Safe Work Practices for Chlorine

WorkSafeBC

About WorkSafeBC

At WorkSafeBC, we're dedicated to promoting safe and healthy workplaces across B.C. We partner with workers and employers to save lives and prevent injury, disease, and disability. When work-related injuries or diseases occur, we provide compensation and support injured workers in their recovery, rehabilitation, and safe return to work. We also provide no-fault insurance and work diligently to sustain our workers' compensation system for today and future generations. We're honoured to serve the workers and employers in our province.

Prevention Information Line

We provide information and assistance with health and safety issues in the workplace.

Call the information line 24 hours a day, 7 days a week to report unsafe working conditions, a serious incident, or a major chemical release. Your call can be made anonymously. We can provide assistance in almost any language.

If you have questions about workplace health and safety or the Occupational Health and Safety Regulation, call during our office hours (8:05 a.m. to 4:30 p.m.) to speak to a WorkSafeBC officer.

If you're in the Lower Mainland, call 604.276.3100. Elsewhere in Canada, call toll-free at 1.888.621.7233 (621.SAFE).

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WorkSafeBC

Health and safety resources

You can find our health and safety resources on worksafebc.com, and many of them can be ordered from the WorkSafeBC Store at worksafebcstore.com.

In addition to books, you'll find other types of resources at the WorkSafeBC Store, including DVDs, posters, and brochures. If you have any questions about placing an order online, please contact a customer service representative at 604.232.9704 or toll-free at 1.866.319.9704.

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Contents

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Introduction

Note

All references in this manual are also listed in "Other resources" on pages 48–50.

Chlorine is a powerful oxidizing agent commonly used for disinfection and bleaching. In both gas and liquid forms, it 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 death can result.

If you as an employer fail to take the necessary precautions to protect your workers against exposure to chlorine, they can become seriously injured and even die from exposure-related injury.

In order to prevent such exposures, there are legal requirements for employers and workers in workplaces where there is chlorine. These requirements are detailed in the Occupational Health and Safety Regulation.

This manual doesn't replace the Occupational Health and Safety Regulation

This manual is meant to give you a basic understanding of your health and safety requirements, but you should also refer to the Regulation to be sure you're meeting your legal responsibilities for workplace health and safety. You can find a searchable version of the Regulation and its accompanying OHS Guidelines at worksafebc.com/law-policy.

Who is this manual for?

This manual is meant for workers and employers in industries that use, produce, or store chlorine.

Workplaces most commonly associated with potential chlorine exposure are those that use it as a disinfectant, such as public pools and water and wastewater treatment facilities. Chlorine is also used as a disinfectant or bleaching agent in manufacturing and processing.

If you are an engineer or architect, this manual will provide you with some information on the safe design of facilities for the use or storage of chlorine.

This manual does not address the use of chlorine bleach, chlorine dioxide, or other substances containing chlorine.

Chlorine gas is a toxic process gas

Employers intentionally producing, or producing and storing, chlorine gas to be used in another process should note that this chlorine gas falls under the definition of toxic process gas in sections 6.116–6.132 of the Regulation.

Terms associated with regulatory requirements

In this manual, the word ***must*** indicates a requirement that's specified in the Regulation. The word ***should*** indicates a recommended action that will improve safety in the workplace even though it's not required by the Regulation. For the purpose of this manual, the word ***worker*** includes supervisors, managers, and workers.

In addition to the information in this manual, you can get specific information from manufacturers and suppliers of chlorine and chlorine equipment. The Chlorine Institute also has information and publishes ***Chlorine Basics*** (formerly the ***Chlorine Manual***). See "Other resources" on pages 48–50.

What is chlorine?

Chlorine typically comes in three forms:

- Chlorine gas — typically provided as a commercial gas cylinder that actually contains liquefied chlorine under pressure.
- Chlorine bleach solution — a solution of chlorine and some caustic agent dissolved in water to form sodium hypochlorite bleach. This bleach solution is typically provided in a range of concentrations, depending on the application.
- Chlorine immobilized in a solid form — for example, chlorine "pucks" containing sodium trichloroisocyanurate, which releases chlorine when mixed with water.

Chlorine is often provided by a supplier in one of the above forms. Chlorine gas can also be generated on demand. This eliminates both the hazard of transporting it and the need to store quantities of chlorine gas to which workers could be exposed.

Pure chlorine changes from a liquid to a gas immediately when released from a compressed-gas cylinder. It vaporizes quickly and does not remain as a liquid under ambient conditions.

Chlorine gas can be released in hazardous amounts from bleach solutions (sodium hypochlorite) or solid chlorine sources. This generally occurs when bleach solutions or solid sources are mixed with incompatible chemicals (most commonly acids) or if they are involved in a fire.

Chlorine has a disagreeable, sharp, pungent, penetrating odour.

In airborne concentrations greater than 1,000 parts per million (ppm), it has a greenish-yellow colour. This is rarely, if ever, seen as these concentrations are extremely rare. In more common smaller concentrations, chorine is colourless but still harmful to people. Chlorine gas is 2½ times heavier than air. It 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.

As mentioned, liquid chlorine is maintained in that state in pressurized containers. Liquid chlorine is a transparent, amber-coloured, oily fluid that is 1½ times heavier than water. It has a high compression ratio: the ratio of chlorine liquid to gas is 1 to 460, which means that 1 L of liquid chlorine expands to 460 L of pure chlorine gas.

If all the liquid chlorine were to escape from a 68 kg (150 lb.) container, enough pure chlorine gas would be released that 24 times the amount of air contained in BC Place stadium would be required to dilute it to a safe level. This translates to a gas concentration of 0.5 ppm, the maximum allowable concentration a person can be exposed to averaged over an eight-hour period.

Uses

Chlorine is mainly used as a disinfectant in the following:

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

Chlorine is also used in the following:

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

Hazards of chlorine

Health hazards

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 result in 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 immediate and potentially irreparable damage to the lungs. Table 1 summarizes the toxic effects of chlorine. Table 2 summarizes the occupational exposure limits of chlorine.

Immediately Dangerous to Life or Health (IDLH) exposure level

The Immediately Dangerous to Life or Health (IDLH) exposure level is the point at which a person without appropriate respiratory protection could be fatally injured or suffer irreversible or incapacitating health effects. Workers are considered to be in an IDLH condition if the airborne concentration reaches the IDLH level or if the airborne concentration is unknown.

According to the National Institute for Occupational Safety and Health (NIOSH), the IDLH exposure level for chlorine is 10 ppm.

Table 1: Toxic effects of chlorine

Chlorine concentration (parts per million)	Health effect
0.03–0.1	Range of odour threshold (the Canadian Centre for Occupational Health and Safety [CCOHS] specifies 0.08 ppm)
1–3	May cause mild irritation of the eyes, nose, and throat
3–5	Stinging or burning in eyes, nose, and throat; may cause headache, watery eyes, sneezing, coughing, difficulty breathing, bloody nose, and blood-tinged sputum
5–15	Severe irritation of the eyes, nose, and respiratory tract
10	IDLH, according to NIOSH
30–60	Immediate breathing difficulty resulting in pulmonary edema (fluid buildup in lungs), possibly causing suffocation and death
430	Lethal after 30 minutes
1,000 ppm or more	Fatal after a few breaths

Note: Chlorine gas is not visible in the air until concentrations exceed hazardous levels, so visibility can't be used to confirm safe conditions. Chlorine may appear as a greenish-yellow cloud at concentrations above 1,000 ppm.

Table 2: Occupational exposure limits of chlorine

Exposure level (parts per million)	Exposure limit
0.5	Maximum allowable concentration averaged over an eight-hour period
1	Maximum allowable short-term exposure (15 minutes)
10 ppm or more	IDLH, according to NIOSH

Fire

Chlorine gas will not burn by itself, but will support or initiate combustion.

Chemical action

In both gas and liquid forms, chlorine reacts with many chemicals and materials, 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 sequentially mixed with water. The process forms chloramines, which provide effective residual disinfection of water. Chloramines are more stable than, and don't dissipate as rapidly as, chlorine. Pure chlorine gas mixed directly with ammonia gas 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, and they are added to the water separately.

Chlorine bleach (sodium hypochlorite with sodium hydroxide in water) is also reactive with a range of chemicals. When combined with acid — including hydrochloric, muriatic, sulfuric, nitric, and acetic acid (vinegar) — chlorine bleach can release hazardous concentrations of chlorine gas.

Ammonia-based cleaning products (such as window, toilet-bowl, and surface cleaners) can form hazardous levels of chloramines in air when they are mixed with bleach.

Chlorine in immobilized solid forms (such as trichloroisocyanurate) has similar reactivity to chlorine bleach. Mixing it with water will cause chlorine gas to be slowly released into the water. When immobilized solid forms of chlorine are mixed with strong acids, chlorine gas can be liberated in hazardous amounts. Trichloroisocyanuric acid is a strong oxidizer that enhances combustion of other substances. It can react violently and cause fires and explosions if it is subjected to heat or exposed to any of the following:

- Chemicals, such as ammonium salts, amines, calcium hypochlorite, hydrogen peroxide, or sodium carbonate
- Combustible materials
- Reducing agents, such as lithium, sodium, or aluminum and their hydrides

Corrosive action

Chlorine reacts with water or moisture in the air to form highly corrosive acids, including hypochlorous acid and hydrochloric acid. Never use water on a chlorine leak.

Employer responsibilities

According to the Regulation, employers must develop and implement an effective health and safety program. This includes training workers and supervisors to understand and apply relevant sections of that program.

Health and safety programs

An occupational health and safety program helps ensure that the workplace remains safe by outlining and reinforcing specific tasks and responsibilities for workers, supervisors, and employers. An effective program 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
- Training and instruction for supervisors and workers
- Regular worksite inspections (conducted frequently enough and in a manner to prevent the development of unsafe conditions in the workplace)
- 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 worker representative, if applicable) should review the program.

Supplemental elements that typically would be required in a facility using and storing chlorine gas and related chemicals may include the following:

- Exposure control plan, including risk identification, assessment, and control
- Emergency response plan and procedures, including procedures for responding to leaks and spills
- Workplace Hazardous Materials Identification System (WHMIS) program
- Personal protective equipment (PPE) program

- Transportation of Dangerous Goods (TDG) program if shipping or otherwise transporting chlorine
- Specific safe work procedures for handling chemicals and performing hazardous work activities, along with associated training and supervision

As an employer, you need to remember that every worksite is unique. While the above requirements may be common features of health and safety programs across the province, you can't expect to copy a program from another worksite. Instead, you must develop and implement a health and safety program that's appropriate to your own operation.

Where to look for information in the Regulation

You can use several elements of your health and safety program and supplemental elements to help ensure that your workers handle chlorine safely. These elements and their locations in the Regulation are summarized in Table 3.

Table 3: Key health and safety program elements for safe handling of chlorine

Element	Regulation sections
Occupational health and safety program	3.1–3.3
First aid requirements	3.14–3.21
Equipment preventive maintenance and critical parts inspections	4.3, 4.9, and 6.132
Emergency preparedness and response	4.13–4.18
WHMIS program	5.3–5.19
Exposure control plan	5.54
Emergency washing facilities	5.85–5.96
Emergency procedures	5.97–5.102 and 6.120
Toxic process gases	6.116–6.132
Personal protective clothing and equipment and PPE program	6.127 and 8.5
Eye and face protection	8.14–8.18

Element	Regulation sections
Body protection	8.19
Appropriate footwear	8.22
Respirators	8.32–8.45

Written safe work procedures

Written safe work procedures explain to workers in reasonable detail how to perform their duties safely. These procedures must be supplemented by appropriate training and supervision to ensure that workers understand and are capable of safely performing the tasks.

The employer must ensure that all workers understand these procedures well enough to perform their duties safely. Employers must review all written safe work and emergency procedures with workers and supervisors at least once a year.

Who is a "qualified person"?

According to the Regulation, *qualified* "means being knowledgeable of the work, the hazards involved and the means to control the hazards, by reason of education, training, experience or a combination thereof." In the context of chlorine, a qualified person is an occupational health and safety professional with experience in the practice of occupational hygiene as it relates to chlorine.

People performing risk assessments and classifying work activities (moderate or high risk) should be certified and educated as follows:

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 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

WHMIS programs

A 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.

With the introduction of WHMIS 2015, some of this information changed. For the current version of WHMIS, go to worksafebc.com and search for "WHMIS 2015" or see Part 5 of the Regulation.

Exposure control plans

Every facility where chlorine gas is used or stored must have and adhere to an exposure control plan (ECP). Written ECPs explain the work procedures and other controls you'll need to use to reduce workers' risk of exposure to chlorine.

A risk assessment is required to determine which workers may be affected by exposure to chlorine and the potential extent of any exposure. A qualified person should conduct this risk assessment. For more information on ECP elements, see sections 5.54 and 6.116–6.132 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" on pages 33–34.

Note

If the amount of chlorine gas on site ever exceeds 1.13 metric tonnes, your workplace must be registered with Environment and Climate Change Canada (ECCC). It must also meet any other requirements of WorkSafeBC, Technical Safety BC, local health authorities, or other regulatory agencies. You are obliged to report any spills or releases of chlorine gas to ECCC and other regulatory agencies. For more details, visit ec.gc.ca.

Risk assessments and written work procedures for toxic process gases

Chlorine is a toxic process gas. As an employer, you must ensure that a risk assessment is conducted for toxic process gases. As mentioned above, you must also conduct a risk assessment as part of your ECP. These risk assessments can be done together as a combined risk assessment.

You must also ensure there are written work procedures that provide instructions for the safe handling of chlorine at your workplace. These procedures must correspond to the risk assessment results, critical technical information, and operations manuals.

Personal protective equipment (PPE) programs

Employers are required to develop and implement an effective PPE program to protect workers from chemical exposure, including inhalation exposure, eye exposure, and skin exposure. This program must meet the requirements of the Regulation. For more information on PPE, see Part 8 of the Regulation.

Employers must ensure that workers are trained in the proper use and care of respirators. They must also ensure that workers are fit tested according to *CSA Standard Z94.4-02 – Selection, Use and*

Care of Respirators. This must be done in all of the following cases:

- Before initial use of a respirator
- Whenever there are changes to the wearer's physical condition that could affect the respirator seal
- At least once a year thereafter

If a respirator is to be worn, the worker must use an appropriate cartridge or canister. Ensure that the chlorine cartridge is from the same manufacturer as the respirator.

Employers must keep records of fit tests. If your company uses self-contained breathing apparatus, you must do annual air testing on compressed breathing air and retain records of such testing. You must also retain your equipment maintenance records, such as hydrostatic testing and regulator recertification records.

Respiratory, eye, and skin protection requirements are covered in more detail under "Personal protective equipment (PPE)" on pages 38–41. You can also find more information on respiratory protection in other WorkSafeBC publications, such as ***Breathe Safer.***

Written emergency procedures

To prepare for workplace emergencies, the employer must do the following:

- Keep an up-to-date inventory of hazardous substances.
- Conduct a risk assessment for potential emergency events, such as an accidental gas release.
- Prepare an emergency plan with detailed response procedures based on the findings of the risk assessment.
- Train workers on these emergency procedures, including conducting evacuation and emergency response drills.
- Inform your local fire department and other relevant emergency responders about your workplace emergency response plan.

Details about these requirements are covered in "Preparing for emergencies" on pages 28–31.

Preventive maintenance procedures

In consultation with equipment manufacturers or suppliers, employers must ensure that all equipment is regularly inspected and maintained, and that it's repaired or replaced when necessary. You must also ensure that everyone who works on the chlorine system has ready access to, understands, and follows the written preventive maintenance and emergency procedures you've developed for any work relating to the chlorine system.

Related incident

Cylinder moved while valve open

A worker was painting the walls of the pump-house 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 fully open position. The worker was not wearing a respirator. He was overcome by chlorine gas and hospitalized with severe respiratory injuries. A large number of people in the surrounding area were evacuated. Several were treated in hospital.

The employer must also have procedures for maintaining, testing, and replacing, where required, all ancillary (secondary) safety equipment, including the following:

- Alarm systems
- Emergency shutdown devices
- Detection equipment
- Radios
- Eyewashes and showers
- Respiratory and skin protection, including eye and face protection
- Other PPE, including appropriate footwear (boots)
- First aid kits
- Chlorine-container emergency kits

To ensure that nothing is overlooked, you may find it useful to develop checklists for inspecting and testing equipment, and to record all use and maintenance of safety equipment in a suitable logbook. For more information on preventive maintenance and hazards that can arise during repair or maintenance, see "Repair and maintenance" on pages 19–20.

Checking on a worker working alone

Workers who work on chlorine-handling equipment commonly work alone or in isolation, where help is not readily available, such as in a chlorine enclosure. If a worker is working alone or in isolation, the employer must establish a system with written procedures to ensure the worker's continued well-being, especially when entering a chlorine enclosure. Depending on the situation, your person-check system may consist of either visual checks, radio contact, or a telephone call-in procedure. The person-check system must include the following:

- A set interval between checks
- A record of each check
- A check at the end of the workshift
- Procedures to follow if the worker can't be contacted or is injured

For more details, see sections 4.20.1–4.23 of the Regulation.

A backup worker is required in any situation where conditions are IDLH or there is a significant risk of IDLH conditions occurring. See section 8.35(1)(b) of the Regulation. These conditions might apply when work is being done on any part of a chlorine system or when

an alarm sounds. Even for routine work, it's a good idea to have a backup worker monitoring exposure levels and ready to assist in case a worker needs help.

Training, instruction, and supervision

Even though workers may have special certification or other external training, the employer is ultimately responsible for providing them with thorough, site-specific training and continued instruction in the programs and procedures outlined above. Your training program should be developed in conjunction with written safe work procedures. Not every element addressed in safety training may have a corresponding safe work procedure, but it's critical to ensure that training is consistent with and complementary to written safe work procedures.

As an employer, you must document the training and instruction you provide to your workers. Your workers must be able to demonstrate competency in doing their work according to the work procedures. Provisions should be in place for evaluating worker competency right after training and periodically afterwards, such as during periodic inspections of work practices. For more information and examples of these procedures, see "Written safe work procedures — examples" on pages 22–27.

Supervisors

Supervisors play an important role in promoting and maintaining workplace safety. Their words and actions demonstrate how they view and value health and safety. Some routine safety-related actions supervisors may take include the following:

- Provide workers with training before they start new tasks.
- Verify that workers' performance meets safety expectations.
- Correct improper and unsafe work activities and conditions.
- Identify any new workplace hazards and take steps to ensure that everyone stays safe.
- Reinforce safe and proper work performance.
- Record a daily entry in a supervisor journal or logbook.
- Ensure that all documentation is clear, appropriate, and frequently updated, showing a systematic approach to safety.

Working safely around chlorine

This section 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.

In all situations, using personal protective equipment (PPE) — particularly eye, skin, and respiratory protection — is essential for working safely around chlorine. For more hazardous work, such as opening valves and conducting repairs, required PPE may be more sophisticated. This section presumes that appropriate PPE is used in every situation. For more information, see “Personal protective equipment (PPE)” on pages 38–41.

Containers

Chlorine gas (liquefied chlorine) comes in three types of containers:

- Cylinders with a 68 kg (150 lb.) capacity
- Ton containers (referred to as “tonners”) with a 907 kg (2,000 lb.) capacity
- Railcars with a capacity of about 88 short tons (176,000 lb. or 80,000 kg)

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 hazardous product under WHMIS 2015, as follows:
   - Oxidizing gases — Category 1
   - Gases under pressure — Liquefied gas
   - Skin corrosion/irritation — Category 2
   - Serious eye damage/eye irritant — Category 2A
   - Acute toxicity — Category 2 (inhalation)
   - Specific target organ toxicity – single exposure — Category 3 (respiratory tract irritation)

Storing chlorine

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

Signage and location

- Use signs to clearly identify all areas where chlorine is used or stored, to identify all chlorine enclosures or tanks, and to list the precautions required for safe entry. Only designated qualified workers 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.
- When storing chlorine cylinders and containers outdoors, shield them from direct sunlight, unless they're 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 cylinders and containers indoors, store them in a well-ventilated building, away from any heat sources, such as steam pipes.
- Store chlorine containers at the lowest working level but not below grade.
- Store chlorine away from locations where vehicles or mobile equipment operate.
- 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 if chlorine leaks from the bottom valve, the container can be quickly rotated so the leak is 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

- Don't store materials that may react violently with chlorine in the same room as chlorine. Examples include hydrogen, ammonia, acetylene fuel gases, ether, turpentine, finely divided metals, and most hydrocarbons, such as solvents, greases or oils, and organic matter.
- Store containers with enough room between them to allow for access and an easy exit path 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. Even residue can be hazardous.

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. Don’t allow containers to strike objects, and don’t drop containers.
- Don’t use slings or magnetic devices to move chlorine containers. Use handling equipment specifically designed for chlorine containers.
- Use new gaskets as recommended by the chlorine supplier each time you connect a cylinder or container.
- Follow the chlorine supplier’s recommended disposal procedures for leaking containers.
- Don’t modify, alter, or repair containers and valves. Only the supplier should perform these tasks.
- Ensure that third parties, such as delivery companies, handle chlorine cylinders with care on your site.
- Ensure that workers responsible for moving chlorine cylinders and those involved in delivery and pickup of cylinders are aware of safe practices for moving and storing cylinders.
- Ensure that responsible parties are supervising any time chlorine containers are moved.

Working with valves

Inappropriate handling of valves can result in valve failure and catastrophic leaks from containers. Follow the suppliers’ procedures for opening and closing valves. Use caution when attempting to open jammed valves. The following are some ways for workers to protect themselves when working with valves:

- Ensure that cylinders have valve-protection hoods (or valve caps) in place when they are not connected to a system.
- Don’t lift a cylinder by its valve-protection hood or cap. The hood or cap is not designed to bear 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 doesn't work, apply a light impact force by lightly tapping the wrench.
- Don't use a wrench longer than 200 mm (8 in.) to open or close valves. Don't 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 counter-clockwise turn. They may be damaged if turned beyond this point. Immediately return to the supplier containers with damaged or inoperable (but not leaking) valves.
- If a valve is very difficult to open, loosen the packing nut slightly. Tighten the packing nut after the valve is opened or closed.
- Make sure lines are purged and valves are shut before disconnecting cylinders.
- Ensure that remote or automatic shutdown devices are set up to tighten the valves to the correct degree.

Repair and maintenance

Chlorine systems must be installed, inspected, tested, repaired, and maintained in accordance with the manufacturer's instructions. As an employer, you're responsible for providing written preventive maintenance procedures and emergency procedures to anyone who works on a chlorine system. You must ensure that workers are familiar with these procedures before they carry out repairs or maintenance on the chlorine system.

Under the Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation, which is enforced by Technical Safety BC, you must ensure that a qualified and certified person performs proper, ongoing maintenance of any chlorine system set at over 15 psi (103 kPa).

Qualified workers must supervise the cleaning and repair of chlorine systems. As an employer, you must ensure that workers are familiar with all the hazards and the safeguards necessary to perform the work safely. This applies whether those conducting and supervising the repairs are your own employees or contractors or suppliers.

Shut off the chlorine system before cleaning or repair. Thoroughly purge all piping and other equipment with dry air or nitrogen. Vacuum systems can be purged by drawing the remaining chlorine into the process. Ensure that the vacuum system is operating at

all times, unless all chlorine cylinder or container valves are in the closed position. Don't weld any part of a chlorine system unless it has been purged with dry air or nitrogen.

After repair or maintenance work and before the system is used, pressurize the chlorine system to 150 psi with dry air or nitrogen and test for leaks by applying soap solution to the outside of joints. Once detectable leaks are repaired, retest the system.

Identifying chlorine leaks

Chlorine can leak from several points in a system containing chlorine gas, so continuous gas monitors are required to monitor any area where workers might be exposed. An ammonia test is used to pinpoint the exact location of a leak. The test uses ammonium hydroxide (ammonia dissolved in water or moist air) rather than pure ammonia. The ammonium hydroxide is applied anywhere along the system where there may be a leak. Chlorine reacts readily with ammonium hydroxide to form a white cloud of ammonium chloride, a relatively harmless compound. The appearance of this white cloud indicates the presence of chlorine. Workers can use the location of the cloud to pinpoint the location of a chlorine leak.

Hazard recognition

Written procedures for the repair or maintenance of chlorine systems must consider the following hazards and include procedures to help workers avoid them.

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:

- 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

Remove all cutting oils, grease, and other foreign material from pipes, lines, and fittings before use. You may use trichloroethylene or other recommended chlorinated solvents, but follow Regulation requirements and take special precautions — these solvents can

Related incident

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.

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 (a mineral form of lead monoxide)
- Teflon tape

A number of other commercial products may also be used to join pipe components. If Teflon tape is used, all remnants must be removed before joints are remade.

Heat

Iron and steel will ignite in chlorine at about 230°C (450–500°F). All welding or burning must be done only after the chlorine equipment has been completely emptied and purged with dry air or nitrogen.

Written safe work procedures — examples

Some tasks require written safe work procedures. They include, but are not limited to, the following:

- Safely receiving deliveries of chlorine cylinders and returning used cylinders
- Changing cylinders
- Detecting and controlling leaks
- Repairing containers and using the chlorine-container emergency kit
- Checking on a worker working alone
- Disposing of damaged containers
- Carrying out routine maintenance of equipment (for example, chlorinators, piping, steam-heating systems, and full and partial startup and shutdown of any system that uses chlorine)

Written safe work procedures should be detailed and complete. They should not assume that the worker will know or remember any unlisted tasks. The following are examples of procedures. It's important to ensure that the procedures take into account the specifics of your particular worksite. That's why employers must create their own detailed written safe work procedures to suit each individual worksite.

Example one: Changing chlorine cylinders

Here is an example of a safe work procedure for changing cylinders in a non-emergency situation, when the alarm has not been activated. If the alarm has been activated, workers should follow the emergency procedures posted in the workplace. In these instructions, "you" refers to the worker changing the cylinder.

Note: This safe work procedure should specify that only competent workers can change cylinders and how many competent workers should be present.

1. Make sure there's a co-worker outside the chlorine enclosure who is observing the cylinder change. This co-worker should be capable, equipped, and trained to perform a rescue. [Note: If the facility is a pool, this is also a requirement under the B.C. Guidelines for Pool Operations.]

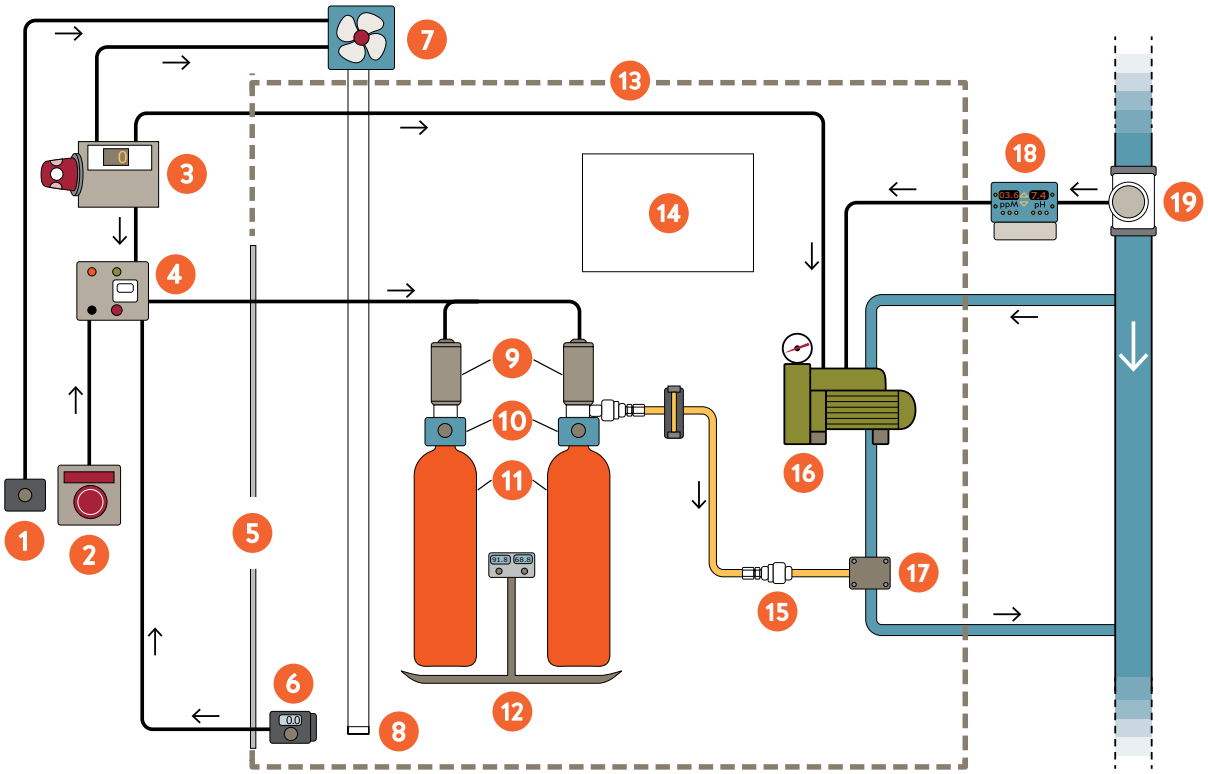
2. Turn on the light and visually confirm that the enclosure is safe to enter (for example, confirm that there are no visible signs of damage).
3. Make sure you're carrying or wearing a portable or handheld chlorine monitor.
4. Put on appropriate PPE. [Be specific about the type of equipment, including the type of respirator cartridge or canister.] You must wear a suitable respirator and cartridges or canister, as well as eye and skin protection. An escape respirator is not acceptable for this operation.
5. Confirm that the readout on the continuous monitoring system (located outside the chlorine enclosure) indicates that no chlorine is being detected by the detector within the enclosure.
6. Before entering the enclosure, confirm that the exhaust ventilation is operating.
7. Close the main chlorine cylinder valve. If you can activate the emergency-cylinder flow shutdown device from outside the enclosure, test it to ensure it is working properly.
8. 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 the weigh scale reads zero.
9. Loosen the chlorinator (auxiliary valve or vacuum regulator) and remove it from the empty cylinder.
10. Replace the cylinder cap on the empty chlorine cylinder. Remove the cylinder to secured storage.
11. Secure the new cylinder in place.
12. Remove the protective hood from the new cylinder.
13. Ensure that there's 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).
14. Ensure that the cylinder valve is closed. Don't open the valve yet.
15. Remove the cylinder outlet cap and check that the cylinder outlet face is clean and smooth.
16. 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.
17. 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, contact your supplier for help.

18. Check all the connections you've made to ensure there are no leaks. Use vapour from the ammonia test bottle to test for leaks (see step 13). If there's a leak, activate the leak control procedure (see example two, below).
19. When there are no leaks, open the chlorine cylinder valve a quarter turn at a time up to one full turn. Leave the cylinder wrench on the valve.
20. Open any additional system valves [be specific for your facility] and test for leaks as each stage is charged with chlorine.
21. Ensure that the alarm system is functioning and that the emergency-cylinder flow shutdown device is properly installed.
22. Check for leaks again with the ammonia test bottle to be sure everything is in order.
23. Turn off the lights and close the door when you leave.
24. Remove your respirator and other PPE.

Safety controls for a typical chlorine system



1. Fan switch
2. Emergency shutdown switch
3. Chlorine alarm
4. Emergency shutdown controller
5. Door
6. Chlorine sensor
7. Exhaust fan
8. Air duct
9. Automatic valve closers
10. Vacuum regulators
11. Tanks
12. Scale
13. Enclosure
14. Enclosure viewing window
15. Check valve
16. Remote pump
17. Ejector
18. Chemistry controller
19. Flow cell

Diagrams can help clarify written safe work procedures. This diagram is from the WorkSafeBC bulletin *Preventing chlorine gas exposure at municipal pools.*

Example two: Detecting and controlling leaks

This example includes two components:

- What to do if a leak is indicated after a cylinder change
- What to do if the chlorine alarm is activated during routine operation of the system

Leak indicated after cylinder change

If the ammonia test indicates a leak after a cylinder change, use this procedure. This procedure assumes that the worker is already

wearing the respirator required for the cylinder change. If not, the worker must first put on appropriate PPE, including the respirator.

Follow these steps:

1. Make sure you're carrying a portable or handheld chlorine monitor.
2. Immediately close the main cylinder valve.
3. If the monitor reads less than 3 ppm, you may repeat the cylinder hookup procedure.
   Note: Ten ppm is immediately dangerous to life or health. Even workers using air purifying respirators with chlorine cartridges or canisters must leave the enclosure before chlorine levels reach 10 ppm.
4. Open and close the main cylinder valve, and repeat the ammonia test.
   Note: If chlorine is in the area because of the leak, it may be difficult to identify the source. You may need to let the air clear before repeating the ammonia test.
5. If a leak is still indicated, make a third and final attempt to get a good seal, using a new lead washer.
6. If you can't correct the leak 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. You must connect a different cylinder to the chlorination system.
7. Leave the chlorine enclosure. Stay nearby to restrict access to the enclosure or to provide other help, as directed, until the chlorine alarm has automatically shut off.

Chlorine alarm activated during routine operation of system

If the chlorine alarm is activated during routine operation of the system and the alarm doesn't automatically activate the emergency-cylinder flow shutdown device, then workers must manually activate the emergency-cylinder flow shutdown device from outside the enclosure. If possible, approach from uphill and upwind.

In this case, at least two workers will turn on the emergency ventilation system and perform necessary repairs. Note that the emergency ventilation system is different from the basic exhaust ventilation, which should always be on. Also note that it's preferable to have an alarm that automatically activates the emergency-cylinder flow shutdown device.

Warning: If chlorine has been smelled in the open, don't use this procedure. Instead, activate full emergency procedures and ensure that everyone leaves the area immediately.

Otherwise, follow these steps:

1. Make sure both of you are wearing an appropriate respirator and carrying a portable or handheld chlorine monitor. See Table 5 on page 42 for information on choosing the right respirator.
2. Approach the location cautiously.
3. If the emergency-cylinder flow shutdown device has not been activated by the alarm, activate the shutdown device from outside the enclosure if it is safe to do so.
4. Check the monitor readout on the continuous monitoring system located outside the enclosure to determine the concentration of chlorine inside the enclosure.
5. If the chlorine concentration is less than 3 ppm and is not rising, turn on the emergency ventilation system and leave the area until the alarm stops.
6. After the alarm has stopped and while you are still wearing respirators and PPE, enter the enclosure. Isolate the leak, and ensure that chlorine has been safely purged from the pipe before performing repairs. All chlorine lines must be free of oil, grease, and moisture before you reopen the chlorine cylinder.
7. After completing repairs, exit the enclosure. From outside the enclosure, monitor the readout of the sensor that's inside the enclosure. If the sensor indicates a rising chlorine concentration that eventually goes above 10 ppm, activate full emergency procedures and ensure that everyone leaves the area immediately. Wait upwind of the building for help to arrive.

Make sure your assistant is diligently watching the exposure level on the monitor in order to alert you if levels begin to rise. If your personal monitor approaches 10 ppm while you're attempting to repair the leak, immediately leave the enclosure. Activate full emergency procedures and ensure that everyone evacuates the area. Wait upwind of the building for help to arrive.

A chlorine leak never gets better — it always gets worse.

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. The water and chlorine mixture will enlarge the release point by corroding the metal, allowing more chlorine to escape.

Preparing for emergencies

Related incident

Not following safety procedures led to chlorine gas exposure

Two workers replacing components on a chlorination system did not follow several of the required safety procedures. As a result, both were exposed to chlorine gas and required hospitalization.

The workers were exposed because they failed to isolate and purge the line. They were unprotected because they were not wearing their respirators. Compounding the risk, they had left the emergency-cylinder flow shutdown devices on the floor rather than attached to the cylinders. Had the devices been attached to the cylinders, the flow of chlorine would have shut down automatically. Instead, the workers remained in the enclosure to try to stop the leak themselves.

Preparing for emergencies includes planning for chlorine leaks and any exposure that may require evacuation and notification of local emergency response units, along with other emergency procedures. The preparation required for these types of emergencies is detailed below under "Written emergency procedures." This preparation should be included in a written emergency plan. For more information about the elements of this required emergency plan, see sections 5.97–5.102 of the Regulation. Preparing for emergencies also includes making appropriate emergency equipment available to workers and ensuring that they know how to use it.

Written emergency procedures

According to sections 6.116–6.132 of the Regulation, employers who use or store toxic process gases, including chlorine, must have written emergency procedures to provide workers with detailed directions in case of an emergency. However, simply having a detailed emergency plan doesn't provide sufficient protection unless workers know how to put it into practice. You must also conduct emergency drills to determine whether your procedures work in practice and to familiarize workers with their roles in an emergency. You must also keep records of these drills, which will help you review and monitor their efficiency, and make refinements and improvements to strengthen the process.

Written emergency procedures must include specific details about the following:

- Notifying workers about the emergency, including its location
- Controlling materials that may become dangerous during the emergency
- Locating and using emergency PPE
- Locating the chlorine-container emergency kit
- Repairing or capping leakage points
- Accessing and using emergency lighting
- Using an evacuation procedure and person-check system to ensure that all workers are evacuated
- Using the search and rescue process
- Bringing the emergency condition under control

- Verifying that hazardous conditions are no longer present and reoccupancy can take place
- Notifying police, fire department, hospital, and other emergency response units
- Notifying adjacent worksites and private homes of the emergency situation
- Notifying appropriate regulatory agencies as required (for example, WorkSafeBC, BC Ministry of the Environment and Climate Change Strategy, and Technical Safety BC)

The emergency plan must be reviewed annually in consultation with the joint health and safety committee or worker health and safety representative, as applicable.

As soon as the written emergency procedures have been developed, reviewed, and approved by the joint health and safety committee, the employer must do the following:

- Provide each worker with a copy of the plan and enough training to ensure that they clearly understand the procedures.
- Post the procedures and other relevant information, such as telephone numbers, in appropriate, conspicuous locations.
- Conduct regular tests of the procedures, including drills.
- Notify the fire department and other emergency response units of the nature, location, and safe handling of all hazardous materials that may endanger firefighters. Consider providing them with a copy of your emergency plan.
- Provide information about the nature of the hazard and a copy of your emergency procedures to all adjacent worksites and homes that could be affected by an emergency.

Besides these general emergency procedures, you must have specific procedures to cover the following:

- Response to an alarm signal
- Control of potential leaks
- Response to the dispersal of leaked chlorine inside the plant
- Response to the dispersal of chlorine dumped (vented) through the fire valve
- First aid response to an incident
- Incident investigation

For more information on emergency planning, see *CSA Standard Z731-03 (R2014) – Emergency Preparedness and Response.*

Emergency equipment

This section includes information on eyewash and shower facilities, first aid kits, and chlorine-container emergency kits to be used for temporary sealing or control of leaks.

Eyewash and shower facilities

Check *ANSI Standard Z358.1-2014* for information on the design of emergency washing facilities. Relevant information is summarized by the Canadian Centre for Occupational Health and Safety on their Emergency Showers and Eyewash Stations webpage (ccohs.ca/oshanswers/safety_haz/emer_showers.html).

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

When conducting a risk assessment, you must consider the following:

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

You must also meet the following requirements for eyewash and shower facilities:

- Ensure that the facilities have a supply of tempered water (15–30°C) for at least 15 minutes — not cold running water. Ensure that workers can't mistakenly turn on just the hot water.
- Determine the most appropriate location for emergency equipment. For example, it's inappropriate to install emergency equipment inside the chlorine room because a worker trying to use the equipment during a chlorine leak would risk further exposure. It's appropriate to locate emergency equipment in an easily accessible location near the chlorine room.
- Take into account the geographic location of the facility when deciding whether or not an outdoor location will be practicable during winter. If the emergency equipment is installed outside, it may need to be protected against freezing.
- Don't locate emergency equipment where members of 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 workers during each visit. In some instances, the first aid kit may need to be located in a worker's vehicle and carried by the worker to the chlorine location. To determine the first aid kit required for a particular worksite, see Part 3 of the Regulation.

Chlorine-container emergency kits

Ideally, a chlorine-container emergency kit for temporary sealing or control of leaks should be available on site. If this kit is not available, the emergency response team must be aware of the nearest readily available kit that's suitable for use with chlorine containers.

There are three types of container emergency kits (A, B, and C). Each has materials specific to the type and size of the chlorine container.

Table 4: Chlorine-container emergency kit requirements

Chlorine container	Type of kit required
68 kg (150 lb.) cylinders	"A" or emergency response containment vessel (ERCV)
907 kg (2,000 lb., or ton) containers	"B"
Railcars, tank cars, or barges	"C"

Chlorine-container emergency kits are designed to repair many types of leaks, but are not suitable in all cases. Repaired containers are not suitable for transportation. However, a damaged cylinder can be placed inside an emergency response containment vessel (ERCV) and transported. ERCVs are also known as cylinder coffins.

For more information about these kits, visit the Emergency Equipment page at the Chlorine Institute's website (chlorineinstitute.org/emergency-preparedness/chlorep/emergency-equipment).

Investigating incidents

Incident investigation is an important way to learn about the causes of hazardous incidents or injuries to prevent them from recurring. According to the ***Workers Compensation Act,*** employers must immediately notify WorkSafeBC of any major release of a toxic substance. A "major release" is described as follows:

> "A major release does not only mean a considerable quantity, or the peculiar nature of the release, such as a gas or volatile liquid, but, more importantly, the seriousness of the risk to the health of workers. Factors that determine the seriousness of the risk include the degree of preparedness of the employer to respond to the release, the necessity of working in close proximity to the release, the atmospheric conditions at the time of the release and the nature of the substance."

What is an incident?

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

As a general guideline, a report would be expected in the following cases:

- The incident resulted in an injury that required immediate medical attention beyond the level of service provided by a first aid attendant, or there were injuries to several workers that required first aid.
- The incident resulted in a situation of continuing danger to workers — for example, a chemical release couldn't be readily or quickly cleaned up.

Any time enough chlorine is released to set off the alarm, you must conduct an investigation to discover the causes of the incident. This investigation must also examine measures to prevent recurrence.

A preliminary incident investigation report must be completed within 48 hours of an incident and must be kept on file.

A full incident investigation report must be completed and forwarded to the joint health and safety committee. Within 30 days of the incident, a full incident investigation report must be submitted to WorkSafeBC. For more information on how to develop and submit these reports, go to worksafebc.com and search for "Employer Incident Investigation Report."

Chlorine releases must also be reported to Technical Safety BC and Emergency Management BC. For more information about the reporting requirements of these and other agencies, contact the agencies themselves. See "Other resources" on pages 48–50.

Preventing and controlling exposure

Engineering and administrative controls are the first line of defence against exposure to chlorine. Proper building design and ventilation are important engineering considerations. Effective monitoring and alarm systems are also essential to prevent chlorine exposure.

Personal protective equipment (PPE) is the last line of defence against exposure. However, when a chlorine leak has occurred or is likely to occur, PPE is vital for controlling exposure. In this case, PPE would include eye, skin, and respiratory protection.

To reduce the effect of a release, it's also imperative to have emergency response equipment, such as eyewash and shower facilities and first aid kits.

Elimination or substitution

Employers can choose to use alternative products, including products that don't contain chlorine. Employers can also choose to use chlorine in puck form (for pools) or in bleach form. Also, chlorine gas can be generated on demand.

With all these options, there are no stored quantities of chlorine gas. This eliminates or significantly reduces the risk of a chlorine gas leak, which reduces the risk of exposure for workers and the community. All these options have the added benefit of eliminating the hazards relating to the transportation of chlorine gas.

Note that an on-demand chlorine generation system must be located inside a chlorine enclosure. The system must be designed so that, in an emergency, chlorine generation can be stopped either by an alarm system or manually from outside the chlorine enclosure.

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

Be aware of 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, house chlorine containers in a room separate from the area where the chlorination equipment is located.

- Chlorine storage enclosures should be designed so chlorine containers and equipment are located at the lowest level. Avoid subsurface locations. 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 outward and be self-closing. They must be fitted with panic hardware (such as a crash bar for easy exit).
- 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.
- If heating is provided to prevent freezing, reduce humidity, or simply for comfort, chlorine containers and equipment must not be overheated.
- All piping carrying chlorine 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.
- Ensure that chlorine can be added to water within the enclosure, where practicable.
- Ensure that chlorine can be drawn into water under vacuum with a valve (often part of the chlorinator). Ensure that the valve is located as close as possible to the cylinder or container and that it's designed to allow chlorine flow if there is a vacuum draw.
- Where practicable, interlock or add sensors to prevent the cylinder or container valve from being in an open position unless water is flowing to create the vacuum. Unlike the previous bullet point, this measure is meant to prevent water from entering the cylinder if water flow is stopped.
- If auxiliary pumps are used to control the rate of chlorine added, ensure that they are designed to shut down if the main flow is stopped.

Related incident

Poorly positioned exhaust stack nearly results in a 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 a strong breeze prevented large quantities of chlorine from contaminating the shopping centre.

For more specific details, refer to the following:

- *Chlorine Basics* (available from the Chlorine Institute, website chlorineinstitute.org)
- Swimming Pool, Spray Pool and Wading Pool Regulations *(B.C. Health Act)*
- Pool Regulations *(B.C. Public Health Act)*
- British Columbia Building Code
- Municipal building bylaws
- Chlorine manufacturer or supplier

Ventilation

All ventilation fans must have switches outside the chlorine room or building, even when an inside switch is also installed. Fans, motors, and airflow must be monitored to ensure that workers are alerted to system malfunctions. Ventilation ducting must be vapour-proof, dedicated, and resistant to corrosion. The Swimming Pool, Spray Pool and Wading Pool Regulations under the *B.C. Health Act* require at least 30 air changes per hour in the chlorinator room for these types of pools.

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.

The grilles that provide make-up air from adjacent occupied areas must be equipped with gas-rated backdraft dampers.

Where practicable, the fan must be located on the outside of the building or structure to maintain the ductwork within occupied areas under a negative pressure differential.

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

Stack height must be sufficiently high above the roof to allow for proper dispersion. This is usually at least 3 m above the highest part of the roof.

Employers must provide emergency ventilation that can be used to ensure containment and control of an accidental release of chlorine. Workers must be able to safely activate this emergency ventilation in an emergency.

Related incident

Supersaturated chlorinated water discharged into pool when auxiliary pumps continued to function during maintenance shutdown

When a pool was shut down for maintenance, the main circulating pumps were shut down but auxiliary pumps providing flow to the gas chlorinators continued to function. This caused supersaturated chlorinated water to accumulate in the piping. When the main pumps were turned back on, the supersaturated chlorinated water was discharged into the pool, creating an exposure risk.

During leak emergencies, the emergency ventilation system must not be activated until it's been confirmed that it's safe to exhaust gas from the contaminated area. This means the emergency ventilation must not be activated if the discharge may expose anyone at the worksite, at adjacent worksites, or in any public or private areas where people may be present.

Automatic or remote shutdown device

An emergency shutdown device is required to stop the flow of gas and to isolate a reserve supply of chlorine, such as a cylinder, ton container, or railcar. When triggered, emergency shutdown devices will close the flow valve on cylinders, ton containers, and railcars. The system must be designed so the gas supply can be shut down manually from a remote location or automatically by the alarm system. That way, workers won't be put at risk when shutting down the system. If this isn't practicable, then other effective measures acceptable to WorkSafeBC must be implemented.

Ideally, emergency shutdown devices should be configured so they are activated in all of the following situations:

- Automatically by an alarm system
- Manually and remotely by a worker
- Automatically if water flow is stopped in a system drawing chlorine under a vacuum using water flow through a pipe narrowing

In addition, operators must be alerted whenever an emergency shutdown device is activated.

Administrative controls

Administrative controls include alarm systems and handheld chlorine detection systems (detector tubes). An effective alarm system includes a monitor that constantly tracks chlorine levels in the air and an alarm that goes off if chlorine concentrations reach a certain preset level.

Alarm systems

All facilities must have a working alarm that can be heard and seen by workers in case of a chlorine leak or emergency. A continuous (24-hour) chlorine monitor must be connected to the alarm system.

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

Before buying an alarm system, consider the following:

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

Some chlorine alarm systems will provide a direct readout of the chlorine concentration and can have more than one alarm level. The readout ensures that emergency response personnel know enough about the concentration of chlorine so they can make an informed decision about what PPE to use before entering the chlorine enclosure.

Basic alarm system requirements

The following requirements apply:

- The alarm 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.
- Monitors must be calibrated at least annually, as specified by the manufacturer. Monitors and alarms must be tested at least monthly (called "bump testing"), following the manufacturer's instructions.
- Monitors and alarms must also be tested and calibrated after any significant chlorine 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 preset alarm level should 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.
- The alarm system should activate the emergency-cylinder flow shutdown device.

Fixed monitors

Fixed monitors inform workers of the chlorine concentration inside the enclosure. Fixed monitors may not reflect conditions at the point of release, which may have a higher chlorine concentration.

Handheld and personal monitors

Handheld and personal monitors are important tools for workers responding to a leak or release. These monitors continually inform workers about the airborne concentration at their location. This enables workers to better follow the requirements for PPE under specific conditions. The monitors can also help identify the approximate location of a leak or release.

Personal protective equipment (PPE)

Controlling exposure requires strict attention to chlorine exposure limits. Appropriate eye, skin, and respiratory protection are essential. Your workers must be familiar with and understand the requirements of your written exposure control program and emergency plan, including the requirements relating to PPE.

Eye protection

When chlorine gas is in the air, safety glasses and face shields will not protect the eyes. Workers in an area with 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 from entering the eyes. At this concentration, respiratory protection is also necessary, so a respirator providing full-face protection is recommended. See Table 5 on page 42.

Skin protection

Emergency response workers who are controlling a serious chlorine leak must have access to full-body chemical protective suits as determined by your exposure control plan. Liquid elemental chlorine will cause eye and skin burns upon contact, similar to frostbite. Workers responding to a release of liquid elemental chlorine should have thermal protection.

Respiratory protection

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

Workers must wear respirators when working where there is a risk of toxic process gas being released directly into the breathing zone. A variety of respirators are available to protect workers from exposure to chlorine. Each type has specific limitations. Choosing the right respirator must be based on the needs of each individual worksite and the requirements of your written safe work procedures.

Full-facepiece air purifying respirator with cartridges or canister

To protect your eyes from the strong irritant effect of chlorine gas, WorkSafeBC recommends full-facepiece air purifying respirators instead of half-facepiece air purifying respirators for most situations where chlorine exposure could occur. Workers should use full-facepiece respirators in situations not immediately dangerous to life or health (IDLH). In IDLH situations, a self-contained breathing apparatus is required, as discussed below.

A full-facepiece respirator with cartridges.

Keep the following in mind:

- When workers are repairing a leak, they can wear cartridges or canisters only when the chlorine concentration is known. See Table 5 on page 42 for information on choosing the right respirator.
- 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 air purifying respirator with goggles

WorkSafeBC does not recommend the use of a half-facepiece air purifying respirator, even with vapour-tight chemical goggles.

This combination is permitted when working on a chlorine system where there's a chance of a small leak, but only when the chlorine concentration is below 5 ppm. However, we recommend the use of full-facepiece air purifying respirators or self-contained breathing apparatus, depending on the circumstances.

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 once the concentration reaches or exceeds 10 ppm. A worker wearing an SCBA must not enter a contaminated atmosphere until a second qualified person, also equipped with an SCBA and ready to perform a rescue, is present.

A self-contained breathing apparatus (SCBA)

The air in compressed breathing-air cylinders must be tested at least annually. Compressed breathing-air cylinders must be slowly depressurized to atmosphere and refilled at least annually.

Related incident

Poorly fitting respirator results in chlorine inhalation

A chlorine leak could not be controlled immediately. The operator, who had 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. He immediately experienced difficulties from chlorine inhalation. He was helped from the area and transported to hospital.

For more information, see “Tips for selecting respiratory protection” on pages 42–43.

Steel and aluminum cylinders must undergo a hydrostatic test every five years, and cylinders made of any other materials must be tested every three years, in accordance with *CSA Standard Z94.4-02 – Selection, Use and Care of Respirators.*

Escape respirators

Anyone entering a restricted-access area, such as a chlorine enclosure, for any reason must carry an escape respirator and keep it within arm’s reach at all times, unless they are wearing an SCBA or full-facepiece respirator with chlorine cartridges or a canister. Escape respirators may be used only for immediate evacuation of the contaminated atmosphere.

In addition to the respirators discussed above, bite-block respirators rated for chlorine may be used for escape purposes only. Bite-block respirators must be worn with nose plugs.

An escape respirator

Table 5: Choosing the right respirator

Situation	Chlorine concentration	Respirator choice
Routine work in chlorine room but not working on the chlorine system	—	• Escape respirator If a leak occurs, the concentration will be unknown. Exit room immediately.
Working on chlorine system, including changing cylinders	—	• Full-facepiece respirator with chlorine cartridges or canister • Half-facepiece respirator with vapour-tight chemical goggles (permitted but not recommended) If a leak occurs, the concentration will be unknown. Exit room immediately.
Leak occurs, enter to repair	Up to 5 ppm	• Full-facepiece respirator with chlorine cartridges or canister (recommended) • Half-facepiece respirator with vapour-tight chemical goggles (permitted but not recommended)
	Greater than 5 ppm to less than 10 ppm	• Full-facepiece respirator with chlorine cartridges or canister
	10 ppm and above	• SCBA
	Unknown; always assume to be IDLH level	• SCBA

Tips for selecting respiratory protection

These tips are based on guideline G8.33-1 of the Regulation.

Section 8.33(1) of the Regulation states the following:

> "The employer, in consultation with the worker and the occupational health and safety committee, if any, or the worker health and safety representative, if any, must select an appropriate respirator in accordance with *CSA Standard CAN/CSA-Z94.4-93, Selection, Use, and Care of Respirators*."

This CSA standard states that "knowledge of respiratory hazards and respiratory protection is essential to ensure appropriate selection of respirators. The respirator selection then becomes a step-by-step elimination of inappropriate respirators until only those which are appropriate remain." Section 6 of the CSA standard prescribes the procedure for selecting an appropriate respirator.

Employers should ensure that the following activities are part of the selection process:

- Identify specific contaminants and determine the airborne concentrations of them.
- Determine the physical, chemical, and toxicological properties of the contaminants. Will they be encountered as a gas or a vapour, a particulate, or a combination of any of these? What is the chemical reactivity and vapour pressure?
- Determine the general-use conditions for the respirator. Evaluate the job task (including the duration, frequency, and physical demands of the task), the health status of the worker, and the comfort of the respirator.
- Assess the potential for exposure via the skin and mucous membranes of the eye.
- Consider odour threshold information, as well as any warning properties of the contaminants. Warning properties can indicate to a worker wearing a respirator that it's not working effectively — for example, a breakthrough has occurred or the facepiece doesn't fit properly. Chlorine has a disagreeable, sharp, pungent, penetrating odour.
- Determine the exposure limits for the contaminants. See Table 2 on page 6 for chlorine exposure limits.
- Identify the IDLH concentration and the lower explosive limit (LEL). The IDLH for chlorine is 10 ppm. The LEL doesn't apply because chlorine is non-flammable according to its safety data sheet.
- Evaluate the potential for oxygen deficiency.
- Consider any service-life information available for the chemical cartridge or canister.
- Determine the hazard ratio (HR), which is the airborne concentration of a substance divided by its exposure limit.
- Determine the protection factor (PF) for the class of respirator using Table 8-1 of the Regulation. For a respirator to be appropriate, the PF must be greater than the HR. Refer to guideline G8.34-1 for more information on protection factors.

For further guidance, see the chart "Selecting the Right Respirator" in guideline G8.33-1 of the Regulation. The chart is based on clause 6 of *CSA Standard Z94.4-93* and NIOSH publication DHHS/NIOSH 87-108, ***NIOSH Respirator Decision Logic.***

Person-check system

The employer must establish a person-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 person-check system may require a radio or telephone. You must ensure that workers who need to use the system are trained in its written procedures. For more information, see “Checking on a worker working alone” on pages 14–15.

First aid

How to deal with unconscious patients

If you are not trained in first aid, do the following:

- As soon as the unconscious patient resumes breathing, place the patient in the drainage/recovery position (on the patient's side) so fluids can drain from the mouth and airways.
- Ensure that the patient is still breathing normally when on the side.
- Never give an unconscious patient anything by mouth.

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

1. Activate the workplace emergency response plan.
2. Ensure that there is no further danger to yourself or the injured worker.
3. Put on appropriate PPE, such as a respirator, gloves, and eye protection. If you are the backup worker, you should already be prepared with your PPE.
4. Using appropriate safety gear, remove the worker from the contaminated area.
5. Don't attempt to provide first aid in a contaminated area.
6. Call 911 (BC Emergency Health Services), if they have not already been contacted. Update them if there are any changes.
7. Call the BC Drug and Poison Information Centre at 1.800.567.8911.

Chlorine inhalation

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

1. Assess the worker's breathing:
   - If the worker has stopped breathing or doesn't appear to be breathing normally, assume that cardiac arrest has occurred and begin cardiopulmonary resuscitation (CPR).
   - Continue CPR until the worker regains consciousness or resumes breathing normally. Pocket masks with a one-way check valve are recommended for CPR, although you can use the chest compression–only method if you're not trained in CPR or don't have a pocket mask.
   - If the worker is conscious and having difficulty breathing (for example, gasping or coughing), move the worker to fresh air. Place the worker 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 rate. Depending on the severity of the exposure, it may also be advisable to ensure that the worker is transported to hospital for examination.
3. If the worker suffers a delayed reaction in the form of pulmonary edema (fluid accumulation in the lungs), ensure transport to hospital without delay. Any physical exertion, excitement, or apprehension increases the chance and severity of a delayed reaction. Keep the injured worker warm and completely at rest. Provide reassurance while waiting for help and transport to hospital.

Skin contact with chlorine

Chlorine comes in various forms — as either a pure gas in air, a solid or powder such as calcium or sodium hypochlorite, or a compressed gas in liquid form. When chlorine combines with moisture on skin, in the eyes, or in the respiratory tract, it forms hydrochloric acid. Skin contact with chlorine can result in severe burns.

Direct contact with hypochlorite solutions, powder, or concentrated vapour causes severe chemical burns, leading to cell death and ulceration. Besides the corrosive effects of all forms of chlorine on skin, contact with liquid chlorine gas can result in localized freezing because of the low temperatures used to store liquid chlorine gas.

Before trying to help an injured worker, make sure it's safe to help without being exposed to hazardous concentrations of chlorine. The chlorine may be in the environment or residual (i.e., on the worker). Wear PPE as necessary to protect yourself.

Follow these steps when treating skin contact with chlorine:

1. Assess the worker's breathing:
    - If the worker is unconscious and has stopped breathing or doesn't appear to be breathing normally, assume that cardiac arrest has occurred and begin CPR.
    - Continue CPR until the worker regains consciousness or resumes breathing normally. Pocket masks with a one-way check valve are recommended for CPR, although you can use the chest compression–only method if you're not trained in CPR or don't have a pocket mask.
    - If the worker is conscious and having difficulty breathing (for example, gasping or coughing), move the worker to fresh air. Place the worker in the most comfortable position, usually semi-sitting.

2. As soon as you have confirmed that the injured worker is breathing normally, flush the worker's contaminated skin and clothing with large amounts of gently flowing lukewarm water for up to 30 minutes. Be careful of the worker's airway when flushing.
3. Remove all contaminated clothing while flushing. If clothing is stuck to the skin, carefully cut around it and remove the rest of the garment.
4. Continue flushing until all obvious traces of chlorine have been removed.
5. Dress obvious burns with sterile gauze, and bandage them loosely. Don't allow the worker to smoke or drink alcohol.
6. Arrange transport to hospital.

Notes

- Don't attempt to neutralize chlorine with other chemicals.
- Don't apply salves, ointments, or medications unless prescribed by a doctor.
- Keep in mind that skin contact with liquid chlorine coming straight out of a cylinder can result in frostbite.

Eye contact with chlorine

Eye contact with chlorine liquid or gas for even a short time can cause permanent disability. Begin flushing as soon as possible. Follow these steps:

1. Flush the eyes immediately with large amounts of running water (preferably lukewarm) for 30 minutes. Hold the eyelids open 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 bandages, enough to keep light out.
3. Arrange to transport worker to hospital for examination.

Notes

- Don't attempt to neutralize chlorine with other chemicals.
- Don't apply oils, ointments, or medications to the worker's eyes.

Other resources

Manufacturers and suppliers

In addition to the information in this manual, you can get specific information from manufacturers and suppliers of chlorine and chlorine equipment.

WorkSafeBC

WorkSafeBC provides a number of services and materials that will help you meet your health and safety requirements:

- Go to worksafebc.com/forms-resources for forms, publications, videos, and other resources, such as the *Breathe Safer* manual.
- Go to worksafebc.com/law-policy for a searchable version of the Regulation and its accompanying guidelines and policies.

Safe handling of chlorine — Key health and safety program elements in the Regulation

Element	Regulation sections
Occupational health and safety program	3.1–3.3
First aid requirements	3.14–3.21
Emergency preparedness and response	4.13–4.18
Equipment preventive maintenance and critical parts inspections	4.3, 4.9, and 6.132
WHMIS program	5.3–5.19
Exposure control plan	5.54
Emergency washing facilities	5.85–5.96
Emergency procedures	5.97–5.102 and 6.120
Toxic process gases and emergency ventilation	6.116–6.132 and 6.125
Personal protective clothing and equipment and PPE program	6.127 and 8.5
Eye and face protection	8.14–8.18
Body protection	8.19
Appropriate footwear	8.22
Respirators	8.32–8.45

The Chlorine Institute

The Chlorine Institute (chlorineinstitute.org) publishes *Chlorine Basics* (formerly the *Chlorine Manual*). They also offer the following resources:

- *Piping Systems for Dry Chlorine* (pamphlet 6)
- *Emergency Shut-Off Systems for Bulk Transfer of Chlorine* (pamphlet 57)
- *First Aid, Medical Management/Medical Evaluation and Occupational Hygiene Monitoring Practices for Chlorine* (pamphlet 63)
- *Emergency Response Plans Chlor-Alkali, Sodium Hypochlorite, and Hydrogen Chloride Facilities* (pamphlet 64)
- *Personal Protective Equipment for Chlor-Alkali Chemicals* (pamphlet 65)
- *Atmospheric Monitoring Equipment for Chlorine* (pamphlet 73)
- *Water and Wastewater Operators Chlorine Handbook* (pamphlet 155)
- *Reactivity and Compatibility of Chlorine and Sodium Hydroxide with Various Materials* (pamphlet 164)

For more information on chlorine-container emergency kits, check out their Emergency Preparedness webpage (chlorineinstitute.org/emergency-preparedness/chlorep/emergency-equipment).

Standards

- *CSA Standard Z94.4-02 – Selection, Use, and Care of Respirators.*
- *ANSI Standard Z358-2014* provides information on the design of emergency washing facilities. Relevant information is summarized by the Canadian Centre for Occupational Health and Safety on their Emergency Showers and Eyewash Stations webpage (ccohs.ca/oshanswers/safety_haz/emer_showers.html).

Other regulatory agencies

Chlorine releases must be reported to WorkSafeBC and other regulatory agencies, including the following:

- Technical Safety BC
- BC Ministry of Environment and Climate Change Strategy
- Environment and Climate Change Canada (ECCC)

You must ensure that a qualified and certified person performs proper, ongoing maintenance of the chlorine system under the Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation, which is enforced by Technical Safety BC.

Technical Safety BC

Tel: 1.866.566.7233

Web: technicalsafetybc.ca

BC Ministry of Environment and Climate Change Strategy

Tel: 1.800.663.3456

Web: www2.gov.bc.ca/gov/content/environment/air-land-water/spills-environmental-emergencies/report-a-spill

Environment and Climate Change Canada (ECCC)

Tel: 1.800.663.3456

Web: canada.ca/en/environment-climate-change/services/environmental-emergencies-program/regulations/reporting-spill-release.html

If the amount of chlorine gas on site ever exceeds 1.13 metric tonnes, your workplace must be registered with ECCC in addition to any other requirements by WorkSafeBC, Technical Safety BC, or other regulatory agencies. Your obligations to ECCC include reporting to them any releases, disposals, and transfers for recycling of chlorine gas. For more information, see ec.gc.ca.

Chlorine enclosures

For more information on enclosures, see the following:

- *Chlorine Basics* (The Chlorine Institute, chlorineinstitute.org)
- Swimming Pool, Spray Pool and Wading Pool Regulations *(B.C. Health Act)*
- Pool Regulation *(B.C. Public Health Act)*
- British Columbia Building Code
- Municipal building bylaws

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