



Standard for Managing Significant Carbon Monoxide Emissions

January 2015

VERSION 1

A decorative graphic element consisting of a large, stylized 'V' shape. The top of the 'V' is formed by three overlapping diagonal bands of color: blue on the left, red in the middle, and yellow on the right. The bottom of the 'V' is a solid grey shape that tapers to a point at the center. The entire graphic is set against a white background.

Working in conjunction
with Communities,
Government, Agencies
and Business.

The Standard for Managing Carbon Monoxide Emissions from Major Fires (the Standard) including all Attachments has been approved and endorsed by the following:

Authorised by:

_____ date _____

Craig Lapsley
Emergency Management Commissioner

_____ date _____

Dr Rosemary Lester
Chief Health Officer

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Governance

The Standard is authorised in accordance with the statutory responsibilities of the Emergency Management Commissioner with respect to responders and community safety in line with the *Emergency Management Act 2013*, and the Chief Health Officer's statutory responsibilities with respect to the protection of public health in accordance with the *Public Health and Wellbeing Act 2008*.

The Standard was produced by a taskforce consisting of representatives from the following agencies:

- Emergency Management Victoria (EMV)
- Department of Health & Human Services (DHHS)
- Country Fire Authority (CFA)
- Metropolitan Fire Brigade (MFB)
- Ambulance Victoria (AV)
- Victorian WorkCover Authority (VWA)
- Environmental Protection Authority (EPA)

Authorising Framework

The Standard is supported by the following legislation and documents:

- *Emergency Management Act 1986*,
- *Emergency Management Act 2013*,
- *Public Health and Wellbeing Act 2008*
- *Occupational Health and Safety Act 2004*
- *Environment Protection Act 1970*
- Emergency Management Manual Victoria (EMMV)

The Standard refers to the following documents:

- Safe Work Australia Workplace Exposure Standards For Airborne Contaminants (Safe Work Australia 18 April 2013)
- Safe Work Australia Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants (Safe Work Australia April 2013)
- Hazardous Substances Information System (HSIS); Exposure standard documentation: Carbon monoxide (Safe Work Australia 1996)
- A Best Practice Approach to Shelter-in-Place for Victoria (MFESB 2011)
- Protective Action Decision Guide for Emergency Services during Outdoor Hazardous Atmospheres (MFESB 2011)
- Committee on Acute Exposure Guideline Levels, Committee on Toxicology; National Research Council Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8 (2010)

Context

This Standard provides direction for all agencies responding to large, extended or complex fires that produce significant levels of carbon monoxide (CO) in the outdoor environment. These may include but are not limited to fires in coal mines, peat bogs, landfill sites or large mulch piles. A large, extended or complex fire may exhibit the following characteristics:

- Risk to fire fighter and emergency responder health
- Impact on communities
- Scale, scope and complexity
- Significant carbon monoxide emissions

Purpose

This Standard has been developed to provide a framework for decision making to assist the incident controller and agency commanders to manage health and safety of all personnel and affected communities during large, complex incidents that have the capacity to produce significantly elevated levels of CO in the outdoor environment.

The Standard concerns:

- the area in immediate proximity to the fire and the protection of responder health and safety; and
- areas around the fire impacted by the smoke plume and the protection of community health and safety.

This Standard should also be used to inform agency-specific standard operation procedures and decision support tools. This Standard should also be considered by industry operators in developing their arrangements.

Review of the Standard

This version is subject to peer review by an expert panel and will be further updated if necessary in April 2015 to incorporate any recommendations made by this panel. The Standard will then be reviewed annually or following major incidents.

Strategic Intent

Consistent with the Emergency Management Manual Victoria (EMMV), the Incident Controller's priorities include the Protection and preservation of life which is paramount – this includes the:

- Safety of emergency services personnel
- Safety of other responding agency personnel
- Safety of community members, including vulnerable community members and visitors/tourists located within the incident area
- Issuing of community information and community warnings

Roles and Responsibilities – Occupational Health & Safety

The *Occupational Health and Safety Act 2004* states that:

- An employer must, so far as is reasonably practicable:
 - provide and maintain a working environment for employees that is safe and without risks to health
 - ensure that persons other than employees of the employer are not exposed to risks to their health and safety arising from the conduct of the undertaking of the employer.
- While at work, an employee must:
 - take reasonable care for his or her own health and safety, or that of other persons who may be affected by their acts or omissions at a workplace
 - co-operate with his or her employer with respect to any action taken by the employer to comply with a requirement imposed by or under this Act or the regulations.

This standard contains important safety provisions that will only be fully effective with the cooperation of all responders, and the willingness of the community to follow the Incident Controller's advice.

Carbon Monoxide Hazard

Carbon monoxide (CO) is an odourless, colourless gas that is produced during incomplete combustion. CO exposure through inhalation of this gas can cause illness and, in some cases death.

The following are susceptible to CO exposure¹:

- The developing baby prior to birth (ie the foetus)
- People with heart and lung disease
- People with anaemia
- Heavy smokers.

Air Exposure Levels for Carbon Monoxide

Occupational exposure standards exist to guide emergency services in protecting personnel who may be exposed to CO during their work.

Community exposure guideline values also exist for CO exposure in the outdoor environment, for generally a one-off, short-term exposure period (e.g. from 10 minutes to 8 hours) during an emergency.

Ambient (i.e. outdoor) air quality values also exist for CO exposure in the general air we breathe. They are applied on a continuous basis at air monitoring stations operated by the Environment Protection Authority (EPA).

These three different sets of exposure standards or values are discussed in more detail the following sections.

¹ S Bull; HPA Compendium of Chemical Hazards: Carbon monoxide (UK Health Protection Agency 2011)

Occupational Exposure Standards

The *Occupational Health and Safety Act 2004* and associated regulations specify that the appropriate occupational exposure standards for use in Victoria are the Safe Work Australia (SWA) Exposure Standards. Safe Work Australia has developed workplace exposure standards for airborne contaminants including CO.

These Exposure Standards are contained in the following documents:

- Workplace Exposure Standards For Airborne Contaminants (Safe Work Australia April 2013)
- Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants (Safe Work Australia April 2013)
- Hazardous Substances Information System (HSIS); Exposure standard documentation: Carbon monoxide (Safe Work Australia 1996)

These Exposure Standards are mandatory under the Victorian *Occupational Health & Safety Regulations 2007*. They establish a maximum upper limit for worker exposure, therefore all reasonably practicable steps must be taken to eliminate or minimise exposure to a level well below the exposure standard.

Exposure standards are also not designed for situations outside a workplace or for exposure of people, such as bystanders or nearby residents.

The following exposure standard and associated short-term excursion levels are included in the arrangements for personnel responding to significant CO producing incidents.

Table 1: Occupational Exposure Standard for CO

Time Weighted Average (TWA) – including short term excursion levels within an 8 hour period ²	Airborne concentration in parts per million (ppm)
8 hour time weighted average (TWA) ³	30
1 hour – short term excursion level allowed within an 8 hour exposure period	60
30 mins – short term excursion level allowed within an 8 hour exposure period	100
15 minutes – short term excursion level allowed within an 8 hour exposure period	200
Note: no short term excursion level measurement should ever exceed this value	400

When reading Table 1, note that the Exposure Standard value is an 8 hour TWA of 30 ppm with a number of possible short-term excursions over 15, 30 and 60 minutes within this 8 hour exposure period. Also, at no time should any reading exceed the value of 400 ppm.

It is important to note the following for occupational exposure standards:

- They are an airborne concentration of a substance that must not be exceeded.

² Safe Work Australia

³ 8 hour TWA exposure standards must not be adjusted upwards for shorter exposure periods or work shifts (e.g. exposure to 8 times the TWA for one hour). This is because the health effects from high exposures for short periods may not be fully understood for each airborne substance. On the other hand, the 8 hour TWA exposure standard can be adjusted for longer work shifts as per Safe Work Australia guidance.

- They do not identify a dividing line between a healthy or unhealthy working environment. Susceptible individuals may experience health effects, therefore these standards are not an acceptable level of exposure but a maximum upper limit.
- They are assumed to apply to healthy adult workers.
- They assume that the setting may well be enclosed, there is a possibility of repeated exposure, and there is a higher breathing rate in workers (responders). The occupational exposure standards apply to all emergency responders and industry operators.

Community Exposure Guideline Values for Emergencies

The development of Acute Exposure Guideline Levels (AEGLs) is a collaborative effort of the public and private sectors worldwide. AEGLs are intended to describe the risk to humans resulting from once-in-a-lifetime, or rare, exposure to airborne chemicals. The US National Substances (AEGL Committee) is involved in developing these guidelines to help authorities, as well as private companies, deal with emergencies involving spills, or other significant emissions resulting in community exposures.

The Protective Action Decision Guide for Emergency Services during Outdoor Hazardous Atmospheres (MFESB 2011) sets out a hierarchy of air quality reference values appropriate for protecting the public from short-term exposure to chemicals in the air.

AEGLs are the preferred short-term community protection standards to be used for the community health protection based on The Protective Action Decision Guide for Emergency Services during Outdoor Hazardous Atmospheres (MFESB 2011).

There are three levels of AEGL values that are adjusted across various time periods of exposure (ie from 10 minutes up to 8 hours). The lowest AEGL level (i.e. AEGL 1) for an air pollutant is the most protective for community exposure. When AEGL-1 values are not available, then AEGL-2 values are used. For example, this is the case for CO.

AEGL-1 is the airborne concentration (expressed as ppm [parts per million] or mg/m³ [milligrams per cubic meter]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death

AEGLs are designed to protect the general population including older people, children and other susceptible groups that are generally not considered in the development of occupational exposure levels.

Table 2 contains the emergency community exposure guideline values for CO.

Table2: Emergency Community Exposure Guideline values for CO

Description of exposure period for monitoring CO levels	AEGL 1	AEGL-2	AEGL 3
8 hours	Not recommended	27 ppm	130 ppm
4 hours	Not recommended	33 ppm	150 ppm
1 hour	Not recommended	83 ppm	330 ppm
30 mins	Not recommended	150 ppm	600 ppm
10 mins	Not recommended	420 ppm	1700 ppm

AEGL 1 are not specified for CO because it does not cause irritation or discomfort in healthy people at airborne concentrations where effects may still occur in people with coronary artery disease.

AEGL 2 values are based on the most susceptible group (i.e. protecting people with coronary artery disease from cardiovascular effects). At or below these values effects are not expected.

AEGL 3 values are levels above which the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

Even though the occupational exposure standard and AEGL values are designed to protect different populations, it is worth noting that the 8 hour AEGL-2 value for CO of 27 ppm is not too different to the 8 hour TWA for CO for occupational exposure of 30 ppm.

It is important to note the following for community exposure guideline values during an emergency event:

- They are designed to be protective of all members of the community including susceptible individuals.
- They are levels at which health effects are generally not expected to occur over the duration of exposure specified.
- They assume a one-off, short term exposure during an emergency incident.

Ambient Air Quality Values for CO

There are ambient (i.e. outdoor) air quality values for the air we breathe, under normal day to day conditions. The EPA monitors a number of common air pollutants in the general air environment, including CO.

For the purpose of monitoring the general quality of a local air shed an 8 hour average value for CO of 9 ppm applies. Although useful to inform normal pollution levels generally, it should not be applied to significant local emergency events where short term poor air quality will far exceed this measure.

Tactical or Operational Considerations

Occupational

In the occupational setting the tactical decisions include:

- Reviewing the task and the time taken to complete it relative to the exposure time
- Options to reduce work load and breathing rate
- Options to work at a place with less atmospheric contamination
- Time to put on Self-Contained Breathing Apparatus (SCBA).
- Consideration of the time required to exit complex environments

Community

For the community the tactical decisions require sufficient time to communicate and implement on a whole-of-population basis. This differs from the individual worker or command line decision-making time in the occupational context.

The tactical options to protect the health of the community include:

- Time to assess the potential risks to public health well below outdoor air concentrations at which health effects could occur.
- Informing the community of potential risk of CO exposure with advice to reduce activity and minimise exposure
- Advice to shelter indoors
- Planned evacuation of impacted community (if required).

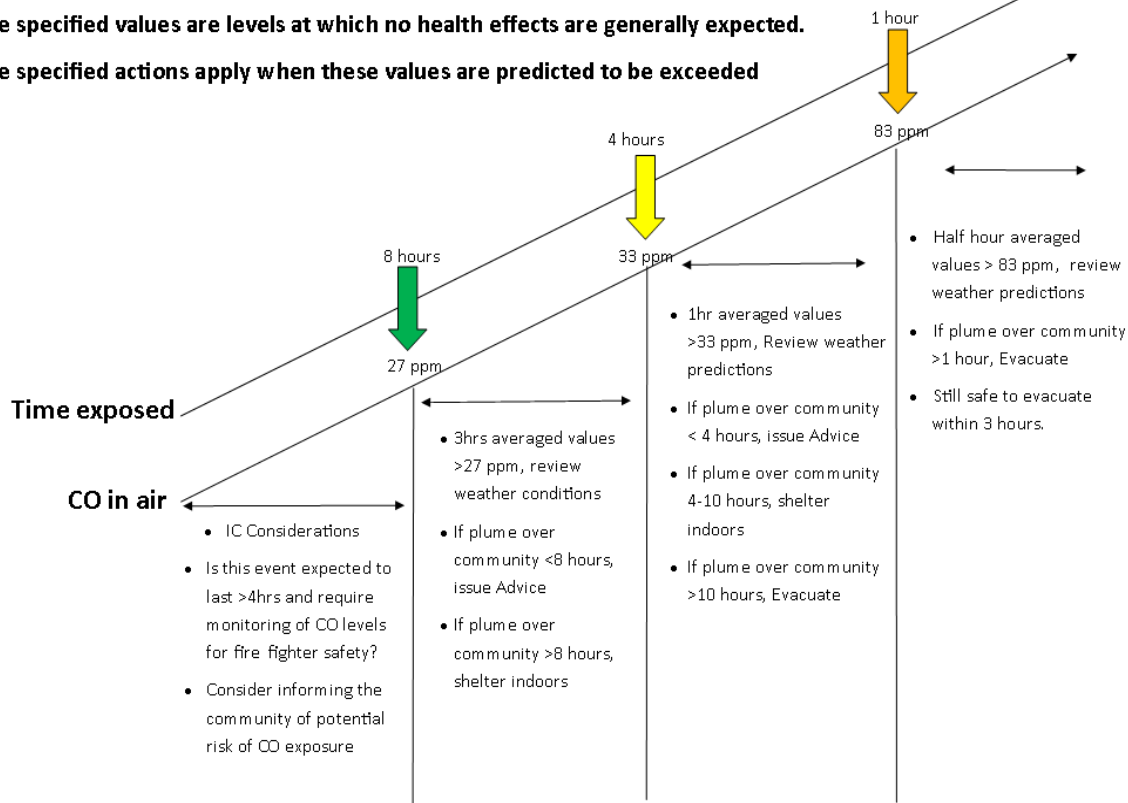
To evacuate a community or a section of a community will take longer than 1 hour.

In these scenarios, available data will be constantly monitored and preparations for appropriate community messaging and action will take place well prior to thresholds being reached.

Exposure to CO for Public

The specified values are levels at which no health effects are generally expected.

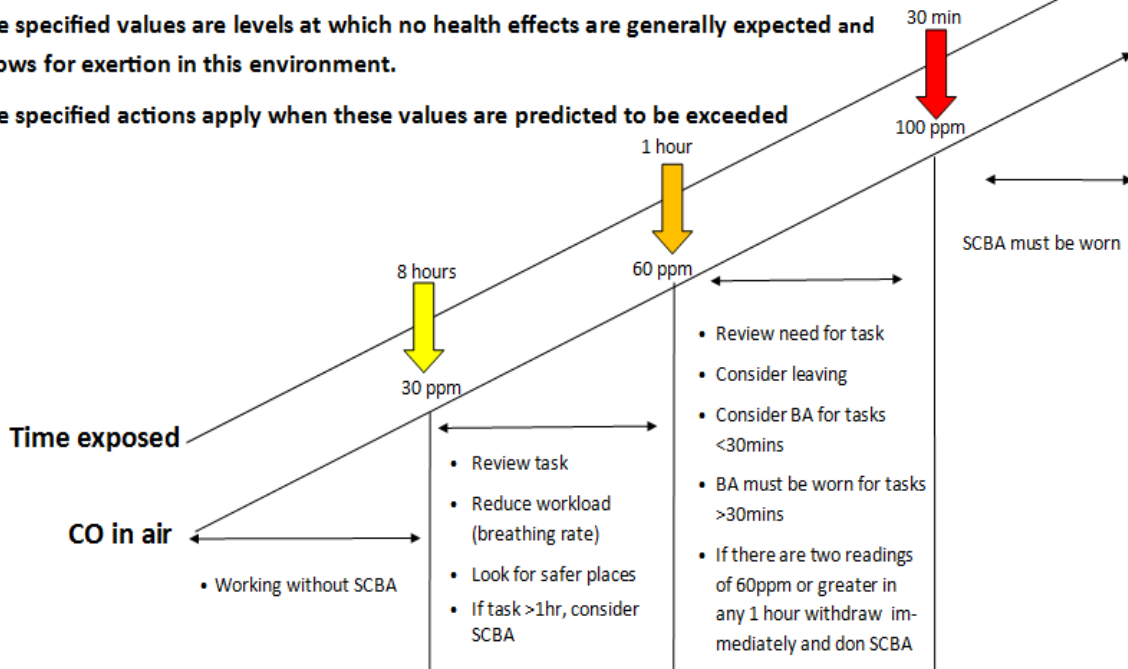
The specified actions apply when these values are predicted to be exceeded



Exposure to CO for Firefighters

The specified values are levels at which no health effects are generally expected and allows for exertion in this environment.

The specified actions apply when these values are predicted to be exceeded



Note: This picture is not the same continuum as for exposure to CO for the public. The exposure standard in the 8 hour TWA is 30 ppm. Within an 8 hour work shift, short term excursions are permitted over 15, 30 and 60 minutes. However, at no time should air monitored values exceed 400 ppm.

CO Monitoring Strategy

Principles

The concentration of CO in the air fluctuates continuously, and spikes in elevated concentrations may occur periodically. As concentrations of CO in the air vary from moment to moment threshold exposure values are based on averaged values. Research has shown that very brief exposure to highly elevated CO concentrations during moderate overall CO exposure does not necessarily result in harmful thresholds being exceeded⁴.

CO atmospheric monitoring results will need to be interpreted and scientific advice obtained. The trends in atmospheric concentration of CO are the most important for decision making.

The following table sets out the equipment and agencies involved in atmospheric monitoring for CO at the incident site for responder safety, and in the community for public health and safety.

Table 2: Resources for monitoring atmospheric CO at an incident

Resources	Responder Safety	Community Safety
Monitoring Equipment Options	Atmospheric <ul style="list-style-type: none"> • Spot • Area Capable Monitors • Personal Health Monitoring (COHb)	Atmospheric <ul style="list-style-type: none"> • Spot • Area Capable Monitors • EPA Equipment
Lead Agency for Atmospheric Monitoring	Fire Services <ul style="list-style-type: none"> • Hazmat Specialists • Scientific Advisors 	EPA
Support Agency	Industry Operator BoM	Fire Services BoM

NB: This table lists monitoring strategies, agencies involved in monitoring CO and weather conditions for responder and community safety.

CO Monitoring Options

Based on currently available equipment the following options are available for consideration:

- **Hand-Held Atmospheric Monitoring:** atmospheric contaminant monitoring equipment used by emergency responders to survey potentially hazardous atmospheres for 'spot' measurements (e.g. MSA Sirius or RAE Systems MultiRAE gas detectors)
- **Fixed Atmospheric Monitoring:** atmospheric contaminant monitoring equipment deployed in locations representative of emergency responder or public exposure with the capability to be monitored remotely (e.g. RAE Systems Area-RAE Rapid Deployment Kit)
- **Personal Atmospheric Monitoring:** atmospheric monitoring equipment worn by responders in the breathing zone for the purposes of assessing personal exposure against workplace exposure standards (e.g. Drager Pac 3500 CO detector)
- **Personal Biological (Health) Monitoring:** chemical exposure assessment involving the analysis of blood, or exhaled breath samples from workers, for a hazardous substance or its metabolites (breakdown products in the body). (e.g. Pulse CO-Oximetry, CO Breath Analysis)

⁴ Reisen F, Mayer M, Hansen D. Carbon monoxide – hazard on the fire ground (Bushfire CRC, 2008)

Concept of Operations

- The industry operator or the first responder agency on scene evaluates potential for CO emissions (based on the risk characteristics in the Standard) and initiates monitoring for responder safety.
 - Industry should activate the appropriate technical staff
 - Hazmat specialists and fire service scientific officers should be activated
- If monitoring suggests there are negligible levels of CO, no further escalation is required. Monitoring should continue until fires are controlled.
- If the first responder agency assesses that CO levels represent a possible occupational health and safety risk but there is no nearby community, implement appropriate procedures to protect responder health and safety. (See next section.)
- First responder agency assesses whether CO levels represent health and safety risks to responders and potential impacts on community.
 - Ensure implementation of appropriate procedures to protect responder health and safety.
 - EPA should be activated and asked to initiate monitoring in the community area.
 - Bureau of Meteorology (BoM) should be requested to provide advice on local weather conditions
 - DHHS should be advised of potential risk to community health and safety.
 - Consider the use of predictive modelling of the smoke plume by fire agencies.
 - If there is a delay to the establishment of EPA community atmospheric monitoring, first responder monitoring equipment should be deployed into community areas impacted by the smoke plume to assess the extent and severity of CO risk to the community.
 - Because of rapid fluctuations of CO levels, atmospheric monitoring should be continuous to enable interpretation of results. If continuous monitoring is not available, 'spot' monitoring (a single reading, a "snapshot in time") should be repeated at frequent intervals at the same monitoring point in order to provide averaged results or trends in data. The frequency of monitoring should be at not more than 5 minute intervals⁵.
 - CO monitoring results need to be reviewed and verified and reported as either a graph or a time series including all results with time and location of measurement.
 - CO monitoring results need to be interpreted with supporting information including maps of affected community specifying monitoring positions, plume modelling of smoke dispersion, and predictions of local weather for the next 12 to 24 hours. Maps should identify facilities with vulnerable people, such as childcare facilities, schools, health services, and residential aged care facilities.
 - CO monitoring results and supporting information should be provided to DHHS for analysis. The Chief Health Officer will assess the risk to the public health of the community and provide advice to the Incident Controller.
 - The Incident Controller will provide warnings and information to the community.
 - For long duration events consideration should be given by the Incident Controller in consultation with the Chief Health Officer and the Emergency Management Commissioner to a communications strategy to keep the community informed of the hazard of CO and potential health concerns.

⁵ Spot monitoring needs to be repeated at frequent intervals or not greater than 5 minutes apart, to develop a time series demonstrating the trends in CO levels.

Responder Safety

Arrangements to protect ESO responders and other agency personnel

- The Incident Controller has ultimate responsibility to ensure safe systems of work are in place to protect responders.
- The Incident Controller will be supported and receive advice from an Incident Safety Officer and Safety Advisors and other specialist resources as required.
- Hazmat Technicians and Scientific Advisors will undertake continuous atmospheric monitoring during the incident.
- Personal CO atmospheric monitors will be utilised by each team.
- Responders must adhere to agency Standard Operating Procedures and safety directions issued by the Incident Controller.
- Health Monitoring Teams will conduct health checks in accordance with the principles outlined in Attachment 4.
- Caches of SCBA will be deployed to strategic locations for rapid access by responders.
- Crew leaders will ensure crews are rotated on a two-hourly basis and undertake entry, exit and re-entry health monitoring protocols.
- All health and safety incidents are to be reported and this information will be shared on an ongoing basis with responders to improve their risk awareness.
- There is a requirement for identified incidents and dangerous occurrences to be notified to the Victorian WorkCover Authority.

Responder Selection

General Health Issues

Increased CO levels in the environment are more likely to cause health impact in people with pre-existing conditions

- Individuals, who are heavy smokers, have a history of cardiovascular or respiratory conditions or anaemia should not be deployed to these incidents.
- The foetus is also very sensitive to high levels of CO. Therefore any female responder, who is known to be pregnant or may be pregnant, should not attend these incidents.

It is the responsibility of all responders to disclose all pre-disposing conditions that may put them in one of the above categories.

It is the responsibility of individuals who are allocating members to this incident to ensure that the responder selection guidelines are followed PRIOR to deployment to the incident and to ensure that all personnel have been clearly briefed.

Ideally, crews previously involved in other fire incidents should have 24 hours of “clear time” prior to being deployed to a large and complex fire producing significant amounts of CO.

Crew Health Management

The following principles should be applied:

- Agencies providing crews for deployment are to ensure the crew selection criteria of pre disposing conditions listed in Responder Selection section are met.
- Where any results of health observations do not meet the criteria established personnel are not to be deployed.

- Crew deployment shift times are to be monitored and recorded to ensure they do not exceed the maximum timeframes. (Attachment 3)
- There will be personal biological monitoring for carboxyhaemoglobin (COHb) pre-shift, at breaks and post-shift.
- Crew health observations are to be recorded in accordance with the Health Monitoring Process (Attachment 4). Crew Health Observations may be undertaken by an advanced first aider under the supervision of a Health Professional.
- The incident is to be deemed a non-smoking incident to reduce the impact of CO build up in individuals.
- All CO health monitoring results are to be logged, reported to communications and maintained by health monitoring team (Attachment 4). Results that exceed 8% COHb are to be investigated as an OH&S breach to ensure crew welfare is not placed at risk and appropriate control strategies are in place
- Community engagement and public information officers when engaged will be issued personal biological COHb monitors to monitor their exposure
- All crew with COHb >5% must have a clear 24 hour break prior to next tour to allow sufficient time for natural clearance of accumulated low levels of CO from the body.
- All crew with COHb >8% must be referred for further health assessment to a doctor or hospital and have a clear 48 hour break prior to next tour to allow sufficient time for natural clearance of accumulated low levels of CO from the body.

Personal Protective Equipment/Clothing (PPE/C)

- Personal protective clothing is to be worn at all times in accordance with agency procedures.
- Crews are to use SCBA in accordance with Attachment 3
- Crews not wearing SCBA are to use a P2 particulate respirator for protection from particulates in smoke (not CO)

Self-Contained Breathing Apparatus

Arrangements for the maintenance, filling and supply of SCBA will be established in light of the expected incident duration and volume of SCBA being used. The Incident Controller should liaise with CFA or MFB to enable appropriate planning. SCBA cylinders must be refilled and maintained in an area with the least amount of atmospheric CO present.

Work Rotations

Shift durations must be managed to prevent accumulation of CO from repeated exposure.

Maximum shift durations for such incidents are outlined in Attachment 3, Crew Leader Instruction.

Shift arrangements should be regularly reviewed and modified based on additional risks identified such as:

- extreme heat, cold or wet conditions
- heavy smoke logging
- work activity
- work rate
- on the advice of the relevant Medical Officer or Health Commander

End of Shift

Prior to end of shift crew members should be made aware of the symptoms of CO exposure and advised to present to hospital should these occur. Symptoms include headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion. (Refer to Attachments 2 and 4)

Air Operations Crews

Aircrew working overhead the defined area are subject to The Standard. The health of aircraft crew is addressed with the monitoring of cockpit CO levels and the maintenance of cockpit air quality (CO below 30 ppm – SWA Workplace Exposure Standards for Airborne Contaminants 2013).

The maximum flying time for aircrew will prevent them exceeding 8 hours and therefore the time weighted average threshold of 30 ppm – SWA Workplace Exposure Standards for Airborne Contaminants (2013) is applicable. Daily health monitoring is available to aircrew.

Community Safety

Standards to protect the health of communities from CO

The Protective Action Decision Guide for Emergency Services (During) Outdoor Hazardous Atmospheres (MFESB, 2011) sets out a hierarchy of air quality reference values appropriate for protecting the public from short-term exposure to chemicals in the air. Acute Emergency Guideline Levels (AEGLs) are the preferred short-term community protection standards⁶. AEGLs represent threshold exposure limits (exposure levels below which adverse health effects are not likely to occur) for the public and are applicable to emergency exposures. The AEGLs for CO are contained in Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8 (US National Academy of Sciences, 2010).

AEGL-1 is the airborne concentration above which it is predicted that people may experience discomfort or irritation. AEGL-1 effects do not exist for CO because it does not cause irritation or discomfort at airborne concentrations where effects may occur in people with coronary artery disease.

Therefore, for CO, AEGL-2 is the airborne concentration above which it is predicted that the general population, including susceptible individuals (those with coronary artery disease⁷), could potentially experience health effects.⁸

The AEGL-2 thresholds are designed to not exceed COHb levels of 4%. The exposure standard for CO aims to minimise the risk to persons with subclinical coronary artery disease as the most sensitive sub-group to the effects of CO.⁹ The relevant thresholds where it is predicted that the general population, including susceptible individuals, could potentially experience health effects for CO are:

- 27 ppm for 8 hours
- 33 ppm for 4 hours
- 83 ppm for 1 hour
- 150 ppm for 30 minutes
- 420 ppm for 10 minutes.

Available data will be constantly monitored and preparations for appropriate community messaging and action will take place well prior to thresholds being reached.

⁶ Protective Action Decision Guide for Emergency Services during Outdoor Hazardous Atmospheres (MFESB 2011)

⁷ People with coronary artery disease constitute the most susceptible subpopulation. The AEGL-2 value is set at 4% COHb. At this exposure level, those with coronary artery disease may experience a reduced time until onset of chest pain during physical exertion. An exposure at this level of 4% COHb is unlikely to cause a significant increase in the frequency of exercise-induced arrhythmias.

⁸ Other air quality guidelines and standards, such as the National Environment Protection Measures (NEPM) and World Health Organisation (WHO) standards, are designed to be protective of populations including sensitive sub-groups over a lifetime of exposure. They have a high level of conservatism built into them and are not appropriate for use in emergency situations, including decision-making in relation to possible evacuation.

⁹ Committee on Acute Exposure Guideline Levels, Committee on Toxicology; National Research Council Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8 (2010)

Using standards to protect the community

In order to protect the community from acute health effects due to CO, air quality will be monitored in communities likely to be impacted by smoke from fires with the greatest CO producing potential. Results of this monitoring will be assessed continually to ensure that early preparation for appropriate community messaging and action will take place well prior to the threshold being reached. CO monitoring will continue to ensure that community health is protected until the fires are sufficiently controlled.

The concentration of CO in the air fluctuates continuously, with frequent spikes in concentration. As concentrations of CO in the air will vary from moment to moment, averaged values will be calculated. Research has shown that very brief exposure to highly elevated CO concentrations during moderate overall CO exposure does not necessarily result in harmful thresholds being exceeded¹⁰.

The averaged values will be considered in relation to the thresholds specified in AEGL-2, along with information about the likely duration of the fire, the fire suppression strategy, and predictions about future wind and weather conditions. If the duration of exposure to elevated levels of CO is a risk to community health, a number of options to protect the community are available.

Options to protect the community

Options to protect the community from prolonged exposure to high levels of CO include:

- Advice about increased levels of CO and the need to minimise physical activity and stay aware of further alerts.
- Warning with instructions to take shelter indoors until conditions improve or further advice is received.
- Emergency Warning - to relocate or instruct to take shelter indoors.
- Evacuation ('prepare to evacuate' and 'evacuate now') – specific instructions on where to go, how to get there and what to take are provided in the warning.

Information issued to the community, as described above, will be issued when it is predicted that the relevant AEGL-2 threshold will be exceeded, according to the expected duration of the impact on the community.

Decision making is based on both observed and predictive information which includes

- Measured results adjusted to hourly averages from monitoring
- Bureau of Meteorology forecast data
- Fire behaviour both actual and forecast
- Predicted duration of prevailing conditions and elevated levels
- Size of community impacted

Any warning will be issued in anticipation of a relevant AEGL-2 threshold being exceeded, adjusted for the known effectiveness of shelter-in-place strategies. In other words, one to two hours prior to the anticipated time that the threshold will be exceeded.

¹⁰Reisen F, Mayer M, Hansen D. Carbon monoxide – hazard on the fire ground (Bushfire CRC, 2008)

Figure 3: Warnings Matrix for CO Readings

Warnings Matrix for CO Readings								
CO Readings ppm	Predicted Duration of ACTUAL Impact of Plume (How long the plume is in the area)							
	<1	1-2	2-4	4-6	6-8	8-10	10-12	>12
83	EW _{stay}	EW _{stay}	EW _{stay}	EW _{leave}	EVAC	EVAC	EVAC	EVAC
33	A	A	A	W _{shelter}	W _{shelter}	W _{shelter}	EVAC	EVAC
27	A	A	A	A	A	W _{shelter}	W _{shelter}	W _{shelter}
Assumptions								
<ul style="list-style-type: none"> Shelter indoors provides 6 hours protection before the equalisation with the external atmosphere CO based on average reading over a 30 to 60 minute period BOM to provide meteorological forecast of wind speed, direction and duration BoM prediction to inform the estimated time of exposure Available data will be constantly monitored and action will take place well prior to thresholds being reached. 								
KEY								
Formal Evacuation	Advice	Warning		Emergency Warnings				
EVAC (Prepare to Evacuate) <small>based on prediction of impact</small>	A - (Advice)	W _{shelter} - (Shelter Indoors)		EW _{stay} - (Shelter indoors)				
EVAC (Evacuate Now)	Downgrade	Upgrade / Update		EW _{leave} - (relocate)				
	All Clear	Downgrade		Upgrade / Update				

Arrangements to Protect the Community¹¹

The following roles and responsibilities are in place to protect the community:

- The Bureau of Meteorology (BoM) will provide advice on predicted weather conditions for affected communities.
- When activated, EPA will undertake continuous monitoring to determine CO concentrations in potentially impacted communities and provide averaged values for DHHS interpretation. The EPA will ascertain relevant weather predictions from the BOM and advise DHHS of these predictions.
- CFA and MFB may support EPA in undertaking monitoring of CO concentrations in impacted communities.
- CFA and MFB may support the Incident Controller by undertaking predictive modelling of the smoke plume
- The Incident Controller will advise the Chief Health Officer (CHO) of the predicted fire duration and suppression strategies.
- The CHO will assess the advice received from the EPA and the Incident Controller. The CHO will determine the risk to public health of impacted communities, and provide advice to the Incident Controller regarding appropriate actions.
- The Incident Controller will determine an appropriate strategy for protection of the community including the issuing of information to the community regarding CO as required.
- The Incident Controller will lead the Incident Emergency Management Team (IEMT) in their consideration whether an evacuation of a community or part of a community is required.

¹¹ Based in part on the Department of Health Carbon Monoxide Response Plan

- Victoria Police will prepare a staged evacuation plan for communities likely to be impacted by smoke from fires with the greatest CO producing potential at the request of the Incident Controller. Such plans should be prepared as early in the emergency as feasible. Staged evacuation will remove those community members and building occupants with greatest proximity to the source of CO first.
- EPA will provide advice on CO levels at locations nominated by DHHS as potential places for relocated communities.
- DHHS in conjunction with Local Government will coordinate relief and recovery arrangements for relocated communities.

Community actions

Members of the community must remain vigilant during the emergency so that they can receive and act on emergency warnings and information in a timely way. The community should use multiple sources to obtain emergency information.

Individuals should prepare and be ready to shelter indoors if told to do so. (See Attachment 5)

Shelter indoors involves:

- Move to an indoor room with the least amount of doors and windows
- Close all doors and windows
- Switch off air-conditioning or reverse-cycle heating
- Seal any gaps under doors or around windows and wall vents with towels, blankets or plastic
- Continue to monitor advice for additional protective actions to take, and for when and how to end shelter-in-place
- Avoiding other sources of CO (e.g. smoking, poorly maintained gas appliances, etc.)

In a prolonged incident, there may be several occasions where shelter indoors is advised. Between these episodes the air may clear and CO levels drop. Advice will be provided at this time to open doors and windows to air out your home.

Attachment 1 - Carbon Monoxide Specific Information

The purpose of this attachment is to provide relevant information to the:

- Incident Controller
- Hazmat Specialists
- Scientific Advisors; and
- Health monitoring team
- Safety Officer/Advisor

Risk of exposure to carbon monoxide

Carbon monoxide is contained in smoke from all types of fires, as well as other sources. The amount of CO in smoke is greatest from fires with partial combustion of materials like coal, peat, landfill and large mulch piles. The amount of CO is greatest closest to the fire, so fire fighters and other personnel responding to the fires are potentially exposed to the most hazardous levels of CO.

The likelihood that the community will be exposed to CO in smoke is influenced by the distance of the community from the fire, the size of fire, fire management strategies, and the prevailing wind direction and weather conditions. As the community is generally further from the source of the CO than fire fighters and other responders, less CO will reach the community.

All people are susceptible to CO, but the risk of CO to health is greatest to people with heart and lung conditions, anaemia, and the foetus. The likelihood of health effects relates to the concentration of CO in the air and the duration of exposure to contaminated air, as well as individual susceptibilities. In addition, physical activity increases the rate of breathing and will increase the amount of air containing CO inhaled¹².

Background

CO has a high affinity for haemoglobin (Hb) in blood. Hb is the compound that transports oxygen (O₂) in the blood stream. CO is absorbed via the lungs into the blood stream where it forms carboxyhaemoglobin (COHb). This means that CO reduces the oxygen carrying capacity of the blood. Organs with a high oxygen requirement, such as the heart and the brain, are especially sensitive for this effect¹³.

Small quantities of CO are produced in the human body naturally. This leads to a background level of approximately 0.4 – 0.7% COHb in healthy non-smoking individuals¹⁴.

Inhalation exposure to CO concentrations within the Australian occupational exposure standard time weighted average of 30 ppm for 8 hours will result (under normal circumstances) in a COHb concentration of less than 5%.

CO takes 10 to 30 hours to clear from the body in fresh air depending on the amount absorbed and other individual factors

¹² S Bull; HPA Compendium of Chemical Hazards: Carbon monoxide (UK Health Protection Agency 2011)

¹³ Committee on Acute Exposure Guideline Levels, Committee on Toxicology; National Research Council Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8 (2010)

¹⁴ World Health Organisation, Regional Office for Europe. Air Quality Guidelines for Europe, Second Edition. (WHO Regional Publications, European Series, No. 91. 2000)

CO – Acute poisoning

The appearance of symptoms in someone suffering from acute exposure is dependent on the following:

- The concentration of CO in air breathed
- The duration of exposure
- The degree of physical exertion
- Individual susceptibility
- Pre-inhalation COHb level ¹⁵

Susceptible individuals include the following¹⁶:

- Pregnant women – because of potential harm to the foetus from low levels of oxygen
- People with anaemia (low blood count or Hb concentration) - because of lowered oxygen carrying capacity of the blood
- People who have cardiovascular or heart conditions, especially angina
- People who have breathing disorders and lung disease
- Smokers because they may have high levels of CO in their blood before they are exposed to contaminated air

Table 2: Summary of acute health effects of carbon monoxide¹⁷

COHb Concentration %	Principal Signs and Symptoms
< 2	No significant health effects
2.5 – 5	Decreased exercise duration due to increased chest pain (angina) in patients with cardiovascular disease. No significant health effects expected in rest of population
5 – 10	Subtle neurobehavioral symptoms
10 – 20	Headache (“frontal tightness”), possible shortness of breath in healthy population. May be lethal for someone with severe heart disease.
20 – 30	Throbbing headache, nausea, flushing
30 – 40	Severe headache, dizziness, nausea, rapid breathing
>40	Collapse, coma, convulsion, death

N.B. This is given as a guide only and there may be considerable variation depending individual characteristics.

¹⁵ Hazardous Substances Information System (HSIS); Exposure standard documentation: Carbon monoxide (Safe Work Australia 1996)

¹⁶ S Bull; HPA Compendium of Chemical Hazards: Carbon monoxide (UK Health Protection Agency 2011)

¹⁷ Adapted from S Bull; HPA Compendium of Chemical Hazards: Carbon monoxide (UK Health Protection Agency 2011); and the Agency for Toxic Substances and Disease Registry; Toxicological Profile for carbon monoxide (US Department of Health and Human Services, June 2012)

Inhalation exposure to high concentrations of CO in susceptible groups may cause flu-like symptoms such as headache and tiredness, progressing to dizziness, confusion, nausea or fainting. Very high amounts of carbon monoxide in the body may result in oxygen deprivation, leading to loss of consciousness or death.

Neurological problems may be seen following an episode of unconsciousness due to CO poisoning. Symptoms may include cognitive and behavioural changes¹⁸. People with symptoms from CO who have not lost consciousness are at very low risk of developing neurological problems.

Primary recovery from a severe CO poisoning may be followed by a subsequent neurobehavioral relapse days or even weeks after poisoning. The degree of brain damage after CO poisoning is determined by the intensity and duration of exposure.¹⁹

Repeated exposure

CO is not stored in the body. It is completely excreted after each exposure if sufficient time in fresh air is allowed. CO takes between 10 and 30 hours to clear from the body in fresh air depending on the amount absorbed and other individual factors. However, it is possible that repeated mild/moderate poisonings can lead to permanent nervous system damage (headaches, dizziness, impaired memory, personality changes and weakness in limbs).²⁰

Exposure to carbon monoxide can result in hearing loss. Hearing loss is more likely to occur if a worker is exposed to both noise and carbon monoxide than if exposure is just to noise or carbon monoxide alone. The *Code of Practice Managing Noise and Preventing Hearing Loss at Work* recommends hearing is monitored with regular audiometric testing in situations where workers are exposed to:

- ototoxic substances where the airborne exposure (without regard to respiratory protection worn) is greater than 50 per cent of the workplace exposure standard for the substance, regardless of the noise level
- ototoxic substances at any level and noise with LAeq,8h greater than 80 dB(A) or LC, peak greater than 135 dB(C)²¹

¹⁸ S Bull; HPA Compendium of Chemical Hazards: Carbon monoxide (UK Health Protection Agency 2011)

¹⁹ ibid

²⁰ ibid

²¹ Safe Work Australia Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants (April 2013)

Attachment 2 – Carbon Monoxide Information Sheet for Personnel²²

Frequently Asked Questions

What is carbon monoxide?

Carbon monoxide, or CO, is an odourless, colourless gas that can cause sudden illness and death at high concentrations.

Where is CO found?

Carbon monoxide is found in smoke and is formed from incomplete combustion of coal, wood, peat, natural gas, petrol, kerosene, oil, or propane. It is also found in exhaust fumes from cars, petrol and gas engines, gas ovens and cooktops, generators, lanterns, BBQs and gas and wood heaters. Cigarette smoke contains carbon monoxide. Regular smokers are expected to have higher levels of carbon monoxide in their body than non-smokers.

What are the symptoms of CO poisoning?

The most common symptoms of CO poisoning are headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion. High levels of CO inhalation can cause loss of consciousness and death. Seek medical advice if you are experiencing any of these symptoms.

How does CO poisoning work?

When breathed in, carbon monoxide replaces oxygen in the blood and deprives the heart, brain and other vital organs of oxygen.

Who is most at risk?

Whether someone develops health effects from exposure to carbon monoxide depends on a number of factors including:

- the levels of carbon monoxide in the air
- how long a person is exposed
- individual factors, such as an existing heart or lung condition; having anaemia; being pregnant (the unborn child)
- the level of exercise or physical activity, which increases the amount of air breathed into the lungs
- other lifestyle factors such as being a smoker.

Individuals who should avoid CO exposure include:

- Pregnant women – because of potential harm to the unborn child from low levels of oxygen
- People with anaemia (low blood count or haemoglobin concentration) because of lowered oxygen carrying capacity of the blood
- People who have heart conditions, especially angina
- People who have breathing disorders and lung disease
- Smokers with high levels of CO in their blood before they are exposed to contaminated air

Why am I being tested?

At the incident site, personnel are required to undergo pre and post deployment health checks personal monitoring for CO and adherence to control agency SOPs.

Testing for raised levels of CO is part of the health monitoring process. There are no symptoms from low levels of CO in the blood. However, if levels are increased, further health checks may be required to rule out any possible health concerns. Work processes may also have to be reviewed to ensure that further exposure to CO is minimised.

The test is painless and involves a probe which very gently clamps onto a finger to take a reading.

During breaks personnel should avoid other sources of CO exposure such as those listed above.

²² S Bull; HPA Compendium of Chemical Hazards: Carbon monoxide (UK Health Protection Agency 2011)

Attachment 3 – Crew Leader Instruction for Carbon Monoxide Management

Briefings – Pre Entry, Pre Tasking and Pre Release

On shift change, strike teams are to be given a specific briefing on health and CO exposure issues (Attachment 2)

All crew members must be checked by Health Monitoring personnel prior to entering the hot zone, at breaks and post-shift when established.

All crew leaders are to collect personal atmospheric CO carbon monoxide detectors and ensure there is at least one detector per crew while working at the site. They are not required to be worn in clean areas e.g. Staging Area.

Log the detector CO reading every 15 minutes on the attached sheet.

Provide average and peak readings and map grid/location reference of location to the Operations Point every hour via radio.

Crews can only work for 2 hours and then must have a 2-hour break.

If in any 1-hour period there are 2 measurements greater than 60 ppm workers must relocate/withdraw immediately or don BA to remain working in this location. This must be reported immediately to the Operations Point.

At any time a CO reading of greater than 100 ppm is recorded, BA must be donned or workers must withdraw immediately. This must be reported immediately to the Operations Point.

All crew must be rechecked by Health Monitoring personnel at the conclusion of their shift prior to leaving the site. Personnel will not be permitted to leave the site without appropriate clearance provided by the Health Monitoring personnel.

Crews are to be advised that if after release from the site they develop symptoms of potential CO poisoning such as headache, dizziness, weakness, nausea, vomiting chest pain and confusion, they should seek medical advice. On return home personnel are advised to rest for 24 hours, avoid further exposure to sources of CO, avoid alcohol and ensure good hydration.

Attachment 4 – Standard Approach for CO Health Monitoring Process

The following process is to be undertaken to monitor and manage the health of all personnel. The health monitoring process will be established for large and complex incidents producing CO when health monitoring resources are available. The health monitoring team may include Advanced First Aiders and qualified Health Professionals. The health monitoring process will be overseen by a qualified Health Professional to ensure the protocol is followed.

Health Monitoring Team

Advanced First Aiders have the following qualifications

- HLTF403C Manage first aid in the workplace
- HLTAID003 Provide first aid
- HLTF402C Apply advanced first aid
- HLTF404C Apply advanced resuscitation techniques

Or equivalent Senior First Aid qualifications from the Public Safety ITAB

Qualified Health Professionals include;

- Registered Medical Health Practitioners
- Registered Nurses, and;
- Paramedics

On Arrival, Break and Exit

All personnel will enter through the staging area and be directed to the Health Monitoring area for biological COHb monitoring

Hand washing and use of a nail brush will be required as measurement of COHb requires clean hands

The Health Monitoring team will obtain COHb readings on all personnel.

A Health Monitoring team member records:

- COHb reading
- Time
- Name
- Organisation and appliance/location point
- Smoker or non – smoker status
- Previous activity associated with fire in the last 24 hours
- Pre-existing medical conditions/pregnancy or possibility of pregnancy
- Symptoms reported

Table 3: COHb Action Levels

COHb Readings by CO-Oximetry	Actions
Reading is less than 5%	<p>Person is released from Health Monitoring assessment area via designated exit and instructed to:</p> <ul style="list-style-type: none"> • enter the incident control centre for tasking, or • return to staging area for deployment and/or • rest, <p>All personnel that have a reading under 5% COHb are approved to enter the staging area for tasking</p>
Initial reading is equal to or greater than 5%	<p>Person is wrist tagged and is unable to start work until all of the following is completed:</p> <ul style="list-style-type: none"> • Wait in Health Monitoring area for 20 minutes and rest • Rewash hands • Must be retested
Repeat reading is equal to or greater than 5% and less than 8%	<ul style="list-style-type: none"> • All personnel who have a second reading equal to or over 5% and less than 8% COHb will be wrist tagged (indicating excessive COHb reading). • If they have no symptoms they should be released from duty for at least 24 hours • Any person reporting any symptoms such as headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion should be referred to a health professional for assessment. • At any time during monitoring of COHb during a shift if the 5% level is exceeded after retesting, the worker will not be allowed back to work in areas of atmospheric CO contamination.
Equal to or Greater than 8%	<ul style="list-style-type: none"> • Immediate referral to a health professional for assessment and either sent home or to hospital for further assessment and monitoring. • Should remain off active duty for at least 48 hours. • Exposures over 8% COHb are to be logged as an OHS Issue

Post Deployment Medical Monitoring

Crews are to be advised that if, after release from the site, they develop symptoms of potential CO poisoning such as headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion they should present to hospital. On return home, personnel are advised to rest for 24 hours, avoid other sources of CO, and alcohol and ensure good hydration.

Attachment 5 – Shelter Indoors



What to do?

When the plume or smoke is passing over it is safer to stay indoors. After the plume or smoke has passed, it is safer to move outdoors.

Sheltering inside your home or a building in an emergency provides immediate protection from contaminated air outside. The fresh indoor air provides short term protection.

Over time some of the contaminated outdoor air will enter the building through small cracks, and eventually, after the plume or smoke has passed, the outdoor air may be cleaner than the indoor air. At this time it is safer to go outside.

Shelter, Shut, Listen

Shelter

- Go inside immediately.
- Take family and pets with you.
- Avoid phone use. Emergency Services may need to contact you.

Shut

- Close the doors and windows.
- Close all external doors and windows. Seal gaps with blankets, towels or duct tape.
- Turn off heaters, air conditioners and exhaust fans. Close fireplace dampers.

Listen

- Listen to the radio for further information and additional instructions.
- Listen to local ABC or any commercial radio station, turn on the television for media messages, or visit the Vic Emergency website www.emergency.vic.gov.au
- Wait for “all clear” message, then open doors and windows to ventilate building.
- Go outside.

Display this information in your home or place of work. Discuss emergency procedures with family, neighbours and colleagues.

How will I be warned of an emergency due to carbon monoxide?

- Warning systems:
- The fire services may contact you via a telephone message or the media with information on the incident and safety advice.
- Some councils provide community information via their customer service and website.
- A warning will be issued on Vic Emergency website www.emergency.vic.gov.au

For an emergency phone 000 for Fire Brigade, Police, and Ambulance