Understanding and managing the health impacts of poor air quality from landscape fires

Australians need to get better at dealing with episodic smoke events

Landscape fires are increasing in frequency and severity, and their associated smoke emissions, both gaseous and aerosolised, have major implications for global warming, rainfall distribution and human health.[1] Globally, about 340 000 deaths each year are estimated to be attributable to landscape fire smoke.[2] While much of the burden falls on poorer regions of the world affected by tropical deforestation and savannah fires, landscape fire smoke regularly affects temperate regions and, under climate change, the impact on the population is projected to increase substantially.[3] Australia's highly flammable fire-adapted biota makes landscape fire smoke an unavoidable and increasingly important environmental exposure. To reduce bushfire risk in Australia, an accepted land management practice is deliberate burning to reduce fuel loads and, hence, the fire hazard.[4] Such prescribed burning is usually limited to calm meteorological conditions when fires can be more easily contained, but smoke dispersal is often less effective. Lighting multiple fires under these conditions may cause severe pollution episodes, as experienced in Sydney in May 2016.[4] In sum, smoke exposure from both uncontrolled and prescribed fires is a fact of life in Australia, so understanding the health consequences and mitigation strategies is essential for community members and their health providers alike. The evidence base for fire smoke pathophysiology, epidemiology and public health interventions has expanded considerably over the past decade, and the key points are summarised in this article.

Pathophysiology and health impacts

Landscape fire smoke is produced by the incomplete combustion of organic material, including plants and organic soils. Similar to tobacco smoke, it contains thousands of chemical species, many of which have adverse health effects.[5] Despite the complexity of smoke toxicology, most studies have focused on the concentration of suspended particulate matter (PM) as a marker for the entire smoke mixture and, at this stage, there is insufficient evidence to characterise the potential role of gaseous copollutants. The short term health effects are generally similar to that of PM from other sources, such as emissions from industry and transport.[5] PM, regardless of its source, drives a range of pathophysiological responses, including the promotion of pulmonary and systemic inflammation, coagulation, oxidative stress, reduced endothelial function and reduced autonomic reactivity.[6] Many of these have also been described for PM from landscape fire smoke, although the smoke-specific evidence base is much smaller.[5] Inflammatory and other immunological changes in the lungs drive the respiratory impacts. Respiratory conditions, especially asthma, worsen with increasing concentrations of smoke-derived PM even at relatively low concentrations.[5,7] For example, in an Australian cohort study of people with asthma, the commencement of oral steroids doubled with each 10 μg/m^3 increase in particles of less than 2.5 μm diameter ($PM_{2.5}$) derived from bushfire smoke.[7] Similar sized increments in fire smoke PM have been associated with 6% increases in same-day salbutamol dispensations and in general practitioner visits for asthma in Canada, and with 5% increases in both asthma emergency department (ED) visits and hospital admissions in Australia.[5] In a population the size of Sydney where, on average, bushfire smoke episodes cause the mean city-wide $PM_{2.5}$ to increase by 35 μg/m^3,[8] these modest increases may translate into hundreds of additional GP visits and pharmacy sales of salbutamol and tens of additional ED presentations or hospital admissions for asthma on a single smoke-affected day.[5,7]

While the pro-inflammatory properties of PM and other constituents of smoke may rapidly induce symptoms in people with existing lung diseases, subtle smoke-induced changes in systemic inflammation, coagulation or autonomic function — important contributors to cardiovascular disease — are generally asymptomatic. The first cardiovascular symptoms may only manifest when these responses precipitate a serious event such as cardiac arrest or acute coronary syndrome in a person already at high risk.[5,6] For example, Australian studies have shown that an increase of 9 μg/m^3 of $PM_{2.5}$ as a 2-day average was associated with a 7% increase in risk of out-of-hospital cardiac arrests and with a 2% increase in both ED attendances and hospital admissions for ischaemic heart disease.[9] Many large studies of wildfire smoke PM have identified associations with mortality of similar magnitude to the better characterised short term mortality increases associated with urban PM.[5,10] In Sydney, for instance, days affected by bushfire smoke

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episodes causing an average $PM_{2.5}$ increase of 35 $\mu g/m^3$ were associated with a 5% increase in mortality or three additional premature deaths.[5]

Strategies for mitigating health impacts

Approaches for reducing the health impacts from bushfire smoke events include:

- clinical strategies for preventing or managing exacerbations of illnesses;
- individual actions to reduce smoke exposure;
- interventions to reduce population level exposure; and
- timely public communication.

The health impacts of air pollution are tied to the prevalence risk factors in the population, such as cardiovascular and lung diseases, older or younger (including prenatal) age groups and lower socio-economic background.[5] The need for intervention will depend on individual and population level vulnerability and the likely severity and duration of the smoke events. The risk of severe adverse events, such as death, is very low unless large populations are affected by smoke or the episode is unusually prolonged or severe. However, increased respiratory morbidity is common. Given that one in nine Australians report having asthma and one in 20 aged over 45 years report chronic obstructive pulmonary disease,[11] respiratory impacts from smoke are important for all affected communities regardless of their size.

Clinical strategies

The primary example of a clinical strategy is for people with asthma, for whom smoke is a known trigger, to commence using an asthma preventer before the smoke impacts, or to use a preventer continuously during a period when frequent prescribed burns are likely to affect local air quality. This is an individual management decision best made in consultation with a GP or as part of an asthma management plan. People with other chronic respiratory diseases should also have a plan for preventing or managing increased symptoms during smoky episodes.

Individual action to reduce exposure

Several strategies are routinely recommended for individual action to reduce personal exposure. These include remaining indoors with closed doors and windows, using portable air cleaning devices in the home, reducing physical activity, using a face mask, or moving to a location with cleaner air.[12] Of these, the only approach that has good quality evidence to support exposure reduction and improved health outcomes is the use of portable air cleaners to create a clean air shelter in a room within the home.[12] However, the cost of about \$200–300 is a barrier to many people, and it is crucial to buy the correct device. High efficiency particulate air filters and electrostatic cleaners are both effective for this purpose, whereas many other devices marketed as "air purifiers" are not. Closing doors and windows and staying inside may be helpful if action is taken before the smoke impacts. However, many older Australian houses are not well sealed, thus indoor and outdoor PM concentrations will eventually equilibrate.[13]

Interventions to reduce population level exposure

Interventions to reduce the exposure of populations predominantly lie in the realm of land and fire management agencies. Whether systematic prescribed burning positively or negatively affects long term population smoke exposure is a complex question beyond the scope of this article.[4] Nevertheless, there are several possible ways to modify fuel management practices to reduce adverse events from smoke exposure while maintaining the benefits of mitigating the bushfire hazard; for example, the strategic use of landscape interventions such as clearing, mechanical thinning or grazing to reduce fuel loads in areas close to communities.[14] An upper limit for prescribed burn smoke impacts (such as Australia's air quality standard for $PM_{2.5}$), associated with a temporary stopping rule for igniting additional fires until air quality improves, is a simple and effective strategy currently used in Tasmania.

Improving public communication

People in higher risk groups due to older or younger age, asthma or other chronic conditions collectively comprise a substantial proportion of our population. Advance notification that smoke from planned fires may affect them is important because many mitigation strategies require preemptive action. If the predicted footprint of smoke affects a major population such as a capital city, the communication task will be substantial. Organisations responsible for lighting prescribed fires should work together with public health agencies to ensure timely risk communication and mitigation. For uncontrolled fires, prior notification is often not possible. However, smartphone applications that provide near real-time, location-specific information about air quality and airborne allergens, with automatic notifications of changed conditions, are increasingly available.[15] These have been associated with behaviour change to support improved self-management and health protection in people with asthma and may potentially be used for other air quality hazards, such as thunderstorm asthma events.[15]

Conclusion

Exposure to smoke is inevitable for Australians. Citizens, health care providers and land managers need to work together to manage the risks through better uptake of existing evidenced-based strategies, including portable air cleaners and provision of timely information to affected populations. However, further research is required to evaluate medical and public health interventions, and to better characterise the health and fire risk trade-offs associated with managing the fuel loads of an inherently flammable country.

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References are available online at www.mja.com.au.

1 Bowman DMJS, Balch JK, Artaxo P, et al. Fire in the Earth system. *Science* 2009; 324: 481-484.

2 Johnston FH, Henderson SB, Chen Y, et al. Estimated global mortality attributable to smoke from landscape fires. *Environ Health Perspect* 2012; 120: 659-701.

3 Liu JC, Mickley LJ, Sulprizio MP, et al. Particulate air pollution from wildfires in the Western US under climate change. *Clim Change* 2016; 138: 655-666.

4 Williamson GJ, Bowman DMJS, Price O, et al. A transdisciplinary approach to understanding the health effects of wildfire and prescribed fire smoke regimes. *Environ Res Lett* 2016; 11: 125009.

5 Reid CE, Brauer M, Johnston FH, et al. Critical review of health impacts of wildfire smoke exposure. *Environ Health Perspect* 2016; 142: 1334-1343.

6 Newby DE, Mannucci PM, Tell GS, et al. Expert position paper on air pollution and cardiovascular disease. *Eur Heart J* 2015; 36: 83-93.

7 Johnston FH, Webby RJ, Pilotto L, et al. Vegetation fires, particulate air pollution and asthma: a panel study in the Australian monsoon tropics. *Int J Environ Health Res* 2006; 16: 391-404.

8 Johnston FH, Hanigan IC, Henderson SB, et al. Creating an integrated historical record of extreme particulate air pollution events in Australian cities from 1994 to 2007. *J Air Waste Manag Assoc* 2011; 61: 390-398.

9 Haikerwal A, Akram M, Monaco A, et al. Impact of fine particulate matter ($PM_{2.5}$) exposure during wildfires on cardiovascular health outcomes. *J Am Heart Assoc* 2015; 4: e001653.

10 Atkinson R, Kang S, Anderson H, et al. Epidemiological time series studies of $PM_{2.5}$ and daily mortality and hospital admissions: a systematic review and meta-analysis. *Thorax* 2014; 69: 660-665.

11 Australian Centre for Asthma Monitoring, Woolcock Institute of Medical Research. Asthma in Australia 2011: with a focus chapter on chronic obstructive pulmonary disease (AIHW Cat. No. ACM 22; Asthma Series No. 4). Canberra: AIHW; 2011.

12 Elliott CT. Guidance for BC public health decision makers during wildfire smoke events. Vancouver: Environmental Health Services, BC Centre for Disease Control; 2014.

13 Morawska L, He C, Hitchins J, et al. The relationship between indoor and outdoor airborne particles in the residential environment. *Atmos Environ* 2001; 35: 3463-3473.

14 Schwilk DW, Keeley JE, Knapp EE, et al. The National Fire and Fire Surrogate study: effects of fuel reduction methods on forest vegetation structure and fuels. *Ecol Appl* 2009; 19: 285-304.

15 Campbell S, Cooling N, Wheeler A, et al, editors. AirRater: early user evaluation of an innovative and unique air quality app in Tasmania. Proceedings of the 2016 Climate Adaptation Conference on Change, Challenge, Opportunity; Adelaide (Australia), 5–7 July 2016. Gold Coast: National Climate Change Adaptation Research Facility; 2016. ■