Department of
Environment and Conservation

Background Air Quality Monitoring in Kwinana 2005–10

Technical Report





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Prepared by
Department of Environment and Conservation
Air Quality Management Branch

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Executive summary

In 2004, the then Department of Environment began developing the Background Air Quality Study (BAQS). The BAQS was initiated to assess ambient concentrations of a class of pollutants known as ’air toxics‘ in the Perth metropolitan and selected regional areas. The study was conducted in three phases—2005–06, 2007–08 and 2009–10.

The Kwinana Airshed Study Advisory Group (KASAG) was formed in 2008 with membership from industry, community and Government to advise on the direction of and validity of the studies performed in Kwinana under this program. The KASAG members provided valuable local knowledge and direction during the planning and implementation of Phase 3 of this program.

The study commenced in 2005, and initially focused on VOCs, heavy metals, PAHs and carbonyl compounds at Duncraig, Queens Buildings, and Hope Valley. After community consultation, this initial phase was extended to include monitoring of volatile organic compounds (VOCs), nitrogen dioxide (NO_2), ammonia (NH_3) and fine particles ($PM_{2.5}$) at seven additional locations within the Kwinana and Rockingham areas. A combination of active and passive air samplers were used in this phase of the BAQS. Following additional community consultation, air monitoring of VOCs, carbonyls and ammonia was conducted from 2007 to 2008 in the Kwinana area. During this second phase of the BAQS, samples were collected using passive samplers. The third phase of the BAQS was conducted at Hillman and Calista from 2009 to 2010 and focused on oxides of nitrogen (NO_x) and $PM_{2.5}$.

The levels of air toxics recorded during the three studies of 2005–06, 2007–08 and 2009–10 were similar to those found elsewhere in the Perth metropolitan area and were within health guidelines, except for acrolein, crotonaldehyde and methacrolein which the Department of Health (DOH) has advised are not sufficiently increased to cause a health concern for the majority of people. The majority of elevated crotonaldehyde, acrolein and methacrolein concentrations occurs in the summer months and is most likely due to various smoke events originating in the south-west of the state. The number of complaints by the local community shows that there is strong interest in air quality in the region. Unfortunately limitations with current monitoring technologies available make it difficult to determine the root cause of many of these complaints.

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Glossary

Aerodynamic diameter	The diameter of a sphere of unit density (i.e. 1 g per cm^3) which has the same settling velocity in the same gas as the particle being measured. It is also known as aerodynamic equivalent diameter (AED). Particles with the same AED are dynamically (although not necessarily physically) identical.
Air toxics	Gaseous, aerosol or particle pollutants which are present in the air in low concentrations with characteristics such as toxicity and persistence so as to be a hazard to human, plant or animal life.
ATSDR	United States Agency for Toxic Substances and Disease Registry
Back trajectory	A trajectory is the path a parcel of air takes as it responds to changes in winds at different locations and times. A back trajectory indicates the recent history of a parcel of air before a given time.
BAQS	Background Air Quality Study
Cumulative frequency graph	The cumulative frequency value corresponding to a particular concentration is the total number of periods where the pollutant concentration is greater than or equal to the indicated concentration.
DEC	Western Australian Department of Environment and Conservation
DOH	Western Australian Department of Health
EPP	Environmental Protection Policy
Heavy metals	Heavy metals are elements and therefore cannot be destroyed, nor can their properties be easily altered. In the context of this study, heavy metals are elements that generally exist as a solid at room temperature and so may not, in the strict sense of the word, actually be a metal or be one of the heavier elements.
HiVol	A high volume sampler draws a large known volume of air through a filter paper over a 24-hour period. This filter is weighed both before and after sampling. The difference in filter weight divided by the volume of air gives the average concentration of particles in the air over the 24-hour sampling period. The filters can be analysed for heavy metals.
Log 10 scale	Scale where each successive period or distance is equal to 10 times the previous period or distance. Presentation of data on a logarithmic scale is helpful when the data covers a large range of values—the logarithm reduces this to a more manageable range.
KIA	Kwinana Industrial Area
KIC	Kwinana Industry Council
Micrometre (µm)	0.000 001 or 10^{-6} metres
Microgram (µg)	0.000 001 or 10^{-6} gram
Nanograms (ng)	0.000 000 001 or 10^{-9} gram
NEPM	National Environment Protection Measure
NH_3	Ammonia
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen— includes both NO and NO_2

OAQC	Ontario Ambient Air Quality Criteria
$PM_{2.5}$	Particulate matter with an equivalent aerodynamic diameter of 2.5 micrometres (0.000 002 5 metres) or less.
PM_{10}	Particulate matter with an equivalent aerodynamic diameter of 10 micrometres (0.000 010 metres) or less.
Pollution rose	The pollution rose shows the mean source strength by wind sector and wind speed category. These plots can indicate the source location for local sources. Winds less than 0.5 ms^{-1} are not used in generating this plot, since the wind direction is not always clear for low winds.
ppb	Parts per billion by volume (equivalent to 0.001ppm)
ppm	Parts per million by volume (equivalent to 1,000ppb)
TCEQ	Texas Commission on Environmental Quality
TEOM	Tapered Element Oscillating Microbalance. An instrument for measuring the mass concentration of aerosol in air
TSP	Total suspended particulates. Particles of solid or liquid matter such as soot, dust, aerosols, fumes and mist up to approximately 30 micrometres in size.
$\mu g/m^3$	Micrograms per cubic metre. A unit of measurement for the concentration of a gas or particulate matter in the atmosphere based on its density. (mass per unit volume of air)
ng/m^3	Nanograms per cubic metre. A unit of measurement for the concentration of a gas or particulate matter in the atmosphere based on its density. (mass per unit volume of air)
UKEA	United Kingdom Environmental Agency
VOC	Volatile organic compounds (VOCs) are compounds with boiling points between 50 and 260 degrees Celsius that readily evaporate and remain in the air as gases at normal ambient temperatures. This group includes a very large group of compounds that have carbon atoms as a primary component
WHO	World Health Organisation
Wind rose	The wind rose correlates wind direction data with wind speed. The length of the line corresponds to the frequency of readings in that direction, while the line thickness corresponds to the magnitude of the speed value.

Introduction

In 2004, the then Department of Environment began developing the Background Air Quality Study (BAQS). The BAQS was initiated to assess ambient concentrations of a class of pollutants known as 'air toxics' in the Perth metropolitan and selected regional areas. Air toxics are gaseous, aerosol or particle pollutants which are present in the air in low concentrations that can be harmful to human, plant or animal life. The term air toxics and 'hazardous air pollutants' can be used interchangeably. Air monitoring for the BAQS was conducted in three phases during the period from 2005 to 2010 (2005–06, 2007–08 and 2009–10). Table 1.1 outlines the phases of the BAQS.

Table 1.1 Kwinana region air toxics sampling conducted since 2005.

Phase	When	What	Where
Phase 1: 2005–06	Jan 05–Jul 06	VOCs Carbonyls Heavy metals PAHs	Hope Valley (HV)
	May 05–Jul 06	VOCs NO_2 Ammonia	Munster (MU) Wattleup (WR) Medina (ME) Calista (CA) Challenger (CH) North Rockingham (NR) Kwinana Beach (KB)
	Sep 05–Sep 06	$PM_{2.5}$ particles	Kwinana (KW) Rockingham (RO)
Phase 2: 2007–08	Jul 07–Aug 08	VOCs Carbonyls Ammonia	Benjamin Way (BW) Governor Rd (GR) Kwinana Beach (KB) Thomas/Mason Rd (TM) Hope Valley (HV) Henderson (HE) James Point (JP) Kwinana Container Terminal (KC) Wellard Rd (WR) Orelia Oval (OO) Kwinana Freeway (KF) Mandogalup Rd MR) Thomas Oval (TO) Kwinana Golf Course (KG)
Phase 3: 2009–10	May 09–June 10	$PM_{2.5}$ particles NO_2 Heavy metals	Calista (CA) Hillman (HI)

2005–06 study

Sampling for air toxics in Perth initially commenced in January 2005 and continued through 2006. The study focused on volatile organic compounds (VOCs), heavy metals, polycyclic aromatic hydrocarbons (PAHs) and carbonyl compounds.
Sampling during this first phase was undertaken at three metropolitan sites; Duncraig, Queens Buildings and Hope Valley. Duncraig is located in a residential area about 16 kilometres north-west of the Perth Central Business District (CBD). Queens Buildings is an inner-city site with a major road intersection and very heavy traffic flow. Hope Valley is a site located south of the Perth CBD in an industrial buffer zone next to the Kwinana Industrial Area (KIA). The KIA has been home to Western Australia's premier industrial site for more than 50 years. Growth of Perth's southern corridor has meant that industrial impacts on urban communities have become increasingly important.

After community consultation, the BAQS was extended to include monitoring of volatile organic compounds (VOCs), nitrogen dioxide (NO_2), ammonia (NH_3) and fine particles ($PM_{2.5}$) at seven additional locations within the Kwinana and Rockingham areas. A combination of active and passive air samplers were used in this phase of the BAQS. The Kwinana region is located about 25 kilometres south of the Perth CBD. A map of the Kwinana region with the locations of the 2005–06 sites is shown in Figure 1.1.

Radiello® passive samplers were used to measure six-day averages of VOCs, NO_2 and NH_3 concentrations over one year. Passive samplers were chosen due to the absence of power at chosen locations. $PM_{2.5}$ sampling was also carried out using a Tapered Element Oscillating Microbalance (TEOM) at the Kwinana Town Centre and Rockingham City Shopping Centre. TEOMs provide information on the concentration of particles in the air and operate continuously with data being collected every 10 minutes.

2007–08 study

After the completion of the 2005–06 study, more consultation was held with community groups resulting in additional sampling in 2007–08 in the Kwinana and Rockingham area. During this second phase of the BAQS, VOCs, carbonyls and ammonia were monitored using passive samplers. A map with the locations of the 2007–08 sites is shown in Figure 1.2.

The main objectives of the 2007–08 study were to:

- collect additional baseline data on levels of ambient air toxics in Kwinana
- compare these measured air toxics levels to NEPM (Air Toxics) guidelines
- collect and compile air quality data in a suitable format to facilitate rapid health risk assessments and future epidemiological studies
- establish baseline values as an aid for assessing industry submissions to either expand existing facilities or future new proposals
- create a database of background atmospheric air toxic profiles for use during HAZMAT chemical incidents (e.g. dangerous chemical spillage or industrial emission).

Figure 1.1 Locations of the 2005–2006 study sites in Kwinana and Rockingham.

(V = VOCs, N = NO_2, A = ammonia, S = SO_2, C = carbonyls, P = PAHs, HM = heavy metals, $PM_{2.5}$ = fine particles)

Figure 1.2 Locations of the 2007–08 study sites in Kwinana and Rockingham.

(V = VOCs, N = NO_2, A = ammonia, S = SO_2, C = carbonyls, P = PAHs, HM = heavy metals, $PM_{2.5}$ = fine particles)

2009–10 study

In 2009–10, air monitoring was conducted at Calista Primary School and Hillman Child Health Centre in conjunction with the Kwinana Child Health Study. NO_2, Total Suspended Particulates (TSP), and $PM_{2.5}$ together with meteorological parameters were monitored for 12 months at both sites. NO_2 and $PM_{2.5}$ monitoring commenced at Calista on 26 May 2009 and at Hillman on 19 May 2009. TSP monitoring was conducted at both sites from 3 June 2009 to 1 June 2010. The TSP filter papers were analysed for 32 heavy metals including aluminium, arsenic, cadmium, iron and nickel. The locations of the 2009–10 sites are shown in Figure 1.3.

Figure 1.3 Locations of the 2009–10 study sites in Kwinana and Rockingham.

(N = NO_2, HM = heavy metals, $PM_{2.5}$ = fine particles)

Ambient air monitoring in Kwinana

In addition to the BAQS monitoring (Table 1.1), ambient air monitoring of SO_2 and other criteria pollutants has been conducted within the Kwinana region for a number of years. The air monitoring sites listed in Table 1.2 are used to assess the effectiveness of the Environmental Protection (Kwinana) (Atmospheric Wastes) Policy (EPP). Industries with SO_2 emission limits determined through the EPP procedure are required to establish and maintain a continuous emissions monitoring system for measuring the quantities of SO_2 being emitted from their premises. In addition to this, each industry is required to monitor the ambient air concentration of SO_2 at specified locations in the EPP area. Currently, industry fulfils this obligation through the Kwinana Industry Council (KIC). KIC operates three ambient air monitoring stations within the EPP area. DEC also currently maintains and operates an additional two (previously three) monitoring stations in the EPP area for monitoring compliance with the ambient air criteria for SO_2.

Table 1.2 Long-term monitoring in the Kwinana region.

Station	**Operated by**	**Currently operating**	**Monitoring**
Abercrombie Road	KIC	Since 1993	SO_2
Fancote Avenue	KIC	Since 2004 Closed February 2010	SO_2, PM_{10}
Tindale Avenue	KIC	Since 2010	SO_2, PM_{10}
Hope Valley	DEC	Since 1989 Closed April 2008	SO_2, NO_2
Miguel Road	KIC	Since 1993	SO_2
North Rockingham	DEC	Since 1992	SO_2, NO_2, O_3
Wattleup	DEC	Since 1990	SO_2

This report summarises the air sampling that was undertaken during the BAQS for the periods from July 2007 to August 2008 and from May 2009 to June 2010. For comparative purposes, data from the 2005–06 study has been included where applicable.

2 Particles as $PM_{2.5}$

$PM_{2.5}$ are particles that have an aerodynamic equivalent diameter of less than 2.5µm (0.000 002 5 metres). The aerodynamic size of a particle is different from its actual size. The aerodynamic equivalent diameter (also called aerodynamic diameter) is the diameter of a sphere, with a density of $1g/cm^3$ (the same as water), that has the same terminal settling velocity under gravity as the airborne particle considered. For example; a 1 µm diameter particle of carbon or 0.22µm diameter lead particle has a similar aerodynamic equivalent diameter as a 2.5µm diameter water particle. The aerodynamic diameter influences the aerodynamic behaviour of an aerosol.

Sources of $PM_{2.5}$ are generally combustion based and include power plants, industrial and commercial boilers/incinerators, mining operations, vehicle exhaust emissions, bushfires, domestic wood heating and the burning of vegetation for agricultural or fuel reduction purposes.

Method

Sampling for $PM_{2.5}$ was conducted in Kwinana in 2005–06 using a TEOM located at the Kwinana Town Centre and the Rockingham City Shopping Centre. Both TEOMs operated continuously taking a sample every 10 minutes.

A TEOM ambient particulate monitor measures ambient particulate concentrations directly and in real time. A known airflow is drawn through a 2.5µm size selective inlet head and maintained over a tapered glass element with a filter cartridge attached. The glass element vibrates at its natural frequency. As particulate matter gathers on the cartridge, the tube's natural frequency decreases. The ambient mass concentration is proportional to this change in frequency and is displayed in real time.

In 2009–10, additional $PM_{2.5}$ sampling was conducted at Calista Primary School and the Child Health Centre in Hillman. The sites and dates of $PM_{2.5}$ monitoring undertaken by DEC in the region are presented in Table 2.1.

Table 2.1 Monitoring in the Kwinana region in 2005–06 and 2009–10

Site	Monitoring dates
Kwinana Town Centre	14 September 2005–14 September 2006
Rockingham City Shopping Centre	14 September 2005–14 September 2006
Calista Primary School	26 May 2009–30 June 2010
Hillman Child Health Centre	19 May 2009–30 June 2010

Results

2005–06 study

Figure 2.1 shows a plot of summary statistics for $PM_{2.5}$ at Kwinana Town Centre and Rockingham City Shopping Centre for 2005–06 in comparison to that of Duncraig for the same time period. Summary statistics have not been provided for South Lake as the $PM_{2.5}$ TEOM was not installed until March 2006.

The highest 24-hour average $PM_{2.5}$ concentration (31.6µg/m^3) in the Kwinana study area was recorded at the Kwinana Town Centre on 18 June 2006. This concentration exceeded the NEPM 24-hour $PM_{2.5}$ advisory standard of 25ug/m^3. On the same day, the highest 24-hour average $PM_{2.5}$ concentration (29.8µg/m^3) at Rockingham City Shopping Centre was measured. On this day, high concentrations of particles were also recorded at most Perth metropolitan sites as well as at Bunbury. As can be seen in Figure 2.2, these high particle levels appear to be a result of a region-wide particle event. The blue trace in Figure 2.2 shows PM_{10} concentrations while the red trace shows $PM_{2.5}$. The high ratio of $PM_{2.5}$ to PM_{10} indicates bushfire or fuel reduction burning activity. The annual average for both sites, Kwinana and Rockingham, was 7.5µg/m^3 which is less than the NEPM advisory standard of 8µg/m^3.

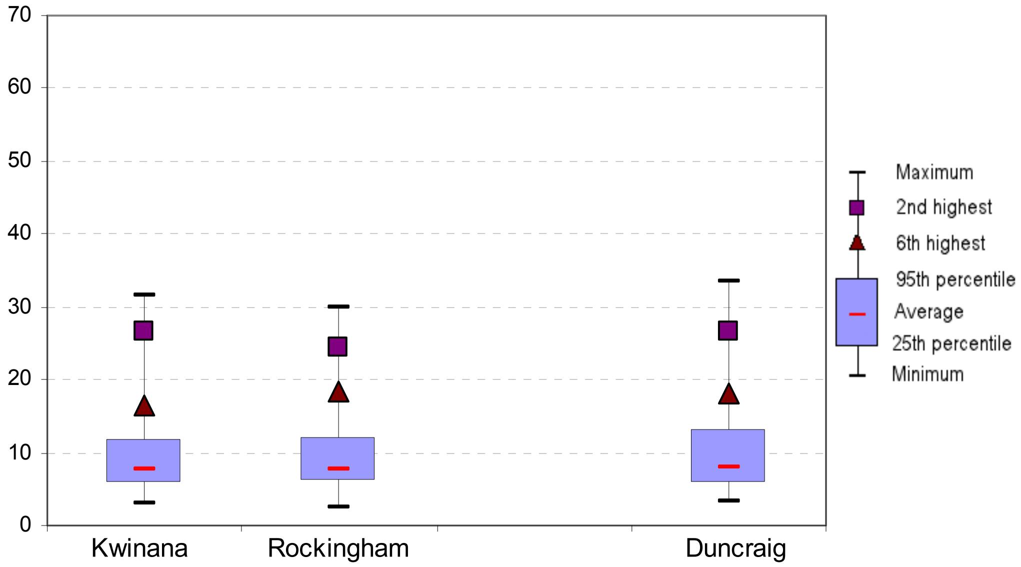


Figure 2.1 $PM_{2.5}$ concentrations during 14 September 2005 to14 September 2006.

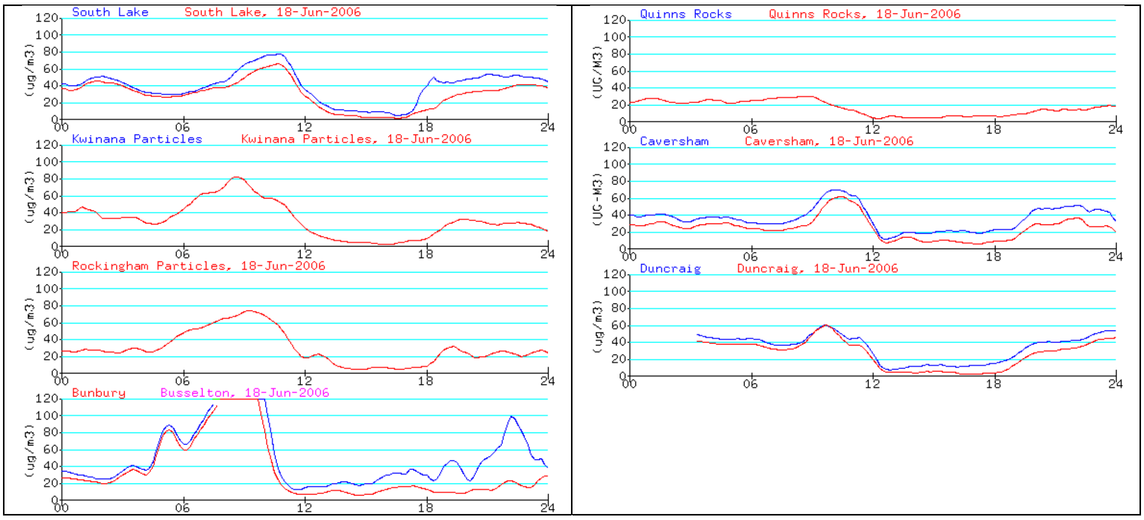


Figure 2.2 One-hour averaged particle concentrations on 18 June 2006.

2009–10 study

The annual average $PM_{2.5}$ concentrations reported from Calista Primary School and the Child Health Centre at Hillman were similar (8.7µg/m^3 and 9.0µg/m^3, respectively). The maximum 24-hour concentration reported at Hillman (61.4µg/m^{-3}) was slightly higher than that at Calista (57.1µg/m^3). The minimum 24-hour concentrations at both locations were similar, with 3.7µg/m^3 recorded at Calista and 3.6µg/m^3 at Hillman.

The moving monthly average $PM_{2.5}$ concentrations during 2009–10 show several broad peaks evident in Figure 2.3. The very low but broad peak during July–August may be partly attributed to emissions from domestic wood heaters during the winter months. The moderate peak centered in December may be due to local dust sources as well as bushfires and sea salt over the summer months. This broad peak is identical at both sites which are more than six kilometres apart. The largest peak occurs during April–May and is most likely due to hazard reduction burns in the south-west of the state together with possible bushfires events.

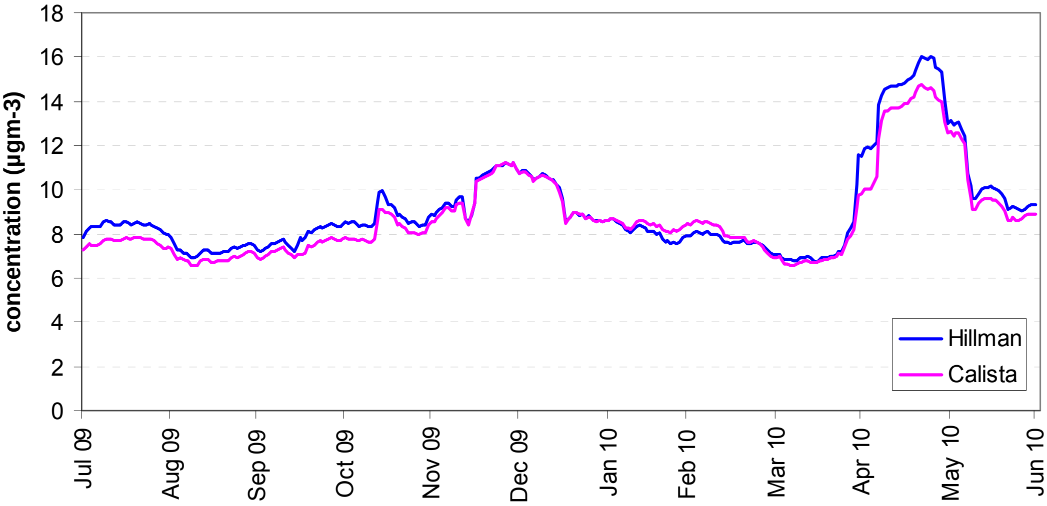


Figure 2.3 Moving monthly averaged $PM_{2.5}$ concentrations.

The maximum, 2nd and 6th highest, mean, minimum, 25th and 95th percentile 24 hour $PM_{2.5}$ concentrations from Calista and Hillman are presented in Figure 2.4. Data from both South Lake and Duncraig for the same time period are also included for comparison purposes.

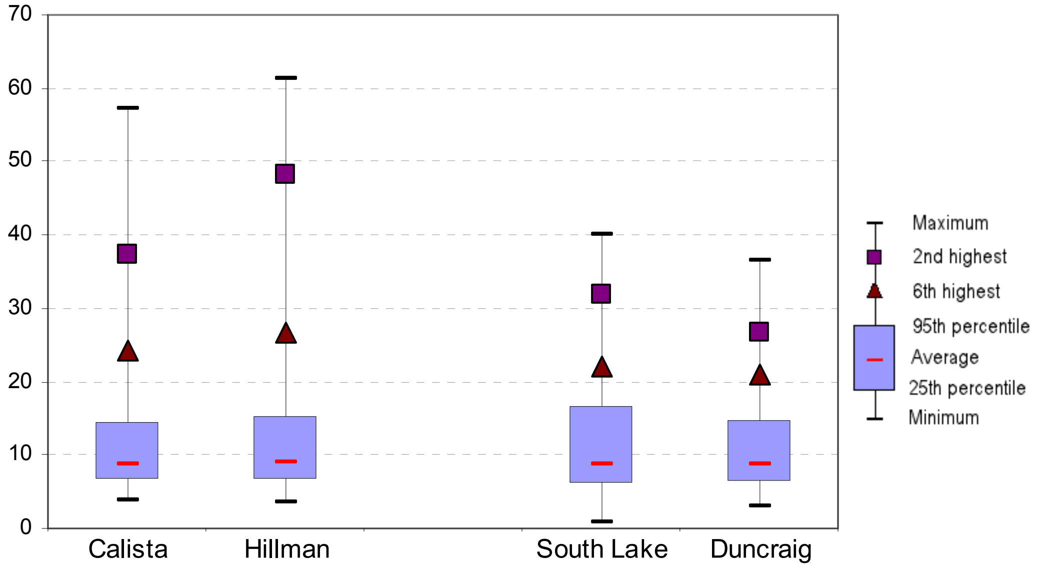


Figure 2.4 PM$_{2.5}$ concentrations during 2009–10 study.

During the study period there were six days when the NEPM 24-hour PM$_{2.5}$ advisory standard of 25µgm^{-3} was exceeded at either or both Calista and Hillman. The locations where exceedences were reported and the concentrations reported at those locations are presented in Table 2.2.

On 6 May 2010, the PM$_{2.5}$ concentration reported at Calista (57.1µg/m^3) and Hillman (61.4µg/m^3) exceeded the NEPM 24-hour PM$_{2.5}$ advisory standard of 25µg/m^3. Exceedences were also reported from Quinns Rocks, Caversham, Duncraig, South Lake and Bunbury. Based on the wind trajectory in the morning, the likely source was from the southeast. Similarly for the following day (7 May 2010), the concentrations reported at Calista (34µg/m^3) and Hillman (26.6µg/m^3) exceeded the NEPM 24-hour PM$_{2.5}$ advisory standard, as was the case at both Bunbury and Busselton. The wind trajectory indicated that the likely source was from the southeast in the morning and from the east in the afternoon. As exceedences were reported from a number of stations across the Perth metropolitan region, it is likely that a regional smoke event on or around 6 May 2010 was the source. Back trajectories of wind directions on all PM$_{2.5}$ exceedence days together with relevant maps are included in Appendix 1 of this report.

Data from all of the sites were also compiled into pollution roses for the period from 1 July 2009 to 30 June 2010 (Figure 2.5). The pollution roses for Hillman and Calista have been overlaid onto a regional map. South Lake and Duncraig have been included for comparative purposes. The red line represents the maximum 10-minute average concentration in µg/m^3 when the wind was from the indicated direction. The mauve and blue lines represent the 99th and 95th percentile, respectively for each direction segment.

Table 2.2 $PM_{2.5}$ exceedences during 2009–10 study.

Date of exceedence	**Exceedence location**	**Concentration (μg/m^3)**	**Wind direction**
11/11/2009	Calista	31.5	east
	Hillman	36.6	
	Duncraig	26.6	
	South Lake	28.5	
	Bunbury	30.0	
	Busselton	30.5	
16/12/2009	Calista	37	south
	Hillman	40.0	
	Quinns Rocks	27.2	
	Duncraig	26.4	
	South Lake	32.0	
28/4/2010	Calista	37.2	south-east
	Hillman	48.2	
	Bunbury	78.3	
	Busselton	62.5	
29/4/2010	Hillman	40.8	east
	Bunbury	115.3	
6/5/2010	Calista	57.1	south-east
	Hillman	61.4	
	Quinns Rocks	33.7	
	Caversham	45.2	
	Duncraig	36.4	
	South Lake	40.0	
7/5/2010	Calista	34	south-east
	Hillman	26.6	
	Bunbury	29.5	
	Busselton	33.5	

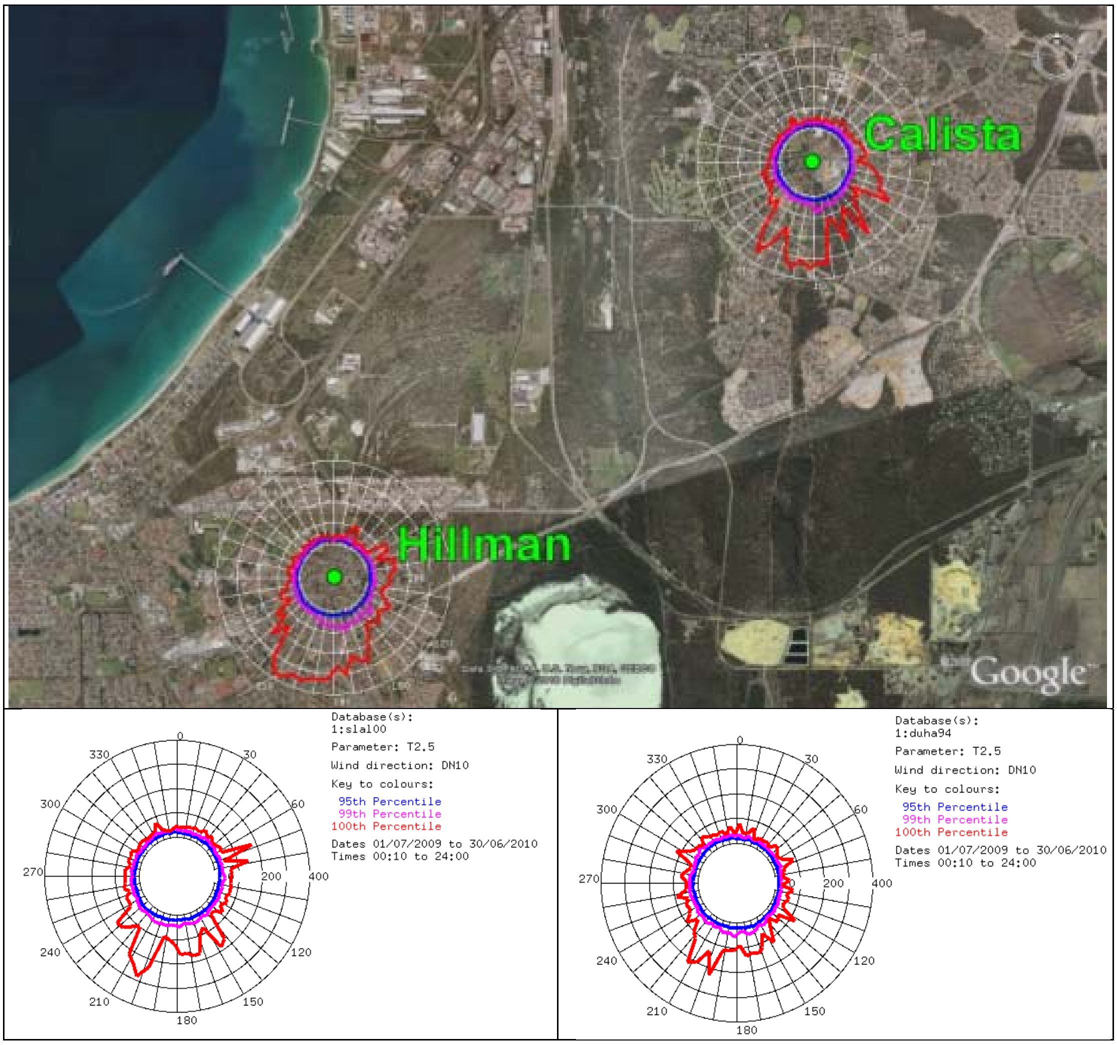


Figure 2.5 $PM_{2.5}$ pollution roses for the period from 1 July 2009 to 30 June 2010.

The pollution roses show that the majority of the high concentrations of $PM_{2.5}$ originate from the south and southwest, with a smaller portion also from the southeast.

Particle events associated with winds from KIA

Periods when the 10-minute $PM_{2.5}$ concentrations were above 50µg/m^3 while the wind direction was from the KIA were also investigated for the Calista and Hillman sites. Figure 2.6 shows the wind arcs of interest—namely, the 260° to 30° sector for the Calista Primary School and 300° to 60° sector for the Hillman Child Health Centre.

Figure 2.6 Wind sectors identified for more investigation.

A cumulative frequency graph for 10-minute $PM_{2.5}$ concentrations at both Calista and Hillman is shown in Figure 2.7. The data only includes concentrations when the wind direction was between 260° to 30° at Calista and 300° to 60° at Hillman. The graph shows that there were nine 10-minute periods at Calista that were above 50µg/m^3 and four 10-minute periods at Hillman. The portion of the graph where concentrations were greater than 50µg/m^3 is shaded yellow.

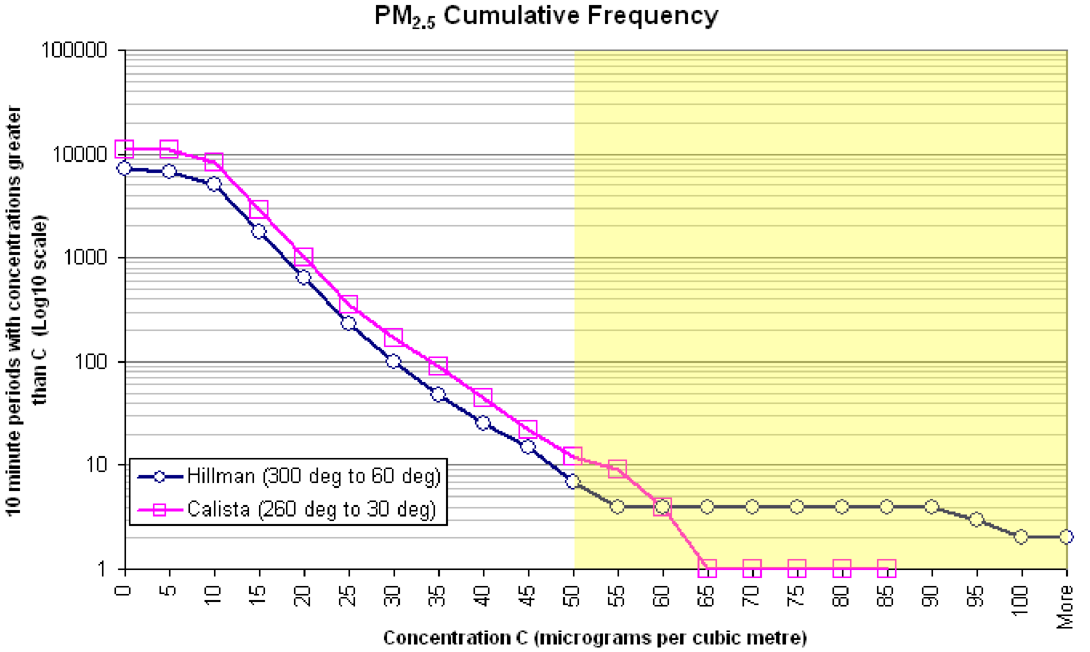


Figure 2.7 Cumulative frequency graph for $PM_{2.5}$ - 1 July 2009 to 30 June 2010.

The 10-minute $PM_{2.5}$ concentrations which were above 50µg/m^3 when the wind direction was from the 260^o to 30^o for Calista and 300^o to 60^o for Hillman are shown in Tables 2.3 and 2.4. All of the 10-minute periods were found to have occurred on days that were impacted by region-wide events. Only three of the six days that recorded 24-hour $PM_{2.5}$ concentrations above the 24-hour $PM_{2.5}$ advisory standard at the Calista and Hillman were associated with periods when the wind direction was from KIA.

Table 2.3 Periods when winds were between 260^o to 30^o and 10-minute averaged $PM_{2.5}$ concentrations at Calista Primary School were greater than 50µg/m^3.

Date	**Time**	**Direction (degrees from north)**	**10 minute averaged concentration (µg/m^3)**	**Comment**
11/11/2009	8:40 9:00 12:00 20:20 21:10	20 28 291 269 4	51.7 55.3 52.1 55.1 57.5	A region wide event originating from an easterly direction. See Appendix 1. 24 hour average = 31.5µg/m^3
22/03/2010	16:50	26	53.7	Metropolitan network wide event occurred between 3pm and 6pm and was most likely due to burning activities to the south. Winds were from the south south-west during the time of the event. See Appendix 2. 24 hour average = 6.9µg/m^3
24/04/2010	23:30 23:40	265 274	52.0 51.5	Metropolitan network wide event occurred between 6pm on 24/04/2010 and 3am on 25/04/2010 with 10 minute averaged $PM_{2.5}$ levels exceeding 80µg/m^3 at Quinns Rocks, Caversham and Duncraig. The event was most likely due to burning activities to the south. Winds were from the south east during the time of the event. See Appendix 2. 24 hour average = 14.8µg/m^3
28/04/2010	4:00	334	80.1	A region wide event originating from a southerly direction. See Appendix 1. 24 hour average = 37.2µg/m^3

Table 2.4 Periods when winds were between 300° to 60° and 10-minute averaged $PM_{2.5}$ concentrations at Hillman Primary School were greater than 50µg/m^3.

Date	Time	Direction (degrees from North)	10 minute averaged concentration (µg/m^3)	Comment
28/04/2010	1:00	29	89.5	A region wide event originating from a southerly direction. See Appendix 1. 24 hour average = 48.2µg/m^3
29/04/2010	4:20 5:10 5:20	59 22 26	137.9 103.3 94.0	A region wide event originating from an easterly and south westerly direction. See Appendix 1. 24 hour average = 40.8µg/m^3

Discussion

During the 2005–06 study, $PM_{2.5}$ levels for both Calista and Hillman were comparable with other sites within the Perth Metropolitan Region. Concentrations exceeding the NEPM advisory standard of 25µg/m^3 averaged over 24 hours were region-wide events caused by fire activity to the south of the metropolitan region.

In 2009–10 study, Calista and Hillman $PM_{2.5}$ concentrations were once again compared with other metropolitan stations. On this occasion, there were a number of concentrations that exceeded the NEPM advisory standard and investigated. Back trajectories were generated and these showed that all exceedences originated either south or east of the respective sites and were predominately from fire activities. Pollution roses for each site also show that the majority of the $PM_{2.5}$ activity originates from the south and to a lesser extent, the east of the sites.

The data collected were also suitable to allow an investigation of all elevated $PM_{2.5}$ concentrations recorded at both sites when the wind was from selected wind arcs that encompassed the KIA. A very conservative concentration of 50µg/m^3 ***averaged over 10 minutes*** was selected as the minimum cut-off for this investigation. Each episode was separately investigated and analysed in Appendix 2, with the source found to be mainly due to fire activities in the south-west of the state.

3 Nitrogen dioxide

Nitrogen dioxide (NO_2) is a pungent acidic gas which is corrosive and strongly oxidising. It is one of several oxides of nitrogen (NO_x) which can be produced as a result of human activity mainly by combustion processes. The combustion of fossil fuels converts atmospheric nitrogen and any nitrogen in the fuel into its oxides, mainly to nitric oxide (NO). The nitric oxide slowly oxidises to nitrogen dioxide in the atmosphere. This reaction is sped up greatly in the presence of ozone. In the presence of sunlight, oxides of nitrogen including nitrogen dioxide react with photochemically reactive volatile organic compounds to form photochemical smog.

The main source of NO_2 resulting from human activities is the combustion of fossil fuels (coal, gas, oil). In cities, about 80 per cent of ambient NO_2 comes from motor vehicles. Other sources include the refining of petrol and metals, commercial manufacturing and food manufacturing. Electricity generation using fossil fuels also produces significant amounts of NO_2.

Method

Sampling for NO_2 was conducted in the Kwinana region in 2005–06 using passive samplers over six-day periods for 12 months. Sampling was conducted at North Rockingham, Medina, Calista and Wattleup.

In the 2009–10 study, additional NO_2 sampling was conducted using a continuous NO_x sampler (TEI Model 42i) at Hillman Child Health Centre and Calista Primary School. The sites and dates of NO_2 monitoring undertaken by DEC in the region are presented in Table 3.1.

Table 3.1 Monitoring in the Kwinana region in 2005–06 and 2009–10

Site	Monitoring dates
North Rockingham	23 May 2005–11 July 2006
Medina	23 May 2005–11 July 2006
Calista	23 May 2005–11 July 2006
Wattleup	23 May 2005–11 July 2006
Calista Primary School	26 May 2009–30 June 2010
Hillman Child Health Centre	19 May 2009–30 June 2010

Results

2005–06 study

The annual average and maximum six-day NO_2 concentrations reported at Wattleup, Calista, Medina and North Rockingham from 1 July 2005 to 30 June 2006 are presented in Figure 3.1. Concentrations at Duncraig and South Lake for the same period are included for comparative purposes. NO_2 data from DEC long-term monitoring sites at Duncraig and South Lake are collected using a USEPA approved continuous NO_x monitor (TEI Model 42i).

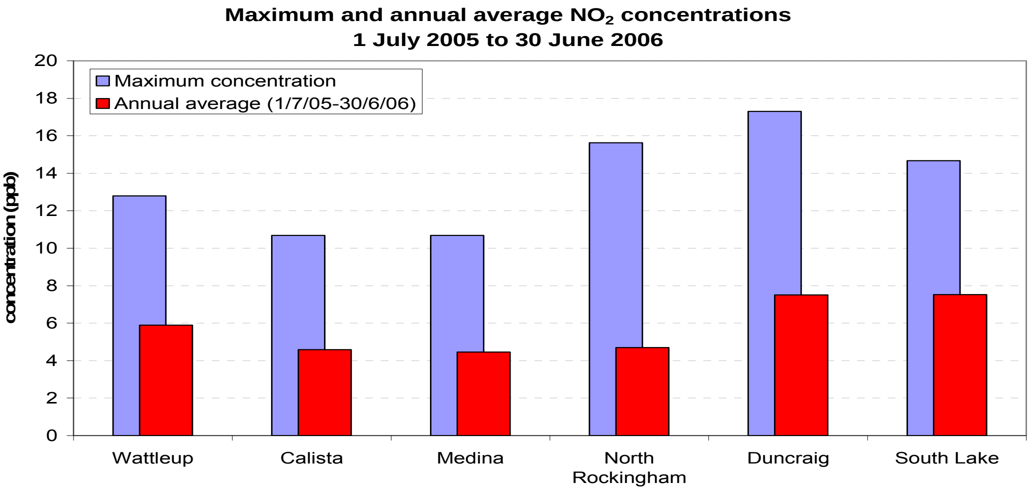


Figure 3.1 Annual average and maximum six-day NO_2 concentrations.

The results of the 2005–06 study showed the annual average NO_2 concentrations for all locations in the study area were less than 20 per cent of the NEPM annual average of 30ppb. While there is no six-day NEPM guideline value for NO_2 to which the maximum concentrations reported at Wattleup, Calista, Medina and North Rockingham can be compared, data from long-term monitoring sites using continuous NO_2 monitors at Duncraig and South Lake covering the same period have been displayed as six-day averages and are included in Figure 3.1 for comparison. The data from the passive samplers and the continuous monitors show similar concentrations.

2009–10 Study

The maximum, 2nd and 6th highest, 95th and 25th percentile, average and minimum daily one-hour maximum NO_2 concentrations reported at Hillman, Calista and North Rockingham during the 2009–10 study are presented in Figure 3.2. Concentrations reported at South Lake and Duncraig for the same period are included for comparative purposes.

During the 2009–10 study, all NO_2 data were collected using a USEPA approved continuous NO_x monitor (TEI Model 42i).

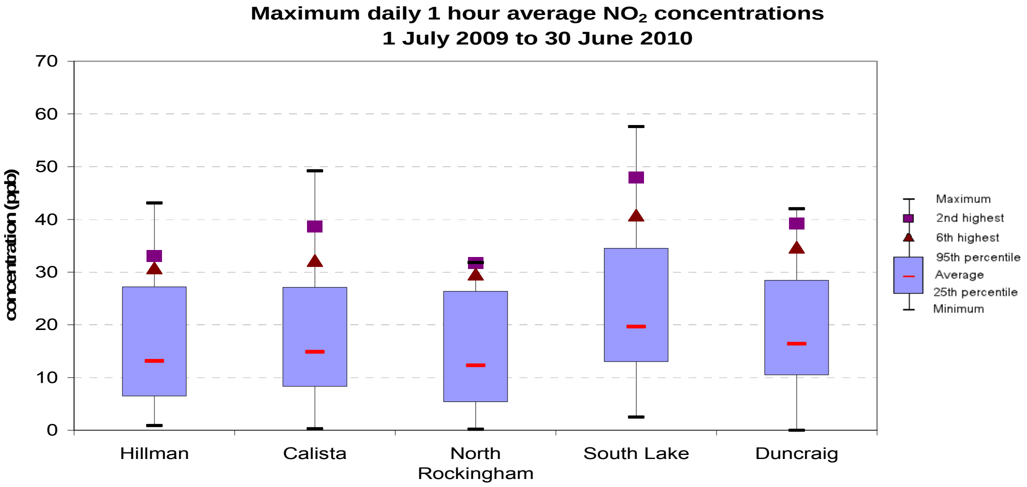


Figure 3.2 NO_2 concentration statistics from 1 July 2009 to 30 June 2010.

The results of the 2009–10 study showed that the highest one-hour maximum NO_2 concentration recorded in the Kwinana study area was 49.2ppb at Calista which was slightly higher than that reported at Hillman (43.1ppb). These concentrations are less than 42 per cent of the NEPM one-hour maximum of 120ppb. There was little difference in the average concentrations across all five sites (13.2 to 19.7ppb), with no study site's maximum exceeding 41 per cent of the NEPM annual standard of 30ppb.

Data from the Hillman and Calista were compiled into pollution roses and are shown in Figure 3.3. Pollution roses bin all the 10-minute averaged concentrations of NO_2 recorded for the year into five degree compass arcs representing where the wind was coming from at the time of the record. The red line is the maximum 10-minute averaged concentration in ppb when the wind was from the indicated direction. The mauve and blue lines are the 99th and 95th percentile respectively for each direction.

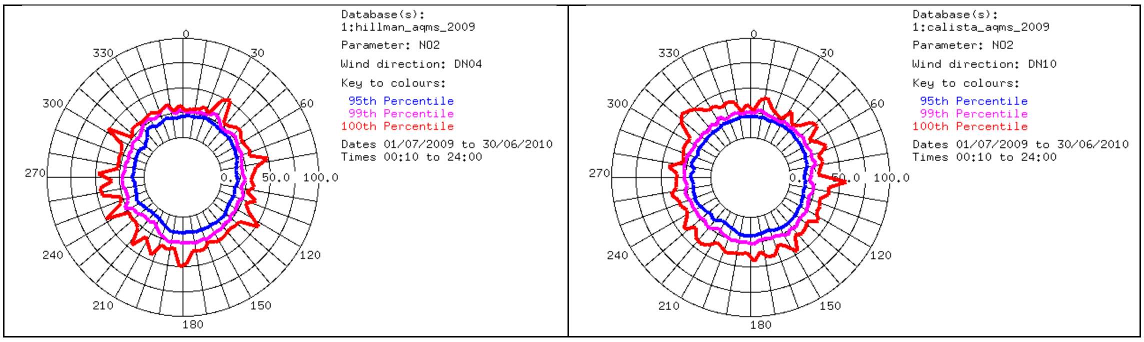


Figure 3.3 NO_2 pollution roses for Calista and Hillman.

The pollution roses do not show any particular direction that dominates as a possible source of NO_2. This is not unexpected as the major contributor to NO_2 levels in major populated regions is motor vehicle exhaust.

Discussion

The passive NO_2 samplers used in the 2005–06 study only provided six-day averages. This data were compared with the continuous monitors at three metropolitan sites averaged over the same period. In all cases, the NO_2 levels were less than other metropolitan sites.

In 2009–10, continuous monitors were used at Calista and Hillman to record NO_2 concentrations. Again the results were comparable with all sites recording similar concentrations. When compared with the NEPM standard of 120ppb averaged over one hour, both Calista and Hillman recorded maximum concentrations that were less than 40 per cent of the standard.

The NEPM standard also provides an annual average of 30ppb. Calista and Hillman recorded annual averages of 6ppb and 5ppb, respectively.

Pollution roses were constructed and show there was no major source of NO_2 within the region. This is expected given that the majority of NO_2 emanates from motor vehicle exhaust.

4 Carbonyls

Carbonyl compounds contain a carbon atom which is double-bonded to an oxygen atom. Commonly known carbonyls include formaldehyde, acetaldehyde and acetone.

Formaldehyde is a colourless flammable gas at room temperature and has a distinct pungent odour. It is commonly used in the production of fertiliser, paper products, plywood, particleboard and fibreboard, insulation material and urea-formaldehyde resins.

Acetaldehyde is a colourless and volatile liquid with a very pungent odour. It is used as an intermediate in the production of a number of chemicals, and in a number of food flavourings. Acetaldehyde is also used in the manufacture of synthetic rubber, perfumes, aniline dyes and plastics.

Acetone is used as a solvent and intermediate in chemical production, drug and pharmaceutical manufacture and surface coatings. It is emitted from a number of consumer products including nail polish and paint removers, paint and industrial chemicals.

Method

Carbonyls were monitored in 2005–06 at Duncraig, Queens Buildings and Hope Valley using DNPH tubes according to USEPA Method TO-11A. Twenty-four hour samples were taken once every six days from 27 July 2005 to 28 July 2006. In the 2007–08 study, carbonyls were monitored over a seven day period once per month using passive samplers from 3 July 2007 to 2 September 2008 at 14 locations. These locations are shown in Figures 1.1 and 1.2.

A number of carbonyls monitored in the 2005–06 and 2007–08 studies have guideline values with which the concentrations reported in these studies can be compared. The guideline values are presented in Appendix 3.

The data from the 2005–06 study has been available on the DEC Air Quality website since 2008.

Results

2005–06 study

The maximum and average concentrations of all carbonyls measured during 1 July 2005 to 30 June 2006 is presented in Figure 4.1. The graph concentration axis has been presented in a logarithmic scale to better display all the concentrations. Where guidelines are available and are less than the maximum value displayed on the graph, these have also been included in the figure. While the highest carbonyl concentration reported was for acetone at Hope Valley on 29 January 2006 (201.2μg/m^3), this concentration was much less than the OAQC 24 hour guideline value of 11,800μg/m^3. The second highest concentration of acetone at Hope Valley was 19.8μg/m^3, with the remainder being less than 5μg/m^3. The highest annual average acetone concentration from 1 July 2005 to 30 June 2006 was also reported at Hope Valley (4.7μg/m^3).

This concentration was much lower than the UKEA annual average guideline value of 18,000µg/m^3.

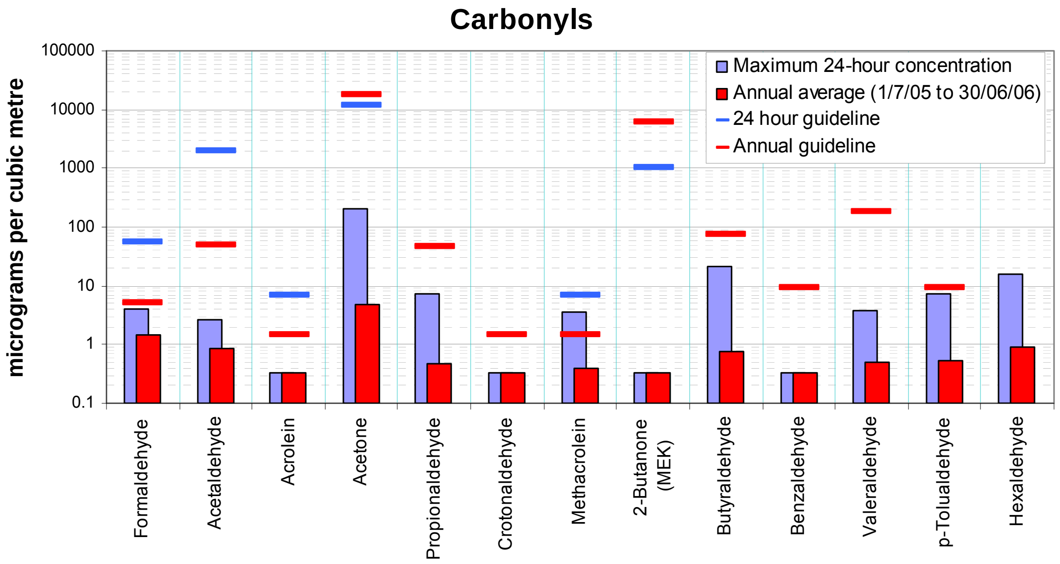


Figure 4.1 Carbonyl concentrations from 1 July 2005 to 30 June 2006.

The 24 hour averaged concentration of acrolein between 1 July 2005 and 30 June 2006 was at or below the laboratory reporting limit at all sites.

The highest 24 hour averaged concentration for methacrolein was measured at Hope Valley at 3.58µg/m^3. There were only three other 24 hour periods, one each at Hope Valley, Perth CBD and Duncraig, where concentrations exceeded the laboratory reporting limit.

The Western Australian Department of Health has indicated that although they are currently reviewing the guidelines for acrolein and methacrolein a 24 hour guideline of 6.8µg/m^3 is appropriate for both acrolein and methacrolein. Acrolein and methacrolein are irritants and low level exposure over a short time can cause eye, nose and throat irritation. The effects are reversible once exposure stops however; if exposure is continual over days or months then the risk increases that the effects will become worse. DOH suggest that a guideline of 1.5ug/m^3 averaged over a year is appropriate to guard against worsening effects. International health agencies advise that neither compound is classifiable as carcinogenic to humans.

The 24 hour maximum and annual average formaldehyde concentrations from each site over the same period are presented in Figure 4.2. The highest maximum formaldehyde concentration from 1 July 2005 to 30 June 2006 was 5.1µg/m^3 at Queens Buildings in the Perth CBD. The highest annual average formaldehyde concentration of 2.5µg/m^3 was also reported from Queens Buildings, which is less than 25 per cent of the NEPM monitoring investigation limit.

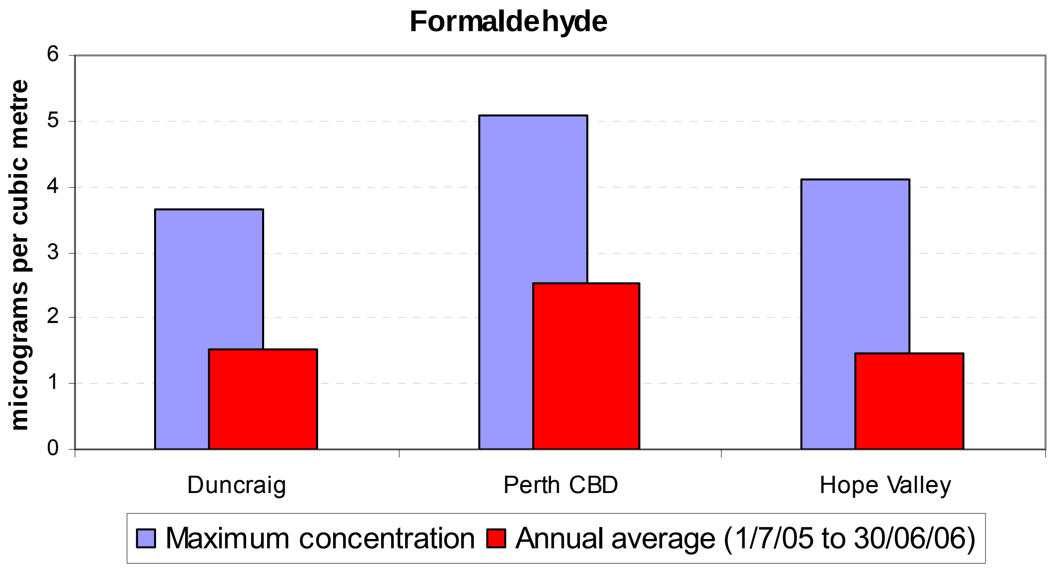


Figure 4.2 Formaldehyde concentrations from 1 July 2005 to 30 June 2006.

2007–08 study

The seven-day averaged maximum and annual average carbonyl concentrations from all sites from 3 July 2007 to 2 September 2008 is presented in Figure 4.3 and the maximum and average formaldehyde concentration from the same period is presented in Figure 4.4.

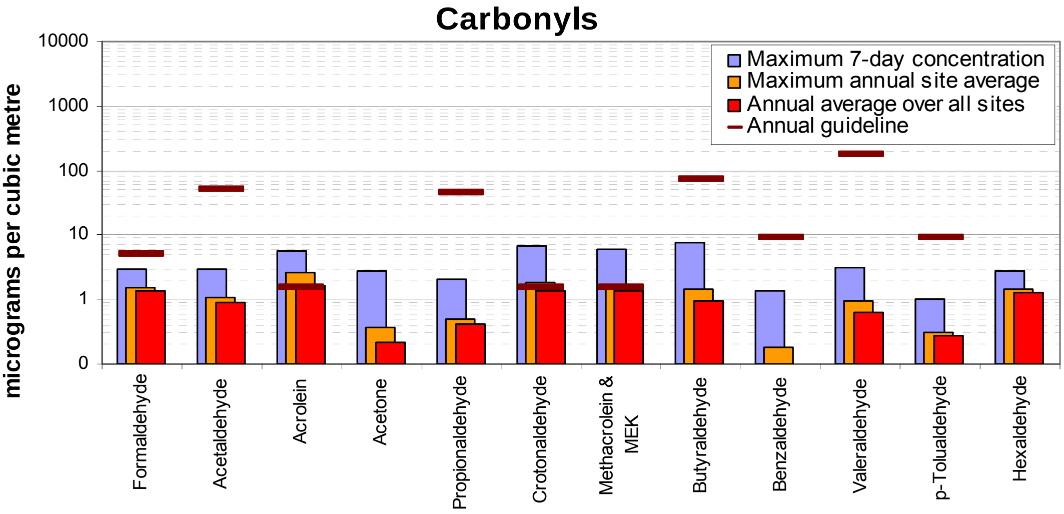


Figure 4.3 Carbonyl concentrations from 3 July 2007 to 2 September 2008.

The highest maximum carbonyl concentration was reported for butyraldehyde (7.7 µg/m^3). The highest annual average carbonyl concentration was reported for acrolein (1.7µg/m^3). DOH suggests that a guideline of 1.5ug/m^3 averaged over a year is appropriate to guard against worsening health effects of acrolein and methacrolein exposure. DOH also advises that the measured annual concentration of 1.7µg/m^3 for acrolein is not sufficiently increased to cause a health concern for the majority of people.

The highest seven-day averaged concentration for crotonaldehyde was 6.8µg/m^3 with an overall annual average for the region of 1.35µg/m^3. The highest site-specific annual average of 1.78µg/m^3 was recorded at Mandogalup Road. Presently crotonaldehyde is not classifiable as a carcinogen by the International Agency for Research on Cancer. DOH is reviewing the basis for this classification and advise that an annual guideline of 1.5µg/m^3 is indicated to guard against long term health effects including cancer.

The highest seven-day averaged concentration for methacrolein was 5.9µg/m^3 with an overall annual average for the region of 1.34µg/m^3. The highest site-specific annual average of 1.66µg/m^3 was recorded at Thomas-Mason Road. DOH suggest that a guideline of 1.5ug/m^3 averaged over a year is appropriate to guard against worsening health effects of acrolein and methacrolein exposure. The measured annual concentration of 1.66µg/m^3 for methacrolein is not sufficiently increased to cause a health concern for the majority of people.

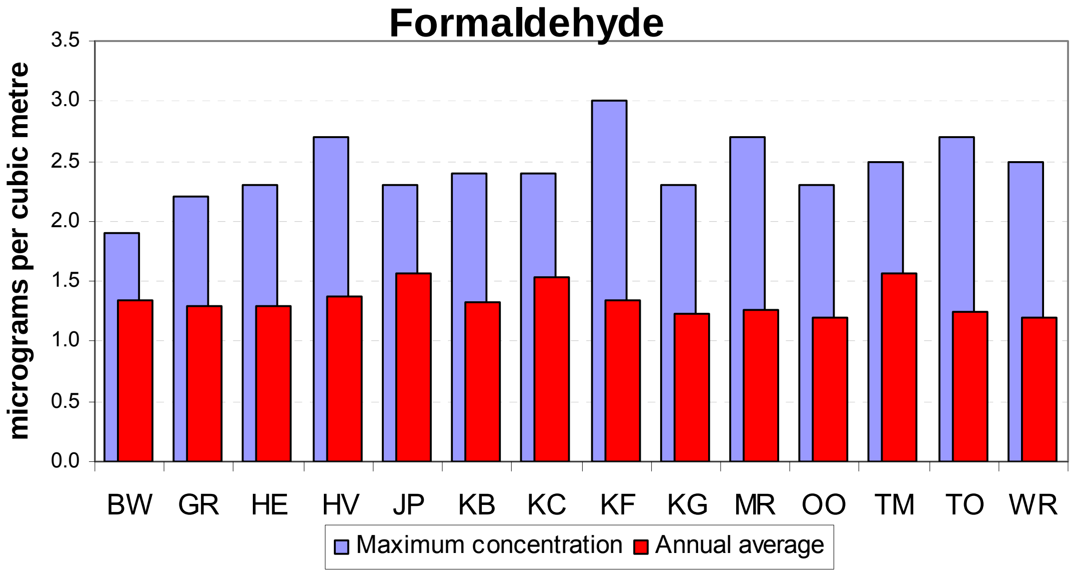


Figure 4.4 Formaldehyde concentrations from 3 July 2007 to 2 September 2008.

BW – Benjamin Way
GR – Governor Road
HE – Henderson
HV - HopeValley
JP – James Point
KB – Kwinana Beach
KC – Kwinana Container Terminal
KF – Kwinana Freeway
KG – Kwinana Golf Course
MR – Mandogalup Road
OO – Orelia Oval
TM – Thomaas/Mason Road
TO – Thomas Oval
WR – Wellard Road

The highest formaldehyde concentration from 3 July 2007 to 2 September 2008 was 3µg/m^3 that was reported from the Kwinana Freeway. The highest annual average formaldehyde concentration (1.6µg/m^3) was reported from James Point (JP) and Thomas/Mason Road (TM). The NEPM annual average monitoring investigation limit for formaldehyde is 10.7µg/m^3, and therefore the average reported from both James Point and Thomas/Mason Road is about 15 per cent of the NEPM monitoring investigation limit.

Discussion

The annual average and maximum 24 hour averaged formaldehyde concentrations reported from the Hope Valley site in the 2005–06 study were similar to those from Duncraig and less than those from Queens Buildings (Perth CBD) over the same period. In the 2007–08 study, the annual average concentrations for acrolein, crotonaldehyde and methacrolein slightly exceeded the relevant guidelines, however the DOH advises that these data do not present sufficient evidence that public health is at risk but advises that future monitoring is recommended to catch unacceptable increases in annual trends early. The highest average formaldehyde concentration (reported from James Point and Thomas/Mason Road) was 15 per cent of the NEPM guideline value of 10.7μg/m^3.

There were seven samples that recorded slightly elevated crotonaldehyde. Five of these samples recorded concentrations of between 4.7 and 5.6ug/m^3 and occurred at five separate sites during the same sampling period 22 January 2008 to 29 January 2008. These were also accompanied by slightly elevated acrolein and methacrolein. Figure 4.5 shows elevated particle levels throughout the Perth metropolitan region throughout the same sampling period indicating possible bushfire smoke. The remaining two crotonaldehyde samples recorded 5.7 and 6.8ug/m^3 and were recorded at the same site, Mandogalup Road, located 1,500 metres west of the Kwinana Freeway and 500 metres from the ALCOA mud lakes.

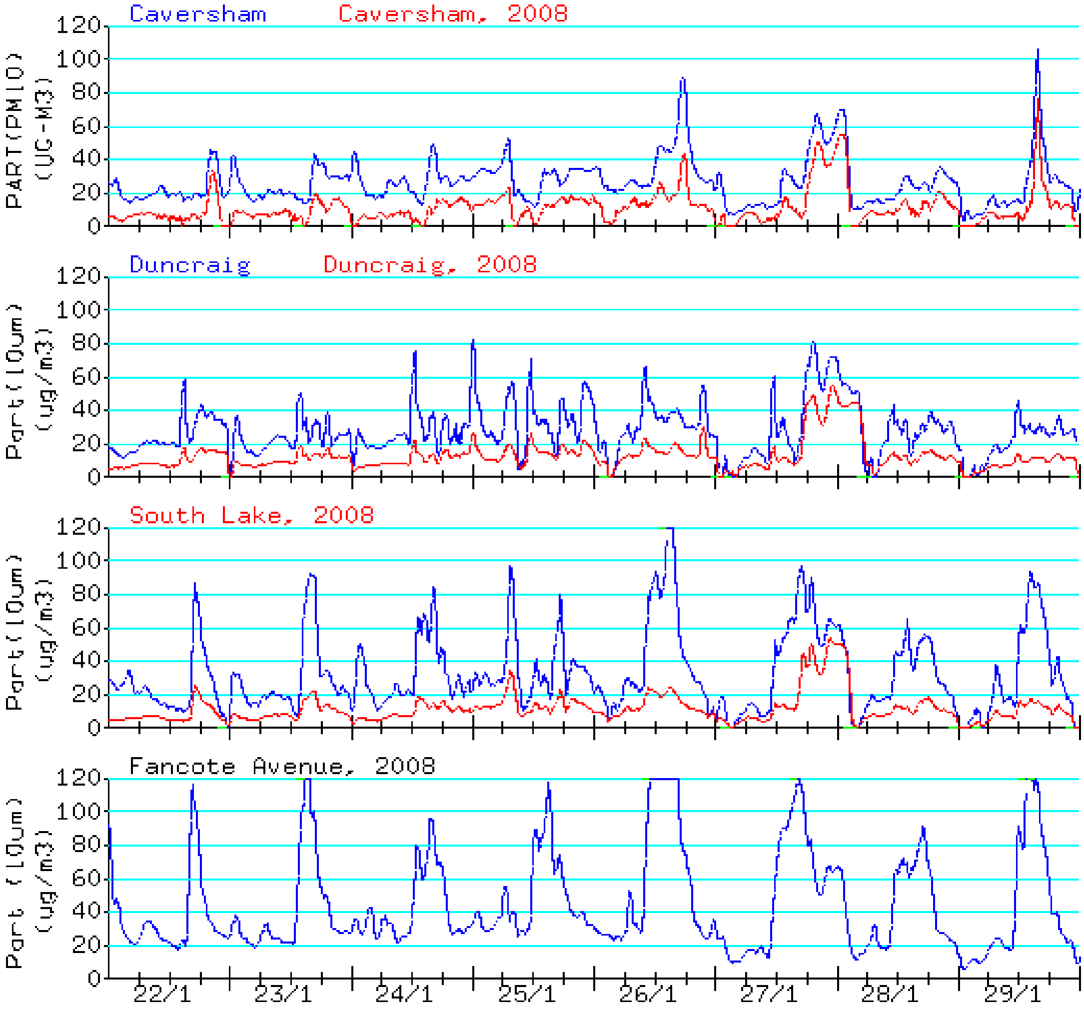


Figure 4.5 PM$_{10}$ (blue) and PM$_{2.5}$ (red) levels in Perth.

Figure 4.6 indicates the majority of elevated crotonaldehyde, acrolein and methacrolein concentrations occurs in the summer months and is most likely due to various smoke events originating in the south-west of the state. Each sampling date has nominally 14 samples. As some of these concentrations are identical for some dates there may appear to be fewer data point visible than one would expect as points depicting the same concentrations are overlaid. The minimum concentration on the plot is one half the limit of reporting for that compound quoted by the analysing laboratory.

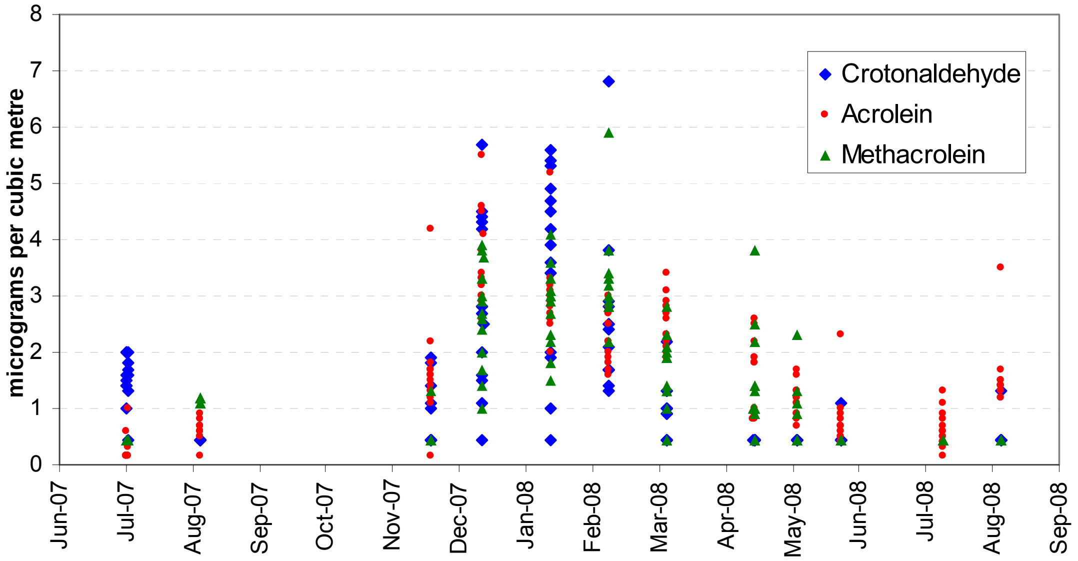


Figure 4.6 Crotonaldehyde, acrolein and methacrolein concentrations collected during 2007–08.

Most people have been exposed to acrolein, methacrolein and crotonaldehyde in both indoor and outdoor air at some time in their life. These compounds are present in cigarette smoke, petrol, diesel and wood fire smoke. People in the wider community are unlikely to be exposed to levels high enough to cause health problems. People living near hazardous industry and waste sites or working with the chemical are likely to be exposed to higher than normal levels.

DOH advises that exposure to high levels of these compounds for short periods of time (hours, days) followed by periods of little or no exposure is unlikely to result in lasting health effects. People, who are chemically sensitive or particularly sensitive to chemicals in the home, may detect these chemicals at lower levels than would normally trigger a health effect. The risk for long lasting health effects increases with many years of exposure to sustained high levels of these compounds. When scientists develop a guideline for long term exposure they factor in a standard 70 years of continual exposure. In other words an average healthy person would need to be exposed all day and everyday for 70 years to develop a serious health effect.

DOH advises that since these compounds are irritants, they may interfere with amenity when present in higher concentrations. These compounds occur at particularly high levels in smoke such as occur during bushfires.

5 Ammonia

Ammonia is a colourless gas that has a very distinct odour and dissolves in water. In its gaseous form it is also known as anhydrous ammonia and when dissolved in water it is known as liquid or aqueous ammonia. Ammonia can react with acidic compounds in the atmosphere to create ammonia aerosols which can be subject to wet or dry deposition.

It is used in nickel refining and the production of fertilisers, synthetic fibres and explosives, and is emitted during the combustion of residential and commercial biomass, from livestock, coal pyrolysis, and in motor vehicle exhaust.

Ammonia has an odour threshold of between 1 and 1.5 parts per million (750ug/m^3 and 1,000ug/m^3)

Method

In the 2005–06 study, ammonia was sampled at the Challenger site (see Figure 1.1) using passive samplers over six-day sampling periods from 22 June 2005 to 11 July 2006. The Challenger site was chosen following an analysis of meteorological data from the Kwinana region and NPI emission data for ammonia. The most common winds were from the sector between east-north-east and south-west, and therefore a site downwind of these prevailing winds and close to the major emission source of ammonia in the region was required. The Challenger site was chosen on this basis.

In the 2007–08 study, ammonia was sampled between July 2007 and September 2008 at a total of 11 sites for a seven-day period every month. The site locations are presented in Table 5.1.

Table 5.1 Ammonia monitoring sites in the Kwinana region in 2007–08.

Site name
Benjamin Way (BW)
Governor Road (GR)
James Point (JP)
Kwinana Beach (KB)
Kwinana Container Terminal (KC)
Kwinana Golf Course (KG)
Mandogalup Road (MR)
Orelia Oval (OO)
Thomas Oval (TO)
Thomas/Mason Road (TM)
Wellard Road (WR)

Results

2005–06 study

The six-day average and the annual averaged ammonia concentrations from the Challenger site are presented in Figure 5.1.

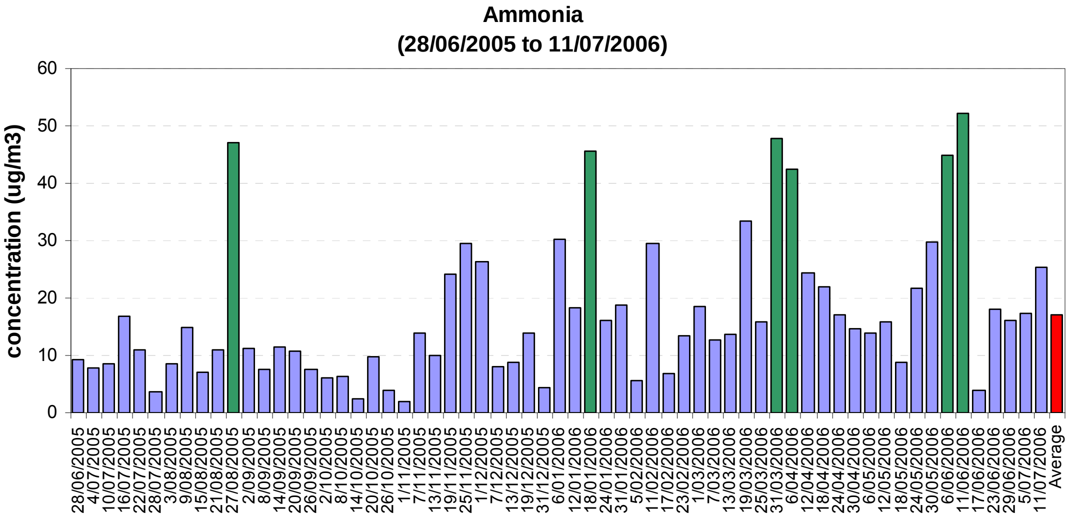


Figure 5.1 Ammonia concentrations at Challenger from July 2005 to June 2006.

The annual average concentration was 17.1µg/m^3. An analysis of the possible origin of the ammonia concentrations reported on the six sampling periods where concentrations exceeded 40µg/m^3 (highlighted green in Figure 5.1) shows that ammonia concentrations were elevated at the site when the winds were predominantly from the direction of a major emission source, located less than 600 metres from the monitoring site, for the majority of the six-day sampling period. The wind roses for these periods are presented in Figure 5.2 and indicate the direction from which the winds came throughout the sampling period.

The annual average ammonia concentration from the Challenger site (17.1µg/m^3) was less than 10 per cent of the UKEA annual standard of 180µg/m^3 with all six day averages also well below the annual standard.

2007–08 study

The seven-day average and annual average ammonia concentrations from 1 July 2007 to 30 June 2008 from each site are presented in Figure 5.3. The highest annual average of 14.1µg/m^3 was reported from the Kwinana Beach site. The highest seven-day average ammonia concentration of 34µg/m^3 was reported from Orelia Oval during the period 26 November 2007 to 3 December 2007. During this same period, the highest seven-day average concentrations of 31µg/m^3 from James Point and 29µg/m^3 Thomas Oval were also reported. The lowest minimum seven-day average ammonia concentration 0.8µg/m^3 reported from Mandogalup Road, Wellard Road and the Kwinana Golf Course.

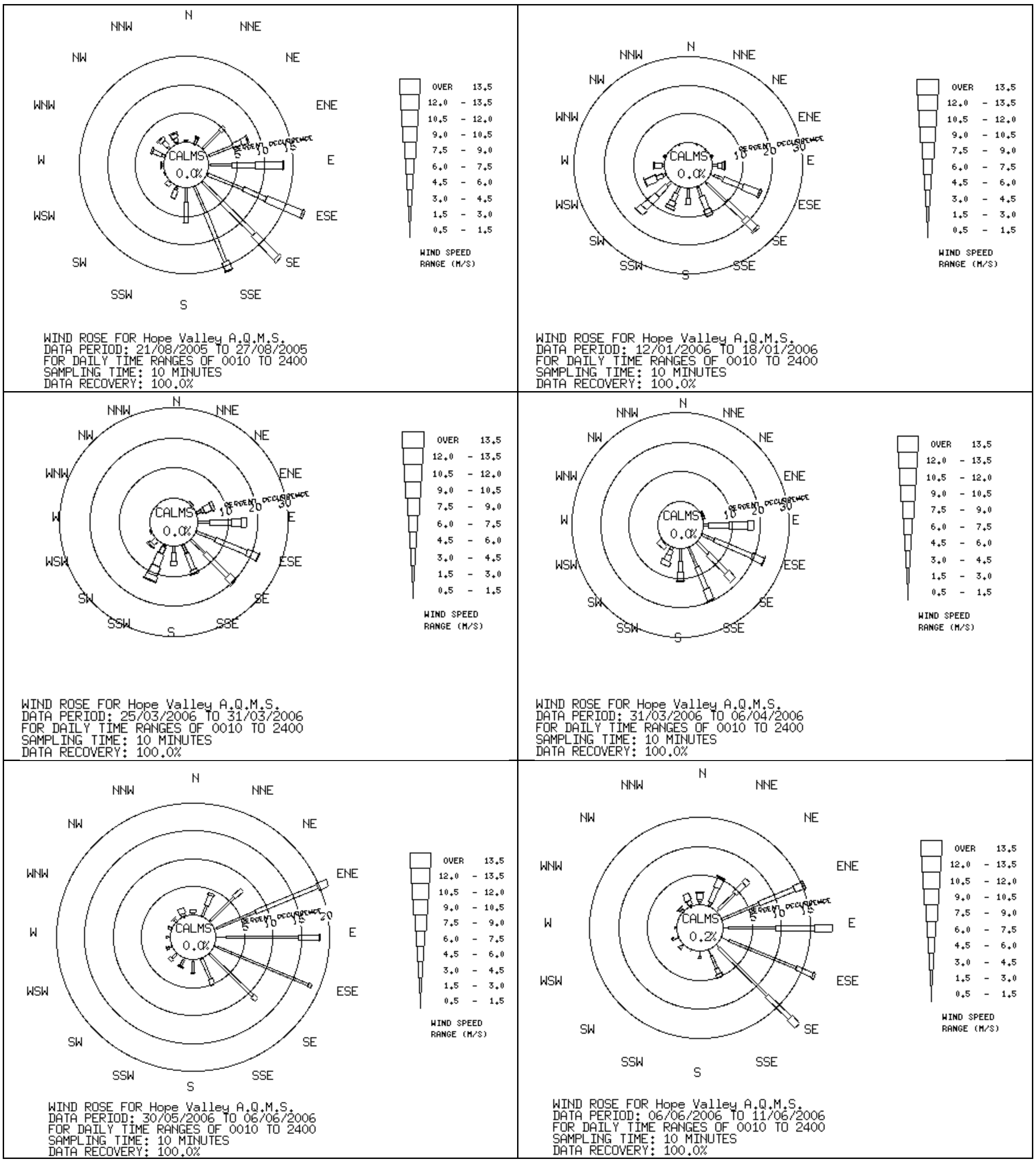


Figure 5.2 Wind roses for the six highest ammonia readings during 2005–06.

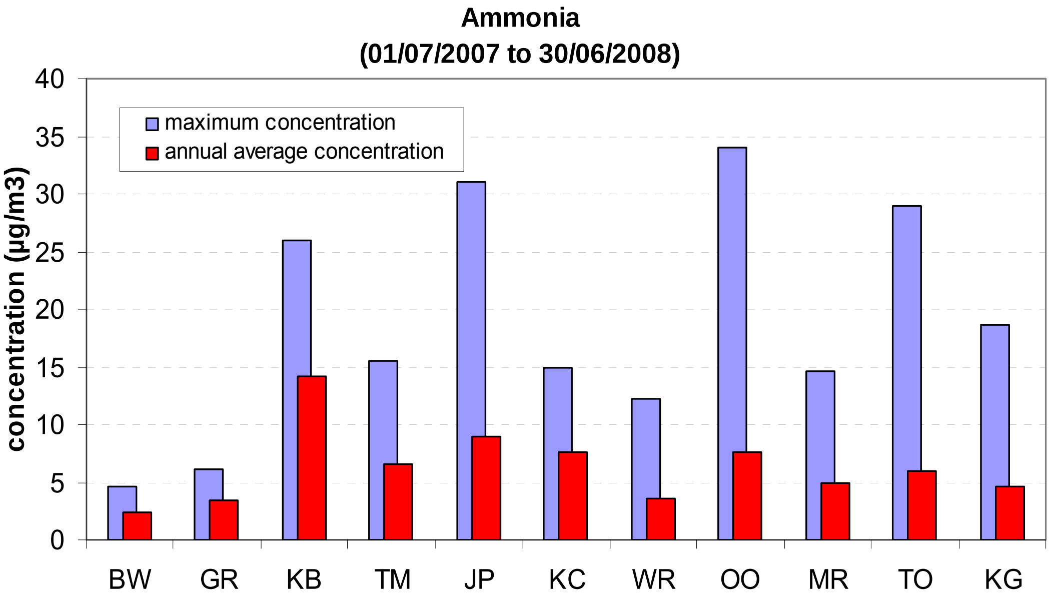


Figure 5.3 Ammonia concentrations in the Kwinana region from 1 July 2007 to 30 June 2008.

The annual average ammonia concentrations from all 11 sites were less than 8 per cent of the UKEA annual standard of 180µg/m^3.

Discussion

In 2005–06, only one site monitored for ammonia. During the year long study, there were six occasions where the six day averaged ammonia concentrations were greater than 40µg/m^3. These particular concentrations were investigated. During each sampling period, the winds were found to be coming predominantly from the east and/or the south-east. The annual average was 18µg/m^3 or 10 per cent of the UKEA annual average guideline for ammonia.

The results from ammonia monitoring in 2007–08 in the Kwinana region showed that the highest seven-day averaged concentration recorded was 34µg/m^3 at Orelia Oval. Figure 5.4 shows a summary of the event and includes a wind rose for the same period.

Figure 5.4 Wind rose and ammonia concentrations from 26 November 2007 to 3 December 2007.

For the majority of the sampling period, the winds were from the south-west. The source of the elevated ammonia concentrations is not known.

All levels were well below the UK annual average with the highest annual average ammonia concentration of 14µg/m^3 recorded at Kwinana Beach.

6 Volatile organic compounds (VOCs)

Volatile organic compounds (VOCs) are gaseous organic compounds that react with other compounds in the atmosphere. Common VOCs include benzene, toluene, ethylbenzene and xylene (BTEX).

Benzene is a highly flammable colourless liquid that has a sweet odour and quickly evaporates in air. Industrial processes are the main sources of benzene emissions to the environment, and in particular combustion processes. Other sources of benzene include cigarette smoke, petrol, vehicle exhaust, evaporative emissions from vehicles and petrol storage operations.

Toluene is a clear colourless liquid that has a distinctive smell and is a good solvent. Toluene is emitted during the refining of crude oil to produce petrol, coal coking and it is a by-product of styrene manufacture. It is also used in the manufacture of paint and paint thinners, nail polish, lacquers, adhesives and rubber.

Ethylbenzene is a colourless, aromatic liquid with an odour similar to that of gasoline. The main use of ethylbenzene is the production of styrene, and it is also used as a solvent in paints, lacquers, rubber and the manufacture of other chemicals. Crude oil, petroleum and combustion products are also sources of ethylbenzene.

Xylene is a colourless liquid at room temperature with an aromatic odour. It has three isomers-ortho, meta and para. The largest use of xylene is in petrol, and it is also used as a solvent in paint and printing ink manufacture, pesticides, adhesives, rubber and plastics.

Benzene, toluene and xylene have a NEPM annual average monitoring investigation level, and ethylbenzene has a WHO annual average guideline value, with which the average concentrations found in these studies can be compared. These guideline values are presented in table 6.1.

Table 6.1: Annual average guideline values for BTEX compounds .

VOC	Annual average (µg/m^3)	Annual average (ppm)
Benzene	10.4	0.003
Toluene	411	0.1
Ethylbenzene	22000	5
Xylene	952	0.2

Method

VOCs were monitored at Hope Valley, Perth CBD and Duncraig from 6 November 2005 to 29 May 2006 using six litre Silco canisters to collect samples over a 24 hour period once every six days. Silco canisters are initially under a high vacuum, which when opened, draws in ambient air at a pre-determined rate. The canister contents were analysed using USEPA method TO14A.

VOCs were also monitored in the Kwinana region using Radiello® passive samplers. Radiello® samplers absorb selected VOCs at a known rate, which when combined with the length of time exposed and the amount of VOC absorbed, can indicate the average ambient concentration of VOCs during the exposure period. These samplers were located at seven sites; North Rockingham (NR), Challenger (CH), Kwinana Beach (KB), Medina (ME), Calista (CA), Wattleup (WT) and Munster (MU). Sampling was continuous for the period from 17 May 2005 to 11 July 2006, with each passive sampler remaining in the field for six days.

In July 2007, more VOC sampling was performed at a total of 14 locations from 3 July 2007 to 2 September 2008 using passive samplers. These samplers were stainless steel tenax tubes fitted with a permeable end cap. These absorb selected VOCs at a known rate, which when combined with the length of time exposed and the amount of VOC absorbed, can indicate the average ambient concentration of VOCs during the exposure period. The tubes were left in the field for a seven-day period once per month.

Results

2005–06 study

The maximum six-day average, maximum annual six-day average of all of the sites and the average six-day average over all of the sites for all VOCs measured during the period from 17 May 2005 to 11 July 2006 are presented in Figure 6.1. The VOC concentrations (vertical axis of graph) have been presented in a logarithmic scale to better display all of the concentrations.

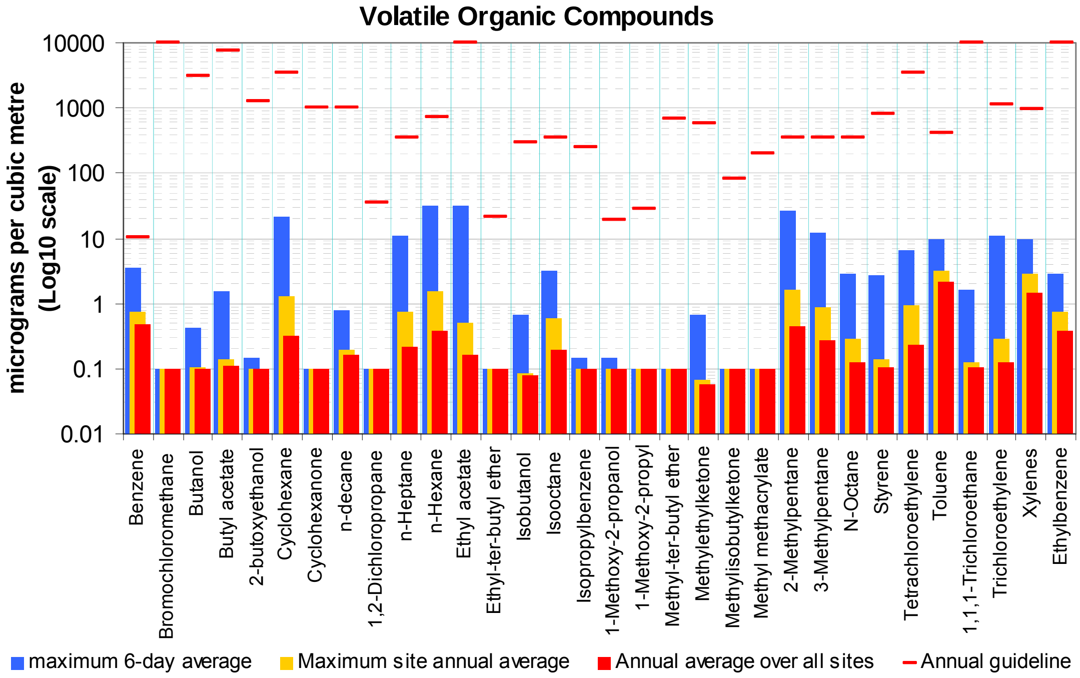


Figure 6.1 VOC concentrations from 23 May 2005 to 11 July 2006.

The highest maximum six-day concentrations for all VOCs recorded were for n-hexane and ethyl acetate (31µg/m3). The highest annual average concentration for all

VOCs from 17 May 2005 to 11 July 2006 was recorded for toluene (2.1µg/m^3). Figure 6.1 also shows annual guidelines where available. Some of these guidelines (e.g. ethylbenzene at 22,000µg/m^3) were greater than the extent of the plot. These guidelines are shown as 10,000 in the figure. For all of the VOCs, the annual average of all the six-day concentrations at each site was less than the applicable guideline.

The maximum and average six-day concentrations for benzene, ethylbenzene, toluene and xylene (BTEX) at each site over the same period are presented in Figure 6.2.

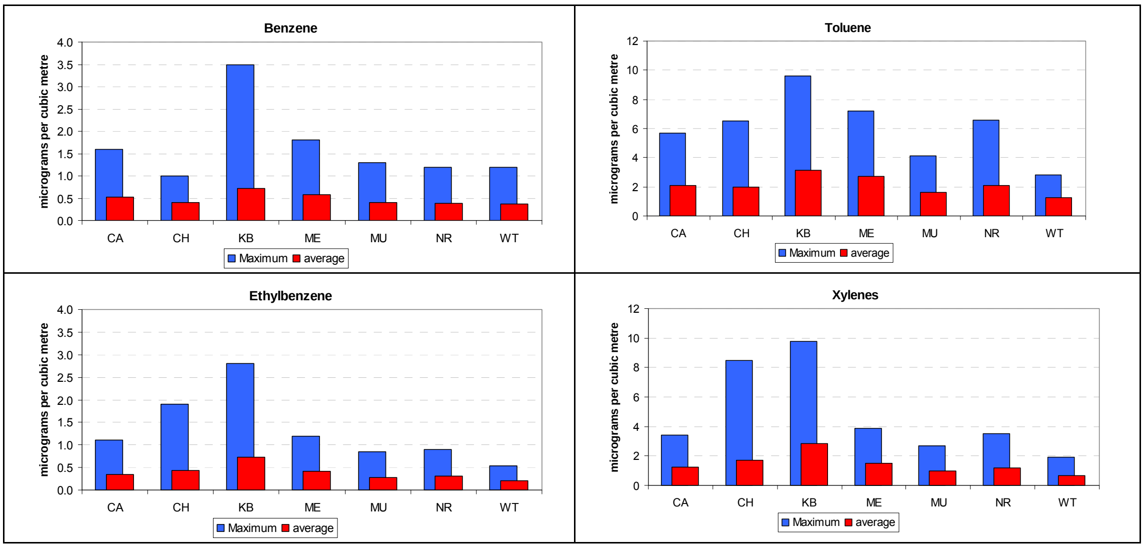


Figure 6.2 BTEX concentrations from 23 May 2005 to 11 July 2006

The highest maximum and average six-day BTEX concentrations for the period from 17 May 2005 to 11 July 2006 were recorded at the Kwinana Beach site. The NEPM annual average monitoring investigation level for benzene is 10.4µg/m^3. The highest six-day average was 3.5µg/m^3, which represents 34 per cent of the NEPM. For toluene, the NEPM annual average monitoring investigation level is 411µg/m^3 (Table 6.1). The highest annual six-day average for toluene was 9.6µg/m^3, approximately 2.4 per cent of the NEPM. The highest annual six-day average xylene concentration at any site (9.8µg/m^3) represents one per cent of the NEPM annual average monitoring investigation level for xylenes (952µg/m^3). The highest six-day average for ethylbenzene was 2.8µg/m^3 and the highest annual six-day average concentration was 0.73µg/m^3. There is currently no NEPM annual average monitoring investigation level for ethylbenzene, however the WHO annual average guideline value is 22,000µg/m^3.

2007–08 study

The maximum and average seven-day concentrations of all VOCs measured during 3 July 2007 to 26 August 2008 are presented in Figure 6.3. The VOC concentrations (vertical axis of graph) have been presented in a logarithmic scale to better display the concentrations.

Across the 14 sites in the Kwinana region, pinene had the highest maximum six-day concentration (28µg/m^3) and highest average seven-day concentration (4µg/m^3) reported for any of the VOCs included in Figure 6.3.

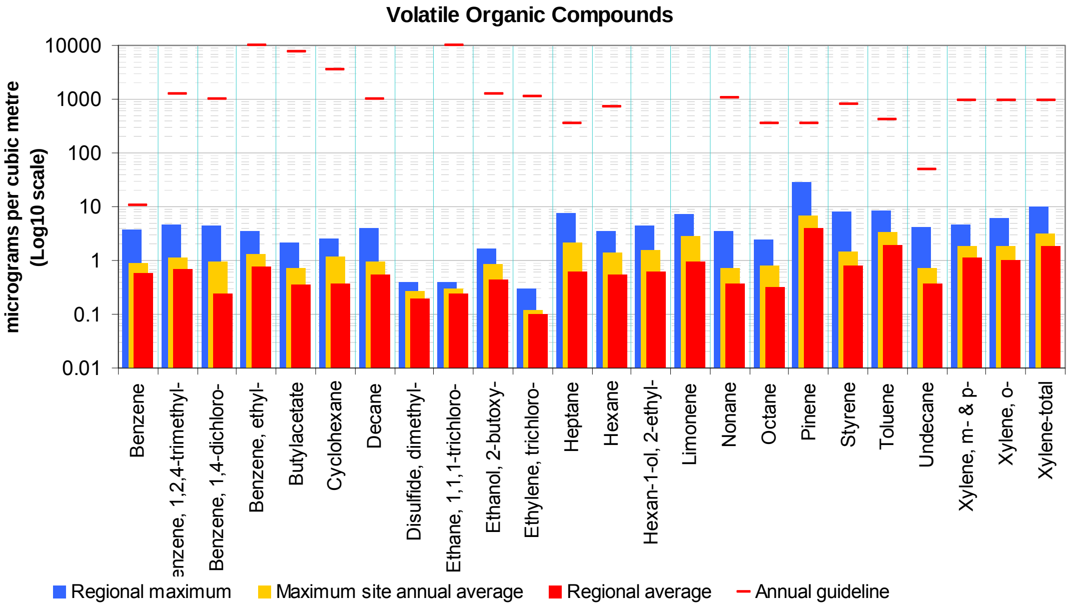


Figure 6.3 VOC concentrations from 3 July 2007 to 26 August 2008

Figure 6.3 also shows annual guidelines where available. Some of these guidelines (e.g. ethylbenzene at 22,000µg/m^3) were greater than the extent of the plot. These guidelines are shown as 10,000 in the figure. No annual guidelines for dimethyl disulfide, 2-ethyl hexanol and limonene are available. For all of the VOCs recorded, the annual average of all seven-day concentrations at each site was less than the applicable guideline.

The maximum and average six-day concentrations for benzene, ethylbenzene, toluene and xylene (BTEX) at each site over the same period are presented in Figure 6.4.

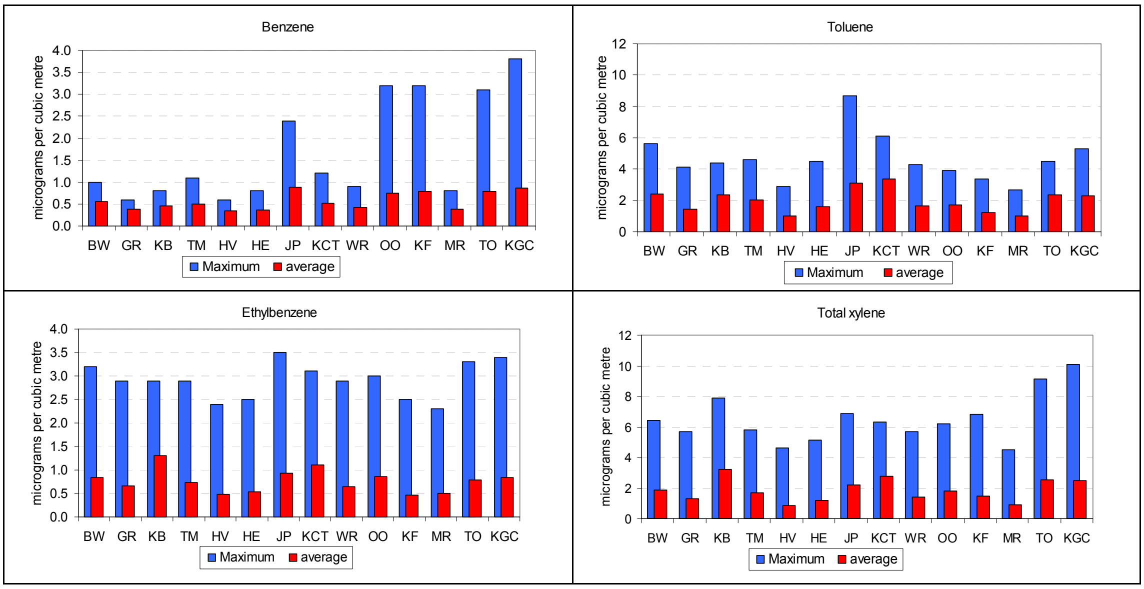


Figure 6.4 BTEX concentrations 3 July 2007 to 26 August 2008

The highest maximum seven-day benzene concentration was recorded at the Kwinana Golf Course (3.8µg/m^3) and the highest annual average benzene concentration was recorded at James Point (0.88µg/m^3). The annual average at James Point represents

8.5 per cent of the NEPM annual average monitoring investigation level. In terms of toluene, the highest maximum seven-day concentration was recorded at James Point (8.7µg/m^3), and the highest annual concentration was reported at the Kwinana Container Terminal (3.4µg/m^3). The annual average at the Kwinana Container Terminal represents 0.8 per cent of the NEPM annual average monitoring investigation level. The highest maximum seven-day ethylbenzene concentration was recorded at James Point (3.5µg/m^3) and the highest annual average was recorded at Kwinana Beach (1.3µg/m^3), which is much lower than the WHO annual average guideline value of 22,000 µg/m^3 (Table 6.1). The Kwinana Golf Course site recorded the highest maximum seven-day total xylene concentration (10.1µg/m^3), and the highest annual average was reported at the Kwinana Beach (3.2µg/m^3). The annual average at Kwinana Beach represents 0.3 per cent of the NEPM annual average monitoring investigation level.

Discussion

In the 2005–06 study, the highest maximum six-day concentration of all of the VOCs from the seven sites was reported for n-hexane and ethyl acetate, and the highest average six-day concentration was reported for toluene. The highest maximum and average six-day BTEX concentrations were reported at the Kwinana Beach site. The average six-day concentrations of benzene, toluene and xylene were all well below the corresponding NEPM annual average monitoring investigation levels and the average six-day ethylbenzene concentrations were much lower than the WHO annual average guideline value.

In the 2007–08 study, the highest maximum seven-day and average seven-day concentrations of all the VOCs from the fourteen sites was reported for pinene. In terms of BTEX, the highest maximum seven-day toluene and ethylbenzene concentrations were reported at James Point, and the highest maximum seven-day benzene and xylene concentrations were reported at the Kwinana Golf Course site. The highest average seven-day ethylbenzene and xylene concentrations were reported at the Kwinana Beach site, and the highest average seven-day benzene and toluene concentrations were reported at the James Point and Kwinana Container Terminal sites respectively. The average seven-day benzene, toluene and xylene concentrations from each of the 14 sites were well below the corresponding NEPM annual average monitoring investigation levels and the average ethylbenzene concentrations were much lower than the WHO annual average guideline value.

7 Heavy metals

Heavy metals occur naturally within the Earths crust. They mainly exist as solid metal particles or metals attached to the surface of other particles. Heavy metals are elements and therefore cannot be destroyed, nor can their properties be easily altered. In the context of this study, heavy metals are elements that generally exist as a solid at room temperature and so may not, in the strictest sense of the word, actually be a metal or be one of the heavier elements. For example, sulfur is not considered a metal, but it is included in the heavy metal suite.

Heavy metals enter our bodies through food, drinking water and air. Minute levels of some heavy metals are essential to human health, however high concentrations may be harmful.

Method

Sampling for heavy metals was conducted in Kwinana, Perth CBD and Duncraig in 2005–06 as part of the Perth wide background Air Quality Study. Samples were collected using a TSP High Volume Samplers (HiVol). These HiVols were run for 24 hours on a six-day rotational cycle. The HiVol filter collects particles on a 203mm x 254mm (8inch x 10inch) glass fibre filter. All filter papers were analysed for TSP loading and a range of heavy metals.

In 2009–10, additional heavy metals sampling was conducted at Calista Primary School and Hillman Child Health centre. These were performed as per the 2005–06 study using TSP high volume samplers.

The sites and dates of sampling undertaken by DEC in the region are presented in Table 7.1.

Table 7.1 Metals monitoring in 2005–06 and 2009–10

Site	Monitoring dates
Duncraig	21/02/2005 – 22/02/2006
Perth CBD	21/02/2005 – 22/02/2006
Hope Valley	21/02/2005 – 22/02/2006
Calista	12/06/2009 – 1/06/2010
Hillman	12/06/2009 – 1/06/2010

Results

2005–06 study

The maximum 24-hour average and annual average concentration for all metals measured at Duncraig, Perth CBD and Hope Valley during the period 21 January 2005 to 22 February 2006 are shown in Figure 7.1. The concentrations (vertical axis of graphs) have been presented in a logarithmic scale to better display all of the concentrations.

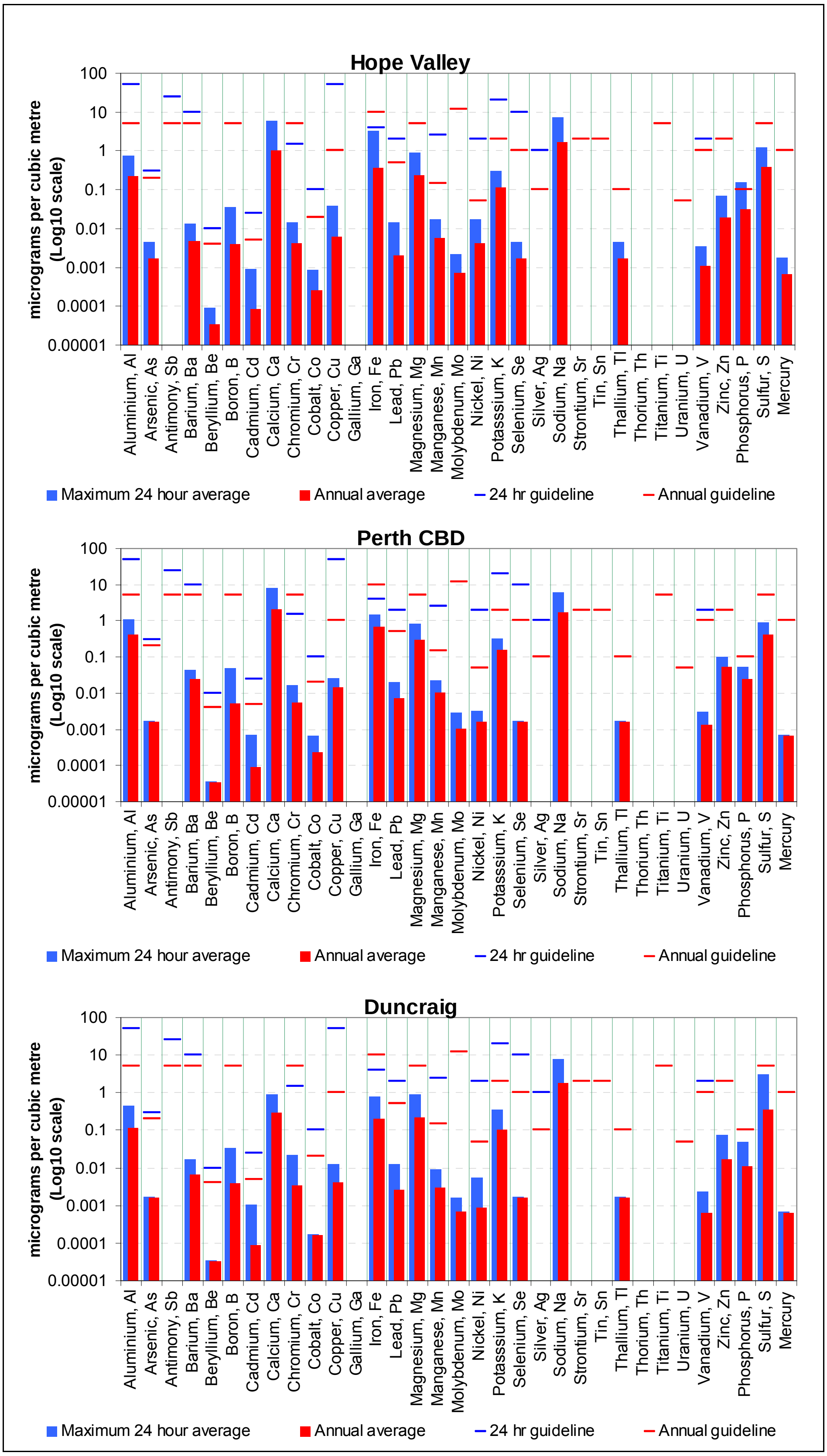


Figure 7.1 Heavy metals concentrations from 21 February 2005 to 22 February 2006.

Both 24-hour and annual guidelines have been included in Figure 7.1. The sources of these annual guidelines are provided in Appendix 3. Where no guideline is available, the relevant position on the graph has been left blank.

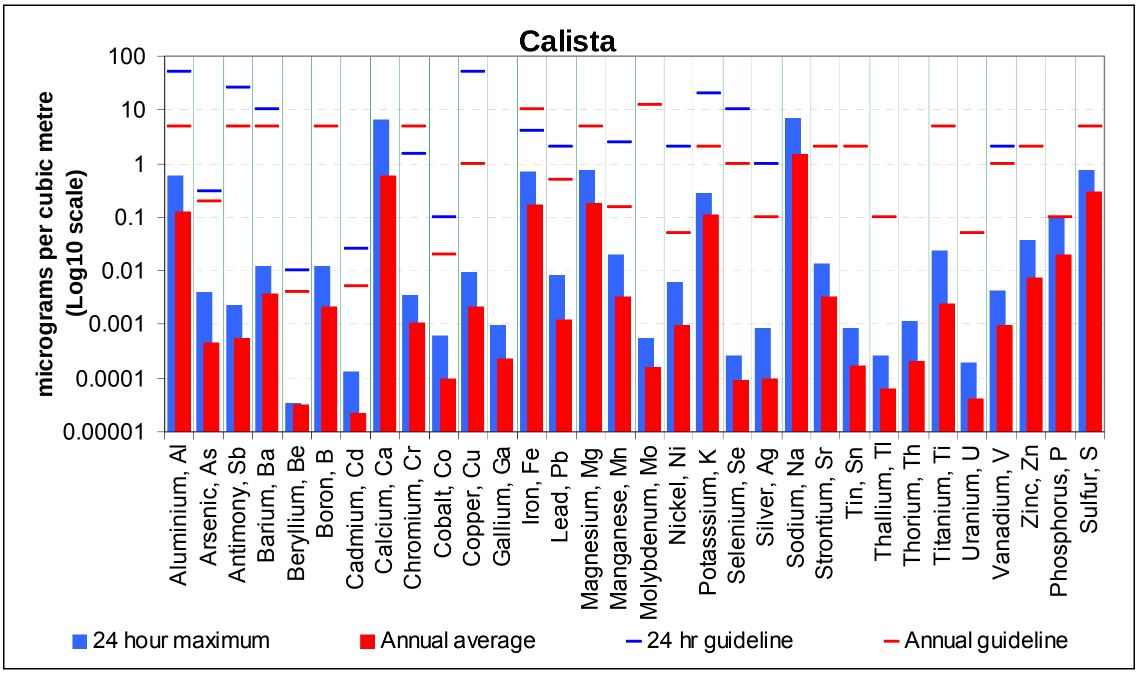
The elements shown as blank in Figure 7.1 are those where no determination was made during the 2005–06 study, but were included and analysed in the 2009–10 study. These elements have been included in Figure 7.2 for comparison to the 2009–10 study.

The highest concentration for each site was sodium. This is not unusual given the close proximity of Perth to the Indian Ocean. Sodium is a major constituent of sea salt. The second highest was calcium at Hope Valley and Perth CBD and sulfur at Duncraig.

For each element, the maximum 24-hour average for each element and overall annual average were below the recommended guideline values.

2009–10 study

The maximum 24-hour average and average 24-hour concentrations for all metals measured at Calista and Hillman during the period from 12 June 2009 to 1 June 2010 is shown in Figure 7.2. The concentrations (vertical axis of the graphs) have been presented in a logarithmic scale to better display all of the concentrations. Both 24 hour and annual guidelines have been included in Figure 7.2. The sources of these annual guidelines are provided in Appendix 3. Where no guideline was available, the relevant position on the graph has been left blank.



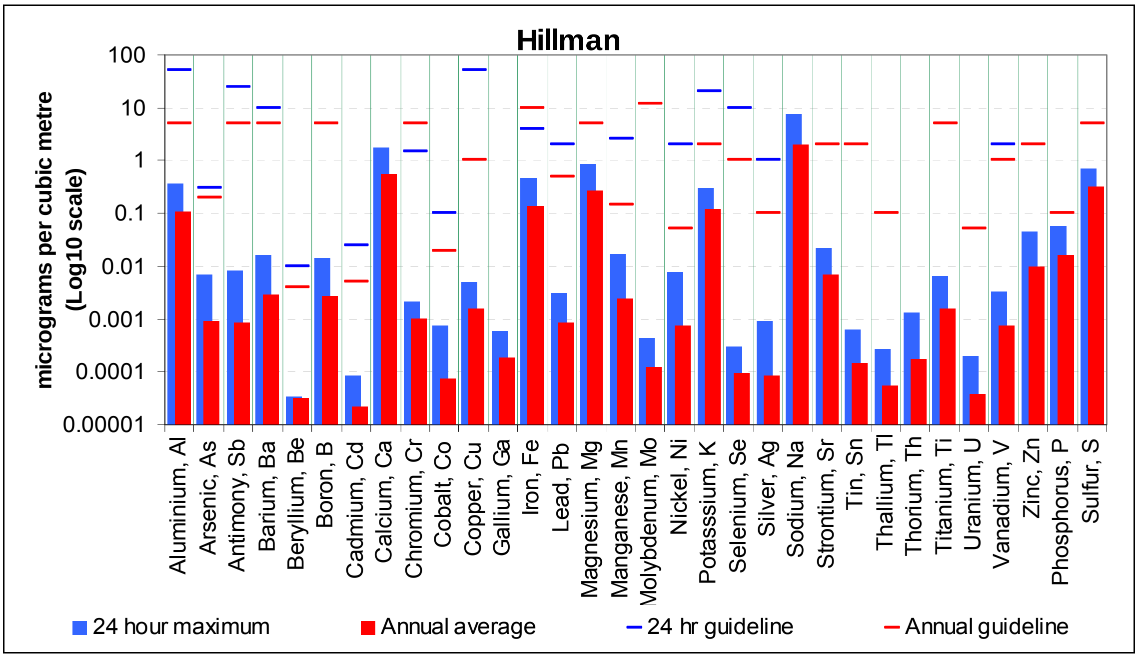


Figure 7.2 Heavy metals concentration 12 June 2009 to 1 June 2010.

The highest 24-hour concentrations across both sites were for sodium and calcium. As in the 2005–06 study, each elements' maximum and average 24-hour concentration were less than the recommended guideline values.

Discussion

In the 2005–06 study, the highest concentration for each site was sodium. This is not unusual given the close proximity of Perth to the Indian Ocean. Sodium is a major constituent of sea salt. The second highest was calcium at Hope Valley and Perth CBD and sulfur at Duncraig.

In the 2009–10 study, the highest 24-hour concentrations across both Hillman and Calista were for sodium and calcium. As in the 2005–06 study, each elements' maximum and average 24-hour concentration were less than the recommended guideline values.

8 Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are the product of incomplete combustion i.e. the fuel has not completely burnt. PAHs are organic compounds which include only carbon and hydrogen atoms with a structure resembling rings. The simplest PAH is called naphthalene and contains two fused benzene (six-sided) rings. As a general rule, the more rings a PAH possesses, the less volatile it is.

Sources of PAHs include motor vehicles, domestic burning of coal and wood for space heating, power generation via coal and oil, incineration, wood burning, cooking, smoking and burning natural gas. Napthalene is used in dyes, explosives, plastics lubricant and moth repellant (moth balls). Anthracene, containing three rings, is used in insecticides and wood preservatives.

PAH levels in the general atmosphere are usually higher during winter months due to the increase in wood heater use and tend to be concentrated in urban areas.

Method

PAHs were monitored in 2005–06 at Duncraig, Queens Buildings and Hope Valley using high volume samplers according to USEPA Method TO-13A '*Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)*'. Twenty-four hour samples were taken once every six days from 29 January 2005 to 29 January 2006.

The data from the 2005–06 study has been available on the DEC Air Quality website since 2008.

Results

2005–06

The annual average concentration for all PAHs measured at Duncraig, Perth CBD and Hope Valley during the period 29 January 2005 to 29 January 2006 are presented in Figure 8.1. The concentrations (vertical axis of the graph) have been presented in a logarithmic scale to better display all of the concentrations.

The annual guidelines have been included in Figure 8.1. The sources of these annual guidelines are provided in Appendix 3. Where no guideline is available, the relevant position on the graph has been left blank.

The compound benzo(a)pyrene is used by the NEPM as a marker for PAH's and has been included in the National Environment Protection (air toxics) Measure. The monitoring investigation level for benzo(a)pyrene is 0.3 nanograms per cubic metre (ng/m^3) averaged over one year.

The NEPM defines monitoring investigation values as levels of air pollution below which lifetime exposure, or exposure for a given averaging time, does not constitute a significant health risk. If these limits are exceeded in the short term, it does not mean that adverse health effects automatically occur.

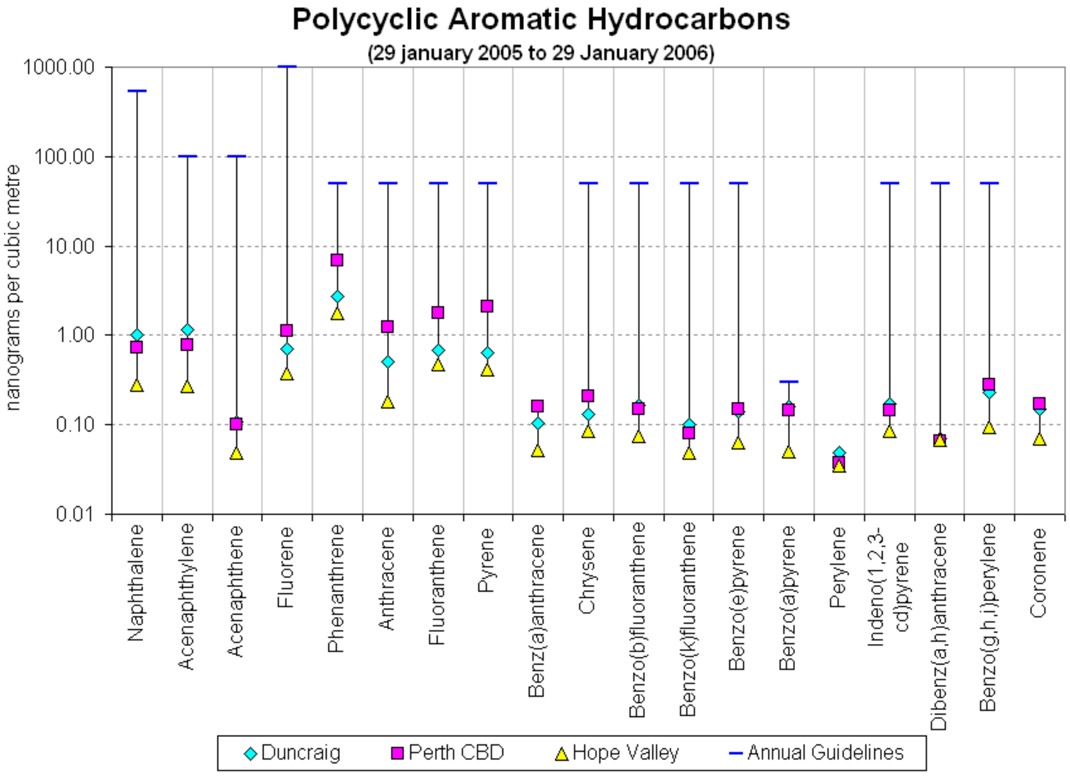


Figure 8.1 Polycyclic aromatic hydrocarbon concentrations from 29 January 2005 to 29 January 2006

The highest annual concentration for benzo(a)pyrene was at Duncraig measuring 0.16 ng/m^3 followed by Perth CBD at 0.14ng/m^3. The annual average at Hope Valley was 0.05ng/m^3.

Whereas there is no 24 hour standard for PAHs, the three highest 24 hour concentrations measured were 1.31ng/m^3, 1.25ng/m^3 and 1.18ng/m^3 and were all recorded at Duncraig.

Discussion

The concentration of PAH’s during the 2005–06 study was lower than all indicated guidelines. The sites with the highest annual concentration were Duncraig and Perth CBD most likely due to wood heater and motor vehicle influences respectively. Hope Valley recorded the lowest overall PAH concentration of the three sites. DOH advises that while the annual PAH levels remain below the air toxics guidelines health effects are very unlikely.

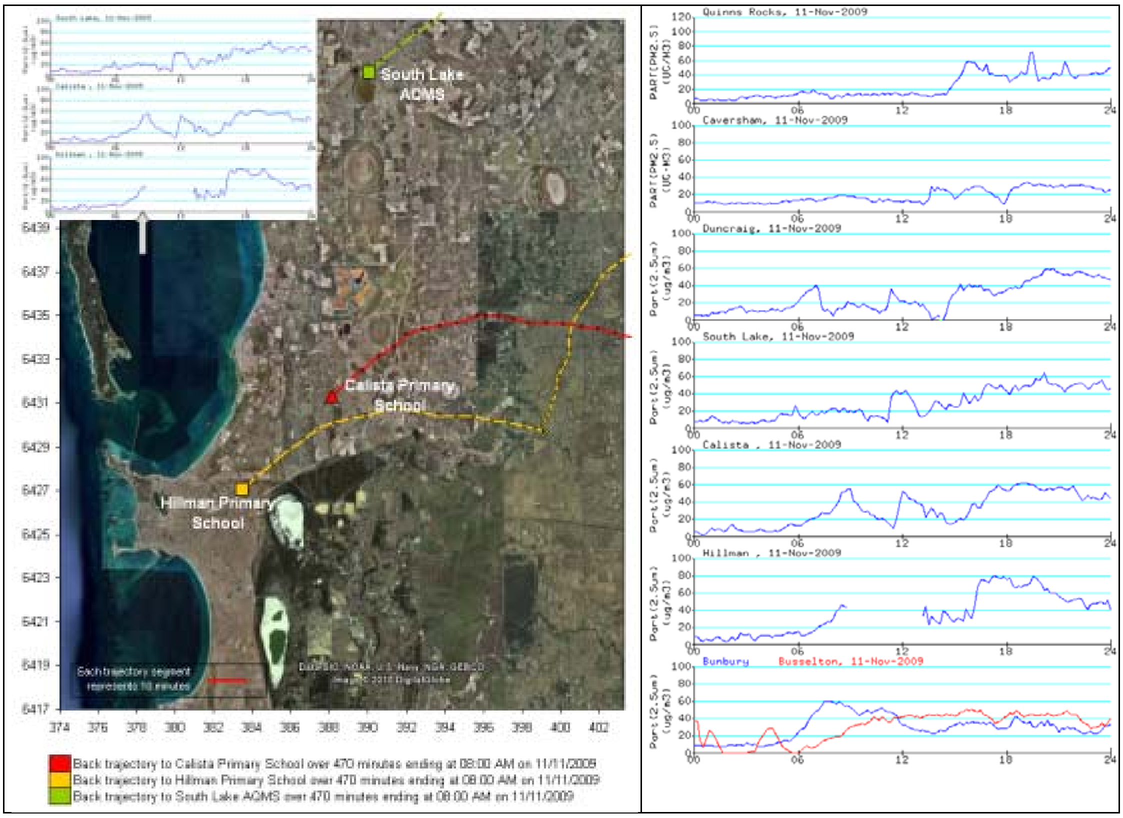
9 Summary outcomes

A number of background air quality studies have been conducted within the KIA and surrounds since 2005. These studies have mainly focused on air toxics such as volatile organic compounds (VOCs), carbonyls, heavy metals, ammonia and particles ($PM_{2.5}$ and TSP). These studies supplemented the existing three KIC and three DEC air NEPM pollutant stations currently operating in the region.

The levels of air toxics recorded during the three studies of 2005–06, 2007–08 and 2009–10 were similar to those found elsewhere in the Perth metropolitan region and were within health guidelines, except for acrolein, crotonaldehyde and methacrolein which DOH has advised are not sufficiently increased to cause a health concern for the majority of people. The majority of elevated crotonaldehyde, acrolein and methacrolein concentrations occurs in the summer months and is most likely due to various smoke events originating in the south-west of the state. The number of complaints by the local community shows that there is strong interest in air quality in the region. Unfortunately limitations with current monitoring technologies available make it difficult to determine the root cause of many of these complaints.

Appendix 1–Back trajectories for NEPM $PM_{2.5}$ advisory standard exceedences

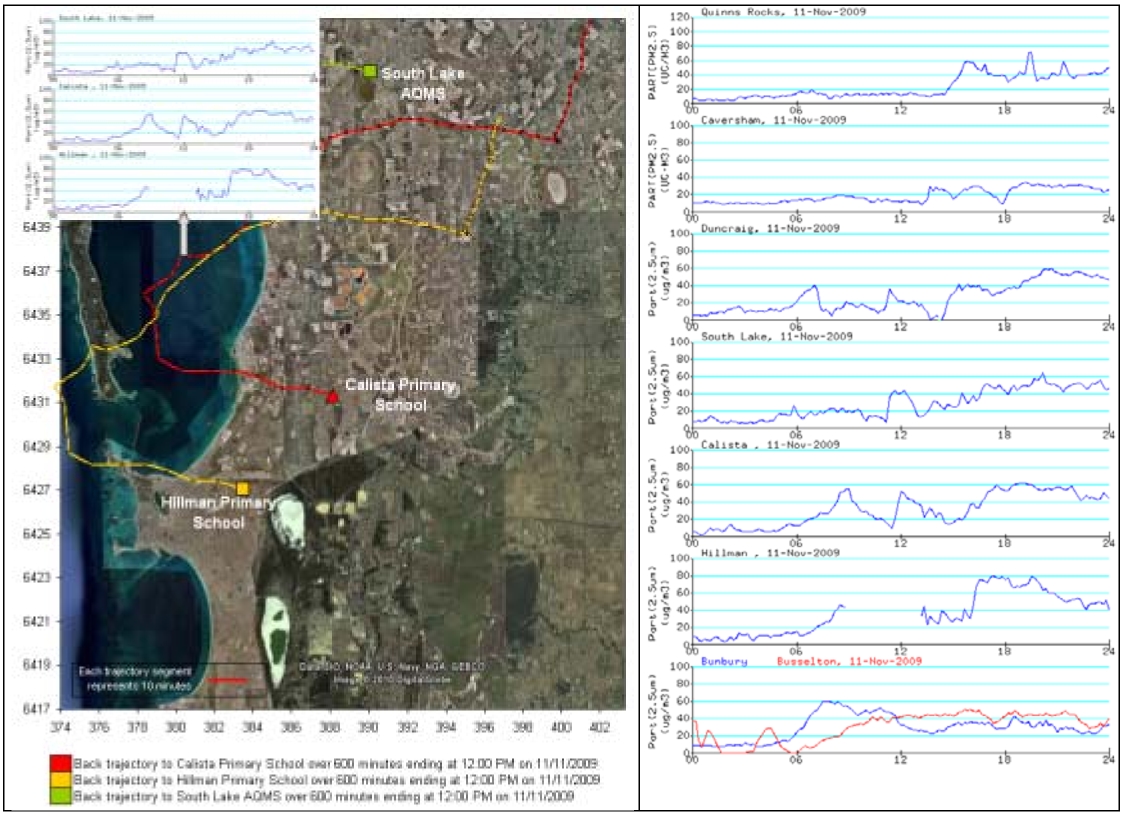
11 November 2009—8am



Wind trajectories for the morning of 11 November 2009 indicate that the source of the $PM_{2.5}$ event to be from the east. In addition to the Calista Primary School and Hillman Child Health Centre sites, Duncraig, South Lake, Bunbury and Busselton also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	23.6µg/m^3	Calista	31.5µg/m^3
Caversham	18.9µg/m^3	Hillman	36.6µg/m^3
Duncraig	26.6µg/m^3	Bunbury	30.0µg/m^3
South Lake	28.5µg/m^3	Busselton	30.5µg/m^3

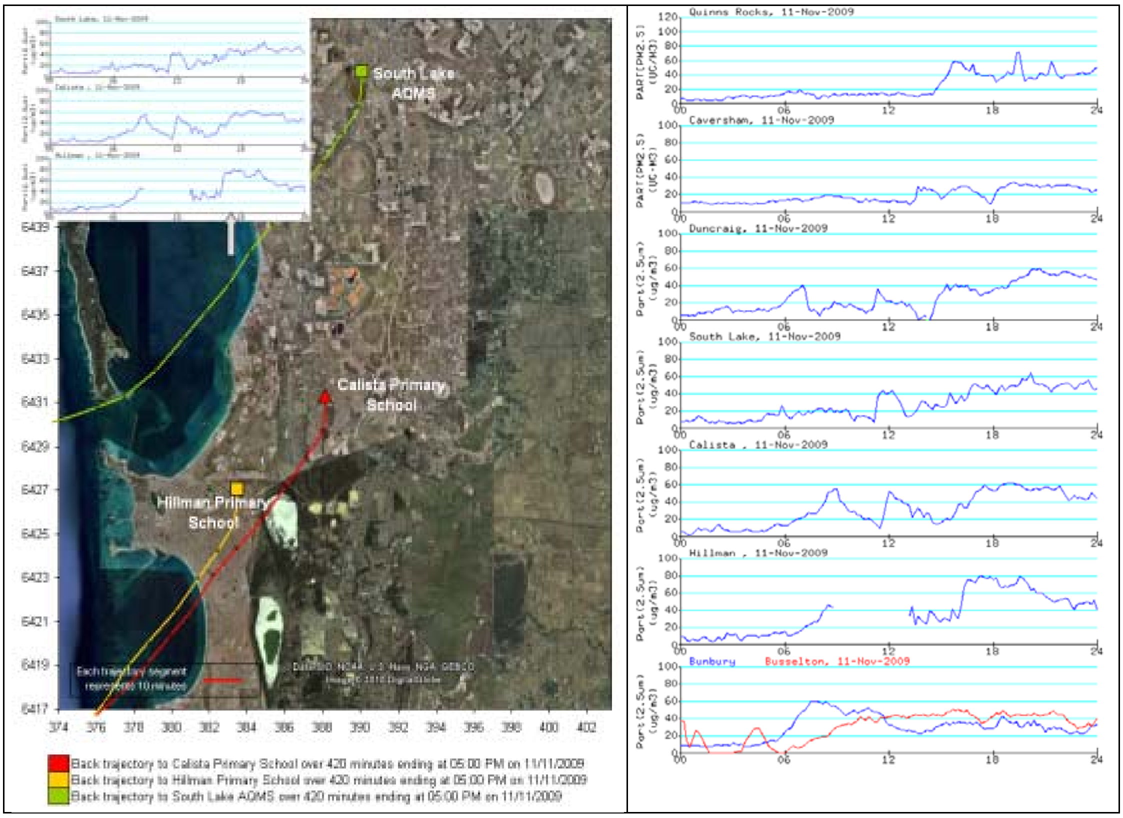
11 November 2009—12 noon



Wind trajectories for the morning of 11 November 2009 indicate that the source of the $PM_{2.5}$ event to be from the east. In addition to the Calista Primary School and Hillman Child Health Centre sites, Duncraig, South Lake, Bunbury and Busselton also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	23.6µg/m^3	Calista	31.5µg/m^3
Caversham	18.9µg/m^3	Hillman	36.6µg/m^3
Duncraig	26.6µg/m^3	Bunbury	30.0µg/m^3
South Lake	28.5µg/m^3	Busselton	30.5µg/m^3

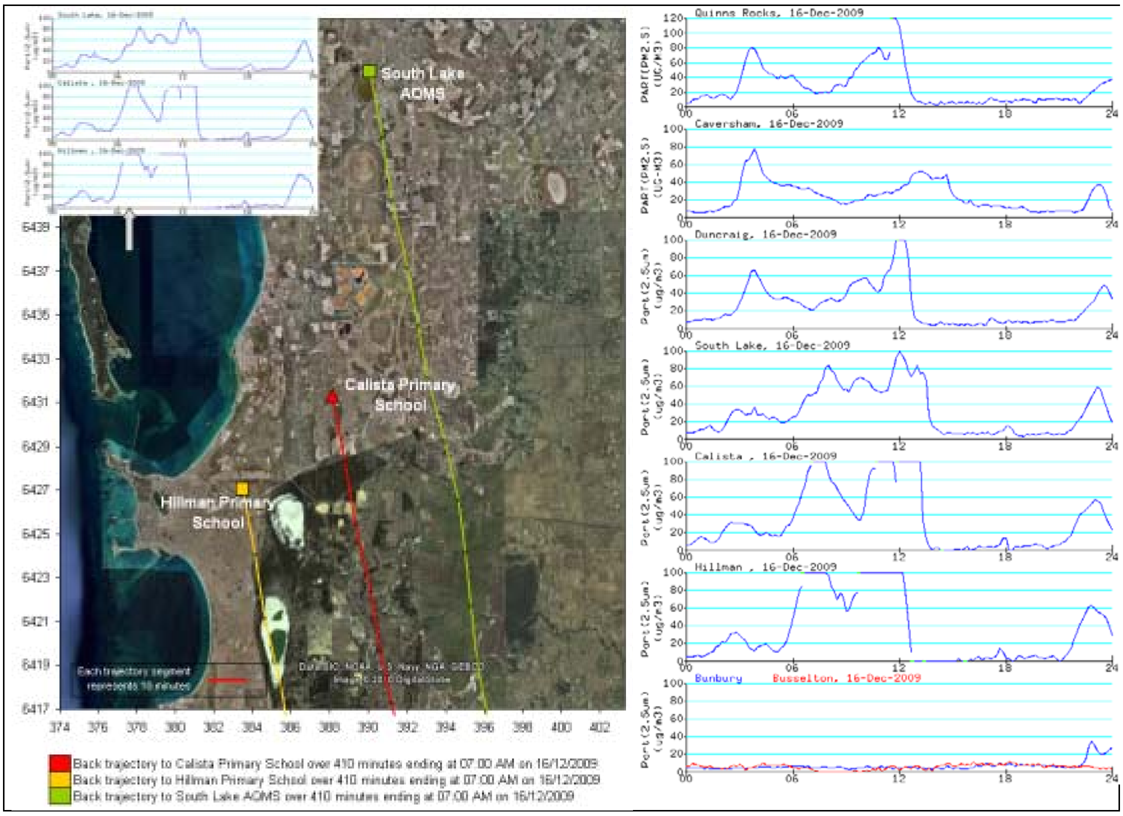
11 November 2009—5pm



Wind trajectories for the afternoon of 11 November 2009 indicate that the source of the $PM_{2.5}$ event to be from the south west. In addition to the Calista Primary School and Hillman Child Health Centre sites, Duncraig, South Lake, Bunbury and Busselton also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	23.6µg/m^3	Calista	31.5µg/m^3
Caversham	18.9µg/m^3	Hillman	36.6µg/m^3
Duncraig	26.6µg/m^3	Bunbury	30.0µg/m^3
South Lake	28.5µg/m^3	Busselton	30.5µg/m^3

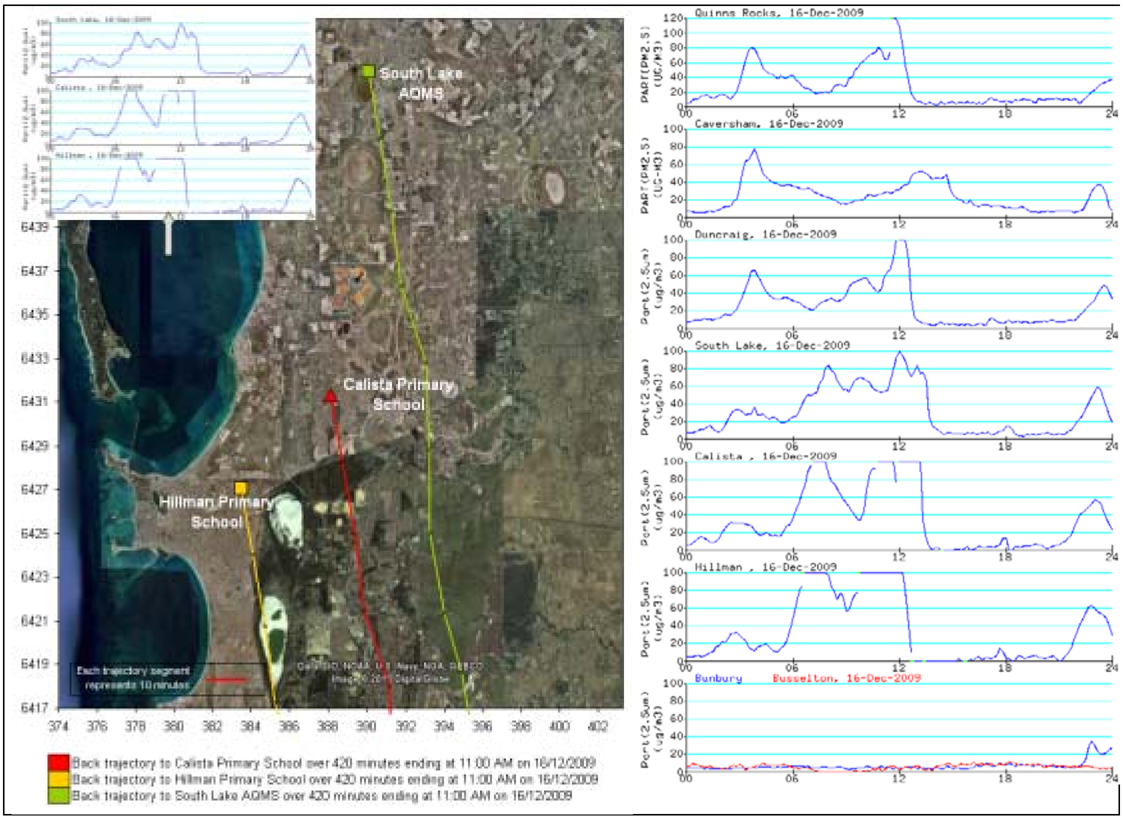
16 December 2009—7am



Wind trajectories for the morning of 16 December 2009 indicate that the source of the $PM_{2.5}$ event to be from the south. In addition to the Calista Primary School and Hillman Child Health Centre sites, Quinns Rocks, Duncraig and South Lake also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	27.2µg/m^3	Calista	37.0µg/m^3
Caversham	24.7µg/m^3	Hillman	40.0µg/m^3
Duncraig	26.3µg/m^3	Bunbury	7.2µg/m^3
South Lake	32.0µg/m^3	Busselton	5.9µg/m^3

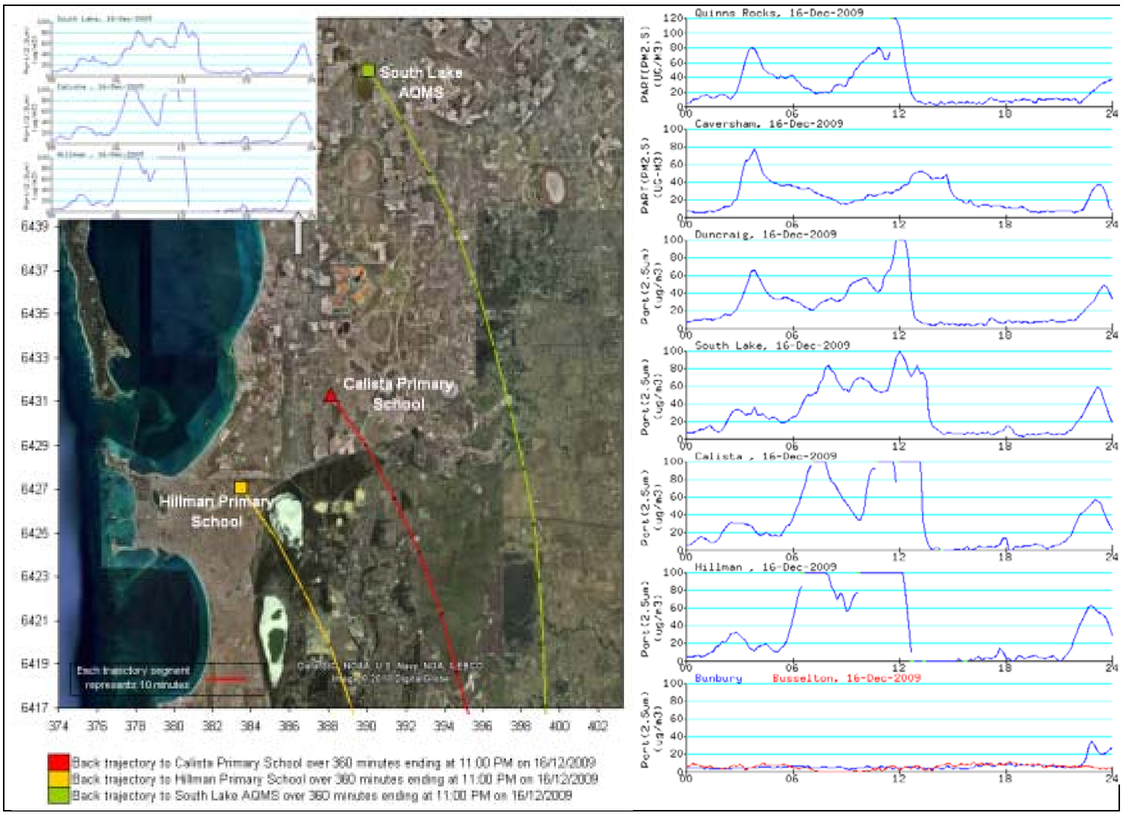
16 December 2009—11am



Wind trajectories for the morning of 16 December 2009 indicate that the source of the $PM_{2.5}$ event to be from the south. In addition to the Calista Primary School and Hillman Child Health Centre sites, Quinns Rocks, Duncraig and South Lake also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	27.2µg/m^3	Calista	37.0µg/m^3
Caversham	24.7µg/m^3	Hillman	40.0µg/m^3
Duncraig	26.3µg/m^3	Bunbury	7.2µg/m^3
South Lake	32.0µg/m^3	Busselton	5.9µg/m^3

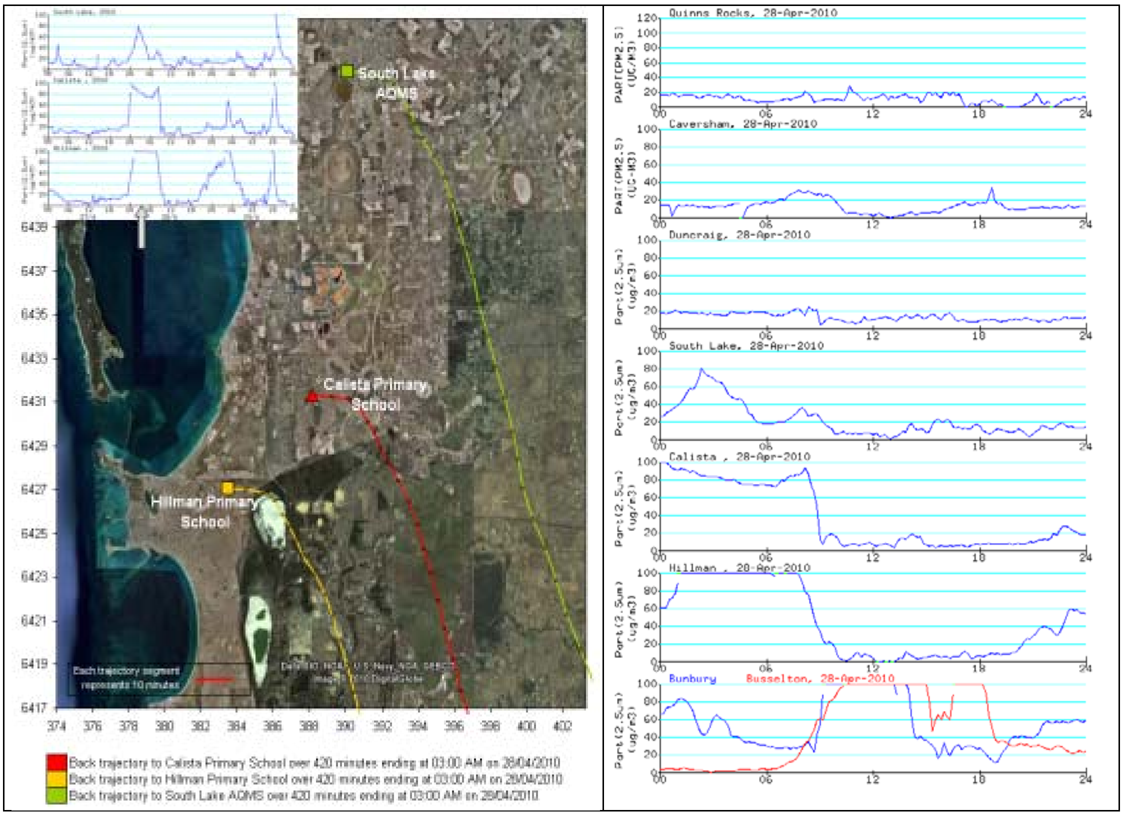
16 December 2009—11pm



Wind trajectories for the evening of 16 December 2009 indicate that the source of the $PM_{2.5}$ event to be from the south. In addition to the Calista Primary School and Hillman Child Health Centre sites, Quinns Rocks, Duncraig and South Lake also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	27.2µg/m^3	Calista	37.0µg/m^3
Caversham	24.7µg/m^3	Hillman	40.0µg/m^3
Duncraig	26.3µg/m^3	Bunbury	7.2µg/m^3
South Lake	32.0µg/m^3	Busselton	5.9µg/m^3

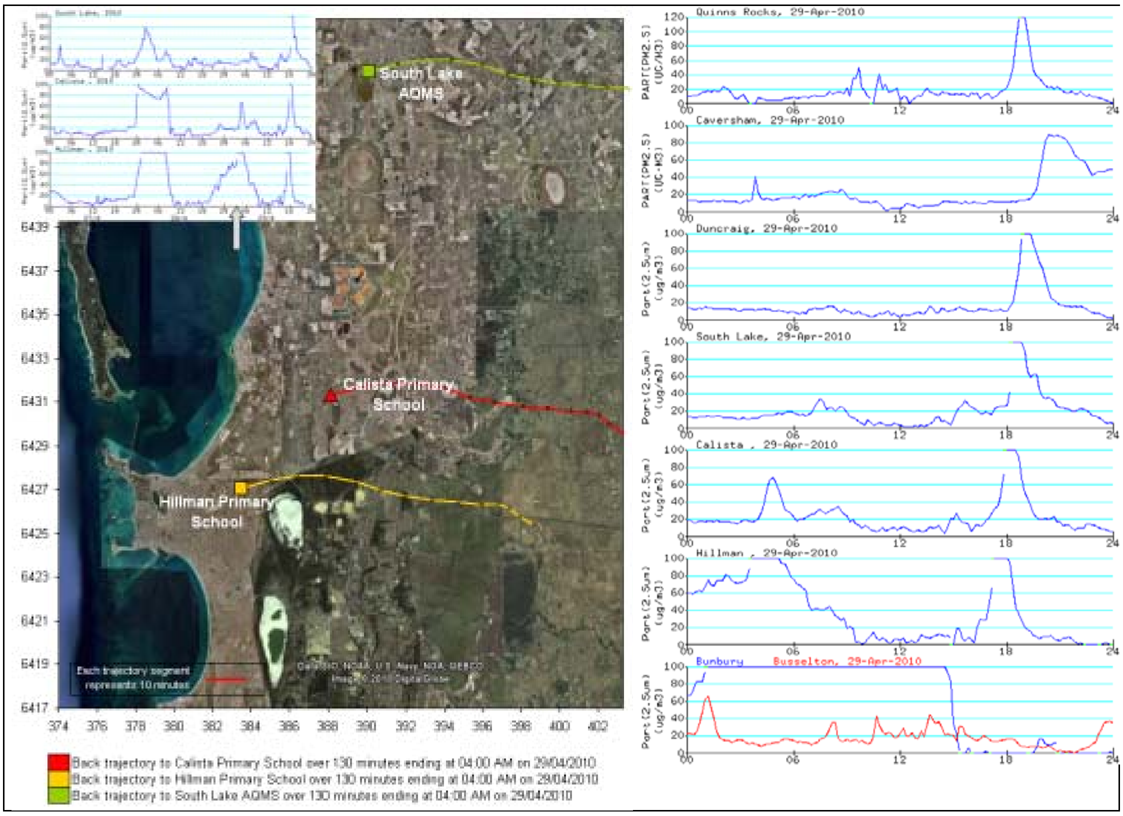
28 April 2010—3am



Wind trajectories for the morning of 28 April 2010 indicate that the source of the $PM_{2.5}$ event to be from the southeast. In addition to the Calista Primary School and Hillman Child Health Centre sites, Bunbury and Busselton also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	11.2µg/m^3	Calista	37.2µg/m^3
Caversham	13.3µg/m^3	Hillman	48.2µg/m^3
Duncraig	13.8µg/m^3	Bunbury	78.3µg/m^3
South Lake	22.3µg/m^3	Busselton	62.5µg/m^3

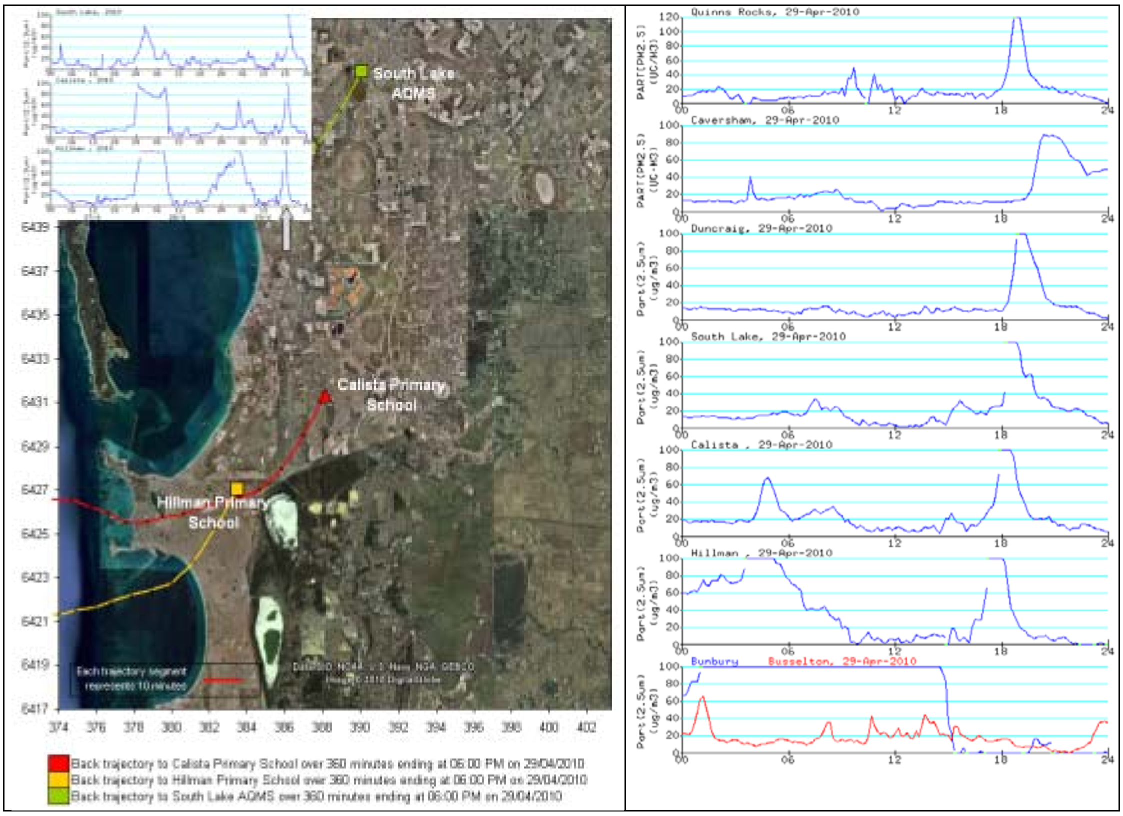
29 April 2010—4am



Wind trajectories for the morning of 29 April 2010 indicate that the source of the $PM_{2.5}$ event to be from the east. In addition to the Calista Primary School site, Bunbury also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	18.5µg/m^3	Calista	37.2µg/m^3
Caversham	22.7µg/m^3	Hillman	24.3µg/m^3
Duncraig	17.0µg/m^3	Bunbury	115.3µg/m^3
South Lake	21.0µg/m^3	Busselton	18.1µg/m^3

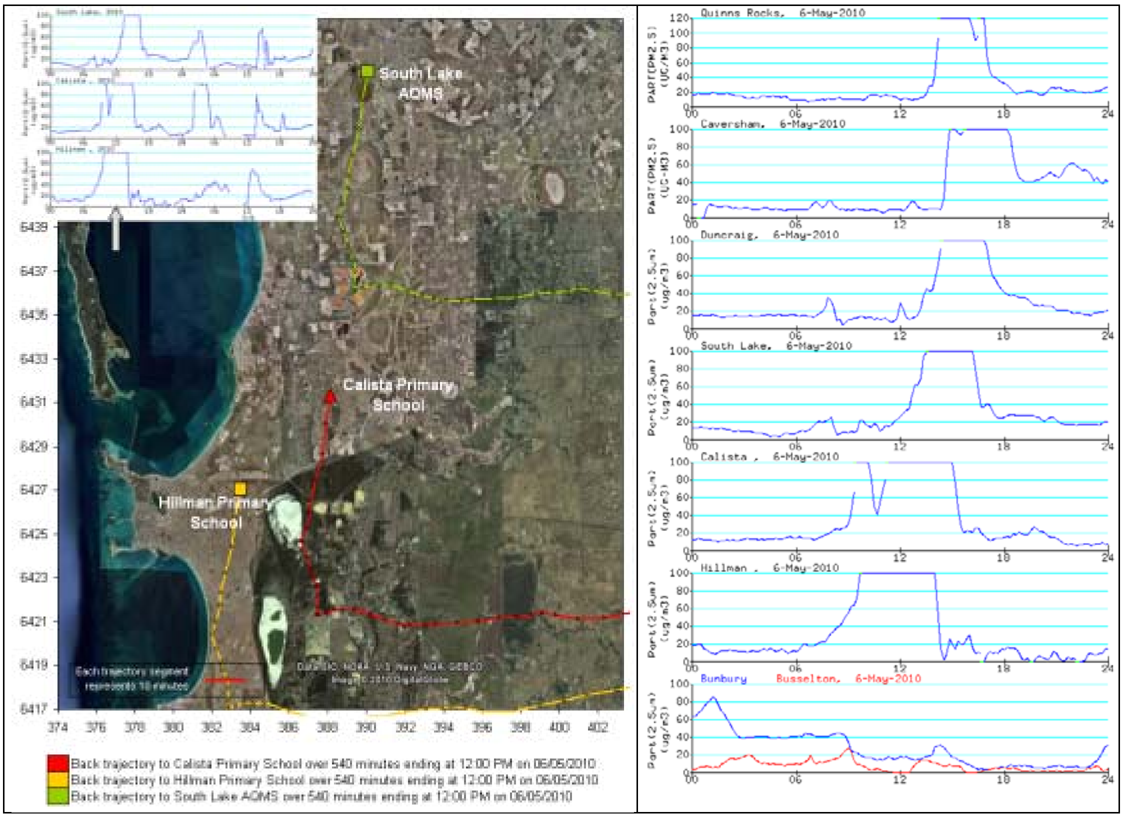
29 April 2010—6pm



Wind trajectories for the morning of 29 April 2010 indicate that the source of the $PM_{2.5}$ event to be from the south west. In addition to the Calista Primary School and Hillman Child Health Centre sites, Bunbury and Busselton also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	11.2µg/m^3	Calista	37.2µg/m^3
Caversham	13.3µg/m^3	Hillman	48.2µg/m^3
Duncraig	13.8µg/m^3	Bunbury	78.3µg/m^3
South Lake	22.3µg/m^3	Busselton	62.5µg/m^3

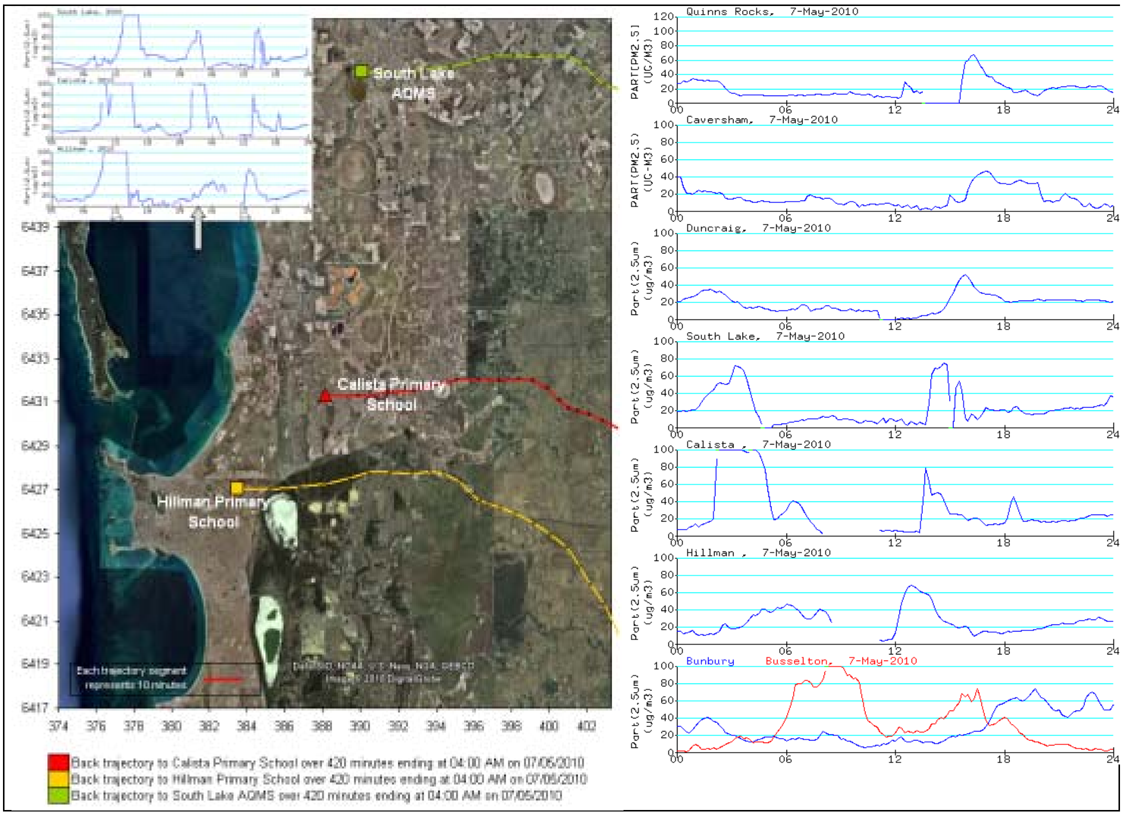
6 May 2010—12 noon



Wind trajectories for the afternoon of 6 May 2010 indicate that the source of the $PM_{2.5}$ event to be from the southeast. In addition to the Calista Primary School and Hillman Child Health Centre sites, Quinns Rocks, Caversham, Duncraig, South Lake and Bunbury also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	33.7µg/m^3	Calista	57.1µg/m^3
Caversham	45.2µg/m^3	Hillman	61.4µg/m^3
Duncraig	36.4µg/m^3	Bunbury	26.5µg/m^3
South Lake	40.0µg/m^3	Busselton	8.0µg/m^3

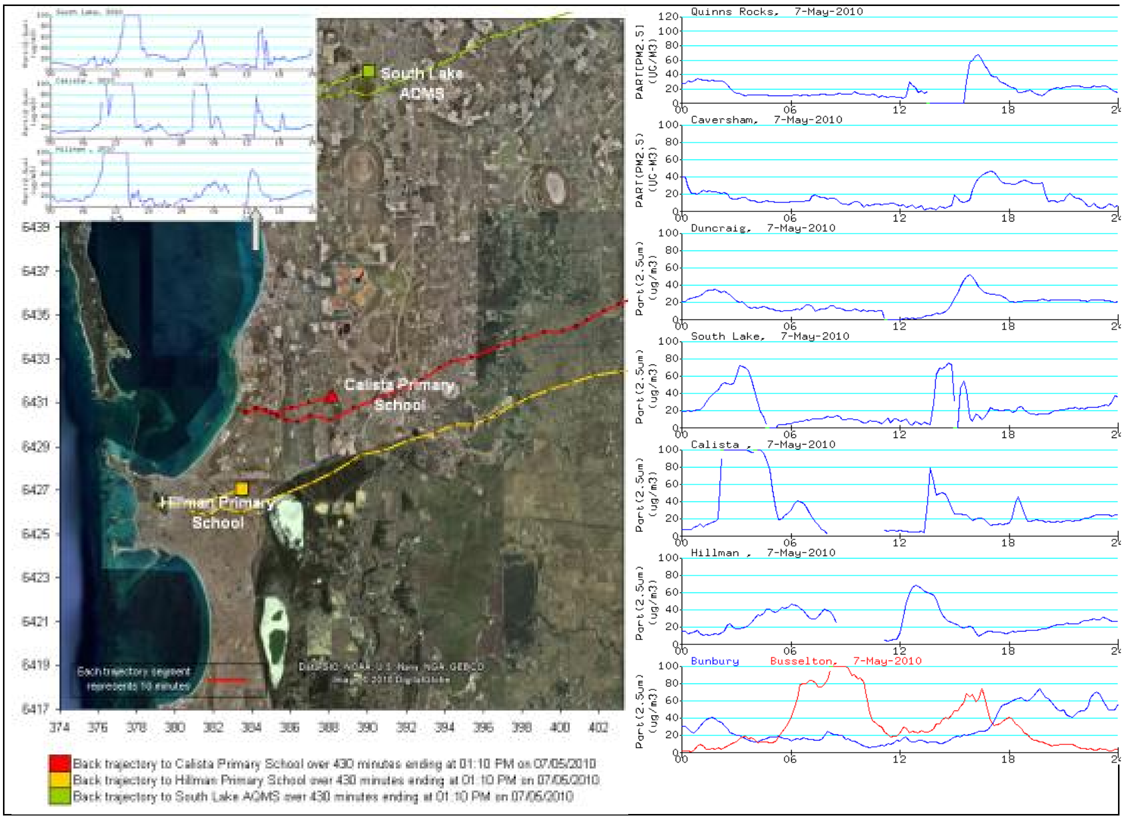
7 May 2010—4am



Wind trajectories for the morning of 7 May 2010 indicate that the source of the PM$_{2.5}$ event to be from the southeast. In addition to the Calista Primary School and Hillman Child Health Centre sites, Bunbury and Busselton also recorded PM$_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's PM$_{2.5}$ network.

Quinns Rocks	17.0µg/m^3	Calista	34.0µg/m^3
Caversham	16.3µg/m^3	Hillman	26.6µg/m^3
Duncraig	18.8µg/m^3	Bunbury	29.5µg/m^3
South Lake	22.0µg/m^3	Busselton	33.5µg/m^3

7 May 2010—1pm

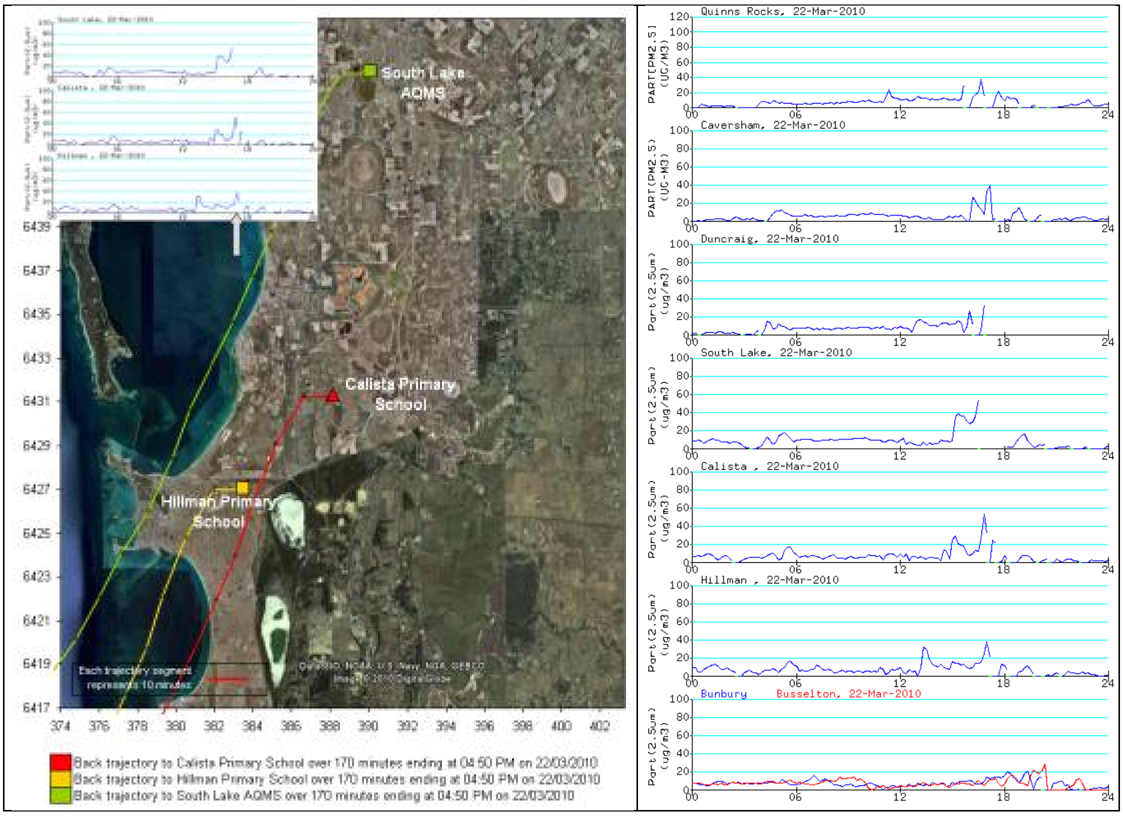


Wind trajectories for the afternoon of 7 May 2010 indicate that the source of the $PM_{2.5}$ event to be from the east. In addition to the Calista Primary School and Hillman Child Health Centre sites, Bunbury and Busselton also recorded $PM_{2.5}$ greater than the NEPM advisory standard of 25µg/m^3. The following 24-hour concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	17.0µg/m^3	Calista	34.0µg/m^3
Caversham	16.3µg/m^3	Hillman	26.6µg/m^3
Duncraig	18.8µg/m^3	Bunbury	29.5µg/m^3
South Lake	22.0µg/m^3	Busselton	33.5µg/m^3

Appendix 2 Particle events while winds were from the KIA

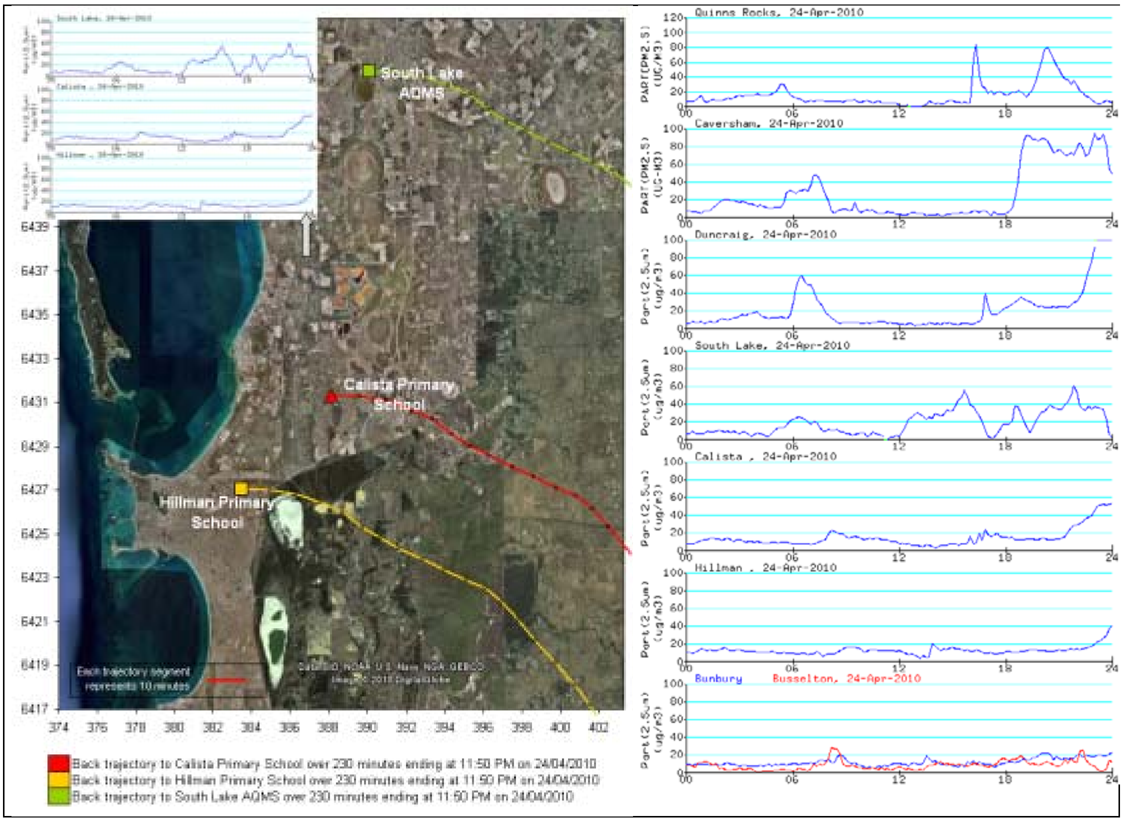
22 March 2010—4:50pm



Wind trajectories for the afternoon of 22 March 2010 indicate that the source of the $PM_{2.5}$ event to be from the south. All sites recorded $PM_{2.5}$ less than the NEPM advisory standard of 25µg/m^3. The following concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	6.4µg/m^3	Calista	6.9µg/m^3
Caversham	5.3µg/m^3	Hillman	7.0µg/m^3
Duncraig	N/A	Bunbury	7.5µg/m^3
South Lake	8.2µg/m^3	Busselton	7.4µg/m^3

24 April 2010—11:40pm



Wind trajectories for the afternoon of 24 April 2010 indicate that the source of the $PM_{2.5}$ event to be from the south east. All sites except Caversham recorded $PM_{2.5}$ less than the NEPM advisory standard of 25µg/m^3. The following concentrations were recorded within DEC's $PM_{2.5}$ network.

Quinns Rocks	15.7µg/m^3	Calista	14.8µg/m^3
Caversham	27.2µg/m^3	Hillman	12.8µg/m^3
Duncraig	22.0µg/m^3	Bunbury	12.1µg/m^3
South Lake	19.3µg/m^3	Busselton	8.7µg/m^3

Appendix 3 Guidelines used in this document

Currently, there is a project underway within DEC and DOH to determine a hierarchy of jurisdictional air quality guidelines suitable for use within Western Australia.

Pending the outcome of this project, where Australian air guidelines have been derived and endorsed at the national level, e.g. National Environment Protection Measure (NEPM), these have been used in this report for comparative purposes. Where no relevant Australian guideline has been derived, the World Health Organisation (WHO) has been used. Where there is no WHO guideline value that can be used for comparison, a descending hierarchy of jurisdictions has been used as follows:

1. United Kingdom Environmental Agency (UKEA)
2. Netherlands National Institute of Public Health and the Environment (RIVM)
3. Ontario Ambient Air Quality Criteria (OAQC)
4. United States of America
    - Agency for Toxic Substances Disease Registry (ATSDR)
    - Texas Commission on Environmental Quality (TCEQ).

Within this report, these jurisdictional guidelines are used to compare concentrations measured during the study. Where these measured concentrations exceed any of these nominated guidelines, DOH is requested to advise of any health impacts.

Guidelines from the following jurisdiction were used:

NEPM – National Environment protection Measure
WHO – World health Organisation
UKEA – United Kingdom Environmental Agency
OAQC – Ontario Ambient Air Quality Criteria
TCEQ – Texas Commission on Environmental Quality
* – Odour
ATSDR – Agency for Toxic Substances and Disease Registry
UKEA – United Kingdom Environmental Agency
NEPM – National Environment protection Measure
OAQC – Ontario Ambient Air Quality Criteria
TCEQ – Texas Commission on Environmental Quality
WHO – World health Organisation

Carbonyls

Substance	**24 Hour guideline (µg/m^3)**	**Jurisdiction**	**Annual average (µg/m^3)**	**Jurisdiction**
Acetaldehyde	2,000	WHO	50	WHO
Acetone	11,800	OAQC	18,100	UKEA
Acrolein	6.8	DOH (WA)	1.5	DOH (WA)
Benzaldehyde	N/A		9	TCEQ *
2-Butanone	1000	OAQC	6,000	UKEA
Butyraldehyde	N/A		74	TCEQ *
Crotonaldehyde	N/A		1.5	DOH (WA)
Formaldehyde	53	NEPM	5	UKEA
Hexaldehyde	N/A		N/A	
Methacrolein	6.8	DOH (WA)	1.5	DOH (WA)
Propionaldehyde	N/A		46	TCEQ *
p-Tolualdehyde	N/A		9	TCEQ
Valeraldehyde	N/A		180	TCEQ *

Volatile organic compounds

Substance	Annual guideline (µg/m^3)	Jurisdiction
Benzene	10.4	NEPM
Benzene, 1,2,4-trimethyl-	1,250	UKEA
Benzene, 1,4-dichloro-	1,000	WHO
Bromochloromethane	10,800	UKEA
Butanol	3,080	UKEA
Butyl acetate	7,420	UKEA
2-butoxyethanol	1,230	UKEA
Cyclohexane	3,500	UKEA
Cyclohexanone	1,020	UKEA
n-decane	1,000	TCEQ
1,2-Dichloropropane	35	ATSDR
n-Heptane	350	TCEQ
n-Hexane	720	UKEA
Ethyl acetate	14,600	UKEA
Ethyl-ter-butyl ether	21	TCEQ
Isobutanol	290	TCEQ
Isooctane	350	TCEQ
Isopropylbenzene	250	TCEQ
1-Methoxy-2-propanol	19	TCEQ
1-Methoxy-2-propyl acetate	28	TCEQ
Methyl-ter-butyl ether	700	ATSDR
Methylethylketone	590	TCEQ
Methylisobutylketone	82	TCEQ
Methyl methacrylate	200	WHO
2-Methylpentane	350	TCEQ
3-Methylpentane	350	TCEQ
Nonane	1,050	TCEQ
N-Octane	350	TCEQ
Pinene	350	TCEQ
Styrene	800	UKEA
Tetrachloroethylene	3,450	UKEA
Toluene	411	NEPM
Undecane	50	TCEQ
1,1,1-Trichloroethane	11,100	UKEA
Trichloroethylene	1,100	UKEA
Xylenes	952	NEPM
Ethylbenzene	22,000	WHO

Guidelines for the following compounds were not found.

Disulfide, dimethyl-
Hexan-1-ol, 2-ethyl-
Limonene

Heavy metals

Substance	24 hr guideline (µg/m^3)	Jurisdiction	Annual guideline (µg/m^3)	Jurisdiction
Aluminium, Al	50	TCEQ	5	TCEQ
Arsenic, As	0.3	OAQC	0.2	UKEA
Antimony, Sb	25	OAQC	5	UKEA
Barium, Ba	10	OAQC	5	UKEA
Beryllium, Be	0.01	OAQC	0.004	UKEA
Boron, B	120	OAQC	5	TCEQ
Cadmium, Cd	0.1	TCEQ	0.005	WHO
Chromium, Cr	1.5	OAQC	5	UKEA
Cobalt, Co	0.1	OAQC	0.2	UKEA
Copper, Cu			1	TCEQ
Iron, Fe	4	OAQC	10	UKEA
Lead, Pb	0.5	OAQC	0.5	NEPM
Magnesium, Mg			5	TCEQ
Manganese, Mn	2.5	OAQC	0.15	WHO
Molybdenum, Mo	120	OAQC	12	RIVM
Nickel, Ni	2	OAQC	0.05	RIVM
Potasssium, K	20	TCEQ	2	TCEQ
Selenium, Se	10	OAQC	1	UKEA
Silver, Ag	1	OAQC	0.1	UKEA
Strontium, Sr	120	OAQC	2	TCEQ
Tin, Sn	10	OAQC	1	UKEA
Thallium, Tl			0.1	TCEQ
Titanium, Ti	120	OAQC	5	TCEQ
Uranium, U			2	UKEA
Vanadium, V	1	WHO	5	UKEA
Zinc, Zn	120	OAQC	2	TCEQ
Phosphorus, P			1	UKEA
Sulfur, S			5	TCEQ
Mercury	2	OAQC	1	WHO

Guidelines for the following heavy metals were not found.

Calcium
Gallium
Sodium
Thorium

Polycyclic aromatic hydrocarbons

Substance	Annual guideline (ng/m^3)	Jurisdiction
Naphthalene	530	UKEA
Acenaphthylene	100	TCEQ
Acenaphthene	100	TCEQ
Fluorene	1,000	TCEQ
Phenanthrene	50	TCEQ
Anthracene	50	TCEQ
Fluoranthene	50	TCEQ
Pyrene	50	TCEQ
Chrysene	50	TCEQ
Benzo(b)fluoranthene	50	TCEQ
Benzo(k)fluoranthene	50	TCEQ
Benzo(e)pyrene	50	TCEQ
Benzo(a)pyrene	0.3	NEPM
Indeno(1,2,3-cd)pyrene	50	TCEQ
Dibenz(a,h)anthracene	50	TCEQ
Benzo(g,h,i)perylene	50	TCEQ

Guidelines for the following compounds were not found.

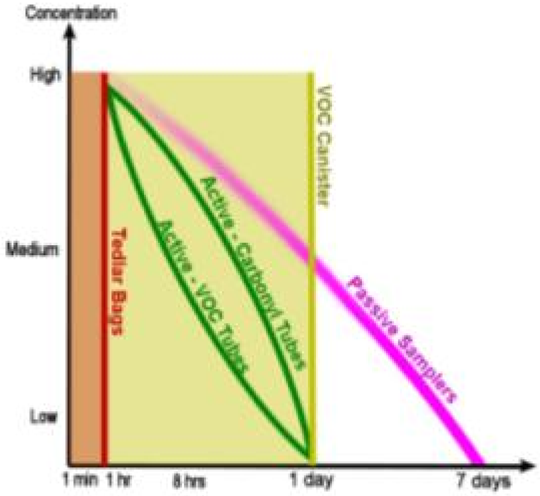
Benz(a)anthracene
Perylene
Coronene

Appendix 4 Quick guide to air sampling methods

There are a number of methods both active and passive available to sample for air pollutants and each method has its own advantages and disadvantages. Active sampling involves the collection of a pollutant sample through some active process such as a pump or physical collection technique. Passive sampling is where a collection device is placed in the field and the pollutant is absorbed onto the device without the need for any powered device.

Each method has particular advantages and disadvantages. For example, passive samplers have been used extensively in this study as they are easy to use and require no infrastructure or pumps to operate in the field. They are also less likely to be vandalised in the field due to their low visibility and value. A disadvantage is that passive samplers need to remain in the field for a week or so to ensure enough pollutant has absorbed onto the sampler to allow a valid laboratory analysis. This makes passive samplers unsuitable for short-term sampling. Canisters on the other hand are able to be used for short-term sampling of between a few seconds and one day and are a NEPC approved method for BTEX sampling, but are expensive to purchase and analyse. The canisters are also prone to vandalism and theft if left unattended in the field.

The following diagram illustrates the usefulness of a number of sampling methods over various time scales.



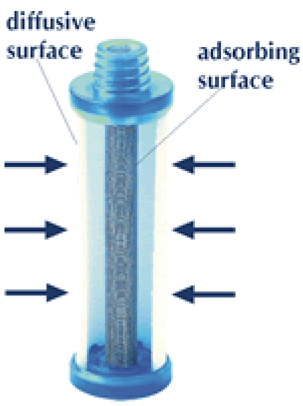
It is notoriously difficult to sample for odours. Whilst one may collect samples, chemical analysis may reveal little or no result. For the time being, the human nose is orders of magnitude more sensitive for certain chemicals than monitoring equipment.

In some cases, practical technologies to monitor for certain pollutants simply do not exist. For example, while many particle monitors can sample real time particle levels, no known technology suitable for field use can perform real time chemical analysis on particles to determine their chemical composition.

The table below outlines some of the monitoring techniques used to obtain the air quality data used in this report.

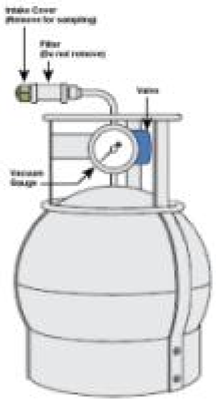
Radiello® passive sampling

Radiello® passive sampling is a method of sampling for a range of air toxics using a cylindrical adsorbing cartridge placed within a cylindrical diffusive membrane. The gaseous molecules move through the diffusive membrane towards the adsorbent bed at a fixed and known rate. Knowing this rate of diffusion for each gas species and the length of time the tube has been exposed; one can calculate the average concentration over the exposure period. To provide enough sample at typical ambient concentrations for a valid laboratory analysis, Radiellos need to remain in the field for one to two weeks. This sampling method cannot be used to sample short-term events and may in fact mask acute pollution events.



Canister sampling

Canister sampling uses an evacuated six litre stainless steel canister to obtain an air sample. These samples can either be a grab sample where the canister valve is simply opened and the vacuum inside the canister draws in a sample within a matter of seconds or a time integrated sample. Time-integrated samples require the addition of a flow controller or critical orifice to be placed in line with the canister which restricts the rate of air flow into the canister. These flow controllers/critical orifice assemblies are equipped with fine particulate filters and are set for any user-defined duration (or flow rate) from five minutes up to 24 hours.



High volume sampling

High volume sampling is used to collect particle samples onto an 8”x10” pre-weighed filter. Generally run for 24 hours at a constant flow rate of 1.1 cubic metres per minute, the filter is reweighed after sampling and the increase in filter weight is the mass of particles collected over 24 hours. The combination of particle mass collected and total air volume sampled gives one the average concentration of particles over the 24 hour sampling period. This method of sampling has the added advantage that the filter can be sent to a laboratory for chemical composition analysis. This sampling method cannot be used to sample short-term events and may in fact mask acute pollution events.

Continuous TEOM

The TEOM ambient particulate monitor measures ambient particulate concentrations directly and in real time using a tapered element oscillating microbalance. A known airflow is drawn through a 2.5µm size selective inlet head and maintained over a tapered glass element with a filter cartridge attached. This glass element is vibrated at its natural frequency. As particulate matter gathers on the cartridge, the tube's natural frequency decreases. The ambient mass concentration is proportional to this change in frequency, and is displayed in real time.

Continuous NO_x

The technique for monitoring nitrogen oxides is known as chemiluminescence and is based on the gas-phase reaction between nitric oxide (NO) and ozone (O_3). This reaction emits light with intensity linearly proportional to the concentration of nitric oxide when electronically excited NO_2 molecules decay to lower energy states. The nitrogen dioxide (NO_2) must first be transformed into nitric oxide (NO) via a NO_2-to-NO molybdenum converter before it can be measured using this technique.

When the sample pathway flows through the NO_2-to-NO converter, the chemiluminescence measured within the reaction chamber represents the total NO_x (NO_2 + NO) concentration. Bypassing the converter allows the measurement of the NO concentration only. The difference between the two signals is the value for NO_2.