Chemical Composition and Source Contribution Analyses of Fine and Coarse Airborne Particulate Matter in the Australian Capital Territory Summary

Background

Whilst Canberra generally experiences very good air quality, periods of elevated levels of particulate matter (PM) pollution do occur and continue to be an issue of concern in the community, particularly in the Tuggeranong Valley. Particulate pollution consists of microscopic solids or liquids that when inhaled are small enough to enter deep into the lungs. Elevated levels of PM has been linked to adverse health effects such as decreased lung function and aggravated asthma, as well as increased risk of cardiac problems.

In the ACT, air quality is monitored by the Health Protection Service (HPS). A review of air quality data from the Tuggeranong valley in 2009 recommended the HPS initiate a study to analyse the elemental composition of PM and identify the sources contributing to PM pollution.

In 2014 the HPS commenced a pilot study to determine the elemental composition and sources of PM in the Tuggeranong valley. Two size fractions of PM were included in the study – PM_{10} (particles with a diameter less than 10 micrometers) and $PM_{2.5}$ (particles with a diameter less than 2.5 micrometers). Both PM_{10} and $PM_{2.5}$ are known to impact negatively on human health. Whilst PM_{10} levels have decreased in the last 10-15 years, $PM_{2.5}$ can still exceed National Environment Protection Measure (NEPM) standard for $PM_{2.5}$ and remains an air quality issue for the ACT.

By determining the elemental composition of PM, it is hoped to gain a better understanding of the sources of PM and how much they contribute to PM in the Tuggeranong valley, and more broadly for the ACT.

Method

The HPS collected PM_{10} and $PM_{2.5}$ samples onto filters using gravimetric particulate samplers at the Monash air monitoring station. The filters were sampled for 24 hours (midnight to midnight) and were weighed before and after sampling to determine the PM concentration for the sampling period.

The filters were then sent to the Australian Nuclear Science and Technology Organisation (ANSTO) for Ion Beam Analysis (IBA). IBA is a detection method able to identify and quantify the chemical elements that make up the PM on the filter.

Being a pilot study, an initial sample set of 25 PM_{10} and 25 $PM_{2.5}$ filters was to be analysed, with an even spread of samples covering all seasons. However technical problems with the PM_{10} sampling instrument resulted in low numbers of PM_{10}

samples being collected with some seasons not adequately represented. Focus then shifted to analysing more $PM_{2.5}$ filters. The final sample set analysed was 12 PM_{10} and 37 $PM_{2.5}$ filters. The $PM_{2.5}$ filters covered both the warmer and colder months.

The elemental concentrations from ANSTO have been analysed using the following methods:

- Spearman's correlation coefficient, to determine which elements are linked together and are thus likely being from the same source.
- The IMPROVE (Interagency Monitoring of Protected Visual Environments) program, which allows a rough apportionment of elements to sources, based on the chemistry of possible sources.
- The PMF (Positive Matrix Factorisation) method which is an advanced computational/statistical tool. An initial assumption of source factors is refined based on statistical correlations (e.g. the frequency of which elements are found together over the analysed time span) until the solution closely matches the observed data.

Results

After analysis of the data from HPS and ANSTO, the most important findings and results of this study were determined:

- In general, the average particulate matter and aerosol pollution levels in the monitored airshed (Tuggeranong valley) were **satisfactorily below** the respective 24-hour ambient air quality NEPM standards of 50.0$\mu g/m^3$ for PM_{10} and 25.0$\mu g/m^3$ for $PM_{2.5}$.
- **$PM_{2.5}$** levels, which usually have more impact on human health, were significantly **elevated during the winter** months (May – August); Exceedances of the 24-hour NEPM standard for $PM_{2.5}$ are more likely to occur (and have occurred) during the colder months.
- The sources of $PM_{2.5}$ in the Tuggeranong valley were strongly associated with:
  - **Biomass burning (or wood smoke)** – particles coming from bush fires, control burns or from burning of wood for home heating.
  - **Soil/dust** – particles resulting mainly from wind erosion.
  - **Sea salt** – particles of sodium chloride and other salts relating to sea water. Formed over oceans and can be blown hundreds of kilometres inland.

    - **Secondary sulfate** – also known as **smog** or **secondary PM**; formed as part of photochemical reactions in the atmosphere involving hydrocarbons and sulfur and nitrogen ions.
    - **Traffic & industry** – particles coming from the abrasion of tyres, motor vehicle or industrial emissions.

- For $PM_{2.5}$ distinct **seasonal fluctuations** were observed for both **biomass combustion** (i.e. wood smoke) and **soil/dust**. During winter 30–40% of the $PM_{2.5}$ can be attributed to wood smoke and less than 5–10% to windblown soil. In summer this ratio is inverted (up to 20% from soil and less than 10% from wood smoke – if no exceptional bushfire events occur).
- The higher contribution of wood smoke in colder months is indicative of increased usage of wood heaters for home heating contributing to the PM levels.
- Both **sea salt** and **secondary sulfate** (smog) contribute to the $PM_{2.5}$ levels and are also subject to seasonal fluctuations. Higher levels for both were found during warmer months due to atmospheric transport and chemistry effects.
- **Traffic and industrial particles** are present all year round and on average make up approximately 56% of the $PM_{2.5}$ in the atmosphere.
- For **PM_{10}** the average levels of windblown crustal **soil/dust** is about 4–5 times greater than in $PM_{2.5}$.
- Wood smoke is mainly found in the atmosphere as $PM_{2.5}$ rather than PM_{10}. In **$PM_{2.5}$** the average amount of **wood smoke** related elements was found to be about three times as high as in PM_{10}.

Graphical representations of the source contribution results for $PM_{2.5}$ are shown in Figure 1 and 2. Figure 1 shows the contribution of sources over different months, indicating the seasonal variation in the sources. Figure 2 shows the total average source factor contributions over all analysed samples.

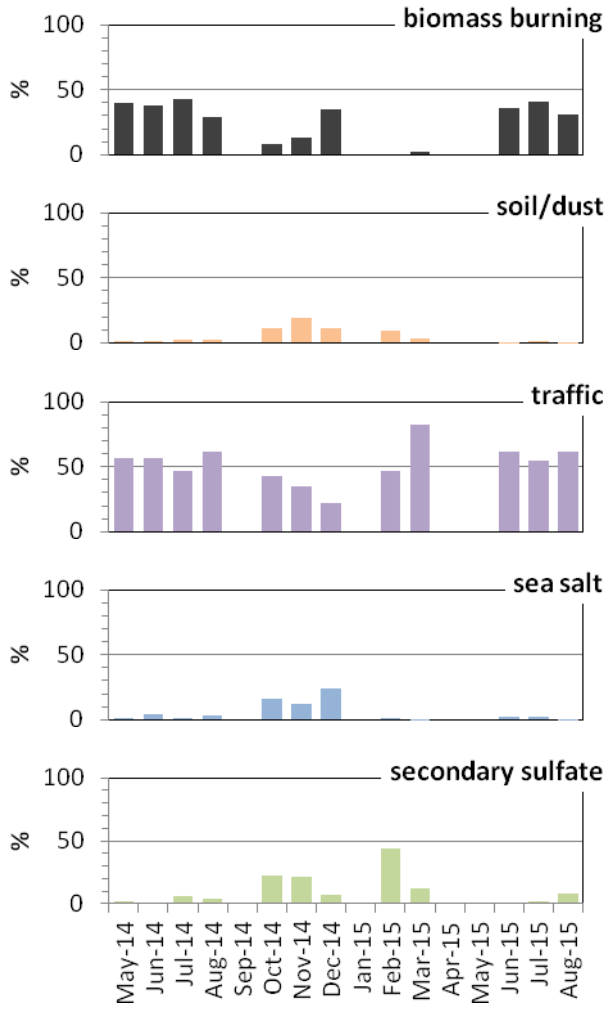

Figure 1 – Percentage of source factor contributions to the $PM_{2.5}$ levels

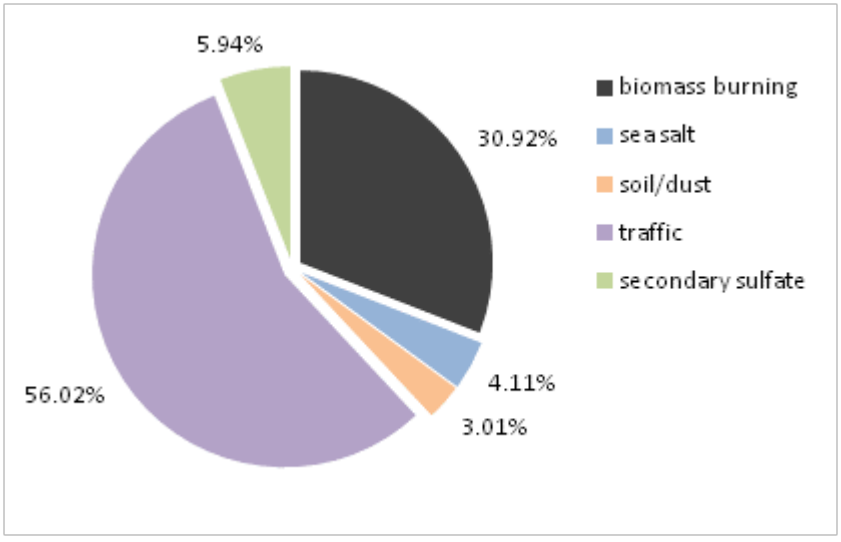

Figure 2 – Total average source factor contributions to $PM_{2.5}$ over all analysed samples

It should be noted that the number of samples analysed is very low for this type of study and the results should be treated as indicative only. However even with the low sample numbers the findings are consistent with what would be expected for PM sources in Canberra and demonstrate that the method is viable for investigating source contribution and seasonal variation of PM. A larger sample set is required to gain a more statistically robust sample set, which in turn will provide more accurate results and conclusions.

Conclusion

This pilot study has shown that the elemental analysis of airborne particulate matter and the accompanying source contribution analysis can provide valuable information on the contribution of individual sources to particulate pollution found in the ACT. This can be used to provide evidence in informing and evaluating, for example, the impact of health and environmental policies to reduce particulate pollution over time, as well as provide information to the public.