KEY OPERATING STRATEGIES FOR CHLORINE DISINFECTION OPERATING SYSTEMS

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ABSTRACT

Chlorine has been used as a standard for disinfecting wastewater for many years. While being the standard There are many levels of automation for control of disinfection. To select the best control approach for your facility both control strategies and chlorination chemistry must be understood. Permit conditions must also be fully identified; organism concentrations and operational data. Many States require compliance with both organism concentrations and residual chlorine concentrations.

Breakpoint chlorination chemistry plays a role in most chlorine disinfection systems. This paper discusses blending on-line monitoring and automated control with chlorine chemistry to develop several levels of process control that will work. Disinfection byproduct formation must also be considered while developing a process control strategy. Trihalomethanes are being regulated in wastewater effluent and the water quality based limits are much stricter than SDWA drinking water standards.

This presentation will highlight the key operating factors for maintaining chlorine gas disinfection systems. Check lists developed from working with successful operations staff will be presented that will allow users the most update information on the operation of chlorine gas disinfection systems.

KEYWORDS

chlorination, dechlorination, breakpoint chlorination, chlorine mixing, chlorine dosage, chlorine safety and handling

Introduction to Chlorination

Chlorine is available for use as a disinfectant or oxidant. This means that it can be used to remove pathogens and other undesirable organisms as well as oxidize such materials as odor causing sulfides, iron and similar metals as well as some organics. It is this multiple capability that makes chlorine such a desirable chemical for disinfection and oxidation in the treatment of wastewater effluents. Whether a wastewater treatment plant is using chlorine for disinfection or not, it is likely that chlorine is used somewhere else in the treatment or collection system process. In addition to chlorine's use in the effluent for disinfection, it is also used in the collection system to maintain wastewater freshness and to control or eliminate sulfide odors. Chlorine is used to control midge flies and odor control applications at locations such as the preliminary treatment section of a facility. Chlorine is also used in the return activated sludge (RAS) process and for algae control at weirs and filters.

Chlorine is available from suppliers in three forms, or it can be generated on-site. On-site generation is covered in the WEF Disinfection Training Manual. It should be noted, the term chlorination applies equally to the process regardless of the form of the chemical.

Physical and Chemical Properties

Chlorine is available to wastewater facilities in three basic forms:

- Chlorine Gas
- Liquid Sodium Hypochlorite, and
- Solid Calcium Hypochlorite

Chlorine gas, sometimes referred to as elemental chlorine, is 2.5 times heavier than air, has a greenish color, and a characteristic pungent odor that is noticeable at levels of 0.2 mg/L (0.2 ppm). Chlorine gas is corrosive in the presence of moisture. Steel, stainless steel, iron and copper will readily corrode in the presence of moist chlorine gas. Chlorine gas is available as a pressured liquid in steel containers.

Sodium hypochlorite, sometimes referred to as liquid chlorine or liquid bleach, is a solution of anywhere from 5 to 15% available chlorine. Occasionally the term "javelle water" is used to refer to hypochlorite solution. Solutions of sodium hypochlorite are unstable and will start to decompose at the time of manufacture. Decomposition will continue until it is used. Exposure to heat, light, and metals (e.g. iron, copper) will enhance decomposition. Higher concentrations have more rapid decomposition rates than lower concentrations. Mixing with materials such as alkalis, acids, alum, and ferric chloride will release chlorine gas. Liquid sodium hypochlorite is available in bulk shipments, plastic carboys or lined tanks, or generated on-site.

Calcium hypochlorite, sometimes referred to as powder chlorine, powder bleach, or highest hypochlorite (HTH) is a solid containing 65 to 70% available chlorine. It is most often used in a compressed form (e.g. tablets, briquettes) but, is also available as a crystalline granule or powder. The compressed form is considered easier and safer to handle compared to the granular or powder form. Both forms contain inert material. When the powder is mixed with water to form a solution, the inert materials will settle in the bottom of the mix tank and require steps to remove or avoid including it in the solution fed to the process. Calcium hypochlorite is very hygroscopic (absorbs water readily) and highly reactive. This material can react with organic compounds (oil, grease, etc.) and may a pose fire risk. It should be stored in a dry location and utilized with equipment that is free of any organic compounds.

Relationship between the Three Forms

The three forms of chlorine produce the same product on mixing with water. Each will form hypochlorous acid, the active ingredient in the disinfection and oxidation processes. In addition, hypochlorous acid can dissociate to hypochlorite ion. Either form acts as a disinfectant or oxidant. (Equation 2.4) The amount of hypochlorous acid and hypochlorite formed is a function of pH and temperature. The more acidic a solution is the greater the concentration of hypochlorous acid. The more alkaline a solution is the greater the concentration of hypochlorite ion. This is illustrated:

$Cl2 + H2O \rightarrow HOCl + H+ + Cl-$
Chlorine Gas + Water → Hypochlorous Acid + Hydrogen + Chlorine

$NaOCl + H2O \rightarrow HOCl + NaOH$
Liquid Sodium Hypochlorite + Water → Hypochlorous Acid + Sodium Hydroxide

$Ca(OCl)2 + 2H2O \rightarrow 2HOCl + Ca(OH)2$
Solid Calcium Hypochlorite + Water → Hypochlorous Acid + Calcium Hydroxide

$HOCl \rightarrow H+ + OCl-$
Hypochlorous Acid → Hydrogen + Hypochlorite Ion

The amount of each component (hypochlorous acid or hypochlorite ion) is important to know in the disinfection process. The hypochlorous acid is the more active disinfectant of the two components. Disinfection is more effective at a pH between 7 and 7.5, since the amount of hypochlorous acid present at that pH is approximately 70 – 80% of the dissociation product. With a higher pH, the primary disinfectant becomes the hypochlorite ion. Disinfection is ineffective at these levels.

The quantities of each of the chlorine forms equivalent to each other in disinfecting capability are compared by the relationship to the amount of hypochlorous acid formed. Approximately 3.4 L (0.9 gal.) of 12.5% sodium hypochlorite or 0.7 kg (1.54 lbs) of calcium hypochlorite will provide the same amount of hypochlorous acid as 0.5 kg (1.1 lb) of chlorine gas. The equivalent amount of sodium hypochlorite solution is directly related to the concentration of the solution, so a larger volume of sodium hypochlorite solution would be needed if the concentration is weaker.

Calculations for converting equivalent amounts of chlorine gas to sodium hypochlorite and calcium hypochlorite are given below.
Given: 23 kg (50 lbs) of chlorine gas
Calculate: The amount of sodium hypochlorite and calcium hypochlorite needed to give an equivalent disinfecting capability

Metric:
Sodium Hypochlorite Calculation
0.5 kg (chlorine gas) ≈ 3.4 L (sodium hypochlorite)
so, 23 kg ≈ an unknown (X) number of liters of sodium hypochlorite. To solve this, set up two equations and then “cross-multiply” them as shown below.
0.5 kg = 3.4 L
23 kg = X L
cross multiplying yields:
$0.5X = 78.2$
$X = 5 . 0$

2 . 78
= 156.4 L

Calcium Hypochlorite Calculation
0.5 kg (chlorine gas) ≈ 0.7 kg (calcium hypochlorite)
so, 23 kg ≈ an unknown (X) number of kilograms of calcium hypochlorite. To solve this, set up two equations and then "cross-multiply" them as shown below.
0.5 kg = 0.7 kg
23 kg = X kg

cross multiplying yields:
0.5X = 16.1
X =
5 . 0
1 . 16
= 32.2 kg

English

Sodium Hypochlorite Calculation
1.1 lb (chlorine gas) ≈ 0.9 gal (sodium hypochlorite)
so 50.7 lbs ≈ an unknown (X) number of gallons of sodium hypochlorite. To solve this, set up two equations and then "cross-multiply" them as shown below.
1.1 lb = 0.9 gal and
50.7 lbs = X gal,
cross multiplying yields:
1.1X = 45.63
X = 1 . 1
63 . 45
= 41.5 gal

Calcium Hypochlorite Calculation
1.1 lb (chlorine gas) ≈ 1.54 lbs (calcium hypochlorite)
so 50.7 lbs ≈ an unknown (X) number of pounds of calcium hypochlorite. To solve this set up two equations and then "cross-multiply" them as shown below.
1.1 lb = 1.54 lbs and
50.7 lbs = X lbs,
cross multiplying yields:
1.1X = 78.1
X = 1 . 1
1 . 78 = 71 lbs

Regardless of the source, chlorine (hypochlorous acid) disinfects by oxidizing any inorganic or organic substrates it comes into contact with. Depending on the organism and chlorine concentration present, the effects of chlorine on organisms may vary somewhat. For example, chlorine may simply affect an organism's ability to reproduce or metabolize. Chlorine can cause mutations in an organism or ultimately kill an organism outright through a process such as cell lysis (disintegration). Organisms such as *Giardia lamblia, Cryptosporidium,* and the eggs of parasitic worms are resistant to chemical disinfection and require other techniques to remove them from an effluent.

Regulatory Requirements

Effluent

The process of effluent disinfection is practiced because it is considered one additional barrier to the spread of water borne diseases. Those swimming and fishing near the discharge water need protection from pathogens. Utilities that rely upon drinking water intakes that are downstream from effluent discharges depend upon effective disinfection of the wastewater effluent. Most states require a maximum level of chlorine residual, as total chlorine, in the effluent from wastewater treatment plants. The exact level may vary but generally 0.05 mg/L (0.05 ppm) is the desired residual level. This may vary from state to state and on the quality of the receiving stream. Some states will not allow any chlorine residual, thus requiring dechlorination before discharge. This might be the case, for example, if the receiving body of water is a trout stream. Excess chlorine levels can kill fish . Others will require disinfection with chlorine only during the warmer months, for example, May to October.

Other

Best practices to be employed when using chlorine gas, sodium hypochlorite, and calcium hypochlorite are documented in several publications including the Ten State Standards and WEF's Manual of Practice FD-10, *Wastewater Disinfection*. In general, these practices include the use of redundant disinfection equipment, separate storage rooms for the various chemicals, training for the operating personnel, safety equipment (masks, gas leak detectors, handling equipment), etc. State and local regulations also often include specific information on requirements for these systems.

Chlorination Equipment Configurations

Chlorine Shipment Containers

Chlorine gas is shipped in pressurized steel containers having capacities of 70 kg (150 lb) and 910 kg (2000 lb). The 910 kg (2000 lb) containers are generally referred to as ton cylinders. The 70 kg (150 lb) containers are vertical cylindrical tanks with a valve threaded into the top of the container (Figure 2.2). The valve body has a metal alloy insert to prevent over pressurization of the containers. The alloy, also referred to as a fusible plug, will melt at between 70° and 74 °C (158° and 165° F). This enables any pressure caused by overheating in the event of a facility fire to be relieved through the fusible plug. The 70 kg (150 lb) container is filled to about 80% of the container volume with liquefied gas to allow for expansion of liquid chlorine in the event of a temperature increase.

Chlorine Room Design

Rooms to handle chlorine gas must have doors exiting to the outside of the building and not to the inside of the building. Building codes specify the number of doors required. These doors must have panic hardware for emergency exiting. Room ventilation must be designed with one air change per minute. Lights must be turned on from the exterior and the same switch must activate the exhaust fan. A window must be available so that the inside can be observed from the outside before entrance. Exhaust discharges must not be near fresh air intakes and, also, be away from areas where people would be present, such as sidewalks, paths, roads, etc. Chlorine should be monitored with a read-out outside of the storage room. The room must be equipped with fire sprinklers, scrubbers, and a containment area for sprinkler water.

Contact Tanks

Contact tanks are used to provide the mixing and detention time for the chlorine to come into contact with all bacteria and other organisms in the wastewater. Most permits have a requirement of 30 minutes contact at average flow and a minimum of 20 minutes at peak flow. There are different types of effluent contact tanks. Some are rectangular, some are serpentine and others are circular. Many contact tanks contain a mixing device to ensure thorough initial mixing and chemical distribution.

Mixing

Effluent disinfection research has demonstrated the value of mixing chlorine with the effluent. Mixing devices have increased the efficiencies of chlorine addition; most facilities provides some sort of mixing. Devices such as agitators externally mounted over the contact tanks or effluent channels have worked successfully in reducing the amount of chlorine added and in improving the control of the feed. Newer devices mounted under the surface not only improve mixing but also improve safety in handling since the chemical can be added under vacuum and pressurized solution lines are no longer required. Dilution water should not be used to mix sodium hypochlorite. The increased pH can cause carbonate scale to form.