolized manner.**

11.• Kurtz JB, Lee TW, Parsons AJ. The action of alcohols on rotavirus, astrovirus and enterovirus. J Hosp Infect. 1980; **This article provides the reader with information on the inhibition of rotavirus, astrovirus and enterovirus growth.**

12.• Smith CR. Alcohol as a disinfectant against the tubercle bacillus. Public Health Rep. 1947; **Provides the reader with details on alcohol's effifacy against disinfecting surfaces contanimated with tubercle bacillus.**

13.• Kampf G. Efficacy of ethanol against viruses in hand disinfection. J Hosp Infection. 2018. **Explains to the reader ethanol's efficacy in disinfecting one's hands if contanimated with several types of known viruses.**

14.•• Harrington C, Walker H. The Germicidal Action of Alcohol. Bost Med Surg J. 1903; **Outlines the action of alcohol in relation to its germicidal properties.**

15.• Nye RN, Mallory TB. A Note on the Fallacy of using Alcohol for the Sterilization of Surgical Instruments. Bost Med Surg J. 1923; **Provides the reader with an essential piece of information. This article describes how alcohol is ineffective in disinfecting spores present on surgical and procedural tools.**

16.• Beck-Sague CM, Jarvis WR. Epidemic Bbloodstream Infections Associated with Pressure Transducers: a persistent problem. Infect Control Hosp Epidemiol. 1989; **Explains the relation of alcohol-based disinfection with increased rates of bloodstream infections in the intensive care unit.**

17.• Rutala WA, Weber DJ. Uses of inorganic hypochlorite (bleach) in health-care facilities. Clin Microbiol Rev. 1997. **Explains the mechanism of inorganic hypochlorite. Also highlights inorganic hypochlorite's inefficacy agaisnt the disinfecting of endo-spore forming bacteria and fungi.**

18.• Fukuzaki S. Mechanisms of actions of sodium hypochlorite in cleaning and disinfection processes. Biocontrol Sci. 2006. **Highlights the two factors in relation to inorganic hypochlorite's germicidal activity: both it's acidity and concentration of hypochlorite.**

19.• Anderson DJ, Chen LF, Weber DJ, Moehring RW, Lewis SS, Triplett PF, et al. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and Clostridium difficile (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study. Lancet. 2017;389(10071):805–14 **This article explains enhanced disinfecting protocols with the turnover of hospital rooms and their effect on clostridium difficule. This article provides the reader with information on the combination of UV light for hospital room turnover.**

20.• Lineback CB, Nkemngong CA, Wu ST, Li X, Teska PJ, Oliver HF. Hydrogen peroxide and sodium hypochlorite disinfectants are more effective against Staphylococcus aureus and Pseudomonas aeruginosa biofilms than quaternary ammonium compounds. Antimicrob Resist Infect Control. 2018; **Demonstrates sodium hypochlorite's ability to eliminate Staphylococcus aureus and Pseudomonas aeruginosa.**

21.• Gallandat K, Wolfe MK, Lantagne D. Surface cleaning and Disinfection: Eefficacy aAssessment of four chlorine tTypes uUsing Escherichia coli and the Ebola Surrogate Phi6. Environ Sci Technol. 2017; **This article provides the reader with information about 0.5% hypochlorite's effects on eliminating both Escherichia coli and Ebola virus when in bodily fluid/ feces.**

22.• Heling I, Rotstein I, Dinur T, Szwec-Levine Y, Steinberg D. Bactericidal and cytotoxic effects of sodium hypochlorite and sodium dichloroisocyanurate solutions in vitro. J Endod. 2001; **Explains to the reader how sodium dichloroisocyanurate, another chloride containing compound, ionizes into an oxidizing bactericial and cytotoxic agent.**

23.• Bloomfield SF, Miles GA. The Antibacterial Properties of Sodium Dichloroisocyanurate and Sodium Hhypochlorite Formulations. J Appl Bacteriol. 1979; **This article is important to the reader as it explains how the newer sodium dichloroisocyanurate, introduced in the last 50 years, is more effective in relation to bactericidal activity.**

24.• Marques SC, Rezende JDGOS, Alves LADF, Silva BC, Alves E, De Abreu LR, et al. Formation of biofilms by Staphylococcus aureus on stainless steel and glass surfaces and its resistance to some selected chemical sanitizers. Brazilian J Microbiol. 2007; **Provides further information to the reader about the efficacy of sodium dichloroisocyanurate is disinfecting stainless steel and glass surfaces.**

25.• Clasen T, Edmondson P. Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level. Int J Hyg Environ Health. 2006; **Highlight's one of sodium dichloroisocyanurate's many uses, treatment of drinking water at the consumer, household level.**

26.• Lantagne DS, Cardinali F, Blount BC. Disinfection by-product formation and mitigation strategies in point-of-use chlorination with sodium dichloroisocyanurate in Tanzania. Am J Trop Med Hyg. 2010; **Explains to the reader the utilization of sodium dichloroisocyanurate in Tanzania for point-of-use chloronation.**

27.• Proto A, Zarrella I, Cucciniello R, Pironti C, De Caro F, Motta O. Bactericidal and Fungicidal aActivity in the gas phase of sodium dDichloroisocyanurate (NaDCC). Curr Microbiol. 2016. **Provides the reader with an additional form of sodium dichloroisocyanurate that is efficacious in eliminating bacteria and fungi: use in its gaseous form when hydrolyzed.**

28.• Griffiths PA, Babb JR, Fraise AP. Mycobactericidal activity of selected disinfectants using a quantitative suspension test. J Hosp Infect. 1999; **Highlight's sodium dichloroisocyanurate effectiveness in disrupting mycobacterial structure and function.**

29.• Bloomfield SF, Smith-Burchnell CA, Dalgleish AG. Evaluation of hypochlorite-releasing disinfectants against the human immunodeficiency virus (HIV). J Hosp Infect. 1990; **Highlight's sodium dichloroisocyanurate effectiveness in disrupting HIV structure and function.**

30.• Tyan K, Kang J, Jin K, Kyle AM. Evaluation of the antimicrobial efficacy and skin safety of a novel color additive in combination with chlorine disinfectants. Am J Infect Control. 2018; **Highlight's sodium dichloroisocyanurate effectiveness in disrupting overall microbial structure and function. Also explains its safety mechanism: it's blue color that dissapears when evacuated.**

31.• Ma JW, Huang BS, Hsu CW, Peng CW, Cheng ML, Kao JY, et al. Efficacy and safety evaluation of a chlorine dioxide solution. Int J Environ Res Public Health. 2017; **Explanation of the mechanism of chlorine dioxide, which is both bactericidal and antimicrobial when used in the medical setting.**

32.• Sanekata T, Fukuda T, Miura T, Morino H, Lee C, Maeda K, et al. Evaluation of the antiviral activity of chlorine dioxide and sodium hypochlorite against feline calicivirus, human influenza virus, measles virus, canine distemper virus, human herpesvirus, human adenovirus, canine adenovirus and canine parvovirus. Biocontrol Sci. 2010; **Explains the strong antiviral activity of chlorine dioxide and tells the reader that it is even stronger (as an antiviral agent) than standard sodium hypochlorite solution.**

33.• Hsu MS, Wu MY, Huang YT, Liao CH. Efficacy of chlorine dioxide disinfection to non-fermentative Gram-negative bacilli and non-tuberculous mycobacteria in a hospital water system. J Hosp Infect. 2016; **This article provides the reader with the efficacy of chlorine dioxide in disinfecting against gram negative bacilli and non-tuberculous mycobacteria in hospital water systems.**

34.• Murphy KL. Water sampling for Legionella: Managing Positive Results. Biol Blood Marrow Transplant. 2014; **This article provides the reader with the efficacy of chlorine dioxide in disinfecting legionella in water systems.**

35.• Farr RW, Walton C. Inactivation of Human Immunodeficiency Virus by a Medical waste disposal Process Using Chlorine Dioxide. Infect Control Hosp Epidemiol. 1993**; Highlight's chlorine dioxide's ability to eliminate HIV in the disposal of medical waste.**

36.• Govindaraj S, Muthuraman MS. Systematic review on sterilization methods of implants and medical devices. Int J ChemTech Res. 2015; **Explains the role of chlorine dioxide in sterilizing medical equipment such as implants and medical devices prior to implantation.**

37.• Gómez-López VM. Chlorine dDioxide. In: Encyclopedia of Toxicology: 3rd Edition. 2014. **Safety information about chlorine dioxide; Chlorine dioxide can cause irritation to the respiratory tract and with direct contact as a solution, is an irritant to skin and eyes.**

38.• Krasner SW. The formation and control of emerging disinfection by-products of health concern. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. 2009. **Explains the carcinogenic by-products of chlorine dioxide (when used to purify water systems).**

39.• Gutierrez A a. The science behind stable, super-oxidized water. Wounds. 2006; **Explanation of the mechanism of super-oxidized water in producing high concentrations of chlorine and reactive oxygen species.**

40.• Gunaydin M, Esen S, Karadag A, Unal N, Yanik K, Odabasi H, et al. In vitro antimicrobial activity of Medilox® super-oxidized water. Ann Clin Microbiol Antimicrob. 2014; **Demonstrates super-oxidized water in eliminating both bacterial and viral elements.**

41.• Selkon JB, Babb JR, Morris R. Evaluation of the antimicrobial activity of a new super-oxidized water, Sterilox®, for the disinfection of endoscopes. J Hosp Infect. 1999; **Outlines the use of oxidized water in the disinfecting of medical equipment such as endoscopes prior to their use in diagnostic and therapeutic procedures.**

42.• Rossi-Fedele G, de Figueiredo JAP, Steier L, Canullo L, Steier G, Roberts AP. Evaluation of the antimicrobial effect of super-oxidized water (sterilo®) and sodium hypochlorite against enterococcus faecalis in a bovine root canal model. J Appl Oral Sci. 2010; **Tells the reader that super-oxidized water has a role in root canal procedures, although this article is a bovine, animal model.**

43.• Eftekharizadeh F, Dehnavieh R, Hekmat SN, Mehrolhassani MH. Health technology assessment on super oxidized water for treatment of chronic wounds. Med J Islam Repub Iran. 2016; **Explains the role of super-oxidized water in the role of antiseptic treatment of chronic wounds.**

44.• Dalla Paola L, Brocco E, Senesi A, Merico M, De Vido D, Assaloni R, et al. Super-oxidized solution (SOS) therapy for infected diabetic foot ulcers. Wounds. 2006; **Explains the role of super-oxidized water in the role of antiseptic treatment of diabetic foot ulcers.**

45.• Yoshida I, Ibuki Y. Formaldehyde-induced histone H3 phosphorylation via JNK and the expression of proto-oncogenes. Mutat Res - Fundam Mol Mech Mutagen. 2014; **Formaldehyde is a chemical that is well known to cause direct DNA damage and hamper DNA repair. This article outlines formaldehyde-induced histone H3 phosphorylation via JNK and the expression of proto-oncogenes.**

46.• Yang G, Komaki Y, Yoshida I, Ibuki Y. Formaldehyde inhibits UV-induced phosphorylation of histone H2AX. Toxicol Vitr. 2019; **Formaldehyde is a chemical that is well known to cause direct DNA damage and hamper DNA repair. This article**

outlines formaldehyde inhibition of UV-induced phosphorylation of histone H2AX.

47.• Griffiths PA, Babb JR, Fraise AP. Mycobacterium terrae: Aa potential surrogate for Mycobacterium tuberculosis in a standard disinfectant test. J Hosp Infect. 1998; **Formaldehyde, in this article, is tested in disinfecting surfaces contaminated with mycobacterium terrae, a surrogate for mycobacterium tuberculosis in this instance.**

48.•• Galvao TF, Silva MT, Araujo MEDA, Bulbol WS, Cardoso ALDMP. Dialyzer reuse and mortality risk in patients with end-stage renal disease: Aa systematic review. Am J Nephrol. 2012. **Explains the role of formaldehyde in the disinfection of dialysis equipment and machinery**.

49.• D'Ettorre G, Criscuolo M, Mazzotta M. Managing Formaldehyde indoor pollution in anatomy pathology departments. Work. 2017. **Formaldehyde is usually administered in liquid form but is known to aerosolize, as evidenced by the concern for its indoor pollution of anatomy labs.**

50.• Razi M, Malekinejad H, Sayrafi R, Hosseinchi MR, Feyzi S, Moshtagion SM, et al. Adverse effects of long-time exposure to formaldehyde vapour on testicular tissue and sperm parameters in rats. Vet Res Forum Int Q J. 2013; **Outlines another effect of long-time exposure to formaldehyde. This article is an animal study rather than a human longitudinal study.**

51.• Vosoughi S, Khavanin A, Salehnia M, Asilian Mahabadi H, Shahverdi A, Esmaeili V. Adverse effects of formaldehyde vapor on mouse sperm parameters and testicular tissue. Int J Fertil Steril. 2013; **Outlines another effect of long-time exposure to formaldehyde. This article is an animal study rather than a human longitudinal study.**

52.• Jang JH, Park SH, Jang HJ, Lee SG, Park JH, Jeong JW, et al. A case of recurrent urticaria due to formaldehyde release from root-canal disinfectant. Yonsei Med J. 2017; **Formaldehyde is also an irritant to skin, putting users at risk for urticaria.**

53.• Simon M, Van Mullem PJ, Lamers AC. Allergic skin reactions provoked by a root canal disinfectant with reduced formaldehyde concentration. Int Endod J. 1984; **Formaldehyde is also an irritant to skin, putting users at risk for dermatitis and urticaria.**

54.• Walt DR, Agayn VI. The chemistry of enzyme and protein immobilization with glutaraldehyde. TrAC - Trends Anal Chem. 1994. **Provides the reader with an outlook on the wide uses of glutaraldehyde in the world of chemistry. In this instance, to immobilize and fix proteins.**

55.• Herruzo-Cabrera R, Uriarte MC, Rey-Calero J. Antimicrobial effectiveness of 2% glutaraldehyde versus other disinfectants for hospital equipment, in an in vitro test based on germ-carriers with a high microbial contamination. Rev Stomatol Chir Maxillofac. 1999; **This article details the many uses of glutaraldehyde against several bacteria and viruses.**

56.• Kariwa H, Fujii N, Takashima I. Inactivation of SARS coronavirus by means of povidone-iodine, physical conditions and chemical reagents. In: Dermatology. 2006. **This article details the use of glutaraldehyde against SARS coronavirus. This is directly applicable to the current SARS-CoV2 global pandemic.**

57.• Babb J, Ayliffe G, Bradley C, Jackson M, Johnson M, Taylor E, et al. Decontamination of minimally invasive surgical endoscopes and accessories. J Hosp Infect. 2000; **This article details the many uses of glutaraldehyde against several bacteria and viruses.**

58.• Suneja T, Belsito D V. Best practices for the safe use of glutaraldehyde in health care. Contact Dermatitis. 2008; **Outlines the risk of contact dermatitis and recommends best safety practices for those handling glutaraldehyde.**

59.• Shaffer MP, Belsito D V. Allergic contact dermatitis from glutaraldehyde in health-care workers. Contact Dermatitis. 2000; **Outlines the risk of contact dermatitis for those handling glutaraldehyde in several cases among healthcare workers.**

60.• Takigawa T, Endo Y. Effects of glutaraldehyde exposure on human health. J Occup Health. 2006. **Further demonstration of the health risks associated with the handling of glutaraldehyde. Gluaraldehyde can be toxic to the respiratory system, increasing the potential risk of bronchitis and nasal symptoms.**

61.• Linley E, Denyer SP, McDonnell G, Simons C, Maillard JY. Use of hydrogen peroxide as a biocide: Nnew consideration of its mechanisms of biocidal action. J Antimicrobial Chemother. 2012. **Explanation of the mechanism in which hydrogen peroxide can disinfect surfaces: oxidizing agent.**

62.• Andersen BM, Rasch M, Hochlin K, Jensen FH, Wismar P, Fredriksen JE. Decontamination of rooms, medical equipment and ambulances using an aerosol of hydrogen peroxide disinfectant. J Hosp Infect. 2006; **Details how hydrogen peroxide can be used in the healthcare setting for decontamination of rooms and surfaces. Hydrogen peroxide can be used in both as a liquid, aerosolized gas, or topical wipe.**

63.• Andersen BM, Syversen G, Thoresen H, Rasch M, Hochlin K, Seljordslia B, et al. Failure of dry mist of hydrogen peroxide 5% to kill Mycobacterium tuberculosis. Int J Infect Dis. 2010; **Details how one form of hydrogen peroxide is ineffective in eliminating mycobacterium tuberculosis. Hydrogen peroxide can be used in both as a liquid, aerosolized gas, or topical wipe.**

64.• Ferrari M, Bocconi A, Anesi A. Evaluation of the effectiveness of environmental disinfection by no touch hydrogen peroxide technology against MDR bacteria contamination and comparison with active chlorine disinfectant. Antimicrob Resist Infect Control. 2015; **No touch hydrogen peroxide technology and its efficacy against MDR bacteria contamination. Hydrogen peroxide can be used in both as a liquid, aerosolized gas, or topical wipe.**

65.• Boyce JM. Modern technologies for improving cleaning and disinfection of environmental surfaces in hospitals. Antimicrobial Resistance and Infection Control. 2016. **Explains the efficacy in disinfecting against spore and biofilm-forming bacteria and both DNA and RNA viruses, including coronavirus.**

66.• Kampf G, Todt D, Pfaender S, Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. Journal of Hospital Infection. 2020. **Hydrogen peroxide has shown efficacy against spore and biofilm-forming bacteria and both DNA and RNA viruses, including coronavirus.**

67.• Lind ML, Johnsson S, Lidén C, Meding B, Boman A. The influence of hydrogen peroxide on the permeability of protective gloves to resorcinol in hairdressing. Contact Dermatitis. 2015; **Explains an integumentary risk associated with the handling of hydrogen peroxide, contact dermatitis.**

68.• Watt BE, Proudfoot AT, Vale JA. Hydrogen peroxide poisoning. Toxicol Rev. 2004. **Lays out other risks associated with the use of hydrogen peroxide exposure for the reader.**

69.• National Center for Biotechnology Information. PubChem Database. Povidone iodine, CID = 410087, https://pubchem.ncbi.nlm.nih.gov/compound/410087 (accessed on June 15 2020). No Title. **Provides the mechanism in which iodophors, e.g. povidone-iodine, for the reader. Through the iodination of lipids and oxidation of cytoplasmic and membrane compounds, this agent effectively kills bacteria, fungi, protozoa, and viruses**

70.• Capriotti K, Capriotti JA. Topical iodophor preparations: chemistry, microbiology, and clinical utility. Dermatol Online J.

2012;18(11):1 **Further clarification of povidone-iodine's mechanism of action. The PVP component itself has no bactericidal properties, but its affinity for cell membranes allows it to deliver the iodine to the target.**

71.• Berkelman RL, Holland BW, Anderson RL. Increased bactericidal activity of dilute preparations of povidone-iodine solutions. J Clin Microbiol. 1982;15(4):635–9 **Provides the reader an interesting point regarding the effectiveness of povidone-iodine; Interestingly, low concentrations of PVP-I have been demonstrated to be more effective antimicrobials in chemistry literature, likely due to the increased free-iodine available in more dilute solutions.**

72.• Isenberg SJ, Apt L, Wood M. A controlled trial of povidone-iodine as prophylaxis against ophthalmia neonatorum. N Engl J Med. 1995;332(9):562–6 **This article provides an example of, and establishes utility of these preparations as prophylactic agents in neonatal and pediatric conjunctivitis.**

73.• Isenberg SJ, Apt L, Valenton M, Del Signore M, Cubillan L, Labrador MA, et al. A controlled trial of povidone-iodine to treat infectious conjunctivitis in children. Am J Ophthalmol. 2002;134(5):681–8 **This article provides an example of, and establishes the utility of these preparations as therapeutic agents in neonatal and pediatric conjunctivitis.**

74.• Jaya C, Job A, Mathai E, Antonisamy B. Evaluation of topical povidone-iodine in chronic suppurative otitis media. Arch Otolaryngol Head Neck Surg. 2003;129(10):1098–100 **This article provides an example of topical povidone-iodine being used in the treatment of suppurative otitis media.**

75.• http://www.waent.org/archives/2008/vol1/chronic_otitis_externa/otomycosis.htm. No Title. p. http://www.waent.org/archives/2008/vol1/chronic_ot. **This article provides an example of topical povidone-iodine being used in the treatment of chronic otitis externa and otomycosis.**

76.• Nagatake T, Ahmed K, Oishi K. Prevention of respiratory infections by povidone-iodine gargle. Dermatology. 2002;204(Suppl):32–6 **This article provides the reader with an example of respiratory infection prophylaxis utilizing povidone-iodine.**

77.• Kaliner M. Treatment of sinusitis in the next millennium. Allergy Asthma Proc. 1998;19(4):181–4 **This article provides the reader with an example of sinusitis treatment utilizing povidone-iodine.**

78.• Bigliardi PL, Alsagoff SAL, El-Kafrawi HY, Pyon J-K, Wa CTC, Villa MA. Povidone iodine in wound healing: aA review of current concepts and practices. Int J Surg. 2017;44:260–8 **This outlines uses of povidone-iodine in the setting of chronic wounds and their healing. Outlines the broad spectrum of microorganisms in which povidone-iodine is effective against.**

79.• Yasuda T, Yoshimura Y, Takada H, Kawaguchi S, Ito M, Yamazaki F, et al. Comparison of bactericidal effects of commonly used antiseptics against pathogens causing nosocomial infections. Part 2. Dermatology. 1997;195(Suppl):19–28 **This article compares povidone-iodine and chlorhexidine. Chlorhexidine is noted to require longer exposure to the organsim of interest to be effective.**

80.• Patrick S, McDowell A, Lee A, Frau A, Martin U, Gardner E, et al. Antisepsis of the skin before spinal surgery with povidone iodine-alcohol followed by chlorhexidine gluconate-alcohol versus povidone iodine-alcohol applied twice for the prevention of contamination of the wound by bacteria: a randomized controlled trial. Bone Joint J. 2017;99-B(10):1354–65 **This article provides an interesting point to the reader. This study determined that the sequential application of povidone-iodine-alcohol (PVI) followed by chlorhexidine gluconate-alcohol reduces surgical wound contamination more effectively than PVI applied twice.**

81.• Eggers M. Infectious Disease Management and Control with Povidone Iodine. Infect Dis Ther. 2019;8(4):581–93 **Further proves to the reader that there have been no confirmed reports of resistance to PVP-I, likely due to its multiple mechanisms of action.**

82.• Domínguez Henao L, Turolla A, Antonelli M. Disinfection by-products formation and ecotoxicological effects of effluents treated with peracetic acid: Aa review. Chemosphere. 2018;213:25–40 **Reviews the toxicological effects of periacetic acid for the reader. Peracetic acid (PAA) is an emerging disinfectant with a low potential to form carcinogenic disinfection by-products and no persistent residues in the environment.**

83.• Zhang C, Brown PJB, Hu Z. Thermodynamic properties of an emerging chemical disinfectant, peracetic acid. Sci Total Environ. 2018;621:948–59 **Outlines the thermodynamic properties of periacetic acid for the reader. Importantly, it leaves no persistent residues in the environment.**

84.• https://www.lenntech.com/processes/disinfection/chemical/disinfectants-peracetic-acid.htm. No Title. Periacetic acid, or PAA, acts as a disinfectant by oxidizing the outer cell membranes of microorganisms.

85.• Leas BF, Sullivan N, Han JH, Pegues DA, Kaczmarek JL, Umscheid CA. No Title. Rockville (MD); 2015. **Outlines the many uses of PAA, including activity against bacterial, fungi, viruses, mycobacteria, and spores.**

86.• Hawley B, Casey M, Virji MA, Cummings KJ, Johnson A, Cox-Ganser J. Respiratory Symptoms in Hospital Cleaning Staff Exposed to a product containing hydrogen peroxide, peracetic acid, and acetic acid. Ann Work Expo Heal. 2017;62(1):28–40 **This article explains the risks associated with increased exposure to PAA. Acute eye and nasal irritation and shortness of breath are associated with increased exposure to this oxidant mixture.**

87.• phenol | Definition, Structure, Uuses, & Facts | Britannica. Phenol (carbolic acid) is the first widely used antiseptic in surgery. Interestingly, In 1865, **British surgeon Joseph Lister used phenol to sterilize his operating field, and his mortality rate for surgical amputations dropped by about 38%.**

88.• Maris P. Modes of action of disinfectants. Rev Sci tech Off Int Epiz. 1995;14(1):47–55 **This article explains the mechanism of action of phenolics. At high concentrations, phenol acts as a gross protoplasmic poison to denature bacterial proteins and lyse the cell membrane.**

89.• https://www.cdc.gov/infectioncontrol/guidelines/disinfection/disinfection-methods/chemical.html. No Title. **This reference is interesting to the reader in that it explains the mechanism of phenols to the reader; Derivatives kill bacteria by inactivating essential enzyme systems, resulting in leakage of key metabolites from the cell wall.**

90.• https://www.drugbank.ca/drugs/DB03255. No Title. This article addresses some of phenol's limitations. **Phenol is active against a wide variety of microorganisms, including some fungi and viruses, but is only slowly effective against some spores.**

91.• https://www.merckvetmanual.com/pharmacology/antiseptics-and-disinfectants/phenols-and-related-compounds. No Title. **This article further clarifies the spectrum of acitivity of phenol against different microorganisms. It is bacteriostatic at concentrations of 0.1%–1% and considered bactericidal, tuberculocidal, fungicidal, virucidal for enveloped viruses at their recommended use-dilution in commercial products.**

92.• Safety O, Branch H. Chemical Ssafety in the workplace guidance notes on safe use of chemical disinfectants. **This reference is a**

great complement to the explanation of the mechanism, in that it clarifies the spectrum of microogranisms in which phenols are active against. It is bacteriostatic at concentrations of 0.1%–1% and considered bactericidal, tuberculocidal, fungicidal and virucidal for enveloped viruses.

93.• C.P. C. Encyclopedia of Food Microbiology. In: 2nd Edition. Second Edi. 2014. **This article defines Quaternary Ammonium Compounds, (QACs), which are cationic surface-active agents with a permanent positive charge that allows them to readily bind to the negatively charged surface of most microbes.**

94.• Mc Donnell G. Sterilization and disinfection. In: Encyclopedia of Microbiology. 3rd Edit. 2009. **This article defines some of the QAC's limitations. Only limited formulations have claimed activity against mycobacteria, and QACs are generally not sporicidal or viricidal against hydrophilic (nonenveloped) viruses.**