Incident Summary #II-1759094-2024 (#51649) (FINAL)

SUPPORTING INFORMATION	Incident Date		September 10, 2024
	Location		Coquitlam
	Regulated industry sector		Gas - Natural gas system - Propane gas system
	Impact – Injury	Qty injuries	17+
		Injury description	Multiple adults and youths experienced carbon monoxide poisoning symptoms, some of which included light headedness, shortness of breath, exhaustion, dizziness, headaches, nausea, and vomiting.
		Injury rating	Moderate
	Impact – Damage	Damage description	N/A
		Damage rating	None
	Incident rating		Moderate
	Incident overview		Dangerous levels of carbon monoxide (CO) were released and contained within the indoor space of an ice rink facility containing employees and members of the public. Several people were unknowingly exposed to the CO over several hours and experienced a variety of CO poisoning symptoms with some seeking medical attention.
INVESTIGATION CONCLUSIONS	Site, system and components		The ice rink facility was built and opened in 1993 and houses four ice rinks. Two rinks are located on either side of a central lobby, restaurant and fitness facility. The building contains several natural gas burning appliances including heaters, boilers, make-up air units, a large dehumidifier, and kitchen equipment for the restaurant. The facility utilizes multiple propane fueled ice resurfacing machines commonly referred to by the manufacturer name Zamboni. The Zambonis are wheeled vehicles driven by operators and are typically used between sessions of ice rink use to smooth and build up the ice for the next sessions. The Zambonis at the facility use internal combustion engines for power that are fueled by propane and exhaust into the indoor space. There are multiple natural gas fired appliances throughout the facility used for heating air, water and for the dehumidification of the air within the rink areas. The dehumidifier is a direct-fired appliance which uses an open gas burner directly in the air stream to temper the incoming air returning to the rink areas. The other heating appliances all utilize venting systems to effectively remove all the flue gasses safely to the outdoors. The Canadian Standards Association (CSA) B149.1 Natural gas and propane installation code requires that vents used for gas appliances provide effective venting and shall remove all flue gases to the outdoors. The CSA B149.2 Propane storage and handling code has a requirement for passive or mechanical ventilation in buildings that utilized propane fueled engines (in other than motor vehicles) indoors. The volume of required ventilation is dependant on the operating time and brake horsepower of the equipment. The ventilation shall be continuous or is acceptable to be only used when the equipment is in use if it meets or exceeds 300cubic feet per minute (cfm) per brake horsepower of the equipment being used.

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	Natural gas and propane require a minimum amount of oxygen for complete combustion. When the minimum amount of required oxygen is not supplied to a gas burner or engine, the result is incomplete combustion. A by-product of incomplete combustion is carbon monoxide. Carbon monoxide is a colourless, odourless, tasteless gas that is toxic to humans and animals. Exposure to carbon monoxide interferes with the body's ability to absorb oxygen, which can result in serious illness or death. For more carbon monoxide information, visit Carbon monoxide safety tips.
Failure scenario(s)	The ice rink facility had been in operation since 1995. The facility did not have any equipment for monitoring carbon monoxide for the common indoor areas or ice rinks. The propane fueled Zamboni ice re-surfacer that was being used on the rinks at the North section of the building for ice rinks 1-2, had an incorrectly operating electronic fuel pressure regulator for the engine. The incorrect regulating of the fuel pressure caused the exhaust gas emissions from the internal combustion engine to produce very high levels of carbon monoxide between 68,000-72,500 parts per million (ppm). The building is equipped with manually operated mechanical ventilation fans and air intake louvers for every rink that are typically used during heavy Zamboni activity. The ventilation fans were not used the day of the incident. Zamboni use the day of the incident The CO concentrations inside the building increased throughout the day as the Zamboni was continually used to clean the ice surfaces of the two rinks without the use of the mechanical ventilation systems. The ice surfaces on rinks 1-2 in the North section of the building were each cleaned with the Zamboni 3-4 times between ice uses from 5:00pm to 9:30 pm that day then both rinks received two consecutive cleanings after the last uses at 11:00pm for cleaning and ice surface buildup for the next day. The last cleanings were completed between 12:30 and 12:45am for a total of 11-12 ice surface cleanings between 5:00pm and 12:30am with the incorrectly operating Zamboni the day of the incident without any mechanical ventilation in operation. Carbon monoxide alarm and initial analysis The elevated CO in the building initially went unnoticed until approximately 8:20pm when a plug-in CO detector alarmed. The CO detector was installed in the central mechanical room of the building which also contained a natural gas heating boiler. At that time, readings on the CO alarm digital display indicated CO levels between 50-80ppm in the mechanical room. A manager was informed of the alarming CO detector by employees of the facility. The manager's initial thought was that the alarm may have been faulty, so they purchased another new CO detector and replaced the original one in the mechanical room around 10:00pm. The new detector also alarmed and indicated the same amount of CO as the previous detector. While further investigating the CO levels in the building, the new detector was installed in a plug outlet in the lobby causing it to alarm again. Through phone consultation with a gas contractor, the natural gas boiler in the mechanical room was suspected as being the source of CO and was shut down around 12:00am. After further consultation over the phone with a gas contractor, the decision was made by the facility management that the boiler was likely responsible for the CO production due to the fact that the CO detector alarmed in the mechanical boiler room, and that since the boiler had been shut down, it was presumed safe to leave the facility in operation and address the CO concern the next morning.

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Ice rink use and CO exposure

The facility remained open after the first CO alarm at 8:20 and several members of the public continued to use the ice rinks while the Zamboni operation continued to increase the levels of CO inside the building. The last use of the rink was a hockey game on rink 2 which started at 9:45 pm and went to approximately 11:00pm. During the game and later in the dressing rooms, several members of both hockey teams experienced illness symptoms from the carbon monoxide exposure inside the building including dizziness, nausea, exhaustion, and confusion.

Later that evening when the skaters who had used both ice rinks 1-2 that evening had returned home, they continued to feel ill with some of them stating that they experienced difficulty breathing, extreme headaches, nausea and vomiting. One of the skaters that evening contacted emergency services, and the fire department was notified at approximately 1:45am.

Emergency service response and CO detection

When the fire department arrived at the facility around 2:00am, they detected high levels of CO inside the building and contacted the gas utility. A technician for the gas utility arrived at approximately 3:00am and using a calibrated test instrument recorded the following levels:

Carbon monoxide measurement (ppm)	Area of building*
100-150	Building lobby
150-200	Upstairs fitness gym
150-350	Entrance to rink 2
350-433	End of rink 2 by Zamboni storage

*These reading were taken approximately 3 hours after the Zamboni had last been used on rink #2. The maximum CO levels in the Rink 2 area during the evening use could be reasonably expected to have been higher than the maximum measured reading by the gas utility technician due to natural dissipation and ventilation in the space.

Continued CO production and testing after initial incident

The gas utility technician believed the direct fired natural gas dehumidifier was the cause of the CO and shut it down. The building was ventilated by the fire department and gas equipment was turned back on other that the dehumidifier and the air indoors was monitored for increases in CO. No increase of CO was detected indoors during this time. The building was then continually ventilated by the fire department and at approximatly11:30am the facility was released back to the managers and reopened.

A gas technician was hired to examine the dehumidifier and when tested, found that it was operating correctly within acceptable parameters and was not the main source of CO in the building. Further examination identified one of the tube heaters for heating the spectator stands on rink #2 had a split open vent pipe indoors and had been spilling flue gasses including CO into the indoor space (Image 4). This became the next expected source of CO for the building as the heater had been operating continuously that evening. The heater is operated by an automatic timer switch accessible to the public but can also be set for continuous operation which it had been that evening from an undetermined time until 11pm the day of the incident. The heater was then turned off and disconnected for use.

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	During the afternoon after the initial CO incident with the facility open to the public and all the gas appliance off other that the dehumidifier that had been tested by the qualified technician. Portable CO monitors from the management and gas technicians identified CO levels in the Rink 2 area had increased again to 70-90 ppm. It was then that the Zamboni was suspected of being the cause of the CO and it was sent out to clean the ice on rink 2 again. During approximately ten minutes of Zamboni operation, the CO levels in the ambient air went from a baseline measurement of 60ppm up to 140ppm. The Zamboni was then taken out of service and the building was ventilated again. Gas equipment testing and analysis Although the gas fired tube heater was operating with a split vent and the flue gas was spilling into the indoor space it was tested by a qualified gas technician with a calibrated analyzer and it was only found to be producing 4-12ppm of CO. The dehumidifier was also tested and found to be producing 1-3ppm of CO. The gas fired tube heater with the split vent and the dehumidifier did contribute negligible amounts of CO into the indoor space, but the Zamboni operation was the main source of CO that elevated the CO levels in the indoor space of Rink 2 to dangerous levels.
Facts and evidence	Witness statements • The CO alarm installed in the boiler mechanical room was the only CO detector in the building. • The detector alarmed at 8:30pm and employees notified the manager. • The detector was believed to be faulty, so a new one was purchased and used to replace the original one. • The new one alarmed the same as the original one • The only two locations the CO detectors were used on the day of the incident were in the mechanical boiler room and in the lobby outside the skate shop. • The tube heater was found to have been set to continuous use on the timer switch on the wall by the spectator stands. • It was not known when it was turned on but was shut off by the manager at around 11:30pm. • The ventilation fans were not used during Zamboni use the day of the incident. • The use of the ventilation fans can occasionally cause humidity and condensation problems in the rink areas and that is why they were not used on a regular basis. Site observations • The vent pipe for a spectator tube heater in rink 2 was found to have staining from leaking flue condensation and was split open down the assembly seam allowing flue gasses for the operating heater to spill into the indoor space. • The two plug in CO detectors were unplugged during the time of investigation. • The original CO detector had a recall max CO reading of 208ppm. • The new CO detector had a recall max CO reading of 467ppm (Image 6). Documents • Documentation for the Zamboni emissions testing by an equipment service contractor showed the Zamboni used for rinks 1-2 were measured to be

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	6.88% (68,800ppm) CO under load and 7.25% (72,500ppm) CO with no load. After the repairs were completed to the electronic fuel pressure regulator. It was tested again, and the emissions measurements improved to 0.34% (3400ppm) CO under load and 0% (0ppm) with no load. • The Zamboni service manual states that rinks must be adequately ventilated during operation of the ice surfacer and that measuring and recording of the engine's emission levels should be completed every 300 operating hours. Testing and measurements The natural gas fueled heating appliances had combustion analysis tests completed by qualified contractors after incident. No significant sources of CO were identified. The radiant tube heater with the damaged vent pipe and the direct fired dehumidifier both allowed flue gasses to enter the indoor space, and the documented tests identified the CO measurements of both appliances were 4-14 ppm. When CO was identified in the rink the next day, a test was conducted to analyze the Zamboni use as a CO source. The Zamboni was sent out to do an ice clean of rink 2 and after 10-12 minutes of operation, the measured CO reading in the ambient air around rink 2 increased by 80 ppm (from 60-140ppm).
Causes and contributing factors	Regulated gas heating/dehumidification equipment was found to have some deficiencies; however, it was unlikely that they were a major contributing factor to the incident. The use of a propane powered Zamboni with a faulty electronic fuel pressure regulator was the main source of high levels of CO in the indoor space of the public ice rink facility. Contributing factors to the carbon monoxide exposures and Illnesses include: 1. Carbon monoxide detection - The facility not having carbon monoxide detection systems inside the ice rink sections of the building prevented the early warning of hazardous levels of CO in the area. 2. Mechanical ventilation operation - The operation of the Zamboni without the use of the mechanical ventilation fans allowed the CO concentrations to increase without the dilution of incoming fresh air. 3. Management decisions - The decisions to assume the boiler was the main source of CO without proper testing and the allowance of continued occupancy of the building by employees and the public after CO was detected indoors allowed for extended periods of exposure. 4. Gas equipment condition and operation - The gas tube heater venting to the indoors through the damaged vent pipe and the direct fired dehumidifier drawing in combustion air containing high levels of carbon monoxide could have contributed to a slight increase in the CO levels indoors.

Image 1 – Outside of ice rink facility. The larger windowless building on the right houses ice rinks 1-2.

Image 2 – Two tube heaters above the spectator stands at rink 2.

Image 3 – Air intake piping and burner unit for tube heater #1 on rink 2.

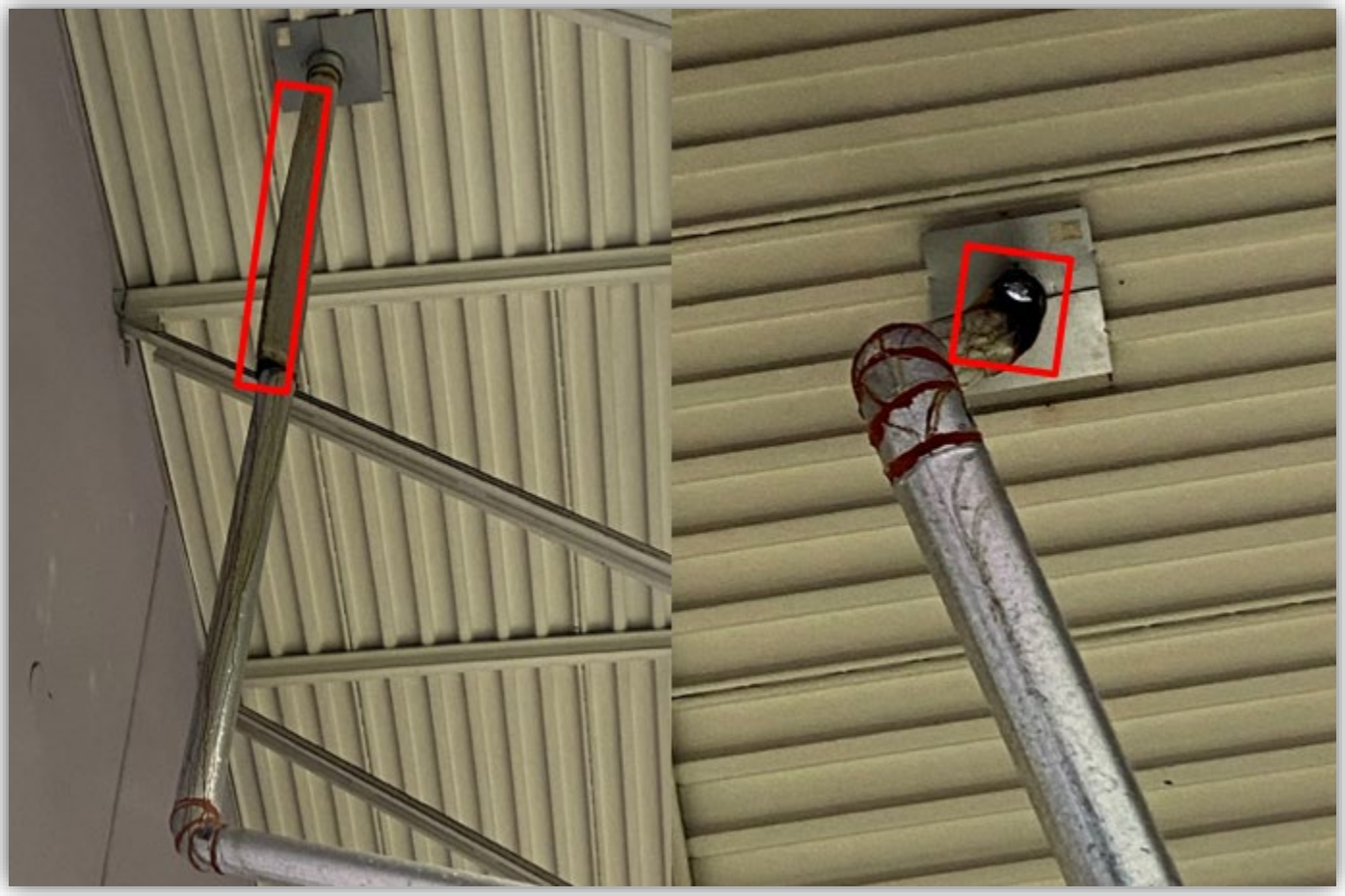

Image 4 – Two angles showing the split and open vent pipe for Tube heater #1. Image on right showing light from the outdoors coming through the open piping.

Image 5 – Faulty Zamboni parked outside of ice rinks 1-2.

Image 6 – New CO detector installed in the building lobby showing a recall of a maximum reading of 467ppm.

Image 7 – Left – The outdoor and indoor views of the rink 2 ventilation fan. Right – The outdoor and indoor view of the rink 2 louvered ventilation intake grate.

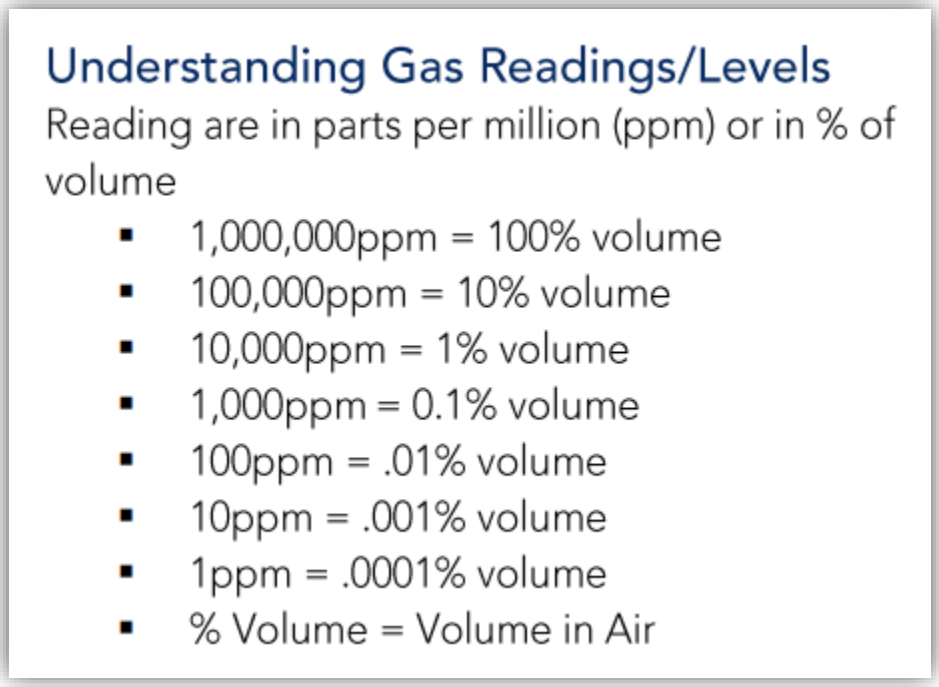

Image 8 – Chart showing the correlation of % vs ppm readings.