CHOOSING THE PROPER SANITIZER OR DISINFECTANT

1. INTRODUCTION

CLEANING IS A PREREQUISITE FOR EFFECTIVE SANITIZATION

Sanitization begins with an effective cleaning program. Organic deposits from food residues, such as oils, greases and proteins not only harbor bacteria but may actually prevent the sanitizer from coming into physical contact with the surface that needs to be sanitized. In addition, the presence of organic deposits may actually inactivate or reduce the effectiveness of some types of sanitizers such as hypochlorites, rendering the procedure ineffective.

In large food processing establishment, a general protocol for maintaining good hygiene works according to the following protocol. Large soils and residues are initially removed by scraping or other mechanical means and usually followed by a high pressure water pre-rinse. The detergent, appropriate for the soil being removed is then applied for a specified period, usually 15 minutes, followed by a potable water rinse to flush away residual soil and detergent.

Once this process has taken place and the surface is visually clean, the sanitizer can then be applied for the specified time recommended by the manufacturer. With sanitizer applications, a further rinse with potable water is not required nor is it recommended, since there is a high probability that in doing so, might result in recontamination of the surface with micro organisms present in the rinse water.

In the removal of soil, a detergent functions in various ways involving both physical and chemical actions. These functions do not occur separately or in any particular sequence, but in a complex and interrelated manner. For cleaning a particular type of soil, certain functions are emphasized more than others to arrive at a balanced product. Surfaces which contain oily food residues might require a product which exhibits a high level of emulsification for fatty material, whereas those contaminated with protein residues usually respond best to highly alkaline and chlorinated cleaners. Regardless of the product used, effective cleaning is dependent on temperature, water hardness, pH of the water used, contact time and method of detergent application. Each establishment will have its own Standard Operating Procedures (SOP), which has been worked out often by trial an error until a proper combination of the variables have found to be both efficient and cost effective.

The discussion in the remaining portion of this article will deal with choosing the proper sanitizer will assume that the surfaces being sanitized have been properly cleaned and rinsed.

2. BASIC DEFINITIONS

The terminology often associated with germicidal activity can be confusing or misleading and in many cases there is an overlap in function.

An iodophor, when used at 25 ppm (parts per million of available iodine), is considered to act as a sanitizer. However that same product when applied at 75 ppm falls into the disinfectant category. Quats (quaternary ammonium compounds) and hypochlorites are still other examples in which the use concentration of the product defines its classification.

In order to clarify some key terms which are often used interchangeably, I have attempted to define the meaning of the products under discussion in their legal sense.

a. SANITIZER

In general, to sanitize means to reduce the number of microorganisms to a safe level. One official and legal version states that a sanitizer must be capable of killing 99.999% known as a 5 log reduction, of a specific bacterial test population, and to do so within 30 seconds. A sanitizer may or may not necessarily destroy pathogenic or disease causing bacteria as is a criteria for a disinfectant.

An alternate definition is that a hard surface sanitizer is a chemical agent which is capable of killing 99.9% (3 log reduction), of the infectious organisms which may be present in a bacterial population, within 30 seconds.

b. DISINFECTANT

A disinfectant is a chemical agent which is capable of destroying disease causing bacteria or pathogens, but not spores and not all viruses. From a technical and legal sense, a disinfectant must be capable of reducing the level of pathogenic bacteria by 99.999% during a time frame greater than 5 but less than 10 minutes.

The main difference between a sanitizer and a disinfectant is that at a specified use dilution, the disinfectant must have a higher kill capability for pathogenic bacteria compared to that of a sanitizer.

c. STERILANT

Sterilants are specialized chemicals, such as glutaraldehyde or formaldehyde, which are capable of eliminating all forms of microbial life, including spores. The term sterilant conveys an absolute meaning; a substance can not be partially sterile.

d. SPORES AND SPORICIDES

Some species of pathogenic bacteria are capable of adapting to hostile conditions by forming a thick outer and chemically impervious shell. They transform from their normal or vegetative state to form spores and are difficult to eliminate since they can resist the effects that sanitizer or disinfectant exposures have on bacteria. Elimination of spores is carried out by specialized chemical agents or physical means, and require several hours for total microbial destruction.

e. HIGH, MEDIUM AND LOW LEVELS OF DISINFECTION:

HIGH LEVEL DISINFECTION

High level disinfection refers to sterilization activities in which all microbial life, including spores and viruses are destroyed. High level sterilization can be accomplished by chemical agents such as glutaraldehyde or ethylene oxide gas over a 10 hour period or by physical means such as auto claving in which surfaces are exposed to steam at elevated temperatures (121C) for 15 minutes. High level disinfection is reserved for special applications such as disinfection of surgical equipment and medical devices.

MEDIUM LEVEL DISINFECTION

Medium level disinfection usually refers to elimination of tuberculocidal causing microorganisms as well as the destruction of the more resistant types of viruses, such as the ones without a protein membrane in their structure. Medium level disinfection is not effective against spores.

LOW LEVEL DISINFECTION

Low level disinfection refers to the destruction of bacteria in their natural state and is not effective against tuberculosis causing microorganisms, spores or viruses which do not have outer protein membranes in their structure.

When choosing a method requiring sanitization, it is necessary to consider which one would have the least harmful environment impact, the most cost-effective, the easiest to apply and the most suitable under prevailing water conditions. If you don't need to get rid of spores then don't sterilize.

3. HOW SANITIZERS EXERT THEIR GERMICIDAL ACTIVITY

When bacterial cells are exposed to a sanitizers or disinfectant, various physical structures within the cell may sustain irreversible damage. The permanent loss of a bacterial cell's capability to reproduce is commonly referred to microbial death. In the presence of germicides, some bacteria, may only be partially damaged. A surface which is swabbed immediately after sanitization can often provide false or negative results, indicating that effective sanitization had occurred. However, depending on the degree, partially inactivated bacteria have the capacity to "heal" or regenerate within 18 to 24 hours and become viable. Such an "apparently" clean and bacteria free surface will show the presence of high levels of bacterial contamination the following day and if left unchecked, can contaminate food products which may come into contact with the surface during the normal course of food processing.

The effectiveness of a specific germicide is a function of several factors, including the number and type of microorganisms which are present on the surface being sanitized.

Some of the factors requiring consideration are whether they are the easy to kill bacteria in their vegetative state or whether they are present on the surface as highly resistant spores. A major consideration that also needs to be addressed is whether other materials such as blood, feces or organic matter are present within the bacterial environment. These contaminants reflecting an unclean surface, can rapidly inactivate some germicides, such as hypochlorites, rendering them ineffective for their intended use.

In general however, germicides exert their effect by either attacking a specific part of the bacterial cell, or causing damage to some of its components. Germicides can fall into three classifications, based on their method of bacterial attack.

a. CELL MEMBRANE DESTRUCTION

Germicides such as sodium hypochlorite of peroxyacetic acid (PAA) are strong oxidizing agents and can cause total destruction of the cells membrane, resulting in vital bacterial components leaking out into their surrounding environment. This process results in a true microbial death.

b. INHIBITION OF FOOD UPTAKE AND WASTE EXCRETION

Some germicides, such as the quaternary ammonium compounds (quats), have the capacity to attach themselves onto specific sites on the bacterial cell membrane. They do this by virtue of the fact that the quats carry a positive electrical charge in solution and are attracted to the negatively charged portions of the bacterial membrane. The end result is that quats block the uptake of nutrients into the cell and prevent the excretion of waste products which accumulate within their structure.

In effect, the cell is both starved and internally poisoned from the accumulated wastes.

c. INACTIVATION OF CRITICAL ENZYMES

Biocides, such as phenolics, which exert their activity in this manner actually enter the cell and chemically react with certain key enzymes which support either cell growth or metabolic activities which supplies the bacteria with the energy needed for growth and multiplication. If inactivation is incomplete the injured bacteria can regenerate several hours later and recontaminate the surface.

4. COMMERCIALLY AVAILABLE PRODUCT

Table I summarizes some of the properties and characteristics of commercially available sanitizers and disinfectants. Although sanitization is distinct from disinfection, common elements exist between the two. The differences are often related to the concentrations of product used and length of exposure of the product on the surface.

a. HYPOCHLORITES

Because of their effectiveness and relatively low cost, hypochlorites are widely used in a multitude of sanitization operations, and have become a standard to which other sanitizers are compared. Hypochlorites exert their germicidal activity by inactivating vital bacterial enzymes.

Their main disadvantage is that they are corrosive to metal surfaces including stainless steel. Hypochlorites also degrade in strength with time, are affected by the presence of organic matter and the pH or alkalinity of the water from which their use-solutions are prepared. Hypochlorites function best within the narrow pH range around neutrality (pH 5 - 7), since hypochlorous acid formed at that pH, is the chemical component which exerts the germicidal activity. High pH waters (>9.0) inhibits the sanitization effect of hypochlorites, requiring longer exposure times to achieve the desired results.

b. IODOPHORS

Iodophors exert their bactericidal activity in a similar manner to that of hypochlorites but to a less rapid degree. They attach themselves to proteins specifically those containing sulfur in their composition (cysteine) and inactivate them. Iodine solutions usually consist of elemental iodine which is complexed to carriers such as PVP (polyvinylpyrolidone) or non ionic surfactants. The iodine carrier provides a sustained-release reservoir of iodine, and the iodine stays bound to the carrier until the free iodine concentration in solution falls below a certain equilibrium level, before additional free iodine is released into solution.

Their main disadvantage is that they can be highly staining on virtually any surface, work only within the acidic pH range and flash off at temperatures greater that 35 C.

West-Agro in Kansas City, Mo is a prime manufacturer of iodophors and supports EPA registration for chemical manufacturers using their concentrates and EPA registered formulas.

c. QUATERNARY AMMONIUM CHLORIDES (QUATS)

The Quats have varied germicidal activity and are generally used in low-level sanitization. Their main advantages are that they are odorless, non-staining, non-corrosive to metals and are relatively non-toxic at use-dilution concentrations. As sanitizers they exhibit a wide latitude in germicidal activity when used in hard water and are effective over a wide pH range.

Quats leave a non-volatile residue on surfaces to which they are applied, rendering the surfaces bacteriastatic for a given time. For this reason they are rarely used in dairies where cheese is manufactured; doing so could increase the risk of inactivating desirable bacterial cultures used in cheese production.

d. ACID SANITIZERS

Acid sanitizers have a broad spectrum germicidal activity and are very cost-effective to apply. They are also relatively unaffected by organic matter. Because of their low pH, acid sanitizers have the added advantage of being able to react with hard water deposits as well as milk stone deposits, a common soil occurring in dairies and for this reason are ideal for use under hard water conditions. Because of their combined acid cleaning, free rinsing and sanitization properties, they are ideal for use in CIP (circulation-in-place) systems.

Alex C. Fergusson of Frazer, PA manufactures 2 types of acid sanitizers; TOPS and LOW FOAMING TOPS, both of which exhibit excellent sanitization properties and have become the standard for measuring acid sanitizer activity. At 1 ounce per 2 gallons of water, LOW FOAM TOPS provides the required 200 ppm of sulfonate in a pH environment that is typically less than 3.0; the combination provides true sanitation according to the legal definitions.

e. ALDEHYDES: (FORMALDEHYDE AND GLUTARALDEHYDE)

Aldehydes are extremely reactive chemicals which combine with and irreversibly denature key bacterial proteins. They are generally not used for routine sanitization and their

application is restricted mainly to high-level disinfection. A 2% solution of either compound exhibits sterilization properties over a given period.

Formaldehyde can leave residual films on the surfaces with which it comes into contact and therefore its use poses a potential health hazard. Formaldehyde films can also combine with certain food-containing components and impart an undesirable medicinal flavor. Because formaldehyde has been identified as a potential carcinogen, its use is declining and limited to specific applications.

f. ALCOHOLS

Alcohols exert their germicidal activity by denaturing bacterial proteins. In the absence of water, proteins are not readily denatured by alcohol and therefore a 70% solution of isopropyl alcohol is a much more effective sanitizer than the pure (99%) product. Isopropyl alcohol is capable of killing most bacteria within 5 minutes of exposure but is ineffective against spores and has limited virucidal activity. The main disadvantage towards the use of isopropyl alcohol is that it is flammable, and can not be diluted as quats or iodophors can and therefore is relatively expensive to use.

g. PHENOLICS

Phenolics are effective at sanitization and disinfection in the presence of biological fluids and are tolerant towards a certain level of organic presence. Their main advantage is that they are highly effective in destroying the bacteria causing tuberculosis. Phenolics suffer from the disadvantage that they are relatively expensive to use, and react with certain types of plastic surfaces. They are also difficult to oxidize and therefore difficult and expensive to dispose of in an environmentally suitable manner.

h. PEROXYACETIC ACID (PAA)

Peroxyacetic Acid or Peracetic acid as it is commonly referred to, is manufactured by reacting Acetic acid with hydrogen peroxide. FMC in Philadelphia, PA, manufactures a highly stable PAA solution containing as major ingredients: Peracetic acid (5.1%); and hydrogen peroxide (22.7%). PAA has grown in popularity because of its effectiveness and environmental compatibility. Upon degradation, PAA breaks down to acetic acid (vinegar), water and oxygen. One of the major advantages in using PAA is that it also functions extremely well under cold conditions (4ºC) and unlike other sanitizers, does not experience cold temperatures failure. For this reason sanitization can be carried out on equipment and vehicles which do not first have to be brought to ambient temperatures. PAA solutions are generally used at 150 to 200 ppm are highly effective against a broad spectrum of bacteria and spores. A major disadvantage of PAA is that it is more expensive to apply than hypochlorite, but is rapidly gaining in popularity because of the multitude of applications for which it has been registered for with the EPA and its environmental compatibility.

i. CHLORINE DIOXIDE

Chlorine dioxide is a powerful sanitizer and disinfectant which is produced by reacting sodium chlorite in solution with an acid. The yellowish-green gas produced in this reaction is allowed to remain in a closed system until it dissolves in the solution from which it was generated. The aqueous solution of chlorine dioxide is subsequently used for sanitization. Chlorine dioxide is 3 to 4 times as potent as sodium hypochlorite as a sanitizing agent and is generally effective against all bacteria and viruses. It does not have the disadvantages that sodium hypochlorite has with respect to corrosivity of metal surfaces. Its main disadvantage is that the extremely reactive nature of sodium chlorite from which chlorine dioxide is generated poses a serious and potential fire hazard. The complex and expensive equipment to generate chlorine dioxide on site requires a significant capital outlay and therefore its use is unattractive for routine sanitization to the majority of end users.

5. HOW BACTERIA BUILD UP RESISTANCE TO SANITIZERS

a. RESISTANT BACTERIA AND SUB-LETHAL SANITIZER DOSAGE

In any given population, bacteria exist within a wide range of sensitivities towards a specific sanitizer dose. Under normal conditions of exposure, sanitizers are capable of destroying 99.999% of the bacteria present. In essence, a surface which initially harbor 1,000,000 bacteria per square centimeter prior to sanitation may be expected to contain only 10 microorganisms per square centimeter afterwards. In such a scenario, the objective of the sanitation process has been achieved in the sense that the total bacterial population has been reduced to safe levels.

What may not be as evident is that the remaining 10 surviving microorganisms capable of withstanding the sanitization procedure have the potential to act as a source of future contamination. If on subsequent clean up and sanitization, proper dosing or procedures were not adhered to, or the surface has not been adequately rinsed, the 10 surviving bacteria will survive a second cycle of sanitization, as will other bacteria. Over a period of time and involving several cleaning and sanitization cycles, the resistant survivors have the capacity to proliferate, especially during periods in which they are exposed to food product. When this occurs the food processing plant is now dealing with a bacterial population which no longer responds to sanitizing doses of germicide, resulting in a failure of the sanitizer to achieve its objectives. In essence by applying the sanitizer at less than lethal doses or for shorter intervals, the end result is the same as if selective culturing of a resistant strain had been carried out with the possibility of the surface becoming enriched with pathogens and hard-to-kill microorganisms.

A surface which is allowed to deteriorate to such a level of poor hygiene needs to be "shocked", by switching to high doses of an alternate product such as hypochlorite and dosing at disinfectant levels. It is not uncommon to require the use of 400+ ppm of available chlorine over a period of a week before the surface can be returned to the desirable and bacterial free-state.

b. BIOFILM FORMATION

Biofilm formation is another mechanism, in which bacterial resistance towards a sanitizer can occur. As previously indicated, proper cleaning is essential before effective sanitization can occur. Certain bacteria secrete a polysaccharide which is a constituent of their membrane. These secretions are very sticky and attach themselves firmly to metal surface. The resulting film so formed containing trapped bacteria is referred to as a biofilm. Bacteria which are responsible for biofilm formation may in themselves not be harmful or pathogenic. However, the gelatinous matrix which they excrete is capable of attracting to itself and embedding pathogenic bacteria, such as Lysteria monocytogenes. Although the pathogens themselves do not contribute towards the integrity of the film, they nevertheless are capable of contaminating products which come into contact with the surface.

Biofilms are often very difficult to remove, since their matrix is very resistant to chemical attack by detergents. They often require higher than normal concentrations of alkaline detergents and strong oxidizing levels of sodium hypochlorite in order to remove them. Several applications may be required before the biofilm can be totally removed.

c. DETERGENT-SANITIZER INTERACTIONS

Most cleaning products contain non-ionic surfactants (emulsifiers and detergents), anionic surfactants or a mixture of both in their composition. In solution, non ionic surfactants are electrically neutral, but anionic surfactants carry a negative charge within their structure. When detergent is applied to a soiled vertical surface the bulk of product runs of within 15 to 20 minutes. However, a small but finite amount of detergent remains on the surface and contains some of the anionic surfactant which was present in solution originally applied to the surface. If the surface is not thoroughly rinsed prior to the application of a quat sanitizer, the sanitizer can be totally inactivated. In solution, quats are positively charged and can therefore combine readily with the negatively charged anionic residue and become totally inactivated.

A metering system may be set to deliver the correct concentration of quat (200 ppm), but once the sanitizer comes into contact with the surface, it reacts with the anionic detergent, and the resulting anionic-quat residue or film so formed has no germicidal activity. Since an anionic-quat complex so formed also contains nutrients favoring microbial growth. Such a complex can actually support bacterial proliferation if left unchecked

6. DOSING OF SANITIZER SOLUTIONS

Accurate dosing is a prerequisite for efficient and cost-effective sanitization. The equipment and procedures which are used to deliver sanitizer solutions vary and depend on the specific application for which they were intended and the industry being serviced.

a. FOOD PLANTS

In large food processing plants, daily clean-up necessitates sanitation of all food contact surfaces. Measured quantities of sanitizer are generally transferred from the drum into a large (500 to 1000 liters) dedicated tote, using a calibrated metering pump. The required volume of water is then added to a predetermined level to make up the end-use solution. The amount of sanitizer which the pump is capable of delivering is based on the volume displaced by each stroke of the pump and the time period that the pump is in actual operation. The volume of each stroke can be adjusted and fine tuned rendering the system capable of dosing accurate and consistent concentrations of sanitizer. More sophisticated equipment (and more expensive) use wall mounted pumps which are electronically connected to water flow meters. As water flows into the dispensing tote, it triggers the pump to operate on an intermittent basis to deliver calibrated quantities of sanitizer, with each transfer to the tote of a predetermined volume of water. This intermittent cycle of dosing provides for a more uniform mixing of sanitizer with water. To insure complete dispersion of sanitizer in solution, large storage tanks also have auxiliary pumps and the capability of recirculating the solution for several minutes.

Since effective sanitization in food processing plants is a crucial step in the over all clean up procedure, the crew leader will usually sample the diluted sanitizer solution using either a test kit or test paper. Once adjustments and verifications, if required are made, the sanitizer solution is applied under low pressure onto the food contact surfaces and the excess is allowed to freely run off. Low pressure applications are preferable since they reduce the risk of generating airborne mists which can cause dislodge bacteria to become airborne and transported over great distances. Following sanitization, a potable water rinse is not required nor is it recommended. Flat horizontal or vertical surfaces can either be air dried or allowed to remain wet. The later method is the preferable one and used more frequently. Leaving the surface wet prevents airborne bacteria which may settle on food processing equipment and tables from surviving, therefore decreases the risk of contamination.

At start-up of operations during the following shift, the remaining residual sanitizer can be rinsed off prior to handling food products. This is not a mandatory or regulatory requirement since sanitizers used in food processing plants also have clearance for incidental food contact at the concentrations used.

b. SUPERMARKET PROGRAM

The areas within a Supermarket deli, meat and bakery sections are relatively small and the equipment requirements for clean up and sanitation can be carried out with simple equipment. Blades, knives, saws, scrapers, and other small utensils are disassembled from the food cutting or processing equipment and placed into a three compartment sink. First, they are allowed to soak in a detergent solution which is dispensed into the sink through a wall mounted plunger type of hand pump. The components are then rinsed with water in the middle sink and sanitized by immersion into the third, sanitizer-containing compartment. Sanitizer is dispensed into the third sink compartment in a manner similar to that used to dispense detergent.

The stationary portion of the equipment as well as the cutting tables are first cleaned with a high foaming detergent then sanitized with a low level disinfectant such as a quat. The equipment used in this type of operation is usually a commercial version of a garden hose sprayer and using city water pressure as a means of delivering product to the affected surfaces. Water flowing through the hose also creates a partial vacuum within the garden sprayer resulting in sanitizer solution being drawn up and mixing with the water stream as it flows past the garden sprayer's orifice. Commercial units designed for sanitizer application are accurately calibrated by the manufacturer to dispense a 0.2% solution, which is equivalent to 200 ppm quat (10% active) or 200 ppm available chlorine (10% sodium hypochlorite).

Small, pressurized portable tanks into which a prediluted sanitizer solution has been added also finds use in this application, especially in enclosed areas where sanitizer has to be applied to surfaces that are not readily accessible. Such a system makes use of the pressurized contents to direct a stream of sanitizer over a larger distance than would be possible with a garden sprayer using city water pressure.

c. HOSPITALS AND NURSING HOMES

Large hospitals and nursing homes usually dispense use-solution from stationary, central units; each one located on a separate floor. Frequently these units operate by mechanical action alone and dispense product using the principles encountered above; suction of product as a result of an internal vacuum which is created through the flow of water past an orifice. A typical installation is wall mounted with a single hose connected to the city water

input line, and contains from 1 to 5 separate dedicated hoses capable of dispensing several products. Adjusting the orifice diameter at the end of each dispensing hose results in dilutions varying from 1:256 to 1:20.

To maintain control in small hospitals and nursing homes, 1 to 2 gallon of end use solutions are prepared and then transferred into smaller, trigger sprayer type dispensers which can easily be used by the house keeping staff. Critical areas, such as operating rooms which require high level sanitation, use specialized computer assisted dosing and rinsing equipment.

d. RESTAURANTS

Aside from the routine clean up and sanitization of food contact surfaces and food preparation utensils, the bulk of the cleaning and sanitization in restaurants is in mechanical ware washing. In small restaurants, the dish washing product is usually a powder manually fed into the machine and also provides a source of available chlorine for sanitization. Sufficient product, whether or not needed for the soils encountered must be used in order to provide a residual available chlorine level of 100-200 ppm; a level which is required under most municipal health codes.

In restaurants serving a large number of meals daily, it becomes more economical to meter product into the ware washing equipment via rotary pumps which accurately dispense the quantity of chemical required. The larger ware washing units are equipped with a 3 head rotary pump dispensing unit and each pump is calibrated according to the amount of chemical dispensed per rotation of the pump and the number of rotations per minute. Once properly adjusted, detergent, rinse aid and sanitizer can be accurately dosed at the different required concentrations.

PROPERTIES OF CHEMICAL SANITIZERS AND DISINFECTANTS

Table 1

	Optimum pH Range for Sanitization	Use Dilution Concentration in ppm	Effect of Hard Water on Sanitization	Effect of Organics in Water	Germicidal Activity	Activity against Gram Positive Bacteria	Activity against Gram Negative Bacterial	Activity against Spores
HYPOCHLORITE	5 - 7	200	Moderate tolerance	Inactivated	High	● ● ● ●	● ● ● ●	● ● ● □
IODOPHORS	1 - 5	25	Activity reduced More sanitizer required	Reduced activity; more stable than hypochlorites	Moderate, less effective than hypochlorites	● ● ● ●	● ● ● ●	□ □ □ □
QUATS	8 - 11	200	Activity reduced	Moderately Stable	Varied	● ● ● ●	● ● ● ●	□ □ □ □
ACID SANITIZERS	1 - 3	200	Activity reduced more sanitizer required	Low reactivity	Very Good	● ● ● ●	● ● ● ●	□ □ □ □
ALDEHYDES	6 - 8	2% for Sterilization	No effect	Activity reduced	High	● ● ● ●	● ● ● ●	● ● ● ●
ALCOHOLS	5 - 8	70%	No effect	Loss of activity	Moderate	● ● ● □	● ● ● ●	□ □ □ □
PHENOLICS	10.5 - 11.5	200 - 400	Moderate tolerance	Moderately stable	Very good	● ● ● ●	● ● ● ●	● ● ● □
PAA	3.5 - 5.5	150 - 200	limited effect	Reacts and looses activity	High, better than hypochlorite	● ● ●□	● ● ● ●	● ● ● ●
CHLORINE DIOXIDE	2 - 5	5 - 15	No effect	Little influence	High, better than hypochlorite	● ● ● ●	● ● ● ●	● ● ● □

●●●● Highly Effective

●●●□ Moderately Effective

● ●□□ Slightly effective

□□□□ Ineffective