Wash Water Sanitation: How Do I Compare Different Systems?

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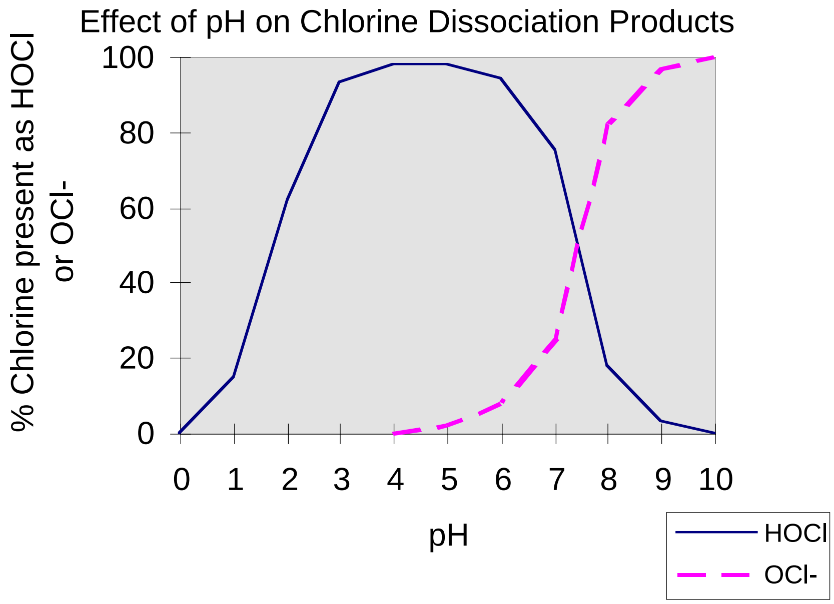
Wash Water Sanitation. Product wash water, if not properly sanitized, can become a source of microbiological contamination for every piece of product that passes through that water. It is a widespread misconception that chlorinated wash water cleans and/or sterilizes produce as it is washed. Chlorinated wash water does little more to clean produce than potable, non-chlorinated water. Chlorine **does** sanitize the wash water and maintains a low microbiological count in the water. In this way the water does not become a reservoir for bacteria to infest the produce. Sodium (or sometimes calcium) hypochlorite is most commonly used in produce wash water. The antimicrobial activity of these compounds depends on the amount of hypochlorous acid (HOCl) present in the water. This, in turn, depends on the pH of the water, the amount of organic material in the water and, to some extent, the temperature of the water. Above pH 7.5 very little chlorine occurs as active hypochlorous acid, but rather as inactive hypochlorite (OCl^-). Therefore, the pH of the water should be kept between 6.0 and 7.5 to ensure chlorine activity. If the water pH gets below 6.0 chlorine gas may be formed which is irritating to workers.



Organic material in the water will reduce the activity of chlorine so periodically replacing or filtering the water is important to maintain cleanliness.

A Few Words About Chlorine Chemistry. Chlorine is very reactive and so combines with almost any oxidizable substrate to form secondary compounds. In addition, the dissociation of chlorine in water depends on the form of chlorine used, the pH of the water and the amounts and kinds of organic materials present in the water. All of these factors make the interactions of chlorine in water complex and hence the widespread confusion within the industry on how best to use chlorine. Terms such as total chlorine, free chlorine, residual chlorine, chlorine gas, hypochlorite and hypochlorous acid are enough to confuse the most dedicated sanitation manager.

Of the many possible forms of chlorine, hypochlorous acid is the really good disinfectant. Thus, in our management of chlorine, we want to maximize the hypochlorous acid and minimize all the other forms of chlorine. When either chlorine gas (Cl_2) or hypochlorite solution (NaOCl) or solid $Ca(OCl)_2$ are added to water, the following reactions occur:

$$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$$

$$OCl^- + H_2O \Leftrightarrow HOCl + OH^-$$

The hypochlorous acid (HOCl) further breaks down:

$$HOCl \Leftrightarrow OCl^- + H^+$$

The pH of the solution determines the relative proportions of hypochlorous acid (HOCl) and hypochlorite (OCl^-). At 0C°, chlorine is present as half active HOCl and half inactive OCl^- at pH 7.9. At lower pH there is relatively more HOCl and relatively better antimicrobial activity.

When chlorine gas dissociates, one of the products is H^+ or hydrogen ions. These cause the pH to be lowered slightly, which improves the chlorine activity. When hypochlorites dissociate, one of the byproducts is OH^-, which raises the pH slightly and reduces the chlorine activity. These effects will be greatest in unbuffered water.

What Is Free Chlorine? Free chlorine (or free active chlorine) refers to the total amount of elemental chlorine gas (Cl_2), hypochlorous acid and hypochlorite. Total chlorine, in turn, would also include NaOCl, $Ca(OCl)_2$, chloramines, chloroform and other less active forms. At high pH the free chlorine content can be high, but it will mostly be in the form of hypochlorite and so will be ineffective as a sanitizing compound. The same free chlorine content at lower pH will be much more effective. Thus, measuring free chlorine does not assure efficacy. It is crucial that the pH be below 7.5 so that the majority of the free chlorine is active hypochlorous acid.

What Chlorine Does and Does Not Do. Chlorine is a very good antimicrobial and sanitizing agent. In high enough concentrations, it kills bacterial cells on contact. It is less effective against bacterial and fungal spores but, given enough time and concentration, chlorine will kill spores too. Chlorine can help prevent buildup of biofilms on machinery and can prevent proliferation of microorganisms in wash water. In fact, the greatest benefit of chlorine in most operations is that it keeps the wash water clean so that product does not become contaminated by microbes in the water.

Chlorine is not a sterilant. While it can reduce microbial populations on produce, it will not make produce microbe-free. Chlorine has virtually no penetrating action so it is not effective against internal fungi and bacteria. While chlorine can help prevent postharvest disease by keeping the wash water clean, it will not cure diseased product that has already been infected in the field or during processing.

Chlorine has no residual effect so it will not prevent recontamination after washing. Prevention of recontamination must be accomplished through care in handling and through a comprehensive program of worker and facility sanitation.

Chlorine will not confer any benefits if the wash water is not kept relatively clean and free of organic matter, if the pH of the water is high, if the concentration of active chlorine (hypochlorous acid) is not high enough, or if the chlorine is not allowed to contact the product for enough time. If the chlorination system is properly monitored and operated, chlorine can be an important and useful part of product sanitation.

Alternatives to Chlorine. Alternatives to hypochlorite are available for produce water sanitation. Chlorine dioxide is less sensitive to pH and organic mater than is hypochlorite and is active at lower concentrations. Chlorine dioxide generation systems are generally more expensive than hypochlorite, though stabilized liquid formulations are now available that are cheaper and easier to use than previous systems. Sodium hypobromite (bromine based) is also approved for use in place of sodium hypochlorite but I am not aware of any use of bromine for water sanitation in the produce industry. Ultraviolet light systems are available for water sterilization as well as for use on produce surfaces. Ultraviolet light leaves no chemical residues and is not affected by water chemistry. However, it is only surface active and so requires clear water to be effective. Ozone is also approved for use as a water sanitizing agent. Ozone is a very good sanitizer but is subject to environmental and worker exposure regulations. It may also be difficult maintain a consistent dosage since it breaks down to oxygen very rapidly. Organic acid formulations, such as peroxyacetic acid mixed with sodium hydroxide, are also available for use in wash water sanitation. These products are active over a broad pH range and are less sensitive to organic matter than is sodium hypochlorite.

Activities and environmental sensitivities of wash water sanitizers.

	pH	Organic Matter	Biocidal Activity
Hypochlorites	6.0-7.5	Very sensitive	Oxidizer
Chlorine dioxide	6.0-10.0	Sensitive	Oxidizer
Ozone	6.0-8.0	Somewhat sensitive	Oxidizer
Peroxyacetic acid	1.0-8.0	Somewhat sensitive	Oxidizer
UV light	Not affected	Somewhat sensitive	Disrupts DNA

How Do We Measure Sanitizer Activity? Of the five classes of sanitizing compounds listed above, four are oxidizing agents. That is, they kill microorganisms through oxidation reactions. Ultraviolet light kills microbes through physical disruption of their genetic material, or DNA.

The various oxidizing compounds have been measured in different ways; free chlorine, total chlorine, available chlorine, parts per million of ozone or chlorine dioxide, percent peroxyacetic acid. What we are really interested in knowing is not how much sanitizer is present, but rather how effectively the sanitizer is killing microorganisms. This could be measured by taking water samples to a lab and counting the microorganisms in the water. However, this would be slow and expensive.

In fact, there is a better way to measure the activity of oxidizing compounds. Since they all kill microbes through oxidation, it is possible to measure their anti-microbial activity by measuring the oxidation-reduction capacity of the water. This is measured as millivolts (mV) of electrical potential in the water. Many years of research have shown that if the oxidation-reduction potential of the water is greater than 650 mV, most pathogens will be killed on contact. By constantly maintaining the potential above 650 mV, we can be assured that our wash water is clean without having to measure the amount of sanitizer in the water. There are automated systems commercially available that monitor the electrical potential of the water and inject sanitizer (and sometimes acid) into the water, as needed, to stay above 650 mV. This is a more direct way to monitor wash water cleanliness than traditional measures of ppm total chlorine, for example.

An effective wash water sanitation system is becoming a necessity in the produce industry due to increased concerns with the safety of fresh fruits and vegetables. Since water can be a source of contamination of produce should the water itself become contaminated, the ability to insure the cleanliness of the water is an essential element of a food safety program. Understanding how different sanitizers work and how they are measured and monitored is an important element in operating that food safety system in an effective and cost efficient manner.