THE AUSTRALIAN BUSHFIRES: IMPACTS ON HEALTH – THE EVIDENCE

The Australian bushfire season of 2019/20, which has been reportedly unprecedented in scale, has had a devastating impact on communities and the environment across Australia.[1] We are likely to see higher frequency and severity of such events over the coming decades, according to the Intergovernmental Panel on Climate Change (IPCC) and the Bureau of Meteorology (BOM).[2,3] Fires on this scale bring significant implications for human health and societal wellbeing. Impacts of smoke exposure and the challenges for mental health have been two widely reported areas of concern, and the fires have revealed gaps in our understanding of these and other aspects of health.

This briefing from the Australian Academy of Health and Medical Sciences outlines the health impacts on individuals, communities and the wider population, and identifies the gaps in our knowledge and our capacity to respond, which need to be addressed to build Australia's future resilience.

Summary

- **Impacts on health are wide-ranging and potentially long-term. The extent, duration and intensity of the 2019/20 bushfires have affected a substantial proportion of the population, bringing new health challenges, some of which are not well understood.** Exposure to heat, smoke and other contaminants can impact directly on health through the respiratory system, eyes and skin, and fine particles can enter the bloodstream causing further risks. Mental health can be seriously affected in multiple ways, especially for first responders and individuals directly affected by fires. Indirect impacts may arise through contamination of waterways and food systems.
- **Australia will need to better understand the short-, medium- and long-term impacts on health if we are to mitigate, adapt and support those affected in future, particularly given that such events are expected to become more common.** There are gaps in our knowledge of impacts on first responders and affected communities, as well as the wider population, especially when the response or threat of fire is so prolonged.
- **There is an opportunity now to undertake research to fill these knowledge gaps – we must take it.** Funding calls from organisations such as the National Health and Medical Research Council (NHMRC) and Medical Research Future Fund (MRFF) are welcome and important, but will need to be supplemented by further work. We know from previous incidents, such as the Black Saturday fires and the Hazelwood mine fire, that the health impacts – both physical and mental – extend far beyond the duration of the fires. Research is essential to gain an adequate understanding of these complex outcomes.
- **Targeted advice and plans are needed for vulnerable population groups.** Targeted interventions and early warnings are needed to prevent impacts such as respiratory problems and heat stress in vulnerable populations groups, including infants, children, the elderly, individuals with pre-existing conditions, pregnant women and Aboriginal and Torres

[1] Australian Academy of Science (2019). Statement to ABC TV's Media Watch Program: The Australian bushfires – why they are unprecedented. Available from: https://www.abc.net.au/cm/lb/11926146/data/aas-data.pdf

[2] Reisinger, A., *et al.* (2014). Australasia; In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., *et* al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1371-1438.

[3] Bureau of Meteorology and CSIRO (2018). State of the Climate 2018. Available from: http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2018.pdf

Strait Island Peoples and communities. Emergency situations can exacerbate health inequalities – plans to provide adequate services are critical.

- **Clear public health advice is needed and will rely on evidence.** There was insufficient health advice available to the public in relation to bushfires this season, in some cases because the evidence does not exist and in others, because it has not been collated and synthesised.
- **Future health system needs must be assessed, including long-term modelling of costs.** The communities most directly impacted are often rural or remote communities with limited services – mechanisms are needed to augment access to medical specialists, potentially at short notice. The quality of this acute response can determine long-term outcomes – poor care after burn injuries, for example, can lead to chronic disease. Further afield, given the widespread impacts across the country, we need to ensure health professionals such as those in primary care, are equipped to provide the best care and advice. The health system will also need capacity to deal with long-term follow up and we know that individuals do not necessarily access services – we must explore the reasons why and then address them.

Exposure to contaminants

Bushfire smoke and respiratory issues

Exposure to bushfire smoke can cause respiratory complications, including breathing difficulties and coughing, due to the complex mixture of molecules in smoke, including varying levels of carbon monoxide, sulphur dioxide and nitrogen dioxide, as well as particulate matter, categorised as $PM_{2.5}$ and PM_{10}. Fine particles, or $PM_{2.5}$ (which have a diameter of 2.5µm (micrometres) or less) are small enough to penetrate deeply into the lung and enter the bloodstream, causing issues beyond the respiratory system. These fine particles, can potentially pose a serious risk, especially for individuals with pre-existing conditions such as heart, lung diseases, asthma and diabetes, and those in vulnerable population groups such as the elderly, children and pregnant women. Respirable particles are a larger group (PM_{10} have a diameter of 10µm or less), which are still small enough to pass through the nose and throat and enter the lungs. Box 1 outlines how air quality is measured.[4,5]

Box 1: Measuring air quality

World Health Organization (WHO) air quality standards specify that for air quality to be considered good:

- Fine particulate matter levels of PM2.5 should not exceed the average of 35 µg/m^3 per 24-hour exposure period and an average of 10 µg/m^3 annually.
- Larger particles, PM10, should not exceed an average of 50 µg/m^3 per 24-hour exposure period and an average of 20 µg/m^3 annually.

The national air quality standard for Australia sets a level of PM2.5 at 25 µg/m^3 per 24 hours or an 8 µg/m^3 annual average.[4] However, both systems acknowledge that there is no known safe threshold for fine particle pollutants.

It has been clear from this season's fires that there remain many unknowns about how bushfires impact on respiratory health in the short, medium and long term. This has made it difficult to provide accurate health advice and has caused anxiety among affected communities and the wider public. Gaps in our knowledge relate not only to the health outcomes, but also to the underlying

[4] World Health Organization (2006). *Air Quality Guidelines: Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. Copenhagen: WHO Regional Office for Europe, 2006.

[5] Australia State of the Environment (2016). *National air quality standards: Ambient air quality*. Available from: https://soe.environment.gov.au/theme/ambient-air-quality/topic/2016/national-air-quality-standards

biological mechanisms and our ability to monitor and assess the risks – and consequently to provide sound advice on management, as follows:

- **We do not fully understand the underlying biological mechanisms for how air pollution from bushfire smoke causes respiratory problems and exacerbates existing conditions**. Our knowledge of the health impacts of ambient air quality from industrial pollution has improved over the past decades. We still need to learn more about the risks of bushfire smoke in the Australian context, including the mechanisms through which particles, especially $PM_{2.5}$ and PM_{10}, cause health problems. Although organisations like WHO set air quality guidelines (Box 1), they also acknowledge that there is no known safe threshold for $PM_{2.5}$.[6] In fact, those guidelines may not provide enough detail to inform health advice, since they are based on particle size and not the composition of the particles, which could be an important factor in determining the health effects – bushfire pollution may not necessarily be the same as traffic pollution, for instance. Research is needed to establish the levels at which health is compromised – and to what extent. Considering the size, length and intensity of the air pollution, and the scale of exposure across the country, there is a prime opportunity to undertake such research.
- **We have not yet identified the most appropriate biomarkers to quantify the health impacts at particular levels of air pollution**. Biomarkers are used to measure the biological processes involved when the body is exposed to chemicals, toxins or environmental contaminants. They can help identify the level at which particulate matter is harmful to health, and in what ways. We can therefore use biomarkers to set clear guidelines, based on known health risks at different levels of pollution, enabling more informative advice to the public. Biomarkers could also help track the effectiveness of therapies and management strategies. Again, considering how many individuals were exposed to bushfire smoke this season, research here could be very informative.
- **More evidence and guidance are needed on the effectiveness of face masks.** Publicly available protection from fine particles is most commonly the P2 or N95 face mask. The correct fit of a P2/N95 mask, which is easily compromised by factors such as facial hair, is key to sufficiently protecting its user. Incorrect use of these facemasks can lead to a false sense of security, in which the user may unknowingly still be exposed to unhealthy levels of air pollution. Furthermore, P2/N95 facemask sizes appropriate for children are not widely available. If facemasks are to be relied upon in future, we need to be able to provide clear advice on proper, effective use.
- **Our understanding of the health impacts of prolonged exposure to bushfire smoke is limited.** Firefighters and other first responders are the most directly affected by inhalation of smoke and have been in the field dealing with the fires for significant periods over the 2019/20 season. The acute effects of smoke exposure on first responders have been described in international studies.[7],[8] However, such studies have not been able to explore the long-term effects, which we know from research elsewhere, e.g. following 9/11, can be profound.[9] This kind of follow up is essential – not only to support individuals, but also to develop better understanding of the

[6] World Health Organization (2006). *Air Quality Guidelines: Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. Copenhagen: WHO Regional Office for Europe, 2006.

[7] Slaughter, JC (2014). Association Between Lung Function and Exposure to Smoke Among Firefighters at Prescribed Burns. J Occup Environ Hyg. 2004;1(1):45-9.

[8] Pedersen, JE (2018). Risk of asthma and chronic obstructive pulmonary disease in a large historical cohort of Danish firefighters. Occup Environ Med. 2018 Dec;75(12):871-876.

[9] Zeig-Owens R, *et al.* (2018) Blood Leukocyte Concentrations, FEV_1 Decline, and Airflow Limitation. A 15-Year Longitudinal Study of World Trade Center–exposed Firefighters. Annals of the American Thoracic Society. 2018;15(2):173-83.

impacts and improve future management. More broadly, the general population in many areas has been exposed to smoke for prolonged periods, with cities such as Sydney and Canberra reaching hazardous fine particle levels on multiple occasions.[10,11,12] The long-term effects of increased inhalation of fine particles from bushfires for prolonged periods, especially in vulnerable groups, is not well understood, meaning that individuals are left without clear health advice.

Other contaminants and issues

Contaminants come not only from bushfire smoke, but as a result of the burning of household chemicals and materials (e.g. asbestos), fuel or other materials, as well as firefighting foam. When they enter the bloodstream, whether through the lungs, ingestion, skin or otherwise, these contaminants can cause harm and can potentially endure in the body for long periods. In many cases, we do not know the long-term impacts of such exposure. There is also a need for clear guidance to individuals who may be dealing with substances such as asbestos for the first time – evidence of health impacts and strategies for safe handling are well known, but need to be clearly shared with relevant communities in these circumstances.

- **We do not currently have evidence for whether there are health benefits associated with removing contaminants from the body.** Although some of these chemicals are known to be harmful to human health, there has not been extensive research to explore whether actively removing them from exposed individuals reduces health risks. In many cases they can be removed, for example using an oral therapy or even removing directly from the blood, but it is hard to formulate evidence-informed policy on such practice; consequently, several states and territories do not actively monitor and treat such exposure, which could occur in first responders, other volunteers and those returning to contaminated sites. Individuals may visit their GP or another health professional for advice, but there is little guidance available to those healthcare works and access to specialists is limited – we need to build greater capacity and capability in environmental medicine for this purpose.

Eye health

Eye irritation is a common issue resulting from the exposure to bushfire smoke. In the case of bushfires, dust, fumes, gases (e.g. nitrogen oxides) and fine particles can irritate the eyes. Individuals with pre-existing eye conditions such as dry eye, eyelid inflammation or allergic conjunctivitis can be particularly sensitive to irritation from smoke triggering sometimes severe symptoms of stinging, grittiness, burning and itching.[13] Air pollution can also increase the frequency of such conditions – a study from China, for instance, found that dry eyes are three to four times more likely in individuals with long-term exposure to air pollutants.[14] Although prescription-free remedial eye drops are available to ease the irritation, we need to better understand the long-term impact of bushfire smoke on eye health. Some findings already suggest that air pollution may have long-term impacts.

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[10] Australian Broadcasting Corporation. *Bushfires, heat, smoke and hail storms: A breakdown of Canberra's extreme summer*. 2 March 2020. Available from: https://www.abc.net.au/news/2020-03-01/canberras-summer-of-fire-heat-rain-and-hail/12011124

[11] Australian Broadcasting Corporation. *Sydney smoke at its 'worst ever' with air pollution in some areas 12 times 'hazardous' threshold*. 10 December 2019. Available from: https://www.abc.net.au/news/2019-12-10/sydney-smoke-returns-to-worst-ever-levels/11782892

[12] Vardoulakis, S *et al.* (2020). Bushfire smoke: urgent need for a national health protection strategy. *Med J Aust* II.

[13] American Academy of Ophthalmology (2018). What to do when smoke get in your eyes. Available from: https://www.aao.org/eye-health/tips-prevention/what-to-do-when-smoke-gets-in-your-eyes

[14] Donhui, Y *et al.* (2019). Air Pollutants are associated with Dry Eye Disease in Urban Ophthalmic Outpatients: a Prevalence Study in China. *J Transl Med* (2019) 17:46

For instance, a recent study from the UK has found that exposure higher levels of $PM_{2.5}$ may be associated with increased cases of glaucoma.[15] Particulate matter in the air also impacts the retinal vasculature, and thus may exacerbate common retinal vascular diseases that have the potential to reduce vision, such as diabetic retinopathy.[16]

Water/food

The runoffs from bushfires can cause contamination of drinking water supplies which increases the risk of gastroenteritis.[17,18] The related symptoms such as diarrhoea and vomiting can lead to dehydration and weakness in those affected. The burned materials from bushfires, including organic matter, not only pose a risk to drinking water quality, but can also impede treatment processes.[19] The intensity of bushfire heat impacts on the contaminants released into the water system. Higher intensity fires can cause the release of inorganic compounds, which, after rainfall, can lead to water contamination from phosphorus, nitrogen, and potentially increase the levels of trace metals such as copper, lead, chromium and methyl mercury.[20] Bushfire run offs from phosphorus and nitrogen can also stimulate the growth of blue-green algae which can cause illness in humans and animals.

Bushfires may also impact the energy grid, and hinder the power supply for several days or weeks, especially in more remote areas. The loss of power for refrigeration may increase the risk of salmonella, campylobacter infections or other pathogens from spoiled foods.[21]

Mental health

There are a range of psychological factors relating to the processing of trauma following bushfire events, especially for the individuals and communities directly impacted, and for first responders. Mental health impacts can include anxiety, depression, post-traumatic stress disorder (PTSD) and other forms of psychological distress.

Recovery from bushfires is a long process and mental health impacts can emerge at any time. Longitudinal research following the Black Saturday fires in 2009 showed that one in five individuals in affected regions still had a psychological disorder five years after the fires, and such outcomes were more likely to be driven by issues financial strain and community recovery, rather than the direct experience of the fires.[22] Another study analysing the impacts of Black Saturday found that women living in highly disaster-affected communities are more likely to experience domestic

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[15] Chua SYL, Khawaja AP, Morgan J, *et al*.; for the UK Biobank Eye and Vision Consortium. The relationship between ambient atmospheric fine particulate matter (PM2.5) and glaucoma in a large community cohort. *Invest Ophthalmol Vis Sci*. 2019;60:4915–4923.

[16] Pan, S-C et al. (2020). Association between air pollution exposure and diabetic retinopathy among diabetics. Environmental Research, Volume 181, February 2020, 108960.

[17] Department of Health Tasmania (2018). Preventing spread of disease in areas affected by bushfires. Accessed on 5 March 2020. Available from: https://www.dhhs.tas.gov.au/publichealth/alerts/public_health_updates/preventing_spread_of_disease_in_areas_affected_by_bushfires

[18] Water Quality Australia. Bushfires and water quality. Available from: https://www.waterquality.gov.au/issues/bushfires

[19] Canning, A *et al*. (2020). *Bushfires and the Risks to Drinking Water Quality: Factsheet.* Water Research Australia, 2020. Available from: https://www.waterra.com.au/publications/document-search/?download=1840

[20] Canning, A *et al.* (2020). *Bushfires and the Risks to Drinking Water Quality: Factsheet*. Water Research Australia, 2020. Available from: https://www.waterra.com.au/publications/document-search/?download=1840

[21] Victoria State Government (2020). *Health concerns related to Victorian bushfires*. Published 24 January 2020. Available from: https://www2.health.vic.gov.au/about/news-and-events/healthalerts/health-concerns-bushfires

[22] Gibbs L, *et al*. (2016). *Beyond Bushfires: Community Resilience and Recovery Final Report*. November 2016, University of Melbourne, Victoria, Australia.

violence than those living in less affected communities.[23] According to the study, domestic violence was closely related to financial strain and mental health issues, such as PTSD, following the disaster. The subsequent COVID-19 pandemic could exacerbate mental health problems by delaying community recovery and adding additional stress to individuals and families, for example those with businesses that have already been damaged by the fires.

Findings like these should inform targeted responses to disasters and we must continue to probe remaining evidence gaps so that we can better support the Australian community through these sorts of disasters in future – for example:

- **There are still gaps in our knowledge of the impacts on first responder and volunteer mental health**. Alongside physical health, mental health follow-up for firefighters, both professional and voluntary, is critical to enable the most appropriate and effective care. While there are often mechanisms in place to provide mental health support to firefighters in the short term, resource limitations mean that long-term follow-up can be difficult, especially for voluntary organisations. Research efforts in Australia to track long-term outcomes for first responders have not been extensive, although we know from examples such as 9/11 that they can be considerable.[24] Appropriate long-term follow-up is crucial if we are to support first responders through the full range of mental health impacts, some of which may not emerge for many years.
- **The uptake of mental health services provided during recovery is sub-optimal.** The uptake of mental health services following emergencies needs to be better understood to equip us to provide the most appropriate support to impacted communities. Similarly, following Black Saturday, only one in four of the individuals identified as severely distressed sought help.[25] It is critical that we examine why individuals are not accessing services and then use this knowledge to improve service provision.

Impacts on vulnerable groups and health inequalities

Vulnerable groups include those with pre-existing health conditions such as asthma, chronic respiratory diseases, and cardiovascular conditions, as well as pregnant women and individuals that have age-related frailty or disabilities. Aboriginal and Torres Strait Island Peoples and communities can be vulnerable in the event of bushfire emergencies and smoke haze. Indigenous children and adults, for instance, are more likely to suffer from acute or chronic respiratory infections – conditions which can be exacerbated by bushfire smoke.[26]

Health inequalities are potentially exacerbated by emergency situations, where access to services and information, including on the management of pre-existing conditions may be lacking. Although authorities have advised avoiding bushfire smoke by staying indoors and by using air conditioning when possible, or in severe cases air purifiers, there are socio-economic factors which make it challenging for financially vulnerable groups to implement these measures and housing standards

[23] Molyneux, R *et al.* (2020). Interpersonal violence and mental health outcomes following disaster. *BJPsych Open* (2020) 6, e1, 1–7.

[24] Giesinger I, Li J, Takemoto E, Cone JE, Farfel MR, Brackbill RM. Association Between Posttraumatic Stress Disorder and Mortality Among Responders and Civilians Following the September 11, 2001, Disaster. *JAMA Network Open* 2020;3(2):e1920476-e.

[25] Bryant, R *et al.* (2014). Psychological outcomes following the Victorian Black Saturday bushfires. *Australian & New Zealand Journal of Psychiatry 2014*, Vol. 48(7) 634–643.

[26] Basnayake, T *et al.(*2017). The global burden of respiratory infections in indigenous children and adults: A review. *Respirology* (2017) 22, 1518–1528.

may not provide adequate protection from air pollution. Areas where further work is needed to inform future preparation include:

- **A need to better understand how bushfires and air pollution from bushfire smoke affect pregnant women, unborn and newborn babies.** Some international studies have linked extended exposure to air pollution from $PM_{2.5}$ to pregnancy outcomes such as pre-term births and lower birth weight.[27] It is critical that we understand these impacts so that we can provide the best health advice in the Australian context. We also need to explore how stress on mothers in emergency situations, or other impacts such as heat stress, affect their infants, for example whether fine particles and other toxins are transferable through breastmilk to babies.
- **Emergency plans and evacuation measures must cater for pregnant women, postnatal women and their babies in the event of bushfires and smoke haze**. Pregnant women and families with young babies and children need more comprehensive information during bushfire situations to reduce their risk. There is also a need to better inform emergency services and health services about how to support pregnant women, and parents with newborns during bushfires and smoke haze. This includes clear guidelines for evacuation if required and policies to support infant feeding. Australia does not currently have clear 'young child feeding in emergency' (IYCF-E) plans. IYCF-E plans concern infant feeding in disaster situations with a focus on the nutritional needs of babies relying on breastmilk and formula in emergency situations. Plans are needed at Federal, State/Territory and local level, in line with international standards, to support mothers and infants in emergency situations.[28]
- **We are not currently able to provide targeted health/health protection advice for families with children.** Children are particularly vulnerable due to their level of activity, developing respiratory system and their relatively high air intake compared to their body size. In the event of bushfire smoke, the general advice has been to remain indoors, but if children have to spend time outdoors, appropriately sized facemasks are not readily available. Evidence-based advice to parents is urgently needed.

Burns and heat stress

Bushfires and heat stress pose a severe risk for anyone in proximity to the flames, but those nearby can also be affected by radiant heat. Burns to widespread parts of the body can be life-threatening or lead to lasting disabilities that require long-term medical treatment and support. Heat can be a serious stressor, causing dizziness, confusion, dehydration, nausea, exhaustion and heat stroke, which in extreme cases can be fatal. Firefighters and volunteers are at the greatest risk of sustaining burn injuries and suffering from heat stress, but other population groups are also at risk. For instance, heat stress in pregnancy has been linked to preterm births, while heatwaves have also been associated with a 28% increase in the average deaths in the elderly population.[29,30] Heat stroke has also been associated with long-term neurological effects, even among the young or individuals without pre-existing medical conditions.[31]

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[27] Abdo, M *et al.* 2019). Impact of Wildfire Smoke on Adverse Pregnancy Outcomes in Colorado, 2007–2015. *Int. J. Environ. Res. Public Health* 2019, 16, 3720.

[28] Gribble, K *et al.* (2019). Emergency preparedness for infant and young child feeding in emergencies (IYCF- E): an Australian audit of emergency plans and guidance. *BMC Public Health* 19, Article number: 1278 (2019).

[29] Supriya, M *et al*. (2017). Examining the Effects of Ambient Temperature on Pre-Term Birth in Central Australia*. Int. J. Environ. Res. Public Health* 2017, 14, 147.

[30] Cheng, J *et al*. (2018). Heatwave and elderly mortality: An evaluation of death burden and health costs considering short-term mortality displacement. *Environmental International*, Volume 115, June 2018, Pages 334-342.

[31] Lawton, EM *et al*. (2019). Review article: Environmental heatstroke and long-term clinical neurological outcomes: A literature review of case reports and case series 2000–2016. *Emergency Medicine Australasia* (2019) 31, 163–173.

Early data suggest that warning messages from emergency services have helped to reduce the severity burn injuries this season. Community awareness needs to be maintained for future bushfire events.

- **We need to be better prepared to deal with co-occurring physical and mental health problems.** The link between burn injuries, for instance, and mental health should not be underestimated. A study on the long-term mental health impacts of childhood burns concluded that children who sustained their burn injury between ages of 5 to 15 years old were up to five times more likely to be admitted to mental health care later in life than those uninjured.[32] These sorts of co-occurring physical and mental health needs may require long-term support.

This briefing has been informed by contributions from AAHMS Fellows and other experts in fields including environmental health, respiratory health, mental health, maternal and child health, burns, Indigenous health, public health and eye health, including through an expert roundtable held on 13 February 2020. We are grateful for their valuable contributions.

[32] Duke, JM *et al*. (2018). Long-term mental health outcomes after unintentional burns sustained during childhood: a retrospective cohort study. *Burns & Trauma* (2018) 6:32.