Disinfect with Sodium Hypochlorite

Sodium hypochlorite is an effective alternative to chlorine gas. Follow these guidelines for its safe use.

Anton G. Callery,
Portacel, Inc.

The use of chlorine gas for disinfection involves numerous risks and restrictions. As a result, there has been increased demand for safer alternative disinfectants.

Chorine is typically stored in compressed gas or liquid form, and inadvertent leaks present a potential hazard to the public and to facility employees. Chlorine gas expands rapidly when released to the atmosphere, creating a low-lying cloud that displaces oxygen in its zone of influence. It reacts with the moisture in the air and in the membrane linings of the eyes, throat and lungs to produce hydrochloric acid, a highly destructive irritant to living tissue.

Section 112(r) of the Clean Air Act requires any facility storing more than 2,500 lb (1,134kg) of chlorine to have a Risk Management Plan (RMP) for chlorine. Industrial plants and municipal utilities that store chlorine are also often required to install scrubber systems and other discharge-protection equipment and to implement release-prevention procedures. U.S. Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910.119) require a Process Safety Management (PSM) program, including a process hazard analysis. Various state agencies have similar regulatory programs. And, the Universal Fire Code contains provisions that regulate the storage of chlorine.

As a result, recent disinfection practice has moved away from chlorine gas to liquid sodium hypochlorite (NaOCl). As an aqueous solution, NaOCl is less hazardous and easier to store and handle than chlorine gas, making it a viable option. Although NaOCl requires more storage space than gaseous chlorine, it can be handled more easily and it creates fewer maintenance problems than other disinfectants, such as ultraviolet or ozone disinfection and gas chlorination. Furthermore, it offers these advantages at a capital cost that is as much as 25–50% lower than the alternatives.

■ A pre-fabricated multiple-use-point NaOCl dosing system with panel-mounted ejectors and gages.

Early users of commercial-grade NaOCl quickly found out that its application can be cumbersome from design, storage and application perspectives. However, NaOCl becomes a simple and effective treatment chemical if several concerns are properly addressed early in the system design.

The first thing to remember, though, is this: Commercial-grade NaOCl is not "bleach." It is a highly corrosive, relatively unstable, very caustic material that has the potential to crystallize in delivery lines, form scale on the water system components that it contacts, and gasify to the point of literally exploding piping and valves — all at the same time.

Operator handling and safety

Personnel who handle NaOCl need to take the same precautions as they would for any other caustic material. Rubber gloves, face shields and rubber aprons should be kept near the storage site and used during off-loading. Care should be taken to assure that the NaOCl does not come into contact with the skin; if it does, the skin should be immediately flushed with water to reduce the hot, itching sensation associated with contact. An emergency eyewash/shower should be available at the loading site.

Sodium hypochlorite emits oxygen when it degrades. However, NaOCl will react with most acidic materials (such as ferric chloride) and release chlorine gas. Extreme care during the unloading process, primarily to ensure that all liquid chemicals occupy only their designated storage containers, will alleviate this problem. Also, tank bunkering should be installed to isolate any potential spills and to prevent them from coming into contact with other reactive materials. Note that in the case of an NaOCl spill, the material can be easily diluted with water and will naturally degrade to oxygen and salt, usually within 72 hours.

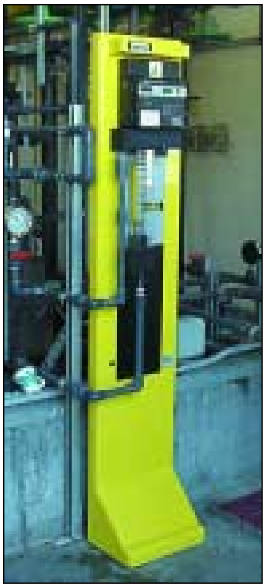
The Chlorine Institute, the Water Environment Federation and the American Water Works Association make the following safe handling recommendations.

1. Do not use different sizes or types of fittings on various storage tanks. Most delivery tank trucks carry adapters for most types of fittings and should be able to accommodate whatever design you standardize on.

2. Only specified and trained operators should be assigned to supervise the unloading process.

3. Blind flanges should be padlocked to fill-line quick-disconnects to prevent tanks from being filled without proper supervision.

4. A delivery checklist should be used to confirm that the delivered material conforms with the placarded storage tank, that the quantity received conforms with the quantity on the shipping papers, that a material sample was collected, and that the facility's safety and handling procedures were followed during the off-loading process. The completed, signed and dated forms should be maintained for accident prevention and for historical record.



■ Floor-mounted vacuum doser used to feed NaOCl to the effluent of a reservoir system prior to distribution.

Material storage considerations

Don't be tempted by a supplier's offer to give your facility a discounted rate for volume loads without careful consideration. As previously mentioned, NaOCl is a fairly unstable material, and it will degrade in storage due to the following factors:

- *Heat.* The degradation rate doubles for every 10°F temperature increase.
- *Concentration.* The degradation rate increases with the square of the concentration.
- *Light.* Degradation occurs as much as four times faster in the presence of ultraviolet light.
- *Contaminants.* Any metallic material (ferrous or nonferrous) will rapidly degrade NaOCl. Non-compatible materials in the storage and delivery system (such as some resins and plasticizers and any oxidizable material) will leach into the stored solution and cause degradation.
- *pH.* Allowing the pH of the stored NaOCl to fall below 12.0 will accelerate degradation.
- *Time.* A delivery schedule that assures a material turnover every 15 days should be established. If this is not feasible, shelf life can be increased by diluting the material *in situ* to a 6% solution using clean, filtered and uncontaminated water.
- *NaOCl quality.* Solution quality can vary considerably from one supplier to another, so pay attention to the supplier's product and its quality-control procedures.

Without proper storage system design, what is delivered to the site may not be what gets delivered to the NaOCl dispensing system. Thus, the chemical storage facilities should be planned and designed carefully.

Tanks. Ideally, the tankage should be installed in a dark and temperature-controlled environment maintained at about 60–70°F. If that is not feasible, it should be in a shaded enclosure with good airflow to slow degradation.

Tankage should be double-walled, constructed of an NaOCl-compatible fiberglass resin with a resin-rich vinyl ester inner wall. The outer containment should be post-cured and incorporate UV inhibitors. If a single tank is used, the tank should be bunkered. As an alternative, tanks can be constructed of high-density polyethylene or titanium, or rubber-lined steel.

Tanks also need to be vented to release any oxygen buildup that occurs during storage. Vents should be gooseneck- or trap-type with screens to prevent contamination.

Level sensors and weighing. Inventory control should be via a non-intrusive ultrasonic level sensor or tank weighing platform. Probe sensors, floats and sight glasses are prone to crystallization problems and corrosion, so they should be avoided if possible. Tankage should be equipped with high-level alarms.

Valves. Valving around the tankage should be polyvinyl chloride (PVC) or chlorinated PVC (CPVC). Rubber-lined steel is not a good choice.

True union ball valves and other quarter-turn devices are ideal for this application. Diaphragm valves have also been used effectively. When using ball valves, it is advisable to drill a small hole in the downstream side of the valve to allow the escape of any gas that may build up in the ball.

Be wary of valve linings that depend on material memory, as the lining material can become brittle in the presence of NaOCl and cause the valve to not seat properly.

Piping

Schedule 80 PVC and CPVC piping and fittings are recommended for transporting neat solution. Although it is more expensive than PVC, CPVC is the preferred material because it provides better resistance to temperature, UV radiation and chemical degradation.

Sodium hypochlorite is very aggressive and will find its way through the smallest leak point, particularly in a pressurized delivery system. Therefore, buried piping runs should be double-walled.

Avoid threaded joints if at all possible. If threaded joints are necessary, threads must be new, sharp and secured with a caustic-resistant Teflon tape and/or paste. Since tape quality tends to be inconsistent, specify a Mil Spec P-27730A-rated tape. Solvent-welded joints must be made as close to perfect as possible. Male ends must be beveled to ensure a secure fusion weld in the socket taper.

Piping assembly is extremely critical to long-term system operation. Thus, the piping assembly procedure should be spelled out in the construction specifications.

Connection to the storage tank should be through solvent-welded or fiberglass fittings located low (in the bottom quadrant) on the tank. While it would appear much easier to use a “dip tube,” *i.e.,* a run of pipe entering the tank from the top, this approach is operationally problematic. The high end of the piping provides a point for gas buildup that will form an airlock in the line, causing downstream dosing equipment to operate in an erratic manner. Flooded lines are much preferred.

Pipe size should be selected to maintain an NaOCl flow velocity of 0.5–1.5 m/s. A slower velocity will contribute to gasification and crystallization, whereas a higher velocity will contribute to a shearing effect that will separate the gas and liquid into alternating slugs, which will affect the accuracy of downstream dosing. Therefore, all piping should be selected with the smallest inside diameter possible to transport the neat solution at the selected velocity. To maintain flow velocity, ells, bends and tees should be avoided as much as possible.

All storage piping and valving should be equipped with a water flushing system to clear the lines during shutdown or intermittent-usage periods. Remember that NaOCl is prone to gasification and crystallization if allowed to lie static for any period of time. In the former case, pressure will build up and cause the valves and piping to explode. The latter situation will jam valves, breaking them or making them inoperative.

Finally, all tankage and piping should be clearly identified and color-coded.

NaOCl solution quality

Many of the problems associated with NaOCl dosing and control can be attributed to the nature of the material itself. As mentioned before, quality can vary considerably from one supplier to the next, depending on the manufacturing process.

The highest-quality sodium hypochlorite has the following characteristics:

- It is a clear, bright greenish-yellow liquid. A dull yellow or cloudy whitish material is an indication of excess caustic or contamination.
- It can pass a suspended solids (*i.e.,* standard filter) test in 3 min or less.
- It has been manufactured by a process that uses caustic filtered through a membrane and site-generated chlor-alkali to reduce contaminants. Processes using chlorine supplied in railcars or containers must carefully filter the chlorine to eliminate contamination and humidity.
- Its manufacturing process uses deionized water (rather than tap water).
- Bromate levels are less than 30 mg/L and chlorate levels less than 2,000 mg/L. This is particularly important in potable water applications because these byproducts, along with chlorite, are considered disinfection byproducts (DBPs).
- Copper, nickel and manganese levels are less than 0.05 mg/L and iron levels less than 0.45 mg/L.
- Sodium hydroxide levels are less than 0.5 mg/L. This is particularly important from an operations and maintenance perspective. NaOH causes scaling problems when it comes into contact with $CaCO_3$ in the water to be treated.
- pH is higher than 12.0, but less than 13.2. A higher pH indicates excess caustic.

Dosing and monitoring methodology

Currently, there are two techniques used to feed NaOCl. Traditionally, metering pumps of either the diaphragm or peristaltic type were standard, but there has been an emphasis in the last few years on vacuum dosing.

Vacuum systems. Vacuum dosing is similar to the process used to feed gaseous chlorine, ammonia and sulfur dioxide. Flow is controlled by positioning a V-notch rate valve at the desired flowrate. A properly sized and placed ejector or induction mixer produces the required vacuum to draw the material through the dosing system. A vacuum regulator at the tank site controls flow/no-flow conditions. Also, to prevent spillage, the regulator provides a positive shutoff to the supply point in the case of a vacuum line failure.

As previously mentioned, system velocities and delivery pipe sizing need to be appropriate for the application, and should not exceed the actual sizing requirement. For example, the chemical feed line to an ejector for a flowrate of 200 lb/d of chlorine would normally be 1/2 in. to 3/4 in., whereas the equivalent volume of 12.5% NaOCl would require a chemical feed line with a maximum size of 3/8 in. The ejector for the NaOCl would only be a 1/2-in. to 3/4-in. unit (depending on the required dilution ratios), rather than the 1-in. or 1-1/2-in. ejector used on an equivalent gas system.

Induction mixers are often used instead of ejectors in wastewater applications. Induction mixers allow the delivery of neat NaOCl solutions to the application point, and they have the advantage of providing a better mixing capability than an ejector/diffuser arrangement.


Three vacuum dosers of varying capacities, with alarms for high and low vacuum and flowmeters.

However, the major design consideration in using this approach is establishing the functional priority of the induction mixer. Is it to be used primarily for mixing in the effluent line or contact basin? Or is the priority to add NaOCl to the system? Manufacturers of induction mixers generally design with chamber mixing as a priority, where the mixing intensity and velocity take precedence over the chemical feed. This is not a problem when feeding gaseous materials, but it may cause a shearing effect if the NaOCl is subjected to excessive velocities. Two effective compromises are to provide a throttling valve on the chemical feed line between the doser and the induction mixer, or to design the induction mixer for the proper chemical feed velocity of 0.5–1.5 m/s.

When using ejectors in combination with diffusers or static mixers, the user must be cognizant of the relationship between dilution water, NaOH levels in the NaOCl solution, and total hardness levels in the receiving water and/or the ejector motive water. Scaling is rarely a problem in motive or carrier waters if the total hardness is less than 40 ppm and the water pH is consistently less than 9.0.

If scaling is deemed to be a problem (in either a vacuum or pressure-feed system), the following approaches, individually or in combination, can be used to solve the scaling problem:

- *Dilution.* Provide a motive water stream with enough volume and flow to keep the pH of the water stream consistently below 9.0. This is a very practical solution except in locations where water volume is restricted or lower pH waters are unavailable.
- *Softening.* Soft water solves the problem, but is impractical in large or remote systems due to the additional chemical, labor and maintenance expenses.
- *CO_2 addition.* This is the most consistent and practical solution in most cases. CO_2 is added as a chelating agent to the motive water stream prior to the point of chemical addition. The process is very predictable, since the CO_2 feed rate is based on water hardness levels and the percentage of NaOH in the NaOCl. Feed rates can be easily adjusted to compensate for changes in either or both of these parameters. In facilities using an amperometric chlorine-residual monitor for free-chlorine control, CO_2 provides an additional benefit of eliminating the need for buffer reagents.
- *Sequesterants.* Several sequesterant products have been tried on a laboratory scale and tested in a limited sense in actual field applications. Initial results are promising for reducing scaling. The products are generally a blend of inorganic phosphates (low in orthophosphate). They are applied to the bulk NaOCl prior to dosing. It appears that acceptable results can be achieved by adding 1 lb of granulated product dissolved in 2 gal of water to each 1,000 gal of 12.5% NaOCl. Additional information on these sequesterants will be available after extended field testing has been completed.
- *Cleaning.* Prepare a general maintenance program that includes regular descaling of ejectors, diffusers and water-contact components by flushing with a weak acid solution. The process is similar to that used for boiler boil-out.

In short, vacuum dosing systems have certain inherent advantages over pumped or pressure systems:

- accurate control of the dosing rate through a variable-control V-notch valve
- system repeatability, since there are no flex or wear points to disturb accuracy
- stability under variable loads and intermittent operation, regardless of gasification issues
- few moving parts, so there is less wear and less maintenance is required
- visual assurance that flow is taking place via a borosilicate glass flowmeter
- no calibration column is required
- increased operator safety compared to pressure systems
- the ability to be programmed with a variety of alarms and control features and signal inputs and outputs
- the ability to be operated without electrical power, making them ideal for disinfection during emergency power-loss situations.

Of course, vacuum technology does have several disadvantages. There is a potential for scaling at the contact point between the chemical and the motive water in the ejector. This can be avoided by accounting for scaling potential during the design phase. Accuracy is less for small applications with a chemical feed rate below 15 gal/d, in which case liquid surface tension effects across the minimized V-notch are deleterious to operation.

Pumps. Metering pumps have a place in NaOCl feed regimes, particularly in applications where the chemical feed rate is continuous with little or no dosage variance or where the feed rate is low. When using metering pumps to feed NaOCl, be aware of the following constraints.

If the pump is used in an intermittent manner, it is advisable to flush the pump head with water between applications. Otherwise, the diaphragm pump head will be prone to gasification, which will form a vapor lock in the pump immediately upon restart, and to crystallization, which will jam the operating mechanism in the pump's wet end.

Placing chemical feed pumps below the elevation of the storage tank or day tank and ensuring a flooded suction at all times from the tank will help alleviate gasification problems from the upstream supply of the pump. Try to keep the suction line length as short as possible.

Install degassing valves on the pump heads. Implement a regular preventive maintenance routine to check the degassing valves for calcification and crystallization that will render them inoperative. Keep in mind that degassing valves will expose the NaOCl solution in the pump head and associated piping to a potentially contaminated environment.

Employ pumps in which the wet end is completely isolated from the mechanical operating assembly. This will prevent corrosion and failure of the operating components. Double-diaphragm or peristaltic pumps are the best choices in this regard.

Pulsation dampeners should be provided on the both the pump suction and discharge.

Utilize flowmeters or calibration columns on the pumps to provide a visual assurance that NaOCl is getting to the system. The fact that the pump is running is no indication that chemical is actually moving through the system.

Use double-wall piping on the discharge side of the pump for operator safety. An unexpected pressure blowout or leak could injure nearby personnel.

Instrumentation considerations

Automatically controlled systems should take advantage of available control technology regardless of the dosing methodology. Because of the degradation potential of NaOCl, chlorine-residual control is warranted. The residual sample point should be no more than 10 min downstream from the NaOCl application point. Otherwise, the doser will be constantly chasing the residual setpoint. Do not deadhead amperometric or colorimetric analyzers from a pressurized sample point. Rather, put them on a "fast loop" back to the inlet side of the system for best accuracy.

As an added precaution, pH monitoring can be installed on the NaOCl storage tank or in the tank discharge line to monitor any drops in the pH of the neat solution that would indicate contamination problems. CEP

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ANTON G. CALLERY is the U.S. operations manager for Portacel, Inc., a division of Thames Water International (118 S. Division St., Zelienople, PA 16063; Phone: (724) 452-4691; Fax: (724) 452-7308; E-mail: tcportacelinc@cs.com), where he is responsible for sales, marketing, systems engineering, manufacturing and operations in the Western Hemisphere. In 1997, he opened Portacel's office in the U.K. Previously, he was an international manager for the FB Leopold Co., an engineered products and systems manufacturer primarily involved in municipal filtration, where his responsibilities included business development in Asia and South America. He also worked as a project/site/process engineer for a small consulting firm specializing in industrial wastewater problems and solutions. He is a graduate of Penn State Univ. with a BS in chemical engineering and a BA in marketing and advertising, and is a member of the American Water Works Association and the Water Environment Federation.