Managing Bushfire Smoke Exposure

PROCEDURAL

GUIDELINE

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Citation

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Review period

This AFAC guideline should be reviewed by the doctrine owner come 25 October, 2023.

Contents

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AFAC would like to acknowledge the work of Dr Fabienne Reisen and Dr Mick Meyer from CSIRO, through the Bushfire Cooperative Research Centre who have contributed significantly to knowledge about the risk of bushfire smoke exposure. This guideline is primarily based on their works *Smoke Exposure on the Fire Ground: A Reference Guide* (Reisen, F and Meyer, CP. (2009) CSIRO / Bushfire CRC) and *Field Guide to Smoke Exposure Management* (Reisen, F and Meyer, CP. (2009) CSIRO / Bushfire CRC). Dr Reisen has contributed to the preparation of this guideline through provision of expert advice and review.

Source of authority

Approved by AFAC Council on 25 October 2018.

Purpose

Exposure to bushfire smoke is a potential hazard for fire, land management and emergency service workers and all personnel, e.g. machinery operators who work on or near the fire ground (hereafter referred to as 'workers').

This AFAC safe work guideline *Managing Bushfire Smoke Exposure* has been developed to assist firefighting, land management and emergency service organisations to develop consistent, yet organisationally specific, procedures and practices to mitigate the risks posed by bushfire smoke exposure.

This guideline has been designed as outlined in Figure 1, to assist organisations to take a structured, industry-consistent approach to the development and implementation of policies, procedures and other risk control measures aimed at proactively managing workplace health and safety risks in emergency and non-emergency operations.

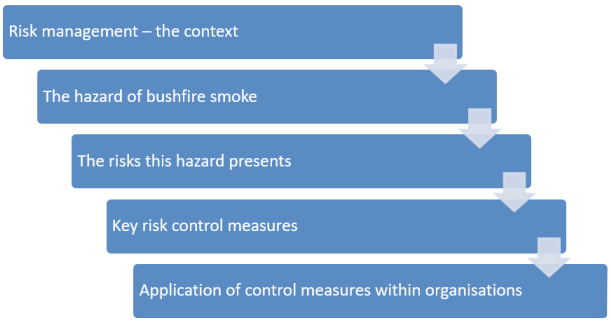

Figure 1 The design of this safe work guideline.

This document should be read in conjunction with the related AFAC Doctrine, *A Work Health and Safety (WHS) Hazard Management Framework for Emergency Service Responders*, and *WHS Hazard Management – A Risk Management Approach to Safety*, and *Selection of Appropriate Respiratory Protective Devices (RPD) During Bushfires* (2017).

Scope

Fire, land management and emergency workers can be exposed to a range of hazards and risks when completing work tasks. These may vary depending on the incident type, the urgency of response and environmental conditions.

Given the nature of emergency response work, it has been acknowledged that established safe work practices and risk management approaches that apply in non-emergency situations may not be appropriate to use while responding to an emergency. Additionally, the practice of prescribed burning gives rise to situations where it is impossible for workers to avoid some exposure to bushfire smoke. Agencies have an obligation to ensure that their responders are protected from hazards, as far as reasonably practicable, regardless of whether they are responding to an emergency or not.

This guideline can be used by fire, land management and emergency service organisations when workers are required to operate in circumstances at risk of exposure to bushfire smoke. This guideline is relevant to emergency response and land management work in Australasia, principally regarding:

- bush firefighting e.g. forest fire, grass fire
- prescribed burning
- urban interface firefighting (where bushfire conditions may be encountered)
- rescue situations where smoke exposure may be a factor, e.g. retrieval of persons from a smoke affected environment.

This guideline provides agencies with evidence-based approaches to inform risk assessments and to develop operational procedures relevant to each organisation. This approach allows for policy development within the context of local conditions and existing organisational arrangements. It also suggests a range of control measures that may be used to manage the safety of fire, emergency and land management workers from exposure to smoke.

It is important to note that this guideline is about worker exposure to bushfire smoke. It is not about the exposure of third parties, including the public, to bushfire smoke and it is not about the exposure of workers to other types of smoke (although reference is made to smoke originating from structures and materials involved in a bushfire).

Statement of engagement

In 2011, the AFAC Council approved the project to develop generic guidelines to reduce the risk of injury to emergency service responders. The project proponent was the AFAC Work Health and Safety Technical Group (WHSTG), working under the guidance of the Workforce Management Group (WMG).

The authors of this guideline have incorporated research findings from the Bushfire CRC Research Project, *Enhancing Emergency Incident Management: A Synthesis of Disciplinary and Stakeholder Knowledge – A Human Factors Perspective*[1], into worker protection and wellbeing, specifically incorporating findings from the Bushfire CRC research project, *Air toxics exposure and management*, as well as other research as referenced.

This guideline has been developed by the WHSTG through consultation with other AFAC collaboration groups, and has been prepared in accordance with the *AFAC Consultation Guidelines*.

Audience

This guideline is intended for personnel who have the responsibility within their organisation for developing doctrine for bushfire smoke exposure related risk-mitigation policies, procedures, practices and training. While this guideline may be of interest to senior managers, incident controllers, trainers and fire and emergency responders, they should refer to their organisation's WHS doctrine for information specifically tailored to their legal jurisdiction and operational and environmental conditions.

Like all guidelines, this document provides organisations with a starting point to produce operational procedures and other processes and documentation relevant to its activities within the context of local conditions and existing organisational arrangements.

Definitions, acronyms and key terms

In this safe work guideline, the following terms have specific meanings.

Bushfire: a general term used to describe a fire in vegetation (includes prescribed fire).

Bushfire smoke: airborne products of combustion from a bushfire.

Dose: what gets ingested or inhaled; it is dependent on the concentration and the duration of exposure and is a function of the workload (how much air is taken in) and whether breathing occurs through the mouth or nose.

Personal Protective Clothing (PPC): clothing that is worn by a person at work and protects them against risks to their health or safety.

Personal Protective Equipment (PPE): equipment that is worn or held by a person at work and protects them against risks to their health or safety.

Respiratory protective device: a device worn by workers to reduce the risk from breathing in harmful particulates, gases and vapours.

Standard Operating Procedures (SOP): a form of guidelines or rules about operations.

Worker: terminology used in health and safety legislation to describe a person, including employees and volunteers that carry out work in any capacity.

1 Ferguson, S., Aisbett, B., Owen, C., Paterson, J., et. al. (2014). *Enhancing Emergency Incident Management: A Synthesis of Disciplinary and Stakeholder Knowledge – A Human Factors Perspective*. Bushfire CRC, Melbourne, Australia.

Introduction

There is a significant level of harmonisation between Australian states and territories in their WHS legislation. Many jurisdictions have adopted model WHS legislation and national policy exists to improve WHS arrangements across the country. Some Australian states do not use the model legislation but have their own legislative arrangements relating to WHS. New Zealand's health and safety legislation is based on Australia's model WHS laws with some variations.

As specified in the AFAC doctrine publication, *A WHS Hazard Management Framework for Emergency Responders*, there are benefits and compelling arguments for the fire, land management and emergency service workers to share knowledge and collaborate on work safety risks. Underpinning the framework is the AFAC doctrine publication, *Hazard Management: A Risk Management Approach to Safety*. This guideline identifies the process that risks faced by responders during operations are identified and controlled, where possible.

AFAC's guideline

Risk management in an emergency, during training and in non-emergency burning operations - the context

Bushfire emergencies are rapidly changing, complex events that, due to their very nature, represent a potential hazard to responders in attendance. Exposure to bushfire smoke is just one of these hazards. Yet, in these challenging situations, hazards still need to be controlled in a way that promotes optimal safety for workers and the community.

In contrast, training situations or planned events (including prescribed burns) allow for greater levels of preparation to occur. However, the nature of prescribed burning operations means that it is impossible for workers to avoid exposure to bushfire smoke.

This guideline supports agencies in the effective management of risks associated with exposure to bushfire smoke by emergency responders and workers in land management, and draws on research conducted by the Bushfire Cooperative Research Centre and other leading researchers in the field. This guideline seeks to inform incident control practices during emergency and non-emergency work (e.g. training or conducting prescribed burns).

The hazard of bushfire smoke and the risks it presents

What is bushfire smoke?

Bushfire smoke is a complex mixture of hundreds of chemicals that are emitted into the air as a result of biomass combustion. It contains potentially toxic gases and particulates that can have adverse effects on the immediate and long-term health of those exposed to it, particularly when it is inhaled but also when it settles on the skin, mucous membranes and clothing.

A significant amount of research has been undertaken on the emissions of a large number of contaminants present in bushfire smoke, including in an Australian context. The nature of bushfires means that emissions can be highly variable as the composition and concentration of bushfire smoke depends on a range of factors including:

- the fuel and its condition (including fuel type, fuel load, fuel size, density and arrangement, fuel moisture content and percentage of fuel that is live)
- the temperature of the fire and its burn rate
- the combustion stage (whether the fire is igniting, flaming or smouldering).

Although the composition of bushfire smoke varies depending on a range of factors, substances that are consistently present and have the potential to impact on health include the following.

Respirable particles (RPs): very small particles that can be inhaled and drawn deep into the lungs where they may cross the lung lining and enter the blood stream. Particles contain organic carbon, graphitic carbon and inorganic ash material as well as act as a carrier for toxic gases.

Polycyclic aromatic hydrocarbons (PAHs): class of organic compounds that may be contained within or adsorbed on respirable particles, and some that are carcinogenic.

Carbon monoxide (CO): a colourless and odourless toxic gas produced through the incomplete combustion of biomass fuels. Carbon monoxide reduces the capacity of blood to carry oxygen throughout the body. It therefore mainly affects organs such as the brain and the heart, which have a high requirement for oxygen.

Aldehydes: a group of chemicals that irritate the respiratory system and reduce the lungs' ability to remove particles and microorganisms from the respiratory tract. Some aldehydes are also carcinogenic e.g. formaldehyde.

Organic acids: substances that are formed when biomass fuels combust including formic acid and acetic acid; exposure can result in a variety of adverse health effects including eye, nose and throat irritation.

Semi-volatile and volatile organic compounds (VOCs): bushfires are known to release a wide range of these substances. Volatile organic compounds may evaporate or sublime to produce vapours at ambient temperatures. One common VOC present in bushfire smoke is benzene, a confirmed human carcinogen. Other VOCs have the potential to cause irritation, headaches, nausea and impact on the central nervous system following exposure. Phenolic compounds are also in this category, many are strong irritants.

Free radicals: although these are produced in large quantities during a bushfire, more research is needed to determine the proportion of these that persist in the atmosphere and therefore represent a risk to human health.

Ozone: ozone is formed toward the top of smoke plumes or further downwind as UV rays react with substances in smoke. On the fire ground exposure to ozone is unlikely; however, those working at high elevation levels close to the top of a smoke plume could conceivably be exposed to damaging levels of this toxin that can affect lung function and cause throat irritation, even at low doses[2].

Other substances: these include nitrogen oxide and sulphur dioxide, which are irritants and are produced when vegetation containing nitrogen and sulphur combust. Many bushfires also burn timbers that have been treated (e.g. fence posts and telegraph poles). These timbers may pose a particular risk to those who inhale the smoke emitted from them or have contact with the ash. The ash or char may contain high levels of arsenic, copper and chromium, and possibly also dioxins and furans formed through combustion.[3] All of these chemicals are toxic, and some are classified as carcinogenic. Workers should be aware of this and wherever possible and reasonably practicable, take steps to avoid the smoke and ash from burnt or burning treated timbers.

Scientific research has shown a clear positive correlation between the different components of bushfire smoke. Put another way, thick smoke will have a high concentration of carbon monoxide and VOCs, as well as particulates.

Workers should therefore understand that the potential adverse effects of exposure to thick smoke is the result of cumulative or synergistic effects from the exposure to all its constituents in relatively high doses.

The conditions under that exposure to bushfire smoke can occur

Exposure to smoke is a reality for workers who may be required to operate in a smoky environment as a result of bushfire or other fire. It is important to note that the circumstances of exposure to bushfire smoke that is experienced can influence the level of risk it presents to workers. Being aware of conditions and circumstances that may contribute to an increased likelihood of becoming exposed to excessive levels of bushfire smoke will assist workers to mitigate the risks this hazard presents.

Risk factors that increase the likelihood of experiencing prolonged and/or higher, and therefore potentially dangerous levels of exposure, can include the following:

2 United States Environmental Protection Agency. 'Ozone and Your Patients' Health'. Accessed: 5 July 2017 (www.epa.gov/ozonepollution-and-your-patients-health).

3 Lavric ED, Konnov AA and De Ruyck J. 2004. Dioxin levels in wood combustion – a review. *Biomass & Bioenergy* 26(2): 115-145.

Risk factor	Reason for risk increase or why the risk is increased?
Hazard	
Bushfire fuel characteristics	Fuel characteristics are a significant factor in driving the combustion process (e.g. flaming or smouldering) and therefore emissions of pollutants. Flaming combustion produces a greater proportion of black carbon whereas smouldering combustion produces a greater proportion of CO, many VOCs and organic particles. High moisture content of fuel lowers the combustion temperature resulting in a slow, smouldering combustion. This leads to increased smoke formation, rich in organic carbon, and a decreased likelihood of strong convective columns that draw smoke away. Low fuel moisture results in a high temperature flaming combustion that produces more graphitic carbon and a strong convective column. Fine woody fuels, leaf litter and grass are mainly consumed by flaming combustion whereas logs, stumps and organic soil are mainly consumed by smouldering combustion. A higher load of coarse woody debris would lead to more smouldering fires.
Hazardous location and / or materials	If a fire occurs in a high-risk location (e.g. an open-cut coal mine), additional toxins or higher levels of toxins may be present. Similarly, if particular materials (e.g. agricultural chemicals, CCA treated timber) burn in the course of the fire, their combustion may release fumes and particulates that add to the risk presented.
Exposure	
The type of task being undertaken	Some tasks are associated with a higher amount of smoke exposure than others, such as: • suppression and patrolling • drip torch (some additional exposures to VOCs have been recorded) • mop-up operations: exposure to ash as well as smoke.
Proximity of an individual to the fire front and thickness of smoke	Being very close to a fire and working in thick smoke means an individual will be exposed to increased levels of toxins; being located downwind of a fire front will result in higher exposure than being upwind.
Meteorological conditions	Wind strength and direction, humidity and heat can all affect the density of smoke where fire fighters are located and affect the fire itself, which can contribute to higher smoke levels. A low-level inversion layer at night can trap pollutants closer to the ground and result in higher pollutant concentrations. High heat and humidity can also affect the breathing rate and hence intake of pollutants.
Lighting pattern	Lighting pattern for prescribed burns vary depending on desired objectives. Lighting patterns can impact whether smoke affects workers on the edge of the burn or whether the smoke gets drawn within the centre of the burn away from workers.
Topography and terrain of fire and location of fire fighters	Fire location can affect the density of smoke, as can proximity of workers, which both affect exposure levels. For example, working on a fire in a gully can result in higher exposure levels as smoke tends to gather in these areas.
Dose	
The length of time an individual is working in the smoky environment	Longer exposure time means the body has an increased window of time to intake toxins.
The intensity of work an individual is undertaking	Heavy physical activity results in deep, rapid breathing that increases the amount of pollutants inhaled and allows pollutants to penetrate deeper into the lungs. Heavy physical activity results in taking a larger proportion of air through the mouth, which means the body's nasal filtration system is utilised less. Air inhaled through the mouth generally leads to more pollutants reaching the lungs compared to air inhaled through the nose.
PPE and PPC usage and effectiveness	PPE and PPC that is appropriate to the situation, used frequently, fits well and is in good condition will offer more protection than those that do not meet these criteria.

Smoke from structures involved in bushfire

Particularly in uncontrolled bushfire situations, structures, vehicles or other man-made (or treated) materials may become involved in a fire and emit additional air pollutants to those described above. These include heavy metals, cyanides, nitriles, acids, organohalides and PAHs. Detailed comment on the effects of these substances and appropriate control measures is beyond the scope of this guideline.

Workers need to be aware that smoke from structures and other artificial materials presents different and additional hazards to bushfire smoke. Workers' exposure to this kind of smoke should be avoided unless they have been trained in the relevant firefighting techniques and have access to appropriate personal protective clothing and equipment.

The risks that bushfire smoke presents

Being exposed to the toxic chemicals and particles present in smoke can potentially have adverse health effects on those who are exposed. Exposure to airborne toxins in smoke is primarily as a result of inhalation, and some of these substances may also settle on the skin and enter the body in this way as well. Everyone who inhales bushfire smoke is inhaling a complex mix of chemicals and particles. For the majority of members of the public who are exposed to bushfire smoke, exposure levels remain low and are unlikely to cause adverse health effects.

Bush firefighters and workers undertaking prescribed burning have a higher risk of experiencing either acute and/or chronic health effects of smoke than the public, as in the course of their work they are often exposed to smoke and particles in higher concentraion and on a more frequent basis. Workers who are exposed to bushfire smoke also need to be aware that some people are more susceptible to the effects of bushfire smoke, for example people with asthma, respiratory or cardio-vascular conditions, smokers and people who are pregnant.

Substances found in bushfire smoke can have both acute and chronic effects.

Acute effects

Acute effects are experienced immediately following or during exposure to a substance and usually disappear once the affected person is moved away from the substance or the substance is removed. Acute effects may be associated with a once-off exposure, even if it is not a particularly high dose.

Acute effects that have been linked to substances present in bushfire smoke can be described as follows. It will be seen that some of the signs and symptoms of acute bushfire smoke exposure are similar to the signs and symptoms of heat stress and/or dehydration. Where this is the case, workers should be encouraged to give consideration to whether heat stress and dehydration, as well as smoke exposure, could be contributing to symptoms.

Asphyxia	• Occurs when not enough oxygen reaches tissues and organs in the body. • Initial symptoms include fatigue, delayed reaction time and impaired ability to perform tasks. • More serious symptoms can include nausea, severe headaches, mental confusion and unconsciousness. • Severe exposure to asphyxiant gases such as hydrogen cyanide and carbon monoxide can cause coma and death.
Irritation and effects on respiratory tract	• Many substances found in both bush and structural fires (volatile organic compounds, isocyanates, polycyclic aromatic hydrocarbons) are irritating to the eyes, nose, throat and respiratory system. • Exposure to these substances can cause breathing difficulties and exacerbate pre-existing medical conditions such as asthma. • Sensitive people can react to even small doses.
Impacts on cardiovascular system	• Respirable particles, carbon monoxide and nitrogen dioxide can all aggravate pre-existing cardiovascular conditions (such as angina) when inhaled. • People who have underlying cardiovascular disease are particularly susceptible to the side effects of smoke inhalation.
Impacts on central nervous system	• Many compounds present in smoke impair the function of the central nervous system. • Symptoms include headaches, nausea, dizziness, fatigue, confusion and loss of coordination and judgement.
Potential effects on pregnant women	• The most significant risk from exposure to bushfire smoke in pregnancy is likely to come from CO exposure. • Generally, cases of mild CO exposure do not result in adverse foetal outcomes.[4] • Regardless, a conservative approach would suggest that significant or repeated exposure to heavy bushfire smoke is not recommended for pregnant women.

Potential effects to health

Scientific studies that have assessed personal exposures of firefighters to smoke at burns and fires in Australia have suggested that air toxins present in significant quantities include carbon monoxide, respirable particles and formaldehyde. Other toxins present in smaller amounts include acrolein, acetaldehyde, furaldehyde, benzene, xylene and phenols.[5]

Based on these findings, the most likely health effects to be experienced by personnel on a fire ground, due to smoke inhalation, include:

- irritation to the eyes, nose and throat
- watering eyes
- headaches (that can occur as a result of smoke exposure and/or dehydration)
- temporary coughing and breathing difficulties
- aggravation of pre-existing respiratory conditions such as asthma, which may mean symptoms are more frequent and severe
- aggravation of pre-existing cardiovascular conditions
- dizziness, fatigue and reduced work capacity (particularly if exposed for longer periods of time to elevated levels of carbon monoxide).

4 Koren G, et al. 1991. 'A multicenter, prospective study of foetal outcome following accidental carbon monoxide poisoning in pregnancy'. *Reproductive Toxicology* 5: 397–403.

5 Reisen F, Brown SK. 2009. Australian firefighters' exposure to air toxics during bushfire burns of autumn 2005 and 2006. *Environment International* 35(2):342–352; Reisen F, Hansen D, Meyer, CP. 2011. Exposure to bushfire smoke during prescribed burns and wildfires: Firefighters' exposure risks and options. *Environment International* 37(2): 314–321.

Chronic effects

Chronic effects are long-term effects that often result from ongoing exposure to a substance, even if that exposure is at a lower dose. Chronic effects may not be evident until significant time has elapsed following exposure(s). Chronic effects are harder to link to an exposure, or repeated exposure.

Chronic effects that have been linked to excessive exposure to some chemicals found in bushfire smoke include the development of some cancers (e.g. benzene is a known carcinogen). Chronic effects from exposure to other substances found in smoke may include development of respiratory diseases.

Although exposure to bushfire smoke does represent a risk to the long-term health of those who are repeatedly exposed, it has been assessed that increased probability of cancer from bushfire firefighters career-long exposure to the carcinogenic air toxics benzene and benzo(α)pyrene is comparable to the cancer risk of residents in major cities as a result of urban pollution.[6]

For more information, see Appendix 1: *Health effects of toxics in bushfire smoke and Reisen, F. and Meyer, C.P. (2009).*

Exposure standards for bushfire smoke toxics

Occupational exposure standards exist for many of the substances found in bushfire smoke. There are legal requirements that apply to persons who conduct a business or undertaking in relation to the exposure of workers to airborne substances or mixtures in excess of exposure standards. Legal advice on these requirements is outside the scope of this document. Fire, emergency service and land management agencies should obtain their own legal advice on this issue if they are uncertain about the implications of this.

Many exposure standards are expressed in terms of an 8-hour time weighted average (TWA). In a fire and land management context, many working shifts may exceed eight hours and this has implications for the relevant exposure standards. The methodology for calculating occupational exposure standards for extended work shifts (longer than 8-hour day) is outside the scope of this document but is available in published materials.[7]

Relevantly for the purposes of this guideline, monitoring of workers in actual prescribed burning and bushfire suppression activities has demonstrated that it is possible to exceed occupational exposure standards for carbon monoxide and respirable particles, in terms of TWAs (over a shift), short-term exposure limits (15-30 minutes) and peak (absolute) limits.[8]

Researchers have also suggested[9] that exposure to a mixture of the substances found in smoke may have different adverse health effects than simply being exposed to individual chemicals one at a time. It has also been noted that the route of exposure (e.g. inhalation, dermal exposure, ingestion) has an effect on the way various chemicals are absorbed in the body and the adverse health effects they may have.

Reisen and Meyer (2009) state: 'due to the uncertainty in assessing exposure risks to a complex mixture of pollutants, exposure to individual compounds should be kept as low as possible to minimise detrimental effects on … health'.[10]

Therefore, consideration should always be given to minimising workers' exposure to smoke so far as possible, even in emergency situations.

6 Reisen F and Meyer CP. 2009. *Smoke Exposure on the Fire Ground: A Reference Guide*. CSIRO/Bushfire CRC. p.65.

7 See for example, Safe Work Australia. 2013. *Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants*; Reisen F and Meyer CP. 2009. *Smoke Exposure on the Fire Ground: A Reference Guide*. CSIRO/Bushfire CRC.

8 Reisen F and Meyer CP. (2009). *Smoke Exposure on the Fire Ground: A Reference Guide*. CSIRO/Bushfire CRC.

9 Laitinen J, Makela M, Mikkola J, Huttu I. 2012. 'Firefighters' multiple exposure assessments in practice', *Toxicology Letters* 213: 129-133.

10 Reisen F and Meyer CP. 2009. *Smoke Exposure on the Fire Ground: A Reference Guide*. CSIRO/Bushfire CRC. p.14..

Key risk control measures

The following control measures are structured according to the hierarchy of risk control.[11] Work health and safety regulations require agencies to work through the hierarchy from the top down when managing risk.

Level 1: Elimination

Elimination of the presence of smoke in a bushfire is not possible unless the fire is extinguished; however, doing so necessitates exposure of workers to smoke as the presence of firefighters in the smoky environment during bush firefighting and prevention work (such as planned burning) is essential. The best method of minimising health risks presented by bushfire smoke is to limit worker exposure to it, as far as reasonably practicable.

As the hazard of bushfire smoke cannot be eliminated, consideration must be given to control measures.

Level 2: Substitution, isolation and engineering controls

The nature of bushfire smoke and the circumstances in that worker exposure to it arises is such that substitution, isolation and engineering controls are not realistic ways of controlling the risks attendant on it. Therefore, consideration must be given to other control measures.

Level 3: Administrative actions

There are a range of work methods and procedures that may assist in mitigating the risks of exposure to smoke. These following approaches rely on effective supervision, consultation and the ongoing engagement of workers.

Planning

Forward planning is key to enhancing the safety of firefighters and other workers likely to be affected by bushfire smoke exposure while attending an emergency or working in a situation where smoke exposure cannot be avoided. Agencies should therefore develop and implement systems and procedures to mitigate risks as far as reasonably practicable.

Planning should take into account terrain, lighting pattern, fuel conditions (e.g. load and moisture) and meteorology, as these will enable managers to evaluate the potential risk of high smoke exposure situations and to plan crew allocations accordingly.

It is important that each agency's risk plan sets standards and identifies the resources required to ensure safe systems of work are maintained. Given that rotation of crews has been identified as a key control measure, pre-planning should take into account the need to rotate crews where practicable through smoky tasks into less smoky ones.

Each agency must assess the hazards and risks in their area relating to this guideline. The assessment should include personnel working for other agencies where interoperability occurs.

Plans and procedures should take into account and specify any variation from the normal operational capability of personnel, appliances and equipment. In particular, recognition should be given to the physical and psychological impacts smoke exposure can have on operational personnel. Planning should include itemising resources required in order to adequately mitigate (where possible) and respond to the effects of smoke exposure.

Debriefing post-incident should occur as appropriate and ensure any significant lessons are captured and fed back into the development of safe work systems, training programs and equipment procurement.

Training

Recognition of the dangers of smoke exposure and the signs of exposure can be gained by using classroom based presentation techniques. Where the opportunity to do so exists, training in the hazards posed by smoke exposure and potential mitigation strategies could be incorporated into live fire training sessions. Casualty management, including variations in exposure types and severity and the management of various symptoms, could usefully be included in this training program.

More detail can be found in Appendix 2: Training considerations.

Training outcomes should be evaluated to ensure that the training provided is effective, current and meets defined operational needs as determined by each agency's risk management plan.

Regular rotation of crews

Research has shown that exposure to bushfire air toxics varies significantly depending on work tasks being undertaken and firefighters' location on the fireground.[12]

This variability offers incident controllers the opportunity to consider mitigation of worker exposure to smoke by rotating crews through different tasks and different locations if this is practicable.

11 Safe Work Australia. 2011. *How to manage work health and safety risks*. p.13.

12 Reisen F and Meyer CP. 2009. *Smoke Exposure on the Fire Ground.*

In situations where the amount of smoke is moderate to very high (moderate being defined as mostly light to moderate smoke with brief exposures to occasional drifts of heavy smoke and very high as continuously thick smoke with very low visibility), the recommendation[13] is to rotate crews to different work tasks and burn areas if the opportunity presents itself.

It is important that incident managers and crew leaders take into consideration a range of factors when deploying crews, including but not limited to:

- the topography of the location that the fire crew has been working and will be deployed next – smoke can be heavier in gullies and valleys, and on steep hills, and less dense in open areas
- the direction of the wind – smoke can be substantially heavier in smoke-logged areas downwind of the fire front; being located upwind can offer significant respite from dense smoke
- activities such as actively suppressing a fire can result in significant exposure to dense smoke
- lighting pattern and how edge burning can lead to high exposures for patrol crews at the edge of the burn area; central ignition drives the smoke towards the centre of the burns area leading to lower exposures for both lighting and patrol crews. Whereas lighting patterns may be dictated by other considerations, it is relevant for decision-makers to be aware of the implications where it is known that a particular lighting pattern may lead to increased levels of smoke being present.

Front-line supervisors are likely to be present at many high-risk areas and activities so bear this in mind when assigning tasks to leaders.

Reducing time spent in heavy smoke

In an emergency situation, it may be difficult to avoid exposure to dense smoke. Many fire and land management agencies already embed in their training and operating procedures the principle that workers should remain out of the smoke wherever possible. This guideline reinforces that principle in the context that exposure to heavy bushfire smoke includes exposure to significant levels of toxics and carbon monoxide, such that it has been demonstrated to be possible to exceed occupational exposure standards both in terms of acute exposure and over the course of a shift.[14] There should therefore be an awareness at all levels from incident / burn managers and planners to front line workers that there are important health reasons for keeping exposure to bushfire smoke – particularly very heavy smoke with visibility of only a few metres – to the minimum possible.

The following images[15] are examples of what various smoke conditions may look like in the field:

Light smoke conditions

Moderate smoke conditions

Heavy smoke conditions

Very heavy smoke conditions

13 Reisen F and Meyer CP. 2009. *Field Guide to Smoke Exposure Management*. CSIRO/Bushfire CRC. pp.6–8.

14 Reisen F and Meyer CP. 2009. *Exposure on the Fire Ground: A Reference Guide*. CSIRO/Bushfire CRC.

15 Image for 'Heavy smoke conditions' supplied courtesy of Queensland Parks and Wildlife Service. All other images are courtesy of the Bushfire and Natural Hazards CRC.

Field based research has determined a good correlation between carbon monoxide and respirable particulate matter in smoke, which means that smoke conditions defined by visibility can be used to approximate exposure risks due to other smoke components.

Prescribed burns, worker tasks and ignition techniques

The way that a prescribed burn is ignited can influence the dispersion of smoke and therefore, the exposure levels of workers to that smoke.[16] Research suggests that exposure to smoke varies depending on the type of ignition (e.g. edge burning, central ignition, slash burns) combined with topography and position of workers in the context of the fire. Particular tasks associated with prescribed burns were also found to have higher exposure levels than others.[17]

High and very high exposure risk tasks include:

- patrolling on top of a ridge at a steep burn area
- patrolling downwind of smoke (edge burning)
- supervision at burns
- suppression with a rake hoe or hose downwind.

Moderate exposure risk tasks include:

- lighting with handheld drip torch within burn area (downwind of smoke)
- patrol upwind of smoke and occasional downwind of smoke
- grass burn flanks
- mop-up within areas with smouldering logs.

Low exposure risks include:

- lighting with handheld drip torch upwind of smoke
- patrol upwind of smoke (edge burning and central ignition)
- patrol during core lighting (edges done previous day)
- favourable meteorological conditions (smoke drawn within centre of burn area)
- lighting at heap or slash burns upwind of main lighting.

It is recommended that agencies take this information into consideration while undertaking planned burns, and evaluate worker exposure to smoke in the context of this information. As discussed above, ignition patterns may be dictated by other considerations, but all concerned should understand their implications.

Allowing for sufficient recovery time in clean air for crews

Although some effects of smoke exposure (such as eye irritation) will rapidly reduce when workers leave a smoky environment for clean air, many toxins found in bushfire smoke can take some time to leave the body. Carbon monoxide (CO) is of particular note due to its significant presence in bushfire smoke, its toxicity and its ability to build up in the body over the course of several hours.

Where CO poisoning is suspected, medical treatment should always be sought. The purpose of this section of the guideline is to reinforce that time spent away from smoky environments in clean air contributes to elimination of CO from the body and maintaining exposure over a shift, or sequence of shifts, below relevant occupational exposure standards.

Recovery time will vary depending on a range of factors, including:

- density of the smoke that the worker has been in
- how clean the air is during breaks and while off shift
- length of the break
- length of time the worker has been exposed to smoke while on shift
- what the worker does during the break (e.g. carbon monoxide can be eliminated faster from the body if physical activity is undertaken during the break in the clean air; given that many workers will be relatively sedentary during breaks and want to use this time to rehydrate, eat, rest and treat heat stress, it cannot be assumed that physical activity levels during breaks will be high)
- smokers will already have higher COHb levels compared to non-smokers. Smoking will increase intake of CO.

A more detailed discussion can be found at Reisen, F. and Meyer, C.P. (2009) p48.

Attention should be paid to the location of rest, staging and accommodation areas to maximise the opportunity for workers to recover in clean air. Although it will not always be practicable to avoid smoke entirely, and changing wind direction may mean that a previously clear area becomes affected by smoke, in principle choices about rest and staging area locations and accommodation sites (such as base camps) should be made with the objective of minimising smoke exposure in mind.

16 Reisen F and Meyer CP. 2009. *Smoke Exposure on the Fire Ground: A Reference Guide*. CSIRO/Bushfire CRC. pp.31–32.

17 Reisen F and Meyer CP. 2009. *Smoke Exposure on the Fire Ground: A Reference Guide*. CSIRO/Bushfire CRC. p.54.

Health and environmental monitoring

Particularly where crews are repeatedly exposed to smoke over multiple shifts, or where extended operations take place in smoke-affected environments, agencies can consider the use of health monitoring to assess the health of workers prior to them entering or re-entering the fire ground. A decision to conduct health monitoring would be taken after a risk assessment and taking into account what is reasonably practicable in the circumstances. Health monitoring may include assessing body temperature, CO levels in blood[18] and asking general questions regarding a worker's health status and symptoms.

Similarly, a risk assessment may indicate that environmental monitoring, to determine the level of exposure to bushfire smoke toxics, is appropriate. This may principally be relevant to locations that are known to be significantly affected by smoke and where crews are required for operational reasons to work in.

Agencies implementing health and environmental monitoring that do not have a standard operating procedure for these functions should obtain expert advice as required from occupational hygienists, medical specialists and environmental monitoring specialists on suitable systems.

Level 4: Use of personal protective equipment

It is important to ensure that any PPE and PPC provided is fit for purpose and meets required standards. Consideration should also be given to the selection of suitable sizes of PPC and PPE for each individual and ensure that equipment such as masks and respirators fit well, and that every worker has received training on their safe and effective use as well as the limitations of this equipment. Refer to AFAC guideline Selection of Appropriate Respiratory Protective Devices (RPD) During Bushfires for details.

Self-contained breathing apparatus (SCBA)

The only protection available against carbon monoxide (CO), which is extremely toxic and may be present at high levels in bushfire smoke, is self-contained breathing apparatus (SCBA). Other masks and respiratory protective devices are ineffective against CO. In the absence of SCBA, it is important to remember that all other respiratory protection options have limitations and cannot be relied upon to protect firefighters from the hazards present in smoke; typical wildfire PPE does not provide adequate protection from the range of toxins present in bushfire smoke.

SCBA is a self-contained unit that provides the wearer with an independent supply of breathable air. The average SCBA weighs approximately 12 kg when ready for use. Specialist training is required to become an SCBA operator. SCBA is normally used at structure fires and other incidents where a wearer has the potential to be exposed to life threatening atmospheres.

Use of SCBA by bushfire firefighters and land management workers during bushfires is considered impractical due to the size, weight and short duration of the available air supply (35-45 minutes).

Reusable powered air respirator

Powered air respirators use a motorised blower unit to draw air through a filter to deliver clean air into the respirator face piece. The units consist of a battery pack, blower unit, filter and face mask.

These are rarely used during bushfires as they tend to be too unwieldy for extended periods of use and are reliant on the availability of replacement batteries to operate.

Reusable filter respirator

Filter respirators use replaceable filters to clean the air. The filters are fitted to half face piece, full face piece, or head covering masks that provide protection from particulates, gases and/or vapours depending on the filters used.

Filter life depends on a number of variable factors including the wearer's breathing rate, the characteristics and level of the contaminant, the length of exposure to a contaminant and environmental conditions such as temperature and humidity.

It should be noted that when a P3 filter (P3 represents the highest level of protection provided by respirators) is used with a half face piece mask, its protection factor is only equivalent to a P2 filter.

Use of reusable respirators requires the implementation of an ongoing respirator maintenance program in accordance with AS/NZS 1715.

The integration of reusable respirators is increasing during bushfire response, but their suitability for extended use – as may be experienced during a major fire – remains questionable due to the increased effort to breathe through cartridge type filters and the ability to maintain an ongoing face seal due to sweat and facial hair. Replenishment of cartridges can also create supply issues when workers are working remotely or are inaccessible.

18 Monitoring methods are outside the scope of this Guideline; non-invasive techniques for CO blood level monitoring have been developed in recent years.

Disposable respirators

Disposable respirators are only available as P1 (the lowest level of protection) or P2. Cloth tied over the lower half of the face, bandanas and disposable dust masks or masks with a P1 rating do not offer any protection from any bushfire toxins as they do not filter out gases or fine particles. Accordingly, if respiratory protection is required, the minimum level that should be contemplated is the P2 mask. The P2 mask is the most commonly used type of respiratory protection at a bushfire, but these are only suitable for filtering out airborne particulates, and have only limited ability to filter out gases or vapours. The masks consist of a paper or composite material that is held in place by rubber or elastic retention straps that fit over the nose and mouth. They may come in a range of sizes, and may have exhalation valves fitted and / or include carbon filters for nuisance vapours. They provide a practical solution for use during bushfires. Like all respiratory protective devices, they are reliant on a good fit to achieve maximum particulate filtration. There is no requirement to have an ongoing respirator maintenance program for disposable masks, but wearers should be trained in how to fit and wear disposable masks and be made aware of their limitations.

Goggles

Eye protection such as goggles may offer some respite from acute eye irritation caused by smoke and provide workers with higher levels of comfort whilst on shift. Training is required on how to fit and wear goggles to maximise their effectiveness.

Provision of personal monitoring equipment

Where a risk assessment shows that exposure to CO is a potential hazard, it is possible to monitor for CO exposure at a personal or crew level by issuing portable monitoring devices. A number of devices are available on the open market and may be body worn or carried in a vehicle cab (see *Health and environmental monitoring*).

The use of personal CO monitoring equipment is not standard practice in Australian or New Zealand bushfire or land management agencies. A decision to implement this tactic would depend on the outcome of a specific risk assessment and consideration of what was practicable or desirable in a given environment to manage a recognised exposure risk.

Laundering of PPC

Prolonged exposure to bushfire smoke and particulates carries the potential for toxic substances to build up in unlaundered PPC. Regular laundering of PPC is recognised as important in the structure firefighting environment and similarly, PPC exposed to bushfire smoke should be laundered appropriately. For similar reasons, workers should be reminded of the benefits of showering and changing clothes as soon as practical after the end of a shift in order to remove ash and other residues from the skin.

Application within agencies

To mitigate the health risks associated with bushfire smoke exposure as far as reasonably practicable, action may be appropriate at each of the organisational, incident management, and front-line crew levels. See Appendix 3: Application within agencies for more information.

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Appendix 1. Health effects of toxics in bushfire smoke

Potential health effects of exposure to various toxics found in smoke

Toxin	Potential health effects (acute and chronic)
Carbon monoxide (CO)	• Fatigue, rapid breathing, headaches, dizziness, nausea, disorientation, confusion, weakness, chest pain • Behavioural effects, e.g. reduced reaction time, impaired judgement, effects on performance of tasks requiring attention and concentration • Reduced work capacity • Exacerbation of pre-existing respiratory or cardiac disease • Passing out or fainting • Skin and mucous membranes appear to have a bluish tinge (cyanosis) • Asphyxia, death • Effects on foetal development.
Respirable particles (RPs)[19]	• Nose and throat irritation • Coughing, shortness of breath • Aggravation of asthma • Impaired lung function • Exacerbation of pre-existing respiratory or cardiac disease • International Agency for Research on Cancer (IARC) – Category 1: Known human carcinogen.
Polycyclic aromatic hydrocarbons (PAHs) e.g. benzo(α)pyrene	• Eye, nose and throat irritation • A number of PAHs are classified by IARC as known, possible or probable human carcinogens.
Formaldehyde (HCHO) (a volatile organic compound – VOC)	• Irritation to eyes, nose and throat • Watering eyes • Can cause skin and lung allergies • Aggravation of pre-existing respiratory conditions (asthma, shortness of breath, wheezing, cough, chest tightness) • IARC – Category 1: Known human carcinogen.
Acrolein (a VOC)	• Irritation to eyes, nose and throat • Aggravation of pre-existing respiratory conditions such as asthma • Can contribute to development of chronic respiratory disease.
Acetaldehyde (a VOC)	• Irritation to eyes, nose and throat • Coughing, nausea, headaches • Aggravation of pre-existing respiratory conditions, asthma exacerbation • IARC – Category 2B: Possibly carcinogenic to humans.

19 Respirable particles refer to particles that reach the alveolar region of the lung and are not easily ejected by exhaling, coughing or expulsion by mucous.

Benzene (a VOC)	• Irritation to skin and eyes, respiratory irritation • Drowsiness, dizziness, headaches, nausea • IARC – Category 1: Known human carcinogen (can cause leukaemia/lymphomas).
Toluene (a VOC)	• Irritation to eyes, nose and throat • Watering eyes • Headache • Light-headedness.
Other Volatile Organic Compounds (VOCs)	• Irritation to eyes, nose and throat • Headaches.
Hydrogen cyanide (HCN)*	• Irritation of the eyes, nose and throat • Weakness, exhaustion, headache, confusion • Nausea, vomiting • Rapid, deep breathing or slow, shallow breathing • Affects organs utilising a lot of oxygen (e.g. heart and brain), thyroid and blood • Asphyxia, death.
Hydrogen chloride (HCl)*	• Irritation of the eyes, nose and throat • Coughing, choking sensation • Dermatitis.
Nitrogen dioxide (NO2)**	• Irritation of the eyes, nose and throat • Aggravation of pre-existing respiratory disease (e.g. asthma) or cardiac disease • Rapid breathing and heart rate • Decrease in lung function.
Hydrogen fluoride (HF)*	• Burning sensation, irritation and watering of eyes • Prickling, burning sensation when inhaled • Cough, pain beneath sternum • Nausea, vomiting, diarrhoea • Irritation of nasal passages, dryness, bleeding from nose.
Dioxins** (a group of environmental pollutants are considered toxic when absorbed in large amounts)	• Skin lesions • Altered liver function • Immune system impairment • Affects nervous system, endocrine system and reproductive functions • IARC – Category 1: Known human carcinogen (TCDD only).

*Not typically emitted in a bushfire, but in structure or other fires where manmade synthetics, plastics and resins are present.

** Emitted in a bushfire, but in greater quantities in structure fires or where manmade fuels are present.

Appendix 2. Training considerations

At a minimum, workers should receive information, instruction and / or training on:

- understanding the hazards and risks presented by bushfire smoke exposure
- being able to recognise when exposure to toxins in bushfire smoke is more likely
- understanding the conditions and risk factors that have the potential to contribute to high levels of bushfire smoke exposure
- knowing how to minimise exposure to bushfire smoke and planning ahead to minimise this, where reasonably practicable
- implementing workforce and rotation strategies that may minimise individual's exposure to smoke exposure and limit arduous physical activity that may exacerbate the risk smoke presents
- monitoring bushfire smoke exposure in the working environment and being able to judge when smoke conditions are low or high
- recognising of the signs and symptoms of bushfire smoke exposure
- knowing first-aid and recovery techniques for those affected by mild and more severe bushfire smoke exposure
- enacting effective use of PPC and PPE
- understanding the limitations of PPE when fighting bushfires.

When formulating a training strategy, agencies should consider:

- the level and nature of training undertaken should be shaped by informed assessment of operational needs in accordance with internal training plans, national standards, agency doctrine and standard operating procedures
- training and development programs should generally be structured so that they move from simple to more complex tasks and from lower to higher levels of risk
- training and development will typically cover standard operational procedures as well as ensuring knowledge and understanding of equipment and the associated skills that will be required to use it
- training and development programmes should consider the need for appropriate levels of assessment and provide for continuous professional development to ensure maintenance of skills and to update personnel whenever there are changes to procedure and equipment.

Appendix 3. Applications within agencies

To mitigate the health risks associated with bushfire smoke exposure – as far as reasonably practicable – action may be appropriate at each of the organisational, incident management and front-line crew levels.

Organisations

- Promote an understanding of the health risks associated with exposure to bushfire smoke within the agency.
- Encourage personnel at all levels of the agency to understand minimising exposure to bushfire smoke as being a health-related issue.
- Consider in general terms what mitigation strategies may be adopted to minimise the health risks from bushfire smoke within the agency, particularly whether on a risk basis it is appropriate to provide environmental or personal monitoring resources in support of mitigation strategies.
- Provide camp locations based as far away from smoky locations as possible, remembering that smoke is easily trapped in valleys and gullies overnight.
- Give consideration to the legal significance of occupational exposure limits to the various substances found in bushfire smoke and any consequential requirements to monitor worker exposure and health in the context of these.

Incident Managers

- Understand that minimising worker exposure to bushfire smoke is an objective in support of worker health and safety.
- Conduct an exposure risk assessment, involving relevant health authorities and environmental protection agency (or equivalent) as necessary, during a prolonged incident. Consider environmental monitoring where indicated by risk assessment.
- Be aware of any available facilities for environmental and personal monitoring where a risk associated with worker exposure to bushfire smoke is identified.
- Wherever possible, consider task rotation during a single shift as a means of minimising the time crews may be exposed to moderate/very high levels of smoke.
- Where practicable, implement rehabilitation strategies such as ensuring recovery time and other breaks can be spent in clean air.
- Crews should be briefed on incident action plans and control measures, particularly those associated with smoke exposure.
- Reinforce the need for respiratory protection and goggles to be utilised, but do not rely on them as a means of mitigating exposure to all substances in bushfire smoke – remember that P2 masks and dust masks do not filter out potentially deadly toxins such as carbon monoxide.

Crew leaders and workers

- Be aware of smoke exposure symptoms and effects and take any practical steps possible to minimise personal and crew exposure.
- Alert others in your team and your supervisor if you feel adversely affected by smoke exposure.
- If a structure is involved, firefighters should not enter the structure or remain in a plume of smoke from the structure unless appropriate SCBA and other PPE for structural fires are utilised.
- Correct PPC and PPE for the task being undertaken should always be maintained, remembering that P2 masks and dust masks have limitations and do not filter out toxins such as carbon monoxide, and only remove particles from the air.
- Adopt a comfortable working pace on the incident ground.
- Monitor personal signs and symptoms of the possible side effects of bushfire smoke exposure, and those of team members.
- Ensure regular breaks are taken in areas away from dense smoke, where possible.