ENVIRONMENT REPORT

VICTORIA'S AIR QUALITY – 2006

Publication 1140 June 2007

OVERVIEW

Victoria's air quality in 2006 was generally good, although major bushfires throughout 2006 led to many days of poor air quality due to high levels of particles.

Under climate change Victoria is predicted to become hotter and drier. As a result bushfires and dust storms are expected to become more frequent and continue to affect our air quality.

The bushfires also led to an increase in the number of days when the ozone objectives were not met. The hotter climate predicted for Victoria in the future will lead to a greater potential for ozone formation. The 2006 air monitoring results provide an indication of the potential effects of climate change on Victoria's air quality.

Although the air quality objectives were met for most pollutants, particle pollution continues to be a key issue. Elevated particle levels and poor visibility occurred particularly during the widespread bushfires in December 2006. Windblown dust and accumulation of combustion particles in calm, highly stable air also affected air quality and resulted in some additional days when the particle objectives were not met.

Compared to similar urban centres, Melbourne's air quality remains relatively good, with little change over the last decade despite increasing pressures such as population growth. Maintaining and improving Victoria's air quality will be a challenge in the context of expected continued population growth and the impacts of climate change.

Figure 1: Bushfires were the dominant influence on air quality in 2006

Photo: Wayne Hawkins courtesy of *The Age*.

EPA'S MONITORING NETWORK

Why do we monitor air quality?

EPA monitors air quality in order to ensure that the health and wellbeing of Victorians are maintained. Monitoring provides information for the community on the concentration of pollutants in the air. Monitoring also enables EPA to assess air quality relative to the established objectives, inform the development of air quality management strategies and evaluate the effectiveness of air quality management activities.

What do we monitor?

EPA monitors a range of pollutants specified in the National Environment Protection Measure (NEPM) for Ambient Air Quality and Victoria's State Environment Protection Policy (Ambient Air Quality). These include:

- *Particles smaller than 10 micrometres* (PM_{10}) – these particles (less than one-tenth the width of a human hair) can exacerbate existing respiratory and cardiovascular disease. High levels can lead to increases in hospitalisations and premature death.
- *Particles smaller than 2.5 micrometres* ($PM_{2.5}$) – these particles can penetrate deeply into the lungs.
- *Visibility-reducing particles* – these particles reduce visual distance and aesthetic enjoyment.
- *Ozone* (O_3) – ozone impacts on the respiratory system. Asthmatics and the elderly are particularly sensitive to the effects of ozone and exposure to high levels can result in increases in hospitalisations for heart and lung conditions.
- *Nitrogen dioxide* (NO_2) – this affects the respiratory system and the body's defence mechanisms. At high concentrations, it can lead to increases in hospitalisations and respiratory effects, particularly in children.
- *Carbon monoxide (CO)* – a gas readily absorbed into the bloodstream that affects transport of oxygen through the body. People suffering from cardiovascular disease are particularly sensitive.
- *Sulfur dioxide* (SO_2) – an irritant gas that affects the respiratory system at high concentrations. Asthmatics are particularly sensitive to sulfur dioxide.

Lead, which is contained in airborne particles, is also specified in the ambient air quality policies. Long-term exposure to it can affect development in children. Monitoring of lead in Melbourne has been discontinued because the levels are now very low (as leaded petrol is no longer used).

EPA is also monitoring for substances specified in the National Environment Protection Measure for Air Toxics (Air Toxics NEPM). Benzene, polycyclic aromatic hydrocarbons (PAHs), formaldehyde, toluene and xylenes were monitored at three inner-Melbourne sites in 2006. The results of this monitoring are available on EPA's website (see www.epa.vic.gov.au/air)

Where does EPA monitor?

In 2006, EPA's air monitoring program recorded representative air quality measurements from 26 sites (both permanent and short-term), with:

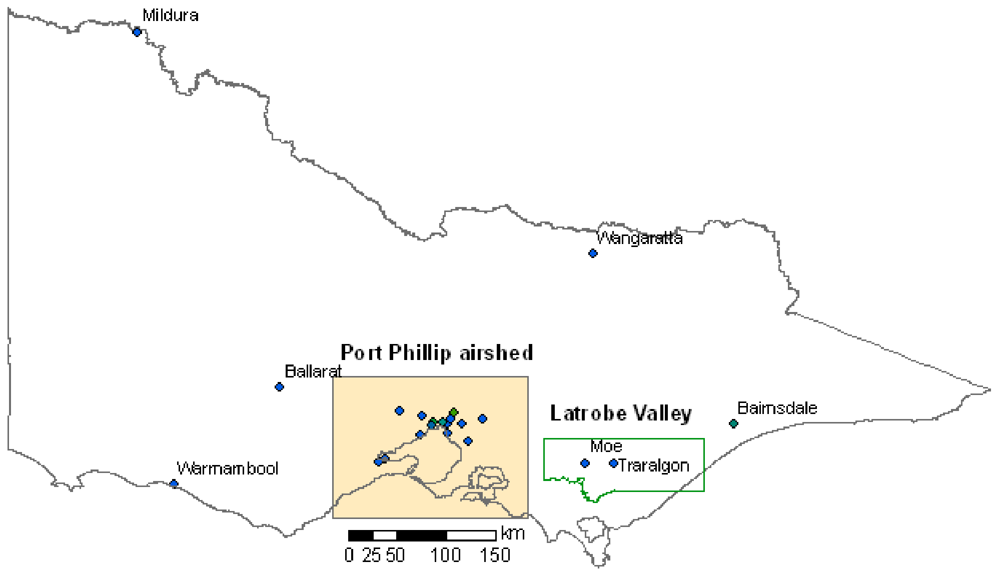
- 16 in metropolitan Melbourne
- two in Geelong
- two in the Latrobe Valley
- three temporary sites in country Victoria (Ballarat, Mildura and Warrnambool for 12-month periods)
- three temporary bushfire monitoring sites (Wangaratta, Bairnsdale and Macleod).

The location of all monitoring stations is shown in Figure 2.

Industry monitoring

In addition to the air quality monitoring performed by EPA, monitoring is conducted for common pollutants by major industries licensed by EPA, including electricity generators in the Latrobe Valley and at Anglesea, aluminium smelters at Geelong and Portland, and the oil refinery at Corio. More information about these specific monitoring programs is available from EPA regional offices (contact details are on EPA's website).

EPA has also undertaken specific monitoring of air quality around the Corio oil refinery. Details of this monitoring is available from EPA's website.



(a) Air monitoring stations in Victoria

(b) Air monitoring stations and subregions in the Port Phillip region

Figure 2: EPA air monitoring stations in 2006

Upgrading the network

A significant upgrade of EPA's air monitoring network continued in 2006, with stations refitted with new instruments and enclosures as older equipment reached the end of its useful life. During 2006 stations were upgraded at Paisley (in January/February, when the station was renamed 'Altona North' to better reflect its geographic location), Moe (March), Alphington (April), Brighton (August), Geelong South (September, see Figure 3), Footscray (October) and Point Cook (November/December). Each of these stations was off-line for periods ranging from two to four weeks to enable the upgrades to occur. This resulted in unavoidable data losses.

During 2006 EPA continued to develop the air monitoring network with:

- mobile air monitoring in Ballarat from August 2005 to July 2006
- mobile air monitoring in Eltham from April 2005 to February 2006
- monitoring for PM_{10} in Mildura from December 2004 to June 2006
- mobile air monitoring in Warrnambool for 12 months from October 2006
- air toxics monitoring conducted at three temporary sites in Melbourne (Carlton, Newport and South Melbourne)
- temporary air monitoring sites established in December 2006 in Wangaratta, Bairnsdale and Macleod to assess bushfire impacts.

Monitoring ceased at the central business district (CBD) station at RMIT University in September, when the lease was terminated due to building extensions. The need for ongoing monitoring in the CBD is currently being reviewed.

Figure 3: Newly upgraded air monitoring station at Geelong South

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HOW DO WE ASSESS AIR QUALITY?

Air quality is assessed against the national and/or State objectives and goals shown in Table 1.

- *Objectives* (referred to as *standards* in the NEPM) are typically concentrations, in parts per million (ppm) or micrograms per cubic metre (µg/m^3), against which air quality can be assessed. The visibility objective is specified as a distance in kilometres.
- *Goals* specify a maximum allowable number of days per year when the objectives can be exceeded and a time frame in which this goal must be met (by 2008). The goals guide the formulation of strategies to improve air quality.

Air quality at each monitoring site is assessed against these objectives and goals.

Table 1: State and national air quality objectives and goals

Pollutant	Averaging period	Objective	2008 goal (maximum allowable days not meeting the objective)
Particles as PM_{10}	1 day	50 µg/m^3	5 days a year
Particles as $PM_{2.5}$	1 day 1 year	25 µg/m^3 8 µg/m^3	Not applicable
Visibility-reducing particles	1 hour	20 km	3 days a year
Ozone	1 hour 4 hours	0.10 ppm 0.08 ppm	1 day a year 1 day a year
Carbon monoxide	8 hours	9.0 ppm	1 day a year
Nitrogen dioxide	1 hour 1 year	0.12 ppm 0.03 ppm	1 day a year none
Sulfur dioxide	1 hour 1 day 1 year	0.20 ppm 0.08 ppm 0.02 ppm	1 day a year 1 day a year none
Lead	1 year	0.50 µg/m^3	none

In general, the objectives have been set to allow for adequate protection of human health and wellbeing. Visibility-reducing particles are an exception to this, where the objective has been set to maintain visual amenity.

The Air Quality NEPM was varied in 2003 to include $PM_{2.5}$. The objectives for $PM_{2.5}$ are called *advisory reporting standards* and do not have a time frame for compliance. EPA is monitoring $PM_{2.5}$ to collect data that will enable a review of the $PM_{2.5}$ standards.

Air toxics monitoring results are assessed against *monitoring investigation levels* specified in the Air Toxics NEPM.

AIR QUALITY IN THE REGIONS IN 2006

Melbourne's air quality

The dominant influence on Melbourne's air quality in 2006 was bushfires, at the start and end of the year. This led to a higher number of days when the objectives for particles (both PM_{10} and $PM_{2.5}$), visibility and ozone were not met. Particle levels were also elevated on days affected by windblown dust or when local emissions (particularly from motor vehicles and wood heaters) were trapped in calm, highly stable conditions.

Because of the bushfires, 2006 also had more days when the ozone objectives were not met, compared to 2005. All Melbourne stations operating during the bushfires had one or more days when the ozone objectives were not met. During major bushfires nitrogen oxides and volatile oils are emitted which can react to form ozone.

In a typical year, ozone levels approach or occasionally exceed the objectives due to ozone generated from urban sources. This occurred at Eltham on one day in 2006.

The air quality objectives for NO_2, CO and SO_2 were met on all days in 2006.

Air toxics levels were low in 2006 and met the investigation limits specified in the Air Toxics NEPM. Further details are available from EPA's website.

Except for days affected by bushfire smoke, Melbourne's air quality remained relatively good and is comparable to other urban centres in Australia and overseas. Despite increasing pressures from a growing population, there has been little change in Melbourne's underlying air quality over the last decade (see Appendix 1). Increased pressure is expected as a result of climate change, with bushfires and dust storms likely to become more frequent, together with continuing population growth.

Geelong's air quality

In Geelong, due to the bushfires, the number of days the objectives for PM_{10} and visibility were not met was approximately twice that in 2005. As Geelong was further away from the bushfires, the impacts from the bushfires were less than in Melbourne.

Whilst bushfires dominated PM_{10} levels, there were also several days impacted by windblown dust. As a result, there were more days when the PM_{10} objective was not met at Geelong than at most stations in Melbourne.

Similarly to Melbourne, because of the bushfires, in 2006 Geelong also had more days when the ozone objectives were not met, compared to 2005.

The objectives for NO_2, CO and SO_2 were all met.

Latrobe Valley's air quality

Like Melbourne and Geelong, air quality in the Latrobe Valley was adversely affected by the 2006 bushfires.

Both stations in the Latrobe Valley exceeded the particles (as PM_{10}), visibility and ozone objectives, with frequencies similar to those in Melbourne. Due to the bushfires, Moe and Traralgon experienced their first days not meeting the ozone objectives in over 20 years of monitoring.

The objectives for NO_2 and SO_2 were met on all days.

Air quality in rural regions

The visibility objective at Ballarat was not met on 24 days before monitoring ceased in August. Ballarat was influenced by bushfire smoke in early 2006 to a similar extent to that experienced in Melbourne. Contributions of emissions from domestic wood heaters also led to poor visibility days during autumn and winter. The objectives for PM_{10}, ozone, NO_2 and CO were met on all days. EPA has published a separate report covering the full 12 months of monitoring at Ballarat (see EPA publication 1111).

Mildura continued to record days when the PM_{10} objective was not met, predominantly due to windblown dust. The monitoring campaign at Mildura concluded in June. A final report covering the full monitoring campaign at Mildura is in preparation.

A 12-month period of monitoring commenced at Warrnambool in October. Again due to bushfire impacts in December, Warrnambool did not meet the visibility objective on five days and the particles (as PM_{10}) objective on three days. The ozone objectives were met at Warrnambool.

THE BUSHFIRES AND AIR QUALITY

In 2006, Victoria experienced severe bushfires from late November through December (and continuing into January 2007). North-east Victoria and Gippsland were particularly affected by smoke during December. Stations in Melbourne and rural areas recorded poor visibility and high particle levels (PM_{10}) on many days in December, when smoke was transported from the fires by the prevailing winds. Major fires occurred in alpine areas, north-east Victoria, Gippsland and western Victoria, burning approximately 20 per cent of the State. Extremely poor visibility caused by bushfires was recorded on 9, 10, 13, 14 and 20–22 December (see Figure 4). Fine particles, as measured by visibility reduction, reached levels between two and four times greater than the previously recorded highest levels at Melbourne stations.

Victoria's air quality was also impacted by bushfires in January 2006.

Bushfires emit large quantities of hydrocarbons and oxides of nitrogen. These pollutants react during transport and in 2006 unusually high ozone levels resulted. All monitoring stations in Melbourne, Geelong and the Latrobe Valley that monitored ozone in December 2006 had days when both the one-hour and four-hour ozone objectives were not met. This is an unusual occurrence, as in recent years ozone objectives have typically been met.

Additional monitoring equipment was deployed to Bairnsdale and Wangaratta as well as in Melbourne. Online data became available in December for visibility (at Wangaratta and Richmond), PM_{10} (at Wangaratta, Bairnsdale and Macleod) and ozone (at Wangaratta and Macleod).

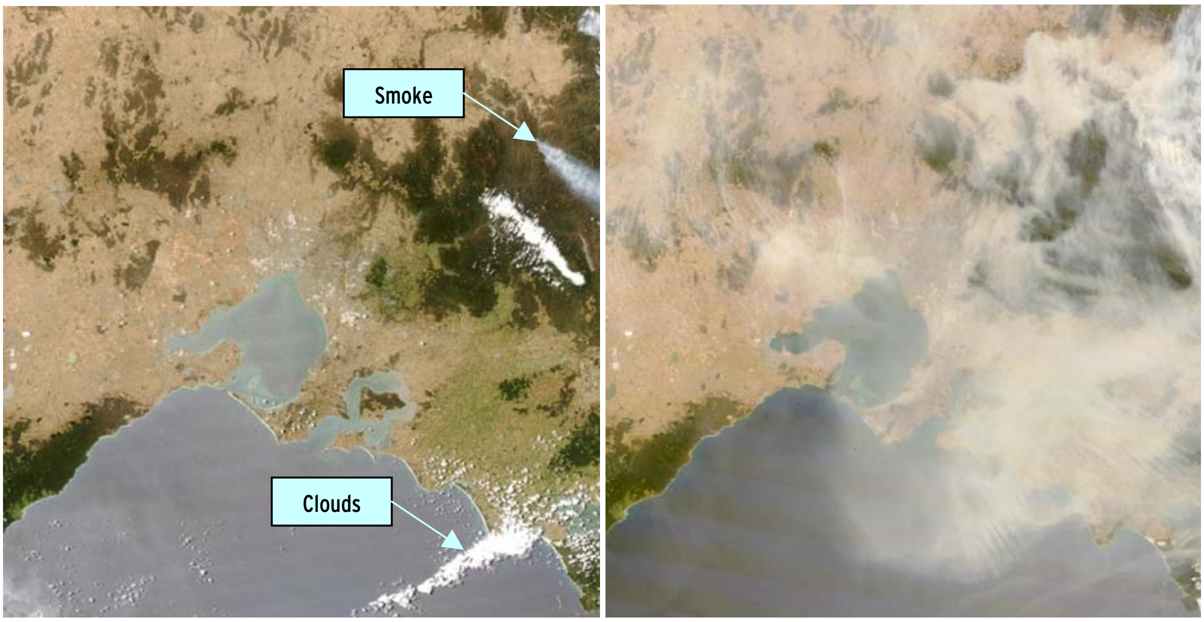
EPA published advice to the public on bushfires and air quality, including how to assess the risks associated with bushfire smoke and actions to take to minimise potential health effects (see www.epa.vic.gov.au/air/bushfires/). Smoke advisories, including health advice, were issued through the media on 13 days in December.

Satellite images of Victoria during the bushfires show the transport of smoke over Melbourne (see Figure 5). On 6 December (Figure 5a), Melbourne had clear skies, with a relatively small smoke plume from a small fire north-east of the city (the whiter traces are clouds). On 9 December, the fires had intensified and there was now a widespread plume of smoke over Melbourne (Figure 5b).

EPA is currently preparing a separate report on the 2006–07 bushfires.

Figure 4: Melbourne's central business district affected by bushfire smoke

Photo: Paul Rovere courtesy of *The Age*.



a) Clear skies over Melbourne, 6 December 2006 **b) Bushfire smoke over Melbourne, 9 December 2006**

Figure 5: Satellite images of smoke from fires in north-eastern Victoria

Images courtesy of MODIS Rapid Response Project at NASA/GSFC.

CAUSES OF PARTICLE POLLUTION IN 2006

In 2006 bushfires were the major cause of days when the particles objectives (both PM_{10} and the finer visibility-reducing particles) were not met. Overall, in 2006 the main sources of high particles levels were:

Fire: Smoke from bushfires and other burning (such as prescribed burning, agricultural burning and domestic or industrial fires). Smoke consists of fine particles and reduces visibility.

Dust: Windblown dust, often from distant sources. Windblown dust is typically coarse and tends to impact PM_{10} more than visibility.

Urban: Predominantly motor vehicle and wood heater emissions accumulating in stable atmospheric conditions. These stable conditions tend to occur on calm, cold autumn or winter nights. These urban sources typically impact visibility more than PM_{10}.

Days not meeting the particles objectives in 2006 have been categorised according to these three broad source types. Results for selected stations across Victoria are shown in Figures 6 and 7.

Whilst Figure 6 shows that fires were the main cause of high PM_{10}, there were also days impacted by windblown dust and, to a lesser extent, by the accumulation of urban emissions. The number of days when the PM_{10} objective was not met due to non-fire causes was similar to previous years. For example, at Geelong South in 2005 non-fire causes led to seven days when the PM_{10} objective was not met, compared to six days in 2006.

Figure 7 shows that, whilst fires were the main cause of poor visibility days, visibility was also affected by the accumulation of urban emissions during the colder months and, to a lesser extent, by windblown dust. The number of days when the visibility objective was not met due to these non-bushfire causes was similar to previous years. For example, at Alphington in 2005 non-bushfire causes led to 19 days when the visibility objective was not met, compared to 18 days in 2006.

The seasonal effects on visibility can be seen in Figure 8, where daily visibility levels are shown at selected stations. This both highlights the urban accumulation of fine particles in autumn and winter and shows the extremely poor visibility (resulting from high levels of fine particles measured as an airborne particle index) that occurred as a result of the bushfires.

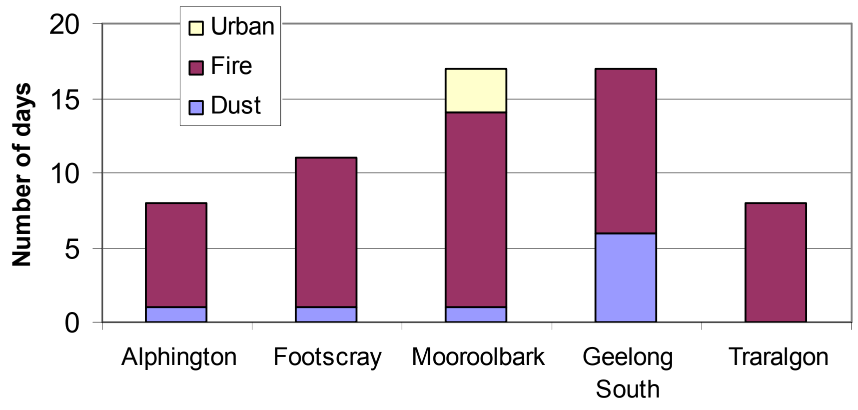


Figure 6: Likely causes of days when PM_{10} did not meet the objective in 2006

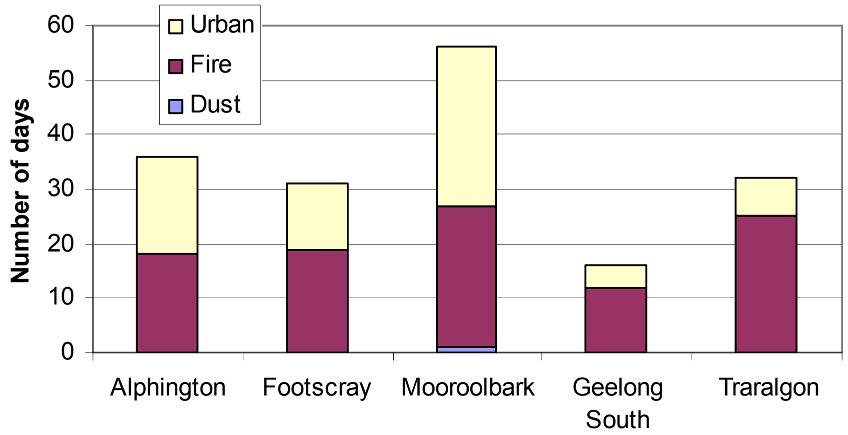


Figure 7: Likely causes of days when visibility did not meet the objective in 2006

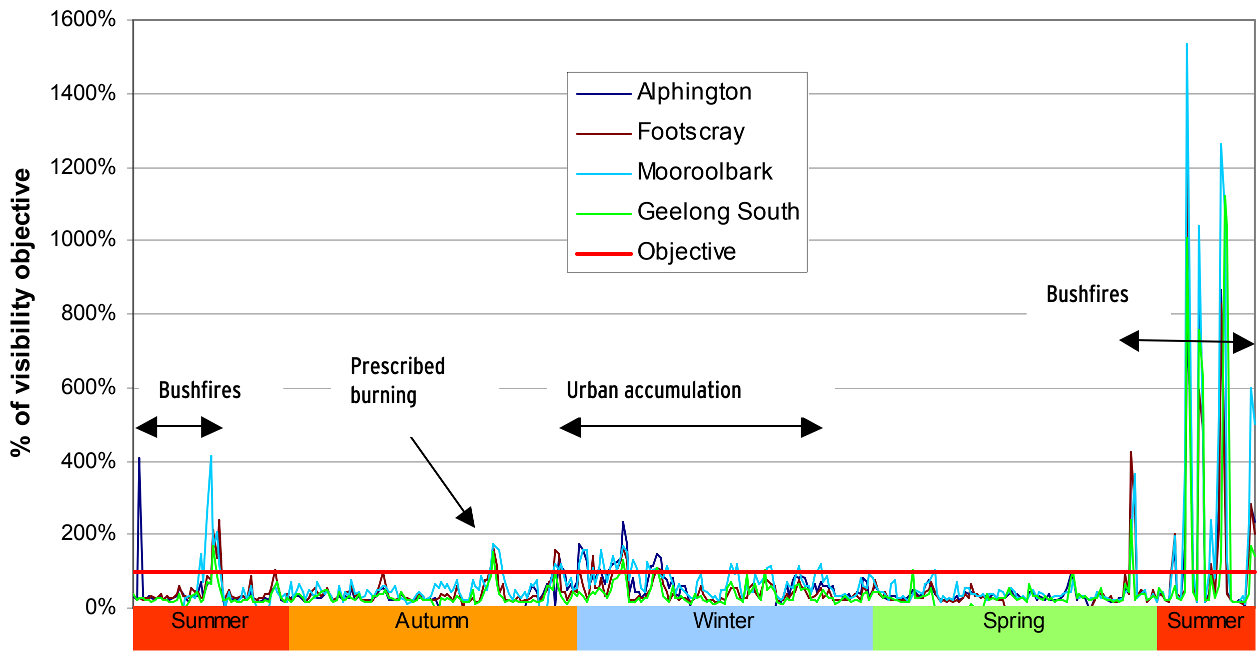


Figure 8: Visibility, as measured by daily maximum airborne particle index at selected stations in 2006

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COMPLIANCE WITH AIR QUALITY OBJECTIVES

On an annual basis, EPA assesses the air quality monitored at each station against the State and national air quality objectives and goals. For 2006, this is presented in Table 2.

There are established procedures for making this assessment, including the need to capture at least 75 per cent of data in each quarter of the year in order to demonstrate compliance with the goal (although an assessment of 'not meeting' the goal can be made with lower data capture).

At many stations compliance with the goal could not be demonstrated as stations were taken off-line to enable EPA to upgrade equipment. This meant that the data capture targets were often not met at these upgraded stations. Also, other stations were only operated for part of the year (for example, those installed in December as part of EPA's bushfire monitoring response and the campaign monitoring stations established in rural regions for 12-month periods).

In Table 2, shading is used to indicate the assessment against the goals, with:

- *green shading* indicating that the 2008 goal was met
- *red shading* that the 2008 goal was not met
- *yellow shading* that, whilst the 2008 goal was met, there were still days when the objective was not met.

The numbers presented in Table 2 show the number of days that an air quality objective was not met.

Monitoring instruments not meeting the data capture target are indicated by an asterisk and cells are not shaded yellow or green. A blank cell indicates that monitoring for a particular pollutant was not performed at this station. Note that, for $PM_{2.5}$, there is no 2008 goal and monitoring occurs on a one-day-in-three basis.

At all stations having insufficient data capture to enable strict assessment against the goals, it was likely that the 2008 goals would have been met for carbon monoxide, nitrogen dioxide and sulfur dioxide.

Further monitoring statistics are available in monthly data tables and in the report on compliance with the Ambient Air Quality NEPM (see www.epa.vic.gov.au/air/monitoring).

Table 2: Assessment of Victoria's air quality on a station-by-station basis

The numbers in the table indicate the number of days the objectives were not met.

Region		Station	Particles			Ozone		NO_2	CO	SO_2
			Visibility	PM_{10}	$PM_{2.5}$	1h	4h			
MELBOURNE	City	Richmond	6*	9				0*	0	
		RMIT+	18*	2*		0*	0*	0*	0*	0*
	East	Alphington	36*	8*	5*	3*	3*	0*	0*	0*
		Box Hill	30	7		1	2	0	0	0
		Brighton	31*	6		1	3	0		
		Dandenong	34	12		1	1	0		
		Eltham+		1*	0*	0*	1*	0*	0*	
		Mooroduc+				0*	0*			
		Mooroolbark	56*	17		1	2			
	West	Altona North				2*	2*	0*		0*
		Footscray	31*	11*	2*	1*	3*	0*	0*	0*
		Melton				1	3			
		Point Cook	16*			1*	1*	0*		
Geelong		Geelong South	16	17		2	2	0	0	0
		Point Henry				1	1			
Latrobe Valley		Moe	31*	15*		1*	3*	0*		0*
		Traralgon	32	8		3	2	0		0
Other rural		Ballarat+	24*	0*		0*	0*	0*	0*	
		Mildura+		13*						
		Warrnambool+	5*	3*		0*	0*			
Bushfire stations		Macleod+		3*		1*	1*			
		Bairnsdale+		6*						
		Wangaratta+	12*	12*		0*	0*			

Colour code (the goals for each pollutant are specified in Table 1):

0 (green)	Objectives and goal met	(yellow)	Exceeded the objective but met the goal	(red)	Goal not met	*	Insufficient data to demonstrate compliance

* Monitoring for this pollutant did not meet the 75% data capture target.
\+ Station only operated for part of the year. The bushfire stations commenced operation in December.

TRENDS IN MELBOURNE'S AIR QUALITY

Air quality has changed very little in Melbourne over the past decade. Melbourne's air quality is considered to be relatively good for a major metropolitan centre; however, levels of particles and ozone do not always meet the objectives.

A growing population and economy place increasing pressure on our air quality. These pressures will make it more difficult for us to meet our air quality objectives into the future. Climate change impacts are also likely to lead to increased ozone levels. This means that, in the absence of other intervention, air pollution levels are likely to increase. For example, increased vehicle use may eventually offset the improvements gained from stronger new vehicle standards and cleaner fuels.

There are also some air pollution impacts over which we have less direct control. Events such as bushfires (as occurred in 2006) and dust storms can have a strong impact on air quality in the region. Climate change is likely to increase the frequency and severity of these events.

Selected trend data are presented in Appendix 1 of this report.

HOW DOES MELBOURNE'S AIR QUALITY COMPARE TO OTHER CITIES?

Melbourne's air quality is better than or comparable to interstate and international cities in countries of a similar level of development to Australia. A limited comparison with other cities is presented in Appendix 2. It shows that Melbourne's particles and ozone levels have been, and continue to be, lower than most of the other international cities. The levels are similar to Sydney and Brisbane. It also shows that, in general, Melbourne's air quality is better than that in the larger overseas cities (such as London and Los Angeles). These trends are a reflection of Melbourne's favourable meteorology, relatively few major industrial emission sources within the airshed, relatively dispersed urban population and no major cities in close proximity.

Improvements are necessary, however, to preserve Melbourne's relatively good air quality under increasing population and economic growth and a changing climate.

HOW CAN I FIND FURTHER INFORMATION ON VICTORIA'S AIR QUALITY?

The media

- Alerts are issued on expected high pollution days, with advice on precautions the public can take to protect health.
- A daily air quality summary and forecast is issued to Melbourne daily newspapers, radio and television.
- The air quality bulletin is issued on a daily basis to electronic media outlets and summarised on EPA's Pollution Watch Line (03 9695 2777).

Information on EPA's website

Further air quality information is available on EPA's website (www.epa.vic.gov.au/air), including:

- current hourly air quality (www.epa.vic.gov.au/air/bulletins/aqbhour.asp)
- the forecast air quality and summary for the previous 24 hours (as provided to the media)
- air pollution information and historical data on the Air Quality for Kids page (www.epa.vic.gov.au/air/AQ4Kids)

In relation to EPA'S annual air reports, see www.epa.vic.gov.au/air/monitoring for:

- tables of monthly air quality data for 2006
- previous annual reports and data tables.

Related publications

A comprehensive range of publications are accessible through the EPA website by clicking on 'Publications and Library' at the homepage. Some that are particularly relevant to air monitoring are listed below.

- *Air monitoring report 2006: Compliance with the National Environment Protection (Ambient Air Quality) Measure.* Includes more detailed data tables and air quality statistics.
- *Air Monitoring at Ballarat, August 2005 to August 2006*, publication 1111. Results of a 12-month air quality monitoring study in Ballarat.
- *Review of air quality near major roads,* publication 1025, 2006. Reviews EPA studies alongside major roads in Melbourne and Geelong.
- *Ambient air quality NEPM monitoring plan Victoria*, publication 763, 2001. Details Victoria's commitments for monitoring under the National Environment Protection Measure.
- State Environment Protection Policy (Ambient Air Quality), *Victoria Government Gazette* No. S19, 09/02/1999 (amended in Dec 2001). Sets air quality objectives and broad monitoring protocol.

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APPENDIX 1: TRENDS IN MELBOURNE'S AIR QUALITY

To fully understand trends in air quality, a range of measures need to be considered. For example, looking at the trend in the number of days not meeting the air quality objectives gives an indication of long-term performance against the policy goals. Maximum levels indicate the peaks and how air quality can deteriorate on any one day. Trends are also best examined over a longer time frame to reduce the impact of specific events in any one year (for example, different stations may be operating or weather conditions can be dramatically different).

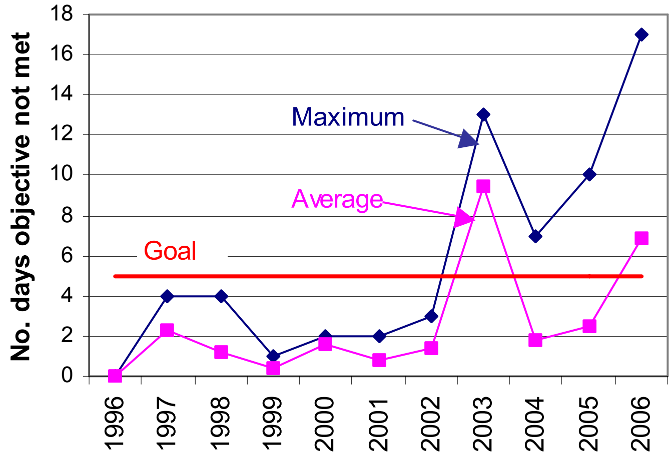
A range of trend parameters for Melbourne are presented in this appendix, as follows:

- *Days not meeting the objective* – two values for this parameter are presented. The *maximum number* gives the value for the station recording the highest number of days not meeting the air quality objective each year (that is, the worst performing station that year). The *average number* (calculated by averaging the number of days at each station in Melbourne) is a better indicator for how Melbourne is performing overall, rather than simply looking at an individual station.
- *Maximum pollutant levels* – this looks at the highest pollutant levels recorded over the year. The value is calculated by averaging the maximum pollutant levels recorded at each monitoring station in Melbourne over any one year.
- *Average pollutant levels* – in addition to the peak levels, we are also interested in the average pollutant level across Melbourne for the year. This is calculated by averaging levels from each station.

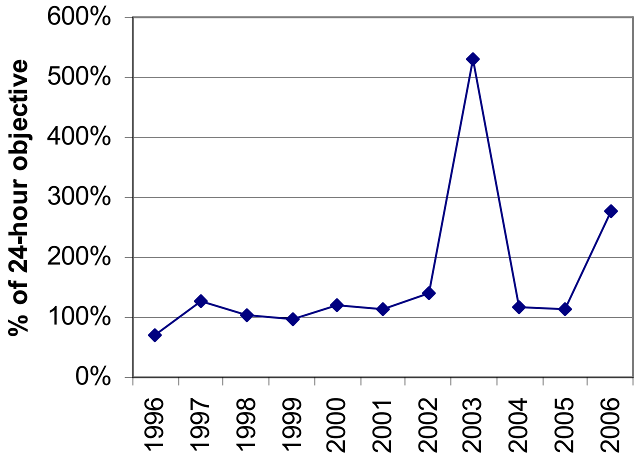
Particles trend

Excluding the effects of bushfires in 2003 and 2006, particle levels (as PM_{10}) have remained relatively constant in Melbourne over the past 10 years (note that extensive continuous monitoring data for PM_{10} is only available since 1996). Levels have remained relatively stable:

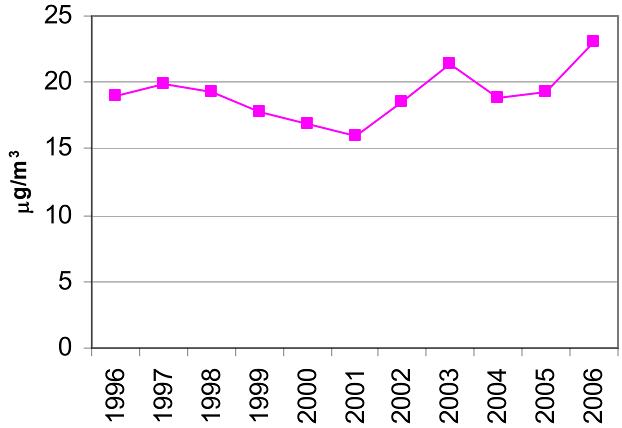
- *Days not meeting the objective* – other than the bushfire years in 2003 and 2006, on average Melbourne stations have met the PM_{10} goal of having no more than five days not meeting the objectives in any year (see Figure A1(a)). Note that the goal for particles was set to allow for events such as bushfires and dust storms that cannot be controlled through normal air quality management strategies. Some stations (but not all) were affected by dust in 2004 and 2005, leading to the maximum number of days being higher than the goal. In 2006, the 17 days of not meeting the PM_{10} objective at Mooroolbark was the highest for any station over the last 10 years (mainly as a result of the bushfires).



(a) Days not meeting the PM_{10} objective



(b) Maximum 24-hour PM_{10}



(c) Annual average PM_{10}

Figure A1: PM_{10} trend in Melbourne

- *Maximum PM_{10} levels* – in a non-bushfire year, the maximum levels in Melbourne are typically only just above the 24-hr PM_{10} objective (see Figure A1(b)). Maximum levels 3–5 times higher than the PM_{10} objective were recorded during the 2003 and 2006 bushfires.
- *Average PM_{10} levels* – over the last 10 years PM_{10} levels have averaged about 40 per cent of the 24-hour objective, with levels higher during the bushfire years of 2003 and 2006 (Figure A1(c)).

Comparing PM_{10} levels in Melbourne in bushfire-affected 2006 to the previous 10 years shows that:

- the number of days not meeting the PM_{10} objective was more than three times the average over the previous 10 years
- the maximum PM_{10} was nearly double the 10-year average maximum
- the average PM_{10} was 20 per cent higher than the 10-year average and also the highest on record.

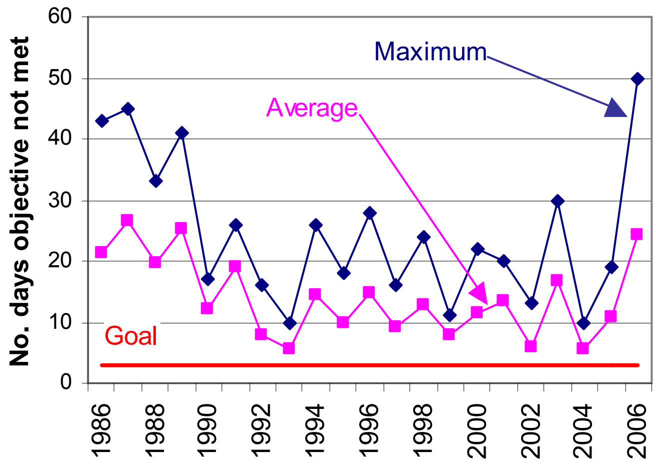
Visibility trend

Visibility shows a similar pattern to PM_{10}, with peaks in 2003 and 2006 caused by bushfires. Visibility is measured as an airborne particle index (API) and the 20 km objective corresponds to an API of 2.35. After the significant improvements observed in the 1980s, visibility levels have been relatively stable over the last 10 years, with levels noticeably poorer in years affected by bushfires. In terms of the trend parameters:

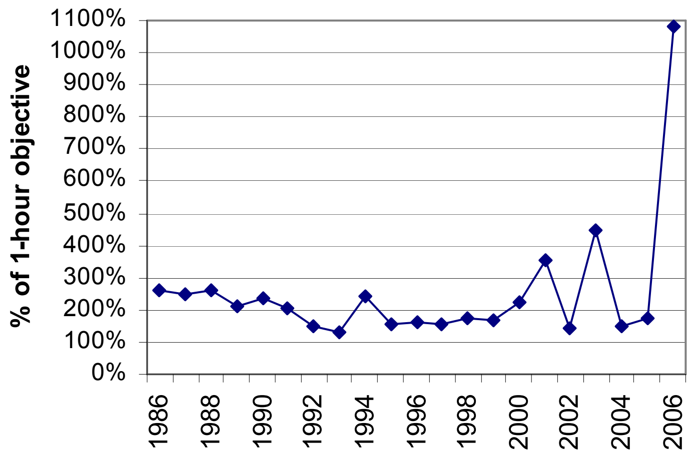
- *Days not meeting the objective* – the significant decrease during the 1980s in the number of days not meeting the visibility objective has tapered off so that, apart from the effects of bushfires in 2003 and 2006, this parameter has been relatively stable over the last decade (Figure A2(a)). Melbourne still fails to meet the visibility goal. EPA continues to undertake a range of actions to further improve Melbourne's air quality in relation to visibility (for example, programs on wood heaters and motor vehicles).
- *Poorest visibility levels* – the effect of bushfires on visibility is clearly seen in the 2006 results, where levels up to 11 times the API objective were recorded in Melbourne (Figure A2(b)).
- *Average visibility levels* – other than the bushfire years, the average visibility level has remained relatively stable over the last 20 years (Figure A2(c)). The annual average API in 2006 was the highest on record, due to the bushfires.

Comparing visibility levels in Melbourne during bushfire-affected 2006 with those for the previous 10 years shows that:

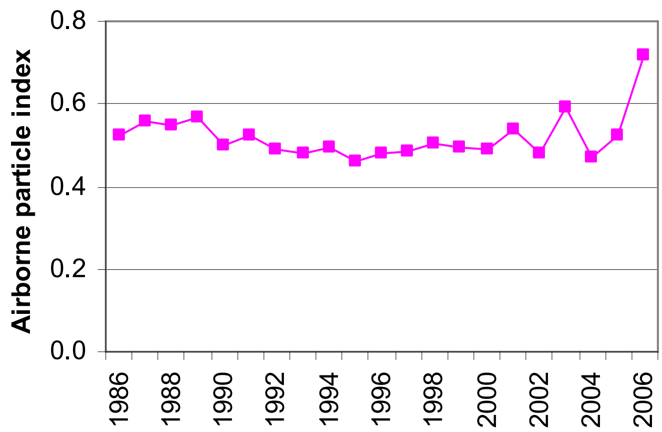
- the number of days not meeting the visibility objective was more than double the average of the previous 10 years and the highest since 1989



(a) Days not meeting the visibility objective



(b) Maximum one-hour API



(c) Annual average API

Figure A2: Visibility trend in Melbourne

- the maximum API (the poorest visibility level) was five times the 10-year average and over double the previous highest value, recorded in 2003
- the average level of visibility-reducing particles was 40 per cent higher than the 10-year average and also the highest on record.

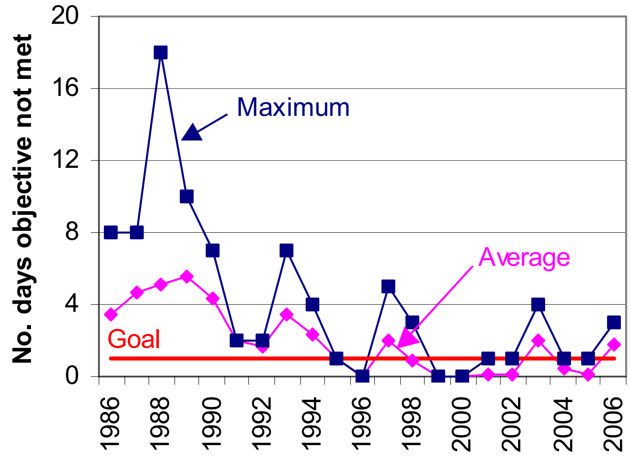
Ozone trend

Over the last 10 years, ozone levels in Melbourne have typically remained low, except for the high levels recorded in 2003 and 2006, due to the impact of bushfires.

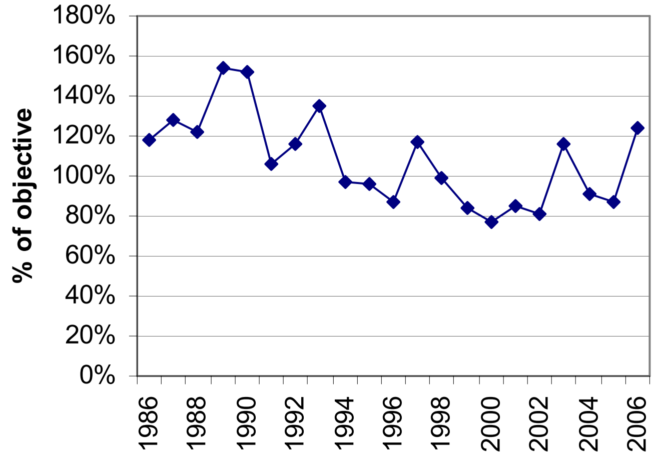
- *Days not meeting the objective* – during the 1980s Melbourne experienced a significant decrease in the number of days not meeting the ozone objective. In recent years, apart from the effects of bushfires in 2003 and 2006, Melbourne has typically met the goal for ozone (Figure A3(a)).
- *Maximum ozone levels* – in recent years, maximum ozone levels have only been higher than the objective in years affected by bushfires (Figure A3(b)). This is a significant improvement over levels in the 1980s.
- *Average ozone levels* – over the last 10 years, whilst the number of days not meeting the objective has decreased, the annual average four-hour ozone levels have tended to increase, reversing the trend of the previous decade (Figure A3(c)). Average levels are 20 per cent of the four-hour objective. EPA is investigating the reasons for this upward trend; however, the average ozone level remains relatively low.

Comparing four-hour ozone levels in Melbourne in bushfire-affected 2006 to the previous 10 years shows that:

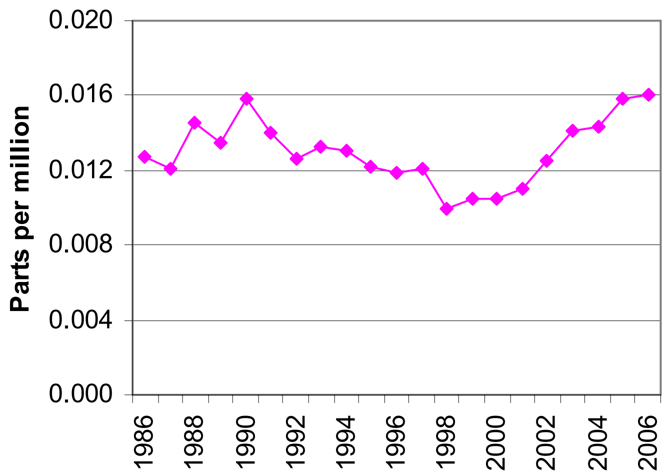
- the number of days not meeting the objective was nearly four times the average of the previous 10 years and the highest since 1994
- the annual maximum in 2006 was 30 per cent higher than the average of the annual maximum over the last 10 years and was the highest since 1993
- the annual average was 30 per cent higher than the 10-year average and also the highest on record.



(a) Days not meeting the four4-hour ozone objective



(b) Maximum four-hour ozone



(c) Annual average ozone

Figure A3: Four-hour ozone trend in Melbourne

Trends in other gases

Carbon monoxide, nitrogen dioxide and sulfur dioxide continued at low concentrations relative to the objectives (see maximum levels in Figure A4). The objective for carbon monoxide has been met at all monitoring sites in Melbourne since 1985. The objectives for nitrogen dioxide have been met since 1991. The objectives for sulfur dioxide have been met since monitoring commenced in Melbourne.

A downward trend is evident for carbon monoxide and nitrogen dioxide, for which motor vehicles are the major source. Sulfur dioxide levels are very low in Melbourne, except where influenced by specific industrial sources.

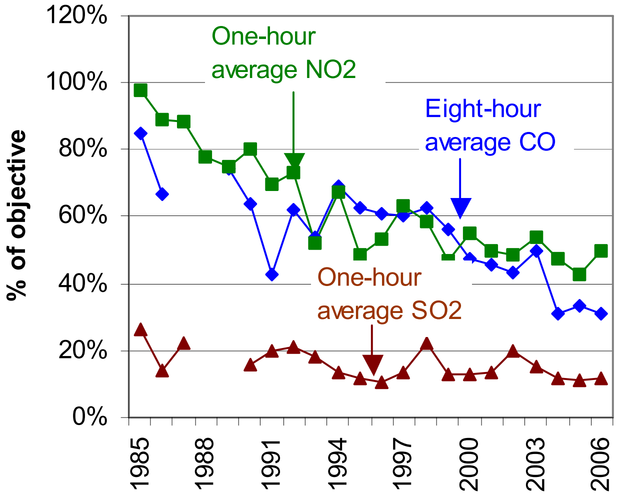


Figure A4: Maximum levels for other pollutants in Melbourne

APPENDIX 2: COMPARISONS WITH OTHER CITIES

Melbourne's air quality has been compared to levels in other Australian, American and European cities. Those presented below represent a range of population and characteristics.

Table A1: Cities compared with Melbourne

	Population
Australia	
Melbourne	3.7 million
Sydney	4.3 million
Brisbane	1.8 million
US cities	
Los Angeles, California	9.5 million
Greater Phoenix, Arizona	4.0 million
Greater Minneapolis, Minnesota	3.2 million
European cities	
Greater London, England	7.5 million
Berlin, Germany	4.2 million
Lisbon, Portugal	2.9 million

Direct comparisons based on monitored levels alone are difficult, as city layout, meteorology, local climate, location, traffic volume and many other variables need to be taken into account when interpreting monitored levels of air pollution.

Obtaining comparable air quality statistics can also be difficult. The US data presented, for example, have unusual events like bushfires removed.

The air quality data quoted here are composite averages – the average of results from individual monitoring stations. For example, the maximum quoted is the average of the annual maximum recorded at individual stations in a monitoring network. Overseas data have also been compared against the Australian air quality objectives.

Comparisons have been made for the two pollutants of most interest to Melbourne: particles (as PM_{10}) and ozone. In general, Melbourne's air quality is better than or comparable to the interstate and international cities.

Particles comparison

A comparison based on annual average particle levels (Figure A5) indicates that:

- on average, Melbourne has similar particle levels to Sydney and Brisbane
- Melbourne has lower particle levels than the three US cities used for comparison. Note also that the US data were only available with 'extreme events' removed. The extreme events have not been removed from the Melbourne data set (for example, dust storms and bushfires are included)
- Melbourne has lower particle levels than the European cities used for the comparison.

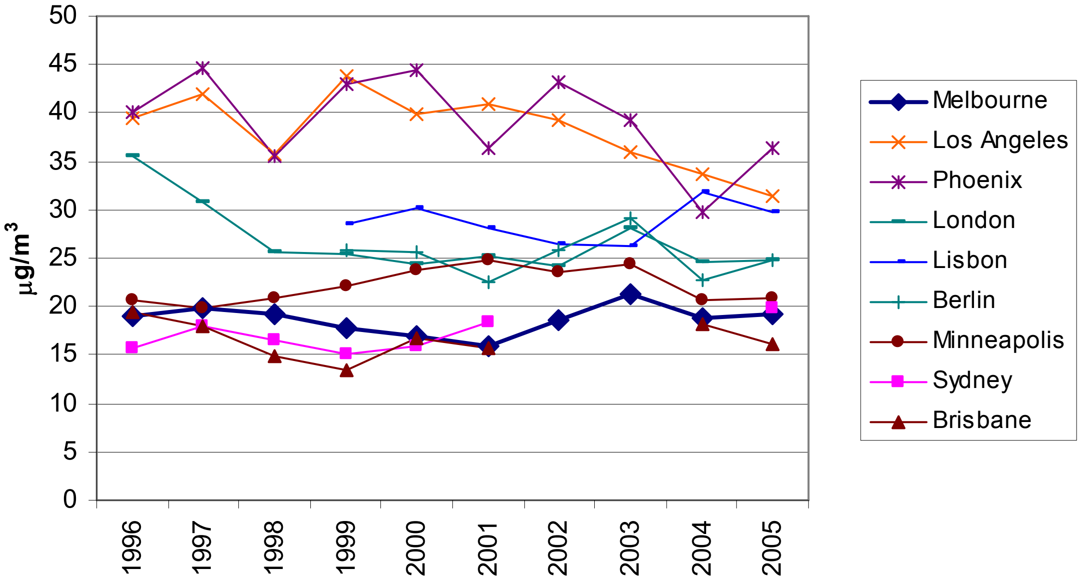


Figure A5: Annual average PM_{10} compared with Australian and overseas cities

Ozone comparison

Due to a lack of comparable data, different statistics had to be used in the comparisons of Melbourne ozone with the other Australian, US and European cities. Comparisons of ozone show that:

- Melbourne has peaks of ozone that are generally lower than in Brisbane and Sydney (Figure A6)
- peak ozone levels in Melbourne are similar to those measured in Minneapolis and lower than in Phoenix and Los Angeles (Figure A7)
- Melbourne's annual average ozone is similar to or better than the European cities used in this study (Figure A8).

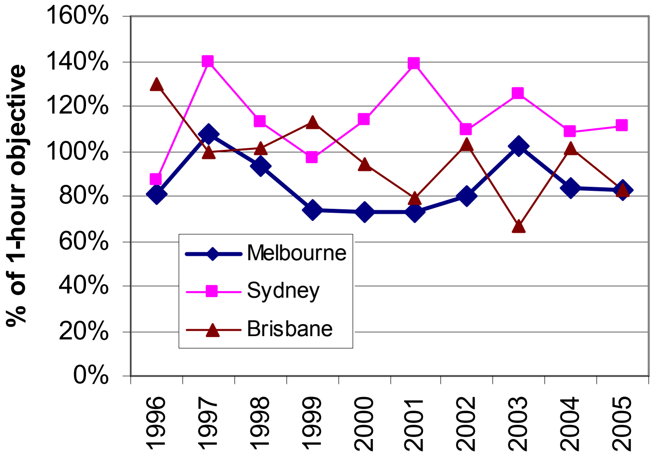


Figure A6: Maximum one-hour ozone compared with Australian cities

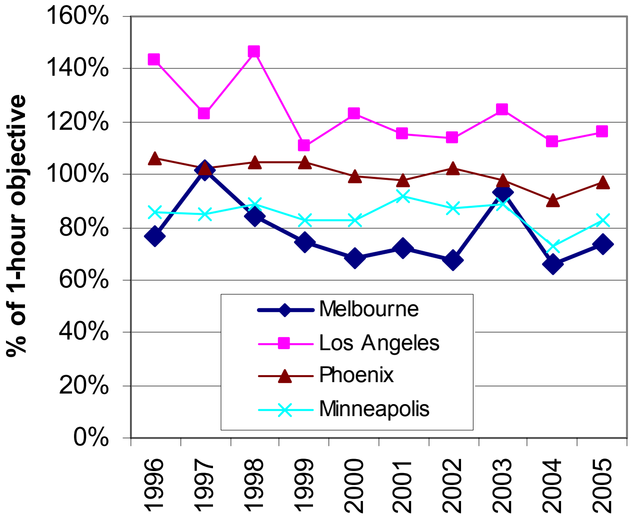


Figure A7: Second-highest one-hour ozone compared with US cities

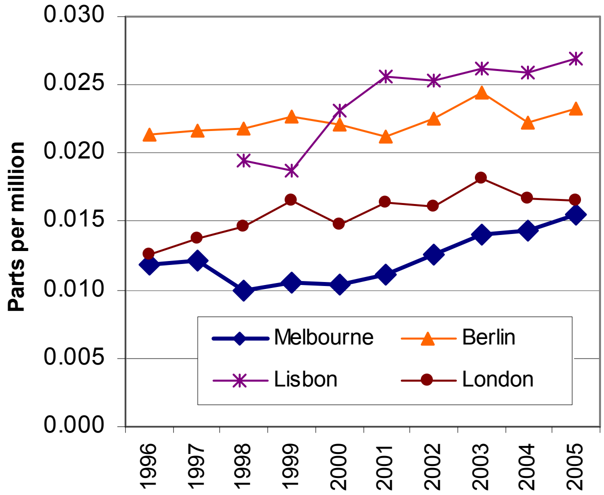


Figure A8: Average ozone compared with European cities