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## **Fulbright Participant Report**

### **Title: Building Collaborations for Bushfire Firefighter Health**

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#### **Abstract:**

**Objectives:** The goal of this Fulbright research project was to build collaborations for firefighter health through establishing an international collaboration to share research and conducting site visits to collect information how Australian firefighters are working to reduce their exposures during bushfires.

**Aims:** The research specific aims were to establish a bush/wildland/wildland-urban-interface (WUI) firefighter health research collaborative between Australia and the United States (US), identify and discuss work practices used by Australian bushfire firefighters to reduce their exposures, and identify research requested by Australian bushfire firefighters to better protect their health.

**Results:** We established an ongoing quarterly virtual collaborative meeting with liaisons for Australian, US, and most recently Canadian fire service partners and academic researchers. Through this meeting we are sharing current bush/wildland/WUI firefighter practices for reducing exposure to carcinogenic combustion products and the research studies that are evaluating their efficacy. I also met with career and volunteer firefighters throughout Australia to determine their level of satisfaction with these practices and their research questions about how to better protect themselves. Each state and territory has different approaches in place, although all offer some level of respiratory protection for bushfire responses. Common themes in respiratory protection include having disposable particulate respirators available for general use and either current availability or movement towards using silicone half- or full-face respirators with cannisters or cartridges effective against a range of contaminants. A general concern is exposure to carbon monoxide for which these respirators do not provide protection. In this regard carbon monoxide monitoring is being used or considered for use in some Australian states to help identify high exposure settings and inform administrative controls. Reduction in dermal exposures has focused on post-use cleaning of the bushfire turnout gear, with limited use of skin wipes and variable showering practices. Research questions covered multiple topics, with the most frequent question being the extent to which the toxicity of the smoke varies based on the type of vegetation burning. Meetings with Australian university, government and other fire service organizations have identified both completed and ongoing research needed to support the exposure reduction policies. The purpose of this participant report is to summarize and share the results of the site visits with all study participants with the goal of informing exposure reduction intervention practices and research planned with US and Australian wildland fire service partners.

## Background and General Findings:

This research was conducted as part of my Fulbright Future Scholarship, funded by the Kinghorn Foundation, and hosted by Dr. Deborah Glass at Monash University in Melbourne. The research was conducted through site visits and interviews with fire service agencies and researchers throughout Australia. This report is a summary, and a great deal of additional information was collected but not included to keep the report succinct.

From August 2022 through August 2023, we held four quarterly virtual collaborative meetings starting with liaisons for Australian and US fire departments responding to bushfire/wildfire incidents and added Canadian fire service partners starting with the May 2023 call. Through this continuing quarterly meeting we are sharing current bush/wildland/WUI firefighter practices for reducing exposure to carcinogenic combustion products and the research studies that are evaluating their efficacy. Please contact me for additional information and interest in participating in ongoing calls.

The fire service in Australia is organized by state and territory, with career and volunteer firefighters either in separate agencies for each state/territory or combined into one. Exceptions include aviation firefighters, who are organized nationally, and which were not contacted as they typically do not respond to bushfires. Separate firefighting activities are carried out by state or territory forestry, parks and/or collaborative agencies. While this project is focused on bushfire firefighting which primarily involves burning vegetation, the bushfire firefighters pointed out that structure protection was often involved and that multiple other exposures including hazardous waste (e.g. chemicals and asbestos) dumps could be present. Indigenous communities in Australia carry out extensive planned burns but their activities were outside of the scope of this project. This study also did not address bushfire prevention as a means of exposure reduction.

An overview of bushfire exposure reduction practices by fire service agency is provided in **Table 1**. For this report, respiratory protection was divided into three types: disposable particulate (referred to P2 or P2 mask) respirators, silicone half-face (referred to as half face or half face mask) respirators with HEPA or other filter type cartridges or cannister, and silicone full facepiece (referred to as P3 or P3 mask) respirators with HEPA or other filter type cartridges or cannister. Based on Australian standards, half face respirators are not P3 respirators even though similar filters (cannisters or cartridges) can be used on both depending on the manufacturer. All agencies provide P2 for their firefighters, and some provide half face and/or P3 as well. Although always provided, P2 use varies by state and territory, with some locations rarely using them. Common concerns with use of both half face and P3 masks are the need to maintain hydration as the masks need to be removed to drink, and the increased work of breathing through the resistance of the filter when firefighting activities involve significant exertion. Specific to half face masks, a common issue was the inability for many firefighters to simultaneously wear both the mask and goggles. More of a concern with the P3 mask was the difficulty of removing the mask to communicate or for other purposes (such as getting a break from the work of breathing through it) due to the need to remove one's helmet as well. P3 (and to a lesser extent half-face) masks cannot easily be carried on the belt or elsewhere, requiring returning to the vehicle where it is stored, whereas P2 can more easily be carried and used when needed. Problems seeing with bright sun were also noted for the P3 mask. Most of the firefighters reported making the choice individually as to when to wear the respirators and when to remove them often based on smoke density and/or symptoms. A general issue for respiratory protection fit was that volunteer firefighters are often not clean shaven. Finally, in locations not providing half mask or P3 respirators firefighters have in some cases brought their own which were not designed specifically for bushfire use or permitted by their agency. The suitability of powered air-purifying respirator (PAPR) use for bushfire exposure reduction is being evaluated by Fire Rescue Victoria (FRV). The establishment of cancer presumptive laws for volunteer firefighters has helped drive the introduction of half face and P3 respirators. Also, the provision of silicone respirators for career firefighters during bushfires helped drive

the interest of volunteer firefighters in being provided them as well. Many agencies reported trials of different respirators prior to settling on their current choices, with the trials largely based on acceptability for use as determined by multiple firefighters in their agency rather than full field effectiveness tests.

**Table 1. Bushfire exposure reduction practices by organization (as of February-May 2023)**

State/ Terr.	Organization	Respiratory*	Dermal	CO Monitoring	Notes
NSW	Fire and Rescue NSW (FRNSW)	Full face (P3) mask with Dräger 6738797 cartridges	No protocol	Not generally used for bushfires	
NSW	Rural Fire Service (RFS)	Choice of half face and full face P3 mask with Dräger 6738817 cartridges.	No protocol	Not generally used for bushfires	SCBA an option if firefighters trained.
NT	NT Fire and Rescue Service (NTFRS)	Choice of half face with ABEK1 Hg P3 filters and P3 mask with Scott Pro2000 CF22 A1P R SL filters	No protocol	Not generally used for bushfires	Heat stress a major issue
NT	Bushfires NT	Disposable P2	No protocol	Testing out CO and other monitors	Heat stress a major issue
QLD	Queensland Fire and Emergency Services (QFES)	Full face (P3) mask with Scott MPC Plus cannister	No protocol	Extensive use personal CO monitors	SCBA only for career FFs
SA	South Australian Country Fire Service (CFS)	Disposable P2	No protocol	Not generally used for bushfires	Plans for trialing half and P3 masks
SA	South Australian Metropolitan Fire Service (MFS)	Disposable P2	Hygiene stations on newer rigs	Not generally used for bushfires	
TAS	Tasmania Fire Service (TFS)	Half face mask with Honeywell N06575009L cartridges	Tyvek suit for return to station	Not generally used for bushfires	
VIC	Fire Rescue Victoria (FRV)	3M Aura 9322A+	Skin wipes for field decon and end of shift	Rolling out personal CO and HCN monitors	Trialing PAPRs and COHb
VIC	Country Fire Authority (CFA)	Disposable P2	No protocol	Not generally used for bushfires	Trialing half face and P3 masks
VIC	Forest Fire Management Victoria (FFMV)	Disposable P2	No protocol	Some personal CO monitors	
WA	Department of Fire and Emergency Services (DFES)	Full face (P3) mask with 3M 6075-ANZ cartridges	Hygiene stations on some career rigs	Not generally used for bushfires	Volunteers can choose from half face and P3 masks

\*All fire agencies provide disposable P2 respirators for their firefighters to use; NSW-New South Wales; NT-Northern Territory; QLD-Queensland; SA-South Australia; VIC-Victoria; WA-Western Australia; CO-carbon monoxide; FF-firefighter; HCN-hydrogen cyanide; PAPR-powered air purifying respirator; SCBA-self-contained breathing apparatus

Heat stress is a critical issue in many parts of Australia and influences both respiratory and dermal protection processes. Most locations (other than the Tasmania Fire Service (TFS) which provides Tyvek coveralls for use after fires although they are not frequently used for bushfires) did not have protocols for dermal protection after bushfires with the variable exception of some use of skin wipes and requiring at least annual turnout gear cleaning. The South Australian Metropolitan Fire Service (MFS) and Western Australia Department of Fire and Emergency Services (DFES) have installed hygiene stations on some of their rigs allowing for soap and water use at the fire scene.

Carbon monoxide (CO) exposure monitoring and guidelines became much more widespread after the Hazelwood coal mine fire, but, with the exception of Queensland Fire and Emergency Services (QFES), it has not been provided to both volunteer and career firefighters for use in bushfires. The importance of CO monitoring for peat fires was also emphasized. For other administrative controls for reducing firefighter exposures, crew rotations to reduce exposures was often reported as not possible given the nature of bushfire responses and the limited number of personnel generally available. All fire agencies reported training their firefighters to stay out of smoke whenever possible when fighting bushfires. There was also general concern that the use of P3 (or half face mask respirators plus goggles) could result in firefighter overcommitment and excess exposure to CO during bushfires, or in their being used for structure fires. For all new technology, not just CO monitoring, the importance of developing protocols prior to use and providing adequate training was emphasized in most states/territories.

An additional observation was the use of fire service vehicle turnover protection systems (BOPS) in many of the states/territory visited. These were initially focused on firefighter survival but have evolved to include vehicle protection. The three main components include a deluge system over the cab and wheels, thermal blankets for the windows, and in cab breathing apparatus (generally standard self-contained breathing apparatus (SCBA) for career firefighters). There was general interest in providing particulate filters within the cabs that the firefighters could access and change.

Research questions that could influence bushfire personal protection use decisions were elicited during all firefighter meetings and are listed on page 14 of this report. Common questions included the extent of toxicity from vegetation smoke and potential variability by the plants being burned and smoke characteristics (such as color). There were also multiple questions focused on dermal exposure. The need for a measure of cumulative exposure which could be used to indicate that the firefighter should leave the fire incident was raised at multiple sites. It was also stressed that results of research should be provided in a clear fashion to firefighters.

This report includes limited information from some academic researchers in Australia working on bushfire firefighter exposure reduction or evaluation of exposures, in addition to Dr. Fabienne Reisen who has done such work in the past. There was not time to contact all Australian researchers currently active in this field or gather all the research studies supporting the current practices. However, in 2021 the Australasian Fire and Emergency Service Authorities Council Ltd (AFAC) provided recommendations for respiratory protection during bushfires with accompanying documentation.

Limitations of this study include that it is a snapshot in time of a dynamic evolving process, and most volunteer stations visited were peri-urban and not rural.

## Individual State and Territory Discussions

### New South Wales

Site visits in NSW included the Fire and Rescue New South Wales (FRNSW) Manly Fire Station and the Rural Fire Service (RFS) facility in Glendenning.

**FRNSW** has over 6,800 Firefighters and over 4,600 Community Fire Unit Members working out of 334 stations across the state. They reported greater exposure in general in hazard reduction burns given longer duration in low wind conditions than in actual bushfires given their shorter duration, higher wind conditions and ability to get upwind. In rural areas when working with RFS they generally deploy to protect structures while RFS focuses on vegetation fires. The Manly firefighters are now using a Dräger P3 full face mask of the same type used in their SCBA and Dräger 6738797 cartridges. Their protocol is to start with a P2 when they arrive and then switch to P3 as conditions worsen. This decision is made by the individual truck team or station officer. They report that the P3 masks are relatively new for them, not comfortable for long-term wear and make communication difficult. CO monitoring is generally not part of bushfire operations and they do not use personal CO monitors. However, they felt that air monitoring at staging areas would be helpful. During bushfires they keep the windows of the cab shut but do not have other clean cab protocols. They have multiple sets of bushfire turnout gear and have a laundry service for cleaning which works well except in the case of multi-day campaign fires where they are not able to return to their station. They have skin wipes available but do not generally use them.

**RFS** has over 72,855 volunteers working out of ~2,000 brigades in 45 districts in seven area commands. Most of their firefighters do not have SCBA. The RFS uses several different brands and variants of disposable P2 respirators with exhalation valves to ensure appropriate fit. They have been testing respiratory protection for bushfires, including usability and the heat effects of wearing respirators. They are also looking at personal protective clothing and reviewing vehicle design. They trialed multiple half face and P3 respirators from different manufacturers on several RFS units for bushfire responses, and selected Dräger 3500 (half) and 5500 (full) facepieces and 6738817 cartridges. There has been good acceptance of the half face and P3 masks with many cannisters used to date. A range of sizes, quantity and mix of half and full face are provided to each appliance based on the number of seats and proposed crew size. As part of the collaboration between RFS and UOW, Jane Whitelaw (University of Wollongong) supported the testing of several of the different canisters, specifically the ability to protect against particulate exposure (from burning dry forest floor matter: eucalyptus leaves and twigs) including respiratory sized and nanoparticles, including looking at efficiency over use time. Through additional thermoregulatory studies, it was also found that respirator use was not associated with an increase in core temperature as compared to the same activities without respirator use but was associated with a slight decrease in oxygen saturation. Their protocol is to provide a new cartridge for each use to provide confidence to the firefighters that their gear is clean. Sharing with the volunteer firefighters that they have addressed all issues will be an important part of the respirator roll-out process. RFS is currently rolling out a second set of turnout gear. They provide laundry services at basecamp for campaign fires and are separately looking at how to improve the laundering of turnout gear across the state.

### Northern Territory

In Northern Territory (NT) I met with the NT Fire and Rescue Service (NTFRS) Berrimah Fire Station, Virginia Bees Creek Volunteer Fire Brigade, Jabiru Fire Station and Yulara Fire Station, as well as with Bushfires NT. Additional individual meetings were held with both managers and front-line firefighters. Beyond the elevated ambient temperatures in NT, there has been a substantial change in the nature of fires in northern NT due to the spread of gamba grass which burns much hotter and slower than the native spear grass. Most firefighting is done while operating vehicles, particularly light trucks (Grass Fire Units or GFUs).

NTFRS has ~200 career firefighters in six structural fire stations and more than 25 volunteer brigades covering rural areas, leading to limited staffing for bushfire responses in general. Their GFUs operate with a driver and a firefighter in the back of the truck spraying water. For hazard reduction burns, they use bugs (drip torches), blowers and muck rakes, and with the latter two items they often have to walk into the smoke. The career firefighters may respond to up to four fires each day during the dry season (May to September) or to larger campaign fires. In the Darwin area they previously did a large number of hazard reduction burns but much of that work is now done by a contractor. Their primary concerns are around heat stress given the challenging ambient temperature (33-34 deg C) and humidity. They also had a few firefighters suffer heat emergencies during structural fires and emphasize the importance of firefighters stating when they are overheating in order to avoid heat emergencies. They reported that the AFAC guidelines for work/rest cycles are not practical for them given their limited number of personnel. They also mentioned that Air Services Australia has implemented ice baths as part of their protocol during hot weather incidents. They have an ambulance turn out for monitoring firefighters and the public during structural fires, but not for grass fires. They have provided P3 masks since 2014 (originally Moldex 9000 with a recent change to Scott Pro2 P3 masks with Pro2000 CF22 A1P R SL filters) and are now adding in Dräger X-Plore 3500 half-face masks (with ABEK1 Hg P3 filters), with firefighters able to choose which they want to wear. For firefighters that had difficulty wearing half face masks and goggles together due to fit issues, P3s were preferred. Seasonal problems were reported with P3s fogging up in the rainy season. They had previously trialed PAPRs but the style tested could not be easily worn while sitting in the truck when the firefighters were responding to fires. They are not currently using CO monitoring for grass fires, although past use of in cab (on the headrest) CO monitors was reported in which the constant alarms resulted in the monitors not being used. They have decontamination kits originally provided for COVID-19 but are not using skin wipes for cleaning up after bushfires. Crews are issued three sets of structure fire clothing including structure fire trousers and jacket, flash hood, structure firefighting gloves, and structure fire boots. Only one structure fire helmet is supplied initially but most will have two at least. Crews are also issued one grass fire fighting jacket and light weight gloves but all end up with at least two. Grass fire turnout gear comprises a lightweight helmet, heavy blue cotton trousers, structure fire boots, light weight grass fire gloves (Fire Pro), Scott Pro2 mask/Pro2000 filter and a light weight Nomex jacket. The heavy cotton trousers for grass fires are also worn around the station and in public so they are issued four sets. Cleaning up the bushfire turnout gear is at the discretion of the firefighter. Until recently they wore their structural turnout gear to bushfires, but now are directed to wear lighter weight bushfire turnout gear due to heat stress. However, some firefighters continue to wear their structural turnout gear and flash helmets during hot fires, such as those involving the invasive gamba grass, for additional protection. They wear shorts and T-shirts on the fireground when not operational in order to cool down. Crews are also issued a baseball cap or broad brim hat which can be worn at any time except during active firefighting duties. The Incident Controller can request an ambulance to a protracted grass fire but this is not an automatic response as is the case for structure fires. They have a rehabilitation trailer (air conditioning/toilet/shower) that responds to structure fires and protracted grass fire and are looking at a purpose-built rehabilitation truck which would respond instead of the trailer.

The firefighters in the Virginia Bees Creek Volunteer Fire Brigade were also previously supplied with P3 masks (with a recent change to Scott Scott "Pro2" P3 masks with Pro2000 CF22 A1P R SL filters) and now also have a choice of half-face masks (Dräger X-Plore 3500 half-face masks (with ABEK1 Hg P3 filters)). They are issued their own masks and have to care for them. They record the use for each filter as part of their incident logs as the filters expire 30 days after opening and also need to be replaced after extensive use. These incident reports are also important given that presumptive cancer legislation for volunteer firefighters in NT requires documentation of number of hours of exposure as well as other requirements. Use issues include difficulty with communications more so with P3 masks as it is easier to pull the half face

mask down to speak without removing it entirely, general inability to clean the equipment in the station, and initial lack of information on changing the filter. They generally report that the P3 facepieces fog up. There is a general preference for half face masks with goggles. They previously trialed backpack-style PAPRs. They choose when to switch from disposable P2 masks to either the half face or P3 masks. They are not provided with skin wipes, although there was some interest in them after a career firefighter recently gave a presentation (in Alice Springs) mentioning wipes. They only have one set of turnout gear, specifically for grass fires, and some firefighters do not wear turnout gear for bushfires. Others have had to wear a single set of gear for 5-7 weeks straight in campaign fires. They have a washer in the station and generally don't wash their turnout gear at home. There was also mention of occasionally having to carry all of their gear in a backpack when responding to fires when they are dropped off and have to walk in. They mentioned interest in using urinary PAH metabolite measurement to evaluate combined inhalation and dermal exposures.

Bushfires NT covers the rural areas of NT (approximately 99% of the land area). They also use GFUs but these are run by a single driver and have side mirror mounts for the hoses near the cab side windows so the driver can spread water while driving. Ideally the driver can stay inside with the windows closed while running AC; however the window is down when operating the hose. Only disposable P2s are used. They are testing out CO and other monitors but their major focus is heat. They are interested in using ingested capsule probes to monitor firefighter core temperature in the future as heat stress is a major risk. They also had an interest in adding ambient contaminant measurements to their existing Fire Mapper software, which they have found extremely useful during bushfires and which is used extensively in other parts of Australia and parts of New Zealand.

## **Queensland**

Queensland Fire and Emergency Services (QFES) includes the career Fire and Rescue Service (FRS) and the predominantly volunteer Rural Fire Service (RFS). It has ~5,000 permanent and auxiliary firefighters and ~28,000 volunteers in approximately 244 urban and ~1400 rural stations, respectively. Sites visited in Queensland included the Cannon Hill Special Operations Centre in Brisbane, the Samford Rural Fire Brigade in Sanford in the Brisbane region, the Little Mulgrave Rural Fire Brigade in the Cairns region, and the Cairns Peninsula Area Office in Cairns. QLD volunteer firefighter fire responses are primarily to bushfires. The Sanford Rural Fire Brigade reported responding to ~100 incidents a year on average, including 30-40 bushfires and ~30 hazard reduction burns, with the rest being predominantly road traffic accident responses and rescues. A unique aspect of QFES was the presence of a scientific research team including volunteer firefighter scientists. The volunteer stations visited also described a culture change from a 'club' to a professional volunteer, which has helped drive exposure reduction activities.

QFES provides full facepiece (P3) masks (with a Scott MPC plus cannister) for bushfire responses as their experience was that half masks generally did not work well with goggles. They initially introduced P3 masks in three volunteer stations and then to 10 rural brigades. In the Samford Rural Fire Brigade the volunteer firefighters stated that the P3 respirator was the best that they have been allocated, with the only downside being the extra work breathing through the respirator and staying hydrated, as well as how to carry it when it was removed during bushfire incidents (as compared to the P2 respirators which can easily be carried when not in use). The P3 masks have inserts for corrective lenses as needed. Fit-testing is carried out for the P3 masks but not disposable P2 masks. Issues that needed to be addressed included training on P3 use and cleaning. For volunteers the P3 masks are stored in the stations and are taken out in individual bags belonging to the firefighters and need to be cleaned prior to return particularly given that they are not assigned to individual firefighters. There are two sizes, small and medium/large, and if these don't fit a separate mask is available. P3 use is not compulsory; the firefighter decides when they want to put it on, usually based on visible smoke or symptoms, and need to take a break from using it at times due

to extra work of breathing against the cartridge resistance. The firefighters reported that P3 respirators worked particularly well when defending structures as this activity generally required less physical exertion. Volunteer firefighters using the P3 masks reported not having a sore throat or headache the next day, which often happened in past fires without P3 use. Only career firefighters are provided SCBA.

QFES has a personal CO monitor (ToxiRAE 3 portable single gas monitor) for all career firefighters and currently one CO monitor for every three volunteer firefighters with plans to provide one to each volunteer firefighter in the future. These were provided at roughly the same time as the P3 masks were rolled out. They provide centralized calibration in Brisbane for all monitors and provide replacement units during this process. They provide their firefighters a chart showing what is an acceptable CO exposure based on duration of exposure. Their volunteer firefighters reported that they did not like that the monitors, set at 30 ppm, would alarm throughout much of a bushfire response. One question by a firefighter was whether the units could be set to vibrate instead or have different alarms at different concentrations. The station commander reportedly uses the readings to determine when the team should don their respirators.

For dermal exposures the volunteer firefighters reported that mopping up was dirtier than direct attack. Other than cleaning up boots, dirty gear was worn in the vehicle. Most firefighters wore very little under their bushfire turnout gear making it hard to take off the turnout gear prior to getting into the vehicles. Cleaning the vehicles varies by station. The Samford Rural Fire Brigade recently had a washing machine installed in the station but had not used it yet. There was a shower in the station, but most firefighters went home to shower instead. However, washing machines were reportedly not available in most rural fire brigade stations. At the *Little Mulgrave* Rural Fire Brigade, the availability of oversize skin wipes for cleaning skin and gear was appreciated but there were no protocols on skin wipe use for bushfires.

In Cairns, the use of low-pressure hose was reported, which was liked by the firefighters as it is longer and lighter than the standard hose and could be more easily deployed. There was a research question about whether use of this hose could reduce exposure by putting the fire out more quickly.

### **South Australia**

Visits in South Australia included a virtual meeting with the Chief Fire Officers of Country Fire Service (CFS) and Metropolitan Fire Service (MFS) and in person meetings at the MFS Adelaide Fire Station and the Morphett Vale CFS Station. There is close collaboration between the CFS and MFS and the current presumptive cancer laws (for 12 cancers) cover both volunteer and career firefighters. Both their Level 1 (bushfire) and Level 2 (structural) turnout gear as well as helmets are the same for both organizations. Both CFS and MFS provide each firefighter two sets of bushfire turnout gear and two sets of structural turnout gear. CFS and MFS support each other in incident response, and protocols/jurisdictions determine who leads the response.

**CFS** has 13,000 personnel including ~12,800 volunteer firefighters and ~190 career firefighter staff. They have 425 stations, 880 heavy vehicles and 27 aircraft. The majority of CFS responses are not to bushfires, with rural response only making up 25% of the annual call outs. P2 use is mandated at bushfires. The need to maintain hydration and operate in elevated ambient temperatures needs to be kept in mind for respirator selection. For disposable P2 respirators the outer material had delaminated and singed during some bushfires, and there was a report of a firefighter with an ember burning through their P2. CFS planned to trial half face and P3 masks working in concert with the NSW RFS testing, with initial use evaluation in both rural and peri-urban stations. Issues that will need to be addressed include storage of cartridges. Hot Shield face masks are used by some volunteers but their use is not officially authorized. There is also interest in bringing in ambient monitoring equipment to help set up hot, warm and cold zones, and consideration of individual CO monitoring. CFS workplace practices include starting the process of mandating laundry of bushfire and urban ensembles. They are making progress on designating clean



and dirty spaces within stations. There is no clean cab protocol at present for bushfires as the firefighters are in and out of their vehicles multiple times during an incident and there is no research available to determine effective processes. CFS has in-cab breathing apparatus for their BOPS as their SCBA are kept in external compartments.

**MFS** has 970 full time and 280 retained firefighters across 20 metro and 17 regional stations. MFS fit tests all respirators and atmospheric monitoring is generally used. MFS follows clean cab protocols and segregates dirty gear in the stations prior to cleaning. There is some use of skin wipes which has increased with the COVID pandemic. There are hygiene stations in their newer rigs. Their old bushfire gear had flame retardants that would wash out, creating issues for cleaning which is not a problem for the current Nomex fabric. Generally, the firefighters want their turnout gear washed after a fire if it appears or smells dirty, and in addition there is a requirement to wash their gear at least once a year. MFS has successfully deployed BOPS during bushfires and have videos of such an event. MFS has extensive expertise in the development of public information systems including providing evacuation instructions for communities at risk of burnover.

### **Tasmania**

Organizations contacted in Tasmania included Tasmania Fire Service, United Firefighters Union of Australia (UFUA) and University of Tasmania. Site visits included career stations in Launceston, Burnie and Hobart, volunteer stations in Taroona and Mt. Nelson, and the Engineering Services Workshop in Cambridge. There are approximately 350 career firefighters in four brigades (Hobart, Launceston, Burnie, and Devonport) and 4,800 volunteer firefighters working out of 232 stations in Tasmania.

Bushfire response is common for career firefighters in Tasmania (e.g. for the Hobart Fire Station, 80-90% of the fire responses in summer are for bushfires). Black soot in nasal discharge is likely after bush fires, but not after structural fires. Peat fires in Tasmania are a particular hazard and can burn all winter. Some career firefighters will do a fuel reduction burn when responding to some small fires, although prescribed burns are typically carried out by the TFS Fuel Reduction unit or other state government agencies, with only ~20% carried out by career firefighters, and 10-20% by volunteers. They report “fire in their face” 70% of the time at a prescribed burn from lighting into the wind. Prescribed burns are also difficult to schedule as there is community concern about potential contamination of wine industry grapes prior to harvest. For respiratory protection during bushfires they previously used Moldex respirators and now use Honeywell 7700 half-face masks with N06575009L (ABEK1 +HF+formaldehyde) cartridges for bushfires, particularly mop-up and other less vigorous activities. In general, half face mask use has increased with knowledge of cancer cases and changes in presumptive cancer laws which also helped push for action. With half face masks the firefighters report problems breathing and seeing, and their current model does not have a speech diaphragm. Some firefighters wear swim goggles as they are unable to wear regular goggles with the half face mask. Fogging is an issue as is wearing glasses. Concerns include masks encouraging people to stay in smoke longer. Training does not always stay up with new equipment, such as changing filters, fit checks, etc. If they don’t wash and dry their masks, mold can grow. They have a hygiene pack for structural fires with disposable coveralls and a P2 mask and have clean gear bag with shorts and T-shirt. They have skin wipes for structural but not bushfires, and instead just shower at the end of the day. They report that keeping a clean cab is difficult for bushfires due to the need to get in and out of the vehicle repeatedly, but there are in-line filtration systems in their new pumpers. There is a 2-3 hour transport time after bushfires, as there are rarely basecamps. It takes 48 hours to turn around dirty gear for dry cleaning, and they are considering microtagging gear to help get it back to its owner more rapidly. Administrative controls using shift rotations are difficult due to limited staff. Ambient monitoring including CO is carried out by fire investigators (who use PAPR) but is generally not used at bushfires. They use a vacuum with HEPA filter designated only for cleaning carpet in the stations.

Volunteer stations have one pair each of structural turnout gear and bushfire gear. In Taroona and Mt. Nelson stations they respond to 6-12 vegetation fires on average a year, often from lightning strikes. Mask use is considered voluntary. They have P2 available but did not feel they fit well and one person stated that they preferred the molded P2 masks used in Queensland. Many really liked the half face masks and some were concerned that they were almost too effective and might lead firefighters to stay too long in the smoke. They reported that after six hours on the job the prefilter is black, and that showing this to other firefighters increases overall willingness to wear the masks. They feel their half face mask respirators are effective but difficult to take off to use radio, and they needed a bag for carrying it. Furthermore a number of firefighters reported not being able to simultaneously wear the half face mask and goggles. They are not allowed to do some bushfire duties if they are not wearing masks. They have been using the half face masks for car fires as well. Air monitoring is not used. Volunteers wash their gear if it is dirty or smells bad and clean it every 12 months regardless. There has been a culture change due to training and other firefighters encouraging wearing clean gear. Previously they did not wash their bushfire gear as this would remove flame retardants, but they have received newer bushfire gear since then which can be washed. They suggested that taking a change of clothes to fires might decrease exposures. Firefighters serving as volunteer and career firefighters in other stations reported that recent changes in education and cultural change started in urban areas and has translated some to bushfire firefighters, but that education through combined career/volunteer stations might not easily make it out to smaller brigades.

## **Victoria**

Organizations contacted in Victoria included Fire Rescue Victoria (FRV), Country Fire Authority (CFA), and Forest Fire Management Victoria (FFMV). Site visits included FRV training academy (Craigieburn) and FRV headquarters. There was also a virtual meeting with the FRV Rural Respiratory Protection Working Group and an in person visit with CSIRO Aspendale to meet Dr. Fabienne Reisen. Studies from 2004-2008 by Dr. Reisen and C.P. (Mick) Meyer with additional fire service partners provided foundational exposure studies during hazard reduction burns to help guide respiratory protection selection.

**CFA:** CFA has over 30,000 members in over 1,200 brigades. For CFA, P2 disposable respirators (3M model 9322) are provided for all bushfire firefighting. SCBA are used for structural fires and may be used in peri-urban areas during bushfires while the firefighters are carrying out asset protection. For the past several years the CFA has been exploring alternate forms of respiratory protection for bushfires and is currently trialing half face and P3 respirators in 300 volunteers. The results of this trial will inform future decisions on additional respiratory protection provided to their firefighters. CO monitoring is currently used for structural fires as part of five gas direct read instruments and personal CO monitors (Dräger 6500) are used specifically for open cut mine fires and peat fires. Provision of personal CO monitors is being considered for bushfire responses but would require protocol development and use training. Dermal decontamination has not been a focus area to date. Elevated temperatures are a concern informing any potential change in extent of personal protective clothing used. CFA also has a health monitoring team for large incidents which addresses fatigue management and other issues.

**FRV:** FRV has approximately 3,742 operational employees in 85 stations across Victoria. They are currently using 3M Aura 9322A+ disposable P2 respirators for bushfire responses and are in the process of rolling out 'next-generation' personal protective clothing (PPC) with lighter fabric to reduce metabolic heat and a two-piece style to promote airflow. Use of skin wipes is encouraged, especially when PPC change over and showers in remote and rural environments are limited. Most firefighters carry a spare set of PPC so changing over of soiled PPC is encouraged. FRV also promotes a clean-cab approach where possible such as cab doors on firegrounds are to remain closed, A/C on low with vents set to recirculation, dirty PPC should be removed where possible or at least partially dressed down, dirty PPE such as SCBA should be swapped out for clean sets or stowed in rear compartments and at the earliest opportunity windows

wound down in clean air to extract any products of combustion or off-gassing. At the end of shift, contaminated PPC and stationwear undergarments, as well as other contaminated equipment are bagged in heavy duty plastic bags and transported for professional cleaning. Firefighters have access to 'pool' PPC garments if their personal stock is low. FRV appliances carry a DEBRIS kit (Decontamination, Entry/Exit, BA Service, Rehab, Incident Accountability & Staging Area) and FRV firefighters have received training on use of the kit. Within each kit is a boot and PPC scrubber, nitrile gloves, dermal wipes, soiled PPC bags, P2 masks, low-pressure PPC cleaning hose, disposable coveralls and x5 DEBRIS placards for decon corridor implementation and compliance. FRV had previously stopped using PFAS firefighting foams and also professionally decontaminated all apparatus including their water tanks. They therefore use their main tank water to immediately rinse down PPC after a fire. FRV has also recently introduced HEPA vacuums for appliance cleaning; appliances are cleaned twice per week often including mopping internal floors and washing and hosing out the apparatus floor. FRV is also in the process of implementing appliance diesel capture systems as part of station designs and retrofitting existing buildings. Fire stations have dedicated warm, transition (where PPC is stored) and clean areas. This has extended to some appliances and areas on the fireground with the same zone delineation such as Command units, Fire watch pods and Rehab units. There is a good culture around maintaining clean PPC/zones and a strong focus on being able to retire healthy. Dedicated fireground Rehab appliances are automatically responded for 3<sup>rd</sup> Alarm fires or greater, with a consideration notation on 2<sup>nd</sup> Alarm. New replacement Rehab appliances have cooling equipment from misting fans all the way through to ice bath chairs, and there has been a concerted effort since introducing these new appliances to provide firefighters with significant training on heat-related illness management. FRV used CO monitoring extensively during the Hazelwood mine fire, with three components, 1) pre-monitoring prior to going to the fire site, 2) monitoring during the incident, and 3) monitoring during rehab. FRV is currently introducing MicroRAE and Altair Advanced Gas Detection training to all firefighters. As part of FRV's trial for PAPR in rural environments a training package using this equipment will be incorporated so that CO monitoring for bushfires will be included. The devices also have HCN sensors, and training on the HCN sensor will involve guidance and procedures on what to do when limits are reached. Training will also involve correct selection of respiratory protection, when to change respirators, how long respirators can be used for and other ways to mitigate exposure with considerations for wind direction and re-positioning. The selected devices are Bluetooth capable and remote monitoring by HAZMAT and Scientific Advisors over the cellular network is available. As part of this program FRV is investigating introducing carboxyhemoglobin (COHb) monitoring on each appliance, which will allow firefighters to check their own exposure levels as early as possible.

The FRV Rural Respiratory Protection Working Group has done extensive work developing a powered air-purifying respirator (PAPR) for trialing in bushfires. Usability testing has been completed and they are working to schedule a second trial soon during a hazard reduction burn. A third trial among stations with elevated non-structure fire risks will be completed once they work with the manufacturer to develop a product fit for purpose including full decontamination.

**FFMV:** FFMV is responsible for 7.1 million hectares of state/natural lands. Their ~3,200 personnel include ~1,800 direct front line employees and 650 seasonal firefighters. Their firefighters respond to a large number of bushfires (e.g. during the Black Saturday fires their personnel provided 60,000 person-shift responses). They also respond to peat fires and support coal fires. Their firefighters are covered by presumptive cancer laws requiring one exposure event. They have an independent cancer claims review panel chaired by a former fire chief with subject matter experts part of the panel. They can carry out remote firefighting including helicopter responses with rappellers for remote lightning strikes. They have a philosophy of aggressive first attack with performance metrics of keeping 80% of all fires <5 hectares and 80% of fires controlled within the first shift. For campaign fires, which can last up to 60-90 days, they set up basecamps of ~300 firefighters each. The firefighters are required to carry but not use P2 masks. Heat

stress is a key issue, and they are developing lightweight jackets and trousers. Other key issues include maintaining hydration and mental health. Carbon monoxide exposure is an important concern. They have used CO monitors and pulse oximeters, and have reported instantaneous CO measurements of up to 800 ppm. Working with Dr. Reisen in previous studies, they determined that burn patrol had the highest exposure, and the ignition crew the least exposure. Being on a slope above a fire tripled the exposure. They have developed rest day policies to allow CO (carboxyhemoglobin) levels in the body to decrease. In the large 2019-2020 fires some firefighters were sent to hospital for CO poisoning and as a result some current firefighters are worried that if they test for CO they may be pulled from the fire line. For other administrative controls, they rotate crews and use root spear and sprinkler systems for peat fires so that they don't have to stand close to the fire. They review the Hazelwood mine fire report as part of their training, in addition to a "What's in smoke" document. They invest in their own research and have an annual research budget of ~\$8-10 million (AUD). Areas of concern include long-term health effects of firefighting, the chronic effects of exposure to PM<sub>2.5</sub> from fires, the effects of exposure to formaldehyde, and exposures during pregnancy.

### **Western Australia**

Meetings in WA included the Malaga Fire Station and the Darlington Volunteer Bush Fire Brigade.

The career firefighters currently use a Scott/3M P3 mask with 3M 6075-ANZ cartridges but had used half face masks in the past. The Malaga Fire Station had been involved in the trial to choose the current respirator. All masks were fit-tested. They generally wear them in visible smoke but take them off during mop-up as there is additional effort required due to having to breathe through the respirator. Communication with P3 was listed as an issue that had to be overcome. If they use a microphone close to the mask and speak clearly then it is generally OK. They can also step into the cab for more detailed communication and similar issues were present with the half face mask although they were easier to remove to speak if required. They mentioned previous research work by Peter Jones as part of a fire investigation unit. In addition to bushfire vegetation smoke, there were concerns about additional exposures in the rural-urban interface and dumped hazardous materials which is why they are currently using A1B1E1K1 filters. Respirator cartridges are supplied with stickers, and they mark the date they were first used so that they can be changed after 10 hours of use or six months. They do not monitor for CO in bushfires. They have seen CO monitoring in training but the monitors are not in most vehicles. They previously had tried PAPRs (SE400s) but felt that more generalized use would be too complex given the need to charge and change batteries. They have two bushfire (Level 1) tunics and as many trousers as are needed. It is up to the firefighter to determine when to clean their gear and practices vary although their protocols states that personal protective equipment is to be cleaned when visually dirty, or when traces of smoke or other contaminants are detectable on the garment. They may bag their gear if it is really contaminated. They have a laundry service. At the time of the interview there was no policy on dermal decontamination, but a new policy and products were to be introduced soon. Some firefighters shower after a bushfire and others choose to sleep instead although they have a post incident hygiene policy, (currently being updated) that recommends showering post incident. They have recently received skin wipes. They have a separate small (four liter) water tank and low-pressure hose so that they can wash with soap and water from the truck (currently used to wash hands and faces prior to eating). They feel that this water is cleaner than water from the main tank which may have foam or other chemical remnants. Administrative crew changes are generally based on overall welfare and fatigue rather than exposure considerations. They clean their vehicles after fires.

Western Australian volunteer bushfire firefighters have the option of both half face and full face (P3) respirators provided by DFES, as well as SCBA for vehicle and structural fires. At the Darlington Volunteer Bush Fire Brigade, the volunteer firefighters have started using 3M Cool Flow Paint Project Quick Latch

6502QLPA1-A-NA half face respirators, with DFES-approved filters. One of their firefighters characterized them as a “game-changer” due to the ability to temporarily drop the facepiece down without removing the straps from under the helmet. One of the several firefighters who prefer to use a full-face mask stated that the Scott full-face mask has a voicebox which allows communication on the radio without removing the respirator and with a full-face mask the volunteer firefighters can stay in smoke for a full shift and at the end of the day go home still able to breathe easily and without black soot from their nasal passages. The concern is that the full-face masks do not help with CO exposure and the firefighters may stay in thicker smoke than they would without respiratory protection, which becomes a training issue. They mentioned that respirator use during mop up is not as rigorous as it should be. Volunteer DFES firefighters are assigned their own respirators which they should clean after each use. They do not monitor for CO during bushfires. In vehicles the windows are kept up with cool air re-circulation on while on the fireground. The vehicle is also cleaned after a fire shift and during weekly checks. There was a desire for positive pressure cabs with HEPA filters that could be changed by the firefighters. Their training includes cleaning their gear after use, but the actual practice varies by firefighter. There is currently peer pressure to keep the turnout gear clean. Many volunteer stations have a single washing machine for their bushfire gear but given multiple firefighters responding to a fire multiple times in a campaign fire many of the firefighters will wash their gear at home. Skin wipes have been present on the vehicles since the COVID-19 pandemic but are not often used after bushfire responses. For peak use there are inadequate showers at most Volunteer Bushfire Brigade stations (up to 12 male and female firefighters returning at the same time from a single 8-hour shift with two pumps and two light tankers) leading to showering at home. Rotations of crews to reduce exposures is done when possible (which in Darlington is most of the time due to numbers available).

**Research questions from the fire service** (some questions were posed multiple times at different sites)

*Exposure and inhalation monitoring questions*

Does bushfire response increase the risk of cancer?

Is there a maximum time (duration) that a firefighter should spend during a shift fighting bushfires?

When is it too dangerous to wear a mask?

Evaluation of toxic products of combustion from different Australian vegetation types, with grass trees mentioned at multiple sites as having dense black smoke with the potential for increased toxicity.

Is there a difference in toxicity with native v. non-native plants?

Is white smoke less toxic than black smoke/does toxicity vary by flame color?

How much of a problem is cyanide exposure during bushfires?

Does oxygen depletion occur during bushfires?

How much of a problem is off gassing of bushfire gear?

How well does CO monitoring predict the concentration of other chemicals?

How should CO exposure guidelines be used with pregnant firefighters?

Does use of personal CO monitors reduce exposure?

Need for real-time monitoring of PM2.5

If the vehicle cab smells like smoke, is that an exposure problem?

During the dry season there is substantial ambient exposure to smoke to everyone in the Darwin area. Is this "background" level of exposure hazardous?

Is there more that can be done to reduce exposures which is practical for areas with very high ambient temperatures?

As volunteer firefighters (in at least one state) have to show that they were at a set number of fire for a set period of time to qualify for presumptive cancer claims, or at a particular fire where toxic materials have been identified, research is needed to show that all bushfire exposures have the potential to cause cancer.

Need to measure CO and particulate concentrations in cabs.

Does using a low-pressure hose (used in northern QLD) reduce smoke exposure?

*Respiratory protection questions*

How well do half-face masks fit?

Have half-face masks reduced or increased exposures?

How do we provide breathing apparatus for long-term incidents?

Does the breathing resistance of a respirator cause increased heat stress?

Improved understanding of how smoke changes during the scope of a fire and whether this would change the respiratory protection needed for each phase. For example, is respiratory protection needed during mop-up?

If the smoke is heavy, how long should a filter be used prior to replacing it?

What is the relative effectiveness of silicone v. P2 masks particularly if the firefighter has facial hair?

Does wearing personal protective equipment religiously substantially reduce adverse health effects as compared to just wearing it when smoke is thick?

Could there be an Australian standard for integration of half face masks and goggles?

#### *Dermal exposure questions*

Does wearing white disposable coveralls decrease or increase exposure?

What should the policy be for regular cleaning of bushfire gear?

How soon do you need to shower after a bushfire?

How much protection from chemical exposure is provided by bushfire turnout gear?

How much contamination deposits on the clothes under the turnout gear and how should you launder this clothing?

Does what you wear under the turnout gear affect how much contamination is absorbed into your body?

Are there differences in dermal exposure by smoke color?

How clean does gear need to be to prevent exposure when wearing it again?

How much dermal exposure occurs in each phase of firefighting (e.g. mop-up)?

Is there a duration of exposure after which you should decontaminate (shower and put on fresh clothes/gear) during extended fire responses?

How effective are firefighting gloves in protection against contaminants?

Are leather boots and gloves important sources of exposure? How should they be cleaned?

Is there a difference in the extent of deposition of chemicals on the skin based on the PPE material (Nomex, etc.)?

What is the impact of particulates/dirty gear on exposure in bushfires? Demonstration of increased absorption of contaminants would help justify the cost of providing extra gear to all firefighters.

Could washable canvas seat covers (or disposable seat covers) and vehicle design reduce exposures?

Does the type of fabric used on vehicle seats affect the ease of cleaning?

How much exposure do you bring home, particularly if you wash your turnout gear and other dirty clothing at home?

Are there barrier creams that could reduce exposure?

#### *Other questions*

What are the toxicity differences between structural smoke, vegetation smoke, and diesel particulate matter (DPM)?

What is the cumulative effect of bushfire responses?

It would be useful to have indicators of cumulative exposure, like a color change, to show when to leave the fireline.

How much contamination occurs with electric vehicle fires? (Note: concern about cobalt exposure in particular)



Is there an organization that helps insure there are not overlaps in Australian research in firefighter health and safety?

What are the long-term effects of CO exposure?

Does bushfire exposure (including CO) result in hearing damage (ototoxicity)?

We need studies with biomarkers to show that the exposure reduction activities are reducing cancer risks.

What chemicals are in the pink fire retardant dropped from planes and is there any toxicity? What about foams and gels?

Does the introduction of respiratory protection and changes in personal protective clothing result in any add-on hazards?

Does theatrical smoke exposure cause cancer?

During a fire response should you rinse your mouth and spit before you drink?

How much DPM gets on gear?

Does DPM break down gear?

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Photo courtesy of Bushfires NT





## Research support

The following is a list of research organizations and individuals with whom I met. There are additional Australian researchers working on firefighter exposures that I did not have time to contact.

AFAC is a combination of 33 organizations and 20+ affiliate organizations. Research is funded by the members. They also organize and run corporate research centers (CRCs) that industry co-funds, usually run for seven years and focus on key research questions. They have published two CRCs on bushfires and subsequently bushfire natural hazards predominantly focused on inhalation hazards and respiratory protection. Dr. Fabienne Reisen, CSIRO (Aspendale) was a lead author of the initial Bushfire CRC. They also have extensive work in dispersion modeling of smoke contaminants from prescribed hazard reduction burns. There has not been much work to date on dermal decontamination.

CFA: Previous research found formaldehyde, but not other contaminants, at high concentrations on used wildland turnout gear. The formaldehyde was determined to be from fire retardant coatings on the gear rather than from fire exposures.

Monash University: Dr. Deborah Glass has carried out epidemiologic studies of cancer rates in Australian firefighters, including the contribution of vegetation fires.

QFES has an embedded research team including volunteer firefighter scientists. QFES research (not yet published) found that there was an average 2-7 fold reduction in aldehydes and VOCs inside structural gear compared to outside. They are also starting testing of seat covers to promote clean cab. They have found increased VOC exposures with drip torch refilling. Future planned research includes measuring PAH exposures and real-time monitoring of PM<sub>2.5</sub> and similar assessments of exposures including dermal and PPE performance in a bushfire context.

University of Queensland: The Queensland Alliance for Environmental Health Sciences (QAEHS) has worked on bushfire emissions of trace organic chemicals since 2000 led by Professor Jochen Mueller. Their research initially focused on dioxins and then expanded to other groups of chemicals such as PAHs, polychlorinated biphenyls and certain pesticides.

University of Tasmania: Professor Fay Johnston, Public Health Physician and Head of Environmental Health, Menzies Institute for Medical Research, and Senior Specialist Medical Advisor, Public Health Services, Department of Health, Tasmania has a chamber for combustion of vegetation and is able to test effluents.

University of Wollongong: Dr. Jane Whitelaw has research (presented but not yet published) on “respirator efficiency against bushfire emissions” and the thermoregulatory effect of respirators. She is working with NSW RFS to inform their selection of respirators and other controls against respiratory hazards.

### *Samples of research beyond bushfires*

QFES (Andrew Banks first author) have published research showing that by changing clothes after each fire the urine PAHs in their instructors don't go up.

QAEHS is carrying out longitudinal analyses on a cohort of Australian Airport Firefighters collected from multiple studies. The firefighter exposure study, funded by Airservices Australia, started in 2014 (n=140) and a follow-up study was conducted in 2019 (n=800, 130 longitudinal). The Australian firefighters are continuing to be followed in a new longitudinal study funded by NHMRC (2020-2025); n=500 firefighters were re-recruited from the 2019 exposure study and had their blood collected in 2021/22. Re-recruitment of these firefighters is currently ongoing. QAEHS also runs the Australian exposure bank and Human Biomonitoring Program, a 20-year relationship with a pathology laboratory with ~10,000 (de-identified) samples including blood collected biannually.

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**Published references (partial list):**

(2009) Dr. Fabienne Reisen and C.P. (Mick) Meyer. Field Guide to Smoke Exposure Management

(2009) Dr. Fabienne Reisen and C.P. (Mick) Meyer. Smoke Exposure Management on the Fire Ground: A Reference Guide

Both available at <https://www.afac.com.au/insight/health/articles/current/smoke-exposure-management>

(2014) Dr. Deborah Glass, et al. Final Report Australian Firefighters' Health Study. Available at [https://www.monash.edu/\\_data/assets/pdf\\_file/0005/982355/finalreport2014.pdf](https://www.monash.edu/_data/assets/pdf_file/0005/982355/finalreport2014.pdf)

(2018) Managing Bushfire Smoke Exposure (AFAC) available at <https://volunteerfirefighters.org.au/wp-content/uploads/2020/02/AFAC-managing-bushfire-smoke-exposure.pdf>

(2019) The Standards for Managing Exposure to Significant Carbon Monoxide Emissions (Emergency Management Victoria). Available at <https://www.emv.vic.gov.au/responsibilities/standards/the-standards-for-managing-exposure-to-significant-carbon-monoxide-emissions>

(2020) Adam Wightwick. *Rural Fire Hazards Respiratory Protective Device Research Summary, Operational Safety* <https://www.frv.vic.gov.au/sites/default/files/2023-06/Rural-Fire-RPD-Research-Summary-v1-5.pdf>

(2021) Selection of appropriate respiratory protective devices (RPD) during bushfires (AFAC) available at <https://volunteerfirefighters.org.au/wp-content/uploads/2020/02/AFAC-selection-respiratory-protective-devices-bushfires.pdf>