



## Hazelwood Health Study Adult Survey

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Volume 2 The relationship between Hazelwood mine fire smoke exposure and health outcomes.

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## Caveat

This report presents a preliminary analysis which has not been submitted to independent peer review. Subsequent scientific manuscripts which undergo independent peer review may vary in their findings or interpretation.

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## Abbreviations

<b>ABS</b>	Australia Bureau of Statistics
<b>AUDIT-C</b>	Alcohol Use Disorders Identification Test
<b>CO</b>	Carbon Monoxide (product of incomplete combustion)
<b>COPD</b>	Chronic Obstructive Pulmonary Disease
<b>CSIRO</b>	Commonwealth Scientific and Industrial Research Organisation
<b>ESCAPE</b>	European Study of Cohorts for Air Pollution Effects
<b>IES-R</b>	Impact of Events Scale – Revised
<b>K10</b>	Kessler 10 item Psychological Distress Scale
<b>MICE</b>	Multiple imputation by chained equations
<b>NHS</b>	Australian National Health Survey
<b>PM<sub>2.5</sub></b>	Particulate Matter less than 2.5 thousandths of a millimetre in diameter
<b>ppm</b>	Parts per million (by volume)
<b>PTSD</b>	Post-traumatic Stress Disorder
<b>RR</b>	Rate Ratio (Relative Risk)
<b>RRR</b>	Relative Rate Ratio
<b>SA1</b>	Statistical Area Level 1
<b>SF12</b>	Short Form 12 item Health Survey
<b>µg/m<sup>3</sup></b>	Millionths of a gram per cubic metre of air
<b>VEC</b>	Victorian Electoral Commission
<b>WHO</b>	World Health Organization

## Executive Summary

This report comprises Volume 2 of the Hazelwood Health Study Adult Survey findings, which aimed to assess whether people who were heavily exposed to emissions from the Hazelwood mine fire in February 2014, compared with otherwise similar people who were less or minimally exposed to emissions from the fire, currently have cardiovascular, respiratory or psychological symptoms or conditions.

The Adult Survey recruited 3,096 people in Morwell (34% of those eligible) and 960 (23%) in Sale approximately 2.5 years after the mine fire event. Participants provided self-reported health and demographic data via an interviewer-administered, or self-administered, survey.

Individual exposures to mine fire-related fine particles < 2.5 thousandths of a mm in diameter (PM<sub>2.5</sub>) were estimated by combining time-location diaries with air quality modelling conducted by CSIRO. The results showed that almost all Morwell participants, and some Sale participants, were exposed to mine fire-related PM<sub>2.5</sub>. Exposed participants were divided into *low*, *medium* and *high* PM<sub>2.5</sub> groups with mean cumulative 24 hour levels of approximately 6, 11 and 28 µg/m<sup>3</sup> respectively. The WHO Air Quality Guideline for 24 hour mean PM<sub>2.5</sub> is 25 µg/m<sup>3</sup>.

Based on an assessment for sampling bias, post-stratification weights for age and gender were developed and analyses were conducted using weighted methods of estimation. The primary analyses were undertaken by comparing the health outcomes in the *low*, *medium* and *high* PM<sub>2.5</sub> exposure groups with the health outcomes in the group who had *no* exposure. Statistical models were fitted to adjust for potential confounding effects of age, sex, education, employment, occupational exposures, tobacco smoking and alcohol consumption.

### General health

Relative to participants with *no* fire related PM<sub>2.5</sub> exposure, participants with *medium* exposure were 41% more likely (adjusted relative rate ratio; adj RRR 1.41, 95% CI 1.03, 1.93), and participants with *high* exposure were 89% more likely (adj RRR 1.89, 95% CI 1.37, 2.61), to report fair or poor health than to report excellent or very good health. Relative to participants with *low* fire related exposure, participants with *high* exposure were 37% more likely (adj RRR 1.37, 95% CI 1.03, 1.83) to report fair or poor health, than to report excellent or very good health. Overall, these findings indicated that poorer self-perceived health status, reported 2.5 years after the mine fire, was associated with all levels of mine fire-related PM<sub>2.5</sub> exposure, and the greatest adverse impact was observed in those with the highest exposure.

### Respiratory health

For all self-reported respiratory symptoms (current wheeze, chest tightness, nocturnal and resting shortness of breath, chronic cough and phlegm and current nasal symptoms) participants in each of the PM<sub>2.5</sub> exposed categories were at greater risk than participants with *no* exposure. The magnitude of the increases in respiratory symptom risk ranged from 15% to 110%. Similarly, risk of 'any' respiratory condition (asthma, COPD and nasal allergy combined) diagnosed in 2014 or later, was more than doubled in exposed participants relative to those with no exposure. However, the total proportion of people effected was less than 4%. Risk of current asthma was elevated in *low* versus *no* PM<sub>2.5</sub> exposure categories, but not in *medium* versus *no*, and *high* versus *no* PM<sub>2.5</sub> exposure categories. However, asthma symptom severity scores were slightly higher in asthmatics with *low* or



*high* fire-related PM<sub>2.5</sub> exposure compared to asthmatics with *no* fire-related PM<sub>2.5</sub> exposure. With the exception of chronic cough, further increments in PM<sub>2.5</sub> exposure severity did not result in increments in symptom prevalence, indicating that any level of fire-related PM<sub>2.5</sub> exposure was sufficient to trigger these respiratory symptoms. However, a more traditional dose response was observed with increasing PM<sub>2.5</sub> exposure category associated with increasing prevalence of chronic cough. This finding was particularly interesting as cough is part of the physiological response of the respiratory tract to clear particles.

Combined, the respiratory health symptoms were generally consistent with the premise that there was no safe level of PM<sub>2.5</sub>. It appeared that the *low*, *medium* and *high* exposure groups were all exposed to more PM<sub>2.5</sub> than was necessary to trigger respiratory symptoms.

### Psychological distress

There was a consistent relationship between exposure to mine fire-related PM<sub>2.5</sub> and trauma-related distress linked to that event, as measured by the Revised Impact of Events Scale (IES-R). This was apparent in all three subscales representing intrusive thoughts, avoidance behaviours and hyper-arousal, and for all three PM<sub>2.5</sub> exposure categories when compared to *no* exposure. The mean total IES-R score rose from 1.65 in the *no* exposure group to 11.17 in the *high* exposure group, representing a moderate traumatic impact of the mine fire on the mental health of the Morwell community 2.5 years after the event. On further examination a classical dose response relationship was identified, with increments in PM<sub>2.5</sub> exposure category associated with increments in some aspects of trauma-related distress, particularly intrusive thoughts.

General psychological distress in the preceding four weeks, measured with the K10 Psychological Distress Scale, was also associated with all categories of PM<sub>2.5</sub> exposure. However increasing severity of exposure made no further difference. The use of the K10 permitted some comparisons with other Australian data. For example, the average K10 scores of approximately 17 for both the *medium* and *high* exposure participants were indicative of *moderate* distress based on ranges used by the ABS. The 2014-2015 National Health Survey (NHS) data indicated that Adult Survey participants categorised as having *medium* or *high* fire-related PM<sub>2.5</sub> exposure, were almost twice as likely to score in the *high* or *very high* K10 severity categories compared to other Victorian rural and regional residents. However, self-reported doctor diagnoses of psychological conditions in 2014 or later were not found to be associated with mine fire exposure.

### Doctor diagnosed conditions

We did not identify any significant relationships between exposure to mine fire-related PM<sub>2.5</sub> and self-reported doctor-diagnosed high blood pressure, high cholesterol, any cardiovascular condition, diabetes or cancer. In the Adult Survey Volume 1 Report we found that Morwell participants were 1.4 times more likely than Sale participants to report doctor diagnosed high blood pressure in 2014 or later, and seven times more likely to report doctor diagnosed high heart attack in 2014 or later. However, the total numbers of cases were small and it was not possible to replicate those findings with the cases divided into four exposure categories in the current analysis.

There are a few explanations for why doctor diagnosed medical conditions may not have increased with PM<sub>2.5</sub> exposure, even though health symptoms have. Possible explanations include that: symptoms have been sub-clinical, participants have not reported their symptoms to medical practitioners and the process from symptom onset to diagnosis may often be protracted.

## Strengths and limitations

The Adult Survey has a number of strengths which gave confidence to the observed findings. These include a satisfactory response rate, statistical weighting for known differences between groups in age and gender, adjustment for known health risk factors, use of validated and reliable questionnaires, and detailed individual exposure estimates incorporating spatially and temporally resolved PM<sub>2.5</sub> concentration modelling based upon coal combustion and weather conditions. Given the small p values for some health outcomes, our findings are unlikely to have occurred by chance, even in the context of multiple comparisons. We concede that the data, self-reported more than two years after the mine fire event, were vulnerable to sampling bias and response bias. However, for some health outcomes the most highly exposed participants did not report more symptoms than those less exposed, suggesting at least that systematic over-reporting by exposed participants has not occurred. Importantly, the use of a refuser questionnaire also indicated that people with poor health were not over-represented amongst the Morwell participants. However, we do acknowledge the likelihood of some residual confounding from unmeasured risk factors.

## Conclusions

This study broadly concludes that Hazelwood mine fire-related PM<sub>2.5</sub> levels were sufficient to adversely impact on self-reported health status, respiratory symptoms and psychological health in the exposed community more than two years after the event.

These findings comprise just one part of a broader complement of research involving the Adult Survey participants. In particular, the Hazelwood Health Study Hazelinks Stream will be linking the Adult Survey participants to hospital, ambulance, cancer and mortality databases. The Psychological Impacts Stream will be adding interview data and a second round of survey data to the Adult Survey. The Cardiovascular and Respiratory Streams will be adding clinical examination data collected from Adult Survey participants. Upon completion, this program of research will provide a comprehensive overview of the health and wellbeing of the Adult Survey participants.

These findings have important public health implications in regard to planning the response to future extended smoke events and planning for the health service needs of the Latrobe Valley. The findings are important for GPs, medical specialists and other health professionals in the Latrobe Valley, when responding to community members' health issues.

## 1. Introduction

During February and March 2014, a brown coal fire burned in the Hazelwood power station open-cut pit, causing a period of smoky conditions in the Latrobe Valley, Victoria. The fire was unusual in that it burned and emitted smoke at the same location, adjacent to the town of Morwell, for over a month and was larger than previous coal fires in Australia or overseas. There were few precedents upon which to base public health protection messages or to assess adverse health effects. In response to community concerns about the potential health impacts of exposure to the smoke, the Victorian State Department of Health and Human Services (DHHS; formerly the Department of Health) determined that it was important to learn from the fire, particularly for:

- the benefit of the local community who [were] exposed to this smoke by monitoring any potential long term health effects; and
- assisting health authorities, environment protection agencies and emergency services to inform and improve future policy and planning in the event of future similar events.

In order to achieve these objectives, the DHHS released a Request for Tender for *A long term study into the potential health effects from the Hazelwood coal mine fire*. On 30 October 2014, the DHHS awarded the tender to a Monash University-led research team with collaborators from Federation University, the University of Tasmania, University of Adelaide and CSIRO.

The Hazelwood Health Study (HHS) is a program of research that comprises several research streams, each with their own aims and objectives. They include the:

- Adult Survey stream (upon which this report is based), which focused on the health of adults who lived in Morwell at the time of the fire, relative to a comparison group of adults who lived in Sale.
- Latrobe Early Life Follow-up (ELF) stream, which focused on the health and development of infants born in the Latrobe Valley close to the time of the mine fire;
- Psychological Impacts stream, which included a focus on school-aged children (also termed the Schools Study) and on adults, including information collected as part of the Adult Survey;
- Community Wellbeing stream, which described the perceived impact of the event on community wellbeing as well as effectiveness of community rebuilding activities and of communications during and after the event;
- Impact on Older People stream, which has completed a review of the policy decisions made in regard to older people during the event and has now merged with the Community Wellbeing stream to share findings;
- Hazelinks stream, which investigated short, medium and long term health effects across the Latrobe Valley by using routinely collected health databases such as ambulance, hospital, cancer, medical services and pharmaceuticals use, and death data.
- Respiratory stream, which has tested adults in Morwell and Sale to determine whether Hazelwood mine fire smoke exposure was associated with respiratory symptoms, asthma control and lung function, gas transfer and small airway function; and the
- Cardiovascular stream, which has tested adults in Morwell and Sale to determine whether Hazelwood mine fire smoke exposure was associated with blood pressure, changes in electrocardiographs, early vascular disease and inflammatory markers.

This Report comprises Volume 2 of the findings from the Hazelwood Health Study Adult Survey. Specifically, Volume 2 presents the Adult Survey aims, methods and results specific to the measurement of the association between estimated individual levels of exposure to the mine fire smoke and the health of adults in Morwell and Sale.

This Volume 2 Report should be read in conjunction with the Adult Survey Volume 1 Report entitled 'Hazelwood Health Study Volume 1 Comparison of Morwell and Sale'. Released in September 2017, the Volume 1 Report can be found on the Hazelwood Health Study website at [hazelwoodhealthstudy.org.au/study-findings/study-reports/](http://hazelwoodhealthstudy.org.au/study-findings/study-reports/).

## **2. Research Question**

The Adult Survey research question addressed in this Volume is as follows:

Is there evidence that people who were heavily exposed to emissions from the Hazelwood mine fire, compared with otherwise similar people who were less or minimally exposed to emissions from the fire, currently have clinical cardiovascular, respiratory or psychological conditions that could be associated with clinically important adverse health consequences in the future?

## **3. Human Research Ethics Committee approval**

The protocol for the Adult Survey was approved by the Monash University Human Research Ethics Committee (Project number 6066) for the period 21 May 2015 to 21 May 2020.

## **4. Methods**

The Volume 1 Report described the Adult Survey aims, methods and results specific to a cross-sectional comparison of the self-reported health of adults in Morwell with those in Sale. Those included the eligibility criteria, sample size, contact and recruitment methods, promotional materials, instruments, scoring, coding and data quality control measures. Where those methods were relevant to the Volume 2 analyses, they have been only briefly summarised here. However, any methods that are new to this Volume 2 Report have been described in full.

### **4.1. Study Design**

This part of the Adult Survey comprised a cross-sectional study of self-reported health.

### **4.2. Eligible subjects**

Participation in the Adult Survey was open to people who, as at 31 of March 2014, were aged 18 years or older and who were residents of Morwell or one of 16 selected statistical areas Level 1 (SA1s) of Sale. The electoral roll maintained by the Victorian Electoral Commission (VEC) was the sampling frame from which eligible subjects and their contact details were first obtained.

### 4.3. Final sample size

At the time of the Hazelwood mine fire in February 2014, the VEC identified 9,448 adults registered on the electoral roll as residents of Morwell, and 4,444 adults registered as residents of the targeted SA1s in Sale. These numbers excluded unknown numbers of 'silent' electors and unregistered residents.

### 4.4. Contact and recruitment timeline and methods

A number of methods were employed in the attempt to contact and maximise recruitment of eligible adults from Morwell and Sale. As recruitment progressed, the researchers monitored feedback and revised their strategies. Recruitment into the Adult Survey launched in May 2016 in Morwell, and June 2016 in Sale, and closed in both towns in mid-February 2017.

#### 4.4.1. Direct contact methods

Using the name and address details provided by the VEC, all eligible adults were initially invited to participate via invitations mailed to their last known address.

Follow up with non-responders included attempts to speak with residents by telephone, mailed reminder postcards and final reminder packs.

#### 4.4.2. Indirect contact methods

In addition to contacting eligible residents directly via mail and calls to their VEC-listed home addresses, the researchers also undertook promotional activities throughout Morwell and Sale. Further to improving recruitment of residents from the VEC list, it was also hoped that these activities would facilitate recruitment of eligible residents who were not on the VEC list. These promotional activities included letter box delivery of promotional flyers, regular media activity, free catered events, posters and road-side banners.

### 4.5. Data collection

#### 4.5.1. Self-report survey

Adult Survey participants were invited to complete a self-report survey that included questions about demographics, health and wellbeing, health-related risk factors, the participants' residential- and work-address(es) during the mine fire period and job types. While the relevant sections of the questionnaire are summarised below, a copy of the questionnaire itself and more-detailed descriptions of some of its sections are available in the Adult Survey Volume 1 Report.

#### Section A - Details about you (questions A1-A14)

Participants were asked to provide demographic information such as their age, gender, marital status, highest level of education completed and employment status.

#### Section B – General health

##### Self-perceived general health status (question B1)

The first question from the Short Form 12 Health Survey (SF-12)<sup>[1]</sup> was used as a broad measure of self-perceived general health status. That question has previously been used as a brief stand-alone measure of health status in the Australian Health Surveys,<sup>[2]</sup> with responses grouped in to three categories: excellent/very good; good; fair/poor.

## Doctor-diagnosed medical conditions (questions B2 – B5)

Participants were asked to report whether or not a medical doctor had ever told them they had high blood pressure, high cholesterol, angina, heart attack, heart failure, irregular heart rhythm, other heart disease, stroke, cancer, diabetes, anxiety, depression, post-traumatic stress disorder, other mental health conditions or other medical conditions not previously listed. If 'yes', the year of first diagnosis or episode was requested. If the response was 'yes' to diabetes, the type of treatment was also requested.

If participants reported a medical condition with year of first diagnosis or episode in 2013 or earlier, these were coded as *prior to the mine fire*. If participants reported a medical condition with year of first diagnosis or episode in 2014 or later, these were coded as *post mine fire*.

## Section C - Respiratory health (questions C1-C14)

A modified version of the European Community Respiratory Health Survey (ECHRS)<sup>[3]</sup> was included to identify respiratory symptoms such as wheeze, shortness of breath, cough and sputum and respiratory conditions such as asthma. Pekkanen *et al*<sup>[4]</sup> developed an asthma severity score based on eight symptoms from the ECRHS questionnaire. Seven of those questions were included in the Adult Survey and formed the basis of a modified asthma severity score.

The specific respiratory outcomes included in the analyses, and their associated ECHRS<sup>[3]</sup> questions in the Adult Survey, are shown in Table 1.

**Table 1 Respiratory outcomes and their associated ECHRS questions in the Adult Survey questionnaire**

Respiratory outcome	Adult Survey question no.	Adult Survey question drawn from the ECHRS
Current wheeze	C1	Wheezing or whistling in your chest at any time in the last 12 months
Chest tightness	C2	Woken up with a feeling of tightness in your chest at any time in the last 12 months
Nocturnal short of breath	C3	Woken by an attack of shortness of breath at any time in the last 12 months
Resting short of breath	C4	An attack of shortness of breath that came on during the day when you were at rest at any time in the last 12 months
Chronic cough	C11	Cough on most days for as much as three months a year
Chronic phlegm	C12	Bring up phlegm from your chest on most days for as much as three months a year
Current nasal symptoms	C9 and C10	Ever had a problem with sneezing, or a runny or a blocked nose when you did not have a cold or the flu; and in the last 12 months
Current asthma	C6	An attack of asthma in the last 12 months
Asthma and/or COPD since 2014	C5A+C13A from 2014	Asthma, chronic obstructive pulmonary disease or emphysema in 2014 or later
Any respiratory conditions since 2014	C5A+C13A+C8A from 2014	Asthma, chronic obstructive pulmonary disease or emphysema, or nasal allergies including hay fever in 2014 or later

## Section D - Smoking history (questions D1-D3)

Cigarette smoking has been associated with many diseases,<sup>[5]</sup> and therefore it was essential to measure participants' exposure to tobacco smoke. Respondents indicated whether they had ever smoked at least 100 cigarettes, or a similar amount of tobacco, in their lifetime. Participants who answered 'No' were defined as *never smokers* as per the World Health Organization (WHO) definition.<sup>[6]</sup> Participants who answered 'Yes', then reported whether they were current daily, weekly or *less than weekly* smokers, or *former* or *occasional* smokers.

## Section E - Current wellbeing in regard to the Hazelwood event (questions 1-22)

The Impact of Events Scale – Revised (IES-R)<sup>[7]</sup> was used to measure the current (at the time of assessment), subjective level of distress associated with the Hazelwood smoke event. The scale involved 22 items which respondents scored on a 0-4 scale (0 = Not at all; 1 = A little bit; 2 = Moderately; 3 = Quite a bit; 4 = Extremely). The items were grouped into three sub-scales which aligned with the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) diagnostic criteria for Post-Traumatic Stress Disorder (PTSD). The sub-scales were *Intrusion* (such as intrusive thoughts of the event), *Avoidance* (such as trying not to think about the event) and *Hyperarousal* (such as being jumpy and easily startled). Scoring the IES-R involved calculating the sum of the response items for each of the sub-scales and for the total score (so the total could range from 0 to 88).

The IES-R subscales have been shown to have high internal consistency, with coefficient alpha scores ranging from 0.79 to 0.95 and acceptable six-month test-retest reliability correlations ranging from 0.57 to 0.92.<sup>[7], [8]</sup>

The IES-R was not designed as a diagnostic tool. However, researchers who have compared the IES-R with results from a diagnostic interview have suggested a range of cut off scores to indicate a probable diagnosis of PTSD, including 22 and above,<sup>[9]</sup> 33 and above<sup>[10, 11]</sup> or even 44 and above.<sup>[12]</sup>

## Section F – Residence during the Hazelwood mine fire and relocation (questions F1 and F7)

Residential address at the time of the mine fire (labelled *mine fire address*) was initially collected in order to determine eligibility to participate in the Adult Survey. Participants were also asked to provide the address for any different location(s) that they slept at during the mine fire period, and the associated dates for those relocations.

The mine fire address, and the relocation addresses with their associated dates, were important to the estimate of each participant's level of exposure to mine fire-related air pollutants (refer section 4.5.3).

The mine fire address was also used to calculate an Index of Relative Socio-economic Advantage and Disadvantage (IRSAD)<sup>[13]</sup> score for each participant. As described by the ABS, the IRSAD summarised information about the economic and social conditions of people and households within an area, including both relative advantage and disadvantage measures. A low score indicated relatively greater disadvantage and a lack of advantage in general. For example, an area could have a low score if there were:

- many households with low incomes, or many people in unskilled occupations, AND
- few households with high incomes, or few people in skilled occupations.



A high score indicated a relative lack of disadvantage and greater advantage in general. For example, an area may have a high score if there were:

- many households with high incomes, or many people in skilled occupations, AND
- few households with low incomes, or few people in unskilled occupations.

### Section G – Work history (questions G1-G11)

From a list provided, participants were asked to report any paid jobs they had held for at least six months which may have involved exposure to dust, fumes, smoke, gas vapour or mist. Examples included construction, farming, driving diesel vehicles, spray painting, saw mill, asbestos removal and cleaning jobs. Participants were also asked to report employment in the Latrobe Valley coal mines or power stations. Information was also requested about paid or volunteer positions with the emergency services and, specifically, fire fighting in the Hazelwood mine fire Controlled Area.

Based upon responses, participants were divided into three occupational exposure categories:

**Not exposed:** These participants reported never holding any of the listed jobs for at least six months, nor any other job that involved breathing a lot of dust, fumes, gas, vapour or mist.

**Coal mine or power station:** These participants reported having worked at a coal mine or coal fired power station in the Latrobe Valley for at least six months, excluding office-based administrative jobs.

**Exposed, but not coal mine or power station:** These participants reported that for at least six months they either had one of the listed jobs or another job that involved breathing a lot of dust, fumes, gas, vapour or mist, but not a coal mine or coal fired power station job.

### Section H – Work location during the period of the fire (questions H1-H14)

Participants were asked to provide the job title, address, average number of hours per week and usual days per week for any jobs held during the mine fire period. For jobs which had multiple, changing addresses, eg. delivery driver, builder or emergency responder, participants were asked whether their job locations were mostly or entirely in Morwell, mostly outside of Morwell but in the Latrobe Valley or mostly or entirely outside of the Latrobe Valley.

Some businesses had relocated during the mine fire period in order to move further away from the smoke. Therefore, participants were asked to report whether their job had relocated and, if applicable, to provide the address and dates for that relocation. Similarly, participants were asked to report whether they took leave from their job during the mine fire period and to provide the address (home or elsewhere) and dates for that leave period.

The job addresses with their associated work hours and usual days per week, in combination with any relocation addresses and associated dates, were important to the estimate of each participant's level of exposure to mine fire-related air pollutants (refer section 4.5.3).

### Section HH – First 20 days/nights of the Hazelwood mine fire (questions H17A-H17B)

It was likely that some participants may have had difficulty recalling the relocation dates and addresses for Sections F and H of the survey. Further to that, air pollution modelling showed that the highest levels of mine fire-related air pollutants occurred in the first three weeks after the fire started (refer to section 4.5.2 for more detail). For these reasons, we asked participants to estimate,



for the 20-day period between 9 February and 28 February 2014, how many days and how many nights were spent entirely or mostly in Morwell.

### Section I - Recent wellbeing (questions I 1–10)

The Kessler Psychological Distress Scale (K10)<sup>[14]</sup> is a brief 10-item scale which was developed as a population screen for psychological distress in the previous four weeks. Kessler *et al.*<sup>[15]</sup> assessed the suitability of the K10 as a screen for serious mental illness and reported that it performed as well as more lengthy clinical measures, with a high Cronbach alpha internal consistency score of 0.93. However, unlike the IES-R, the K10 was not specific to an event.

The K10 has been commonly used in Australian population health surveys, such as the ABS Australian National Health Survey (NHS)<sup>[16]</sup>, the Victorian Population Health Survey<sup>[17]</sup> and the 45 and Up Study.<sup>[18]</sup> Therefore, there were useful benchmarks against which the Adult Survey K10 results can be compared.

Each item was scored on a 1-5 scale (1=none of the time; 2=a little of the time; 3=some of the time; 4=most of the time; 5=all of the time), resulting in a total score ranging from 10 to 50. There were no set cut-offs for the K10. However we decided to adopt the groupings used by the ABS,<sup>[19]</sup> those being 10-15=Low, 16-21=Moderate, 22-29=High and 30-50=Very high.

### Section K - Alcohol use (questions K1-K3)

High alcohol consumption has been associated with numerous diseases in the Australian population including cardiovascular diseases, also social problems, hospitalisations and death.<sup>[2]</sup> The three-item Alcohol Use Disorders Identification Test (AUDIT-C), which was based upon the longer 10-item AUDIT,<sup>[20]</sup> was included in the Adult Survey as a brief measure of alcohol consumption. The utility of the AUDIT-C has been extensively assessed, including a systematic review of 47 articles which confirmed the psychometric properties of the measure.<sup>[21]</sup>

The three items related to the frequency of drinking alcohol in the past year, the number of drinks on a typical day and the frequency of drinking more than six standard drinks on the one occasion. Each item was scored on a zero (never) to 4 scale. The total score was the sum of the three items, thus ranging from zero to 12. Amongst drinkers, a threshold score of 3 or more for women, and 4 or more for men, has been used to identify high risk drinkers.<sup>[22]</sup>

### Modes of health survey completion

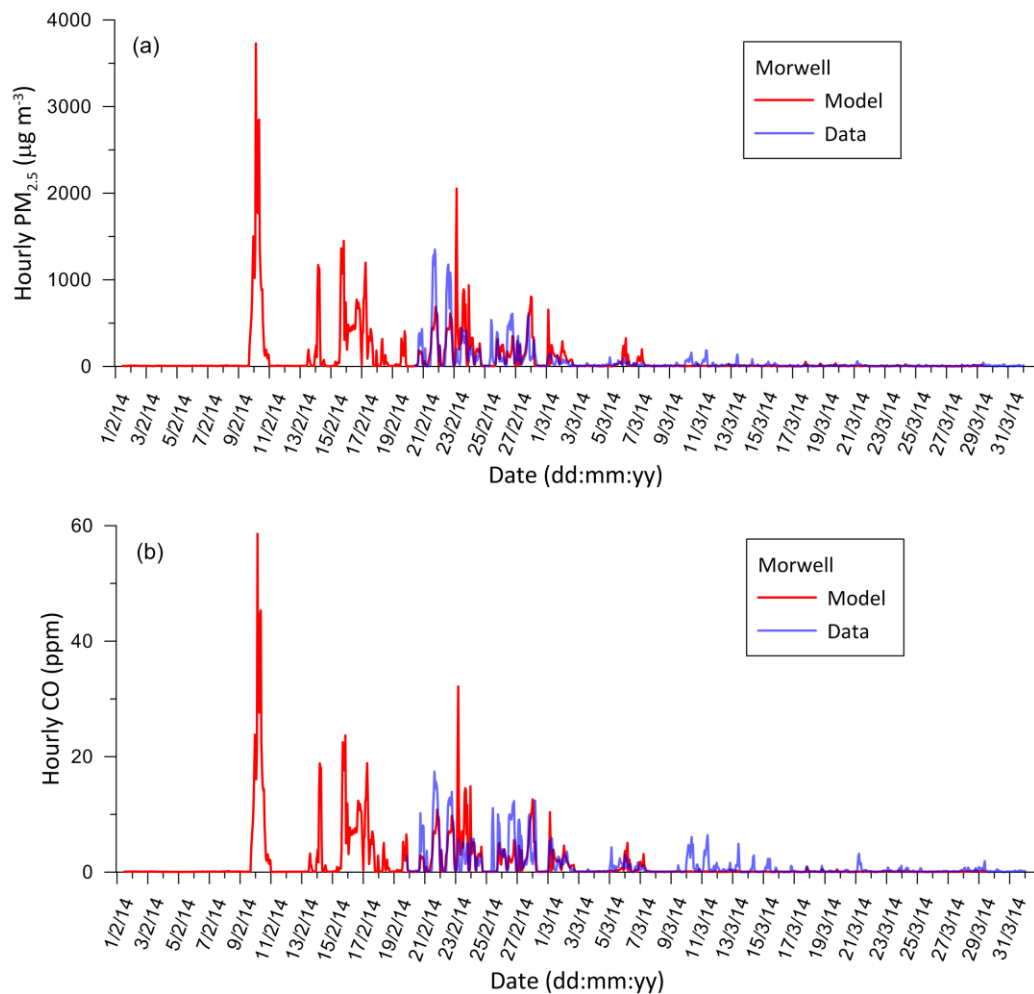
Participants were offered the option of completing the self-report health survey in one of three ways:

1. Computer assisted telephone interview (CATI)
2. Computer assisted web-based interview (CAWI)
3. Paper questionnaire

### 4.5.2. Air quality modelling

In order to address the research question about health outcomes in adults who were heavily exposed to emissions from the Hazelwood mine fire, compared with those less or minimally exposed, it was necessary to obtain measurements, or estimates, of mine fire-related air quality. The mine fire period was considered to be the 51 days and nights from 9 February to 31 March 2014

inclusive. However, air quality measurements in the southern part of Morwell, closest to the mine fire, did not start until 10 days after the fire started.



**Figure 1 Hourly-averaged observed and modelled concentrations of (a) fine particles (PM<sub>2.5</sub>) and (b) Carbon Monoxide (CO) at southern Morwell.**

Source: Emmerson et al (2016) Air quality modelling of smoke exposure from the Hazelwood mine fire. CSIRO Australia. Available at <http://hazelwoodhealthstudy.org.au/study-findings/study-reports/>

To complement air quality measures that were made during the mine fire, the CSIRO Oceans and Atmosphere Flagship conducted an air quality modelling study.<sup>[23]</sup> To assess the air quality impacts on nearby communities, concentrations of two major pollutants from the fire were estimated, namely fine particles smaller than 2.5 thousandths of a millimetre (PM<sub>2.5</sub>) and carbon monoxide (CO) which is a product of incomplete combustion. PM is a common proxy indicator for air pollution and may contain a number of solid or liquid pollutant particles. PM<sub>2.5</sub> particles are considered sufficiently small so as to penetrate the lungs and some may enter the blood stream ([http://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)). The CSIRO scientists used weather information such as wind direction, wind speed and temperature, combined with an estimate of how much coal was burned each day during the fire using fire activity maps provided by the Country Fire Authority. Air quality measurements made by the Environmental

Protection Authority (EPA) Victoria near the fire location were used to calculate the amount of PM<sub>2.5</sub> and CO released per unit mass of burning coal. All of this information was entered into computer models to predict the levels of PM<sub>2.5</sub> and CO in the Latrobe Valley and surrounding areas for the duration of the fire.

Figure 1 shows that within the southern area of Morwell, a very high resolution model (100 to 300 meters - about street size) estimated hourly averaged concentrations of PM<sub>2.5</sub> to peak as high as 3700 micrograms per cubic metre of air ( $\mu\text{g}/\text{m}^3$ ) during the early period of the fire. The concentrations of PM<sub>2.5</sub> returned to usual levels of about 6  $\mu\text{g}/\text{m}^3$  in the Latrobe Valley by 12 March 2014. Modelled peak hourly concentrations of CO in the southern area of Morwell reached 60 parts in one million (ppm), with usual levels being about 0.07 ppm. The modelled concentrations were compared with measured data when available and found to be similar (Figure 1).

Using a lower resolution model (3 km) the peak hourly averaged PM<sub>2.5</sub> concentration predicted at Sale was only 17  $\mu\text{g}/\text{m}^3$  on 10 February 2014, while peak CO was 0.46 ppm on 22 February 2014. These data validated the selection of Sale as a comparison community with minimal to no mine fire smoke exposure.

#### 4.5.3. Exposure assessment

In order to estimate individual Adult Survey participant's exposure to mine fire-related PM<sub>2.5</sub>, it was necessary to blend the modelled air quality data with the locations of participants on each day and night of the mine fire period.

Using information provided by participants in sections F, H and HH of the self-report survey (see section 4.5.1), a metric was created which included every residential-, work- or relocation-address reported, the SA1s in which those addresses were located (if that could be determined) and an estimate of the fraction of each 12-hour day (6am to 6pm), or 12-hour night (6pm to 6am), that the participant spent at that address. If a participant's time-location diary was incomplete or inconsistent, eg. the participant reported being on leave and at work on the same day, this was manually reviewed by the researchers, cross-checked against other information known about the participant and supplemented with the most likely correct response. All work was assumed to be during the day.

CSIRO's gridded high resolution hourly PM<sub>2.5</sub> estimates were concatenated (aggregated and averaged) to create hourly SA1 area level concentrations. The hourly SA1 concentrations were then aggregated to create average 12-hour day and 12-hour night SA1 concentrations. The participant's address SA1s, and their associated fractions, were then matched with the relevant modelled 12-hour average PM<sub>2.5</sub> levels for those SA1s in order to give each participant a mine fire-related PM<sub>2.5</sub> exposure for every 12-hour day and night of the mine fire period.

When only the SA2 for a given address could be identified, that address was given the mean exposure level for that SA2. All interstate or international addresses were given a zero exposure score.

It was assumed that the exposure dose was proportional to the fraction of time that a participant spent at a given address. For example, if a participant spent six hours of a 12-hour day (0.5 fraction) on 9 February 2014 at Address A, and the mine fire-related mean PM<sub>2.5</sub> exposure for Address A's SA1 during this time period was 50  $\mu\text{g}/\text{m}^3$ , then the exposure dose for the participant was  $0.5 \times 50 = 25 \mu\text{g}/\text{m}^3$ . The cumulative mine fire-related PM<sub>2.5</sub> exposure for each participant was then obtained by

summing the exposure doses for all time periods and for all addresses that the participant reported being at during the mine fire period.

For easy comparison, the cumulative 12-hour mine fire-related PM<sub>2.5</sub> exposure was averaged across 102 12-hour time blocks (51 days and nights of the data collection period) to obtain the mean mine fire-related PM<sub>2.5</sub> exposure for all participants.

#### **4.5.4. Refuser Questionnaire**

Residents not wishing to participate in the study were offered the option of completing five brief questions in relation to their current health, smoking status, reasons for not participating, sex and age. The responses to these questions were included in the Adult Survey Volume 1 report as a source of information from which to assess the representativeness of participants relative to refusers.

### **4.6. Data quality**

There were a number of strategies used to optimise the quality of the data collected from Adult Survey participants.

#### **4.6.1. Instrument selection**

Where possible the Adult Survey used previously-validated data collection instruments and previously-published scoring procedures as described in section 4.5.

#### **4.6.2. Pilot studies**

The Adult Survey Information Sheet, Consent Form and questionnaire were piloted in two phases which are described in Volume 1. Feedback from pilot study participants was used to improve the Survey materials so as to minimise misconceptions about, or barriers to, participation, also to maximise readability, provide clarification around the purpose of some questions and improve instructions.

#### **4.6.3. Training**

All staff involved in Adult Survey recruitment, data collection or data entry completed a course on *Ethics and Good Research Practice* run by the Monash University. A *Database Procedures Manual*, developed and maintained by the Hazelwood Health Study Data Manager, was reviewed by all staff to ensure consistency in data entry across the project. All interviewers received training in regard to the background to the Adult Survey and the purpose of the questions in the questionnaire.

#### **4.6.4. Data entry, cleaning and missing data**

Survey data collected by CATI or CAWI were direct-entered online. There were a number of checks programmed into the online database in order to detect missing, invalid, inconsistent or outlying results. Completed paper questionnaires were double keyed by Datatime Pty Ltd with disparities assessed and corrected by a supervisor.

All data were subject to statistical checks for missing, invalid, inconsistent or outlying results. Where such problems were found in the data, decision rules were made which allowed most records to be

'cleaned' in preference to being treated as missing. Where data remained missing after cleaning and decision rules were applied, methods of imputation were employed as part of the statistical analysis (see 4.7 for further details).

## 4.7. Statistical analyses

Statistical analysis and data transformations were predominantly performed using Stata version 15 (Stata Corporation, College Station, Texas 2015).

### 4.7.1. Imputation for missing values

Missing data could sometimes lead to biased estimates, if the reasons for the data being missing were related to the variables of interest. For most of the variables in the Adult Survey data, the missing proportion was generally less than 1%. However, for some multi-scaled instruments the missing proportions were as high as 5%. To obtain more accurate estimates, and to control for non-response bias, multiple-imputation (MI) procedures<sup>[24, 25]</sup> were incorporated in the analysis. These were described in more detail in Volume 1.

### 4.7.2. Assessment of sampling bias and weighting of participant results

*Sampling (participation or selection) bias* could occur if participants differed from non-participants on characteristics which were associated with the study outcomes, such as health status. A complete examination of sampling bias would require the collection of comprehensive and current health, demographics and mine-fire smoke exposure information for all of the non-participating Morwell and Sale subjects. Such comprehensive data were not available for non-participants. However, there were some data sources available which could be used to assess the extent to which the study participants were representative of the populations from which they were drawn.

These sources included data on gender, age, self-perceived health status and smoking status which was collected in the Refuser Questionnaire; Australian Bureau of Statistics (ABS) 2011 Census data<sup>[16]</sup> on age and gender in Morwell and Sale; Victorian Population Health Survey 2011-12 data<sup>[17]</sup> on smoking status in Latrobe City and the Shire of Wellington; and CSIRO modelled data on air pollution for each SA1 in Morwell for the period of the mine fire.

Based on the findings of the assessment for sampling bias, post-stratification weights were developed and all further analyses were conducted using weighted methods of estimation. Details can be found in Volume 1.

### 4.7.3. PM<sub>2.5</sub> exposure category (smoke exposure)

All participants from Morwell and Sale with zero cumulative exposure to mine fire related PM<sub>2.5</sub> were combined as the reference group with no PM<sub>2.5</sub> exposure. Remaining participants were divided into tertiles (thirds) representing *low*, *medium* and *high* exposure groups based on their average exposure to PM<sub>2.5</sub>.

#### **4.7.4. Comparison of health outcomes between participants with no, low, medium and high-smoke exposure.**

Differences in demographic characteristics and health-related risk factors, between participants with *no, low, medium* and *high* PM<sub>2.5</sub> exposure, were assessed using weighted Pearson chi-squared tests for categorical measures and weighted t-tests for continuous measures. When the distribution of a continuous variable was extremely skewed, the non-parametric Kruskal-Wallis test was used to compare groups.<sup>[26]</sup>

The difference in incidence of health outcomes diagnosed after the fire (in 2014 or later), between participants with *no, low, medium* and *high* PM<sub>2.5</sub> exposure, were quantified as crude rate ratios (RR) and adjusted rate ratios (adj RR). The adj RRs were obtained by fitting a log binomial regression model and controlling for a set of key confounders that was used throughout: comprising age, gender, education, employment, level of alcohol consumption, smoking and occupational exposure. When log binomial regression failed to converge, log Poisson regression was used instead.

Continuous outcomes and sums of dichotomous or scaled items (e.g. IES-R scores) were compared between participants with *no, low, medium* and *high* PM<sub>2.5</sub> exposure, using mean differences (mean diff) and adjusted mean differences (adj mean diff) using multiple linear regression to control for the key confounders.

Differences between exposure groups in outcomes measured as categorical variables (e.g. SF-12 categories 'excellent/very good'; 'good'; 'fair/poor'), were presented as crude and adjusted relative risk ratios (adj RRR) using multinomial logistic regression which incorporated the key confounders.

All of the regression analyses accounted for post-stratification weights, sampling stratification (Morwell vs Sale) and clustering at household level.

#### **4.7.5. Comparison of health outcomes between participants with medium versus low, and high versus low PM<sub>2.5</sub> exposure**

In order to further investigate the exposure dose response-relationship within Morwell participants, a separate set of regression analyses were conducted using only information from 3,095 Morwell participants who had mine fire-related PM<sub>2.5</sub> exposure. In those analyses, the reference group was set as the *low* PM<sub>2.5</sub> exposure. Adjusted RR, RRR and mean differences were reported for *medium* and *high* PM<sub>2.5</sub> exposure groups each compared with the *low* PM<sub>2.5</sub> exposure group, controlling for key confounders.

## 5. Results

### 5.1. Recruitment and assessment for sampling and response bias

The Adult Survey recruitment results and assessment of sampling bias have been described in detail in the Volume 1 Report and are only summarised briefly here.

The researchers attempted to recruit adults who were on the electoral roll, and also others who had lived in Morwell or Sale, but were not on the VEC list. Of the 9,448 adults identified by the VEC as residing in Morwell at the time of the mine fire, 435 were ascertained to be either deceased (n=326) or ineligible. Consequently the recruitment denominator for the Morwell group was **9,013**.

Of the 4,444 adults identified by the VEC as residing in the targeted areas of Sale, 238 were identified as being deceased (n=174) or ineligible. Consequently, the recruitment denominator for the Sale group was **4,206**.

Table 2 shows that over a third (34%) of the eligible Morwell sample, and almost a quarter (23%) of the eligible Sale sample, participated in the Adult Survey.

**Table 2 Recruitment outcomes for the Morwell and Sale residents on the Victorian Electoral Roll.**

	Morwell	Sale		Study total
VEC list recruitment rate denominator	N=9,013	N=4,206		N=13,219
	n (%)	n (%)	$\chi^2$ p-value	n (%)
Participants	3037 (34%)	957 (23%)	<0.001	3994 (30%)
Refusers	1170 (13%)	829 (20%)		1999 (15%)
Non-responders	4806 (53%)	2420 (58%)		7226 (55%)

While registration on the Electoral Roll is compulsory in Australia, there would have been a number of Morwell and Sale residents who were not listed in the VEC data for various reasons. However these residents remained eligible to participate. Termed 'opt-ins', 59 Morwell residents and three Sale residents, who were not included on the VEC list, participated in the Adult Survey.

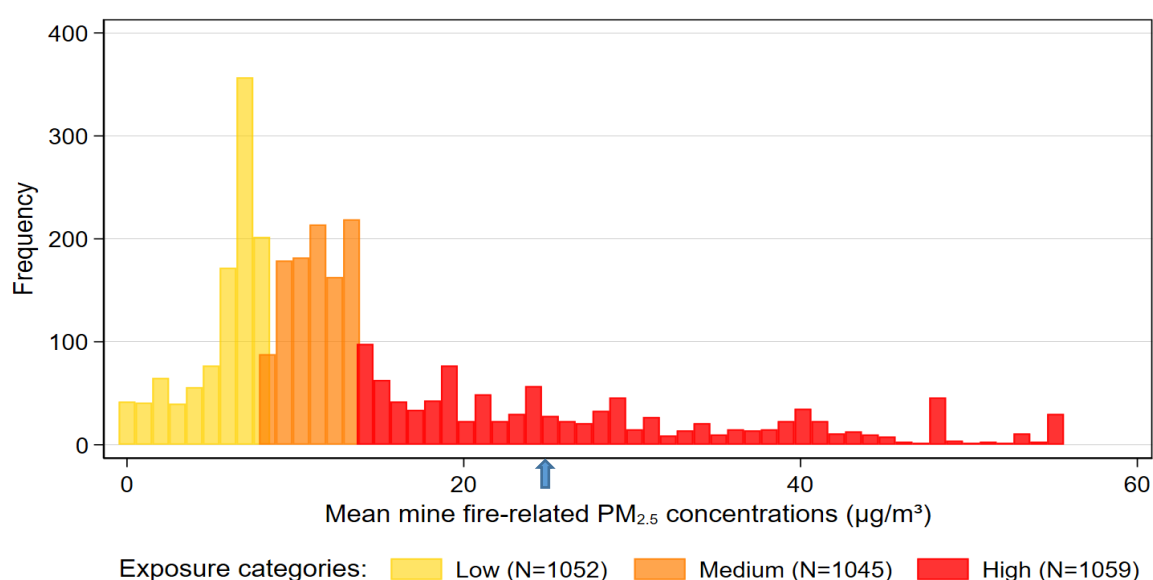
The final number of participants in the Adult Survey was **3,096 in Morwell** and **960 in Sale**.

There were some data sources available which could be used to assess the extent to which the study participants were representative of the populations from which they were drawn. They included the ABS 2011 Census, 2011-2012 Victorian Population Health Survey and a questionnaire administered to 358 Adult Survey refusers. Based on our assessment of these, it was determined that there was some over-representation of women and older people participating in the Adult Survey, in both Morwell and Sale. There were also some differences between participants and their communities in smoking patterns. To minimise the possible bias conferred by these factors and promote confidence in the findings, results were weighted to account for the differences between participants and non-participants in gender and age, and smoking was included in all statistical analysis as a potential confounding variable.

Morwell participants reported a similar pattern of self-perceived health as Morwell refusers on the refuser questionnaire. This was an important observation because, if people with poor health were over-represented in the Morwell participants, that would artificially inflate the observed differences between Morwell and Sale.

## 5.2. Exposure to PM<sub>2.5</sub>

There were 899 Sale participants and one Morwell participant with zero cumulative exposure to mine fire related PM<sub>2.5</sub>. They comprised the 'no exposure' reference group. The Morwell participant with zero exposure had been out of the Latrobe Valley for the duration of the mine fire period. The remaining participants were divided into *low*, *medium* and *high* PM<sub>2.5</sub> exposure, groups based on tertiles of their average cumulative 24-hour exposure to PM<sub>2.5</sub>. The distributions are shown in Figure 2 and **Error! Reference source not found.** along with the WHO Air Quality Guideline for 24-hour mean PM<sub>2.5</sub>.



↑ The WHO Air Quality Guidelines recommend a 24-hour mean PM<sub>2.5</sub> limit of 25 µg/m<sup>3</sup>

**Figure 2 Frequency of participants across mean cumulative 24-hour fire-related PM<sub>2.5</sub> levels.**

**Table 3 Mean cumulative 24-hour fire-related PM<sub>2.5</sub> concentrations by exposure category.**

No exposure N=900	Category of PM <sub>2.5</sub> exposure		
	Low N=1052	Medium N=1045	High N=1059
Weighted mean (Range)	Weighted mean (Range)	Weighted mean (Range)	Weighted mean (Range)
0 (0-0)	5.8 (>0.0-8.3)	11.2 (>8.3-14.1)	27.8 (>14.1-56.0)

The *low* exposure group included 992 participants from Morwell and 60 from Sale and the *medium* exposure group included 1,045 participants from Morwell and none from Sale. The *high* exposure group, comprising 1,058 participants from Morwell and one from Sale, represented the participants with the heaviest mine fire smoke exposure. In that group the mean cumulative 24 hour fire-related



PM<sub>2.5</sub> level of almost 28 µg/m<sup>3</sup> exceeded the WHO Air Quality Guideline of a 25 µg/m<sup>3</sup> limit ([http://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)). Sale participants with mine fire-related PM<sub>2.5</sub> exposure were found to have been exposed because they worked, or travelled for other reasons, in the areas effected by mine fire smoke.

### 5.3. Health-related risk factors

In order to estimate the independent health impact of the mine fire, it was necessary to consider other risk factors that may have affected the health of participants.

#### 5.3.1. Demographic measures

Table 4 shows that there was a relatively even distribution of males and females across the mine fire PM<sub>2.5</sub> exposure categories. The highly exposed participants were slightly older (by an average of 2 years) than those less exposed. However, slightly fewer participants with *medium* or *high* mine fire PM<sub>2.5</sub> exposure had achieved Certificate, Diploma or Tertiary level education compared to participants with *low* or *no* mine fire PM<sub>2.5</sub> exposure. Similarly, compared to participants with *low* or *no* mine fire PM<sub>2.5</sub> exposure, slightly fewer participants with *medium* or *high* mine fire PM<sub>2.5</sub> exposure were in paid employment and slightly more were not working due to ill health. The differences between exposure categories, in education and employment were unlikely to have arisen by chance and therefore reflect the importance of statistical adjustment for these health-related risk factors.

**Table 4 Demographic characteristics of participants by PM<sub>2.5</sub> exposure category.**

Characteristics	Category of PM <sub>2.5</sub> exposure				p-value
	No exposure N=900	Low N=1052	Medium N=1045	High N=1059	
	Weighted %	Weighted %	Weighted %	Weighted %	
<b>Gender</b>					
Male	44%	48%	50%	47%	0.104
Female	56%	52%	50%	53%	
<b>Highest education</b>					
Up to year 10	21%	25%	28%	26%	<0.001
Year 11-12	18%	20%	27%	23%	
Certificate/Diploma	42%	35%	32%	35%	
Tertiary degree	18%	19%	12%	15%	
<b>Employment</b>					
Paid employment	55%	53%	54%	50%	0.003
Student/volunteer/ home-duties/retired	37%	36%	33%	37%	
Unemployed	3%	6%	7%	5%	
Not working due to ill-health	4%	6%	7%	8%	
	<b>Weighted mean (SE)</b>	<b>Weighted mean (SE)</b>	<b>Weighted mean (SE)</b>	<b>Weighted mean (SE)</b>	
<b>Age</b>	50.4 (1.0)	50.3 (0.8)	49.0 (0.7)	52.3 (0.8)	0.031

<b>IRSAD Score</b>	904.8 (2.6)	901.2 (6.5)	846.8 (3.6)	840.0 (2.0)	<0.001
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### 5.3.2. Occupational risk factors

Table 5 shows the distribution of mine fire PM<sub>2.5</sub> exposure category for participants in each of the occupational exposure categories. It is apparent that participants who were categorised as having *high* mine fire PM<sub>2.5</sub> exposure were much more likely to have held coal mine or power station jobs, than participants categorised with *medium*, *low* or *no* mine fire PM<sub>2.5</sub> exposure. Furthermore, participants who were categorised as having *no* mine fire PM<sub>2.5</sub> exposure were slightly more likely to be in the 'not exposed' occupational category.

These findings highlighted the importance of statistically adjusting for occupational exposures, so that the health impacts of the mine fire could be assessed independently of the health impacts associated with past employment.

**Table 5 Occupational exposure category for participants by mine fire PM<sub>2.5</sub> exposure category.**

Jobs held for > 6 months	Category of PM <sub>2.5</sub> exposure				p-value
	No exposure N=900	Low N=1052	Medium N=1045	High N=1059	
	Weighted %	Weighted %	Weighted %	Weighted %	
Not exposed	66%	64%	63%	59%	<0.001
Coal mine or power station	2%	13%	12%	16%	
Exposed, but not coal mine or power station	32%	23%	24%	25%	

### 5.3.3. Tobacco and alcohol use

Participants' responses to questions about smoking cigarettes or other tobacco products were used to categorise their smoking status as shown in Table 6.

**Table 6 Participants' smoking status, and alcohol drinking risk, by mine fire PM<sub>2.5</sub> exposure category.**

Tobacco and alcohol exposure	Category of PM <sub>2.5</sub> exposure				p-value
	No exposure N=900	Low N=1052	Mid N=1045	High N=1059	
	Weighted %	Weighted %	Weighted %	Weighted %	
<b>Smoking status</b>					
Current smoker	13%	15%	19%	20%	<0.001
Former smoker	28%	27%	27%	30%	
Occasional	1%	2%	2%	3%	
Never	58%	55%	52%	47%	
<b>AUDIT-C risk</b>					
Non-drinker	21%	25%	25%	26%	0.005
Low risk drinker	33%	35%	38%	36%	
High risk drinker	46%	40%	37%	38%	

Participants who were categorised as having *high* mine fire PM<sub>2.5</sub> exposure were much more likely to have been 'current smokers' than participants categorised with *low* or *no* mine fire PM<sub>2.5</sub> exposure.

Similarly, participants who were categorised as having *no* mine fire PM<sub>2.5</sub> exposure were much more likely to have ‘never’ smoked relative to participants categorised with *medium* or *high* mine fire PM<sub>2.5</sub> exposure. Similar to the occupational exposure data, it was important to statistically adjust for smoking status so that the health impacts of the mine fire could be assessed independently from the health impacts associated with tobacco exposure.

Also shown in Table 6, the AUDIT-C responses were used to categorise participants as ‘non-drinkers’, ‘low risk drinkers’ and ‘high risk drinkers’. In contrast with the previous findings for occupational and tobacco exposures, results did not show that participants with *high* mine fire PM<sub>2.5</sub> were more likely to be ‘high risk drinkers’. Instead, participants categorised as having *high* mine fire PM<sub>2.5</sub> (all but one were Morwell participants) were more likely to be ‘non-drinkers’ relative to participants categorised with *no* mine fire PM<sub>2.5</sub> exposure (mostly Sale participants). Similarly, participants who were categorised as having *no* mine fire PM<sub>2.5</sub> exposure were much more likely to be ‘high risk drinkers’ than participants categorised with *low*, *medium* or *high* mine fire PM<sub>2.5</sub> exposure. Whilst alcohol consumption is not considered an important risk factor for respiratory disease, it is important to statistically adjust for alcohol use when investigating self-perceived health status, cardiovascular disease and mental health outcomes.

## 5.4. Health outcomes

### 5.4.1. Self-perceived health status

Table 7 shows the weighted proportion of participants, in each mine fire exposure category, who reported their health status to be excellent, very good, good, fair or poor. Between the *low*, *medium* and *high* exposure categories, there was little difference in self-reported health status (Table 7). However, it can be observed that participants in the *no* exposure category were generally more likely to report that their health was very good or excellent, and less likely to report that their health was fair or poor, when compared with the mine fire exposed participants.

This finding is further explored in Table 8, which compares each of the *low*, *medium* and *high* exposure categories, respectively, to the *no* mine fire PM<sub>2.5</sub> exposure category in regard to their perceived health status after controlling for key confounders. Relative to participants with *no* fire related exposure, participants with *high* exposure were 89% more likely, and participants with *medium* exposure were 41% more likely, to report fair or poor health than to report excellent or very good health.

**Table 7 Distribution of self-perceived health status responses by mine fire-related PM<sub>2.5</sub> exposure category.**

Health status	Category of PM <sub>2.5</sub> exposure				p-value
	No exposure N=900	Low N=1052	Medium N=1045	High N=1059	
General Health	Weighted %	Weighted %	Weighted %	Weighted %	
Excellent	17%	14%	12%	10%	<0.001
Very good	36%	31%	29%	26%	
Good	29%	34%	33%	33%	
Fair	14%	15%	18%	23%	
Poor	4%	6%	7%	8%	

**Table 8 Self-perceived health status reported by participants with low, medium or high mine fire PM<sub>2.5</sub> exposure, each compared to those with no exposure.**

Health status	Low vs. No exposure N=1052 vs. N=900			Medium vs. No exposure N=1045 vs. N=900			High vs. No exposure N=1059 vs. N=900		
	RR	Adj RRR* (95% CI)	p-value	RR	Adj RRR* (95% CI)	p-value	RR	Adj RRR* (95% CI)	p-value
In general would you say your health is:									
Excellent / Very Good	Ref	Ref		Ref	Ref		Ref	Ref	
Good	1.42	<b>1.43 (1.11, 1.84)</b>	<b>0.006</b>	1.49	<b>1.35 (1.03, 1.77)</b>	<b>0.031</b>	1.70	<b>1.47 (1.12, 1.92)</b>	<b>0.005</b>
Fair / Poor	1.39	1.32 (0.97, 1.79)	0.075	1.79	<b>1.41 (1.03, 1.93)</b>	<b>0.034</b>	2.56	<b>1.89 (1.37, 2.61)</b>	<b>&lt;0.001</b>

\* Adjusted for age, gender, education, employment, drinking risk, smoking and occupational exposure.

Ref = No exposure category

The findings shown in Table 8 indicated that each category of PM<sub>2.5</sub> exposure (be that *low*, *medium* or *high*) was associated with poorer self-perceived health status, when compared with *no* exposure. Supplementary analysis was conducted to determine whether self-perceived health status differed across the categories of exposed participants in Morwell (ie. those with *low*, *medium* or *high* PM<sub>2.5</sub> exposure). As shown in Table 9, there were no statistically significant differences in self-perceived health status between the *medium* and *low* PM<sub>2.5</sub> exposure categories. However those in the *high* category were 37% more likely to report fair or poor health than those with *low* PM<sub>2.5</sub> exposure. Overall, these findings indicated that poorer self-perceived health status was associated with all levels of mine fire-related PM<sub>2.5</sub> exposure, and the greatest adverse impact was observed in those with the highest exposure. These differences in risk, attributed to PM<sub>2.5</sub> exposure, were independent of health-related risk factors including age, gender, education, employment, alcohol, tobacco and occupational exposures.

**Table 9 Self perceived health status reported by Morwell participants with medium or high mine fire PM<sub>2.5</sub> exposure, each compared to those with low exposure.**

Health status	Medium vs. Low exposure N=1045 v.s. N=992			High vs. Low exposure N=1058 v.s. N=992		
	RR	Adj RRR* 95% CI	p-value	RR	Adj RRR* 95% CI	p-value
In general would you say your health is:						
Excellent / Very Good	Ref	Ref		Ref	Ref	
Good	0.95	0.89 (0.69, 1.15)	0.384	1.08	0.97 (0.75, 1.24)	0.786
Fair / Poor	1.19	1.02 (0.77, 1.36)	0.864	<b>1.70</b>	<b>1.37 (1.03, 1.83)</b>	<b>0.032</b>

\* Adjusted for age, gender, education, employment, drinking risk, smoking and occupational exposure.

Ref = Low exposure category

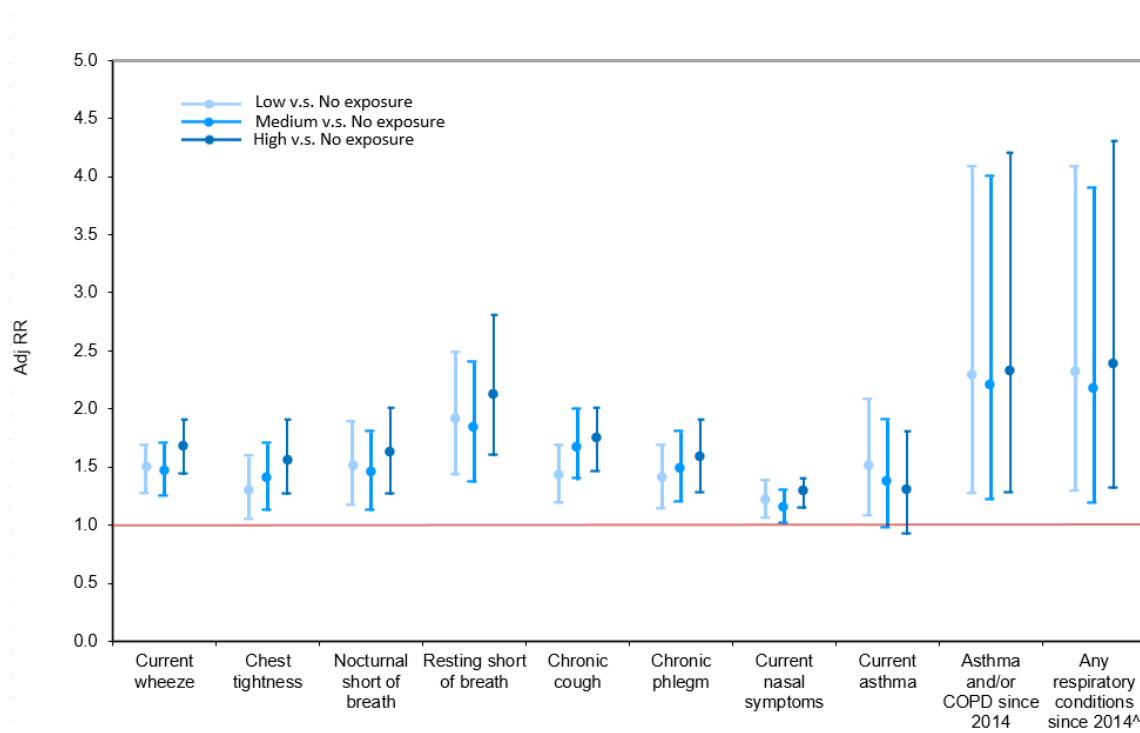
### 5.4.2. Self-reported respiratory health

Table 10 shows the weighted proportions of participants in each mine fire exposure category who reported respiratory symptoms or conditions. It can be seen that respiratory symptoms were common, reported by between 9 and 47% of participants. COPD since 2014 (not shown) was reported by less than 4% of participants making the number of cases too small to be further investigated. The prevalences of all respiratory symptoms and current asthma were significantly associated with mine fire-related PM<sub>2.5</sub> exposure category. Mean asthma symptom severity scores were also significantly associated with mine fire-related PM<sub>2.5</sub> exposure category.

**Table 10 Distribution of self-reported respiratory symptoms and conditions by mine fire-related PM<sub>2.5</sub> exposure category.**

Respiratory symptom or condition	Category of PM <sub>2.5</sub> exposure				p-value
	No exposure N=900	Low N=1052	Medium N=1045	High N=1059	
	Weighted %	Weighted %	Weighted %	Weighted %	
Current wheeze	26%	40%	40%	46%	<0.001
Chest tightness	17%	23%	26%	29%	<0.001
Nocturnal short of breath	12%	19%	19%	21%	<0.001
Resting short of breath	9%	19%	19%	22%	<0.001
Chronic cough	17%	26%	31%	34%	<0.001
Chronic phlegm	15%	23%	25%	27%	<0.001
Current nasal symptoms	36%	44%	41%	47%	<0.001
Current asthma	7%	12%	11%	11%	0.012
Any respiratory condition since 2014 <sup>†</sup>	1%	3%	3%	4%	0.002
<b>Amongst asthmatics (N=985)</b>	<b>Mean (SE)</b>	<b>Mean (SE)</b>	<b>Mean (SE)</b>	<b>Mean (SE)</b>	
Pekkanen asthma severity score	2.89 (0.14)	3.75 (0.15)	3.49 (0.14)	3.79 (0.15)	<0.001

<sup>†</sup> Comprises asthma, COPD and nasal allergy.



The red line indicates no difference in risk between the exposed group and the not exposed group.

<sup>A</sup> Comprises asthma, COPD and nasal allergy.

**Figure 3 Risk of respiratory symptoms or conditions in participants with low, medium or high exposure, each compared to those with no exposure.**

Figure 3 and Table 11 compare each of the *low*, *medium* and *high* exposure categories, respectively, to the *no* exposure category in regard to self-reported respiratory outcomes. For all respiratory outcomes except current asthma, participants in each exposure category were at greater risk than participants with no exposure. For symptoms, the increases in risk ranged from 15% to 110%. For the 'any respiratory condition' outcome, the increase in risk between the *high* exposure and *no* exposure category was 137% (adj RR 2.37 95% CI 1.30, 4.31). However, due to low number of records, the confidence intervals for the RRs for 'any respiratory condition' outcome were wide. The asthma symptom severity score was slightly higher in those with *low* or *high* versus *no* exposure, but no greater in those with *medium* exposure

**Table 11 Respiratory symptoms and conditions reported by participants with low, medium or high mine fire PM<sub>2.5</sub> exposure, each compared to those with no exposure.**

Respiratory symptom or condition	Low vs. No exposure N=1052 vs. N=900			Medium vs. No exposure N=1045 vs. N=900			High vs. No exposure N=1059 vs. N=900		
	RR	Adj RR* (95% CI)	p-value	RR	Adj RR* (95% CI)	p-value	RR	Adj RR* (95% CI)	p-value
Current wheeze	1.56	<b>1.51 (1.29, 1.76)<sup>†</sup></b>	<b>&lt;0.001</b>	1.55	<b>1.46 (1.25, 1.70)<sup>†</sup></b>	<b>&lt;0.001</b>	1.81	<b>1.66 (1.42, 1.93)<sup>†</sup></b>	<b>&lt;0.001</b>
Chest tightness	1.40	<b>1.32 (1.06, 1.65)<sup>†</sup></b>	<b>0.012</b>	1.56	<b>1.40 (1.12, 1.73)<sup>†</sup></b>	<b>0.003</b>	1.72	<b>1.54 (1.25, 1.90)<sup>†</sup></b>	<b>&lt;0.001</b>
Nocturnal short of breath	1.67	<b>1.53 (1.19, 1.98)<sup>†</sup></b>	<b>&lt;0.001</b>	1.62	<b>1.45 (1.12, 1.88)<sup>†</sup></b>	<b>0.005</b>	1.82	<b>1.60 (1.24, 2.07)<sup>†</sup></b>	<b>&lt;0.001</b>
Resting short of breath	2.07	<b>1.93 (1.44, 2.57)<sup>†</sup></b>	<b>&lt;0.001</b>	2.11	<b>1.84 (1.37, 2.47)<sup>†</sup></b>	<b>&lt;0.001</b>	2.40	<b>2.10 (1.58, 2.80)<sup>†</sup></b>	<b>&lt;0.001</b>
Chronic cough	1.51	<b>1.44 (1.20, 1.73)<sup>†</sup></b>	<b>&lt;0.001</b>	1.82	<b>1.67 (1.39, 2.00)<sup>†</sup></b>	<b>&lt;0.001</b>	1.99	<b>1.75 (1.45, 2.10)<sup>†</sup></b>	<b>&lt;0.001</b>
Chronic phlegm	1.55	<b>1.43 (1.15, 1.78)<sup>†</sup></b>	<b>0.001</b>	1.70	<b>1.49 (1.20, 1.85)<sup>†</sup></b>	<b>&lt;0.001</b>	1.85	<b>1.57 (1.26, 1.95)<sup>†</sup></b>	<b>&lt;0.001</b>
Current nasal symptoms	1.23	<b>1.23 (1.08, 1.40)<sup>†</sup></b>	<b>0.002</b>	1.16	<b>1.15 (1.01, 1.32)<sup>†</sup></b>	<b>0.033</b>	1.31	<b>1.29 (1.13, 1.46)<sup>†</sup></b>	<b>&lt;0.001</b>
Current asthma	1.62	<b>1.52 (1.09, 2.12)</b>	<b>0.013</b>	1.50	1.38 (0.98, 1.93)	0.064	1.43	1.29 (0.91, 1.84)	0.159
Any respiratory condition since 2014 <sup>^</sup>	2.45	<b>2.34 (1.31, 4.17)</b>	<b>0.004</b>	2.35	<b>2.18 (1.19, 3.97)</b>	<b>0.011</b>	2.80	<b>2.37 (1.30, 4.31)</b>	<b>0.005</b>
	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>
<b>Amongst asthmatics (N= 920):</b>									
Pekkanen asthma score	0.85	<b>0.56 (0.18, 0.95)</b>	<b>0.004</b>	0.60	0.31 (-0.09, 0.71)	0.129	0.89	<b>0.48 (0.05, 0.92)</b>	<b>0.030</b>

\* Adjusted for age, gender, education, employment, drinking risk, smoking and occupational exposure.

<sup>†</sup> Log binomial model failed to converge, hence adjusted RR was estimated using log Poisson model.

<sup>^</sup> Any respiratory condition comprises asthma, COPD and nasal allergy.

**Table 12 Respiratory symptoms and conditions reported by Morwell participants with medium or high mine fire PM<sub>2.5</sub> exposure, each compared to those with low exposure.**

Respiratory symptom or condition	Medium vs. Low exposure N=1045 v.s. N=992			High vs. Low exposure N=1058 v.s. N=992		
	RR	Adj RR* (95% CI)	p-value	RR	Adj RR* (95% CI)	p-value
Current wheeze	0.97	0.95 (0.84, 1.07) <sup>†</sup>	0.396	1.14	1.09 (0.97, 1.22) <sup>†</sup>	0.138
Chest tightness	1.05	1.01 (0.85, 1.20) <sup>†</sup>	0.898	1.16	1.12 (0.95, 1.32) <sup>†</sup>	0.185
Nocturnal short of breath	0.92	0.91 (0.75, 1.12) <sup>†</sup>	0.382	1.04	1.02 (0.84, 1.23) <sup>†</sup>	0.865
Resting short of breath	0.97	0.93 (0.76, 1.14) <sup>†</sup>	0.461	1.10	1.07 (0.88, 1.30) <sup>†</sup>	0.516
Chronic cough	1.19	1.15 (1.00, 1.33) <sup>†</sup>	0.055	1.29	<b>1.22 (1.05, 1.42)<sup>†</sup></b>	<b>0.009</b>
Chronic phlegm	1.09	1.05 (0.89, 1.25) <sup>†</sup>	0.544	1.19	1.13 (0.95, 1.34) <sup>†</sup>	0.178
Current nasal symptoms since 2014	0.93	0.93 (0.82, 1.04)	0.205	1.05	1.04 (0.93, 1.16)	0.477
Current asthma	0.89	0.89 (0.68, 1.17)	0.397	0.85	0.85 (0.64, 1.13)	0.266
Any respiratory condition since 2014 <sup>^</sup>	1.01	1.00 (0.62, 1.61)	0.993	1.17	1.08 (0.65, 1.78)	0.772
<b>Amongst asthmatics (N=715):</b> Pekkanen asthma score	<b>Mean diff</b> -0.42	<b>Adj mean diff* (95% CI)</b> <b>-0.41 (-0.81, -0.01)</b>	<b>p-value</b> <b>0.046</b>	<b>Mean diff</b> -0.12	<b>Adj mean diff* (95% CI)</b> -0.20 (-0.64, 0.24)	<b>p-value</b> 0.375

\* Adjusted for age, gender, education, employment, drinking risk, smoking and occupational exposure.

<sup>†</sup> Log binomial model failed to converge, hence adjusted RR was estimated using log Poisson model.

<sup>^</sup> Any respiratory condition comprises asthma, COPD and nasal allergy.

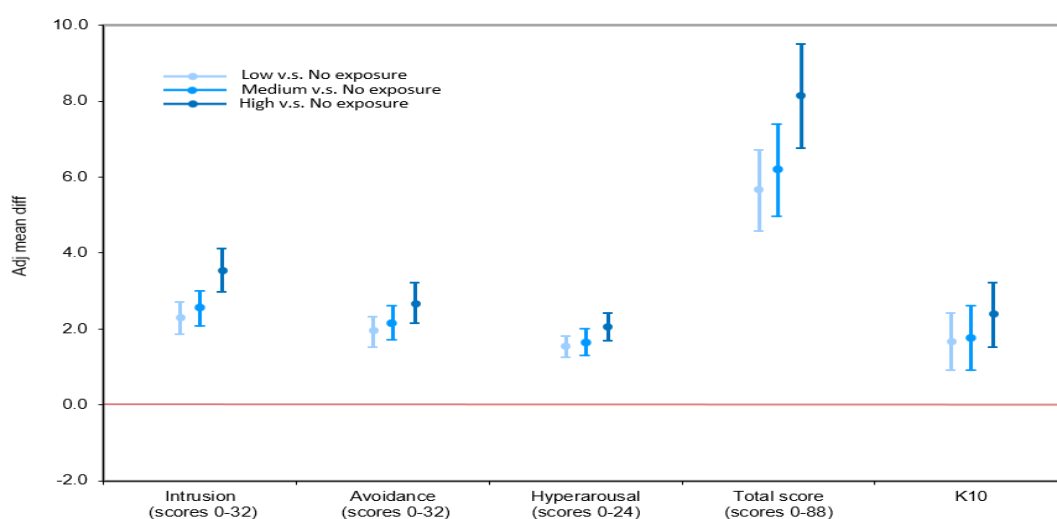
Within exposed Morwell participants, risk of chronic cough was 15% higher in those with *medium* PM<sub>2.5</sub> exposure compared to those with *low* PM<sub>2.5</sub> exposure, although this difference just failed to reach statistical significance (Table 12). However, there was a statistically significant 22% increase in risk of chronic cough amongst those with *high* PM<sub>2.5</sub> exposure compared to those with *low* PM<sub>2.5</sub> exposure implying a dose response relationship. For other respiratory symptoms and conditions, there were no observable differences between these exposure levels.

### 5.4.3. Psychological wellbeing

Table 13 shows the weighted proportion of participants in each mine fire PM<sub>2.5</sub> exposure category who reported having a doctor diagnose them with anxiety, depression or 'any' mental health condition in 2014 or later. Also shown are the mean scores achieved on the IES-R and K10 Psychological Distress Scale by participants in each exposure category. There were marked increases in IES-R scores, reflecting poorer mental health, with greater PM<sub>2.5</sub> exposure. There was a small increase in the K10 psychological distress score, also reflecting poorer mental health, with increasing PM<sub>2.5</sub> exposure. Slight but consistent trends in self-reported doctor-diagnosed mental health conditions increasing with PM<sub>2.5</sub> exposure, were too small to reach statistical significance.

**Table 13 Self-reported psychological wellbeing measures by mine fire-related PM<sub>2.5</sub> exposure category.**

Psychological wellbeing measure	Category of PM <sub>2.5</sub> exposure				p-value
	No exposure N=900	Low N=1052	Medium N=1045	High N=1059	
<b>Self-reported doctor-diagnosed in 2014 or later</b>	<b>Weighted %</b>	<b>Weighted %</b>	<b>Weighted %</b>	<b>Weighted %</b>	
Anxiety	4%	4%	6%	5%	0.102
Depression	3%	3%	5%	5%	0.070
Any mental health condition	6%	6%	7%	8%	0.206
<b>K10 severity</b>					
Low	76%	67%	62%	58%	<0.001
Moderate	14%	16%	18%	18%	
High	6%	9%	11%	15%	
Very high	5%	8%	9%	10%	
<b>Revised Impact of Events Scale</b>	<b>Weighted mean (SE)</b>	<b>Weighted mean (SE)</b>	<b>Weighted mean (SE)</b>	<b>Weighted mean (SE)</b>	
Intrusion (range 0-32)	0.61 (0.09)	3.00 (0.20)	3.71 (0.23)	4.65 (0.26)	<0.001
Avoidance (range 0-32)	0.73 (0.10)	2.69 (0.20)	3.31 (0.20)	3.90 (0.25)	<0.001
Hyper-arousal (range 0-24)	0.31 (0.06)	1.97 (0.16)	2.43 (0.17)	2.87 (0.19)	<0.001
Total score (range 0-88)	1.65 (0.24)	7.50 (0.54)	9.25 (0.57)	11.17 (0.66)	<0.001
<b>K10 score</b>	<b>14.02 (0.28)</b>	<b>15.79 (0.29)</b>	<b>16.65 (0.31)</b>	<b>17.23 (0.32)</b>	<0.001



The red line indicates no difference in mean score between the exposed group and the not exposed group.

**Figure 4 Difference in mean IES-R and K10 scores between Morwell participants with low, medium or high PM<sub>2.5</sub> exposure, each compared to participants with no PM<sub>2.5</sub> exposure.**



Figure 4 and Table 14 compare each of the *low*, *medium* and *high* PM<sub>2.5</sub> exposure categories, respectively, to the *no* PM<sub>2.5</sub> exposure category in regard to the IES-R and K10 scores. Consistent with the pattern observed in Table 13, being exposed to the mine fire-related PM<sub>2.5</sub> was associated with increased IES-R and K10 scores. Table 14 also compares post-mine fire, self-reported doctor-diagnosed mental health conditions for each of the PM<sub>2.5</sub> exposure categories against the *no* PM<sub>2.5</sub> exposure category, and shows no difference in those measures.

**Table 14 Psychological wellbeing outcomes in participants with low, medium or high mine fire PM<sub>2.5</sub> exposure, each compared to those with no exposure.**

Psychological wellbeing measure	Low vs. No exposure N=1052 vs. N=900			Medium vs. No exposure N=1045 vs. N=900			High vs. No exposure N=1059 vs. N=900		
<b>Self-reported doctor diagnosed in 2014 or later</b>	<b>RR</b>	<b>Adj RR* (95% CI)</b>	<b>p-value</b>	<b>RR</b>	<b>Adj RR* (95% CI)</b>	<b>p-value</b>	<b>RR</b>	<b>Adj RR* (95% CI)</b>	<b>p-value</b>
Anxiety	1.00	1.03 (0.62, 1.73)	0.905	1.60	1.60 (0.99, 2.58)	0.054	1.38	1.43 (0.86, 2.38)	0.163
Depression	1.05	1.02 (0.56, 1.84) <sup>†</sup>	0.947	1.63	1.48 (0.86, 2.53) <sup>†</sup>	0.154	1.68	1.61 (0.93, 2.79) <sup>†</sup>	0.091
Any mental health conditions	1.11	1.12 (0.74, 1.70)	0.594	1.26	1.21 (0.81, 1.80)	0.361	1.46	1.43 (0.96, 2.14)	0.082
<b>Revised Impact of Events Scale</b>	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>
Intrusion (scores 0-32)	2.42	<b>2.29 (1.86, 2.71)</b>	<b>&lt;0.001</b>	3.11	<b>2.56 (2.08, 3.04)</b>	<b>&lt;0.001</b>	4.08	<b>3.53 (2.96, 4.10)</b>	<b>&lt;0.001</b>
Avoidance (scores 0-32)	2.06	<b>1.95 (1.52, 2.37)</b>	<b>&lt;0.001</b>	2.64	<b>2.16 (1.70, 2.63)</b>	<b>&lt;0.001</b>	3.17	<b>2.66 (2.13, 3.20)</b>	<b>&lt;0.001</b>
Hyperarousal (scores 0-24)	1.65	<b>1.55 (1.24, 1.87)</b>	<b>&lt;0.001</b>	2.12	<b>1.65 (1.28, 2.03)</b>	<b>&lt;0.001</b>	2.52	<b>2.06 (1.67, 2.46)</b>	<b>&lt;0.001</b>
Total score (scores 0-88)	6.03	<b>5.67 (4.56, 6.78)</b>	<b>&lt;0.001</b>	7.72	<b>6.21 (4.97, 7.46)</b>	<b>&lt;0.001</b>	9.67	<b>8.15 (6.75, 9.56)</b>	<b>&lt;0.001</b>
<b>K10 score</b>	<b>1.72</b>	<b>1.67 (0.91, 2.43)</b>	<b>&lt;0.001</b>	<b>2.70</b>	<b>1.77 (0.92, 2.62)</b>	<b>&lt;0.001</b>	<b>3.21</b>	<b>2.39 (1.52, 3.26)</b>	<b>&lt;0.001</b>

\* Adjusted for age, gender, education, employment, drinking risk, smoking and occupational exposure.

<sup>†</sup> Log binomial model failed to converge, hence adjusted RR was estimated using log Poisson model.

In order to put the K10 Psychological Distress Scale scores in context, Table 15 replicates the breakdown of K10 severity by mine fire PM<sub>2.5</sub> exposure for Adult Survey participants (previously shown in Table 13), and also shows comparison data for rural Victoria from the 2014-2015 NHS.<sup>[27]</sup> Gippsland data were excluded to reduce any possible influence of exposure to the mine fire on the NHS findings.

**Table 15 K10 severity levels in participants with no, low, medium or high mine fire PM<sub>2.5</sub> exposure and in NHS 2014-2015 participants from rural Victoria excluding Gippsland.**

K10 severity	Category of PM <sub>2.5</sub> exposure				Rural Victoria (excl Gippsland) N=928
	No exposure N=900	Low N=1052	Medium N=1045	High N=1059	
	Weighted %	Weighted %	Weighted %	Weighted %	
Low	76%	67%	62%	58%	66%
Moderate	14%	16%	18%	18%	20%
High	6%	9%	11%	15%	9%
Very high	5%	8%	9%	9%	5%

It is apparent from Table 15 that the *no exposure* group was broadly comparable to the rest of rural Victoria in terms of psychological distress. As the PM<sub>2.5</sub> exposure level increased, however, the proportion of participants scoring high and very high on the psychological distress measure diverged from the rural Victorian figures. Specifically, compared to NHS participants in the rest of rural Victoria, participants in the Adult Survey categorised as having *high* fire-related PM<sub>2.5</sub> exposure were more likely to score in the *high* K10 severity category (15% vs. 9%) or in the *very high* severity category (9% vs. 5%). However, these differences were not assessed for statistical significance as that was considered to be outside the scope of the current report.

The analysis shown above includes the finding that ‘any’ exposure (be that *low*, *medium* or *high*) was associated with poorer IES-R and K10 scores when compared with *no exposure* (Table 14). However for those exposed, the analysis above did not indicate whether severity, or level, of PM<sub>2.5</sub> exposure made any difference. That was addressed in supplementary analysis, shown in Table 16, which excluded participants categorised as having *no exposure*.

**Table 16 Psychological wellbeing outcomes in Morwell participants with medium or high mine fire PM<sub>2.5</sub> exposure, each compared to those with low exposure.**

Psychological measure	Medium vs. Low exposure N=1045 vs. N=992			High vs. Low exposure N=1058 vs. N=992		
	RR	Adj RR* (95% CI)	p-value	RR	Adj RR* (95% CI)	p-value
<b>Self reported doctor-diagnosed in 2014 or later</b>						
Anxiety	1.52	1.45 (0.90, 2.36)	0.128	1.31	1.33 (0.80, 2.21)	0.269
Depression	1.47	1.36 (0.81, 2.29) †	0.251	1.52	1.54 (0.92, 2.59) †	0.103
Any mental health conditions	1.08	1.02 (0.70, 1.49)	0.917	1.24	1.24 (0.85, 1.81)	0.274
<b>Revised Impact of Events Scale</b>	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>	<b>Mean diff</b>	<b>Adj mean diff* (95% CI)</b>	<b>p-value</b>
Intrusion (scores 0-32)	0.48	0.07 (-0.54, 0.67)	0.828	1.45	<b>1.04 (0.36, 1.72)</b>	<b>0.003</b>
Avoidance (scores 0-32)	0.36	0.01 (-0.57, 0.60)	0.967	0.88	0.49 (-0.15, 1.14)	0.133
Hyperarousal (scores 0-24)	0.31	-0.07 (-0.54, 0.41)	0.782	0.70	0.35 (-0.14, 0.85)	0.164
Total score (scores 0-88)	1.13	0.00 (-1.58, 1.58)	0.996	3.11	<b>1.98 (0.26, 3.70)</b>	<b>0.024</b>
<b>K10</b>	0.84	-0.02 (-0.85, 0.82)	0.971	1.34	0.60 (-0.27, 1.48)	0.177

\* Adjusted for age, gender, education, employment, drinking risk, smoking and occupational exposure

† Log binomial model failed to converge, hence adjusted RR was estimated using log Poisson model.

The results show no difference between *medium* and *low* exposed participants on any of the psychological outcomes measured. However, participants in the heaviest (*high*) exposure category reported greater IES-R intrusion and IES-R total scores than participants with *low* exposure. However the size of the differences in means scores were very small at 1.04 (p=0.003) for IES-R intrusion and 1.98 (p=0.024) for IES-Total.

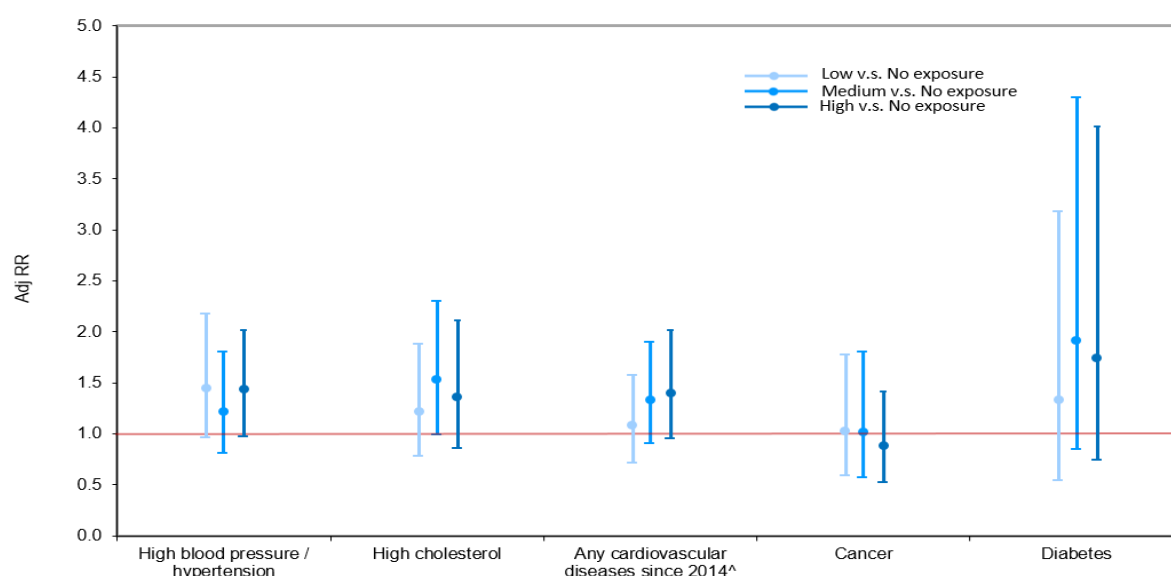
#### 5.4.4. Doctor diagnosed cardiovascular disease, diabetes and cancer

Table 17 shows the weighted proportions of participants, in each mine fire exposure category, who reported having a doctor diagnose them with hypertension, high cholesterol, any cardiovascular disease, cancer or diabetes in 2014 or later. There were no notable differences across exposure category in regard to these diagnoses. These finding were further supported by the risk estimates shown in Figure 5 and Table 18. Not surprisingly, additional analysis showed no differences in those diagnoses between *medium* and *low* exposure categories, or between *high* and *low* exposure categories (not shown).

**Table 17 Distribution of medical conditions reported to be doctor diagnosed in 2014 or later, by mine fire-related PM<sub>2.5</sub> exposure category.**

Medical condition	Category of PM <sub>2.5</sub> exposure				p-value
	No exposure N=900	Low N=1052	Medium N=1045	High N=1059	
	Weighted %	Weighted %	Weighted %	Weighted %	
High blood pressure / hypertension	5%	7%	6%	7%	0.106
High cholesterol	4%	5%	6%	5%	0.234
Any cardiovascular disease*	5%	5%	6%	7%	0.167
Cancer	2%	3%	2%	2%	0.980
Diabetes	1%	1%	2%	2%	0.136

\* Any cardiovascular disease comprised self-reported doctor diagnosed angina, heart attack, heart failure, arrhythmia, stroke or other heart disease in 2014 or later.



The red line indicates no difference in risk between the exposed group and the not exposed group. <sup>^</sup> Comprised self-reported doctor diagnosed angina, heart attack, heart failure, arrhythmia, stroke or other heart disease in 2014 or later.

**Figure 5 Risk of self-reported doctor-diagnosed medical conditions in participants with low, medium or high exposure, each compared to those with no exposure**

**Table 18 Self-reported doctor-diagnosed medical conditions in participants with low, medium or high mine fire PM<sub>2.5</sub> exposure, each compared to those with no exposure.**

Medical condition	Low vs. No exposure N=1052 vs. N=900			Medium vs. No exposure N=1045 vs. N=900			High vs. No exposure N=1059 vs. N=900		
	RR	adj RR* (95% CI)	p-value	RR	adj RR* (95% CI)	p-value	RR	adj RR* (95% CI)	p-value
High blood pressure / hypertension	1.52	1.47 (0.98, 2.20)	0.062	1.28	1.22 (0.81, 1.84)	0.345	1.51	1.42 (0.96, 2.08)	0.076
High cholesterol	1.23	1.24 (0.80, 1.94)	0.336	1.51	1.53 (0.99, 2.37)	0.054	1.37	1.35 (0.84, 2.15)	0.210
Any cardiovascular disease <sup>^</sup>	1.08	1.10 (0.74, 1.62)	0.649	1.26	1.33 (0.91, 1.95)	0.141	1.49	1.38 (0.94, 2.04)	0.104
Cancer	1.03	1.05 (0.61, 1.82)	0.848	0.92	1.02 (0.57, 1.81)	0.958	0.94	0.87 (0.51, 1.48)	0.600
Diabetes	1.57	1.35 (0.56, 3.26) <sup>†</sup>	0.500	2.23	1.91 (0.85, 4.30) <sup>†</sup>	0.119	2.13	1.73 (0.73, 4.07) <sup>†</sup>	0.214

\* Adjusted for age, gender, education, employment, drinking risk, smoking and occupational exposure.

<sup>†</sup> Log binomial model failed to converge, hence adjusted RR was estimated using log Poisson model.

<sup>^</sup> Any cardiovascular disease comprises self-reported doctor diagnosed angina, heart attack, heart failure, arrhythmia, stroke or other heart disease in 2014 or later.

## 6. Discussion

This second volume of Hazelwood Health Study Adult Survey findings sought to determine whether adults who had low, medium or high cumulative 24-hour mine fire-related PM<sub>2.5</sub> exposure, had greater self-reported prevalences of respiratory, psychological, cardiovascular and other conditions/symptoms compared to adults who had no Hazelwood fire-related PM<sub>2.5</sub> exposure. These health outcomes were measured approximately 2.5 years after the mine fire.

### Recruitment, sampling and response bias

As fully described in Volume 1, substantial effort was invested in the contact and recruitment of eligible participants. The consequent recruitment rates of 34% for Morwell and 23% for Sale were considered satisfactory relative to other population health surveys. For example, Sinclair *et al.*<sup>[28]</sup> tested a number of different recruitment methods for an Australian community-based survey with response rates ranging from 2% to 30%. The assessment for sampling-, and response-, bias reported in Volume 1 indicated that differences between the groups in gender and age were unlikely to affect the strength or direction of the results observed in this study. Morwell residents in poor health were not over-represented. Weighting of results to account for differences between participants and non-participants in gender and age, and statistical adjustment for known health-risk factors such as smoking, further minimised the possible bias conferred by these factors and promoted confidence in the findings.

### Mine fire related PM<sub>2.5</sub> exposure

To estimate individual Adult Survey participant's exposure to mine fire-related PM<sub>2.5</sub>, we blended the CSIRO high resolution hourly PM<sub>2.5</sub> model with participants' detailed address diaries. The results showed that almost all Morwell participants, and some Sale participants, were exposed to mine fire-related PM<sub>2.5</sub>. Exposed participants were divided into *low*, *medium* and *high* PM<sub>2.5</sub> groups with mean cumulative 24-hour levels of approximately 6, 11 and 28 µg/m<sup>3</sup> respectively. The WHO Air Quality Guideline for 24-hour mean PM<sub>2.5</sub> is 25 µg/m<sup>3</sup> ([http://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)) indicating that at least the high exposure group were certainly exposed to concentrations likely to be associated with adverse health effects. However, the PM<sub>2.5</sub> concentrations were lower than those experienced in Asian smog events, such as in Beijing, Hebei and Tianjing in 2014-2016, where ground level measured concentrations of PM<sub>2.5</sub> were regularly between 85 and 105 µg/m<sup>3</sup>.<sup>[29]</sup> Unlike China, Australian fuels are generally quite low in Sulphur and SO<sub>2</sub> concentrations in the Latrobe Valley did not exceed National Environment Protection Measures for ambient air quality [<https://www.epa.vic.gov.au/~media/Publications/1598.pdf>].

### Determinants of health other than the mine fire

It was important that the Adult Survey assessed likely determinants of health other than the Hazelwood mine fire. There were some differences across the fire-related exposure categories in levels of education, employment, occupational exposure category, smoking status and category of alcohol consumption. These observations highlighted the importance of statistical adjustment for known demographic and lifestyle risk factors.

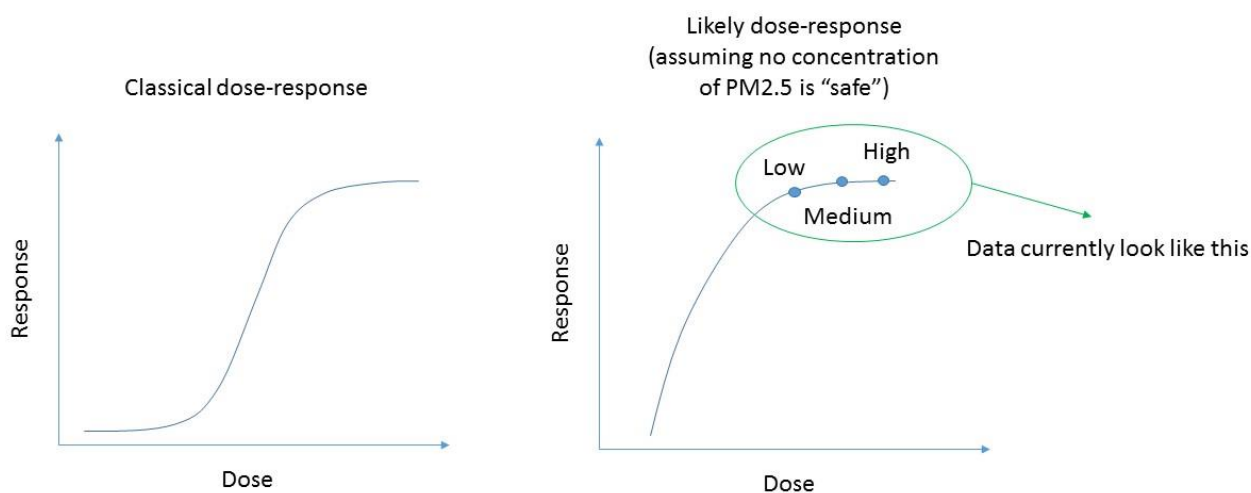
### Self-perceived general health status

The Adult Survey findings showed a clear pattern of decreasing (poorer) self-perceived health status with increasing fire-related PM<sub>2.5</sub> exposure. For example, compared to those with no fire related exposure, participants with high exposure were 89% more likely, and participants with medium exposure were 41% more likely to report fair or poor health than to report excellent or very good health. The importance of self-perceived health status should not be understated, as it has been shown to be a good predictor of subsequent illness, future health care and premature mortality.<sup>[30]</sup>

## Respiratory symptoms

Respiratory symptoms were reported by a large proportion of study participants and the prevalences were significantly associated with mine fire-related PM<sub>2.5</sub> exposure category. Self-report of 'all' respiratory conditions (asthma, COPD and nasal allergy combined) doctor diagnosed in 2014 or later, was also higher in exposed compared to not exposed participants; however the total proportion effected was less than 4%. The prevalence of current asthma also showed a pattern of increasing with increased PM<sub>2.5</sub> exposure, however, this increase did not achieve statistical significance probably due to relatively small numbers. Nonetheless asthmatics with fire-related PM<sub>2.5</sub> exposure reported more severe symptoms than asthmatics with no fire-related PM<sub>2.5</sub> exposure. Within exposed participants chronic cough, but not other respiratory symptoms or conditions, was significantly increased amongst those with *high* exposure compared to those with *low* PM<sub>2.5</sub> exposure.

We have demonstrated some evidence for a dose-response relationship between PM<sub>2.5</sub> and respiratory symptoms. The classical sigmoid dose response curve is shown in Figure 6 (courtesy of Prof Graeme Zosky, a member of our Scientific Reference Group). This type of dose response is typically seen in pharmacology experiments or clinical trials with different doses of a drug. However there is now good evidence that there is no safe level of PM<sub>2.5</sub> ([http://www.euro.who.int/\\_\\_data/assets/pdf\\_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf](http://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf)), so it is quite likely that the *low*, *medium* and *high* exposure groups have all been exposed to more PM<sub>2.5</sub> than was necessary to trigger respiratory symptoms. The findings for cough, which demonstrated a more classical dose response, are particularly interesting as this symptom is part of the physiological response of the respiratory tract to clear particles.



**Figure 6 Interpretation of dose response curves.**

We have not been able to identify any directly comparable studies of exposure to coal mine fire smoke in the peer reviewed literature. However there are some studies of exposure to PM<sub>2.5</sub> from bushfires (or wildfires) which have shown associations with emergency attendances for asthma<sup>[31]</sup> and dispensing of the reliever medication salbutamol.<sup>[32]</sup> There are also studies of exposure to background urban fine particulate which have shown that PM<sub>2.5</sub> was associated with chronic respiratory symptoms<sup>[33]</sup> and that children with asthma were more sensitive than adults.<sup>[34]</sup> The European Study of Cohorts for Air Pollution Effects (ESCAPE) was unable to find consistent effects of PM<sub>2.5</sub> upon chronic bronchitis, but there were some effects on chronic phlegm in never-smokers and chronic cough in older subjects.<sup>[35]</sup> ESCAPE also found some evidence for a deleterious effect of urban air pollution upon incident asthma in adults, but the only significant association was with coarse particles.<sup>[36]</sup> A more recent analysis of the European Lifelines and UK Biobank cohorts using similar methods demonstrated that PM<sub>2.5</sub> was associated with wheeze and shortness of breath, particularly in participants from low income households.<sup>[37]</sup>

Given the small p values, our findings are unlikely to have occurred by chance, even in the context of multiple comparisons, but could still be affected by reporting bias. We adjusted for known demographic, lifestyle and occupational risk factors that could have confounded the associations. However, given that the main differences observed were between those with some mine fire related PM<sub>2.5</sub> exposure and those with none, there remains the possibility of residual confounding by unmeasured differences between Morwell and Sale. Findings from a series of studies of the community around an open cut coalmine in Northern England suggest a greater underlying awareness of respiratory symptoms, but not necessarily a greater prevalence of respiratory diseases.<sup>[38]</sup>

## Psychological health

The Adult Survey included two measures of psychological morbidity. The Revised Impact of Events Scale measured the participant's current (at the time of assessment) trauma-related distress specifically in relation to the mine fire event 2.5 years prior, and the K10 measured general psychological distress in the previous 4 weeks.

There were consistent relationships between being exposed to fire-related PM<sub>2.5</sub> at any level, and elevated IES-R total score and IES-R subscale scores representing intrusive thoughts, avoidance behaviours and hyperarousal. The mean total IES-R score rose from 1.65 in the *no exposure* group to 11.17 in the *high* exposure group. At that upper end, the average score for highly exposed Adult Survey participants was below previously published IES-R thresholds for PTSD.<sup>[10-12]</sup> That suggests the impact of the mine fire on psychological distress in exposed Morwell residents, 2.5 years after the event, was moderate.

The clear differences in IES-R scores between the *no* PM<sub>2.5</sub> exposure category and each of the *low*, *medium* and *high* categories, broadly represented a Morwell versus Sale impact. Additional analyses of the differences in IES-R scores between those in the *low* PM<sub>2.5</sub> exposure category and the *medium* and *high* categories, effectively looking at the gradient of exposure within Morwell, found significantly higher IES-R total and IES-R Intrusion in *high* versus *low* PM<sub>2.5</sub> exposure groups. These differences imply a more classical dose response relationship (see Figure 6) with increments in PM<sub>2.5</sub> exposure associated with increments in some aspects of trauma-related distress.

There is only one previously published study on IES-R distress levels associated with smoke exposure, that being exposure to forest fires in Indonesia in 2013, where the average total score was 18.5.<sup>[39]</sup> The Indonesian study measured trauma-related distress during the smoke event rather than over two years post-event, as in the Adult Survey, and therefore our lower IES-R scores may reflect regression to the mean during elapsed time period.

While average IES-R scores, at each level of fire-related PM<sub>2.5</sub> exposure, were below any proposed clinical thresholds for PTSD, further analysis is necessary to identify the most vulnerable sub-groups including the influence of existing mental health diagnoses and previous traumatic exposures.

General psychological distress in the previous 4 weeks, as assessed by the K10, was also found to be associated with all levels of fire-related PM<sub>2.5</sub> exposure, however increasing severity of exposure made little difference to this measure. This is an important finding as, unlike the IES-R, the K10 measure was not specifically linked to the mine fire event and so should be less prone to response bias. While the adjusted mean difference in K10 score, between the *no* exposure and *high* exposure categories, was only 2.39 points, the average score of about 17 for both the *medium* and *high* exposure categories was above the ABS cut-off of 16 for moderate distress.<sup>[19]</sup> The K10 was specifically chosen because of its regular use in Australian population health surveys. The 2014-2015 NHS,<sup>[27]</sup> for example, provides useful comparative data. Participants in the Adult Survey who were categorised as having *medium* or *high* fire-related PM<sub>2.5</sub> exposure, were almost twice as likely to score in the *high* or *very high* severity categories on the K10, than NHS participants residing in rural and regional areas of Victoria.

While we observed a trend towards higher risk of self-reported doctor-diagnosed mental health conditions, in 2014 or later, amongst Adult Survey participants with higher fire-related PM<sub>2.5</sub> exposure, the total numbers were small and could not be interpreted further.



These psychological health findings will be complemented by an Adult Psychological Impacts Survey to be conducted in 2019. That survey will repeat these core measures and add further measures to better understand the impacts of the mine fire and the determinants of vulnerability.

### Cardiovascular disease, diabetes and cancer

The Adult Survey Volume 1 report showed that Morwell participants were 1.4 times more likely than Sale participants to report that a doctor had diagnosed them with high blood pressure in 2014 or later. In the current analysis, with the high blood pressure cases divided into four fire-related PM<sub>2.5</sub> exposure categories, the numbers in each category were small and no significant differences were observed.

Similarly, in the Volume 1 report, we showed that Morwell participants were approximately seven times more likely than Sale participants to report that a doctor had diagnosed them with a heart attack in 2014 or later. However, the prevalences were extremely small (1% in Morwell compared with 0.1% in Sale), and it was not possible to repeat that analysis with heart attack cases divided into four exposure categories for this Volume 2 report. Instead, self-reported doctor diagnosed angina, heart attack, heart failure, arrhythmia, stroke or other heart disease in 2014 or later were combined to form one broader outcome termed 'any cardiovascular disease'. As for high blood pressure, no difference between exposure categories were observed for any cardiovascular disease.

Post-mine fire diagnoses of high cholesterol, diabetes and cancer were reported by small numbers of participants, and no evidence of a clear relationship was found between those conditions and PM<sub>2.5</sub> exposure. In terms of the numbers of those diagnoses that we might expect in the 2.5 years between the mine fire and the Adult Survey, there are some limited Australian data. The Australian Diabetes, Obesity and Lifestyle Study in 2008<sup>[40]</sup> reported age standardised annual incidence of diabetes to be about 0.8% which is similar to the 1 to 2% we observed for our 2.5 year period. In 2014, the Australian Institute of Health and Welfare estimated the age-standardised cancer incidence rate to be approximately 0.5% (<https://canceraustralia.gov.au/affected-cancer/what-cancer/cancer-australia-statistics>), a little lower than our range of 2 to 3% over 2.5 years. For the period 2014-2015, the ABS found that 7% of all Australians reported having high cholesterol (ie. total prevalence, not incidence).<sup>[41]</sup> On that basis, our 2.5 year incidence of between 4 and 6% would appear quite high.

More definitive information about the risk of cardiovascular disease or diabetes conferred by the mine fire may be provided by the HHS Cardiovascular Stream sub-study which completed data collection in the first half of 2018. Similarly, more definitive information about the risk of cancer conferred by the mine fire may be provided by the HHS Cancer Stream which will be undertaking further data linkage with the Victorian Cancer Registry.

### Self-reported doctor diagnosed conditions and self-reported symptoms

In general, the prevalences of self-reported symptoms were greater in the exposed versus not exposed groups, whereas prevalences of self-reported doctor-diagnosed conditions were not. Possible explanations for these difference could include that participant's symptoms have been sub-clinical, that participants have not reported their symptoms to medical practitioners, or that the process of symptom onset to medical consultation to diagnosis has been protracted.

### Strengths and weaknesses

The Adult Survey has a number of strengths which gave confidence to the observed findings, but also some limitations which affected interpretation. An adequate response rate was achieved and weightings were applied to best reflect the source population. An assessment of some refusers indicated that Morwell residents with ill health were not over-represented in the sample. Individual exposures to PM<sub>2.5</sub> were estimated from a combination of detailed time-location diaries, including residential-, relocation- and work-addresses, and spatially and temporally resolved modelling of PM<sub>2.5</sub> concentrations, based upon coal combustion and weather conditions. Whilst we accept that some participants may have had difficulty recalling their precise locations and dates more



than two years after the fire, we went to considerable effort to manually review any detected inconsistencies in those data.

Many outcomes were based on self-reported data, rendering these findings vulnerable to response bias. However, well validated and reliable questionnaires were used whenever available. Furthermore, for some health measures there were no differences reported between exposure categories, suggesting that exposed participants were not systematically over-reporting their symptoms. All statistical analysis allowed for known demographic and lifestyle confounders, but we acknowledge the likelihood of some residual confounding from unmeasured risk factors.

## Conclusions

This study broadly concluded that Hazelwood mine fire-related PM<sub>2.5</sub> levels were sufficient to adversely impact self-reported health status, respiratory symptoms and psychological health in the exposed community more than 2 years after the event. These findings held irrespective of exposure severity. In other words, community members in *low*, *medium* and *high* exposure groups were all exposed to more PM<sub>2.5</sub> than was necessary to adversely impact these aspects of their health.

For some health measures, namely self-perceived health status, chronic cough and the IES-R total and Intrusion subscale scores, a more classical dose response relationship was observed with increments in exposure severity associated with decrements in health. It is likely that these measures were more sensitive to the level of exposure. The IES-R was specifically related to the Hazelwood event and therefore it is to be expected that those with more exposure would report more distress. Self-perceived health is very sensitive to environmental effects. Coughing is part of the physiological response to inhaled particles, so would be expected to show an exposure-response relationship.

Very small p values, consistent unidirectional trends, statistical adjustment for known demographic, lifestyle and occupational risk factors, and evidence that participants were not systematically over-reporting, all added confidence to the robustness of these findings. However there remains the possibility of residual confounding by unmeasured differences between Morwell and Sale, such as socio-economic status.

These Adult Survey findings comprise just one part of a broader complement of research involving the Adult Survey participants. In particular, the Hazelinks Stream will be linking the Adult Survey participants to hospital, ambulance, cancer and mortality databases. The Psychological Impacts Stream will be adding interview data and a second round of survey data to the Adult Survey. The Cardiovascular and Respiratory Streams will be adding clinical examination data collected from Adult Survey participants. Combined, we anticipate that this program of research will provide a comprehensive overview of the health and wellbeing of the Adult Survey participants.

These findings have important public health implications when planning the response to future extended smoke events. These findings also have important implications for Latrobe Valley health and related services when planning for the future. The findings are important for GPs, medical specialists and other health professionals, particularly those who were not in the region at the time of the mine fire, when responding to community members' health issues.

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## Document History

Version	Date approved	Approved by	Description
1.0	22 Nov 2018	SPM	Submitted to DHHS
1.1	17 Dec 2018	SPM	Link to Table 3 repaired