Chloramines

Safe work practices

WorkSafeBC

About WorkSafeBC

WorkSafeBC (the Workers' Compensation Board) is an independent provincial statutory agency governed by a Board of Directors. We are 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, we are accountable to the public through government in our 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. We are 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 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 Canada.

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Safe Work Practices

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WorkSafeBC publications

Many publications are available on the WorkSafeBC website. 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 worksafebc.com.

Some publications are also available for purchase in print:

Phone:	604.232.9704
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Online ordering:	worksafebc.com and click on Publications; follow the links for ordering

ISBN 978-0-7726-6808-0

Acknowledgments

WorkSafeBC thanks the many organizations and individuals who generously donated their time and knowledge to reviewing this edition of *Chloramines: Safe Work Practices*, including the City of Vancouver and the BC Municipal Safety Association.

This book is dedicated to Ian Salomon, the driving force behind this project. Ian's commitment to excellence in occupational health and safety over the years has helped many employers maintain safe worksites and many workers stay safe on the job.

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Introduction

Swimming pools, water parks, hot tubs, and spas are popular places for playing, exercising, and relaxing. Due to British Columbia's varied climate and people's desire to swim or soak year-round, many of these facilities are located indoors. Various disinfectants, including chlorine, are used to kill pathogens (viruses, bacteria, parasites, etc.) in the water. Chlorine interacts with material from bathers (sweat, urine, sunscreen, cosmetics, etc.) to form chemical by-products such as chloramines.

Chloramines have been associated with upper respiratory and eye irritation. They may also lead to longer-term heath issues such as asthma. In order to reduce their workers' exposure to these chemicals, employers need to monitor and maintain water quality at these facilities. Employers should also remind people who use the pool to shower before entering the water and to use the proper washroom facilities.

Who should read this manual

This manual is mainly for the following groups:

- Recreational facility owners and managers who use chlorine or chloramines for water treatment
- Maintenance personnel, lifeguards, and others who work in these facilities
- Consultants who provide occupational health and safety services

Consultants and employers will find information in this manual to help them comply with the Occupational Health and Safety Regulation and ensure a safe environment for workers and others who may be exposed to chloramines. Workers will find information to help them recognize the health effects of exposure to chloramines and know how to protect themselves.

Use this manual as a starting point

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 employers and workers to work safely. When used in this manual, the word "must" 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, is recognized as an industry standard by occupational hygiene and/or safety professionals and will improve safety in the workplace. Please note also that the word "worker" includes supervisors, managers, and workers.

WorkSafeBC has produced a number of related safe practices manuals, such as *PoolSafeBC: Best Practices Guide*. For copies, visit worksafebc.com.

Industry terms

8-hour TWA limit
The time-weighted average (TWA) concentration of a substance in air which may not be exceeded over a normal 8-hour work period.

Engineering controls
The physical arrangement, design, or alteration of workstations, equipment, materials, production facilities, or other aspects of the physical work environment, for the purpose of controlling risk.

Hazard
A thing or condition that may expose a person to a risk of injury or occupational disease.

Incident
An accident or other occurrence which resulted in, or had the potential to cause, an injury or occupational disease.

Practicable
Defined in the Regulation as "that which is reasonably capable of being done."

Qualified person
A person who is knowledgeable of the work, the hazards involved, and the means to control the hazards, by reason of education, training, experience, or a combination thereof.

Risk
A chance of injury or occupational disease.

Risk assessment
A comprehensive document, developed to select appropriate workplace controls, which evaluates the probability and degree of possible illness, injury, or death in a hazardous situation.

Sensitizer
A substance that has been shown to elicit an allergenic type of response in a person after an initial exposure, resulting in the person developing symptoms upon subsequent exposure at much lower concentrations.

Workers
Includes supervisors, managers, and workers.

Part 1 – About chloramines

What are chloramines?

Chloramines are chemical by-products formed when chlorine or hypochlorite (used for disinfecting water sources) and a source of nitrogen (such as ammonia, urine, and sweat) react in water.

There are three distinct chloramine compounds:

- Monochloramine – NH_2Cl
- Dichloramine – $NHCl_2$
- Trichloramine (nitrogen trichloride) – NCl_3

All three chloramine compounds are relatively stable in water, which is why they're used as disinfectants. Monochloramine and dichloramine do not readily vaporize. People can be exposed to these compounds if they inhale airborne droplets or mist formed by spray equipment and splashing. By contrast, trichloramine does evaporate from water and can be inhaled as a vapour by anyone in the facility.

Chloramines may have a distinct odour. Trichloramine is largely responsible for the typical "chlorine" smell in the air in swimming pools and other recreational facilities. Monochloramine is effectively odourless and not as much of an irritant as dichloramine and trichloramine.

If the pool water has a yellow-green colour, the concentration of chloramines in the water may be above 5 milligrams per litre (mg/L). This concentration would cause eye irritation in swimmers.

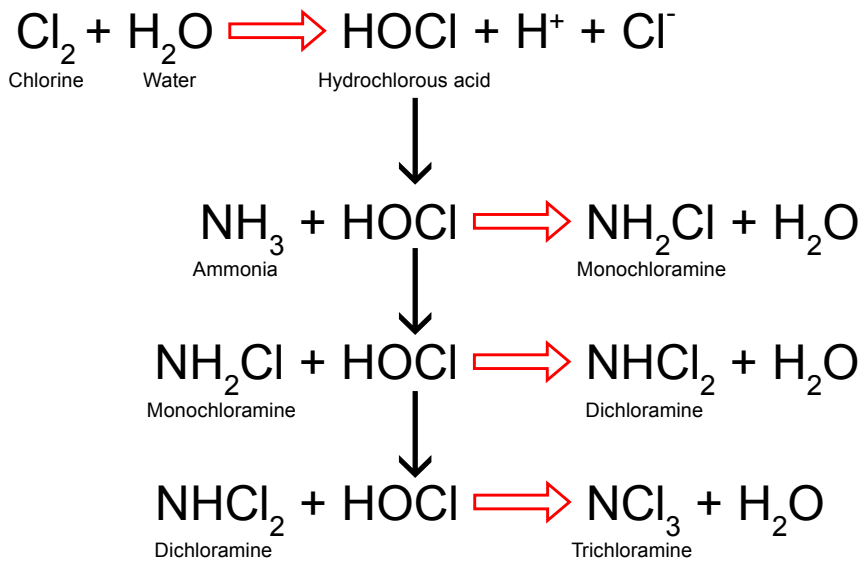
Uses of chloramines

Chloramines are effective disinfectants and have been used in potable water systems in North America since 1900. Monochloramine is the most effective of the three major chloramine types and has been used to disinfect some municipal water supplies. Chloramines are also occasionally used as anti-fouling agents in cooling towers.

When used for disinfection of municipal water supplies, chlorine (either as gas or hypochlorite solution) is introduced first. A short distance downstream, concentrated ammonia is added to the water and reacts with the chlorine. The chloramines form in the water and remain in solution for longer than chlorine. This is because chloramines react more slowly with organic materials and disease-causing organisms. When chloramines (rather than chlorine) are used for disinfection, the formation of some hazardous by-products is greatly reduced. Trihalomethanes, for example, may be reduced by up to 80 percent.

Formation of chloramines

The reaction of the chlorine and the ammonia-containing compounds from human sweat and urine is the primary route by which chloramines are formed, as shown below.



Chemical formation of chloramines

Monochloramine is preferentially formed in mildly alkaline conditions (pH 7.0 to 8.5), such as the water in a swimming pool.

Dichloramine and trichloramine are of particular concern with regard to potential health issues. These chloramine compounds form as the pH becomes more acidic. Depending on the pH of the water and the relative amounts of free chlorine and ammonia, most of the monochloramine present could convert to dichloramine and then trichloramine.

While trichloramine is preferentially formed below pH 4.0, the continual presence of free chlorine (or hypochlorous acid) in the water drives the equilibrium of the reactions to form trichloramine.

Health hazards of chloramines

Acute effects

Chloramines are irritants. Swimmers have complained of eye irritation when chloramine concentrations in the water exceeded 1 mg/L. Respiratory tract irritation has been reported in several studies and becomes obvious at about 0.5 parts per million (ppm) in air.

There are a number of reports of ill effects in groups of swimmers and bathers. In each case, eye irritation occurred within a couple of minutes, followed by respiratory tract irritation within an hour. Many of these people required medical attention. Other people who entered the pool area also reported health effects.

Respiratory health effects are even more pronounced for competitive swimmers because they're exposed to higher concentrations of airborne chloramines (whether vapour or mist). These individuals are breathing at the water's surface at a much greater rate and more deeply than regular swimmers or bathers.

Respiratory and eye symptoms among employees of a hotel indoor water park

From January to March of 2007, 665 complaints of respiratory and eye irritation were received from patrons and workers at a hotel indoor water park. Lifeguards reported the most work-related symptoms, including coughing, wheezing, shortness of breath, chest tightness, and eye irritation. Measured airborne trichloramine concentrations exceeded 1 mg/m^3. (Significant health complaints are typically reported when concentrations exceed 0.5 mg/m^3.)

An examination of the pool's ventilation system identified that the system may not have provided sufficient air movement and distribution to adequately capture air contaminants at the pool surface and deck. Following extensive modifications to the ventilation system, the complaints ceased.

Chronic effects

There is some evidence that exposure to chloramines, particularly trichloramine, may cause occupational asthma. Research has also shown that exposure to trichloramine can significantly decrease lung function. There are no reports that chloramines cause cancer, reproductive or developmental effects, or genetic damage.

Chloramine exposure leads to long-term health effects in pool workers

Three pool workers with 10 or more years of experience as lifeguards or swim instructors reported coughing, wheezing, chest tightness, and breathlessness. The symptoms were worse when they came to work. The workers all showed symptoms of asthma when exposed to trichloramine under controlled conditions in a clinic.

Regulation requirements

Several sections of the Occupational Health and Safety Regulation and their corresponding OHS Guidelines may relate to chloramine exposure. The key requirements are found in the sections listed below.

Section 2.2, General duty

Despite the absence of a specific requirement, all work must be carried out without undue risk of injury or occupational disease to any person.

Sections 4.70 to 4.80, Indoor air quality

These sections describe general requirements for the operation, maintenance, and monitoring of ventilation systems that supply and distribute air and remove indoor air contaminants, and include:

- Submission of ventilation system plans
- Design and operation of a ventilation system
- Distribution of outdoor air
- System balancing
- Location of discharged air outlets
- Preventive maintenance
- Investigation of occupant complaints and sampling for airborne contaminants
- Temperature and humidity levels

Section 5.2, General information requirement

If a worker is or may be exposed to a chemical agent that could cause an adverse health effect, the employer must ensure that:

- The chemical is identified, and its effects on worker health are clearly indicated by labels, material safety data sheets, or similar means.
- Information is clearly communicated to the worker.
- Written procedures are prepared to eliminate or minimize the risk of exposure, including procedures for emergencies and spill cleanup.
- Supervisors and workers are trained in the safe handling, use, storage, and disposal of the chemical.

Sections 5.48 to 5.59, Controlling exposure

These sections describe general requirements for controlling exposure to various hazardous materials in the workplace. The requirements include the following:

- Exposure limits
- Workplace monitoring to assess exposure levels
- Monitoring methods acceptable to WorkSafeBC
- Exposure control plans
- Types of risk controls
- Designated hazardous substances
- Investigating symptoms of overexposure

Guideline G5.53-4, Occupational hygiene methods acceptable to WorkSafeBC

The purpose of this guideline is to provide information on the publications that detail occupational hygiene methods (such as sampling and analytical methods) acceptable to WorkSafeBC.

WorkSafeBC accepts methods detailed in standard occupational hygiene references published by the National Institute for Occupational Safety and Health (NIOSH), the American Industrial Hygiene Association (AIHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and the U.S. Environmental Protection Agency (EPA).

Before using occupational hygiene methods that are not discussed in references published by the organizations listed above, the employer must obtain approval from the Regulatory Practices Department of WorkSafeBC.

Exposures and exposure limits

Exposure to chloramines in a green salad processing plant

Workers in the washing room of an industrial facility that processes green salads complained of acute eye and upper respiratory irritation. Airborne chloramine levels in the washing room ranged from 0.4 mg/m^3 to 16 mg/m^3. The chloramines were released when sap proteins from cut vegetables reacted with hypochlorite (bleach) in the wash water.

Several jurisdictions, including Canadian provinces, have established limits for the concentration of chloramines (as combined chlorine) in water. In British Columbia, the limit is 3 mg/L. There are no occupational exposure limits for chloramines in air in any jurisdiction.

Numerous studies have measured chloramines (as trichloramine) in the air of indoor swimming pools and water parks, with results ranging from 0.05 mg/m^3 to 2 mg/m^3. Proposed guideline and occupational exposure limits currently range from 0.1 mg/m^3 to 0.5 mg/m^3. However, the proposed 0.5 mg/m^3 limit may be too high, as irritant health effects occur at much lower airborne concentrations. A European country may be the first to adopt a legal exposure limit for chloramines in air. The value proposed is a 0.35 mg/m^3 8-hour time-weighted average.

Based on research that has been conducted to date, WorkSafeBC recommends that the airborne concentration of chloramines in indoor water recreation facilities be kept below 0.35 mg/m^3.

If there is no exposure limit for a substance, employers are encouraged to reduce exposures to below the recommended guidelines.

Part 2 – Programs and documentation

Health and safety program

Under the Occupational Health and Safety Regulation, employers must develop and implement an effective health and safety program for their workplace. Employers must also train workers and supervisors in relevant sections of the program.

A health and safety program helps ensure a safe, productive workplace by describing specific tasks and responsibilities for the different aspects of an employer's operation. An effective health and safety program for any workplace 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 owner, employer, supervisors, and workers
- Written safe work procedures and emergency response procedures
- Training for supervisors and workers
- Regular worksite inspections (the definition of "regular" depends on the conditions and number of shifts for each individual site)
- Regular health and safety meetings
- Accident investigation
- Records and statistics
- A joint health and safety committee or representative, if required

Remember that every worksite is different. Although these general elements may be the same in health and safety programs across the province, employers can't expect to copy a program from another worksite. Instead, they must develop and implement a health and safety program unique to their own operation.

Responsibilities

Everyone in the workplace, including owners, employers, supervisors, and workers, has health and safety responsibilities. The responsibilities listed below generally apply to all workplaces in British Columbia.

Owners

Owners have the following responsibilities:

- Provide and maintain the land and premises that are being used as a workplace to ensure the health and safety of anyone at or near the workplace.
- Provide the employer or contractors at the workplace with the information they need to identify any hazards.
- Comply with the relevant sections of the Occupational Health and Safety Regulation and the *Workers Compensation Act* (the Act), as well as any applicable orders.

Employers

Employers have the following responsibilities:

- Ensure the health and safety of all workers at the worksite.
- Identify workplace hazards and assess the risks of injury associated with those hazards.
- Conduct risk assessments for hazardous materials.
- Develop an exposure control plan and written safe work procedures.
- Implement controls as required by the exposure control plan.
- Ensure that workers and supervisors are adequately instructed and trained.
- Keep written records of training (detailing who, what, and when).
- Establish and maintain an occupational health and safety program, including a written health and safety policy and a procedure for incident investigations.
- Support supervisors, safety coordinators, and workers in their health and safety activities.
- Take action immediately when a worker or supervisor reports a potentially hazardous situation.
- Investigate incidents as soon as possible after they occur.
- Report exposure incidents to WorkSafeBC.

- Provide adequate first aid facilities and services.
- Provide and maintain personal protective equipment, clothing, and devices as required.
- Ensure that workers follow the requirements of the Regulation and the Act, and that they have access to these documents.

Supervisors

Supervisors have the following responsibilities:

- Instruct your workers in safe work procedures.
- Ensure that your workers are familiar with and follow any exposure control plans that might be required.
- Train your workers for all tasks assigned to them, and regularly check that they are doing their work safely.
- Ensure that only authorized, adequately trained workers operate tools and equipment or use hazardous chemicals.
- Ensure that your workers follow safe work procedures for handling, storing, and maintaining equipment and materials.
- Enforce health and safety requirements.
- Correct unsafe acts and conditions immediately.
- Identify workers with problems that could affect safety at the worksite, and follow up with interviews and referrals where necessary.
- Create health and safety rules, and inspect the workplace regularly for hazards.

Workers

Workers have the following responsibilities:

- Know and follow health and safety requirements that apply to your job.
- If you don't know how to do something safely, ask your supervisor for training before you begin work.
- Participate in all required health and safety education and training.
- Work safely, and encourage your co-workers to do the same.
- Use all required personal protective equipment and clothing.
- Correct any unsafe conditions or immediately report them to your supervisor.
- Immediately report any injury to a first aid attendant or supervisor.
- Inform your supervisor of any physical or mental impairments that may affect your ability to work safely.
- Make suggestions to improve health and safety.

Exposure control plan

What is an exposure control plan?

An exposure control plan explains the work procedures and controls that will be used to reduce workers' risk of exposure to a chemical or biological agent. The plan must detail steps to eliminate risk, or to control and reduce risk by:

(1) Substituting with safer materials, where feasible
(2) Using engineering controls
(3) Using administrative controls
(4) Using personal protective equipment (PPE)

PPE must not be used as the only means of controlling exposure unless other controls are not practicable.

Who needs an exposure control plan for chloramines?

An exposure control plan may be required for:

- Municipal workers who monitor potable water quality
- Swimming pool and water park maintenance staff
- Spa workers and maintenance staff
- Lifeguards
- Food (vegetable) processing workers
- Workers who monitor cooling tower disinfection systems
- Sewage plant workers (where chloramination is used for disinfection)

The appendix in this document includes a sample exposure control plan for chloramines.

Elements of an exposure control plan

Each workplace is unique, so an exposure control plan must be specific to your workplace or operation. Only a qualified person should develop exposure control plans.

The exposure control plan must include the sections described on the next three pages.

Statement of purpose

The purpose of an exposure control plan is to prevent harmful exposure of workers to chemicals and other potentially harmful substances in the workplace. The following is an example of a typical statement of purpose:

> Our company is committed to providing a safe and healthy workplace for all of our staff. A combination of measures will be used to achieve this objective, including the most effective control technologies available. Our work procedures will protect not only our workers but also any other workers who enter our workplace. All employees must follow the procedures described in this plan to prevent or reduce exposure to chloramines.

Responsibilities of employers, supervisors, and workers

Employers must do the following:

- Ensure that the resources required to implement and maintain the exposure control plan (such as safe work procedures, worker training, and PPE) are readily available.
- Select, implement, and document the appropriate site-specific control measures.
- Ensure that supervisors and workers are educated and trained to an acceptable level of competency.
- Conduct a periodic review of the plan's effectiveness, including a review of the available control technologies to ensure that these are selected and used when practicable.
- Maintain records of training and inspections.
- Ensure that a copy of the exposure control plan is available to workers.

Supervisors must do the following:

- Ensure that workers are adequately instructed in the workplace controls.
- Direct work in a manner that eliminates or minimizes the risk to workers.

Workers must do the following:

- Know the hazards of the workplace.
- Follow established safe work procedures as directed by the employer or supervisor.
- Report any unsafe conditions or acts to the supervisor.
- Know how and when to report exposure incidents.

In the Regulation

For more information about the requirements for exposure control plans, see Section 5.54 of the Occupational Health and Safety Regulation.

Risk identification and assessment

A risk assessment must be conducted by a qualified person and take into account the health hazards involved (for example, from exposure to chloramines).

Risk controls

Some types of controls are more effective than others, but it may not always be practicable to use the more effective solution. Whenever possible, however, controls must be implemented in the following order of preference:

(1) Substitute less-hazardous materials or processes (may not be practicable in all situations).
(2) Use engineering controls, such as enclosures and exhaust ventilation.
(3) Use administrative controls, such as signage and proper use of washing facilities.
(4) Use personal protective equipment (PPE). PPE may not be practicable in all situations and is usually a "last resort" for worker protection. The proper use, fit, and disposal of PPE must also be considered.

Controls for chloramine exposure will likely include both engineering controls and administrative controls.

Written safe work procedures

Written safe work procedures describe how to carry out specific tasks safely and efficiently. In general, safe work procedures are written for the following:

- Hazardous tasks
- Complicated tasks, so that important steps are not missed
- Frequently performed tasks
- Less-routine tasks, to remind workers of the hazards and how to control the risks

It may be difficult to write safe work procedures to reduce chloramine exposure. The challenge employers face is that the concentration of chloramines in the air is determined mainly by how patrons behave (failing to shower, urinating in the pool, etc.). If the odour of chloramines is strong, administrative procedures can be put in place to limit the time any worker spends in the pool area.

Worker education and training

Employers must ensure that their workers are informed about the contents of the exposure control plan. Employers must also educate workers about the hazards of exposure to chloramines and train them to work safely. Exposure control plans should describe worker education and training, and how they will be carried out. Education and training are particularly important for new and young workers.

Written records

The exposure control plan must be written down, and records must be kept for each component of the plan. For example, document education and training activities – keep track of who was trained, when the training took place, and what it included. Other documentation must include the following:

- Workplace inspections
- Health and safety meetings
- Accident investigations
- Results of water testing and sampling for airborne contaminants

Hygiene facilities

Employers must provide good housekeeping procedures, washing facilities, and clean eating and drinking areas.

Health monitoring

Regular medical monitoring of workers may be required. A WorkSafeBC officer may request that such monitoring be carried out depending on what the workers are exposed to and the duration of the exposure. Many tests (for example, lung function tests) can be conducted by family physicians.

Exposure control plan review

Review the exposure control plan at least once a year, and update it as necessary. During this process, consult with the joint health and safety committee (or the worker health and safety representative, if applicable).

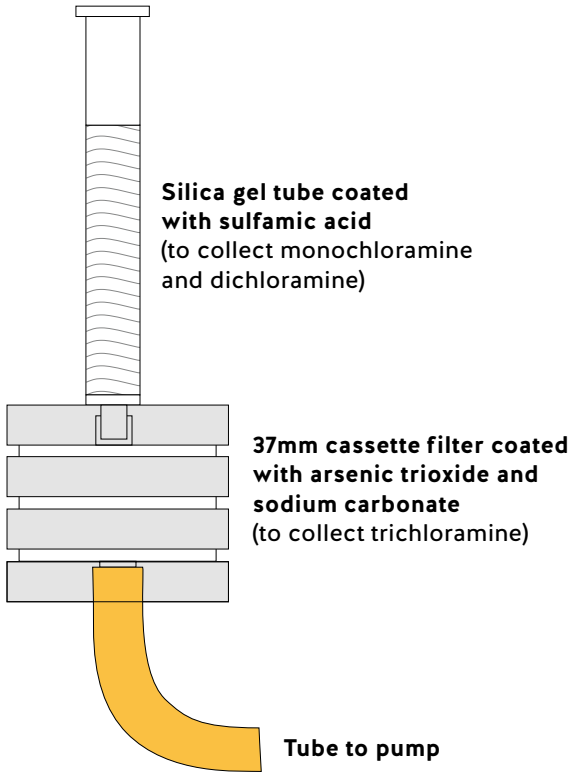
A sample exposure control plan for chloramines for workers in recreational facilities, such as water parks, is included in the appendix.

Testing for chloramines in air

If pool patrons or staff complain of upper respiratory irritation, eye irritation, or difficulty breathing after being in pool or spa areas, conduct sampling for airborne chloramines. Air samples should only be collected by qualified occupational hygiene professionals in accordance with methods acceptable to WorkSafeBC.

Samples can be collected using a sampler composed of a silica gel tube and a 37 mm sampling cassette (see below). The silica gel must be treated with sulfamic acid, and the cassette must be equipped with a polytetrafluoroethylene (PTFE or Teflon) filter coated with arsenic trioxide and sodium carbonate. A qualified laboratory can supply pre-treated gel tubes and cassettes.

Immediately before and after each air sample is collected in the field, each sampling pump must be calibrated with the cassette and gel tube attached. Pumps must be calibrated against a primary standard to a flow rate of about one litre per minute (L/min). Sampling should be conducted for a minimum of four hours. Pumps should be fully charged before use.



Apparatus for chloramine sampling

Training, instruction, and supervision

Employers must ensure that their workers:

- Are provided with information about chemicals the workers may be exposed to in the workplace. This information would include chemical information sheets for chloramines, as these chemicals are formed in pool water.
- Are educated about the hazards and trained in the safe handling, proper use, and disposal of any chemicals used in the workplace.
- Are informed of the health hazards associated with exposure to chloramines and other chemicals used in the workplace.
- Can demonstrate competency in doing their work according to the safe work procedures.

Employers must document education and training and ensure effective supervision of their workers at all worksites.

First aid services

Workers must have immediate access to appropriate first aid services. This may include an occupational first aid attendant and a first aid kit. To determine the appropriate first aid equipment and services required for a particular worksite, see Part 3 of the Occupational Health and Safety Regulation and the related OHS Guidelines at worksafebc.com. (Click on OHS Regulation, and then go to Part 3 and the respective Guidelines).

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."

Investigating incidents is important for preventing repeat accidents. As far as possible, the investigation must do the following:

- Determine the cause of the incident.
- Identify any unsafe conditions, acts, or procedures that contributed to the incident.
- Recommend corrective action to prevent similar incidents.

Should a worker report ill effects from exposure to the air in a swimming pool or other water recreational facility, section 5.59 of the Occupational Health and Safety Regulation requires the employer to investigate the circumstances. This would include when a worker receives professional medical attention or at least three workers receive first aid as the result of an exposure incident.

The investigation must also examine measures that will prevent similar incidents in the future.

Employers must forward copies of the investigation report to their occupational health and safety committee and to WorkSafeBC.

Part 3 – Controlling chloramines in swimming pools and water parks

How to minimize exposure to chloramines in existing facilities

Chloramines are formed when chlorine in the water binds with a source of nitrogen. Some nitrogen sources include body lotions, sweat, and urine. Other sources include chemicals such as ammonia-based cleaning products used on a pool deck. The most likely source of nitrogen contamination is from urination into a pool or hot tub.

A number of relatively simple steps can be taken to reduce the production of chloramines in recreational facilities such as swimming pools and water parks.

Conduct a shower education campaign

Patrons should shower before entering pools, hot tubs, or other water recreational facilities. This removes sweat and other sources of nitrogen from the body, which reduces the nitrogen load that the chlorination system has to handle.

When patrons enter and sign in to a facility, staff should remind them to shower before they enter the water. Signs posted in the change rooms, pool areas, and near hot tubs can also act as reminders. Staff should also remind patrons to use proper washroom facilities.

Control the use of ammonia-based cleaning products

Areas of visible residue buildup (for example, scum around a pool basin perimeter) are cleaned frequently. At some facilities, cleaning happens daily. Facilities with fewer patrons may not have to clean as often.

Ammonia-based cleaning products contain nitrogen. If these products get into the water, they can accelerate the production of chloramines. All cleaning around pools, hot tubs, and other services should be done using products that will not negatively affect the water chemistry. Before using a cleaning product, check the label or safety data sheet to make sure it doesn't contain ammonia.

Monitor water chemistry

Supply water

Check supply water (potable water that is supplied from the city or municipal water system) to determine how much chlorine it contains. The level of chlorine in potable water depends on how far the water recreational facility is from the nearest chlorine injection station. Modern stations have improved filtration, which means the chlorine injected into the water is not consumed too quickly. The expected supply water chlorine concentration should be around 0.5 parts per million (ppm).

Recreational facility operators should be aware that water quality will change throughout the year, so chlorine concentration should be monitored frequently. Too much or too little chlorine can affect water chemistry and the production of chloramines. In addition, many commercial pools may draw their water directly from lakes, rivers, hot springs, or wells without any treatment beyond simple filtration.

Free and combined chlorine

Test the water frequently for free chlorine and combined chlorine. Free chlorine levels must be greater than 0.5 ppm but, ideally, maintained between 1 and 1.5 ppm in a lap pool and 1.5 to 2 ppm in a hot tub. Pool chemical control should include pH and oxidation reduction potential (ORP) monitoring. ORP is an automatic sensor system used along with chlorine injection to buffer changes in pH. ORP testing can be performed manually or through an automatic chemical controller.

The current B.C. Pool Regulation requires that pool pH be in the range of 7.2 to 7.8 and that free available chlorine be present. Pool operators are required to conduct manual tests for chlorine and pH every four hours during pool operation. To best manage pool chlorine and pH, most commercial recreational facilities have a computerized chemical controller installed. The controller feeds chlorine when needed and maintains the pH.

Checking pool water chemistry

Ideal pH differs from pool to pool and in every community, and is influenced by factors such as source water chemistry. Pool operators generally keep hot tubs at the lower end of the acceptable pH range for better disinfection, as chlorine works better at a lower pH. The main pool basin is frequently kept in the middle of the range.

Dilute water periodically

Over time, organic pollutants accumulate in the water. Pool operators can either treat or replace water in order to keep water near optimal for bathers. Many pool operators subscribe to a regular replacement strategy. One approach is a daily or trickle replacement. Another approach is to dilute the water on a schedule based on the experience of the operator. For example, a seasoned operator may know that his/her pool should be diluted twice a week as a good practice.

Dilution should be performed on all water bodies. This can be accomplished by bleeding water off from the recirculation system. Water is automatically replaced as the system compensates for the loss. Target dilution should be based on an estimate of usage, averaged on a 24-hour basis. For example, in a lap pool, dilution rates should be 20 to 40 litres per person per day. In smaller pools, such as hot tubs, the rate can be reduced. In hot tubs, the dilution strategy should permit a reduction in how frequently the hot tub needs to be emptied and refilled, which may be as often as every two days. It's beneficial to have a water meter on each pool system (for example, main pool, hot tub, or leisure pool) to help monitor water replacement volumes.

All water must meet health regulations and customer temperature expectations. Any dilution strategy must not allow the water quality to fall outside of the allowable levels. Within these limits, operators may regularly schedule dilution. (For example, an operator might drain the hot tub every Wednesday night, whether it truly needs it or not.)

Check water circulation

Dye testing

Dye testing should be performed after a pool or other facility is built or about to go through an annual refit. The purpose is to identify water circulation patterns and make sure water is circulating properly throughout the pool, hot tub, etc. Adjust the pool return fittings as required during the refit. If the water is not circulating properly, many water chemistry problems can develop.

Use a red- or blue-coloured, food-based, powdered dye. Turn off the water circulation pump and add the dye to the filter. Have the

pool staff stand around the pool with cameras, prepared to record the dye patterns (i.e., the direction the nozzles are spraying and whether or not all of the nozzles are working). When ready, turn on the pump. The pool nozzles will "blossom" as the dye comes through. The staff will have to work quickly because the nozzles will become difficult to see, and the chlorine breaks down the dye rapidly. Dye testing can also be done before chlorine is first added to the pool water.

Pump operation and water turnover requirements

Pool circulation pumps must run continuously in order to maintain the design flow rate. Pumps should deliver the recommended turnover rate for the specific type of pool (for example, public pool, hot tub, or wave pool). These and other requirements are detailed in the B.C. Pool Regulation and/or the B.C. Guidelines for Pool Design. In some cases, the B.C. Ministry of Health may grant exemptions. The regulation and guidelines may change, so pool operators should consult these documents and their local health officer for guidance and any updates.

Inspect and maintain the ventilation system

Ventilation systems must be inspected and maintained on a regular basis, as required by the Occupational Health and Safety Regulation. This includes regular inspections of the critical components of the system, such as dampers, fans, belts, ductwork, diffusers, and control systems. Check to make sure diffusers are appropriately located, not damaged, and pointed in the right direction. All deficiencies must be corrected.

If a ventilation system isn't operating properly or is undersized, contaminants such as chloramines may accumulate in the air. In particular, the outdoor air, return and exhaust dampers, and actuators should be checked to make sure they are all working properly. The average flow of air from outdoors can be measured by traversing the outdoor damper grille with an anemometer (a device that measures airflow).

Due to the potential for corrosion from moisture and chloramines, an inspection of ventilation system components and hangers should be conducted at least every two months. Look for rust and other physical damage.

The effectiveness of a ventilation system can also be measured using smoke injected into the supply duct. To perform the test, the system is turned off and a small smoke generator (or smoke "bomb") is inserted into the duct and activated. The air handling system is then turned back on. There will be a window of several minutes to observe the air flow in the pool area before the smoke becomes too thick. (The smoke will quickly clear once the smoke generator is removed.) The smoke test can identify "dead spots" with little airflow, especially around hot tubs.

Smoke tubes or "pencils" can also provide some information about airflow; however, the volume of a recreational facility is generally too large for these devices. At best, they can provide insight into local airflow around both supply and return air grilles.

Pay close attention to hot tubs

Hot tubs are major sources of chloramines in water recreational facilities. As the temperature of the water is increased, more chloramines are produced. Trichloramines released from hot tubs can negatively affect indoor air quality.

Superchlorination and dilution of the water in swimming pools may help resolve trichloramine problems. If the water still has a high combined chlorine level or the airborne trichloramine concentration is high following this treatment, try emptying any adjacent hot tub(s). Then monitor the water chemistry in the main pool to see if conditions improve. Once the airborne trichloramine level has dropped, fill and open the hot tub(s) again.

Capital upgrades to consider

UV treatment system

It's increasingly popular to use ultraviolet radiation (UV) to disinfect recreational pool water. UV is a very effective disinfectant that has no residual effect in pool water. UV can break down chloramines and other organic pollutants into less harmful chemicals like nitrogen gas, oxygen, and weak hydrochloric acid. However, UV doesn't eliminate the requirement for free chlorine.

UV systems are available with low- and medium-pressure lamps. The low-pressure lamps deliver a light wavelength that disrupts cellular components, which makes it ideal for disinfection. However, these low-pressure lamps don't produce the proper wavelengths or the necessary light intensity to break down organic pollutants. Medium-pressure lamp systems, however, do provide the much broader spectrum of UV light at higher intensities that will destroy chemicals such as chloramines. To ensure full chloramine reduction, the power delivered from the lamp shouldn't fall below 60 millijoules per square centimetre (mJ/cm^2). The pool operator should be aware that the power delivered just before the lamp is due to be replaced (typically 8,000 hours) can be 25 percent below the minimum required for effective treatment. Extend the lamp life by selecting a unit with a power-switching option to limit dosage to 70 mJ/cm^2.

A UV system should treat the entire flow of water that the pool pump delivers. If UV and pool circulation systems are working properly, the water should remain at a very low combined chlorine level. However, turning the UV lamp off allows the chloramines to rebuild, and it then takes one or more pool turnovers (4–8 hours) to fully reduce the chloramines. This is why turning a UV system off at night to save power doesn't produce the consistent water and air quality results that an operator should be expecting.

A UV system can change water chemistry because it produces hydrochloric acid as a byproduct when it breaks down organic pollutants. Expect to increase the use of sodium bicarbonate. Depending upon the local water quality, the reduced pH may cause the UV lamp housing to develop crevice crack corrosion (this is the case in the Lower Mainland). One solution is to eliminate crevices through the design of the lamp housing. Another solution is to replace some parts of the housing with parts made of stainless steel (for example, SMO 254) or titanium.

Ozone treatment system

Ozone can help break down ammonia and nitrogen-containing pollutants (including chloramines) in the water. These systems work effectively, although only a small amount of water is treated at any one time. Ozone only works in the contact tank, so it may take more than 24 hours to treat an entire pool. For example, an ozone system with a 10 percent bypass ratio may only treat 60 percent of the pool water (with six turnovers) in a 24-hour period.

It's important to validate and frequently check every aspect of an ozone system's operation. For example, confirm that the ozone injectors are working, and make sure that the water from the contact tank is actually circulating into the pool. Keep in mind that ozone will not help with chloramine odours and can be a respiratory health hazard, depending on the amount of airborne exposure.

Heat recovery system

Heat loss is one of the problems associated with a dilution strategy to minimize water chloramine levels. A heat recovery system, consisting of heat exchangers connected to discharged pool water, can help recover that loss. Keep in mind that this type of system may not be cost effective and should only be considered after significant research.

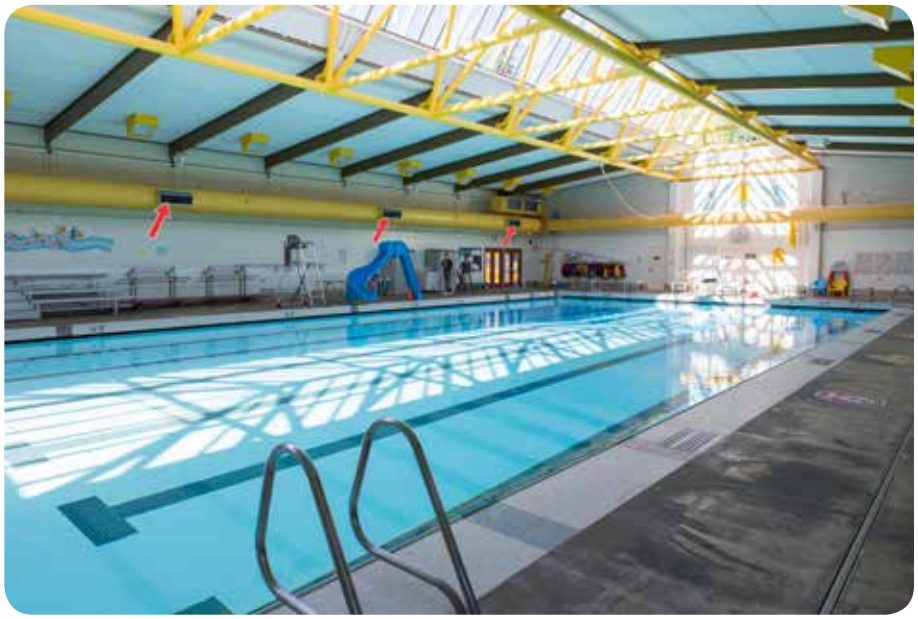
Heat exchangers should be made of stainless steel (SMO 254 is recommended) and sized based on the time required to warm up a cold lap pool or hot tub. During normal pool operations, this equipment will improve the efficiency of the condensing boilers. Heat recovery for shower water may be challenging due to blockage from soap, hair, and other materials that pass down shower drains.

Upgrades or modifications to the ventilation system

At times when the outdoor air damper is closed because of very cold external temperatures or malfunction, the lack of air movement will result in elevated levels of chloramines and other contaminants (for example, carbon dioxide) throughout the building. Adding more outdoor air (make-up air) to the building, by itself, will not solve all indoor air quality problems. Reducing the amount of outdoor air as a means of budget control will only contribute to the problem.

One restriction of using make-up air in many locations is the cost of heating it. There are a number of heat recovery systems that can be used in pools, and the payback improves significantly when air temperatures are low.

The air handling system should draw air into the building somewhere near roof height and exhaust it at floor level. This design results in the downward flow of air through the building, providing there are several inlets across one side and several exhaust outlets across the other side.



Additional supply vents (red arrows) have been added to the ventilation system around this pool.

Corrosion control

In leisure pools, such as wave pools with spray/play equipment, the water is typically warmer and more children are present. The presence of urine in the pool is likely more common, which means increased chloramine production. This leads to the release of more trichloramine from the water and increased corrosion in these parts of the building.

Airborne trichloramines can cause corrosion in components hung above the pool deck. Pool equipment made from stainless steel is typically 304 or 316 grade. There have been instances where objects hung from these types of stainless steel wire have dropped to the pool deck. Only SMO 254 stainless steel or equivalent should be used to suspend objects or ventilation components in these facilities. Stainless steel equipment in pool areas should be electro-polished and maintained according to best practices (for example, do not use any abrasive products or cleaners on the equipment).

Woman injured when the ceiling of a swimming pool collapsed

A woman and her two children were swimming in a public swimming pool when, without warning, the entire ceiling collapsed. All three were hit by falling debris. An investigation discovered that the support mechanisms holding up the heating and air conditioning units and ductwork above the ceiling were severely corroded. This corrosion caused the support mechanisms to fail, and the equipment collapsed (along with the ceiling) into the swimming pool.

Research has also shown that airborne chloramines are capable of corroding metal surfaces and piping in water distribution systems.

Appendix

Exposure control plan for chloramines in swimming pools and water parks

Company information

Name_____

Address _____

Contact information (names and phone numbers) _____

_____

_____

_____

Health hazards from exposure to chloramines

Chloramines are irritants. Swimmers have complained of eye irritation when chloramine concentrations in the water exceeded 1 mg/L. Respiratory tract irritation has also been shown in several studies and becomes obvious at about 0.5 parts per million (ppm) in air. Both patrons and workers who enter pool and spa areas have reported these health effects.

There is some evidence that exposure to chloramines, particularly trichloramine, may cause occupational asthma. Research has also shown that exposure to trichloramine can significantly decrease lung function. There are no reports that chloramines cause cancer, reproductive or developmental effects, or genetic damage.

Purpose and responsibilities

Our company is committed to providing a safe and healthy workplace for all of our staff. A combination of measures will be used to achieve this objective. These controls and procedures will protect not only our workers but also any other worker who enters our facilities. All workers must follow the procedures described in this plan to prevent or reduce exposure to chloramines.

Our company will do the following:

- Ensure that the resources (such as safe work procedures and worker education) required to implement and maintain the exposure control plan are readily available where and when they are required.
- Implement and document the appropriate site-specific control measures.
- Ensure that supervisors and workers are educated and trained to an acceptable level of competency.
- Conduct a periodic review of the plan's effectiveness.
- Maintain records of education and training.
- Ensure that a copy of the exposure control plan is available to workers.

Our supervisors will do the following:

- Ensure that workers have been adequately educated and trained in the workplace controls.
- Direct work in a manner that eliminates or minimizes the risk to workers.

Our workers will do the following:

- Know the hazards of the workplace.
- Follow established safe work procedures as directed by the employer or supervisor.
- Report any unsafe conditions or acts to the supervisor.
- Know how and when to report exposure incidents.

Risk identification and assessment

Chloramines are effective disinfectants and have been used in potable water systems in North America since 1900. Monochloramine is the most effective of the three major chloramine types and has been used to disinfect some municipal water supplies. Chloramines are also occasionally used as anti-fouling agents in cooling towers.

In recreational water facilities, chloramines are formed when ammonia-containing compounds from human sweat and urine react with free chlorine in pool or spa water. Monochloramine is preferentially formed in water that is mildly alkaline. However, if more free chlorine is available, dichloramine and trichloramine concentrations increase.

Monochloramine and dichloramine do not readily vaporize. Exposure happens through inhalation of airborne droplets or mist formed by spray equipment and splashing. By contrast, trichloramine does evaporate from water and can be inhaled as a vapour by both staff and patrons.

Workers can be exposed to chloramines while working in the water, on the pool deck, or even within the recreational facility itself.

Exposure limit

Numerous studies have measured chloramines (as trichloramine) in the air of indoor swimming pools and water parks, with results ranging from 0.05 mg/m^3 to 2 mg/m^3. Proposed guideline and occupational exposure limits in many jurisdictions range from 0.1 mg/m^3 to 0.5 mg/m^3. However, the proposed 0.5 mg/m^3 limit may be too high, as irritant health effects occur at much lower airborne concentrations.

Based on research that has been conducted to date, WorkSafeBC recommends that the airborne concentration of chloramines in indoor water recreation facilities be kept below 0.35 mg/m^3.

Control of worker exposure to airborne chloramines

Control of worker exposure to airborne chloramines will be accomplished using a combination of engineering and administrative controls, as follows:

- Our staff will regularly monitor the pool water chemistry to ensure that the concentration of chemicals that might lead to the excessive formation of chloramines is controlled.

- Signs are posted in the pool and spa areas that list rules regarding patron behaviour. For example, patrons must shower before entering the pool, waterslide, or hot tubs, and must not urinate in the pool. Our staff will regularly point out these rules to our patrons. This will help reduce the amount of ammonia-containing compounds entering the water.
- Staff will be instructed to leave the pool deck area, or limit their time spent on the pool deck, if they experience eye irritation or difficulty breathing.

Worker education for chloramine exposure

Education and training will be conducted by the employer or the employer's designate. Records of attendance, dates of education, and educational material will be documented and retained. Additional reference material on chloramine exposure will be made available to workers upon request.

Training topics will include the following:

- An overview of chloramines and how they are produced in pool and spa water
- Health hazards of chloramine exposure (including signs and symptoms)
- Engineering controls and administrative controls used to protect workers
- Details of the exposure control plan for chloramines

Annual review

This exposure control plan will be reviewed at least annually and updated as necessary by the employer, in consultation with the workplace health and safety committee or the worker health and safety representative.

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