Environment Protection Authority

SmokeWatch Mount Gambier 2010 campaign report

EPA
South Australia

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Abbreviations

(The) Act	Environment Protection Act 1993
APVMA	Australian Pesticides and Veterinary Medicines Authority
EAD	equivalent aerodynamic diameter
EMS	environmental management system
EPA	South Australian Environment Protection Authority
Air NEPM	National Environment Protection Measure (Air Quality) 2003
TEOM	tapered element oscillating microbalance
TSI	Thompson scientific instrument

Summary

The SmokeWatch program in Mount Gambier is a collaborative partnership between the Environment Protection Authority (EPA), Department of Health, City of Mount Gambier, Firewood Association of Australia (FAA) and Australian Home Heating Association (AHHA). Since its launch in 2009, SmokeWatch has also gained the support of several local schools, businesses and community organisations.

SmokeWatch Mount Gambier 2010 is the second phase of a three-year program that integrates community education, health and air science campaigns based on monitoring and community surveys to address and investigate about wood smoke pollution in Mount Gambier.

Partner organisations acknowledge the strong positive responses from newspapers, radio and television stations in Mount Gambier, which have given great support in broadcasting the important messages of the program.

Community surveys were used to elicit perceptions and attitudes towards wood smoke, its possible health effects, strategies to reduce exposure and actions that people might take. Groups susceptible to wood smoke exposure, including children, older people, and people with existing illnesses were identified as a focus for the survey in 2010. Stakeholders and the general public were also engaged.

To assist with the survey of children as a susceptible group, a survey was conducted by EPA and Department of Health in collaboration with Flinders University to explore the perception and attitudes of wood smoke exposure on the health and well-being of children in the city. The results of this survey show a polarisation of views between those who operate solid fuel fires and those who do not. Although a significant proportion of respondents believe there are health issues associated with wood smoke, there is a low level of willingness to take action to ameliorate the problem.

Although feedback from older people, people with existing illnesses, stakeholders and the general public was not statistically significant due to low sample size, there are some trends among groups. Clean and healthy air was identified as important by a majority of respondents. Nearly half of respondents used a wood heater at home. Few felt that they were negatively impacted by wood smoke, or were unaware of the presence of a wood smoke pollution issue in Mount Gambier. Stakeholders were willing to support the SmokeWatch program through promotion of key messages especially where there is common benefit between the program and stakeholders.

Increased monitoring at the Gordon Education Centre and Mount Gambier Showgrounds in 2010 confirmed previous results and provided additional information on sources and particle makeup. It highlighted poor winter air quality in Mount Gambier, pointing to the major contributions of wood smoke to high concentrations of fine $PM_{2.5}$ particles, particularly during cold, still weather conditions overnight. A large proportion (see Appendix 1) of fine particles emanates from areas of the city that are residential. Additionally it indicated that the fine particles were mostly PM_1, characteristic of smoke from fuel combustion.

The 2010 monitoring program also recorded episodes of coarser particles from sources at both ends of Mount Gambier. Possibly industry, development and agricultural activities in the region contribute to the high levels of PM_{10} particles. It showed clear differences between the daily patterns of coarse and fine particles. Further monitoring during the warmer months of the year may be needed to fully define the sources of coarse particles in Mount Gambier.

Particle concentrations are adjusted in accordance with *National Environment Protection (Ambient Air Quality) Measure 1998* (Technical Paper no. 10). The adjusted data summarised in Appendix 1 showed a large number of exceedences of the NEPM standards. The data also showed an increase in PM_{10} particles over the 2009 monitoring.

Overall, winter patterns of fine particle pollution are entirely consistent with the dominance of wood smoke on cold winter nights.

The monitoring results strengthen the previous conclusions that wood smoke is a major winter pollutant in Mount Gambier, with the clear message that programs to reduce smoke will achieve the most effective improvements in air quality. This provides the partners in SmokeWatch Mount Gambier with a strong focus for the final year of the program.

The results also show the presence of coarser particles, for which the next level of improvement program should be considered.

1 Introduction

SmokeWatch Mount Gambier commenced in March 2009 in response to sporadic evidence becoming available over a long period, pointing to the influence of wood smoke on air quality in the city. In earlier years, progressive improvements in industrial emissions from wood fueled plants in the city were achieved through the efforts of the EPA and its predecessors. As that has happened, it became apparent that other activities, particularly domestic wood burning, may be significant contributors to fine particle levels.

SmokeWatch Mount Gambier is a collaborative partnership between the Environment Protection Authority (EPA), City of Mount Gambier, Australian Home Heating Association and Firewood Association of Australia. In 2010 the Department of Health also came on board as a formal partner, reinforcing the important messages regarding the potential effects of wood smoke on human health. SmokeWatch also has the support of several local schools, businesses and community organisations in assisting to promote key wood heater efficiency messages of the program.

SmokeWatch programs have been operated by the EPA for many years to develop and implement regional strategies to reduce wood smoke pollution caused by the inefficient use of domestic wood heaters. The program is about engaging the community and other relevant stakeholders to build awareness and understanding of local air quality, and promote broad ownership of wood smoke pollution.

The three-year Smoke Watch Mount Gambier program is the first major SmokeWatch program to combine traditional education and awareness activities with air and health science. While an important component was to understand air pollution and its sources in the city, the primary focus was to provide and reinforce a positive message: that everyone in the community can participate in improving air quality by operating their wood heaters more efficiently.

The first year, SmokeWatch Mount Gambier 2009 focused on alerting the community of the program, the issue of wood smoke and its potential health effects. Ambient air quality monitoring was initiated at a local school, Gordon Education Centre, in early June 2009. It included instruments to measure PM_{10} particles directly and to estimate levels of $PM_{2.5}$. Weekly graphical summaries of daily PM_{10} concentrations were published in *The Border Watch* to provide the community with up-to-date information. *SmokeWatch Mount Gambier 2009 Winter Campaign Report* (2010) is available on the EPA website.

Acquisition of additional instrumentation by the EPA allowed air quality monitoring to be strengthened during SmokeWatch 2010, with equipment to measure $PM_{2.5}$ directly and a further station to assist understanding of patterns of particle pollution around the city. Weekly summaries were again published in The Border Watch, but this time included both PM_{10} and $PM_{2.5}$, and the graphs were redesigned to present information in terms of air quality descriptions rather than scientific units. The aim was to provide Mount Gambier residents with current information to assess the impacts of wood smoke in the area, and provide feedback on the effectiveness of their collective actions in improving air quality over the life of the SmokeWatch program. The graphs have also been posted on the EPA website.

SmokeWatch Mount Gambier 2010 included a community survey undertaken in concert with department of Health aimed at evaluating wood smoke impacts on vulnerable people and to gauge attitudes to wood heaters. The results will assist in targeting future education and awareness programs.

The messages of the SmokeWatch program are clear: householders can reduce wood smoke from their wood heaters by observing how their wood heaters operate and by taking some simple actions to ensure a good, bright and hot fire. Not only will this improve air quality, but it will also reduce wasted fuel.

This report details results of SmokeWatch Mount Gambier 2010, which commenced in April with the implementation of a community engagement strategy, providing the local community with an opportunity to actively participate in SmokeWatch and voice their aspirations, ideas and concerns about local air quality. Air monitoring also began in the same period to provide residents with current information to assess the impacts of wood smoke in the area.

2 Objectives

The key objectives of SmokeWatch Mount Gambier are to:

- raise community awareness of the environmental and health effects of inefficient wood heating
- build community understanding of the importance of following efficient wood heating practices to reduce unnecessary pollution, maximise home comfort, promote energy efficiency and reduce the health effects of wood smoke pollution
- advise wood heater users of the correct practices for efficient wood heater use
- develop and implement creative solutions to enable wood heater users to easily and conveniently follow the key practices to efficient wood heater use
- engage schools, businesses, organisations and key community groups in promoting clean air messages
- raise awareness amongst the community of the role of the EPA and the City of Mount Gambier in managing wood smoke pollution
- define the magnitude and sources of the wood smoke pollution
- measure the effectiveness of actions to reduce wood smoke through air quality monitoring.

3 Activities in 2010

SmokeWatch Mount Gambier 2010 commenced with a range of community engagement activities providing residents with an opportunity to provide their views and ideas on local air quality and wood heater use. These included:

- two 'open house' displays held at the Mount Gambier Rotary Markets to raise awareness of the program and gain feedback about community values, concerns and ideas for improving local air quality
- public conversations with local firewood suppliers, wood heater retailers, chimney sweeps and the local Metropolitan Fire Service to raise awareness about the program, identify any issues of relevance to these stakeholders and discuss potential involvement in the program
- survey with groups susceptible to wood smoke to explore potential health effects of wood smoke and subsequent actions.

Other activities undertaken in 2010 included:

- approaching stakeholders to become (or continue to be) supporters of SmokeWatch and assist in the promotion of key messages
- continued dissemination of a range of communication materials to wood heater users (including website information) display at the markets and library, and through program supporters
- undertaking enhanced monitoring from May to September 2010
- publication of a re-designed weekly graphical summaries of air monitoring data in The Border Watch, with daily results also available on the EPA website
- the loan of monitoring equipment to a local high school to undertake their own monitoring and raise awareness.

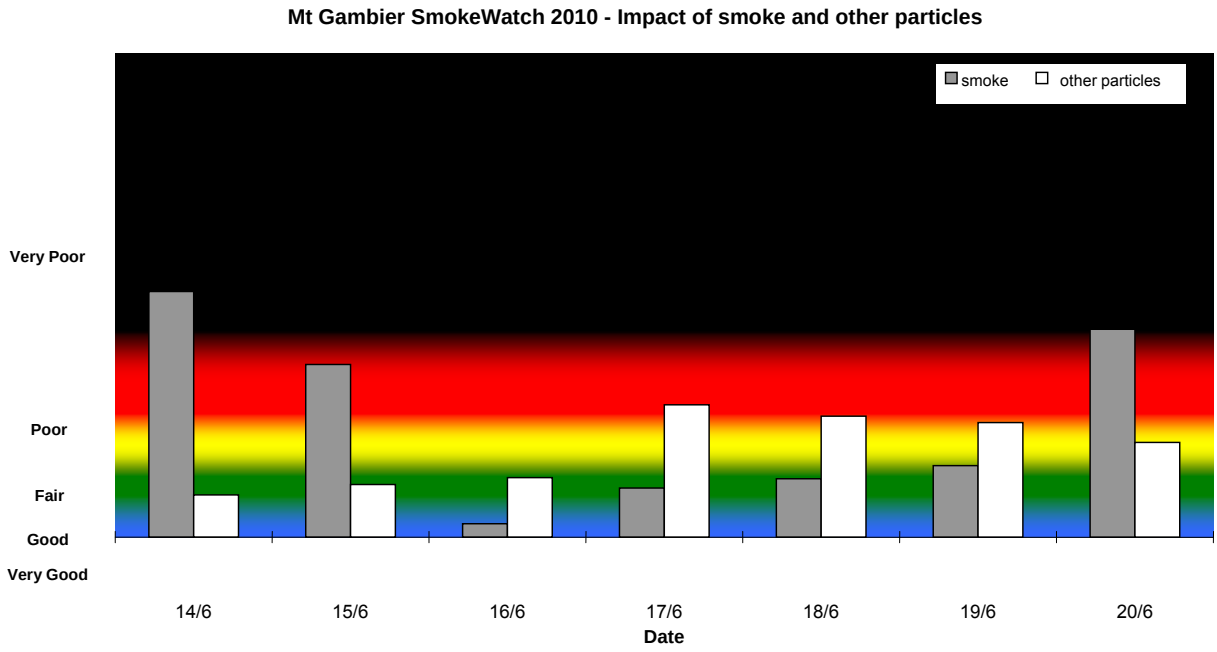

Figure 1 An example of the weekly air quality summary published in *The Border Watch*

4 Outcome of residents survey

Children, older people, and people with existing illnesses were identified as groups susceptible to wood smoke. These groups were surveyed to explore perceptions and attitudes of wood smoke exposure, the potential health effects of wood smoke and subsequent actions.

To assist with the survey of children as a susceptible group, in 2010 the SmokeWatch program obtained the services of a Flinders University Environmental Health student, Claudia Galicki, to undertake a survey in Mount Gambier to explore the perception and attitudes of wood smoke exposure on the health and well-being of children in the city. The perception of the respondents' opinion of the city's air quality was also explored. A total of 114 parents of primary school children in Mount Gambier participated completing a 24-item survey. The respondents appeared to be polarised:

- Groups of respondents with asthmatic children and respondents who do not use wood heaters believe that there are health issues and air quality could be improved.
- Respondents who use wood heaters tend not to support the view that there were significant health and air quality issues.

Summary

- Graphs for this summary were reproduced from *Perception & attitudes of wood smoke exposure on the health and well-being of children in the City of Mount Gambier* (Galicki 2010). About 35% of respondents used wood as a primary form of heating

  The analysis revealed that, in general, respondents who have a child with asthma or do not use a solid fuel fire had more negative attitudes towards wood smoke than those who do use one, perceiving there to be greater health risks associated with wood smoke.

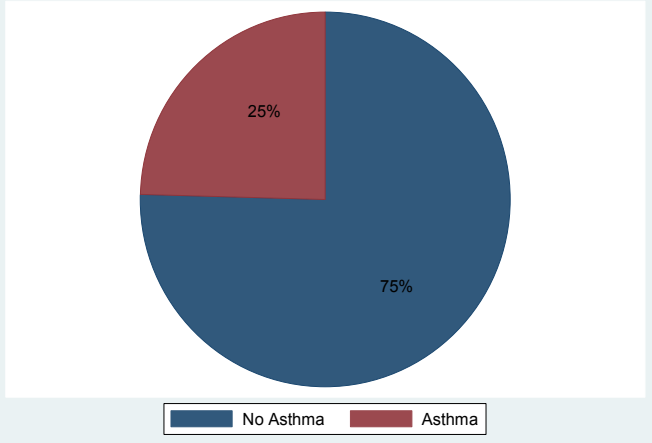

Figure 2 Percentage of respondents who have a child diagnosed with asthma

- The majority of respondents perceived Mount Gambier's air quality to be good and did not believe wood smoke was a problem in the city.

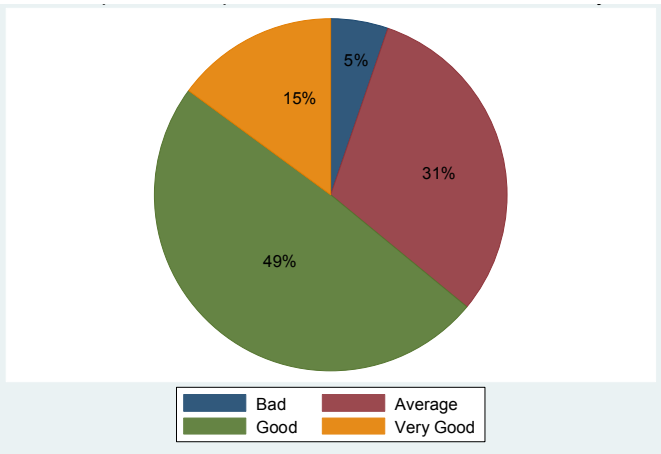

Figure 3 Respondents' opinion of Mount Gambier's air quality

- It appears that those with wood heaters may lack the knowledge about the adverse health effects of wood smoke, and further education may be necessary to ensure the risk of exposure is minimised to the most susceptible individuals in the community.
- Only 6% of respondents felt the need to take steps as a result of believing their child's health being affected by wood smoke. However it may be that those with asthmatic children had taken action by default in not using wood heaters.

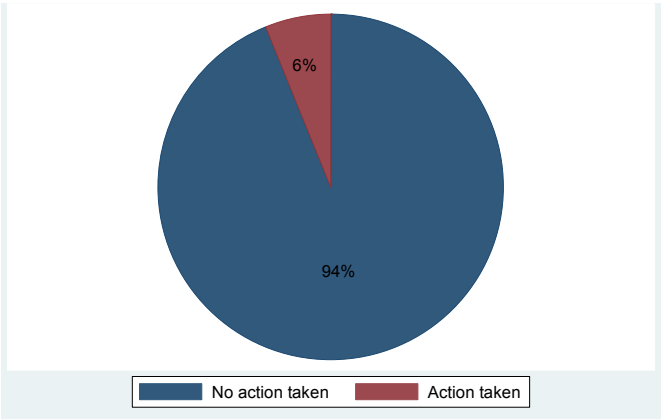

Figure 4 Percentage of respondents who had action taken to reduce exposure to wood smoke if child's health was affected

- In general the majority of respondents felt that they could play a role in improving air quality, with 11% stating that they would do whatever it takes and 16% would be prepared to campaign to help improve local air quality.

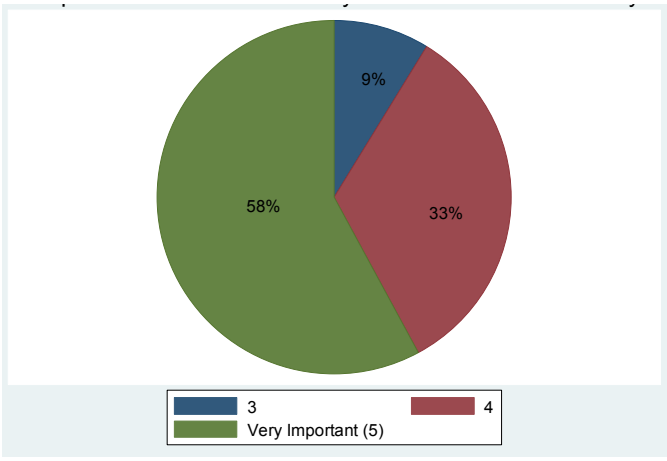

Figure 5 Importance of clean and healthy air

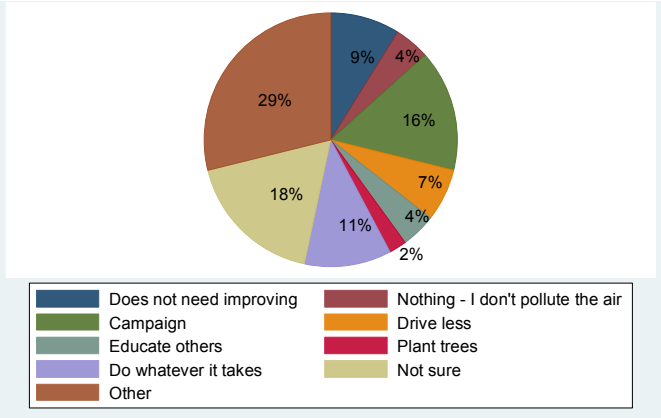

Figure 6 Actions respondents were prepared to undertake for improving air quality

- The majority of respondents are also not aware that the EPA monitors and reports particulate matter concentrations in ambient air in Mount Gambier during winter and therefore may not realise how it compares to national standards.

The remaining susceptible groups (older people and those with existing illnesses) were surveyed through questionnaires provided at the Regional Health Service. Survey boxes were also placed in public places (including at the local library and at a local wood heater retailer) to provide another opportunity, in addition to the 'open house' displays for the general public to provide input.

A total of 74 responses were returned by the general public. Seven responses were from people with an existing illness and 11 responses from older people were received. Nine key stakeholders provided feedback.

Although feedback from older people, people with existing illnesses, stakeholders with an interest, and the general public is not statistically significant due to low sample size, it does suggest some trends among groups and can be used to inform activities in the next program year.

Clean and healthy air was identified as important by a majority of the general community but less than half of respondents were aware of Mount Gambier's air quality as monitored and reported by the EPA. Very few respondents believed they were negatively impacted by wood smoke during winter. Around half of respondents used a wood heater at home.

Older people and people with existing illnesses were more aware of health impacts associated with wood smoke than the general public and felt the need to take action as a result. Approximately half of the respondents in these two susceptible groups were aware of Mount Gambier's air quality as monitored and reported by the EPA. Wood heater use was lower among older people and people with existing illnesses than in the general public.

Industry was believed to be the largest source of wood smoke pollution in both susceptible groups and the general community. Overall, few respondents believed there was a wood smoke problem in Mount Gambier. Suggested actions to support residents in improving wood heater use included education and the availability of dry wood.

Stakeholders were generally willing to support the SmokeWatch program through promotion of key messages especially where there is common benefit between the program and stakeholders.

5 Air monitoring

A summary of air quality in Mount Gambier (May to September 2010)

Additional monitoring was conducted for SmokeWatch Mount Gambier 2010 to assist with further characterising and quantifying the size range of particles, their patterns of emission and possible sources. Several types of particle measuring instruments and techniques were used in concert with weather instruments, and a second station was established to provide more comprehensive information about particle pollution.

This section provides a brief summary of the findings of the air science component of the program. Conclusions are consistent with previous monitoring. More detailed information on particles and their measurement during this campaign can be found in Appendix 1and includes some comparisons with results from SmokeWatch Mount Gambier 2009.

During the campaign period:

- Particle size, source and patterns indicated that a significant portion of fine particles smaller than $PM_{2.5}$ (PM_1) was derived from residential wood smoke but there are also other contributors.
- Significant amounts of fine particles ($PM_{2.5}$) came from the direction of residential areas of Mount Gambier and nearly all of those particles (greater than 94% of numbers of particles) were shown to be smoke (PM_1), with maximum concentrations at night, especially under cool still weather conditions.
- Coarse particles (PM_{coarse}) showed different characteristics and patterns from those of fine particles, indicating that they generally arose from different sources (see Appendix 1). The concentrations were more evenly dispersed throughout the day and are likely to come from other activities from mixed industrial, agriculture, residential areas of the city.
- There were a significant number of exceedences of national air quality standards for particles. Average values for PM_{10} were shown to be higher in 2010 than for the same period in 2009.

It is noted that while comparisons between results from the two years of the program so far provide useful information, characterisation of any trends in air quality is not possible over such a short period. Any long-term impacts of particle reduction programs would start to become apparent only over period of five to 10 years.

6 Future actions

The EPA has committed to a third and final season of SmokeWatch Mount Gambier in 2011.

To complete the understanding of sources, information on industrial and agricultural processes such as burning of waste material and its impact on air quality need to be collated and clarified. It is intended that SmokeWatch Mount Gambier 2011 will commence earlier in autumn with a view to capture any planned burning activities that may impact on the city.

The results of the community survey indicate that there are still areas of community awareness that need improvement. These results will be taken into account in designing the engagement program for 2011, so that resources can be clearly focused on the relevant issues. If long-term improvements are to be made then programs that can implement change in the performance and use of solid fuel fires as well as other sources of particles would need to be implemented.

It should be noted that programs to develop nationally consistent approaches to wood heaters are continuing as part of Environment Protection and Heritage Council programs. These will influence management of solid fuel domestic heating appliances in various jurisdictions, so may well provide pointers for future actions in Mount Gambier.

7 References

Galicki Claudia 2010, *Perception & attitudes of wood smoke exposure on the health and well-being of children in the City of Mount Gambier*, supervised by Assoc Prof John Edwards (Flinders University), Dr Monika Nitschke (Department of Health), Ms Polly Weckert (Environment Protection Authority), Flinders University, Adelaide.

National Environment Protection Council 2001, *National Environment Protection (Ambient Air Quality) Measure, Technical Paper No. 10, Collecting and Reporting of TEOM PM_{10} Data,* prepared by the Peer Review Committee, May 2001, NEPC, Adelaide.

Appendix 1 Detailed air science for Mount Gambier SmokeWatch 2010

Summary of air monitoring data at Mount Gambier 2009 and 2010

There is a significant issue with PM_{10} and $PM_{2.5}$ particle concentrations in Mount Gambier as shown in the comparison of data against NEPM standards. A major source of $PM_{2.5}$ particles is the residential areas suggesting it is from solid fuel fires. It is concluded that the coarse fraction of PM_{10} appears to have a largely separate source as evidenced by direction of emissions and pattern of concentrations throughout the day differing from those of $PM_{2.5}$. Possible sources are from further afield such as industry and agriculture to the east and west.

The data collected in 2010 supported previous testing and further clarified possible sources.

Comparison against NEPM

The 2010 TEOM mass concentration data showed multiple exceedences of the daily NEPM standards that would not comply with the NEPM PM_{10} goal. This data also showed a large number of exceedences of the daily $PM_{2.5}$ NEPM reporting standard. This indicates a need to work towards reducing particle concentrations of both PM_{10} and $PM_{2.5}$ particles

Comparison between years

Comparison of TEOM PM_{10} data between 2009 and 2010 show that, on average, the particle concentrations were significantly higher in 2010 than in 2009.

Sources of particles

It is considered that major sources of fine particles are solid fuel fires, industry and motor vehicles with a possibility of PM_{coarse} files from nearby agricultural land. A comparison of particle concentrations with wind direction, particle size and time of day indicates that a significant proportion of fine particles come from a sector of the town that is mainly residential. These fine particles are most likely smoke, as the highest levels occur overnight when there is little traffic. Given that those directions include primarily residential areas, solid fuel fires are the most likely source.

The source of PM_{coarse} particles most likely includes industry as indicated by the direction and concentrations throughout the day.

PM_{coarse} particles

Concentrations of coarse particles show different patterns throughout the day from those of the fine particles and they generally come from different directions. This fraction of particles is generally distributed more evenly across the day and slightly higher than at night.

There are higher amounts than the regional average of the PM_{coarse} fraction (Figure 11) from the 130–300° sector. This includes the TEOM PM_{coarse} sector of 180–300° and the 130–180° sector. These sectors contain some industry and as there is no corresponding outstanding $PM_{2.5}$ source in this direction it is possible the particles are from industry or agricultural areas outside the main city area. In addition coarse particle concentrations are more even throughout the day in line with industry operations, whereas fine particles peak at night and vehicle emissions peak in the mornings.

The source of particles from the 130–180° sector appearing in data at the Gordon Education Centre is unclear but could be from further afield such as industry or agriculture at the eastern end of town.

$PM_{2.5}$ particles at Gordon Education Centre and Showground

The data show a predominance of particles from the 10–100° sector at the Gordon Street site with the Showground site showing higher than average concentrations from the 270–90° sector with a majority from the 340–90° sector which is an anticlockwise shift compared to Gordon Street. This indicates a strong contribution from the northern residential area of the town. Using the Gordon Education Centre mass concentration data for $PM_{2.5}$, in 2010 approximately 42% of $PM_{2.5}$ come from the northerly to easterly sector (10–100°), which is only one quarter of the compass.

Most of the fine particles are PM_1 particles collected by TSI automatic particle sizer (APS). These are of a size that can penetrate deeply into the lungs.

Although a large proportion of fine particles come from residential areas, some do emanate from other parts of town that include vehicles and industry.

Hour of day

This analysis reveals a mid-morning peak of fine particles ($PM_{2.5}$) likely from traffic. The maximum levels of fine particles occur overnight decreasing after about 11 pm. This aligns with expected solid fuel fire use. Conversely coarse particles are generally spread more evenly throughout the day, with the noted exception in July 2010 due to one high day of indeterminate source. This further supports that PM_{coarse} particles have a different source than $PM_{2.5}$.

Background

Monitoring

As part of a three-year project to examine and improve air quality in Mount Gambier the EPA monitored over the 2009 winter. In 2010 the monitoring was expanded to improve understanding of the particles in Mount Gambier's air and to better examine the sources of particles.

Monitoring was conducted as follows:

1 Gordon Education Centre, Browne Street, Mount Gambier
   - Two continuous mass concentration monitors (TEOMs) measuring PM_{10} and $PM_{2.5}$ particles.
   - TSI particle sizing device that counts particles of different aerodynamic sizes in the range 0.5 to 20 microns EAD.
   - Nephelometer that measures light scattering, which can be used to estimate $PM_{2.5}$ particle concentrations.

2 Mount Gambier Showgrounds
   - A second nephelometer provides independent information on $PM_{2.5}$ particles at a different location in the city.

3 Green Triangle Forest Products, Mount Gambier
   - Wind speed and direction were measured continuously by the EPA in Mount Gambier with equipment located on company property.

Particles

Particles are of interest for their health effect on the human population. Assessment of initial monitoring in 2001 showed that particles were of potential concern in Mount Gambier. Results from SmokeWatch 2009 confirmed the need to further monitor and characterise particle pollution and its sources.

Particles come from a wide variety of sources. Dusts from soils and minerals are largely inorganic (they contain little or no carbon) and are relatively simple. They generally have low volatility; there are no liquids that can evaporate from them.

In contrast, particles from combustion of fuels such as petrol, diesel or wood are generally very complex mixtures of solids, liquids and dissolved gases, containing high proportions of organic compounds (carbon compounds) from unburnt fuel. They often contain high concentrations of volatile materials such as water and volatile organic compounds (VOCs), some of which are reactive, toxic or carcinogenic.

Particles that are small enough to be breathed in by humans are grouped into two main classes or 'fractions' known as PM_{10} and $PM_{2.5}$[1]. 'PM' means 'particulate material'. The numbers refer to the size[2] of the particles in micrometres, or millionths of a metre, written as 'μm'.

Particles with sizes between PM_{10} and $PM_{2.5}$ are also important for air quality. In Mount Gambier the air may contain a mixture of particle types at any one time. For example, dust from the soil and smoke from wood fires. Smoke is made of very small particles of around 1 μm in size, which fit well within the $PM_{2.5}$ size range. In contrast, soil particles and dusts from other activities such as industry and agriculture are often much larger, with sizes between PM_{10} and $PM_{2.5}$. These particles are called 'PM_{coarse}'[3] and their concentrations are simply the difference between PM_{10} and $PM_{2.5}$ concentrations.

The concentrations of these three groups of particles are generally measured as mass per cubic metre of air, by methods that weigh particles trapped on filters, either manually or automatically. The weights are very small, so the concentrations are measured as micrograms/cubic metre of air, or millionths of a gram per cubic metre, written as '$\mu g/m^3$'.

Concentrations of particles can also be measured as the number of particles per cubic metre. Instruments that do this are known as particle counters[4], and the EPA has been using one of these instruments at Mount Gambier throughout the whole program.

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1 Instruments for measuring particle mass concentrations in air normally have air intakes or sampling heads designed to accept those particles which would enter the human respiratory system —that is, PM_{10}— and reject those that would not. If we want to measure $PM_{2.5}$, then the air is passed through a second device which rejects those that are too large, but allows the $PM_{2.5}$ particles through to the measuring instrument.

2 Particles come in all shapes and sizes, it is important to note whether they can be breathed into our noses and mouths, and beyond that, whether they can enter our lungs. Whether they are long and thin or spherical, or some other shape; it is how they behave in the air we breathe that is most important.

How each particle behaves in the air depends on a combination of its size, shape and density (weight divided by volume). For example, every particle of smoke or dust has a different shape.

Water droplets with diameters of around 10 μm and smaller can enter the nose, throat and lungs when a person breathes in. Larger droplets either do not get in at all, or are trapped in the nose. If a particle of dust also enters the person's body in the same way as a 10 μm water droplet, then we say that the particle has an equivalent size of 10 μm. This is known as the particle's equivalent aerodynamic diameter or EAD. Similarly, if a particle behaves the same way as a 5 μm water droplet, it is said to have an EAD of 5 μm. For simplicity, this report uses particle size to mean EAD.

- Some particles will not enter our noses at all; others may enter our noses or mouths, but will be trapped there. They can be irritating and cause soiling of surfaces, but are otherwise much less a concern than smaller particles.
- Many smaller particles can reach our throats and upper lung passages, and some may penetrate into the deep lungs. These are the groups of particles that are 10 μm and smaller, and are known as PM_{10}.
- Those very tiny particles that may enter our lungs have sizes that are 2.5 μm and smaller. Groups of these particles are called $PM_{2.5}$.

3 An important point to note for this report is that particles measured as PM_{10} may also contain $PM_{2.5}$ particles. Research indicates that both types of particles have effects on health, and PM_{10} is often divided into two groups: the smaller particles as $PM_{2.5}$; and the larger ones are called PM_{coarse} in this report.

4 Particle counters use a beam of light to count particles as they pass through a sampling system. The more sophisticated counters also measure the size of each particle as it passes. The TSI instrument used by EPA counts particles in each of 30 different size ranges, providing what is known as a particle size distribution. For example, wood smoke particles are of fairly uniform size around 0.9 to 1.0 μm. Particle sizes of other types of dust may vary between 10 μm or more, down to 1 or 2 μm. In combination with data from other methods and from weather instruments, this information assists in identifying the

A fourth type of instrument, called a nephelometer measures the haziness of the air; that is, how particles in the air scatter light[5]. During the 2010 winter campaign, EPA operated two of these instruments: one at the main station in Gordon Education Centre and a second at the showgrounds, to determine patterns of particle pollution around the city. This arrangement will be repeated for the 2011 winter campaign.

The measurement process itself can affect the particle concentration. For example temperature can affect the volatility of organic chemicals. This is not so much a problem for inorganic dusts such as soil particles. It becomes significant for organic particles such as smoke, which have a large proportion of volatile organic compounds, and can evaporate from the samples as they collect in an instrument. This is especially so where the instrument is held at a higher temperature than the outside air, such as happens in the TEOM instruments.

To compensate for these losses, robust adjustment factors were developed by the National Environment Protection Council (2001). So when this report refers to adjusted data, it means that EPA has applied these factors to monitoring data.

Such adjustments were made to PM_{10} data, both during the current SmokeWatch Mount Gambier program and in a previous campaign in 2001. This allows comparisons of the two sets of data both with each other and against the national standards. This adjustment was also made when reporting the daily air quality index for Mount Gambier.

The TEOM is a reference method for measuring particles, but other less costly methods can be used in combination with them to provide useful information on patterns of particle pollution, provided a clear relationship between the two types of data can be established. Nephelometers and particles counters are being used in this way for the SmokeWatch Mount Gambier program, providing robust additional evidence of types and sources of particles in a cost-effective way.

In Australia the national environment protection standards for air quality are used to gauge impacts on health effects of particles in air. They are contained within the *National Environment Protection Measure (Ambient Air Quality) 199* or Air NEPM (as amended 2004), and are listed in Table 1.

Table 1 Ambient Air NEPM PM_{10} standard and goal

Pollutant	Averaging period	Maximum concentration	10 years goal: maximum allowable exceedences
Particulate matter, as PM_{10}	1 day	50 $\mu g/m^3$	5 days a year

In addition to these goals, the Air NEPM has advisory reporting standards for particulate matter, as $PM_{2.5}$.

Table 2 Ambient Air NEPM $PM_{2.5}$ reporting standard

Pollutant	Averaging period	Maximum concentration
Particulate matter, as $PM_{2.5}$	1 day	25 $\mu g/m^3$
	1 year	8 $\mu g/m^3$

different types of particles and their likely sources around Mount Gambier and the weather conditions under which they can build up to significant levels.

5 Nephelometers produce data on light scattering called B_{scat}. For certain types of particles B_{scat} readings are proportional to mass concentrations, so nephelometers can be used to provide an indirect estimate of particle concentrations, especially the finer particles in the $PM_{2.5}$ range, including smoke. With two or more of these instruments, EPA can build up an indication of pollutant patterns around Mount Gambier.

Data analysis

Data from the 2010 winter monitoring were utilised to investigate:

- comparison against NEPM standards
- changes from the previous year
- sources of particles.

This required summarising the data in a variety of ways, making adjustments as in the NEPC (2001) Peer Review Committee paper, and examining the different particle sizes along with wind direction.

A graphical summary of the data is presented below along with an explanation of its significance.

Comparison against NEPM standards

Comparison of TEOM PM_{10} and $PM_{2.5}$ at Gordon st Education Centre site with Air NEPM standards.

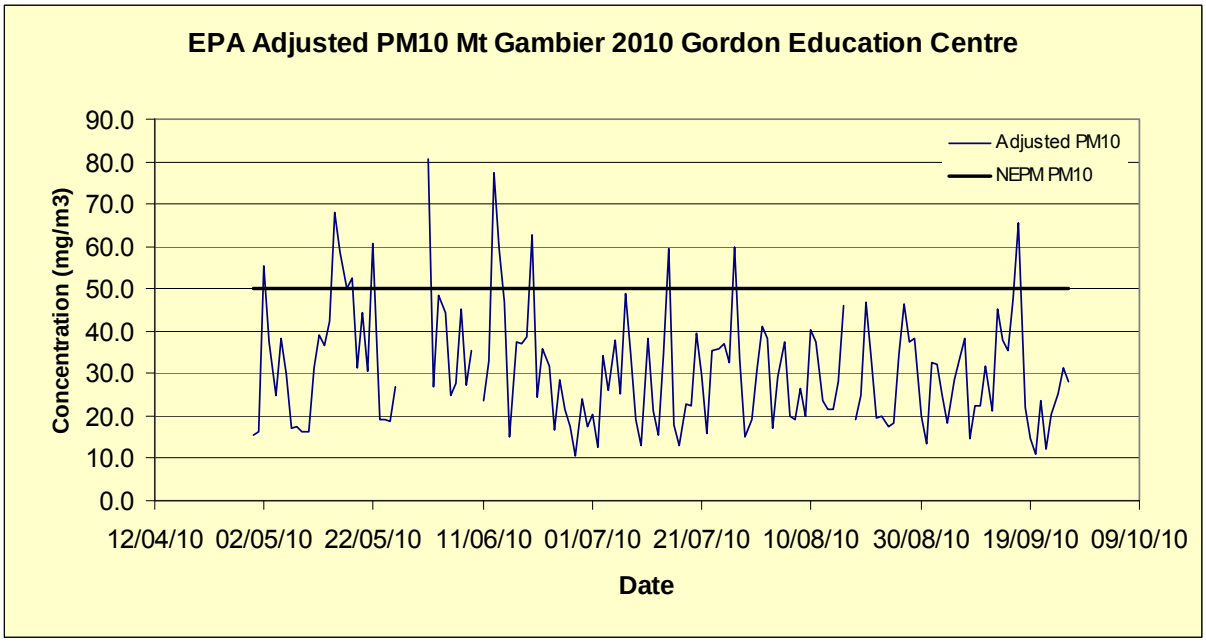

Figure 7 TEOM PM_{10} data NEPM exceedences 2010

For the period the data showed 13 exceedences of the PM_{10} standard, mostly during May to July (Figure 7). This would clearly breach the NEPM goal of five exceedences per year. Option 1 adjustment in Technical Paper 10 Collection and reporting of TEOM PM_{10} Data, Peer Review Committee, NEPC, May 2001 has been used.

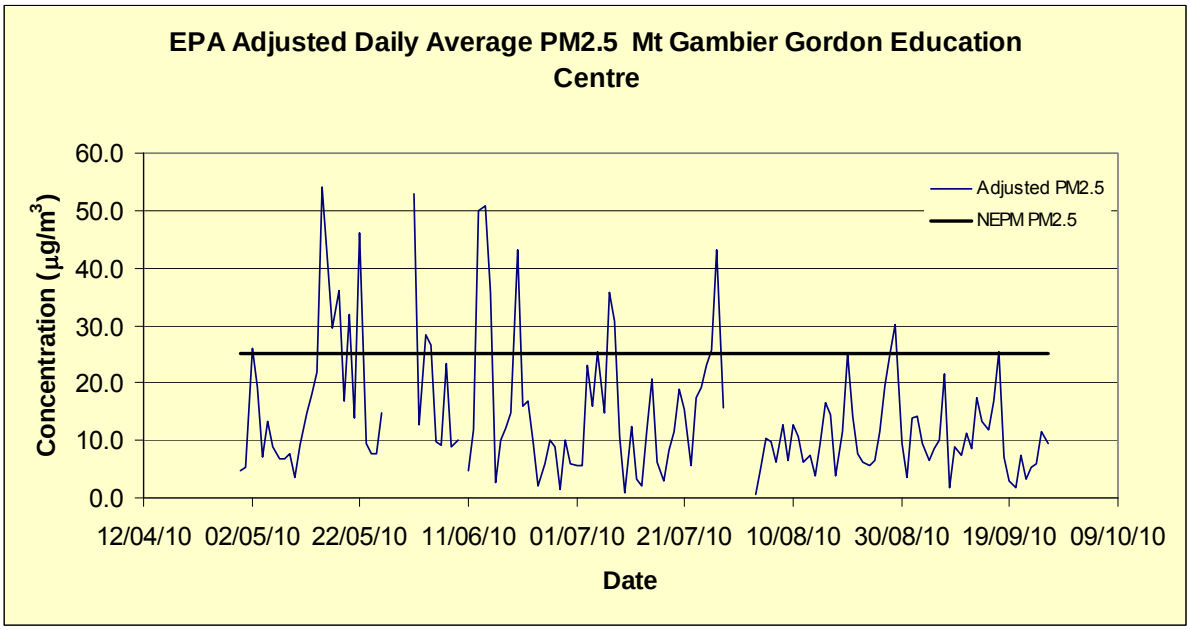

Figure 8 TEOM $PM_{2.5}$ Data NEPM exceedences 2010

The daily reporting standard for $PM_{2.5}$ was also exceeded on 23 days, during the earlier part of the winter period. Figure 8 shows that when these exceedences occurred, the concentrations were much greater than the 25 µg/m^3 standard—in several cases reaching more than twice that level.

Comparison of TEOM PM_{10} data for 2009 and 2010

Was the average air quality worse for winter 2010 than for 2009?

Figures 7 and 8 clearly show that both PM_{10} and $PM_{2.5}$ concentrations exceeded the national daily standards and goals in Mount Gambier during the winter campaign of 2010. However, research shows that exceedences are only half the story — average concentrations of particles are also very important in evaluating health impacts on people.

Air quality varies markedly during the day, from day to day, month to month and year to year, depending very much on the weather, so it is extremely difficult to say anything about trends in less than five years. Figures 7 and 8 illustrate how widely the daily results for PM_{10} and $PM_{2.5}$ varied in 2010, showing many peaks and troughs in the graph lines.

However, there is value in comparing results for the first two years of the program to see whether the patterns of pollution were similar. As PM_{10} was measured directly during both years those results were chosen to make the comparison. It is noted that on completion of the third winter campaign in 2011, EPA will also be able to do some similar comparisons for $PM_{2.5}$.

One way of comparing air quality is to look at the average particle concentrations for the whole campaign period in each year. In this case statistical testing of the data showed that the 2010 average PM_{10} was indeed higher than the 2009 average. Intuitively, the reverse may have been expected from the higher rainfall in 2010 than in 2009 — rain washes particles out of the air—but there are many factors, such as persistent cold or still conditions that can trap pollution or perhaps more people were using their woodheaters for longer periods.

Comparison of nephelometer and $PM_{2.5}$ TEOM data from Gordon Education Centre site 2010 data

Analyses of data from the Gordon Education Centre are presented for three instruments. described previously, which operated side by side:

- two TEOM instruments for measuring PM_{10} and $PM_{2.5}$ particles
- one nephelometer, producing B_{scat} readings

- one TSI particle size counter, which uses light to count the number of particles in about 30 different size categories.

The reason for running the TEOM and nephelometer together is to compare the nephelometer B_{scat} readings with TEOM readings, so that the nephelometer at the Mount Gambier Showgrounds can be used to estimate concentrations of $PM_{2.5}$. When we plot B_{scat} against $PM_{2.5}$ results on a graph, the points cluster around a line, as shown in Figure 9. This line allows us to use nephelometer readings to predict concentrations of $PM_{2.5}$ with reasonable precision demonstrating the relationship.

Why undertake this kind of comparison?

During 2010 EPA also installed a second nephelometer station at the showground site, to help determine patterns of fine particles and their sources around Mount Gambier. Figure 9 demonstrates that we can be confident in using nephelometer B_{scat} numbers alone to estimate $PM_{2.5}$ concentrations at the showground.

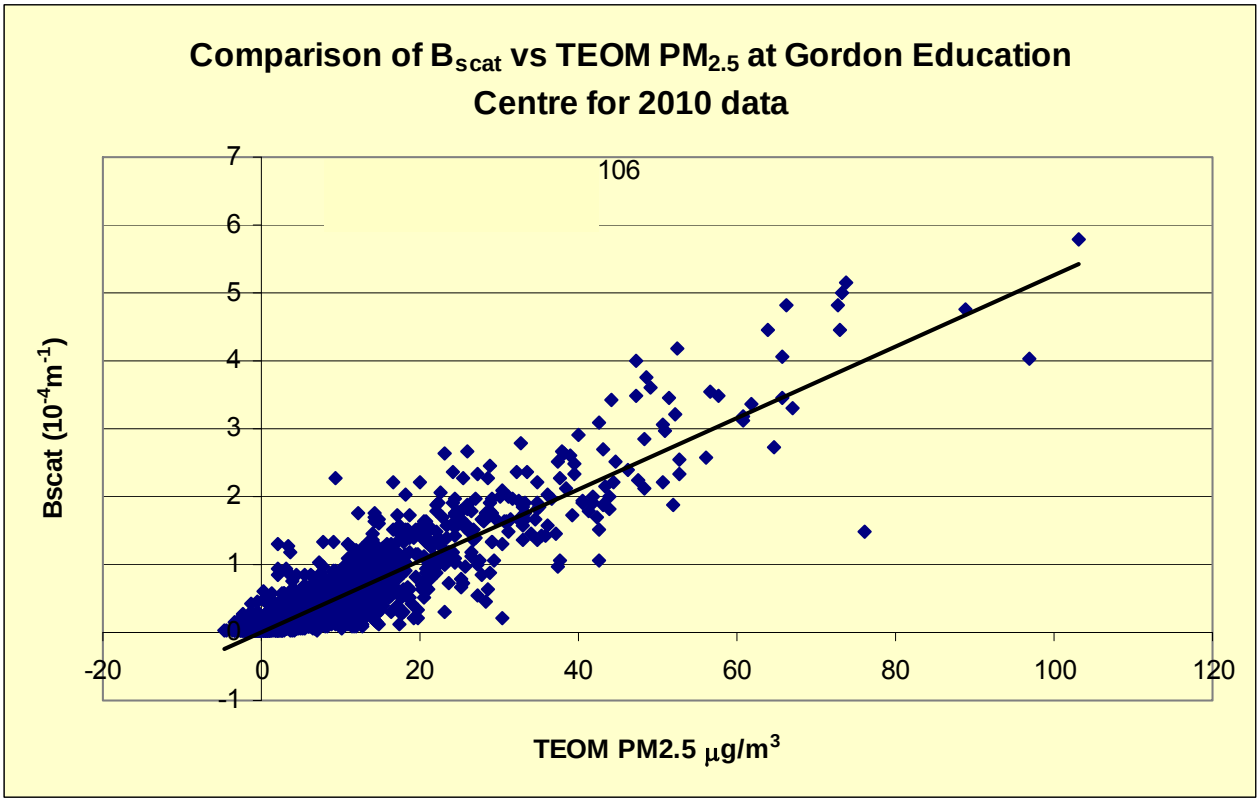

Figure 9 Correlation between nephelometer B_{scat} and TEOM mass particle concentration at Gordon Education Centre for 2010

Polar graphs

What is a polar plot?

A polar plot compares the percentage of particle readings from each direction with the percentage of winds from the same direction. When the two sets of readings are plotted on a circular graph, known as a polar plot, the difference between the two shows whether more particles are coming from some directions within Mount Gambier than from others. In figures 10 to 19, the frequencies of wind coming from each direction are plotted in green and the frequencies of particles coming from each direction are in red. Where data is available, graphs are shown for both 2009 and 2010.

Wind frequencies

The green lines show how the percentages of wind readings vary on average with direction within Mount Gambier. In this report, this percentage is called the *frequency* of winds. If the frequency of winds were the same for each direction, the

green lines would all be perfect circles. Clearly none of the green lines in the graphs are circles, meaning that the wind frequency is not the same for all directions. This is because winds tend to come from particular directions through the year, known as *prevailing wind directions*.

Particle frequencies

In the same way, the red lines show how the percentages of particle readings (the particle frequency) vary with directions, for either $PM_{10,}$ PM_{coarse} and $PM_{2.5}$. $PM_{2.5}$ is also represented by nephelometer data (B_{scat}) in Figures 14 and 15, as discussed earlier. Clearly none of the red patterns are circles either, so they show that particle levels also vary on average with direction.

Coarser particles (PM_{10}, PM_{coarse})

Note that the patterns of the red lines for the coarser material ($PM_{10,}$ PM_{coarse}) tend to follow those for the wind, with perhaps a slight bias from the easterly directions (around 270–300°), and in some cases from the southwesterly directions (around 150°). They also are quite sharp and well-defined, like fingers.

This is because these larger particles are often raised and carried by the wind towards the monitoring stations and probably represent quite specific sources, such as dust from industry or agricultural activities.

Fine particles ($PM_{2.5}$)

The red lines for the finer $PM_{2.5}$ material show much stronger and broader bulges towards the northwesterly directions, where the green wind line is relatively small (see Figures 13 to 16), covering a sector from north to west-north-west (0–60°) or more.

This implies that fine particles are coming from the northwesterly area of the city and are often recorded when the wind speeds are low. This is an area that is essentially residential, indicating that domestic sources predominate when the weather conditions are cool and still. We also know from size distributions of these particles that that are virtually all smoke particles.

Gordon Education Centre polar plots of data

TEOM mass concentration PM_{10}, PM_{coarse} AND $PM_{2.5}$ graphs

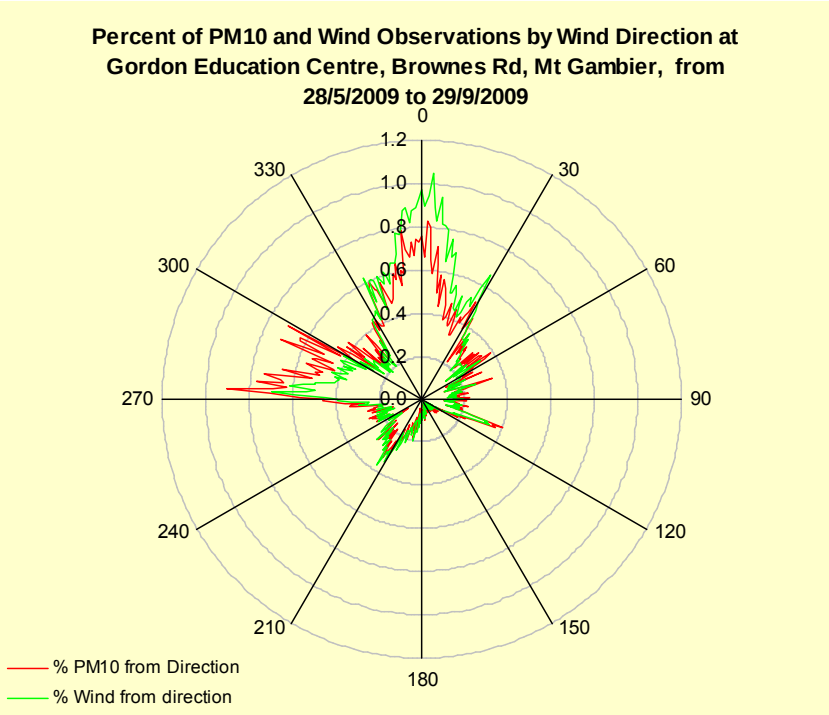

Figure 10 Polar graph TEOM PM_{10}, mass concentration, 2009 data

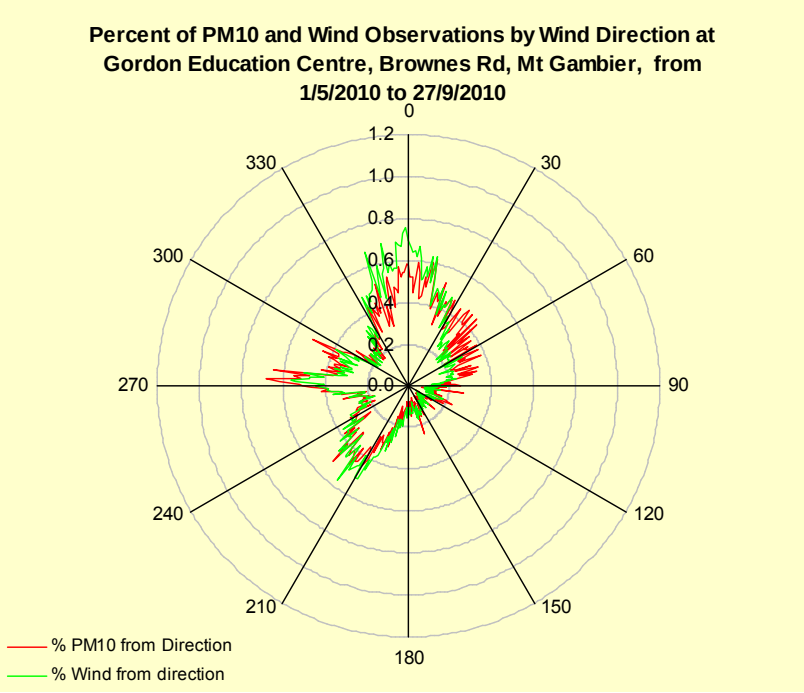

Figure 11 Polar graph TEOM PM_{10}, mass concentration, 2010 data

The above graphs indicate higher than average concentrations from the directions 270–300° and the 30–90° sector. As this size fraction includes $PM_{2.5}$ then a clearer picture is obtained by the separation of PM_{coarse} particles.

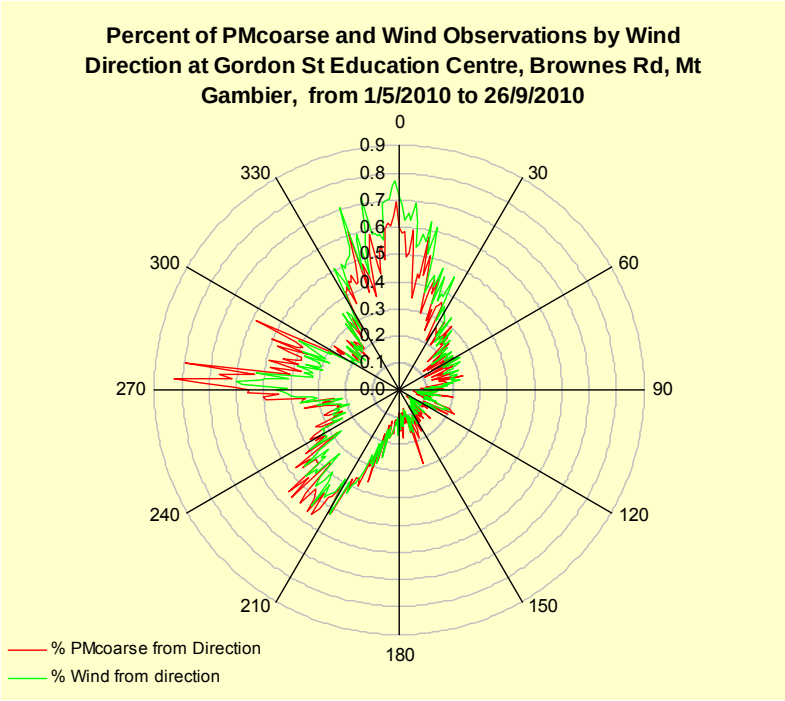

Figure 12 Polar graph TEOM PM_{coarse}, mass concentration, 2010 data

This graph indicates higher than average PM_{coarse} particles coming from the 210–300° sector and also from 120–180°. These sectors are mixed residential, industrial and CBD.

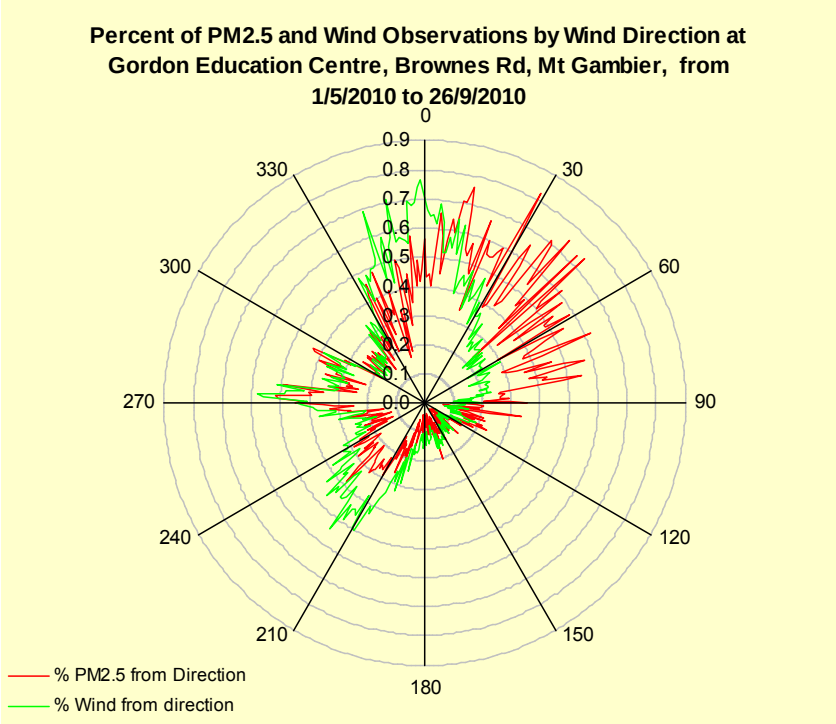

Figure 13 Polar graph TEOM $PM_{2.5}$, mass concentration, 2010 data

This graph indicates higher than average $PM_{2.5}$ from about 10–100°.

Nephelometer B_{scat} for 2009 and 2010 (estimation of PM2.5 particles)

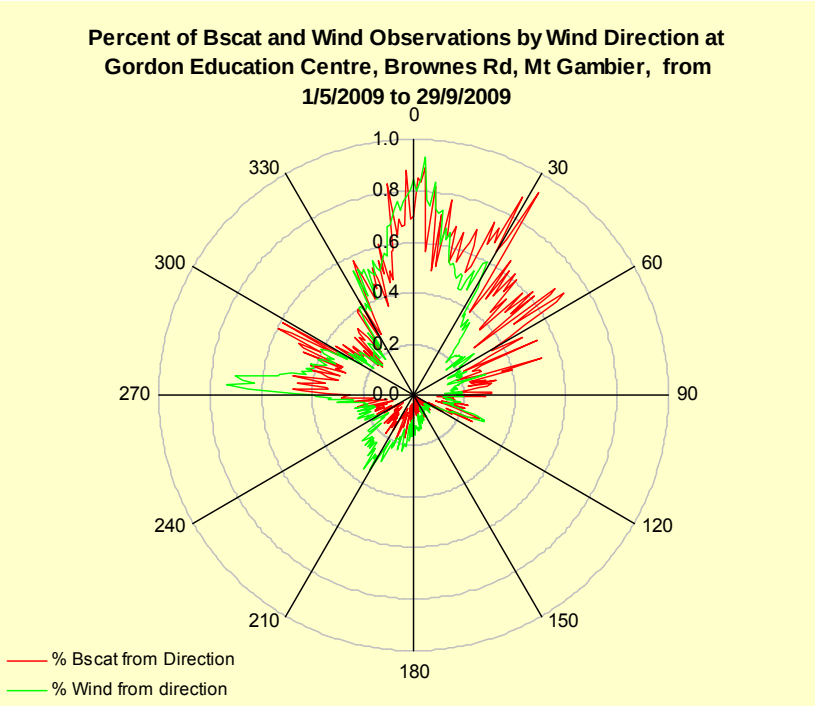

Figure 14 Polar graph nephelometer B_{scat} data 2010 (surrogate $PM_{2.5}$)

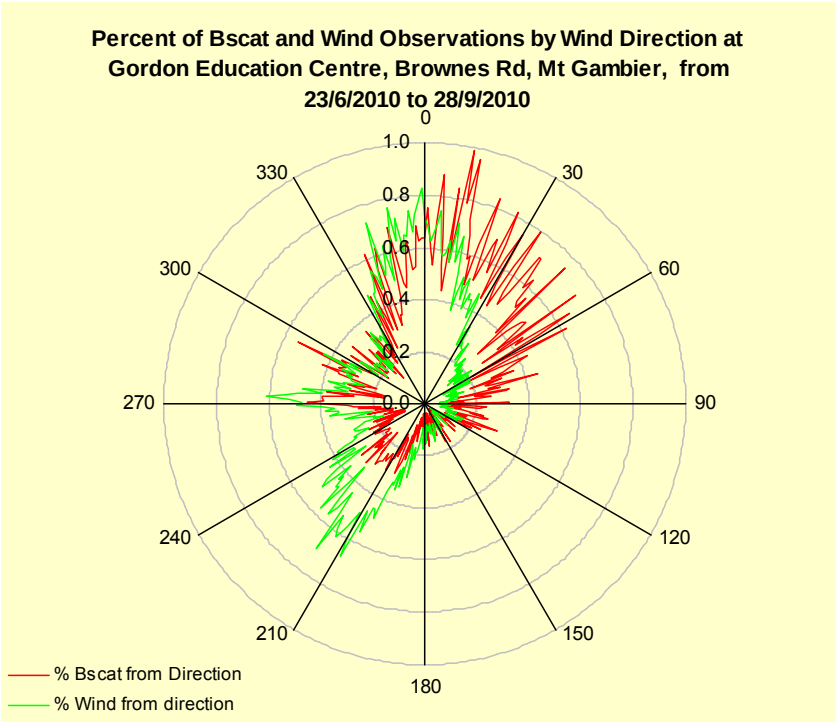

Figure 15 Polar graph nephelometer B_{scat} data 2010 (surrogate $PM_{2.5}$)

Figure 15 shows that the fine particles have a source in the sector 10–120° which includes the major residential area of Mount Gambier but also some from around 300°.

Graphs of results from the particle size counter

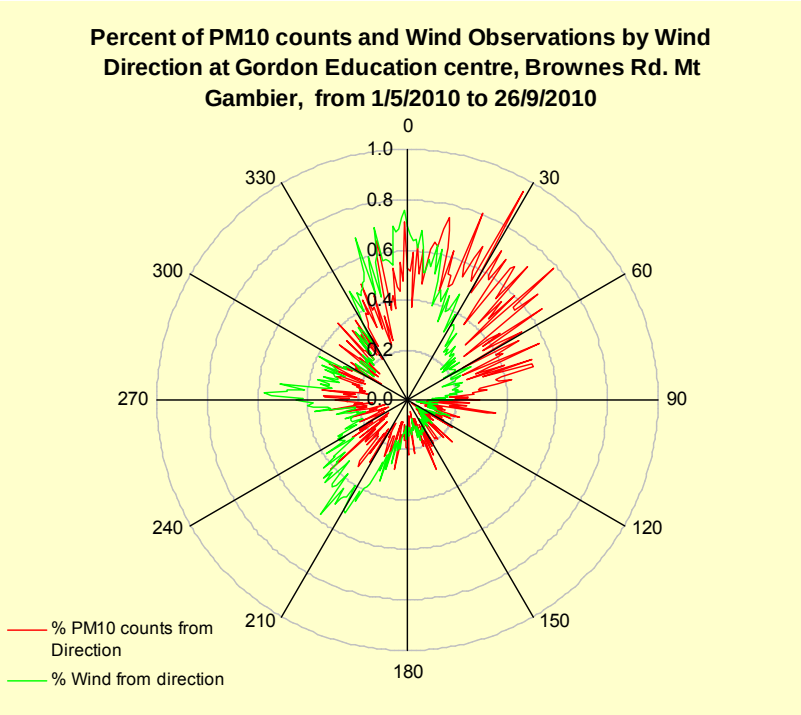

Figure 16 Polar graph of PM_{10} particle counts for 2010 data

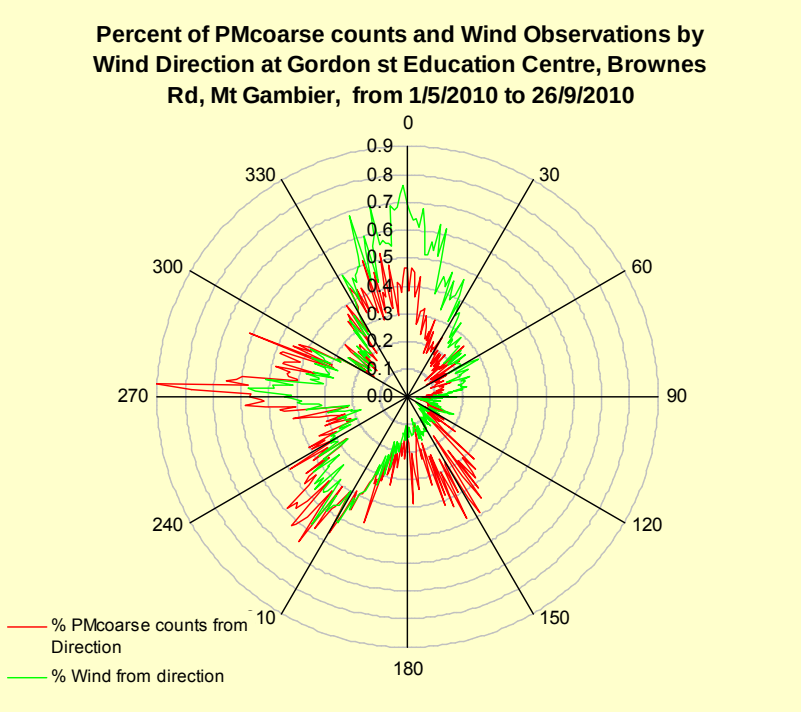

Figure 17 Polar graph of PM_{coarse} particle counts for 2010 data

Figure 17 shows an unidentified source centred around 150°, which may be from activities at the eastern end of town.

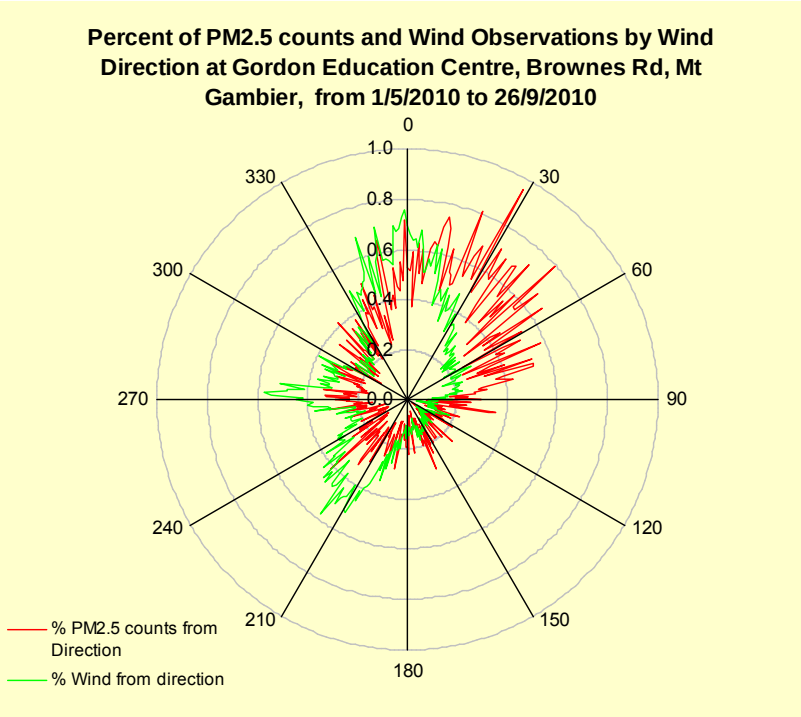

Figure 18 Polar graph of $PM_{2.5}$ particle counts for 2010 data

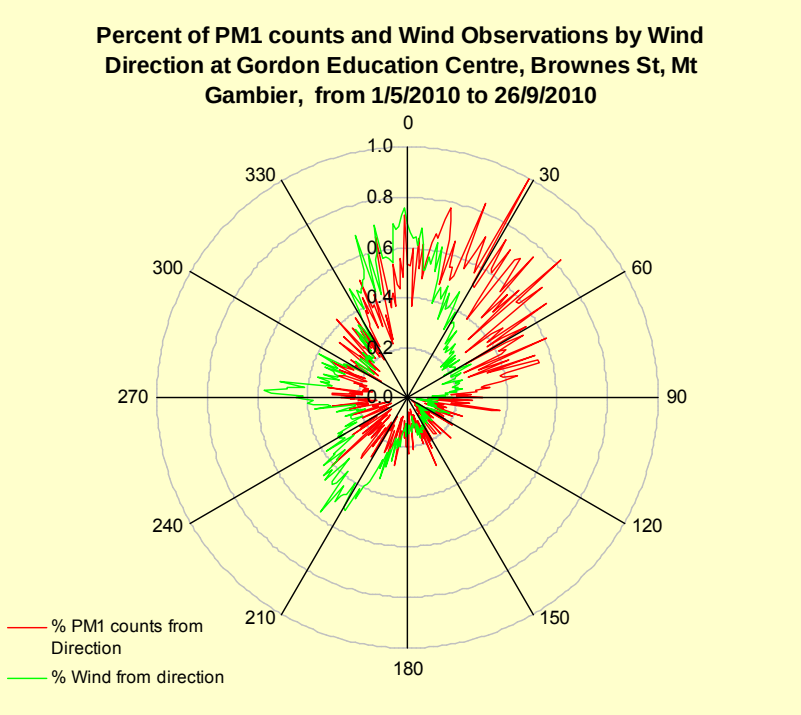

Figure 19 Polar graph of PM_1 particle counts for 2010 data

The particle count data show consistency with the particle mass graphs for PM_{10} and $PM_{2.5}$ particle sizes in that the fine particles are coming predominantly from the 10–120° sector. However the PM_{coarse} fraction (Figure 17) indicates sources from the 130–300° sector. This includes the TEOM PM_{coarse} sector of 180–300° and the 130–180° sector. The source of particles from the 130–180° sector is unclear but could be from further afield.

Average ratios of particles by weights and numbers

Table 3 Comparison of particle size ratios– average ratios at Gordon Education Centre for 2010 data

	TEOM mass particle data	TSI particle count data
$PM_{2.5}/PM_{10}$	46.2%	99.1%
$PM_{2.5}/PM_{coarse}$	56.6%	115%
$PM_1/PM_{2.5}$	–	94.2%

Average ratios of particle size and count fractions were calculated using available data from the TEOM and the particle counter.

As can be seen from the above ratios most of the mass of particles occurs in the coarser particle size (PM_{10} down to $PM_{2.5}$) whereas the greatest numbers of particles are in the fine particle fraction.

When looking at even finer particles (PM_1) that are most likely to be either smoke or vehicle emissions, 93.4% of $PM_{2.5}$ particles are PM_1 particles. Thus by number count most of the $PM_{2.5}$ particles are PM_1. This suggests that most of the fine particles are smoke and automobile emissions.

Mount Gambier Showgrounds

For the 2010 campaign a nephelometer measuring B_{scat} was installed at the Mount Gambier Showgrounds to provide estimates of $PM_{2.5}$ particles which are comparable with results from Gordon Education Centre.

This was done to ascertain effects (if any) from industry at that end of town and to give a different direction from residential areas. It was thought that this would allow a better assessment of the directional factors and hence assist in identifying the source of particles.

It can be seen from the polar plots that the excess levels of fine particles impact on the site from 270–90°. This is similar to the measurements at the Gordon Education Centre but with a slight anti-clockwise shift consistent with the direction of the main residential areas of the town.

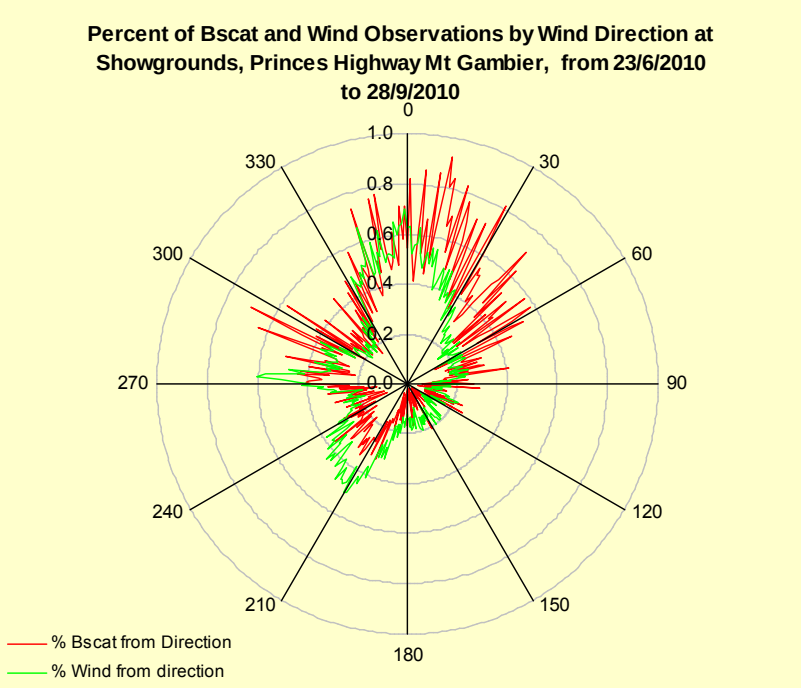

Figure 20 Nephelometer B_{scat} at showgrounds, 2010 data ($PM2_{.5}$ surrogate)

Hour of day

To examine when the particles are at their highest levels the percent of particles for each hour of the day was plotted against the hour of day on a monthly basis. This analysis was conducted for all measurements at both sites for 2009–10. The results showed that the daily pattern of particle levels were consistent across 2009 and 2010 at both sites. Typical data are presented in Figures 21 to 24 using TEOM mass concentration data for 2010 and TSI particle counts for $PM_{2.5}$ and PM_{coarse} data.

The daily particle patterns show some difference between particle mass and particle counts were examined. The peak that occurs in particle mass graphs at about 08:30 does not show as distinctly in the particle count graphs. However it must be remembered that the fine particle numbers are much higher than the coarser particles where most of the particle mass exists so that in relative plots of particle counts the morning peak is not as distinct.

During the monitoring period fine particles consistently reached a maximum overnight with a noticeable peak at about 8.30am possibly due to morning traffic. Thus maximum fine particle levels occur overnight when conditions are likely to be cool and still and when wood heaters would be most in use but not vehicles.

PM_{coarse} particles show a different pattern and are more evenly distributed throughout the day but appear to be higher during daytime with a peak around 8.30 am.

It should be noted that the peak for July in the morning in PM_{coarse} seen in Figures 21 and 23 is due to high levels of dust on 15 July 2010 lasting from about 5 to 10 am when winds were from the north west direction towards the Gordon Education Centre. This peak does not occur in the showground data as only B_{scat} was measured

This different hour of day pattern between PM_{coarse} and $PM_{2.5}$ data reflects the different mechanisms and sources of generation of the fine and coarse particles.

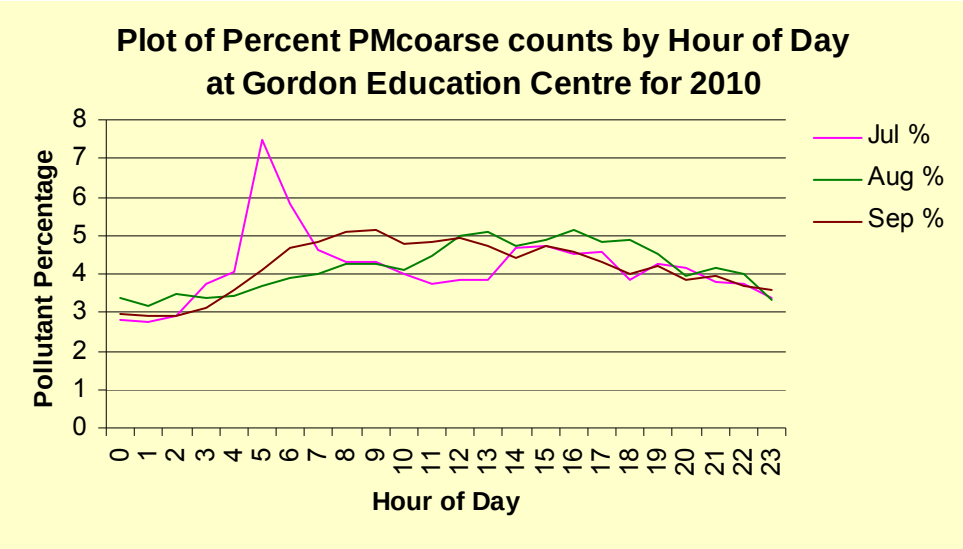

Figure 21 **Percent of PM_{coarse} particles by hour of day, particle count data for 2010**

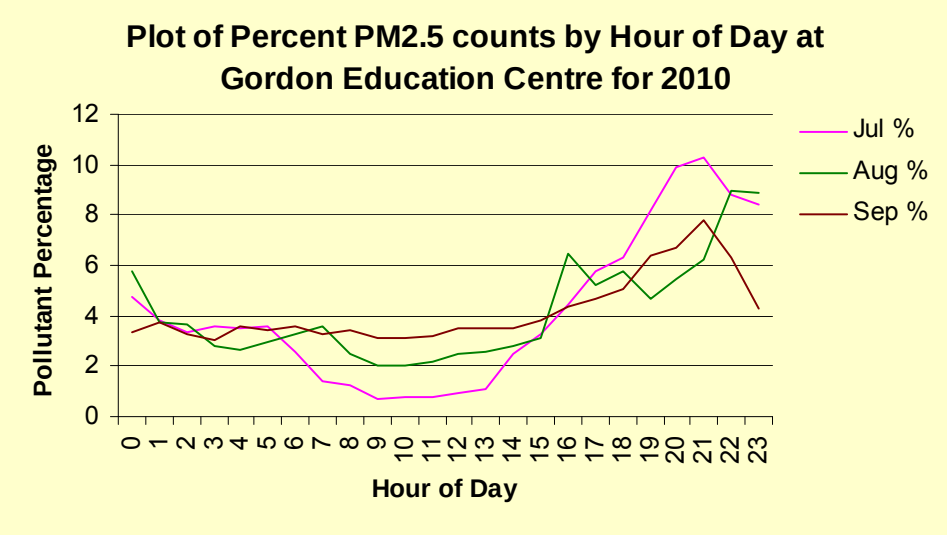

Figure 22 **Percent of $PM_{2.5}$ particles by hour of day, particle count data for 2010**

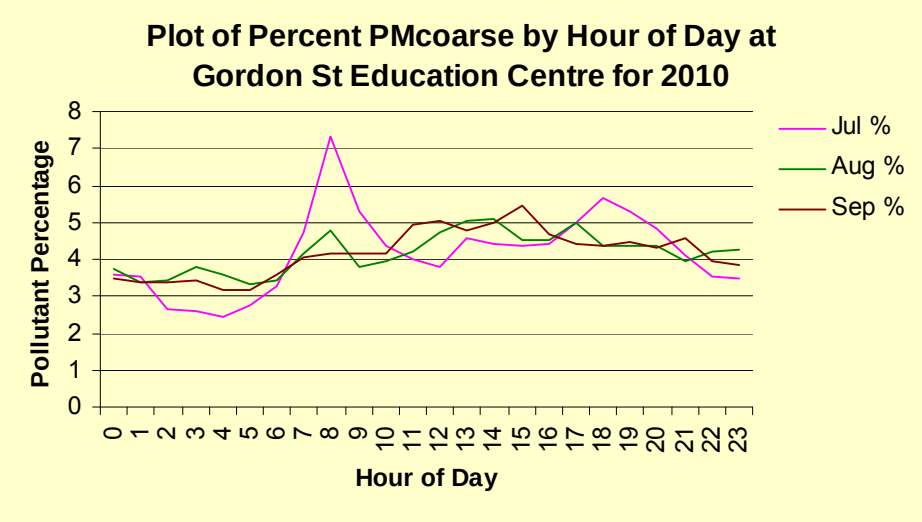

Figure 23 **Percent PM_{coarse} particles by hour of day, TEOM mass concentration data for 2010**

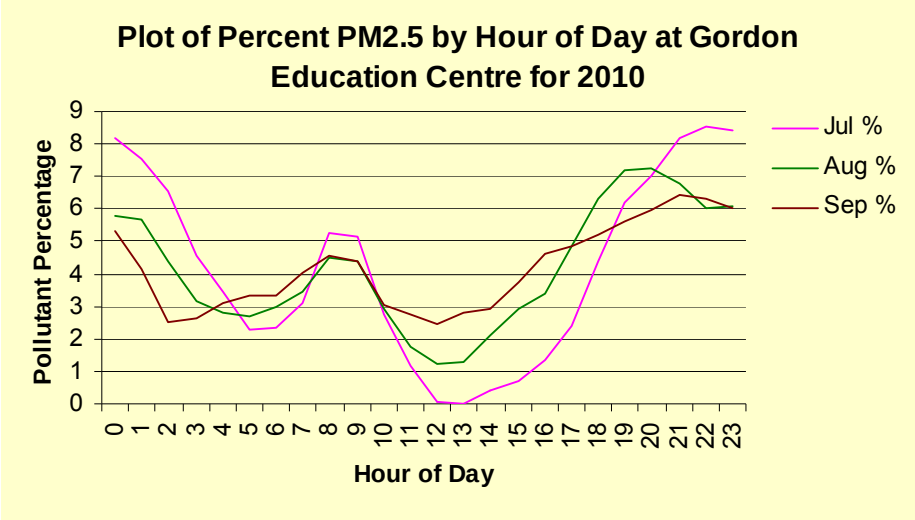

Figure 24 **Percent $PM_{2.5}$ particles by hour of day, TEOM mass concentration data for 2010**

Table 4 **EPA licensed Industries in Mount Gambier as shown on map (Figure 25)**

EPA Licensee	Marker
MTU Detroit Diesel Australia Pty Ltd	1
Carter Holt Harvey Wood Products Australia Pty Ltd	2
Van Schaik Organic Soils & Bark Suppliers Pty Ltd	3
GJ & TL Douglass Pty Ltd	4
Carter Holt Harvey Wood Products Australia Pty Ltd	5
South Pacific Seeds Pty Limited	6
Quickmix Concrete	7
South East Handymix	8
Kraft Foods Limited	9
Mount Gambier Pistol Club Inc	10
Mount Gambier Gun Club Incorporated	11
Gambier Earth Movers Pty Ltd	12
N F McDonnell & Sons	13
City of Mount Gambier	14
Gribbles Pathology (Vic) Pty Ltd	15
Green Triangle Recyclers Pty Ltd	16
SA Pathology t/a Institute of Medical & Veterinary Science	17
Fairsea International (SA)	18
Transpacific Cleanaway Pty Ltd	19

EPA Licensee	Marker
Mount Gambier Cemetery Trust	20
Carter Holt Harvey Wood products (Southern Region) Pty Limited	21
Whiteheads Timber Sales Pty Ltd	22
SE Battery Service Pty Ltd	23
Hanson Construction Materials Pty Ltd	24
Carter Holt Harvey Wood Products Australia Pty Ltd	25
Carter Holt Harvey Wood Products Australia Pty Ltd	26
Osmose (Aust) Pty Ltd	27
Holcim (Australia) Pty Ltd	28
AA Scott Pty Ltd	29
K & S Freighters Pty Ltd	30
Powder coating & Electroplating Professionals	31
Southern Blasters	32
Lowndes Abrasive Blasting	33
Scotts Agencies Proprietary Limited	34
Landmark Operations Ltd	35
De Bruin Engineering Pty Ltd	36
Bin It	37
Hexcon Pty Ltd	38
Metalcycle	39

Figure 25 is a map of the Mount Gambier region showing EPA licensed industries overlaid with the polar plots of the B_{scat} data (surrogate for $PM_{2.5}$). Directions from which higher than expected fine particles emanate are primarily residential areas.

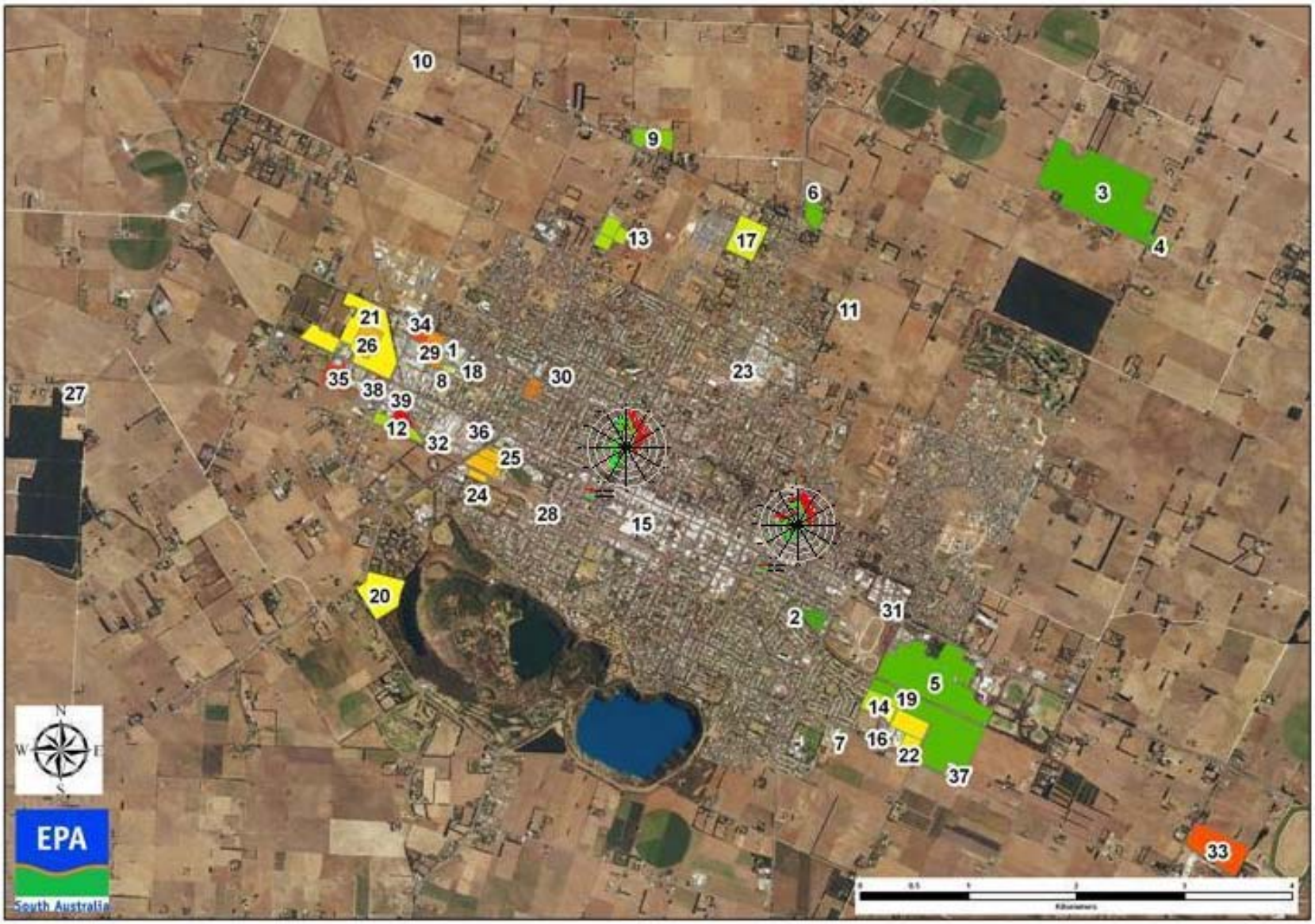

Figure 25 **Map of EPA licensed industries in and around Mount Gambier with a polar plot of B_{scat} 2010 data, a surrogate for $PM_{2.5}$**

Appendix 2 Glossary

APS	automatic particle sizer; an instrument used to count the number of particles in a given size range. This particular model counts particles in about 30 different size ranges.
micrometre	µm or one millionth of a metre
nephelometer	an instrument used to measure light scattered by fine particles (B_{scat}) and as an indicator for $PM_{2.5}$ particles
$PM_{2.5}$	the fraction of particles less than 2.5 µm in aerodynamic diameter
PM_{10}	A class (or fraction) of particle matter that includes particles from 10 µm (micrometres) aerodynamic diameter down to very small particles much less than 1 µm . In instruments such as the TEOM, size of the smallest particles is limited only by the ability of the filter material to trap them (about 0.5 µm) PM_{10} also includes the $PM_{2.5}$ fraction and PM_{coarse}.fraction (see below). In instruments using light to detect particles, the size is limited by the instrument's ability to "see" the smallest particles.
PM_{coarse}	the fraction of particles with aerodynamic diameters between $PM_{2.5}$ and PM_{10}
PM_1	particle matter less than 1 µm in aerodynamic diameter
sampling head or sampling intake	a device fitted to the sampling system which allows on particles smaller than a certain aerodynamic size to enter the instrument. In the case of a PM_{10} instrument the intake will be designed to admit only those particles that are 10 µm or smaller into the instrument. This aims to mimic the way in which particles enter the human respiratory system.
TEOM	an instrument used to measure the mass concentration of particles in air. It uses an automatic electronic balance to 'weigh' particles as they collect on a small filter.

Appendix 2 Instruments and methods

Monitoring undertaken in Mount Gambier used the following instrumentation:

PM_{10} and $PM_{2.5}$

TEOM 1400A tapered element oscillating microbalance (AS 3580.9.8–2001)

The TEOM was used to determine the PM_{10} concentrations in the air. The values were adjusted for temperature as per the National Peer Review Committee recommendations as to the use of a TEOM in climates that are cold and likely to have smoke. A site specific adjustment was made as per the technical paper.

To obtain $PM_{2.5}$ using a TEOM, a second unit was operated with a very sharp cutoff cyclone operated as above.

$PM_{2.5}$

Nephelometer–radiance research (AS 2724.4–1987)

The nephelometer was used as a surrogate method to determine a value for $PM_{2.5}$ within a smoke prone region. The nephelometer measures the scatter of light and through a mathematical conversion is able to estimate the $PM_{2.5}$ mass concentration. This was further confirmed against a TEOM measuring $PM_{2.5}$ mass concentration.

Particle sizer

TSI APS 3221–aerodynamic particle sizer

This instrument was used to obtain a particle size distribution in the air. It allows us to determine the particle size that is most prevalent and provide some information as to the nature of the particles in the air. It was also used to confirm the accurate determination of the conversion of the nephelometer values to $PM_{2.5}$.

Weather conditions

Vaisala meteorology equipment (AS 2923–1987)

A Vaisala ultrasonic anemometer was used to determine the wind speed and direction near the site. The height of the tower used was 10 metres to provide a more accurate measurement of regional air movements.