

Workplace Health and Safety Bulletin



Carbon Monoxide at the Work Site

Carbon monoxide is a colourless, odourless gas. It is usually formed from the incomplete combustion of fuels such as coal, coke, wood, oil and gasoline. Most of the carbon monoxide released into the atmosphere comes from internal combustion engines.

Carbon monoxide is a flammable gas. Mixtures of 12 to 75 per cent carbon monoxide in air can catch fire and explode when there is a source of ignition present. Also, when heated to high temperatures, carbon monoxide can react violently with oxidizing agents such as oxygen, ozone, peroxides and chlorine.

Sources of carbon monoxide at the work site

There are many potential sources of carbon monoxide at the work site. These include emissions from:

- internal combustion engines
- kilns
- furnaces and boilers
- welding
- moulding of plastics
- forging, ceramic, petroleum, steel and waste management industries,
- space heaters and improperly adjusted oil or gas burners
- fires and explosions
- cigarette smoking.

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Small gasoline-powered engines and tools may present a serious health risk. Gasoline-powered tools such as floor buffers, power trowels, high-pressure washers, concrete cutting saws, and generators give off combustion products that include carbon monoxide. Carbon monoxide can build-up even in areas of the work site that appear to be well-ventilated. As well, propane forklifts and ice resurfacing equipment (Zamboni®) have been found to be major sources of carbon monoxide at many work sites.

Health effects of exposure to carbon monoxide

Carbon monoxide enters the body through the lungs. Since it has no colour or odour and is not irritating, workers may be unaware for some time that they have been exposed.

Carbon monoxide is eventually breathed out. Approximately four hours after exposure stops, about half of the carbon monoxide present in the body will be exhaled. The amount of carbon monoxide taken up by the body depends on:

- the concentration of the gas in the air that is inhaled
- the length of time the person is exposed
- the person's rate of breathing.

The health effects of carbon monoxide may be greater in persons:

- with certain health conditions
- performing physically demanding work
- working in high temperatures
- working at high altitudes.

Carbon monoxide affects a person because it reduces the amount of oxygen available to the body. After carbon monoxide enters the body, it quickly combines with hemoglobin in the blood. Hemoglobin is a compound that usually carries oxygen. However, hemoglobin takes up carbon monoxide much more readily than it takes up oxygen, forming a compound called carboxyhemoglobin (COHb). The more COHb that is formed, the less oxygen the blood will be able to carry. The health effects that occur when carbon monoxide is inhaled depend on the amount of COHb in the blood.

Exposure to the solvent methylene chloride (also called dichloromethane), commonly used for degreasing and paint stripping,

can also cause COHb levels in the blood to increase because of the way it is metabolized in the body.

It is difficult to say how much COHb in the blood causes death.

- In healthy workers, COHb levels over 25 per cent are dangerous.
- In workers with heart conditions, COHb levels of as low as 10 per cent can be hazardous.
- Older workers and workers with anemia, heart or lung disease are particularly sensitive to exposure to carbon monoxide.
- Exposure to carbon monoxide can aggravate heart and artery disease and cause chest pain in people with heart problems. Workers with heart conditions should avoid exposure to carbon monoxide.

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Table 1: Health effects and COHb levels from acute exposure to carbon monoxide

Percentage of COHb in Blood	Health Effects
Less than 1.0	No health effects, normal COHb levels
2.5 to 5	No symptoms, although those with heart disease or angina may experience symptoms related to their illness with less than normal or little exertion
5 to 10	Difficulty seeing, visual disturbances
10 to 20	Slight headache, may be lethal to a fetus and persons with severe heart disease
20 to 30	Slight to moderate headache, flushing, nausea, decreased fine manual dexterity
30 to 40	Severe headache, dizziness, nausea and vomiting, weakness, irritability, impaired judgment, fainting or exertion
40 to 50	Similar to 30 to 40 per cent effects but more severe and with a greater possibility of collapse and fainting
50 to 60	Possible coma, convulsions
60 to 70	Coma, convulsions, depressed breathing rate; death can occur
70 to 80	Weak pulse and slow breathing, depression of respiratory centre leading to death

Table 2: Air concentrations and acute health effects of carbon monoxide

Concentration (ppm)	Health Effects
Less than 50	Mild headache
50 to 200	Severe headache
200 to 400	Weakness, dizziness, nausea, fainting
400 to 1200	Increased/irregular heartbeat
1200 to 2000	Loss of consciousness, death
2000 to 5000	Death may occur in minutes

Note: At very high levels of exposure (> 5000 ppm), death from cardiac arrhythmia can occur before there is a rise in blood COHb levels.

Workers who smoke should be aware that smoking a pack of cigarettes a day, with no other carbon monoxide exposure, creates a level of 5 to 6 per cent of COHb in the blood. Heavy cigar smokers can reach up to 20 per cent.

A pregnant worker who may be exposed to carbon monoxide at the work site should consult a physician. Carbon monoxide crosses the placenta and clears from the blood of a fetus at a much slower rate. As a result, a fetus is at a higher risk for health effects compared to the mother. The employer should remove the pregnant worker from exposure.

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Health assessment

A worker with symptoms of excess exposure to carbon monoxide should see a doctor at once (see Tables 1 and 2). COHb can be measured in a blood sample. Workers with high levels of COHb in their blood may need to be treated, or at least watched, to ensure their safe recovery.

To ensure the validity of a blood sample:

- The blood test must be done immediately following a worker's exposure. (COHb has a half-life of about four hours, with a person at rest and breathing room air).
- Identify other sources of carbon monoxide the worker may have been exposed to, such as smoking.

Measuring COHb measures exposure after the fact and is not a substitute for monitoring workplace air.

Interpreting COHb measurements

According to the American Conference of Governmental Industrial Hygienist (ACGIH), the Biological Exposure Index (BEI[®]) for carbon monoxide is 3.5 per cent COHb in the blood, measured at the end of a shift. Alternatively, the BEI for carbon monoxide in end-exhaled air measured at the end of shift is 20 ppm. BEIs[®] adopted by the ACGIH represent levels of a substance likely to be found in samples taken from healthy workers who have been exposed to a chemical to the same extent as workers exposed at the Occupational Exposure Limit (OEL) in Alberta's health and safety legislation. Exposure at the 8-hour OEL of 25 ppm would typically result in a COHb level in the blood of between 3 and 4 per cent. The BEI for carbon monoxide is not applicable to smokers, who may have a level of over 3.5 per cent without workplace exposure.

Preventing exposure

Preventing exposure to carbon monoxide is the best way to protect health. The most effective way to prevent exposure is to identify the source of the carbon monoxide and eliminate it. When this is not possible or practicable, sources of carbon monoxide must be controlled to prevent exposure. To control exposure to sources of carbon

monoxide, employers may choose from the following options (listed in order of preference):

- use of engineering controls
- changes in work practices to reduce exposure (administrative controls)
- use of personal protective equipment.

Engineering controls

Engineering controls are mechanical processes used to eliminate exposure to a substance. These controls remove the substance from the air or provide a barrier between the worker and the substance. Examples of engineering controls that can be used to prevent exposure to carbon monoxide include:

- installation of local or general ventilation that is properly designed for the space
- substituting, wherever practical, electrical or air-powered equipment for tools or vehicles that use fuels such as gasoline or propane
- providing enclosures and exhaust systems for work processes that produce carbon monoxide
- ensuring regular inspection, maintenance and tuning of fuel-powered equipment and tools
- providing properly designed and located air-supply and exhaust systems for fuel-burning appliances such as furnaces, hot water boilers and heaters.

If engineering controls are working properly, they will eliminate or greatly reduce the potential hazard of carbon monoxide exposure. They need only be installed once and do not place a physical burden on workers. However, an initial investment is required, and the systems must be properly operated and maintained once installed.

Internal combustion engines

Equipment powered by fuels such as gasoline, propane or diesel should be operated outside, where possible, and away from the building's fresh air intakes. When this type of equipment must be used indoors, it is essential to install properly designed ventilation systems and to ensure they are properly maintained. For example, when performing vehicle maintenance, flexible ducting can be connected to the vehicle exhaust to discharge the exhaust outside the building. Where local ventilation systems like this are used, they must be designed so as to not vent back into the work area.

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Equipment powered by fuels such as gasoline, propane or diesel should be operated outside, where possible, and away from the building's fresh air intakes.

Opening doors and windows or operating fans is not considered a ventilation system and may not ensure adequate ventilation to remove build-ups of carbon monoxide.

ACGIH has developed recommendations and design criteria for ventilation systems for vehicle exhaust. For more information, refer to ACGIH publication, *Industrial Ventilation, A Manual of Recommended Practice*, 26th Edition, Chapter 13, pages 13-149 to 13-151. The same reference also provides guidance for local exhaust ventilation for vehicles operated inside a building. ACGIH publications are available for purchase at:

 www.acgih.org/store

The indoor use of propane- or gasoline-fuelled equipment, such as forklifts, has been linked to carbon monoxide exposure in workers. To protect workers' health it is worth considering replacing such equipment with electric or diesel-powered alternatives. If the equipment cannot be replaced, employers must ensure there is regular engine maintenance and it is equipped with catalytic converters.

Good driving can also help reduce the amount of carbon monoxide vehicles produce. Drivers increase the amount of carbon monoxide produced (as well as burn more fuel) when they:

- race a vehicle's engine
- brake erratically
- allow vehicles to idle
- operate hydraulic systems in a jerky manner
- start forklift trucks after they have been parked in cold areas such as freezers, or outdoors in winter (cold starts tend to generate higher concentrations of carbon monoxide).

Administrative controls

Work practices that can be implemented to reduce the potential exposure to carbon monoxide include:

- educating workers about the hazards associated with carbon monoxide and warning signs of overexposure. Workers must participate in training and monitoring programs at the workplace.
- ensuring that engineering controls and other equipment used to reduce exposure are used and maintained properly.
- use of personal or area carbon monoxide monitoring equipment, where there are potential sources of carbon monoxide. This

equipment should have audible alarms that will warn workers when carbon monoxide concentrations are too high. These instruments should alarm at a level below the OEL for carbon monoxide.

Monitoring equipment

It is important to select monitoring equipment that fits the needs of the work environment. Carbon monoxide detectors sold for use in residential homes are not be designed for use in work settings. When selecting equipment, the user should also find out what substances could interfere with the equipment. For example, some gases, such as nitrogen dioxide or sulphur dioxide, can interfere with the instrument sensor if they are present in concentrations above 5 ppm. Purchasers should discuss potential interference with the supplier of the equipment and buy appropriate accessories, if necessary. The equipment must also be calibrated and maintained according to the manufacturer's recommendations. If air monitoring is performed to determine compliance with Alberta's OEL for carbon monoxide, a method specified in Section 20 of the Occupational Health and Safety Code must be used.

Carbon monoxide monitors sold for use in residential homes may not be designed for use in work settings.

Although implementing work practices to reduce exposure is often less expensive than other control measures, employers must ensure that workers are properly trained and follow the safe-work practices.


Personal protective equipment


If it is not practicable or feasible to use engineering controls or change work practices to reduce the potential for exposure to carbon monoxide, the employer must provide workers with appropriate respiratory protective equipment. There are many types of respirators available. It is important to select the correct level of respiratory protection depending on the type of work being done and the airborne concentrations of carbon monoxide that may be encountered.


Since carbon monoxide has no odour and no irritation effects, use of air-purifying respirators is not recommended unless the cartridges are equipped with end-of-use indicators. An air-purifying respirator may be used if a qualified person calculates a change-out schedule according to

the manufacturer's product information or makes estimates based on knowledge of the effectiveness of the cartridge or canister to remove the contaminant. Calculated change-out schedules must be based on the U.S. Occupational Safety and Health Administration (OSHA) method, or an equivalent. The employer must also provide written procedures that explain how the calculations are made, confirm the method used for calculations and ensure workers understand and use the system for cartridge change-out.

For more information about respirators, see:

 www.osha.gov/SLTC/etools/respiratory/change_schedule.html
OSHA method for calculating change-out schedules

 http://employment.alberta.ca/documents/WHS/WHS-PUB_ppe004.pdf
Guideline for the Development of a Code of Practice for Respiratory Protective Equipment (PPE004)

 http://employment.alberta.ca/documents/WHS/WHS-PUB_ppe001.pdf
Respiratory Protective Equipment: An Employer's Guide (PPE001)

 CSA Standard Z94.4-02, *Selection, Use and Care of Respirators*

Although the use of personal protective equipment may initially seem to be less costly, workers must be properly trained to use the protective equipment. Employers must monitor use and ensure that the protective equipment is properly maintained.

In some cases, personal protective equipment can create hazards for workers using the equipment, such as heat stress, limited vision and allergic reactions to the equipment material. All such health-related considerations should be examined when selecting personal protective equipment.

Regulatory requirements

Alberta occupational health and safety legislation includes specific

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requirements related to carbon monoxide. The OEL for carbon monoxide is 25 ppm, based on an 8-hour work shift. If work shifts are longer than 8 hours, the exposure limit must be adjusted.

For more information about adjusting Alberta's exposure limits for work shifts longer than 8 hours, see:



http://employment.alberta.ca/documents/WHS/WHS-PUB_ch055.pdf

The Effects of Unusual Work Schedules and Concurrent Exposures on Occupational Exposure Limits (CH055)

OELs apply to all workers who may be directly or indirectly exposed to carbon monoxide in the workplace. It is important to note that OELs represent standards for the protection of *most* healthy workers. Steps must be taken to keep carbon monoxide levels as low as reasonably practicable, since workers with health conditions such as anemia, lung disease, heart disease or hardening of the arteries can be adversely affected at lower concentrations.

Legislation also requires employers to:

- develop safe-work procedures
- train workers about the health hazards associated with exposure to carbon monoxide and safe-work procedures
- ensure the amount of ventilation required is properly assessed
- ensure the ventilation systems installed are properly designed and maintained
- train workers to properly operate installed ventilation systems.
- provide appropriate personal protective equipment, including respirators, where airborne concentrations of carbon monoxide cannot be kept below safe limits.

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