



SUMMER SMOG IN VICTORIA

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1 SUMMARY

Summer smog is a common problem in large cities, caused by everyday activities that emit pollutants into the air. The result is a mixture of air pollutants, such as ozone, which may be harmful to human health.

Summer smog may appear in Victoria on hot afternoons between November and March, mostly around Melbourne. It is usually seen on the horizon as a white or grey haze (see photo below). Motor vehicles are the main source of pollutants that lead to smog in the city.

Summer smog can also form downwind of bushfires, as bushfire smoke contains some of the same smog-forming pollutants that are in motor vehicle exhaust fumes.

This report reviews recent and historical air monitoring results, describes where and when Victorians may be exposed to summer smog and suggests some simple actions you can take to help reduce smog levels and avoid exposure.

Summer smog levels reduced significantly during the 1980s in response to car exhaust controls. Over the last 10 years, there has been little change in the total emissions of smog-forming pollutants in the Melbourne area. This has resulted in fairly stable levels of summer smog, except for high levels recorded in 2003 and 2006, due to bushfires. This underlying stable trend in smog levels may change, as global

warming will cause higher temperatures and more hot days each year. EPA is currently investigating how ozone levels may be affected by a changing climate.

You can reduce your contribution to summer smog by simple actions, such as minimising use of your car on hot days in summer and keeping your car tuned.

During a smog episode, you can reduce your exposure to pollutants by staying indoors. The latest hourly air quality readings can be found online at:

www.epa.vic.gov.au/Air/Bulletins/aqbhour.asp.



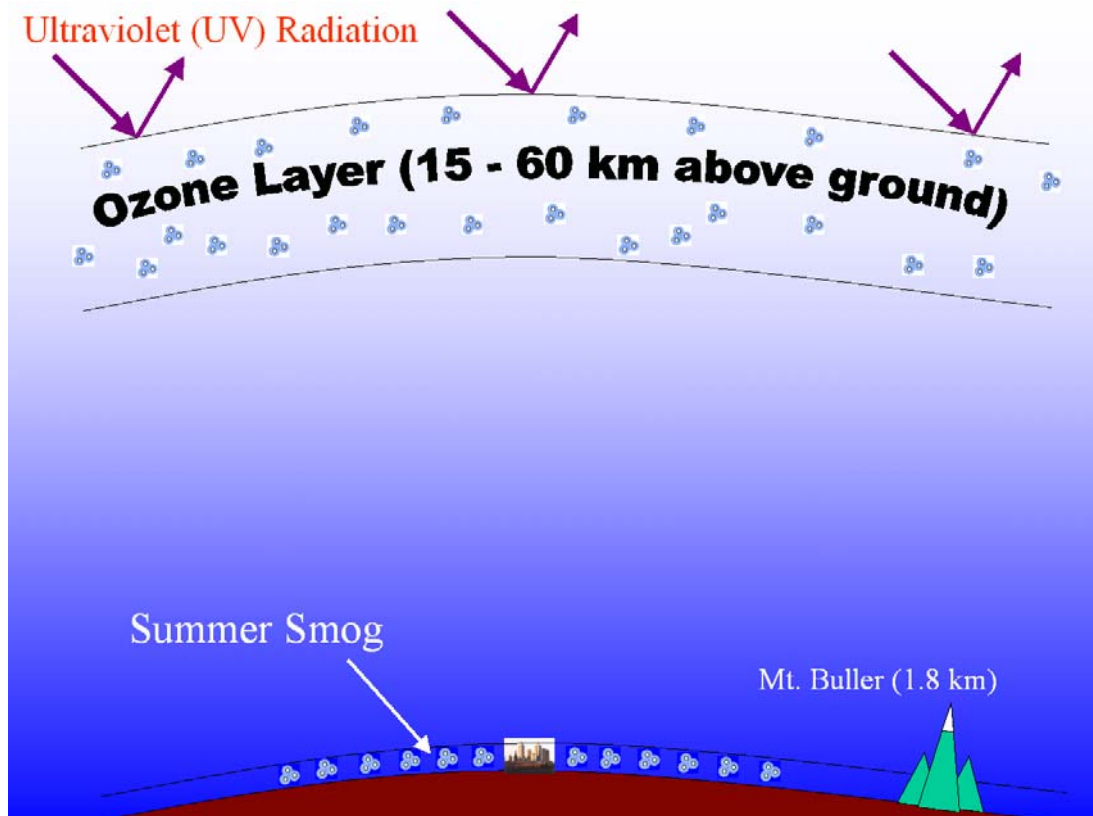


Figure 1 (not to scale): Ozone is useful in the upper atmosphere, but harmful near us.

2 INTRODUCTION

2.1 What is summer smog?

Summer smog is a mixture of gases and particles, with ozone being the largest component. Ozone measurements are used as an indicator of summer smog levels.

2.2 What's special about ozone?

Ozone (O₃) is a naturally occurring gas. It is like oxygen (O₂), but has one extra atom, which makes it quite reactive.

Exposure to high levels of ozone can result in increases in asthma attacks and hospitalisations associated with heart and lung conditions. Ozone is also known to affect some healthy individuals who spend prolonged periods of time outdoors during summertime. The effects of ozone are strongest in children, the elderly and those with chronic lung conditions such as asthma.

In the air we breathe, ozone is found naturally in low concentrations. Higher concentrations of ozone are formed when chemical reactions between nitrogen

oxides and hydrocarbons take place in the presence of sunlight.

Ozone in the air we breathe should be distinguished from ozone in the stratosphere (the ozone layer), which has the beneficial effect of absorbing harmful radiation (see Figure 1). This report examines ozone in the lower atmosphere and, in particular, the thin layer just above the ground that forms our air environment.

3. WHAT CAUSES SUMMER SMOG?

In general, ozone is not directly emitted into the air by human activities¹. Instead, ozone primarily develops as various pollutants react together in the air on hot afternoons. As the reactions take many hours, the pollutants must either remain in place or be blown away by winds but return later in the day. In Melbourne, the most common weather pattern leading to ozone involves light morning winds followed by an afternoon sea breeze.

The chemical ingredients needed to form smog mainly come from motor vehicle exhaust and petrol vapours. Other contributions come from industry, domestic fuel burning, lawn mowing, soil bacteria and natural volatile oils emitted by plants in hot weather.

Usually, high ozone levels are caused by pollution generated in the city, but extraordinary ozone events may occur downwind of large bushfires². This happened during the major fires of January–February 2003 and December 2006 – January 2007.

The pictures in Figure 2 demonstrate smog formation. The first image shows pollutants accumulating in the morning; the second image shows the pollutants being blown out over the bay. The third image shows the smog 'cloud' changing colour, indicating that a chemical reaction has taken place. The final image shows a sea breeze blowing the smog towards the city.

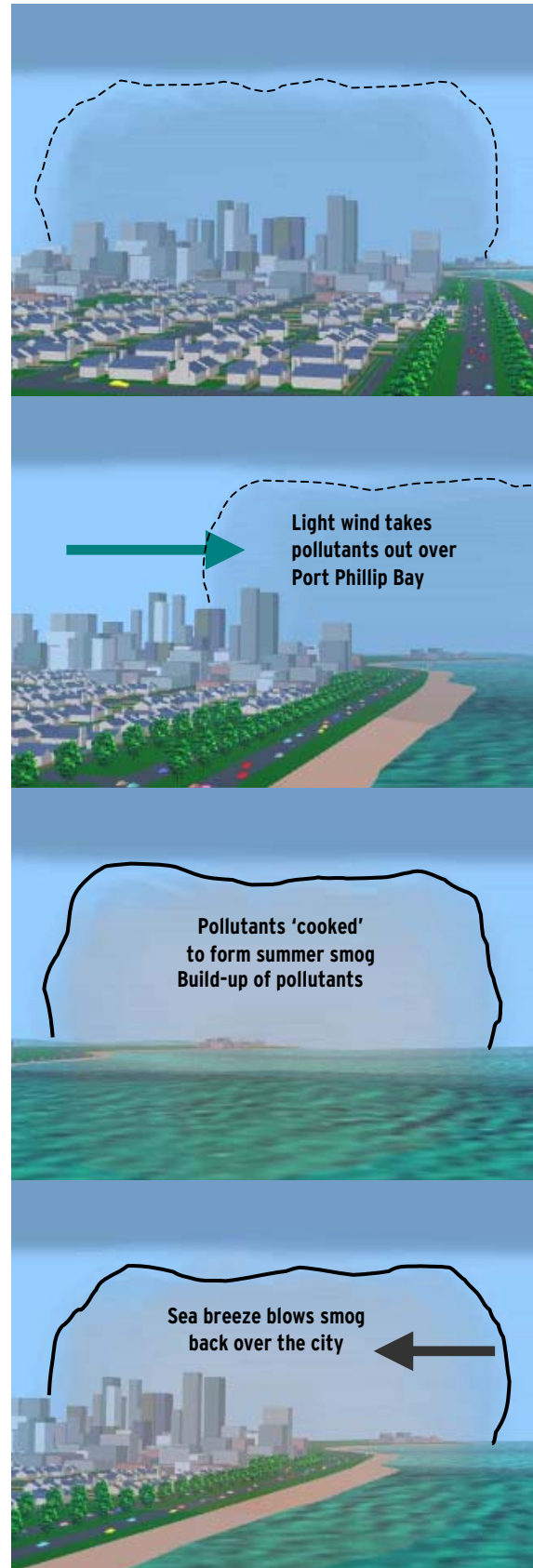


Figure 2: Smog formation in Melbourne

1 There are a few exceptions, e.g. industries that use high-voltage electric arcs can generate some ozone. These sources typically affect only a localised area.

2 Air Quality During Victorian Bushfires of 2002-03, EPA Publication SR5.

4. TRACKING SMOG LEVELS

4.1 Monitoring

Ozone is measured in ppb or 'parts per billion'. One ppb is equivalent to 0.0000001% of our air. Specialised equipment is required to detect these low levels.

EPA Victoria monitors ozone 24 hours a day, 365 days a year at a number of air monitoring stations in Melbourne and regional centres³.

4.2 Targets

Ozone is one of the seven air pollutants for which Victoria has set target levels (policy objectives).⁴ The objectives are pollutant concentrations against which air quality can be assessed, and are intended to protect human health. The objectives for ozone are:

- average over a one-hour period ('one-hour ozone') less than 100 ppb
- average over a four-hour period ('four-hour ozone') less than 80 ppb.

There are two separate averages (one and four hours) because studies have found different health effects from different durations of exposure.

In Melbourne, according to recent measurements, ozone levels go above the four-hour objective about twice a year, whereas levels go above the one-hour objective only about once every two years⁵.

Ozone levels below the objectives are considered safe for most people. Those with asthma or other respiratory conditions may be affected at lower levels.

Note that the national ozone objectives are currently being reviewed. For further information see:

www.ephc.gov.au/nepms/air/air_nepm_ozone_review.html
www.ephc.gov.au/nepms/air/air_nepm_review_issues_paper.html

4.3 Trends

In the early 1980s, high ozone levels were common in Melbourne. On average, more than 20 days each year were affected⁶. Since that time there have been significant improvements in pollution control, mainly through vehicle emission standards and the introduction of catalytic converters for cars. Now there are only a few days each year with high ozone levels.

Figure 3 shows the highest ozone level measured in each year since 1979. Peak levels dropped from 1980 to 1995, but have been relatively stable since then, except for 2003 and 2006, when major bushfires caused increased ozone levels.

The figure shows that, although pollution from Melbourne has stabilised, sources outside Melbourne (in this case bushfires) may contribute to increases in ozone in the future.

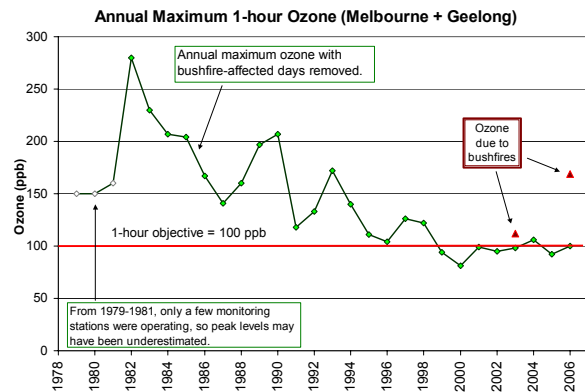


Figure 3: Ozone trend 1979–2006

4.4 Daily forecasts

Ozone levels in Melbourne can be predicted using weather forecasts and knowledge of ozone behaviour.

Air quality forecasts are produced every day for Melbourne and can be accessed by telephone (03 9695 2777) or on EPA's website, (www.epa.vic.gov.au).

³ *Ambient air quality NEPM monitoring plan Victoria*, EPA publication 763, November 2001.

⁴ *State environment protection policy (Ambient Air Quality)*, Victoria Government Gazette No. S19, 9 Feb 1999 (amended Dec 2001).

⁵ Based on monitoring data from 2001 to 2005.

⁶ Based on the number of days with four-hour average ozone above the objective (see section 4.2).

5 SMOG PATTERNS IN VICTORIA

5.1 Where does smog occur?

Overseas experience has shown that it is generally in large cities, or downwind of major fires, that there are enough pollutants to cause high ozone levels.

In Victoria, ozone is routinely monitored at a range of locations in Melbourne, Geelong and the Latrobe Valley. Additional monitoring has been undertaken at regional population centres on a short-term basis.

Computer modelling was undertaken to estimate ozone levels across the whole of Victoria. Figure 4 shows the results of a simulation for the summer of 2002–03. During the 2002–03 summer, weather conditions were particularly suitable for smog development, so there was significantly more ozone than usual. Consequently these maps represent a worst-case scenario for estimating how many high ozone days might be expected in a year.

The maps show that coastal areas are generally affected more than inland areas. Water is very slow to heat up and cool down, so the air above it is kept at a fairly even temperature. This means that the sun's heat causes less turbulence and movement in the air over water than in the air over land areas. As a result, pollutants remain more concentrated over the water.

The figure also shows that the south-western coastal suburbs of Melbourne are affected more than other suburbs. This happens because, on typical smog days, morning pollution emissions from the eastern suburbs are blown out over Port Phillip Bay by light north-easterly winds, where they are converted into smog, sitting over the water south-west of the city. Then a southerly afternoon sea breeze brings smog to coastal south-western suburbs, and sometimes further inland.

The computer predictions have been confirmed by monitoring at Point Cook (see Figure 6), which has recorded the most high ozone days in Victoria.

Table 1: Variability in smog 1996–2006

Summer season	Number of days on which four-hour ozone level is above the objective (80 ppb) in Melbourne/Geelong
1996–97	6
1997–98	3
1998–99	1
1999–2000	0
2000–01	1
2001–02	0
2002–03	5
2003–04	1
2004–05	3
2005–06	1

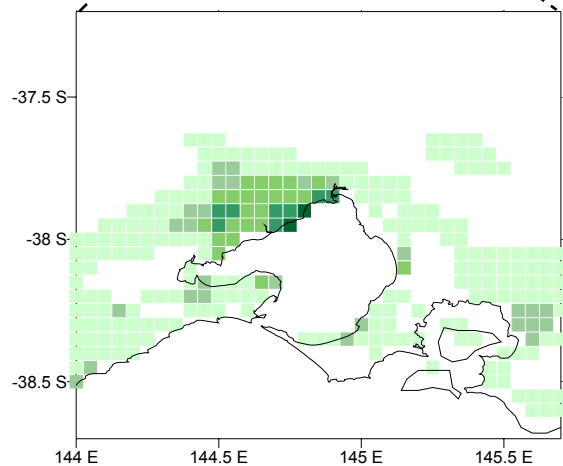
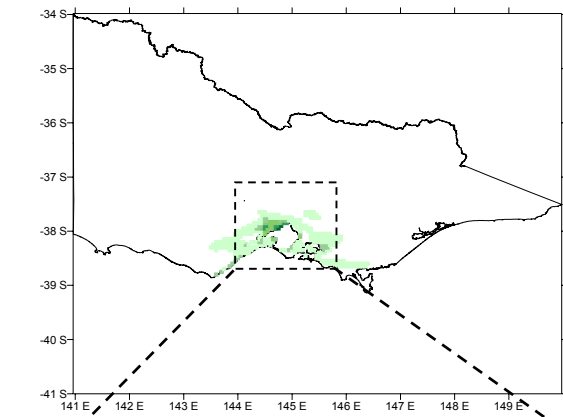
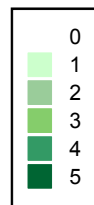


Figure 4: Number of high ozone days per year during the 2002–03 summer.
(Values represent number of days when four-hour ozone > 80 ppb.)



5.2 When is smog a problem?

Smog forms in Melbourne on hot summer afternoons with light winds. There is some natural variation from year to year in the weather patterns that lead to smog. Table 1 shows the extent of this variation.

Figure 5a shows how ozone levels are strongly dependent on season. High ozone levels are most likely during February, but can occur any time between November and March.

Figure 5b summarises eight years of ozone data by temperature⁷, with each dot representing a single day. It shows that the highest levels of ozone occur when the temperature is over 30 °C.

Figure 5c shows how ozone levels depend on wind speed. It shows that average winds need to be fairly light (less than 11 km/h) for summer smog to form.

Figure 5d shows that summer smog is most often experienced between 2 pm and 7 pm.

5.3 How much ozone is there near a road?

Figure 5d shows that the lowest ozone level occurs at 8 am, corresponding to morning peak-hour traffic. Other studies have also shown that ozone levels are lowest adjacent to major roads and in the central part of the city. Whilst car exhausts are the major reason that ozone is a problem in large cities, ozone is also very reactive, so when it contacts fresh vehicle emissions it reacts locally with those pollutants and is consumed⁸.

This does not mean that roadside air is especially clean; any pollutants directly emitted from cars (such as carbon monoxide and fine particles) are typically at their highest concentrations close to major roads.

5.4 What about inside my house?

Ozone concentrations tend to be much lower indoors than outdoors. Again this is because of the reactive nature of ozone – it is quickly destroyed by reacting with surfaces such as carpets, upholstery and curtains. So, if you are sensitive to ozone, the best place to be on a smoggy afternoon is indoors.

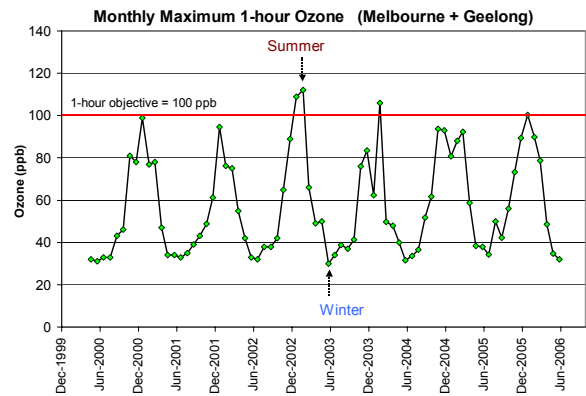


Figure 5a: Effect of season on ozone level

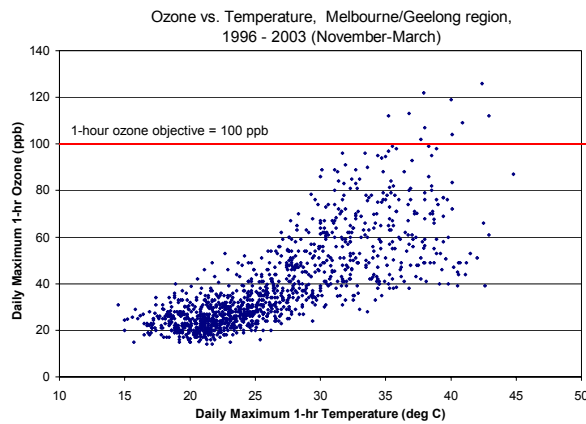


Figure 5b: Effect of temperature on ozone level

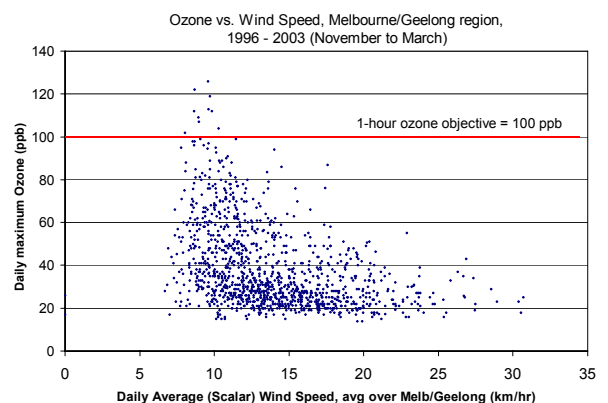


Figure 5c: Effect of wind speed on ozone level

7 Note that Figure 5b uses the highest measured suburban temperature. Forecast temperatures prepared by the Bureau of Meteorology are for the city area and may be 3-4 degrees cooler than the highest suburban temperature. So, although this graph shows peak ozone levels on days of 33-44 °C, such days actually correspond to Bureau forecasts of 30-40 °C. If the forecast temperature is more than 40 °C, this usually means strong northerly winds will blow all day. High levels of ozone cannot develop under these conditions.

8 Nitric oxide (NO) from motor vehicles combines with ozone (O₃) to form nitrogen dioxide (NO₂) and oxygen (O₂).

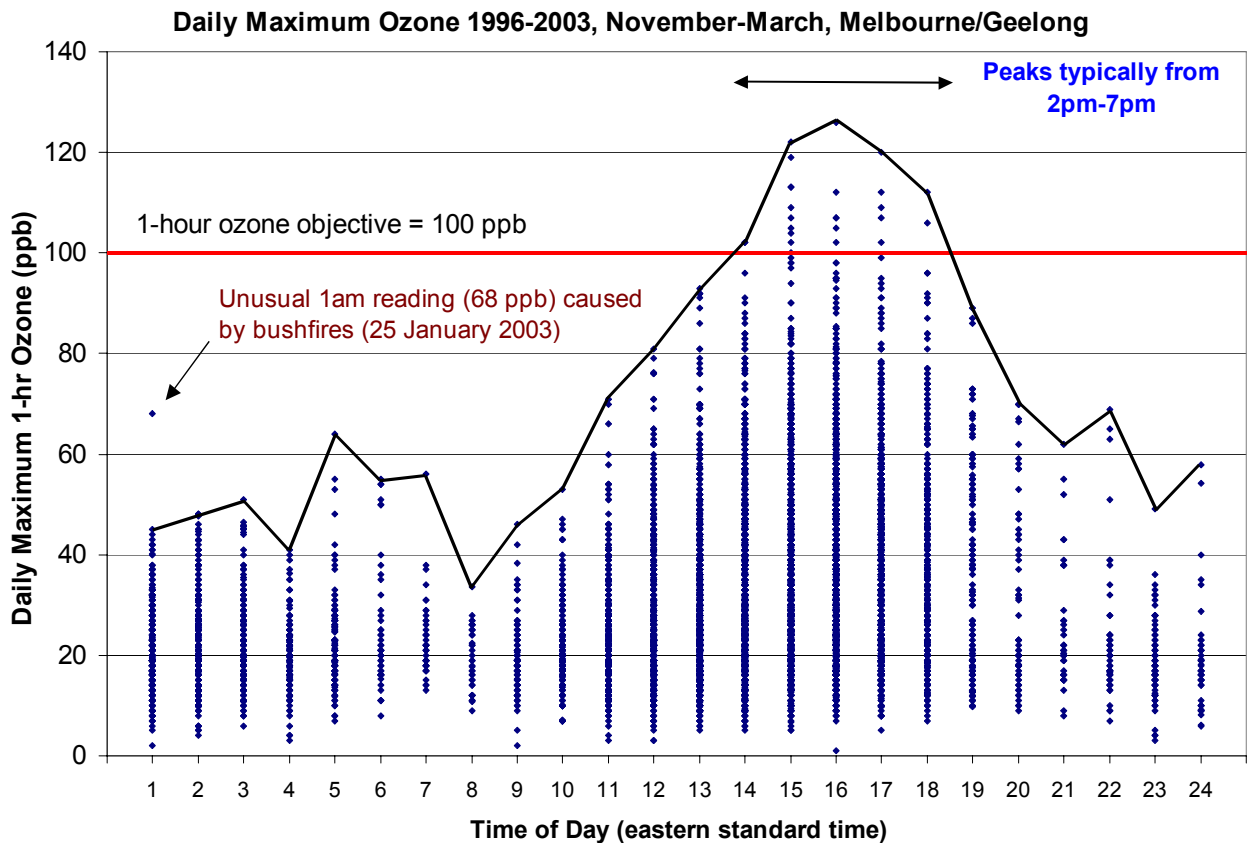


Figure 5d: What time of day to expect smog

5.5 Bushfires and summer smog

When a major bushfire is burning, nitrogen oxides and volatile oils are emitted, which can react to form ozone. High ozone levels may be recorded in areas not normally prone to summer smog, and the city may experience more ozone than usual.

Bushfires have affected ozone in Victoria on several occasions. For example:

- On 3 February 2003, an ozone level of 112 ppb was recorded at Melton (compared to the objective of 100 ppb), as a result of bushfire smoke from north-eastern Victoria.
- On 9 December 2006, an ozone level of 169 ppb was recorded at Geelong South. On this day, complex weather patterns transported smoke from eastern Victoria to Melbourne, then across the bay in very stable conditions to Geelong.
- On 10 December 2006, 138 ppb of ozone was measured at Traralgon – the highest level of ozone recorded in the Latrobe Valley since monitoring began in 1979.

Note that ozone will not be present immediately near the fire. Peak levels are expected downwind, where smoke has been transported over several hours and exposed to sunlight, allowing it to react and form ozone.

5.6 Is smog ever a problem in regional centres?

Figure 4 shows that ozone is not normally expected to reach high levels in regional population centres. This has been confirmed by 27 years of monitoring in the Latrobe Valley, recent campaign studies in Bendigo and Ballarat, and other studies from around Australia.

Sometimes smog generated in Melbourne may reach a nearby population centre such as Geelong. However, most regional centres are far enough away for Melbourne smog to be dispersed by the time it reaches them.

Regional centres may also experience high ozone levels if they are downwind of a major bushfire.



5.7 How will climate change affect smog?

Victoria’s climate is changing, and will continue to change over the coming decades. Average temperatures are predicted to increase⁹, which will cause:

- higher evaporative emissions from motor vehicles
- greater emissions of volatile oils from vegetation
- an increase in the speed of reactions that form ozone.

There is also a slow increase in background ozone in the southern hemisphere (0.1 ppb per year). These factors may increase summer smog in future. Drier conditions may also result in more frequent bushfires, further increasing the ozone burden in Victoria.

EPA is undertaking further work to predict future summer smog conditions.

6. RECENT MONITORING CAMPAIGNS

6.1 The ozone monitoring network

Ozone is routinely monitored at 13 locations in the Melbourne/Geelong region and at two locations in the Latrobe Valley. Figure 6 shows the ozone monitoring network for Melbourne/Geelong.

6.2 Why was extra monitoring done?

To confirm whether ozone monitoring in Victoria was sufficient, we undertook short-term studies in outer suburbs of Melbourne and in regional centres of Victoria (see Table 2 and Figures 7a–b). The Melbourne ‘campaign’ monitoring projects covered four summers from 2002–03 to 2005–06; regional projects ran from 2004–05 to 2005–06¹⁰.

Table 2: Ozone monitoring campaigns

	Site	Monitoring period	EPA Publication no.
Melbourne	Pakenham	14 August 2002 to 19 June 2003	934
	Craigieburn	12 September 2003 to 24 June 2004	1003
	Moorooduc	23 December 2004 to 31 March 2006	See note ¹¹
	Eltham	1 October 2005 to 28 February 2006	1141
Regional	Bendigo	15 May 2004 to 4 July 2005	1041
	Ballarat	2 August 2005 to 9 August 2006	1111
	Warrnambool	12 October 2006 to 30 October 2007	See note ¹²
	Wangaratta	13 December 2006 –	See note ¹³

9 CSIRO has predicted an increase of 1 to 5 °C by the year 2070 for Australia. For details see *Climate Change in Australia – Observed Changes and Projections*, available from www.climatechangeinaustralia.gov.au.

10 Further ozone monitoring work is currently under way at Warrnambool and Wangaratta; results will be available at a later date.

11 Moorooduc ozone data are presented in this report (see Table 3 and Figure 8) and in the *Victoria’s air quality* report series (years 2005 and 2006).

12 A report on the monitoring campaign at Warrnambool is currently being prepared.

13 Monitoring is still in progress at Wangaratta.

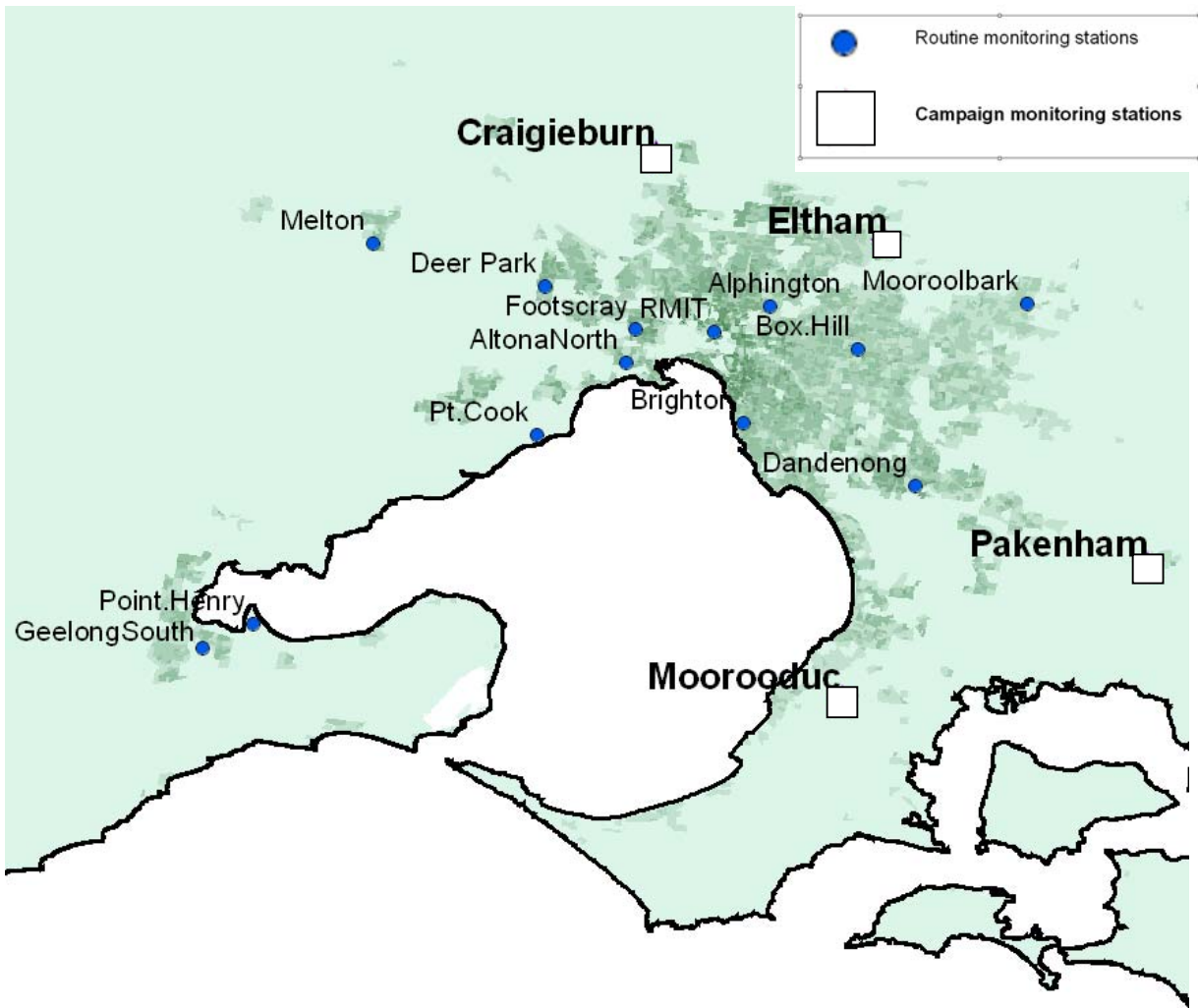


Figure 6: Metropolitan ozone network (shaded areas indicate population density).



Figure 7a: Moorooduc campaign site (standard monitoring hut)



Figure 7b: Ballarat campaign site (mobile laboratory – MoLab)

6.3 What did the studies find?

Because ozone levels vary from year to year, a single year or summer of monitoring at a campaign site only provides an indication of the likely ozone levels.

As a consequence, the campaign site results were compared against all other sites over a one-year period around the time of the campaign. By doing this, the weather effects that cause year-to-year variation can be accounted for, as they will tend to affect all stations.

The study results are summarised in Table 3, which shows the number of days on which measurements were above the four-hour ozone objective, for the financial years 2002–03 to 2005–06.

Table 3: Monitoring results during campaign studies (campaign station names in bold)

Station	Number of days on which four-hour ozone level > 80 ppb			
	July 2002 – June 2003	July 2003 – June 2004	July 2004 – June 2005	July 2005 – June 2006
Alphington	1	0	0	0
Altona North	2	1	0	0
Box Hill	2	0	0	0
Brighton	2	1	0	1
Craigieburn	-	0	-	-
Dandenong	2	0	0	0
Footscray	2	1	0	1
Geelong South	0	0	1	0
Melton	4	0	0	1
Moorooduc	-	-	0	0
Mooroolbark	3	0	0	0
Pakenham	0	-	-	-
Point Henry	1	0	1	0
Point Cook	2	0	2	0
RMIT	1	0	0	0
Eltham	-	-	-	1
Moe	0	0	0	0
Traralgon	0	0	0	0
Bendigo	-	-	0	-
Ballarat	-	-	-	0

Table 3 shows that there is some variation from year to year. For example, there were four days when ozone levels were above the objective at Melton during the Pakenham campaign (2002–03), but none during the Craigieburn campaign (2003–04).

Campaign monitoring at Pakenham, Craigieburn and Moorooduc indicated that ozone levels were all within the four-hour objective. Other stations in Melbourne experienced high ozone levels during these campaigns (see Table 3 for a comparison against the four-hour objective).

During the Eltham campaign, there was one day (16 February 2006) when ozone levels were above the four-hour objective. This was a warm, humid day in Melbourne¹⁴, with light/variable winds in the morning and a strong sea breeze in the afternoon. The strong sea breeze was able to bring the smog far enough inland to reach the north-eastern suburbs. Further details of the readings on this day can be seen in Figure 8.

Ozone readings at the regional stations Bendigo and Ballarat remained within the four-hour objective.

Ozone measurements were also compared with the one-hour objective (100 ppb). Measurements at campaign sites were within the one-hour objective at all times during the study.

The results from the campaign monitoring program confirm that the regional centres and the outer Melbourne suburban sites that were examined do not experience frequent high ozone levels. The results are consistent with predictions from modelling studies.

¹⁴ Eltham's temperature reached 34 °C on this day.

4-hour average Ozone 15-17 February 2006

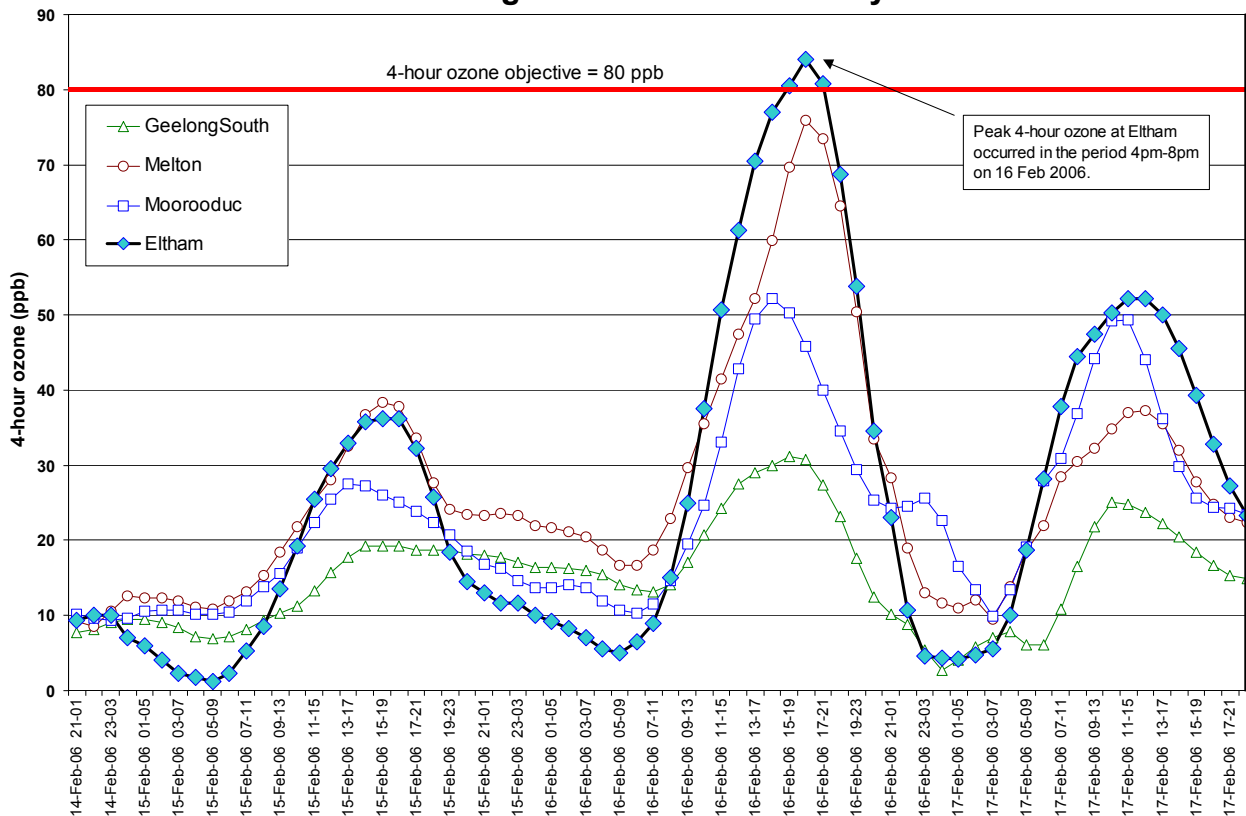


Figure 8: Ozone peak on a hot day (34 °C) in the north-eastern suburbs

7. HOW DOES MELBOURNE COMPARE WITH OTHER CITIES¹⁵?

There are many factors that determine how much summer smog will be experienced in a city. These include city size, population density, local terrain, how much sunlight is received, typical summer temperatures, distance to the nearest ocean or sea¹⁶, the type of vehicles driven in the city and what condition they are in.

Figures 9a and 9b compare Melbourne’s ozone with overseas cities. Cities of similar population to Melbourne and with a substantial monitoring network have been considered.

Melbourne’s ozone is similar to (or lower than) ozone levels in comparable overseas cities.

Figure 9c shows a similar graph for Australian cities where ozone is measured. In general, ozone levels in Melbourne are lower than in Sydney, higher than in Canberra, and similar to levels in Brisbane, Perth and Adelaide. Most Australian cities lie further north (closer to the equator) than Melbourne and are exposed to greater sunlight and higher temperatures, so they have greater potential for smog formation.

¹⁵ The data presented here are the second highest ozone level recorded each year - this measure is less variable from year to year than the highest reading, so that underlying trends can be more clearly seen. All second highest values for cities were calculated with the method used by USEPA.

¹⁶ Both inland cities and coastal cities can suffer from smog, but cities near water are more likely to be affected (see section 5.1).

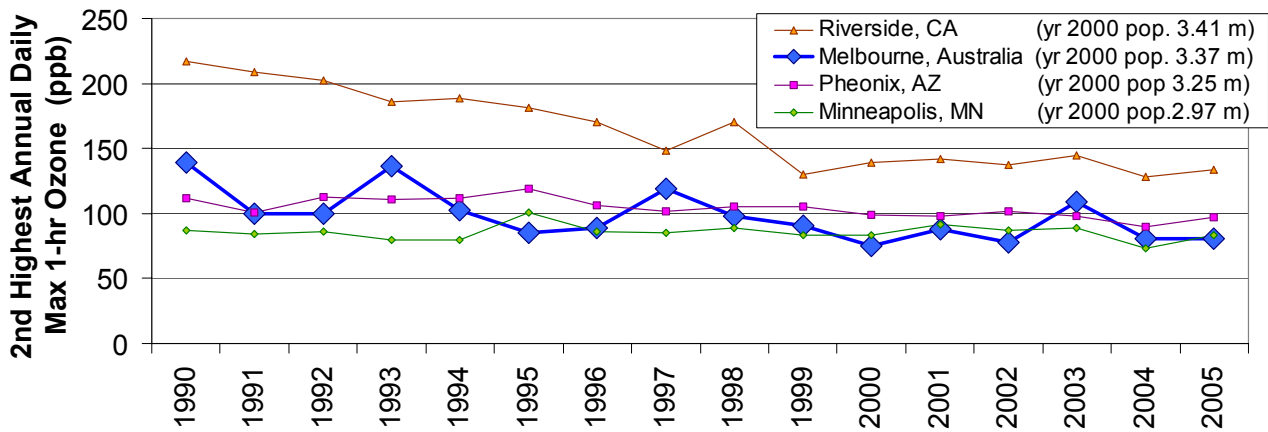


Figure 9a: Comparison of Melbourne with US cities of similar population

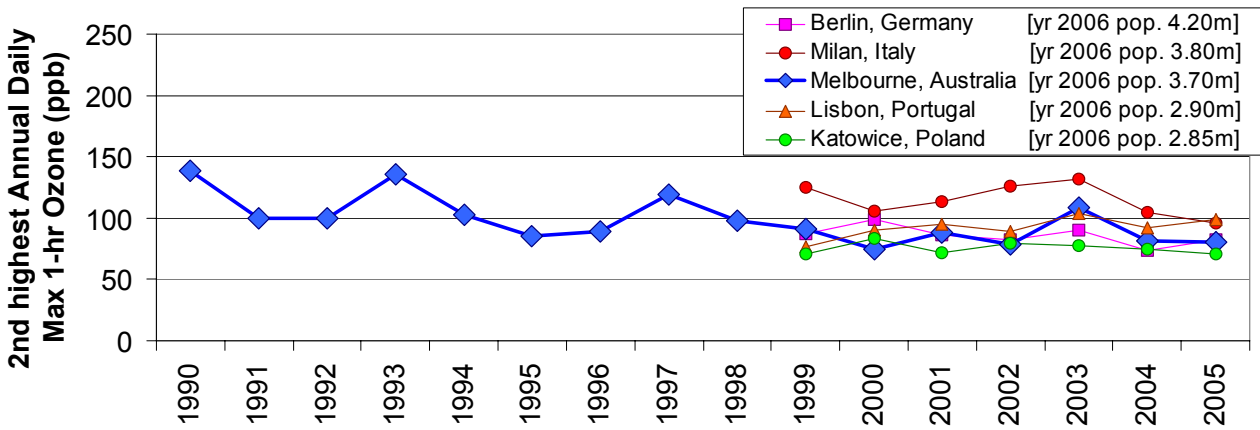


Figure 9b: Comparison of Melbourne with European cities of similar population

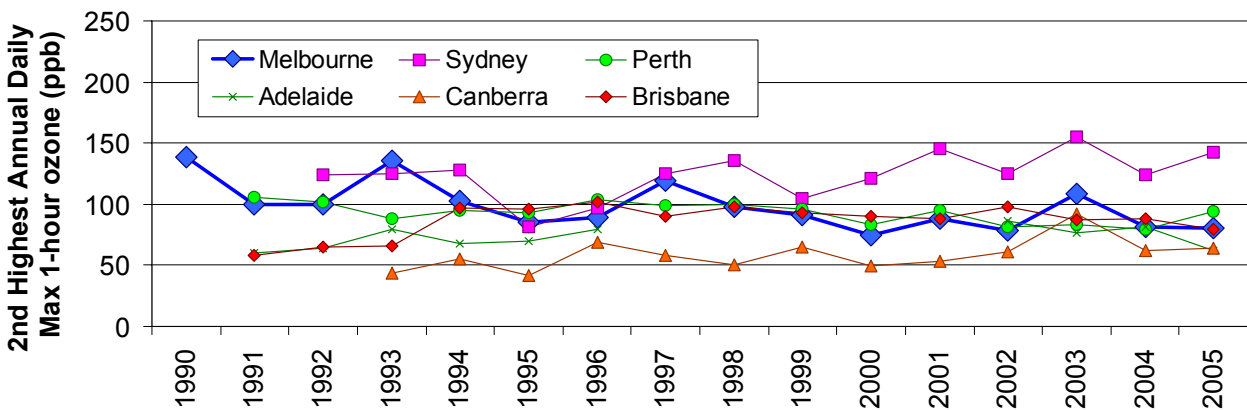


Figure 9c: Comparison of ozone levels in Australian cities

8 OUR CONCLUSIONS

8.1 Is summer smog a problem in Victoria?

The evidence from monitoring and modelling studies in Victoria shows that high levels of summer smog can be experienced:

- in the Melbourne metropolitan area and immediate coastal surrounds, on hot summer days with light morning winds and an afternoon sea breeze

or

- anywhere in the state if major bushfires are burning and smoke has been transported for some hours whilst exposed to sunlight.

Such events occur a few times each year and are likely to affect the health of sensitive people. Due to the particular meteorology and geography of Melbourne, the coastal suburbs west of the city are the most affected by summer smog. However, any suburban area may occasionally be affected by summer smog. The central business district of Melbourne and areas close to major roads tend to have the lowest levels of summer smog.

An international comparison has found that summer smog levels in Melbourne are similar to or lower than levels in comparable cities in the USA and Europe.

8.2 Future trends

Pollutant emissions from city sources leading to smog in Melbourne have been relatively stable in recent years. This has happened because changes to the vehicles on our roads have balanced out increases in city population and vehicle ownership rates.

Changes to the vehicle fleet include the introduction of new cars with tighter emission standards, regular retirement of old cars and improvements to fuel quality¹⁷. These changes result in less pollution from individual vehicles.

The introduction of biofuels, although a positive step towards renewable fuel use, may have mixed implications for air quality. At this stage it is unclear how an increased use of ethanol blends and biodiesel will affect summer smog. Studies to clarify these effects are continuing both in Australia and internationally.

Climate change will cause higher temperatures in Victoria, leading to more frequent droughts and bushfires and, consequently, greater pollutant emissions leading to smog. More hot days may also mean more frequent city smog events.

Further to this, background ozone levels in the southern hemisphere are slowly rising, which will increase ozone levels across Victoria in all seasons.

8.3 What you can do to reduce smog

Changing the way you use your car can significantly help to reduce smog-forming pollutants. Here are some suggestions:

- Minimise the use of your car, especially on hot, still days in summer. Consider alternatives such as public transport or riding a bike.
- Drive smoothly. This will save fuel, reduce wear and tear and reduce pollution.
- Restarting your car engine uses less fuel than idling. So if you are parked and waiting, switch off the engine.
- Keep your car tuned so it runs more efficiently and generates less pollution.
- If you see a smoky car or truck, ring the EPA Pollution Watch Line¹⁸.
- When buying a car, ask about pollutant emissions and choose a car with lower emissions. For more information check out the 'Car EcoMeter' at www.epa.vic.gov.au/air/carecometer/default.asp

There are also some things you can do at home. Minimise your use of petrol-based tools (such as lawnmowers and leaf-blowers) and, where possible, use water-based paints in your home. This will also help to reduce smog-forming pollutants.

8.4 What is EPA doing about smog?

EPA seeks to reduce the pollutants that lead to smog by:

- working with industry to reduce emissions
- contributing to national developments in fuel standards and vehicle emission controls
- running educational programs to encourage regular car maintenance and low-emissions driving
- promoting alternatives to car use (for example, public transport)
- operating a program aimed at identifying smoky vehicles and requiring owners to have these vehicles serviced or repaired.

Through modelling studies and 25 years of monitoring, EPA has developed a substantial body of knowledge about ozone pollution in Melbourne. EPA is also continuing to refine this knowledge through monitoring and other studies, including a current research project to examine how climate change and other trends will affect ozone levels in the future.

¹⁷ For more information, see 'What is EPA doing to improve motor vehicle emissions?': www.epa.vic.gov.au/air/vehicles/epa_improve.asp

¹⁸ Pollution Watch Line: Call 9695 2777 from Melbourne or 1800 444 004 from other areas in Victoria.



8.5 Protecting yourself¹⁹

If you are sensitive to the effects of ozone, stay indoors on days when light winds are forecast and the temperature is expected to be over 30 °C.

During a smog episode avoid engaging in strenuous exercise. Take any prescribed medication as advised by your doctor; seek medical advice if you are concerned.

You can check the daily newspaper, EPA website or phone the EPA Pollution Watch Line for today's forecast and the latest measurements from monitoring stations.

¹⁹ For more information, refer to the Victorian Government Better Health Channel, www.betterhealth.vic.gov.au, and search for 'smog'.