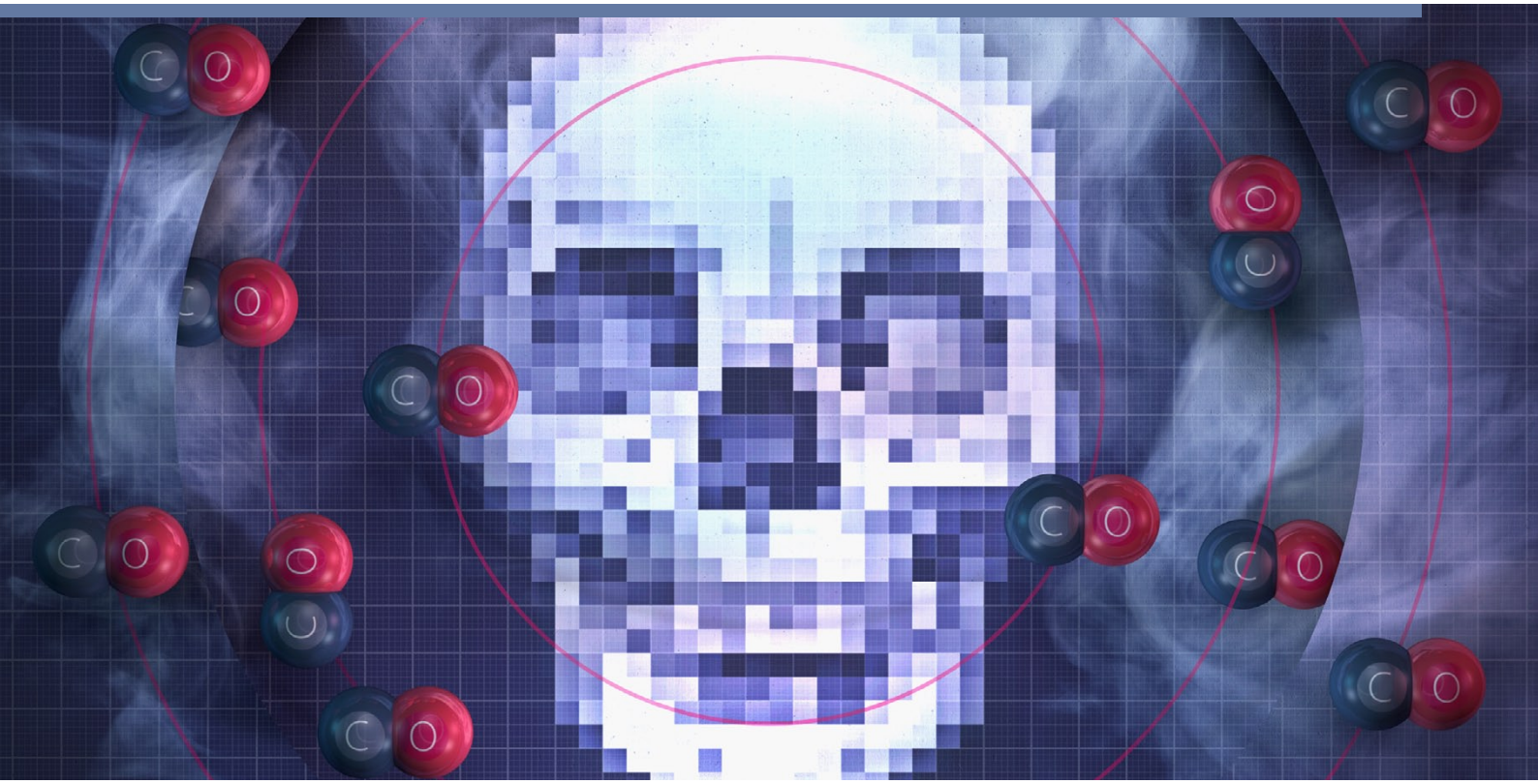


Carbon monoxide poisoning: a hidden danger

Carbon monoxide is an odourless, colourless and tasteless gas. People exposed to high levels are likely to require emergency management. However, lower levels of exposure may go unnoticed. People who are repeatedly exposed to carbon monoxide may present to primary care with a range of non-specific symptoms such as headache, lethargy, memory difficulties, sleep disturbances or mood changes. Consider carbon monoxide poisoning as a potential differential diagnosis by asking patients about possible sources of exposure in their home or workplace.

KEY PRACTICE POINTS:

- Exposure to carbon monoxide can occur via many common household or occupational activities, e.g. heating, some cooking appliances and exhaust fumes
- Repeated exposure to low levels of carbon monoxide may be overlooked as people do not realise they are exposed and symptoms are non-specific, such as headache, lethargy, dizziness or loss of balance, mood changes, difficulty concentrating or sleep disturbances.
- To assess the likelihood of carbon monoxide poisoning: establish a potential source of exposure, look for a pattern of symptoms, e.g. worsening while at home in the evening and improving when out of the house, and enquire whether other people in the same location have symptoms
- People with repeated low-level exposure typically experience a resolution of symptoms once the source of carbon monoxide is eliminated, unless there has been underlying neurological damage.
- Testing of carboxyhaemoglobin levels is unlikely to be useful for patients with low level carbon monoxide exposure as levels begin to decrease once a person leaves the source; results can also be confounded by smoking
- Pulse oximetry is not useful for diagnosing carbon monoxide poisoning as it is unable to distinguish between carboxyhaemoglobin and haemoglobin bound to oxygen so will give falsely high readings
- All cases of suspected carbon monoxide poisoning must be notified to the Medical Officer of Health, which can be done using the Hazardous Substances Disease and Injury Reporting Tool available via Medtech, MyPractice and Profile Patient Management Systems. Contact your local Public Health Unit directly to report the exposure if your practice does not have access to the tool.

Exposure to carbon monoxide can occur from a range of sources

Carbon monoxide is produced by combustion of fossil fuels such as liquid petroleum gas (LPG), diesel and petrol, as well as other combustible materials such as wood and paper. Exposure can occur from a range of activities involving heating, cooking and transport, particularly if appliances are not correctly ventilated, are faulty or poorly maintained (Table 1). The use of appliances in an inappropriate manner, such as moving a barbecue inside or using a gas oven for heating, is also a cause of exposure. Carbon monoxide cannot be detected by smell, taste or irritation of the airways, therefore people can be unaware of exposure, particularly if the symptoms are not severe enough to be recognised as an acute poisoning event.[1]

High levels of carbon monoxide exposure requires emergency management

Exposure to moderate to high levels of carbon monoxide can rapidly cause severe symptoms and progress to fatality, due to hypoxia and other factors associated with carbon monoxide poisoning (see: "Effects of carbon monoxide poisoning"). In New Zealand, carbon monoxide exposure resulted in 379 deaths from 2006 to 2014, with 96% of these intentional exposures.[2] The severity of carbon monoxide poisoning depends on the level and duration of exposure, although some people are more susceptible than others.

People who are particularly vulnerable to the effects of carbon monoxide poisoning include:[3]

- Infants and children, due to a higher respiration rate for their body mass
- Pregnant females
- Older people with frailty
- Those with co-morbidities such as cardiovascular disease, respiratory conditions or anaemia

Carbon monoxide is inhaled in cigarette smoke, and people who smoke appear to have an increased tolerance to carbon monoxide exposure, with fewer symptoms until higher concentrations are reached.[4]

For further information, see: "Emergency management of carbon monoxide poisoning"

Table 1: Potential sources of exposure to carbon monoxide [6, 7]

Potential source	Precautions to prevent exposure
■ Un-flued fuel heaters, e.g. LPG, wood or charcoal ■ Portable, un-flued gas cookers, e.g. for camping ■ LPG-powered fridges without venting, e.g. in caravans ■ Diesel generators or diesel or petrol-powered machinery used indoors, in an attached garage or with exhaust entering an open window ■ Running a vehicle in an enclosed garage, particularly if attached to a house ■ Using petrol or diesel chainsaws or cutting equipment or welding in confined spaces ■ LPG powered forklifts or platforms, particularly if used in poorly ventilated spaces such as cold storage rooms ■ Working on fossil fuel powered vehicles or machinery, e.g. a car mechanic ■ Inhalation of smoke from a fire, e.g. bonfires or burn-offs	These sources normally produce carbon monoxide and require adequate ventilation to prevent exposure
■ Gas or wood burning for heating or cooking: – Open fireplaces or wood burners – Flued LPG gas fires – Flued gas cookers or gas ranges with rangehoods – Pellet fires – Outdoor barbecues – Boilers or central heating systems – Kilns ■ Vehicles with faulty exhaust systems or with a blockage in the exhaust, such as snow or mud from driving off-road	These sources are typically associated with little risk but can result in exposure if equipment is faulty, poorly maintained or used improperly, e.g. a BBQ or patio heater used indoors, a gas oven used with the door open for heating
■ Cigarette smoking ■ Waterpipe (hookah) smoking, which results in more carbon monoxide exposure than cigarette smoking[8]	These activities involve inhaling carbon monoxide and quitting or smoking less is the only way to reduce exposure

Lower levels of carbon monoxide exposure may go unnoticed

It is uncertain how many people are exposed to non-fatal levels of carbon monoxide, as not all exposures are recognised or reported, and some people do not seek treatment or receive a diagnosis.

Depending on the specific circumstances, low level repeated exposure to carbon monoxide may result in a combination of both acute and chronic symptoms (Table 2).[4] There is little evidence available regarding the long-term health effects of this type of exposure. Patients may have a complete resolution of symptoms once the source is discovered and removed.[4] However, in some instances repeated low level exposure has caused underlying neurological damage resulting in permanent symptoms.[5] People who are unknowingly being exposed are also at risk of a potential fatal or severe poisoning event if the level of exposure increases.

Table 2: Symptoms of exposure to carbon monoxide. Adapted from Ashcroft *et al.*[4]

Acute exposure, i.e. short-term inhalation of moderate to high concentrations	**Chronic exposure**, i.e. repeated exposure to lower concentrations
■ Headache ■ Tiredness ■ Nausea and vomiting ■ Abdominal or chest pain ■ Shortness of breath ■ Delayed neurological symptoms†	■ Memory difficulties ■ Fatigue ■ Mood changes ■ Hearing loss* ■ Ataxia, coordination difficulties, tremors and slow movement

* Exposure to carbon monoxide can cause hearing loss and may also increase the risk of noise-induced hearing loss in industrial settings[17]

† For further information, see: "Effects of carbon monoxide poisoning"

Diagnosing carbon monoxide poisoning in primary care

There can be a wide range of potential causes of non-specific symptoms associated with carbon monoxide exposure, such as headache, dizziness, loss of balance, mood changes, difficulty concentrating, memory loss or visual disturbances (Table 2). Differential diagnoses could include a variety of neurological, infectious or endocrine conditions. However, the possibility of carbon monoxide poisoning should always be considered.

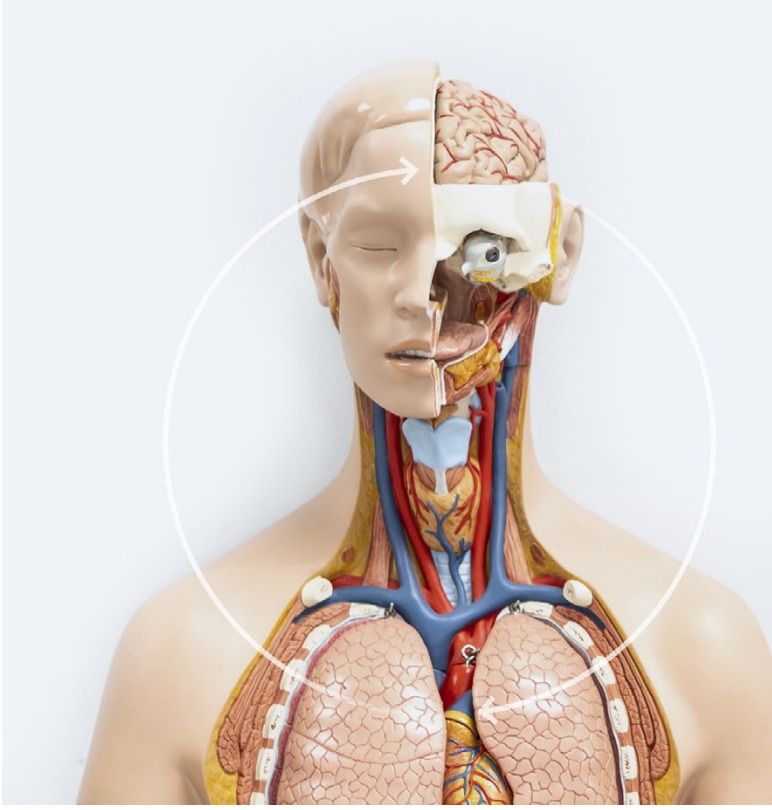
Assessing the likelihood of carbon monoxide poisoning begins with establishing if there is a potential source (Table 1) and identifying whether the patient's symptoms have a pattern of onset or worsening consistent with exposure to that source. In published cases, people with repeated exposure to carbon monoxide typically experience worsening of symptoms such as headache in the hours after the exposure starts, and symptoms reduce within hours after leaving the source.[4] A

Effects of carbon monoxide poisoning

When a person is exposed to carbon monoxide, it binds to haemoglobin with an affinity of over 200 times that of oxygen, resulting in the formation of carboxyhaemoglobin.[4] This prevents oxygen binding to haemoglobin and reduces oxygen delivery to tissues, resulting in hypoxia.

It is thought that carbon monoxide poisoning also involves other processes, including directly affecting the brain and heart. A range of mechanisms have been proposed such as diffusion of carbon monoxide into tissues, free radical formation and disruption of critical proteins such as myoglobin and mitochondrial oxidases.[9,10] Carbon monoxide is also produced naturally in the body during the metabolism of haemoglobin, and it is possible that carbon monoxide poisoning may interfere with the normal biological signals linked to this endogenous carbon monoxide.[11]

People with acute carbon monoxide poisoning are at increased risk of a range of delayed neurological sequelae, which occur in the weeks following exposure.[12] These include hearing loss, impaired concentration, depression, difficulties with language or memory, or gait and co-ordination problems.[9, 12] People who lose consciousness, have a greater severity or duration of exposure or are of an older age (e.g. aged over 40 years) are at greater risk of neurological complications.[13] These may improve over the course of months, but may be permanent depending on the extent of underlying injury.[14]



carbon monoxide detector installed at a patient's home* can provide evidence of a source of exposure. If potential exposure at work is suspected, workplaces can arrange for employees to wear portable carbon monoxide detectors or have other assessments carried out to establish whether safe working levels of carbon monoxide have been breached, with guidance from Worksafe New Zealand.[7]

A definitive diagnosis of carbon monoxide poisoning can usually only be made after a source is eliminated, resulting in resolution in the patient's symptoms.

A simple four-letter acronym which can guide questioning is **COMA**:[15]

- **C**o-habitants or companions: Do other people living at the same address or at the same workplace have similar symptoms? This could also include pets with signs of lethargy, difficulty walking or loss of balance.
- **O**utside or away: Do symptoms improve when outdoors or away from the normal place of work or residence for a number of hours?
- **M**aintenance: What sources of heating are used, are gas heating or cooking facilities or fireplaces well maintained and regularly serviced?
- **A**larm: Is there a carbon monoxide alarm in the house or workplace?

* Available at hardware stores for approximately $60-$70. Some smoke alarms also detect carbon monoxide.

Patterns of symptoms may be useful for diagnosis

There is no single symptom which is diagnostic for carbon monoxide exposure.[10] Headache is commonly reported, however, there are no specific characteristics of headache caused by carbon monoxide exposure which can help diagnosis.[16] Nausea or fatigue often accompanies headache with carbon monoxide exposure, but can also indicate migraine or many other causes.[4]

Patterns which could indicate exposure to carbon monoxide include symptoms which only occur:

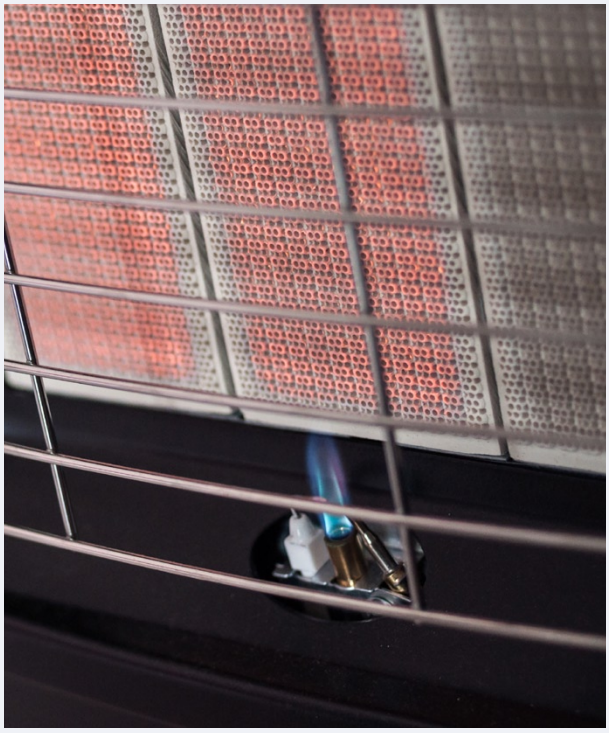
- After arriving home or during the evening (if the source is at home)
- During the course of work (if the source is at work)
- During winter, e.g. due to use of a heater which emits carbon monoxide
- After moving to a different house or using a different form of heating

Patients exposed to low levels of carbon monoxide over a long period are unlikely to show any obvious signs on physical examination. Cherry coloured skin or lips was previously considered a tell-tale sign of carbon monoxide poisoning, however, it is not a reliable diagnostic sign as it is very rare and typically only occurs after exposure to very high levels or post-mortem.[4]

Portable LPG heaters should be avoided

Portable LPG heaters should be used with ventilation, e.g. an open window, and are not recommended for use in bedrooms.[7] Signs that an LPG heater or cooker may be burning inefficiently, which is associated with increased carbon monoxide formation, include black marks on the heater around the flame, flames with orange or red tips* or unusual sounds during use.[7] The Energy Efficiency and Conservation Authority (EECA) of New Zealand regards portable LPG heaters as the most expensive form of heating available; informing patients of this may convince them to change heating sources and therefore reduce their risk of carbon monoxide poisoning.[18] In addition, portable LPG heaters can also cause or exacerbate respiratory illnesses and asthma as they release nitrogen dioxide and water vapour, which increases growth of moulds and dust mites.[19]

* Except for flame-effect heaters which are designed to appear this way



Testing for low-level exposure may be difficult

Testing carboxyhaemoglobin levels forms part of diagnosis during emergency management of carbon monoxide poisoning (see: "Emergency management of carbon monoxide poisoning"). However, this is likely to be less useful and more difficult to interpret in patients with repeated low-level exposures, as carboxyhaemoglobin levels will not be as elevated as in an acute poisoning event, and the delay between exposure and drawing blood for analysis means that test results will give falsely low readings. Detecting low-level exposure in people who smoke is further complicated by the fact that smoking results in the formation of carboxyhaemoglobin, with levels up to 9% classified as the upper limit of the reference range for smokers, compared to 1.5% for non-smokers.[20]

Pulse oximetry is not useful for detecting carbon monoxide exposure: Standard pulse oximeters use two wavelengths of light to determine oxygen saturation. These are unable to differentiate between haemoglobin bound to oxygen and haemoglobin bound to carbon monoxide (carboxyhaemoglobin). Therefore, they are not useful for the assessment of carbon monoxide poisoning as they will give a falsely elevated reading of oxygen saturation.[21] Newer pulse oximeters have been developed using additional wavelengths of light which detect carboxyhaemoglobin, however, these are not widely available.

Management of suspected low-level exposure to carbon monoxide

If low-level exposure to carbon monoxide is suspected and a potential source identified, develop a plan for the patient to avoid future exposure, such as switching to an alternative form of heating.

For patients with repeated low-level exposures, it would be reasonable to expect improvement in most symptoms within the first days of avoidance. However, some patients may have ongoing symptoms if exposure has resulted in underlying neurological damage, such as problems with vision, hearing loss or tremors.[4, 12]

General Practitioners are required to report suspected exposures to the Medical Officer of Health via the Hazardous Substances Disease and Injury Reporting Tool in the Practice Management System (PMS; see: "Notifying cases of suspected carbon monoxide poisoning"). Contact your local Public Health Unit directly to report the exposure if your practice does not have access to the tool. Patients with suspected exposure can be reported based on clinical suspicion and confirmation of exposure is not required when submitting a notification.[22] Advise patients to discuss potential exposures in the workplace with their employer.

Emergency management of carbon monoxide poisoning

For patients with moderate to severe symptoms of carbon monoxide poisoning, a diagnosis can be made relatively quickly due to the sudden onset of severe symptoms, a probable source being readily apparent, occupants of the same area all being affected and carboxyhaemoglobin testing in secondary care. In emergency situations, oxygen treatment (below) is typically initiated prior to carboxyhaemoglobin results being available, with levels used to confirm a diagnosis.[10] The severity of symptoms is the key factor in treatment decisions, as the extent of elevation of carboxyhaemoglobin levels correlates poorly with symptom severity, and may give a falsely low reading due to delays between exposure and blood sampling.[27]

Supplemental oxygen is the key treatment for acute poisoning. In the absence of treatment, the half-life of carboxyhaemoglobin is approximately five hours. With 100% oxygen at normal atmospheric pressure the half-life of carboxyhaemoglobin is reduced to approximately 90 minutes.[9] Hyperbaric oxygen treatment reduces the half-life of carboxyhaemoglobin to approximately 20 minutes and is recommended in some circumstances, such as for patients with severe symptoms or who are pregnant.[9] Treatment with oxygen is typically continued until immediate symptoms have resolved, with a treatment time of six hours often used.[10]

Notifying cases of suspected carbon monoxide poisoning

General Practitioners are required by law to report cases of suspected carbon monoxide poisoning, preferably using the Hazardous Substances Disease and Injury Reporting Tool; this is available via MedTech and the MyPractice and Profile PMS systems.[23] In MedTech, go to:

- "Module List"
  - "Hazardous Substances & Lead Notifications"
    - "Hazardous Subs & Lead Notifications"

The notification tool will show three tabs for clinicians to complete: "Exposure Event", "Assessment" and "Notifier/Patient Details". In the "Substance" category on the "Exposure Event" tab, carbon monoxide poisonings should be entered as "Other" with carbon monoxide poisoning specified in the text box below.

This tool will notify the local Public Health Unit (PHU) and Medical Officer of Health about a potential exposure; the PHU may take further action such as investigating further or forwarding notifications to Worksafe New Zealand.[24]

For further information on hazardous substances disease and injury notifications, see: **www.bpac.org.nz/BPJ/2016/May/e-notification.aspx**

For further information about this module, see: **www.bestpractice.net.nz/feat_mod_HSDIRT.php**

* Reporting cases of carbon monoxide poisoning to the Medical Officer of Health is required under Schedule 2 of the Health Act 1956, as it is an example of poisoning arising from chemical contamination of the environment.[25] It is also required in the Hazardous Substances and New Organisms Act 1996 under Section 143.[26]

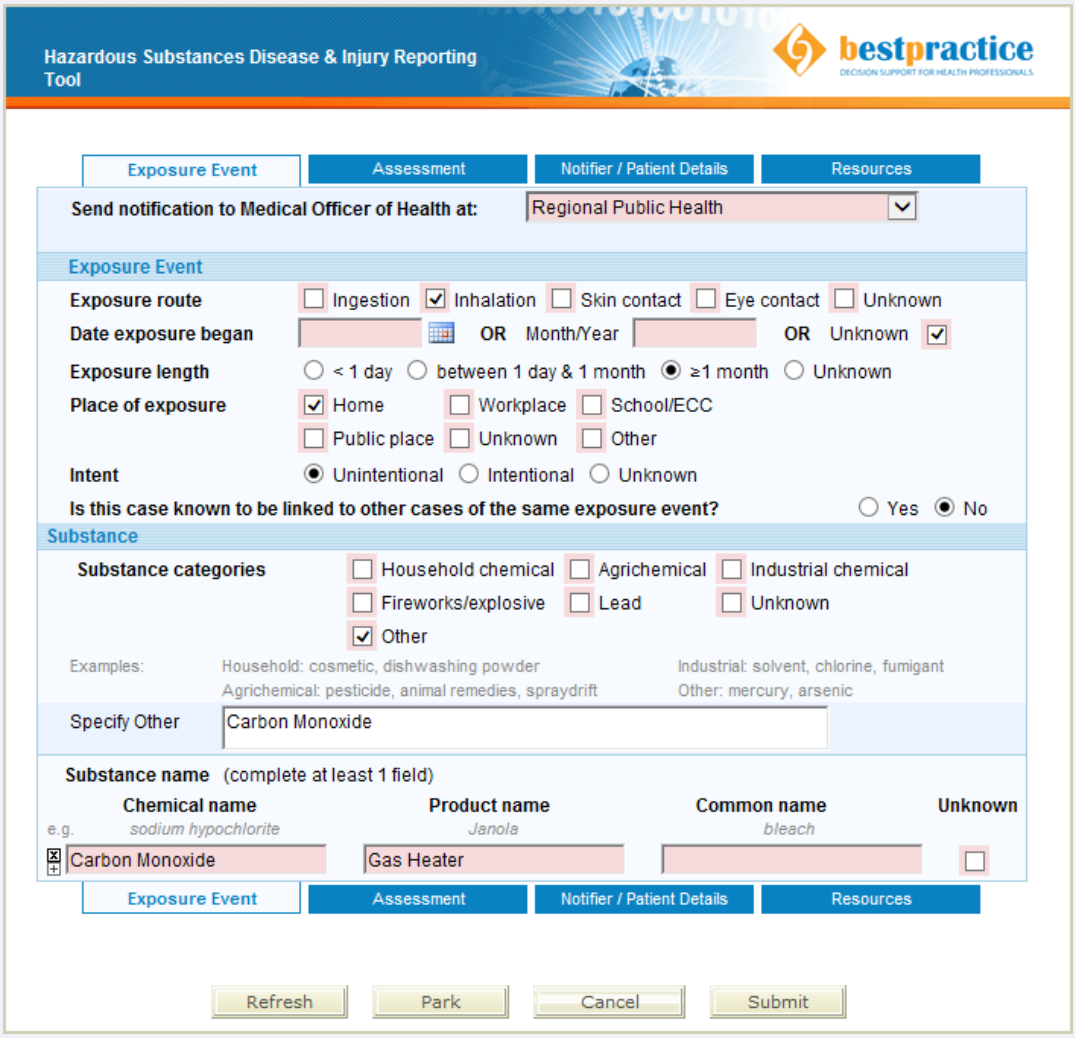


Figure 1: An example of reporting carbon monoxide poisoning in the Hazardous Substances Disease and Injury Reporting Tool.

Acknowledgement: Thank you to **Associate Professor Deborah Read**, Environmental Health Indicators Programme, Centre for Public Health Research, Massey University for expert review of this article.

N.B. Expert reviewers do not write the articles and are not responsible for the final content

References:

1. Reumuth G, Alharbi Z, Houschyar KS, et al. Carbon monoxide intoxication: What we know. Burns 2019;45:526–30. doi:10.1016/j.burns.2018.07.006
2. Environmental Health Indicators Programme, Centre for Public Health Research. Hazardous substances injury report. 2017. Available from: www.ehinz.ac.nz/assets/Reports/Annual-Hazardous-Substances-Injury-Report-2017.pdf (Accessed Oct, 2019).
3. Centers for Disease Control and Prevention (CDC). Clinical guidance for carbon monoxide poisoning after a disaster. 2019. Available from: www.cdc.gov/disasters/co_guidance.html (Accessed Oct, 2019).
4. Ashcroft J, Fraser E, Krishnamoorthy S, et al. Carbon monoxide poisoning. BMJ 2019;365:l2299. doi:10.1136/bmj.l2299
5. Kasbekar S, Gonzalez-Martin JA. Chronic carbon monoxide poisoning resulting in bilateral cataracts and a cystic globus pallidus lesion. BMJ Case Rep 2011;2011. doi:10.1136/bcr.03.2011.3985
6. Eichhorn L, Michaelis D, Kemmerer M, et al. Carbon monoxide poisoning from waterpipe smoking: a retrospective cohort study. Clin Toxicol (Phila) 2018;56:264–72. doi:10.1080/15563650.2017.1375115
7. WorkSafe New Zealand. Keep yourself safe from carbon monoxide. Available from: https://worksafe.govt.nz/managing-health-and-safety/consumers/gas-2/carbon-monoxide-hazards/ (Accessed Oct, 2019).
8. World Health Organization (WHO). Waterpipe tobacco smoking: health effects, research needs and recommended actions for regulators - 2nd edition. Available from: www.who.int/tobacco/publications/prod_regulation/waterpipesecondedition/en/ (Accessed Oct, 2019).
9. American College of Emergency Physicians Clinical Policies Subcommittee (Writing Committee) on Carbon Monoxide Poisoning, Wolf SJ, Maloney GE, et al. Clinical policy: Critical issues in the evaluation and management of adult patients presenting to the emergency department with acute carbon monoxide poisoning. Ann Emerg Med 2017;69:98-107.e6. doi:10.1016/j.annemergmed.2016.11.003
10. Hampson NB, Piantadosi CA, Thom SR, et al. Practice recommendations in the diagnosis, management, and prevention of carbon monoxide poisoning. Am J Respir Crit Care Med 2012;186:1095–101. doi:10.1164/rccm.201207-1284CI
11. Hess DR. Inhaled carbon monoxide: from toxin to therapy. Respir Care 2017;62:1333–42. doi:10.4187/respcare.05781
12. Weaver LK. Clinical practice. Carbon monoxide poisoning. N Engl J Med 2009;360:1217–25. doi:10.1056/NEJMcp0808891
13. Weaver LK, Valentine KJ, Hopkins RO. Carbon monoxide poisoning: risk factors for cognitive sequelae and the role of hyperbaric oxygen. Am J Respir Crit Care Med 2007;176:491–7. doi:10.1164/rccm.200701-026OC
14. Lee WK, Yu ZHS, Lee CC. Delayed neurological sequelae after carbon monoxide poisoning. Aust N Z J Psychiatry 2008;42:430. doi:10.1080/00048670801961198
15. Kar-Purkayastha I, Finlay S, Murray V. Low-level exposure to carbon monoxide. Br J Gen Pract 2012;62:404. doi:10.3399/bjgp12X653480
16. Hampson NB, Hampson LA. Characteristics of headache associated with acute carbon monoxide poisoning. Headache 2002;42:220–3.
17. Vyskocil A, Truchon G, Leroux T, et al. A weight of evidence approach for the assessment of the ototoxic potential of industrial chemicals. Toxicol Ind Health 2012;28:796–819. doi:10.1177/0748233711425067
18. Energywise. Gas heating. Available from: www.energywise.govt.nz/at-home/heating-and-cooling/types-of-heater/gas-heating/ (Accessed Oct, 2019).
19. Ministry of Health. Unflued gas heaters. 2012. Available from: www.health.govt.nz/your-health/healthy-living/environmental-health/household-items-and-electronics/unflued-gas-heaters (Accessed Oct, 2019).
20. Kyle C (Ed). Sonic pathology handbook: a guide to the interpretation of pathology tests. New South Wales: Sonic Healthcare 2014. Available from: www.snp.com.au/ (Accessed Oct, 2019).
21. Pretto JJ, Roebuck T, Beckert L, et al. Clinical use of pulse oximetry: official guidelines from the Thoracic Society of Australia and New Zealand. Respirology 2014;19:38–46. doi:10.1111/resp.12204
22. Environmental Health Indicators New Zealand (EHINZ). Hazardous substances disease and injury and lead absorption notifications via BPAC - Information for GPs. 2013. Available from: www.ehinz.ac.nz/assets/Other/Users-Guide-for-GPs.pdf (Accessed Oct, 2019).
23. Environmental Health Indicators New Zealand (EHINZ). Hazardous substances disease and injury reporting tool. A user's guide for public health units. 2017. Available from: www.ehinz.ac.nz/assets/Other/HSDIRT-PHU-Users-Guide-2017-Released-May2017.pdf (Accessed Oct, 2019).
24. Parliamentary Counsel Office. Health and Safety at Work Act 2015 No 70, Section 199. 2018. Available from: www.legislation.govt.nz/act/public/2015/0070/latest/DLM5977194.html (Accessed Oct, 2019).
25. Parliamentary Counsel Office. Health Act 1956 No 65, Public Act Schedule 2. 2019. Available from: www.legislation.govt.nz/act/public/1956/0065/latest/DLM308746.html (Accessed Oct, 2019).
26. Parliamentary Counsel Office. Hazardous Substances and New Organisms Act 1996 No 30, Section 143. 2017. Available from: www.legislation.govt.nz/act/public/1996/0030/93.0/DLM385138.html (Accessed Oct, 2019).
27. Hampson NB, Dunn SL, UHMCS/CDC CO Poisoning Surveillance Group. Symptoms of carbon monoxide poisoning do not correlate with the initial carboxyhemoglobin level. Undersea Hyperb Med 2012;39:657–65.

This article is available online at:
www.bpac.org.nz/2019/co.aspx