Hazelinks

Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data: Time Series Analyses

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Acknowledgements

Abbreviations

ACE	Angiotensin Converting Enzyme
ATC	Anatomical Therapeutic Chemical classification
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHS	Commonwealth Department of Human Services
EREC	External Request Evaluation Committee
GLM	Generalised linear model
GP	General Practitioner
MBS	Medicare Benefits Schedule
PBS	Pharmaceutical Benefits Scheme
PM$_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres (thousandths of a millimetre) or less
PM$_{10}$	Particulate matter with an aerodynamic diameter of 10 micrometres (thousandths of a millimetre) or less
RR	Relative Risk
SA	Statistical area level
95% CI	95% Confidence Interval

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1. Executive Summary

From 9 February 2014, smoke and ash from a fire in the Morwell open cut brown coal mine adjacent to the Hazelwood power station covered parts of the Latrobe Valley, eastern Victoria, for up to 6 weeks. In response, the Hazelwood Health Study was established in order to monitor any long-term health effects of that smoke event. This report describes analyses which examined whether mine fire-related air pollutants were associated with increased use of health services and medications for cardiovascular diseases, respiratory diseases and mental health conditions in the Latrobe Valley area. The analyses utilised daily concentrations of mine fire-related air particulate matter smaller than 2.5 thousandths of a millimetre in diameter ($PM_{2.5}$) modelled by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Oceans & Atmosphere Flagship.

Daily counts of health service visits were derived from Medicare Benefits Schedule (MBS) data for the period July 2012 to June 2016, based on date of service for GP consultations and date of referral for specialist attendances, diagnostic procedures, investigations and diagnostic imaging services. Daily counts of prescription medications dispensed by pharmacies were derived from Pharmaceutical Benefits Scheme (PBS) data for the period January 2013 to December 2016. Time series statistical models were used to assess the associations between daily mine fire-related $PM_{2.5}$ and health service use or medications dispensed, after controlling for seasonality, long-term temporal trends, day of the week, maximum ambient temperature and public holidays.

The analyses showed clear evidence that mine fire-related $PM_{2.5}$ was significantly associated with an increased utilisation of all health service types examined (short and long general practice (GP) consultations, cardiovascular service visits, respiratory service visits and mental health consultations) and dispensing of all examined medication types (cardiovascular, respiratory and mental health), after a lag of 2 to 5 days from exposure.

For each 10 µg/m^3 increase in mine fire-related $PM_{2.5}$, the estimated percentage increase in health service visits were: 19% for all short and long GP consultations, 29% for all cardiovascular services, 27% for all respiratory services and 13% for all mental health consultations. During the mine fire period, there were 5,137 visits for all short and long GP consultations, 405 visits for all cardiovascular services, 174 visits for all respiratory services and 286 visits for all mental health consultations, attributable to mine fire-related $PM_{2.5}$ exposure in the Latrobe Valley. Correspondingly, the attributable fractions were 11%, 16%, 15%, and 8%, respectively.

Increases in medications dispensed were also observed, with estimated increases of: 12% for cardiovascular medications, 15% for respiratory medications and 17 % for mental health medications,

for each 10 $\mu g/m^3$ increase in mine fire-related $PM_{2.5}$. Among medications dispensed, there were 2,501 cardiovascular, 574 respiratory and 1,429 mental health medications, attributable to mine fire-related $PM_{2.5}$ exposure during the mine fire period. Correspondingly, the attributable fractions were 8%, 9%, and 10%, respectively.

This study should be helpful to develop and implement effective and timelier adaptive strategies to mitigate cardiovascular, respiratory and mental health risks due to possible future coal mine fire derived air pollution exposure in the community.

2. Introduction

On 9 February 2014, the Morwell open cut brown coal mine adjacent to the Hazelwood power station in the Latrobe Valley, eastern Victoria, caught fire resulting in nearby areas being covered in plumes of smoke and ash over a six-week period. Subsequently, a Monash University-led consortium of researchers have been contracted by the Victorian Department of Health and Human Services to undertake a comprehensive study of the long term health and wellbeing of Latrobe Valley residents following exposure to the smoke from the Hazelwood mine fire.

The Hazelinks component of the Hazelwood Health Study aims to use administrative health data sets to investigate short, medium and long-term health outcomes in the Latrobe Valley region. This report draws upon data routinely collected by the Australian Government on specific health services utilisation and dispensing of prescription pharmaceuticals.

3. Background

The adverse effect of air pollution on health has long been appreciated and due to improved methods of monitoring and measurement, has become a more active research area in the last twenty years. Extensive clinical, epidemiological, and toxicological studies have provided evidence of relationships between exposure to ambient air pollutants and human health (Brunekreef and Holgate, 2002, Beelen et al., 2014). The short-term effects of air pollution have mainly been demonstrated by increases in respiratory (Haikerwal et al., 2016) and cardiovascular-related morbidity (Haikerwal et al., 2015) and mortality (Dennekamp et al., 2010, Strickland et al., 2010, Faustini et al., 2012, Milojevic et al., 2014, Pope et al., 2006). There is also a growing body of research investigating the relationship between air pollution and adverse mental health outcomes such as depression and suicide (Lim et al., 2012, Szyszkowicz et al., 2010).

Large, destructive coal mine fires such as the Hazelwood mine fire, are often beyond human control, despite technologically advanced fire-fighting services and the resources allocated to fire control. Pollutants generated by coal combustion are similar to those generated from domestic solid fuel combustion and outdoor biomass fires (Melody and Johnston, 2015). Pollutants may be broadly categorised as gases, particles with a median aerodynamic diameter less than 10µm or 2.5µm (PM_{10} or $PM_{2.5}$), volatile organic compounds, and trace elements. Many of these are known to be deleterious to human health. The immediate impact of coal mine fires can be devastating, with loss of life, livelihood and infrastructure at the fire fronts. However, to date there is limited evidence on the impacts of smoke from coal mine fires on health outcomes.

4. Aim and objectives

The aim of the analyses was to examine whether the coal mine fire-related $PM_{2.5}$ was related to increased use of health services and medications dispensed for respiratory diseases, cardiovascular diseases and mental health conditions.

5. Human Research Ethics Committee and other approvals

Monash University Human Research Ethics Committee (MUHREC) approved the Hazelwood Adult Survey & Health Record Linkage Study on 21 May 2015. The application was also approved by the Commonwealth Department of Human Services (DHS) External Request Evaluation Committee (EREC). MBS and PBS data were initially requested to be aggregated at the Statistical Area (SA) 1 level, for each of the 38 SA1s contained within the Morwell SA2 boundary. However due to privacy considerations the data were finally released at the aggregated SA3 level for the Latrobe Valley as a whole. The Commonwealth DHS holds 4.5 years of data, therefore the earliest data available for extraction were from 1 July 2012.

6. Methods

6.1. Datasets

Data on health service use

Data on health service use were collected from the Medicare Benefits Schedule (MBS) database held by the Commonwealth DHS. The dataset contained de-identified information on patient health care utilisation for GP, specialist, diagnostic procedures, investigations and diagnostic imaging services. The dataset only included claim records of services that qualified for Medicare benefits and for which a claim had been processed.

Data for all ages were analysed from the MBS database for the period 1 July 2012 – 30 June 2016, based on date of service for GP consultations and date of referral for specialist attendances, diagnostic procedures, investigations and diagnostic imaging services. These dates of analyses were selected to reflect the distinction between primary medical services (GP consultations) and secondary medical services requiring a GP referral. This distinction was made because it may be possible that primary medical service utilisation is more responsive to short term changes in air quality than secondary services.

Residents should have been able to consult GPs relatively quickly and therefore the date of service may reflect short term health responses to air quality. In comparison, there is often a waiting period to access secondary services and therefore the date of referral rather than the date of service should better reflect possible short term health responses to changes in air quality. MBS data were broken down into category, group, subgroup and item number for each unit record (category being the broadest description, and item number the most specific). The MBS data request was restricted to specific categories/groups/subgroups that were relevant to the study research questions (e.g. Category: Professional Attendances, Group: GP Mental Health treatment).

Data on medication dispensing

Data on medication dispensing were obtained from the Pharmaceutical Benefits Scheme (PBS) database also held by the Commonwealth DHS. This dataset contained de-identified information on prescription medicines dispensed to patients at a Government subsidised price, where the cost of the medication was greater than the patient contribution and therefore the pharmacist supplying the medication required reimbursement for the remaining cost. Since 2012, PBS data also included prescription medications where the cost of the medication was covered by the patient, so the pharmacist did not require reimbursement. The PBS dataset only contained information on prescription medicines where the prescription had been processed (i.e. the prescription had been filled by the pharmacist).

Data for all ages were analysed from the PBS database for the period 1 January 2013 – 31 December 2016 (based on date of supply). The PBS data were broken down using the Anatomical Therapeutic Chemical (ATC) Classification System (WHOCC, 2011). As the study aimed to identify changes in medication use for respiratory, cardiovascular and mental health conditions during and after the mine fire, only records relating to these categories of medications were requested (e.g. Group name: Cardiovascular System).

Data on air pollution

The CSIRO Oceans & Atmosphere Flagship provided modelled exposure fields for $PM_{2.5}$ ranging from 100-500 m resolution close to the fire to 3-9 km resolution further away from the fire. The 24 hourly average $PM_{2.5}$ concentrations were calculated for the Latrobe Valley SA3 area. Further details of the modelling approach can be found in the CSIRO report (Emmerson et al., 2016).

The coal mine fire period in the analyses was determined by the modelled average daily $PM_{2.5}$ concentrations. For this report, the period when the modelled fire-generated $PM_{2.5}$ concentration averaged across the Latrobe Valley SA3 area exceeded 1µg/m^3 was considered the fire period, which corresponded to between 9 February and 10 March 2014 (30 days). After 10 March 2014, daily

average PM$_{2.5}$ concentrations attributable to the coal mine fire fell below 1μg/m^3. However, it should be noted that data collection for the adult survey continued until the 31 of March 2014. The median modelled daily average PM$_{2.5}$ concentration attributable to the coal mine fire during the 30 day analysis period for the Latrobe Valley area was 5.2 μg/m^3 and the interquartile range was 0.1 – 31.2 μg/m^3.

Data on ambient maximum temperature

As ambient temperature can have significant impacts on health (Guo et al., 2014, Guo et al., 2017), we controlled for temperature when we assessed associations between air pollution and health outcomes. Daily maximum temperatures were collected from the Australian Bureau of Meteorology (http://www.bom.gov.au/climate/data-services/station-data.shtml) during the same study period.

Data on geographical boundaries

The geographical boundary used for the analyses was defined using the Australian Statistical Geography Standard 2011 classification SA3 spatial unit. The Latrobe Valley SA3 area incorporated five SA2 regions: Morwell, Churchill, Moe - Newborough, Traralgon and Yallourn North – Glengarry. Figure 1 shows a map of the Latrobe Valley SA3 geographical area, and the corresponding SA2 areas, included in the analysis.
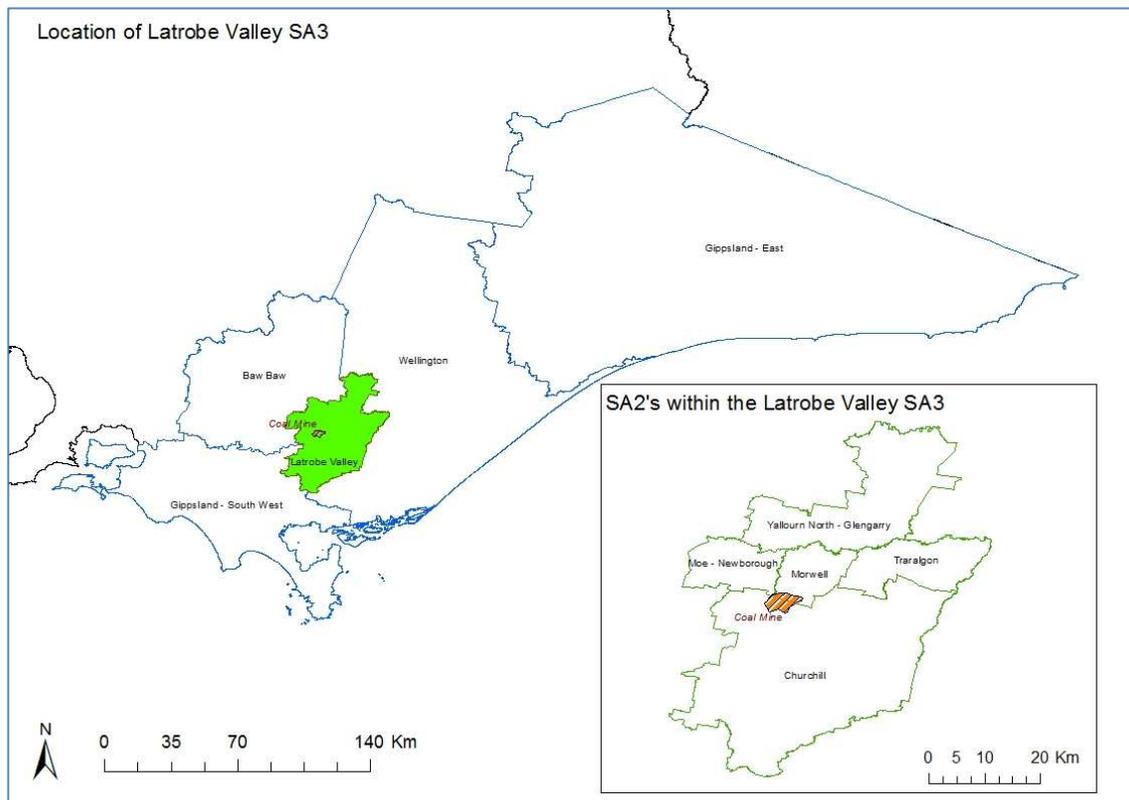
Figure 1 Geographical location of the Latrobe Valley SA3 area

6.2. Definition of outcome data

Health service data

The health service data were reviewed by a panel of researchers and clinicians (see acknowledgments) and Service types considered relevant for the hypothesis were included in the analysis. For the purpose of the analyses, all item numbers that were considered relevant were grouped into one of five categories: short GP consultations, long GP consultations, cardiovascular services, respiratory services and mental health consultations.

Short GP consultations were defined as consultations lasting less than 20 minutes and incorporated standard consultations (Item 23) and long GP consultations were defined as consultations lasting 20 minutes or more. Cardiovascular and respiratory service groups incorporated their respective specialist/consultant consultations and diagnostic and imaging tests. Mental health consultations incorporated GP mental health and specialist/consultant mental health consultations. A small number of service types were not considered relevant and were excluded, for example Subgroup: Cardiovascular, Item Number: Blood Dye test. Supplementary Table 1 presents the full list of item numbers by health service group included in the analyses.

Dispensed medication data

The PBS medication classifications were also reviewed by a panel of researchers and clinicians and medications considered relevant for the hypothesis were included in the analyses. The ATC grouping was used in analyses. Cardiovascular medications included cardiac glycosides, anti-arrhythmics, nitrates, antihypertensives, diuretics, beta blockers, calcium channel blockers, ACE inhibitors, angiotensin antagonists and lipid modifying agents. Respiratory medications included systemic and inhaled glucocorticoids, beta agonists, anticholinergics, combination inhalers, xanthines, leukotriene antagonists and cough suppressants. Medications for mental health conditions included psycholeptics such as phenothiazines, haloperidol, indoles, thioxanthenes, benzodiazepines, benzamides and other antipsychotics; antidepressants such as MAO inhibitors, serotonin reuptake inhibitors, other antidepressants; and stimulants including dexamphetamine and methylphenidate. A small number of medications not considered relevant were excluded, for example analgesics and anti-Parkinsonian drugs. Supplementary Tables 2-4 present the full medication classifications and examples of medications in each class that were used in the analyses.

6.3.   Statistical analyses

Descriptive analysis

The results of the analyses for both health service use and medication dispensing were investigated using multiple techniques. Weekly time series counts of service use and medication dispensing plotted over the duration of their respective analyses periods provided a high level of insight regarding the potential time dependent patterns within the data. As our aim was to assess the short-term associations between air pollution and health outcomes, plotting the raw data would help us to understand if there were long-term trends and/or seasonality. In addition, daily time series counts of service use and medication dispensing were compared across two comparison time periods to ascertain whether utilisation varied during the 30-day fire period, compared to the 30 days immediately pre and post the fire and the same dates one year pre and post the fire.

Time series regression

Time-series analyses relating daily data on air pollutants to health outcomes (e.g. medical service use and pharmaceutical dispensing) are frequently used to assess the short-term health effects of air pollution (Bhaskaran et al., 2013). The method allows for adjustment of an outcome-exposure relationship by confounders stable over time, and examines the outcomes in a population repeatedly over the days in a specific time period under varying daily exposure conditions.

We used time series regression to examine the associations between daily mine-fire-related $PM_{2.5}$, health service use and dispensing of medications. Initial exploratory analyses of the time series data plots confirmed the presence of seasonality, trend and effects of public holidays (e.g. Christmas). A generalised linear model (GLM) with Poisson regression was used to model the impacts of air pollution on the outcomes: health service use and medication dispensing. In the GLM structure, the modelled daily fire-generated $PM_{2.5}$ was included alongside potential confounders including seasonality, long-term trend, day of the week, maximum ambient temperature and public holidays. Additional details relating to the parameters used in the statistical model may be found in Appendix 2.

Total health service use and medication dispensing records during the fire period for the MBS item codes and PBS ATC codes listed in Supplementary Table 1 and Table 2-4 respectively were first examined in preliminary analyses. The results of these analyses indicated that the number of records were too few for many of the specific conditions to yield reliable statistical inference. Hence the subsequent time series analyses were performed using larger condition groups: all respiratory diseases, all cardiovascular diseases and all mental health conditions.

The dose response relationships between a 10 $\mu g/m^3$ increase in fire-related $PM_{2.5}$ and health service utilisation and medication dispensing were examined to determine whether there were increases in the risk of utilisation and dispensing as fire-related $PM_{2.5}$ concentrations increased.

Cumulative relative risks (RR) over a lag period per 10 $\mu g/m^3$ increase in fire-related $PM_{2.5}$ were also calculated with their associated 95% confidence intervals (CIs) for each service type and medication. Cumulative RR could be interpreted as the sum of lag effects associated with air pollution exposure over the specified lag days. Estimated cumulative RR over 1 indicated elevated risks for service use associated with mine fire-generated $PM_{2.5}$. The 95% CI indicated the uncertainty of the cumulative RR value as an estimate of the true underlying association between the air pollutant and the health outcome. Smaller p-values indicated stronger evidence of a true underlying association (with the threshold of $p<0.05$ commonly referred to as statistically significant). However it must be borne in mind that p-values and the width of the confidence interval were dependent on not just the size of the estimated cumulative RR, but also on the number of occurrences of the health outcome being analysed.

Attributable counts and fractions were also calculated. Attributable counts indicated the number of service visits or medication dispensing that occurred in the Latrobe Valley as a result of population exposure to fire-related $PM_{2.5}$ emissions. Attributable fractions were the percentage change in service visits or medication dispensing, attributable to fire-related $PM_{2.5}$ emissions.

7. Results

7.1. MBS health service usage

Total counts of health service use for the Latrobe Valley for both the entire period analysed and the fire period are summarised in Table 1. Median daily health service use counts for the 2014 fire period and the equivalent 30-day period one year earlier are summarised in Table 2. During the 2014 fire period, the median daily health service use for all long and short GP consultations were 1,982, for all mental health consultations 140, for all cardiovascular services 96 and for all respiratory services 44. All four service types had marginally elevated utilisation compared to the equivalent 30-day period one year prior to the fires. Short GP consultations (76%) accounted for the majority of health services used during the fire period.

Table 1 Total number of MBS health service visits by service type for the Latrobe Valley

Health service type	Analysis period July 2012 June 2016	Mine fire period 9 Feb 2014 - 10 March 2014
	No. of records	No. of records
Short GP consultations	1,932,076	38,446
Long GP consultations	258,401	5,327
All Long & Short GP consultations	2,190,477	43,773
Mental Health- GP consultations	52,964	1,176
Mental Health- Specialist consultations	93,418	2,219
All Mental Health consultations	146,382	3,395
Cardiovascular specialist consultations	25,938	466
Cardiovascular diagnostic & imaging tests	86,267	1,859
All Cardiovascular service visits	112,205	2,325
Respiratory specialist consultations	16,906	370
Respiratory diagnostic & imaging tests	39,729	793
All Respiratory service visits	56,635	1,163
All above service types combined	2,505,699	50,656

Table 2 Median number of daily health service visits by service type for the Latrobe Valley

Health service type	1 Year pre fire 9 Feb 2013 - 10 March 2013		Mine fire period 9 Feb 2014 - 10 March 2014	
	Median	Interquartile Range	Median	Interquartile Range
Short GP consultations	1,704	272-1,816	1,720	273-1,869
Long GP consultations	209	21-230	240	30-267
All Long & Short GP consultations	1,922	292-2,049	1,982	304-2,139
Mental Health- GP consultations	53	5-58	48	10-58
Mental Health- Specialist consultations	74	10-106	86	15-118
All Mental Health consultations	130	13-166	140	19-173
Cardiovascular specialist consultations	18	6-37	12	5-24
Cardiovascular diagnostic & imaging tests	74	17-87	78	9-93
All Cardiovascular service visits	92	21-119	96	15-120
Respiratory specialist consultations	8	0-17	14	0-21
Respiratory diagnostic & imaging tests	30	6-35	30	7-40
All Respiratory service visits	40	7-57	44	10-58
All above service types combined	2,240	323-2,321	2,318	354-2,456

The weekly time series graphs for health service use were used to visualise the sequences of data and detect underlying seasonality and trends (Figure 2). There was some evidence of a trend of increased utilisation across the four year analysis period and the annual fluctuations within each calendar year reflected troughs in utilisation during public holiday periods. There were apparent increases in health service use during the mine fire compared to pre-fire periods and continuing increases following the fire. Figure 3 and Figure 4 compare the 30 day fire period to 30 days pre and post the fire (Figure 3) and the same 30 day period one year pre and post the fire (Figure 4).
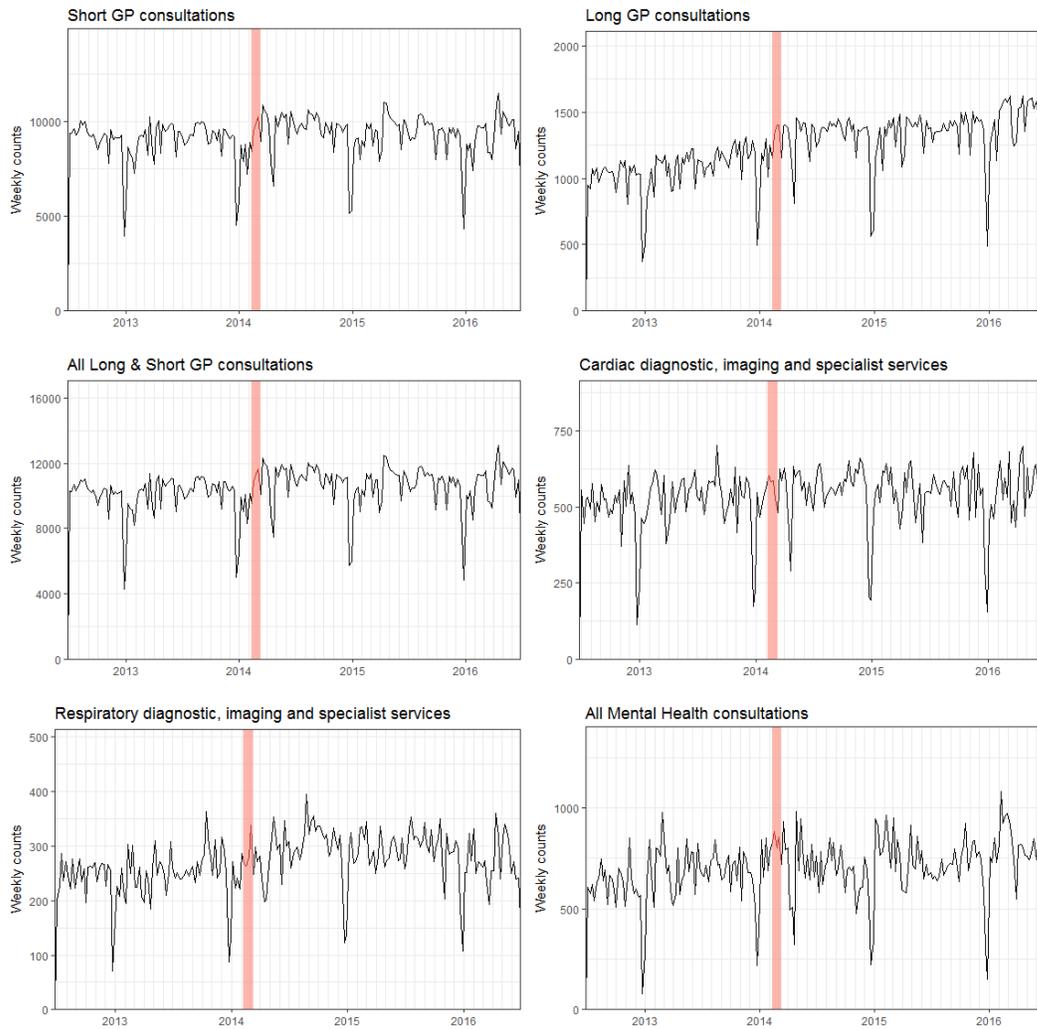
Figure 2 Raw unadjusted weekly time series for health service counts for the Latrobe Valley, 1 July 2012 to 30 June 2016.

Note: Red bars indicate the fire period.
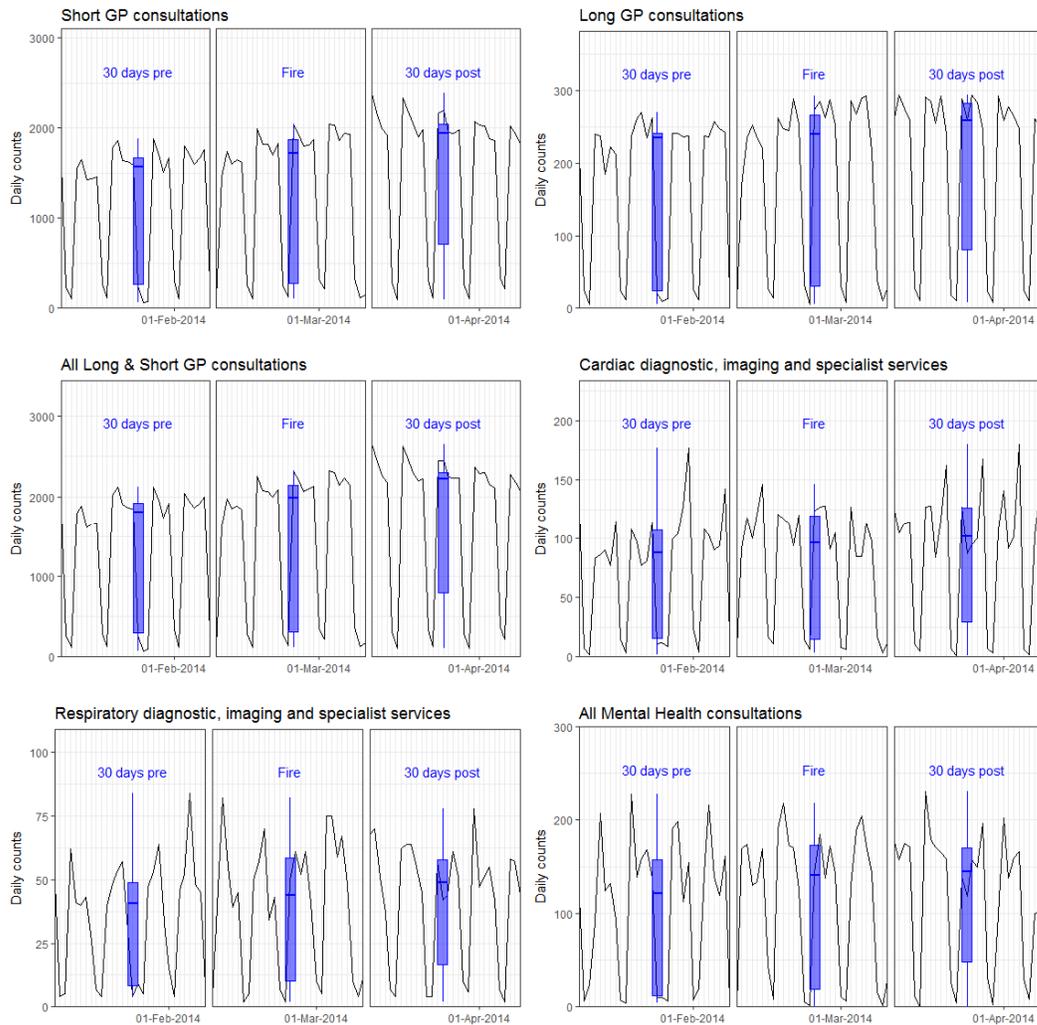
Figure 3 Raw unadjusted daily time series for health service counts for the Latrobe Valley, for the 30 days during the fire, 30 days before the fire and 30 days after the fire.

Note: Blue bar is the boxplot of distribution of daily counts where the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers the lowest and highest values.

Initial investigation of the health service use data for short and long GP consultations, all cardiovascular services, all respiratory services and all mental health consultations, indicated a rise over the three time periods i.e. the 30 days pre-fire, the 30 days during the fire and the 30 days post the fire (Figure 3).
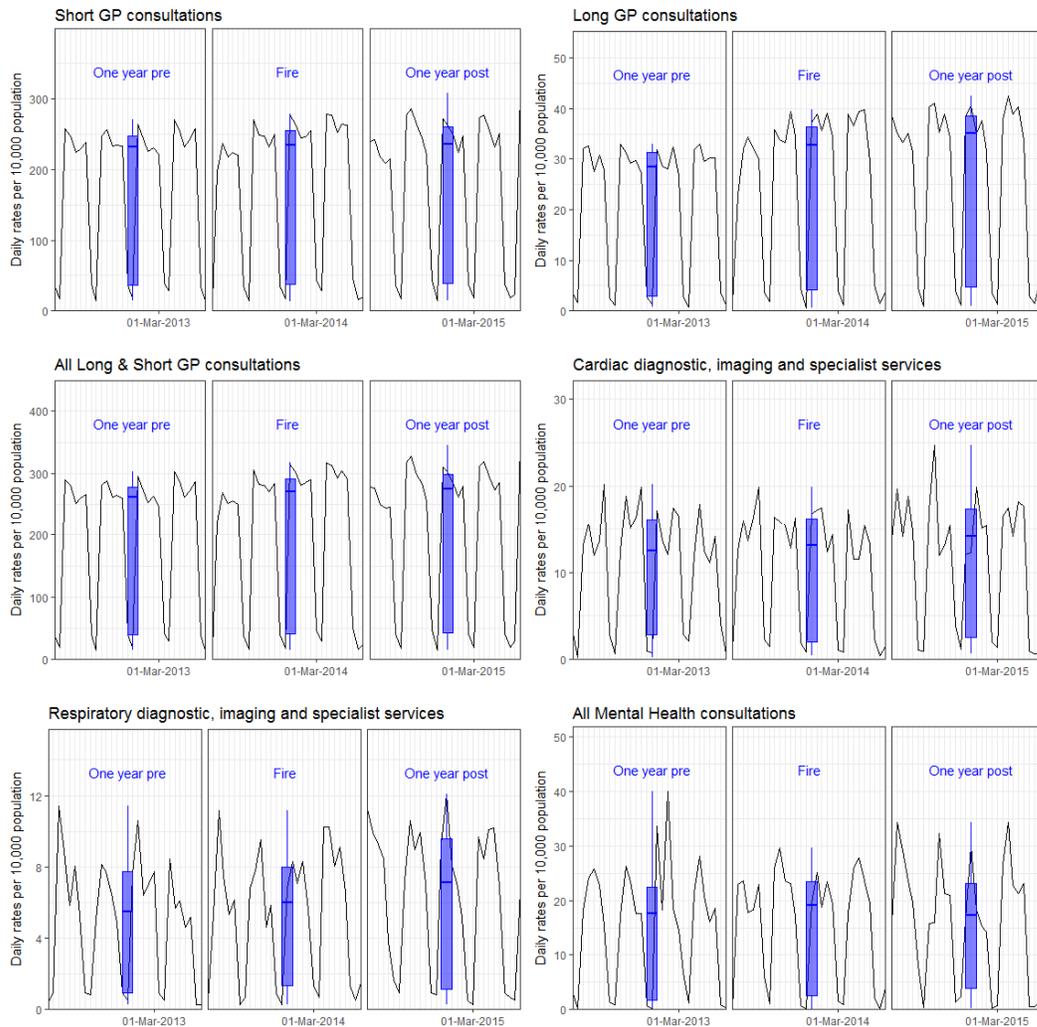
Figure 4 Raw unadjusted daily time series for health service counts for the Latrobe Valley, for the 30 days during the fire and the same 30-day period one year before the fire and one year after the fire.

Note: Blue bar is the boxplot of distribution of daily rates per 10,000 where the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers the lowest and highest values.

Initial investigations of the health service use data for short-GP consultations indicated a relatively constant trend for the same 30 day period, when one year prior to the fire, the year of the fire and the year post the fire were compared. Long GP consultations, all cardiovascular services and all respiratory services indicated increased use during the fire period compared to one year earlier and use appeared to increase one year post the fire. Health service use for all mental health consultations indicated an increase from the year of the fire compared to one year prior, before returning to pre fire levels one year later (Figure 4).
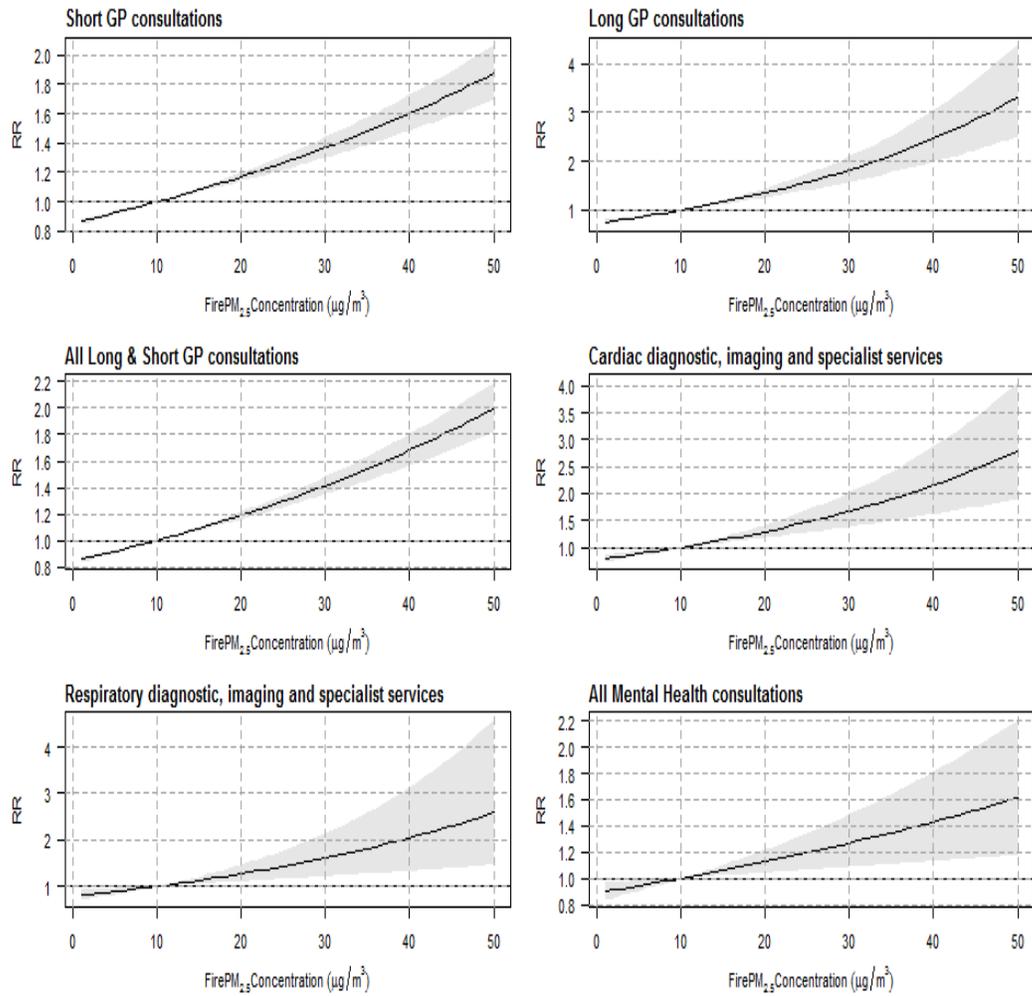
Figure 5 Exposure response relationships between 10 µg/m3 increase in fire-related PM$_{2.5}$ and health service use, at lags of 2-5 days after controlling for seasonality, public holidays, day of the week, long-term temporal trends and daily maximum temperature.

Our initial analyses showed that the associations between fire-related PM$_{2.5}$ and health service use appeared after a 2 day lag and disappeared after a 5 day lag (see Figure A1 in Appendix 2). Thus, we only examined further the cumulative associations over a 2 to 5 day lag, shown in Figure 5. These associations tended to be log-linear (Agresti et al., 2011).

Table 3 Cumulative relative risks of daily health service use associated with 10 μg/m3 increase in fire-related PM$_{2.5}$ after lag 2-5 days.

Health service	RR	95% CI	p-value
Short GP consultations	1.17	1.14 - 1.20	<0.001
Long GP consultations	1.35	1.26 - 1.45	<0.001
All Long & short GP consultations	1.19	1.16 - 1.22	<0.001
All Cardiovascular service visits	1.29	1.17 - 1.42	<0.001
All Respiratory service visits	1.27	1.10 - 1.46	0.001
All Mental health consultations	1.13	1.04 - 1.22	0.003
All above service types combined	**1.19**	**1.16 - 1.22**	**<0.001**

Note: Cumulative relative risks (RR) over 3 days' lag period (days 2-5) adjusting for seasonality, public holidays, day of the week, and daily maximum temperature, long-term temporal trends and their associated 95% confidence intervals (CIs).

It was estimated that each 10 μg/m^3 increase in fire-related PM$_{2.5}$ was associated with an estimated 19% increase (95%CI 16-22%) in the number of all long and short GP consultations, a 29% increase (95%CI 17-42%) in all cardiovascular services, a 27% increase (95%CI 10-46%) in all respiratory services and a 13% increase (95%CI 4-22%) in all mental health consultations, over the 2 to 5 day lag period (Table 3).

Table 4 Attributable fraction and attributable counts for lag 2-5 days of health service use due to coal mine fire-related PM$_{2.5}$ in the Latrobe Valley SA3, during period of the coal mine fire.

Health service type	Mean attributable fraction (95%CI)	Total attributable counts (95%CI)
Short GP consultations	10% (8%, 11%)	4,111 (3491, 4717)
Long GP consultations	18% (14%, 21%)	1,035 (818, 1237)
All Long & Short GP consultations	11% (10%, 12%)	5,137 (4481, 5777)
All Cardiovascular service visits	16% (10%, 20%)	405 (266, 532)
All Respiratory service visits	15% (6%, 22%)	174 (74, 261)
All Mental Health consultations	8% (3%, 12%)	286 (101, 457)
All above service types combined	**11% (10%, 12%)**	**5,977 (5279, 6661)**

The attributable fractions and attributable counts for health service utilisation due to mine fire-related PM$_{2.5}$ concentrations are presented in Table 4. There were 5,137 short and long GP consultations, 405 cardiovascular services, 174 respiratory services and 286 mental health consultations attributable to mine fire-related PM$_{2.5}$ in the Latrobe Valley. Correspondingly, the attributable fractions were 11% for short and long GP consultations, 16% for cardiovascular services, 15% for respiratory services and 8% for mental health consultations.

7.2. PBS medication dispensing

Total counts of medications dispensed for the Latrobe Valley for the entire period analysed and the mine fire period are summarised in Table 5. Median daily medication dispensing during the 2014 mine fire period and the equivalent period one year earlier are summarised in Table 6. During the 2014 mine fire period, the median numbers dispensed daily were 1,256 cardiovascular medications, 239 respiratory medications and 558 for mental health medications. This represented a slight increase in respiratory and mental health medications being dispensed on a daily basis, and a slight reduction in cardiovascular medications, compared to the equivalent 30 day period one year prior to the fire.

Table 5 Numbers of medications dispensed by medication type in the Latrobe Valley SA3

Medication type	Analysis Period Jan 2013 - June 2016	Mine Fire Period 9 Feb 2014 - 10 March 2014
	No. of records	No. of records
Cardiovascular	1,617,221	30,593
Respiratory	305,377	6,066
Mental Health	703,271	13,354
All above medications	**2,625,869**	50,013

Table 6 Median of medications dispensed daily by medication type for the Latrobe Valley SA3

Medication type	1 Year pre fire 9 Feb 2013 - 10 March 2013		Mine Fire Period 9 Feb 2014 - 10 March 2014	
	Median	Interquartile Range	Median	Interquartile Range
Cardiovascular	1,301	674-1,404	1,256	620-1,384
Respiratory	199	88-218	239	128-273
Mental Health	528	252-605	558	258-598
All above medications	**2,044**	**1,008-2,216**	**2,111**	**1,020-2,249**

As with health service utilisation, the initial investigation into medication dispensing (Figure 6) appeared to indicate an increased trend in dispensing across the four-year analysis period and annual fluctuations within each calendar year, which were reflected in peaks pre-Christmas and troughs during public holiday periods. This meant we had to allow for seasonality and public holidays when assessing potential associations between daily air pollution and medication dispensing. Variations in medication dispensing are hard to visually detect in Figure 6, hence subsequent figures are presented that compare the 30-day fire period to the 30 days pre and post the fire (Figure 7) and the same 30-day period one year pre and post the fire (Figure 8).
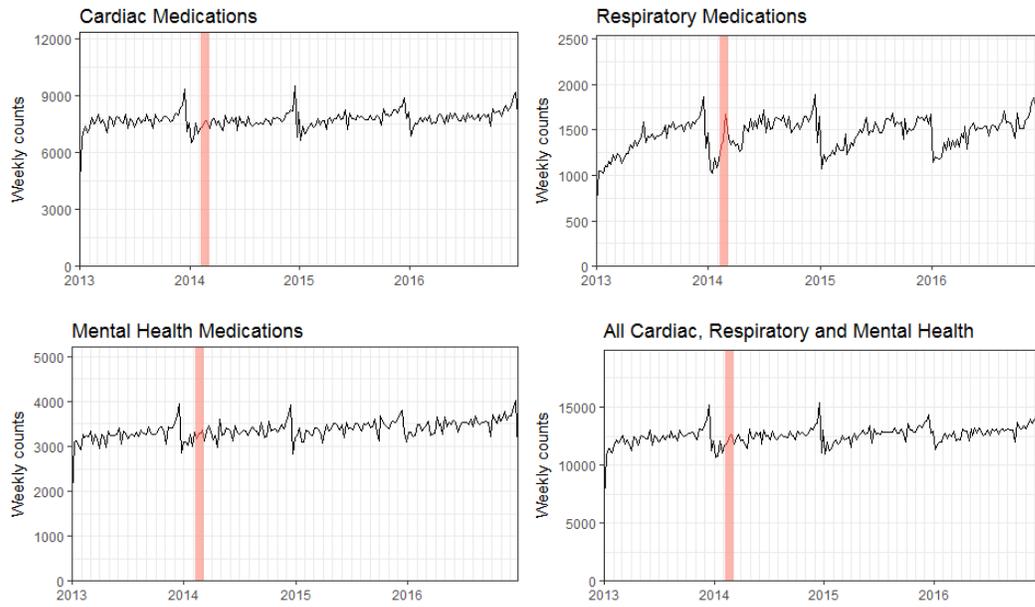
Figure 6 Raw unadjusted weekly time series for PBS medications dispensed in the Latrobe Valley, 1 Jan 2013 to 31 Dec 2016.

Note: Red bar indicates the fire period.
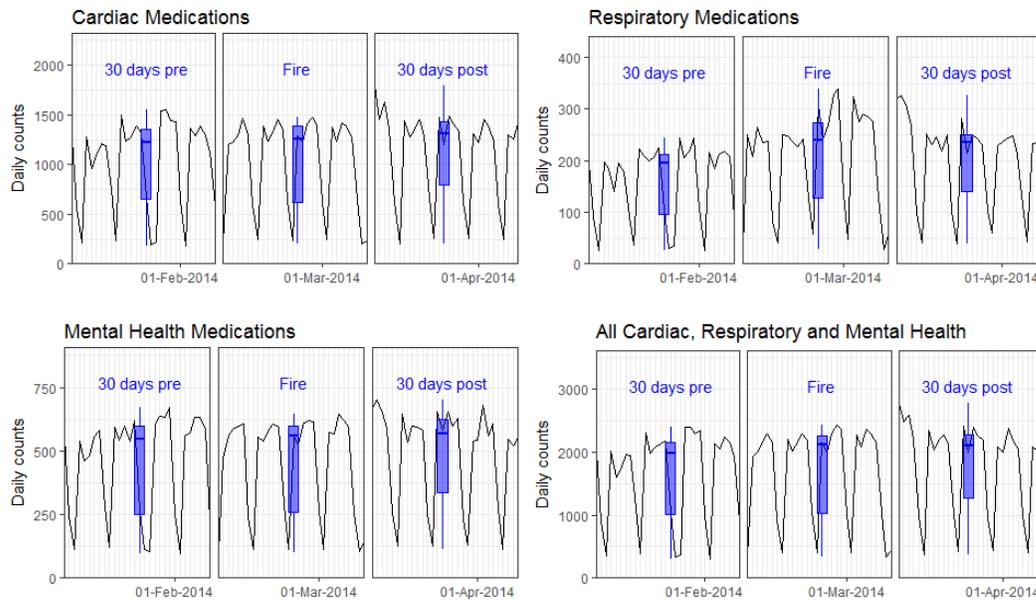
Figure 7 Raw unadjusted daily time series for medications dispensed in the Latrobe Valley for the 30 days during the fire, 30 days before the fire and 30 days after the fire.

Note: Blue bar is the boxplot of the distribution of daily counts where the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers the lowest and highest values.

As seen in Figure 7, initial investigation indicated cardiovascular medication dispensing appeared to fall marginally during the fire period, compared to the 30 days prior and then increased in the 30 days post the fire. Respiratory medication dispensing appeared to increase during the fire period compared to the pre-fire period and declined post the fire, however dispensing appeared to remain above pre-fire levels. Dispensing of medications for mental health conditions increased during the fire compared to pre-fire and continued to increase slightly post fire.
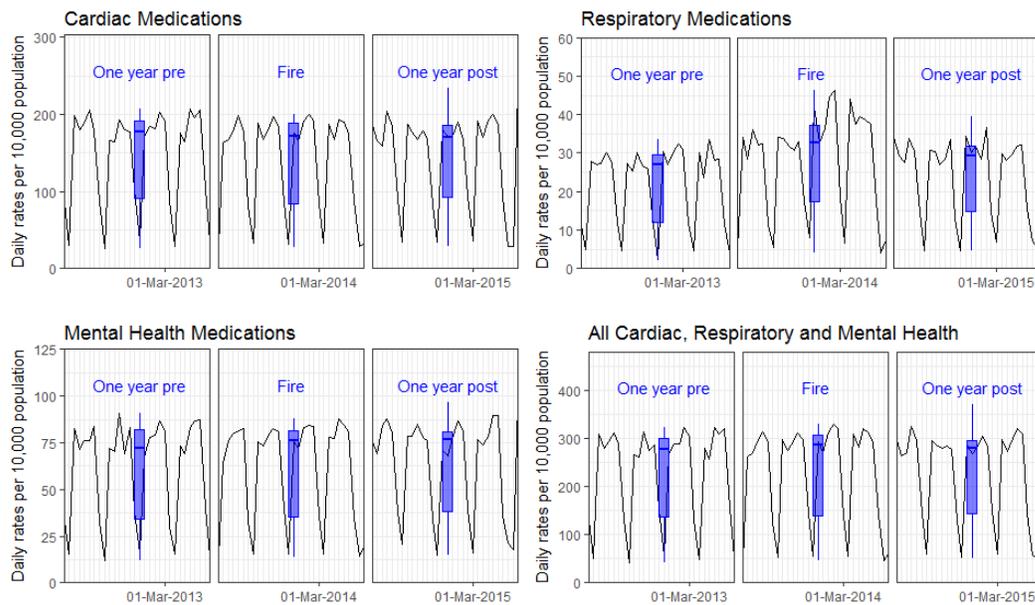
Figure 8 Raw unadjusted daily time series for PBS medication dispensing in the Latrobe Valley for the 30 days during the fire and the same 30 day period one year before the fire and one year after the fire.

Note: Blue bar is the boxplot of distribution of daily rates per 10,000 where the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers the lowest and highest values.

As seen in Figure 8, initial investigation of cardiovascular medication dispensing indicated a slight downward trend for the same 30 day period when one year prior to the fire, the year of the fire and the year following the fire were compared. Respiratory medication dispensing appeared to increase in the fire year and then declined the following year but remained above pre fire levels. Dispensing of medications for mental health conditions appeared to increase in the fire year and then remain stable at the higher level one year later.
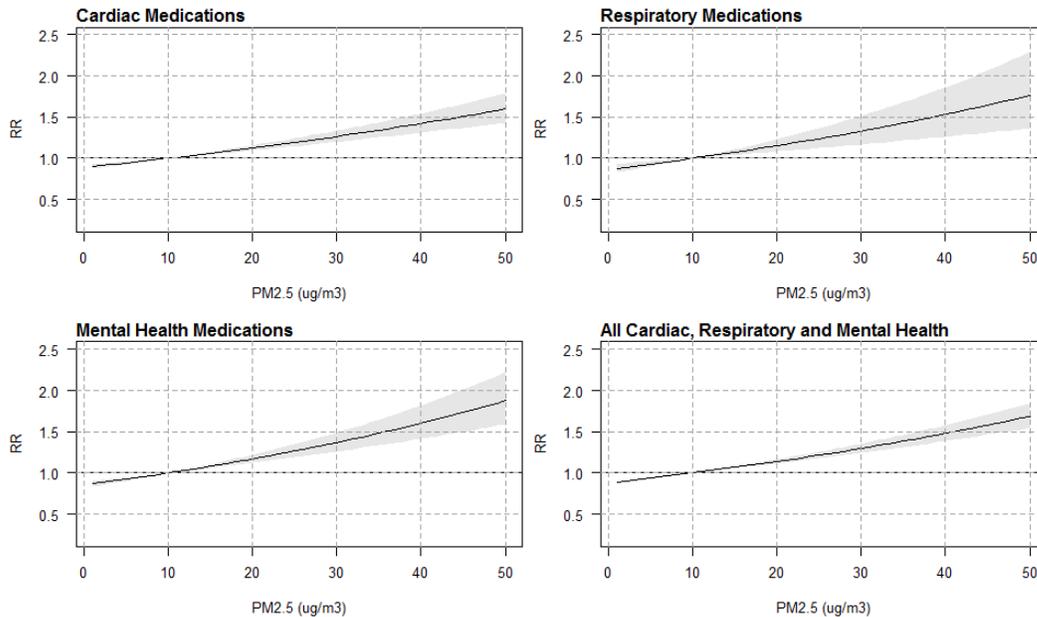
Figure 9 Exposure response relationships between 10 µg/m3 increase in fire-related PM$_{2.5}$ and medication dispensing at lags of 2-5 days, after controlling for seasonality, holidays, day of the week, long-term temporal trends and daily maximum temperature.

Our initial analyses showed that the associations between fire-related PM$_{2.5}$ and medication dispensing appeared after a 2 day lag and disappeared after a 5 day lag (see Figure A2 in Appendix 2). Thus, cumulative associations were confined to a 2 to 5 day lag period, shown in Figure 9. The association tended to be log-linear (Agresti, et al. 2011).

Table 7 Cumulative relative risks of PBS medication dispensing associated with 10 µg/m3 increase in fire-related PM$_{2.5}$, along lag 2-5 days.

Medication type	RR*	95% CI	p-value
Cardiovascular	1.12	1.09 - 1.16	<0.001
Respiratory	1.15	1.08 - 1.23	<0.001
Mental Health	1.17	1.12 - 1.22	<0.001
All above medications	**1.14**	**1.12 - 1.16**	**<0.001**

Note Cumulative relative risks (RR) over 3 days' lag period (days 2-5) adjusting for seasonality, public holidays, day of the week, long-term temporal trends and daily maximum temperature and their associated 95% confidence intervals (CIs).

Each 10 µg/m^3 increase in fire-related PM$_{2.5}$ was associated with an estimated 12% increase (95% CI 9-16%) in the dispensing of cardiovascular medications, a 15% increase (95% CI 8-23%) in the dispensing of respiratory medications and a 17% increase (95% CI 12-22%) in the dispensing of mental health medications, over the 2 to 5 day lag period (Table 7).

Table 8 Attributable fractions and attributable counts for lag 2-5 days of PBS medication dispensing due to mine fire-related PM$_{2.5}$ in the Latrobe Valley SA3, during the period of the coal mine fire.

Medication type	Mean attributable fraction (95% CI)	Total attributable counts (95% CI)
Cardiovascular	8% (6%, 10%)	2,501 (1942, 3045)
Respiratory	9% (5%, 13%)	574 (321, 812)
Mental Health	10% (8%, 12%)	1,429 (1071, 1773)
All above medications	**8% (7%, 10%)**	4,497 (3792, 5188)

The fractions and counts for dispensing of respiratory medications, cardiovascular medications and mental health medications, attributable to mine fire-related PM$_{2.5}$ are presented in Table 8.

There were 2,501 prescriptions dispensed for cardiovascular medications, 574 for respiratory medications and 1,429 for mental health medications attributable to mine fire-related PM$_{2.5}$ in the Latrobe Valley. Correspondingly, the attributable fractions for dispensed medications were 8% for respiratory, 9% for cardiovascular and 10% for mental health medications.

8. Discussion

8.1. Summary of main findings

This is the first study to examine the impacts of the 2014 Hazelwood coal mine fire on Commonwealth reimbursed health service use and medication dispensing. Time series analyses showed that the coal mine fire-related $PM_{2.5}$ was significantly associated with an estimated increase in the utilisation of all health service types examined (short and long GP, respiratory, cardiovascular and mental health) and dispensing of all medication types examined (cardiovascular, respiratory and mental health) after a 2 to 5 day lag from exposure.

Descriptive analyses

Rates of health service utilisation for all service types were found to be elevated during the mine fire period, in comparison to the period 30 days prior to the fire, and continued to increase in the 30 days following the fire. In addition, it was found that the number of respiratory and mental health medications dispensed increased during the fire period, compared to 30 days before the fire, while cardiovascular medication dispensing fell marginally over the same time frame. This may reflect that cardiovascular medications are primarily used to manage long term cardiovascular risk and their utilisation would not be expected to be responsive to short term changes in air quality. However care should be taken when interpreting these results as they simply compare the raw data without any statistical correction for confounders or measurement error.

Time series analyses

After statistically adjusting for long-term trend, seasonality, temperature, day of the week and public holidays, for each 10 μg/m^3 increase in mine fire-related $PM_{2.5}$ the estimated percentage increases in health service visits were: 19% for all short and long GP consultations, 29% for all cardiovascular services, 27% for all respiratory services and 13% for all mental health consultations. During the mine fire period, there were 5,137 visits for all short and long GP consultations, 405 visits for all cardiovascular services, 174 visits for all respiratory services and 286 visits for all mental health consultations attributable to mine fire-related $PM_{2.5}$ exposure in the Latrobe Valley. Correspondingly, the attributable fractions were 11%, 16%, 15%, and 8%, respectively.

Increases in the dispensing of medications were also observed. For each 10 μg/m^3 increase in mine fire-related $PM_{2.5}$ there were estimated increases of: 12% for cardiovascular medications, 15% for respiratory medications and 17 % for mental health medications. There were 2,501 cardiovascular medications, 574 respiratory medications and 1,429 mental health medications, attributable to mine

fire-related $PM_{2.5}$ exposure during the mine fire period. Correspondingly, the attributable fractions were 8%, 9%, and 10%, respectively.

8.2.   Relationship to previous published work

There have been no previously published studies on the associations between coal mine fire-related $PM_{2.5}$ concentrations and health service utilisation or medication dispensing. These analyses show clear evidence that the mine fire-related $PM_{2.5}$ was significantly associated with an increased risk for both health service utilisation for all types of service analysed (short and long GP, respiratory, cardiovascular and mental health) and prescriptions dispensed for all types of medication analysed (respiratory, cardiovascular and mental health) for the Latrobe Valley region.

However our findings are consistent with epidemiological studies that have typically reported positive associations between bushfire $PM_{2.5}$ and respiratory morbidity (Haikerwal et al., 2016). In four Canadian based studies, positive associations were found between wildfire $PM_{2.5}$ and increased dispensing of the bronchodilator salbutamol (Elliott et al., 2013; Yao et al., 2013; Yao et al., 2016; Yuchi et al., 2016). In three of those studies a positive association was also found between wildfire $PM_{2.5}$ and increased respiratory physician visits (Yao et al., 2013; Yao et al., 2016; Yuchi et al., 2016). In two additional Canadian studies, a positive association between PM_{10} and increased respiratory physician visits was found (Henderson et al., 2011; Moore et al., 2006). In a Spanish study a positive association was found between counts of bushfires per municipality during the fire season and increased dispensing of medications for obstructive airways disease (Caamano-Isorna et al., 2011).

Associations between bushfire $PM_{2.5}$ and health service use and cardiovascular medications dispensed are less consistent. In a Canadian study, a significant association was found for both dispensing of fast-acting nitro-glycerine (a common medication for angina) and cardiovascular physician visits, when the analyses was limited to extreme fire days. However no association was found for either health indicator when the entire fire season was analysed (Yao et al., 2016). In another Canadian study, a largely null association was found between bushfire PM_{10} and cardiovascular physician visits, however a small positive association was found for those aged 40-50 years and over 80 years (Henderson et al., 2011). In an earlier Canadian study, no association was found between bushfire PM_{10} and cardiovascular physician visits (Moore et al., 2006).

The relationship between the mine fire-related $PM_{2.5}$ with estimated increases in health service utilisation and dispensed medications for mental health conditions for the Latrobe Valley is significant. Previous research related to bush fires has found increased mental health problems following a major bushfire event in Australia (McFarlane et al., 1997). However few studies have

looked at the association between bushfire $PM_{2.5}$ and health service use or medication dispensing for mental health morbidity. In the Spanish study above, a positive association was found between bushfire counts and increased dispensing of anxiolytics-hypnotics, for both male pensioners and non-pensioners (age not specified), (Caamano-Isorna et al., 2011). In one of the above Canadian studies, no association was found between bushfire PM_{10} and mental health physician visits (Moore et al., 2006).

It should be noted that most bushfires are much shorter in duration than the Hazelwood mine fire event and therefore our analysis have contributed new findings to the literature. Additionally, in contrast to the above bushfire studies which found inconsistent patterns between the utilisation of health services and medication dispensing for different health categories, our analyses found similar patterns for all health categories examined: respiratory, cardiovascular and mental health.

8.3.   Strengths & weaknesses

These Hazelinks analyses have several strengths:

- This research provides the first known report of health services use and medication dispensing after a prolonged brown coal open cut mine fire event, thereby providing direct evidence regarding the impact of prolonged coal mine fire smoke on human health.

- This study had access to two very complete government administrative health datasets (MBS and PBS), from which to source health service utilisation and medication dispensing data.

- The use of a distributed nonlinear lag model to examine the potential delayed effects has been helpful to understand which days of exposure were associated with estimated increases in health service use and medication dispensing. A major benefit of using these statistical models is that they are able to account for the delayed and nonlinear effects of ambient maximum temperature and pollutants to provide cumulative risk estimates for health outcomes along with lag specific ones. We were able to identify a lagged impact of $PM_{2.5}$ across a number of days and establish where the significant lagged effects lay. The flexibility of this type of modelling technique lies in the ability to set the number of degrees of freedom, number of lags and type of smooth spline used.

- The analyses controlled for the potential confounding effects of maximum daily ambient temperature, long-term trend, public holidays, day of the week and seasonality.

- The use of a high spatial resolution air exposure model allowed $PM_{2.5}$ smoke concentrations, attributable to the coal mine fire, to be estimated for geographic areas where air quality monitor measurements were not available.

However these analysis also have some limitations:

- This study design was semi-ecological and, therefore, it was not possible to explore effect modification or confounding at an individual level.

- Our analyses only investigated the impact of coal mine fire-related $PM_{2.5}$ and did not include other criteria pollutants such as carbon monoxide, ozone, nitrogen dioxide, sulphur dioxide. However the levels of those other pollutants were lower than National Environment Protection Measures. Focusing on one measure, rather than the cumulative impact of multiple (mostly lower level) exposures, might underestimate the health risks in relation to the coal mine fire smoke.

- The use of modelled $PM_{2.5}$ concentration levels in lieu of individual level measurements, may have introduced exposure misclassification. This would bias effect estimates towards the null, reducing the likelihood of detecting an association. Additionally, the exposure analysis was conducted at a relatively coarse spatial resolution. This was because health utilisation and medication dispensing data were only provided at the aggregated SA3 level due to privacy concerns. Aggregating concentration estimates over large areas also has the potential to introduce exposure misclassification, biasing the effect estimates towards the null. The potential for such misclassification can be seen in Figure 10 which compares modelled $PM_{2.5}$ concentrations attributable to the coal mine fire at different levels of aggregation. The comparison indicates that concentrations experienced in the Morwell SA2 area (red line) were considerably higher than the Latrobe Valley average concentration values (black line) used in the analyses and therefore any potential health effects may have been underestimated for Morwell residents.

- The datasets used in these analyses were collected for administrative billing purposes and therefore presented some limitations. One limitation relates to the fact that MBS service coding may not be standardised across all health services, as it is dependent on the treating physician or practice staff. A further limitation is the fact that the dispensing of medications does not necessarily reflect disease exacerbation nor actual medication consumption. PBS data is also limited in that it does not include all medications. For example salbutamol inhalers are available over the counter at pharmacies, without any PBS subsidy. The MBS

dataset only includes claim records for services that qualified for Medicare benefits and for which a claim had been processed. The PBS dataset only contained information on prescription medicines where the prescription had been processed (i.e. the prescription had been filled by the pharmacist). Both the MBS and PBS exclude some allied health and complementary medicine services.

- It was not possible to sub-divide short and long GP consultations into specific health categories as GP data in the MBS did not specify health information and therefore had to be analysed at group level.
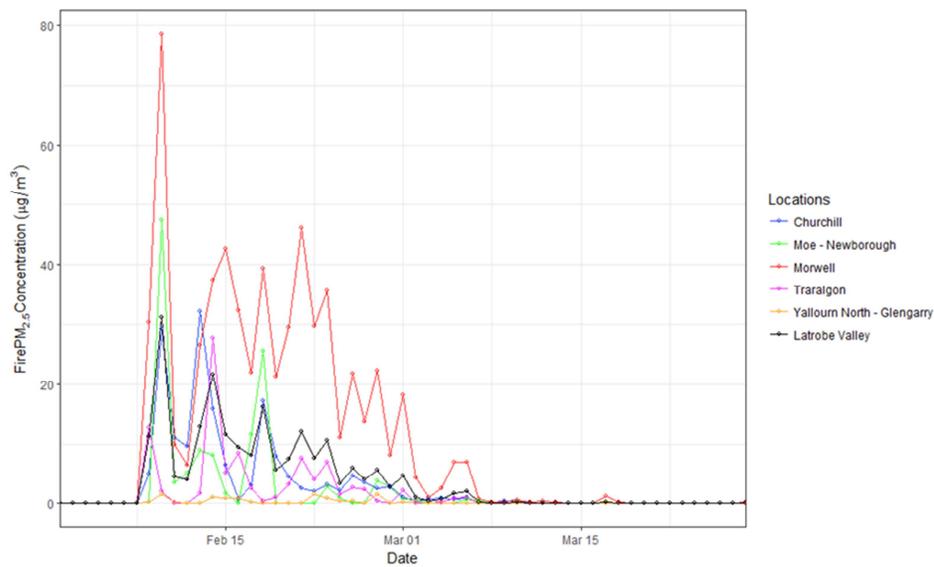
Figure 10 Daily average modelled PM$_{2.5}$ concentrations attributable to the mine fire aggregated at different spatial scales: the SA2 areas within the Latrobe Valley and the Latrobe Valley SA3

9. Conclusions

This analysis shows clear evidence that coal mine fire-related PM$_{2.5}$ was significantly associated with an estimated increase in the utilisation of all health service types examined (short and long GP, respiratory, cardiovascular and mental health) and the dispensing of all medication types examined (respiratory, cardiovascular and mental health). This contributes to filling the knowledge gap which currently exists regarding the health impact of open cut brown coal mine fire smoke exposure. Such robust evidence-based research is important to improve health impact assessment of at-risk groups, and to improve targeted health advice and emergency health services. This study should be helpful to develop and implement effective and more timely adaptive strategies to mitigate cardiovascular, respiratory and mental health risks due to possible future coal mine fire derived air pollution exposures in the community.

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Appendix 1: Supplementary Tables

Supplementary Table 1:   MBS health service use by service type included in the analysis

Health service type	
Group	**Item Numbers**
Short GP consultations	
A1 General Practitioner	3, 4, 20, 23, 24, 35
A2 Other non-referred	52, 53, 58,59, 92, 93
A11 After Hours	597, 598,5 99,600
A21 Medical Practitioner (Emergency Physician) attendances	501, 503
A22 GP after-hours attendances to which no other item applies	5000, 5003, 5010, 5020, 5023, 5028
A23 Other non-referred after-hours attendances to which no other item applies	5200, 5203, 5223, 5260, 5263
Long GP consultations	
A1 General Practitioner	36, 37, 43, 44, 47, 51
A2 Other non-referred	54, 57, 60, 65, 95, 96
A5 Prolonged	160, 161, 162, 163, 164
A21 Medical Practitioner (Emergency Physician) attendances	507, 511, 515, 520
A22 GP after-hours attendances to which no other item applies	5040, 5043, 5049, 5060, 5063, 5067
A23 Other non-referred after-hours attendances to which no other item applies	5207, 5208, 5227, 5265, 5267
GP Mental Health consultations	
A20 GP Mental Health Treatment	2700, 2701, 2712, 2713, 2715, 2717, 2721, 2725
Specialist Mental Health consultations	
A8 Consultant Psychiatrist	288, 289, 291, 293, 296, 297, 299, 300, 302, 304, 306, 308, 310, 319, 320, 322, 324, 326, 328, 330, 332, 334, 336, 338, 342, 346, 348, 350, 352, 355, 356, 357, 359, 361, 367, 369
M6 Psychological Therapy Services	80000, 80005, 80010, 80015, 80020
M7 Focussed Psychological Strategies	80100, 80105, 80110, 80115, 80120, 80125, 80135, 80140, 80145, 80150, 80155, 80160, 80165,80170
Cardiovascular specialist consultations	
A4 Consultant Physician (other than Psychiatry) Where Provider Derived Specialty Description = "CP-CARDIOLOGY"	110, 112, 116, 119, 132, 133

Cardiovascular diagnostic & imaging tests	
D1 Miscellaneous Diagnostic Procedures and Investigations	11602, 11610, 11611, 11612, 11700, 11701, 11702, 11708, 11709, 11710, 11711, 11712, 11713, 11718, 11719, 11721, 11722, 11724, 11725, 11727
I1 Ultrasound (Echocardiography)	55113, 55114, 55115, 55116, 55117, 55118, 55130, 55135, 55224, 55227, 55233, 55238, 55244, 55246, 55248, 55252, 55274, 55276, 55278, 55280, 55282, 55284, 55292, 55294, 55296,
I3 Diagnostic Radiology	59903, 59912, 59925, 59970, 59972, 59973, 60000, 60003, 60006, 60009, 60012, 60018, 60021, 60024, 60027, 60030, 60033, 60039, 60042, 60045, 60048, 60051, 60054, 60057, 60060, 60063, 60066, 60069, 60072, 60075, 60078
T1 Miscellaneous Therapeutic Procedures	13400
Respiratory specialist consultations	
A4 Consultant Physician (other than Psychiatry) Where Provider Derived Specialty Description = "CP-THORAC-MED"	110, 112, 116, 119, 132, 133
Respiratory diagnostic & imaging tests	
D1 Miscellaneous Diagnostic Procedures and Investigations (Lung function tests)	11503, 11506, 11512
I3 Diagnostic Radiology	58503

Supplementary Table 2:   Cardiovascular system medication classifications included in the analyses

NAME2	NAME4	ATC	DRUG_NAME
Cardiac Therapy		**C01**	
	Digitalis Glycosides	C01AA05	Digoxin
	Antiarrhythmics, Class IA	C01BA03	Disopyramide
	Antiarrhythmics, Class IB	C01BB01	Lignocaine Hydrochloride
	Antiarrhythmics, Class IC	C01BC04	Flecainide Acetate
	Antiarrhythmics, Class III	C01BD01	Amiodarone Hydrochloride
	Adrenergic & Dopaminergic Agents	C01CA24	Adrenaline
	Organic Nitrates	C01DA02	Glyceryl Trinitrate
	Organic Nitrates	C01DA08	Isosorbide Dinitrate
	Organic Nitrates	C01DA14	Isosorbide Mononitrate
	Other Vasodilators used in Cardiac Diseases	C01DX16	Nicorandil
Antihypertensives		**C02**	
	Methyldopa	C02AB01	Methyldopa
	Imidazoline Receptor Agonists	C02AC01	Clonidine
	Imidazoline Receptor Agonists	C02AC05	Moxonidine
	Alpha-Adrenoreceptor Antagonists	C02CA01	Prazosin Hydrochloride
	Hydrazinophthalazine Derivatives	C02DB02	Hydralazine Hydrochloride
	Pyrimidine Derivatives	C02DC01	Minoxidil
	Other antihypertensives	C02KX01	Bosentan
	Other antihypertensives	C02KX02	Ambrisentan
	Other antihypertensives	C02KX04	Macitentan
Diuretics		**C03**	
	Thiazides, Plain	C03AA03	Hydrochlorothiazide
	Sulfonamides, Plain	C03BA04	Chlorthalidone
	Sulfonamides, plain	C03BA11	Indapamide
	Sulfonamides, Plain	C03CA01	Frusemide
	Aryloxyacetic Acid Derivatives	C03CC01	Ethacrynic acid
	Aldosterone Antagonists	C03DA01	Spironolactone
	Aldosterone Antagonists	C03DA04	Eplerenone
	Low-ceiling Diuretics & Potassium-Sparing Agents	C03EA01	Hydrochlorothiazide with Triamterene
	Low-ceiling Diuretics & Potassium-Sparing Agents	C03EA01	Hydrochlorothiazide with Amiloride Hydrochloride
Beta Blocking Agents		**C07**	
	Beta Blocking Agents, Non-selective	C07AA02	Oxprenolol Hydrochloride
	Beta Blocking Agents, Non-selective	C07AA03	Pindolol
	Beta Beta Blocking Agents, Non-selective	C07AA05	Propranolol Hydrochloride
	Beta Blocking Agents, Non-selective	C07AA07	Sotalol Hydrochloride
	Beta Blocking Agents, Selective	C07AB02	Metoprolol Tartrate
	Beta Blocking Agents, Selective	C07AB02	Metoprolol Succinate

	Beta Blocking Agents, Selective	C07AB03	Atenolol
	Beta Blocking Agents, Selective	C07AB07	Bisoprolol
	Beta Blocking Agents, Selective	C07AB12	Nebivolol
	Alpha & Beta Blocking Agents	C07AG01	Labetalol Hydrochloride
	Alpha & Beta Blocking Agents	C07AG02	Carvedilol
Calcium Channel Blockers		**C08**	
	Dihydropyridine Derivatives	C08CA01	Amlodipine
	Dihydropyridine Derivatives	C08CA02	Felodipine
	Dihydropyridine Derivatives	C08CA05	Nifedipine
	Dihydropyridine Derivatives	C08CA13	Lercanipidine
	Phenylalkylamine Derivatives	C08DA01	Verapamil Hydrochloride
	Benzothiazepine Derivatives	C08DB01	Diltiazem Hydrochloride
Agents Acting on the Renin-Angiotensin System		**C09**	
	Ace Inhibitors, Plain	C09AA01	Captopril
	Ace Inhibitors, Plain	C09AA02	Enalapril Maleate
	Ace Inhibitors, Plain	C09AA03	Lisinopril
	Ace Inhibitors, Plain	C09AA04	Perindopril
	Ace Inhibitors, Plain	C09AA05	Ramipril
	Ace Inhibitors, Plain	C09AA06	Quinapril
	Ace Inhibitors, Plain	C09AA09	Fosinopril
	Ace Inhibitors, Plain	C09AA10	Trandolapril
	Ace Inhibitors & Diuretics	C09BA02	Enalapril with Hydrochlorothiazide
	Ace Inhibitors & Diuretics	C09BA04	Perindopril with Indapamide
	Ace Inhibitors & Diuretics	C09BA06	Quinapril with Hydrochlorothiazide
	Ace Inhibitors & Diuretics	C09BA09	Fosinopril with Hydrochlorothiazide
	Ace Inhibitors & Calcium Channel Blockers	C09BB02	Enalapril & Lercanidipine
	Ace Inhibitors & Calcium Channel Blockers	C09BB04	Perindopril & Amlodipine
	Ace Inhibitors & Calcium Channel Blockers	C09BB05	Ramipril & Felodipine
	Ace Inhibitors & Calcium Channel Blockers	C09BB10	Trandolapril & Verapamil
	Angiotensin II Antagonists, Plain	C09CA01	Losartan
	Angiotensin II Antagonists, Plain	C09CA02	Eprosartan
	Angiotensin II Antagonists, Plain	C09CA03	Valsartan
	Angiotensin II Antagonists, Plain	C09CA04	Irbesartan
	Angiotensin II Antagonists, Plain	C09CA06	Candesartan
	Angiotensin II Antagonists, Plain	C09CA07	Telmisartan
	Angiotensin II Antagonists, Plain	C09CA08	Olmesartan Medoxomil
	Angiotensin II Antagonists & Diuretics	C09DA02	Eprosartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Diuretics	C09DA03	Valsartan with

			Hydrochlorothiazide
	Angiotensin II Antagonists & Diuretics	C09DA04	Irbesartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Diuretics	C09DA06	Candesartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Diuretics	C09DA07	Telmisartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Calcium Channel Blockers	C09DB01	Amlodipine & Valsartan
	Angiotensin II Antagonists & Calcium Channel Blockers	C09DB02	Olmesartan with Amlodipine
	Angiotensin II Antagonists & Calcium Channel Blockers	C09DB04	Telmisartan & Amlodipine
	Angiotensin II Antagonists, Other Combinations	C09DX01	Amlodipine with Valsartan & Hydrochlorothiazide
	Angiotensin II Antagonists, Other Combinations	C09DX03	Olmesartan with Amlodipine & Hydrochlorothiazide
Lipid Modifying Agents		**C10**	
	HMG COA Reductase Inhibitors	C10AA01	Simvastatin
	HMG COA Reductase Inhibitors	C10AA03	Pravastatin
	HMG COA Reductase Inhibitors	C10AA04	Fluvastatin
	HMG COA Reductase Inhibitors	C10AA05	Atorvastatin
	HMG COA Reductase Inhibitors	C10AA07	Rosuvastatin
	Fibrates	C10AB04	Gemfibrozil
	Fibrates	C10AB05	Fenofibrate
	Bile Acid Sequestrants	C10AC01	Colestyramine
	Bile Acid Sequestrants	C10AC02	Colestipol Hydrochloride
	Other Lipid Modifying Agents	C10AX09	Ezetimibe
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA02	Simvastatin & Ezetimibe
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA05	Atorvastatin & Ezetimibe
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA05	Ezetimibe with Atorvastatin
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA06	Ezetimibe & Rosuvastatin
	HMG COA Reductase Inhibitors, Other Combinations	C10BX03	Atorvastatin & Amlodipine

Supplementary Table 3:   Respiratory system medication classifications included in the analyses

NAME2	NAME4	ATC	DRUG_NAME
CORTICOSTEROIDS FOR SYSTEMIC USE		**H02**	
	GLUCOCORTICOIDS	H02AB01	BETAMETHASONE
	GLUCOCORTICOIDS	H02AB02	DEXAMETHASONE
	GLUCOCORTICOIDS	H02AB04	METHYLPREDNISOLONE
	GLUCOCORTICOIDS	H02AB06	PREDNISOLONE
	GLUCOCORTICOIDS	H02AB07	PREDNISONE
	GLUCOCORTICOIDS	H02AB08	TRIAMCINOLONE
	GLUCOCORTICOIDS	H02AB09	HYDROCORTISONE
	GLUCOCORTICOIDS	H02AB10	CORTISONE
DRUGS FOR OBSTRUCTIVE AIRWAY DISEASES		**R03**	
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC02	SALBUTAMOL
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC03	TERBUTALINE
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC12	SALMETEROL
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC13	EFORMOTEROL
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC18	INDACATEROL
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK06	SALMETEROL & FLUTICASONE
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK07	EFORMOTEROL with BUDESONIDE
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK10	FLUTICASONE with VILANTEROL
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK11	FLUTICASONE with EFORMOTEROL
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL03	UMECLIDINIUM with VILANTEROL
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL04	INDACATEROL with GLYCOPYRRONIUM
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL05	ACLIDINIUM with EFORMOTEROL
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL06	TIOTROPIUM with OLODATEROL
	INHALED GLUCOCORTICOIDS	R03BA01	BECLOMETHASONE DIPROPIONATE
	INHALED GLUCOCORTICOIDS	R03BA02	BUDESONIDE
	INHALED GLUCOCORTICOIDS	R03BA05	FLUTICASONE
	INHALED GLUCOCORTICOIDS	R03BA08	CICLESONIDE
	ANTICHOLINERGICS	R03BB01	IPRATROPIUM
	ANTICHOLINERGICS	R03BB04	TIOTROPIUM
	ANTICHOLINERGICS	R03BB05	ACLIDINIUM
	ANTICHOLINERGICS	R03BB06	GLYCOPYRRONIUM
	ANTICHOLINERGICS	R03BB07	UMECLIDINIUM
	XANTHINES	R03DA04	THEOPHYLLINE
	LEUKOTRIENE RECEPTOR ANTAGONISTS	R03DC03	MONTELUKAST
COUGH AND COLD PREPARATIONS		**R05**	
	COUGH SUPPRESSANTS	R05DA04	CODEINE
	COUGH SUPPRESSANTS	R05DA08	PHOLCODINE

Supplementary Table 4: **Mental Health* medication classifications included in the analyses**

NAME2	NAME4	ATC	DRUG_NAME
PSYCHOLEPTICS		**N05**	
	PHENOTHIAZINES WITH ALIPHATIC SIDE-CHAIN	N05AA01	CHLORPROMAZINE HYDROCHLORIDE
	PHENOTHIAZINES WITH PIPERAZINE STRUCTURE	N05AB02	FLUPHENAZINE DECANOATE
	PHENOTHIAZINES WITH PIPERAZINE STRUCTURE	N05AB04	PROCHLORPERAZINE
	PHENOTHIAZINES WITH PIPERAZINE STRUCTURE	N05AB06	TRIFLUOPERAZINE HYDROCHLORIDE
	PHENOTHIAZINES WITH PIPERIDINE STRUCTURE	N05AC01	PERICYAZINE
	BUTYROPHENONE DERIVATIVES	N05AD01	HALOPERIDOL
	INDOLE DERIVATIVES	N05AE04	ZIPRASIDONE
	INDOLE DERIVATIVES	N05AE05	LURASIDONE
	THIOXANTHENE DERIVATIVES	N05AF01	FLUPENTHIXOL
	THIOXANTHENE DERIVATIVES	N05AF05	ZUCLOPENTHIXOL
	DIAZEPINES, OXAZEPINES, THIAZEPINES & OXEPINES	N05AH02	CLOZAPINE
	DIAZEPINES, OXAZEPINES, THIAZEPINES & OXEPINES	N05AH03	OLANZAPINE
	DIAZEPINES, OXAZEPINES, THIAZEPINES & OXEPINES	N05AH05	ASENAPINE
	BENZAMIDES	N05AL05	AMISULPRIDE
	OTHER ANTIPSYCHOTICS	N05AX08	RISPERIDONE
	OTHER ANTIPSYCHOTICS	N05AX12	ARIPIPRAZOLE
	OTHER ANTIPSYCHOTICS	N05AX13	PALIPERIDONE
	BENZODIAZEPINE DERIVATIVES	N05BA01	DIAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05BA04	OXAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05BA08	BROMAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05BA12	ALPRAZOLAM
	BENZODIAZEPINE DERIVATIVES	N05CD02	NITRAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05CD03	FLUNITRAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05CD07	TEMAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05CD08	MIDAZOLAM
	BENZODIAZEPINE RELATED DRUGS	N05CF01	ZOPICLONE
PSYCHOANALEPTICS		**N06**	
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA02	IMIPRAMINE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA04	CLOMIPRAMINE HYDROCHLORIDE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA09	AMITRIPTYLINE HYDROCHLORIDE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA10	NORTRIPTYLINE HYDROCHLORIDE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA12	DOXEPIN
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA16	DOTHIEPIN
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB03	FLUOXETINE HYDROCHLORIDE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB04	CITALOPRAM
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB05	PAROXETINE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB06	SERTRALINE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB08	FLUVOXAMINE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB10	ESCITALOPRAM
	MONOAMINE OXIDASE INHIBITORS, NON-SELECTIVE	N06AF03	PHENELZINE SULPHATE
	MONOAMINE OXIDASE INHIBITORS, NON-SELECTIVE	N06AF04	TRANYLCYPROMINE SULPHATE
	MONOAMINE OXIDASE A INHIBITORS	N06AG02	MOCLOBEMIDE
	OTHER ANTIDEPRESSANTS	N06AX03	MIANSERIN HYDROCHLORIDE
	OTHER ANTIDEPRESSANTS	N06AX11	MIRTAZAPINE

|		
OTHER ANTIDEPRESSANTS	N06AX12	BUPROPION
OTHER ANTIDEPRESSANTS	N06AX16	VENLAFAXINE
OTHER ANTIDEPRESSANTS	N06AX18	REBOXETINE
OTHER ANTIDEPRESSANTS	N06AX21	DULOXETINE
OTHER ANTIDEPRESSANTS	N06AX23	DESVENLAFAXINE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA02	DEXAMPHETAMINE SULPHATE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA04	METHYLPHENIDATE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA07	MODAFINIL
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA09	ATOMOXETINE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA12	LISDEXAMFETAMINE

Appendix 2

Parameters used in the time series analysis models

In the GLM structure, the modelled daily fire-generated $PM_{2.5}$ was included alongside potential confounders including seasonality, long-term trend, day of the week, maximum ambient temperature and public holidays (Buckingham-Jeffery et al., 2017). A natural cubic spline of time with 7 degrees of freedom per year was employed to control for seasonality and long-term trend, which allowed for a complex non-linear pattern of outcome rates over time. A variable was used to control for day of the week. A distributed lag non-linear structure was applied to allow for flexible relationships between health outcomes and lag effect of daily fire-generated $PM_{2.5}$. The effect of $PM_{2.5}$ was assumed linear and the lagged effect up to 7 days with a natural cubic spline set with knots at day 2 which means 3 degrees of freedom for the lag. The effect of ambient maximum temperature was assumed nonlinear with a natural cubic spline with 3 degrees of freedom and the lagged effect up to 21 days with a natural cubic spline set with 3 degrees of freedom for the lag.

Most of the data cleaning and variable transformation, and all of the analyses were conducted using the statistical analysis software package R (version 3.4.1: R Development Core Team 2017). General linear models were implemented using R function "glm" and distributed lag non-linear structures using R package "dlnm" (Gasparrini, 2011). Stata Version 15 (StataCorp, College Station, TX) was used for additional data manipulation and data management.

Modelling of the lag structure
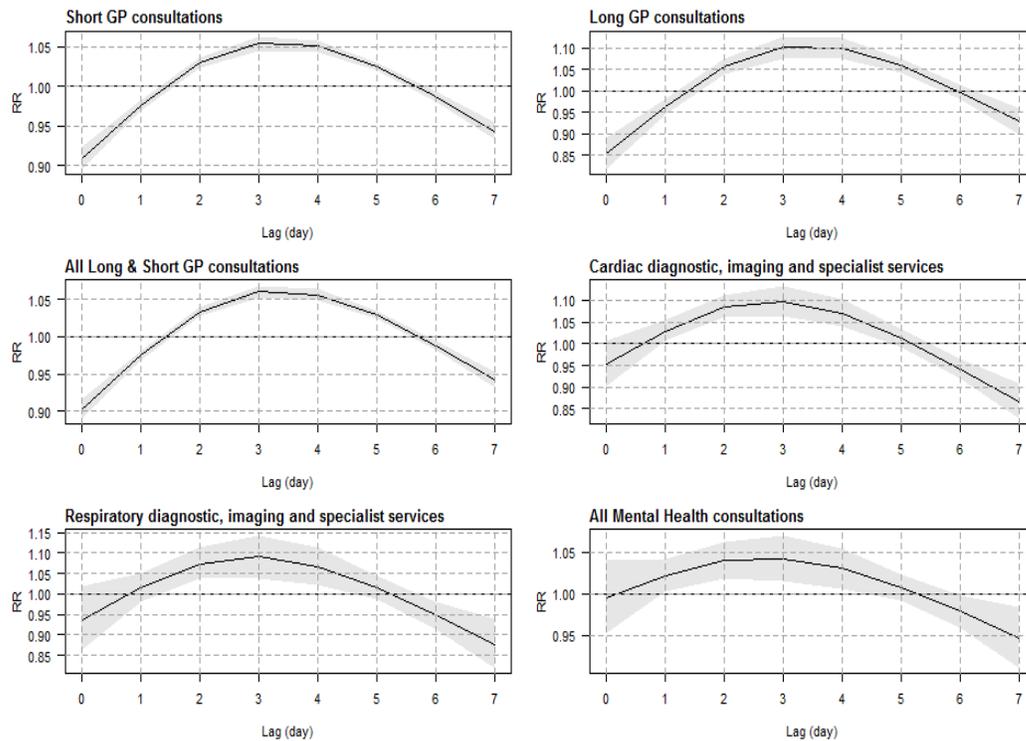
Figure A1: The associations (relative risks, RR and 95% CI) between health service use and a 10 μg/m³ increase in fire-related PM₂.₅ at lags of 0-7 days, after controlling for seasonality, long-term temporal trends, public holidays, day of the week and daily maximum temperature.

After modelling the time series data, the associations between mine fire-related PM₂.₅ and health service use was found to be signification after a 2 to 5 day lag from exposure for short and long GP consultations and all cardiovascular services, and after a 2 to 4 day lag from exposure for all respiratory services and all mental health consultations (Figure A1).
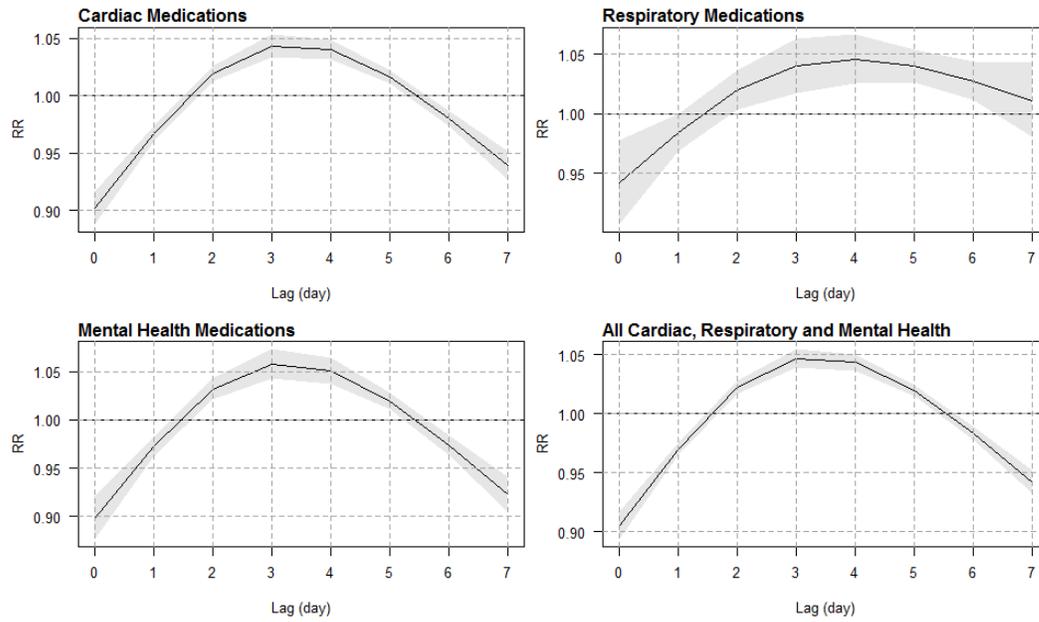
Figure A2: **The associations (relative risks (RR) and 95%CI) between PBS medication dispensing and a 10 µg/m³ increase in fire-related PM$_{2.5}$ at lags of 0-7 days, after controlling for seasonality, long-term temporal trends, public holidays, day of the week and daily maximum temperature.**

After modelling the time series data, the associations between mine fire-related PM$_{2.5}$ and medication dispensing appeared after 2 to 5 day lag from exposure for cardiovascular, respiratory and mental health medications (Figure A2).

Document History

Version Number	Date	Contact	Brief description
1.0	20 November 2017	Hazelwood Health Study Senior Project Manager	Submitted to DHHS for approval for public release
1.1	19 December 2017	Hazelwood Health Study Senior Project Manager	Minor corrections at p 2 and p 12
1.2	19 February 2018	Hazelinks Coordinator	Corrections made in response to feedback from Commonwealth Department of Human Services at p 10
1.3	20 March 2018	Hazelinks Coordinator	Corrections made in response to feedback from EREC at p 11 and p 33. Dates of PBS analysis period corrected throughout the report.