Drinking-water disinfection

TECHNICAL ANNEX

Contents

The various commercial forms of chlorine

The products available for chlorination of water are:

- chlorine gas;
- sodium hypochlorite or Javel water;
- calcium hypochlorite;
- chlorine produced on site by the electrolysis of a sodium chloride solution (electrochlorination).

The choice of product will depend on a number of parameters:

- the quantity of reagent required;
- the supplies available;
- ease of operation;
- safety (risks related to storage and operation),
- cost

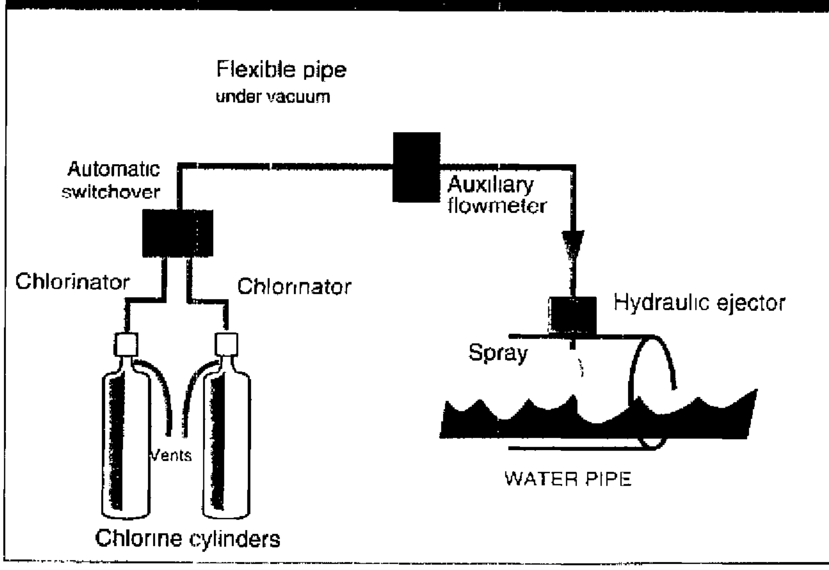
The various commercial forms of chlorine

	Form of presentation	Chlorine content	Stability over time	Safety
Chlorine gas	Liquified gas under pressure	99%	Very good Check carefully for leaks	Highly toxic gas
Sodium hypochlorite	Yellow liquid solution	15% maximum	2–4% loss per month, more if temperature exceeds 30°C	Corrosive liquid, contains soda
Calcium hypochlorite	White solid	60–70%	2–2.5% loss per year	Corrosive. Inflammation possible in case of contact with certain materials
Electro-chlorination	NaCl solution	1–3 g/l after electrodialysis	Very great for NaCl	

Chlorine gas

Chlorine gas is stored in liquid form in a steel container (cylinder or tank). In most cases, the chlorine is drawn off as a gas by partial vacuum. This partial vacuum is produced by a hydraulic ejector, which makes it possible to draw off the gas in safety. However, non-return valves should be fitted to prevent return flows of water, especially if the appliance stops.

Chlorine gas injector with automatic switchover



Safety precautions

Chlorine is an extremely toxic and corrosive gas, and very strict safety precautions must be taken when using it.
Storage of and operations involving chlorine gas are accordingly subject to special regulations in many countries.

- In case of fire, give priority to removing the tanks or cylinders, since their heat resistance is guaranteed only to a temperature of 88°C (at a pressure of 30 bars).
- Steel burns in chlorine. The containers should therefore not be heated with a flame (do not use a blow-torch to free or unfreeze a valve).
- Damp chlorine is highly corrosive: a chlorine leak will cause external corrosion, while the penetration of water into a chlorine supply pipe will lead to internal corrosion.
- Gas masks must be worn when handling containers and in all premises where chlorine is stored. Masks fitted with cartridge filters have only a limited working life.
- A system must always be installed for detecting leaks and chlorine-neutralizing products must be kept available.
- The various materials which may come into contact with chlorine behave differently with regard to oxidation. The table below describes the resistance of some materials commonly used.

Resistance of some materials to various forms of chlorine

	Mild steel	Stainless steel	Copper	PVC	Teflon (PTFE)
Dry chlorine gas	Good up to 120°C	Good up to 150°C	Good up to 200°C	Good up to 40°C	Good up to 200°C
Damp chlorine gas	None	None	None	Good up to 40°C	Good up to 200°C
Liquid chlorine	Good	Good	Good	None	Acceptable

Hypochlorites

Javel water or sodium hypochlorite may be injected as supplied or after dilution so that the pumped volume can be precisely regulated. Calcium hypochlorite must be made up in solution before injection. It is not very soluble: maximum solubility is 25 g/l at 20°C. In addition, the process is very slow: sufficient agitation time must therefore be allowed. If the water used for dilution is rich in calcium, calcium carbonate will be precipitated and the sludge thus formed may affect pumping equipment. Correct injection of the product should be ensured at all times.

Injection is carried out either by means of dosing pumps or using systems supplying a constant volume, such as a Mariotte's flask.

The dosage can be controlled in terms of the flow of water to be treated, a predetermined level of residual chlorine, or both parameters. Many devices are available for regulating the dosage and they are relatively inexpensive.

Safety rules

Sodium hypochlorite is a highly alkaline product which contains soda. It can burn the skin and eyes. Protective gloves and glasses must therefore be worn.

Warning! Never pour acid into a solution of Javel water or calcium hypochlorite, since this causes chlorine gas (a toxic gas that may be fatal) to be given off.

Calcium hypochlorite is an irritant powder. This product should be kept away from sources of heat, acids or oxidizable organic substances since they can lead to spontaneous combustion.

Calcium hypochlorite is also a corrosive. Gloves and glasses must be worn when handling this reagent.

Choice of product

When all three products are readily available, the choice will be between chlorine gas (the most economical, but dangerous) and Javel water (the simplest to use in small installations).

When the product is imported, chlorine gas should be chosen where permitted under the transport regulations in force; otherwise, calcium hypochlorite should be used.

Owing to its low concentration of the active substance, it is not economically viable to transport Javel water over long distances.

Implementation of chlorine disinfection

Chlorine disinfection is implemented in three successive stages, depending on the product used:
- assessment of the dose of chlorine to be injected into the network;
- preparation of solutions for non-gas products;
- regulation of injection equipment.

Dose of chlorine to be injected into the network

The dose of chlorine to be injected corresponds to the total chlorine demand, which in turn is closely linked to the chemical and microbiological quality of the water and the residual level desired at the end of the network.

Before starting disinfection, therefore, chlorine uptake tests should be carried out.

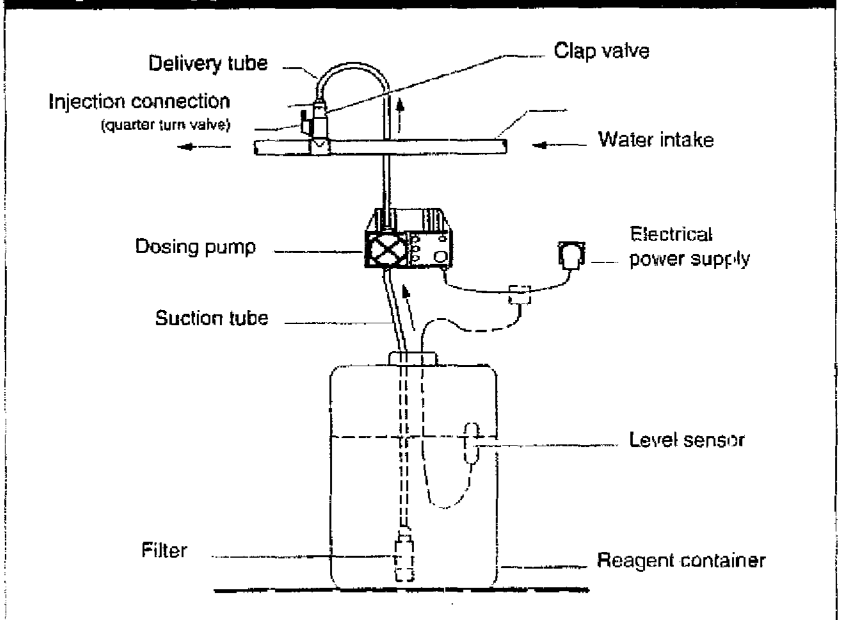
When disinfection is not *urgent* (preventive chlorination), the dose to be introduced may be found by directly injecting increasing quantities of chlorine into the network until the desired residual concentration is obtained at the end of the network. It may take several days to adjust the dose of chlorine. Indeed, a certain amount of time must elapse between two successive doses, in view of the time taken by the water to travel from the injection point to the end of the network.

In emergencies, a rough initial estimate should be made under laboratory conditions. The method consists of introducing increasing quantities of chlorine (for example, between 1 mg/l and 10 mg/l) into samples of the water to be treated. After 30 minutes, the levels of residual chlorine are measured in each sample. The dose of chlorine to be injected is given by the sample which contains the level of residual chlorine closest to that required. The dose will, of course, need to be adjusted when the disinfection operation is started on the network.

Preparation of solutions for non-gas products

Not all disinfectants can be used as they are, either because they are sold in powder form or because they are in concentrations unsuitable for precise adjustment. They should therefore be dissolved or diluted to take account of the output of the dosing pump.

Installation for injection of a chlorinated solution using a dosing pump



Examples of preparation of a chlorinated solution

Preparation of a solution with 20 g of chlorine/litre:

• From a sodium hypochlorite solution (Javel water)
Javel water is sold in liquid form, at concentrations of either 152 g/l (48° chlorometric) or approximately 38 g/l (12° chlorometric).
One litre of Javel water at a concentration of 152 g/l yields some 7.5 litres of solution at 20 g/l.
One litre of Javel water at a concentration of 38 g/l yields some 1.9 litres of solution at 20 g/l.

• From calcium hypochlorite
Sold in powder form. The chlorine content of this product is approximately 60%.
One kilogram of calcium hypochlorite yields approximately 30 litres of 20 g/l solution.
Special attention must be paid to ensuring that the product is completely dissolved in water. This may be facilitated by the use of an electric agitator.

Adjustment of injection equipment

Adjustment depends on:
• the level of residual chlorine desired at the end of the network (see previous paragraph);
• the flow of water to be treated, (where there are uncontrolled variations in the flow (e.g. from springs), the maximum flow should be assumed).

Chlorine gas chlorinator
The rate of injection of chlorine is calculated using the following formula:
D = C X Q
where: **D** (g of chlorine/hour): flow of chlorine as shown on the chlorinator's flowmeter
C (mg of chlorine/litre of water or g of chlorine/m³ of water): amount of chlorine to be injected
Q (m³/hour): flow of water to be treated.

Example.
Dose of chlorine to be injected:
1 mg/l or g/ m³
flow of water to be treated:
100 m³/hour
dose of chlorine as indicated on the chlorinator's flowmeter:
1 X 100 = 100 g of chlorine/hour.

Dosing pump for liquid solution:
The dose of *chlorinated solution* to be injected is calculated using the following formula:
D = (C X Q)/S
where: **D** (litres of solution/hour): dosing pump output
C (mg of chlorine/litre of water or g of chlorine/m³ of water): dose of chlorine to be injected
Q (m³/hour): flow of water to be treated
S (g of chlorine/litre of solution): concentration of the solution supplied by the dosing pump.

Example.
Dose of chlorine to be injected:
1 mg/l or g/ m³
flow of water to be treated:
100 m³/hour
concentration of the solution: 20 g/l
flow of solution as supplied by the dosing pump: (1 X 100)/20 = 5 l/hour.

Dosing method for residual chlorine

The functioning of equipment and the absence of contamination in the network can be monitored by regularly measuring the level of residual chlorine. It is therefore essential to do this.

Field analysis kits are now commercially available which make it easy to determine the correct dosage of chlorine. Only the DPD[12] measurement method must be used. **Warning! Do not exceed the use-by dates for reagents.**

Chlorine must be measured at the following locations:

• after chlorination: **when the water leaves the treatment plant**, to verify that the correct quantities of disinfectant have been injected;

(**Warning:** if chlorination products are not stored on site, the contact time when the measurement is taken may be too short for the break-point to have been reached. In such cases, the measurement may indicate the presence of "active chlorine", whereas this may be taken up by organic matter in the following few minutes. At least 30 minutes should therefore elapse between introducing the chlorine into the water and measuring the residual level of disinfectant.)

• **at the tap of the consumer** furthest away from the treatment plant (this measurement makes it possible to check that no contamination has occurred within the network).

These measurements must be taken several times a day, every day of the year.

Practical information on these questions is contained in Volume 3 of WHO's *Guidelines for drinking-water quality* (a second edition will be published in 1996).

Guideline values for disinfection by-products

The *Guidelines for drinking-water quality* issued by WHO in 1993 establish guideline values for various disinfection by-products

For some compounds, the WHO guideline value has been calculated on the basis of the following probability the risk of a single excess case of cancer in a population of 100 000 people each drinking 2 litres of water per day for 70 years. This risk is extremely low.

WHO guideline values for disinfection by-products

By-products	Guideline value (µg/l)	Remarks
Bromate (1)	25 (P)	for 7 x 10^{-5} excess risk
Chlorite (2)	200 (P)	
2,4,6-Trichlorophenol (3)	200	for excess risk of 10^{-5}
Formaldehyde (1)	900	
Bromoform (3)	100	
Dibromochloromethane (3)	100	
Bromodichloromethane (3)	60	for excess risk of 10^{-5}
Chloroform (3)	200	for excess risk of 10^{-5}
Dichloroacetic acid (3)	50 (P)	
Trichloroacetic acid (3)	100 (P)	
Chloral hydrate (3) (trichloroacetaldehyde)	10 (P)	
Dichloroacetonitrile (3)	90 (P)	
Dibromoacetonitrile (3)	100 (P)	
Trichloroacetonitrile (3)	1 (P)	
Cyanogen chloride (3)	70	as CN^-

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Titles available or in preparation as of March 1996

Air
- Air and health
- Indoor air pollution
- Industrial air pollution
- Traffic and air pollution
- Air pollution from wastes and solvents
- Energy and air pollution
- Monitoring of air quality
- Asthma
- Air and global issues
- Smog warning

Water
- Water and health
- Monitoring of water quality
- Lead and water
- Nitrates
- Algal blooms
- Protection of drinking-water sources
- Disinfection
- Treatments I
- Treatments II
- Leakage detection and water metering
- Safety of distribution
- Rain water
- On-site sanitation
- Sewerage and waste water treatment plants
- Maintenance and management of waste water networks
- Recreational waters

Solid wastes
- Solid waste and health
- Landfill
- Waste incineration
- Waste collection
- Health care waste
- Biological treatment of waste
- Recycling
- Waste minimization
- Toxic waste in the city

Urban planning
- Urban planning and health
- The tools for urban planning
- Transport and circulation
- Green cities, blue cities
- Urban networks
- Administration and management
- Urban health and socio-cultural aspects
- The city of the future
- Urban indicators
- Neighbourghood facilities
- Contaminated soil
- Walking and cycling

Noise
- Noise and health
- Noise at schools
- Discotheque
- Trafic noise
- Airport and noise
- Insulation of housing
- Healthy sound environment

Accidents
- Local policy for accident prevention
- Child accident prevention
- Accidents and the elderly
- Home safety
- Road safety
- Fire safety
- Water safety
- Play and leisure
- Nursery and school safety

Housing
- Sick building syndrome
- Kitchen and health
- Lead and housing
- Energy and housing

Radiation
- Radon
- UV rays
- Before, during and after a nuclear accident
- Electromagnetic fields
- Radioactive wastes

Toxicology
- Lead and health
- Allergies
- Carbon monoxide poisoning
- Pesticides and health
- Mercury and health
- Abestos and health

Hygiene
- Rodents
- Mosquitoes
- Birds
- Pets
- Cockroaches
- Cleaning the city

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