Is Onsite Sodium Hypochlorite Generation Your Disinfection Solution?

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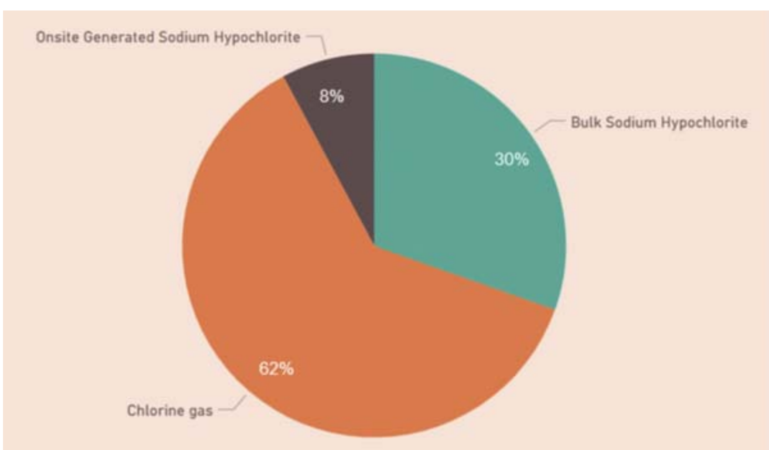
Chlorine is the most commonly used disinfection method in water and wastewater treatment plants. Chlorination was first used in the early 1900s, and alternative chlorination methods include the use of chlorine gas, commercial bulk sodium hypochlorite, and onsite generation of sodium hypochlorite (Figure 1). Onsite sodium hypochlorite generators (OSHG) were introduced to the water treatment industry in the 1970s.

In 2007-2008, the American Water Works Association (AWWA) Disinfection Systems Committee conducted a user survey of drinking water disinfection practices. The disinfection practices surveyed included chlorination in the three forms mentioned, along with other disinfection practices, like chloramine, chlorine dioxide, ultraviolet light, and ozone. As reported in the 2008 survey, 62 percent used chlorine gas, 30 percent used bulk sodium hypochlorite, and 8 percent used OSHG.

Although initially not widely embraced, recent advances in OSHG technology and increased safety concerns of chlorine gas have made OSHG a viable option for both water and wastewater treatment facilities. Since the AWWA survey, 29 percent of users switched from chlorine gas to bulk sodium hypochlorite. Although bulk delivery was the most popular replacement for chlorine gas, OSHG appears to have gained popularity among users.

Figure 1. Alternative Chlorination Methods



(Source: AWWA Disinfection System Committee 2008 Disinfection Survey Report)

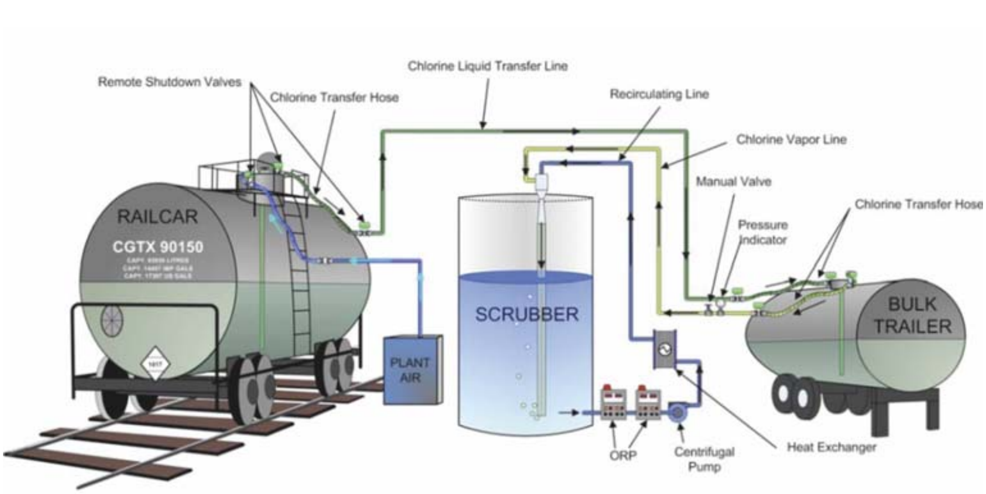


Figure 2. Chlorine Gas Delivery System
(Source: U.S. Chemical Safety and Hazard Investigation Board)

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Chlorine Gas

Traditional chlorine gas is an effective disinfectant and is shipped and stored in pressure vessels as a liquefied gas under pressure. Typical chlorine gas vessels are transported in 150-lb cylinders, ton containers, and rail car tanks. Gaseous chlorine is injected in solution by using a vacuum-operated gas regulator and flow control valve. The venturi-type injector helps generate the necessary vacuum.

Chlorine gas has been used in the water treatment industry for over 100 years, but recently, regulations have increased concerning the safe handling of gaseous chlorine. New chlorine gas systems (Figure 2) have several safety features to minimize risks by providing storage in an enclosed facility equipped with gas scrubbers and connected to an emergency ventilation system. Operational changes have also been introduced, like disconnection of chlorine vessels from withdrawal piping manifolds, and loading and unloading of containers from delivery trucks that must be performed by at least two operators wearing safety equipment.

But even with these safety features, there are risks. The delivery trucks transporting the cylinders through residential commercial areas can pose a high risk if the truck is involved in an accident, which could cause large-scale toxic-release incidents (Figure 3). Risk management and added insurance requirements add to the total operating costs.

Bulk Sodium Hypochlorite:

Between 12.5 and 15 percent solution of commercial sodium hypochlorite is delivered by tanker trucks (Figure 4). Storage container sizes largely vary and are available to meet site-specific requirements. Dosing is accomplished by means of a chemical metering pump and/or a liquid vacuum injection device, similar to those used in chlorine gas dosing systems. Bulk sodium hypochlorite is probably the easiest to

Figure 3. 2005 Train Crash in Graniteville, S.C.

Figure 4. Commercial Truck Delivering Sodium Hypochlorite

transport in terms of operational procedures and normal day-to-day operational requirements are minimal. Per the AWWA Disinfection Systems Committee survey report, utilities utilizing bulk sodium hypochlorite have more than doubled.

Although use of bulk hypochlorite appears to be hassle-free, it has some drawbacks. Bulk hypochlorite is currently cheap at less than $1/gal, but future price fluctuations may occur. Historical pricing fluctuations have been observed and are shown in Figure 5. Temperature and storage duration affects the concentration of the solution, and temperature rise also increases the formation of chlorate, which is a byproduct of degradation. The speed of degradation also correlates to concentration, and higher concentrations degrade more rapidly. Due to degradation, gasification occurs in the storage tanks and piping, which causes operational problems; also, high pH of high-strength hypochlorite causes scaling due to hard water and leakage in the chemical pipelines that may result in frequent piping system replacement.

Since commercial sodium hypochlorite is very corrosive, efforts must be taken to minimize spills. Unlike gaseous chlorine, surrounding areas are not threatened by a leak of high-concentration sodium hypochlorite. The liquid spills can be contained onsite by using a containment area or double-walled storage tanks, but the risk of transportation with the bulk delivery trucks persists. The trucks may have an accident, and containing the spill becomes difficult (Figure 6). Also, operational errors during delivery have been reported where another chemical (ferric chloride, for example) was delivered into a sodium hypochlorite tank, causing the pH to drop and release chlorine gas.

Continued on page 50

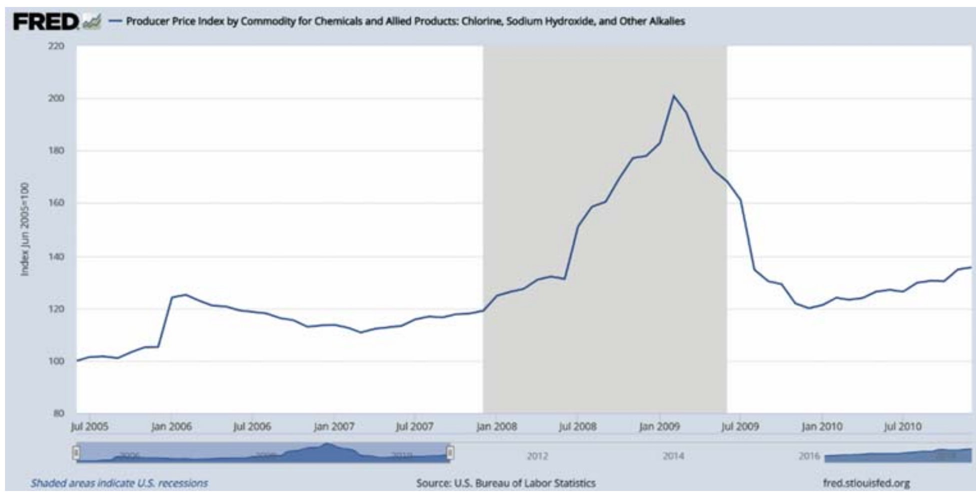

Figure 5. Fluctuations in Hypochlorite Price *(Source: U.S. Bureau of Labor Statistics, Producer Price Index by Commodity for Chemicals and Allied Products: Chlorine, Sodium Hydroxide, and Other Alkalies [WPU06130302], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/WPU06130302, Oct. 5, 2018)*

Figure 6. Tanker Truck Filled With Liquid Sodium Hypochlorite Overturns

Figure 7. Overpressurized Electrolytic Cells

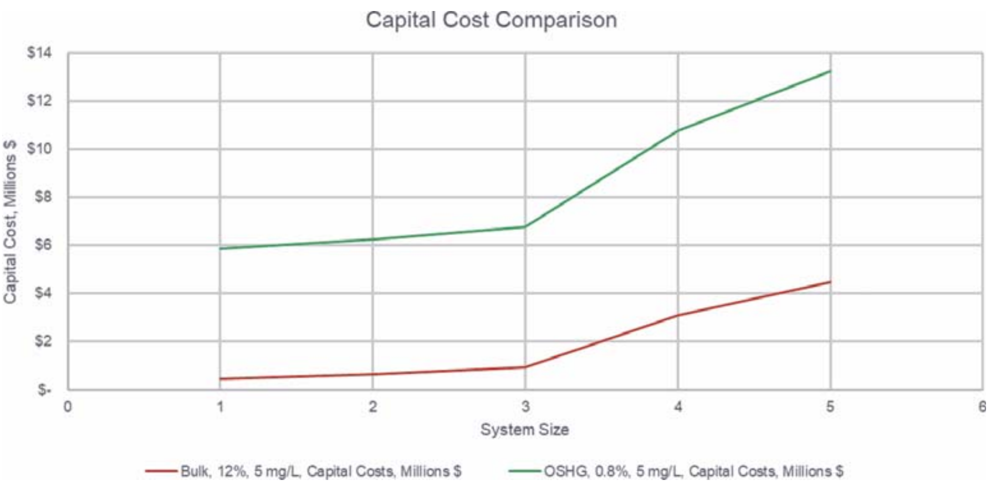

Figure 8. Capital Cost Comparison

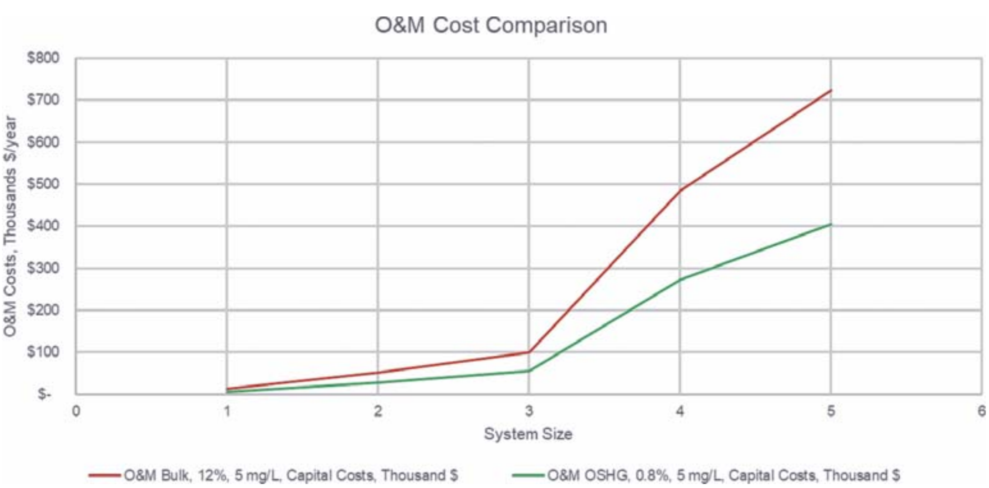

Figure 9. Operation and Maintenance Cost Comparison

Continued from page 49

Onsite Sodium Hypochlorite Generators

Three common materials are used by OSHG: salt, water, and electricity. The salt dissolves to form a brine solution in a brine tank, and sodium hypochlorite is produced by passing a solution of salt through an electrolytic cell and using electricity for electrolysis. The following is the chemical equation:

$NaCl + H_2O + 2e = NaOCl + H_2$
3 lbs + 15 gal. + 2.2 KWH = 0.8 % NaOCl + 1/35 lb H_2

The key components of an OSHG system are:

- *Brine Tank and Pump*
  - Mixture of salt and water is stored in a brine tank or salt saturator. Morton Solar Salt is typically used and is blown into the tanks. The brine is pumped to the generator.
- *Water Softeners*
  - Water softeners are essential for removal of minerals, like calcium and magnesium, from the source water.
- *Electrolytic Cells*
  - Electrolytic cells include electrodes with titanium anode and cathode, which convert brine to sodium hypochlorite.
- *Direct Current (DC) Rectifier*
  - DC Rectifier consists of a fully isolated 6-pulse three-phase step-down transformer, which converts alternate current (AC) to DC.
- *Control Panel*
  - Control panel includes the programmable logic controller (PLC), operator interface terminal (OIT), terminal strips, and variable frequency drives (VFDs) for pumps.

Continued on page 52

Continued from page 50

- *Hydrogen Dilution Blowers*
  - Blowers dilute the off-gassed hydrogen from the electrolytic cells.

- *Storage Tanks*
  - Sodium hypochlorite storage tanks store the generated solution for usage. Typical storage duration is two to four days.

Some of the advantages of 0.8 percent onsite generated hypochlorite are:

- Very stable due to low concentration; hence, reduced risk of chlorate formation due to degradation.
- Batch process; hence, storage volume is reduced.
- Lower pH than bulk hypochlorite; thus, not resulting in increased scaling and pipe failures.
- Greatly reduced risk to plant personnel due to lower concentration.

Figure 10. Old Onsite Sodium Hypochlorite Generators at Lake Park Water Treatment Plant

Figure 11. New 2000-ppd Onsite Sodium Hypochlorite Generators at Lake Park Water Treatment Plant

- No requirement to purchase, handle, or transport hazardous chemicals; hence, no risk to public safety.
- Low-risk management issues.

The main disadvantage of onsite generation is very high capital cost and high life cycle cost compared to chlorine gas and bulk hypochlorite. For utilities wanting to switch from other disinfection options, the operation and maintenance (O&M) of OSHG may seem cumbersome without extended operator training. Another concern is hydrogen gas management and the potential of combustion.

Hydrogen Management Safety

Hydrogen produced during the electrolysis combines with dissolved air and oxygen generated at the anode. The undiluted gas exiting the cell is approximately 3 percent air and oxygen; therefore it's below the lower explosive limit (LEL) of 4 percent in an air environment. If this diluted gas is not released immediately, there will be hydrogen buildup exceeding the LEL. Older systems without passive venting from each closed electrolytic cell can overpressurize, causing an explosion (Figure 7).

Dilution of hydrogen byproduct to safe limits by dilution blowers and new electrolytic cell designs allow passive venting from each cell to reduce the risk of explosion.

Design Considerations

- Increase in water temperature affects the generation process and brine at higher temperatures than 80°F, which can result in higher power consumption exceeding the 2-2.5 kilowatt hour (kWh) range. Installation of water chillers or brine tanks in covered space can be considered.
- Hydrogen vent pipe design needs to be given special attention. Hydrogen dilution blowers shall be sized correctly with air flow sensors. Hydrogen gas monitors should be installed at multiple locations. Consideration should be given to installation of redundant blowers.
- Consider 30 days of brine storage.
- Consider generator installation, as well as power load management protocols.
- Consider bulk sodium hypochlorite backup with a dilution system for usage during catastrophic events and extended power outage.

Cost Comparisons

Figures 8 and 9 show capital and O&M cost comparison of bulk hypochlorite and OSHG, which are from the AWWA M65 Manual, *Onsite Generation of Hypochlorite*. Major capital cost items for bulk-delivered hypochlorite solution include storage tanks, buildings, and chemical feed pumps; for OSHG, capital cost items include brine tanks, electrolytic cells, rectifiers, water softeners, control panel, hydrogen vent blowers, feed pumps, and hypochlorite storage tanks. The system size categories, per AWWA M65, range from a 1.5-mil-gal-per-day (mgd) treatment plant size to 112.5 mgd. Size 3 represents a 15-mgd plant.

As seen from the graphs, the capital cost of OSHG systems is considerably higher than bulk hypochlorite, but the O&M costs for smaller plants (less than 15 mgd), are comparable between the two options. Major items contributing to the O&M costs of bulk include chemicals, equipment maintenance, and labor costs. For OSHG, the cost of salt, power, equipment maintenance, period replacement of cells, and labor contribute to the O&M costs.

Onsite Sodium Hypochlorite Generators at Lake Park Water Treatment Plant

The older 1200-pounds-per-day (ppd) onsite sodium hypochlorite generator at Hillsborough County's Lake Park Water Treatment Plant (Figure 10) was replaced with a new 2000-ppd onsite sodium hypochlorite generator (Figure 11); the lowest bid received was $800,000. The plant-permitted capacity is 15.5 mgd.

The project included replacement of water softeners, installation of a new brine pump and skid-mounted generator, new rectifier, control panel, upsized exhaust fan, new piping, and vent stack.

Lessons Learned

The brine tanks are located outside in a containment barrier. A canopy-style cover was installed over it as part of this project, but it doesn't cover the tanks completely. Since water temperature affects the OSHG operation, other utilities might consider enclosing the brine tanks, similar to the hypochlorite storage tanks, to avoid overheating. Installation of a chiller can also be considered.

Conclusion

As utilities look at disinfection options, other noncost factors as discussed should be considered, besides the cost of bulk hypochlorite versus OSHG:

- Chemical availability (location of manufacturers)
- Neighborhood risks of chemical exposure
- Chemical handling
- Frequency of chemical deliveries based on solution strength ◊