Sanitizers for Food Plants

The selection of a sanitizer depends on the type of equipment to be sanitized, the hardness of the water, the application equipment available, the effectiveness of the sanitizer under site conditions, and cost. Sanitizing compounds which contain phenols impart strong undesirable odors and flavors to foods and should not be used.

Thorough cleaning is essential before using a sanitizer. Sanitizers are less effective when food particles or dirt are present on equipment surfaces. Use only approved sanitizers in food processing plants. Approved sanitizers are listed in "List of proprietary substances and nonfood compounds authorized for use under USDA inspection and grading programs" (USDA, 1985). Request technical advice from a reputable sanitizer manufacturer, if you have questions on the best sanitizer to use.

Chlorine Gas, Hypochlorites, Chloramines

Chlorine-based sanitizers are the most commonly used sanitizers in food plants. They are available in solid, liquid, and gas injection forms, and they are effective against all bacteria. In diluted form, chlorine-based sanitizers are colorless, relatively nontoxic, and nonstaining. They are the easiest sanitizers to prepare and apply, and they are generally the most economical. Usually, no water rinse is required if chlorine solutions do not exceed 200 parts per million (ppm). Chlorine concentrations can be easily measured by a test kit. Chlorine solutions prepared from chlorine gas, hypochlorites, and chloramines are not compatible with quaternary ammonium compound sanitizers.

Chlorine Gas. Chlorine gas is a highly volatile compressed gas which forms hypochlorous acid (HOCl) when injected into water. It may make the pH (acidity/alkalinity) of water slightly lower (more acidic).

Hypochlorites. Sodium hypochlorite and calcium hypochlorite are formed by treating alkalis with chlorine gas. In water, they form hypochlorous acid and sodium or calcium salts. These salts can raise the pH of the water (more alkaline) and reduce the killing action of the chlorine. Hypochlorites are unstable; they lose chlorine during storage. Under controlled conditions, the germicidal action of hypochlorites equals that of chlorine gas.

Chloramines. Chloramines are formed by a reaction of chlorine with ammoniacal nitrogen in water. In solution, they slowly form hypochlorous acid and organic salts. Chloramines are more stable and less corrosive than hypochlorites, and they have a longer lasting germicidal action. Chloramines require a long contact time to be effective sanitizing agents.

The rate at which gaseous chlorine, hypochlorites, and chloramines kill bacteria is directly related to the amount of free chlorine (hypochlorous acid) in the water. In general, killing rates decrease as the pH becomes higher (more alkaline). Very acidic chlorinated water is corrosive to equipment. Very alkaline chlorinated water is also corrosive and has a reduced killing ability. A pH range of 6.0 to 7.5 is recommended for chlorine sanitizing solutions.

Organic matter will react with hypochlorous acid, leaving less free chlorine. Since it is the free chlorine that kills bacteria, large amounts of organic matter will reduce the germicidal activity of a chlorine solution.

The killing rate of chlorinated water increases with temperature, but the increased killing rate is counteracted by increased corrosiveness and vaporization (loss of chlorine). Apply chlorine-based sanitizers in cold water.

Chlorine Dioxide

Chlorine dioxide (ClO_2) is formed by reacting chlorine gas (Cl_2) or hydrochloric acid (HCl) with sodium chlorite ($NaClO_2$). In water, chlorine dioxide is the active sanitizing compound. It differs from hypochlorous acid in several significant ways.

Chlorine dioxide is uniformly active across a wide pH range, while the germicidal activity of hypochlorous acid varies with the pH of the solution. Hypochlorous acid becomes ineffective above pH 8.5, but chlorine dioxide retains some sanitizing power up to pH 10.0. Chlorine dioxide is a stronger oxidizer than other chlorine sanitizers and it is less likely to form chlorinated organic compounds. Chlorine dioxide is desirable whenever the organic load of the water is high. In addition, chlorine dioxide removes iron, manganese, odors, flavors, and colors from the water. Concentrations of chlorine dioxide can be easily measured by a test kit.

Chlorine dioxide is more expensive than chlorine gas or hypochlorites. It is highly reactive and cannot be manufactured and shipped in bulk; an on-site generating system is required. Chlorine dioxide decahydrate may be commercially prepared, but must be refrigerated because it decomposes at room temperature and can explode under certain conditions.

Iodine Compounds

Iodophors are a combination of iodine and a solubilizing agent that releases free iodine when diluted with water. Iodophors are fast-acting and effective against all bacteria. In diluted form, they are nonstaining, relatively nontoxic, nonirritating to skin, and stable. Iodophors are widely used in hand sanitizing solutions. They are most effective in acidic conditions, and have minimal activity at pH 7. No water rinse is required if iodophor solutions do not exceed 25 ppm. Iodophor concentrations can be easily measured by a test kit. The color of an iodophor hand-dip solution gives a visual check on concentration. Iodophor solutions may stain porous surfaces and some plastics.

Quaternary Ammonium Compounds

Quaternary ammonium compounds (QAC), in diluted form, are odorless, colorless, and nontoxic. They are stable at high temperatures, over a wide pH range, and in the presence of organic materials. QAC's are effective against some bacteria, but are slow-acting against some common spoilage bacteria. No water rinse is required if QAC solutions do not exceed 200 ppm. However, QAC solutions may leave objectionable films on equipment and should be rinsed off with fresh cold water. Quaternary ammonium compounds may be combined with nonionic wetting agents in detergent-sanitizer formulations. QAC are not compatible with other common detergent compounds or chlorine sanitizers.

Acid-Anionic Surfactants

Acid-anionic surfactants are combinations of acid, usually phosphoric acid, with surface-active agents. They are effective only below pH 2.5. These sanitizers are effective against most bacteria, and are odorless, relatively nontoxic, stable, and noncorrosive to stainless steel. They are effective in removing and controlling milkstone and water hardness films.

Peracetic Acid Solutions

Peracetic acid solutions contain a mixture of peracetic acid, acetic acid and hydrogen peroxide. These sanitizers are effective against all microorganisms, including bacterial spores. They are effective over a wide pH range and are applied in cool or warm water. Peracetic acid solutions have a pungent odor and should be used in a well ventilated area. Concentrated solutions are strong oxidizers and can be corrosive to the skin.

Personnel Safety

Most sanitizers are unstable, highly reactive compounds and must be handled safely. Sanitation crews should wear protective equipment and clothing including a hard hat, face shield or goggles, an apron or protective coat and pants, rubber boots, and gloves. Safety information on specific products is available from product labels, product technical sheets, and product material safety data sheets (MSDS).

Specific sanitizer safety problems include:

- Strong acids and alkalis are highly corrosive to skin, and should not be sprayed in plants.
- Sodium hydroxide reacts with aluminum to form hydrogen gas. Hydrogen gas is explosive at a 4% concentration level.
- Chlorine gas is a deadly poison. Gas cylinders must be handled carefully, stored securely, and kept away from heat.
- Liquid chlorine solutions are highly corrosive.
- Mixing a chlorine sanitizer with acid generates chlorine gas.
- Mixing sodium hypochlorites with quaternary ammonium compounds generates heat and nitrogen chloride (explosive).
- Solid chlorine compounds are strong oxidizers and must be stored away from organic materials.
- When diluting sanitizers, always add concentrated sanitizer to water; not water to sanitizer. Adding water to a concentrated sanitizer may rapidly generate heat.

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Sanitizer Properties	Chlorine Gas	Hypochlorites: potassium, sodium or calcium hypochlorite	Chloramines: di-, tri-chloroisocyanurate	Chlorine Dioxide
Germicidal:				
Activity	High	High	High	High, better than chlorine
Specificity	Generally effective, even spores, viruses; reference sanitizer	Generally effective, even spores, viruses; reference sanitizer	Generally effective, similar to sodium hypochlorite	Generally effective against all bacteria, viruses, yeast, algai, mold
Speed	fastest	fastest	not as fast as hypochlorite	fast-acting

Sanitizer Properties	Chlorine Gas	Hypochlorites: potassium, sodium or calcium hypochlorite	Chloramines: di-, tri-chloroisocyanurate	Chlorine Dioxide
Form:	compressed gas	concentrated hypochlorite solution or powder	Powder	Precursors, or sodium chlorate and hypochlorite solutions
Stability	Good	Good as powder, fair as liquid	Good	Good
Toxicity	Yes	Yes	Yes	Yes
Irratancy	Yes	Yes	Yes	Yes

Sanitizer Properties	Chlorine Gas	Hypochlorites: potassium, sodium or calcium hypochlorite	Chloramines: di-, tri-chloroisocyanurate	Chlorine Dioxide
Dilution:				
Preparation	Easy	Easy	Easy	Complex equipment or procedure
Measurement	Easy, idometry, test its available	Easy, idometry, test its available	Easy, idometry, test its available	Difficult, titrations, interference
Stability	Good	Good	Good, lasts longer than hypochlorite	Moderate, decays to chloride
Toxicity	Low	Low	Low	Moderate
Irritancy	Low	Low	Low	Very irritating vapors, even at 17ppm
Vapors	None at correct pH	None at correct pH	None at correct pH	Typical odor, yellow-green, dangerous
Color	None	None	None	Yellow-green or red-brown
pH Range	Most active at pH of 6-7.5	Most active at pH of 6-7.5	Most active at pH of 6-7.5	Effective at broad pH, best at 8.5
Temperature	Cold water, maximum temp. 115°F	Cold water, maximum temp. 115°F	Cold water, maximum temp. 115°F	Use at low temp. To avoid vaporization
Conc.	25 to 200 ppm	25 to 200 ppm	25 to 200 ppm	.25 to 5 ppm

Sanitizer Properties	Chlorine Gas	Hypochlorites: potassium, sodium or calcium hypochlorite	Chloramines: di-, tri-chloroisocyanurate	Chlorine Dioxide
Formation	No	No	No	No
Penetration	Poor	Poor	Poor	Poor

Sanitizer Properties	Chlorine Gas	Hypochlorites: potassium, sodium or calcium hypochlorite	Chloramines: di-, tri-chloroisocyanurate	Chlorine Dioxide
Effectiveness:				
Hard Water	Activity decreases in very hard water (>500 ppm)	Activity decreases in very hard water (>500 ppm)	Activity decreases in very hard water (>500 ppm)	No effect
Organic Matter	Reacts to from chloramines	Reacts to from chloramines	Reacts to from chloramines	Little influence, even at high organic load

Sanitizer Properties	Chlorine Gas	Hypochlorites: potassium, sodium or calcium hypochlorite	Chloramines: di-, tri-chloroisocyanurate	Chlorine Dioxide
Corrosion:				
Solution	Slight to moderate	Slight to moderate	Low	Very Corrosive at low pH
Vapor Space	Possible, through vapor condensation	Possible, through vapor condensation	Possible, through vapor condensation	Slight corrosion
Other	Very corrosive below pH 6	Very corrosive below pH 6	Very corrosive below pH 6	Vapor space corrosion with high temp.

Sanitizer Properties	Chlorine Gas	Hypochlorites: potassium, sodium or calcium hypochlorite	Chloramines: di-, tri-chloroisocyanurate	Chlorine Dioxide
Used For:	All food contact surfaces, CIP	All food contact surfaces, CIP	Good sanitizer for all stainless utensils, food contact surfaces	High organic load situations: poultry, fruit, ultrafiltraion, water treatment.
Advantages:	Best sanitizer for clean stainless food contact surfaces; lower price than hypochlorites,organic chlorine.	Excellent sanitizer for clean stainless food contact surfaces; lower price than organic chlorine	Fast, effective; excellent for all stainless steel surfaces	Not affected by organic matter; effective against all types of organisms
Disadvantages:	Requires tight pH and concentration control; highly corrosive, particularly to stainless steel, when improperly used; produces corrosive gas above 115°F	Requires tight pH and concentration control; highly corrosive, particularly to stainless steel, when improperly used;	May be corrosive if not properly used; produces corrosive gas above 115°F	Complex preparation; corrosive in acid solution; very difficult to handle unless

		produces corrosive gas above 115°F		preparation is automated

Sanitizer Properties	Iodine Compounds: iodophor, 12-30% iodine stabilized in surfactant and acid	Quaternary Ammonium Compounds: QUATS, QAC, benzalkonium chloride, N-alkyl dimethybenzyl ammonium chloride (ADBAC)	Acid Anionic: organic acids (formic, acetic, propionic) and anionic surfactant	Peracetic Acid Solutions: peracetic acid, acetic acid and hydrogen peroxide
Germicidal:				
Activity	Less effective than chlorine	Varied, poor	Good	High
Specificity	Good against yeasts, viruses, bacteria, algae, molds	Good against molds, ineffective with some gram-negative bacteria	Good, broad spectrum, vegetative cells	Good, particularly psychrotrophs and spores
Speed	Not as fast as hypochlorite	Moderate	Good at proper pH	Fast

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Form:	Solution of iodine, stabliized in surface active agent and acid.	Concentrated solution	Solution of concentrated acid and surfactant	Stablilized solution of about 25% H2O2 in acetic acid.
Stability	Good at room temp., avoid >120°F	Good	Good	Good
Toxicity	Yes, some toxic surface-active agent	Yes	relatively low	Yes
Irritancy	Yes	Yes, moderate	Yes	Yes, pungent smell, potent and possibly hazardous oxidizer on skin

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Dilution:				
Preparation	Easy	Easy	Easy	Easy
Measurements	Easy, iodometry, test kits available	Test kit	Good, pH is measured	Easy, titration of oxides
Stability	Stable at room temp. and below	Excellent	Excellent, even at high temperature	Good
Toxicity	Some wetting agents may be toxid	None	low	low

Irritancy	None, used for hand wash	None	Low	Irritating to nose
Vapors	Iodine odor, vaporizes above 120°F	None	None	Pungent
Color	Red-brown, used to judge concentration	None	None	None
pH Range	Effective at low pH, 4 or lower	Effective over broad pH range	pH 1.9-2.5 for best activity	Effective over broad pH range
Temperature	Maximim temp. 120°F	Broad range	Cool to Warm	
Conc.	25 ppm	200 ppm	400 ppm	0.20 to 0.35%
Sanitizer Properties	**Iodine Compounds: iodophor, 12-30% iodine stabilized in surfactant and acid**	**Quaternary Ammonium Compounds: QUATS, QAC, benzalkonium chloride, N-alkyl dimethybenzyl ammonium chloride (ADBAC)**	**Acid Anionic: organic acids (formic, acetic, propionic) and anionic surfactant**	**Peracetic Acid Solutions: peracetic acid, acetic acid and hydrogen peroxide**
Films:				
Formation	Slight, loses activity	Yes	Yes	Yes
Penetration	Good, depends on weeting agent	Very good, penetrates porous surfaces	Good, depends on wetting agent	Good
Sanitizer Properties	**Iodine Compounds: iodophor, 12-30% iodine stabilized in surfactant and acid**	**Quaternary Ammonium Compounds: QUATS, QAC, benzalkonium chloride, N-alkyl dimethybenzyl ammonium chloride (ADBAC)**	**Acid Anionic: organic acids (formic, acetic, propionic) and anionic surfactant**	**Peracetic Acid Solutions: peracetic acid, acetic acid and hydrogen peroxide**
Effectiveness:				
Hard Water	Activity decreases in water of high alkalinity (>500 ppm)	Inactivated in hard water	Slower, more sanitizer needed in hard water	Limited effect
Organic Matter	Somewhat more stable than chlorine	inactivate QUATS	Reacts with milkstone, low reactivity with organic matter	
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Corrosion:				
Solution	Low	None	Possible, uncommon	safe 304, 316 stainless and aluminum
Vapor Space	Possible, through vapor condensation	None	None	None
Other	Pitting with low pH, high-chloride water	None	Corrosion with high-chloride water	Do not use above 0.4%

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Used For:	Aluminum, hand sanitizer, plastics, tile, all food contact surfaces	Non-food contact, porous materials, walls, drains	Combined acid cleaning, rinsing sanitizing; ideal in CIP systems	All food-contact surfaces
Advantages:	Good for farm uses; effective, eliminates milkstone	Useful on non-food contact surfaces; lasting film; detergent properties; good environmental sanitizer at 1,000 ppm; persistent	Eliminates milkstone; best for hard water and CIP	Use on all food-contact surfaces
Disadvantages	Discolors; off-flavors at even low concentrations; less effective than chlorine	Ineffective against some organisms at 200 ppm (no rinse dilution), i.e., *S. aureus, P. fluorescens, and E. coli*; slows cheese cultures at 20 ppm; irritating to user if fogged	Less active against spores; may leach Cu from dairy metal; amount of foam varies with wetting agent	Odor in confined areas; store concentrated in plastic only because of metal reaction