Effective Drinking Water Disinfection
- an Assessment of Chlorine-based Methods

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The need for drinking water disinfection is as old as public water supply itself. Microbiological parameters for drinking water treatment include coliform bacteria and specific pathogenic species of bacteria, vira, and protozoan parasites. Although the objective is the same – to provide safe clean water – the methods used to do so are numerous. The most common methods for water disinfection are chemical ones. This article gives a brief overview of chlorine-based disinfection methods and the factors that can influence the choice of method.

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"No single method can meet all needs," explains chemist Dr Carsten Persner at Grundfos Alldos, who designs systems for chlorine gas dosing, and for electrolytic hypochlorite and chlorine dioxide generation. "Local regulations are probably the one factor that makes it most difficult to draw general conclusions and make recommendations. The next is availability of raw materials and the costs associated with each method – energy costs, chemical costs and so on,"

Chlorine gas – still the No. 1 choice

Chlorine continues to be the most prevalent method of disinfection worldwide. This can primarily be attributed to its long-proven track record as a reliable means of providing safe drinking water and to its relatively inexpensive price tag.

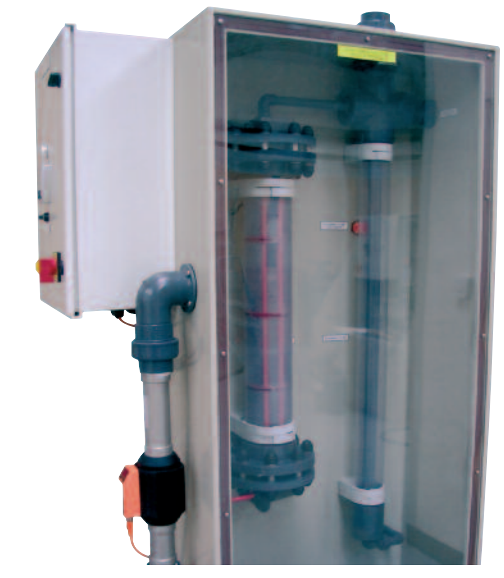
Chlorine works by forming hypochlorite (HClO) when dissolved in water. HClO is a fast-acting oxidant with a wide biocidal effect. It is highly effective at low concentrations that do not pose a danger to human health. The excellent sustained-release of chlorine is of particular benefit as it continues to disinfect a pipeline system over a relatively long period of time.

The challenges with chlorine gas disinfection are associated with the transport, storage and handling of the gas itself. In pressurized form it is stored onsite, requiring investment in a separate gas room and gas warning unit that can contain and deal with the gas in the event of a leak. Dr Persner: "Chlorine gas has to be handled with respect for the risks involved. Operators need to be trained in handling and safety procedures – both to prevent accidents and deal with the situation in the event one happens."

In terms of dosing the gas, it is a steady and precise dosing that will give the best results. Gas chlorination systems under full vacuum, such as Grundfos' Vaccuperm, are the proven ways of ensuring this while also being inherently safe.

	General disinfection effect	Residual effect	pH dependency	Possible by-products	Advantages	Disadvantages
Chlorine gas	High	Hours	Strong	Chloramines, chlorphenoles, THM, AOX	Low-priced agent Approved technology	Demanding chlorine gas storage Chlorine resistance
Chlorine (electrolytic)	High	Hours	Strong	Chloramines, chlorphenoles, THM, AOX	Cheap reagent (salt NaCl) Reliable process No hazard risks	Salt storage for higher capacities Chlorine resistance
Chlorine dioxide	Very high	Days	Medium	Chlorite, chlorate	No chlorine resistance Destroys biofilm	Min. two chemicals to handle

A long-proven track record and sustained-release make chlorine a reliable and favoured disinfectant for public water supply.



The Selcoperm electrolysis system generates hypochlorite on demand and is considered safer to use compared to chlorine gas or commercial sodium hypochlorite.

If the vacuum in the system is lost, the gas container is immediately isolated and no gas can escape.

Chlorine dioxide – no change in taste or smell

Chlorine dioxide (ClO_2) provides excellent and long-lasting water disinfection. As a bactericide, sporicide, virucide and algicide, chlorine dioxide is highly effective, also against microorganisms exhibiting chlorine resistance. In terms of sensory parameters, chlorine dioxide does not change the taste or smell of the water. It is less corrosive than hypochlorite in the water pipeline and is effective against biofilm. This removes the nutrient source and safe haven for microorganisms and in doing so further prolongs the disinfection effect.

The significant advantages associated with ClO_2 stem from its outstanding sustained-release and residual effect. In low flow periods – even if there is no flow at all – chlorine dioxide continues to prevent microorganisms evolving in the pipeline. Unlike chlorine gas, chlorine dioxide remains effective in alkaline environments without extra pH modification.

Chlorine dioxide is produced on-site from sodium chlorite using either a chlorine gas or acid. The gas method gives a higher yield of disinfectant but of course necessitates a chlorine gas facility and training in gas handling and procedures.

$$2NaClO_2 + Cl_2 = 2\ ClO_2 + 2\ NaCl$$

Theoretical yield: 100 % (one part ClO_2 from one part $NaClO_2$)

$$5NaClO_2 + 4\ HCl = 4\ ClO_2 + 5\ NaCl + 2\ H_2O$$

Theoretical yield: 80 % (4 parts ClO_2 from 5 parts $NaClO_2$)

Grundfos' Oxiperm ClO_2 generators work with both methods and are suited to small to medium-sized water treatment plants. Compared to other similar ClO_2 generators the Oxiperm Pro systems consume only a third of the acid, significantly reducing operating costs.

To eliminate the risk of explosion that can occur with ClO_2, the Oxiperm systems are designed to avoid concentrations of ClO_2 that exceed safety limits both in air and in solution. "The gas space in the system is restricted so that gas cannot collect," explains Dr Persner. "And the concentration in solution is so low that gas levels cannot reach a critical level."

Electrolytic chlorine generation – safe and simple

On-site electrolytic generation of hypochlorite has a number of advantages compared to other methods of disinfection as it only requires salt, water and electricity. The simple and effective electrochlorination process is based on passing a brine solution through a series of electrodes contained within an electrolytic cell. As the brine solution passes through the cell, DC current in the electrodes results in the generation of caustic soda solution, chlorine and hydrogen. The chlorine produced reacts immediately with the caustic soda solution, resulting in a high-quality, low-strength sodium hypochlorite solution of less than 8 g/l. In Grundfos' Selcoperm system the hydrogen gas is removed from the HClO and safely vented. Tests have shown that any residual entrained hydrogen is at such a low level that the concentration does not exceed the lower explosion limit (LEL) in the storage or buffer tank.

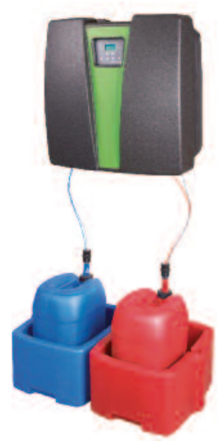
The biggest advantages of on-site electrolytic generation are, according to Dr Persner, related to the simple precursors: salt and water. "There are no safety issues associated with the storage or handling of these materials; they're also widely available and inexpensive, and the salt can be stored indefinitely."

Hypochlorite is generated on demand, reducing the need for bulk storage of chemicals on-site. Moreover, there are no expenses required for safe transport and storage of chlorine gas. In preparation for peak periods, the HClO generated on-site can easily be stored in buffer tanks and dosed as required.

Compared to commercially available hypochlorite solution, the sodium hypochlorite generated electrolytically is not subject to the same rate of degradation as commercial hypochlorite. "This is vital in terms of dosing precision," points out Dr Persner, "because you can be more confident in how much you are effectively dosing." The process is also considered safer for operators to use rather than chlorine gas or commercial sodium hypochlorite. For example, the EC Chemical Agents Directive does not apply to the product of electrochlorination as the concentration of active chlorine is less than 1%. Additionally, the high pH of commercial hypochlorite (pH 11) can also give problems with calcification of injection points. This is not the case with electrolytically generated HClO (pH 8.5-9.5). Finally, on-site chlorine generation does not result in significant, unpleasant by-products

Concerns about chlorination disinfection by-products (DBPs) have long been the subject of study although results have been inconsistent. WHO insists that high levels of protection from disinfection should not be compromised in an effort to control concentrations of by-products. "A more appropriate strategy is instead to minimise DBPs by removing natural organic precursors," advises Dr Persner.

More about the dosing and disinfection systems available from Grundfos can be found at **www.grundfosalldos.com**



Compared to other ClO_2 generators the Oxiperm Pro consumes only a third of the acid in the reaction with sodium chlorite.

A gas chlorination system under full vacuum, such as Grundfos' Vaccuperm, is the well-established method for safe and reliable disinfection.