Rural Fire Hazards

Respiratory Protective Device Research Summary

Operational Safety

November 2020

FIRE RESCUE VICTORIA

VICTORIA State Government

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Subject:	Respiratory Protection for Rural Firefighting	Version:	1.5

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List of Abbreviations

APR – Air Purifying Respirator, Negative Pressure

CBRN – Chemical, Biological, Radiation, Nuclear

CFA – Country Fire Authority

CO – Carbon Monoxide

COHb – Carboxyhemoglobin (Measurement of Carbon Monoxide exposure)

FMMV – Forest Fire Management Victoria

FRV – Fire Rescue Victoria

HCN – Hydrogen Cyanide

IGEM – Inspector-General Emergency Management

MFB – Metropolitan Fire Brigade

P2 – Face Filtering Disposable Respirator

PM – Particulate Matter

PAH – Polycyclic Aromatic Hydrocarbons

PAPR – Powered Air Respirator

RPD – Respiratory Protective Device

RUI – Rural Urban Interface

SCBA – Self Contained Breathing Apparatus

VOC – Volatile Organic Compounds

WH&S – Work Health and Safety

RPD Research Summary

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Background:

For many years research and anecdotal evidence has shown that firefighters are facing greater exposures to smoke hazards particularly within our changing rural landscape[30,31,45]. An overview from the FRV WH&S Executive Summary of 'Non-structure' incidents from 2013-2020 found 798 cases of reported smoke exposure. The mechanism of injury (what happened) for 41% was 'Contact with chemicals', the nature of injury (what type of injury) for 49% was 'Poisoning and toxic effects including smoke/gas' and the agency of injury (primary cause) for 100% of cases was 'Smoke/Particulates/Fumes'[39].

This is likely to be underestimated as further data from Ambulance Victoria, Worksafe and the Brigade Medical Officer was not accessible. There are instances where firefighters have exhibited symptoms of over-exposure to smoke post-fire and off-duty where medical treatment was accessed privately and as such no data on this is available unless the firefighter chose to submit an FRV Safe (Hazelwood Complex[58], Cheltenham Park Fire[58], Seaford Fire[57] and Gippsland Complex[60] 2019/20). There are also reports of some firefighters exhibiting symptoms of Rhabdomyolysis[57], the knowledge of this risk is poor amongst FRV and limited even amongst Paramedics. Firefighters are often thought of as elite athletes so health professionals do not always consider Rhabdomyolosis, many of its symptoms conflict with heat-related illness. As rural fire risks increase and more firefighters are exposed worldwide, this disease is becoming more prevalent[41,42].

Purpose:

The purpose of this study is:

- to conduct a comprehensive assessment of respiratory risks in FRV rural operations (comprising of Grassland, Wildland, Forest and RUI)
- assess whether current commercially available RPD are appropriate for the risk
- if current RPD are not suited present options that will immediately improve firefighter safety, wellbeing and significantly reduce cumulative exposure

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Scope:

This study will only review RPD for Operational Fireground use in the context of rural firefighting and should not be considered for any specialist roles.

The study will present a pathway to establishing a practical trial and suitable device recommendations.

Summary:

- *What are the risks?*
    - Bushfire smoke is complex, it is ultimately impossible to identify every chemical compound as there are too many variables affecting the smoke produced from these types of fires[4,9,15,25,27,33,34,]. The type of vegetation, geographic location of the vegetation and even the time of year can contribute to altering the chemical composition of smoke[3,4,14,15,27,34]. However, through national and international research we have a much better understanding of the average risk profile for bushfire smoke. PM, Carbon Monoxide (CO), Formaldehyde, Acrolein, Acetaldehyde, Hydrogen Cyanide (HCN) and other lower amounts of various VOCs/PAHs have been detected[10]. A field of research of particular interest is the little-acknowledged area of synergistic effects caused by CO exposure.

- *What are synergistic effects?*
    - CO is attracted to red blood cells, it binds to red blood cells 210 times more efficiently than oxygen[33,43]. This presents a major issue as the cardiovascular system (heart and lungs) respond to compensate for lack of oxygen (elevated heart rate, increased respiratory rate). That effect is observable even at ambient temperatures without any physical exertion[43]. The net result is firefighters are exposed to chemicals that target specific organs, those compounds are transported faster and attack those sites directly[8]. HCN for example affects the heart, lungs and brain all of which are involved with the compensation of CO and

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presents an extreme risk[8,9]. Factoring in the physical exertion of firefighting at elevated temperatures during bushfires is a critical consideration as this has a demonstrable physiological response through hormone reaction, heart rate elevation, increased core temperature and respiratory reactions, increasing the synergistic risk three-fold[4,8,32]. Synergistic risks are not related to just one chemical either. Regardless of the chemical, even at safe thresholds when monitored individually, there is a cumulative effect if they all target the same organ and the additive effects formula needs to be applied[19]. The additive effects formula when applied to bushfire smoke readjusts CO's time weighted average (TWA)[8,9,25,44]. Normally CO has a TWA of 30ppm. When factoring the various chemicals in bushfire smoke, their target organs and exposure time, the TWA in reality should be reduced to at least 16.2ppm for fire fighters wearing P2 disposable masks[34].

- *What is wrong with continuing to use disposable P2 respirators?*
    - P2 respirators are perfectly acceptable for protecting firefighters from risks predominately involving larger average PM (dust, glass, asbestos etc). Research into smoke toxicity has progressed significantly in the past two decades with research focus on rural firefighter health exposures increasing exponentially from 2005 onwards. Bushfire smoke (as already discussed) contains much more than just PM. We now know there is a mixture of toxins emitted as volatile organic compounds, gases and vapours some of which are known carcinogens[15,25,34]. A P2 filter is only rated to offer protection for 94% of Particulates[38] (Protection Factor of 10)[37]. This means that all gases/vapours/fumes and 6% of Particulates are not being blocked. There is no method to identify when the filter is becoming blocked until it is too late, leaving the firefighter with no option other than to inhale smoke while changing P2. Historically there has been little training on fit-testing and safe use of P2 respirators, in fact the MFB Wildfire Learner's manual does not address this and in light of current research offers potentially unsafe and incorrect advice[46]. The issue has only been raised through the numerous WHS reports submitted by CFA & MFB firefighters reporting issues in arduous conditions where some firefighters have even required hospitalisation where P2 straps have failed or mask fabric has disintegrated[39].

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- *Can we mitigate the risk (Hierarchy of Controls)?*
    - Unfortunately no, like structural firefighting there are circumstances where this is not always possible and we use PPE to mitigate risk even though PPE should be considered as a last option in the Hierarchy[1]. All effort should be made to mitigate risk where able, though it is not always possible to eliminate, substitute, engineer or use administrative controls. While it may be easy to consider eliminating the risk by ordering crews to withdraw we have statutory obligations in the Fire Rescue Victoria Act 1958 relating to the Protection of Life and Property from Fire[2]. We also need to consider the FRV 2020-2021 Strategic Actions mandate which states "we must ensure there is no reduction in service to the community, and that the service response meets community expectations". There are situations such as the defence of critical infrastructure or rescue where the ability or option to withdraw may endanger more lives. In these instances where other risk mitigation strategies are not possible, RPD's must be factored up higher into the Hierarchy the same way Breathing Apparatus is used at structural fires[15]. There is a need to inform all firefighters from Operations, to Incident Controllers and even the Executive Team of the complexities of rural fire situations that correlate to firefighter health which includes:
        - smoke risks[34]
        - environmental considerations[3]
        - initial weight of attack[25]
        - crew rotation[2,15,33]
        - mitigation strategies[3]
        - firefighter wellbeing and health monitoring as required by Schedule 9 of the OHS Regulations[3,17,19,53,54]

- *Can we use SCBA?*
    - Rural firefighting is not conducive to operating in SCBA, structural firefighting in the urban context is different as resources such as additional personnel and PPE is readily available[15,24,25]. SCBA are designed for short duration operations in

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oxygen deficient, toxic or explosive atmospheres[3,25]. Rural firefighting is often performed where temperatures are consistently high, deployments are long-duration, resources can be stretched, work is physically demanding and mental focus is required[2,3,15,25]. SCBA is ideal as it provides 100% respiratory protection (as long as mask face-fit testing is performed) and carries a Protection Factor of 100+[37,38]. Unfortunately SCBA will only provide approximately 20 mins of practical use in a rural fire fight due to the added weight and extra physical effort required under tough environmental conditions[3,5, 32]. Crews in rural scenarios performing asset protection may encounter car fires, house fires or atmospheres where SCBA use is imperative. Conservation of cylinders is critical where servicing facilities are stretched or limited and time at the fire perimeter is critical for asset defence.

- *What other devices are available then?*
    - The next step up from a disposable respirator is a reusable, air purifying negative pressure respirator (APR) [37]. These are available with half-face and full face masks and are operated by the user's own lung power to force air in and out. Powered air purifying respirators (PAPR) are another option[37], these units consist of a mask, filter system and battery to drive a fan unit. The fan draws ambient air inside the cartridges to supply the user with filtered air. PAPRs are available in fixed flow or variable/demand options and can be positively pressurised to force contaminants out of the mask in case of accidental slippage[23].

- *Would an APR be suitable?*
    - Some advantages to using a negative pressure APR are:
        - similar to a PAPR or SCBA they are reusable so they can be decontaminated and returned to service quickly
        - filter cost like a PAPR (dependant on type and industry use) would bear the same or less financial burden as a P2 mask program

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        - They achieve a significantly higher level of protection compared to a P2 mask[47] but not as high as a PAPR.

    - A disadvantage of an APR is when used with a half-face mask, only a P2 efficiency rating is achieved as the eye and sinus entry paths are still exposed[2,37]. A half mask (regardless of filters attached) would therefore achieve a Protection Factor of 10 and 94%, no different to a P2[25,37]. A Protection Factor of 50 could be achieved though it requires an SCBA–style full facepiece[37]. Scientific research highlights the extra demand already placed on firefighters and researchers have identified the extreme risks when using lung power to perform the act of filtration, among other things increasing the chances of heat related illness and Rhabdomyolosis[1,2,8,18,23,24,25,32,35,36]. Tolerability and workforce must be considered before implementing any RPD, where one person may find little discomfort or resistance using an APR the physiological effects may be different for other users. Therefore selecting an RPD that does not impose a high physiological burden should be a priority[32]. Placing a negative pressure, full face APR on a firefighter would increase lung effort while performing physically demanding work at elevated temperatures in a CO rich environment. This would produce more sweat compromising the face mask seal, lead to fogging and allow the ingress of toxic atmosphere [15,16,17,32]. There are also issues similar to the P2 as there is no method to detect when the filter is clogged other than the user becoming aware of smells within the facepiece[15,17]. This is called filter breakthrough and while breakthrough times can be discovered with research, almost no manufacturer can account for every potential variable, though filter service life could be based on the contaminant with the shortest breakthrough time[17]. Poorly designed masks, restrictive masks and disposable respirators also increase the risk of Hypercapnia (Carbon Dioxide poisoning) the symptoms of which are almost identical to those of CO poisoning[20,35]. The risk of Hypercapnia would be increased with additional physical activity, further exacerbated with firefighting and CO exposure.

- *Are there any safer options?*

    - RPD that have a neutral or positive pressure feature would be a much safer option. As already addressed due to their limited capabilities, SCBA should not be

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recommended for rural firefighting unless for Structural, Non-structure, HAZMAT responses or a situation where HCN is detected or high levels of CO are present. Several studies (including recent COVID research papers) have highlighted the advancements of PAPRs as a RPD and the physiological benefits they present[17,36]. As an example, battery technology can now allow 4 hrs protection at a minimum with some units offering up to 8+ hrs depending on concentration of toxins[38]. PAPRs significantly reduce respiratory effort, physiological stress and responses[25,28,32,36]. With a P3 filter and full face mask we would expect to see a Protection Factor of 100+ (same as Australian Standard for SCBA) while capturing 99.95% of thermally and mechanically generated particulates[37,38]. At present all states with the exception of Victoria and South Australia offer career firefighters P3 (99.95%) ABEK1 (gas/vapour) protection and as such that style of filter should be considered at a minimum[48]. By filtering with a gas/vapour cartridge we can significantly reduce the risk of previously mentioned synergistic exposure[15]. PAPRs also have the advantage of flow detection for particulate filter expenditure. Instead of relying on the operator's sense of smell (which can vary and is an unsafe practice) the PAPR can sound an alarm and/or vibrate to let the user know filter replacement is required. Many PAPRs now offer spectacle inserts and speech amplifiers similar to the FRV MSA SCBA. If a PAPR has these optional extras they should be considered to enhance visibility and clear communication especially in environments where shouting requires additional respiratory effort and current goggles have no prescriptive options and are not smoke rated[16,23,32].

- *What are the risks with this option?*
    - There are no options without some level of risk and critical to a safe, successful implementation is the need to ensure good training and control practises, no different to SCBA[17]. With a PAPR eliminating PM by 99.95% and significantly reducing the risk of air toxics, the only remaining risk to address is CO exposure. Currently there are a limited amount of CO filters available for APRs and PAPRs but there is significant costs and restrictions in the way they can be used[50]. As technology and manufacturing processes advance this may become an option for future application or upgrades. With the imminent introduction of MicroRAE detectors (to replace FRV QRAE personal detectors) firefighters will have the

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ability to detect and monitor CO and HCN meeting Action 233 of the Hazelwood IGEM Annual Report[40]. Where firefighters may inadvertently be exposed to a peak emission of CO we have scientific research to provide Officers with simple, safe effective guides to reduce exposure rapidly in a Rural or RUI environment[11,17]. Issues related to CO metabolism not addressed in current operations could be improved upon. Research highlights the need to monitor this as it will empower firefighters and health officials with information that will provide another layer of protection and validation for any CO exposure[3,8,19]. This information and training will also save the lives of any at-risk groups such as smokers or those with undetected pre-existing conditions and would address Recommendation 7 of the Hazelwood IGEM Report[40]. Underpinning all of these options is the absolute critical component of education and training as well as disciplined and rigorous implementation of controls and procedures[9,17,26,33]. We need to be as dynamic as the threat firefighters are exposed to in bushfires by addressing all of these aspects and not just focusing on one.

- *Are there any additional benefits to Fire Rescue Victoria?*

  - Currently when structures or vehicles (such as sheds, tractors and even fence posts) are involved in a rural fire they have the ability to emit considerable quantities of HCN[11]. Fires such as those in Canberra of January 2003 have been studied in great detail[11]. Rural boundaries are now encroaching on Greater Melbourne and coupled with a changing climate presents new firefighting challenges which we hope this project can address[51]. With the selection of a suitable PAPR and the appropriate filters we can offer an unprecedented level of protection to firefighters who are often unaware of what is burning at the fire front. International research is so advanced that with HAZMAT assessment, safe work practices and new technology, PAPRs are being used for structural overhaul operations[50]. Another potential area for further research and investigation would be the opportunity to use PAPRs to enhance our CBRN response capability. PAPRs were originally designed for this purpose where long-duration respiratory protection in challenging conditions is required. When the selected device has been successfully integrated as standard PPE only then should CBRN response suitability be considered. This advancement would require significant investigation

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for an approved CBRN filter and the selected RPD would need to support this capability. To this end as part of the selection process upgradability and capability to support future research or development opportunities should be considered. This potential though, should not be prioritised as part of the selection process over the primary objective of providing significant respiratory protection from rural hazards. ACT Fire Rescue have been through this process and are already implementing dual functionality to support CBRN response capabilities [48].

- *What are the immediate benefits to Fire Rescue Victoria and the State Government?*
  - Aside from the immediate improvement to rural fire response and firefighter health, PAPRs can be used to improve our response to major disasters such as the recent Pandemic response. PAPRs are already used by health professionals for this purpose and would provide firefighters with a significantly higher level of protection while allowing them to perform intensive advanced life support (ALS) activities such as CPR with considerably less effort[36]. Using disposable or negative pressure masks during activities like ALS would fatigue firefighters faster and could induce hypercapnia especially during EMR response on heat-health related days[20,32,35].
  - Another critical benefit would be a reduction in lost-time-injuries, an assumed reduction in some claims for presumptive legislation and consequent reduction in smoke injury related FRV Safe reporting[17].
  - Moving to a PAPR would reduce our waste and carbon-footprint in line with the FRV Environmental Policy[52].
  - This project further meets the needs for many of FRV's commitments in the FRV 2020-2021 Plan, the FRV Year One Outcomes Framework and components of the Victorian Government's Year One Fire Service Reform Implementation Plan. Some examples of this are listed below.

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- FRV Year One Outcomes Framework[55]:
  - Outcome 2.1 We utilise modern technology and our skilled workforce to deliver effective, responsive and sustainable services. Outcome statements include ability to manage peak events, strategic and workforce planning to ensure appropriate resourcing and identify opportunities for improvement and our people are always ready to respond to the threat of fire and other emergencies.
  - Outcome 2.2 Provide an adaptable response that meets the emergent needs of the community.
  - Outcome 2.3 Our services are innovative, evidence-based and forward looking to plan for the future. Outcome statements include strategic, risk-based focus continually improving capabilities and operations through research, planning and evaluation. Planning enables us to manage the changing environment in which we operate. Our decisions are evidence-based, transparent and accountable. Outcome indicators include increase in evidence-based policy and service design, increase in research and evaluation programs and increased use of evaluation.
  - Outcome 3.2 FRV supports and promotes the health, wellness and safety of our people. The health and wellness of our employees is integral to our success. Indicators include increased workforce satisfaction, increased workforce wellness and decrease workplace incidents, accidents and near misses.
  - Outcome 3.3 FRV values innovation and invests in the skills, knowledge and experience of our workforce. Outcome indicators include increase in staff participating in elective training and programs.
  - Domain 4 – Collaboration Outcomes 4.1, 4.2 and 4.3. Outcome indicators include increased consultation with other agencies, increase staff participation on development of policies, protocols and procedures, including collaborating with partners and increased consultation with other agencies.

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- FRV Plan 2020-2021[56]:
  - Further elevate the importance of health and wellbeing, recognising it as a key enabler of individual and organisational performance.
  - Embed risk-based, strategic planning approaches across the organisation to ensure FRV meets current and future needs.
  - Investigate new and emerging technologies to increase rescue outcomes and minimise firefighter exposure to dangerous/harmful situations.
  - Rapid growth and development on Melbourne's peri-urban fringe, exposing a large population to grass and bushfire threats. Many of whom have no or little experience with such threats.
  - Maintaining visibility of trends and potential applications is key to utilising technologies and ensuring rapid advances by business and community are utilised and can be responded to by FRV to improve operational capability.
  - Climate variability is set to exacerbate under the impacts of climate change. The 2019/20 bushfire season shortly followed by COVID-19, two unprecedented events demonstrate the real potential for cascading events in our operating future.
  - As the likelihood of non-routine, high-consequence events increases, there is growing political interest in major events, and community expectations for efficient and effective services are high.
  - Drive operational reforms in the emergency management sector, in collaboration with key sector partners and the community, to deliver a safe and sustainable fire and rescue service across emergency preparedness, planning, mitigation, response and recovery.

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- Improve organisational capacity to operate jointly with other agencies and government departments to plan and prepare for the response to, and in responding to major emergencies.

- Victorian Government Year One Fire Services Reform Implementation Plan[57]:

  - Priority Four, Value Our Firefighters - Firefighters put their lives on the line to protect Victorians. Volunteer and career firefighters deserve to have the right skills and access to training; access to the right resources to succeed at their jobs and to keep them safe

  - The 2017 Fire Services Statement (the Statement) articulated the Victorian government's vision for the state's fire services – a modern, integrated and sustainable system that keeps Victorians safe. "Looking after our firefighters also means making sure they have world class, contemporary appliances and equipment to keep them safe on the ground while they protect our lives and assets."

- *What would a device selection and evaluation program look like?*

  The establishment of a Working Group for this is critical and would most likely contain three steps to selecting suitable respiratory protection and supporting PPE:

  - **Step 1:** Proof of Concept
  - **Step 2:** Controlled Trials and Evaluation
  - **Step 3:** Field Testing

Progress to date:

As of 03/05/2021 we have engaged FRV ELT (DCC. Freeman and DCC. Braid). With the support of FRV ELT and Ops CC we are prepared to establish the Working Group and report back with recommendations to Ops CC via the V&E Subcommittee.

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