Hazelinks – Emergency presentations and hospital admissions analysis (First Data Extraction)

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Abbreviations

ASGS	Australian Statistical Geography Standard
COPD	Chronic Obstructive Pulmonary Disease
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHHS	Department of Health and Human Services
ICD10	International Classification of Diseases, 10th revision
MUHREC	Monash University Human Research Ethics Committee
$PM_{2.5}$	Particulate matter < 2.5 thousandths of a millimetre in diameter
PM_{10}	Particulate matter < 10 thousandths of a millimetre in diameter
SA	Statistical area level
VAED	Victorian Admitted Episodes Dataset
VEMD	Victorian Emergency Minimum Dataset
95%CI	95% Confidence Interval

Executive Summary

The aim of this analysis was to examine whether coal mine fire-related fine particles ($PM_{2.5}$) were associated with increased risks of emergency presentations or hospital admissions for cardiovascular and respiratory diseases. We analysed daily concentrations of coal mine fire-related $PM_{2.5}$ modelled by CSIRO and the daily counts of hospital emergency department presentations and hospital admissions for the fire-impacted areas, between January 2009 and June 2015. Time series statistical models were used to quantify the associations between daily coal mine fire-related $PM_{2.5}$ and emergency presentations or hospital admissions, controlling for seasonality, day of the week, daily maximum temperature, long-term temporal trends and area variation. We found increased rates of emergency presentations and hospital admissions for asthma and COPD, and all respiratory diseases during the coal mine fire period, in comparison with the non-fire periods, but no evidence of increased rates for cardiovascular diseases. Emergency presentations for asthma and COPD, all respiratory diseases, and hospital admissions for asthma and COPD were increased by 21%, 12%, and 16%, respectively, for each 10 $\mu g/m^3$ increase in coal mine fire-related $PM_{2.5}$. There were 14 emergency presentations for asthma/COPD and 22 for all respiratory diseases attributable to coal mine fire-related $PM_{2.5}$ in the fire impacted areas. Further analysis will be conducted later this year to examine the effects of coal mine fire-related $PM_{2.5}$ on ambulance call-outs, medical services and dispensing of medications, and to assess the effects of other air pollutants, particularly carbon monoxide on health outcomes.

1. Introduction

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

The Hazelwood Health Study will investigate whether exposure to smoke from the Hazelwood Mine Fire smoke event in February-March 2014 has affected the health of residents. The study will determine the health status of the population at the time of the fire and will ascertain individual risk and lifestyle factors for different conditions.

2. Background

The adverse effect of air pollution on health has long been appreciated and due to improved methods of monitoring and measurement this has become an 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 mortality and morbidity due to respiratory and cardiovascular causes (Strickland et al., 2010, Faustini et al., 2012, Milojevic et al., 2014, Pope et al., 2006).

Large, destructive coal mine fires, such as the Hazelwood coal mine fire in Victoria in February and March 2014, 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 and many 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; and increased morbidity and mortality in smoke affected regions, which can often be far from the fires themselves. However, there is to date limited evidence on the impacts of the smoke from coal mine fires on health outcomes.

As part of the overall Hazelwood Health Study, there is a particular focus on respiratory and cardiovascular health outcomes. In this report, we investigate whether the coal mine fire-related $PM_{2.5}$ was associated with increased risks of emergency presentations and hospital admissions for these conditions. Association between exposure level and risk of short term health outcomes using emergency presentation and hospital admission datasets and fine resolution modelled exposure metrics will be explored later this year.

This report details the results of the first data extraction of emergency presentations and hospital admissions data that includes de-identified unit records for the period 1 January 2009 to 30 June 2015 for all Statistical Areas Level 2 (SA2s) that were considered exposed (where the modelled daily average $PM_{2.5}$ concentration from the fire reached 1µg/m^3 for at least one day).

3. Aim and objectives

The aim of the analysis was to examine whether the coal mine fire-related $PM_{2.5}$ was related to increased risks of hospital emergency department presentations and hospital admissions for cardiovascular and respiratory conditions.

4. Human Research Ethics Committee approval

Monash University Human Research Ethics Committee (MUHREC) approved the Hazelwood Adult Survey & Health Record Linkage Study on 21 May 2015. This included approval to access emergency presentation and hospital admission data from the Department of Health and Human Services (approval number: CF15/872 – 2015000389).

5. Methods

5.1 Datasets

Data on emergency presentations

Data on emergency presentations were collected from the Victorian Emergency Minimum Dataset (VEMD) held by the Department of Health and Human Services (DHHS). The dataset contained de-identified demographic, administrative and clinical data with details of Emergency Department presentations at Victorian public hospitals, and some private hospitals as directed by the Department (Department of Health and Human Services, 2017).

Data on hospital admissions

Data on hospital admissions were obtained from the Victorian Admitted Episodes Dataset (VAED) held by the DHHS. The data comprised demographic, clinical and administrative details for all admitted episodes of care occurring in Victorian hospitals, rehabilitation centres, extended care facilities and day procedure centres (Department of Health and Human Services, 2016).

The daily data on emergency presentations and hospital admissions were extracted from the VEMD and VAED, respectively, for the period 1 January 2009 to 30 June 2015. Each unit record was assigned a Statistical Area Level 2 (SA2) based on residential address.

Data on air pollution

CSIRO provided modelled exposure fields for $PM_{2.5}$ ranging from 100-500m resolution close to the fire to 3-9km resolution further away from the fire. The 24 hourly average $PM_{2.5}$ concentrations were calculated for each SA2 area. Further details of the modelling approach can be found in the CSIRO report (Emmerson et al., 2016).

Data on ambient maximum temperature

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

5.2 Dataset parameters for analysis

Data from 1 January 2009 to 30 June 2015 from the VAED (extracted based on the date a patient commenced an episode of care) and VEMD (extracted based on arrival date), for all ages were analysed. The geographical boundaries used for the analysis were defined using Australian Statistical Geography Standard (ASGS) 2011 classification Statistical Area Level 2 (SA2) spatial units.

The CSIRO simulated $PM_{2.5}$ from the coal mine fire (Emmerson et al., 2016) was used to calculate daily average exposure in each of the SA2 areas. Only SA2 areas where the modelled daily $PM_{2.5}$ concentrations from the fire reached 1µg/m^3 (for at least one day) were considered exposed (fire impacted SA2 areas) and included in the analysis (refer to table 1). The coal mine fire period in this analysis was determined by the modelled daily $PM_{2.5}$ concentrations. The period when the modelled fire-generated $PM_{2.5}$ exceeded 1µg/m^3 was considered the fire period, which corresponds to the period between 9 February 2014 and 10 March 2014 (30 days).

Table 1 Distribution of modelled daily PM2.5 emissions (µg/m3) from the coal mine fire during the fire period (median and Interquartile range) for fire impacted SA2 areas

SA2 area name	Median	Interquartile range	Range
Bunyip - Garfield	0.04	0-0.15	0-2.7
Churchill	2.70	0.84-6.27	0.23-27.76
Drouin	0.05	0.01-0.29	0-6.67
Foster	0.02	0-0.05	0-3.25
Korumburra	0.02	0-0.28	0-8.31
Leongatha	0.09	0.02-0.5	0-23.26
Moe - Newborough	0.54	0.13-6.83	0-59.67
Morwell	22.2	9.71-38.46	0.42-108.4
Mount Baw Baw Region	0.02	0-0.16	0-2.49
Rosedale	0.24	0.06-0.85	0-3.83
Trafalgar (Vic.)	0.13	0.04-1.86	0-33.67
Traralgon	1.54	0.16-3.02	0-15.91
Upper Yarra Valley	0.02	0-0.07	0-1.27
Warragul	0.06	0.01-0.65	0-12.03
Yallourn North - Glengarry	0.19	0.04-0.61	0-2.16

Figure 1 shows a map of the geographical areas included in the analysis.

Figure 1 Geographical boundaries of hospital admissions and emergency presentation records included in the analysis

5.3 Definition of outcome data

Table 2 presents the disease classifications that were used in the analysis with the associated ICD10 codes. Only principal diagnoses were considered for the initial analysis and records for hospital admissions over 28 days were excluded from analysis.

Table 2 Disease classification used in the analysis

Category Name	ICD-10 Code Definition
Total Cardiovascular	I*** G45#, G450, G451, G452, G453, G458, G459, G46*
AtheroThrombotic Disease	I20*, I21*, I22*, I23*, I24* I25#, I250, I251, I252, I255, I256, I257, I258, I259, I46*, I490 I61*, I62*, I63*, I64*, I65*, I66* I67#, I670, I671, I672, I674, I675, I676, I677, I678, I679, I68*, I69* G45#, G450, G451, G452, G453, G458, G459, G46# I71*, I72*, I73*, I74*
Ischaemic Heart Disease	I20*, I21*, I22*, I23*, I24* I25#, I250, I251, I252, I255, I256, I257, I258, I259, I46*, I490
Cerebrovascular Disease	I61*, I62*, I63*, I64*, I65*, I66* I67#, I670, I671, I672, I674, I675, I676, I677, I678, I679 ,I68*, I69* G45#, G450, G451, G452, G453, G458, G459, G46*
General Atherothrombotic Disease	I71*, I72*, I73*, I74*
Total Respiratory Disease	J00* - J99*
Asthma / COPD	J41* - J44* J45*, J46*
Asthma	J45*, J46*
COPD	J41* - J44*
Pneumonia and Acute Bronchitis	J12* -J18* J20*, J21*
Injuries	S***

* - refers to any character in this position in the ICD-10 code
# - refers to a space in this position in this ICD-10 code

5.4 Statistical analysis

Time-series analysis relating daily data on air pollutants to health outcomes (e.g., emergency presentations, hospital admissions and deaths) is frequently used to assess the short-term health effects of air pollution. The method allows for adjustment of an outcome-exposure relationship by time-invariant confounders, 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 coal mine-fire-related $PM_{2.5}$ and the rates of emergency presentations/hospital admissions. As daily data on emergency presentations and hospital admissions were over dispersed (greater variability than expected under a Poisson distribution), we used quasi-Poisson regression to model the impacts of air pollution on the outcomes: emergency presentations and hospital admissions. Generalised additive mixed models were used to control for SA2 area as a random effect.

In the generalized additive model structure, the modeled daily fire-generated $PM_{2.5}$ was included alongside potential confounders including seasonality, long-term trend, day of the week, and ambient maximum temperature. A natural cubic spline with 7 degrees of freedom per year was employed for time to control for seasonality and long-term trend and allowed for a complex non-linear pattern of outcome rates over time. A categorical variable was used to control for day of the week. A distributed lag non-linear structure was included in the model to allow for flexible relationships between outcome rates and lags of daily fire-generated $PM_{2.5}$ (linear effect and 2 degrees of freedom natural cubic splines for lag up to 7 days) and ambient maximum temperature (nonlinear effect with 3 degrees of freedom cubic spline and 1 degrees of freedom cubic spline for 2 days' lag).

The total increase of air pollution is not only associated with the increase of health outcomes on the current day, but also the following days. Previous studies show that the associations last for no more than 7 days (Guo et al., 2009, Guo et al., 2013, Guo et al., 2010). Thus, cumulative relative risks over all 0-7 days were calculated for the associations between each 10 $\mu g/m^3$ increase in fire-related $PM_{2.5}$ and emergency presentations and hospital admissions.

Total number of emergency presentation and hospital admission records during the fire period for conditions listed in Table 2 were first examined in exploratory analyses and the results of these analyses suggested that the number of records were too few for many of the specific conditions to yield reliable statistical inference. Hence time series analyses were performed with condition groups including: asthma/COPD (i.e. asthma and COPD combined); all respiratory diseases, atherothrombotic diseases and all cardiovascular diseases. Records for injuries and all conditions combined were also analysed, however these outcomes were regarded as "control" conditions since they were not expected to be impacted on by coal mine fire exposure.

Most of the data cleaning and variable transformation, and all of the analyses were conducted using the statistical analysis software package R (Version 3.3.2) (R Core Team (2016), 2016). Generalised additive mixed models were implemented using R function "gamm" included in package "mgcv" (Wood, 2004) and distributed lag non-linear structures using R package "dlnm" (Gasparrini, 2011). Stata Version 14 (StataCorp, College Station, TX) was used for additional data manipulation and data management.

6. Results

Daily rates for emergency presentations and hospital admissions among SA2 areas are summarised in Tables 3 and 4. The daily rates were generally comparable in impacted areas with slightly uplifted rates in Morwell, potentially corresponding to the age structure differences and lower socioeconomic status. Most fire impacted areas had higher rates of emergency presentations and hospital admissions during the coal mine fire period (9 February 2014 to 10 March 2014) compared with the whole study period analysed (between Jan 2009 and Jun 2015). Particularly, Morwell, the area most affected by the coal mine fire, had higher rates of emergency presentations and hospital admissions than all other surrounding areas. This indicated that when assessing the impact of coal mine fire-related $PM_{2.5}$ on emergency presentations and hospital admissions, the generic differences between SA2 areas had to be adjusted for. In the generalised additive mixed models this was addressed via introducing random intercepts for modeled SA2 areas.

Table 3 Summary of daily emergency presentation rates for all conditions: number of presentations per 10,000 population (median and interquartile range) in impacted SA2 areas during the fire period and between January 2009 and June 2015.

	Between Jan 2009 and Jun 2015		During mine fire	
SA2 area	Median	Interquartile range	Median	Interquartile range
Bunyip - Garfield	7.2	4.9-9.5	7.7	5.1-9.4
Churchill	10.3	8.4-12.4	12.3	9.3-13.9
Drouin	10.5	8.5-12.5	9.9	8.6-11.7
Foster	2.4	1.2-3.6	2.5	2.4-3.7
Korumburra	3.5	2.3-5.6	4.5	3.3-6.5
Leongatha	2.8	1.8-3.7	2.8	2.1-4.3
Moe - Newborough	9.6	7.9-11.4	11.7	10.2-13.4
Morwell	**13.2**	**11.0-15.4**	**15**	**13.9-18.7**
Mount Baw Baw Region	7.7	5.4-10.1	8.2	5.6-10.3
Rosedale	8.5	5.6-11.6	11.3	8.3-12.1
Trafalgar (Vic.)	8.3	5.7-10.9	9.5	8.2-11.9
Traralgon	10.2	8.9-11.8	10.9	9.3-12.5
Upper Yarra Valley	3.4	1.7-5.1	1.7	0.4-3.4
Warragul	10.5	8.7-12.5	10.5	9.1-12.4
Yallourn North - Glengarry	8.8	6.3-11.9	10.1	7.4-13.8

Table 4 Summary of daily hospital admission rates for all conditions: number of admissions per 10,000 population (median and Interquartile range) in impacted SA2 areas during the fire period and during January 2009 and June 2015.

	Between Jan 2009 and Jun 2015		During mine fire	
SA2 area	Median	Interquartile range	Median	Interquartile range
Bunyip - Garfield	9.5	4.8-13.2	9.4	8.3-15.9
Churchill	12.3	6.8-16.1	12.7	8.7-15.1
Drouin	10.3	6.0-14.0	11.6	6.2-15.1
Foster	12.1	6.0-16.9	14.0	7.3-18.2
Korumburra	12.5	6.9-16.8	12.3	10-17.6
Leongatha	11.9	6.4-15.7	12.9	6.7-18.1
Moe - Newborough	14.5	7.4-17.9	15.5	8.1-18.1
Morwell	**16.3**	**9.9-19.9**	**18.1**	**13.7-20.4**
Mount Baw Baw Region	9.9	5.0-14.6	15.1	8.4-18.4
Rosedale	8.5	4.2-12.7	10.6	4.8-16.4
Trafalgar (Vic.)	8.3	4.4-12.3	9.5	5.8-12.2
Traralgon	14.1	7.1-16.6	15.7	9.5-16.8
Upper Yarra Valley	3.4	0.0-8.5	0.0	0.0-0.0
Warragul	11.2	5.8-14.6	13.9	6.5-16.4
Yallourn North - Glengarry	10.0	5.1-15.2	11.2	5.1-15.7

Tables 5 and 6 present summaries of the total number of emergency presentations and hospital admissions among the impacted SA2 areas during the fire days. There was a median of 182 daily emergency presentations and 363 hospital admissions among Morwell and surrounding areas. Injury had the highest counts of emergency presentations, while cardiovascular diseases had the highest counts of hospital admissions. It can be seen that the numbers of emergency presentations and hospital admissions were very low for many specific conditions of interest. For example, there were few hospital admissions for general atherothrombotic disease during the whole mine fire period for impacted SA2 areas. Hence our analyses focussed on condition groups rather than individual conditions, in the time series analysis.

Table 5 Summary for the total number of emergency presentations for different conditions (median and interquartile range) during the fire period among impacted SA2 areas

Condition	Median	Interquartile range
All respiratory diseases	10	6-39
Asthma and COPD	3	2-13
Asthma	3	1-9
COPD	2	0-3
Pneumonia and acute bronchitis	3	1-10
Other respiratory diseases	5	2-12
All cardiovascular diseases	8	7-25
Atherothrombotic disease	3	1-8
Ischaemic heart disease	3	0-3
Cerebrovascular disease	1	0-3
General atherothrombotic disease	0	0-0
Other cardiovascular diseases	7	3-15
Injury	42	21-68
All conditions	182	134-515

Table 6 Summary for the total number of hospital admissions for different conditions (median and interquartile range) during the fire period among impacted SA2 areas

Condition	Median	Interquartile range
All respiratory diseases	11	7-22
Asthma and COPD	4	2-6
Asthma	2	0-3
COPD	1	0-4
Pneumonia and acute bronchitis	3	1-6
Other respiratory diseases	6	3-10
All cardiovascular diseases	22	10-26
Atherothrombotic disease	9	4-13
Ischaemic heart disease	6	1-8
Cerebrovascular disease	2	0-4
General atherothrombotic disease	1	0-2
Other cardiovascular diseases	11	7-14
Injury	11	6-14
All conditions	363	222-586

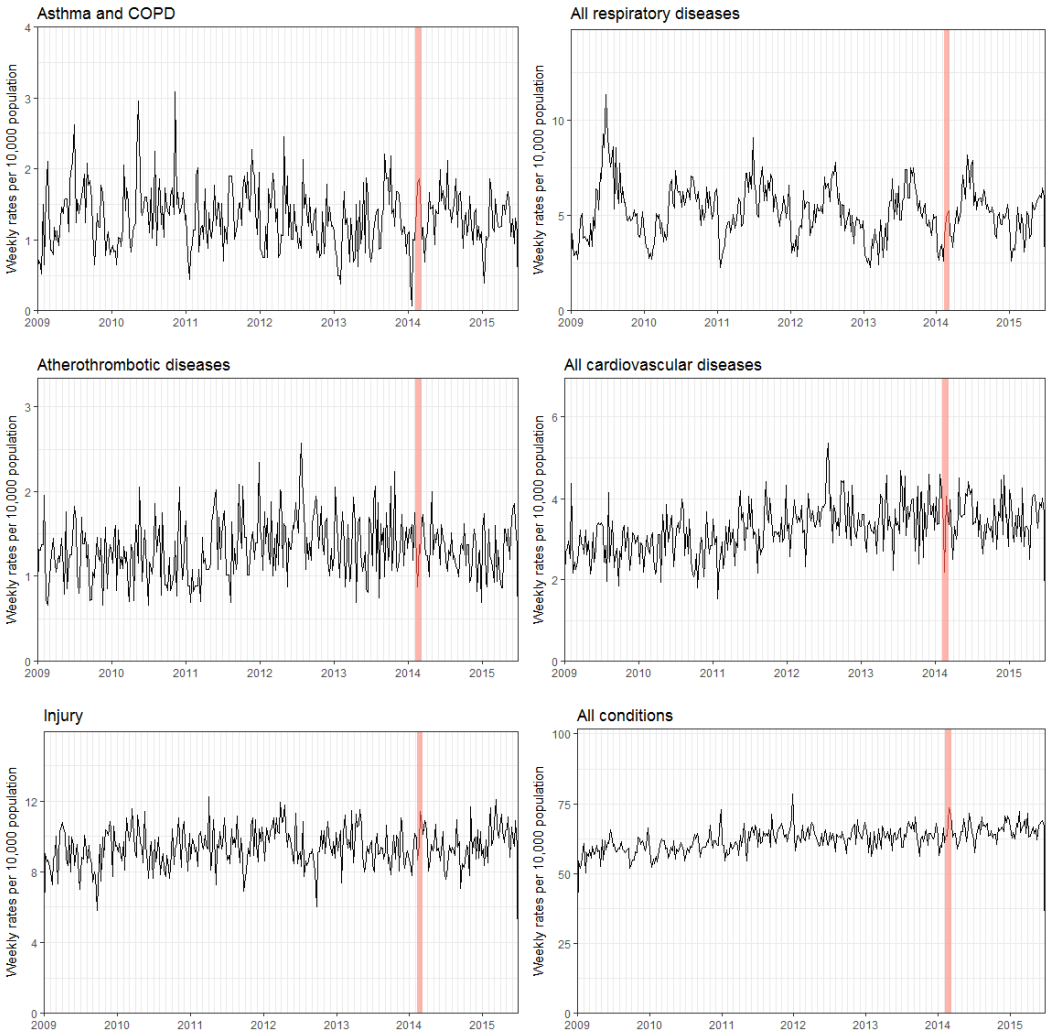

Figure 2 Weekly time series for <u>emergency presentations</u> in all impacted SA2 areas combined from 1 Jan 2009 to 30 June 2015. Red bar indicates the fire period.

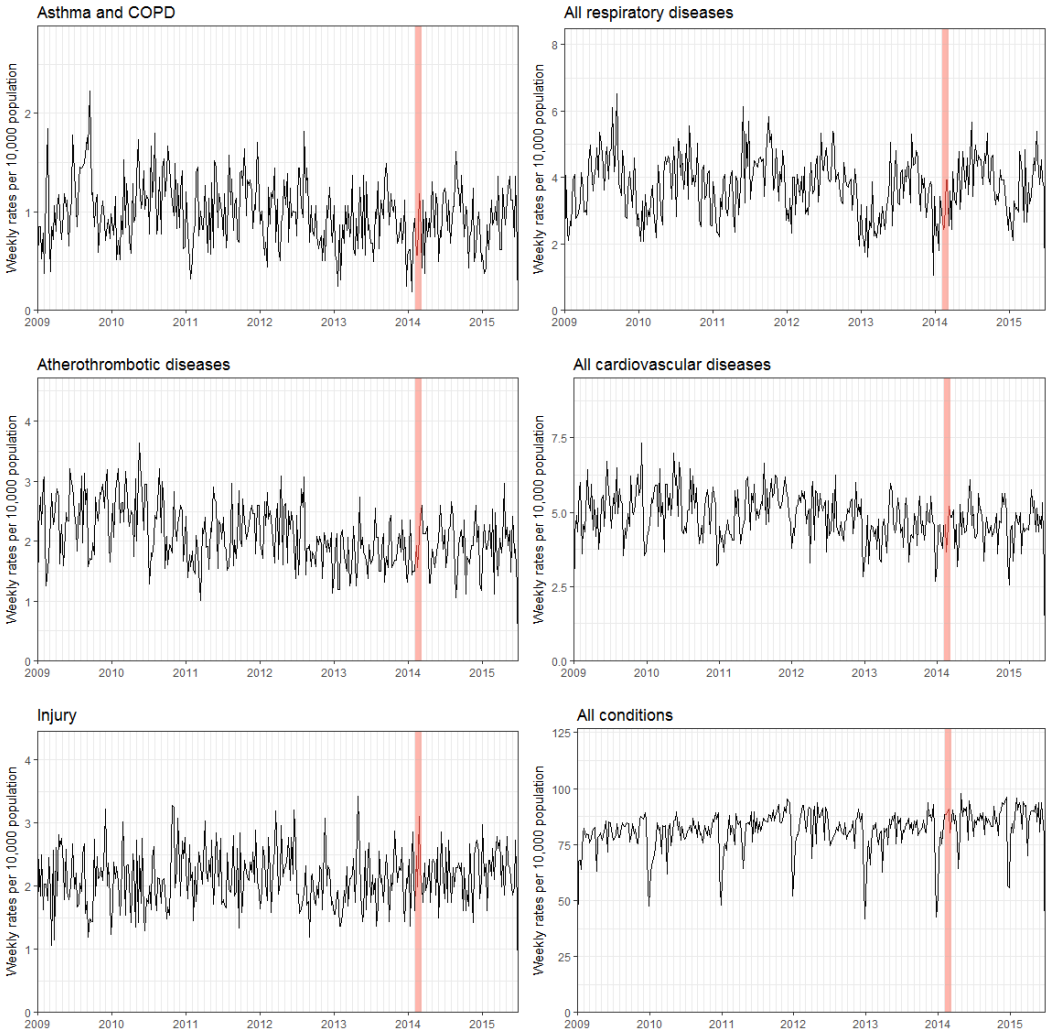

Figure 3 Weekly time series for <u>hospital admissions</u> in all impacted SA2 areas combined from 1 Jan 2009 to 30 June 2015. Red bar indicates the fire period.

Both emergency presentations (Figure 2) and hospital admissions (Figure 3) had clear seasonal trends, with highest rates in winter and lowest rates in summer, most evident to the eye for “all respiratory diseases” and “all conditions”. This motivated allowance for seasonality when assessing potential associations between daily air pollution and emergency presentations / hospital admissions. There were peaks for both emergency presentations and hospital admissions during the coal mine fire for all types of respiratory conditions (e.g., COPD and asthma, respiratory diseases). However these are hard to see by eye in Figures 2 and 3 hence subsequent figures are presented that focus in on the periods of, and immediately surrounding, the fire.

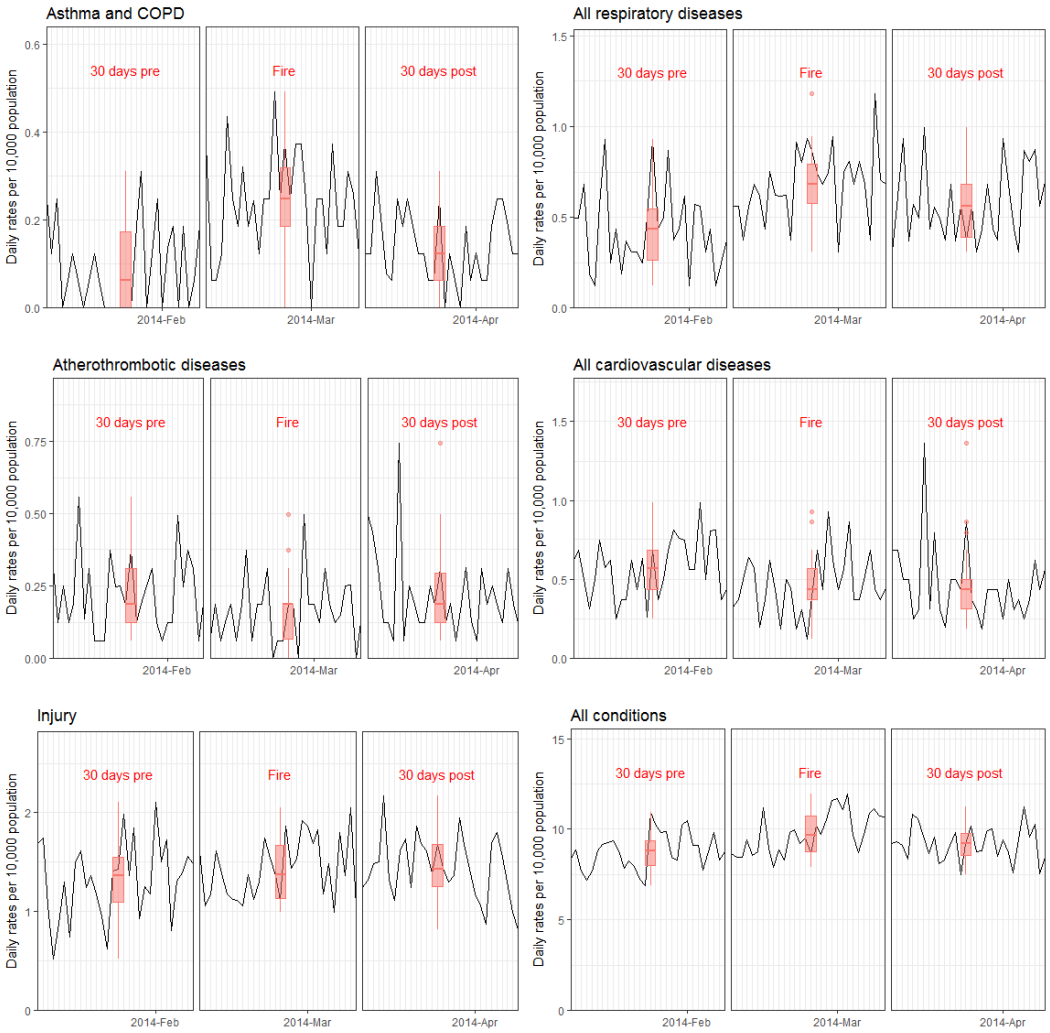

Figure 4 Daily time series of <u>emergency presentations</u> in all impacted SA2 areas during the fire, 30 days before the fire, and 30 days after the fire. Red bar is the boxplot of distribution of daily rates

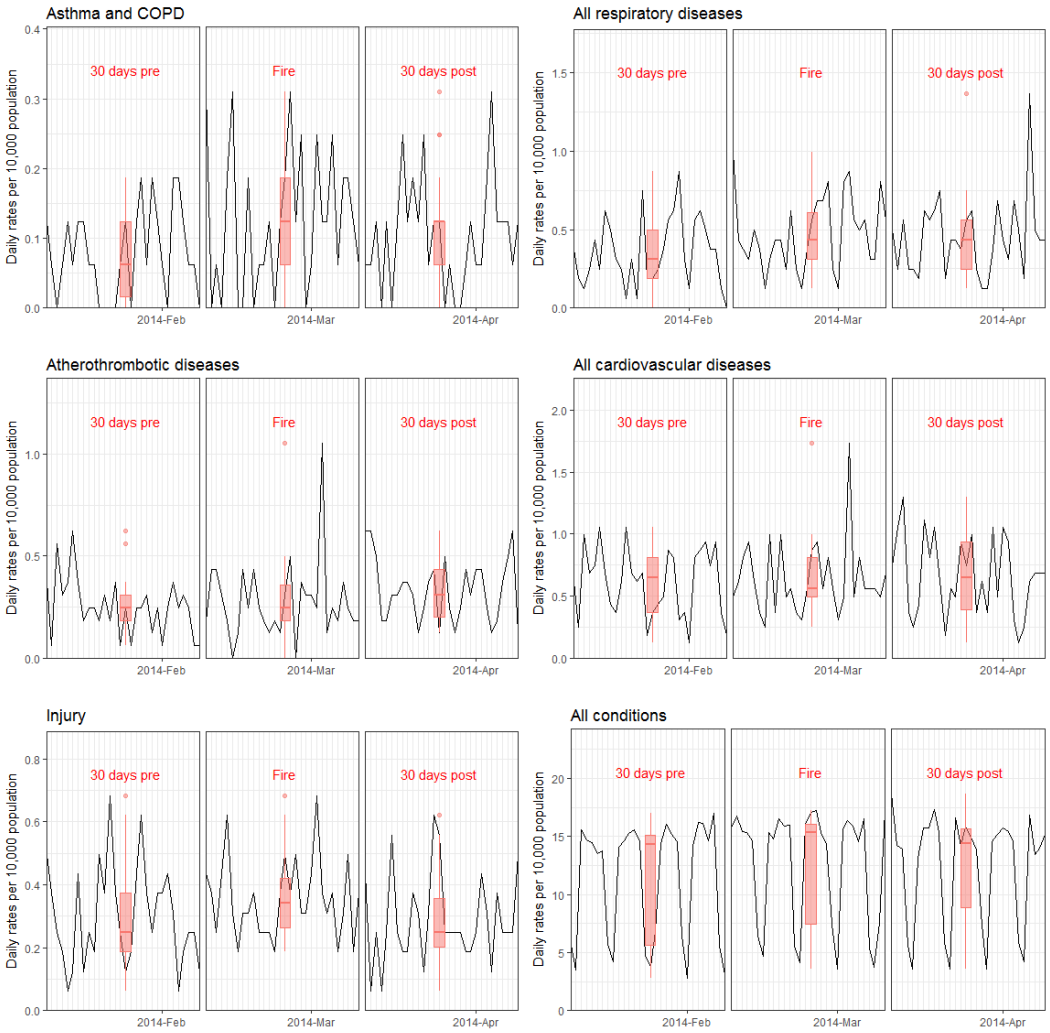

Figure 5 Daily time series of hospital admissions in all impacted SA2 areas combined during the fire, 30 days before the fire, and 30 days after the fire. Red bar is the boxplot of distribution of daily rates

Emergency presentations and hospital admissions for asthma and COPD and all respiratory diseases had higher rates during the coal mine fire period than the days before and after the coal mine fire (Figure 4 and Figure 5). But there were no substantial differences for other conditions.

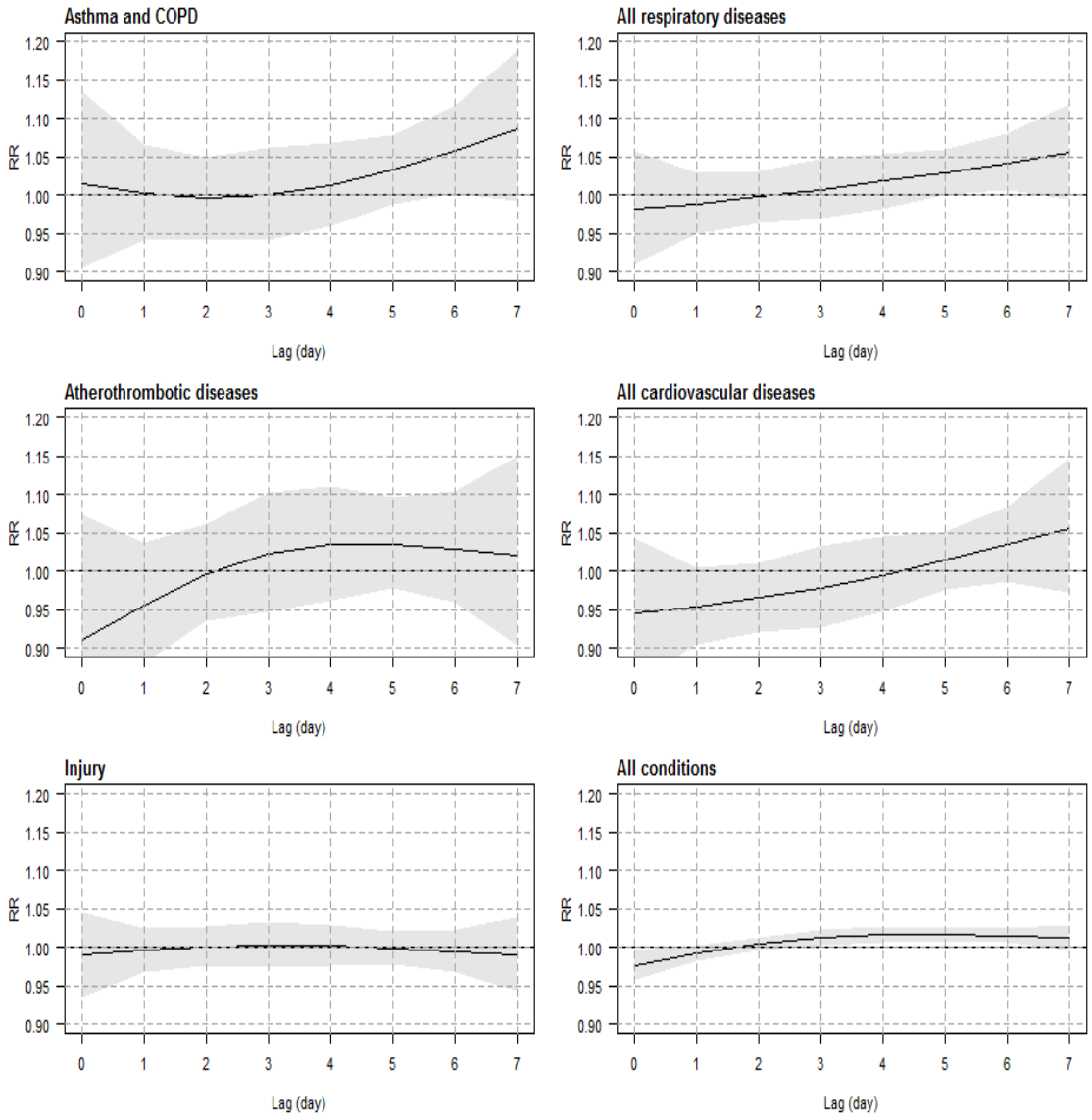

Figure 6 The associations (relative risks, RR, and 95%CI) between daily <u>emergency presentations</u> and 10 µg/m3 increase in fire-related PM2.5 at lags of 0-7 days, controlling for seasonality, day of the week and daily maximum temperature.

The associations between coal mine fire-related $PM_{2.5}$ and emergency presentations appeared after 6 days' exposure for asthma and COPD, 5 days for respiratory diseases and 3 days for all conditions (Figure 6). There were no significant associations at any lag days for atherothrombotic diseases, cardiovascular diseases, or injury.

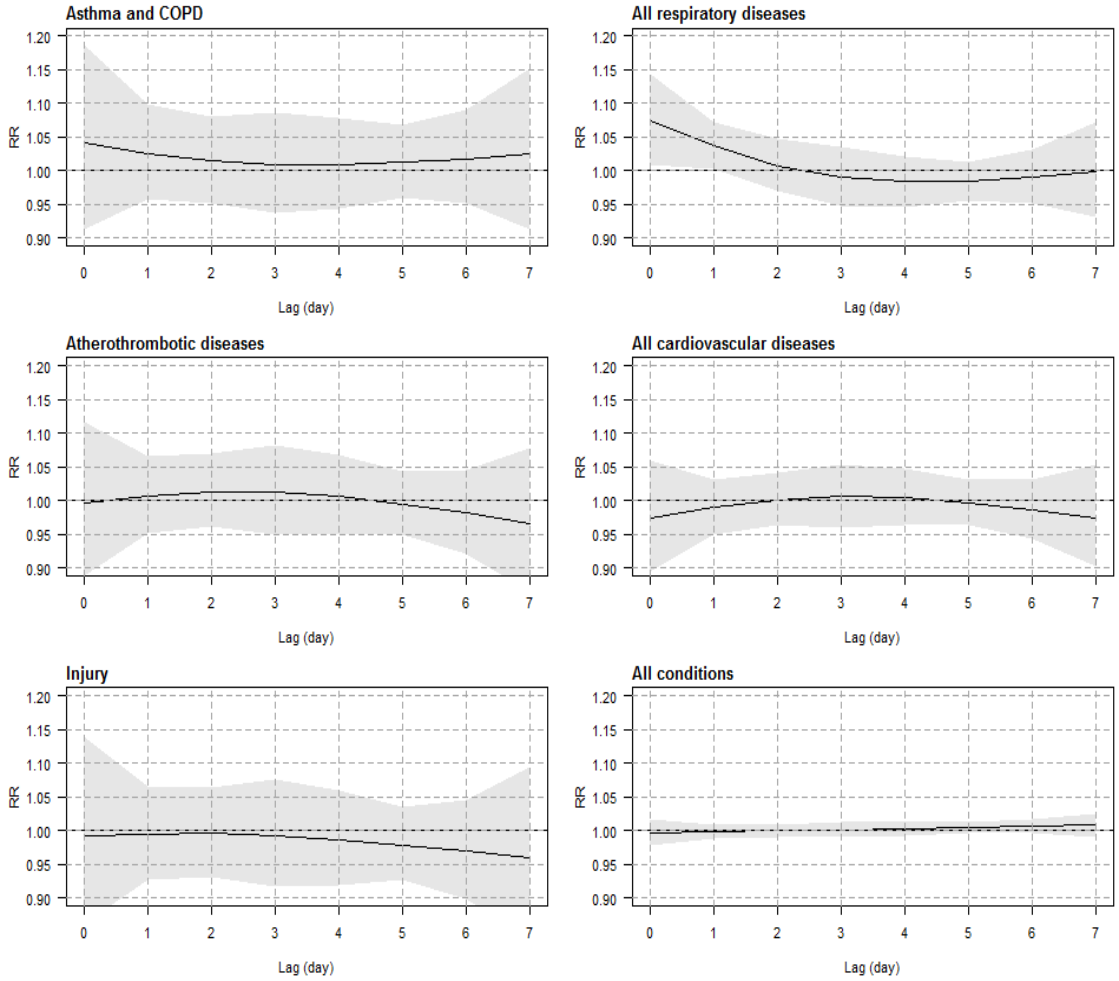

Figure 7 The associations (relative risk, RR, and 95%CI) between daily hospital admissions and 10 µg/m3 increase in fire-related PM2.5 at lags of 0-7 days, controlling for seasonality, day of the week and daily maximum temperature.

The impacts of coal mine fire-related $PM_{2.5}$ on hospital admissions for respiratory diseases appeared immediately after the exposure, and lasted for 1 day (Figure 7). There were no significant effects on other conditions at any lags.

Table 7 Cumulative relative risks of daily emergency presentations associated with 10 µg/m3 increase in fire-related PM2.5

Condition	RR*	95% CI	p-value
Asthma and COPD	**1.21**	**1.08 - 1.36**	**0.001**
All respiratory diseases	**1.12**	**1.04 - 1.21**	**0.004**
Atherothrombotic diseases	1.00	0.84 - 1.18	0.956
All cardiovascular diseases	0.94	0.83 - 1.05	0.272
Injury	0.97	0.91 - 1.04	0.445
All conditions	**1.05**	**1.02 - 1.07**	**<0.001**

* Cumulative relative risks (RR) over 7 days' lag period adjust for seasonality, day of the week, and daily maximum temperature.

Cumulative relative risks over 7 days' lag period per 10 µg/m^3 increase in fire-related $PM_{2.5}$ were calculated with associated 95% confidence intervals (CIs) for each condition group. Cumulative relative risk can be interpreted as relative risk over all 7 days. Estimated cumulative relative risk over 1 indicates elevated risks for emergency presentations or hospital admissions associated with fire-generated $PM_{2.5}$. The 95% confidence interval indicates 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 indicates 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 are dependent on not just the size of the estimated cumulative RR but also on the number of occurrences of the health outcome being analysed.

Each 10 µg/m^3 increase in fire-related $PM_{2.5}$ was associated with a 21% increase (95% CI: 8%–36%) in the risk of emergency presentations for asthma and COPD, a 12% (95% CI: 4%–21%) increase for all respiratory diseases, and a 5% (95% CI: 2%–7%) increase for all conditions, over the lags of 0-7 days (Table 7). No statistically significant associations were found for atherothrombotic diseases, cardiovascular diseases or injury.

Table 8 Cumulative relative risks of daily hospital admissions associated with 10 µg/m3 increase in fire-related PM2.5

Condition	RR*	95% CI	p-value
Asthma and COPD	1.16	0.99 - 1.36	0.066
All respiratory diseases	1.06	0.96 - 1.18	0.269
Atherothrombotic diseases	0.98	0.83 - 1.15	0.785
All cardiovascular diseases	0.93	0.83 - 1.05	0.241
Injury	0.87	0.72 - 1.06	0.181
All conditions	1.02	0.99 - 1.04	0.249

* Cumulative relative risks (RR) over 7 days' lag period adjust for seasonality, day of the week, and daily maximum temperature.

The cumulative effects of fire-related $PM_{2.5}$ on hospital admission were not statistically significant for any condition (Table 8). However for asthma and COPD, the least common reason for hospital admission among health outcomes analysed in Table 7, there was a 16% (95% CI -1%–36%) increase associated with a 10 µg/m^3 increase in fire-related $PM_{2.5}$ over all lags up to 7 days.

The attributable fractions and attributable counts for emergency presentations for asthma and COPD, all respiratory diseases, and all conditions due to coal mine fire-related $PM_{2.5}$ in the period of the coal mine fire are presented in Table 9. There were 14, 22, 132 emergency presentations for asthma/COPD, respiratory diseases, and all conditions, respectively, attributable to coal mine fire-related $PM_{2.5}$ in these fire impacted areas, of which 9, 14, 83 emergency presentations for asthma/COPD, respiratory diseases, and all conditions were from Morwell. Correspondingly, the attributable fractions were 41%, 28%, and 12% for emergency presentations for asthma/COPD, respiratory diseases, and all conditions, respectively in Morwell.

Table **9** Attributable fraction and attributable counts of emergency presentations due to coal mine fire-related PM2.5 in fire-impacted area and Morwell only, during period of the coal mine fire**.**

Area	Condition	Attributable fraction (95% CI)	Attributable counts (95% CI)
Fire-impacted area	Asthma and COPD	6% (2%, 8%)	14 (6, 20)
	All respiratory diseases	4% (1%, 6%)	22 (8, 34)
	All conditions	2% (1%, 2%)	132 (69, 191)
Morwell	Asthma and COPD	41% (20%, 56%)	9 (4, 12)
	All respiratory diseases	28% (1%, 41%)	14 (5, 20)
	All conditions	12% (7%, 18%)	83 (44, 120)

7. Discussion

Summary of findings

This is the first study to examine the impacts of 2014 Hazelwood coal mine fire on emergency presentations and hospital admissions. We found that the rates of emergency presentations and hospital admissions for Asthma and COPD and all respiratory diseases were elevated during the coal mine fire period, in comparison with the non-fire periods (30 days before and 30 days after the fire), but not for cardiovascular diseases. Time series analysis showed that the coal mine fire-related $PM_{2.5}$ was significantly associated with emergency presentations for asthma and COPD after 6 days' exposure and for all respiratory diseases after 5 days' exposure, and associated with hospital admissions for all respiratory diseases at lag 0-1 days. The emergency presentations for asthma and COPD, all respiratory diseases, and hospital admission for asthma and COPD were increased by 21%, 12%, and 16%, respectively, for each 10 $\mu g/m^3$ increase in coal mine fire-related $PM_{2.5}$. The counts of emergency presentations for asthma and COPD, respiratory diseases, and all conditions were 14, 22, 132, respectively, attributable to coal mine fire-related $PM_{2.5}$ in the fire impacted areas. Morwell counted for most of the burden, with 9 emergency presentations for asthma and COPD, 14 for respiratory diseases, and 83 for all conditions. The attributable fractions were 41%, 28%, and 12% for emergency presentations for asthma and COPD, respiratory diseases, and all conditions, respectively in Morwell.

Relationship to previous published work

There were very few studies on the associations between coal mine fire-related $PM_{2.5}$ and emergency presentations and hospital admissions. However, many epidemiological studies have consistently reported positive associations between short-term $PM_{2.5}$ exposures (traffic emissions, industrial emissions, and bushfire smoke) and respiratory morbidity (emergency presentations and hospital admissions), including asthma and COPD (Atkinson et al., 2014, Reid et al., 2016). In a time-series study conducted in New York City, $PM_{2.5}$ was associated with increased emergency department visits for asthma (Ito et al., 2007). In Taiwan, the $PM_{2.5}$ concentration on the current day (lag 0) was associated with increased hospital admissions for COPD (Tsai et al., 2014). In Beijing, $PM_{2.5}$ was positively associated with emergency department visits for respiratory diseases (Xu et al., 2016). In Australia, bushfire-related $PM_{2.5}$ was significantly associated with increased risk of emergency department attendance for asthma during the bushfire event (Haikerwal et al., 2016).

However, this Hazelinks study did not find any significant associations between coal mine fire-related $PM_{2.5}$ and emergency presentations or hospital admissions for cardiovascular diseases. This is not consistent with findings from previous studies on urban $PM_{2.5}$ (Lee et al., 2014), but consistent with bushfire $PM_{2.5}$ (Reid et al., 2016). One potential reason might be that previous studies focused on urban background $PM_{2.5}$, while this study focused on coal mine fire-related $PM_{2.5}$. The toxicity might differ between urban background $PM_{2.5}$ and coal mine fire-related $PM_{2.5}$. It has been suggested that variation in the chemical composition of $PM_{2.5}$ derived from different sources could be responsible for differences in toxicity (Naeher et al., 2007, Peel et al., 2005). Alternatively the respiratory system might be more sensitive to coal mine fire than the cardiovascular system. Toxicological evidence suggests that the exposure of $PM_{2.5}$ can directly cause lung inflammation and affect pulmonary immune function (Zhao et al., 2014).

Strengths & weaknesses

This Hazelinks study has several strengths: 1) This study was unique, as it examined the health impacts of the large, destructive coal mine fire which lasted for more than one month. It should provide direct evidence on whether this serious coal mine fire had impacted human health or not. 2) We used a distributed lag model to examine the potential delayed effects. This is helpful to understand which days of exposure were associated with increased risks of emergency presentations and hospital admissions. 3) We have controlled for the potential confounding effects of daily temperature, long-term trend and seasonality.

However this study also has some limitations: 1) We do not yet have information on individual exposures to $PM_{2.5}$. This would result in biasing the effect estimates toward null. 2) We only investigated the impact of coal mine fire-related $PM_{2.5}$ and did not include other criteria pollutants (e.g. carbon monoxide, ozone, nitrogen dioxide, sulphur dioxide) in this analysis. This might underestimate the health risks in relation to the coal mine fire. 3) We used spatially resolved modelled air exposure data from wider geographical areas including areas with no monitoring facilities. This could have introduced measurement error, again biasing the effect estimates toward null (underestimating the effect). 4) The datasets used in the analysis were collected for administrative purposes and therefore presented some limitations, such as missing primary diagnosis data in the VAED and VEMD data. They only included individuals who lived in the area of interest (i.e. people who visited a hospital in the area of interest but did not live in the area were not included in the dataset).

Future work will include assessing the impacts of coal mine fire-related $PM_{2.5}$ on ambulance call-outs, medical services (MBS) and dispensing of medications (PBS). We will also assess the impacts of other air pollutants, particularly carbon monoxide on health outcomes.

Conclusions

This study shows clear evidence that coal mine fire-related $PM_{2.5}$ was significantly associated with increased risks of emergency presentations for asthma and COPD, and all respiratory diseases. No significant association was found for cardiovascular diseases. This study contributes to filling the knowledge gap which currently exists in this area of public health importance. Such robust evidence-based research is important to improve health impact assessment of at-risk groups (those with chronic respiratory diseases, such as asthma and COPD), and to improve targeted health advice and emergency health services. This study is helpful to develop and implement effective and timely adaptive strategies to mitigate respiratory health risks due to possible future coal mine fire derived air pollution exposure in the community.

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8. Document History

Version number	Date approved	Approved by	Brief description
1.0	4 July 2017	DHHS	Hazelwood Health Study Hospital Analysis Extract 1 Technical Report
1.1	30 August 2017	Senior Project Manager	Minor reformatting
1.2	20 August 2018	Linkage Manager	Correction in *executive summary* and *summary of findings*