Controlling and Counteracting Bacterial, Fungal, and Viral Contamination in Water Treatment Equipment

A concise overview of prevailing theory and best practices within the industry.

NOTICE

While every reasonable effort has been taken to ensure the accuracy of the research data as presented, use of this and any other research data is at your own risk. Always consult with you local Certified Water Specialist before attempting any water treatment system sanitization procedure.

Original research summary compiled January 2001
Revision 4.3 - July 2009

Introduction

All water treatment systems are susceptible to bacterial contamination. Benign bacteria like HPC's can lurk in safe city water supplies and slowly colonize traditional water treatment equipment. Heterotrophic plate count (HPC) bacteria are a generally benign family of chlorine-resistant bacteria that inhabit most plumbing systems. HPCs are evident as part of the slimy coating that can be found on drinking filters and inside water softeners known as a 'biofilm'.

A biofilm is a collection or organic and inorganic material, as well as living and dead organisms, responsible for numerous water quality & distribution problems such as loss of residual disinfection levels, odors, color, microbial-induced corrosion, reduced material life and a reduction in dissolved oxygen content. While HPCs themselves are generally not harmful to human health, they can provide nutrition and protection for pathogenic organisms.

Pathogenic organisms can be introduced into a water quality management system through a variety of ways, including through the influent water supply, during regeneration, or through outside action. For this reason, biological risk management (BRM) protocols are necessary to prevent, contain and eliminate the colonization pathogenic and non-pathogenic entities within water treatment equipment.

Properly implemented disinfection protocols can be a cost-effective means of reducing both benign & pathogenic organisms. Prevention of contamination is obviously easier and more cost-effective than addressing an incident after colonization has occurred. The development and implementation of a step-by-step disinfection protocol for the control and prevention of bacterial contamination in water treatment equipment is essential for all installations, whether residential, commercial or industrial.

Disinfection protocols may vary depending on the need specific site. No single disinfectant or protocol is ideal for all situations. Always consult with your local Certified Water Specialist for location-specific guidelines.

The purpose of this document is to discuss:

- Factors to consider when developing and implementing an effective disinfection protocol
- Chemicals used for disinfection, their advantages and limitations
- Steps for developing an effective disinfection protocol.
- Procedures for maintaining ongoing system cleaning and disinfection

After the development of a disinfection protocol, it is equally important to train personnel of the proper procedures to use and safety issues involved as well as to have the procedures posted in prominent locations throughout the facility to serve as a reminder of proper disinfecting techniques.

Disinfectants

Disinfecting agents are registered by the Environmental Protection Agency (EPA) as "antimicrobial pesticides" and are substances used to control, prevent, or destroy harmful microorganisms (bacteria, viruses, or fungi) on inanimate objects and surfaces. These antimicrobial products have traditionally included **sterilizers**, **disinfectants** and **sanitizers**. (Data on a product's chemistry, efficacy, toxicity to humans, animals and plants, and other parameters are submitted to the EPA prior to the marketing of the chemical after comprehensive testing). **Antiseptics and germicides** are used to prevent infection and decay by inhibiting the growth of microorganisms. Since these products are used on or inside living humans or animals, they are considered drugs and are regulated by the food and drug administration (FDA); those products are outside the scope of this document.

Chemical disinfectants can have various effects against microorganisms. Therefore, a basic understanding of the different chemical agents is important.

Biocide or germicide refers to chemical agents that kill microorganisms. These general terms includes disinfectants, antiseptics and antibiotics. Germicides and biocides generally react with proteins, specifically essential enzymes of microorganisms. Actions may include oxidation, hydrolysis, denaturation or substitution. When a killing action is implied, the suffix –cide (biocide, bactericide, virucide, sporicide) is used, while –static (biostatic, bacteriostatic, virostatic, sporostatic) is added when an organism's growth is merely inhibited or it is prevented from multiplying.

Sanitizers do not destroy or eliminate all bacteria or microorganisms, but reduce the number of microbial contamination on inanimate surfaces to levels that are considered safe from a public health standpoint. Many sanitizers are a formulation of a detergent and disinfectant.

Disinfectant describes a product applied directly to an inanimate object. It destroys or irreversibly inactivates most pathogenic microorganisms, some viruses, but not usually spores. In comparison, antiseptics are applied to the surface of living organisms or tissues to prevent or stop the growth of microorganisms by inhibiting the organism or by destroying them.

Sterilization refers to the process, either physical or chemical that destroys or eliminates all forms of life, especially microorganisms.

Detergents serve to disperse and remove soil and organic material from surfaces allowing a disinfectant to reach and destroy microbes within or beneath the dirt. These products also reduce surface tension and increase the penetrating ability of water, thereby allowing more organic matter to be removed from surfaces. Some disinfectants have detergent properties (chlorine compounds, iodophors, and Quats). Detergents are classified in three categories: cationic, anionic and non-ionic. Cationic detergents are positively charged solutions, and with the exception or quaternary ammonium compounds, are seldom used as cleaning ingredients. Anionic detergents, or soaps, are negatively charged alkaline salts of fatty acids. They are less ideal for cleaning because they can be excessively foamy, creating a residue that may allow soil and microorganisms to accumulate. Nonionic (uncharged) detergents are very good emulsifiers, have good penetration and dispersion, are effective at lowering surface tension, and have reduced foaming properties. These products do not typically complex the metallic ions typically found in hard water. Most commercial detergents are a combination of anionic and non-ionic surfactants.

Disinfectant Labeling

Product labels contain important information on the proper use and potential hazards of a chemical. Strict attention must be given to the proper use of a product with regard to its application, effectiveness, and associated hazards (human, animal, and environmental).

Label Claims

Disinfectants may have a range of uses and label claims, such as cleaner, deodorizer, sanitizer, disinfectant, fungicide, Viricide or 'for hospital, institutional and industrial use'. Label claims are primarily determined by the product's efficacy against three test microorganisms: Staphylococcus aureus, Salmonella cholerasuis, and Pseudomonas aeruginosa.

Limited efficacy is a claim of disinfection or germicidal activity against one specific microorganism group (eg. Gram-negative or Gram-positive). Gram-positive designation comes from effectiveness against Staphylococcus aureus, while Gram-negative bacteria claims must be effective against Salmonella cholerasuis. The label must specify the group against which the product is effective.

General-purpose or broad-spectrum is a claim of effectiveness against Gram-positive **and** Gram-negative bacteria. This claim must be supported by efficacy testing against Staphylococcus aureus and Salmonella cholerasuis.

Hospital or medical environment claim must be supported by efficacy testing against S.aureus **and** S. cholerasuis but **also** efficacy against the nosocomial bacterial pathogen, Pseudomonas aeruginosa. Claims against pathogenic fungi or other microorganisms are permitted, but not required, on the label following standardized testing procedures.

Other Important Information on a Product Label and/or MSDS

Effectiveness of Product Under Certain Conditions. Product testing for the EPA requires testing under "hard" water conditions up to 400 ppm hardness ($CaCo_3$) in the presence of 5% serum contamination to simulate the product's effectiveness under field conditions. If the product is tested under additional conditions, it may be listed on the label.

Active Ingredients. The active ingredients of the product are listed as percentages and are the chemicals responsible for the control of the microorganisms.

Inert Ingredients. Biologically Inactive ingredients are often lumped into one statement and include items such as soaps or detergents, dyes or coloring agents, perfumes, and water.

Precautionary Statement/s describe the potential hazards of the product (to people or animals) and actions to take to reduce those hazards (wearing gloves or goggles). Specific "signal words" are used to indicate the degree of hazard. Descriptors used (from least harmful to most harmful) are: "Caution", "Warning", "Danger" and "Danger-Poison".

The **First Aid** section lists the actions to take in the event of accidental swallowing, inhalation or contact with the product. A **Notes to physicians** area may be listed with specific medical information needed by medical professionals and first responders.

Additional Precautionary Statements contained on the label includes additional safety and precautionary information such as environmental hazards, physical or chemical hazards, (corrosiveness or flammability), and storage and disposal information.

The **Directions for Use** section describes what the product controls, as well as where, how and when to use it. Some products may have multiple uses, require different dilutions and/or contact times for such specific actions (-cidal versus –static). The best application method to use with the product will also be listed.

Considerations and assessment for a disinfection action plan

Before selecting a disinfectant to use, there are several factors that must be considered. Some disinfectants are effective for routine disinfection protocols on water treatment equipment, while others are necessary for contamination situations. For an effective disinfection protocol, consideration should be given to the microorganism being targeted, the characteristics of a specific disinfectant, and operational environmental issues. Additionally, the health and safety of personnel are always the primary consideration.

Microorganism considerations

Microorganisms vary in their degree of susceptibility to disinfectants. In general, Gram-positive bacteria are more susceptible to chemical disinfectants while mycobacteria or bacterial endospores are more resistant. The hydrophilic, non-enveloped viruses (adenoviruses, picornaviruses, reoviruses, rotaviruses) are more resistant to disinfection than lipophilic, enveloped viruses (coronaviruses, herpesviruses, orthomyxoviruses, paramyxoviruses, retroviruses). Pathogenic microorganisms also vary in their ability to survive or persist in the environment additionally, some microorganisms are also effective at creating a biofilm that enhances their ability to survive and avoid the action of disinfectants. These also are important considerations when selecting a disinfectant and disinfection protocol to use. Whenever possible, the target microorganism should be identified, however if the organism has not been identified, a broad-spectrum approach should be used.

Disinfectant considerations

An ideal disinfectant is one that is broad spectrum, works in any environment and is non-toxic, non-irritating, non-corrosive and relatively inexpensive. Unfortunately, no known disinfectant meets all these criteria. Careful consideration of the characteristics of a disinfectant are essential to select the most useful, effective and cost-efficient product.

Disinfectant concentration. Use of the proper concentration of a disinfectant is important to achieve the best results for each situation. Some products will have different dilutions depending on the desired use of the product (-static versus –cidal action). Although some disinfectants may be more efficacious at higher concentrations, these levels may be limited by the degree of risk to personnel, surfaces or equipment, as well as the cost of the chemical. However, over-dilution of a product can render the disinfectant ineffective. The product label will list the best concentration to use for each situation.

Application method. There are a variety of ways to apply disinfectants. Disinfectants can be applied directly into an open media tank, injected through an automatic electronic disinfection injection apparatus, or through a regenerant feed tank.

Contact time. Appropriate contact times are essential. Disinfectants may vary in the contact time needed to kill versus inactivate microorganisms. i.e., 70% isopropyl alcohol can destroy M.tuberculosis in 5 minutes, whereas 3% phenol requires 2-3 hours. Minimum contact time needed is normally stated on the product label. Equipment being disinfected should be well soaked with the disinfectant selected to avoid dilution before the end of the optimum contact time. Some chemicals may have residual activity while others may dissipate and rinse away quickly.

Stability and storage. Some disinfectants lose stability quickly after being prepared for use or when stored over extended periods, especially in the presence of heat or ultraviolet light. Disinfectant product labels will list the shelf life of the concentrated product within a particular temperature range. To maximize stability and shelf life, products should be stored in a cool, dark place and preferably in standard concentrations. Use of an outdated or inactivated product will cause poor results.

Instructions for use. Misuse of a disinfection product is in direct violation of EPA regulations. The label of a disinfectant may include limitations of the product and must be followed carefully. This will ensure maximum effectiveness, as well as properly protecting workers, the equipment, and the environment.

Safety precautions. Most disinfectants can cause irritation to eyes, skin and/or the respiratory tract, therefore, the safety of all personnel should be considered. Training on proper storage, mixing and application procedures is essential. Personal protective equipment such as gloves, masks and eye protection, should be worn during the mixing or application of disinfectants. All disinfectants have a Material Safety Data Sheet (MSDS) listing the stability, hazards and personal protection needed, as well as first aid information. This information should be available to all personnel.

Expense. Economic considerations are always important when selecting a disinfectant. Since disinfectants vary in cost, contact time and dilution, costs should always be calculated on a per gallon of use/dilution rather than the cost of concentrate. Always place health and safety requirements before the false security of cost-savings.

Environmental considerations

Operating environmental factors can greatly impact the effectiveness of a disinfection protocol; Organic loads, equipment design, water hardness, temperature, pH, heavy metals, oils and other contaminants are all important environmental factors to consider.

Organic load. Removal of all organic material prior to application of a disinfectant is essential. The level of organic material within the equipment to be disinfected can greatly impact the efficacy of a disinfection protocol. Organic matter provides a physical barrier that protects microorganisms from contact with the disinfectant. Debris and organic material can also neutralize many disinfectants; especially chlorine and iodine containing compounds. Certain disinfectants may have some efficacy or residual activity in the presence of organic material and should be considered in circumstances where complete removal of organic debris before disinfection is difficult. However, application of these products to a heavy organic load (heavily fouled ion exchange media) is neither smart nor effective.

Equipment Design. The type of equipment to be disinfected can have a great impact on effectiveness of a disinfection plan. Equipment that includes electronic apparatus for the injection of a cleaning/disinfection fluid is much easier to work with than equipment that was never designed to be properly disinfected. Components used in the manufacture of the equipment also have an impact on the protocol, since most filtration media is extremely sensitive to oxidizing disinfectants. Porous, uneven, cracked, or pitted surfaces can protect microorganisms and are quite difficult to disinfect. An ideal surface to be disinfected is smooth, clean and non-porous.

Water hardness. The water source used when cleaning and diluting disinfectants is also important. Water hardness can inactivate or reduce the effectiveness of many disinfectants. Hard water contains calcium and magnesium ions at varying concentrations. These ions can react with certain cleaning/disinfection compounds, causing chemical precipitation, which may reduce their cleaning action. Many disinfection compounds include chelating agents, such as EDTA, to help bind these ions. Disinfectants should always be diluted with deionized water to ensure appropriate stochiometry.

Temperature. Most disinfectants work best at temperatures above 68°F. However, elevated temperatures may cause damage to the equipment being treated and increase the potential occupational hazard to personnel applying the disinfection protocol. Colder temperatures can reduce the efficacy of some products.

pH. The activity of some disinfectants is also affected by pH. For example, the efficacy of glutaraldehyde is entirely dependent on pH, working best at a pH greater than 7. Some quats have the greatest efficacy at pH of 9-10 while others are still effective down to pH levels as low as 6. The pH can dramatically affect the activity of phenolics, hypochlorite and iodine compounds.

Heavy Metals and other metallic ions in water can inactivate certain disinfectants while also potentially creating other complications due to precipitation of solids when using oxidative disinfectants and certain halides.

Oils in mineral or organic form can obstruct surface contact with disinfectants as well as creating undesirable byproducts. The equipment should be properly degreased before any disinfectant is applied to ensure consistent results.

Presence of other chemicals. Many other chemicals can affect the efficacy of disinfectants. For example, iodine agents are inactivated by quats, while phenols will achieve improved penetrability when applied with soaps or other surfactants. Always consult with your specifying engineer or manufacturer's representative to ensure that deleterious chemical interactions are not overlooked.

Health, safety and the environment. The health and safety of humans and other animals should always be a primary consideration when selecting a disinfectant product. Most disinfectants have some level of hazard associated with their use. Some disinfectants even pose a serious threat to human and animal health (aldehydes, phenols, sodium hydroxide). Personnel training, personal protective measures and safety precautions should always be taken. Environmental factors, such as septic tank discharge, sewer drainage, and runoff into the environment, must also be considered when selecting a disinfectant. Many agents are known ecological hazards for plants and aquatic life (sodium carbonate, hypochlorites, phenolics), therefore drainage, runoff, and biodegradability of disinfectants should be considered when developing a disinfection protocol.

Non-chemical Disinfection

In addition to chemical disinfectants, heat, light and radiation can also be appropriately used to reduce or eliminate microorganisms in a water treatment system. The use of heat is a one of the oldest methods of sterilization. Although both moist heat (steam or autoclave) and dry heat (direct flame or baking) can inactivate microorganisms, moist heat is much more effective and requires significantly less time than dry heat. Ultraviolet (UV) light can have a detrimental effect on a number of microorganisms and may be a practical method for inactivating viruses, mycoplasma, bacteria and fungi. UV light sterilizing capabilities are limited on surfaces because of its lack of penetrating power. Ultraviolet light also suffers from complicating factors such as "shadowing" and fluctuations in delivered electrical energy to the lamp. Other forms of radiation are less frequently used but may include the use of microwaves or gamma radiation. Freezing is not a reliable method of sterilization and the risk of significant equipment damage makes this an entirely unsuitable option.

Classification of Chemical Disinfectants

Disinfectants are classified by their chemical nature and each class has its unique characteristics, hazards, toxicities and efficacy against various microorganisms. Environmental conditions, such as the presence of organic matter, pH or water hardness will also impact the action of a disinfectant. **Before using any chemical disinfectants - thoroughly read and follow the manufacturer's instructions.**

Acids

Acidic disinfectants function by destroying the bonds of nucleic acids and precipitating proteins. Acids also change the pH of the environment making it detrimental to many microorganisms. Concentrated solutions of acids can be corrosive, cause chemical burns, and can be toxic at high concentrations in the air. These characteristics limit their use. The antimicrobial activity of acids is highly pH dependant. Acids have a defined but limited use as disinfectants. Acetic acid is usually sold as "glacial" acetic acid (95% acetic acid) which is then diluted with water to make a working solution concentration of 5%. The concentrated form is corrosive to the skin and lungs, but the typical dilution (5%) is considered non-toxic and non-irritating. Acetic acid is typically applied by spraying, misting or immersing an item in a diluted solution. Household vinegar is a 4-5% solution of acetic acid by volume. Acetic acid has poor activity in and around organic material.

Alcohols

Alcohols are broad spectrum antimicrobial agents that damage microorganisms by denaturing proteins, causing membrane damage and cell lysis. Alcohols are used for surface disinfection, topical antiseptic and hand sanitizing lotions. Alcohols are considered fast-acting; capable of killing most bacteria within five minutes of exposure but are limited in virucidal activity and are ineffective against spores. (Ethanol is considered virucidal; isopropanol is not effective against non-enveloped viruses.) An important consideration with alcohols is the concentration used, with 70-90% being optimum. Higher concentrations (95%) are actually less effective because some degree of water is required for efficacy (to denature the proteins). Alcohols evaporate quickly but leave no residue behind. The activity of alcohols is limited in the presence of organic matter. Alcohols are highly flammable, can cause damage to rubber and plastic, and can be very irritating to injured skin. Due to the high concentrations, flammability risks and dilution concerns, alcohol is generally unsuitable for comprehensive disinfection.

Aldehydes

Aldehydes are highly effective, broad spectrum disinfectants, which typically achieve sterilization by denaturing proteins and disrupting nucleic acids. The most commonly used agents are formaldehyde and gluteraldehyde. Aldehydes are effective against bacteria, fungi, viruses, mycobacteria and spores. Aldehydes are noncorrosive to metals, rubber, plastic and cement. These chemicals are highly irritating, toxic to humans or animals with contact or inhalation, and are potentially carcinogenic; therefore their use is limited. Personal protective equipment (nitrile gloves, fluid resistant gowns, eye protection) should be worn if you ever use these chemicals. Glutaraldehyde can provide sterilization at prolonged contact times. A 2% concentration is used for high-level disinfection. Glutaraldehyde efficacy is highly dependent on pH and temperature, working best at a pH greater than 7 and at high temperatures. It is considered far more efficacious in the presence of organic matter, soaps and hard water than formaldehyde.

Alkalis

Alkaline agents work by saponifying lipids within the envelopes of microorganisms. The activity of alkali compounds is slow but can be increased by raising the temperature. Alkalis have good microbicidal properties, but are very corrosive agents and personal protection precautions should be observed. Sodium hydroxide (lye, caustic soda, soda ash) is a strong alkali used to disinfect buildings but is highly caustic. Protective clothing, rubber gloves, and safety glasses should be worn when mixing and applying the chemical. Lye should always be carefully added to water. **Never pour water into lye**; a very violent reaction will occur as well as the production of high heat that can melt plastic containers. Sodium hydroxide is corrosive to most metals. Ammonium hydroxide is an effective disinfectant against coccidial oocysts however strong solutions emit intense and pungent fumes. This substance is not considered effective against most bacteria. General disinfection should follow the use of this compound. Sodium carbonate (soda ash, washing soda) can be used in a high temperature solution (180°F). It is more effective as a cleanser than a disinfectant since it lacks efficacy against some bacteria and most viruses. This disinfectant has poor activity in the presence of organic material and can be deactivated by hard water. It can be irritating and requires protective clothing and is harmful to aquatic life.

Product	Dilution	Comments
5.25% Sodium hypochlorite (NaOCl) (household bleach)	3%	Inactivated by organic contaminants – highly unstable in warm sunny conditions.
Acetic acid	4-5%	Vinegar is a 4% solution of acetic acid.
Sodium carbonate (soda ash)	4%	The solution is mildly caustic, but can dull paint and varnished surfaces.
Sodium hydroxide (NaOH) (lye)	2%	This solution is highly caustic. Use protective rubber clothing, gloves and safety glasses. **Always add the lye to the water.** Never pour the water over the lye.

Biguanides

Biguanides are detrimental to microorganisms by reacting with the negatively charged groups on cell membranes which alters the permeability. Biguanides have a broad antibacterial spectrum, however they are limited in their effectiveness against viruses and are not sporicidal, mycobacteriocidal, or fungicidal. Biguanides can only function in a limited pH range (5-7) and are easily inactivated by soaps and detergents. These products are toxic to fish and should never be discharged into the environment.

Halogens

Halogen compounds are broad spectrum compounds that are considered low toxicity, low cost and easy to use. They lose potency over time and are not active at temperatures above 110F or at high alkalinities (pH >9). Since these compounds lose activity quickly in the presence of organic debris, sunlight and some metals, they must be applied to thoroughly cleaned surfaces for disinfection. Chlorine compounds function through their electronegative nature to denature proteins and are considered broad spectrum, being effective against bacteria, enveloped and non-enveloped viruses, mycobateria and fungi. At elevated concentrations, chlorine compounds can be sporicidal. Sodium hypochlorite (Bleach) is one of the most widely used chlorine containing disinfectants. (Commercial chlorine bleach contains 5.25% sodium hypochlorite in aqueous solution and 50,000 ppm available chlorine). Biocidal activity of chlorine solutions is determined by the amount of the available chlorine of the solution. Low concentrations (2 to 500 ppm) are active against vegetative bacteria, fungi and most viruses. Rapid sporicidal action can be obtained at approximately 2500 ppm, however this concentration is very corrosive so should be limited in its use. High concentrations are highly irritating to the mucous membranes, eyes and skin. Chlorine compounds are rapidly inactivated by ultraviolet light and certain metals so fresh solutions should always be used. Hypochlorites should **never be mixed with acids or ammonia** as this will liberate chlorine gas out of solution.

Sodium hypochlorite %	**Bleach Solution Ratio**	**Dilution Procedure**	**Available Chlorine**	**Comments** Always use on cleaned surfaces.
0.025%	1:200	1.5 Tbsp (0.6 oz) bleach to 1 gallon water	250 ppm	Common household use
0.1%	1:50	1/8 C (1 oz.) bleach to 1 gallon water	1000 ppm	Commonly used
0.16%	1:32	1/2 cup (4 oz.) bleach to 1 gallon water	1562.5 ppm	Commonly used
0.5%	1:10	1.5 cups (12 oz.) bleach to 1 gallon water	5000 ppm	Very strong solution
3.33%	2:3	2 parts bleach to 3 parts water	33,333 ppm	Use with extreme caution

Iodine Compounds are broad spectrum and considered effective for a variety of bacteria, mycobacteria, fungi and viruses. Iodines function by denaturing proteins to interfere with the enzymatic systems of microorganisms. Iodines are often formulated with soaps and considered relatively safe. Concentrated iodine compounds can be irritating to the skin; can stain clothes or damage rubber and many metals. Iodine agents are inactivated by quats, and certain organic materials. Iodophors are iodine complexes that have increased solubility and sustained release of iodine. One of the more commonly used iodophors if povidone-iodine, which is good for general use and less readily inactivated by organic matter than elemental iodine compounds. The dilution of iodophors increases the free iodine concentration and antimicrobial activity.

Oxidizing Agents

Oxidizing agents are broad spectrum peroxide based compounds that function by denaturing the proteins and lipids of microorganisms. Peroxygen compounds vary in their microbiocidal range, but are generally considered effective on hard surfaces and inside equipment. In their diluted form, these agents are relatively safe but may be irritating and damage clothing when concentrated. Hydrogen peroxide in the home is in diluted form (3-10%) whereas industrial use involves concentrated solutions (30% or greater). Hydrogen peroxide at a 5-20% concentration is considered bactericidal, virucidal (non-enveloped viruses may be resistant), fungicidal and at higher concentrations sporicidal. Its activity against mycobacteria is limited. Peracetic acid is a strong oxidizing agent and is a formulation of hydrogen peroxide and acetic acid. It is considered bactericidal, fungicidal, sporicidal and virucidal. It is also effective against mycobacteria and algae and has some activity in the presence of organic material. Extreme caution should be exercised when applying these disinfectants against ion exchange media as irreversible oxidative damage can occur.

Phenols

Phenols are broad spectrum disinfectants that function by denaturing proteins and inactivating membrane-bound enzymes to alter the cell wall permeability of microorganisms. Phenols can be coal-tar derivatives or synthetic formulations and usually have a milky or cloudy appearance when added to water and a strong “pine” odor. “Pine-Sol™” is an example of a phenol found in the home. Phenols are typically formulated in soap solutions to increase their penetrative powers and at 5% concentrations are considered bactericidal, tuberculocidal, fungicidal and virucidal for enveloped viruses. Phenols are not effective against non-enveloped viruses and spores. Phenols do maintain activity in hard water and in the presence of organic matter and have some residual activity after drying. Phenolic disinfectants are generally safe for humans but prolonged exposure to the skin may cause irritation. Concentrations over 2% are highly toxic to all animals, especially cats.

Quaternary Ammonium Compounds

Also known as “QACs” or “Quats”, these ammonium compounds are cationic detergents that are attracted to the negatively charged surfaces of microorganisms, where they irreversibly bind phospholipids in the cell membrane and denature proteins impairing permeability. Quats can be from different “generations” depending on their chemistry, with later generations being more germicidal, less foaming and more tolerant to organic loads. QACs are highly effective against Gram-positive bacteria, and have good efficacy against Gram-negative bacteria, fungi and enveloped viruses. They are usually not effective against non-enveloped viruses or mycobacteria and are considered sporostatic but not truly sporocidal. Quats have a residual effect, keeping surfaces bacteriostatic for a brief period of time after application. Quats are more active at neutral to slightly alkaline pH but lose their activity at pH less than 3.5. Quats are considered stable in storage but can be inactivated by organic matter, detergents, soaps and hard water unless specially formulated.

Implementing a Disinfection Action Plan

There are several important areas to be addressed in an effective disinfection action plan.

Threat Assessment

Assessing the level of bacterial contamination includes observing odor and appearance of contact surfaces as well as plate culture to determine presence and species of pathogens.

Physical Cleaning

After the initial assessment, cleaning is the next step and must be thoroughly performed before applying the disinfectant. Experts agree that cleaning alone can remove over 90% of bacteria from surfaces, significantly enhancing the efficacy of the disinfectant compound and minimizing the chances of regrowth/colonization.

This initial cleaning step involves scrubbing, brushing and scraping to physically remove as much gross dirt, biofilm, debris and organic material as possible from all contact surfaces. Cleaning is also important since many disinfectants may be inactivated or ineffective in the presence of organic debris or waste. Disposal of debris into dumpsters should only occur if there is no zoonotic risk of disease transmission. All personnel should wear appropriate protective clothing and footwear. If a zoonotic disease is suspected, enhanced personal protective equipment should be used according to NIOSH protocol.

Surfactant Wash

Washing or sanitizing further reduces the number of microorganisms in the area to a safer level. Educt an anionic or non-ionic surfactant into the treatment equipment, allow sufficient contact time and then rinse vigorously to remove organic and other material. Although cleaning may appear to remove all debris, microscopic biofilm may remain on surfaces and interfere with disinfection efficacy. Biofilm is a complex aggregation of bacteria adhering to surfaces in an exopolysaccharide matrix, resulting in a thin residue that could still remain after cleaning. These bacteria are highly resistant to disinfection. Surfactant detergents, mechanical scrubbing, brushing and scraping during cleaning help reduce biofilm. Adding phosphoric acid to the surfactant mixture can be quite efficacious in reducing biofilm accumulation. Multiple bed volumes of fresh water should be rinsed through the system to ensure complete removal of surfactants and contaminants. Some disinfectants can be inactivated by residual soaps and detergents.

Disinfection

Selection of the proper disinfectant will depend on the microorganism suspected, as well as environmental factors and safety issues. Always read the entire product label and follow dilution instructions explicitly to ensure that the safest, most effective concentration is applied.

To achieve effective disinfection, surfaces must be thoroughly wet and clean; properly mixed disinfectant should be applied at a rate of 0.1 - 0.4L/minute or according to manufacturer's specifications. Dilution ratios of disinfectant will vary according to type of disinfectant and the specific application. Disinfectant should remain for the appropriate contact time, which will vary with the product and particular application. Equipment should be thoroughly rinsed before returning the system to service.

Evaluation

To verify that all pathogens have been destroyed or reduced to acceptable levels, a follow-up evaluation of the equipment should be conducted. While visual inspection of cleanliness is important, bacteriological samples should be obtained to determine the true effectiveness of the cleaning and disinfection protocol. Failure of a disinfection program usually results from the selection of an ineffective disinfectant, careless use of an effective disinfectant, or environmental factors, such as water hardness, heavy metals, pH, additional contaminants, and water temperature. The timing of sample collection is important. The best time to sample is 2-3 days after disinfection. Surface samples for small, smooth areas, can be collected by wiping or swabbing a sterile swab across a non-porous surface. Commercially available methods include RODAC™ and Petrifilm™ Plates (3M). These small, flat, sample-ready plates allow on-site microbial testing and are commonly used in the food processing industry. These plates are available for a variety of specific microorganisms or classes (aerobic count plates, coliform count, environmental Listeria etc…) as well as yeast and mold counts and can also be used direct contact or swab applications. Other methods of environmental sampling include surface samples collected by Ultrafilter membrane.

Each step of the disinfection action plan (assessment, cleaning, washing/sanitizing, disinfection) should be evaluated for problems encountered and usefulness or efficiency of the cleaning or disinfection techniques.

Sample Disinfection Protocol # SP-5000

Every location is different, with varying water-usage patterns and expectations of water quality. The annual service and disinfection model is clearly deficient, so service intervals should be based upon the aggregate amount of hardness and other inorganics processed by the system. Many industry experts agree that a system should be serviced and completely disinfected after processing approximately 1,000,000 grains or at least every 12 months, whichever is sooner. Disinfection frequency should be increased if there is any suspicion that the influent water supply is not microbiologically safe.

Industry standard employee safety precautions should always be taken before implementing this or any other disinfection protocol.

While every possible effort has been made to ensure the efficacy of this protocol, you are still ultimately responsible for the microbiological safety of the equipment in your facility and you should completely familiarize yourself with the advantages, disadvantages and liabilities of this or any other protocol before applying it. Proceed with caution, and at your own risk.

Disinfection of Contaminated Water Treatment Equipment

Quantities, types and concentrations as per manufacturer's instructions

Chemicals required

Anionic Surfactant concentrate
Detergent
EDTA
Deionized Water
Concentrated Biodegradable Disinfectant

Tools required

Appropriate protective equipment (eye protection, respirator, gloves)
Mechanical scrubbing apparatus
Approved waste disposal materials

Procedure

- Discard all salt from regenerant tank in an environmentally friendly manner
- Disconnect regenerant tank & scrub until clean with detergent until residue is removed
- Rinse detergent from regenerant tank in an appropriate manner with clean water
- Apply concentrated detergent to all contact surfaces in regenerant tank
- Allow detergent to remain in contact with regenerant tank for at least 20 minutes
- Rinse regenerant tank with clean water
- Replace all regenerant tank tubing and fittings and reconnect to system
- Safely bypass and depressurize water treatment system
- Open pressure vessel and inspect for evidence of bacterial overgrowth
  - If evidence of overgrowth is found, all media should be discarded
- Reassemble pressure vessel and pressurize with clean water
- **Surfactant Injection**
  - Mix surfactant and deionized water to appropriate concentration & volume
  - Educt 4 bed volumes of surfactant solution into pressure vessel
  - Allow 10 minutes of contact time
  - Rinse at least 8 bed volumes or until no surfactant residual remains
- **EDTA Injection**
  - Educt 0.5 bed volume of EDTA into pressure vessel
  - Allow 5 minutes of contact time
  - Rinse at least 4 bed volumes or until no EDTA residual remains
- **Disinfectant Injection**
  - Mix disinfectant and deionized water to appropriate concentration & volume
  - Educt 2 bed volumes of disinfectant solution into pressure vessel

    - Allow 60 minutes of contact time
    - Rinse at least 4 bed volumes or until no disinfectant residual remains
  - **Testing and evaluation**
    - Swab inside of regenerant tank and culture as per instructions
    - Draw sample of effluent water and culture as per instructions

Periodic Disinfection Procedure

Quantities, types and concentrations as per manufacturer's instructions

Chemicals required

Anionic Surfactant concentrate
Detergent
EDTA
Deionized Water
Concentrated Biodegradable Disinfectant

Tools required

Appropriate protective equipment
Mixing apparatus

Procedure

- **Surfactant Injection**
  - Mix surfactant and deionized water to appropriate concentration & volume
  - Educt 0.1 bed volumes of surfactant solution into pressure vessel
  - Allow 5 minutes of contact time
  - Rinse at least 2 bed volumes or until no surfactant residual remains
- **EDTA Injection**
  - Educt 0.1 bed volume of EDTA into pressure vessel
  - Allow 5 minutes of contact time
  - Rinse at least 2 bed volumes or until no EDTA residual remains
- **Disinfectant Injection**
  - Mix disinfectant and deionized water to appropriate concentration & volume
  - Educt 0.25 bed volumes of disinfectant solution into pressure vessel
  - Allow 10 minutes of contact time
  - Rinse at least 2 bed volumes or until no disinfectant residual remains
- **Prophylactic application of disinfectant**
  - Mix disinfectant and deionized water to appropriate concentration & volume
  - Add disinfectant solution directly to regenerant tank
  - Initiate delayed regeneration/cleaning of water treatment equipment

NOTE – Surfactant, EDTA, and Disinfectant can be blended together to improve on-site efficiency if performed within manufacturer's specifications and according to industry best-practices.

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