Carbon monoxide in industry

Carbon monoxide (CO) gas is one of the most widespread and dangerous industrial hazards. It is the most common cause of occupational gas poisoning leading to death. It can be lethal at concentrations as low as 1000 parts per million (ppm).

This document provides basic information about the danger of CO in the workplace. It describes situations in which CO is a hazard, how to recognize and treat CO poisoning, and how to prevent poisoning.

What is carbon monoxide?

CO is a toxic, odourless, invisible gas that comes from incomplete combustion of any carbon-containing material (for example, wood, coal, oil, kerosene, gasoline, diesel fuel, natural gas, or propane). CO burns well when mixed with air, and in certain concentrations is explosive. Victims of CO poisoning cannot see or smell the gas, so they don't realize they are in danger.

CO interferes with the ability of blood to carry oxygen to tissues, most importantly the brain. Normally, oxygen is transferred from the lungs to the blood, where it combines with hemoglobin carried in the red blood cells. CO can also be transferred from the lungs to the blood, where it combines with hemoglobin to form carboxyhemoglobin (COHb).

Hemoglobin and CO have an attraction and tendency to combine that is approximately two hundred times greater than that of hemoglobin and oxygen. CO displaces oxygen from the blood, and then prevents further uptake of oxygen by the blood. As long as CO continues to be breathed, it progressively blocks more and more of the blood's oxygen-carrying capability.

Where is CO found?

Natural sources of CO such as forest fires create the largest amount of CO worldwide, but human-made sources such as internal combustion engines are a greater concern to workers. This is because they can produce localized high-hazard areas, particularly in confined spaces or areas where there is poor ventilation.

Potential sources of CO include emissions from:

- Vehicles
- Portable generators
- Gasoline-powered tools (for example, chop saws)
- Fires and explosions
- Natural gas space heaters
- Kilns, furnaces, and boilers
- Welding
- Cigarette smoking

Tobacco smoking can be as much a CO hazard to workers who smoke as work-related exposure. Smoking produces COHb levels 10–20 times the normal low levels produced by breathing city air. Tobacco smoke contains 4–6% of CO (40,000–60,000 ppm). This CO is diluted in the mouth and upper airways, but the remaining 400 ppm that is inhaled is still a very large amount. Workers who smoke put themselves at higher risk of serious harm if they are also exposed to CO in their jobs.

CO warning signs and symptoms

The effects of CO poisoning vary from worker to worker, but there are certain predictable responses that result from the lack of oxygen available to the body tissue as the level of CO increases. The progression of signs and symptoms of CO poisoning depends on muscular activity, time of exposure, and concentration of CO.

The worker first notices a slight headache, usually in the forehead, which gradually increases in intensity. Dizziness, drowsiness, and a feeling of nausea may then develop. Weakness and mental confusion may be mistaken for drunkenness. Weakness and confusion can contribute to death as the worker becomes unable to escape the CO. The headache becomes more severe and throbbing, and weakness and confusion progresses to collapse and coma. If the worker is not removed from further exposure, death may result quite rapidly.

CO turns the blood a bright cherry-red colour. With acute poisoning, this may cause a bright red face, lips, and tongue. However, these signs are not reliable enough to be depended on for diagnosis.

Because nerve and heart tissue are very sensitive to a lack of oxygen, they are affected most quickly and severely by CO exposure.

CO may be overlooked as a cause of poisoning in certain situations. Firefighters are particularly prone to CO exposure. A worker who is assumed to be suffering from smoke inhalation may also be seriously affected by CO.

CO poisoning incident

Two carpet cleaners were using a truck-mounted unit to clean carpets in an unoccupied townhouse. The truck was parked in a garage attached to the townhouse, and the main garage door was closed. The door from the garage into the townhouse was open so that the hoses could run from the cleaning unit to the house.

Throughout the day, the cleaning unit was running. CO from the gasoline-powered engine built up and entered the open door into the townhouse. Both carpet cleaners died from CO poisoning.

The following table describes the signs and symptoms that may occur at specific CO levels.

CO warning signs and symptoms

Concentration in parts per million (ppm)*	Observations and health effects
1 to 3	Normal.
25	Occupational exposure limit averaged over a period up to 8 hours.
30 to 60	Exercise tolerance reduced.
100	15-minute short-term exposure limit (STEL).
60 to 150	Frontal headache. Shortness of breath on exertion.
150 to 300	Throbbing headache, dizziness, nausea, and impaired manual dexterity.
300 to 650	Severe headache; nausea and vomiting; and confusion and collapse.
700 to 1000	Coma and convulsions.
1200	Immediately dangerous to life and health (IDLH).
1000 to 2000	Heart and lungs depressed. Fatal if not treated.
Above 2000	Rapidly fatal.

** 1 ppm = 1 part of gas per million parts of air by volume*

WorkSafeBC designates CO as a reproductive toxin because of its effect on the developing fetus.

CO is generally not considered to be a chronic poison. As soon as the worker is removed from further CO exposure, the CO in the blood is gradually released from the COHb and replaced by oxygen. As this occurs, any signs or symptoms of CO poisoning disappear. A complete recovery usually occurs within several hours, except when CO poisoning has been so severe as to cause unconsciousness.

Detecting CO

There is no way to detect CO by odour, colour, or irritation. Special detection methods such as the following must be used:

- *Gas detector tubes* – These clear tubes are about the size and shape of a ballpoint pen, and can be read much like a thermometer. The tube contains a material that may change colour when it reacts with air drawn through it by a small hand pump. The amount of colour change depends on the CO level.
- *Electronic detectors* – These range from small personal samplers to large, stationary monitors. A display screen shows the gas level. When CO levels exceed a set limit, these detectors sound an alarm, flash a light, or vibrate.

  Note: Never use a home CO detector to measure CO levels in a workplace.
- *Blood samples* – If there is particular concern about the effects of CO in a workplace, blood samples can be taken from workers to determine the amount of COHb in their blood.

CO poisoning incident

The owner-operator of a flooring installation business experienced headache and dizziness after working for 2.5 hours in the stairwell of a building. The stairwell contained a gasoline-powered generator that supplied power to the construction site. The owner-operator left the building, and rested in his car. Upon returning to the stairwell, he collapsed in a grand mal seizure related to CO poisoning.

Occupational exposure limit

Employers must ensure workers are not exposed to CO levels above the occupational exposure limits (OELs). The OEL is the level of an airborne substance that workers may be exposed to without wearing protective equipment, and without normally suffering adverse health effects.

In British Columbia, *the OELs for CO are an 8-hour time weighted average (TWA) of 25 ppm and a 15-minute short-term exposure limit (STEL) of 100 ppm*. The STEL must not be exceeded more than four times in an 8-hour work shift, with at least 1 hour between any two successive 15-minute periods.

Employer responsibilities

Employers must develop and implement an effective exposure control plan (ECP), which includes training workers and supervisors in relevant sections of the plan.

An effective ECP for any workplace where workers are exposed to CO must include:

- A written policy that:
  - States the employer's commitment to health and safety
  - States the plan's objectives
  - Defines the responsibilities and roles of the employer, supervisors, and workers
- An assessment of the workplace hazards (for example, where workers are likely to be exposed to CO)
- Controls used to reduce the hazards (for example, local exhaust ventilation, barriers, or personal protective equipment)
- Written safe work procedures and emergency response procedures (for example, rescue procedures)
- Monitoring for CO (for example, when, where, and how monitoring devices such as personal monitors will be used in the workplace)
- Training for supervisors and workers
- Records and statistics (for example, first aid records for workers poisoned by CO)

Worker responsibilities

Workers also have responsibilities to help reduce the risk of exposure to CO. Workers (including subcontractors) must:

- Attend education and training sessions provided by the employer
- Use controls and follow safe work practices outlined in the ECP
- Use personal monitors and available personal protective equipment (for example, self-contained breathing apparatus), as required
- Learn to recognize the symptoms of CO poisoning
- Report exposure incidents or potentially hazardous situations

Breathing protection

Do not use quarter- or half-face piece respirators fitted with chemical cartridges.

If there is prolonged exposure to CO or a high concentration of CO, workers must wear one of the following two types of breathing protection:

- *Positive-pressure, self-contained breathing apparatus (SCBA)* – This consists of an air cylinder, which is normally worn on the back, and a full-face mask to protect the eyes and face. A hose connects the face mask to the regulator and the air cylinder. "Positive pressure" means that the air pressure in the mask is higher than the air pressure outside the mask. This reduces the chance of toxic gases entering the face piece.
- *Positive-pressure, supplied-air (airline) respirator* – This consists of an airline attached to a regulator and a full-face piece. The worker must also wear an "escape" air bottle to allow escape if the air supply is cut off.

Workers who use respirators must be clean shaven where the respirator seals with the face. This helps provide a good seal that keeps harmful gases out.

Emergency respiratory equipment should be available at high-risk worksites. All workers must understand the proper use and limitations of the respirator equipment available to them.

CO poisoning incidents

A farm owner died of CO poisoning while using an 11-horsepower, gasoline-powered pressure washer to clean his swine-farrowing barn. He worked about half an hour before being overcome by the CO.

A drywall finisher collapsed and fell from the scaffold on which he was standing. He was using a small gasoline-powered compressor to apply a textured surface to a cathedral ceiling in a house. He landed on a balcony below, and was later rescued by co-workers.

First aid and rescue

In the event of a poisoning, follow these guidelines:

- Summon the first aid attendant for your worksite as outlined in the posted written procedures for providing first aid.
- To attempt a rescue in an area with high CO levels, wear only a positive-pressure, self-contained breathing apparatus (SCBA), or a full-face, supplied air (airline) respirator with an "escape" air bottle.

  Note: Only qualified personnel should attempt a rescue.
- If your worksite does not require a first aid attendant, follow these steps:
  - Move the poisoned worker to fresh air.
  - Keep the worker warm and at rest. Activity may worsen the effects of CO by increasing oxygen demand.
  - If available, give 100% oxygen through a tight-fitting mask. Oxygen therapy should be continued for at least two hours – it takes 80 minutes to get rid of half of the CO in the body when breathing 100% oxygen.
  - If the worker is having trouble breathing or is not breathing, start assisted ventilation using a pocket mask. Add oxygen to the mask, if available. If the worker has no pulse, begin cardiopulmonary

resuscitation (CPR). Because the body rids itself of CO when removed from the exposure, it is critical to continue giving the worker assisted ventilation with oxygen until medical aid arrives.
  - Call for a doctor or get the worker to a hospital while continuing first aid treatment.

Treatment must begin right away – delay is a significant factor in permanent brain damage.

Workers who are accidentally exposed to CO usually recover fully, if the exposure has not caused unconsciousness. It's a good idea to see a doctor before returning to work because weakness or lack of coordination may lead to accidents.

CO risk factors

The following factors may increase the risk of workers being exposed to unsafe levels of CO:

- *Confined or enclosed spaces* – Toxic levels of CO can quickly build up where ventilation is poor and combustion of carbon-containing materials occurs. This is particularly dangerous during winter months in locations such as garages or construction sites, where ventilation is further reduced as windows and doors are closed to conserve heat (or propane heaters are used).
- *Tobacco smoking* – Smoking raises the level of COHb in the blood as well as causing lung disease. Smoking a pack of cigarettes a day may produce a COHb level of 5% in the blood. Three packs a day may produce a level of 9%. Exposure to CO on the job in addition to smoking can quickly produce toxic effects.
- *Pre-existing medical conditions* – Chronic lung and cardiovascular disease and severe anemia can limit the amount of oxygen carried in the blood to the tissues.
- *Worker training* – Workers are more likely to be harmed if they don't know the hazards of CO.

CO poisoning incident

Five workers who experienced dizziness, confusion, headaches, and nervousness were treated for CO poisoning. They were using two 8-horsepower, gasoline-powered pressure washers for four hours in an empty, poorly ventilated underground garage. When one of the five workers collapsed, his co-workers carried him outside, and remained with him for a short time. Unaware of the hazard, the co-workers then re-entered the garage. Only after a second worker collapsed did the remaining workers recognize that a hazard existed, evacuate the area, and seek help.

Reducing the CO risk

The risk of unsafe levels of CO can be reduced with the following controls:

- *Engineering* – Increase the efficiency of burning processes, repair leaks in burners, switch from petroleum to electric energy when risk is high, and use catalytic converters on engine exhaust.
- *Ventilation* – Prevent the buildup of CO through the proper design of general ventilation for enclosed spaces and the use of properly designed local exhaust ventilation systems (such as tailpipe exhaust systems).
- *Isolation controls* – Isolate workers from dangerous work areas.
- *Monitoring* – CO levels must be monitored where there is a risk of CO exposure.
- *Education* – Workers must be taught how to prevent and recognize CO poisoning, and how to give first aid to those overcome by the gas.
- *Labelling and posting* – Post appropriate warning signs in areas where significant exposures to CO are likely to occur.
- *Stop smoking* – Cut down on smoking or quit entirely to reduce the personal hazard from CO on the job.

CO levels emitted by construction equipment

Equipment	Concentration in parts per million (ppm)
Propane floor polisher	155
Water pump	200 to 400
Air compressor	320
Chainsaw	455
Pressure washer	450 to 575
Chop saw	up to 900

For more information

For more information on reducing the risk of worker exposure to CO, see the following documents:

- WorkSafeBC Guidelines G5.73 and G5.75, Internal Combustion Engines (www2.worksafebc.com/publications/OHSRegulation/GuidelinePart5.asp#SectionNumber:G5.73)
- NIOSH Safety and Health Topic: Carbon Monoxide Hazards from Small Gasoline Powered Engines (www.cdc.gov/niosh/topics/co)

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