Hazelwood Recovery Program air quality assessment – Morwell and surrounds

February 2014 – May 2015

Technical report

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Contents

1. About this report

This report is a technical analysis of the Hazelwood Recovery Program's air quality data collected by Environment Protection Authority Victoria (EPA) during the Hazelwood mine fire, and in the 14-month period since the fire was declared safe on 25 March 2014. For the purpose of this report, the collection of data has been classified into two phases: the Response Phase (mid-February to 7 April 2014) and the Recovery Phase (8 April 2014 to 21 May 2015). The Recovery Phase start date was set at 8 April rather than 25 March to coincide with water and soil sampling time periods.

Air quality monitoring data from the fire has been available to the community since February 2014 on EPA's website:

www.epa.vic.gov.au/hazelwood/environmental-reporting/air-quality/air-monitoring-results

As part of the writing process, this report has been reviewed by EPA, external scientific experts and relevant government agencies. A draft of this report was also reviewed by members of the Latrobe Valley community at an EPA engagement event on 10 June 2015. Following this event changes were made to the text and overall community feedback about the report has been included in the appendices.

This publication is a technical report. For further details about any aspect of this report, or to access data, please contact EPA Victoria on 1300 372 842 or contact@epa.vic.gov.au.

2. Aim of air quality assessment

The aim of the Hazelwood recovery air quality assessment was to determine whether there have been any ongoing changes to air quality in the Latrobe Valley as a result of the Hazelwood mine fire. The assessment was not designed to analyse the overall air quality in the region. Information on water, soil and ash results can be found in a companion report – EPA publication 1600: *Water, soil and ash assessment – Morwell and surrounds February 2014 – May 2015*.

In order to determine if the mine fire has impacted on ongoing air quality in the Latrobe Valley, EPA has compared air monitoring and sampling data collected during the Recovery Phase, with the data collected during the Response Phase. The air quality data has also been compared to historical data where it is relevant.

3. Background

The Hazelwood Recovery Program is a state government-funded, EPA initiative in response to the Hazelwood mine fire that occurred in February and March 2014. As part of EPA's commitment to the Hazelwood recovery effort, EPA conducted air, water and soil testing in the region over a 14-month period.

The aim of this environmental monitoring program was to determine if there have been any long-term changes to ambient air quality in the region as a result of the Hazelwood mine fire, and to inform the community of any identified changes.

The Hazelwood recovery environmental monitoring program also fulfilled EPA's obligation to have an air quality monitoring program and station in the south of Morwell for 12 months, in accordance with Affirmation 22 from the Hazelwood Mine Fire Inquiry Report[1].

3.1. Response Phase

The response to the Hazelwood mine fire was a multi-agency effort. EPA's role was to measure, validate and assess the impacts of the smoke and ash on local air, water and soil. EPA provided data to the Department of Health (now the Department of Health and Human Services), whose role was to assess potential impacts on human health and to inform the community on appropriate actions to minimise health impacts. A summary of EPA air monitoring data collected during the Hazelwood mine fire is available in the publication *Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014* (publication 1598).

3.2. Primary air monitoring

During the Response Phase, EPA monitored air quality using sophisticated air monitoring equipment that was housed in air monitoring stations (AMSs). Temporary AMSs were located at strategic locations in the east and south of Morwell, in addition to the permanent air monitoring station in Traralgon. The different types of equipment used for this monitoring comply with Australian Standards (see Tables 1 and 4; and Sections 4.3 & 4.5). They provide data that can be directly compared with air quality standards (see Table 3).

[1] http://report.hazelwoodinquiry.vic.gov.au/

3.3. Other air monitoring

As part of EPA's rapid-response monitoring, mobile monitoring instruments were used to measure very small airborne particles ($PM_{2.5}$). These instruments can be deployed quickly during a pollution event. Data from rapid-response monitoring is considered indicative. In this case it was used to inform some response-related activities, such as the development of air quality protocols. This indicative data was not, however, used for all operational decisions taken at the time. This is because at the time of the fire, EPA believed that further work was needed to understand how the indicative data could be compared to the air quality standards. The data has also been useful in the analysis conducted after the fire was declared safe by providing a better understanding of air quality conditions in the early days of the fire. Information about this process is available in the EPA publication 1599: *Estimating air quality in the early stages of the 2014 Hazelwood mine fire*.

3.4. Air sampling

EPA also tested the air to Australian Standards for a wide range of other pollutants including metals, crystalline silica, volatile organic compounds (VOCs), dioxins and polycyclic aromatic hydrocarbons (PAHs), using periodic air sampling processes. This occurred at locations close to the Hazelwood mine site.

3.5. Recovery Phase

After the fire was declared safe on 25 March 2014, EPA designed a year-long environmental monitoring program as part of the Recovery Phase to determine if the fire had impacted on the quality of air, water and soil in the region. The air sampling and monitoring locations, the extent of the area monitored, and the main chemicals analysed were largely the same as those during the mine fire. This consistency has allowed EPA to compare air quality data from the Recovery Phase to data collected during the Response Phase. For the purposes of this report the Recovery Phase started on 8 April 2014. This is to be consistent with the classification of data from the water and soil sampling program presented in EPA publication 1600: *Water, soil and ash assessment – Morwell and surrounds February 2014 – May 2015*.

4. Methods used in the Recovery Phase air quality assessment

4.1. Where did we sample and monitor air quality?

During the Hazelwood mine fire Response and Recovery phases, EPA monitored and sampled air quality using different types of equipment at various locations in and around Morwell (see Tables 1 and 2; and Figure 1). The main focus of the Recovery Phase air quality monitoring has been on very fine breathable airborne particles ($PM_{2.5}$) as it is present in smoke and potentially poses the greatest risk to human health.

Table 1. Location of air monitoring equipment during the Response and Recovery phases

Site	Monitoring equipment *	What was measured?*	Sampling period
Traralgon air monitoring station	TEOM, BAM, gas analyser, nephelometer	PM_{10}, $PM_{2.5}$, CO, O_3, NO_2, SO_2, visibility reduction	1981 – present
Morwell (South) air monitoring station[1]	DustTrak, BAM, gas analyser, nephelometer	$PM_{2.5}$, CO, O_3, NO_2, SO_2, visibility reduction	February 2014 – present
Morwell (East) air monitoring station	BAM, gas analyser, nephelometer	$PM_{2.5}$, CO, SO_2, visibility reduction	February 2014 – present
	Radiello	VOCs	February 2014 – present
Kernot Hall, Morwell	DustTrak	$PM_{2.5}$, PM_{10}	February 2014 – March 2015
St Luke's Uniting Church, Morwell	DustTrak	$PM_{2.5}$, PM_{10},	February 2014 – March 2015
Churchill[2]	ADR 1500 BAM	$PM_{2.5}$	February 2014 – present
Moe[2]	ADR 1500 BAM	$PM_{2.5}$	February 2014 – present

** See sections 4.2 and 4.3 for explanations of acronyms and equipment*

[1] Located at Morwell Bowling Club until 6 October 2014 when it was relocated to Maryvale Crescent Preschool

[2] Area dust monitors (ADRs) were in place at Moe and Churchill during the fire. These were replaced with air monitoring stations (which house beta attenuation monitors (BAMs)) in early 2015. As they did not become operational until late during the Recovery Phase, data from these stations have not been included in this report.

Table 2. Location of air sampling equipment during the Response and Recovery phases

Site	Sampling equipment *	What was measured? *	Operational from
Morwell (East) air monitoring station	Radiello	VOCs	26 February 2014 – present
Morwell Bowling Club[1]	Radiello	VOCs	24 April 2014 – present
Maryvale Crescent Preschool[1]	HiVol Partisol Radiello	PAHs and metals Respirable silica VOCs	21 May 2014 – present 09 April 2014 – present 26 February 2014 – present

** See sections 4.2 and 4.3 for explanations of acronyms and equipment*

[1] The site of Morwell (South) AMS was located at Morwell Bowling Club until 6 October 2014 when it was relocated to Maryvale Crescent Preschool

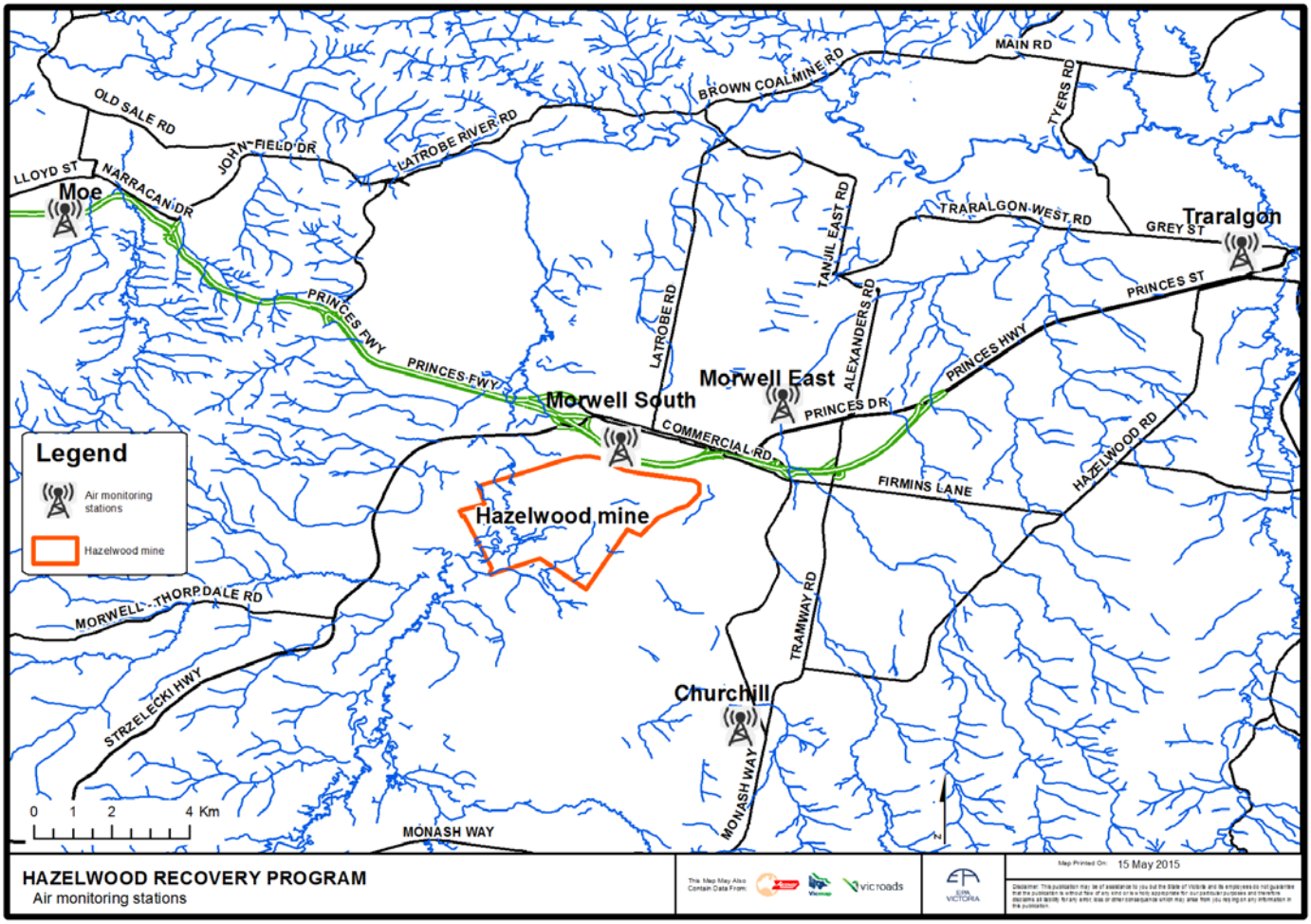

Figure 1. Location of air monitoring stations (AMSs) in the Latrobe Valley at April 2015. Blue lines are drainage courses, not waterways.

4.2. What pollutants did we monitor?

EPA tested for a number of pollutants during the Recovery Phase including breathable airborne particles (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs). Information on each of these pollutants is provided below.

The pollutant of primary concern during the fire was breathable airborne particles (in particular $PM_{2.5}$). Carbon monoxide was also raised as a concern, particularly for fire fighters during the early stage of the fire. While these pollutants were the focus of early monitoring, other pollutants were measured by EPA to assess the state of the air quality and assess community concerns.

Up-to-date information on the impacts of air pollution on human health can be found on the Department of Health and Human Service's Better Health Channel website.[2]

Airborne particles or particulate pollution is the presence of liquid droplets or solid particles (such as dust and smoke) in the air. Particles come in a wide range of sizes. They are measured in micrometres (μm) – 1 micrometre is 0.001 millimetres (mm). EPA measures two categories of particle size:

- **$PM_{2.5}$** are airborne particles with a diameter of less than 2.5 μm. General sources of these particles include all types of combustion, including motor vehicles and power plant emissions and, in this case, a coal fire. Very fine particles pose the greatest risk to human health, as their very small size means they can be breathed deep into the lungs.
- **PM_{10}** are particles less than 10 μm in diameter. Sources of these particles include combustion sources, but also crushing or grinding operations, pollen, road dust and sea salt.

Carbon monoxide (CO) is a colourless and odourless gas that is produced when fuels are burned. The most common source of carbon monoxide in the outdoor environment is car exhaust emissions. As a result, low levels of carbon monoxide are always present in the air in Australian towns and cities. High levels of carbon monoxide are known to have toxic health effects.

Sulfur dioxide (SO_2) is a strong-smelling, colourless gas that can irritate the lungs, and be particularly harmful for people with asthma. In this area, coal-fired power stations are a major source of sulfur dioxide in the air.

Nitrogen dioxide (NO_2) is an invisible gas with a strong, unpleasant odour. It is produced by combustion. The most common source of nitrogen dioxide in the air is car exhaust emissions.

Ozone (O_3) is a colourless gas with a strong, distinctive odour. Although ozone occurs naturally, a higher than normal concentration of ozone found closer to the ground is a main part of air pollution called smog. Ozone forms when other air pollutants combine on warm or hot days.

Visibility reduction measurements are a good indicator of smoke intensity: the greater the smoke intensity, the higher the visibility reduction measurement and the lower the visual range. Visibility is reported as an airborne particle index, which is based on the measurement of the amount of fine particles in the air.

Silica exists naturally in the environment in soils, rocks and sand and is a main component used in the construction industry. Environmental emissions of silica can arise from both natural and industrial activities, including crushing or grinding operations.

While the emission of crystalline silica from the coal mine fire was not specifically mentioned in the Hazelwood Inquiry Report as a pollutant of concern, community interest meant that EPA monitored levels of airborne silica (cristobalite and α-quartz) in the vicinity of the Hazelwood mine as part of the 12-month sampling program. Respirable silica refers to the smaller airborne particles which are of a size that can be inhaled deep into the lungs.

Metals are contained within the brown coal found in the Latrobe Valley and can be released during combustion (Brockway, Ottrey & Higgins, 1991). EPA therefore had air samples analysed for numerous different metals, including arsenic, cadmium, chromium, lead and mercury.

Polycyclic aromatic hydrocarbons (PAHs) are found naturally in the environment but they can also be manmade. PAHs are produced as a result of incomplete combustion of organic matter, such as coal and other fossil fuels. The Hazelwood mine fire burned at varying temperatures and oxygen concentrations, which may have potentially produced PAHs such as benzo[a]pyrene, fluorene and naphthalene.

Volatile organic compounds (VOCs) are organic compounds that can be found both naturally in the environment and from manmade sources. Most scents and odours are made up of VOCs. Some VOCs are considered harmful to humans. One VOC that is a known human carcinogen is benzene, which is a chemical found in environmental tobacco smoke, stored fuels and exhaust from cars. Many VOCs are also known to react with nitrogen oxides to form ground-level ozone, a component of smog.

Other

In addition to the pollutants listed above, meteorological conditions (wind speed, wind direction, relative humidity, barometric pressure and temperature) were measured at each air monitoring station.

4.3. How did we monitor air quality?

EPA's scientists measure air quality using rigorous monitoring systems and best practice technology. During the Response and Recovery phases, EPA used different types of automated and passive instruments to monitor air quality in the Latrobe Valley.

[2] www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/pages/Air_pollution

4.3.1. Continuous monitoring equipment

BAM – a standard beta attenuation monitor automatically measures and records airborne particles. This instrument works by measuring the absorption of beta radiation by particles collected on the filter tape. From this, the concentration of airborne particles is calculated.

TEOM – a tapered element oscillating microbalance monitor continually measures the concentration of airborne particles. It does this by collecting and weighing the particles using a very sensitive balance.

Gas analysers – these instruments are used to measure the concentrations of different gases in the air. Each gas is measured by a different digital analyser.

Nephelometer – this instrument measures the amount of particles in the air using highly sensitive light-scattering sensors and calculates a visibility reduction index.

DustTrak™ – a portable, 'rapid-response' instrument which uses an optical sensor. The data produced by the DustTraks helped EPA map particle level variations and exposures. A summary of EPA air monitoring data collected during the Hazelwood mine fire is available in the publication *Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014* (publication 1598) and EPA publication 1599: *Estimating air quality in the early stages of the 2014 Hazelwood mine fire*.

ADR– Area dust monitors use highly sensitive sensors, like nephelometers, to detect smoke particles in the air. A summary of EPA air monitoring data collected during the Hazelwood mine fire is available in the publication *Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014* (publication 1598); and EPA publication 1599: *Estimating air quality in the early stages of the 2014 Hazelwood mine fire*.

4.3.2. Periodic sampling equipment

Radiello tubes – these solid, adsorbent tubes absorb volatile organic compounds (VOCs) in the air. They are a stand-alone, passively sampling tube deployed at different sites in Morwell.

HiVol – the high-volume sampler collects particles smaller than PM_{10} on to a filter. External laboratories analyse these filters to measure the amount of metals and PAH particles in the air.

Partisol – an air sampler that provides samples of the concentrations of respirable silica in the air. Silica is collected on filters and sent away for laboratory analysis.

4.4. Guidelines

Air quality data collected by EPA is measured against the Australian *National Environment Protection (Ambient Air Quality) Measure*, commonly known as the Air NEPM. These national air quality standards have been used across Australia since 2002 and include a set of air quality goals and standards for a range of air pollutants (see Table 3).

The standards set out the acceptable levels of key air pollutants as agreed by all Australian jurisdictions. Further information about these standards can be found on the Australian Government Department of the Environment's air quality standards webpage [3]. The number of allowable exceedances associated with the standards has been set to account for unusual meteorological conditions and, in the case of particles, natural events such as bushfires and dust storms that cannot be controlled through normal air quality management strategies.

To find out more about how EPA Victoria carries out its responsibilities under the standards, see Victoria's Air NEPM monitoring plan [4].

For other pollutants not covered in the Ambient Air NEPM, such as visibility-reducing particles (measured as visual distance, and reported as an index), EPA reports against air quality objectives defined in the *State Environmental Protection Policy (Ambient Air Quality)*[5] (Air SEPP AAQ). The Air SEPP AAQ sets air quality objectives and goals for the State of Victoria. It mirrors the requirements in the Ambient Air NEPM. EPA also uses the *State Environmental Protection Policy (Air Quality Management) (Air SEPP AQM)* for some objectives and monitoring. This SEPP provides a framework for managing air emissions in the air environment.

During the Response and Recovery phases, EPA primarily used the SEPP AAQ and the Ambient Air NEPM to assess the concentration of pollutants in the air.

NEPM and SEPP guidelines do not exist for a number of air pollutants that EPA tested for during both the Response and Recovery phases of the mine fire. Where available, alternative guidelines from other jurisdictions were used, including from the US Texas Commission on Environmental Quality (TCEQ); US Department of Health Agency for Toxic Substances and Disease Registry (ATSDR); and the US National Ambient Air Quality Standards (NAAQS). Relevant guidelines are presented with air assessment results in the Results and Discussion section of this report.

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[3] www.environment.gov.au/protection/air-quality/air-quality-standards
[4] www.epa.vic.gov.au/our-work/publications/publication/2002/january/828
[5] www.epa.vic.gov.au/about-us/legislation/air-legislation

Table 3. National Environment Protection Council (Ambient Air Quality) Measure (NEPM) and State Environmental Protection Policy (Ambient Air Quality) (SEPP) guidelines. Relevant guidelines not presented here can be found in the Results and Discussion section of this report.

Pollutant	Averaging time #	Standard *	Origin	Maximum allowable exceedences
Particles as $PM_{2.5}$	24 hours	25 μg/m^3	Air NEPM (advisory)^	5 days a year^
	Annual	8 μg/m^3		–
Particles as PM_{10}	24 hours	50 μg/m^3	Air NEPM	5 days a year
Carbon monoxide (CO)	8 hours	9 ppm	Air NEPM	1 day a year
Nitrogen dioxide (NO_2)	1 hour	0.12 ppm	Air NEPM	1 day a year
	Annual	0.03 ppm		none
Ozone (O_3)	1 hour	0.10 ppm	Air NEPM	1 day a year
	4 hours	0.08 ppm		1 day a year
Sulfur dioxide (SO_2)	1 hour	0.20 ppm	Air NEPM	1 day a year
	24 hours	0.03 ppm		1 day a year
	Annual	0.02 ppm		none
Lead (Pb)	Annual	0.50 μg/m^3	Air NEPM	none
Minimum visible distance	1 hour	20 km	Air SEPP	3 days a year

#Each pollutant has a specific averaging time. Averaging is done over defined time periods (1 hour, 8 hours, 24 hours and annually) to compare against the standards and criteria for health effects. Most air monitoring instruments measure air quality over minutes, and these are then averaged over longer time periods

** μg/m^3 means micrograms per cubic metre; ppm means parts per million*

^ Under the current Air NEPM, there is no direct standard for $PM_{2.5}$; however, there is an agreed advisory standard of 25μg/m^3. The Australian Government is currently leading work to finalise agreement on a national standard for $PM_{2.5}$.

4.5. What methods and standards did we follow?

EPA ensures the accuracy of its air quality data by using fit-for-purpose technologies and applying relevant standards for monitoring, sampling and analysis.

EPA staff collected air samples according to EPA's documented processes and in line with internal data quality management plans. Once collected, the samples were analysed by independent laboratory service providers, who are accredited by the National Association of Testing Authorities (NATA).

4.5.1. Air monitoring

NATA status

Traralgon air monitoring station is part of EPA's ambient air quality network and is set up, maintained and operated in accordance with EPA's NATA accreditation (Number 15119).

Morwell (South) and Morwell (East) AMSs are investigative monitoring stations so are not part of EPA's NATA accreditation. However, some parameters are monitored in accordance with approved NATA procedures, including: SO_2, CO, NO_x (from which concentrations of NO_2 are calculated), O_3 and visibility.

Thermo Fisher Beta Attenuation Monitor (BAM) 5014i instruments are not part of EPA's NATA accreditation. These instruments are newer so are still being integrated into EPA's processes, and they may be included in EPA's NATA accreditation in the future. BAMs at Traralgon, Morwell (South) and Morwell (East) are set up according to the relevant Australian Standard (AS 3580.9.12: 2013).

Data validation

All of the gaseous data (SO_2, CO, NO_2, O_3) and visibility data presented in this report has been validated for Traralgon AMS, Morwell (South) AMS and Morwell (East) AMS to NATA accreditation standards.

All of the $PM_{2.5}$ and PM_{10} data measured on BAMs and TEOMs presented in this report has been validated according to the relevant Australian Standards as set out in Table 4. TEOM PM_{10} data has been adjusted according to the approved procedure [6], as outlined in Appendix A.

[6] http://www.scew.gov.au/system/files/resources/9947318f-af8c-0b24-d928-04e4d3a4b25c/files/aaqprctp10collectionandreporting200105final.pdf

4.5.2. Air sampling

Sampling was carried out in accordance with relevant standards outlined in Table 4 and managed in accordance with EPA's accredited internal quality systems by trained EPA staff. The following NATA accredited laboratories were used for sample analysis:

- analysis of crystalline silica: WorkCover NSW (NATA Accredited Laboratory Number: 3726)
- analysis of metals, PAHs and VOCs: SGS Leeder Consulting (NATA Accredited Laboratory Number: 14429).

Table 4. Methods used for air quality monitoring, sampling and analysing during the Recovery Phase period

Pollutant		Standard	Title	Method Used
Particles	$PM_{2.5}$ *	AS/NZS 3580.9.12: 2013	Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors	Beta attenuation monitor (BAM)
	PM_{10}	AS 3580.9.8: 2008	Determination of suspended particulate matter – PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser	Tapered element oscillating microbalance (TEOM)
Carbon monoxide	CO	AS 3580.7.1: 2011	Ambient air – Determination of carbon monoxide - Direct reading instrument method	Gas filter correlation/infrared
Sulfur dioxide	SO_2	AS 3580.4.1: 2008	Ambient air – Determination of sulfur dioxide. Direct reading instrument method	Pulsed fluorescence
Nitrogen dioxide	NO_2	AS 3580.5.1: 2011	Ambient air – Determination of oxides of nitrogen – Chemiluminescence method	Gas phase chemiluminescence
Photochemical oxidant (ozone)	O_3	AS 3580.6 .1: 2011	Ambient air – Determination of ozone. Direct reading instrument method	Non-dispersive ultraviolet
Visibility reduction		AS/NZS 3580.12.1: 2001 (R2014)	Determination of light scattering – Integrating nephelometer method	Integrating nephelometer method
Silica		Sampling: AS/NZS 3580.9.10: 2006	Determination of suspended particulate matter – $PM_{2.5}$ low volume sampler	Gravimetric method
		Analysis: WorkCover NSW method WCA.220	Determination of crystalline silica (Alpha-quartz & cristobalite) in respirable dust	X-Ray diffractometry
Metals		Sampling: AS/NZS 3580.9.6: 2003 (R2014)	Determination of suspended particulate matter – PM_{10} high volume sampler with size-selective inlet	Gravimetric method
		Analysis: MA-1400.FL.02		
Polycyclic aromatic hydrocarbons (PAHs)		Sampling: AS/NZS 3580.16:2014	Determination of polycyclic aromatic hydrocarbons (PAH)	High-volume sampler – gravimetric method
		Analysis: MA-72.FL.01		
Volatile organic compounds (VOCs)#		Sampling: RAD120[7]		
		Analysis: MA-5.RAD.02[8]	Volatile organics in air	High-resolution gas chromatography – mass spectrometry

Air sampling units are expressed in concentrations at 0°C and one atmosphere pressure unless otherwise stated.
Particle concentration units of μg/m³ refer to volumes at 0 °C and one atmosphere of pressure.
** BAMs were set -up and maintained in accordance with AS/NZS 3580.9.12: 2013. Calibration schedules and techniques were done in accordance with manufacturer specifications [9]*
 # Concentrations are at 25°C and one atmosphere pressure

[7] www.radiello.com/english/cov_chim_en.htm
[8] www.leederconsulting.com/enviro_air_analysis_ambient_vocs_ma5.html
[9] www.thermoscientific.com/content/dam/tfs/ATG/EPD/EPD%20Documents/Product%20Manuals%20&%20Specifications/Air%20Quality%20Instruments%20and%20Systems/Particulate/EPM-manual-Model%205014i.pdf

5. Results and discussion

This section summarises EPA's air sampling and monitoring results from the Recovery Phase. This data has come from the monitoring and sampling instruments located around the Latrobe Valley as detailed in Tables 1 and 2.

To interpret these results, EPA has – where possible – compared the Recovery Phase data to other sources of data. This includes data gathered during the Response Phase and data collected prior to the mine fire.

The VOCs, metals and PAHs data collected since February 2015 has not been analysed and processed in time to present in this report.

5.1. $PM_{2.5}$

Particulate matter was the major pollutant during the mine fire. Concentrations of $PM_{2.5}$ were recorded well above the NEPM advisory guideline, particularly at Morwell (South) where $PM_{2.5}$ levels exceeded the 24-hour guideline on 21 days during the fire. The highest peak was estimated to be up to 800 $\mu g/m^3$ (32 times the reporting standard), which occurred early during the fire).[10]

Figure 2 shows daily average $PM_{2.5}$ concentrations in the Latrobe Valley measured using BAMs since mid-February 2014. After a peak of 417 $\mu g/m^3$ at Morwell (South) on 21 February 2014, levels dropped off sharply over the following weeks as the fire was brought under control, and remained at a stable concentration at all three stations for the rest of the monitoring period, with the exception of a few exceedances. There current allowable number of exceedances per year of the NEPM 24-hour guideline is five, though this number has not been designated formally.[11]

These spikes, exceeding the NEPM daily advisory guideline of 25 $\mu g/m^3$, were seen during two periods (31 $\mu g/m^3$ and 34 $\mu g/m^3$ at Traralgon in mid-May 2014; and 35 $\mu g/m^3$ and 33 $\mu g/m^3$ at Traralgon and Morwell (East), respectively, on 1 April 2015). These guideline breaches are associated with elevated smoke levels that may have originated from landholder burning off, forest regeneration burns and planned burning. Smoke is often persistent in the Latrobe Valley in autumn due to the stable atmospheric conditions at that time of year.

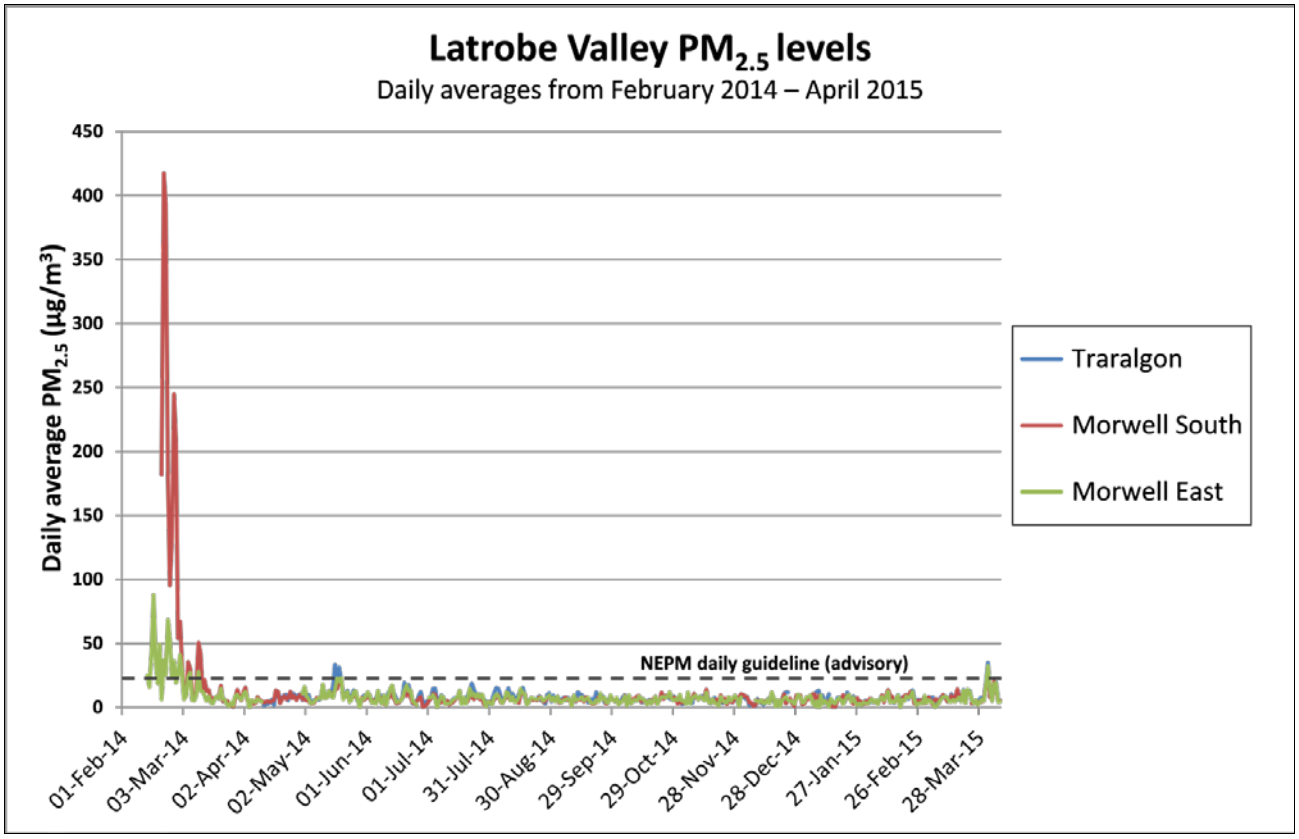

Figure 2. Daily 24-hour average $PM_{2.5}$ concentrations in the Latrobe Valley measured using BAMs from 13 February 2014 to 7 April 2015. Daily average is measured from midnight to midnight, in line with the NEPM standards.

[10] www.epa.vic.gov.au/~/media/Publications/1599.pdf
[11] www.comlaw.gov.au/Details/C2004H03935

Figure 3 shows long-term daily $PM_{2.5}$ concentrations in the Latrobe Valley since 9 February 2012. It can be seen from observation that pre-fire levels of $PM_{2.5}$ at Morwell (East) are generally consistent with Recovery Phase levels for all three stations. Concentrations remain consistently lower than 25μg/m³ during both periods, occasionally rising above the guideline, but never above 50 μg/m³. There was only one pre-fire exceedance of the NEPM daily advisory guideline of 25μg/m³ on 21 January 2013 due to bushfires at Aberfeldie. This is consistent with events causing exceedances in the Recovery Phase.

While Figure 3 looks at daily $PM_{2.5}$ averages, Table 5 compares longer averaging periods. It can be seen in Table 5 that there is a significant drop in the average concentration at Morwell (South) when comparing the incident (up to 25 March 2014) average, to that starting on 8 April 2014 (Recovery average). The Incident (to 25 March 2014) recorded an average $PM_{2.5}$ concentration of 68.5μg/m³ compared to 6.5μg/m³ for the Recovery Phase.

A regional comparison of annual Recovery Phase $PM_{2.5}$ concentrations reveals that Morwell (South) had the lowest annual average of the three stations. Traralgon's average of 7.7μg/m³ came closest to the NEPM guideline of 8μg/m³, while Morwell (East) recorded an average of 6.8μg/m³. The starting point of 8 April 2014 as the beginning of the Recovery Phase does little to influence post-fire averages, where it can be seen that if a starting point of 25 March 2014 (the day the fire was declared safe) is used, 12-month $PM_{2.5}$ averages are 6.6μg/m³, 6.5μg/m³ and 7.6μg/m³ for Morwell (East), Morwell (South) and Traralgon, respectively, which are comparable to Recovery Phase values.

A comparison of these Recovery Phase averages with pre-fire data shows that post-fire concentrations have returned to generally normal values for the region. Pre-fire data is taken from a BAM at Morwell (East) from 8 February 2012 to 18 February 2013[12]. The average $PM_{2.5}$ level during this period is 7.8μg/m³. This number is consistent with Recovery Phase averages as shown in Table 5.

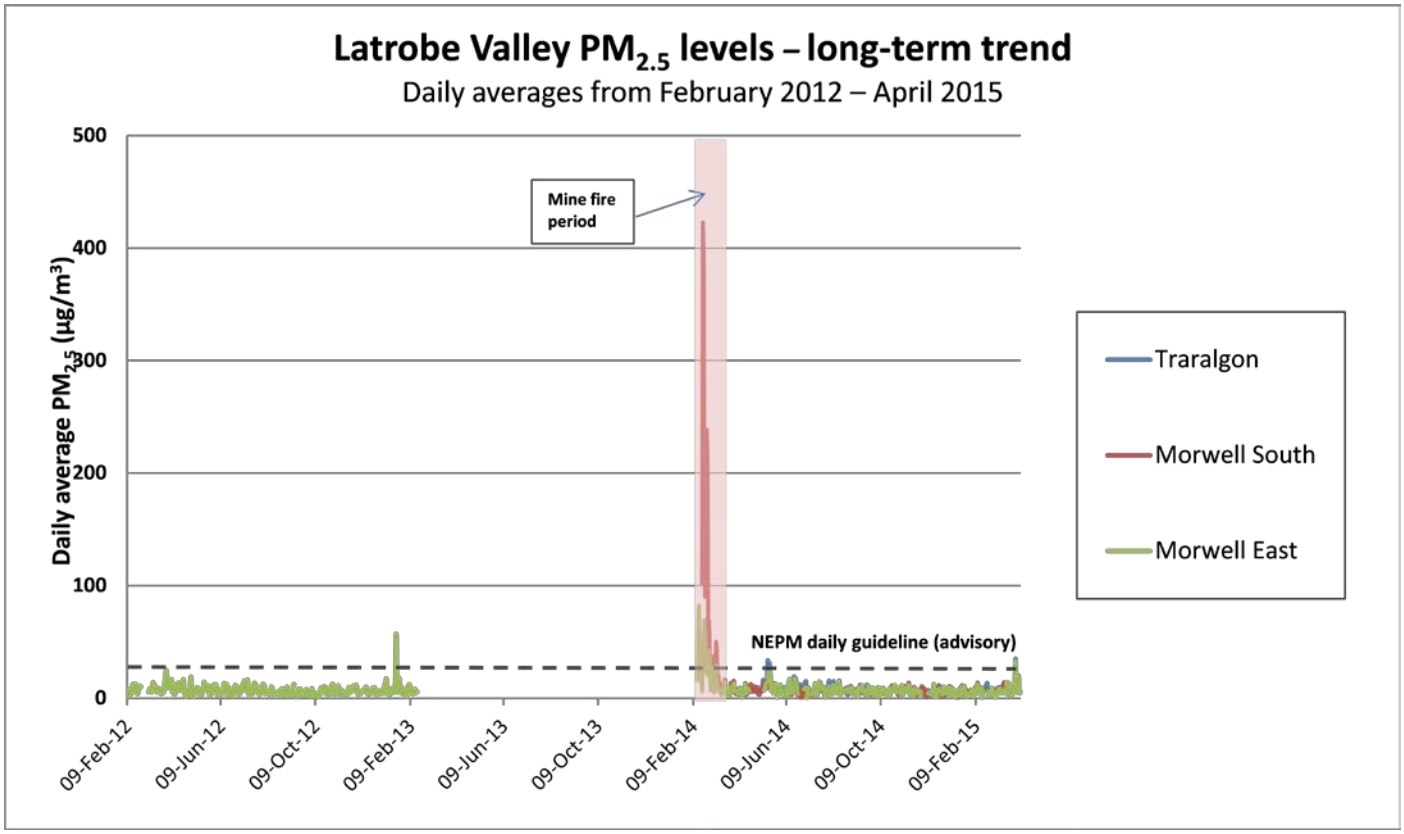

Figure 3. Long-term trend of daily average $PM_{2.5}$ concentrations in the Latrobe Valley during the time period from 9 February 2012 to 8 April 2015. No $PM_{2.5}$ monitors were in place in the Latrobe Valley between 18 February 2013 and 13 February 2014.

NB: This figure records data from 9 Feb 2012 instead of 8 Feb 2012 as less than 18 hours of data is available from 8 Feb 2012. Seventy-five per cent of a day's data is necessary for computing a daily average.

[12] www.epa.vic.gov.au/our-work/publications/publication/2013/september/1547

Table 5. Comparison of Latrobe Valley $PM_{2.5}$ average concentrations for varying time periods between 2012 and 2015.

Long-term $PM_{2.5}$ averages – Latrobe Valley

Pre-fire
Morwell East (8 Feb 12 – 18 Feb 13) – **7.8 µg/m³**

Incident*
Morwell South (20 Feb 14 – 25 Mar 14) – **68.5 µg/m³**

Post-fire (all 8 Apr 14 – 8 Apr 15)
Traralgon – **7.7 µg/m³**
Morwell East – **6.8 µg/m³**
Morwell South – **6.5 µg/m³**

NEPM annual guideline (advisory) – 8 µg/m³

* Morwell South averages are from 20 February 2014, when validated data was first available.

5.2. PM_{10}

Figure 4 shows a long-term trend of PM_{10} levels in the Latrobe Valley since 2013, including part of a BAM deployment at Morwell (East) to mid-2013. Three periods recorded exceedances of the NEPM daily guideline of 50μg/m³: January 2013 – due to local bushfires at Aberfeldie[13], May 2013 – due to private and public planned burning; and February 2014 during the mine fire. The mine fire in February–March 2014 saw three guideline exceedances at Traralgon. The NEPM guideline has a stated goal of less than or equal to five exceedances per year, allowing Traralgon to meet the goal for 2014. During the Recovery Phase, there were no guideline breaches.

Aside from the 2013 bushfire and 2014 mine fire, the long-term trend of PM_{10} in the Latrobe Valley is one of reasonably consistent, low levels with a few instances of peaks during public and private planned burns (May 2013 and April 2015). The trend of the graph shows that by April 2014 PM_{10} decreased back to pre-fire levels. This pre-fire average for 2013 was 14.2μg/m³, where for 2014 it was 16.1μg/m³; indicating that the mine fire did not cause average PM_{10} to be much above the normal concentrations for the area (PM_{10} annual averages for Traralgon in 2011 and 2012 were 14.6μg/m³ and 13.9μg/m³, respectively; and 15μg/m³ in 2012 for Morwell (East)). These annual averages were all below the draft, preferred NEPM PM_{10} annual standard of 20μg/m³ .[14]

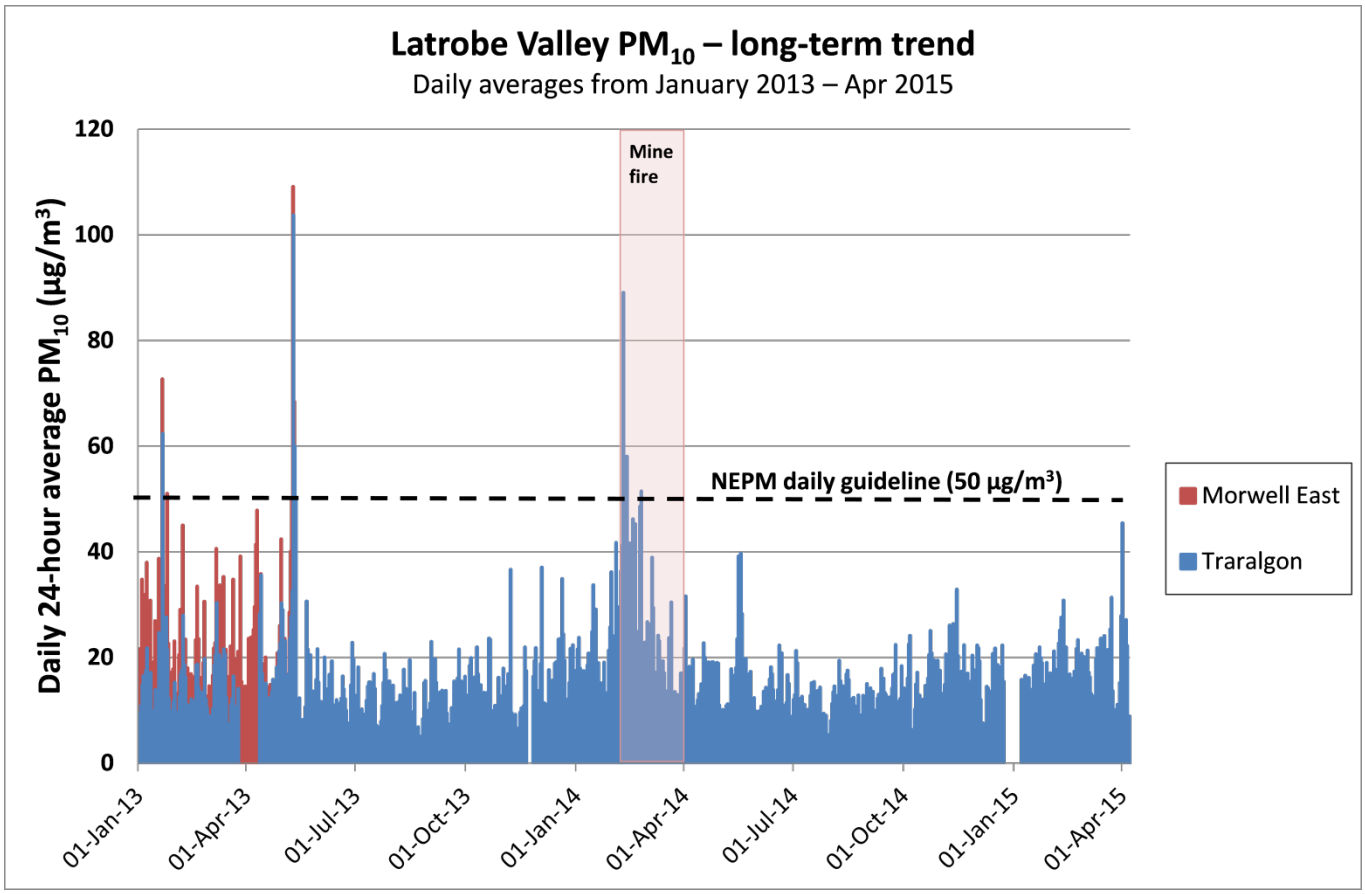

Figure 4. Long-term trend of daily average PM_{10} concentrations in the Latrobe Valley measured using a BAM at Morwell (East) and a TEOM at Traralgon. The graph records the time period from January 2013 to April 2015.

[13] www.epa.vic.gov.au/our-work/publications/publication/2013/september/1547
[14] http://www.environment.gov.au/protection/nepc/nepms/ambient-air-quality/variation-2014/impact-statement

5.3. Carbon monoxide

The area experienced higher than normal concentrations of carbon monoxide (CO) during the mine fire, particularly in the early period. CO monitoring at the fixed air monitoring sites was complemented with a network of portable AreaRAE™ monitors undertaken by the fire services and EPA. These AreaRAE monitors were not used during the Recovery Phase so were not included in the analysis here.

Figure 5 shows CO trends since instruments were installed during the mine fire in February 2014. The NEPM guideline for CO was exceeded on three days at Morwell (South) during February 2014. The higher than normal levels recorded at Morwell (South) AMS during the fire rapidly decreased to low, stable levels by April 2014 and have since stayed low, relative to the NEPM guideline.

Historical ambient carbon monoxide levels in the Latrobe Valley are low, so there was no need for EPA to have CO monitors installed until the mine fire started. The low CO levels during the Recovery Phase mirror these low historical levels..

Figure 5 shows that there have been no breaches of the NEPM eight-hour rolling average guideline of 9 ppm during the Recovery Phase. The average eight-hour CO level during the Recovery Phase was 0.2 ppm, 0.1 ppm and 0.1 ppm at Traralgon, Morwell (South) and Morwell (East), respectively.

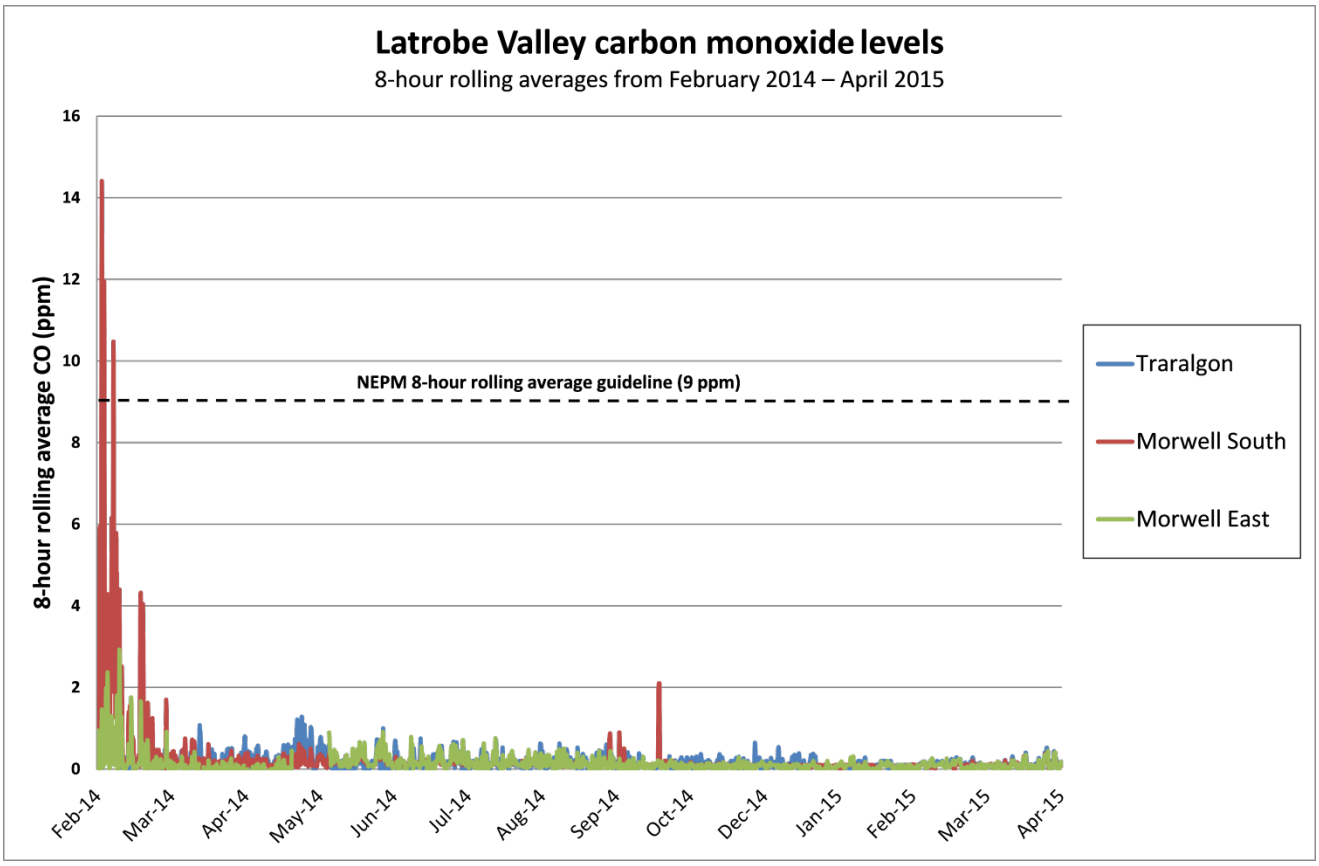

Figure 5. Eight-hour rolling carbon monoxide averages in the Latrobe Valley monitored from February 2014 to April 2015.

5.4. Sulfur dioxide

Sulfur dioxide (SO_2) concentrations were well below air quality standards during the mine fire: the peak one-hour reading since the mine fire started was at Morwell (East) on 23 February 2014 (63 ppb), was well below the hourly NEPM guideline of 200 ppb. Possible reasons for these low levels are that the coal in the Hazelwood mine has low sulfur content (Brockway, Ottrey & Higgins, 1991); and the total amount of coal burned was probably not that great (Fisher, Torre & Marshall, 2015).

An analysis of long-term SO_2 trends in the Latrobe Valley, as seen in Figure 6, shows a lack of discernible impact due to the mine fire. Monthly averages at all three stations show slight seasonal trends, with rising levels during the warmer months, but the mine fire has not impacted on this stable trend. All long-term annual averages are well below the annual NEPM guideline of 20 ppb.

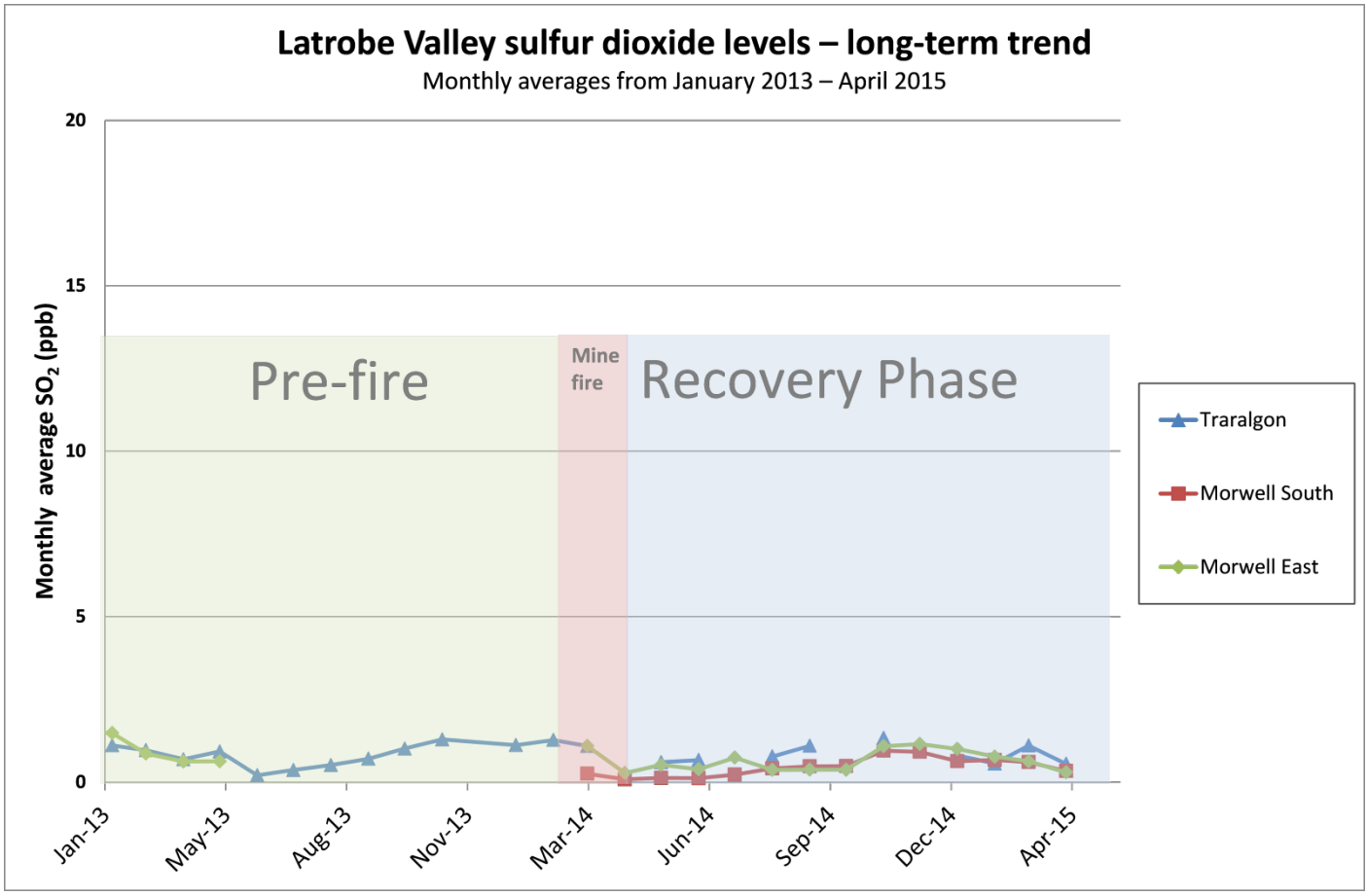

Figure 6. Monthly sulfur dioxide averages in the Latrobe Valley from January 2013 to April 2015.

5.5. Nitrogen dioxide

Although brown coal found in the Latrobe Valley had low nitrogen concentrations compared to other large brown coal reserves in the world (Brockway, Ottrey & Higgins, 1991), nitrogen dioxide (NO_2) was emitted in the smoke from the mine fire and was subsequently monitored at Morwell (South) and Traralgon during and after the fire.

Figure 7 displays long-term NO_2 trends in the Latrobe Valley since January 2013. It can be seen that NO_2 levels have been relatively consistent across the time period. Seasonal peaks were observed at Traralgon through autumns and winters, followed by seasonal dips in summer. The complete effect of the mine fire on NO_2 levels at Morwell (South) AMS cannot be confirmed as valid data only began arriving on 6 March 2014. However, the data we have indicates that any contribution from the fire was still well under the guideline (March monthly average of 8.47 ppb at Morwell (South)). Concentrations at Morwell (South) then fell in April 2014, following Traralgon AMS trends through the Recovery Phase.

NO_2 annual averages for 2014 were well below the NEPM annual guideline of 30ppb, with Morwell (South) recording 6.6ppb and Traralgon recording 6.5ppb. Morwell (South)'s annual average would have been different had the instrument been present from the start of the fire (validated data only became available from 6 March 2014).

A brief period of the Morwell (East) AMS 2012–13 station deployment is captured in the graph. The data accords well with that of Traralgon for the same period.

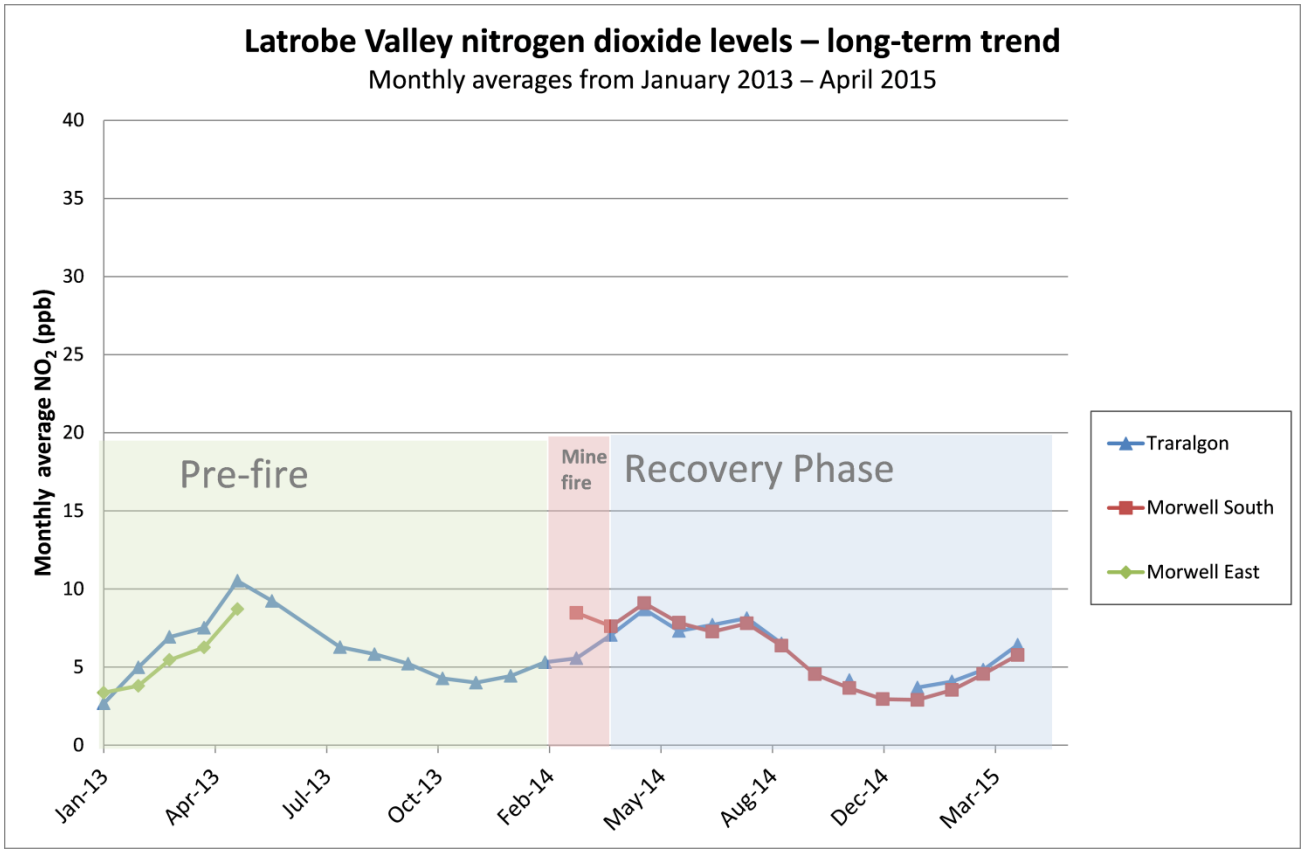

Figure 7 Monthly average nitrogen dioxide concentrations in the Latrobe Valley from January 2013 to April 2015.

5.6. Ozone

Ozone (O_3) concentrations at Traralgon during February 2014 came close to exceeding the four-hour NEPM guideline (Figure 8). However, the peaks were recorded before the start of the mine fire, so were likely due to bushfires in the local area, not the mine fire. After the February peaks a sharp drop in concentrations at Morwell (South) and Traralgon was seen into autumn 2014, as smoke production from the mine fire and bushfire ceased, and sunlight diminished, before seasonal increases started again into summer 2014–15.

Morwell (South) had an ozone monitor in place later during the incident period.

A number of breaches of the four-hour NEPM guideline can be seen to have occurred in January 2013. These were due to bushfires near Aberfeldy, north of the Latrobe Valley.

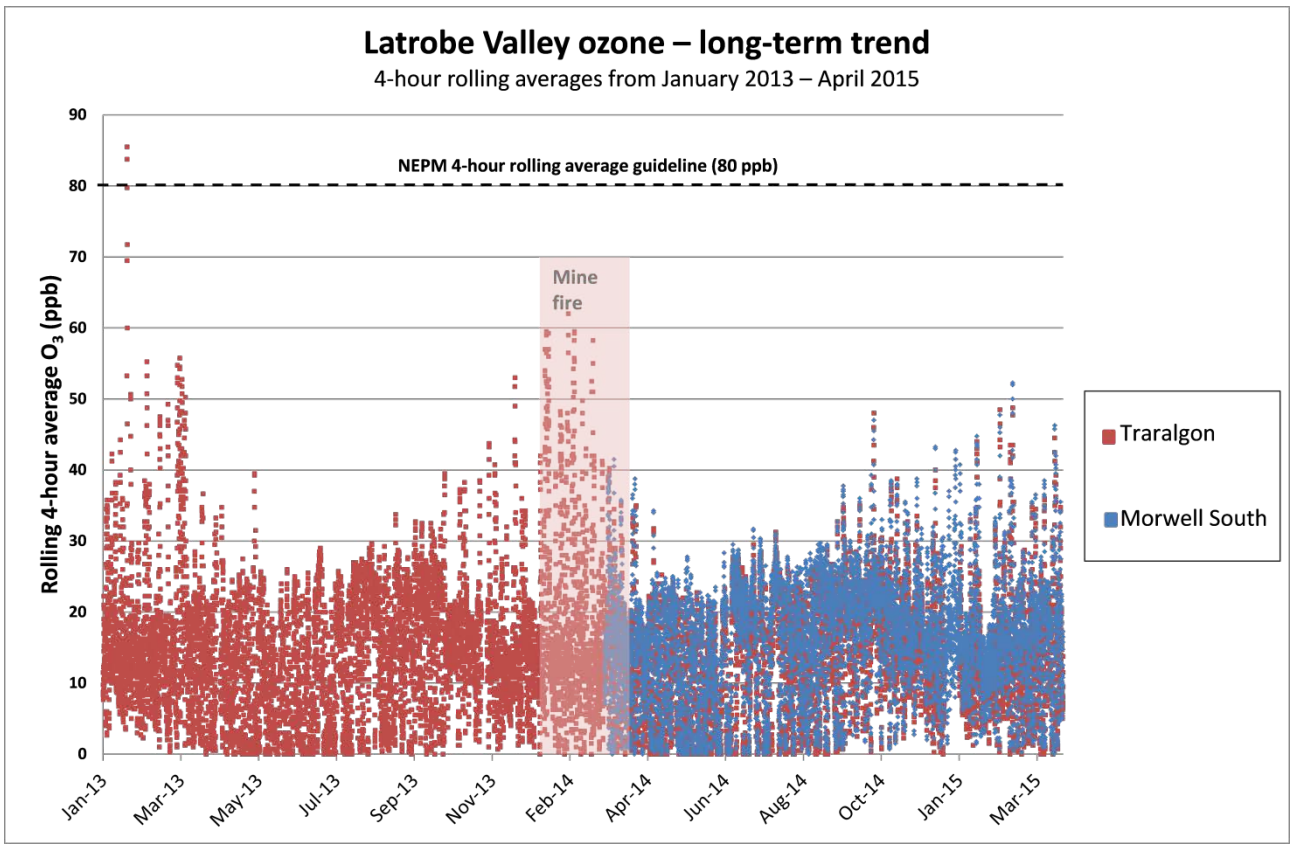

Figure 8 Long-term ozone trends in the Latrobe Valley from January 2013 to April 2015.

5.7. Visibility

Concentrations of visibility-reducing particles can correlate well with PM_{10} and $PM_{2.5}$ concentrations and therefore can be helpful as an indicative measure of relative levels of these pollutants.

Figure 9 shows long-term visibility reduction in the Latrobe Valley between January 2013 and April 2015. The large reduction in visibility, particularly at Morwell (South), during high smoke days can be clearly seen in the area shaded pink. A sharp reduction in concentrations occurred in the weeks following the mine fire, with a relatively steady state through the Recovery Phase. This steady state is similar to average Airborne Particle Index (API) levels recorded in the 13 months before the fire. Significant peaks in January 2013 and May 2013 were due to bushfires near Aberfeldy and planned burns, respectively.

API values were much lower in the Recovery Phase when compared to the Response Phase; however, the SEPP hourly guideline was still breached periodically in this post-fire period as seen in Figure 9. The SEPP (Ambient Air Quality) guideline states that the maximum allowable days per year with guideline breaches for visibility reducing particles is three (SEPP (Ambient Air Quality), 1999. During 2014 Traralgon had 29 days breaching the guideline; Morwell (East) had 25; and Morwell (South) had 32.

While most breaches happened during the mine fire, a significant proportion happened in the Recovery Phase: Morwell (South) recorded 11 days breaching the SEPP guideline post-fire. Many of the Recovery Phase breaches can be attributed to These guideline breaches are associated with elevated smoke levels that may have originated from landholder burning off, forest regeneration burns and planned burning activities in the region; or wood heater use at the start of winter (when unburned chimney residue is expelled for the first time in months).

The SEPP guideline shown in Figure 9 is a one-hour average guideline: no guideline exists in the SEPP for a longer averaging period.

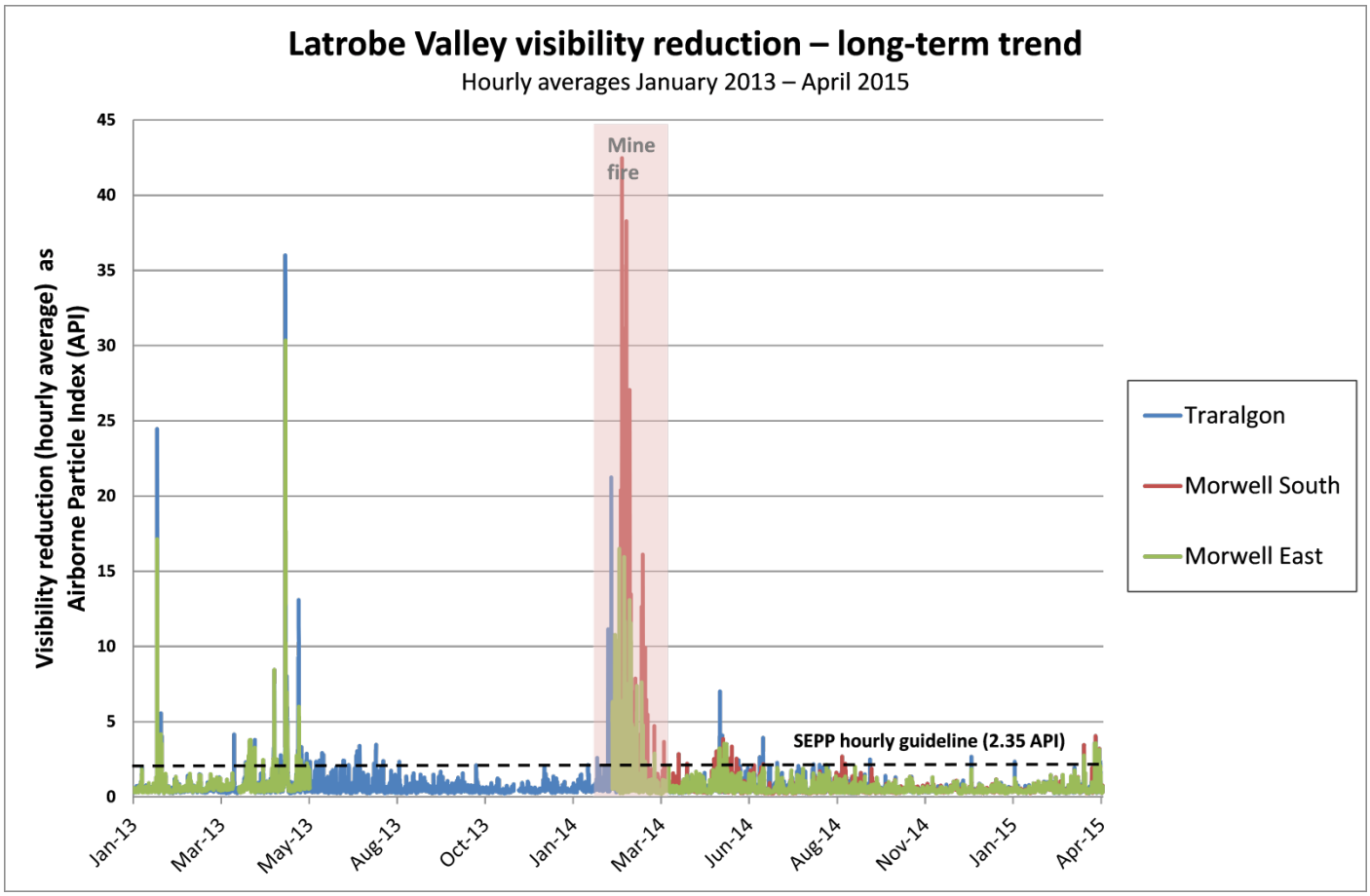

Figure 9. Long-term visibility reduction trends in the Latrobe Valley from January 2013 to April 2015. An API of 2.35 = 20 km visibility. 42.5API recorded at Morwell (South) on 21 February 2014 is equal to a visible distance of 1.1 km.

5.8. Respirable silica

Silica (α-quartz and cristobalite) particles smaller than $PM_{2.5}$ (respirable) have been sampled at Morwell (South) since 9 April 2014. All samples analysed so far (to 28 April 2015) have returned values less than the laboratory detection limit (<1.77μg/m³). The guideline being used for comparison states that a maximum allowable annual average for each polymorph of silica (with a diameter less than 2.5μm) is 3μg/m³.[15]

The sampling instrument used for this testing is a Partisol, which takes one 24-hour air sample every six days. An annual average is computed from these one-in-six day results.

Samples from during the fire recorded detectable levels of silica; however, the instrument used only filtered particles to smaller than $PM_{10.}$ The guideline (and the Recovery phase level) was used was for particles smaller than $PM_{2.5}$. As such, these detections cannot be compared to either the SEPP guideline or to the Recovery Phase results. However, respirable silica (<2.5μm) has not been detected in the 12 months since 9 April 2014.

5.9. Metals

The majority of metals decreased in concentration from the Response Phase to the Recovery Phase as seen in metals samples results from Morwell (South) in Table 6.

Arsenic, antimony, cadmium, silver and tungsten recorded slight increases between these two periods. The reason for the increases in these particular metals is not clear. The unexpected readings seem to be heightened from April to October 2014 (Recovery Phase 1), when in addition to arsenic, antimony, silver and tungsten, copper and thorium also recorded higher levels than during the Response Phase. Again, a reasonable explanation for this trend is unclear. However, the results indicate that the mine fire was not a major contributor to the levels of these metals in the air at Morwell (South).

A comparison of all of the metals to their appropriate annual guideline shows that there have been no guideline breaches for any of the elements during any of the time periods.

Note that the Recovery Phase sampling is broken into two periods due to the move of the Morwell (South) AMS from the Morwell Bowling Club, Hazelwood Rd to Maryvale Crescent Preschool on 6 October 2014.

The equipment used (a Hi-Vol sampler) takes one 24-hour sample of air every six days and an annual average is computed from these one-in-six day results.

Table 6. (previous page) shows the average concentrations in ng/m³ for a range of metals measured in ambient air at Morwell (South). Guidelines are taken from the TCEQ with the exception of lead, which is taken from the NAAQS.

Compound	Annual average (ng/m³) (26 Feb 14 – 26 Feb 15)	Response (ng/m³) (26 Feb 14 – 8 Apr 14)	Recovery (1 &2) (ng/m³) (8 Apr 14 – 4 Feb 15)	Recovery 1 (ng/m³) (8 Apr 14 – 1 Oct 14)	Recovery 2^ (ng/m³) (29 Oct 14 – 3 Feb 15)	Annual guideline~ (ng/m³)
Aluminium	218.42	409.2	63.2	31.9	99.1	5000
Antimony	0.21	0.11	0.23	0.31	0.13	500
Arsenic	0.49	0.37	0.52	0.72	0.27	67
Barium	8.45	47.9	1.10	0.90	1.34	500
Beryllium	0.06	0.06	0.06	0.06	0.05	2
Bismuth	0.06	0.08	0.05	0.08	0.01	5000
Boron	6.36	24.0	3.09	5.41	0.42	5000
Cadmium	0.03	0.02	0.03	0.05	0.01	10
Calcium	764.2	1582	98.4	51.14	152.8	5000
Cerium~	0.36	1.08	0.23	0.13	0.35	-
Chromium	0.91	1.55	0.39	0.07	0.76	41
Cobalt	0.61	1.11	0.20	0.24	0.15	20
Copper	1.25	1.32	1.20	2.16	0.11	1000
Gallium	1.29	7.19	0.19	0.16	0.23	2000
Gold	0.22	0.35	0.20	0.31	0.07	2500
Iron	428.3	758.0	159.9	105.7	222.2	5000
Lanthanum	0.16	0.25	0.14	0.10	0.18	5000
Lead	1.68	2.26	1.20	1.77	0.54	150*

[15] http://www.epa.vic.gov.au/~/media/Publications/1191.pdf

Lithium	0.26	0.40	0.24	0.34	0.11	1000
Magnesium~	520.0	2534.0	145.3	71.6	230.0	-
Manganese	7.12	12.7	2.60	1.05	4.38	200
Mercury	0.02	0.05	0.01	0.01	0.01	25
Molybdenum	0.10	0.18	0.09	0.09	0.08	3000
Nickel	0.72	1.02	0.48	0.31	0.67	59
Phosphorus	6.21	8.70	4.19	0.42	8.52	100
Potassium	93.2	133.2	60.6	46.2	77.1	2000
Rubidium	0.20	0.26	0.19	0.20	0.18	2500
Selenium	1.15	2.40	0.13	0.09	0.19	200
Silver	0.22	0.06	0.25	0.40	0.09	10
Sodium~	1360	3287	1002	538.4	1534	-
Strontium	8.71	17.8	1.31	0.73	1.98	2000
Sulfur	653.5	1272	150.35	46.0[#]	270.3	5000
Tellurium	0.06	0.06	0.06	0.06	0.06	100
Thallium	0.06	0.06	0.06	0.06	0.06	100
Thorium~	0.27	0.31	0.26	0.36	0.15	-
Tin	0.32	0.43	0.30	0.23	0.37	2000
Titanium	36.6	72.5	7.49	3.10	12.5	5000
Tungsten	0.77	0.73	0.78	1.39	0.07	1000
Uranium	0.05	0.06	0.05	0.06	0.03	50
Vanadium	0.72	0.94	0.54	0.58	0.51	50
Yttrium	0.23	0.30	0.21	0.04	0.41	1000
Zinc	10.3	13.4	7.87	8.03	7.69	2000
Zirconium	0.66	2.16	0.38	0.46	0.28	5000

Values below the laboratory detection limit are given a value above the maximum detection value. I.e., <0.001 ng/m^3 is assumed to be 0.001 ng/m^3 for the purpose of calculating averages.

^ Recovery 2 begins on 29 October 2014 rather than 8 October 2014 due to delays caused by a change of sampling location from Morwell Bowling Club to Maryvale Crescent.

~There are no TCEQ guidelines for thorium, sodium, magnesium and cerium

[#] Sulfur was not detected in samples collected between 8 June 2014 and 1 October 2014 likely due to analysis problems. Therefore the averaged value for sulfur during the Recovery Phase (1 &2) period is likely to be incorrect

** National Ambient Air Quality Standards (NAAQS)–Rolling three-month average*

Figure 10 shows the differences in metal distributions between the Response and the Recovery phases. Overall, the upper percentiles (75th and 90th percentiles) for the selected metals are consistently higher in the Response Phase when compared to Recovery; while the median values between the Response and Recovery phases generally decrease with time. Zinc is an exception to this trend in median values; however, the increase in median value has been calculated as being statistically non-significant (using a Mann-Whitney U test). Furthermore, the average zinc levels across the two periods shows a decrease (Table 6), indicating the lack of clear upward or downward trend in the data.

The metals in Figure 10 were chosen for analysis as some of them are known to make up significant proportions of the major and trace metals of Hazelwood brown coal (Brockway, Ottrey & Higgins, 1991), and were found in significant proportions in mine fire ash collected during the Response phase.

The concentration ranges of each metal observed during the Response Phase is quite large. This is due to the elevated levels of metals measured in February 2014, followed by significant decrease in concentrations by late March 2014.

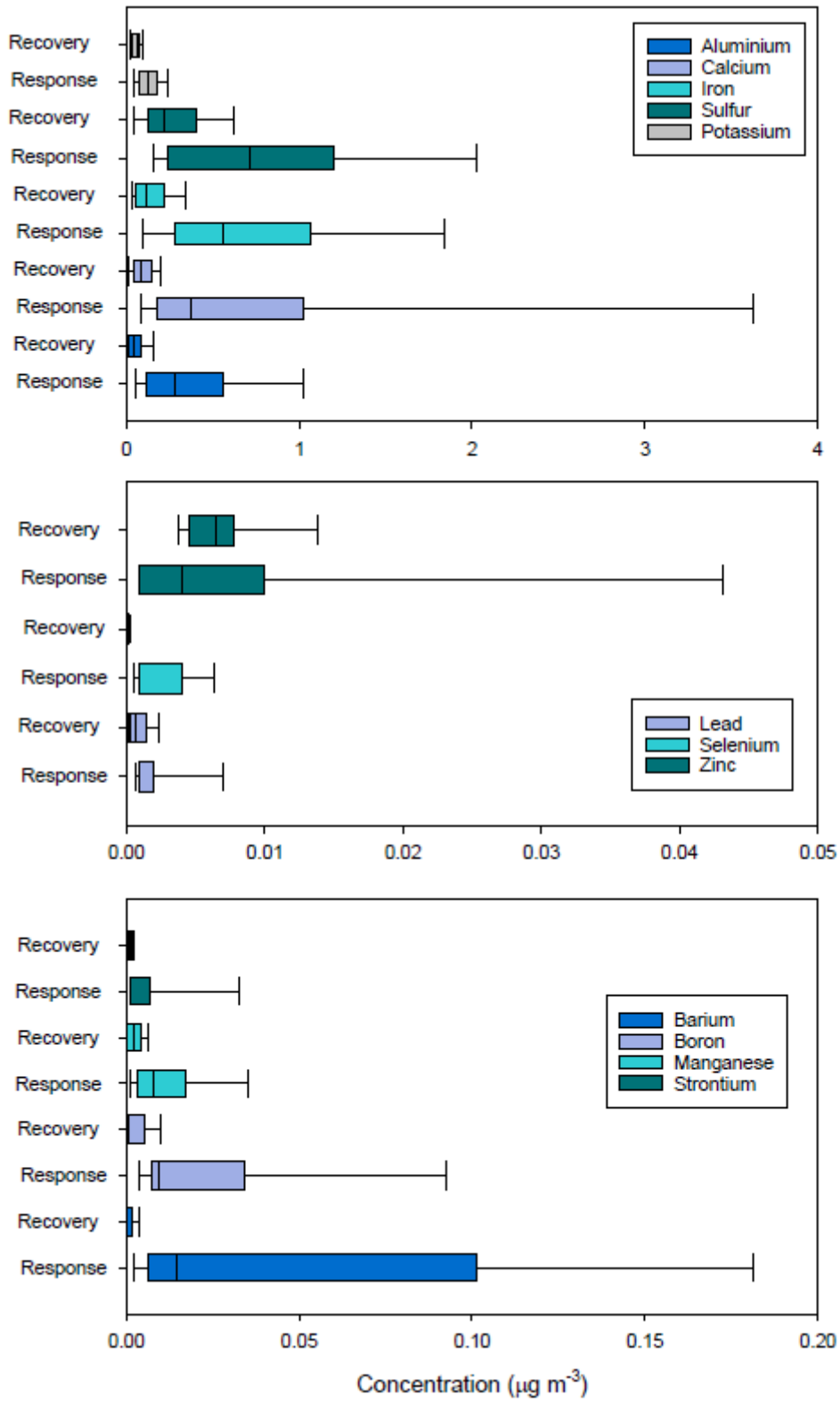

Figure 10. Modified boxplots of trace metals measured in ambient air during and after the Hazelwood mine fire. The ends of the boxes define the 25th and 75th percentiles, with a line at the median and bars defining the 10th and 90th percentiles.

NB: For sulfur, Recovery Phase data only covers October 2014 until February 2015 as it was not detected in samples collected between 8 June 2014 and 1 October 2014, likely due to analysis problems. The Recovery Phase covers samples collected to 3 February 2015. Results post-February 2015 are still being processed. Where concentrations were below the detection limit, the practical quantification limit (PQL) was used for analysis purposes.

Figures 11–13 show time series plots of selected metals at Morwell (South) AMS since February 2014. The plots allow for higher resolution of metals trends to be identified than do Table 6 and Figure 10, which treat the Response and Recovery data as homogenous groups, potentially failing to pick up information on potential fluctuations caused by seasonal variations, temperature changes and meteorological impacts.

The metals in the plots below were selected based on the fact that they were measured at levels above the detection limit for the majority of samples. It can be seen from the plots that there is generally a significant decrease in concentrations observed between the end of February 2014 and the beginning of April 2014, as ash and smoke production decreased and eventually stopped. Concentrations after the mine fire remained consistently low for all metals displayed, except for potassium, boron and phosphorous. These three metals (see Figures 12 and 13) had variable concentrations during the Recovery Phase, with no clear trends observed. Nevertheless, each of them recorded a decrease in average concentrations since the Response Phase.

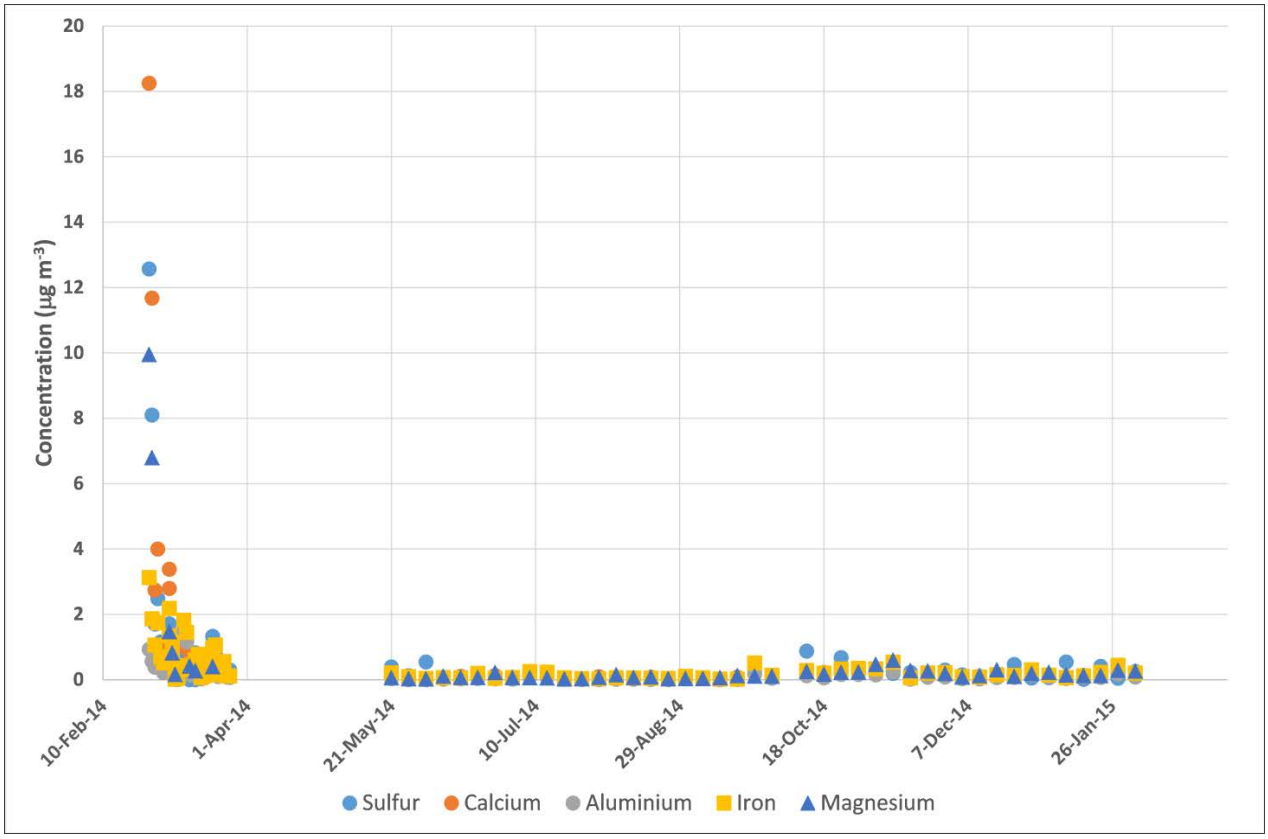

Figure 11. Time series of ambient concentrations (in µg/m³) for sulfur, calcium, aluminium, iron and magnesium at Morwell (South) AMS from 26 February 2014 to 3 February 2015

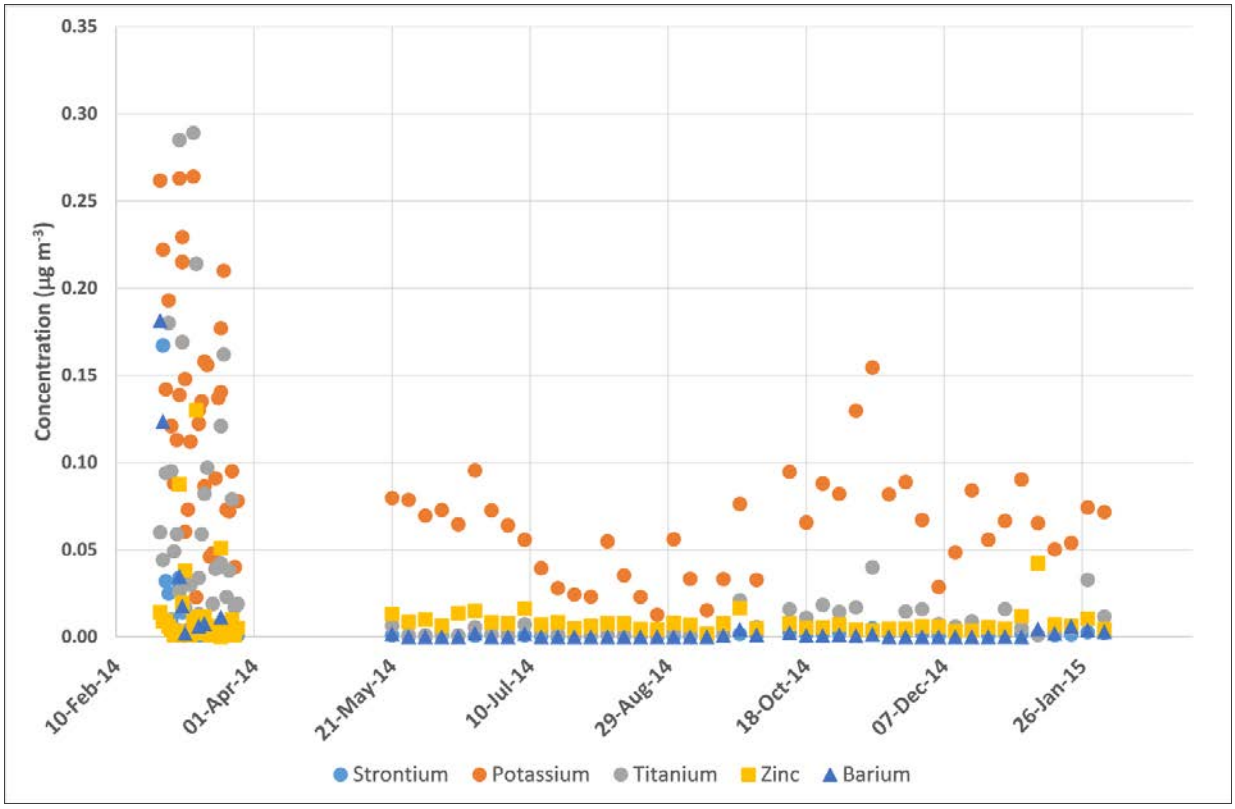

Figure 12. Time series of ambient concentrations (in µg/m^3) for strontium, potassium, titanium, zinc and barium at Morwell (South) AMS from 26 February 2014 to 3 February 2015

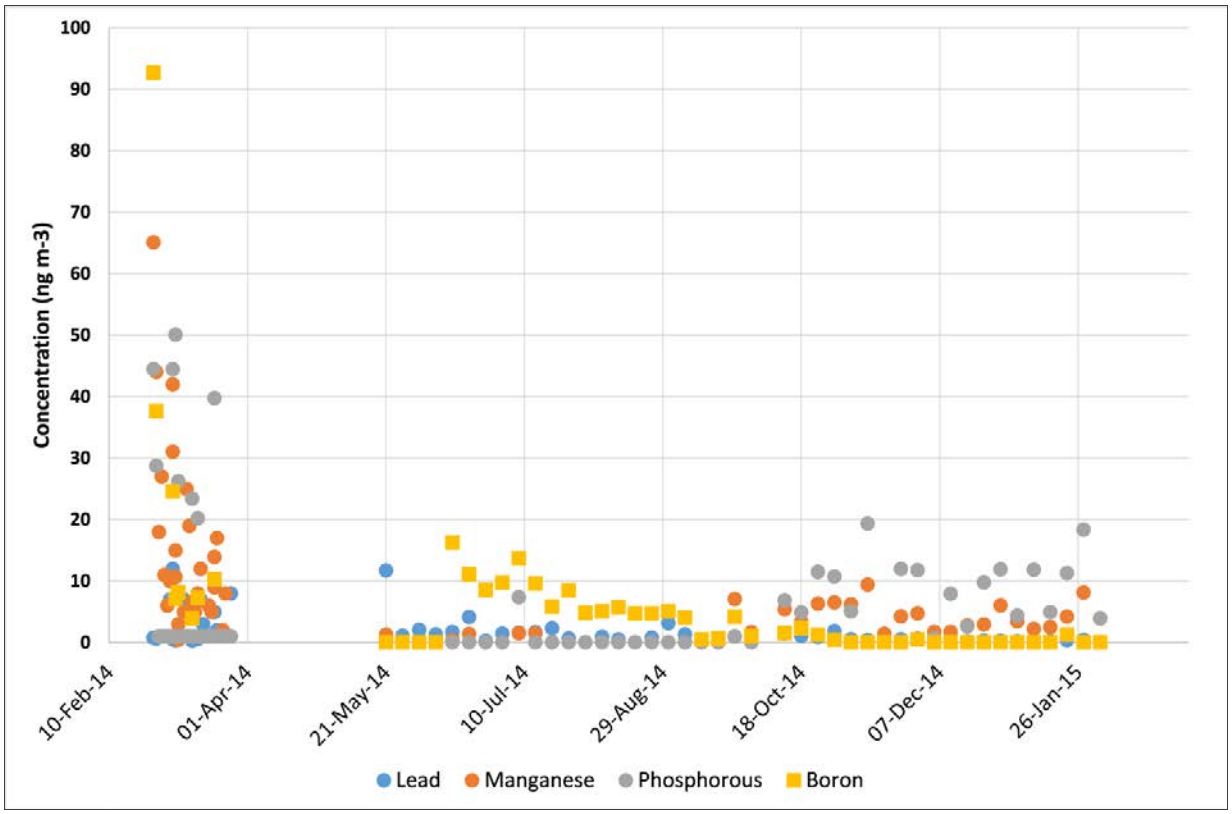

Figure 13. Time series of ambient concentrations (in ng/m^3) for lead, manganese, phosphorus and boron at Morwell (South) AMS from 26 February 2014 to 3 February 2015

5.10. Polycyclic aromatic hydrocarbons (PAHs)

During the mine fire, the community expressed concerns about the potential effects of the toxic components of the smoke – especially PAHs. Short-term concentrations of PAHs (as B(a)P equivalents) were a little higher than some historical peak measurements made in Melbourne, however, these peak values only appeared in measurements made during the mine fire when smoke emission was particularly intense (Fisher, Torre & Marshall, 2015).

Figure 14 shows trends in selected PAHs since mine fire sampling began on 26–27 February 2014. The compounds were chosen either because they have associated guidelines, or they recorded relatively high concentrations during the mine fire. PAH peaks in chrysene and benzo(a)anthracene in particular rapidly dropped away once smoke production reduced. Concentrations of the selected PAHs have been consistently below laboratory detection limit, or only slightly above, during the Recovery Phase of sampling.

For total PAHs (as B(a)P equivalents), the NEPM assessment annual concentration is 0.3 ng/m^3 . This is the only NEPM guideline for particle-bound PAHs in air. Table 7 shows that the average annual concentration of B(a)P was 0.4 ng/m^3 from February 2014 to February 2015, exceeding the guideline. However, the Response Phase average of 2.36ng/m^3 was largely responsible for this guideline breach. Recovery Phase average B(a)P levels have been less than the laboratory detection limit of 0.026 ng/m^3, far lower than Response Phase concentrations . It is predicted (based on 10 months of data) that B(a)P levels for the year post-fire will not exceed this guideline; however, final analysis results will confirm this.

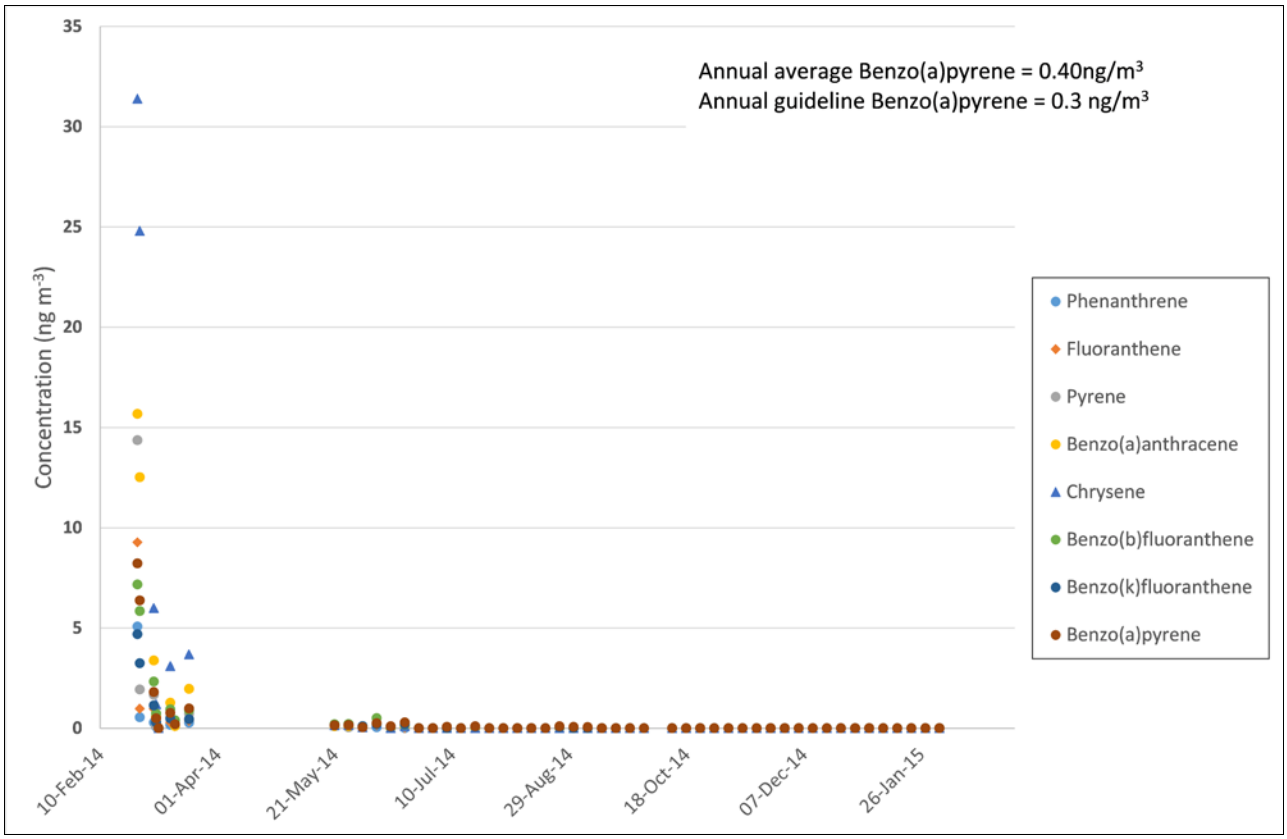

Figure 14. Concentrations of selected PAHs (in ng/m^3) measured at Morwell (South) AMS during the Response and Recovery phases to 3 February 2015.

NB: For graphing purposes, where levels were less than the laboratory detection limit, the maximum detection limit was used.

Table 7. Concentrations of PAHs (in ng/m^3) measured at Morwell (South) AMS during the Response and Recovery phases to 3 February 2015. This table includes data to February 2015.

Compound	Annual	Response Phase	Recovery Phase	Annual guideline
Phenanthrene	0.14	0.82	< 0.006	-
Fluoranthene	0.24	1.51	< 0.006	-
Pyrene	0.40	2.45	< 0.008	-
Benzo(a)anthracene	0.71	4.44	< 0.009	-
Chrysene	1.40	8.82	< 0.009	-
Benzo(b)fluoranthene	0.39	2.29	< 0.016	-
Benzo(k)fluoranthene	0.23	1.32	< 0.016	-
Benzo(a)pyrene	0.40	2.36	< 0.026	0.3

5.11. Volatile organic compounds (VOCs)

Benzene was the only VOC found to exceed guidelines during the Response Phase, recording a number of breaches of the 24-hour NEPM standard in late February 2014 at the sampling sites in the south of Morwell, close to the mine. These breaches were recorded using 24-hour sampling canisters on high-smoke days. Along with these canisters, EPA deployed solid adsorbent tubes to sample VOCs over seven-day periods during the fire and continuing through the Recovery Phase. Figures 15 and 16, and Table 9 show that while higher concentrations were recorded for some VOCs during the mine fire, concentrations have dropped to consistently low levels during the Recovery Phase. Annual averages are all well below guidelines (where present). VOCs without guidelines, or not presented below, have similar, consistently low concentrations during the Recovery Phase. Overall, the concentrations of VOCs tested have decreased since the mine fire.

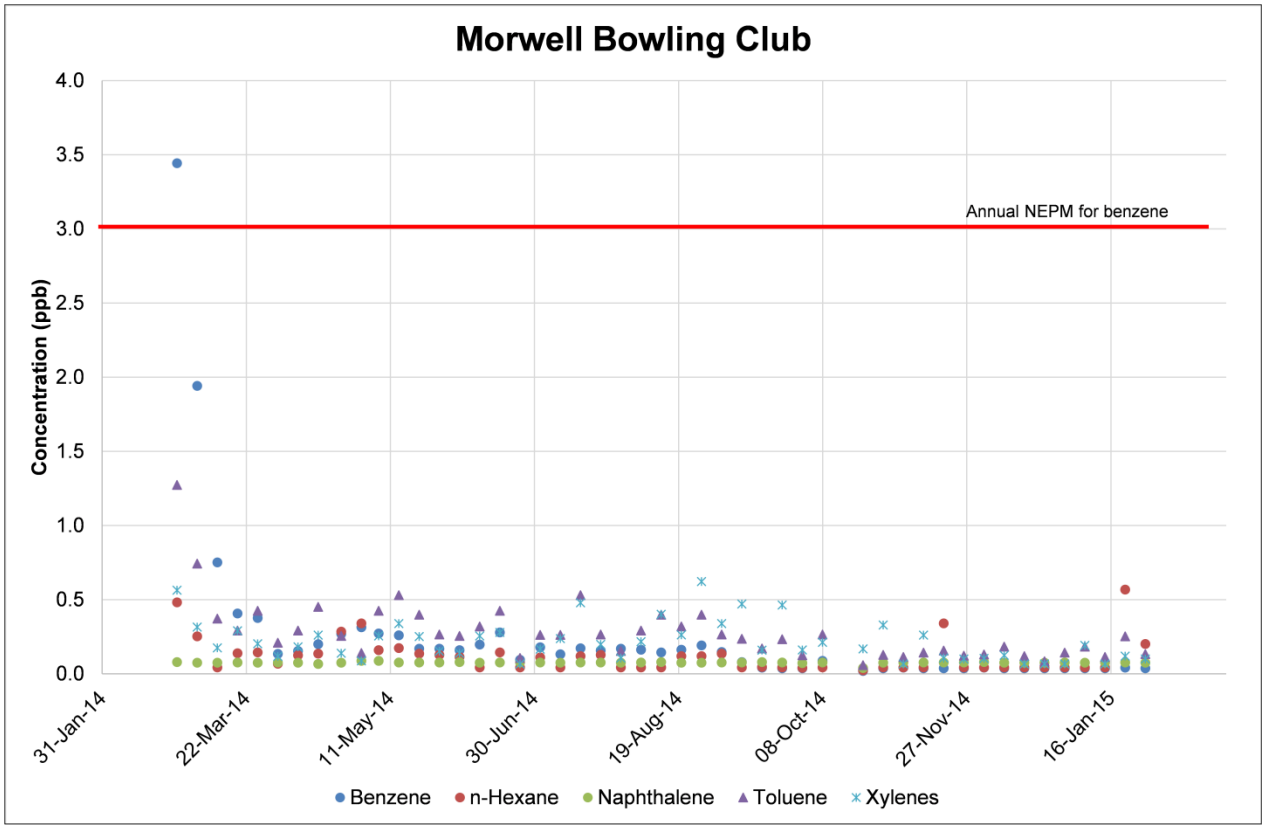

Figure 15. Time series of weekly ambient measurements (in ppb) of benzene, n-hexane, naphthalene, toluene and xylenes taken using solid adsorbent tubes at Morwell Bowling Club to 11 February 2015.

Figure 15 shows the time series of selected VOCs known to be combustion products (benzene, n-hexane, naphthalene, toluene and xylenes – o-xylene and m&p-xylene) at Morwell Bowling Club (previously Morwell (South) AMS) observed during the mine fire and on into the Response Phase. Benzene was found in a concentration higher (3.44 ppb) than the NEPM annual guideline (3 ppb) early in the Response Phase; however, it quickly fell to consistently low levels, leading to an annual average concentration of 0.251 ppb (Table 8). Toluene followed a similar pattern, but does not have an annual guideline for comparison.

Figure 16 shows benzene concentrations at the three VOC sampling locations in Morwell: Morwell Bowling Club (Morwell (South)), Maryvale Crescent Preschool, and Morwell (East) AMS. The highest concentrations were measured at the two locations closest to the mine, indicative of both the source and extent of benzene dispersion in the air during the mine fire. Benzene levels fell at all three locations by early April, and have since remained lower than 0.5 ppb for the Recovery Phase.

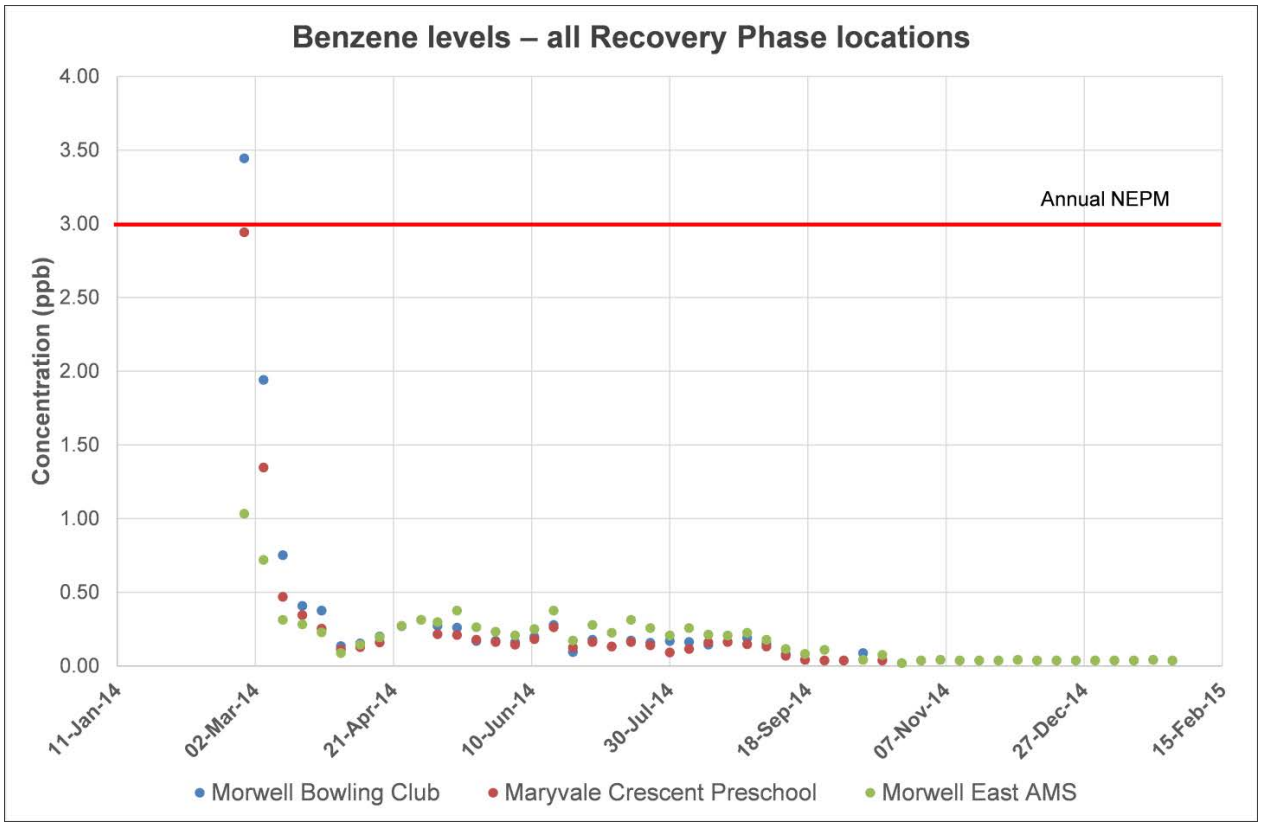

Figure 16. Time series of weekly ambient concentrations (in ppb) of benzene measured at three sites in Morwell to 11 February 2015.

Table 8 shows a comparison of selected average VOC concentrations in the Latrobe Valley during the Response and Recovery phases. All VOCs recorded a fall in concentrations between the two time periods apart from the xylenes at Morwell (East) Air Monitoring Station, which rose slightly. It is unknown as to the cause of these increases; however, o-xylene averages are orders of magnitude lower than the annual guideline, suggesting that it could be normal background fluctuations rather than caused by point source emissions. The distance of the Morwell (East) AMS from the mine means that significant xylene emissions from the fire may have simply not reached this part of Morwell.

The Latrobe Valley data shows three different time periods for benzene, n-hexane, naphthalene, toluene and xylenes at the three sample locations. The three time periods are: the year from 26 February 2014 (when sampling began); the Response Phase (26 February 2014 to 7 April 2014); and the Recovery Phase (7 April 2014 onwards). All VOC annual averages (including the Response Phase) were less than the corresponding guideline.

Naphthalene was not found above the level of laboratory detection at the three Latrobe Valley sites; for analysis purposes it was given the value of the detection limit in each analysis.

Table 8 Average concentrations of selected VOCs for varying time periods at Latrobe Valley sampling sites to 11 February 2015. Annual NEPM guidelines are provided where available.

Compound (ppb)	Morwell Bowling Club			Maryvale Crescent Preschool			Morwell (East) AMS			Annual guideline
	Annual	Response	Recovery	Annual	Response	Recovery	Annual	Response	Recovery	
Benzene	0.251	1.384	0.121	0.208	1.071	0.108	0.190	0.515	0.152	3
n-Hexane	0.118	0.212	0.105	0.085	0.190	0.073	0.104	0.112	0.103	-
Naphthalene	0.075	0.076	0.075	0.075	0.076	0.075	0.075	0.076	0.075	-
Toluene	0.280	0.621	0.242	0.222	0.455	0.195	0.336	0.367	0.332	100
o-Xylene	0.061	0.088	0.059	0.052	0.062	0.051	0.068	0.044	0.071	200
m&p-Xylenes	0.158	0.222	0.152	0.123	0.136	0.122	0.181	0.123	0.188	-

6. Conclusion

An extensive program of air sampling and monitoring conducted during the Recovery Phase of the Hazelwood mine fire showed that any air quality impacts recorded during the mine fire have now dissipated. All of the compounds tested during the incident returned to background, or low, stable concentrations shortly after emissions from the fire ceased. This has remained the case for the duration of the Recovery Phase.

Any further changes in Latrobe Valley air quality into the future are not expected to be linked to the mine fire. Traralgon air monitoring station will continue as a long-term monitoring site within EPA's Ambient Air Quality Network, allowing observation of key pollutants into the future.

7. References

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USEPA (2015a) Particulate Matter (PM). www.epa.gov/pm/. Accessed 4/5/15.

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USEPA (2015d) Ozone. www.epa.gov/ozone/. Accessed 12/5/15.

8. Appendix A

TEOM PM_{10} data validation

PM_{10} data measured on the TEOM at Traralgon AMS has been adjusted using a temperature-dependent formula with a constant value of K equal to 0.04. The resulting adjustments vary from no change to PM_{10} concentrations at average daily temperatures, when they are at or above 15 °C, to an increase in PM_{10} concentrations of 40 per cent at a temperature of 5 °C. This process is in line with the approved procedure: http://www.scew.gov.au/system/files/resources/9947318f-af8c-0b24-d928-04e4d3a4b25c/files/aaqprctp10collectionandreporting200105final.pdf

9. Appendix B – Community Feedback

On 10 June 2015, EPA held a community engagement event to seek feedback from Latrobe Valley community members about draft versions of the reports: *Hazelwood Recovery Program Air Quality Assessment – Morwell and Surrounds, February 2014 – May 2015* (publication 1601) and *EPA Hazelwood Recovery Program water, soil and ash assessment – Morwell and surrounds, February 2014 – May 2015* (publication 1600). EPA received a wealth of excellent and detailed feedback on the draft publications. The community feedback received that is directly relevant to these reports is listed in the table below.

Community Feedback	EPA Comments
EPA should explain more clearly about the ash that was airborne during the fire, and the ash that settled on the ground. For example, particle size explanation in report would be helpful.	In response to this feedback, EPA has further clarified about the size of ash particles on page 2 of the water, soil and ash report (publication 1600).
Further explanation is needed for some graphs in the water, soil and ash graphs.	In response to this feedback, graphs on pages 9–15 of water, soil and ash report (publication 1600) were modified to make them easier to understand, or in some cases, more text was added to explain the meaning of the graphs.
Showing only trace metals components of brown coal is confusing.	In response to this feedback, further charts were added on page 4 and figure 2 of the water, soil and ash report (publication 1600) to show the other components of brown coal.
Could drinking water and recreational standards be included in the reports, either on graphs or listed separately?	In response to this feedback, figures have been updated on pages 13–15 of the water, soil and ash report (publication 1600).

Heavy metals detected at very low levels, zinc, lead, arsenic – why aren't they included in graphs?	In response to this feedback, text has been modified to page 13 of the water, soil and ash report (publication 1600) to explain why these metals haven't been included in the graph.
Clearer explanation is needed for some of the metal graphs in the water results section	In response to this feedback, figures have been updated on pages 13–15 of the water, soil and ash report (publication 1600).
Is there is a World Health Organization (WHO) standard that can be included in the graphs in the report?	EPA reports against the relevant national or state environmental guidelines for air, water and soil. There are also standards set by WHO or the Department of Health and Human Services. Often they influence national or state environmental standards. For more information about the standards EPA reports against, visit: http://www.epa.vic.gov.au/about-us/legislation/air-legislation
Where is the information about the history of air monitoring data in the Latrobe Valley?	See information given by then CEO John Merritt as evidence during the Hazelwood Mine Fire enquiry for a discussion of the history of air monitoring in the Latrobe Valley http://report.hazelwoodinquiry.vic.gov.au/part-four-health-wellbeing/environmental-effects-response/epa-latrobe-valley
Where is the detailed information about what EPA did during the mine fire?	This has been published in a separate report that focuses on EPA's response and air quality data during the mine fire: *Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014* (publication 1598). http://www.epa.vic.gov.au/our-work/publications/publication/2015/june/1598
What lessons have EPA learnt from the mine fire?	In accordance with specific recommendations from the Hazelwood Mine Inquiry, EPA has made a number of changes to its procedures and procedures about how we monitor air quality and communicate that data with the community: http://www.parliament.vic.gov.au/file_uploads/_Hazelwood_Mine_Fire_Inquiry_Report__dprsnQjH.pdf The approach taken with engaging the community early with the results from these publications is another concrete example of learning and doing things differently.
Some of the metal graphs in the air report are difficult to understand	In response to this feedback, some text has been added to figures 11–13 pages 21–22 of the air report (publication 1601), and some graphs have been modified or removed.
Some annual guidelines were missing on the metal tables in the air report	In response to this feedback, the guideline values were added to page 7 of the air report (publication 1601).
Why is only $PM_{2.5}$ been monitored at the Moe and Churchill air monitoring stations?	In response to this feedback, a sentence has been added to page 3 the air report (publication 1601) to explain the decision behind monitoring $PM_{2.5}$ more clearly.
Some information about what happened with air monitoring during the fire is not clear, such as number of breaches of $PM_{2.5}$ and when monitoring started.	This has been published in a separate report that focuses on EPA's response and air quality data during the mine fire: *Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014* (publication 1598). http://www.epa.vic.gov.au/our-work/publications/publication/2015/june/1598
The report is technical and quite difficult to understand at times.	Publications 1600 and 1601 are technical reports. EPA will be looking at other ways to communicate the results to a general audience. EPA has asked for direct feedback from the community on what format this should take. To date ideas have included short plain-English information bulletins, short YouTube videos and public talks.