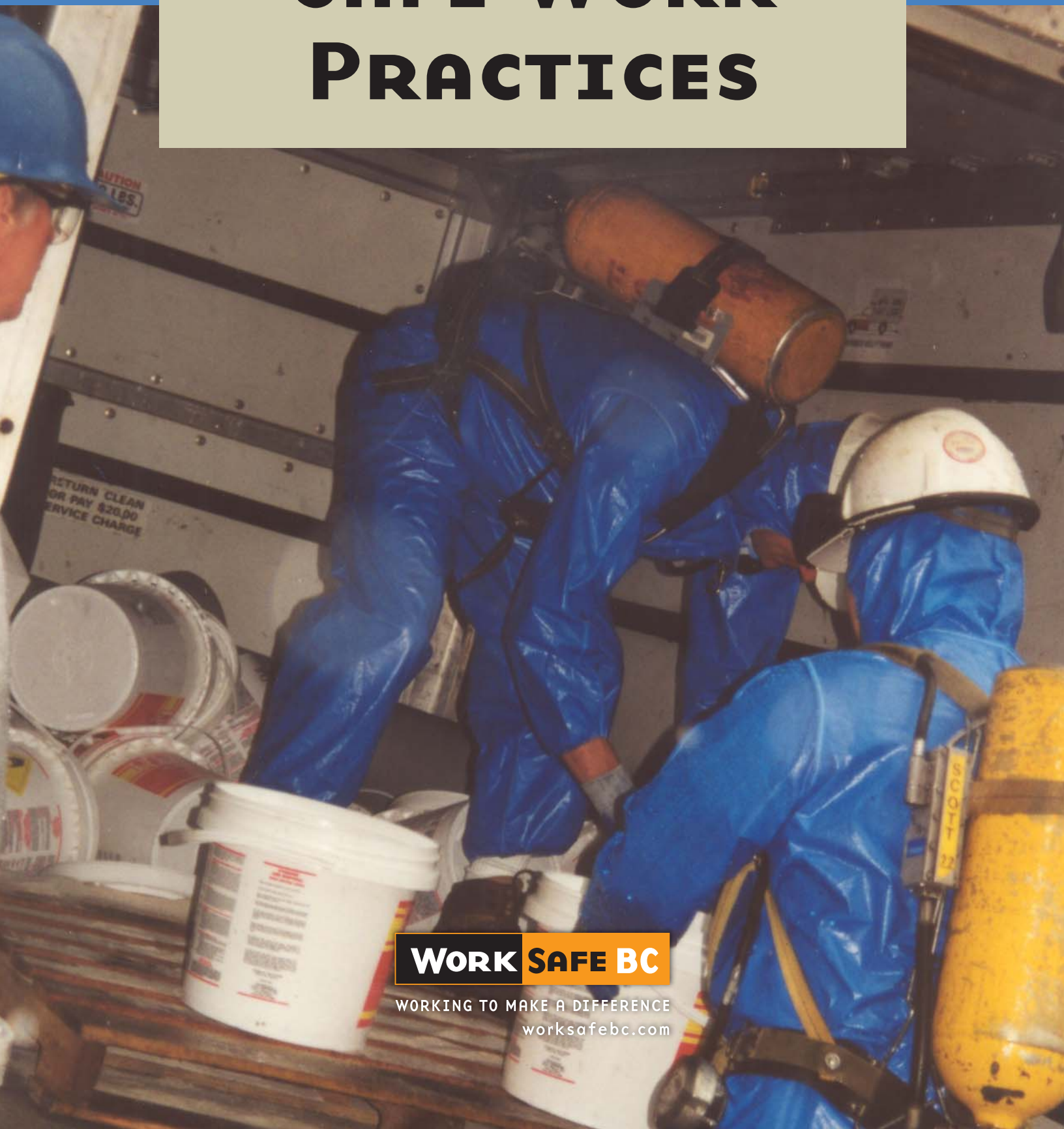
Chlorine Safe Work Practices



WorkSafeBC

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About WorkSafeBC

WorkSafeBC (the Workers' Compensation Board) is an independent provincial statutory agency governed by a Board of Directors. It is funded by insurance premiums paid by registered employers and by investment returns. In administering the *Workers Compensation Act*, WorkSafeBC remains separate and distinct from government; however, it is accountable to the public through government in its role of protecting and maintaining the overall well-being of the workers' compensation system.

WorkSafeBC was born out of a compromise between B.C.'s workers and employers in 1917 where workers gave up the right to sue their employers or fellow workers for injuries on the job in return for a no-fault insurance program fully paid for by employers. WorkSafeBC is committed to a safe and healthy workplace, and to providing return-to-work rehabilitation and legislated compensation benefits to workers injured as a result of their employment.

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The WorkSafeBC Prevention Information Line can answer your questions about workplace health and safety, worker and employer responsibilities, and reporting a workplace accident or incident. The Prevention Information Line accepts anonymous calls.

Phone 604 276-3100 in the Lower Mainland, or call 1 888 621-7233 (621-SAFE) toll-free in British Columbia.

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WorkSafeBC Publications

Many publications are available on the WorkSafeBC web site. The Occupational Health and Safety Regulation and associated policies and guidelines, as well as excerpts and summaries of the *Workers Compensation Act*, are also available on the web site: WorkSafeBC.com

Some publications are also available for purchase in print:

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Introduction

Chlorine is a powerful disinfectant and bleaching agent. In both gas and liquid forms, chlorine is a toxic substance that presents a number of hazards. If proper precautions are not taken while working with or around pure chlorine, serious injury or even death can result. In order to prevent injury, WorkSafeBC has developed requirements detailed in the Occupational Health and Safety Regulation.

This manual is mainly for two groups: employers whose businesses include the use of chlorine gas for water or sewage treatment; and workers who work with or around chlorine gas, including those who repair or maintain chlorine systems. Employers will find information on what they need to do to comply with the Regulation and to ensure a safe environment both for workers and for communities around facilities in which chlorine is stored or used. Workers will find information that will help them work safely around chlorine.

Employers whose businesses include the use of chlorine gas for other purposes (for example, in plastics manufacturing) will also find this manual useful.

Engineers and architects will find information on building design for facilities in which chlorine is to be used or stored.

This manual does not replace the Occupational Health and Safety Regulation or the *Workers Compensation Act*. It complements the Regulation and is a tool to help industry work safely. The word must used in this manual means that a particular safety step is required by the Regulation. The word *should* indicates that a particular action, although not specified in the Regulation, will improve safety in the workplace. Please note also that the word worker includes supervisors, managers, and workers.

In addition to the information in this manual, you can get specific information from chlorine and chlorine-equipment manufacturers and suppliers. The Chlorine Institute has further information and publishes the *Chlorine Manual*. See their web site at www.chlorineinstitute.org or phone 703 741-5760.

What is chlorine?

Pure chlorine comes in two forms: gas and liquid. Chlorine gas is easily liquefied under pressure. Typically, a commercial cylinder contains liquefied gas under pressure.

Chlorine gas has a disagreeable, sharp, pungent, penetrating odour. In airborne concentrations above 1000 parts per million (ppm) it has a greenish-yellow colour. In smaller concentrations it is colourless. Chlorine gas is 2½ times heavier than air and tends to flow downhill and pool in lower areas. Wind and weather, however, will cause a chlorine gas cloud to disperse, spreading it in all directions, even uphill.

Liquid chlorine is a transparent, amber-coloured, oily fluid that is 1½ times heavier than water. Liquid chlorine has a high compression ratio. The ratio of liquid to gas is 1 to 460, which means that 1 L of liquid chlorine expands to form 460 L of pure chlorine gas.

If all the liquid chlorine in a 68 kg (150 lb.) container escaped, it would release so much pure chlorine gas that it would take 24 times the amount of air in BC Place stadium to dilute the gas concentration to 0.5 ppm, the maximum allowable concentration a person can be exposed to in an eight-hour period.

Uses

Chlorine gas is mainly used as a disinfectant in:

- Swimming pools
- Water treatment plants
- Sewage treatment
- Community water supplies, including water used for irrigation

Chlorine is also used in:

- Pulp and paper industries
- Pool chemical products
- Cleaning products
- Mining processes
- Bleach manufacturing
- Plastics manufacturing

Hazards of chlorine

Health

Chlorine is corrosive. It can burn moist body surfaces such as the eyes, nose, throat, lungs, and wet skin because it forms harmful acids when it reacts with moisture.

Repeated exposure to chlorine does not produce an immunity or tolerance. Long-term exposure to low concentrations of chlorine may cause a gradual decrease in lung efficiency. A single exposure to a high concentration can cause the same effect.

Table 1: Toxic effects of chlorine

Chlorine concentration (parts per million)	Effect
0.03–0.1 ppm	Range of odour threshold (the Canadian Centre for Occupational Health and Safety specifies 0.08 ppm)
1–3 ppm	May cause mild irritation of the eyes, nose, and throat
3–5 ppm	Stinging or burning in eyes, nose, and throat; may cause headache, watering eyes, sneezing, coughing, breathing difficulty, bloody nose, and blood-tinged sputum
5–15 ppm	Severe irritation of the eyes, nose, and respiratory tract
10 ppm	Immediately Dangerous to Life or Health (IDLH)
30–60 ppm	Immediate breathing difficulty resulting in pulmonary edema (fluid buildup in lungs), possibly causing suffocation and death
430 ppm	Lethal after 30 minutes
1000 ppm or more	Fatal after a few breaths

Note: Chlorine gas is not visible as a greenish-yellow cloud at concentrations below 1000 ppm.

Table 2: Exposure limits of chlorine	
Exposure level (parts per million)	**Exposure limit**
0.5 ppm	Maximum allowable concentration averaged over an eight-hour period
1 ppm	Maximum allowable short-term exposure (15 minutes)
10 ppm or more	Immediately Dangerous to Life and Health (as published by NIOSH)

Note: The Immediately Dangerous to Life and Health (IDLH) exposure level is the point at which a person without appropriate respiratory protection could be fatally injured or could suffer irreversible or incapacitating health effects. NIOSH is the National Institute for Occupational Safety and Health in the United States.

Fire

Chlorine will not burn by itself, but will support combustion.

Chemical action

Chlorine, in both gas and liquid forms, reacts with almost all chemicals, usually with a release of heat. At high temperatures, chlorine reacts vigorously with most metals. For instance, a chlorine reaction can cause stainless steel to catch fire or melt.

Some water treatment facilities use *chloramination*, a process in which chlorine and ammonia are mixed in a water solution. Chloramination is safe because chlorine and ammonia mixed in a water solution do not present a serious risk. The process may form chloramines, which are toxic, but only at concentrations higher than for chlorine gas. Pure chlorine gas, however, may react vigorously with ammonia gas. An excessive mix of the two gases in air can produce hazardous compounds such as the explosive nitrogen trichloride. In facilities that use chloramination, the pure chlorine and ammonia must be stored in separate, sealed rooms or buildings.

Chlorine leaks are usually confirmed using a standard *ammonia test*. This test is safe because it uses ammonium hydroxide (ammonia dissolved in water or moist air) rather than pure ammonia. Chlorine reacts readily with ammonium hydroxide to form ammonium chloride, a relatively harmless compound. This reaction forms a white cloud, indicating a chlorine leak. The continuous monitors now required indicate chlorine leaks automatically, but the ammonia test is still useful for pinpointing the exact location of a leak.

Corrosive action

Chlorine reacts with water or moisture in the air to form highly corrosive acids. Every precaution must be taken to keep chlorine and chlorine equipment moisture-free. Never use water on a chlorine leak.

According to the Occupational Health and Safety Regulation, employers must develop and implement an effective health and safety program, which includes training workers and supervisors in relevant sections of the program.

Health and safety programs

A health and safety program helps ensure a safe, productive workplace by describing specific tasks and responsibilities for many different aspects of an employer's operation. An effective health and safety program for any workplace in which chlorine is used or stored must include the following:

- A written occupational health and safety policy that:
  - States the employer's commitment to health and safety
  - States the program's objectives
  - Defines the responsibilities and roles of the employer, supervisors, and workers
- Written safe work procedures and emergency response procedures
- Training and instruction for supervisors and workers
- Regular worksite inspections (the definition of *regular* depends on the conditions and number of shifts for each individual worksite)
- Regular health and safety meetings
- Incident investigations
- Records and statistics (for example, reports of inspections and incident investigations)
- A joint health and safety committee or representative, if required

It is important to remember that every worksite is different. Although these general elements may be common to health and safety programs across the province, employers cannot expect to copy a program from another worksite. Instead, they must develop and implement a health and safety program unique to their own operation.

Written safe work procedures

A health and safety program is an overall program that describes, in writing, a number of individual written safe work procedures and specific, smaller programs. Written safe work procedures and programs tell workers how to perform their duties safely. Employers must ensure that all workers understand these procedures well enough to perform

their duties competently. Employers and workers must jointly review all written safe work and emergency procedures at least once a year.

WHMIS program

A Workplace Hazardous Materials Information System (WHMIS) program helps ensure that workers who work with or near chlorine are instructed in its safe use, storage, handling, and disposal. This includes the use of labels or other means of identifying chlorine containers or systems. For more information, see Part 5 of the Regulation.

Exposure control plan

Written exposure control plans explain the work procedures and other controls that will be used to reduce workers' risk of exposure to chlorine. Strict adherence to chlorine exposure limits and use of appropriate respiratory and skin protection are essential elements of such a plan. Employers must also ensure that *qualified persons* perform a formal risk assessment to determine which workers may be affected by exposure to chlorine and the extent of any exposure. For more information about the elements of exposure control plans, see Section 5.54 of the Regulation.

For more detailed information on preventing exposure (through building design, ventilation, and alarm systems) and controlling exposure (using eye, skin, and respiratory protection), see "Preventing and controlling exposure," pages 24–31.

Respiratory protection program (personal protective equipment)

Providing protective equipment and ensuring that workers use it properly are essential to any effective occupational health and safety program. Employers must develop and implement a written respiratory protection program that is acceptable to WorkSafeBC and that meets the requirements of the Regulation. For more information on personal protective equipment and clothing, see Part 8 of the Regulation.

Employers must ensure that workers are trained in proper use and care of respirators. Employers must also provide fit-testing (using a WorkSafeBC-accepted protocol, such as described in the WorkSafeBC publication *Breathe Safer* or in *CSA Standard Z94.4-02*) when a worker is first fitted

Who is a "qualified person"?

A qualified person is an occupational health and safety professional with experience in the practice of occupational hygiene as it relates to chlorine. Persons performing risk assessments and work activity classifications (moderate or high risk) should be certified and must be educated as follows, in order:

1. Certified Industrial Hygienist (CIH) or Registered Occupational Hygienist (ROH) *with education specific to chlorine risk assessments and work procedures*
2. Certified Safety Professional (CSP), Canadian Registered Safety Professional (CRSP), or a Professional Engineer, *with education specific to chlorine risk assessments and work procedures*
3. Other combinations of education, training, and experience specific to chlorine risk assessments and work procedures

Safe handling of chlorine: Where to look in the Regulation

Employers can use several elements of their health and safety program to help ensure the safe handling of chlorine. For the purposes of this manual, these key elements (and their location in the Regulation) include:

- Emergency preparedness and response (Part 4, sections 4.13–4.18)
- Emergency procedures (Part 5, sections 5.97–5.102; Part 6, section 6.120)
- Equipment preventive maintenance and critical parts inspections (Part 4, section 4.3, and Part 6, section 6.132)
- Toxic process gases (Part 6, sections 6.117–6.132)
- Exposure control plan (Part 5, section 5.54)
- Respiratory protection programs (Part 8, sections 8.5 and 8.32–8.45)
- Eye protection (Part 8, section 8.14)
- First aid requirements (Part 3, sections 3.14–3.21)

with a respirator and once a year thereafter. Fit-test kits are available from respirator suppliers. One type of test, the qualitative fit-test, determines if the worker can detect any amount of a test compound leaking through the respirator. Employers must keep records of these tests and the fit-test program.

Respiratory, eye, and skin protection are covered in more detail in "Personal protective equipment," pages 28–31. You can also find more information on respiratory protection programs in other WorkSafeBC publications, such as the *Breathe Safer* manual.

Written emergency procedures

Employers must conduct a risk assessment and prepare emergency procedures, including escape and evacuation, drills, and notification of emergency services. For more information on written emergency procedures, see "Preparing for emergencies," pages 14–17.

Written preventive maintenance procedures

Employers, in consultation with equipment manufacturers or suppliers, must ensure that all equipment is inspected regularly and replaced when necessary. Employers must ensure that written preventive maintenance procedures *and* written emergency procedures are readily available to and understood by all workers required to work on the chlorine system.

Employers must also include plans for testing and replacing, where required, all ancillary (secondary) safety equipment, including:

- Alarm systems
- Detection equipment
- Radios
- Eye washes and showers
- Respiratory and skin protection
- First aid kits
- Chlorine container repair kits

To ensure that nothing is missed, employers may find it useful to develop checklists for inspecting and testing equipment. All use and maintenance of safety equipment must be recorded in a suitable log book. For more information on preventive maintenance and hazards that can arise during repair or maintenance, see "Repair and maintenance," pages 21–22.

Checking on a worker working alone

Employers must establish a system with written procedures to ensure the continued well-being of workers entering a chlorine enclosure on their own or working in isolation. Depending on the situation, the check system may consist of either visual checks, radio contact, or a telephone call-in procedure. The check system must include:

- A set interval between checks
- A record of each check
- A check at the end of the work shift
- Procedures to follow if the worker cannot be contacted or is injured

Training, instruction, and supervision

Although workers may have special certification or other external training, employers are responsible for providing them with thorough, site-specific training and continued instruction in the programs and procedures outlined above. Written safe work procedures must form the basis of an employer's ongoing training program.

Employers must document training and instruction. Workers must be able to demonstrate competency in doing their work according to the work procedures. For more information and examples, see the next section, "Written safe work procedures — examples."

Hazard alert: Cylinder moved while valve open

A worker was painting the walls of the pumphouse chlorine room in a water treatment plant. He decided to move a 150 lb. cylinder of chlorine away from the wall to paint behind it. He inadvertently disconnected the cylinder while the valve was in the full open position. The worker, who was not wearing a respirator, was overcome by chlorine gas and was hospitalized with severe respiratory injuries. A large number of people in the surrounding area were evacuated and some were treated in hospital.

Written safe work procedures — examples

Some tasks that require written safe work procedures include (but are not limited to):

- Cylinder change
- Leak detection and control
- Container repair and use of the repair kit
- Checking on a worker working alone
- Respirator program
- Disposal of damaged containers
- Routine maintenance of equipment (for example, chlorinators, piping, and steam heating systems)

Written safe work procedures must be detailed and complete, and must not assume the worker will know or remember any unlisted tasks. Two examples below demonstrate the amount of detail required. **These examples will not apply to all worksites. Employers must create their own detailed written safe work procedures to suit each individual worksite.**

Example one: Changing chlorine cylinders

This work procedure should specify that only competent workers can change cylinders and how many of these workers should be present.

The following example of a safe work procedure for changing cylinders is for a non-emergency situation, when the alarm has not been activated. (If the alarm has been activated, workers would follow the emergency procedures posted in the workplace.)

1. Turn on the light and visually ensure that the room is safe to enter (there may be visible signs of damage).
2. Put on appropriate personal protective equipment (be specific about the type of equipment). This procedure requires a respirator other than an escape respirator.
3. Turn on the exhaust ventilation before entering the room.
4. Close the main chlorine container valve.
5. Allow the system to purge itself of chlorine. Ensure that the float drops to the bottom of the feed-rate indicator (rotameter). Verify that there is a high vacuum and that the weigh scale reads zero.
6. Loosen the chlorinator (auxiliary valve or vacuum regulator) and remove it from the empty cylinder.
7. Replace the cylinder cap on the empty chlorine cylinder and remove the cylinder to secured storage.

8. Secure the new cylinder into place.
9. Remove the protective hood from the new cylinder.
10. Ensure that there is no chlorine leaking from the packing gland. Use ammonia vapour from the ammonia test bottle, which contains a strong ammonia solution (25% or 26° Baumé).
11. Ensure that the cylinder valve is closed. **Do not** open the valve yet.
12. Remove the cylinder outlet cap and check that the cylinder outlet face is clean and smooth.
13. Using a new washer, connect the vacuum regulator or the yoke assembly (be specific for the system in use) to the valve outlet using the supplied wrench only.
    Note: Never use oil-based material or water to clean the mating surfaces.
14. Crack open the chlorine cylinder valve and then quickly close it again. This will let enough chlorine into the lines to charge them. The valve should open with no more than a sharp rap from the heel of your hand. **Never** use a "helper" wrench or a larger wrench than the one supplied. If the valve will not open, carefully loosen the packing gland slightly.
15. Check all the connections you have made to ensure there are no leaks. Use the vapour from the ammonia test bottle (see step 10). If a leak is indicated, activate the leak control procedure (see example two below).
16. When no leaks are indicated, open the chlorine cylinder valve no more than half a turn and leave the cylinder wrench on the valve.
17. Open any additional system valves (be specific for your facility) and test for leaks as each stage is charged with chlorine.
18. Check for leaks again with the ammonia test bottle to be sure that everything is in order.
19. Ensure that the alarm system is functioning.
20. Turn off the exhaust ventilation and lights and close the door when you leave.
21. Remove your respirator and other personal protective equipment.

Example two: Leak detection and control

This example includes two components: what to do if a leak is indicated after a cylinder change and what to do if the chlorine alarm is activated during routine operation of the system.

If the ammonia test indicates a leak after a cylinder change, follow these steps. Note that the worker will already be wearing a respirator:

1. Immediately close the main cylinder valve.
2. As long as the monitor reads less than 10 ppm, the cylinder hookup procedure may be repeated. (See Table 4 on page 30 for information on choosing the right respirator.)
3. Open (and close) the main cylinder valve and repeat the ammonia test.
4. If a leak is still indicated, make a third and final attempt to get a good seal using a new lead washer.
5. If the leak cannot be corrected after three attempts, remove the cylinder from service and contact the supplier. Ensure that there is no leak from this cylinder with the main valve closed. A different cylinder must be connected to the chlorination system.
6. Leave the chlorine room and remain nearby to restrict access to the room or provide other assistance, as directed, until the chlorine alarm has automatically shut off.

If the chlorine alarm has been activated during routine operation of the system, at least two people must respond. Follow these steps:

1. Approach the location cautiously.
2. If chlorine gas can be smelled in the open, immediately leave the area and activate full emergency procedures. Do not attempt to turn on the exhaust ventilation.*
3. If there is no smell of chlorine gas outside the room, put on respiratory protection (see Table 4, page 30) and check the monitor readout.
4. If the chlorine concentration is less than 10 ppm:
   - Put on the appropriate personal protective equipment.
   - Enter the room and close the main cylinder valve.
   - Turn on the ventilation system and leave the area until the alarm stops.

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* Depending on the location. See "Ventilation," page 25.

- While still wearing the respirator, enter the room after the alarm has stopped, isolate the leak, and perform necessary repairs. Remember that all chlorine lines must be free of oil, grease, and moisture before re-opening the chlorine cylinder.

5. If the continuous monitor indicates a chlorine concentration greater than 10 ppm, immediately leave the area and activate full emergency procedures. Do not turn on the ventilation system* and do not wait downwind of the building for help to arrive.

Note: Never apply water to a chlorine leak. Moist chlorine is more corrosive than dry chlorine and the leak will worsen rapidly if water is applied to it. Remember also that a chlorine leak never gets better — it always gets worse.

* Depending on the location. See "Ventilation," page 25.

Preparing for emergencies

Preparing for emergencies includes planning for chlorine leaks that may require procedures such as evacuation and notification of local emergency response units. The preparation required for these types of emergencies is detailed under "Written emergency procedures," below. Preparing for emergencies also includes making appropriate emergency equipment available to workers and ensuring that they know how to use it.

Hazard alert: Proper emergency procedures allow quick response

A chlorinator developed a serious leak, filling the chlorine room with a high concentration of chlorine gas. This triggered the alarm system, and the emergency team responded within minutes. After checking through the view window and seeing a concentration of chlorine gas in the room large enough to cause a visible green haze, the trained emergency team, wearing SCBAs, entered the room and shut the system down. Because this sewage treatment plant is in an isolated area, the escaped gas was automatically vented to the atmosphere and repairs were made shortly thereafter.

Written emergency procedures

Formal written emergency procedures provide workers with detailed directions in case of an emergency. A detailed emergency plan is not enough by itself, however. Employers must also conduct emergency drills to determine whether the procedures work in practice and to familiarize workers with their roles in an actual emergency. Employers must keep records of these drills to monitor efficiency.

Written emergency procedures must include specific details concerning the following:

- How to notify workers of the emergency location
- How to control materials that may become dangerous during the emergency
- Emergency personal protective equipment and its location
- Chlorine repair kit location
- Repair or capping procedure
- Emergency lighting
- Evacuation procedure and a check system to ensure all personnel are evacuated
- Search and rescue
- How to notify police, fire department, hospital, and other emergency response units
- How to notify adjacent worksites and private homes of the emergency situation

As soon as the written emergency procedures are created, the employer must:

- Provide each worker with a copy of the plan and enough training to ensure that workers clearly understand the procedures
- Post the procedures and other relevant information (such as telephone numbers) in appropriate, conspicuous locations
- Hold regular tests of the procedures, including drills
- Notify the fire department and other emergency response units of any specialized information
- Provide nearby worksites and private homes that could be affected in an emergency with information about the nature of the hazard and a copy of appropriate emergency procedures

In addition to these general emergency procedures, employers must also have specific procedures to cover concerns such as:

- Response to an alarm signal
- Leak control
- First aid response
- Dispersal of leaked chlorine
- Disposal of a leaking container
- Incident investigation

For more information on emergency planning, see *CSA Standard Z731-95 (R1999), Emergency Planning for Industry*.

Emergency equipment

This section includes information on eye wash and shower facilities, first aid kits, and container repair kits.

Eye wash and shower facilities

Sections 5.85 to 5.96 of the Regulation describe requirements for emergency washing facilities. Employers must conduct a risk assessment for each workplace hazard. In the Regulation, use Table 5-2: Risk Assessment to help determine risk levels relating to hazardous materials, including chlorine. Use Table 5-3: Provision and Location of Emergency Washing Equipment to help determine the type of eye wash equipment required, where it must be located, and whether or not a shower is required.

Employers must consider the following when conducting a risk assessment:

- The nature of the workplace chemical (corrosive or irritant). In pool facilities, many of the chemicals are corrosive — for example, chlorine gas, sodium hypochlorite, soda ash, and hydrochloric (muriatic) acid.
- The state of the substance (gas, liquid, or solid).
- The potential for exposure to skin or eyes and the extent of any exposure.
- The number of potentially affected workers.
- The availability of first aid and professional medical help.

Employers must follow these requirements for eye wash and shower facilities:

- Ensure that the facilities have a supply of tempered water — not running cold water. Ensure that workers cannot mistakenly turn on hot water alone.
- Determine the most appropriate location for emergency equipment. It is inappropriate, for example, to install emergency equipment inside the chlorine room because a worker trying to use the emergency equipment during a chlorine leak risks further exposure.
- Take into account the geographical location of the facility when deciding whether or not an outdoor location will be practicable during the winter.
- Do not locate emergency equipment where the public may access and possibly damage it.

First aid kits

Workers must have immediate access to an appropriate first aid kit at each chlorine location. First aid kits may be permanent on-site kits or may be transported to the site by the worker for each visit. In some instances, the first aid kit may need to be located in the worker's vehicle and carried by the worker to the chlorine location. To determine the appropriate first aid kit required for a particular worksite, see Part 3 of the Regulation.

Container repair kits

Ideally, a chlorine container repair kit should be available on-site. If a container repair kit is not available, the emergency response team must be aware of the nearest readily available kit. There are three types of repair kit (A, B, and C), each with materials specific to the type and size of the chlorine container.

Table 3: Chlorine container repair kit requirements

Chlorine container	Repair kit
68 kg (150 lb.) cylinders	"A" kit
907 kg (2000 lb., or ton) containers	"B" kit
Rail cars, tank cars, or barges	"C" kit

Investigating incidents

What is an incident?

The Occupational Health and Safety Regulation defines an *incident* as "an accident or other occurrence which resulted in or had the potential for causing an injury or occupational disease."

Incident investigation is important for preventing future incidents and educating workers and employers. According to the *Workers Compensation Act*, employers must immediately notify WorkSafeBC of any major release of a toxic substance. In the case of chlorine, a major release is defined as:

- A leak or spill resulting in at least one person receiving professional medical attention or
- A leak or spill resulting in at least three people receiving first aid

Any time enough chlorine is released to set off the alarm, the employer must conduct a formal investigation to discover the causes of the incident. This investigation must also examine measures that will prevent similar incidents in the future. Employers must forward copies of the investigation report to their joint health and safety committee and to WorkSafeBC.

Working safely around chlorine

This section should be useful to anyone who works with or around chlorine. It includes information on chlorine containers, storing chlorine, handling chlorine, repair and maintenance of chlorine systems, and recognizing hazards that may arise during repair or maintenance.

Personal protective equipment — particularly eye, skin, and respiratory protection — is essential to working safely around chlorine. For more information, see "Personal protective equipment," pages 28–31.

Containers

Liquid chlorine comes in two types of containers:

- Cylinders with a 68 kg (150 lb.) capacity
- Ton containers with a 907 kg (2000 lb.) capacity

Cylinders and ton containers have fusible plugs designed to melt at 71°C (160°F). When containers are exposed to extreme heat, such as fire, the plug melts, relieving pressure and preventing the container from rupturing violently.

Notes:

1. All chlorine containers must meet Transport Canada requirements.
2. Chlorine is classified as a controlled product under the WHMIS regulations, Classes A, C, D-1A, and E.

Storing chlorine

This section describes what you must and must not do when storing chlorine.

Location

- Use signs to clearly identify all areas where chlorine is used or stored. Only qualified personnel are permitted to enter these areas.
- Store chlorine cylinders and containers in a cool, dry, and relatively isolated area, protected from weather and extreme temperatures. If storing cylinders and containers outside, shield them from direct sunlight, unless they are specifically designed for unshaded, outdoor storage.
  Note: Never apply heat to pipes, containers, or container valves unless they have been thoroughly purged of chlorine.

- When storing chlorine containers inside, store the containers in a well-ventilated building, away from any heat sources, such as steam pipes.
- Store chlorine containers on the lowest working level but not below grade.
- Do not store chlorine near busy roadways or anywhere else where vehicles operate. Chlorine reacts with carbon monoxide to produce phosgene, an extremely poisonous gas.
- Store cylinders upright and secure them against falling. Cylinders will discharge vapour when upright and discharge liquid when upside-down.
- Store ton containers on their sides, on steel or concrete supports. The supports should be equipped with trunnion wheels so that, if chlorine leaks from the bottom valve, the container can be quickly rotated with the leak at the top to minimize leakage. Discharge ton containers while they are horizontal, with the two valves in a vertical line (vapour from the top valve, liquid from the bottom).

Housekeeping

- Do not store materials that may react violently with chlorine in the same room as chlorine (for example, hydrogen, ammonia, acetylene fuel gases, ether, turpentine, and most hydrocarbons, such as solvents, greases or oils, finely divided metals, and organic matter).
- Store containers with enough room between them to allow for complete accessibility during an emergency.
- Use cylinders and containers on a "first-in, first-out" basis.
- Clearly tag or mark empty cylinders and separate them from full cylinders.
  Note: Never assume a container is empty and therefore non-hazardous even though it may weigh empty.

Handling chlorine

This section describes what you must and must not do when handling chlorine.

Moving containers

- Handle containers with care while moving or storing them. Do not allow containers to strike objects and do not drop containers.

- Do not use slings or magnetic devices to move chlorine containers.
- Use new gaskets as recommended by the chlorine supplier each time a cylinder or container is connected.
- Follow the chlorine supplier's recommended disposal procedures for leaking containers.
- Do not modify, alter, or repair containers and valves. Only the supplier should carry out these tasks.

Valves

- Ensure that cylinders have valve protection hoods in place when not connected to a system.
- Do not lift a cylinder by its valve protection hood. The hood is not designed to carry the weight of a cylinder.
- If possible, open valves by applying a steady force to a 200 mm (8 in.) wrench, without applying an impact force and without using an extension on the wrench. If this does not work, apply a light impact force by smacking the wrench with the heel of your hand.
- Do not use a wrench longer than 200 mm (8 in.) to open or close valves. Do not use tools such as pipe wrenches or hammers. This will help prevent valve damage that could cause leaks. Valves on cylinders and ton containers are designed to deliver full volume after one complete counterclockwise turn. Valves may be damaged if turned beyond this point. Immediately return containers with damaged or inoperable (but not leaking) valves to the supplier.
- If the valve is very difficult to open, loosen the packing nut slightly. Tighten the packing nut after the valve is opened or closed.

Repair and maintenance

Employers are responsible for providing written preventive maintenance procedures and written emergency procedures to any person who works on a chlorine system. Workers should be familiar with these procedures before carrying out repairs or maintenance on the chlorine system.

Qualified workers must supervise the cleaning and repairing of chlorine systems. Workers must be familiar with all the hazards and the safeguards necessary to perform the work safely.

The chlorine system must be shut off before cleaning or repairing it, and all piping and other equipment must be thoroughly purged with dry air or nitrogen. Vacuum systems can be purged by drawing the remaining chlorine into the process. Do not weld any part of a chlorine system until it has been purged with dry air or nitrogen.

After repair or maintenance work and before using the system, the pressurized part of the chlorine system must be pressurized to 150 psi with dry air or nitrogen and tested for leaks by applying soap solution to the outside of joints. Once detectable leaks are repaired, the system must be retested.

Hazard recognition

When repairing or maintaining a chlorine system, taking proper precautions will help avoid a number of hazards. Written procedures for the repair or maintenance of chlorine systems must consider the following hazards and include procedures that will help workers avoid these hazards.

Hazard alert: Moisture causes chlorine to rupture steel pipe

There was enough moisture in a chlorine line for the chlorine to react with the mild steel pipe. The pipe ruptured, releasing over 45 kg (100 lb.) of chlorine. The entire delivery pipe was replaced with schedule 80 carbon steel to prevent a recurrence.

Moisture

Chlorine reacts with moisture to form corrosive acids. Every precaution must be taken to keep chlorine and chlorine equipment free of moisture, including the following steps:

- Close pipes, lines, valves, and containers tightly when not in use to keep moisture out of the system.
- Avoid contact between chlorine and any residual material that drips from the equipment when pipes or lines are being dismantled before repair.
- Dry pipes and lines before use by purging with dry air (air that has a dew point of at least -40°C) or nitrogen.

Foreign material

Pipes, lines, and fittings must have all cutting oils, grease, and other foreign material removed from them before use. Trichloroethylene or other recommended chlorinated solvents may be used; however, follow Regulation requirements and take special precautions because these solvents can produce serious health effects. Never use hydrocarbon or alcohol solvents for cleaning because they can react vigorously with chlorine.

The following may be used as a lubricating pipe dope for threaded joints:

- Linseed oil with graphite or white lead
- Freshly mixed glycerine and litharge
- Teflon tape

A number of available commercial products may also be used. If Teflon tape is used, all remnants must be removed before joints are remade.

Heat

Because iron and steel will ignite in chlorine at about 230°C (450–500°F), all welding or burning must only be done after the chlorine equipment is completely emptied and purged with dry air or nitrogen.

Engineering and administrative controls are the first line of defence against exposure to chlorine. Proper building design and ventilation are important engineering considerations. Alarm systems are also essential in preventing chlorine exposure.

Personal protective equipment is the last line of defence. It is vital in controlling exposure when a chlorine leak has occurred or there is a possibility of such a leak. Personal protective equipment includes eye, skin, and respiratory protection. It also includes emergency equipment such as eye wash and shower facilities and first aid kits.

Engineering controls

This section is intended mainly for engineers and architects. It outlines specific design and ventilation requirements and guidelines for chlorine systems and storage facilities.

Chlorine enclosure

Consider the following points when designing a chlorine system or storage facility:

- Shipping containers and equipment containing chlorine should be located indoors in a suitable, fire-resistant building. If a separate building is not provided, containers and equipment must be located in a separate enclosure with fire-resistant floors and walls. If possible, chlorine containers should be housed in a room separate from the area where the chlorination equipment is located.
- Chlorine storage enclosures must be designed so that chlorine containers and equipment are located at the lowest level. Sub-surface locations should be avoided. During any new construction, work areas should not be located below the chlorine system.
- Storage rooms with floor areas larger than 19 square metres (rooms approximately 20 ft. x 10 ft.) must have two or more exit doors to ensure accessible escape routes.
- All exit doors must open outwards and must be fitted with *panic hardware* (a crash bar for easy exit).
- Doors should not be self-locking.

- Each room or building housing chlorine containers or equipment should have a viewing window at least 30 cm (12 in.) square or larger that will provide a clear view of the container and distribution system.
- All openings in chlorination rooms (for example, in walls or ceilings) must be tightly sealed, including electrical conduits.
- Chlorine containers and equipment must not be overheated if heating is provided to prevent freezing, to reduce humidity, or simply for comfort.
- All piping carrying chlorine gas or liquid must be identified according to WHMIS requirements.
- Hoses used to transfer chlorine should be lined with materials that are resistant to chlorine, and constructed with an appropriate structure braiding layer.

For more specific detail, refer to the:

- *Chlorine Manual* (available from the Chlorine Institute, phone 703 741-5760, web site www.chlorineinstitute.org)
- Swimming Pool, Spray Pool and Wading Pool Regulations (B.C. *Health Act*)
- British Columbia Building Code
- Municipal building bylaws
- Chlorine manufacturer or supplier

Ventilation

A suitable fan, providing at least 15 air changes per hour, must ventilate the chlorine storage room. Regulations concerning swimming pools, spray pools, and wading pools require at least 30 air changes per hour in the chlorinator room. All ventilation fans must include switches outside the chlorine room or building, even when an inside switch is installed.

Because chlorine gas is much heavier than air and tends to collect at floor level, ventilation fan suction must be located at or near floor level. Air inlets must be located to provide cross-ventilation using outside air.

Chlorine must not be discharged into areas where it may cause damage or injury, such as schools, worksites, private homes, or shopping centres. Ventilation exhaust must not be positioned where it can be captured by the air intake system of the same or another building.

Hazard alert: Poorly positioned exhaust results in near-disaster

Chlorine gas leaking from a faulty valve connection resulted in evacuation of a swimming pool. The leaked gas was discharged outside the building near the air intake for a shopping centre. Only the strong breeze prevented large quantities of the chlorine from contaminating the shopping centre.

Hazard alert: No alarm system results in near-disaster

A leak in the delivery line from a ton container released 45–227 kg (100–500 lb.) of chlorine into a storage room. The chlorine passed through a pipeline into a nearby creek and was carried through town. Because there was no alarm system and the chlorine facility is several kilometres from the town, the leak went unnoticed until someone saw dead fish in the creek. If the leak had not occurred during spring runoff, a very serious situation would have developed. Alarm systems have since been installed in each station to prevent a recurrence.

Automatic or remote shut-down device

For the application of section 6.126(1) from Part 6 of the Regulation, please call your local WorkSafeBC office to discuss this with an occupational hygiene officer.

During emergency leaks, the ventilation system must be shut down until an operator can confirm that it is safe to exhaust gas from the contaminated area. Automatic ventilation must not be triggered when the discharge may affect access to the worksite, adjacent worksites, or private homes.

Administrative controls

Administrative controls include alarm systems and hand-held chlorine detection systems (detector tubes).

Alarm systems

In case of a chlorine leak or emergency, all facilities must have a working alarm that can be heard and seen by workers. A continuous (24-hour) chlorine monitor must be connected to the alarm system. The continuous monitor checks chlorine concentrations in the air and the alarm responds if chlorine concentrations reach a certain pre-set level.

There are several commercially available automatic chlorine alarm systems. They fall into two basic categories: chemical reaction cell and solid state. Each type has advantages and disadvantages. Before buying an alarm system, consider its:

- Reliability
- Accuracy
- Response speed
- Calibration and system drift
- Operating temperature range
- Service and maintenance
- System testing

Some systems will provide a direct readout of chlorine concentration, while others may provide more than one alarm level. Equipment suppliers and other users can provide more information.

Basic alarm system requirements

- The system must be installed according to the manufacturer's instructions. Routine maintenance procedures and tests must follow a strict timetable, and records must be kept.
- Qualified workers must test and calibrate the system using the manufacturer's instructions. Systems must be tested for proper operation at least monthly and calibrated at least annually. Systems must also be tested and calibrated after any significant exposure. See the manufacturer's instructions to determine what a significant exposure is.
- Workers must know the *alarm level* (the chlorine concentration that triggers the alarm). This information must be clearly posted outside the building.
- The pre-set alarm level must be at or below 0.5 ppm. Alarm response procedures must account for minor leaks — action is required at concentrations above 0.25 ppm — that may not require the services of an emergency response team.
- The system must include a visible and audible alarm at the chlorine location, preferably connected to a radio or telephone system to alert the operator in case of emergency.
- In most circumstances the chlorine alarm system will turn off any activated ventilation system. Circumstances in some remote locations, however, allow for exhaust ventilation to be triggered automatically.

Multi-gas instruments

Many portable multi-gas instruments are available that can detect chlorine. Workers must be trained in the proper calibration and use of these devices.

Detector tubes

Several hand-held chlorine detection systems are available. These systems use detector tubes to give a direct reading of the chlorine concentration.

Workers must be properly trained in detector tube use and maintenance. Unused detector tubes should be discarded after two years (refrigerated) shelf life. The pump must be checked before each use, using an unopened detector tube.

When taking measurements to determine the extent and severity of a leak outside the enclosure, workers must wear appropriate respiratory protection. (See Table 4, page 30.)

Workers required to use a respirator must be clean-shaven where the respirator seals with the face to ensure a proper fit.

Personal protective equipment

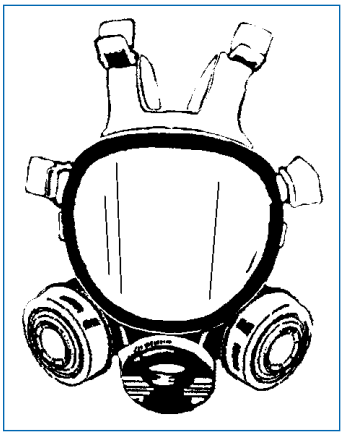
Controlling exposure requires strict attention to chlorine exposure limits. Appropriate eye, skin, and respiratory protection are essential. Workers must be familiar with and understand the requirements of their employer's written exposure control program.

Eye protection

When chlorine gas is in the air, safety glasses and face shields will not protect the eyes. Workers in an area that contains a chlorine concentration that may irritate the eyes (for example, greater than 0.5 ppm) must wear eye protection with a tight seal around the eyes or face to prevent chlorine gas entering the eyes. At this concentration, eye protection will be worn with the required respiratory protection (see Table 4 on page 30).

Skin protection

Emergency response workers who are controlling a serious chlorine leak must have access to full-body protective suits.



A full-facepiece respirator with cartridges

Respiratory protection

This section outlines the types of respirators available to protect workers from exposure to chlorine and the limitations of each respirator. Respirator choices must be based on the needs of each individual worksite and the requirements of the employer's written safe work procedures.

Full-facepiece respirator with cartridges

A worker must wear a full-facepiece respirator fitted with acid gas cartridges during any hazardous work where there is a chance of a chlorine leak. Full-facepiece respirators are also appropriate for leak control where tests show the chlorine concentration to be less than 10 ppm (IDLH level).

Full-facepiece respirator with canister

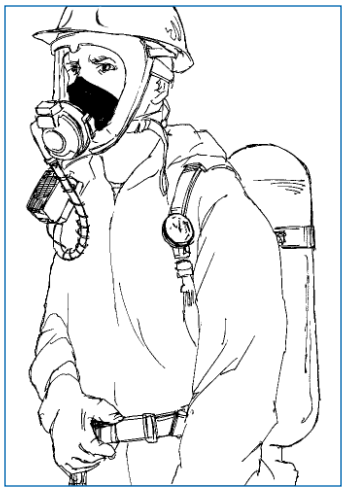
Although cartridges are preferable, a worker may use a full-facepiece respirator fitted with an air-purifying canister for leak control and repair or maintenance procedures in chlorine concentrations less than 10 ppm.

Notes:

1. When a worker is repairing a leak, cartridges or canisters can only be worn when the chlorine concentration is known. See Table 4 on page 30 for information on choosing the right respirator.
2. Canisters with an indicator window must be replaced when the material in the window has changed colour. Canisters without an indicator window must be replaced after each use. In either case, canisters must never be used after the expiration date stamped on the label.

Half-facepiece respirator with goggles

A worker may use a half-facepiece respirator with vapour-tight chemical goggles when working on a chlorine system where there is a chance of a small leak. This type of respirator is permitted only when the chlorine concentration is below 5 ppm.



A self-contained breathing apparatus (SCBA)

Self-contained breathing apparatus (SCBA)

A worker must use an SCBA when a chlorine leak is suspected and the airborne chlorine concentration is unknown or is measured at more than 10 ppm. A worker wearing an SCBA must not enter a contaminated atmosphere until a second, qualified person is present, also equipped with an SCBA, and ready to perform a rescue.

SCBA air cylinders should be refilled every six months or after each use, whichever comes first. Cylinders must have a hydrostatic test at least every five years. Since workers rely on this equipment in IDLH conditions, it is essential that maintenance and inspections be carried out according to the manufacturer's instructions.

An escape respirator

Escape respirator

There are two acceptable types of escape respirators: bite-block respirators and half-facepiece cartridge respirators fitted with acid gas cartridges. Bite-block respirators must be worn with nose plugs. Escape respirators may only be used for immediate evacuation of the contaminated atmosphere.

Hazard alert: Poorly fitting respirator results in chlorine inhalation

A leak could not be controlled immediately. The operator, who has a beard, put on an SCBA and entered the contaminated area to shut down the system. The operator's beard prevented his respirator from sealing properly, and he immediately had difficulties due to chlorine inhalation. He was helped from the area and transported to hospital.

Anyone entering a chlorine room for any reason must carry an escape respirator and keep it within arm's reach at all times. There is one exception: As long as the worker is not working on the system itself, an escape respirator may not be necessary if the worker is never more than 2 m (6 ft.) from the exit door and no part of the chlorine system is between the worker and the exit door. This is because it would take longer to put on the respirator than it would to exit the room.

Table 4: Choosing the right respirator

Situation	Chlorine concentration	Respirator choice
Routine work in chlorine room	—	• Escape respirator (If a leak occurs, the concentration will be unknown. Exit room immediately.)
Working on chlorine system	—	• Half-facepiece respirator with tight chemical goggles, or • Full-facepiece respirator (If a leak occurs, the concentration will be unknown. Exit room immediately.)
Leak occurs, enter to repair	Up to 5 ppm	• Half-facepiece respirator with tight chemical goggles, or • Full-facepiece respirator
	Greater than 5 ppm up to 10 ppm	• Full-facepiece respirator
	Greater than 10 ppm	• SCBA
	Unknown; always assume to be IDLH level	• SCBA

Person-check radio or telephone

Employers must establish a check system to ensure the continued well-being of workers who are working alone or at an isolated worksite. Where visual checks are not possible, the check system may require a radio or telephone. Workers who will need to use such a system must be trained in the written procedure.

Emergency equipment

Emergency equipment includes eye wash and shower facilities, first aid kits, and container repair kits. Workers must have immediate access to each of these items and must know how to use them in case of emergency. Emergency equipment is covered in more detail on pages 15–17. For first aid information, see pages 32–33.

For more detailed information on personal protective equipment, contact:

- Chlorine suppliers
- Equipment manufacturers
- Safety equipment suppliers
- WorkSafeBC offices (listed at the end of this manual)

Unconscious patients

As soon as they resume breathing, always place unconscious patients in the drainage position (on their side, so fluids can drain from the mouth and airways). Never give an unconscious patient anything by mouth.

When someone is injured in a chlorine-related incident, first aid can help reduce the impact of their injuries and prevent further injuries from occurring. The following steps apply to any situation in which someone is injured:

1. Do not panic.
2. Ensure that there is no more danger to yourself or the victim.
3. Using appropriate safety gear, remove the victim from the contaminated area.
4. Send for medical help.

Chlorine inhalation

Someone who has inhaled chlorine may be unconscious, and may have difficulty breathing or may have stopped breathing completely. Follow these steps when treating a victim of chlorine inhalation:

1. Assess the victim's breathing:
   - If breathing has stopped, begin artificial respiration and continue until the victim resumes breathing. Pocket masks are recommended for artificial respiration, although the mouth-to-mouth method may also be used.
   - If the victim is having difficulty breathing (for example, gasping or coughing), place the victim in the most comfortable position, usually semi-sitting.
2. If an oxygen therapy unit and trained personnel are available, administer oxygen at a 10-litre flow.
3. Ensure that the victim is transported to hospital in case the victim suffers a delayed reaction in the form of pulmonary edema. Any physical exertion, excitement, or apprehension increases the chance and severity of a delayed reaction. Keep the victim warm and completely at rest. Reassure the victim while waiting for assistance and transportation to hospital.

Skin contact

Skin contact with chlorine can result in severe burns. Before attempting to flush a victim's contaminated skin, make sure the victim is breathing properly. Follow these steps:

1. Assess the victim's breathing:
   - If breathing has stopped, begin artificial respiration and continue until the victim resumes breathing. Pocket masks

are recommended for artificial respiration, although the mouth-to-mouth method may also be used.
    - If the victim is having difficulty breathing (for example, gasping or coughing), place the victim in the most comfortable position, usually semi-sitting.
2. As soon as the victim resumes breathing, flush the victim's contaminated skin and clothing with large amounts of water for 30 minutes.
3. Remove all contaminated clothing while flushing.
4. Continue flushing until all traces of chlorine have been removed.
5. Dress obvious burns with sterile gauze and bandage them loosely. Apply insulated cold packs to help reduce pain.
6. Get the victim to hospital.

Notes:

1. Do not attempt to neutralize the chlorine with other chemicals.
2. Do not apply salves, ointments, or medications unless prescribed by a doctor.
3. Skin contact with liquid chlorine coming straight out of a cylinder can result in frostbite.

Eye contact

Eye contact with chlorine (liquid or gas) for even a short period can cause permanent disability. Flushing must begin within 10 seconds. Follow these steps:

1. Flush the eyes immediately with large amounts of running water (preferably lukewarm) for 30 minutes. Hold the eyelids forcibly apart to ensure full flushing of the eyes and eyelids.
2. After flushing has removed all traces of chlorine, cover both eyes with moistened sterile gauze pads and bandage, enough to keep light out.
3. Apply insulated cold packs to help reduce pain.
4. Get the victim to hospital.

Notes:

1. Do not attempt to neutralize the chlorine with other chemicals.
2. Do not apply oils, ointments, or medications to the eyes.

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WorkSafeBC Offices

Visit our web site at WorkSafeBC.com.

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