Department of
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Air Quality Monitoring for Particulate Matter in Collie, 2004-2007

Technical Report

December 2008

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2004 – 2007

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Definitions and abbreviations

Air NEPM	National Environmental (Ambient Air Quality) Protection Measure
Ambient air	the external air environment, does not include the air environment inside buildings or structures
Microgram	One millionth (1/1,000,000) of a gram (ug)
Micrometre	One millionth (1/1,000,000) of a metre (um) or one thousandth (1/1,000) of a millimetre
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NPI	National Pollutant Inventory
Percentile	Value of a variable below which a certain percent of observations fall. For example, the 90^{th} percentile is a value above which 10% or (10/100) and below which 90% (or 90/100) of all observations fall
PM_{10}	Particles with an equivalent aerodynamic diameter of 10 microns or less
$PM_{2.5}$	Particles with an equivalent aerodynamic diameter of 2.5 microns or less
TEOM	Tapered Element Oscillating Microbalance
WHO	World Health Organisation
$\mu g/m^3$	Micrograms per cubic metre

SUMMARY

The town of Collie has a population of 9000 people and is located in the south-west of Western Australia. Major industries in the region are mining and electricity production.

Particle matter is the sum of all solid and liquid particles suspended in air. Based on size, particles are often divided into two main groups, namely, PM_{10} and $PM_{2.5}$. PM_{10} is particle matter with an aerodynamic diameter of up to 10 µm. $PM_{2.5}$ is particle matter with an aerodynamic diameter of up to 2.5 µm and is commonly referred to as the fine particle fraction.

This report provides an assessment of particle monitoring in Collie for the period 2004-2007, and examines the need for future monitoring in the area.

Data were compared to the National Environment Protection (Air Quality) Measure (Air Quality NEPM) and other international health guidelines (i.e. WHO), and concentrations measured at other West Australian sites. Temporal patterns in the PM_{10} and $PM_{2.5}$ data were established by examining annual, seasonal, daily and hourly variations. An overview of the final findings is provided below:

- During the study period the daily average concentration of particles (PM_{10}) exceeded the standard set by the Air NEPM on an average of four days a year. In 2006, the daily average exceeded the Air NEPM standard on nine days and so failed to meet the goal set by Air NEPM in one of the study years.

- The daily averaged $PM_{2.5}$ concentration exceeded the Air NEPM advisory standard of 25 $\mu g/m^3$ 10 times in 2004, 3 times in 2005, 13 times in 2006 and 9 times in 2007. Similarly annual average concentration of $PM_{2.5}$ also exceeded the 8 ug/m^3 advisory standard in each year of the study.

- The maximum monthly average concentration for both PM_{10} and $PM_{2.5}$ occurs in May.

- The highest concentrations of PM_{10} and $PM_{2.5}$ generally occur in autumn as does the highest number of exceedences.

- The periods of high PM_{10} and $PM_{2.5}$, when the Air NEPM is exceeded, is almost always due to emissions from fuel reduction burning aimed at the protection of community values from the impact of severe bushfires, domestic wood heating and other fires.

- The duration of exceedences from prescribed burning is usually quite short compared to those produced by other sources.

- The night time averages for both PM_{10} and $PM_{2.5}$ are the highest during autumn and winter months and also significantly higher than the day time values during these months.

- When compared to the other sites around Western Australia (i.e. Bunbury and Duncraig) Collie had the highest number of exceedences for both PM_{10} and $PM_{2.5}$ for the period investigated by this report.

Based on this assessment of ambient PM_{10} and $PM_{2.5}$ data, it is recommended that measures are implemented to reduce community exposure to particles. It would be appropriate to continue to monitor particle concentrations to confirm longer term trends. Any plans for future industry also warrant that monitoring should continue for particles in Collie.

1.0 INTRODUCTION

The term particle pollution or particle matter (PM) includes both solid particles and liquid droplets found in the air. These solid and liquid particles come in a wide range of sizes. The sizes of particles are measured in micrometres (µm) which is 1/1,000,000 of a metre. There are two types of air-borne particles generally measured in the air, these being $PM_{2.5}$ and PM_{10}. $PM_{2.5}$ is particle matter with an aerodynamic diameter of up to 2.5 µm and is sometimes referred to as the fine particle fraction. PM_{10} is particle matter with an aerodynamic diameter of up to 10 µm which by definition also includes fine particles.

This report provides an assessment of available data[1] (January, 2004 to December, 2007) for ambient particle concentrations in Collie and examines the need for future monitoring in the Collie area.

The main objectives of the study were to:

- Compare particle concentrations in Collie with the ambient air quality National Environment Protection Measure (NEPM) standards and goals;
- Examine day-night and seasonal variations in PM_{10} and $PM_{2.5}$ concentrations;
- Determine if and when periods of high concentrations occur;
- Assess the need to monitor PM_{10} and $PM_{2.5}$ in Collie in the future.

This study is a component of a systematic review of the air quality within Western Australia. The study will aim to provide a strategic basis for government and industry decision making on key issues such as land use planning and infrastructure development. This will ensure the ongoing maintenance of acceptable air quality in the area whilst accommodating for the impact of future development.

The town of Collie is located at 33° 21’ 35”S, 116° 09’ 09”E in the south-west of Western Australia and is approximately 170 km from Perth. Collie is situated at the junction of the Collie and Harris rivers, with a population of approximately 9000 people. The major industries in the Collie area are mining and electricity production.

January and February are typically the hottest months of the year with mean maximum temperatures of 30.5 °C and 30.1 °C respectively. The coldest month is July with a mean daily maximum temperature of 15.5 °C. The average minimum temperatures range from 4.2 °C in July to 13.2 °C. The average annual rainfall for Collie is 940 mm. The highest rainfall generally is in

[1] Data was provided by Verve Energy.

winter, with June averaging 180.5 mm. The driest period is during summer with approximately 15 mm rainfall per month.

1.1 Sources of particles in Collie

In Collie, there are various sources that contribute to elevated particle concentrations

1.1.1 Industrial Processes

The National Pollutant Inventory (NPI) identified a number of industrial facilities that emit sources of PM_{10} emissions to the Collie area. The locations of these industrial sources are shown in Figure 1. The relative PM_{10} source contribution of the various industry sectors within the Collie area as identified by NPI is depicted in Figure 2.

1.1.2 Fuel reduction burns

Throughout the south-west of Western Australia, including around Collie, the Department of Environment and Conservation, industry and private landowners, use fire as an important land management tool. Prescribed burns have been used around Collie for many years for a range of purposes, including to provide strategic protection to community assets (including life and property) and to protect, maintain and enhance biodiversity and ecological processes.

1.1.3 Domestic sources

Wood heaters are another important source of particles in Collie.

DEC undertook a major review of the use of woodheaters in the Collie area in 2006 as part of the Synovate Pty Ltd survey. More than 200 householders were interviewed, providing a high level of confidence in the results.

The survey revealed that wood heaters are the most prevalent form of home heating in Collie, with 93 per cent of the surveyed homes having a wood heater (e.g. potbelly, open-fire place, slow combustion) (Synovate, 2006). Gas heaters, split system reverse cycle air conditioners, electric heaters and other forms of heating are in the minority as the main source of home heating in Collie.

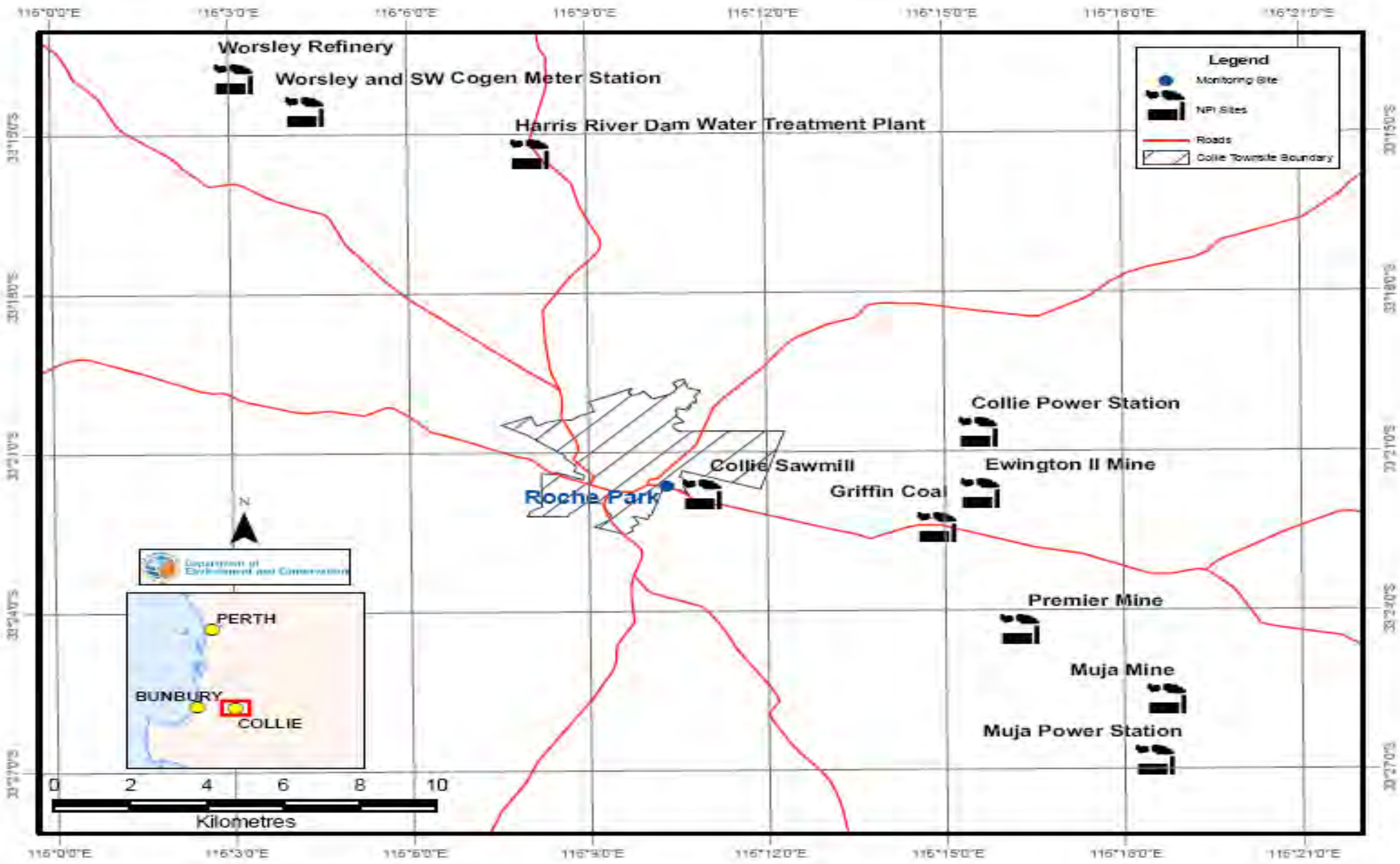


Figure 1 Collie region showing the Collie metropolitan area, Roche Park monitoring site and NPI reporting facilities

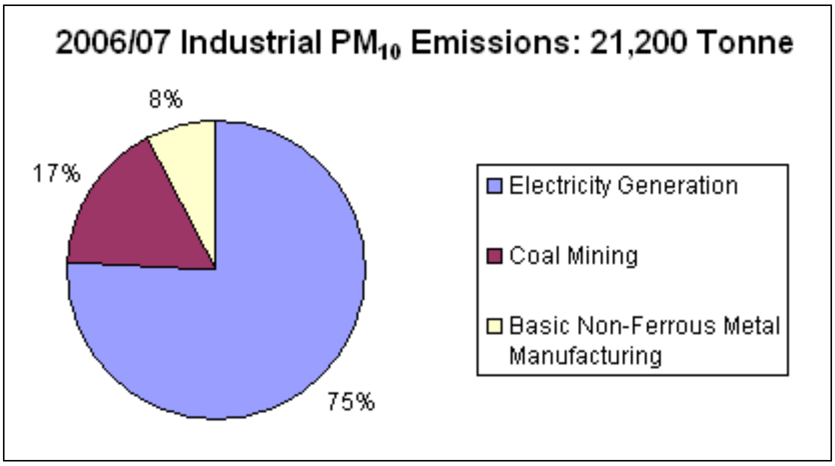


Figure 2 Relative contribution of major sources to PM_{10} in Collie during 2006/ 2007 (Data source: http://www.npi.gov.au).

1.1.4 Future sources of particles in Collie

The ongoing expansion of the energy industries in Collie will lead to additional sources of particles. At present, the following are under construction:

- Bluewaters Power Station Phase I – Griffin Energy is constructing a 200 MW sub critical coal-fired power station on a site 4 km north-east of Collie.
- Bluewaters Power Station Phase II – Griffin Energy is also beginning construction on another 200MW coal-fired power station adjacent to Phase I.

1.2 Health impacts of particles

Many anthropogenic and natural sources emit particles directly or emit other pollutants that react in the atmosphere to form particles. Generally, any activity that involves burning of materials or any dust generating activities are sources of particles. The relative contribution of each source type varies from day to day, depending on meteorological conditions and quantities of emission from mobile and static sources.

The range of adverse health effects associated with particle pollution is broad and includes various respiratory, cardiopulmonary, and cardiovascular diseases and mortality from a variety of causes (US EPA, 1996a, b). Inhalable particles such as PM_{10} and $PM_{2.5}$ are associated with increases in respiratory illness (e.g. asthma, bronchitis and emphysema). Particles as $PM_{2.5}$ are thought to represent a particular risk due to their ability to penetrate further into the lungs and be absorbed in the bloodstream.

Some people are more sensitive than others – for example, the elderly and those suffering from pre-existing heart or lung disease. The young are also sensitive, with evidence of increased frequency of respiratory tract infections, coughing and wheezing following exposure to airborne particles. Recent research has also linked exposure to relatively low concentrations of particles with premature death (WHO, 2003).

2.0 AUSTRALIAN AIR QUALITY STANDARDS AND SCREENING PROCEDURES FOR PARTICLES

In Australia in 1998, the National Environment Protection Council (NEPC) introduced an ambient air quality National Environment Protection Measure (NEPM) which set out air quality standards applicable to all states and territories. The standards cover six pollutants, including PM_{10}. Air NEPM standards for particles are summarised in Table 1. The NEPM air quality standard for PM_{10} is 50 µg/m³ averaged over one day with five exceedence days allowed each year (NEPC, 2003).

While there are no NEPM air quality compliance standards for $PM_{2.5}$, the NEPC has recommended an ambient air quality advisory reporting standard of 25 µg/m³ averaged over one day and 8 µg/m^3 measured as an annual average. There have been no allowable exceedences set for $PM_{2.5}$ with the goal being to gather sufficient data to facilitate a review of the standards.

Table 1 Air NEPM standards for particles

	Averaging period	Concentration	Allowable exceedences (NEPM goal)
PM_{10}	1 day	50 µg/m³	5 days/year
$PM_{2.5}$	1 day 1 year	25 µg/m³ 8 µg/m³	

A screening procedure to determine the necessity for continued monitoring within a region was developed by the NEPC Peer Review Committee (NEPC, 2001a). This screening procedure was in the form of an acceptance limit and was set at 65 per cent of the Air NEPM standard (i.e. 32.5 ug/m^3 averaged over on day for PM_{10}) for 2-4 years of data. Compliance with the screening procedures is determined by using historical data within a region the purpose being to demonstrate that a full compliment of monitoring stations may not be required within a particular region either to detect exceedences or gain a more representative depiction of pollutant distribution. (NEPC, 2001a).

The screening limit for PM_{10} will apply to the 5th highest daily reading, where the higher readings can be shown to be due to bushfires or controlled burns. This is consistent with the procedure developed by the NEPC Peer Review Committee.

3.0 SAMPLING LOCATION AND MONITORING METHOD

Ambient PM_{10} and $PM_{2.5}$ data assessed in this study has been taken from the Roche Park monitoring station (Figure 1) in Collie. This monitoring station is situated on the outskirts of Collie at the corner of, Gibbs Road and Paul Street. The main land use around the station is residential land and remnant native vegetation. The station was established in 1985 by Verve Energy.

The monitoring station uses the TEOM (Tapered Element Oscillating Microbalance) method of sampling and is operated and calibrated in accordance with the Australian Standards (AS) 3580.9.8-2001. The TEOM draws air through a hollow tapered tube, with the wide end of the tube fixed, while the narrow end oscillates in response to an applied electric field. The filter cartridge is at the narrow end of the tube. The sampled airflow passes from the sampling inlet, through the filter, to a flow controller. The flow rate through the sample filter is set at a nominal 3.0 litres per minute (L/min). As particles are collected on the filter, the filter mass changes, resulting in a change of the natural oscillating frequency of the tapered tube. Using the rate of mass accumulation on the filter and the flow rate through the sample (main) flow controller, the TEOM's microprocessor calculates the mass concentration.

4.0 RESULTS AND DISCUSSION

Ambient data for PM_{10} and $PM_{2.5}$ from the Roche Park monitoring site in Collie has been analysed from the 1 January 2004 until 31 December 2007. Data capture in every year except 2005 was above a 95 per cent capture rate (Table 2 and 3) and is considered sufficient to enable comparison of the data against the Air NEPM standard. The annual data availability for this report is based on the number of valid hourly data of particle concentrations. The high data availability also allows calculation of seasonal effects in the behaviour of airborne particles (NEPC, 2001).

4.1 Comparison with Air NEPM standards

All the valid ambient PM_{10} and $PM_{2.5}$ data for the period (2004-2007) were compared to the standards outlined by Air NEPM (Table 1) and the screening acceptance limit (for PM_{10} only). The results are discussed below.

4.1.1 PM10 concentration

Table 2 shows comparison of the daily average PM_{10} concentration with the essential requirements of the Air NEPM standard and its acceptance limit.

Daily average PM_{10} concentration exceeded the Air NEPM standard of 50 µg/m³ twice in 2004 and 2007, once in 2005 and nine times in 2006.

The Roche Park monitoring site did not meet the Air NEPM goal of no more than five exceedences per year in 2006. The site also did not meet the screening procedure acceptance limit where the fifth highest daily concentration is required to be less than 65 per cent of the Air NEPM standard.

Table 2 Particles, as PM_{10}, 24-hour average concentration and compliance

Year	Data recovery	Number of days air NEPM standard was exceeded	Was NEPM goal met?	Number of days acceptance limit was exceeded	Was acceptance limit met?
2004	99%	2	Yes	19	No
2005	49%	1	Incomplete	9	No
2006	99%	9	No	26	No
2007	99%	2	Yes	20	No

Figure 3 compares the daily average PM_{10} concentration to the standard set by the Air NEPM and acceptance limit for the years with the highest data recovery (i.e. 2004, 2006 and 2007).

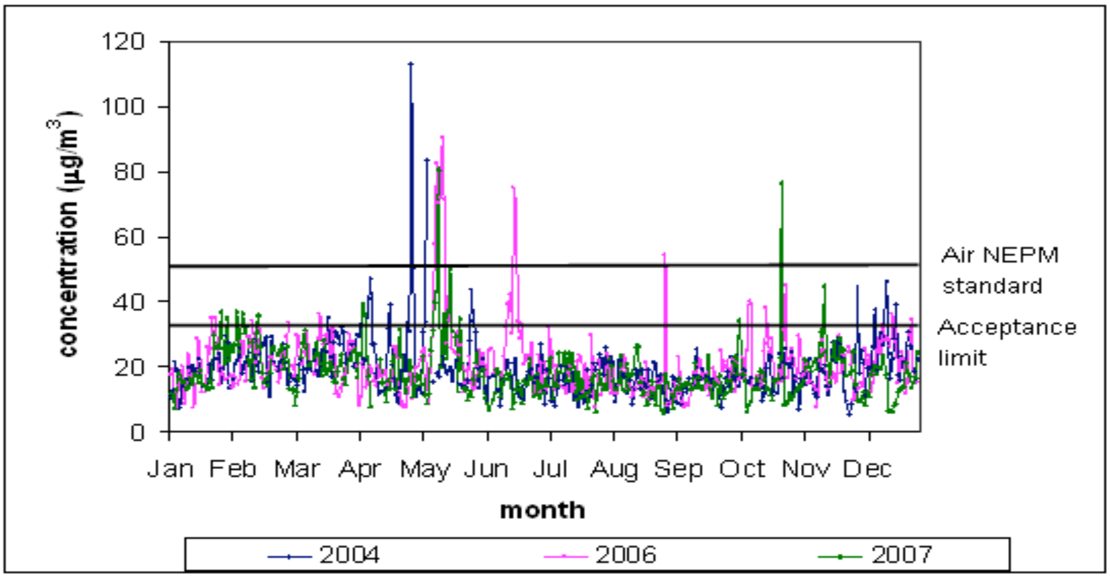


Figure 3 PM_{10} daily concentration at Roche Park

The maximum daily concentration of PM_{10} of 116.8 µg/m³ was recorded in April 2004 while the minimum concentration was 5.1 µg/m ³ recorded in November 2004.

As there is no Air NEPM standard for the annual concentration of PM_{10}, the annual average concentration was compared to the World Health Organisation (WHO) standard of 20 µg/m³ (WHO, 2005). In general, annual average concentration of PM_{10} is lower than the WHO standard (Table 5) but in 2006 it exceeded the standard by 5 per cent.

4.1.2 $PM_{2.5}$ concentration

Table 3 shows the daily average $PM_{2.5}$ concentration compared to the Air NEPM advisory reporting standard of 25 µg/m³. The daily averaged concentration of fine particles exceeded advisory standard 10 times in 2004, three times in 2005, 13 times in 2006 and nine times in 2007. Annual average concentration of fine particles exceeded the Air NEPM standard in each of the years studied.

Table 3 Particles, as $PM_{2.5}$, 24-hour average concentration and compliance

Year	Data recovery	Number of days advisory air NEPM standard was exceeded
2004	98%	10
2005	49%	3
2006	99%	13
2007	99%	9

4.2 Temporal Variation

The following section provides an analysis of PM_{10} and $PM_{2.5}$ concentrations at the Roche Park monitoring site in Collie during January 2004 to December 2007. The objective was to determine the diurnal and seasonal patterns of PM_{10} and $PM_{2.5}$ with the aim of identifying the main emission sources and meteorological factors responsible for these patterns.

4.2.1 PM_{10} and $PM_{2.5}$ concentration at Roche Park

Tables 4 and 5 summarise PM_{10} and $PM_{2.5}$ concentrations respectively from the Roche Park monitoring site.

The maximum daily concentration of PM_{10} decreased from 116.8 µg/m³ in 2004 to 79.2 µg/m³ in 2007. The annual average concentration increased by 7 per cent from 2004 to 2006[·], however, in 2007 the annual average fell to 18.4 µg/m³. The median PM_{10} concentration shows slight variation from year to year with the maximum value occurring in 2006.

Table 4 Summary of PM_{10} concentration at Roche Park, (µg/m³)

Year	Annual average	Maximum	6^{th} highest	90^{th} percentile	Median	Minimum
2004	19.6	116.8	43.5	28.8	17.8	5.1
2005	18.9	56.4	36.9	28.9	17.1	5.3
2006	21.0	88.8	69.6	30.9	18.3	7.4
2007	18.4	79.2	40.0	26.9	16.6	6.3

[·] Data for 2005 is incomplete.

Table 5 Summary of $PM_{2.5}$ concentration at Roche Park, (µg/m³)

Year	Annual average	Maximum	95th percentile	90th percentile	Median	Minimum
2004	10.7	105.9	20.6	16.5	8.8	3.4
2005	10.1	45.4	18.5	16.3	8.4	3.5
2006	10.7	73.2	19.7	16.1	8.6	3.2
2007	9.0	66.7	17.3	13.4	7.6	3.2

The lowest annual average concentration of $PM_{2.5}$ was observed in 2007 with a value of 9.0 µg/m^3. The maximum daily concentration of $PM_{2.5}$ was recorded in 2004 with a value of 105.9 µg/m^3. The 90th percentile decreased from 16.5 µg/m³ in 2004 to 13.9 µg/m³ in 2007. The percentile results give an indication of underlying trends and exclude the influence of extraordinary events.

Monthly percentiles of ambient PM_{10} and $PM_{2.5}$ data were estimated for each month during the study period and the results are graphed in Figures 4 and 5.

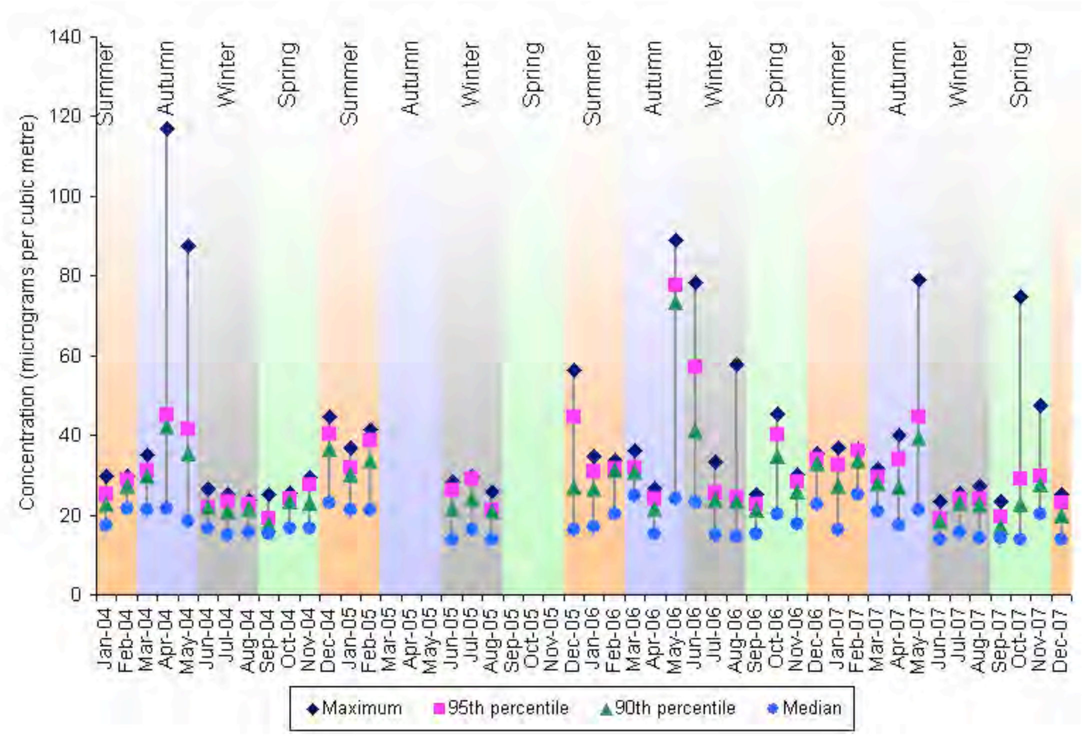


Figure 4 Daily averaged percentiles for PM_{10}, during 2004 - 2007

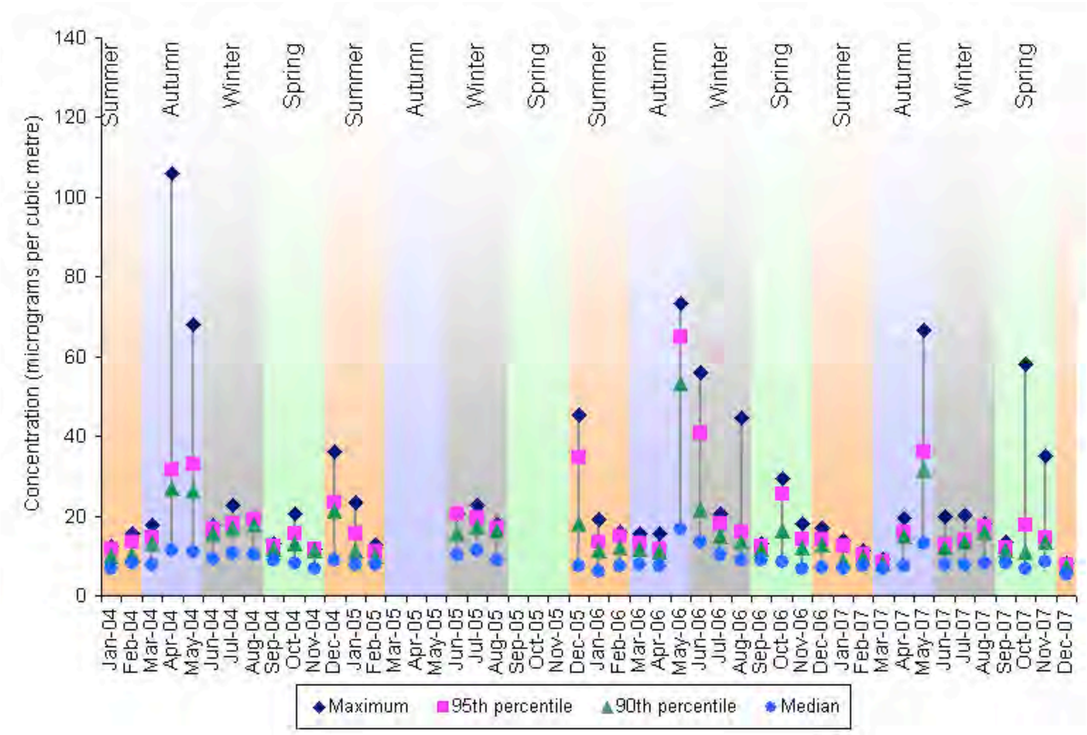


Figure 5 Daily averaged percentiles for $PM_{2.5}$, during 2004 – 2007

The maximum monthly average concentration for PM_{10} and $PM_{2.5}$ occurs between April and June and October to December.

4.2.2 Seasonal and daily variation

The data from Roche Park, Collie was divided into summer, winter, autumn and spring and further subdivided into day time (7am-6pm) and night time (7pm-6am). These are shown in Tables 6 and 7.

Table 6 Seasonal PM_{10} concentrations (in ug/m^3)

	Summer		Autumn		Winter		Spring	
	day	night	day	night	day	night	day	night
2004	20.8	17.9	23.3	27.6	14.3	17.4	16.7	16.1
2005	25.3	21.7	n/a	n/a	14.5	17.3	n/a	n/a
2006	21.1	19.3	23.1	24.6	18.9	21.2	19.6	18.2
2007	23.8	19.9	21.5	22.2	13.6	16.5	16.8	18.2

Table 7 Seasonal $PM_{2.5}$ concentrations (in ug/m^3)

	Summer		Autumn		Winter		Spring	
	day	**night**	**day**	**night**	**day**	**night**	**day**	**night**
2004	8.1	7.5	11.8	14.9	9.0	13.4	8.1	9.1
2005	9.5	9.0	n/a	n/a	8.9	12.9	n/a	n/a
2006	8.8	9.6	10.8	15.0	10.1	14.6	8.5	9.7
2007	8.2	7.8	9.4	12.7	7.2	11.0	7.7	10.5

It can be seen from Tables 6 and 7 that in general, the highest concentration of PM_{10} and $PM_{2.5}$ occurs in autumn. This correlates well with the highest number of exceedences registered during this season (as depicted in Appendix 1).

It is also clear from Tables 6 and 7 that during autumn and winter, both PM_{10} and $PM_{2.5}$ particles exhibit a higher concentration at night time than during the day time. It is likely that the higher night time particle concentrations may be due to a high frequency of nocturnal inversions and, as a consequence pollution being trapped above the surface (BoM, 1998). This is graphically demonstrated in Figure 6 showing the regular cycle of the day:night particle ratios during each season.

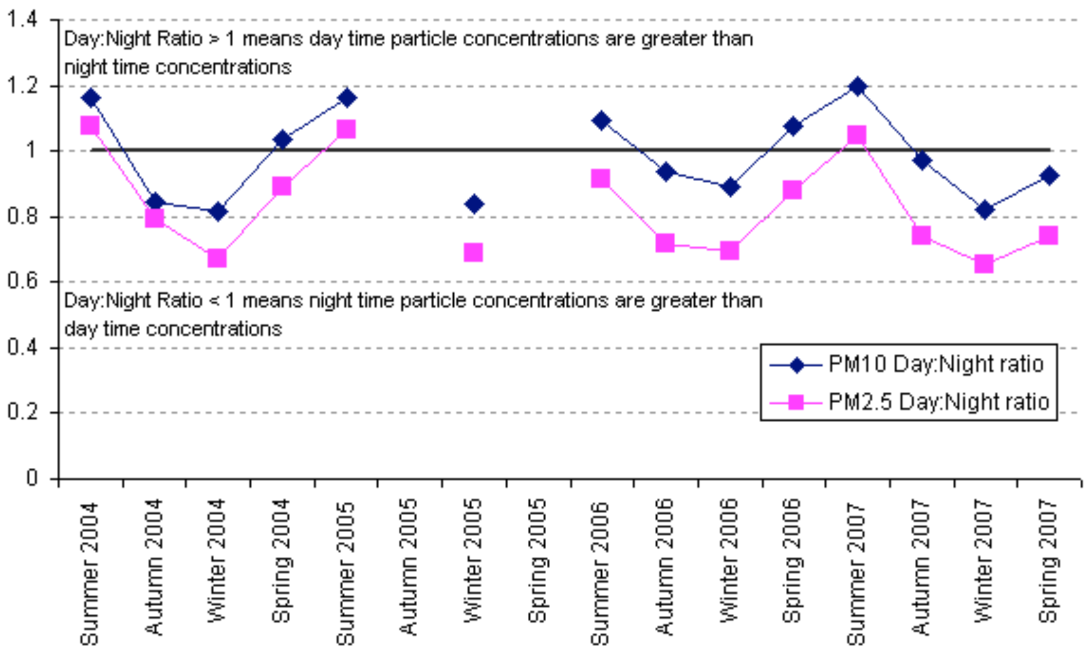


Figure 6 Day:night particle ratios during each season

Seasonal wind roses for Collie in Figure 7 show that in summer, winds prevail from the east-south-east. A number of the industrial facilities (Figure 1) are located in this direction (i.e. upwind of the monitoring station). In contrast, winter winds are predominantly from the north-west, from the direction of Collie town site. It maybe that residential activity and home heating could impact the particle concentrations in winter. In autumn and spring, no particular wind arc dominates (Figure 8). The highest frequency (37.1 per cent) of calm conditions occurs in winter.

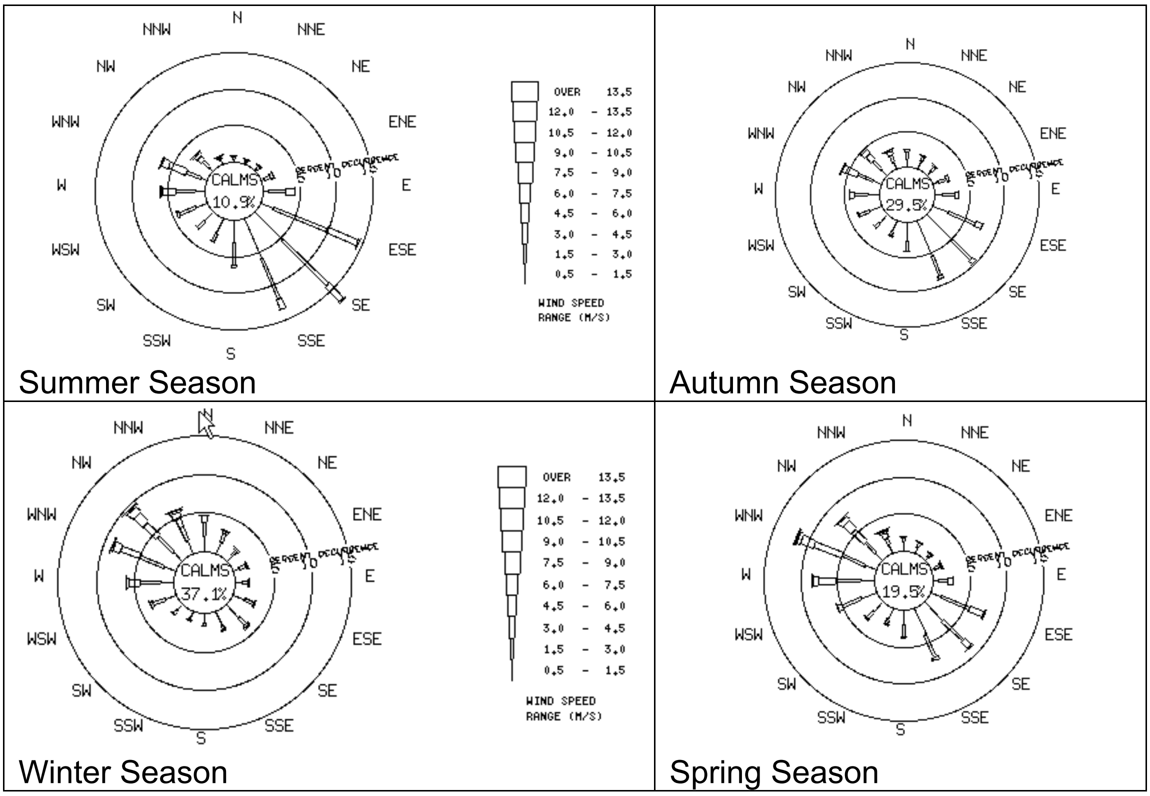
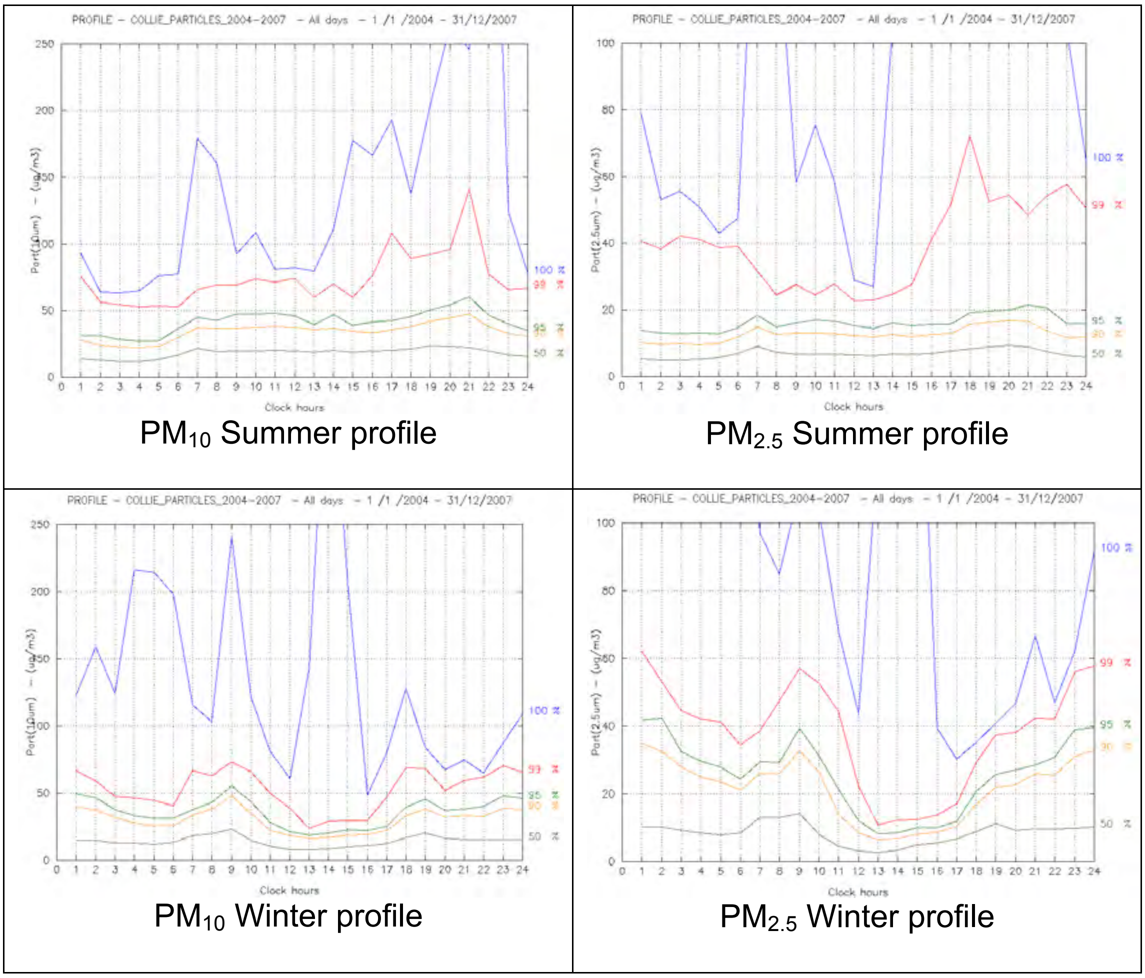


Figure 7 Seasonal wind roses for Roche Park monitoring site (2004-2007)

4.2.3 Diurnal variation of particle concentrations in winter and summer

Figure 8 shows the diurnal patterns of particles during summer and winter. The graph shows one-hour averaged 100th (maximum), 99th, 95th, 90th and 50th (median) percentile levels for each hour of the day. During summer PM_{10} generally starts increasing from about 6 am onwards, peaking around 9 pm and then declines overnight. Typically in summer, the minimum concentration occurs in the early morning hours.

In contrast, the diurnal variability of both PM_{10} and $PM_{2.5}$ in winter is characterised by two periods of elevated concentration: one during the morning at 9 am and one later in the day between 6 and 7 pm. The PM_{10} concentration after 7 pm remains generally steady into the night and declines into the early hours of the morning while the $PM_{2.5}$ continues to rise, declining only after midnight. A possible reason for these trends is that throughout the night, pollution becomes trapped in the nocturnal inversion layer above the surface. In the morning, a breakdown of the inversion layer can transport particles down to the surface where high concentrations may last for a few hours. Also, these peaks may be the result of increased transportation and residential (home heating) emissions during the early morning and evening hours.



PM_{10} Summer profile

$PM_{2.5}$ Summer profile

PM_{10} Winter profile

$PM_{2.5}$ Winter profile

Figure 8 Diurnal variation of PM_{10} and $PM_{2.5}$ for winter and summer (2004-2007)

(maximum concentrations in Figure 8 have been truncated to better display the characteristics of lower percentiles)

4.3 Comparison with other monitoring stations

By way of comparison the particle data from Collie was compared with monitoring data from DEC operated monitoring stations in Duncraig and Bunbury.

The Duncraig monitoring station is located in a northern metropolitan suburb of Perth, and is considered an upper bound performance monitoring station measuring PM_{10} from a combination of vehicle and wood heater emissions during stable meteorological conditions. PM_{10} monitoring started in Duncraig 1994, while $PM_{2.5}$ monitoring started in 1995. The site was established as part of the Perth Photochemical Smog and Haze Studies. Bunbury station (160 km south of Perth) was established in the south-west region to determine the impact of land management activities on key regional centres and commenced monitoring $PM_{2.5}$ and PM_{10} in 1997 and 1999, respectively. The Bunbury monitoring station is a suburban site and will remain in use at this location indefinitely with the intention of developing long term trend data.

4.3.1 Comparison with Air NEPM standards

Table 8 contains the daily peak 24-hour PM_{10} and the number of exceedences for each year 2004 to 2007 at Collie, Duncraig and Bunbury. Collie had two exceedences in 2004 and 2007 with one and nine exceedences in 2005 and 2006 respectively. Bunbury had four exceedences in 2004, three in 2005 and three in 2006 when the peak daily concentration reached 123.5 $\mu g/m^3$. Duncraig had the least number of exceedences with one in 2005.

Table 8 Peak daily averaged PM_{10} concentration ($\mu g/m^3$) and number of exceeedences for 2004-2007

	Collie		**Duncraig**		**Bunbury**	
	Daily peak	**Number of exceedences.**	**Daily peak**	**Number of exceedences.**	**Daily peak**	**Number of exceedences.**
2004	116.8	2	45.1	0	99.5	4
2005	56.3	1	59.2	1	63.3	3
2006	88.8	9	40.6	0	123.5	3
2007	79.2	2	40.3	0	46.5	0

Table 9 contains the daily peak 24-hour $PM_{2.5}$ and the number of exceedences for each year 2004 to 2007 at each monitoring station. Collie had the highest number of exceedences (10 in 2004, 3 in 2005, 13 in 2006 and 9 for 2007). Duncraig had three exceedences in 2005 and two in 2006. Bunbury had five exceedences in 2004 and 2005, eight in 2006 and three in 2007.

Table 9 Peak daily averaged $PM_{2.5}$ concentration ($\mu g/m^3$) and number of exceeedences for 2004-2007

	Collie		**Duncraig**		**Bunbury**	
	Daily peak	**Number of exceedences.**	**Daily peak**	**Number of exceedences.**	**Daily peak**	**Number of exceedences.**
2004	105.8	10	24.4	0	94.8	5
2005	45.4	3	40.6	3	64.2	5
2006	73.2	13	33.4	2	113.5	8
2007	66.7	9	19.6	0	34.5	3

Table 10 depicts the annual averaged concentration of fine particles in Collie, Duncraig and Bunbury for 2004-2007. The Air NEPM Advisory standard for particles as $PM_{2.5}$ of 8 $\mu g/m^3$ averaged over one year was exceeded Duncraig in 2006 and Bunbury in 2004, 2005 and 2006. The annual concentration in Collie exceeded the Air NEPM advisory standard by between 15-35% for each year of the study. For the south-west region in general, the annual average of $PM_{2.5}$ is relatively higher than in Perth.

Table 10 Annual averaged $PM_{2.5}$ concentrations ($\mu g/m^3$) for 2004-2007

Monitoring station	2004	2005	2006	2007
Collie	10.7	10.1	10.7	9.0
Duncraig	7.9	7.8	8.2	7.3
Bunbury	9.2	8.6	8.7	7.8

A comparison of the three sites for both PM_{10} and $PM_{2.5}$ are presented in Figures 9 and 10. Although the maximum PM_{10} and $PM_{2.5}$ concentration for 2005 and 2006 is highest in Bunbury, the 95th, 90th and median percentiles are at their maximum in Collie for all years.

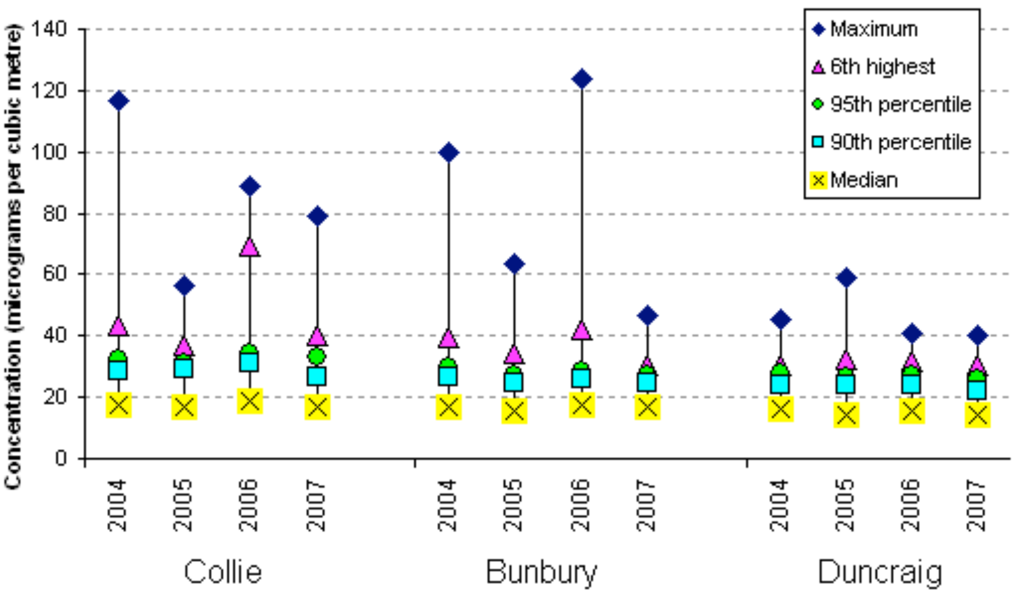


Figure 9 Daily averaged particles as PM_{10} in Collie, Bunbury and Duncraig

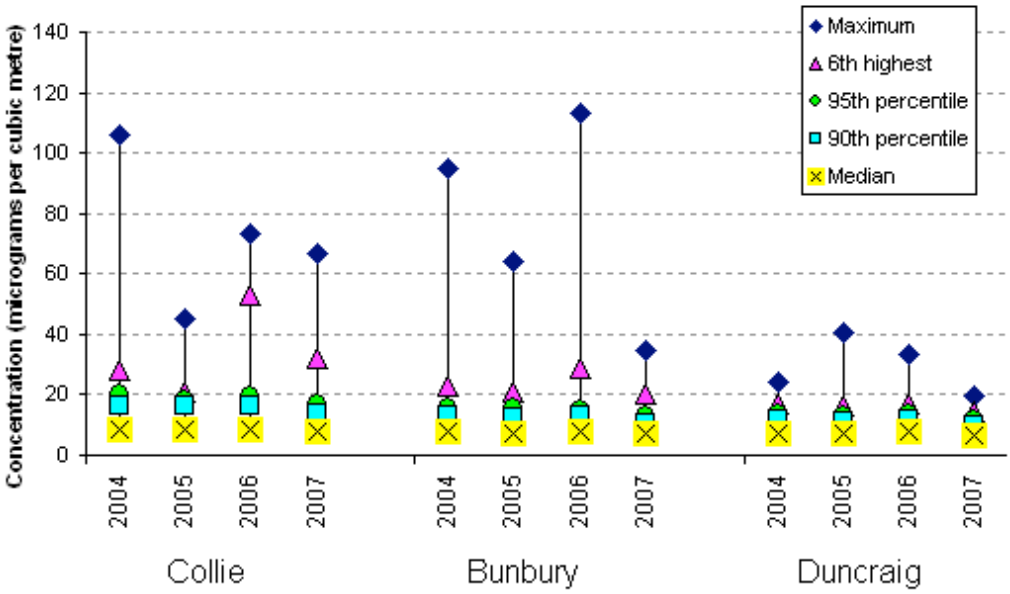


Figure 10 Daily averaged particles as $PM_{2.5}$ in Collie, Bunbury and Duncraig

4.3.2 Mass ratio

Table 11 gives the mass ratio of particles ($PM_{2.5}/PM_{10}$) during the different seasons in Collie and at a number of other urban/residential sites in Western Australia.

It can be seen that on average, $PM_{2.5}$ accounted for between 40 and 65 per cent of $PM_{10.}$ The $PM_{2.5}/PM_{10}$ mass ratios were relatively low (<0.45) during summer, indicating that the PM_{10} minus $PM_{2.5}$, also known as coarse particles, were a relatively large portion of PM_{10}. On the other hand, at Collie 65 per cent of the PM_{10} mass is composed of $PM_{2.5}$ particles during winter (Table 11). This figure is compared with $PM_{2.5}/PM_{10}$ mass ratios recorded in Duncraig, and Bunbury.

Table 11 Ratio of $PM_{2.5}$ to PM_{10} in Collie, Duncraig and Bunbury for 2004-2007

Monitoring site	Summer	Autumn	Winter	Spring
Collie[2]	0.40	0.54	0.65	0.51
Duncraig	0.44	0.50	0.55	0.48
Bunbury	0.42	0.49	0.50	0.48

4.4 Back trajectories

To investigate a relationship between particle concentrations and wind characteristics, which are considered to be one of the most important explanatory variables, wind trajectories were back-plotted for those days when

[2] The values for autumn and spring 2005 were not included for Collie

both PM_{10} and $PM_{2.5}$ exceeded 24-hour NEPM standards. Results are shown in Appendix 2.

The wind trace displayed in each map indicates the trajectory or path of air pollutants to the receptor. Wind speed determines the distance from the source to the receptor and also the time taken for the ambient pollutants to reach the receptor.

The back-trajectories enable tentative identification of the source of the pollution on the given day. As discussed in Appendix 2 the wind trajectories indicate that an apparent contribution to the particle exceedences experienced in Collie were controlled burns and private burns.

It is interesting to note that the ratios of $PM_{2.5}/PM_{10}$ in Appendix 2 are significantly different from the ratios estimated for the seasons shown in Table 11. This is understandable given most of the particles in the events discussed in Appendix 2 were generated by some form of combustion where the vast majority will be in the 2.5um fraction. Seasonal ratios, by their very length (3 months), incorporate both combustion events and anthropogenic sources such as wind borne dust and soil which tend to have a higher proportion of course particles.

5.0 CONCLUSIONS

An assessment of ambient particle data (PM_{10} and $PM_{2.5}$) was conducted for the period 2004-2007 with the aim to identify the need for future monitoring in the Collie area. Analysis indicates that the daily average concentration of PM_{10} exceeded the Air NEPM standard on an average of four days a year. However, in 2006, the daily average exceeded the Air NEPM standard on nine days. There were 20 days on average during the study period (2004-2007) when the daily average PM_{10} concentration exceeded the NEPM screening level acceptance limit.

The daily average concentration for $PM_{2.5}$ exceeded the Air NEPM advisory standard 10 times in 2004, 3 times in 2005, 13 times in 2006 and 9 times in 2007. When compared to Bunbury and Duncraig, Collie has the highest number of exceedences for both PM_{10} and $PM_{2.5.}$

Airborne particles exhibit distinct seasonal and diurnal patterns. The highest concentration of PM_{10} and $PM_{2.5}$ along with the highest number of exceedences occurred in autumn.

The study shows particle concentrations in Collie exceeded the advisory reporting standard for $PM_{2.5}$, and also recorded the highest number of exceedences when compared to Bunbury and Duncraig.

Results from the back trajectories analysis suggest that the most, if not all, of the PM_{10} and $PM_{2.5}$ exceedences were associated with emissions from fires. It should also be noted that there is a mix of conflicting land uses in the Collie area and potential sources of particles, which will also contribute to ambient concentrations. In some cases residential premises are located close to industrial operations. The area also includes transport related combustion sources such as domestic vehicles and heavy vehicles associated with industrial operations (including open-cut mines). All of these sources, under adverse meteorological conditions could affect the particle concentrations at the Roche Park monitoring station.

A draft of this report was critically reviewed by staff from the Marine and Atmospheric Research Division of CSIRO. Following the review it was recommended that particle sampling should be carried out, especially, during periods of high PM_{10} and $PM_{2.5}$ to determine the chemical composition of the samples. Results from this could include gravimetric mass concentration, organic carbon and elemental carbon concentration and estimation of the biomass burning contribution to PM_{10} and $PM_{2.5}$ by use of chemical tracer, such as levoglucosan.

It is recommended to continue the active monitoring of PM_{10} and $PM_{2.5}$ at Roche Park to give a longer temporal record in Collie, especially to assess any changes made to the power stations in future.

DEC has also installed a monitoring station in Collie in March 2008. This site has a PM_{10} TEOM and includes meteorological data. This site is close to the centre of town and will remain in place for the foreseeable future.

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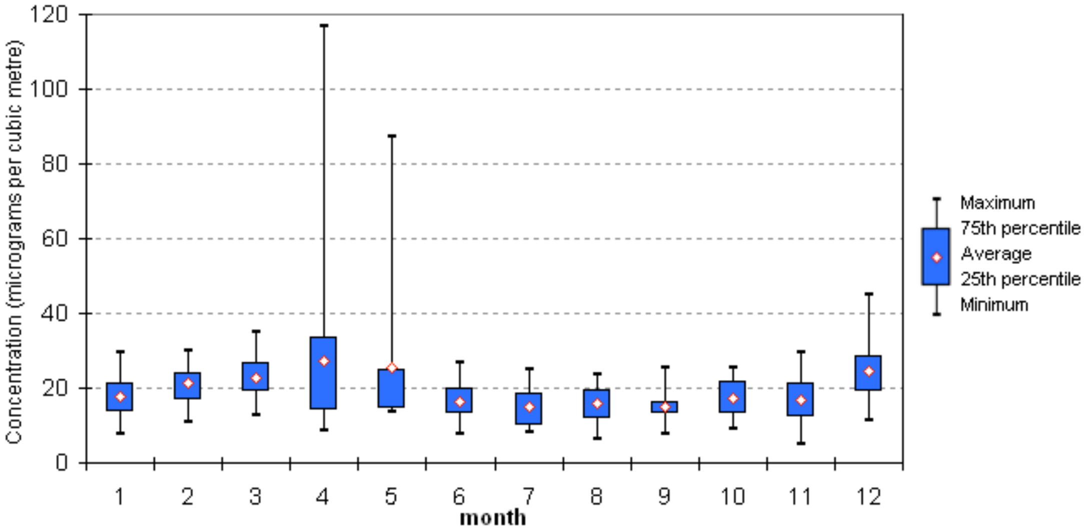
Appendix 1 – Box-whisker plot and monthly summaries of ambient particle concentrations at Roche Park, Collie monitoring station

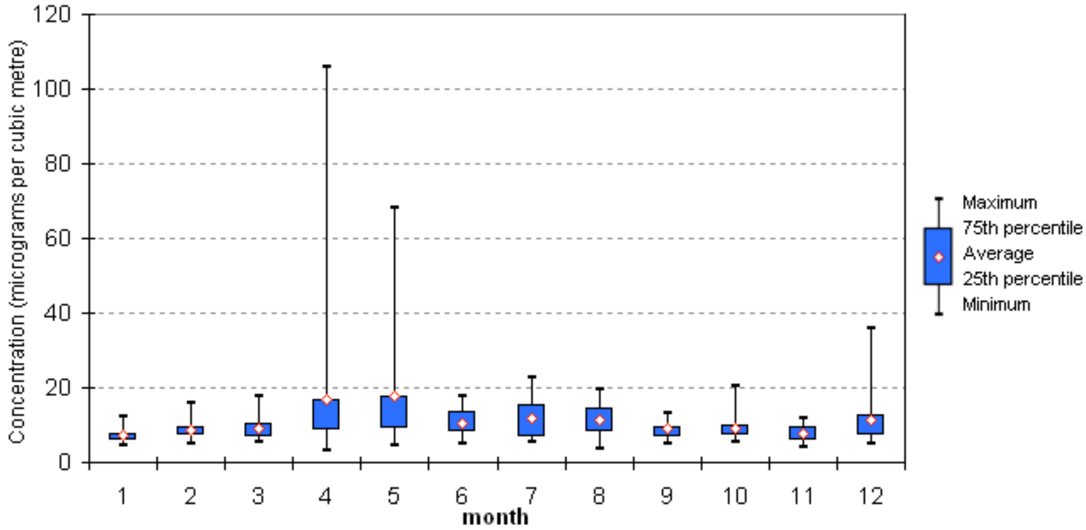
2004 PM_{10}



Monthly summary of PM_{10} data (2004)

Month	Maximum $\mu g/m^3$	2^{nd} highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 50 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	29.8	27.3	17.7		
February	29.8	28.9	21.3		
March	35.0	32.3	22.8		
April	116.8	46.8	27.5	1	1
May	87.5	43.5	25.5	1	
June	26.7	22.1	16.6		
July	25.1	24.6	15.1		
August	23.8	23.0	15.8		
September	25.2	20.1	15.0		
October	25.6	24.9	17.4		
November	29.6	27.9	16.9		
December	44.8	44.4	24.6		

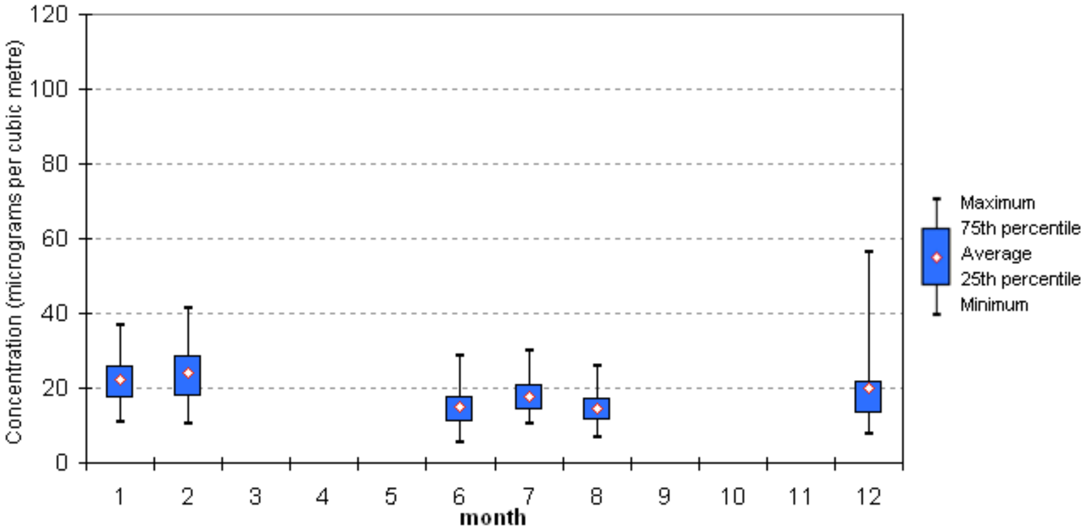
2004 $PM_{2.5}$



Monthly summary of $PM_{2.5}$ data (2004)

Month	Maximum $\mu g/m^3$	2^{nd} highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 25 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	12.5	11.6	7.1		
February	15.7	14.7	8.7		
March	17.9	15.6	8.9		
April	105.9	34.9	16.7	5	
May	68.0	34.6	17.7	4	
June	17.7	17.4	10.6		
July	22.7	18.9	11.6		
August	19.6	19.5	11.4		
September	13.1	12.8	8.9		
October	20.6	15.8	9.1		
November	11.8	11.6	7.7		
December	36.0	25.0	11.3	1	

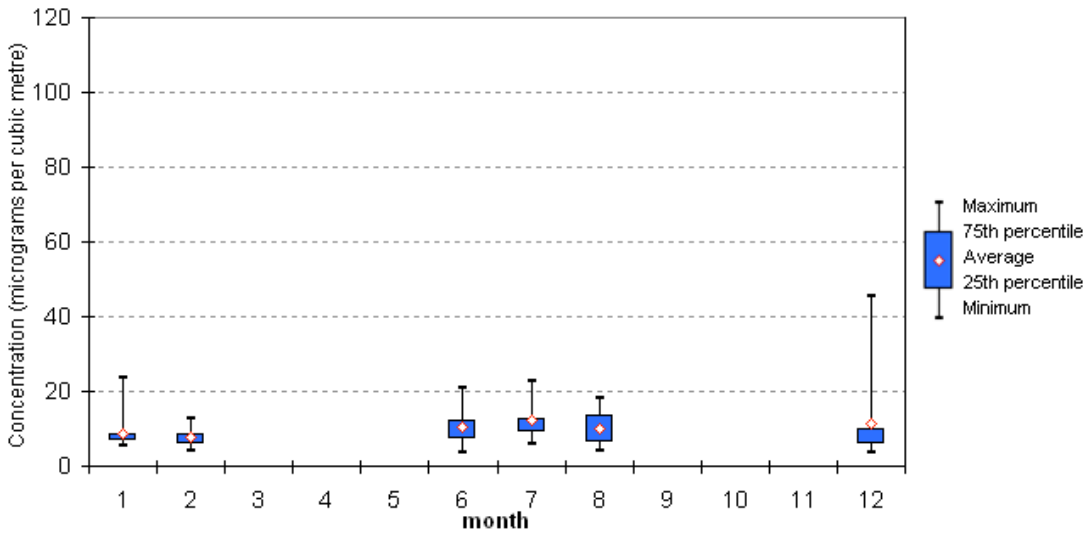
2005 PM_{10}



Monthly summary of PM_{10} data (2005)

Month	Maximum $\mu g/m^3$	2^{nd} highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 50 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	36.9	33.0	22.2		
February	41.5	40.3	23.9		
March					
April					
May					
June	28.5	27.2	15.0		
July	29.9	29.4	17.9		
August	26.0	21.4	14.7		
September					
October					
November					
December	56.4	48.6	19.8	1	

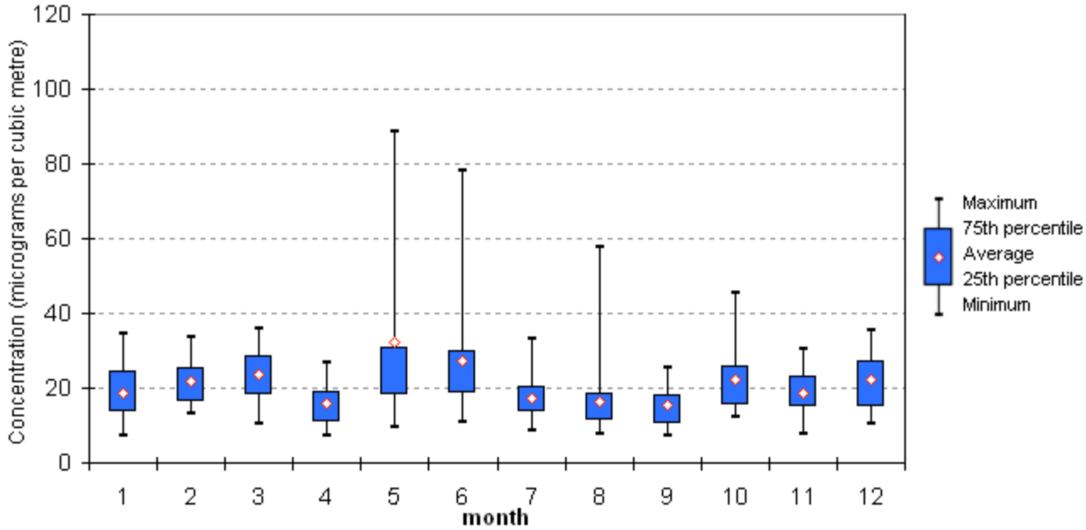
2005 $PM_{2.5}$



Monthly summary of $PM_{2.5}$ data (2005)

Month	Maximum $\mu g/m^3$	2^{nd} highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 25 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	23.4	17.2	8.7		
February	12.8	11.1	7.7		
March					
April					
May					
June	20.7	20.6	10.5		
July	22.7	20.4	12.1		
August	18.1	17.5	10.0		
September					
October					
November					
December	45.4	37.0	11.1	3	

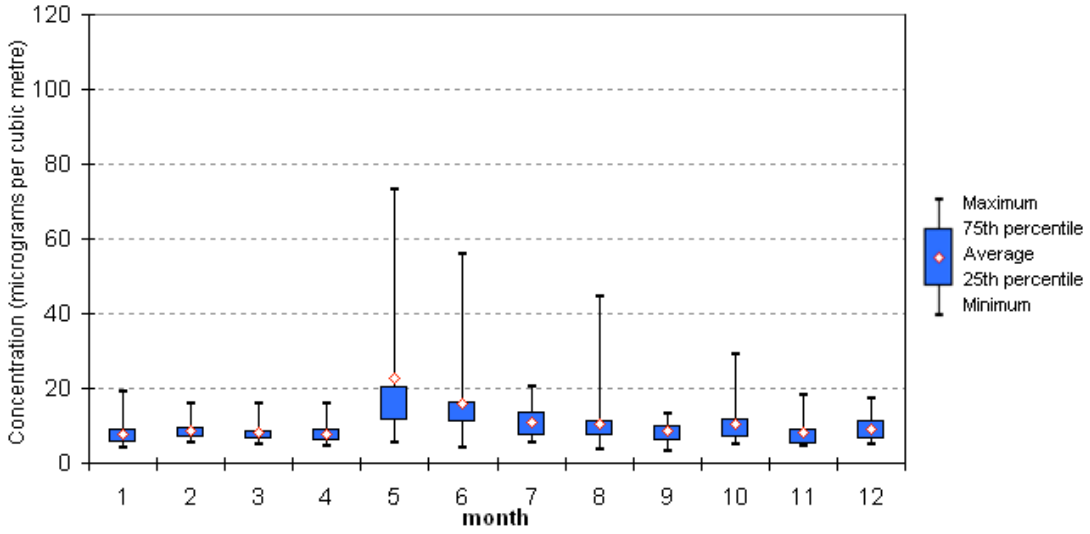
2006 PM_{10}



Monthly summary of PM_{10} data (2006)

Month	Maximum $\mu g/m^3$	2^{nd} highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 50 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	34.6	33.0	18.7		
February	33.8	31.7	22.0		
March	36.0	32.2	23.6		
April	26.6	26.2	15.7		
May	88.8	81.8	32.4	6	
June	78.3	66.9	27.2	2	
July	33.2	26.4	17.1		
August	57.6	24.4	16.6	1	
September	25.3	24.0	15.4		
October	45.5	42.7	22.4		
November	30.3	28.7	18.8		
December	35.6	34.3	22.2		

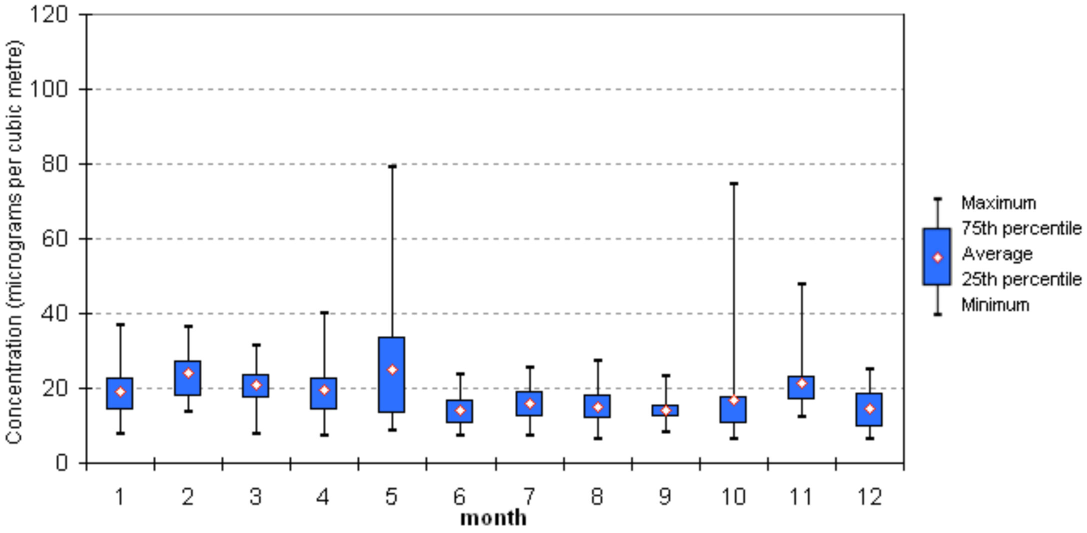
2006 $PM_{2.5}$



Monthly summary of $PM_{2.5}$ data (2006)

Month	Maximum $\mu g/m^3$	2nd highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 25 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	19.0	14.5	7.6		
February	16.0	15.3	8.6		
March	15.7	13.4	8.1		
April	15.7	12.1	7.9		
May	73.3	67.0	22.9	7	
June	55.8	53.0	16.0	2	
July	20.4	20.4	10.9		
August	44.7	16.6	10.5	1	
September	13.0	12.7	8.5		
October	29.3	25.5	10.7	3	
November	18.1	15.7	8.0		
December	17.1	14.7	8.9		

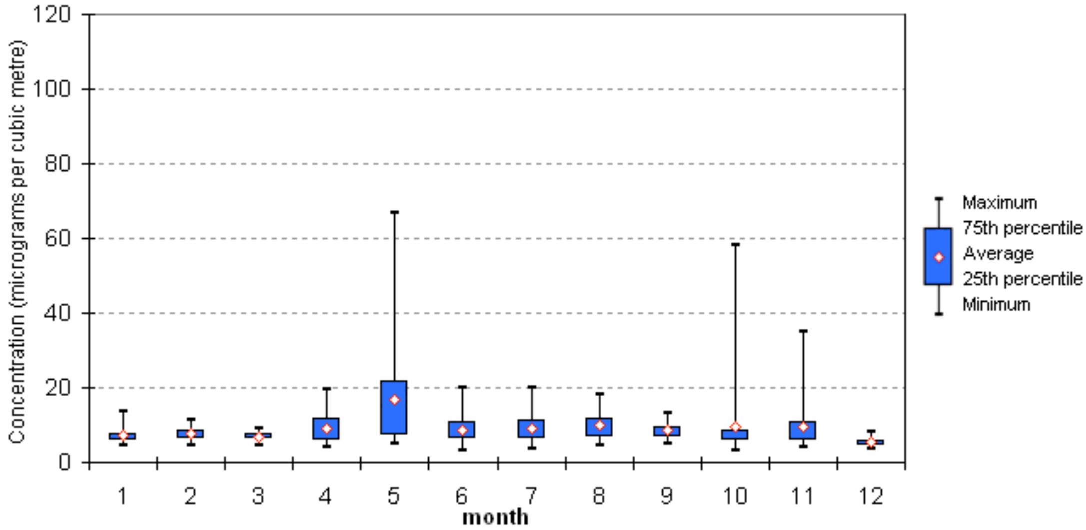
2007 PM_{10}



Monthly summary of PM_{10} data (2007)

Month	Maximum $\mu g/m^3$	2nd highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 50 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	36.8	35.9	19.0		
February	36.5	36.4	24.1		
March	31.6	29.7	20.8		
April	40.0	35.3	19.5		
May	79.2	45.9	24.9	1	
June	23.5	19.3	14.1		
July	25.5	24.1	16.1		
August	27.2	24.9	15.1		
September	23.4	21.6	14.2		
October	74.7	34.5	16.8	1	
November	47.6	30.9	21.5		
December	25.2	23.9	14.5		

2007 $PM_{2.5}$

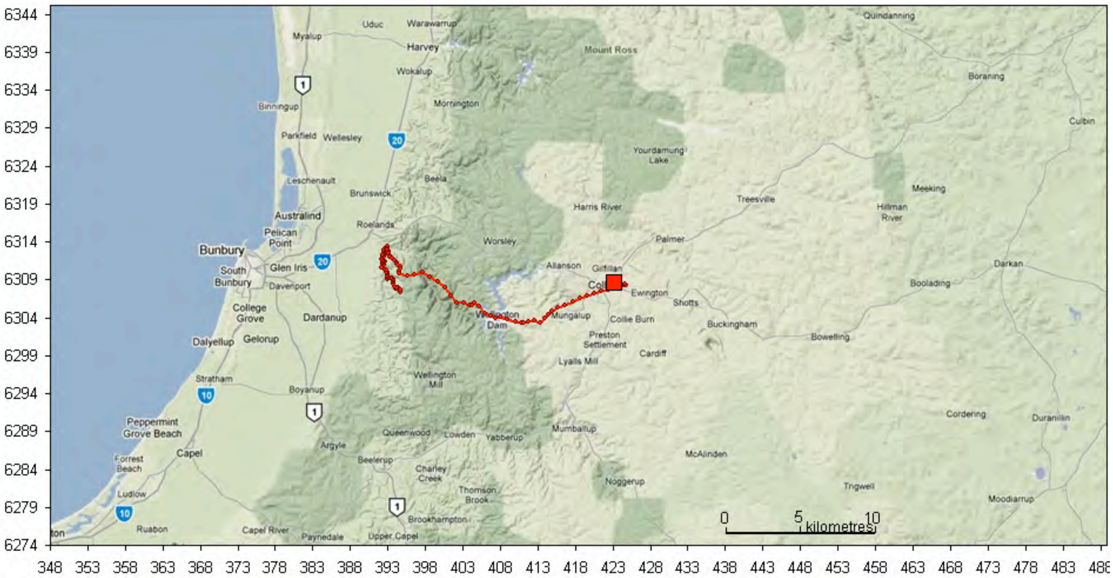


Monthly summary of $PM_{2.5}$ data (2007)

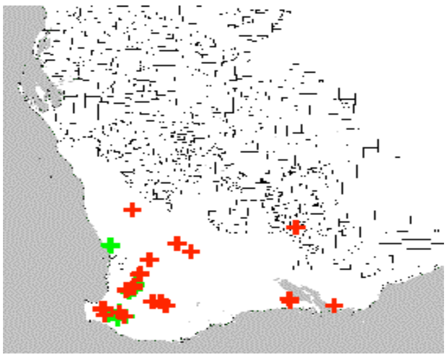
Month	Maximum $\mu g/m^3$	2nd highest $\mu g/m^3$	Monthly average $\mu g/m^3$	No of daily averages > 25 $\mu g/m^3$	No of daily averages > 100 $\mu g/m^3$
January	13.8	12.9	7.3		
February	11.3	11.1	7.7		
March	9.2	8.7	7.0		
April	19.6	17.0	9.1		
May	66.7	40.4	17.0	7	
June	19.8	13.1	8.5		
July	20.1	14.3	9.0		
August	18.0	17.5	9.8		
September	13.4	12.2	8.6		
October	58.1	23.4	9.3	1	
November	35.2	15.2	9.4	1	
December	8.2	8.0	5.6		

Appendix 2 Back-trajectories for exceedences of the NEPM PM_{10} standard and the NEPM $PM_{2.5}$ advisory standard.

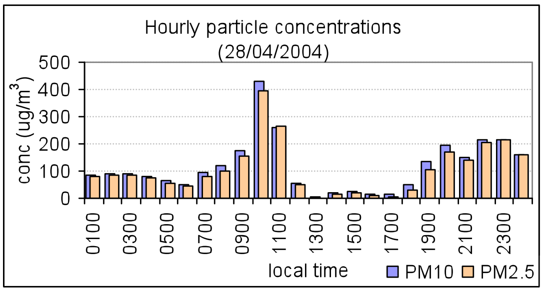
PM_{10} and $PM_{2.5}$ exceedences on 28 April 2004

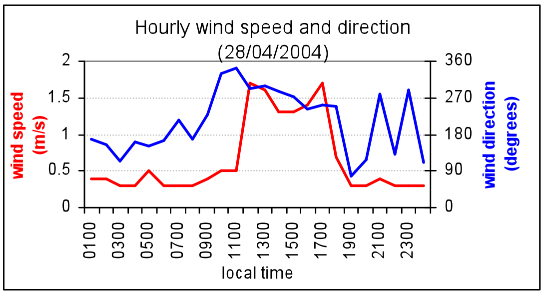


Back trajectory to Collie AQMS over 1380 minutes ending at 11:00 PM on 28/04/2004



MODIS hotspot detection [Terra-1 APR 28 22:20 2004 WST]





Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

PM_{10}	116.8 µg/m³
$PM_{2.5}$	105.9 µg/m³
Ratio $PM_{2.5}/PM_{10}$	0.91

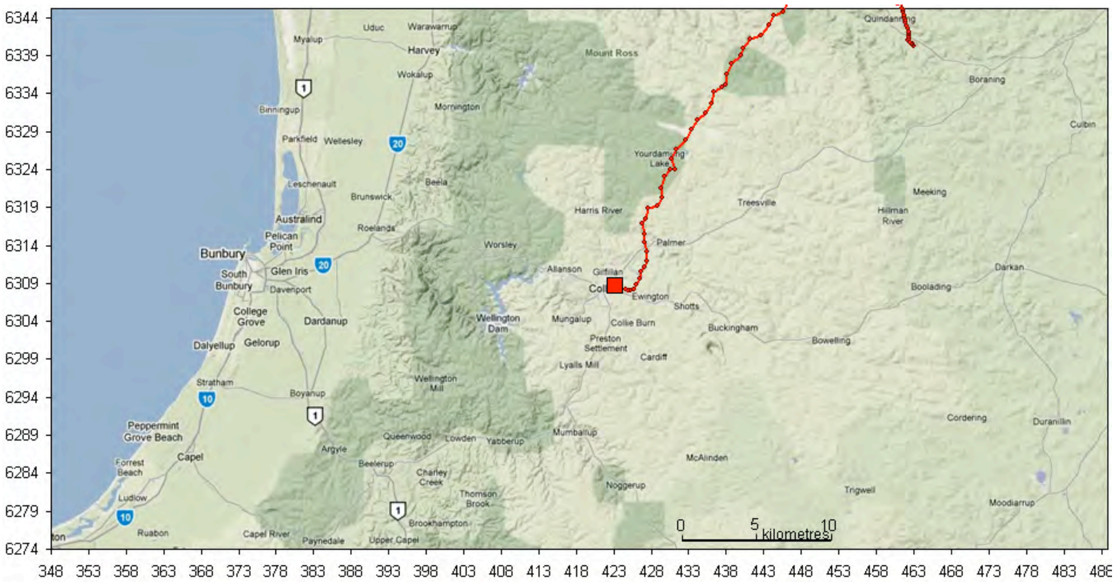
NEPM standard

PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

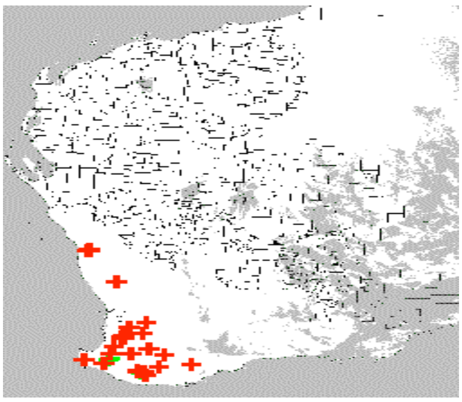
Description of event

The wind trajectory and measurements of wind speed and directions indicate a possible cause to the PM_{10} and $PM_{2.5}$ exceedences in Collie was controlled burns at Davis (20 km south-east of Collie), Mungalup (17 km north-east of Collie), Westralia (2 km west of Collie) and Yabberup (25 km south-west of Collie) as shown by satellite map (the fires as red crosses in the region of interest).

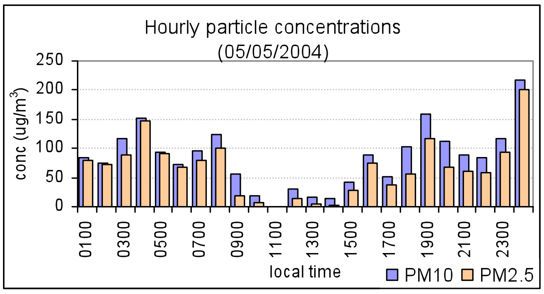
PM_{10} and $PM_{2.5}$ exceedences on 5 May 2004

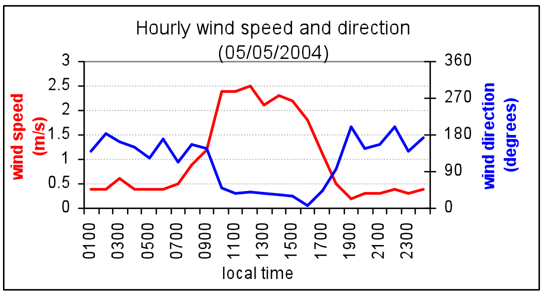


Back trajectory to Collie AQMS over 1140 minutes ending at 07:00 PM on 05/05/2004



MODIS hotspot detection [Aqua-1 MAY 05 00:56 2004 WST]





Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

PM_{10}	87.5 µg/m³
$PM_{2.5}$	68.0 µg/m³
Ratio $PM_{2.5}/PM_{10}$	0.78

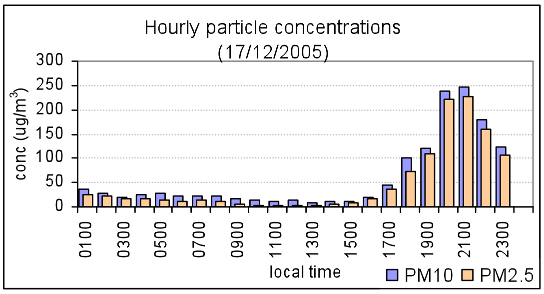
NEPM standard

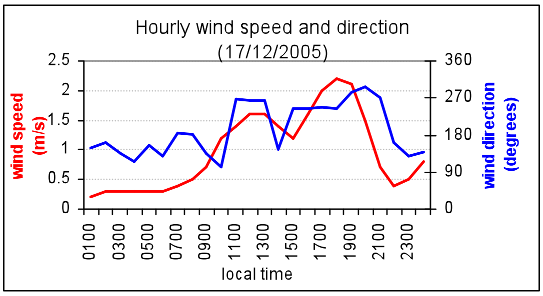
PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

Description of event

The wind trajectory and wind speed and directions observations indicate the likely cause to the PM_{10} and $PM_{2.5}$ exceedences in Collie was controlled burns 30 km east of Harvey which started to burn on 4 May 2004 and continued to the next day. The satellite map shows the fires as red crosses in the region of interest.

PM_{10} and $PM_{2.5}$ exceedences on 17 December 2005





Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

PM_{10}	56.4 µg/m³
$PM_{2.5}$	45.4 µg/m³
Ratio $PM_{2.5}/PM_{10}$	0.81

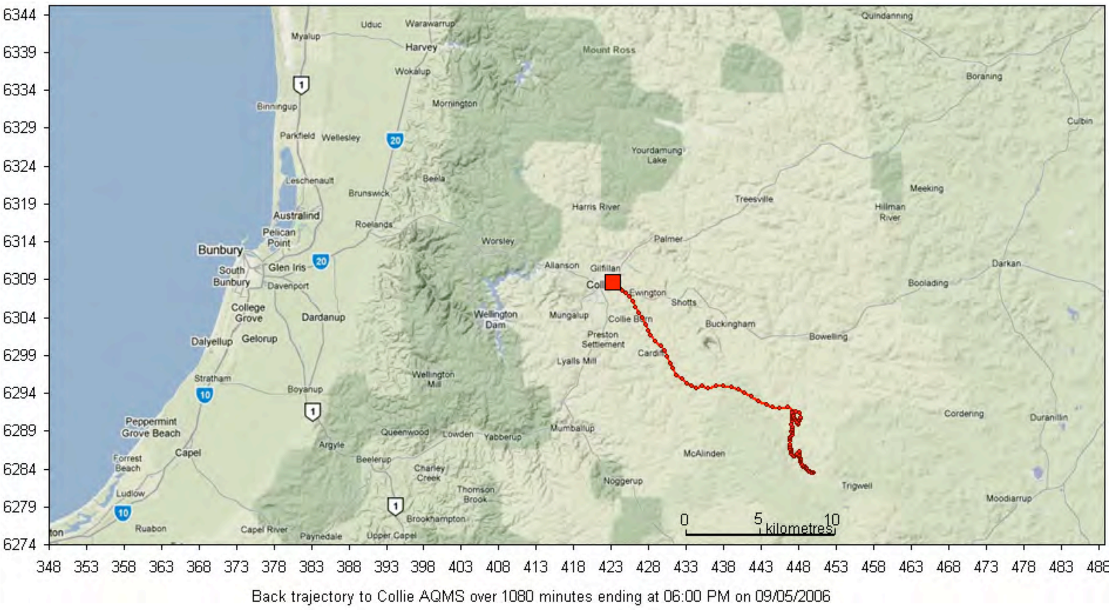
NEPM standard

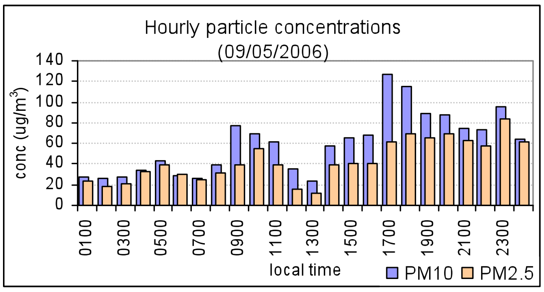
PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

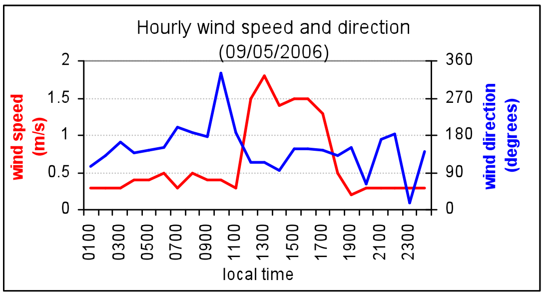
Description of event

Controlled burns conducted for biodiversity protection at Gervasse 15 km west of Collie and Davis 18 km south-west of Collie on 16 December 2005 caused exceedences of PM_{10} and $PM_{2.5}$ in Collie as indicated by back trajectory and wind observations.

PM_{10} and $PM_{2.5}$ exceedences on 9 May 2006







Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

PM_{10}	59.7 µg/m³
$PM_{2.5}$	43.1 µg/m³
Ratio $PM_{2.5}/PM_{10}$	0.72

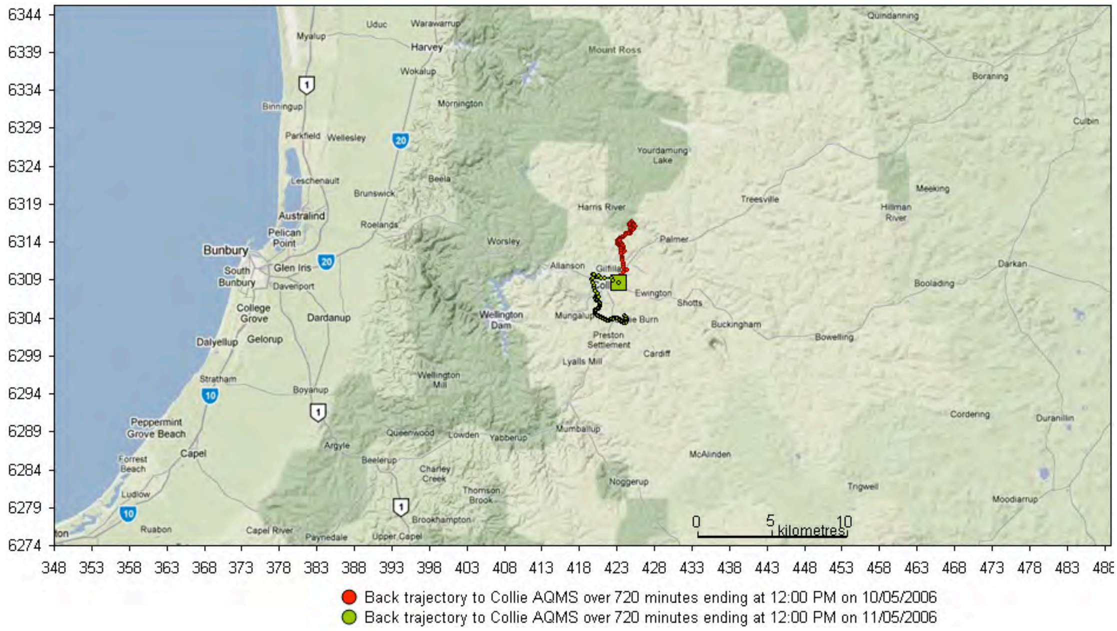
NEPM standard

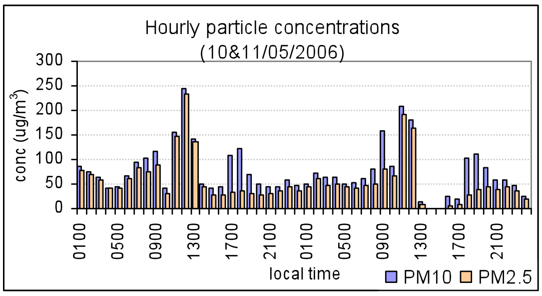
PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

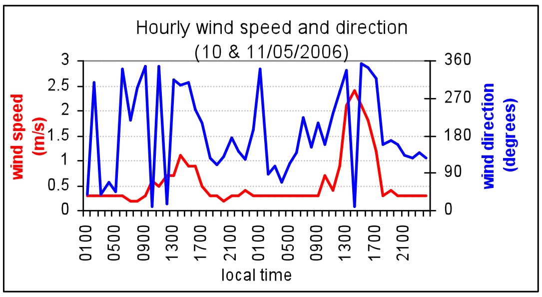
Description of event

The wind trajectory indicates that a likely cause to the PM_{10} and $PM_{2.5}$ exceedences in Collie was wood-heater smoke with contributions from a 1390 ha controlled burn at Muja 26 km south-east of Collie on 8 May 2006. Hourly measurements of wind speed and wind directions plotted for the day confirmed the cause of elevated particle matter concentration.

PM_{10} and $PM_{2.5}$ exceedences on 10 and 11 May 2006







Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

	10/05/06	11/05/06
PM_{10} (µg/m³)	81.8	69.6
$PM_{2.5}$ (µg/m³)	63.1	48.1
Ratio $PM_{2.5}/PM_{10}$	0.78	0.69

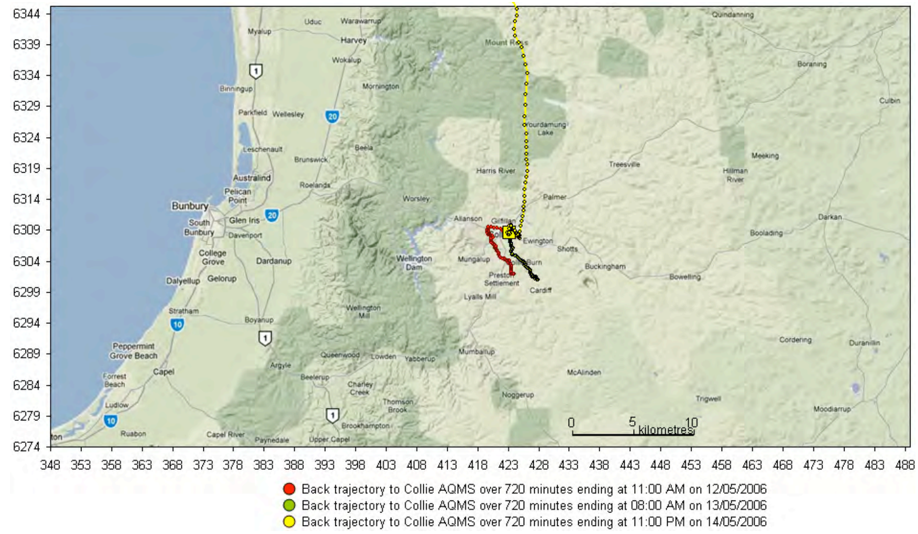
NEPM standard

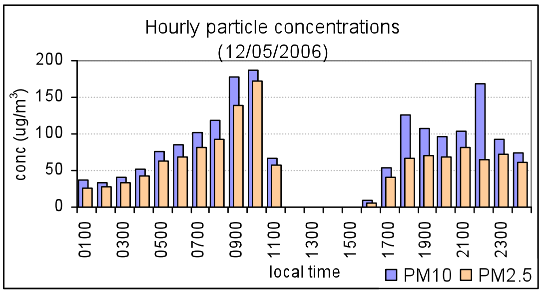
PM_{10} : 50 µg/m³
$PM_{2.5}$: 25 µg/m³

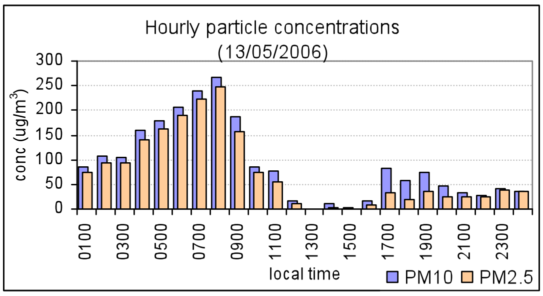
Description of event

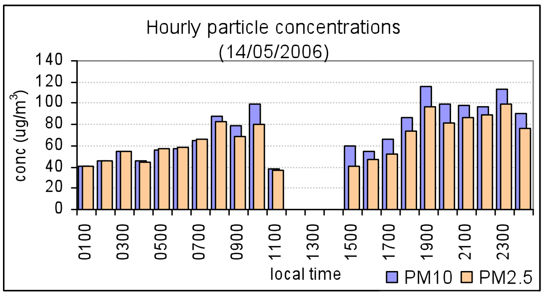
Low wind speed caused an accumulation of wood heater smoke within the Collie area as identified by plotted wind observations and estimated back trajectory.

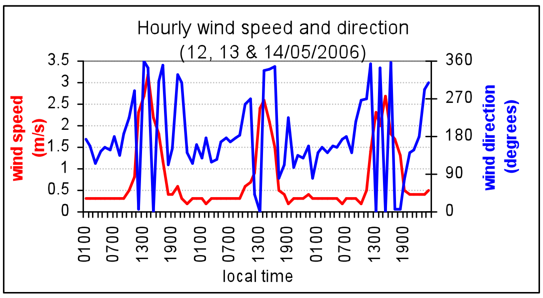
PM_{10} and $PM_{2.5}$ exceedences on 12, 13 and 14 May 2006











Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily average concentration

Date	12/05/06	13/05/06	14/05/06
PM_{10}	74.0	88.8	73.8
$PM_{2.5}$	53.8	73.3	67.0
Ratio $PM_{2.5}/PM_{10}$	0.73	0.83	0.91

Concentrations in µg/m³

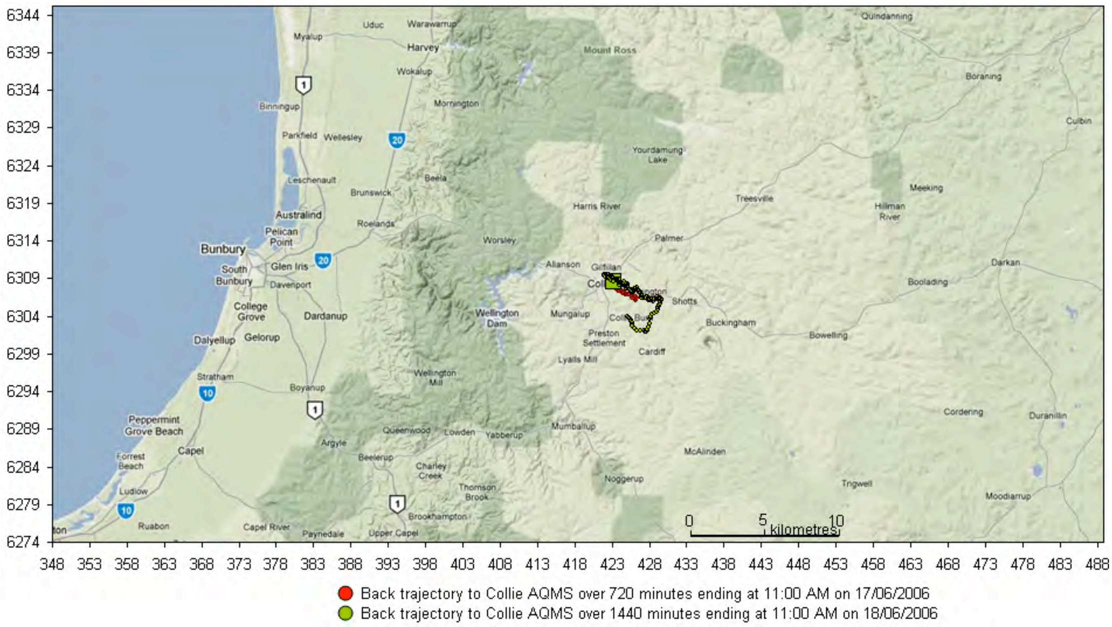
NEPM standard

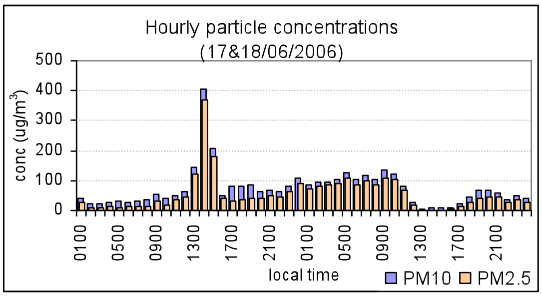
PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

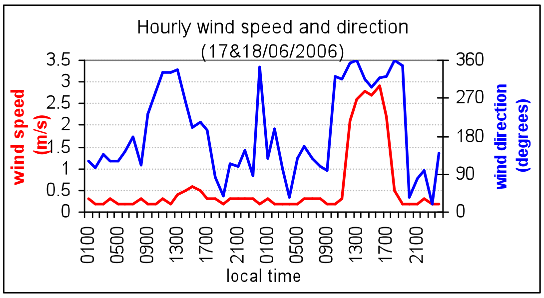
Description of event

Private property burns and wood-heater smoke around Collie together with a prescribed burn at Palmer 17 km north-east of Collie under lower wind speed caused an elevated level of particle matter in the Collie area.

PM_{10} and $PM_{2.5}$ exceedences on 17 and 18 June 2006







Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

	17/06/06	18/06/06
PM_{10} (µg/m³)	78.3	66.9
$PM_{2.5}$ (µg/m³)	55.8	53.0
Ratio $PM_{2.5}/PM_{10}$	0.71	0.79

NEPM standard

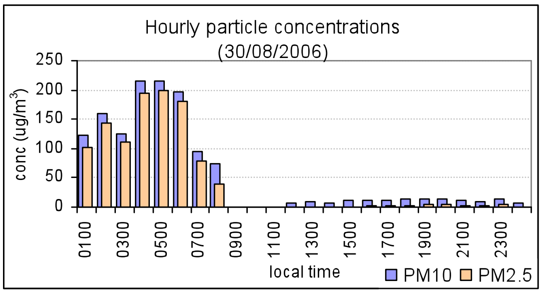
PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

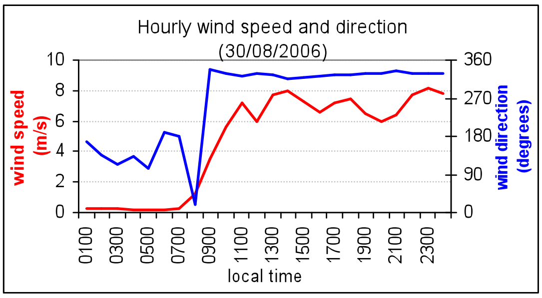
Description of event

The likely cause to the PM_{10} and $PM_{2.5}$ exceedences in Collie as indicated by backward wind trajectories and wind observations was bushfires around Collie (15 km north-west, 15 km west-north-west, 17 km north on 14 June 2006), a controlled burn at Wellington 13 km north-west, private burns by property owners and wood-heater smoke.

PM_{10} and $PM_{2.5}$ exceedences on 30 August 2006

Back trajectory to Collie AQMS over 1440 minutes ending at 06:00 AM on 30/08/2006





Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

PM_{10}	57.6 µg/m³
$PM_{2.5}$	44.7 µg/m³
Ratio $PM_{2.5}/PM_{10}$	0.78

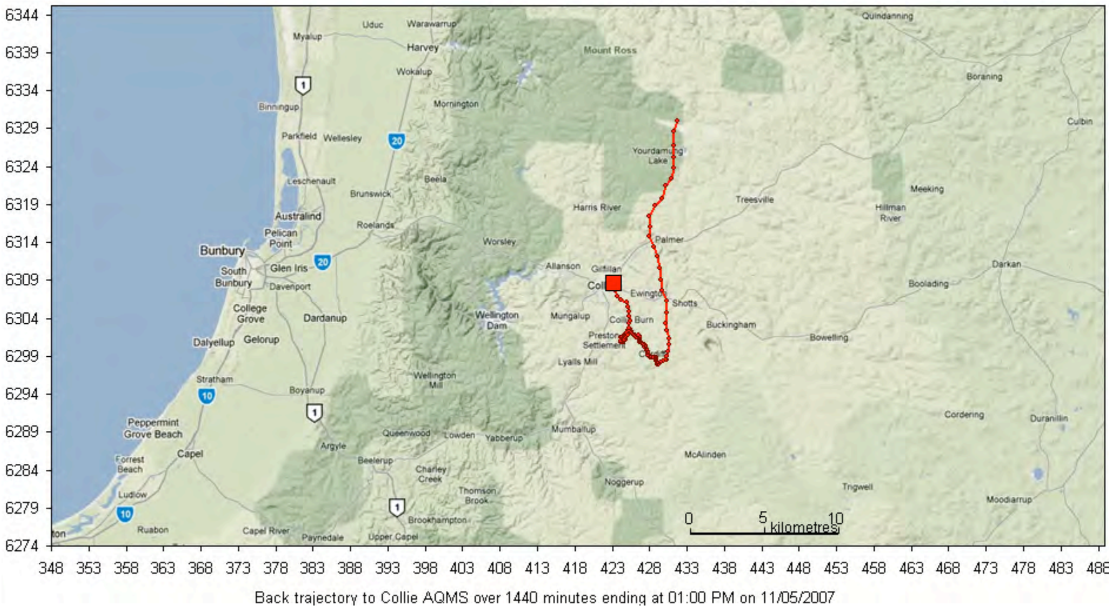
NEPM standard

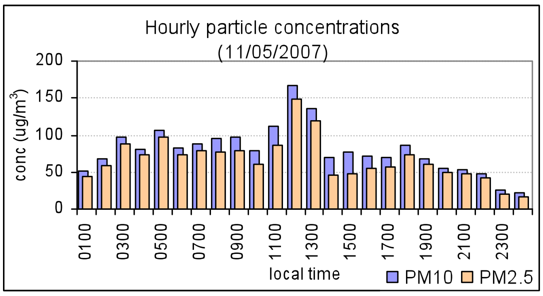
PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

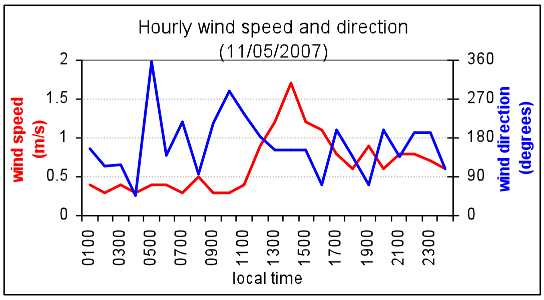
Description of event

The likely cause to the PM_{10} and $PM_{2.5}$ exceedences in Collie as indicated by backward wind trajectories and wind observations are controlled burns at Armadale and private burns by property owners and wood-heater smoke.

PM_{10} and $PM_{2.5}$ exceedences on 11 May 2007







Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily averaged concentration

PM_{10}	79.2 μg/m³
$PM_{2.5}$	66.7 μg/m³
Ratio $PM_{2.5}/PM_{10}$	0.84

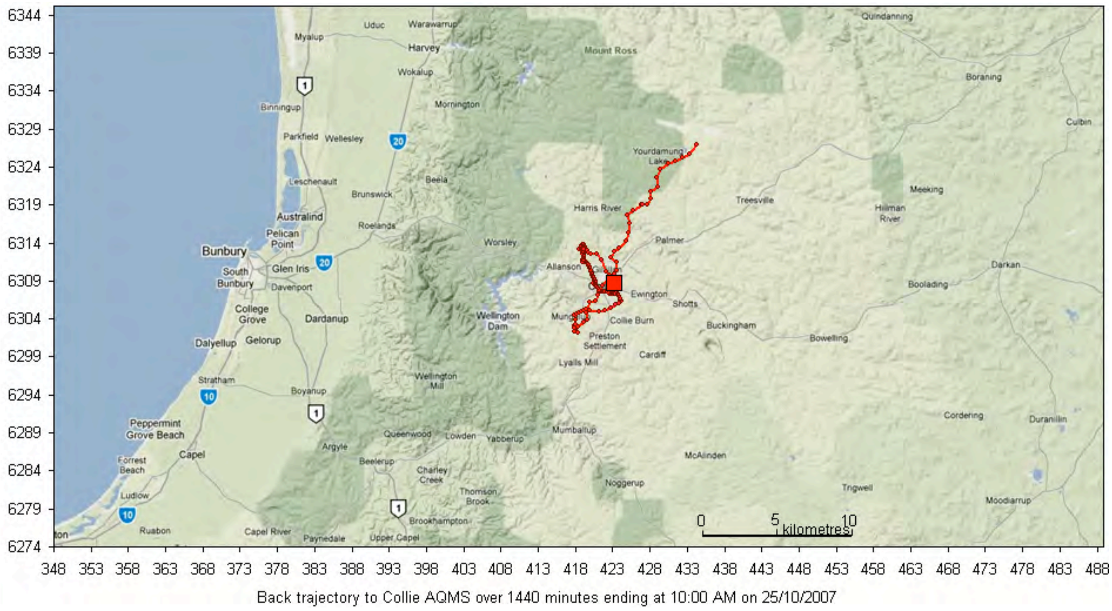
NEPM standard

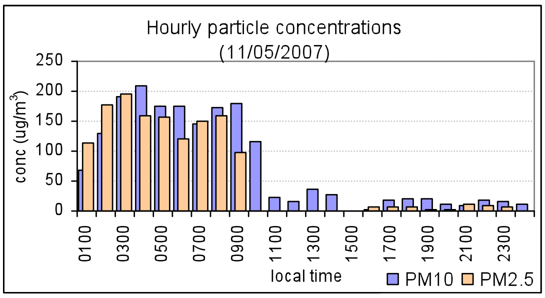
PM_{10} : 50 μg/m³
$PM_{2.5}$: 25 μg/m³

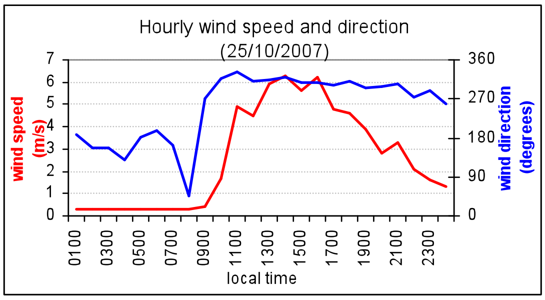
Description of event

The wind trajectory and wind observations indicate that a likely cause of the exceedences of PM_{10} and $PM_{2.5}$ in Collie was controlled burns at Morgan and Bennelaking on 11 May 2007 and at Palmer on 16 May 2007.

PM_{10} and $PM_{2.5}$ exceedences on 25 October 2007







Pollutant

PM_{10}, $PM_{2.5}$

Monitoring site

Collie

Daily average concentration

PM_{10}	74.7 µg/m³
$PM_{2.5}$	58.1 µg/m³
Ratio $PM_{2.5}/PM_{10}$	0.78

NEPM standard

PM_{10}: 50 µg/m³
$PM_{2.5}$: 25 µg/m³

Description of event

The wind trajectory indicates that an apparent cause to the PM_{10} and $PM_{2.5}$ exceedences in Collie was controlled burns at Palmer 10 km north, Edward 15 km north, Sherwood ,17 km south of Collie on 23 October 2007 and at Batalling-35 km east, Darkan, 17 km west of Collie on 24 October 2007.