CENTRE OF EXCELLENCE IN
SEVERE ASTHMA
Innovative solutions for severe asthma

Version 1

2023

CLINICAL MANAGEMENT OF ASTHMA DURING BUSHFIRE SMOKE PERIODS

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1. KEY FACTS

- Globally, 4.2 million premature deaths occur every year because of exposure to outdoor air pollution, and 2.3 million deaths are attributable to exposure to household (indoor) air pollution. On average approximately 10% of premature deaths are attributable to smoke from landscape fires (including bushfires) (1).
- Bushfire smoke is a key component of outdoor air pollution along with climate change (2).
- Bushfires have always been integral to Australian landscapes and the associated pollution is often an inevitable environmental health hazard (3).
- People with asthma are more vulnerable to the health impact of bushfire smoke exposure compared to general populations (4, 5). Exposure to bushfire related fine particulate matter ($PM_{2.5}$) is associated with an increased risk of hospital admissions, medication use and emergency visits for asthma (6, 7). Exposure to landscape fire smoke also increases the risk of respiratory mortality including asthma (8).
- People with asthma were more likely to report respiratory and non-respiratory symptoms during the 2019/20 bushfire smoke period than after the bushfire period (9).
- Women, including pregnant and breastfeeding women with asthma were more likely to report anxiety during the bushfire period than following the bushfire period (10).
- There is no '**safe**' level of air pollution (11).

2. INTRODUCTION

Severe air pollution resulting from landscape fires (including prescribed fires and uncontrolled wildfires, tropical deforestation fires, peat fires, agricultural burning, and grass fires) has become an escalating environmental threat to human health along with climate change (2, 12). Large, vegetated areas of the Australian continent burn every year, and episodic severe bushfire disasters have been documented since European colonisation. However, in context of climate change, more extreme and highly polluting fires are becoming more common, and the duration of fire seasons is lengthening (13).

Bushfires have always been integral to Australian landscapes (3). The escalation in severe bushfires was illustrated during the Australian 'Black Summer' of 2019-20 (14, 15). This bushfire period was unprecedented in relation to the geographical scale of the fire, and its severity and duration (14, 15). More than 10 million Australians were exposed to bushfire smoke for periods ranging from weeks to months (13, 14). Bushfire smoke has an adverse effect on human health (4, 8-10, 14). Pregnant and breastfeeding women and their children, people with pre-existing medical conditions (especially respiratory and cardiovascular conditions), indigenous Australians, and older population are particularly vulnerable to the health risks associated with bushfire smoke (5, 16). One in nine (11%) Australians have asthma (17) hence, a large proportion of the population are particularly vulnerable to bushfire smoke. A longitudinal study of effect of bushfire smoke exposure on lung function showed that prolonged exposure to bushfire smoke was associated with a significant reduction in lung function (18).

The purpose of this document is to provide information for health care providers to advise people with asthma during the bushfire smoke period.

3. WORLD HEALTH ORGANIZATION (WHO) AND AUSTRALIAN AIR QUALITY GUIDELINES

There are two air quality standards that are used to describe/quantify particulate matter (PM) air pollutants (i.e., $PM_{2.5}$ and PM_{10}) and these apply to $PM_{2.5}$, regardless of its source: **a 24-hour standard** and an **annual standard**. The 24-hour standard is intended to protect the public from short-term exposure and the annual standard is intended to protect the public from long-term exposure (Table 1). There is no safe level of air pollution, the adverse health effects are observed at all levels of air pollution, including those below the current WHO annual standard and Australian standards (11, 19). The purpose of the WHO and Australian guidelines is to place continual downward pressure on emissions but not to imply that concentrations below the thresholds are safe.

Table 1: The WHO and Australian air quality guidelines for particulate matter

Pollutant	Averaging time	WHO Air quality guidelines	Australian Air Quality Guidelines
$PM_{2.5}$ (µg/m³)	Daily (24 hour)	15	25
	Annual	5	8
PM_{10} (µg/m³)	Daily (24 hour)	45	50
	Annual	15	25

Source: Australian Government Federal Register of Legislation, National Environment Protection (Ambient Air Quality) Measure. Available at: https://www.legislation.gov.au/Details/F2016C00215 ; WHO. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. Retrieved from https://apps.who.int/iris/handle/10665/345329

Figure 1 shows the population weighted mean $PM_{2.5}$ for Sydney greater metropolitan region during period of extreme bushfire smoke from 1 October 2019 to 29 February 2020. The peak daily average $PM_{2.5}$ exposure concentration during this period was 87.6 µg/m³ on 5 December 2019, exceeding the national air quality 24-hour standard (25 µg/m³) and the WHO air quality 24-hour guidelines (15 µg/m³) by 4 and 6 times, respectively. On approximately 35% of days during this period, the $PM_{2.5}$ concentration during the fire period exceeded the WHO guidelines air quality 24-hour standard (Figure 1).

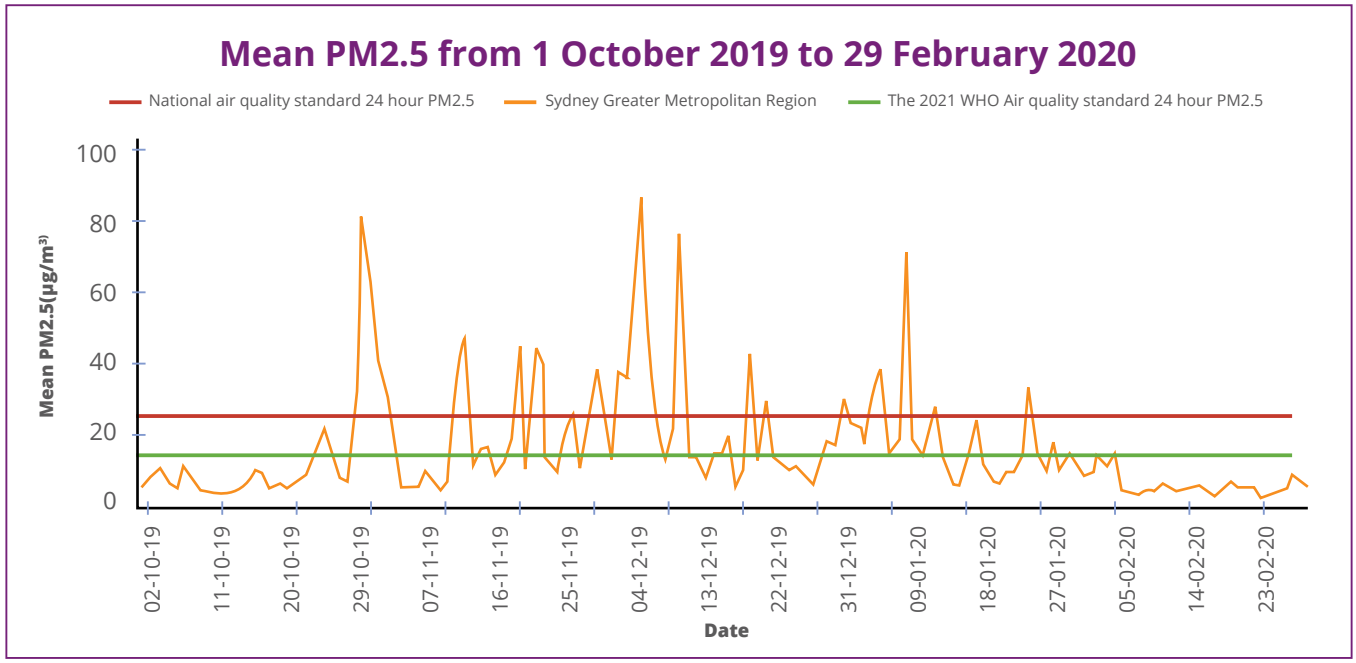


Figure 1: Population weighted mean daily $PM_{2.5}$ concentration in the Sydney Greater Metropolitan Region, 1 October 2019 to 29 February 2020.

Table 2: Types of fire and their definitions

Name	Definitions
Landscape fire	Comprise several different types including bushfires (also known as wildfires, forest fires and wildland fires), cultural burns, prescribed fires, tropical deforestation fires, agricultural burning, grass fires, and ground fires due to burning peat or coal deposits (12)
Bushfire	Is an unplanned or unwanted and uncontrolled vegetation fire. This term is used in Australia. Equivalent terms used in other parts of the world include wildfire, wildland fire and forest fire.
Agricultural burning	Refers to any open-air burning of biomass that is driven by agriculture or silviculture. Examples include the burning of sugar cane, stubble in agriculture, and the burning of forest residues in forestry.
Peat fires	Combustion of dried peat soils Peat fires burn at relatively lower temperatures and are associated with smouldering and less complete combustion leading to much greater smoke production than high intensity flaming combustion. Peat fire related PM2.5 has been associated with a similar spectrum of health impacts to bushfire smoke including premature death, respiratory and cardiovascular mortality, and lung cancer (20).
Prescribed burning /planned burning	is the purposeful application of fire to reduce or modify fuel loads for wildfire/ bushfire risk reduction purposes (21).

4. WHAT IS IN BUSHFIRE SMOKE?

- Bushfire smoke is made up of a complex mixture of hundreds of individual compounds including PM, carbon dioxide, water vapor, carbon monoxide, aldehydes, polycyclic aromatic hydrocarbons (PAHs) and other organic chemicals, nitrogen oxides and trace elements (figure 2) (22-24).
- PM is a complex mixture of solid and liquid particles and is classified according to size:
  - **PM_{10}** – refers to particles with an aerodynamic diameter of 10 micrometres or smaller. These contribute to visible smoke haze or dust and can irritate eyes, nose, and throat. Once these particles get into the lungs, they further irritate the lung tissue and can trigger asthma attacks. Note that PM_{10} includes $PM_{2.5}$.
  - **$PM_{2.5}$** – refers to particles with an aerodynamic diameter of 2.5 micrometres or smaller.
  - These can reach the gas exchange regions of the lungs, which induces oxidative stress and inflammation locally (25), and may even get into the bloodstream impairing vital organ function (26, 27).
- While all pollution in the air from bushfire smoke has the potential to cause a range of health effects, there is evidence that $PM_{2.5}$ pollution poses the greatest health risk at the population level and is also a good indicator of the mix of fire smoke pollutants (7, 22).
- $PM_{2.5}$ in bushfire smoke adversely impacts human health. There is growing evidence that short term respiratory outcomes including asthma symptoms and attacks are greater from bushfire related $PM_{2.5}$ compared to $PM_{2.5}$ from other sources (7, 28). Toxicological studies suggest that bushfire smoke PM may be more toxic to the lungs than equal doses of ambient $PM_{2.5}$ (29, 30).

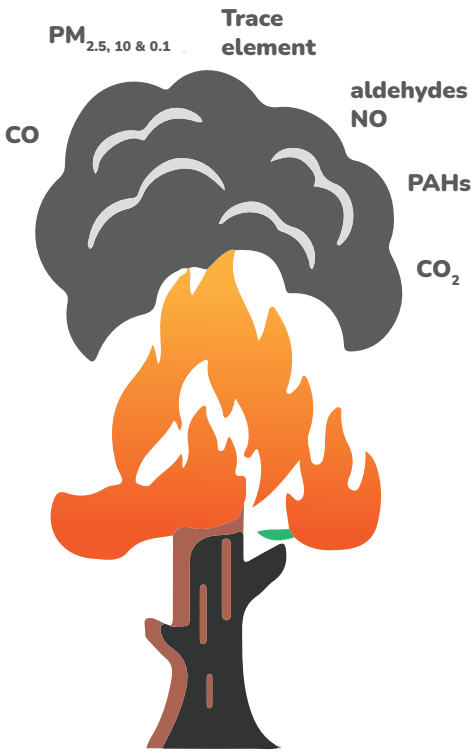


Figure 2: Elements found in bushfire smoke

5. IMPACT OF BUSHFIRE SMOKE ON PEOPLE WITH ASTHMA

- $PM_{2.5}$ due to the 2019/2020 Australian Black Summer bushfire was associated with 429 smoke-related premature deaths, 3,230 hospital admissions for cardiovascular and respiratory disorders and 1,523 emergency attendances for asthma (14).

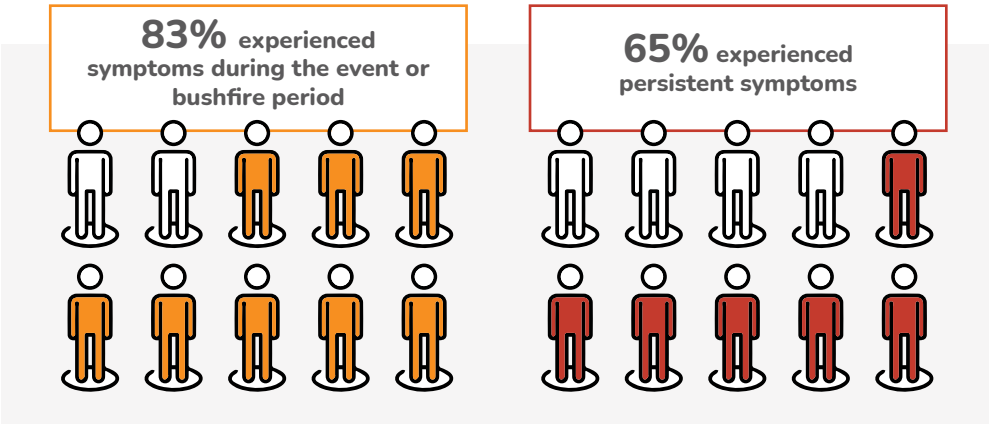


Figure 3: Proportion of people with asthma who reported symptoms during the 2019/2020 Black Summer (9).

- During the bushfire period, people with asthma reported more respiratory symptoms, health care service utilisation and financial burden than those without asthma (4).
- Prolonged bushfire smoke exposure increases symptoms in people with asthma (82.9%) (9) (Figure 3). The most common symptoms being breathlessness (57.1%), wheeze or whistling chest (53.3%), cough (50.0%) and throat irritation/dry throat (45%) (figure 4). Two thirds (65.0%) of people with asthma experienced persistent symptoms months even after the fire period (figure 3). Breathlessness (44.6%), cough (39.2%) and wheeze or whistling chest (38.8%) were most prevalent among persistent symptoms.

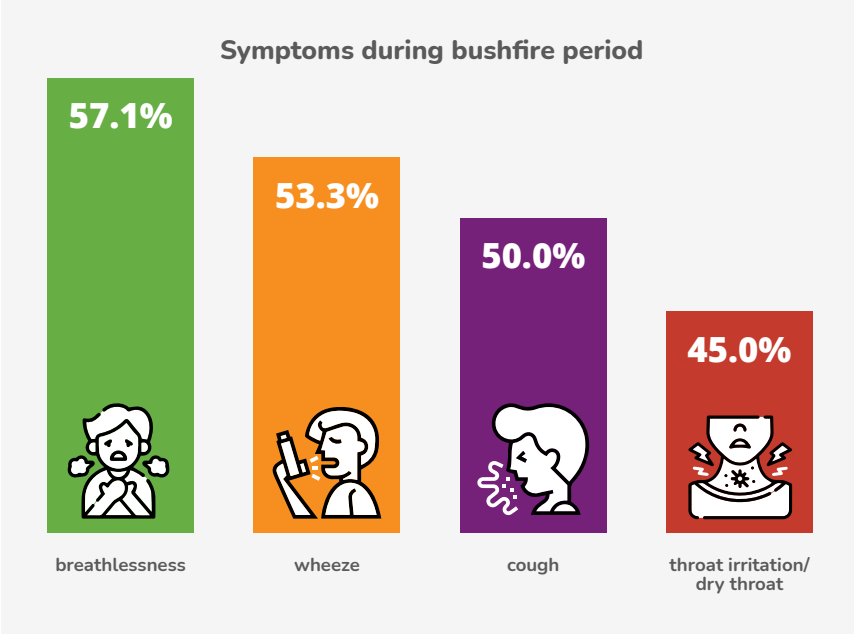
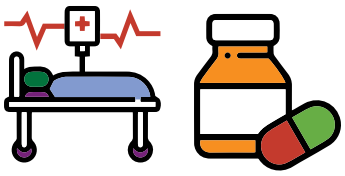


Figure 4: Self-reported symptoms during the bushfire period in people with asthma

- Prolonged exposure to bushfire smoke reduces participation in daily activities and results in people taking time off work (9, 31). These data indicate that sustained exposure to bushfire smoke affect quality of life.
- Anxiety and depression symptoms are common during bushfire smoke periods (10, 31-33). These might be because of being unable to spend time outdoors, difficulty breathing, persistent fire and financial strain (31). The psychological health effect of direct threats from bushfires can continue for years following the event (34).

- Bushfire related $PM_{2.5}$ and PM_{10} is associated with an increased risk of asthma symptoms, medication use, hospital admission, unscheduled doctor visits and emergency attendance for asthma (7, 35-40).



- Pregnant women are more vulnerable to the impacts of bushfire smoke exposure than others due to changes during pregnancy, such as 20% increase in oxygen consumption, 40% increase in volume of air inhaled or exhaled, 50% increase in cardiac output, change in immune function and increased insulin resistance (41) (Figure 5). Exposure to bushfire smoke during pregnancy increases the risk of adverse pregnancy outcomes such as low birth weight, preterm birth, gestational diabetes, hypertension, and child mortality (42-45).

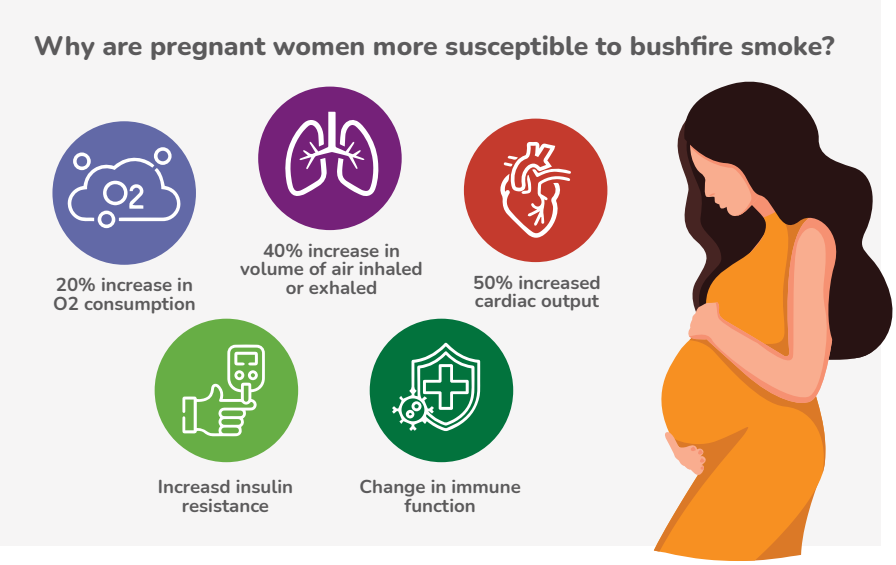


Figure 5: Pregnant women are vulnerable to bushfire smoke

6. MANAGEMENT OF ASTHMA DURING BUSHFIRE PERIODS

Health care professionals need clear, high quality and evidence based information in order to support their patients who are vulnerable to the impacts of bushfire smoke (46). There are a few evidence-based tools on how to advise people to manage their asthma during bushfire smoke exposure (3, 5, 47, 48). Health care providers require up-to-date and evidence-based information about smoke mitigation strategies and asthma management in order to effectively support patients and families (Centre of Excellence in Severe Asthma, and Environmental Health Standing Committee (enHealth) (49). Health care providers also need to be aware of the effect of exposure to bushfire smoke on vulnerable populations, particularly people with asthma, and those most vulnerable within the cohort of people with asthma.

6.1 WRITTEN ASTHMA ACTION PLANS

When coupled with asthma self-management education and regular review, Written Asthma Action Plans are an effective strategy for self-management of acute asthma attacks (50). Ensuring patients have an up-to-date written asthma action plan prior to and during the bushfire smoke period is recommended. Specific asthma action plans alert patients to escalating symptoms and provide clear directions on what to do in response.

Ensuring patients understand the action plan, accept the recommendations, know how to follow them, and have access to the treatment recommendations included in the action plan are essential requirements. Patients should be encouraged to seek immediate medical advice if experiencing persistent symptoms such as prolonged coughing or wheezing, shortness of breath and throat irritation, especially if use of short acting beta2 agonists do not result in improvement of symptoms. Written action plans should also include recommendations for how to manage asthma during a crisis. This is particularly important during bushfire smoke exposure. An example template from Asthma Australia is included in Figure 6 and can be downloaded (https://asthma.org.au/treatment-diagnosis/asthma-action-plan/).

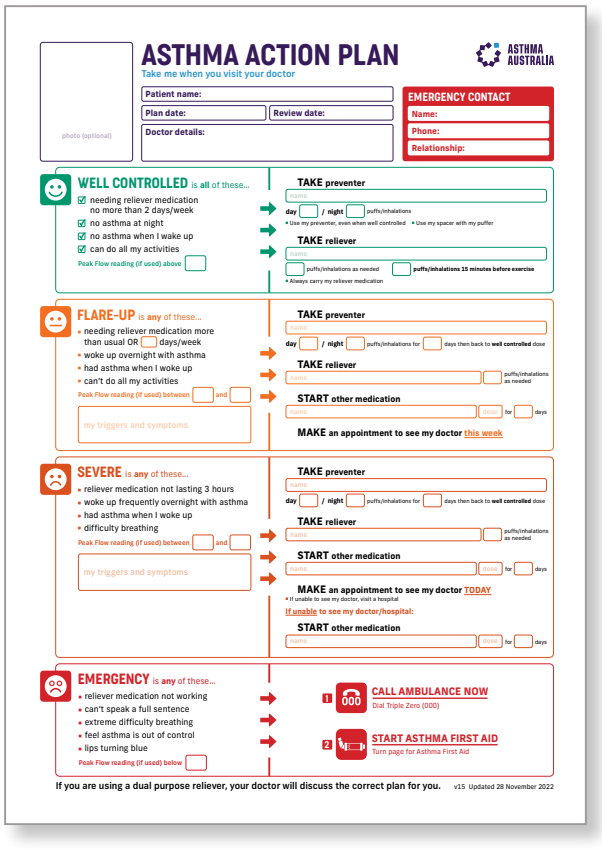


Figure 6: Asthma action plan

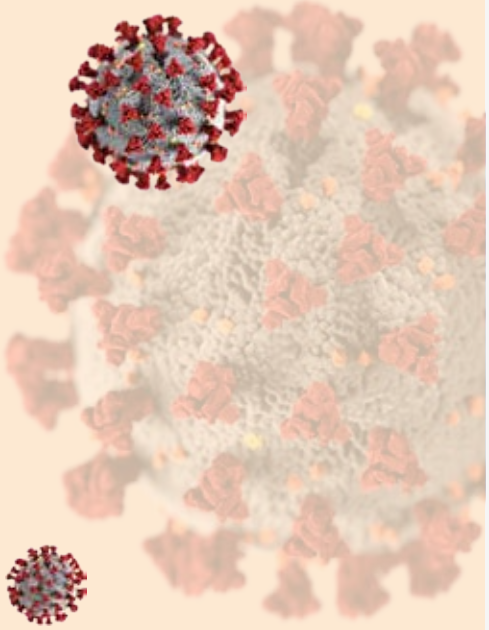
SYMPTOMS FROM BUSHFIRE SMOKE EXPOSURE AND COVID-19

During the COVID-19 pandemic, it has been important for patients to differentiate between symptoms of COVID-19 and those of asthma and bushfire related triggers. For example, difficulty in breathing and coughing can happen with both conditions. However, other symptoms of COVID-19 including fever, loss of taste or smell, diarrhoea/vomiting, muscle/joint pain, and fatigue are not associated with asthma.

For further information on asthma action plans consult: https://toolkit.severeasthma.org.au/management/written-action-plans/ ; https://asthma.org.au/wp-content/uploads/2021/12/AAAAP2022-Asthma-Action-Plan-A4_v8_Toolkit_editable.pdf

Covid symptoms

- Cough
- Sneezing
- Runny nose/ congestion
- Shortness of breath
- Headache
- Itchy/burning eyes
- Sore throat
- Fatigue
- Fever
- Diarrhoea/ vomiting
- Temporary loss of smell/altered sense of taste
- Nausea/loss of appetite
- Muscle/joint pains



Symptoms of bushfire smoke irritation

- Cough
- Sneezing
- Runny nose
- Shortness of breath
- Headache
- Itchy/burning eyes
- Throat irritation
- Chest tightness/ pain
- Wheeze

DIGITAL TECHNOLOGY SUPPORT

There are also digital asthma action plans (Asthma Buddy or KISS MYASTHMA) available for people with asthma in Australia to monitor their asthma symptoms and store action plans. These apps will help people with asthma to identify if their asthma is getting worse and provide guidance on what they should do in response. It is important that patients understand how to use the apps.

6.2 ASTHMA CONTROL

Good asthma control helps mitigate the risk of having an asthma attack which may be triggered by bushfire smoke (31). Therefore, it is important to work in partnership with patients to assess and optimise asthma control. Patients should understand their asthma triggers and how to respond to exposure and symptoms. Asthma control includes both the patient's symptoms and the future risk of adverse asthma outcomes (e.g future attacks and treatment-related adverse events) (51). Good asthma control means asthma symptoms occur less than twice a week, there are no nocturnal symptoms due to asthma, and they experience no activity limitation. It is also important to assess whether your patient is at risk of attacks and treat these with inhaled preventer therapy accordingly.

For further information on asthma control consult: https://asthma.org.au/about-asthma/understanding-asthma/asthma-control-test/

6.3 MEDICATION

Adherence to asthma preventer medication reduces the risk of asthma attacks (52, 53). A study in Australia showed that exposure to low levels of particulate matter ($PM_{2.5}$ and PM_{10}) emitted from bushfires was significantly associated with increased medication use for asthma (39). Furthermore, a study in Canada showed that small communities exhausted their supplies of salbutamol puffers during serious smoke events (40). Adherence to inhaled preventer therapy during periods of poor air quality is particularly important. There are studies which report non- adherence to asthma medications among pregnant women with asthma (56, 57). Adherence to asthma medication should be assessed at each health care professional contact. Methods of adherence assessment may include patient self-report, pill counts, adherence questionnaires, electronic monitoring, and provider prediction of adherence.

Patients should also be prepared in the lead up to the bushfire period. Encourage patients to have a 30-day medication supply. Ensure that patients have continued access to medication during and after the bushfire prone period. People with asthma should continue regular preventer medication as prescribed before the bushfire period. Furthermore, people with asthma who require oral corticosteroids should continue to take these as recommended and have them on hand if their written action plan indicates. Encourage your patient to keep spare medications during prescribed burn seasons in autumn and spring and throughout summer in case of extreme bushfire events. The health care provider needs to be aware of when prescribed burns occur in order to alert the patient regarding the prescribed burn.

Further information on prescribed burn can be found: https://knowledge.aidr.org.au/resources/national-burning-project-prescribed-burning-guidelines-and-frameworks/

6.4 RELIABLE INFORMATION SOURCES

People with asthma can get reliable information from their health care providers when health care providers know where to access accurate and consistent information regarding air pollution. The Bureau of Meteorology has links to each state and territory's air pollution data (http://www.bom.gov.au/catalogue/warnings/air-pollution.shtml). In addition, the AirRater app provides an Australia-wide service.

We recommend that people with asthma are informed of the local air quality and advised how to check and follow air quality advice and forecasts, if available. Encourage people with asthma to download the free Australian app AirRater to observe air quality in their local area. Ensure that they understand how to read the AirRater.

Air pollution ($PM_{2.5}$)	AirRater Category	What does the air look like?	What does this mean for me?
0 to 9	**Good**	Air quality is excellent, it's a clear day.	You can enjoy the outdoors.
10 to 24	**Fairly good**	The air quality has changed from usual background conditions. It might appear a little hazy on the horizon.	Brief, minor increases in air pollution rarely cause serious health problems. Keep an eye on conditions in case they are getting worse. If the smoke has been much worse and is now improving, this is a good time to open and air your house. If air quality remains in or above this category over a full year, it would exceed Australia's mean annual air quality standard for $PM_{2.5}$ of 8 µg/m^3.
25 to 49	**Fairly poor**	You can usually see or smell smoke when $PM_{2.5}$ is over 25.	The smoky air could worsen the health of people at higher risk from smoke. If this is you, consider taking action. For more information about what you can do, see 'What can I do when its smoky outside?' Air quality remaining in or above this category over a full day would exceed Australia's 24-hour air quality standard for $PM_{2.5}$ of 25 µg/m^3.
50 to 99	**Poor**	Smoke will be clearly visible in the air. Distant landmarks may not be visible.	People at higher risk from smoke should take action to manage any health conditions and reduce the amount of smoke they breathe. For more information about what you can do, see 'What can I do when its smoky outside?'
100 to 299	**Very poor**	It will be smoky and unpleasant. You will smell smoke strongly and may taste it.	Everyone needs to take action to reduce the smoke they breathe. For more information about what you can do, see 'What can I do when its smoky outside?'
300+	**Extremely poor**	Smoke will likely be thick and impair your vision.	Avoid breathing the smoke as much as possible. Stay at home if it's safe to do so, or in a shelter if you have been evacuated from a bushfire. Unless it is an emergency, it is not safe to drive in these conditions due to poor visibility.

Figure 7: AirRater category for $PM_{2.5}$

Please refer to these links for bushfires and asthma https://www.nationalasthma.org.au/living-with-asthma/resources/patients-carers/factsheets/bushfires-and-asthma, https://www.nationalasthma.org.au/news/2020/bushfire-season-and-your-asthma-patients.

6.5 SMOKE MITIGATION STRATEGIES

Ensure that patients receive clear and consistent information regarding the effectiveness, benefits, and drawbacks of different smoke mitigation strategies. There is an opportunity to mitigate the adverse effect of bushfire smoke exposure through effective public health communication (58). However, there is a lack of relevant information regarding the effectiveness of public health messaging during bushfires, particularly for vulnerable populations (59, 60). A study of the 2019/2020 Black Summer fire period in Australia has shown that scarcity of relevant information and ineffective public health messaging were the main factors that limited the ability of people, including people with asthma, to avoid exposure to bushfire smoke (31). Given the paucity of information regarding public health messaging for people with asthma, it is imperative to develop consistent advice to protect the health of people with asthma.

There are a few guidelines about bushfire smoke mitigation strategies in Australia: https://www.health.nsw.gov.au/environment/air/Pages/bushfire-protection.aspx; https://www.epa.vic.gov.au/for-community/environmental-information/air-quality/smoke/smoke-your-health; https://www.car-cre.org.au/factsheets.

Table 3 shows some personal smoke mitigation strategies that can be implemented during episodes of high air pollution including bushfire smoke events.

Table 3: Personal smoke mitigation strategies during air pollutions including bushfire smoke

Personal smoke mitigation strategies	Benefits	Disadvantages
Staying indoors and avoid other sources of indoor air pollutions	Effective in minimising exposure to particulate matter in well-sealed or airtight house with air conditioning, air purifiers with a high efficiency particle air (HEPA) filter and non-indoor pollution sources (49, 61).	The level of protection depends on the airtightness and ventilation (62). Low ventilation and overheating may result in high indoor carbon dioxide and temperature (5). Impractical over extended periods of time (5, 63).
Face masks (P2/ N95)	P2/N95 masks that fit properly and used correctly can be effective protection from particulate matter exposure (64, 65).	Uncomfortable to wear over prolonged period (5). Wearing a face mask may lead to a false sense of security where people may increase outdoor activities assuming that masks are fully protective (66). Adequate fit may not be possible for people with certain face shape and facial hair (64). Face masks may cause discomfort and breathing resistance, particularly for people with respiratory problems.
Avoiding strenuous activities or exercising outdoors	Effective in reducing individual exposure to air pollutions including bushfire smoke (49)	Impractical for long periods It may increase the risk of other health problems such as cardiovascular disease and mental problems (61).
Portable air cleaners (air purifiers)	HEPA filter lower indoor particulate matter exposures (68). The air purifier must be fitted to the size of the room and the room should be well sealed (49).	Less effective in less airtight houses (5) Costly
Awareness of the local smoke and air pollution alert	Effective to make informed decision to minimise personal exposure including seeking alternate low air pollution area or avoiding outdoor activities (49).	The information may not reach some vulnerable populations (e.g older people) (5).

Source: Adapted with permission from Vardoulakis S, Jalaludin BB, Morgan GG, Hanigan IC, Johnston FH. Bushfire smoke: urgent need for a national health protection strategy. Med J Aust. 2020; 212(8):349-353.e341.

6.5.1 STAY INDOORS

Evidence shows that older Australian homes can be leaky, and smoke can be trapped indoors, as a result, they provide the least protection during smoke events (62, 69). Well-sealed and air-conditioned indoor environments such as libraries, shopping centres, modern apartments, and offices (5) may provide relief from smoke pollution, when effective air filtration systems are in place.

Encourage people with asthma to stay indoors during the bushfire smoke periods to reduce the risk of exposure to bushfire smoke. If staying at home, people with asthma should close all windows and doors and use an air-conditioner if available. Staying indoors can be effective at minimising bushfire smoke exposure when the house/building has little air infiltration from outside. If doors and windows are open, the indoor air quality will become similar to that outside the house, and this can happen quickly. Moreover, advise people with asthma to turn off ventilation fans that pull in outdoor air. These can be turned on again when bushfire smoke clears.

Staying indoors can be unrealistic when severe smoke pollution persists over long periods (weeks to months) since it might result in other problems and the quality of indoor air might be affected during non-smoky days. Even the best sealed houses will equilibrate in a few days (5, 62). Keeping the windows closed can result in higher levels of indoor humidity, overheating, and $PM_{2.5}$ and CO_2 can increase due to lack of air circulation (ventilation) (5, 62). During prolonged and localised bushfire smoke periods, it is recommended that people with asthma relocate to a different area that has better air quality where possible, for example a library or shopping centre.

Advise people with asthma to reschedule outdoor work where possible during the bushfire smoke period. This might reduce the risk of exposure to bushfire smoke.

Other strategies that should be advised include staying hydrated and cool, to reduce the risk of heat stress which might pose a substantial health risk in addition to the risks of smoke exposure. In high heat conditions, windows and doors might need to be opened to allow cooling even if smoke enters the home.

Encourage people with asthma who do not have air conditioning at home to visit a large public building with air conditioning and good air filtration like libraries and shopping malls since staying inside with the windows closed may be dangerous in extremely hot weather.

We recommend people with asthma have sufficient food on hand to last for a few days to minimise going outdoors. However, foods stored for use during the bushfire smoke period should not need frying or grilling, as this can add particulates to indoor air.

During prolonged bushfire smoke periods, health care providers should offer telehealth for patient appointments unless face to face assessment is required, to reduce the need for travel to their appointments. During these assessments, ensure that patients are continuing to take their asthma medication as prescribed before the bushfire period and consider using video consultations to support telehealth and assessment of inhaler technique. Furthermore, ensure that they are familiar with their written asthma action plan.

6.5.2 MINIMISE OTHER SOURCES OF INDOOR AIR POLLUTION

Encourage patients to avoid indoor sources of air pollution like candles, and woodfires. Vacuums without filter, frying food, gas stoves and cigarettes should also be avoided. These sources can increase the levels of carbon monoxide, PAHs, and nitrogen oxide, which are potentially harmful to health. For example, only 10 minutes is required for the smoke of a cigarette in a closed room of 11.6 square meters to produce hazardous levels of $PM_{2.5}$ (160 µg/m^3) (24), which corresponds to an AirRater $PM_{2.5}$ category in the "Very Poor" range.

Advise people with asthma who wish to clean their home during and after bushfire smoke events to use damp mopping and dusting to ensure the particles are removed rather than made airborne. Encourage patients not to vacuum unless using a HEPA-filter equipped vacuum. Note that HEPA filters do not remove the gaseous chemicals that cause odours linked to bushfire smoke. Portable air cleaner with an activated charcoal prefilter should be used to remove gaseous chemicals that cause odours associated with bushfire smoke (24).

6.5.3 AIR CONDITIONING OR AIR PURIFIERS

HEPA filters can filter particles as small as 0.3 microns, which can include house dust mites in the indoor air (5, 70). This is the only intervention that has an evidence base supporting reduced particulates exposure and improved health outcomes (3, 71). We, therefore, recommend that people with asthma use a HEPA filter air purifier. People with asthma should ensure the HEPA filter air purifier is appropriately sized for the intended room and the room must be well sealed. The filters should be cleaned regularly and must be replaced every 12 to 18 months.

People with asthma should also be encouraged to use an air conditioner to stay cool during bushfire smoke events, if available. Household air conditioners are not made to filter out particles, but they may still help in improving air quality. Do not use an air conditioner that draws air in from outside. Thus, people with asthma should use air conditioners that contain filters that remove airborne particles, where possible or accessible. Make sure that the filter is clean enough to allow good airflow indoors.

Negative ion generators, humidifiers, and odour absorbers do not minimise the number of particles in the air during bushfire smoke events and are not recommended. They can make respiratory symptoms worse.

6.5.4 VEHICLES

Whilst we recommend against outdoor activities, we acknowledge that this is not always possible. People with asthma who are required to go outside should use car air conditioners and close windows and vents when they are inside a vehicle to avoid drawing smoky air into the car. They should take extra care because a vehicle's interior can become very hot very quickly to temperatures that may surpass the outdoor temperature and can result in heat stress.

6.5.5 AVOID EXERCISING OUTSIDE

Minimising outdoor physical activity reduces the amount of inhaled air pollutants and reduces adverse health risks during a bushfire smoke event (61, 67). During exercise, air intake may increase 10 to 20 times over resting level, and as a result, increased pollutants may enter the lower airways. Furthermore, people tend to inhale through their mouths during physical activity, which may bypass the natural filtering capacity of the nasal passages, and as a result, more pollutants enter the airways. We recommend that people with asthma should avoid outdoor exercise or strenuous physical activity during the bushfire smoke period. They should check AirRater before going outside to exercise. Encourage people with asthma to exercise at places and periods when air pollutants concentrations are lower, which might help to maintain the benefits of exercise, whilst minimising the health risks from exposure to air pollution (61). Advice to reduce physical exercise outdoors might be challenging over a longer period, due to the known health benefits from exercise. Encourage people with asthma to utilise in an air conditioned gym to reduce the risk of other chronic diseases (61). They should drink sufficient fluids to keep their respiratory membranes moist.

6.5.6 FACEMASKS

A laboratory study has indicated that face masks (P2/N95) are effective in protecting against smoke exposure (65). Furthermore, the use of P2/N95 facemasks can reduce respiratory hospitalisations attributable to bushfire smoke by 22% - 39% (65). Ensure the patient receives clear information regarding the effectiveness, benefits, and drawbacks of different types of face masks. A well-fitted P2/N95 facemask can help filter out over 94% of airborne particles greater than 0.3 microns in size. Face masks might be appropriate for those who cannot avoid being outdoors during periods of poor air quality. However, they must be fitted well and maintain a tight seal to be effective. People with asthma have reported discomfort and shortness of breath while wearing a face mask (72). We recommend that people with asthma should be taught how to use face masks during bushfire periods.

Please refer to this link for tips in face mask; https://asthma.org.au/blog/face-mask-coverings-tips-to-ease-into-wearing-one/

If patients are having difficulty breathing or experiencing other symptoms while wearing a facemask, they should remove it, seek a place with clear air and return to a comfortable pattern of breathing and try again.

P2/N95 masks should be removed and disposed of when they become moist or after about four hours of continuous use since the seal will not be as effective. People using a face mask should still practice diligence with other strategies where possible.

THE TECHNIQUE FOR FITTING P2/N95 FACE MASKS

1. Remove glasses and hats. Tie back long hair so it does not become tangled in the straps of the face mask
2. Put the mask on your face, ensuring the nose piece is at the top of the mask
3. Place the headband or ties over the head and at the base of the neck
4. Compress the mask against the face to ensure a seal across the bridge of the nose
5. Compress the mask to ensure a seal across the cheeks and the face; and
6. Conduct a fit check; check the seal of the mask by gently inhaling. If the mask is not drawn in towards the face, or air leaks around the face seal, readjust the mask and repeat the process or check for defects in the mask. If the mask still leaks you may need to try a different size or style of mask.

Please refer to this link for the technique for fitting P2/N95 face masks: https://www.health.nsw.gov.au/environment/factsheets/Pages/face-mask.aspx

Dust, cloth and surgical masks, handkerchiefs, bandanas, and tissues do not filter out particles related to bushfire smoke and should be avoided unless it is an emergency and nothing else is available.

7. ASTHMA, BUSHFIRE SMOKE EXPOSURE, AND WELLBEING

7.1 MENTAL HEALTH DURING BUSHFIRE PERIODS

Psychological factors can trigger asthma symptoms and influence medication adherence (73, 74). During a prolonged bushfire period, people with asthma may experience impacts on their mental health, including symptoms of anxiety and depression, contributed to by a reduction in physical activities, reduction in daily activities, increased time off work, reduction in social engagement, increased sickness, increased financial stress, loss of salary, missed appointments, absences from school, and isolation resulting from staying at home (9, 31). Therefore, it is necessary to recognise the possible adverse mental health effects of bushfire smoke exposure in people with asthma. These mental health effects might be short-lived or persist for many years after the bushfire period (31, 34). For people with asthma, breathing smoky air and reading or watching different media reports can create headline stress disorder. This can leave people feeling anxious and depressed.

After a natural disaster like a bushfire, people may feel sad, numb and mad (75, 76). These reactions are common in relation to stress. However, this becomes problematic when it interferes with daily activities or causes high anxiety (76). Therefore, it is important to communicate with patients with respect to coping mechanisms for stress during bushfire periods. Health care providers can encourage people with asthma to stay calm when they experience stress by taking deep and long breaths, which will assist them to feel calmer and prevent them from hyperventilating (76). It is best to breathe through the nose if possible.

Encourage people with asthma to do things that help them relax and enjoy when they feel anxious and distressed. Furthermore, encourage people with asthma to continue a healthy lifestyle such as eating well, exercising indoors, and sleeping well to reduce stress related to bushfire events.

For further information on anxiety and depression consult: https://toolkit.severeasthma.org.au/co-morbidities/extra-pulmonary/anxiety-depression/

Health care providers should encourage their patients to check in on their own wellbeing and access mental health and counselling services if needed during bushfire periods. Furthermore, health care providers can discuss with their patients, plans for controlling their asthma when they are feeling anxious and depressed during and after the bushfire period (77).

For more information on mental health please see: https://psychology.org.au/ , Beyond Blue, Lifeline, Black Dog, Head to Health

7.2 TIPS FOR MANAGING MENTAL HEALTH DURING THE BUSHFIRE PERIOD

7.2.1 MEDIA COVERAGE

- Access reliable information from government and health authorities during the bushfire period.
- Limit news and social media use as this may increase the risk of mental health issues.
- Limit activity on social media and discuss something else.

7.2.2 MAINTAIN CONNECTIONS

- Studies have shown that people with limited social connectedness have poorer physical and mental health (78, 79). This implies that social connectedness protects and promotes mental health.
- Spend time with family and friends who care about you.
- Have regular contact with others and maintain routines at home

7.2.3 GET PREPARED EMOTIONALLY

- The Australian Psychological Society suggests three steps to being mentally prepared, using the abbreviations 'AIM' (Anticipate, Identify and Manage):
- **ANTICIPATE** that the situation will make you anxious and think of these as a normal reaction to a potentially life-threatening situation.
- **IDENTIFY** the typical physical feelings related to anxiety, and whether you are having any frightening thoughts that are adding to the fear.
- **MANAGE** your feelings using simple breathing and self-talk to stay as calm as possible so you can concentrate on the everyday tasks that need your attention.

7.3 NUTRITION

A healthy and balanced diet can help reduce the risk of chronic diseases compounded by air pollution (49). Evidence has shown that food rich in antioxidant compounds and fish oil supplementation and dietary intake can have a protective effect against air pollution (80-82).

Carotenoids and vitamins D and E may help to prevent against air pollution damage which can trigger respiratory diseases including asthma (80). Vitamin C, curcumin, choline and omega-3 fatty acids may also have a protective role against air pollution (80, 81). It has been suggested that a healthy diet, rich in fruits and vegetables, may protect against air pollution by lowering airway inflammation (80, 83). We recommend that people with asthma eat a healthy diet focusing on fresh fruit and vegetables, and minimising processed foods high in saturated fats and sugar. We have provided a link to the Australian Dietary Guidelines for further information https://www.eatforhealth.gov.au/guidelines.

7.4 PHYSICAL ACTIVITY

Studies indicate that outdoor activity may increase the effect of air pollution on respiratory health due to inhaled doses of air pollutants (67). We recommend that people with asthma should avoid outdoor physical exercise or activity when the outside air quality is poor. However, advice to reduce physical exercise outdoors is difficult to follow for the patient when it is for an extended period of time. We suggest that people with asthma should be encouraged to continue indoor exercise during prolonged bushfire periods to reduce the risk of other chronic diseases.

8. BUSHFIRE SMOKE AND PREGNANCY

Physiologic changes during pregnancy, such as increases in blood and plasma volumes and higher respiratory rates, increase a woman's vulnerability to environmental exposures including bushfires. Furthermore, maternal exposure to bushfire smoke during pregnancy can harm the mother as well as the developing fetus (42, 43). Therefore, it is important that health care providers need to understand the effects of bushfire smoke on maternal and infant health outcomes. There is evidence in the general population showing that exposure to bushfire related $PM_{2.5}$ or bushfire smoke during pregnancy increases the risk of adverse health outcomes for the mothers including:

- Gestational hypertension (42)
- Gestational diabetes (42)
- Miscarriage (84)

And specifically in pregnant women with asthma:

- Respiratory and non-respiratory symptoms (10)
- Stress and depression (10)
- Oral corticosteroid for an asthma exacerbation (10)

Maternal exposure to bushfire smoke during pregnancy in the general population has also been indicated to increase the risk of adverse health outcomes for fetus/newborn including:

- ✔ Low birth weight (42)
- ✔ Preterm birth (42, 85, 86)
- ✔ Birth defects (cleft palate, congenital anomalies of the respiratory system, congenital anomalies of the nervous system) in middle income country (87)
- ✔ Fetal gastroschisis (88)
- ✔ Child death in low – and middle- income countries (44, 89)

Communicate with pregnant women to follow the above recommendations such as staying indoors, avoid going outdoors, avoid exercising outdoors, minimise other sources of indoor air pollution, use a face mask and HEPA filters, use reputable sources of information such as local mass media and local health and emergency services websites, and use AirRater. Advise pregnant women with asthma how, where and when to seek health care services if there is bushfire smoke. Furthermore, teach them how to know the signs of labour and early labour.

Advise pregnant women with asthma to seek advice on mental health support from their health care providers to reduce the combined effect of bushfire smoke exposure and stress. Stress can increase the risk of preterm birth and low birth weight. Encourage them to continue taking their medications and prenatal vitamins as prescribed by the health care providers to keep themselves and their baby in good health.

Further information about air pollution and pregnancy is available from the Royal Australian and New Zealand College of Obstetricians and Gynaecologists.

9. INFANT FEEDING DURING THE BUSHFIRE PERIOD

Natural disasters including bushfires can have impacts on infant feeding methods (90-92). Infants have very specific fluid and food requirements for their growth and development. This might be compromised during bushfire events (90). Therefore, women and their children might need support from healthcare providers during bushfire events.

9.1 BREASTFEEDING DURING THE BUSHFIRE PERIOD

Breastfeeding gives a safe and nutritious option for continued infant feeding during natural disaster, including bushfire. Evidence shows that breastfeeding provides comfort for the mother and child during bushfire events (90,92). Furthermore, it has been reported that breastfeeding has the potential to reduce the impacts of environmental contaminants on the infant by supporting the development of strong immunity (93, 94). Therefore, we recommend women to continue breastfeeding during the bushfire events because they are providing safe and effective nutrition to their baby that meets the infants' fluid and energy requirements for adequate growth and development, including supporting the development of a strong immune system. Even during extreme heat conditions in summer, breast milk provides all the fluid the baby needs.

Advise women to take protective measures to avoid exposure to bushfire smoke including staying indoors, avoid going outdoors, avoid exercising outdoors, minimise other sources of indoor air pollution, use face mask and HEPA filters, seek information from reputable sources such a local mass media and local health and emergency, and use AirRater. Health care providers should discuss the advantages of breastfeeding with women. Breast milk provides a baby with the best defence against environmental contaminants. Furthermore, breastfeeding helps to mitigate climate change caused by environmental degradation and global warming as breastfeeding uses little water or other resources, produces no contaminants (e.g. carbon footprint emission) and minimal waste (95).

Advise women who are breastfeeding to call breastfeeding Helpline (1800 686 268) and Child and Family Health Nursing if they need help. Encourage women to take care of their asthma and prepare an emergency kit before the bushfire events.

EMERGENCY KIT FOR A BREASTFED BABY

To provide basics to feed and care for a breastfed baby having around 8 feeds a day for up to 3 days without access to water and electricity.

- 10L water for mother to drink
- 10 – 30L water for washing hands
- Detergent/ sanitiser for washing hands
- 36 nappies
- 100 nappy wipes

For further information on breastfeeding during natural disaster refer the link: https://www.breastfeeding.asn.au/resources/feed-baby-emergency

EMERGENCY KIT FOR A BABY FED EXPRESSED BREASTMILK

To provide basics to feed and care for a baby who is fed breast milk, having around 8 feeds a day for up to 3 days without access to mains water and electricity.

- 10L water for mother to drink
- 10-30L water for washing hands
- Detergent/ sanitiser for washing hands
- 30 cups or bottles for expressing and feeding
- 36 nappies and 100 nappy wipes

For further information refer the link: https://www.breastfeeding.asn.au/resources/feed-baby-emergency

9.2 FORMULA FEEDING DURING THE BUSHFIRE PERIOD

Only 61% of babies aged 4 - 47 months in Australia were exclusively breastfeed to at least 4 months of age. A study of breastfeeding and respiratory outcomes in infants born to mothers with asthma showed that only 37% of infants were exclusively breastfeed for up to 4 months (96). This means that many mothers may be providing formula to their infants and will require support to do so during natural disasters such as bushfires. Ensure women are provided with detailed information on the supplies necessary for an emergency preparedness kit and with information on how to make formula feeds during bushfire events.

EMERGENCY KIT FOR A FULLY FORMULA-FED BABY

To provide basics to feed and care for a baby who is formula fed having around 8 feeds a day for up to 3 days without access to mains water and electricity.

- 1 unopened tin of infant formula
- 14 small bottles water for making up formula
- 27 feeding bottles and teats (one for each feed)
- 15L water for washing hands and preparation area
- Detergents for washing hands and preparation area
- 100 sheets paper towel for drying hands and preparation area
- Large storage container with sealing lid, the lid to be used as a preparation surface
- 36 nappies and 100 nappy wipes

For more information on preparing to feed your baby in an emergency consult: Australian Breastfeeding Association

WHAT CAN HEALTH CARE PROVIDERS DO TO SUPPORT WOMEN WITH A BABY DURING BUSHFIRE EVENTS?

- ✔ Ensure access to lactation support
- ✔ Encourage women to seek the support of significant others
- ✔ Create safe and comfortable locations for infant feeding
- ✔ Reassure mothers that breastfeeding can provide enough nutrition for babies in the absence of safe complimentary foods
- ✔ Support breastfeeding by ensuring adequate nutrition and hydration of women
- ✔ Ensure adequate rest and psychological support for mother
- ✔ Encourage women to continue breastfeeding rather than weaning
- ✔ Ensure that detergent/sanitiser is available

10. USEFUL RESOURCES

Information regarding the bushfire smoke can be accessed through the links below

- Smoke and air quality information from the Australian Government Bureau of Meteorology
  Website: http://www.bom.gov.au/catalogue/warnings/air-pollution.shtml
- Australian Bureau of Meteorology: Fire Weather Knowledge Centre
  Website: http://www.bom.gov.au/weather-services/fire-weather-centre/index.shtml
- Health alert: bushfires and smoke from the Australian Government via the Department of Health
  Website: https://www.health.gov.au/news/health-alert-bushfires-and-smoke
- Bushfire smoke and your health: translated information about health and wellbeing via Health Translation
  Website: https://www.healthtranslations.vic.gov.au/bhcv2/bhcht.nsf
- Bush Fire Smoke Health Alert Information for NSW General Practitioners
  Website: https://www.health.nsw.gov.au/environment/air/Pages/bushfire-smoke.aspx
- Reducing bushfire smoke exposure
  Website: https://www.health.gov.au/news/information-about-bushfire-smoke-from-the-acting-chief-medical-officer
- Bushfire smoke- vulnerable groups fact sheet
  Website: https://www.health.gov.au/resources/publications/bushfire-smoke-vulnerable-groups-fact-sheet

11. MENTAL HEALTH SUPPORT RESOURCES IN AUSTRALIA

- **Beyond Blue:** 1300 224 636 or Beyond blue. Available by phone or online via chat or email, to provide support on a range of mental health issues. Available 24 hours a day, 7 days a week.
- **MensLine Australia** 1300 789 978 or MensLine. Counselling and resources for men in crisis 24 hours a day, 7 days a week
- **Lifeline's:** 13 HELP (13 43 57)
- **Lifeline Australia:** 13 11 14 or Lifeline Australia. A crisis support service that gives short-term assistance at any time for people who are having difficulty coping or staying safe. Lifeline text 0477 13 11 14, 6pm-midnight (AEDT), 7 nights a week. Lifeline webchat https://www.lifeline.org.au/, 7 pm-midnight (AEDT), 7 nights a week.
- **PANDA:** call 1300 726 306 or PANDA for those experiencing anxiety and depression during or after pregnancy
- **Pregnancy, Birth and Baby:** 1800 882 436 or mental wellbeing during pregnancy
- **Mind the Bump** for a free mindfulness meditation app to help expectant and new parents support their mental and emotional wellbeing
- **Kids Helpline:** 1800 551800 or Kids Helpline. A free, private and confidential 24/7 phone and online counselling service for young people aged 5 to 25 years.
- **NSW Mental Health Line:** 1800 011 511 or NSW Mental Health Line. Mental health crisis telephone service in NSW.
- **Apps for air quality**
  - Fires Near Me NSW
  - AirRater

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REFERENCES

1. Roberts G, Wooster MJ. Global impact of landscape fire emissions on surface level $PM_{2.5}$ concentrations, air quality exposure and population mortality. Atmospheric Environment. 2021;252:118210.
2. Xu R, Yu P, Abramson MJ, Johnston FH, Samet JM, Bell ML, et al. Wildfires, Global Climate Change, and Human Health. N Engl J Med. 2020;383(22):2173-81.
3. Johnston FH. Understanding and managing the health impacts of poor air quality from landscape fires. Med J Aust. 2017;207(6):229-30.
4. Bui D, Davis S, Flynn A, Bell R, Dharmage S. Impact of recent catastrophic bushfires on people with asthma in Australia: Health, social and financial burdens. Respirology. 2021;26(4):296-7.
5. Vardoulakis S, Jalaludin BB, Morgan GG, Hanigan IC, Johnston FH. Bushfire smoke: urgent need for a national health protection strategy. Med J Aust. 2020;212(8):349-53.e1.
6. Reid CE, Jerrett M, Tager IB, Petersen ML, Mann JK, Balmes JR. Differential respiratory health effects from the 2008 northern California wildfires: A spatiotemporal approach. Environ Res. 2016;150:227-35.
7. Borchers Arriagada N, Horsley JA, Palmer AJ, Morgan GG, Tham R, Johnston FH. Association between fire smoke fine particulate matter and asthma-related outcomes: Systematic review and meta-analysis. Environmental Research. 2019;179:108777.
8. Chen G, Guo Y, Yue X, Tong S, Gasparrini A, Bell ML, et al. Mortality risk attributable to wildfire-related PM2·5 pollution: a global time series study in 749 locations. The Lancet Planetary Health. 2021;5(9):e579-e87.
9. Beyene T, Harvey ES, Van Buskirk J, McDonald VM, Jensen ME, Horvat JC, et al. 'Breathing Fire': Impact of Prolonged Bushfire Smoke Exposure in People with Severe Asthma. Int J Environ Res Public Health. 2022;19:7419.
10. Beyene T, Murphy VE, Gibson PG, McDonald VM, Van Buskirk J, Holliday EG, et al. The impact of prolonged landscape fire smoke exposure on women with asthma in Australia. BMC Pregnancy and Childbirth. 2022;22:919.
11. Zosky GR, Porta Cubus A, Morgan G, Tham R, Heyworth J, Marks GB, et al. Centre for Air pollution, energy and health Research (CAR) position paper: There is no "safe" level of air pollution, Implications for Australian policy. Centre for Air pollution, energy and health Research. 2021.
12. Johnston FH, Henderson SB, Chen Y, Randerson JT, Marlier M, Defries RS, et al. Estimated global mortality attributable to smoke from landscape fires. Environmental health perspectives. 2012;120(5):695-701.
13. Abram NJ, Henley BJ, Sen Gupta A, Lippmann TJR, Clarke H, Dowdy AJ, et al. Connections of climate change and variability to large and extreme forest fires in southeast Australia. Communications Earth & Environment. 2021;2:8.
14. Johnston FH, Borchers-Arriagada N, Morgan GG, Jalaludin B, Palmer AJ, Williamson GJ, et al. Unprecedented health costs of smoke-related $PM_{2.5}$ from the 2019–20 Australian megafires. Nature Sustainability. 2021;4:42-7.
15. National Indicative Aggregated Fire Extent Dataset 2020 (Australian Government Department of Agriculture Water and the Environment, 2020). Available : https://go.nature.com/38wZSRr.
16. Hanigan IC, Johnston FH, Morgan GG. Vegetation fire smoke, indigenous status and cardio-respiratory hospital admissions in Darwin, Australia, 1996–2005: a time-series study. Environmental Health. 2008;7:42.
17. Australian Bureau of Statistics. National Health Survey: First Results, 2017–18. ABS Cat no. 4364.0.55.001. Canberra: ABS 2018 [Available from: https://www.abs.gov.au/statistics/health/health-conditions-and-risks/asthma/latest-release#data-download
18. Orr A, Migliaccio CAL, Buford M, Ballou S, Migliaccio CT. Sustained Effects on Lung Function in Community Members Following Exposure to Hazardous $PM_{(2.5)}$ Levels from Wildfire Smoke. Toxics. 2020;8(3).
19. Yu W, Guo Y, Shi L, Li S. The association between long-term exposure to low-level $PM_{2.5}$ and mortality in the state of Queensland, Australia: A modelling study with the difference-in-differences approach. PLOS Medicine. 2020;17(6):e1003141.
20. Uda SK, Hein L, Atmoko D. Assessing the health impacts of peatland fires: a case study for Central Kalimantan, Indonesia. Environmental science and pollution research international. 2019;26(30):31315-27.
21. Penman TD, Christie FJ, Andersen AN, Bradstock RA, Cary GJ, Henderson MK, et al. Prescribed burning: how can it work to conserve the things we value? International Journal of Wildland Fire. 2011;20:721-33.
22. Reid CE, Brauer M, Johnston FH, Jerrett M, Balmes JR, Elliott CT. Critical Review of Health Impacts of Wildfire Smoke Exposure. Environ Health Perspect. 2016;124(9):1334-43.
23. Naeher LP, Brauer M, Lipsett M, Zelikoff JT, Simpson CD, Koenig JQ, et al. Woodsmoke health effects: a review. Inhal Toxicol. 2007;19(1):67-106.
24. US Environmental Protection Agency. WILDFIRE SMOKE: A GUIDE FOR PUBLIC HEALTH OFFICIALS 2019 [Available from: https://www.epa.gov/] (Accessed 29 September 2021).

25. Lodovici M, Bigagli E. Oxidative stress and air pollution exposure. Journal of toxicology. 2011;2011:487074-.

26. Pope CA, 3rd, Dockery DW. Health effects of fine particulate air pollution: lines that connect. J Air Waste Manag Assoc. 2006;56(6):709-42.

27. Brook RD, Rajagopalan S, Pope CA, 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. Circulation. 2010;121(21):2331-78.

28. Aguilera R, Corringham T, Gershunov A, Benmarhnia T. Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California. Nature Communications. 2021;12(1):1493.

29. Wegesser TC, Pinkerton KE, Last JA. California wildfires of 2008: coarse and fine particulate matter toxicity. Environ Health Perspect. 2009;117(6):893-7.

30. Kim YH, Warren SH, Krantz QT, King C, Jaskot R, Preston WT, et al. Mutagenicity and Lung Toxicity of Smoldering vs. Flaming Emissions from Various Biomass Fuels: Implications for Health Effects from Wildland Fires. Environmental health perspectives. 2018;126(1):017011-.

31. Goldman M, Flynn A, Cartwright A, Bell R, Davis S, Bui D, et al. Bushfire Smoke Impact Survey 2019-2020 2020 [Available from: https://asthma.org.au/wp-content/uploads/Resources/AA6_Smoke-Impact-Survey-1920_Revised.pdf.

32. Rodney RM, Swaminathan A, Calear AL, Christensen BK, Lal A, Lane J, et al. Physical and Mental Health Effects of Bushfire and Smoke in the Australian Capital Territory 2019–20. Frontiers in Public Health. 2021;9(1522).

33. Arjmand H-A, Seabrook E, Bakker D, Rickard N. Mental Health Consequences of Adversity in Australia: National Bushfires Associated With Increased Depressive Symptoms, While COVID-19 Pandemic Associated With Increased Symptoms of Anxiety. Frontiers in Psychology. 2021;12(1675).

34. Bryant RA, Gibbs L, Gallagher HC, Pattison P, Lusher D, MacDougall C, et al. Longitudinal study of changing psychological outcomes following the Victorian Black Saturday bushfires. Aust N Z J Psychiatry. 2018;52(6):542-51.

35. Haikerwal A, Akram M, Sim MR, Meyer M, Abramson MJ, Dennekamp M. Fine particulate matter ($PM_{2.5}$) exposure during a prolonged wildfire period and emergency department visits for asthma. Respirology. 2016;21(1):88-94.

36. Johnston FH, Kavanagh AM, Bowman DM, Scott RK. Exposure to bushfire smoke and asthma: an ecological study. Med J Aust. 2002;176(11):535-8.

37. Walter CM, Schneider-Futschik EK, Knibbs LD, Irving LB. Health impacts of bushfire smoke exposure in Australia. Respirology. 2020;25(5):495-501.

38. Martin KL, Hanigan IC, Morgan GG, Henderson SB, Johnston FH. Air pollution from bushfires and their association with hospital admissions in Sydney, Newcastle and Wollongong, Australia 1994-2007. Aust N Z J Public Health. 2013;37(3):238-43.

39. Johnston FH, Webby RJ, Pilotto LS, Bailie RS, Parry DL, Halpin SJ. Vegetation fires, particulate air pollution and asthma: A panel study in the Australian monsoon tropics. International Journal of Environmental Health Research. 2006;16(6):391-404.

40. Henderson SB, Morrison KT, McLean KE, Ding Y, Yao J, Shaddick G, et al. Staying Ahead of the Epidemiologic Curve: Evaluation of the British Columbia Asthma Prediction System (BCAPS) During the Unprecedented 2018 Wildfire Season. Front Public Health. 2021;9:499309.

41. Koman PD, Hogan KA, Sampson N, Mandell R, Coombe CM, Tetteh MM, et al. Examining Joint Effects of Air Pollution Exposure and Social Determinants of Health in Defining "At-Risk" Populations Under the Clean Air Act: Susceptibility of Pregnant Women to Hypertensive Disorders of Pregnancy. World Med Health Policy. 2018;10(1):7-54.

42. Abdo M, Ward I, O'Dell K, Ford B, Pierce JR, Fischer EV, et al. Impact of Wildfire Smoke on Adverse Pregnancy Outcomes in Colorado, 2007-2015. Int J Environ Res Public Health. 2019;16(19).

43. Amjad S, Chojecki D, Osornio-Vargas A, Ospina MB. Wildfire exposure during pregnancy and the risk of adverse birth outcomes: A systematic review. Environ Int. 2021;156:106644.

44. Xue T, Geng G, Li J, Han Y, Guo Q, Kelly FJ, et al. Associations between exposure to landscape fire smoke and child mortality in low-income and middle-income countries: a matched case-control study. The Lancet Planetary Health. 2021;5(9):e588-e98.

45. Li J, Xue T, Tong M, Guan T, Liu H, Li P, et al. Gestational exposure to landscape fire increases under-5 child death via reducing birthweight: A risk assessment based on mediation analysis in low- and middle-income countries. Ecotoxicology and Environmental Safety. 2022;240:113673.

46. Powell P, Brunekreef B, Grigg J. How do you explain the risk of air pollution to your patients? . Breathe. 2016;12:201-3.

47. Johnston FH. Bushfires and human health in a changing environment. Australian Journal for General Practitioners. 2012;38:720-4.

48. The Departement of Health and Aged Care. enHealth Guidance for Public Health Agencies – Managing Prolonged Smoke Events from Landscape Fires (2021). Available: https://www1.health.gov.au/internet/main/publishing.nsf/Content/health-pubhlth-publicat-environ.htm. Access date: 11 September 2022.

49. Carlsten C, Salvi S, Wong GWK, Chung KF. Personal strategies to minimise effects of air pollution on respiratory health: advice for providers, patients and the public. Eur Respir J. 2020;55(6).

50. Gibson PG, Powell H. Written action plans for asthma: an evidence-based review of the key components. Thorax. 2004;59(2):94-9.

51. Global Initiative for Asthma. Global Initiative for Asthma. Global Strategy for Asthma Management and Prevention. 2019.

52. Engelkes M, Janssens HM, de Jongste JC, Sturkenboom MC, Verhamme KM. Medication adherence and the risk of severe asthma exacerbations: a systematic review. Eur Respir J. 2015;45(2):396-407.

53. Bårnes CB, Ulrik CS. Asthma and adherence to inhaled corticosteroids: current status and future perspectives. Respir Care. 2015;60(3):455-68.

54. Vora C, Renvall MJ, Chao P, Ferguson P, Ramsdell JW. 2007 San Diego wildfires and asthmatics. J Asthma. 2011;48(1):75-8.

55. Lipner EM, O'Dell K, Brey SJ, Ford B, Pierce JR, Fischer EV, et al. The Associations Between Clinical Respiratory Outcomes and Ambient Wildfire Smoke Exposure Among Pediatric Asthma Patients at National Jewish Health, 2012-2015. Geohealth. 2019;3(6):146-59.

56. Robijn AL, Jensen ME, Gibson PG, Powell H, Giles WB, Clifton VL, et al. Trends in asthma self-management skills and inhaled corticosteroid use during pregnancy and postpartum from 2004 to 2017. Journal of Asthma. 2019;56(6):594-602.

57. Robijn AL, Jensen ME, McLaughlin K, Gibson PG, Murphy VE. Inhaled corticosteroid use during pregnancy among women with asthma: A systematic review and meta-analysis. Clinical & Experimental Allergy. 2019;49(11):1403-17.

58. Heaney E, Hunter L, Clulow A, Bowles D, Vardoulakis S. Efficacy of Communication Techniques and Health Outcomes of Bushfire Smoke Exposure: A Scoping Review. International Journal of Environmental Research and Public Health. 2021;18(20):10889.

59. Fish JA, Peters MDJ, Ramsey I, Sharplin G, Corsini N, Eckert M. Effectiveness of public health messaging and communication channels during smoke events: A rapid systematic review. Journal of Environmental Management. 2017;193:247-56.

60. Van Deventer D, Marecaux J, Doubleday A, Errett N, Isaksen TMB. Wildfire Smoke Risk Communication Efficacy: A Content Analysis of Washington State's 2018 Statewide Smoke Event Public Health Messaging. J Public Health Manag Pract. 2021;27(6):607-14.

61. Laumbach R, Meng Q, Kipen H. What can individuals do to reduce personal health risks from air pollution? Journal of Thoracic Disease. 2015;7(1):96-107.

62. Reisen F, Powell JC, Dennekamp M, Johnston FH, Wheeler AJ. Is remaining indoors an effective way of reducing exposure to fine particulate matter during biomass burning events? J Air Waste Manag Assoc. 2019;69(5):611-22.

63. Cowie CT, Wheeler AJ, Tripovich JS, Porta-Cubas A, Dennekamp M, Vardoulakis S, et al. Policy Implications for Protecting Health from the Hazards of Fire Smoke. A Panel Discussion Report from the Workshop Landscape Fire Smoke: Protecting Health in an Era of Escalating Fire Risk. Int J Environ Res Public Health. 2021;18(11).

64. Cherrie JW, Apsley A, Cowie H, Steinle S, Mueller W, Lin C, et al. Effectiveness of face masks used to protect Beijing residents against particulate air pollution. Occup Environ Med. 2018;75(6):446-52.

65. Kodros JK, O'Dell K, Samet JM, L'Orange C, Pierce JR, Volckens J. Quantifying the Health Benefits of Face Masks and Respirators to Mitigate Exposure to Severe Air Pollution. GeoHealth. 2021;5(9):e2021GH000482.

66. McDonald F, Horwell CJ, Wecker R, Dominelli L, Loh M, Kamanyire R, et al. Facemask use for community protection from air pollution disasters: An ethical overview and framework to guide agency decision making. International Journal of Disaster Risk Reduction. 2020;43:101376.

67. Giles LV, Koehle MS. The health effects of exercising in air pollution. Sports Med. 2014;44(2):223-49.

68. Barn PK, Elliott CT, Allen RW, Kosatsky T, Rideout K, Henderson SB. Portable air cleaners should be at the forefront of the public health response to landscape fire smoke. Environmental Health. 2016;15(1):116.

69. Morawska L, He C, Hitchins J, Gilbert D, Parappukkaran S. The relationship between indoor and outdoor airborne particles in the residential environment. Atmospheric Environment. 2001;35(20):3463-73.

70. Jia-Ying L, Zhao C, Jia-Jun G, Zi-Jun G, Xiao L, Bao-Qing S. Efficacy of air purifier therapy in allergic rhiniti. Asian Pac J Allergy Immunol. 2018;36(4):217-21.

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

72. Polivka BJ, Eldeirawi K, Huntington-Moskos L, Nyenhuis SM. Mask Use Experiences, COVID-19, and Adults with Asthma: A Mixed-Methods Approach. J Allergy Clin Immunol Pract. 2022;10(1):116-23.

73. Lavoie KL, Cartier A, Labrecque M, Bacon SL, Lemière C, Malo JL, et al. Are psychiatric disorders associated with worse asthma control and quality of life in asthma patients? Respir Med. 2005;99(10):1249-57.

74. Boulet LP, Boulay M. Asthma-related comorbidities. Expert Rev Respir Med. 2011;5(3):377-93.

75. Better Health Channel. Trauma - reaction and recovery. 2016.

76. Australian Psychological Society. Australian bushfires: Psychological preparation and recovery. 2020.

77. Stubbs MA, Clark VL, Gibson PG, Yorke J, McDonald VM. Associations of symptoms of anxiety and depression with health-status, asthma control, dyspnoea, dysfunction breathing and obesity in people with severe asthma. Respiratory Research. 2022;23:341.

78. Saeri AK, Cruwys T, Barlow FK, Stronge S, Sibley CG. Social connectedness improves public mental health: Investigating bidirectional relationships in the New Zealand attitudes and values survey. Australian & New Zealand Journal of Psychiatry. 2018;52(4):365–74.

79. Cruwys T, Dingle GA, Haslam C, Haslam SA, Jetten J, Morton TA. Social group memberships protect against future depression, alleviate depression symptoms and prevent depression relapse. Social Science & Medicine. 2013;98: 179-86.

80. Whyand T, Hurst JR, Beckles M, Caplin ME. Pollution and respiratory disease: can diet or supplements help? A review. Respir Res. 2018;19(1):79.

81. Lin Z, Chen R, Jiang Y, Xia Y, Niu Y, Wang C, et al. Cardiovascular Benefits of Fish-Oil Supplementation Against Fine Particulate Air Pollution in China. J Am Coll Cardiol. 2019;73(16):2076-85.

82. Lim CC, Hayes RB, Ahn J, Shao Y, Silverman DT, Jones RR, et al. Mediterranean Diet and the Association Between Air Pollution and Cardiovascular Disease Mortality Risk. Circulation. 2019;139(15):1766-75.

83. Romieu I, Barraza-Villarreal A, Escamilla-Núñez C, Texcalac-Sangrador JL, Hernandez-Cadena L, Díaz-Sánchez D, et al. Dietary intake, lung function and airway inflammation in Mexico City school children exposed to air pollutants. Respir Res. 2009;10(1):122.

84. Xue T, Geng G, Han Y, Wang H, Li J, Li H-t, et al. Open fire exposure increases the risk of pregnancy loss in South Asia. Nature Communications. 2021;12(1):3205.

85. Heft-Neal S, Driscoll A, Yang W, Shaw G, Burke M. Associations between wildfire smoke exposure during pregnancy and risk of preterm birth in California. Environmental Research. 2022;203:111872.

86. Requia WJ, Papatheodorou S, Koutrakis P, Mukherjee R, Roig HL. Increased preterm birth following maternal wildfire smoke exposure in Brazil. Int J Hyg Environ Health. 2022;240:113901.

87. Requia WJ, Kill E, Papatheodorou S, Koutrakis P, Schwartz JD. Prenatal exposure to wildfire-related air pollution and birth defects in Brazil. J Expo Sci Environ Epidemiol. 2022;32(4):596-603.

88. Park BY, Boles I, Monavvari S, Patel S, Alvarez A, Phan M, et al. The association between wildfire exposure in pregnancy and foetal gastroschisis: A population-based cohort study. Paediatr Perinat Epidemiol. 2022;36(1):45-53.

89. Li J, Xue T, Tong M, Guan T, Liu H, Li P, et al. Gestational exposure to landscape fire increases under-5 child death via reducing birthweight: A risk assessment based on mediation analysis in low- and middle-income countries. Ecotoxicol Environ Saf. 2022;240:113673.

90. DeYoung SE, Chase J, Branco MP, Park B. The Effect of Mass Evacuation on Infant Feeding: The Case of the 2016 Fort McMurray Wildfire. Matern Child Health J. 2018;22:1826-33.

91. Hwang CH, Iellamo A, Ververs M. Barriers and challenges of infant feeding in disasters in middle- and high-income countries. Int Breastfeed J. 2021;16(1):62.

92. Beyene T, Zosky GR, Gibson PG, McDonald VM, Holliday EG, Horvat JC, et al. The impact of the 2019/2020 Australian landscape fires on infant feeding and contaminants in breast milk in women with asthma. Int Breastfeed J. 2023;18:13.

93. van den Berg M, Kypke K, Kotz A, Tritscher A, Lee SY, Magulova K, et al. WHO/UNEP global surveys of PCDDs, PCDFs, PCBs and DDTs in human milk and benefit–risk evaluation of breastfeeding. Archives of Toxicology. 2017;91(1):83-96.

94. Mead MN. Contaminants in human milk: weighing the risks against the benefits of breastfeeding. Environmental health perspectives. 2008;116(10):A427-A34.

95. Karlsson JO, Garnett T, Rollins NC, Röös E. The carbon footprint of breastmilk substitutes in comparison with breastfeeding. Journal of Cleaner Production. 2019;222:436-45.

96. Harvey SM, Murphy VE, Gibson PG, Collison A, Robinson P, Sly PD, et al. Maternal asthma, breastfeeding, and respiratory outcomes in the first year of life. Pediatr Pulmonol. 2020;55(7):1690-6.

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