Guidance Notes on Prevention of Carbon Monoxide Poisoning in Workplaces

Labour Department

safety at work

These Guidance Notes are published by the
Occupational Safety and Health Branch
Labour Department

First edition December 2025

Publications and Media -
Occupational Health

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Contents

1. Introduction

1.1 Carbon monoxide (CO) is a colourless, odourless and tasteless gas that can cause severe health issues, including poisoning and death. Exposure to CO at work is a significant concern, particularly in workplaces where fuel-powered (diesel/ petrol/ liquefied petroleum gas (LPG)/ towngas) equipment, engines or heating systems are used and ventilation is insufficient. These Guidance Notes offer practical information to help employers and employees prevent CO poisoning in workplaces.

1.2 According to the Occupational Safety and Health Ordinance (Cap. 509) and the Factories and Industrial Undertakings Ordinance (Cap. 59) and their subsidiary regulations, employers and proprietors are obliged to provide or maintain a working environment that is, so far as reasonably practicable, safe and without risks to health. Employers, proprietors and occupiers must ensure that any plants kept or installed in the premises are safe and without risks to health to any persons working on the premises. The responsible persons have to ensure that workplaces are adequately ventilated by fresh air, and that the air within workplaces is kept free of impurities as far as reasonably practicable. They must also take all reasonably practicable steps to protect employees from inhaling impurities and to prevent accumulation of impurities in workplaces.

1.3 CO is a chemical asphyxiant that significantly impairs the body's capacity to transport oxygen. Exposure to CO can result in a range of adverse health effects, from headaches, dizziness, tiredness and nausea to unconsciousness and even death, depending on the level and duration of exposure. Common sources of CO in occupational settings include petrol-powered machinery, gas appliances, internal combustion engines, LPG fork-lift trucks, etc. To mitigate the risk of CO exposure, employers and employees should adopt preventive measures, which should encompass ensuring adequate ventilation, conducting regular equipment maintenance, using/ installing CO detectors, and providing comprehensive training for workers on hazard recognition and emergency protocols.

1.4 These Guidance Notes provide employers, proprietors, contractors, occupiers and employees with practical information to prevent CO poisoning in workplaces. It outlines the sources and hazards of CO, risk assessment, preventive measures, monitoring and measurement, emergency response plan, and training requirements. These Guidance Notes should be read in conjunction with other relevant publications published by the Labour Department.

1.5 These Guidance Notes mainly focus on the risk of gas poisoning or asphyxiation arising from CO exposure while at work. It is applicable to both industrial and non-industrial workplaces. The duty holders (including employers, proprietors or occupiers) should comply with the relevant requirements of these Guidance Notes where practicable. These Guidance Notes, however, do not cover all the occupational safety and health matters in workplaces.

2. Carbon Monoxide (CO) Hazards in Workplaces

2.1 CO is a colourless, odourless, and tasteless gas that is highly poisonous. It is a common occupational hazard with a major source from the incomplete combustion of carbon-based fuels, such as natural gas, petrol, kerosene, diesel, oil, propane, coal, and wood. While CO can be produced by using gas appliances or charcoal grills, one of the most prevalent reasons of exposure in workplaces is the use of internal combustion engines, such as those used in mobile generators.

2.2 Inhaled CO prevents blood from carrying oxygen to body tissues, consequently depriving vital organs like the heart and brain of this essential gas. Concentration of CO as little as 0.4% or 4,000 parts per million (ppm) in the air can cause unconsciousness and death in a few minutes.

Symptoms of CO Poisoning

2.3 Awareness of the symptoms is crucial for early detection of CO poisoning. The severity of health effects depends on factors such as duration of exposure and concentration of CO inhaled. Common symptoms of CO poisoning include:

- Headache (most common)
- Nausea
- Dizziness
- Drowsiness and tiredness
- Impaired vision
- Disturbed coordination
- Confusion
- Loss of consciousness
- Brain damage
- Myocardial ischemia
- Death

Note: "Cherry red" skin colouration is a classical description for CO poisoning but it is neither sensitive nor specific.

2.4 The presentation of CO poisoning can vary significantly from person to person. All people are at risk of CO poisoning if the gas is inhaled. Those at higher risk include children, the elderly, individuals with anaemia, lung or heart disease and smokers.

2.5 CO poisoning can be reversed if detected early and refrained from further exposure. However, complications related to the nervous system such as memory loss, personality changes and movement problems can appear after recovery from CO poisoning and the risk of such complications is higher in the elderly and people who lost consciousness due to CO poisoning.

Sources of CO in Workplaces

2.6 CO is produced during incomplete combustion of carbon-based fuels. Common sources of CO in workplaces include fuel-powered equipment such as generators, pressure washers, chain saws, and floor polishers. Other sources include fuel-powered fork-lift trucks, certain welding machines, heating and cooking appliances (such as gas stoves, gas heaters, and charcoal grills), and exhausts from the operating motor vehicles, etc.

2.7 Workers in various occupations may face a risk of CO poisoning, particularly when using fuel-powered equipment in enclosed or partially enclosed areas. Common examples include workers operating concrete cutters, pressure washers, and generators indoors or in basements; vehicle mechanics working on running engines in garages; and operators of LPG or diesel fork-lift trucks in warehouses or cold stores.

2.8 It is essential to avoid using petrol, gas or diesel powered equipment in enclosed or partially enclosed areas. Poor ventilation is a critical factor that allows CO to build up to dangerous levels. Even in areas that appear to be well-ventilated, CO may still accumulate to high concentrations locally if the gas is generated or released rapidly. In addition, disrupted gas flues or defective exhaust systems in buildings can also lead to accumulation of CO. Inadequate maintenance of fuel-powered equipment can also lead to increased CO emissions and a higher risk of CO poisoning. Even brief use of fuel-powered equipment in enclosed areas can rapidly accumulate CO to a dangerous level.

Occupational Exposure Limit for CO

2.9 Under the “Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace” issued according to Section 7A(1) of the Factories and Industrial Undertakings Ordinance (Cap. 59), occupational exposure limit (OEL) refers to the airborne concentration(s) of individual chemical agents that represent levels that are regarded to impose no adverse health effects to nearly all workers on exposures by the route of inhalation. The "Occupational Exposure Limit - Time-Weighted Average (OEL-TWA)" for CO is 25 ppm, based on an eight-hour workday for a five-day workweek. Short term excursions above the OEL-TWA may be allowed provided that they are compensated by lower exposure during the workday and the overall OEL-TWA is not exceeded. The exposure level should not be permitted to exceed 75 ppm for more than an accumulated period of 30 minutes during a workday, and under no circumstances should be allowed to exceed 125 ppm.

3. Examples of CO Poisoning Happened in Workplaces

CO poisoning is preventable. This chapter features some common examples of workplace accidents in which workers suffered from CO poisoning and the corresponding preventive measures.

3.1 Use of fuel-powered equipment in poorly ventilated or enclosed areas

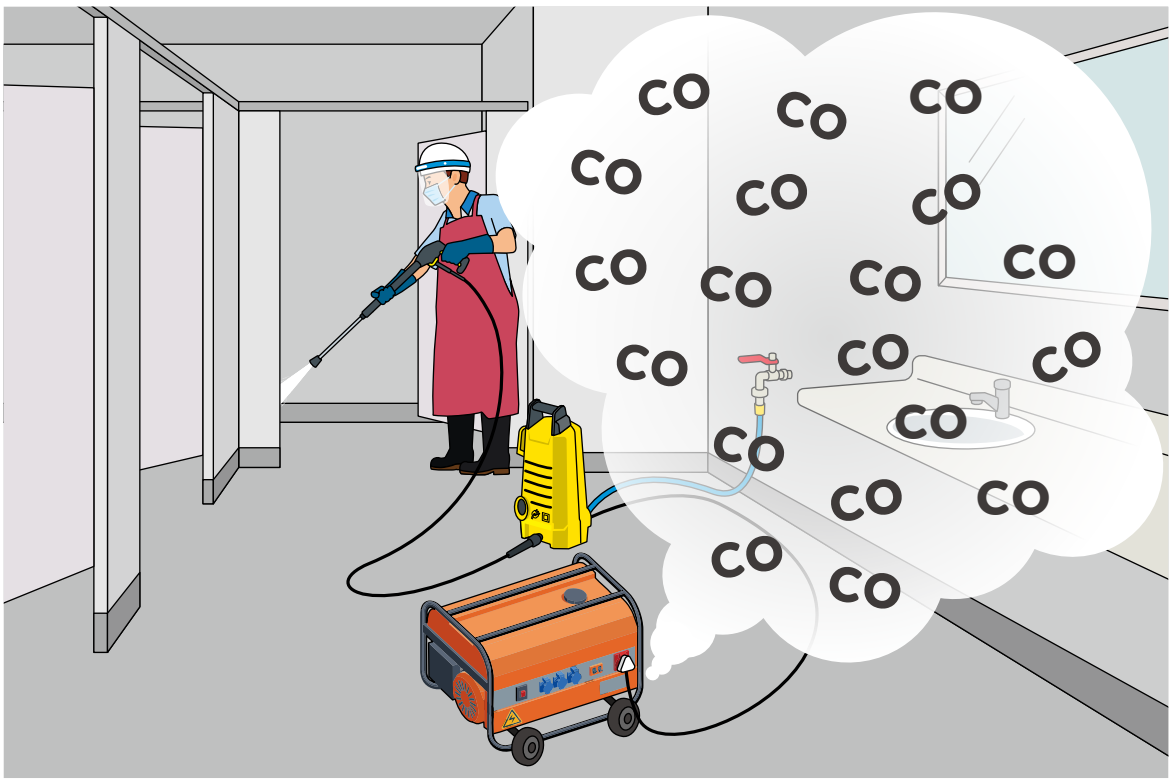
Brief case description

Case 1: A plumber felt dizzy and then fell unconscious when using a high-pressure water jet connected to petrol-powered generator inside a public toilet.

Case 2: A group of concrete workers felt dizziness and later lost consciousness when working with petrol-powered vibrators for packing wet concrete in an indoor construction site.

Case analysis

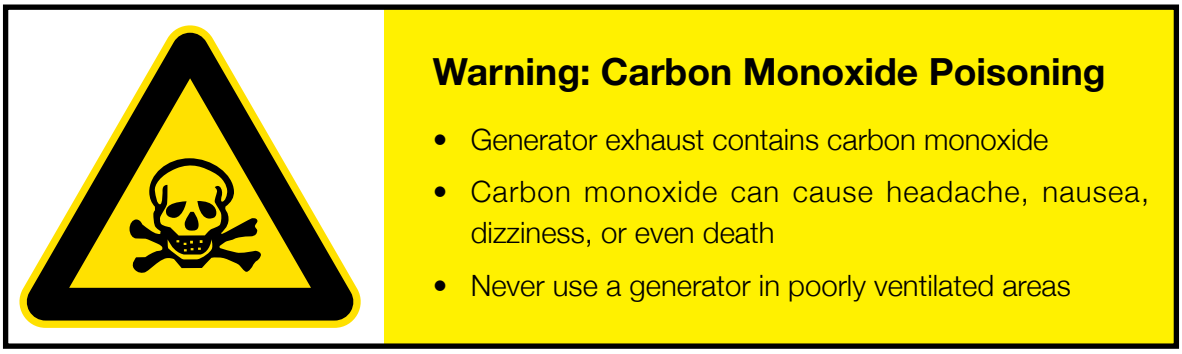
- Fuel-powered equipment and generator with internal combustion engines emitted exhaust containing CO.
- As the work areas were enclosed and poorly-ventilated, CO could not be removed effectively and then accumulated indoors.
- The management and workers lacked awareness of CO emission from equipment and did not follow the precautions provided by the manufacturer of the equipment. Thus they took no precautions by using petrol-powered equipment in poorly ventilated indoor areas.



Using petrol-powered equipment in a poor ventilated area poses risk of CO poisoning

Preventive measures

- Responsible persons should conduct a risk assessment to identify all potential sources of CO exposure in workplaces. They should always eliminate the use of petrol-powered engines in poorly ventilated areas, even when doors and windows are open. They should substitute with electric, hydraulic or pneumatic powered equipment without emission of CO, if possible.
- The generator and internal combustion engine should be placed away from the work area. A suitable CO detector should be used for monitoring the concentration of CO and alerting workers to take actions accordingly.
- Responsible persons should follow the precautions in the operation manual and ensure proper repair and maintenance of equipment. Warning signs of potential CO hazards should be displayed on the equipment.
- Employers should provide or arrange sufficient information, instruction, training and supervision for employees on CO hazards, symptoms of CO poisoning, controls of CO exposure and emergency procedures.



Sample warning sign for a generator

3.2 Improper maintenance of gas appliances or ventilation system failure

Brief case description

Case 3: The cooks found the kitchen hotter and stuffier than usual. They noticed that the mechanical exhaust system above the gas stoves and steamers turned weaker. While waiting for repair service, they continued using all gas stoves and steamers and later felt shortness of breath, drowsiness and tiredness.

Case 4: A cook noticed a yellow flame on the gas stoves but did not arrange for cleaning or inspection. He had a headache when cooking with the malfunctioning stoves, which subsided after he turned them off.

Case analysis

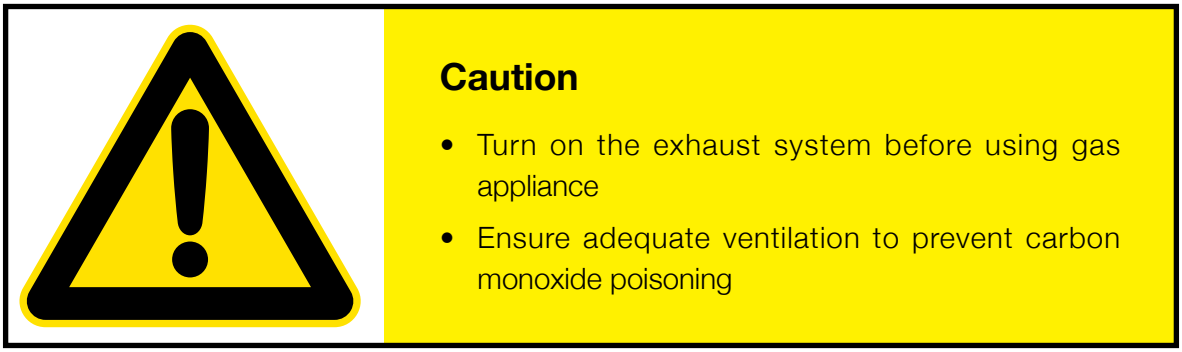
- The flue gas and air contaminants including CO will be generated when gas appliances are in operation, and poor exhaust ventilation will allow CO to build up to dangerous levels rapidly. Although the mechanical exhaust ventilation system was installed with an electrical interlock to cut off the gas supply if ventilation system failed, the interlocking mechanism did not function properly.
- The gas appliances were not properly maintained and eventually malfunctioned. The presence of a yellow flame indicated incomplete combustion of fuels, resulting in high levels of CO. Even when the ventilation system functions properly, CO can still accumulate to dangerous level if it is generated or emitted quickly.
- Both management and workers neglected the importance of effective exhaust ventilation and proper maintenance of the gas appliances and ventilation systems.

Preventive measures

- Responsible persons should conduct a risk assessment to identify all potential sources of CO exposure in workplaces.
- Responsible persons should ensure that the gas appliances connected to the mechanical exhaust system have been fitted with an interlocking device and such device is in good working condition.
- Responsible persons should ensure proper inspection, cleaning, testing and preventive maintenance of the gas appliances and mechanical exhaust ventilation system.
- Employers should provide employees with sufficient information, instruction, training and supervision on CO hazards, symptoms of CO poisoning, controls of CO exposure and emergency procedures.
- For gas installation, the statutory requirements of the Gas Safety Ordinance (Cap. 51), administered by the Electrical and Mechanical Services Department, shall be complied with.

Ensuring the exhaust ventilation system operates properly is essential when using gas stoves in kitchens

Schedule regular preventive maintenance for gas appliances and ventilation systems



Sample warning sign for using gas appliances in kitchen

3.3 Use of LPG fork-lift trucks in partially enclosed areas

Brief case description

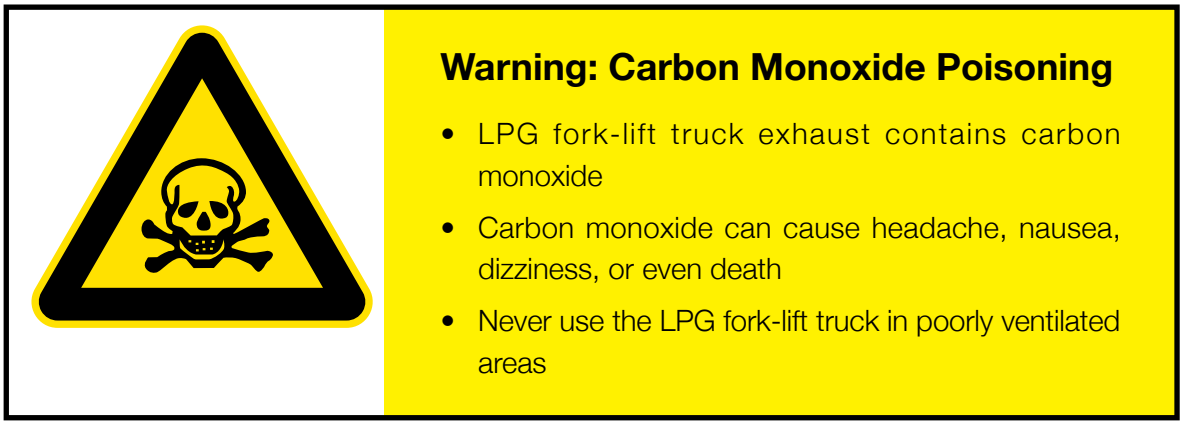
Case 5: A LPG fork-lift truck operator felt headache, tiredness and nausea after unloading pallets of goods from the freight containers at the loading bay of a warehouse. The LPG fork-lift truck was just borrowed from an open storage area.

Case analysis

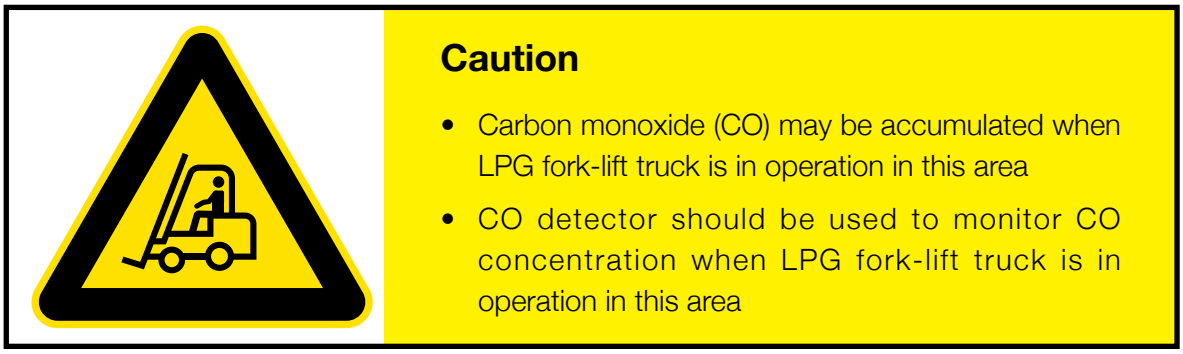
- Fork-lift trucks that run on LPG, petrol or diesel emit CO in the exhaust. In general, dangerous level of CO will not occur where fuel-powered fork-lift trucks are used outdoors or in open areas where there is good air movement. However, when fuel-powered fork-lift trucks are operated inside buildings and partially enclosed worksites, it can produce and accumulate CO to a toxic level. In tightly insulated and enclosed areas, high concentrations of CO can linger for several hours after a fork-lift truck has been operated.

Using fuel-powered fork-lift trucks in partially enclosed area can produce and accumulate CO to a toxic level

- Poorly tuned or infrequently maintained engines are likely to produce higher amount of CO. Even new, factory-tuned fuel-powered fork-lift trucks can pose a risk of CO poisoning when used in poorly ventilated environments.
- Both management and workers lacked awareness on CO emission from fuel-powered fork-lift trucks and the importance of proper maintenance.



Sample warning sign for fuel-powered fork-lift truck



Sample warning sign for fuel-powered fork-lift truck operated in partially enclosed workplaces

Preventive measures

- Responsible persons should conduct a risk assessment to identify all potential sources of CO exposure in workplaces.
- Responsible persons should maintain fuel-powered engines and other equipment regularly to minimise CO emission during operation.
- Electric fork-lift trucks instead of fuel-powered fork-lift trucks should be used in poorly ventilated workplaces.
- CO detector should be used to monitor the CO concentration if fuel-powered fork-lifts are operated in partially enclosed workplaces.
- Responsible persons should ensure adequate ventilation to remove contaminants effectively from workplaces.
- Employers should provide employees with sufficient information, instruction, training and supervision on CO hazards, symptoms of CO poisoning, controls of CO exposure and emergency procedures.

4. Preventive Measures for CO Poisoning

Prevention of CO poisoning is of paramount importance given its potential serious consequences. The prevention strategies should include identifying all potential sources of CO, eliminating or substituting harmful practices where possible, ensuring adequate ventilation in workplaces, using/installing CO detector for determining the extent of the hazard, conducting regular air quality tests, providing thorough training and awareness programs, and adhering to established exposure limits and safe work practices, etc.

4.1 Elimination and Substitution

4.1.1 The best way to prevent CO poisoning is to remove the sources of CO entirely from the working environment. Employers should substitute fuel-powered engines or equipment with electric, hydraulic or pneumatic equipment without emitting CO during operation, and eliminate using fuel-powered engines or equipment in poorly ventilated or enclosed areas.

Substitute fuel-powered equipment with electric, hydraulic or pneumatic equipment in poorly ventilated or enclosed areas

4.2 Engineering Controls

4.2.1 Effective ventilation is another means to reduce accumulation of CO from the working environment. Direct venting, local exhaust ventilation system, or portable exhaust device can be deployed to remove exhaust gas from work areas.

4.2.2 The responsible persons of the workplaces should ensure that proper ventilation is in place in work areas when using any fuel-powered equipment. The following types of mechanical ventilation should be prioritised for controlling CO at the source or reducing CO accumulation in workplaces.

- **Direct venting:** Ensure all fuel-powered appliances (such as boilers, heaters) are properly installed with flues or chimneys that vent exhaust containing CO directly outdoors. Inspect and maintain these venting systems regularly to prevent blockages.
- **Local exhaust ventilation (LEV):** Capture CO at the source before it diffuses to the general workplace air. Examples include installing exhaust hoods over cooking appliances or industrial processes to capture exhaust directly. LEV systems must be properly designed, installed, used and maintained to ensure effective performance.

An LEV system can be used during the welding process to remove contaminants

- **General ventilation:** Increase the number of air changes in workplaces by using mechanical ventilation such as extraction fans, or air conditioning systems with fresh air intake supplemented by natural ventilation (e.g. through windows, doors, vents) can dilute the concentration of CO in workplaces. The responsible persons of the workplaces should ensure ventilation systems are functioning properly, well-maintained, with adequate airflow and sufficient fresh air supply relative to the potential CO generation rate. It is also important that there is a dedicated source of fresh air and a directional airflow from clean to dirty areas to improve the dilution efficiency. In general, appropriate air change rate should be determined if removing CO from indoor environment is required, depending on factors such as the dimension of workplaces and the number and condition of any fuel-powered equipment in use.

  Caution: Natural ventilation by opening windows and doors is unlikely to be sufficient for removing exhausts with CO from workplaces, especially with significant emissions.

4.3 Administrative Controls

4.3.1 Administrative controls can also minimise the risk of CO poisoning, including:

- **Work practices:** Prohibit idling engines indoors, maintain equipment properly, reduce workers' exposure time, arrange workers to work in well-ventilated areas.
- **Warning signs:** Clearly mark potential CO sources/hazardous areas.
- **Training:** Provide training for employees on CO hazards, symptoms of CO poisoning, appropriate control measures, and emergency procedures.
- **Monitoring programme:** Implement a programme to regularly measure and monitor CO levels in workplaces.

4.3.2 Poorly maintained fuel-powered equipment produces more CO. Regular inspections and preventive maintenance of equipment (e.g. fork-lift trucks, heaters, backup generators, gas appliances etc.) that can produce CO is vital to ensure that they function properly and produce minimal CO. Stop using malfunction equipment immediately. Replace or repair the equipment.

4.3.3 Regularly inspect and maintain ventilation systems to ensure that they are functioning properly. Ineffective ventilation systems fail to remove CO from workplaces and lead to CO accumulation, thus increasing risk of CO poisoning.

4.3.4 Responsible person should obtain the user instructions from the equipment manufacturers or suppliers to understand the dangers of CO emission and when using such equipment indoors. Clear instruction and suitable warning signs should be posted in areas and on equipment with potential CO hazards.

4.3.5 Fuel-powered generators, compressors, and other engine-driven equipment should be operated in well-ventilated outdoor areas, at least 5 metres away from any building openings (windows, doors, garages, etc.) and away from air intakes, to prevent exhaust contaminants from being drawn into the buildings.

4.3.6 It is recommended to provide personal CO detectors with both audible and visible alarms to workers in situations where potential high levels of CO exposure exist. Regular air testing should also be conducted in areas where CO may be present, particularly in poorly ventilated areas. Additionally, installing CO detectors in areas where internal combustion engines are operated (e.g. using fuel-powered fork-lift trucks in semi-enclosed loading bay) can offer early warning of accumulation of CO and is an effective measure to prevent CO poisoning in workplaces. Be sure to regularly calibrate and maintain these detectors according to the manufacturer's instructions.

5. Safe System of Work

In accordance with the Occupational Safety and Health Ordinance (Cap. 509) and the Factories and Industrial Undertakings Ordinance (Cap. 59), employers and proprietors have the duty to ensure, so far as reasonably practicable, the safety and health of their employees at work. Such duty includes the provision and maintenance of systems of work that are, so far as reasonably practicable, safe and without risks to health. Failure to comply with these general duty provisions may lead to prosecution. An employer/proprietor/occupier who commits an offence is liable to a maximum fine of $3 million and imprisonment for 6 months on summary conviction, or to a maximum fine of $10 million and imprisonment for 2 years on conviction on indictment.

5.1 Risk Assessment and Control Measures

5.1.1 Employers/proprietors/contractors must conduct a thorough risk assessment which can identify potential CO sources in workplaces and evaluate the likelihood and level of CO exposure to facilitate the formulation of necessary measures to control workers' CO exposure at minimal:

- **Identifying equipment** that may produce CO, e.g. equipment powered by fuel-powered engines (such as generators, pressure washers, fork-lift trucks, small petrol engines), and gas appliances (such as heaters and stoves). Processes like carbon dioxide arc welding or oxy-acetylene brazing may also be sources of CO. It should be noted that the condition and maintenance of equipment may affect the CO emission; and
- **Evaluating workplaces and ventilation systems** to ensure adequate air exchange and dissipation of CO. When considering ventilation for effective control of CO, direct venting or LEV for capturing CO at source before its dispersion is recommended. In addition, attention should be given to the renovation or maintenance work in existing buildings that may disrupt the ventilation systems.

5.1.2 The findings of any significant risks during the risk assessment and the corresponding control measures implemented should be recorded properly. The risk assessment results should be reviewed regularly (e.g. annually), and whenever there is significant change (e.g. new equipment or processes) or occurrence of incidents at work. Preventive measures should be updated as necessary to ensure appropriate control of altered risks.

5.2 Monitoring and Measurement of CO

5.2.1 Air monitoring can be conducted to assess workers' exposure, evaluate the effectiveness of control measures, detect potential faults and alert personnel to activate emergency procedures:

- **Instrumentation:** Use direct-reading CO detectors (portable or fixed) equipped with electrochemical sensors or other suitable detection means. Ensure instruments are appropriate for the expected CO range and are regularly calibrated according to manufacturer's instructions. The short-term exposure alarm level should be set at 35-37 ppm.
- **Monitoring strategy:** Conduct monitoring in areas where CO sources are located and where workers are present. Personal CO detectors can be worn by workers when working in areas with potential high CO level. Conduct monitoring during representative work periods, including peak emission periods or when performing specific high-risk tasks to ensure the CO exposure of workers in workplaces is below the OELs, i.e. not exceeding the OEL-TWA and excursion mentioned in paragraph 2.9.
- **Record keeping:** Maintain records of all monitoring results, including date, time, location, monitoring duration, instrument details, calibration records, and comparison with OELs, etc.

5.3 Information, Instruction, Training and Supervision

5.3.1 Employers/proprietors/contractors must provide adequate information, instruction, and training to all workers potentially at risk of CO exposure. The following areas should be covered:

- What CO is and its properties
- Health hazards and symptoms of CO poisoning
- Potential sources of CO in their specific workplaces
- Safe work procedures and risk control measures required
- Proper use and maintenance of equipment and ventilation system and reporting of malfunction
- How to use CO detectors and respond to alarms, if provided
- Emergency procedures and reporting of CO poisoning

5.3.2 Training shall be provided upon induction, repeated periodically (refresher training), and whenever work processes or hazards change. Ensure information is provided in a language and format workers can easily understand.

5.3.3 Proper supervision should be exercised to ensure that preventive measures are effectively implemented.

5.4 Emergency Procedures and Record Keeping

5.4.1 Establish proper emergency procedures for CO poisoning and conduct drills for emergency evacuation periodically:

- **Recognise symptoms:** Train workers to recognise the symptoms of CO poisoning.
- **Immediate action:** If a CO alarm is triggered and CO poisoning is suspected:
  - Assess the surrounding environment. Ensure safety before entering the scene. **Do not enter an area where CO is suspected to be present** to rescue someone without appropriate self-contained breathing apparatus and training
  - Immediately turn off the source of CO ***if safe to do so.***
  - Evacuate everyone from the affected area promptly
  - Move the injured person to a well-ventilated and safe place
  - Call for an ambulance and report suspected CO poisoning. Wait for emergency services

5.4.2 Report any CO-related accident which occurs in a workplace to the Labour Department according to Section 13 of the Occupational Safety and Health Ordinance (Cap. 509).

5.4.3 Maintain comprehensive records related to CO poisoning prevention, including:

- Risk assessments
- Details of control measures implemented (e.g. ventilation specifications, maintenance logs)
- Equipment inspection and maintenance records (for engines, appliances, ventilation, CO detectors)
- Air monitoring results and calibration records
- Emergency procedures
- Training records for employees
- Records of any incidents or accident, if applicable

6. List of References

1. Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace (Labour Department, Hong Kong)

2. Reporting Workplace Accidents and Dangerous Occurrences (Labour Department, Hong Kong)

3. Carbon Monoxide Poisoning (Hong Kong Poison Control Network, Hong Kong)

4. Handbook on Design, Operation and Maintenance of Gas Utilisation Facilities (Electrical and Mechanical Services Department, Hong Kong)

5. Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers - Centralised Processing of Building Plans (Buildings Department, Hong Kong)

6. GB 2894-2008 Safety signs and guideline for the use
中華人民共和國國家標準 GB 2894-2008安全標誌及其使用導則 (中華人民共和國國家質量監督檢驗檢疫總局、中國國家標準化管理委員會)

7. GBZ/T 223-2009 Specification of setting monitoring and alarming devices for toxic gas in the workplace
中華人民共和國國家職業衛生標準 GBZ/T 223-2009 工作場所有毒氣體檢測報警裝置設置規範 (中華人民共和國衛生部)

8. Carbon Monoxide Poisoning (U.S. Centers for Disease Control and Prevention, USA)

9. Carbon monoxide poisoning in workplaces (Government of Ontario, Canada)

10. Controlling the risk of carbon monoxide poisoning - Forklifts and carbon monoxide (WorkSafe New Zealand, New Zealand)

7. Enquiries and Complaints

If you wish to enquire about these Guidance Notes or require advice on occupational safety and health (OSH) matters, please contact the Occupational Safety and Health Branch of the Labour Department (LD) through:

Telephone : 2852 4041 or
2542 2172 (auto-recording service available outside office hours)

Fax : 2915 1410

E-mail : enquiry@labour.gov.hk

If you have any complaint about unsafe operations and environments at workplaces, please call the LD's OSH complaint hotline at 2542 2172 or fill out and submit an online OSH complaint form on the LD's website. All complaints will be treated in the strictest confidence.

Online OSH Complaint Form

Information on the services offered by LD and major labour legislation is also available on our website at https://www.labour.gov.hk. The latest OSH information can be obtained through the LD's "OSH 2.0" Mobile Application. For details on the services offered by the Occupational Safety and Health Council, please visit www.oshc.org.hk or call 2739 9000.

Labour Department's Website

"OSH 2.0" Mobile Application

Published by the Labour Department
Printed by the Government Logistics Department
12/2025-1-OHB134e