

## Public Health Response to Prolonged Smoke Events

**Summary** This guideline is an evidence-based resource for NSW Public Health Units (PHUs) and Health Protection NSW (HPNSW) designed to inform the risk assessment of, response to, and mitigation of health risks caused by reduced air quality as a result of a prolonged major fire.

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## **PUBLIC HEALTH RESPONSE TO PROLONGED SMOKE EVENTS**

### **PURPOSE**

The purpose of this guideline is to provide NSW Public Health Units (PHUs) and Health Protection NSW (HPNSW) with an evidence-based resource designed to inform the risk assessment of, response to and mitigation of health risks caused by reduced air quality as a result of a prolonged major fire.

### **KEY PRINCIPLES**

Reduced air quality as a result of smoke from major fires, such as industrial fires, coal mine fires and bushfires, can have significant impacts on population health. There is strong evidence that prolonged exposure to fine particles emitted from these fires is detrimental to health.

The guideline outlines suggested activities for the prevention, preparedness, response and recovery of such events. In particular, the document outlines proposed public health messages and actions for Public Health Units in response to a prolonged smoke event.

A risk-based approach should be used when considering communication and actions.

### **USE OF THE GUIDELINE**

The guideline should be considered when smoke from a major fire affects a community or populated area for three days or longer. Public health responses may be required for acute smoke events with a shorter duration than three days but this document focuses on the additional challenges that prolonged events produce.

The guideline provides a risk response summary to guide decision making, where the categories of risk are defined by the exposure to fine particulate matter over time.

### **REVISION HISTORY**

<b>Version</b>	<b>Approved by</b>	<b>Amendment notes</b>
1.0	Deputy Secretary, Population and Public Health	New guideline

### **ATTACHMENTS**

1. Public Health Response to Prolonged Smoke Events

## Public Health Response to Prolonged Smoke Events



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## 1 BACKGROUND

### 1.1 Introduction

Reduced air quality as a result of smoke from major fires, such as industrial fires, coal mine fires and bushfires, can have significant impacts on population health. Smoke from major fires contains many air contaminants in both particle and gaseous phases (1).

When evaluating air quality generally, there are three major pollutant categories to consider:

- particulate matter – PM<sub>10</sub> and PM<sub>2.5</sub>
- gases – carbon monoxide, ozone, sulphur dioxide and nitrogen dioxide
- air toxins – volatile organic compounds and metals.

Particulate matter (PM) refers to the mixture of solid particles and liquid droplets suspended in air (2). PM can be divided into several categories depending on size:

- PM<sub>10</sub> particles are less than 10 micrometres in diameter
- PM<sub>2.5-10</sub> particles are coarse and are between 2.5-10 micrometres in diameter
- PM<sub>2.5</sub> particles are fine and are less than 2.5 micrometres in diameter.

There is strong evidence that fine particles (PM<sub>2.5</sub>) are detrimental to health and have a wider range of respiratory and cardiovascular health effects than larger particles as they can be inhaled deeply into the lungs. Although coarse particles are not benign, there is greater evidence around the detrimental health effects of PM<sub>2.5</sub> (3) on which to estimate health risk.

The health impacts of exposure to PM can be severe and the magnitude of health impact on a population depends on concentration and duration of exposure. For example, short-term exposure (hours) at high levels can cause nose, throat and eye irritation and exacerbate pre-existing respiratory and cardiovascular conditions (4). Long-term exposure (years) has been associated with adverse respiratory, cardiovascular, neurological and birth outcomes and cancer (4).

There are several groups that are particularly vulnerable to the adverse health impacts of PM exposure. Elderly people are more prone to respiratory and cardiovascular morbidity from PM exposure, while children are at increased risk of respiratory effects. There is also an increased susceptibility for individuals with underlying cardiovascular disease (hypertension, diabetes, ischaemic heart disease) and respiratory disease (asthma, chronic obstructive pulmonary disease) and pregnant women (3).

When considering the health risk to a population from prolonged exposure (days to months) to PM, it is important to consider the socio-economic demographic of a community. Populations with lower socio-economic backgrounds may be more vulnerable to the effects of air pollution due to a higher prevalence of chronic disease and reduced capacity to avoid exposure.

## 1.2 Aim

This guideline is an evidence-based resource for NSW Public Health Units (PHUs) and Health Protection NSW (HPNSW) designed to inform the risk assessment of, response to, and mitigation of health risks caused by reduced air quality as a result of a prolonged major fire.

## 1.3 Scope

This guideline will be used primarily to inform the public health response to smoke emergencies that arise from major fires of duration three days or longer. It is acknowledged that NSW Health would not be the lead agency in responding to these incidents but that it is likely that NSW Health would be asked to advise on the assessment, communication and management of health risks from these incidents. This guideline is to be considered when smoke from a major fire affects a community or populated area for three days or longer. Examples of major fires include coal mine fires, landfill fires, industrial fires and some bushfires. This guideline is also relevant for other prolonged events unrelated to fires, such as dust storms, where the concentration of PM is significantly increased.

Public health responses may be required for acute smoke events with a shorter duration than three days but this document focuses on the additional challenges that prolonged events produce.

All multi-agency emergency responses follow the arrangements set forth in the NSW State Emergency Management Plan (EMPLAN).

As the evidence of health effects is strongest for PM<sub>2.5</sub>, this guideline will focus on PM<sub>2.5</sub>, but this risk-based approach is relevant to the response to other air pollutants that could be produced as a result of a major fire.

## 2 PREVENTION

In this guideline, the prevention phase includes identifying, analysing, assessing, treating and mitigating the risk of conditions that may contribute to the adverse health impacts of a prolonged smoke event.

Public health services can comment on development proposals (through the Environmental Impact Assessment process) that may increase the risk of a prolonged fire. For example, a development proposal for a coal mine close to bushland could benefit from consideration of how to best mitigate the risk of ignition of a coal mine fire consequent on a bushfire.

While public health may work with partner agencies to provide advice during the development of measures to prevent some smoke emergencies, the primary role of public health services is to assist with consequence management (i.e. conducting a risk assessment once an incident has occurred).

### 3 PREPAREDNESS

Local Health Districts (LHDs) must fulfil the general preparedness requirements detailed in the Public Health Emergency Response Preparedness Minimum Standards (PD2013\_039).

The following sections outline key elements of preparation for a public health response to a prolonged smoke event:

#### 3.1 Planning

Consider what additional plans or resources may be useful at a local level in preparation for a prolonged smoke event.

As part of all-hazards planning, populations that are particularly vulnerable to a prolonged smoke event, such as the elderly and children, should be spatially identified (for example, know where nursing homes and schools are located).

Through existing emergency management channels, via LHD Health Services Functional Area Coordinators (HSFACs) to local emergency management committees, PHUs can advocate for and contribute to preparedness activities relevant to smoke events.

This can include discussion with partner agencies about facilities that may be appropriate for use as clean air shelters during times of severe air pollution (for example a re-purposed library or community centre). A clean air shelter provides significantly cleaner air indoors compared to outdoors through air conditioning or another type of air filtration system, and tight-sealing windows and doors (5).

#### 3.2 Capability development and training

Ensure an appropriate level of skill is maintained to respond to increased health risks from PM due to a prolonged smoke event. This includes the ability to perform rapid risk assessments, technical knowledge of the health effects of air pollutants and an understanding of air quality readings. Supplementary technical expertise is also available from HPNSW.

#### 3.3 Conducting exercises

Participate in or lead discussion exercises which consider the health impacts of prolonged smoke events in order to ensure that guidelines and communication channels are robust and understood. Lessons from these exercises should be fed back into planning and response processes.

#### 3.4 Stakeholder engagement and partnership development

Develop and maintain appropriate local partnerships with relevant agencies, such as the NSW Environment Protection Authority and the NSW Office of Environment and

Heritage, to promote understanding of inter-organisational roles, technical capabilities and responsibilities during prolonged smoke events.

Public health services may contribute to relevant preparedness activities supported by partner activities, for example, activities which promote community resilience during prolonged smoke events.

### 3.5 Communication preparation

Public health services should work with their public affairs teams to consider the most appropriate risk communication channels for providing information to the public, including public meetings and multi-media broadcasts.

In some cases, risk communication messages and materials can be prepared in advance (see section 4 for proposed messages). Appropriate spokespeople for media engagement can also be identified. Communities vulnerable to prolonged smoke events (principally due to proximity of residences to combustion sources) may be identifiable and consideration should be given to how best to communicate to these communities.

## 4 RESPONSE

### 4.1 Risk assessment

A rapid health risk assessment is required to estimate the nature and probability of adverse health effects from PM exposure and exposure to other harmful chemicals or substances emitted during a fire. This involves identifying hazardous materials that may be present in addition to PM. At-risk groups within the population should also be identified. A separate risk assessment may be required for other noxious compounds identified in the smoke from a specific incident. This document concentrates on PM, but the methodology could be applied to other hazardous material.

The rapid health risk assessment should include a dose-response assessment, where the category of risk is defined by the level of exposure to PM, which includes both PM concentration and duration of exposure. Risk as defined in this guideline is for the exposed population as a whole, which includes susceptible groups (children, pregnant women, elderly people and individuals with existing respiratory or cardiac conditions).

PHUs are expected to lead the rapid health risk assessment, with support from HPNSW or other relevant agencies. Site visits by Environmental Health Officers can increase situational awareness of the incident, the surrounding area and the affected community.

To assist with the assessment of risk, an analysis of the potential estimated mortality risk from varying levels of PM<sub>2.5</sub> over time is included in the Appendix of this guideline.

Although it is important to consider health impacts in terms of morbidity and mortality risk, only mortality risk is applied in this document. Concentration-response relationships of PM<sub>2.5</sub> and mortality risk are well described and the acceptability of various levels of mortality risk has been considered by others; whereas concentration-response



relationships of PM<sub>2.5</sub> and morbidity risk are not as well described and are less consistent between epidemiological studies. Hence mortality risk has been used to construct a consistent risk-based response over time.

Table 1 shows the ambient PM<sub>2.5</sub> concentration associated with different levels of response for a range of durations of exposure from three days to three months. It also provides guidance on the recommended level of response for these concentrations of PM<sub>2.5</sub>. For the associated mortality risk curves see Figure 1 in the Appendix.

For concentrations equal or greater consider:	Low level response	Moderate level response	High level response
Duration of exposure	Average ambient PM <sub>2.5</sub> concentration (µg/m <sup>3</sup> ) over the duration of exposure		
<b>3 days</b>	28	191	1,058
<b>1 week</b>	16	91	613
<b>2 weeks</b>	12	50	362
<b>1 month</b>	10	28	191
<b>2 months</b>	9	18	104
<b>3 months</b>	>approx. NSW background 8*	14	73

*Table 1: Guidance on the level of response to be considered for various ambient concentrations of PM<sub>2.5</sub> and durations of exposure.*

*\*Background levels of PM<sub>2.5</sub> are normally approximately 8µg/m<sup>3</sup> in NSW. Exposures to point source smoke emergencies above background levels for 3 months or more should result in a low level response.*

While PM levels can fluctuate within a short period of time (hours), with peak levels expected for short periods, health risks are best estimated using longer averaging periods (days).

The thresholds for Table 1 differ from the National Environment Protection Measure (NEPM) as they focus on mortality risk during an acute smoke event whereas NEPM focuses on targets for ambient air quality that a community is exposed to on a day-to-day basis.

An exposure assessment will determine the magnitude and duration of PM exposure based on the best available evidence and will consider the nature of future exposure in terms of magnitude and duration. This process will require assistance and support from the agencies mentioned in *4.3 Intersection with partner agencies*. PHUs should ensure that communication channels with partner agencies during a prolonged smoke event are agreed upon with the LHD Health Services Functional Area Coordinator (HSFAC).

In the event that PM readings are not available in a reasonable timeframe, other smoke response plans have suggested using visibility to assess smoke levels (6). However, visibility assessments are less accurate than PM readings.

HPNSW can assist the impacted PHU(s) with additional expertise to support the risk assessment, if needed. This may include convening the Environmental Health Expert Advisory Panel (EHEAP). Representatives with additional specific expertise can be added to the Panel as required.

It is difficult to predict future exposure to PM during a smoke event, as this is dependent on changeable factors such as wind speed and direction, and the emission source. Therefore, although consideration should be given to likely future exposure, risk assessments are often based on immediate past exposure, and risk must be re-assessed regularly as the situation evolves to ensure that the recommended actions remain appropriate. The PM<sub>2.5</sub> concentrations in Table 1 can be used to guide the escalation or de-escalation of the response as circumstances change during a prolonged smoke event.

### 4.2 Risk communication

As with any other significant response, timeliness, relevance and accuracy of information are integral when communicating to communities.

Risk should be communicated to the public, either directly or by contributing to whole of government messages coordinated by the combat agency or Public Information Functional Area Coordinator (via the NSW Health Information Controller). PHUs should work closely with their LHD public affairs teams and key experts to consider what additional resources may be helpful for the affected community (for example, fact sheets for the public and local GPs). Communications should be tailored to a broad range of local health services, including Aboriginal Community Controlled Health Services.

It is useful to note any questions received from the public to tailor future communications accordingly.

### 4.3 Intersection with partner agencies

Depending on the district and nature of the fire, Fire and Rescue NSW or Rural Fire Service will be the initial lead agency. Previously, in some instances of prolonged fires (for example, a rubbish tip fire), the responsibility for ongoing incident management has been transferred to the NSW Environment Protection Authority. Other factors, such as whether hazardous materials are involved, could result in a different arrangement.

To effectively respond to a prolonged smoke event, public health services should understand what specific expertise is held by partner agencies, in addition to standard 'core business' responsibilities. Although the response may be coordinated at a local level, requests for expertise are likely to involve state offices of the relevant agencies; HPNSW will liaise with partner agencies about requests such as:

- Immediate mobile monitoring of PM concentrations and data on routine ambient air quality monitoring in a local region can be provided by the Office of Environment and Heritage. Consideration should be given to appropriate placement of the devices to reflect community exposures.

- Smoke plume modelling may be provided by a number of agencies including the NSW Rural Fire Service, Office of Environment and Heritage and the Bureau of Meteorology.
- Meteorological data may be supplied by the Bureau of Meteorology.
- Other relevant air pollution or fire advice may be provided by the NSW Environment Protection Authority and NSW Fire and Rescue.
- The Spatial Services Division of the Department of Finance, Service and Innovation can assist with mapping at-risk groups in the affected area.

PHUs are encouraged to work closely with local councils as per normal arrangements.

During a prolonged smoke event, public health services may be requested by the LHD HSFAC to deploy a liaison officer to a health or a multi-agency operations centre.

### 4.4 Field response

Partner agencies may decide to open a specific clean air shelter, such as a re-purposed library or community centre. Alternatively, community members can be reminded of options that are already accessible for most people and may have cleaner air, for example, a shopping centre outside of the affected area (6).

Public health personnel may be deployed to support partner agencies with the assessment of conditions in clean air shelters, particularly if new functions are being introduced (for example, large groups of people eating in a facility where this does not normally occur). Public health personnel undertaking such assessments should refer to the Environmental Health Assessment Form - GL2011\_011 *Major Evacuation Centres: Public Health Considerations*. If clean air shelters are not available, or respite of sufficient duration is not practical, it may be appropriate to consider recommending evacuation of affected residents. When participating in a multiple agency decision-making process regarding evacuation, public health services must ensure adequate consideration is given to the considerable health risks of evacuation for vulnerable groups.

### 4.5 Surveillance and epidemiology

The Public Health Rapid, Emergency, Diseases and Syndromic Surveillance (PHREDSS) system provides near real-time monitoring of presentations to NSW public hospital emergency departments and all (000) emergency calls to NSW Ambulance. PHREDSS also receives death notifications but with a median delay to report of 14 days. PHREDSS monitors these data daily 365 days a year. The PHREDSS system may provide timely intelligence to inform the risk assessment and communication related to the response to a prolonged smoke event.

### 4.6 Risk response summary

This response guideline uses a risk-based approach to guide decision making. The categories of risk are defined by the exposure of PM over time. Risk is defined as a measure for the population as a whole, including vulnerable groups (children, pregnant women, elderly people and individuals with existing respiratory or cardiac conditions).

The proposed public health messages and actions apply to varying levels of mortality risk (Table 2). Responses need to be tailored to the specific event as not all interventions and messages will be appropriate or feasible for all events.

<b>Risk of mortality over time</b>	<b>Proposed public health messages</b>	<b>Proposed actions for Public Health Units</b>
Negligible ( $< 1$ in 1,000,000)	No routine messaging.	Be aware of air quality forecasts.
Low (1 in 1,000,000 – 1 in 100,000)	<p>Pay attention to symptoms, particularly if you are susceptible to the effects of air pollution (elderly people, children, pregnant women and individuals with existing cardiovascular or respiratory conditions).</p> <p>If symptoms of lung and heart disease persist, such as repeated coughing, shortness of breath, wheezing, chest pain, palpitations or nausea, seek medical attention.</p>	<ul style="list-style-type: none"> <li>Advise public about health effects of smoke, related symptoms and ways to minimise exposure.</li> <li>Monitor conditions and forecasts to continually inform risk assessments.</li> </ul>
Moderate (1 in 100,000 – 1 in 10,000)	<p>All of the above and consider also:</p> <ul style="list-style-type: none"> <li>Keep doors and windows closed; turn on re-circulated air in home air-conditioners and car ventilation if safe to do so.</li> <li>Keep house clean to avoid re-suspension of particles.</li> <li>Avoid sources of pollutants such as smoking, wood fire heaters, candles, air fresheners, incense, fragrance or cleaning products.</li> <li>Take advantage of any breaks in smoky conditions and air out your home as conditions may deteriorate.</li> <li>Reduce or reschedule prolonged strenuous activities and limit time spent outdoors.</li> </ul>	<p>All of the above and consider:</p> <ul style="list-style-type: none"> <li>Issue public messaging through agreed communication channels.</li> <li>If a smoke event is projected to be prolonged, consider recommending to emergency management partners that planning for clean air shelters be activated; support related risk assessment activities.</li> </ul>

High (> 1 in 10,000)	<p>All of the above and consider:</p> <ul style="list-style-type: none"> <li>• Reschedule outdoor events.</li> <li>• Avoid all strenuous activities and stay indoors if possible.</li> <li>• Where available stay in air-conditioned premises and/or use an air cleaner if available.</li> <li>• Consider temporarily staying with a friend or relative living outside the smoke-affected area.</li> <li>• Discuss the use of particulate respirator masks (P2/N95 masks) if supplies are available, including benefits and concerns.</li> <li>• If it is safe and feasible to move, consider spending time in a location with cleaner air, such as a shopping centre outside of the affected area.</li> <li>• If a decision is made to open a specific clean air shelter or respite centre, consider temporarily relocating to this facility if safe to do so.</li> </ul>	<p>All of the above and consider:</p> <ul style="list-style-type: none"> <li>• Review health benefits and risks for affected, particularly vulnerable, groups leaving the area until air quality improves.</li> <li>• Consider health benefits from use of masks or air cleaners.</li> <li>• Discuss with partner agencies the possibility of closing schools and non-essential services.</li> <li>• Provide health risk information to partner agencies to inform decision-making about opening clean air shelters and evacuation/relocation.</li> </ul>
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*Table 2: Proposed public health messaging and actions for various levels of mortality risk*

Note: While portable air cleaners and particulate respirator masks (P2/N95 masks) may potentially reduce exposure to PM, there is limited current evidence on the health outcomes of these interventions during a prolonged smoke event. Particulate respirator masks may not be practical for some individuals or for prolonged events.

Other health impacts, such as heat stress, need to be considered before issuing public health messages.

## 5 RECOVERY

‘Recovery’ describes measures taken to assist people and communities affected by an emergency to achieve a proper and effective level of functioning.

Recovery-related activities may commence when the public health response is still underway, for example, establishing a community information and recovery centre as a single point of contact for information and assistance to disaster-affected people. Consider the deployment of public health personnel to recovery centres if requested.

Ongoing monitoring of the health status of affected individuals is best managed by their primary health providers, with advice from specialists as required.

Sharing of knowledge through conducting or participating in debrief sessions, both internally and with external stakeholders, and subsequent review of any relevant plans is also important for identifying what worked well and areas for improvement.

## 6 REFERENCES

1. Lemieux P.M. et. al (2004). Emissions of organic air toxics from open burning: a comprehensive review. *Progress in Energy and Combustion Science* 30(1): 1-32.
2. NSW Health - Environmental Health: Particulate Matter.  
<http://www.health.nsw.gov.au/environment/air/Pages/particulate-matter.aspx>  
Accessed 27/10/2016.
3. Hime N. et. al (2015). Review of the health impacts of emission sources, types and levels of particulate matter air pollution in ambient air in NSW. Woolcock Institute of Medical Research, Centre for Air Quality and Health Research and Evaluation.
4. World Health Organization Regional Office for Europe (2013). Review of evidence on health aspects of air pollution – REVIHAAP Project: final results.  
[http://www.euro.who.int/\\_data/assets/pdf\\_file/0020/182432/e96762-final.pdf](http://www.euro.who.int/_data/assets/pdf_file/0020/182432/e96762-final.pdf)  
Accessed 15/11/2016.
5. Interior Health, British Columbia (2016). Air Shelters during Wildfires.  
<https://www.interiorhealth.ca/YourEnvironment/EmergencyPreparedness/Documents/Air%20Shelters%20During%20Wildfires.pdf> Accessed 17/11/2016.
6. U.S Environmental Protection Agency, U.S. Forest Service. U.S Centers for Disease Control and Prevention and California Air Resources Board (2016). Wildfire Smoke – A Guide for Public Health Officials - Revised May 2016.



## 7 APPENDIX

There is clear evidence of the impacts for short-term exposure to PM<sub>2.5</sub>. However, nearly all studies of health effects have used PM<sub>2.5</sub> exposures of either 24 hours or at least one year and there are inherent uncertainties in estimating the mortality risk associated with exposure to PM<sub>2.5</sub> over time periods of days to months because there is little evidence of the health effects associated with these periods of exposure.

Figure 1 below and Table 1 in the body of the document uses the best available evidence from time-series studies of 24 hour exposures to estimate the mortality risks for exposures between three days and three months.

The concentration of ambient PM<sub>2.5</sub> that is associated with a given risk of all-cause mortality decreases as the duration of the exposure increases (Figure 1). To estimate the concentration of ambient PM<sub>2.5</sub> associated with a given mortality risk for three days to three months of exposure, the risk associated with 24 hours of exposure was summed for each day out to three months (Figure 1). The risks associated with various concentrations of PM<sub>2.5</sub> from three to 90 days that result in various levels of response are based on 10-fold increases in risk from 1 in 1,000,000 (which is considered as negligible in many health risk assessments).

These levels were calculated using the health impact function which describes the log-linear relationship between a change in exposure and the change in incidence of a health outcome in the population. The function is represented by:

$$\Delta y = y_0(e^{\beta \Delta x} - 1) \times \text{days}$$

where  $\Delta y$  is the change in incidence, or risk, in the population due to the exposure,  $y_0$  is the baseline incidence without the change in exposure,  $\beta$  is the concentration-response effect estimate and  $\Delta x$  is the change in concentration of PM<sub>2.5</sub> (associated with the  $\Delta y$ ). If it is assumed that the concentration-response remains constant, the total change in incidence over time is the daily change in incidence multiplied by the number of days the population is exposed. By solving this equation for  $\Delta x$ , the change in concentration for a specific risk can be calculated:

$$\Delta x = \frac{\ln\left(\frac{\Delta y}{y_0} \times \frac{1}{\text{days}} + 1\right)}{\beta}$$

This equation was used to estimate the change in concentration of PM<sub>2.5</sub> which would result in a defined increase in risk of mortality over the periods of 3-90 days which is presented in Table 1 and Figure 1. The concentration-response,  $\beta$ , was taken to be 0.00115 as determined by an analysis of PM<sub>2.5</sub> and mortality in 75 U.S. cities for 2000-2006 (Dai et. al (2014) Environmental Health Perspectives 122:837-842). The baseline rate of all-cause mortality ( $y_0$ ) was taken to be that of Sydney, 1.42 per 100,000 population per day.

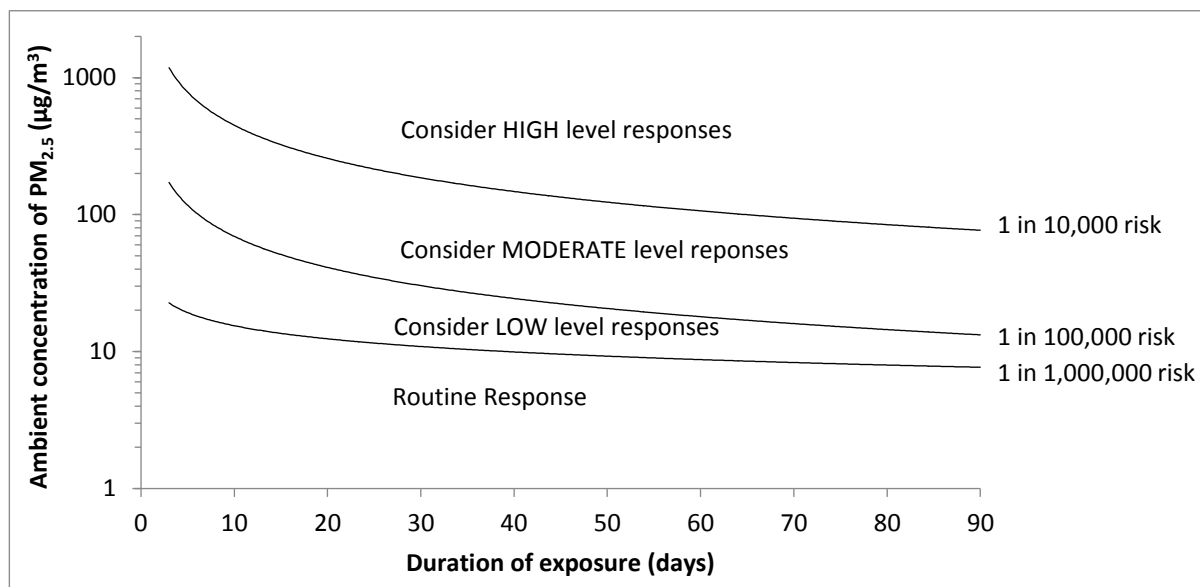


Figure 1: Characterisation of mortality risk for ambient  $PM_{2.5}$  exposure from 3 to 90 days.