Tech Brief

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On-Site Generation of Disinfectants

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Summary

On-site generators (OSGs) produce chlorine when a solution of sodium chloride is passed through an electrolytic cell and electricity is added. Many communities are turning to OSGs for their water distribution systems because of the benefits inherent in the process, including better safety, high quality disinfection, greener operations, and substantial economic savings.

What is On-site Generation?

On-site generation of chlorine and other disinfectants is a technology that is based on decades-old scientific principles. In essence, OSGs take a solution of sodium chloride (salt) and water and apply electricity, which produces chlorine and other oxidant species. While OSGs have a number of applications in the industrial world, including providing disinfectants for swimming pools and cooling towers, the largest application of OSG technology is for municipal drinking water disinfection. Because of the benefits that OSGs provide, many water municipalities are switching to OSG systems as opposed to more traditional chlorine delivery systems such as chlorine gas, concentrated sodium hypochlorite, and bulk calcium hypochlorite.

How do On-site Generators Work?

While there are many different types of OSG systems available, there are also a number of components that almost every OSG uses (See Figure 1). Water coming into the OSG first goes through a softener, after which it is split into two lines. One line feeds directly into the electrolytic cell while the other is used to fill the brine tank. The brine tank stores a con-

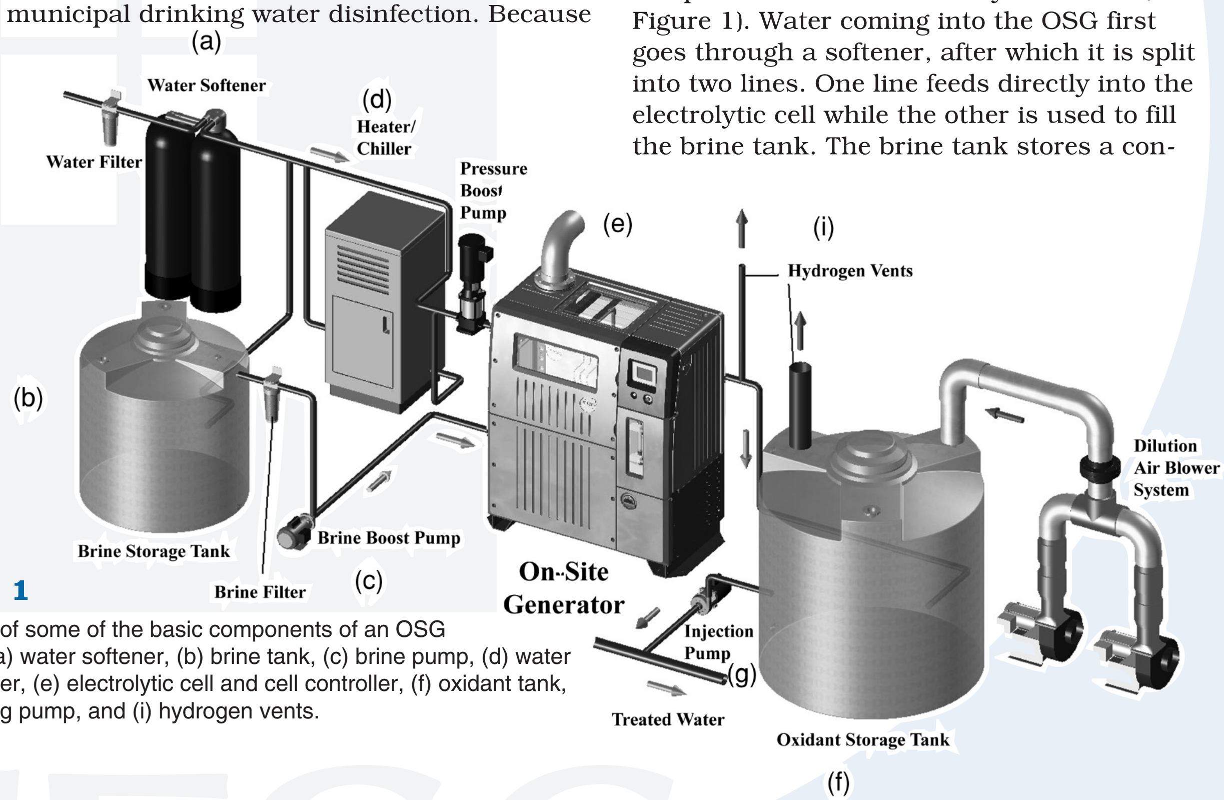

Figure 1

Illustration of some of the basic components of an OSG including (a) water softener, (b) brine tank, (c) brine pump, (d) water heater/chiller, (e) electrolytic cell and cell controller, (f) oxidant tank, (g) metering pump, and (i) hydrogen vents.

centrated salt solution, prepared by having an excess of salt in the tank so that the solution is a near-saturated brine, which is then injected into the softened water stream entering the electrolytic cell.

When the dilute salt solution is inside the electrochemical cell, a current is passed through the cell, producing the oxidant (sodium hypochlorite or other oxidants) solution. After leaving the electrolytic cell, the oxidant solution is stored temporarily in the oxidant tank and is then metered into the water moving through the treatment process. Hydrogen gas is also produced inside the electrolytic cell, and the hydrogen is removed from the cell and oxidant storage tank through vents.

The electrolytic cell, where the oxidants are actually produced, is central to the OSG (See Figure 2). Electrolytic cells consist of two electrodes, the anode and cathode, arranged so that both make contact with the mixed water and brine solution. When the OSG is activated, a voltage is applied to the cell so that current flows through the cell, causing chemical reactions to take place at the surfaces of both electrodes that eventually produce the disinfectants. The overall chemical equation for reaction of salt (NaCl) and water (H_2O) to form sodium hypochlorite (NaOCl) is:

Oxidation reactions are carried out at the an-

$$NaCl + H_2O \rightarrow NaOCl + H_2$$

ode where two chloride ions (Cl^-) are stripped of one electron each to produce chlorine gas:

Depending on the physical and working pa-

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

rameters of the cell (e.g., electrode to electrode spacing, cell applied potential, etc.), it is also possible to produce oxidants other than chlorine, which can provide enhanced removal of microbiological contaminants from water and other benefits. After it is produced, the chlorine gas dissolves in water to produce hypochlorous acid (HOCl) in the same way that bulk chlorine gas from cylinders acts:

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

Chlorine production is balanced by the reduction reactions that occur at the cathode where water (H_2O) is converted into hydroxide ions (OH^-) and hydrogen gas (H_2):

$$2\ H_2O + 2e^- \rightarrow 2\ OH^- + H_2$$

During electrolysis, the hydrogen gas is produced as bubbles that must later be removed from the OSG and oxidant storage tanks to prevent buildup of the gas. The hydroxide ions produced at the cathode then react with the hypochlorous acid produced at the anode, producing the hypochlorite anion (OCl^-), which is charge balanced with sodium cations (Na^+) that

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

originally came from the salt:

Typically, the pH of oxidants that OSGs produce is around nine. The addition of these

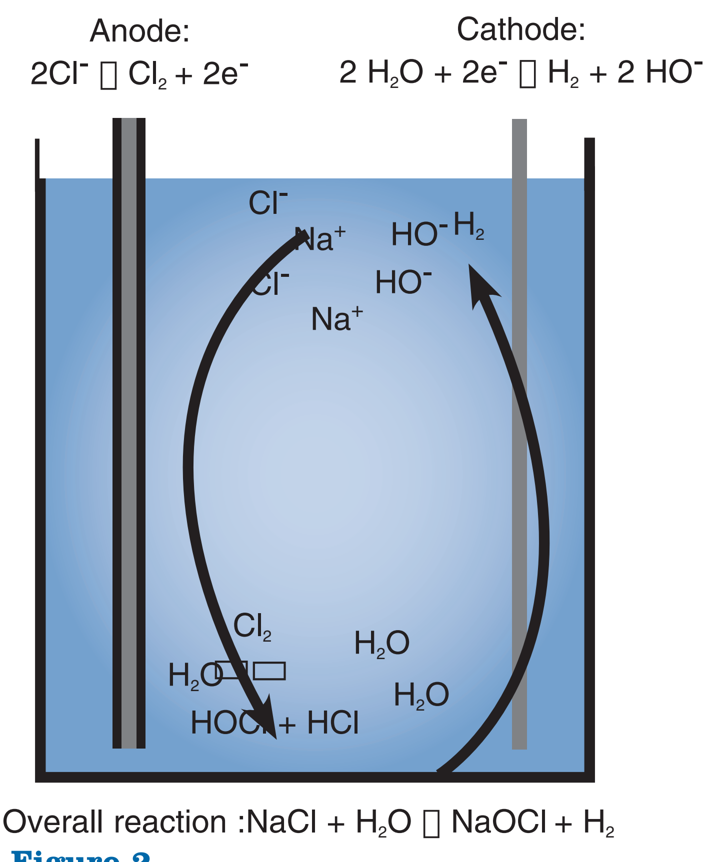

Figure 2

Diagram showing the different electrochemical reactions that take place inside of electrolytic cells that OSGs use.

solutions often does not alter the pH of the water that is to be treated.

What are the Benefits of Using OSGs?

There are four principal benefits associated with OSGs: (1) improved operator safety, (2) higher quality chemicals, (3) greener applications, and (4) cost savings.

Improved Operator Safety

Chlorine sources traditionally used in water disinfection pose a variety of hazards to the operator. Chlorine gas is probably the most hazardous source of chlorine used by water treatments plants; it is toxic and the use of chlorine gas cylinders also poses a pressure hazard. Industrial strength bleach used for water disinfection is a 12.5 percent-by-weight solution, which is caustic. OSG systems use only water and salt and produce nonhazardous oxidant solutions with a chlorine content that typically contains less than 0.8 percent free available chlorine. Treatment plants that use OSG systems typically have to face less oversight from state health agencies, provide less safety training for operators, and have less of an insurance issue compared to those using traditional forms of chlorine.

Higher Quality Chemicals

Recent research has indicated that hypochlorite storage leads to chlorate (ClO_3^-), and perchlorate (ClO_4^-) production from hypochlorite anions. Additionally, factors such as time in storage, temperature at storage, and exposure to sunlight can cause hypochlorite loss through other chemical degradation pathways. These observations indicate that older hypochlorite will contain less and less free available chlorine and more degradation products. Storage issues mount in areas that are required to have 30-day or higher supplies of disinfectant chemicals on hand. OSG systems, on the other hand, typically produce only a two- to three-day supply of chlorine at a time, thus providing a potent disinfectant. Salt does not decompose, so that long-term requirements can be met by storing enough salt to comply with regulations.

Greener Application

OSGs mean greener operations compared to traditional chlorination methods. In addition to the reduction in use and potential accidental release of toxic chemicals, transportation of chemicals from factories to the water plant is reduced. For example, it takes one delivery of salt to produce the same amount of chlorine as more than three deliveries of 12.5 percent sodium hypochlorite solution. This, therefore, lessens the carbon footprint of the plant because less fossil fuel is needed to supply the plant with disinfectant.

Cost Savings

OSGs typically produce chlorine at a much lower cost than traditional delivery methods, primarily because there is no need to continuously purchase expensive chlorine chemicals. This is especially the case for systems using calcium hypochlorite. Additional savings come from decreased transportation and safety-related costs, and lower insurance premiums. Although OSG systems usually present a large, up-front capital equipment cost, most water plants realize a return on their investment in OSG equipment within two to three years.

What are Some Considerations of Using On-site Generators?

Although OSGs are basically safe, there are a few items to consider.

Hydrogen Safety

Hydrogen gas is colorless, odorless, and is flammable. All electrochemical systems that employ aqueous solutions—disinfectant OSGs included—produce hydrogen at the cathode as a byproduct of the electrochemical process. Hydrogen is more than 13 times lighter than air, so it will rapidly dissipate from an electrolytic cell or OSG system. Because OSGs are typically installed inside a building, the system and tanks need to be properly ventilated. Hydrogen safety concerns are mitigated by careful engineering of the OSG itself, as well as good planning when the OSG is installed. When considering an OSG system for a water treatment plant, it is important to ensure that the system meets standards set by groups such as Hydrogen Safety LLC.

Water Quality and Temperature

Water is the most common component of the salt solution that enters the electrolytic cell of an OSG and, thus, the composition of that water is important. Potable water supplies can feed most OSG electrolytic cells, but it is very important that the water be softened so as to have the lowest possible hardness. If hard water is used to provide either the water or brine solutions for an electrochemical cell, scales will rapidly form on the surfaces of the electrodes, causing the electrolytic cell to fail. Similarly, the temperature of the water entering the electrolytic cell should be maintained within a range of 40 to 80 degrees Fahrenheit, to avoid damaging the electrolytic cell. If an OSG is installed in an area where water feeding the OSG will be outside of that temperature range a heater/chiller unit is typically added to the overall system.

Salt Quality

Sodium chloride is the only chemical added to the water stream that is employed by OSGs to produce disinfectants so it is vital that the salt be of high purity. Some contaminants in salt can cause damage to the electrolytic cell, typically calcium and magnesium salts found in sea salt. Another concern is that some salts contain other chemical species that are subject to oxidation, the most common being bromide (Br^-). In any electrochemical cell that produces chlorine, bromide will be oxidized to form bromates (BrO_3^-), which are regulated and have a MCL of 0.01 mg/L. Food quality salt is the most common form of salt recommended for OSGs.

Cell Maintenance

The electrolytic cell is the most expensive part of an OSG and appropriate care should be taken. Flushing the cell with soft water after every usage helps to prevent salt-deposit buildup. Most OSG systems perform this action automatically upon system shutdown. Using appropriately softened water and high-quality salt are the two most important factors of cell maintenance. Even under these conditions, though, electrochemical cells will develop scales over time. This scale will impede the ability of the cell to generate chlorine and, if left unchecked, will eventually destroy the electrodes. Wash the cell periodically by flushing it with muriatic acid (hydrochloric acid) to remove the scale and clean the electrode surfaces. How much acid is needed and how often the electrolytic cell needs to be rinsed are factors that rely on variables such as how often the cell is in operation and the quality of water and salt that go into the cell.

References

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For More Information

To learn more about on-site generation of chlorine, visit the MIOX Corporation site at *www.miox.com*.

Environmental Expert has a feasibility study about OSGs at *www.environmental-expert.com/resultEachArticle.aspx?cid=5306&codi=24371&level=0&idproducttype=6*

Hydrogen Safety LLC provides information

Andrew K. Boal obtained his Ph.D. in organic chemistry from the University of Massachusetts, Amherst. He has worked for Sandia National Labs, NASA, and currently is the research scientist at MIOX Corporation, a company specializing in the development, manufacture, and installation of on-site chlorine and mixed-oxidant generators for potable water disinfection. Boal can be reached at (505) 224-1068 or *andrew.boal@miox.com*.

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