CASANZ

Clean Air Society Of Australia and New Zealand
Victoria and Tasmania branch

# Submission to the Board of Inquiry into the Hazelwood Coal Mine Fire of 2014

16th May 2014

## 1. Our Context

The Clean Air Society of Australia and New Zealand is the region's professional society related to air pollution science and technology – see www.casanz.org.au/about. This submission has been prepared by a working group within the Society's Victoria and Tasmania branch that was formed to provide the Board of Inquiry with independent technical information about the science of air pollution and related health effects, which is central to points 4(iii-v) of the Terms of Reference.

This submission draws on the Society's members who have expertise and qualifications in relevant aspects of epidemiology, health standards, pollution behaviour, pollution measurement and protective measures. If the Board of Inquiry wishes to discuss such matters further with the experts, the Society will facilitate such discussion.

## 2. Smoke Constituents

### *2.1 Introduction to Smoke Composition*

Smoke contains a mixture of gases and particles. The smaller particles and some of the gases are known to cause health effects. All particle sizes impair visibility, which can create problems such as traffic hazards. Larger particle sizes, including ash, deposit on surfaces and can be a nuisance (e.g. ash in homes) and occasionally cause a hazard (e.g. arcing of electricity transmission lines or excessive build-up of persistent toxic chemicals in soil or homes).

Both the gases and particles in smoke vary in composition according to factors such as the fuel type, combustion temperature and availability of oxygen. The relative concentrations of the constituents and their movement through the atmosphere vary according to meteorological conditions and the heat (and hence buoyancy) of the smoke.

The Hazelwood coal mine fire involved a lot of smouldering compared with the hot, efficient combustion of a furnace or car engine. This affected the proportions of the constituents released to the atmosphere, in the same way that side-stream smoke from a smouldering cigarette is more toxic, per gram, than when the smoker draws on the cigarette (Schick & Glantz 2005).

## 2.2 Measurement Methods and Siting

Different constituents of smoke must be measured in very different ways with different sorts of instruments. Some constituents can be measured continuously at the monitoring site, while other constituents require air samples to be collected over a period of time and taken to a specialised laboratory for analysis. The accuracy of measurements depends on the instruments used and what happens to the air between being extracted from the atmosphere and undergoing final analysis. Some constituents of concern are reactive and/or volatile, requiring prompt, careful handling and temperature control to minimise losses.

With all these complexities, it is understandable that the Victorian EPA called upon several other organisations to help monitor pollutants in the smoke from the Hazelwood coal mine fire.

The rapid deployment of the EPA's own monitoring equipment for the fire, and the hourly updates of the resultant data on the internet, were commendable achievements. Other monitoring took longer to deploy or complete and publish, and some remains incomplete or unpublished and unavailable for us to prepare this submission.

The usefulness of air monitoring depends not only on the accuracy and precision of the measuring instruments and the care involved in collecting and processing air samples, it relies at least as much on the representativeness of the monitoring. The air monitoring sites chosen by the EPA for the Hazelwood coal mine fire produced very different results from each other, and further differences would be expected if another equally reasonable site was selected. The instrument readings may be precise to two or three significant figures, but the relevance to a community member is far less precise because of variations from person to person in their location and their exposure to the open air. The published data are not relevant to people such as fire fighters who were much closer to the fire.

We understand that the Tasmanian EPA used a mobile 'DustTrak' instrument to help determine the spatial distribution of smoke in the Latrobe Valley during the Hazelwood coal mine fire. The instrument provides an indirect measure of fine particle concentrations by analysing the degree of light scattering in the sampled air. It is cheap, quick to deploy (except that in this case, it had to be brought from Tasmania) and its mobility enables it to:

- Determine indicative pollutant concentrations within impacted communities when the direction of smoke is not toward fixed monitoring stations;
- Determine the level of impact at multiple candidate sites for relocation of affected people;
- Detect movement of the smoke plume, thereby aiding forecasts and interpretation of data from the fixed stations.

However, we cannot comment on whether these potential benefits were achieved during the Hazelwood coal mine fire because we have been able to obtain very little information about the monitoring and how its results have been used. If not for the delay in obtaining the DustTrak and its operator from Tasmania, it could have helped the initial response by indicating whether more elaborate monitoring equipment should be established, and if so, how urgently and at what location(s).

Highly mobile instruments are also available for some other smoke constituents such as carbon monoxide. However, fine particles appear to have been the most important constituent of the Hazelwood coal mine smoke (see below) and we are unaware of whether other pollutants were monitored with mobile instruments except in close proximity to the fire.

## *2.3 Measured concentrations*

The websites of the Victorian EPA and the Victorian Health Department list pollutants and environmental parameters that were monitored in association with the Hazelwood coal mine fire, excluding the DustTrak monitoring. Of those measurements, Table 1 summarises the ones that we believe to be significant to the Inquiry, based on the websites' content on 13th May 2014.

**Table 1. Summary of air pollutant measurements most relevant to the Inquiry.**
Note that, as opposed to many other things that have standards, it is desirable for a pollution concentration to be 'below standard', not exceed it.

| Pollutant Name | Pollutant Description | Measured Concentrations relative to Health Standards |
|---|---|---|
| $PM_{2 \cdot 5}$ | Particles so small (nominally up to 2·5 µm across) that they act like a gas, some of them able to pass through the lungs into the bloodstream | far above standards (i.e. hazardous) |
| $PM_{10}$ | Particles that include $PM_{2 \cdot 5}$ as well as larger particles that can deposit in lungs but not blood | far above standards (i.e. hazardous) |
| Carbon monoxide | A gas formed by incomplete combustion, it displaces oxygen in the blood when inhaled | above standards |
| Benzene | A gas that can cause cancer after years of exposure or acute effects at levels found in some industries | approx. 1% of standards for short-term occupational exposure |
| PAHs (polycyclic aromatic hydrocarbons) | A group of persistent, toxic products of incomplete combustion that condense onto particles ($PM_{2 \cdot 5}$, $PM_{10}$, ash) and can cause cancer and birth defects | measured, but not available to us |
| Dioxins and furans | Extremely toxic, bio-accumulated chemicals that can be transported by smoke but are most harmful when they enter the food chain | measured, but not available to us |
| Sulfur dioxide | A pungent-smelling gas that can rapidly promote respiratory irritation and disease | far below standards |
| Deposited ash | Particles too large to enter lungs. Deposition on surfaces can be a nuisance and transport toxins such as PAHs into soil, water and buildings. | no deposition rates have been published |

Sulfur dioxide is only relevant from the perspective that the very low measured concentrations demonstrate that although it is a principal pollutant from coal combustion in a power station, it was not a significant component of smoke from the coal mine fire. Water sprayed on the fire would have dissolved some of the sulfur dioxide and hence washed it out of the smoke.

Conversely, carbon monoxide is not a principal constituent of power station emissions but it is a major product of incomplete combustion, associated with low combustion temperatures and/or low oxygen availability. The Hazelwood coal mine fire smouldered and therefore produced carbon monoxide concentrations that breached public health standards at the EPA's Morwell South monitoring station and would have been much higher, immediately downwind from the fire.

To dispel a myth that emerged in association with the Black Saturday fires, carbon monoxide is not heavier than ambient air (particularly when it is heated by a fire) and it does not tend to sink to the ground or concentrate in low-lying places.

Like carbon monoxide, the production of $PM_{2\cdot5}$ in smoke is worsened by low combustion temperatures and/or low oxygen availability. The same is true of $PM_{10}$ because the particles that make up $PM_{2\cdot5}$ usually also make up the vast majority of $PM_{10}$ in smoke (noting that particles smaller than $2\cdot5$ µm are also smaller than 10 µm). Measured $PM_{2\cdot5}$ concentrations breached health standards more frequently and by a higher margin than any published measurements of other air pollutants from the Hazelwood coal mine fire.

The smouldering nature of the Hazelwood coal mine fire and the high measured concentrations of carbon monoxide and $PM_{2\cdot5}$ are indicative of incomplete combustion. Therefore, attention should be paid to polycyclic aromatic hydrocarbons (PAHs) as another major product of incomplete combustion, with a very high toxicity and persistence in the environment. We understand that the Victorian EPA has referred two samples of $PM_{10}$ on filter paper to a laboratory for analysis of PAHs but results are not yet finalised, as at 14th May 2014.

The Victorian EPA website provides data about the chemical composition of ash samples from the Hazelwood coal mine fire but it does not indicate the amount of ash that has fallen, nor explain the sampling strategy or its representativeness. Knowing the proportion of a chemical such as a PAH in the ash is of diminished value if we do not know how much ash has been deposited. Even if the proportion of such a chemical in the ash is not high, the ash fallout from the Hazelwood coal mine fire might conceivably have been so high in places that hazardous amounts may have accumulated in soil or homes. This would be of particular concern in the case of chemicals like PAHs that decay slowly and accumulate in our bodies or the food chain.

The air pollutants that the EPA website lists as having been monitored include many for which no data are provided (as at 13th May 2014), including dioxins, furans, formaldehyde, soluble ions, arsenic, selenium and other toxic metals. Of these, dioxins and furans seem to deserve particular attention but we can make no further comment without more data and time.

## 2.4 Health Effects

Short-term pulses in concentration are unimportant for some pollutants whose health impact is related to the dose accumulated over decades, as in the case of many carcinogens. Conversely, some pollutants (like bad odours) can have practically instant effects when the concentration is high enough, and no effect at all as soon as the concentration falls below a threshold level. Some pollutants can cause one type of effect from short-term pulses and other effects from longer term exposure, e.g. sulfur dioxide.

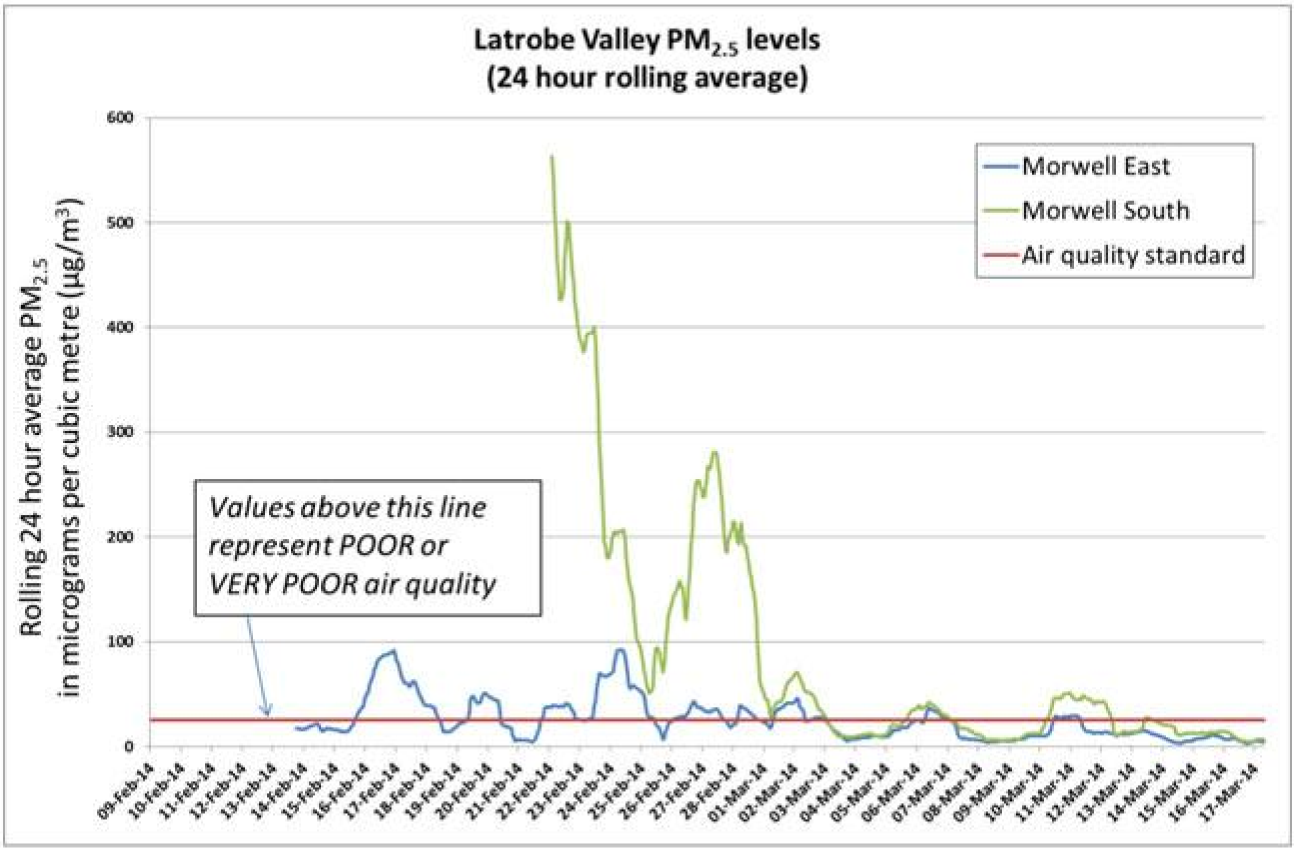
The response time(s) over which a particular pollutant acts are usually taken into account in the health standards that are specified for them. For example, the response of the human body to carbon monoxide is believed to be affected by concentrations experienced in the preceding eight hours (typically), so the measured concentrations and health standard reported for carbon monoxide on the Victorian EPA's website are for rolling averages over eight hours. Once concentrations of carbon monoxide fall safely below the health standard, the impacts are expected to soon abate without lasting consequences.

Therefore, while carbon monoxide concentrations at Morwell South exceeded the public health standard of 9 ppm as an eight-hour average on several occasions during the Hazelwood coal mine fire, modest precautions should have allowed the public to avoid significant effects, and no ongoing effects would be expected (except perhaps as a small increment to the more serious risk of $PM_{2\cdot5}$). The highest measured concentrations of carbon monoxide did not approach any occupational standard for regular daily exposure of healthy workers, such as the Safe Work Australia standard of 30 ppm as an eight-hour average.

$PM_{2\cdot5}$ is of greater concern. It can cause effects from exposure at various durations, with impacts that vary in nature, severity and duration. At high enough levels, $PM_{2\cdot5}$ can prompt an instant, brief reaction, as in the case of someone coughing when barbecue smoke suddenly blows in their face. Over a longer exposure, epidemiological studies have shown strong associations between 24-hour average $PM_{2\cdot5}$ concentrations and respiratory, cardio-vascular and cerebro-vascular incidents of various durations and severity, including death (World Health Organisation 2013). These associations are why the Victorian EPA website reports $PM_{2\cdot5}$ concentrations as 24-hour rolling averages. Epidemiological and mechanistic studies have drawn links between long-term (e.g. annual) average concentrations of $PM_{2\cdot5}$ and a range of additional health impacts (*ibid.*), justifying air quality standards for annual-average $PM_{2\cdot5}$ that apply in Australia, the United States of America, the European Union and some other countries. The World Health Organisation (WHO) has also set 24-hour and annual standards, stating that *'There is a close, quantitative relationship between exposure to high concentrations of small particulates ($PM_{10}$ and $PM_{2\cdot5}$) and increased mortality or morbidity, both daily and over time'* (WHO 2014).

The published $PM_{2\cdot5}$ measurements from Morwell South during the Hazelwood coal mine fire represent major breaches of the Australian and international public health standards for both 24-hour average exposure and the annual average. As seen from the red line in Figure 1, the WHO's 24-hour average guideline of 25 µg/m³ (the same as the Australian national 'reporting standard') was exceeded continuously from the time monitoring commenced (c. 22nd February 2014) until 3rd March 2014 (over three weeks after the fire started). This level was subsequently exceeded for a total of approximately four more days. The initial reading was approximately twenty-three times the national standard. By the time the Morwell South monitoring station commenced operating, the worst period of $PM_{2\cdot5}$ concentrations had probably already passed, as it had in Morwell East (Figure 1) and as can be observed in the $PM_{10}$ data from Traralgon (EPA website).

**Figure 1. $PM_{2.5}$ levels at Morwell South and Morwell East, from the EPA website.**




Based on these considerations and the Morwell South data in Figure 1, a reasonable estimate of the average $PM_{2.5}$ concentration at Morwell South over the four weeks beginning 9th February 2014 is 300µg/m³. Even if we were to ignore $PM_{2.5}$ for the entire remainder of the year, the corresponding annual average concentration would be 300 µg/m³ × 28 / 365 = 23 µg/m³. This is approximately three times the national 'reporting standard' for annual average $PM_{2.5}$ concentrations, which is 8 µg/m³, and 2½ times the equivalent WHO guideline of 10 µg/m³.

There is clearly a basis for concern about both the short-term and long-term health effects of Morwell South's $PM_{2.5}$ concentrations from the Hazelwood coal mine fire. We will therefore now consider the implications in detail.

## 2.5 Inferences from Epidemiological Studies

Interpretation of the consequences of high $PM_{2.5}$ concentrations, such as those experienced in the Hazelwood coal mine fire, is surprisingly complex and often misunderstood. The relevant epidemiological studies have generally been done in cities where concentrations of airborne particles fluctuate from day to day and month to month, but without any sudden, massive increase of the kind experienced around Morwell during the Hazelwood coal mine fire.

As summarised by the WHO (2013), many studies have found that upward fluctuations in 24-hour average particle concentrations have a strong association with increased deaths and medical presentations, either immediately or soon thereafter. This association has been found across many cities and countries, though the magnitude of the association varies. The studies have statistically separated the impact of $PM_{2.5}$ from the independent influences of weather, other pollutants etc. The association has been observed down to concentrations below the current WHO standards for $PM_{2 \cdot 5}$.

The most famous and well-documented episodes of particle pollution in history include:

- The London 'Great Smog' of 1952, with an estimated 12,000 excess deaths (Bell *et al.* 2004); and
- 1966 in New York City, with 80 estimated excess deaths.

The magnitude of the association between 24-hour average particle concentrations and adverse health outcomes varies among epidemiological studies and it is possible that none of the studies are highly representative of the exposure of the Morwell community to the coal mine smoke. Any estimate of the number of illnesses and deaths caused by the smoke must therefore be imprecise. With that caveat, it is still important to seek such an estimate.

The WHO (2013) states, *'Several new multicity studies have confirmed the previously reported small increases (0.4–1% per 10 μg/m³) in daily mortality associated with $PM_{2 \cdot 5}$ (and $PM_{10}$)'*. If the lower limit of this range were to apply when the $PM_{2 \cdot 5}$ concentration at Morwell South was 300 µg/m³ (c.f. Figure 1), the number of deaths would have risen by $0 \cdot 4\% \times (300/10) = 12\%$ due to $PM_{2 \cdot 5}$ alone. If the higher limit of the quoted range were to have applied, deaths would have risen by 30%. The true figure may be outside this range but is unlikely to be so much less as to be insignificant. Higher figures would apply when the $PM_{2 \cdot 5}$ concentrations were higher (Figure 1).

Other approaches could be taken to estimate the number of excess deaths from the Hazelwood coal mine fire and we would welcome them being aired.

At present, it appears that the likelihood of increased deaths as a result of $PM_{2 \cdot 5}$ from the Hazelwood coal mine fire is too large to dismiss, even allowing for the inevitable uncertainties.

Similar estimates can be made for non-fatal health outcomes ('morbidity'), and for the impacts of the measured $PM_{2 \cdot 5}$ concentrations when averaged over a year. They could perhaps also be made for PAHs, dioxins or furans if enough monitoring data becomes available to be representative of exposure during the fire.

Though subject to uncertainties, such calculations raise concerns that deserve further investigation and analysis. The time available for preparing this submission does not allow us to do this topic justice. The proposed study of long-term health impacts from the Hazelwood coal mine fire will presumably help but in the short term, existing information such as medical presentation data are also worth investigating.

We would like to comment on the controversy that arose in the news media during the Hazelwood coal mine fire about whether 'long-term effects' were to be expected from the fire, and particularly from $PM_{2 \cdot 5}$.

The excess deaths and illness associated with high smoke concentrations principally affect people with pre-existing risk factors, such as infants, elderly people and sufferers of cardio-vascular disease or chronic obstructive pulmonary disease. Some of the people who die because of an episode of high particle pollution might otherwise die soon after in any case; i.e. the pollution brings forward a death that would have occurred soon anyway. This is known in epidemiology by the rather gruesome term, 'harvesting'. However, research suggests that most deaths from urban particle pollution are brought forward by months or years, not just days (Schwarz 2001).

It may be that someone who died as a result of smoke from the Hazelwood coal mine fire (if there was any such person) may have died within a few months anyway. In that case, it may be true (if heartless) to say that there was no long-term effect. However, it is more likely that the hypothetical person succumbed because the $PM_{2.5}$ concentration was so far above normal, and the person would otherwise have gone on to live much longer. It would be reasonable to deem such a death a long-term health impact.

## 3. Conclusion

Our focus in this submission has been to assist the Board of Inquiry with independent, easily digested information and interpretation of technical issues that must be understood to meet the Terms of Reference. If more time were available, we would also have liked to include discussion of matters such as:

- The benefits and limitations of protective measures such as face masks, ionisers and staying indoors;
- The issues surrounding evacuation; and
- Communication of health information to the affected community.

We hope and expect that the inquiry will investigate these matters.

More time would have also allowed us to make more suggestions about what can be done to improve responses to future incidents of similar nature, including smoke from protracted bushfires like those commencing on Black Saturday.

One recommendation that does emerge from this submission is that for future major smoke incidents, it would be beneficial to have low cost, highly mobile, indicative monitors on standby. If that were the case at the start of the Hazelwood coal mine fire, useful monitoring could have commenced earlier than it did and with better spatial coverage. In future incidents, it could also help to determine early on whether more elaborate monitoring equipment should be established, and if so, how urgently and at what location(s).

## References

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