



Reflections on the Catastrophic 2019–2020 Australian Bushfires

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While fire is an inherent part of the Australian landscape, the bushfires that occurred in eastern Australia from September 2019 to early February 2020 were unprecedented (Figure 1). Bushfires across the nation burned more than 12.6 million hectares (an area slightly bigger than Belgium, Denmark, and the Netherlands combined), emitted about 430 tonnes of carbon dioxide into the atmosphere (about three-quarters of the country's total annual carbon dioxide emissions), directly caused at least 33 deaths and over one billion animals were killed (<https://www.abc.net.au/news/science/2020-03-05/bushfire-crisis-five-big-numbers/12007716>).

In Sydney, the largest city in Australia with a population of about 5.2 million, levels of particulate matter $\leq 2.5 \mu\text{m}$ in aerodynamic diameter ($\text{PM}_{2.5}$, also known as fine particles) exceeded $700 \mu\text{g}/\text{m}^3$ and the average maximum 24-h $\text{PM}_{2.5}$ levels from November 2019 to January 2020 (the worst months for the fires) was about $64 \mu\text{g}/\text{m}^3$ (<https://www.dpie.nsw.gov.au/air-quality/search-for-and-download-air-quality-data>). In a national poll conducted in early January 2020, just over half the respondents (57%) reported experiencing some kind of direct impact from the bushfires or smoke.¹ In New South Wales, the worst affected state, nearly three-quarters of the respondents reported being affected in some way by the bushfires or smoke, 33% changed their usual routine in some way, and a quarter experienced health effects because of the smoke.¹ In the eastern states of Australia, up to about mid-January 2020, the bushfire smoke was responsible for an estimated 417 premature deaths, 3,151 cardio-respiratory hospitalizations, and 1,305 visits to the emergency department for asthma.²

All authors of this paper were extensively involved with the media, both local and international, government agencies, and the public during the height of the bushfires. We were mainly asked about measures that the public could take to reduce personal exposure to the smoke, the health effects of bushfire smoke, and especially, whether exposure to the high levels of smoke would lead to health problems many months and years later in life. For example, is the risk of chronic diseases, such as chronic obstructive pulmonary disease, ischemic heart disease, and diabetes, increased because of the exposure to weeks of high levels of smoke?

As the extreme levels of bushfire smoke continued week after week, the community sought more nuanced information about the associated health risks. It soon became apparent to us that although we know much about the acute health

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Figure 1 Bushfires Can Have Devastating Consequences for the Ecosystem (Source: iStock)

effects of smoke, there was limited information about the medium and long-term health effects of smoke, which was the information that communities and governments required or expected. In this paper, we reflect on our experiences of this extreme bushfire smoke event, share our insights, and identify gaps in knowledge regarding the longer-term (or future) health effects of prolonged smoke exposure, advice on reducing exposure to smoke, and the health risks to individuals.

Most of what we know about the effects of high levels of bushfire smoke relates to short-term exposure (hours to days) and the associated acute effects,³ and we know something about the adverse mental health effects 1 to 2 years following exposure to bushfires.⁴ However, we know little of the future health effects following many weeks to a few months of smoke exposure. Will any acute effects persist for months and years following the bushfires? Will people exposed to 3 months of high levels of smoke have a higher incidence of cardio-respiratory disease later in life? A series of studies investigating the effects of a 6- to 7-week coal mine fire in Victoria, Australia, may provide some answers. Children aged less than 2 years at the time of the coal mine fires and who were followed up 3 years after the coal mine fire demonstrated increased arterial wall stiffness⁵ and increased respiratory system stiffness.⁶ The clinical significance of these small changes and whether they will

persist into later childhood and adulthood are yet to be determined. These are important questions to be answered.

The advice we gave the public to reduce their risk centered around reducing smoke exposure by staying indoors, ensuring the home is well sealed to reduce infiltration of smoke, using air purifiers with high-efficiency particulate air filters at home, and minimizing vigorous physical activity outdoors. Such advice might be suitable for fire smoke episodes that last a few days, but what advice should we give when the smoke persists for weeks and months? How long to stay indoors? At what concentrations of fine particles is there a trade-off between adverse health effects from smoke and health benefits from outdoor physical activity? Is there an easy way to assess how leaky a house is? Can air conditioners significantly reduce air pollutants inside the house? How effective are face masks? At what fine particle levels should schools cancel outdoor sporting activities? Similarly, what advice can we give to outdoor workers regarding the types of face masks that they should be using and when they should stop outdoor work altogether?

The answers are complex. Staying indoors may not afford complete protection. Reissen et al.⁷ showed that staying indoors during a planned burn provided

a variable reduction in indoor smoke levels (from 12% to 76%), and it depended on the age of the house and ventilation. Increasing walking and cycling have shown health benefits despite exposure to background urban air pollution.⁸ However, what is not clear is whether the same health benefits accrue on smoky days? Tainio et al.⁹ suggest that for 30 min of cycling, the risk from air pollution starts to outweigh the benefits at a PM_{2.5} concentration of 160 µg/m³, and for 30 min of walking, the risks outweighed the benefits at a PM_{2.5} concentration of 200 µg/m³. Wearing a face mask while outdoors may not be a solution either. Well-fitted P2 or N95 masks will reduce fine particle exposure and are appropriate for outdoor workers and firefighters. Cloth/medical masks, however, do not filter out the fine particles nor the toxic gasses. Even masks claiming to be certified to local or international standards for PM_{2.5} do not offer complete protection.¹⁰ People wearing such masks may stay outdoors for unnecessarily long periods and inadvertently increase their exposure to air pollutants. Air purifiers with HEPA filters are highly effective, but the effectiveness is highly dependent on how well sealed the indoor space is and whether the flow rate of the purifier is appropriate for the size of the space.

How do we advise the public on their risk of the serious but rare health outcomes associated with exposure to air pollution such as death? We think that the risks to the healthy individual from fire smoke are generally low except for those people (for example, firefighters) who are in the frontline. In a study of short-term exposure to bushfires and mortality conducted in Sydney, the risk for non-accidental mortality was increased by 5% on a bushfire day.¹¹ In New South Wales, 80-year-old men have an annual mortality rate of around 4.7% (<https://www.abs.gov.au/ausstats/abs@.nsf/mf/3302.0.55.001>). This equates to a daily risk of death of 1.29 per 10,000. On a bushfire day, this risk increases by 5% to 1.35 per 10,000, an absolute increase of 6 per million, which is a very small additional risk. Therefore, while we often talk in terms of relative risk, the absolute risk may be more helpful for the public to understand. How-

ever, if we do experience more frequent and more intense bushfires in the future under climate change conditions, the risks to health will also increase.

We identified several gaps in knowledge that limit our ability to give accurate, timely, and more importantly, meaningful advice to the public, government, and the media. We need better evidence regarding the advice we give on personal measures to reduce exposure to smoke. We do not know enough about future health effects due to exposure to bushfire smoke over weeks and months, and this is an area for urgent further research. Of particular concern is the limited information around the effects of smoke on pregnant women, the fetus, and the newborn. Pregnant women exposed to the Hazelwood coal mine fires in Australia had a higher risk of gestational diabetes.¹² This is particularly salient as insults in the perinatal period can have lifelong consequences.¹³

Many factors influence fire behavior, for example, the nature and availability of biomass and meteorological conditions. Climate change will increase extreme events such as drought and heatwaves, which will increase the risk of bushfires.¹⁴ Increasing bushfires will, in turn, increase carbon emissions and exacerbate climate change. There is no silver bullet to this conundrum. Hand in hand with ambitious climate mitigation strategies, we have also called for the urgent establishment of a national health protection strategy to future proof the health of our communities and our ecosystems.¹⁵

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