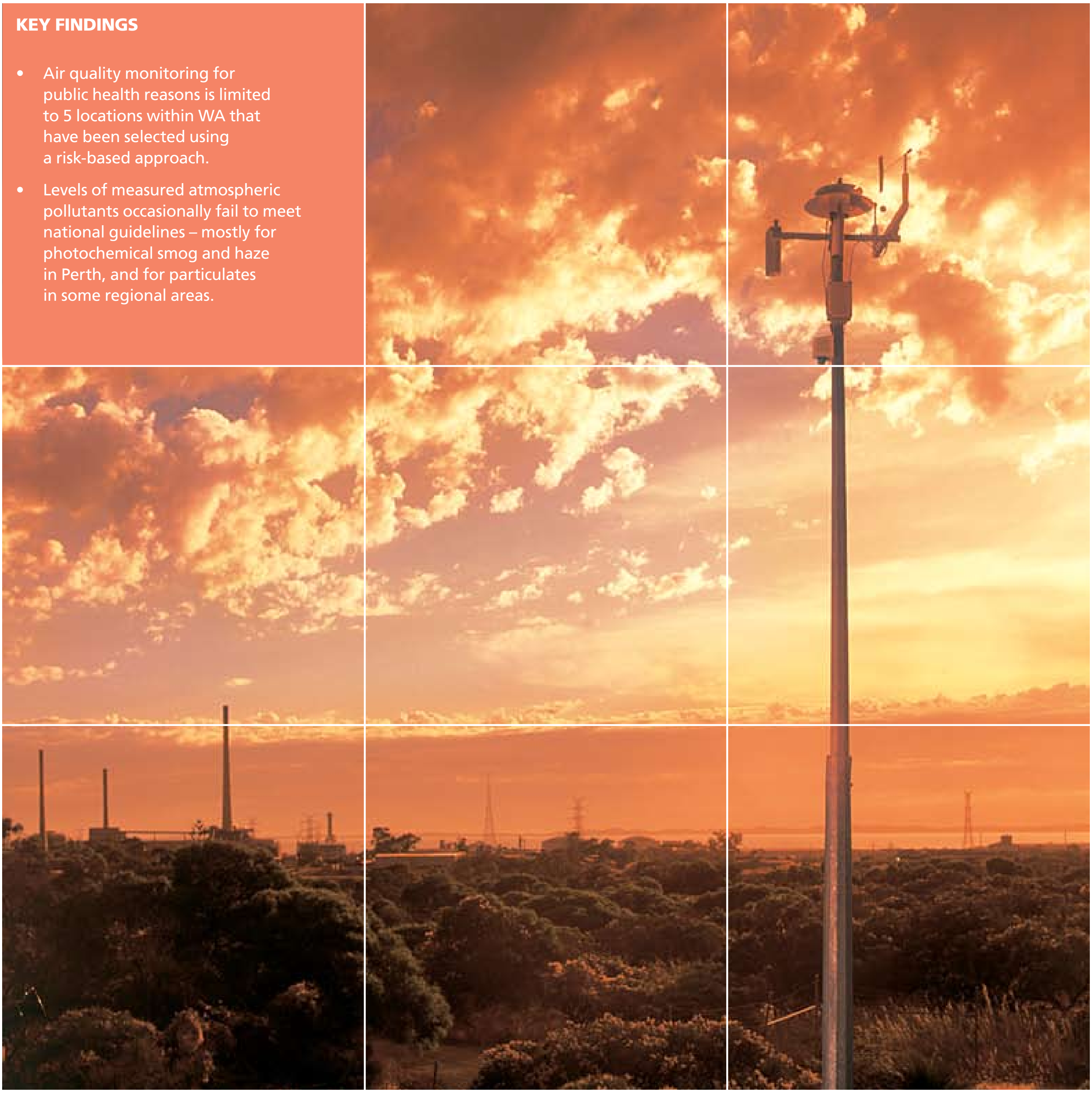
STATE OF THE ENVIRONMENT REPORT Western Australia 2007

# Theme 2

**KEY FINDINGS**

- Air quality monitoring for public health reasons is limited to 5 locations within WA that have been selected using a risk-based approach.
- Levels of measured atmospheric pollutants occasionally fail to meet national guidelines – mostly for photochemical smog and haze in Perth, and for particulates in some regional areas.



# ATMOSPHERE

## INTRODUCTION

'Atmosphere' refers to all air above the ground up to and including the stratosphere. It includes indoor air within houses and vehicles but not workplaces. The atmosphere surrounding the Earth consists of 79% nitrogen, 20% oxygen and a range of other gases and particles make up the balance (1%). It consists of several layers including the troposphere (in which we live), the stratosphere (in which the ozone layer is contained), and outer layers including the mesosphere, thermosphere and exosphere. The atmosphere plays a critical role in regulating global, regional and local climate and is essential to supporting life on Earth. Oxygen is required for life, ozone protects us from harmful solar radiation and historically greenhouse gases have helped maintain a temperature range suitable for life. However, the composition of the atmosphere is changing with increasing human pressures.

Atmospheric pollutants can have an adverse effect on human heath and the environment, and are derived from both human activity and natural processes. Significant sources from human activity include combustion of fossil fuels and wood, motor vehicles, release of hydrocarbons from oil and gas refining, emissions from industrial processes or intensive agriculture, and particulate matter associated with mining, land clearing and bushfires. Natural sources of pollutants include volcanic eruptions, wind erosion and bushfires. Some pollutants can chemically react in the atmosphere to form secondary pollutants, for example photochemical smog.

Air pollutants continue to be of community concern (Australian Bureau of Statistics, 2004) and there are several mechanisms in place to protect human and environmental health. These include a series of national environment protection measures (NEPMs) related to ambient air quality, air toxics, data collection for the National Pollutant Inventory and diesel vehicle emissions. It is a requirement that all measures be implemented by Australian states and territories, who must report on compliance. Standards for ambient air quality may be set over various timeframes to determine persistence and associated health impacts. They may also specify a number of allowable exceedences of a standard per year. As requirements to monitor for compliance with NEPM standards only apply in areas of more than 25 000 people, many areas in Western Australia are not monitored, but the standards are still considered relevant for all human settlements in WA.

The impacts of changes in the atmosphere can be observed on different scales. The 'greenhouse effect' (now generally known by the more accurate term climate change) and depletion of the stratospheric ozone layer are significant global atmospheric issues. On the regional and local scale, photochemical smog, particulates (including particulate haze and dust) and sulfur dioxide are well-recognised air quality problems.

### Objectives

- To protect human health and the natural environment from atmospheric pollutants.
- To ensure atmospheric pollutant levels do not exceed relevant standards.

### Headline indicators

**Indicator A1:** **Compliance with National Environment Protection (Ambient Air Quality) Measure.**

There have been 39 exceedences of the ambient air quality NEPM standards for all pollutants between 1998 and 2005 (Table A0.1). This figure does not include the smallest type of particulate matter ($PM_{2.5}$) because at present it is an advisory standard only. Although serious, the number of exceedences does not appear to have increased over time. The increase in background concentration of ozone is potentially serious, with a greater number of days expected to approach or exceed the standard in the future.

Clouds over the WA wheatbelt (Tourism WA)

**Table A0.1:** Exceedences of National Environment Protection (Ambient Air Quality) Measure standards, 1998–2005.

| Pollutant | Averaging Period (hours) | Maximum number of exceedences allowed per site per year[a] | Number of exceedences over all sites | Number of sites over the allowed number of exceedences | Years over the maximum number of exceedences | Number of sites measuring pollutants (2005) |
|---|---|---|---|---|---|---|
| Carbon monoxide (CO) | 8 | 1 | 0 | 0 | n/a | 4 |
| Nitrogen dioxide ($NO_2$) | 1 | 1 | 1 | 0 | n/a | 9 |
| Ozone ($O_3$) | 1 | 1 | 6 | 0 | n/a | 6 |
| Ozone ($O_3$) | 4 | 1 | 7 | 3 | 1998 (twice) | |
| 2001 | 6 | | | | | |
| Sulfur dioxide ($SO_2$) | 1 | 1 | 0 | 0 | n/a | 4 |
| Sulfur dioxide ($SO_2$) | 24 | 1 | 0 | 0 | n/a | 4 |
| Particle matter ($PM_{10}$) | 24 | 5 | 25 | 0 | n/a | 4 |
| Particle matter ($PM_{2.5}$)[b] | 24 | n/a | 43 | n/a | n/a | 2 |
| Total (not including Particle matter ($PM_{2.5}$)[b] | | | 39 | | | |
| Total (including Particle matter ($PM_{2.5}$)[b] | | | 82 | | | |

Data source: Department of Environment and Conservation [ver. 2007]. Notes: (a) Department of Environment monitoring sites only. (b) Advisory standard, not yet a defined standard.

**Indicator A2:** Number of WA settlements where air quality monitoring is currently undertaken for public health reasons.

In 2007, air pollutants were being measured at 5 settlements in WA (Perth, Bunbury, Albany, Geraldton and Busselton) for public health reasons. Within Perth, air pollutants are measured at 10 sites throughout the metropolitan area (Figure A0.1). The extent of air pollutant monitoring varies over time; usually in response to community health concerns, research studies and investigations, or regulatory requirements such as NEPM requirements or environmental conditions. In addition, shorter term studies are sometimes conducted as necessary but the monitoring is not on-going.

Sites are usually selected based on risk of pollutants being present, low exposure or background sites and population requirements under the NEPM.

Monitoring stations are also located in Busselton and Bunbury for particulates, including $PM_{10}$ (10 microns (µm) or less in size) and $PM_{2.5}$ (2.5 microns or less). Particle monitoring equipment has recently been installed at Albany and Geraldton but no monitoring data is available yet. A monitoring station operated in Dampier between 1998 and 2000, measuring carbon monoxide (CO), nitrogen dioxide ($NO_2$), ozone ($O_3$), and $PM_{10}$, but has now been decommissioned. In the past Bunbury's station measured carbon monoxide.

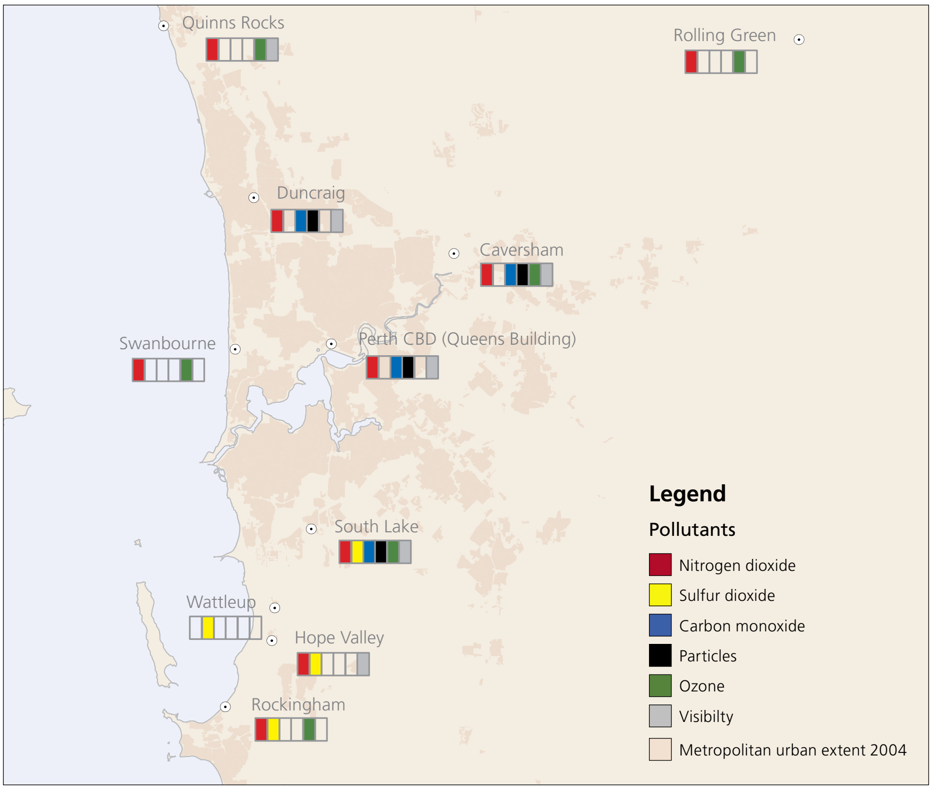



**Figure A0.1:** Metropolitan air quality monitoring sites and the pollutants measured.

Data source: Department of Environment and Conservation – Air quality monitoring sites [ver. 2007], Department of Planning and Infrastructure – Urban extent [ver. 2004]; Presentation: EPA.

**Table A0.2:** Change in annual estimated emissions in the Perth airshed between 1992–93 and 1998–99.

| | Oxides of nitrogen ($NO_x$) | Particulates ($PM_{10}$) | Sulfur dioxide ($SO_2$) | Carbon monoxide (CO) | Total reactive organic compounds (ROCs) | Lead |
|---|---|---|---|---|---|---|
| Motor vehicles (on road) | 22% | 18% | 36% | -2.3% | -27% | -88% |
| Industrial and commercial sources | 28% | 262%[a] | -6.1% | 81% | -52% | |
| Biogenic and natural sources | 0% | | | | 0% | |
| Area-based sources (not included elsewhere) | 169% | 0.5% | 514% | -2.2% | 13% | |
| Total | 28% | 52% | 4% | -1% | -14% | -88% |

Data source: Department of Environmental Protection (2002b). Analysis: EPA. Note: (a) This does not include particulate estimates for brickworks in 1992-93.

## Overall condition

An inventory of emissions to Perth's airshed was first completed in 1992–93 and followed up in 1998–99, allowing for an analysis of change over the two periods (Department of Environmental Protection, 2002b) (Table A0.2). The emissions were divided into four source categories – motor vehicles on the road, industrial and commercial, biogenic and natural and other area-based (diffuse) sources that are not included elsewhere (eg. wood heaters, gas used in homes, solvents, cigarettes, railways, marine craft, service stations, off-road vehicles, lawnmowing, aircraft, leakage of gas from supply network, swimming pools, dry cleaning and cutback bitumen).

Emissions estimates for oxides of nitrogen, particulates and sulfur dioxide all increased between 1992-93 and 1998-99 - overall 28%, 58% and 3.6% respectively (Department of Environmental Protection, 2002b). Emissions for carbon monoxide, total reactive organic compounds and lead were estimated to have decreased by 1%, 14% and 88% respectively. Some of these changes can be attributed to sampling - more industrial facilities were included and additional area-based source categories were added to the 1998-99 inventory. Increases in some motor vehicle emissions appear to be related to an increase in vehicle numbers and activity levels. Decreases in emissions often appear to be related to regulations, for example emissions estimates for reactive organic compounds and carbon monoxide from motor vehicles appear to have decreased as more cars on the road comply with design regulations for emissions from new vehicles (Department of Environmental Protection, 2002b).

Changes in emissions from some sources may also be attributed to the use of updated emission factors (numbers used for technical calculations) for the 1998/99 inventory (Department of Environmental Protection, 2002b). Therefore it is difficult to directly compare the 1992-93 and 1998-99 emissions for these sources. Also, variation in emissions may be attributed to improvements in methodology and data quality, rather than an actual change in emissions. For example, particulate emissions from brickworks were not included in 1992-93 data but were included in the calculations for 1998-99 (Department of Environmental Protection, 2002b).

Work on a third inventory of emissions into Perth's airshed is underway; however details are not yet available.

Some industries are required to measure atmospheric pollutants as part of development or operational requirements to protect the environment and the health of local communities (Table A0.3).

**Table A0.3:** Industry operated air monitoring sites across Western Australia.

| Location | Organisation | Pollutant monitored |
|---|---|---|
| Kwinana (several locations) | Kwinana Industries Council | $SO_2$, $PM_{10}$, TSP |
| Collie | Verve Energy, Worsley Alumina and Bureau of Meteorology | $SO_2$, $PM_{10}$, $PM_{2.5}$, $NO_x$, TSP |
| Kalgoorlie–Boulder, Coolgardie, Kurrawang, Kambalda | WMC, Kalgoorlie Consolidated Gold Mines, Kanowa Belle Gold Mines, Bureau of Meteorology | $SO_2$ (10 sites), $NO_x$, $PM_{10}$ |
| Dampier | Rio Tinto | $PM_{10}$ |
| Karratha | Rio Tinto | $PM_{10}$ |
| Point Sampson | Rio Tinto | $PM_{10}$ |
| Pilbara | Study by the former Department of Environment | $PM_{10}$, $PM_{2.5}$, $NO_2$, $O_3$, $SO_2$, CO |
| Pinjarra | ALCOA | $PM_{2.5}$, $PM_{10}$, TSP |
| Wagerup | ALCOA (Opsis) | $NO_x$, ROCs, formaldehyde, $PM_{10}$, TSP |

## Effectiveness

Twenty actions were identified for the 'Atmosphere' theme in response to the *1998 State of the Environment Report* (Government of Western Australia, 1998). Of these, 40% remain incomplete, 25% have been completed but not evaluated and 35% have been completed and evaluated. Compared to many other environmental issues affecting the State, air quality is monitored and reported in select locations. The nature of emissions and ambient air pollutants means that changes in condition and pressure are easy to detect, and that rigorous reporting procedures and management practices are in place.

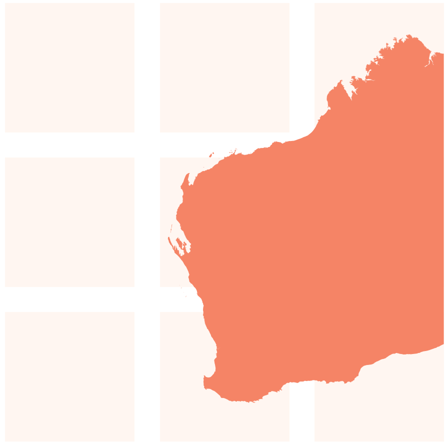
**SUGGESTED RESPONSES**

2.1 Implement the *Perth Air Quality Management Plan*. Although the plan was released in 2000 and much progress made, many parts have yet to be implemented.

2.2 Develop and implement air quality management plans for regional areas. Management plans should be developed for problem regional areas using the *Perth Air Quality Management Plan* as a model.

Carnarvon jetty (Tourism WA)

# 2.1 STRATOSPHERIC OZONE DEPLETION



INDICATIVE EXTENT OF ISSUE

**PRIORITY RATING: 5**

> **KEY FINDINGS**
>
> - The Montreal Protocol, an international agreement, has been successful in phasing out the use of ozone-depleting substances in Australia and around the world.
> - Global atmospheric concentrations for most ozone-depleting chemicals have either stabilised or are falling.
> - Ozone-depleting substances have been successfully controlled in WA through an environmental protection policy.
> - The largest ever hole in the ozone layer was recorded in September 2006 at 27.4 million square kilometres (three and a half times the size of Australia). The hole in the ozone layer is expected to peak in size by 2010, but is predicted to recover by 2065.

## Description

Depletion of stratospheric ozone ($O_3$), commonly known as 'the hole in the ozone layer', is an issue of international concern. Most ozone is found in the stratosphere (upper part of the atmosphere), more than 10 to 16 kms from the surface of the Earth (Fahey, 2003). The natural distribution of ozone around the Earth is not uniform, as seasonal winds and formation patterns contribute to lower concentrations at the equator and higher concentrations at the poles. Ozone in the stratosphere protects life on Earth as it limits penetration of ultraviolet radiation through the atmosphere, but it is considered a pollutant in the troposphere (close to the ground).

The ozone molecule is highly reactive and prone to splitting into oxygen atoms (O) and oxygen molecules ($O_2$) in the presence of ultraviolet radiation. Ozone can reform naturally, but it is usually a slow process. In the 1970s it was discovered that some human made chemicals could destroy ozone at a much faster rate, and by the early 1980s a hole in the ozone layer had formed above Antarctica (Fahey, 2003). Increases in concentration of ozone-depleting chemicals can change the balance of ozone production and destruction, which has resulted in a large area over Antarctica having very little or no ozone present during spring. Ozone-depleting chemicals include chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, hydrochlorofluorocarbons and methyl bromide. In the past, these chemicals were commonly used as refrigerants, foam blowing agents, industrial cleaning solvents, fire retarding chemicals and pest fumigants. The Montreal Protocol (which came into effect in 1989) provided a worldwide plan to phase out use of ozone-depleting substances.

Without adequate ozone protection, ultraviolet radiation reaches the Earth's surface and can increase the incidence of sunburn, skin cancers and cataracts, and can damage the immune system in humans and animals. Ultraviolet light can also disrupt plant photosynthesis and marine food chains. Some parts of WA are particularly susceptible to ultraviolet radiation due to predominantly clear atmospheric conditions and proximity to Antarctica – resulting in ambient ultraviolet radiation which is 10–15% higher than for comparable locations in the Northern Hemisphere (McKenzie et al., 1996, cited in Gies et al., 2004).

## Objectives

To protect health, amenity and the environment by ensuring emissions of stratospheric ozone-depleting substances are reduced or eliminated.

## Condition

**Indicator A3:** Trends in stratospheric ozone concentration.

The amount of ozone in the atmosphere is measured in Dobson units (DU). The average thickness of the atmospheric ozone layer over Perth varies from month to month, but is generally between 260 and 330 DU (Figure A1.1). In Perth, the maximum ozone thickness occurs in September and October, and the minimum in February, March and April. It is too early to detect trends in ozone layer data during the months of lowest layer thickness.

This differs from the data collected in Antarctica, where the hole in the ozone layer is largest in August, September and October (National Aeronautics and Space Administration, 2006). The United Nations Environment Program's most recent assessment showed that ozone depletion in spring remains substantial in the Antarctic region. Daily local total ozone column thicknesses are 60–70% less than in the period prior to formation of the ozone hole, with minimum values of about 100 DU seen every year since the early 1990s (United Nations Environment Programme, 2006).

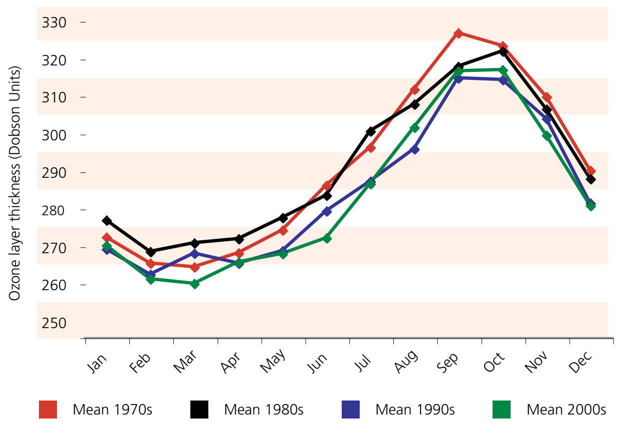



**Figure A1.1**: Average decadal seasonal variation in ozone layer thickness, measured at Perth Airport, 1970s–2000s.

Data source: Bureau of Meteorology – Ozone layer thickness at Perth airport [ver. 2006]; Analysis: EPA.

Data from southern parts of Australia (including Perth) and New Zealand shows a decline of about 4% in summer ozone concentration per decade between the late 1970s and 2000 (Manins, 2001).

**Indicator A4:** Size of the 'hole in the ozone layer' over Antarctica.

There is recent evidence that the 'hole in the ozone layer' over Antarctica in 2006 was the largest on record (National Aeronautics and Space Administration, 2006). From 21-30 September 2006, the average area of the hole was 27.4 million km$^2$ – the largest average area ever observed (Figure A1.2). The largest daily average ozone hole occurred during the same period, equalling a day in 2000 where the hole reached 29.5 million km$^2$. However, cold weather conditions are likely to have also influenced the size of the ozone hole, as well as the action of ozone-depleting substances (National Aeronautics and Space Administration, 2006).

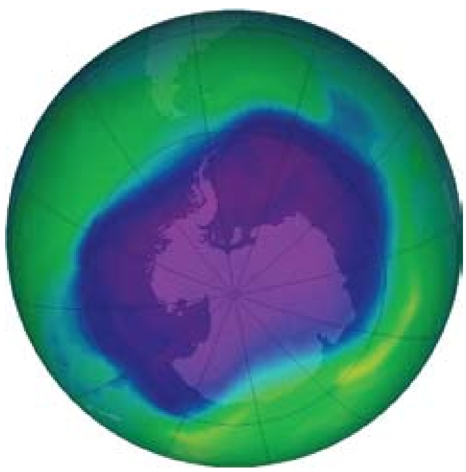


**Figure A1.2:** Image of the hole in the ozone layer on September 24 2006, equal record for single-day largest hole size.

Data source: National Aeronautics and Space Administration (2006). Note: purple colours indicate very little ozone cover (i.e. the area of the 'hole') while blue, yellow and green indicate progressively thicker ozone layers.

While the largest hole in the ozone layer was seen in 2006, the average size of the ozone hole has been generally increasing over time (Figure A1.3).

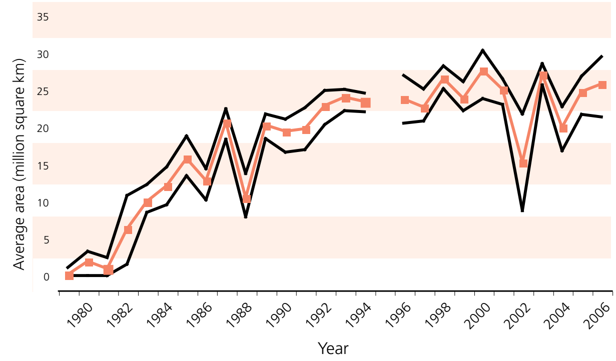



**Figure A1.3**: Average size of the 'hole in the ozone layer' over time, 1979 to 2006.

Data source: National Aeronautics and Space Administration – minimum, maximum and average areas of hole in the ozone layer [ver.2007]. Note: All data was collected by the Earth Probe Total Ozone Monitoring System (EP TOMS) except 1993 and 1994 (Meteor 3 TOMS) and 2005 and 2006 (OMI). Data from EP TOMS was unreliable between 2002 and 2004, and corrections have been made to these data.

**Indicator A5:** Trends in ultraviolet radiation for Western Australia.

Analysis of satellite data sets from 1979 to 1992 shows that trends for ultraviolet radiation, ozone and cloud cover were not uniform over Australia (Udelhofen et al., 1999). During this period ultraviolet radiation levels showed a 4% increase over tropical Australia, increased marginally over the mid latitude areas and either decreased or remained constant over the southern portions of Australia. These patterns of ultraviolet radiation were in part a result of complex interactions between cloud cover changes and ozone depletion, but were due principally to cloud cover variations. Cloud cover over the tropics decreased by approximately 8% from 1979 to 1992, thus leading to an increase in ultraviolet radiation. In contrast, cloud increased over the southern regions by 4% and resulted in a slight decrease in ultraviolet radiation.

It should be noted that the data for 1979 to 1992 is the only data on ultraviolet radiation levels to have been analysed so far for Australia. In this period, programs to reduce use of ozone-depleting substances had not yet begun. A follow-up study covering the period from 1992 to present is planned to commence in summer of 2007-08, through a collaboration of the Australian Radiation Protection and Nuclear Safety Agency and the Bureau of Meteorology. It is likely there will have been further increases in ultraviolet radiation reaching Earth's surface since 1992 (P Gies, Australian Radiation Protection and Nuclear Safety Agency, pers. comm.).

## Pressures

Ozone-depleting chemicals are responsible for causing the hole in the ozone layer. These chemicals include chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, hydrochlorofluorocarbons (HCFCs) and methyl bromide. Though the production of ozone-depleting substances was restricted by the Montreal Protocol, ozone-depleting chemicals still exist in refrigerators and air conditioners. In addition, many ozone-depleting substances have relatively long lifetimes in the atmosphere. Many developing countries have significant stores of these chemicals and lack the necessary resources and institutions for preventing illegal trade and the unauthorized production and consumption of ozone-depleting substances (United Nations Environment Programme, 2006; National Aeronautics and Space Administration, 2005). However, total phasing out of these chemicals is expected between 2010 and 2040.

This has largely been achieved in WA, although several exceptions are allowed under the Australian Chlorofluorocarbon Management Strategy (Environment Australia, 2001a).

**Indicator A6:** **The concentration of ozone-depleting substances over Australia.**

The concentrations of all ozone-depleting gases were seen to rise steadily after measurements were initiated in the late 1970s (Figures A1.4, A1.5 and A1.6). Most have begun to decline in concentration, demonstrating the benefit of a global reduction in use of ozone-depleting substances. The Montreal Protocol phased out CFC-11 (primarily used in aerosol spray cans) in developed countries. Consequently, atmospheric levels of this gas have been falling since the mid 1990s (Figure A1.4).

In comparison, CFC-12 concentrations have stabilised (Figure A1.5). This gas, used in refrigerants and air conditioners, took longer to phase out than those used in aerosols and has a longer chemical lifetime in the atmosphere. Atmospheric concentrations of methyl chloroform (Figure A1.6) show a dramatic reduction from the mid 1990s. The compound was used as an industrial solvent and in dry cleaning and has a much shorter chemical lifetime.

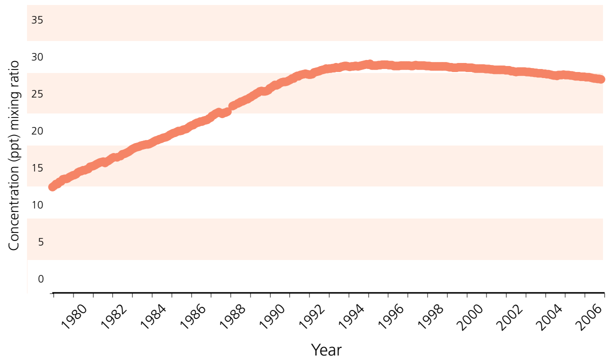



**Figure A1.4:** Monthly averaged atmospheric concentrations of chlorofluorocarbon 11 at Cape Grim Tasmania.

Data source: CSIRO Atmospheric Research and Australian Bureau of Meteorology - Cape Grim Baseline Air Pollution Station monthly averaged atmospheric chlorofluorocarbon 11

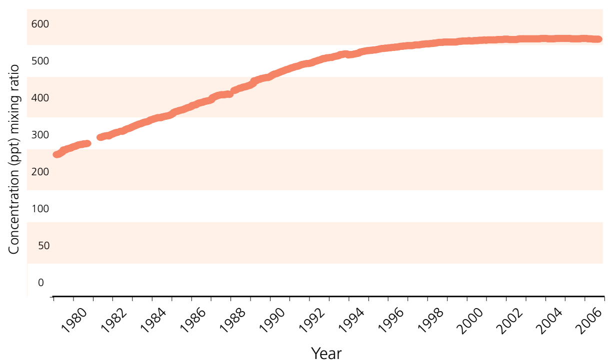



**Figure A1.5:** Monthly averaged atmospheric concentrations of chlorofluorocarbon 12 at Cape Grim Tasmania.

Data source: CSIRO Atmospheric Research and Australian Bureau of Meteorology - Cape Grim Baseline Air Pollution Station monthly averaged atmospheric chlorofluorocarbon 12.

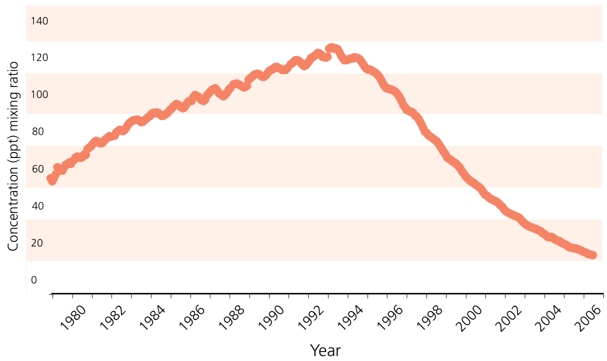



**Figure A1.6:** Monthly averaged atmospheric concentrations of methyl chloroform at Cape Grim Tasmania.

Data source: CSIRO Atmospheric Research and Australian Bureau of Meteorology - Cape Grim Baseline Air Pollution Station monthly averaged atmospheric methyl chloroform.

Although the atmospheric concentrations of ozone-reducing chemicals are generally declining, much of the damage to the ozone layer has been done, and minimum ozone concentrations are likely to occur between 2000 and 2010. Recovery of the ozone layer to 1980 levels is likely to occur around 2050.

## Current responses

Montreal Protocol: an international commitment came into force in 1989 (and was amended in 1990 and 1992) to protect the stratospheric ozone layer. It stipulates the phasing out of production and use of ozone-depleting substances, with varying timelines depending on the chemical and the status of developing countries.

*Australian Chlorofluorocarbon Management Strategy:* was published by Environment Australia (2001a). It provides a framework for the responsible management and use of CFCs in Australia. The strategy recognises some continuing need for these chemicals in pharmaceutical and laboratory uses, but commits to their gradual phasing out.

*Environmental Protection (Ozone Protection) Policy 2000:* this WA policy aims to minimise the discharge of ozone-depleting substances into the environment, and has been extended to cover use of alternative refrigerants (where relevant). This has been done to prevent current stocks of ozone-depleting substances from being released to the atmosphere by tradespeople that are not accredited, or with inadequate training and/or equipment working on systems that contain these substances.

United Nations Environment Programme: has published several assessments of the environmental effects of ozone depletion (United Nations Environment Programme, 1998; World Meteorological Organization, 2002).

*Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (and associated regulations and amendments): was implemented by the Commonwealth Government to meet its commitments under the Montreal Protocol.

CSIRO Marine and Atmospheric Research: analyses information about a wide range of greenhouse gases and ozone-depleting substances.

Ultraviolet index forecast: The Bureau of Meteorology has developed a model to predict the amount of ultraviolet exposure and the times of day at which it will occur for 45 WA locations. It is designed to help people minimise their exposure to dangerous levels of ultraviolet radiation.

## Implications

As a result of the Montreal Protocol and its amendments, the concentrations of ozone-depleting substances in the troposphere peaked around 1995 and are decreasing in both the troposphere and stratosphere. It is estimated these gases reached peak levels in the Antarctica stratosphere in 2001. However, some ozone-depleting substances have very long lifetimes in the atmosphere (more than 40 years). As a result, the ozone hole is predicted to very slowly decrease in area by about 0.1 to 0.2 percent for the next five to 10 years. This slow decrease is masked by large year-to-year variations caused by Antarctic stratosphere weather fluctuations. Scientific research predicts a slow recovery of the ozone layer by the year 2065 (World Health Organisation and United Nations Environment Program, 2006).

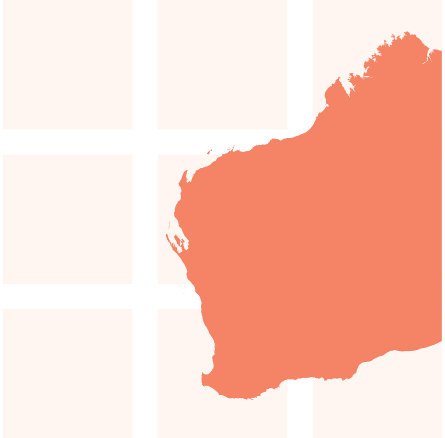
Increased ultraviolet radiation reaching the Earth's surface can have significant detrimental impacts on animal and plant life. The radiation damages cells, causing damage to DNA and can lead to cell death or mutation and cancers. Radiation can also cause photochemical reactions in freshwater and marine waters, forming radicals (such as peroxide and hydroxide) that can cause further biological damage. Marine ecosystems in the Southern Ocean are most at risk. Zooplankton and phytoplankton, the foundation of the marine food chain, are particularly susceptible to certain types of ultraviolet radiation and impacts have flow-on effects to fish stocks and larger organisms such as whales. On land, increased ultraviolet light can cause significant damage to native vegetation and agricultural crops, such as reduced plant height, reduction in foliage area and changes to tissue composition (Caldwell et al, 2003). Like humans, some native animals and livestock may be susceptible to skin cancers. Australia has a predominately fair-skinned population and exposure to high doses of ultraviolet radiation can lead to high rates of skin cancer due to changes to the DNA caused by ultraviolet radiation (Gies et al., 2004). Increased exposure is also likely to damage the immune system and lead to increased risk of infection. Consequently, the Australian community is learning to embrace a 'Sun Smart' culture when outdoors (i.e. wearing sunscreen and protective hats, sunglasses and clothing, etc).

### SUGGESTED RESPONSES

2.3 Maintain existing programs to ensure that ozone-depleting substances are not released: existing responses have virtually eliminated ozone-depleting substances in WA, but ongoing vigilance is required.

Broome sunset (Tourism WA)

# 2.2 GREENHOUSE GAS EMISSIONS



INDICATIVE EXTENT OF ISSUE

## PRIORITY RATING: 1

### KEY FINDINGS

- Atmospheric greenhouse gas levels are increasing at a faster rate than at any other time in recorded history and are a major contributor to global climate change.
- WA's net greenhouse gas emissions increased 17% between 1990 and 2005. If land use concessions are excluded, then emissions have increased 45% over the same period.
- On a per capita basis, WA's greenhouse gas emissions are higher than Australia's and other developed countries, including the United States and the United Kingdom.

### Description

Life on Earth is made possible by the 'greenhouse effect', a process in the atmosphere that creates the relatively warm environment near the Earth's surface. About 70% of incoming solar radiation is absorbed by the Earth, warming the land, oceans and atmosphere and providing energy for life forms. The remainder is reflected back into space. Some of the reflected radiation is absorbed by certain gases (known as greenhouse gases) in the atmosphere, trapping heat near the surface layers of the atmosphere (Bureau of Meteorology, 2003). This is the greenhouse effect and without it, the Earth would be considerably cooler. The amount of greenhouse gases in the atmosphere affects how much heat is absorbed. The major greenhouse gases are carbon dioxide, water vapour, methane, nitrous oxide and ozone.

Since the industrial revolution (late 1700s) human activities have led to an increase in the concentration of greenhouse gases in the atmosphere, contributing to an 'enhanced greenhouse effect'. The Earth's climate has demonstrably changed on both global and regional scales since the pre-industrial era: global average air and ocean temperatures have warmed; global mean sea level has risen and there has been widespread melting of snow and ice (Intergovernmental Panel on Climate Change, 2007). These changes have already affected hydrological systems and terrestrial and marine ecosystems in many parts of the world, including WA. The increase in greenhouse gas concentrations is largely due to fossil fuel use (such as oil, coal and natural gas), widespread land clearing, and agricultural activities (Intergovernmental Panel on Climate Change, 2007). The main greenhouse gases generated by human activities are carbon dioxide, nitrous oxide, methane and 65 other gases termed 'halocarbons' (Bureau of Meteorology, 2003). Greenhouse gases can remain active for centuries and it is expected that even if atmospheric concentrations were stabilised, warming of global climate and sea level rise would continue for centuries (Intergovernmental Panel on Climate Change, 2007). However, climate modelling indicates that the scale of climate change and associated impacts will be substantially greater if greenhouse gas concentrations continue to rise (Intergovernmental Panel on Climate Change, 2007).

Scientists warn that reductions in annual global greenhouse gas emissions of about 60% by 2050 are needed to stabilise atmospheric concentrations (Coleman et al., 2004). The 1997 Kyoto Protocol (which came into effect on 16 February 2005) imposed binding, quantifiable emission targets for signatory countries. To date, Australia has not ratified the protocol, but the Government of WA and other state and territory governments support its adoption. The Commonwealth Government has committed to meeting Australia's target under the protocol – stabilising greenhouse gas emissions at 108% of 1990 levels between 2008 and 2012. In 2005 national greenhouse gas emissions were 102.2% of 1990 levels (Australian Greenhouse Office, 2007a).

### Objective

- To reduce WA's greenhouse gas emissions.

## Condition

**Indicator A7:** Current atmospheric concentrations of greenhouse gases.

The concentration of greenhouse gases over the last few decades has been increasing (Figures A2.1, A2.2 and A2.3). Atmospheric concentrations of carbon dioxide have increased approximately 15% and nitrous oxide has increased 7% over the last 30 years (Figures A2.1 and A2.2). Methane has increased about 17% over the same period, but its concentration has stabilised over the last five years or so (Figure A2.3). The stabilisation of atmospheric methane concentration is largely due to a decline in anthropogenic emissions. Since 1999 the anthropogenic sources have begun to rise again, but this has been offset by the decline in methane emissions from wetlands (resulting in a likely overall increase in methane emissions again) (Bousquet et al., 2006). Data on atmospheric concentrations of pollutants is collected at Cape Grim in western Tasmania (which has very good air quality) and forms the baseline for measuring atmospheric greenhouse gas concentrations for the whole of Australia.

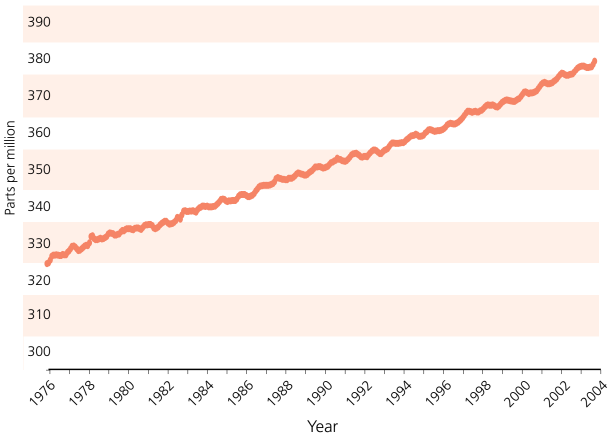



**Figure A2.1:** Monthly averaged atmospheric concentrations of carbon dioxide at Cape Grim Tasmania.

Data source: CSIRO Atmospheric Research and Australian Bureau of Meteorology - Cape Grim Baseline Air Pollution Station monthly averaged atmospheric carbon dioxide.

Energy consumption by transport contributes 14% of WA's greenhouse gas emissions (Department of Environment and Conservation)

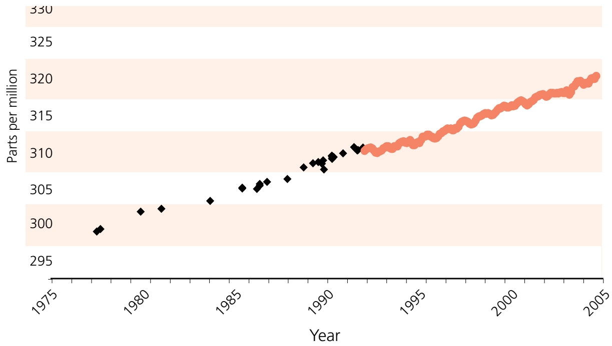



**Figure A2.2:** Monthly averaged and air archive atmospheric concentrations of nitrous oxide at Cape Grim Tasmania.

Data source: CSIRO Atmospheric Research and Australian Bureau of Meteorology - Cape Grim Baseline Air Pollution Station monthly averaged atmospheric nitrous oxide.
Note: Air archive data are indicated in black, April 1978 to May 1984.

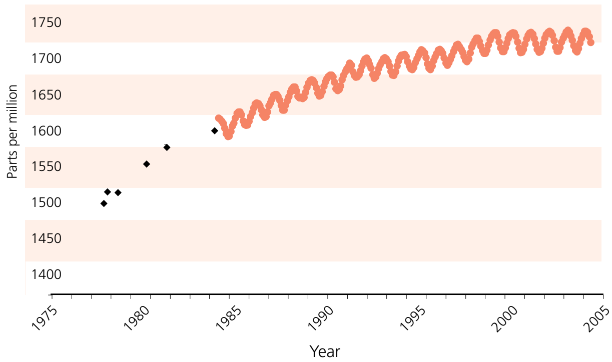



**Figure A2.3:** Monthly averaged and air archive atmospheric concentrations of methane at Cape Grim Tasmania.

Data source: CSIRO Atmospheric Research and Australian Bureau of Meteorology - Cape Grim Baseline Air Pollution Station monthly averaged atmospheric methane.
Note: Air archive data are indicated in black, April 1978 to May 1984.

**Indicator A8:** Historical atmospheric concentrations of greenhouse gases.

Measurements of historical atmospheric concentrations in greenhouse gases put the recent trends observed in these gases into perspective. Modelling data based on ice core samples show the relatively stable atmospheric concentrations of these gases before the 19th Century and an exponential rise over approximately the last 200 years (Figure A2.4). Since the beginning of the industrial revolution, the amount of carbon dioxide in the atmosphere has increased by 33%, methane levels have increased 100% and nitrous oxide levels have increased by 15% (Western Australian Greenhouse Taskforce, 2004). The atmospheric concentration of carbon dioxide in 2005 far exceeds the natural range over the last 650 000 years (Intergovernmental Panel on Climate Change, 2007). The rate of increase in concentration of these gases is significantly faster than any natural rates of variation in recorded history.

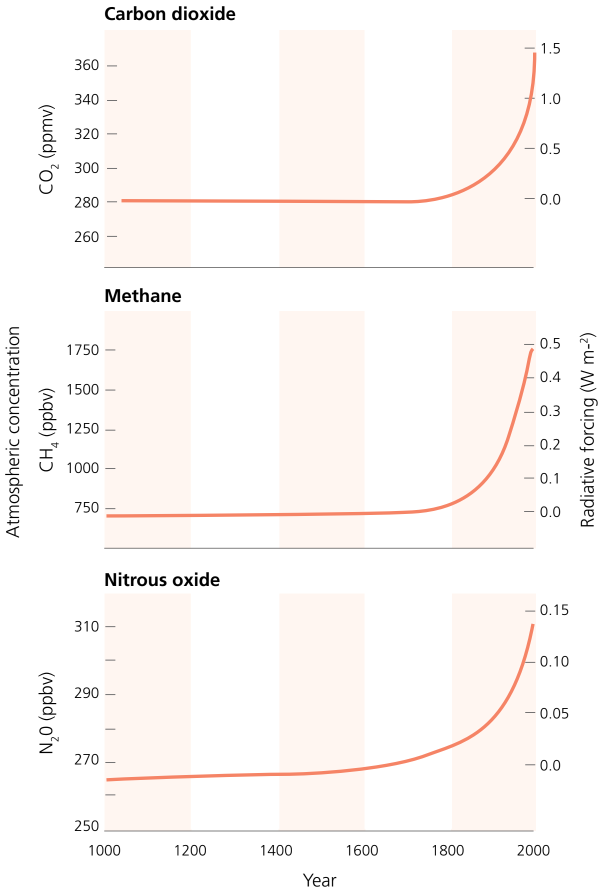



**Figure A2.4:** Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 1000 years.

Data source: Bureau of Meteorology (2003). Note: Based on measurements from Antarctic ice cores and, since the 1970s, analyses conducted at Cape Grim Baseline Air Pollution Station. Radiative forcing is a measure of the influence the gas has in altering the balance of incoming and outgoing radiation, and is measured in watts per square metre. Positive forcing tends to warm the surface while negative forcing tends to cool it.

## Pressures

### **Indicator A9:** Trends in total greenhouse gas emissions.

Greenhouse gases vary in their capacity to induce global warming, and therefore the warming potential of each gas has to be taken into account when assessing its effects. This common measure is called carbon dioxide equivalent ($CO_2$-e). In 2005, WA's greenhouse gas emissions were 66.6 million tonnes of $CO_2$-e, a 17% increase compared to 1990 levels (Figure A2.5). The State's proportional contribution to national greenhouse gas emissions also increased from 10.4% in 1990 to 11.9% in 2005.

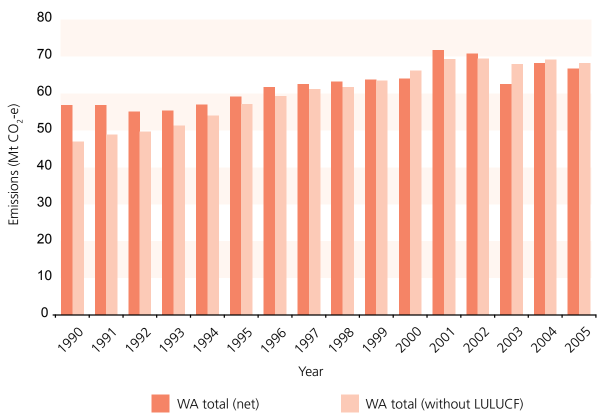



**Figure A2.5:** Western Australia's greenhouse gas emissions, 1990–2005.

Data source: Australian Greenhouse Office (2007b).Note: This figure depicts greenhouse gas emissions in carbon dioxide equivalents ($CO_2$-e).

Most of WA's greenhouse gas emissions are linked to the energy and agricultural sectors (Table A2.1. The energy sector (including stationary and transport energy) was responsible for 74% of WA's emissions in 2004 and increased by 58% between 1990 and 2005 to 49 million tonnes $CO^{2}$-e. About half of the increase was from growth in electricity and heat production, petroleum refining, manufacture of solid fuel and other industries (Australian Greenhouse Office, 2005; Government of Western Australia, 2005). WA has a large number of energy-intensive, export-oriented industries including oil and gas, minerals, bauxite refining and iron ore production. With continued growth expected in these industries, increasing emissions from the energy sector are anticipated (Government of Western Australia, 2005).

Transport energy consumption generates about 19% of emissions from the energy sector (and 14% of overall emissions), due to WA's overwhelming reliance on motor vehicles for moving people and freight. This is exacerbated by historical patterns of low density urban development and the vast distances between settlements in WA (see '*Transport*').

WA's agricultural sector produces approximately 19% of the State's greenhouse gas emissions, most of which are from methane generated by livestock and the burning of savanna grasslands. Emissions from the land use, land change and forestry sector declined markedly (about 115%) between 1990 and 2004, due to reductions in land clearing and an increase in the area of plantations. The reduction in clearing for agriculture represents a one-off accounting credit against the State's gross emissions unless substantial revegetation occurs. If the overall benefit from this sector is excluded from the State's greenhouse gas emission profile, the State's emissions increased 45% (as opposed to 17%) over this period.

If current trends in WA's greenhouse gas emissions are projected forward to 2008, there is expected to be an increase of 39% on the 1990 baseline figure compared to an 8% 'allowable increase' (Australian Greenhouse Office, 2005). WA is therefore in a challenging situation for reducing emissions, particularly when considered in a global context. This challenge is exacerbated by the nature of WA's economy, which is primarily focussed on trade-exposed export industries, mostly with high emissions intensities. However, WA is well placed to take action on reducing greenhouse gas emissions through development of alternative energy sources (e.g. wind, solar), improving energy efficiency and offsets (e.g. tree planting to offset carbon dioxide emissions).

### **Indicator A10:** Trends in per capita greenhouse gas emissions.

Australia's greenhouse emissions constitute about 1.5% of global emissions. However, Australians have the highest greenhouse gas emissions per capita for industrialised nations (Figure A2.6). Some of the main reasons for Australia's high per capita emissions include the reliance on greenhouse-intensive fuels for electricity generation, extensive use of passenger and freight transport over long distances and the extremely high energy usage of the aluminium smelting industry (Turton, 2004).

**Table A2.1:** Western Australia's greenhouse gas emissions.

| Greenhouse gas source and sink categories | 1990 | 2005 | Percentage change 1990 to 2004 |
|---|---|---|---|
| | Million tonnes of carbon dioxide equivalents ($CO_2$-e) | | |
| 1. Energy | 31.1 | 49.2 | 56.0% |
| 2. Industrial | 2.0 | 4.5 | 200.2% |
| 3. Solvent and other product | — | — | — |
| 4. Agriculture | 12.0 | 12.4 | 5.4% |
| 5. Land use, land use change and forestry (LULUCF) | 9.8 | -1.6 | -110.2% |
| 6. Waste | 1.7 | 2.0 | 10.3% |
| 7. Other | — | — | — |
| Total including net $CO_2$-e from LULUCF (Row 5 above) | 56.7 | 66.6 | 17.5% |
| Total excluding net $CO_2$-e from LULUCF | 46.9 | 68.1 | 45.4% |

Data source: Australian Greenhouse Office, 2007b. Note: The 'Solvent and other product' and 'Other' categories are not relevant in WA. However, they were included to make this table consistent with the national and international format for greenhouse gas emissions reporting.

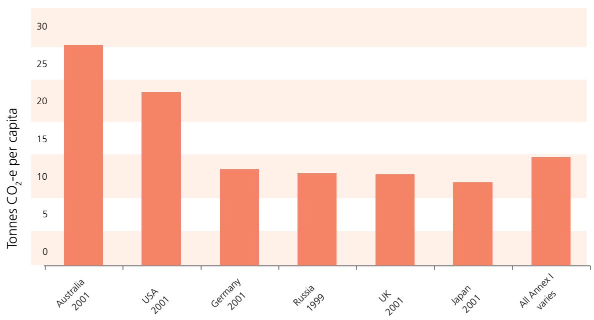



**Figure A2.6:** Greenhouse gas emissions per capita for selected industrialised countries (Annex I), measured in millions of tonnes of carbon dioxide equivalent.

Data source: Turton (2004).

WA's average per capita greenhouse gas emissions are considerably higher than for Australia (Figure A2.7). This can be attributed largely to WA's high level of economic output relative to population and the heavy emphasis of the State's economy on resources and energy development and exports. Average per capita emissions in WA decreased slightly between 1990 and 2005 to 33.1 tonnes $CO_2$-e. This decrease is largely a function of economic restructure and reductions in land use clearing over this period.

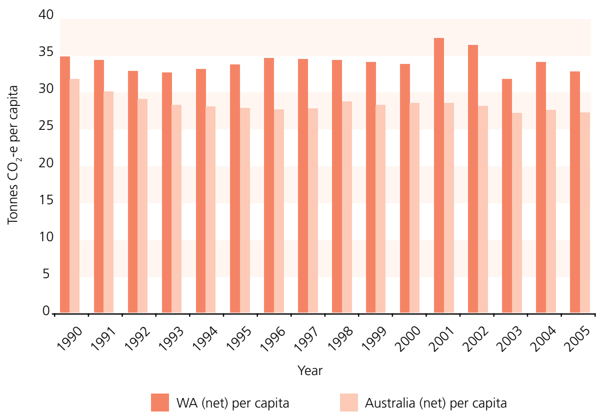



**Figure A2.7:** Net greenhouse gas emissions per capita for Western Australia and Australia, 1990–2005.

Data source: Australian Bureau of Statistics (2006a), Australian Greenhouse Office (2007a & 2007b). Note: This figure depicts greenhouse gas emissions in carbon dioxide equivalents ($CO_2$-e) per capita.

WA's greenhouse gas emissions relative to the level of economic output decreased by 37% between 1990 and 2005 (Figure A2.8). This decrease is consistent with the national trend which is attributed to emissions management actions across sectors, reductions in land use clearing and structural changes in the economy (Australian Greenhouse Office, 2006).


**Figure A2.8:** Net greenhouse gas emissions per dollar of gross state product or gross domestic product for Western Australia and Australia.

Data source: Australian Bureau of Statistics (2006b); Australian Greenhouse Office (2007a & 2007b). Note: This figure depicts greenhouse gas emissions (in carbon dioxide equivalents ($CO_2$-e) per dollar of gross state product (GSP) or gross domestic product (GDP).

## Current responses

Commonwealth Government programs: The Australian Greenhouse Office delivers programs such as implementing targets from the United Nations Framework Convention on Climate Change and the Kyoto Protocol, the National Greenhouse Gas Inventory, implementing the National Carbon Accounting System, and working with industry on the Greenhouse Gas Abatement Program, Greenhouse Challenge Program and the Greenhouse Friendly initiative, to encourage industry action to abate greenhouse gas emissions. The Commonwealth Government has also joined the Asia–Pacific Partnership on Clean Development and Climate (also known as AP6) along with the USA, China, India, Japan and South Korea. The partnership aims to reduce greenhouse gas emissions through the use of clean technology, and exploring ways to reduce the greenhouse intensity of the economy, build capacity and engage the private sector.

State Government programs: a Greenhouse Taskforce was established in 2002 and later released the *Western Australian Greenhouse Strategy* (Western Australian Greenhouse Taskforce, 2004).The strategy aims to guide State efforts to reduce greenhouse gas emissions and to respond to opportunities and challenges generated by climate change. A Greenhouse and Energy Task Force has recently released a report providing recommendations to manage greenhouse gas emissions from the stationary energy sector in the short term, and to investigate the feasibility of long-term greenhouse gas emissions reduction, emissions trading, energy conservation initiatives and on-ground rules for greenhouse offsets.

Local government: the 'Cities for Climate Protection' is an international organisation that has been established to help local governments integrate greenhouse gas mitigation strategies into their decision-making processes.

Guidance statement for minimising greenhouse gas emissions: the Environmental Protection Authority released the *Guidance Statement for Minimising Greenhouse Gas Emissions in 2002* (Environmental Protection Authority, 2002). It provides guidance about considering greenhouse gas emissions in environmental impact assessments. However, the EPA cannot demand that proponents of projects or industries releasing greenhouse gases offset those emissions or comply with targets (Environmental Protection Authority, 2006).

Greenhouse Challenge: this program provides an opportunity for businesses and industries to demonstrate commitment to reducing emissions of greenhouse gases by calculating their greenhouse gas emissions, implementing reduction measures and maintaining independent verification.

Carbon sequestration: policies on technical and regulatory issues for sequestration of carbon below ground (geosequestration) or in vegetation (biosequestration) are being developed.

### Implications

Greenhouse gas-driven climate change is a global issue that will have significant implications for WA's environment, society and economy (see '*Climate Change*'). Ongoing increases in greenhouse gas emissions are likely to impact the WA economy, particularly with the likely establishment of carbon trading. Until Australia ratifies the Kyoto Protocol, WA will be unable to participate in, or benefit from, international trading schemes. Quantifying the cost of climate change is complex. The environmental cost of greenhouse gas emissions is largely excluded from the price of goods and services. This provides little incentive for investment in reducing greenhouse gas emissions or in developing greenhouse mitigation technologies. Until Australia recognises this shortfall, the country will fall behind in developing new and sustainable solutions for addressing greenhouse gas emissions.

**SUGGESTED RESPONSES**

2.4 Establish a legislative framework to achieve greenhouse gas emission reduction targets.

2.5 Establish a target to reduce emissions by at least 60% below 1990 levels by 2050 and establish interim targets for 2010, 2020, 2030 and 2040.

2.6 Establish a 20% renewable energy target for the State.

2.7 Develop standards for carbon offsets to ensure their integrity and to support a carbon trading market.

2.8 Establish a carbon trading market, with a preference for participating in a national emissions trading scheme.

2.9 Implement all actions of the *Western Australian Greenhouse Strategy*, including a comprehensive review and update by the end of 2008.

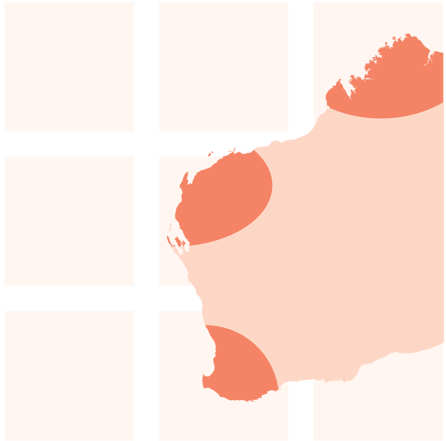
2.10 Reduce the greenhouse gas intensity of the State's economy: emission reduction strategies and long term targets need to be developed for each sector of the economy.

2.11 Implement the recommendations of the WA Greenhouse and Energy Taskforce report: *Strategies to Reduce Greenhouse Gas Emissions from the Western Australian Stationary Energy Sector.*

2.12 Undertake a comprehensive review of energy subsidies and remove subsidies that increase greenhouse gas emissions.

An industrial site in Geraldton (B. Jakowyna)

# PARTICULATES




## PRIORITY RATING: 2



### KEY FINDINGS

- Particulate levels in some areas of the State regularly exceed health standards.
- Particulate problems in the Pilbara are associated with bushfires, dust storms, and some mining and port facility operations.
- Particulate problems in Perth can be attributed to bushfires, controlled burns, and wood heater emissions.

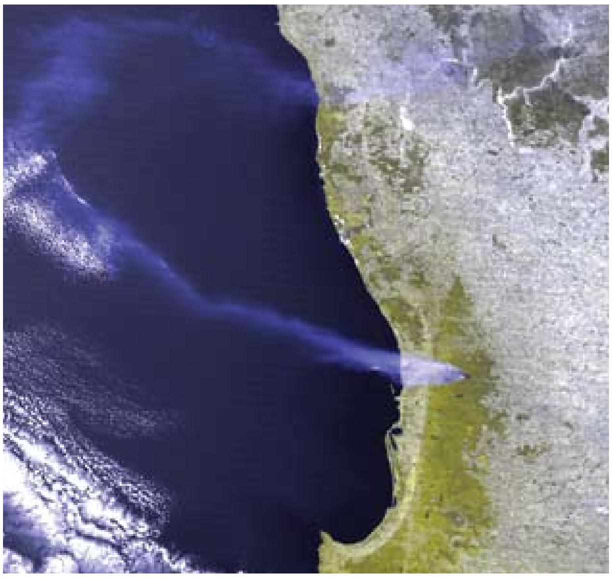
## Description

Airborne particulates (or particles) are produced by a wide range of natural phenomena and human activities, and may be solid or liquid (a suspension of solid and liquid particles is often called an aerosol). Natural sources of particulates include fine soil mobilised by wind erosion, sea salt blown from the ocean, and smoke from bushfires. Human generated sources of particulates include combustion processes in motor vehicles (especially diesel), industrial and commercial boilers and incinerators, power generation plants, mining operations, solid fuel domestic heating, domestic incineration and burning of vegetation (including agricultural and fuel reduction burning).

Particulate size is the main determinant of pollutant behaviour, and is usually expressed in terms of the 'aerodynamic diameter'. Particulates are commonly categorised or classified (Department of Environment, 2003a) as follows:

- total suspended particles (TSP), which include all particles less than 50 µm;
- inhalable particles which includes the $PM_{10}$ (coarse fraction; 10 µm and smaller) and $PM_{2.5}$ (fine fraction; 2.5 µm and smaller); and
- visibility-reducing particles ($PM_2$; ranging from 0.1 to 2 µm in size) which scatter light and cause haze.

Large inert particulates are typically associated with adverse aesthetic and environmental effects rather than health effects. Inhalable particulates ($PM_{10}$ and smaller) are associated with increases in respiratory illness (e.g. asthma, bronchitis and emphysema). Smaller particulates, such as



Smoke from bush fires in the Perth Hills in January 2005, as seen from space (Department of Environment and Conservation)

$PM_{2.5}$ are thought to represent a higher risk due to their ability to penetrate further into the lungs and be absorbed into the bloodstream (Department of Environmental Protection, 2000a). A significant positive relationship exists between air pollutants and daily hospital admissions for respiratory disease, cardiovascular disease and respiratory hospitalisation of the elderly in particular (Department of Environment, 2003b). Particulates have been responsible for the majority of NEPM exceedences recorded since 1998.

## Objectives

- To protect health, amenity and the environment by ensuring the level of particulates in the air meet the relevant standards.

## Condition

There are standards in place for particulates via the *National Environment Protection (Ambient Air Quality) Measure* (NEPM) to ensure community health is not compromised. They include:

- Particles as $PM_{10}$:
  Averaging period: one day, Maximum concentration: 50 micrograms per cubic metre, Goal by 2008 (maximum exceedences): five days a year

- Particles as $PM_{2.5}$:
  Averaging period: one day, Maximum concentration: 25 micrograms per cubic metre

  Averaging period: one year, Maximum concentration: 8 micrograms per cubic metre
- Visibility-reducing particles – $PM_2$ and below: no NEPM standard or goal has yet been set.

**Indicator A11:** Comparison of ambient particle levels with National Environment Protection (Ambient Air Quality) Measure standards and goals ($PM_{10}$ and $PM_{2.5}$).

Both sizes of particulates are monitored at Caversham, South Lake, Duncraig (Figure A0.2), Bunbury and Busselton ($PM_{2.5}$ only). Exceedences of NEPM standards occur occasionally, but the standard allows up to five exceedences per year. As examples, levels of particulates $PM_{10}$ and $PM_{2.5}$ are shown for Bunbury and the Perth metropolitan suburb of Duncraig (Figures A3.1, A3.2, A3.3 and A3.4 respectively). Exceedences of NEPM standards have occurred frequently at both sites. The common cause of exceedences at Bunbury and other South West sites is smoke caused by bushfires (summer), bushfire hazard reduction burns (other times of the year), and domestic wood heaters. Particulates measured at the Duncraig site are mostly from traffic emissions, sea salt and wood heaters (especially during winter).

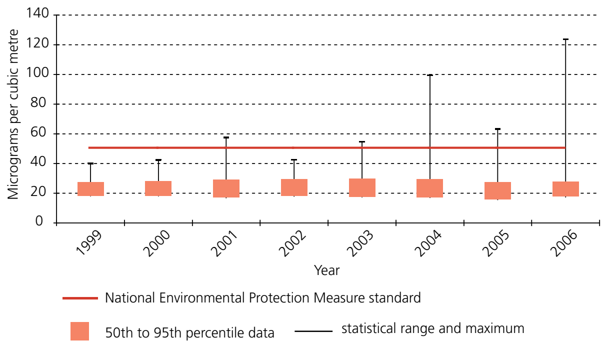



**Figure A3.1:** Ambient yearly range of $PM_{10}$ levels at Bunbury air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

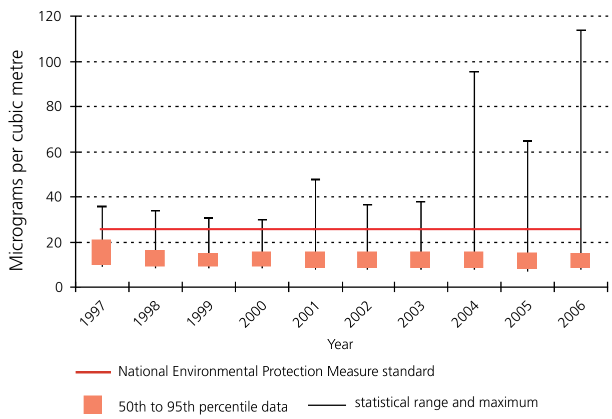



**Figure A3.2:** Ambient yearly range of $PM_{2.5}$ levels at Bunbury air quality monitoring station, compared with the advisory reporting standard for exposure.

Data source: Department of Environment and Conservation.

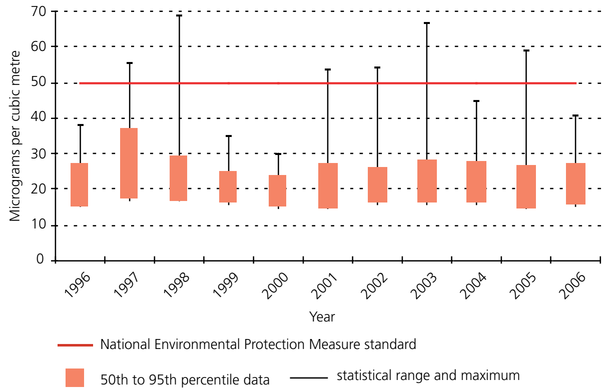



**Figure A3.3:** Ambient yearly range of $PM_{10}$ levels at Duncraig air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

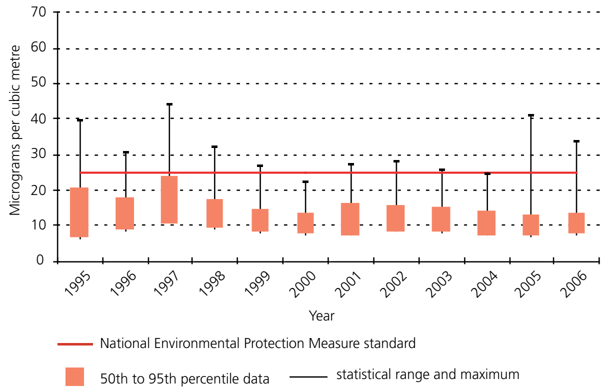



**Figure A3.4:** Ambient yearly range of $PM_{2.5}$ levels at Duncraig air quality monitoring station, compared with the advisory reporting standard for exposure.

Data source: Department of Environment and Conservation.

The *Air Quality in Perth: 1992–2002* (Department of Environmental Protection, 2003) study found that annual mean daily maximum 24-hour total suspended particulate concentrations at monitoring stations fell during the study period, ambient $PM_{10}$ did not change and $PM_{2.5}$ levels fluctuated. Visibility readings around Perth also fluctuated, with bushfire events, controlled burns and domestic wood combustion being major contributors to poor visibility.

Data from industry monitoring sites are also collected at some locations (Table A3.1). High particulate levels frequently occur in the Pilbara and Kimberley due to bushfires, but dust generated from wind erosion and mining activities is also significant. Port Hedland has traditionally had high loads of particulate matter due to past port management practices, planning decisions and the arid climate of the area. The *Pilbara Air Quality Study* (Department of Environment, 2004a) found that the concentration of particulates (as $PM_{10}$) at Boodarie (near Port Hedland) and Dampier was generally high. Exceedences of the NEPM standard were caused by 'background' sources such as dust storms and bushfires, but dust from ore handling facilities and other industry activities in the immediate vicinity of the town were dominant. The ratio of $PM_{10}$ to $PM_{2.5}$ particles is lower than that generally found in Perth, indicating that Pilbara air generally contains coarser particulate matter. Karratha is also well known for having high particulate levels. However, there is no current monitoring of particulate matter in the Pilbara or Kimberley regions.

**Table A3.1:** Summary of $PM_{10}$ exceedences of the Australian standard at sites outside the Department of Environment and Conservation monitoring network in Western Australia.

| Location | Measurement Period | Range of $PM_{10}$ exceedences per year (> 50 $\mu g/m^3$) | Average number of $PM_{10}$ exceedences per year (> 50 $\mu g/m^3$) | Type of monitoring equipment used |
|---|---|---|---|---|
| Port Hedland – Hospital[a] | 1996–2003 | 29–62 | 48.8 | Hi Vol |
| Port Hedland – Boodarie[a] | 1996–2001 | 0–22 | 8.5 | Hi Vol |
| Dampier Foreshore[d] | 1999–2000 | 3–18 | 10.5 | TEOM |
| Dampier Primary School[e] | 2002 | 13 | — | TEOM |
| Perth – Duncraig[b] | 1996–2004 | 0–4 | 0.9 | TEOM |
| Perth – South Lake[b] | 2000–2004 | 0–2 | 0.8 | TEOM |
| Bunbury[b] | 1999–2004 | 0–4 | 1 | TEOM |
| Collie East (Town)[c] | 1998–2003 | 0–5 | 2.2 | TEOM |
| Collie – Bluewaters (Rural)[c] | 2001–2003 | 0–1 | 0.7 | TEOM |

Data source and notes: (a) Department of Environment (2004a). The monitoring was for only 166 to 225 days per year at Boodarie (background site) and from 166 to 286 days at the hospital site. Therefore both will understate the actual number of exceedences per year. See Figure 4.3 on p. 10 of this reference. (b) Department of Environment (2005a). A Grieco (Department of Environment and Conservation, pers. comm.) confirmed that monitoring commenced in mid 1998, but only the two complete years have been used for the analysis. (c) Sinclair Knight Merz (2005). (d) Department of Environment (2005b). (e) Sinclair Knight Merz (2003).

## Pressures

**Indicator A12:** Level of particulate emissions.

Wood heaters are a cause of particulate matter in the Perth airshed especially in winter. The National Woodheater Audit Program (Department of the Environment and Heritage, 2004a) found that 58% of wood heaters failed to meet Australian and New Zealand standard (Standards Australia and Standards New Zealand, 1999) on particle emission limits, 55% had serious design faults that could affect performance and 72% had labelling faults that could affect emissions performance. In addition to faults in appliances, Todd (2003) found that incorrect operation of wood heaters was common, including not using wood correctly or allowing flues to becoming blocked or break down over time.

Comparison between summer and winter readings of particulates ($PM_{2.5}$ and $PM_{10}$) for the Perth suburb of Duncraig over time reveal the different types of particulates that make up the air column (including from wood heaters, dust and salt). Concentrations of the larger $PM_{10}$ particles peak in summer due to presence of dust and sea salt. Smaller $PM_{2.5}$ particles generally peak in winter, reflecting low background levels (due to rain washing particulates out of the airshed) but more frequent smoke events due to wood heater emissions.

The *Perth Airshed Inventory Update 1998–1999* (Department of Environmental Protection, 2002b), followed an earlier study in 1992–93 to contrast the estimated emissions for $PM_{10}$ from a range of sources (Figure A3.5). Burning vegetation (from bushfires or controlled burns) was considered in the area-based (or diffuse) sources and emission estimates but did not change between 1992–93 and 1998–99. In contrast emissions from motor vehicles, and industrial and commercial sources increased by 174% (Department of Environmental Protection, 2002b). The move towards direct-injection petrol engines and possibly diesel engines in passenger cars may have increased particulate emissions. Particulate emissions from industry have traditionally been very difficult to estimate accurately and any estimates for particulate matter are likely to be conservative (Department of Environmental Protection, 2002b). The large increase in $PM_{10}$ is most likely a result of the exclusion of brickworks as a source of emissions in the 1992–93 inventory (Department of Environmental Protection, 2002b). A change of methodology allowed $PM_{10}$ emissions from brickworks to be included in the 1998–99 inventory, and included many small and medium businesses that were not included in the previous inventory.

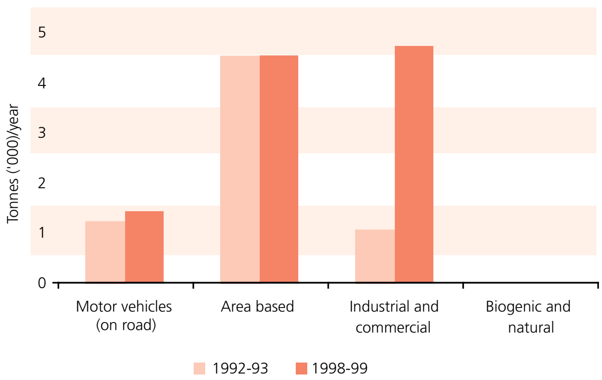



**Figure A3.5:** Change over time in estimated amounts and sources of particulate matter, as $PM_{10}$, in the Perth airshed.

Data source: Department of Environmental Protection (2002b).

Work on a third inventory of emissions into Perth's airshed is underway, however details are not yet available.

Estimates of particulate emission trends outside Perth are extremely limited. Significant sources of particulate matter in the North West, apart from local industry and mining, are dust storms and smoke from bushfires. Particulate levels can vary markedly from year-to-year depending on the condition of pastures and rainfall. A succession of dry years may lead to more land becoming susceptible to wind erosion, and severe tropical cyclones, heavy rainfall and flooding can scour areas, also leaving them susceptible to erosion. Bushfires (and resultant smoke) can also vary from year-to-year, depending on rainfall and vegetation growth, but are significant as they occur frequently and can burn for long periods of time.

## Current responses

National Environment Protection Measures: were established in 1998 by the National Environmental Protection Council to set uniform standards for ambient air quality. Amongst other pollutants, standards have been defined for $PM_{10}$ and an 'advisory standard' was implemented in 2003 for $PM_{2.5}$ (while further research about a suitable standard is undertaken).

High particulate levels in Perth city following a bushfire, January 2005 (M. Copeman)

Bushfires and prescribed burning: The *Perth Air Quality Management Plan* (Department of Environmental Protection, 2000a) includes a strategy for reducing emissions and particulates from bushfires and controlled burns in Perth and other areas of the South West. The Smoke Management Liaison Group includes representatives from the Department of Environment and Conservation and the Fire and Emergency Services Authority and meets to reduce the impact of planned burns on air quality and the community. In addition, the Bushfire Cooperative Research Centre and the Department of Environment and Conservation in conjunction with the Bureau of Meteorology have developed a smoke trajectory model to assist decision making regarding planned burning and to reduce the impact of smoke on particulate levels in Perth.

The Perth Airshed Inventory Updates: The Department of Environment and Conservation has contracted work on a third inventory of emissions into Perth's airshed. Two airshed inventories have already been completed in 1992-93 and 1998-99 (Department of Environmental Protection, 2002b).

*The Pilbara Air Quality Study:* was initiated in 1998 to gain an understanding of air quality, pollutant emissions, and the meteorology influencing transport and dispersion of air pollutants in the Pilbara coastal centres of Karratha–Dampier, Wickham–Cape Lambert and Port Hedland (Department of Environment, 2004a).

*Environmental Protection Authority Guidance Statement no. 18:* provides information on prevention of impacts on air quality from dust and smoke generated on land development sites, and advises proponents what the Environmental Protection Authority will consider when making an assessment of air quality impacts from land developments.

Community education: The AirWatch program operates in schools and uses school students to make observations and record data about weather and air quality with the intention of increasing awareness of air pollution issues.

TravelSmart: is a community based program that encourages people to use alternatives to travelling in their private car. TravelSmart forms part of the *Metropolitan Transport Strategy* and aims to reduce car-as-driver trips of Perth residents by 35% over the next 30 years.

The Halt the Haze trial: aimed to increase public understanding of the impact of wood heaters on air quality. It was later expanded to a heater replacement program in several local councils, but the program has since ceased.

Regulations and codes: The Domestic Solid Fuel Burning Appliances and Firewood Supply Regulations were introduced to prohibit the sale of firewood with high moisture content and painted, plastic coated or chemically treated wood. It also regulated the use of any domestic solid fuel heating appliance that does not comply with Australian Standards (Department of Environment, 2004b). The *Kwinana Environmental Protection Policy* sets total suspended particle standards and limits in the Kwinana region for industrial and residential areas.

## Implications

A number of health effects are associated with particulates depending on the nature of the pollutant. For example, prolonged exposure to smoke from bushfires can aggravate breathing problems (including coughing, wheezing, asthma and bronchitis), cause watery eyes, and may increase hospital admissions and reduce workplace productivity. Very fine particulates may enter the bloodstream and affect the cardiovascular system. The health effects may worsen if the fine particulates are associated with pollutants, which may cause allergic reactions and permanent lung damage, diseases and cancer in some susceptible individuals. Severe atmospheric particulate problems may cause coat vegetation and reduce photosynthetic ability, clog air conditioning systems, cover roads and buildings and adversely affect tourism potential in an area. Current responses are largely inadequate to deal with the particulate problem on a widespread scale. Without better management in future, health and environmental problems caused by particulates are likely to worsen.

**SUGGESTED RESPONSES**

2.13 Implement the *Perth Air Quality Management Plan*. Although the plan was released in 2000 and much progress made, many parts have yet to be implemented.

2.14 Develop and implement air quality management plans for regional areas. Management plans should be developed for problem regional areas using the *Perth Air Quality Management Plan* as a model.

2.4

# PHOTOCHEMICAL SMOG



INDICATIVE EXTENT OF ISSUE

## PRIORITY RATING: 3



### KEY FINDINGS

- Background levels of ozone and nitrogen dioxide (both precursors of photochemical smog) appear to be stable but are still of concern.
- Ozone levels exceeded the national health standard limit 13 times in Perth between 1998 and 2006.

## Description

Photochemical smog is considered to be a problem associated with modern industrialised cities. It is characterised by the reaction of ozone ($O_3$), oxides of nitrogen ($NO_x$) and reactive organic compounds (also known as volatile organic compounds) in sunlight and at high temperatures. A mixture of these chemicals forms a layer of visible, brown or white haze in the sky (Government of Western Australia, 1998). Perth is most susceptible to smog, especially from late spring through to early autumn, when sunlight is abundant, temperatures are hot, and oscillating wind patterns mean that the city's air is recirculated. In contrast, visible haze at other times of the year is likely to be caused by particulates (see '*Particulates*').

Changes in precursor pollutants can influence the formation of photochemical smog. Sources of the precursor pollutants include motor vehicles (for both oxides of nitrogen and reactive organic compounds), combustion processes (oxides of nitrogen and ozone), and refining, petrochemical and solvent based industries (reactive organic compounds). The concentration of ozone in a polluted atmosphere is typically used as an indicator of the total amount of photochemical smog, as it usually makes up about 85% of the total photochemical smog concentration. Photochemical smog can also be transported over large distances, with weather patterns principally influencing its dispersal. The absence of vertical air mixing, as occurs with temperature inversion layers close to Earth, also prevents its dispersion. Ozone as a pollutant in the troposphere (close to the surface of the Earth) should not be confused with the hole in the ozone layer (see '*Stratospheric ozone depletion*').

Photochemical smog can cause a number of human health issues, the most common being respiratory problems. It also contains peroxyacetyl nitrate, a compound that causes the eyes to water profusely. Hospitalization rates often rise during incidents of photochemical smog, and mortality of people aged 65 and older from cardio-vascular problems increases with exposure to ozone. The health of native vegetation and crop productivity may also be detrimentally affected.

## Objectives

- To protect health, amenity and the environment by ensuring that the levels of photochemical smog in the air meet the relevant standards.

## Condition

There are standards in place for photochemical smog via the *National Environment Protection (Ambient Air Quality) Measure* (NEPM) to ensure community health is not compromised. They include:

*Photochemical oxidants (as ozone):* Averaging period: One hour; Maximum concentration: 0.10 parts per million;
Goal by 2008 (maximum exceedences): one day per year
Averaging period: Four hours; Maximum concentration: 0.08 parts per million;
Goal by 2008 (maximum exceedences): one day per year

*Nitrogen dioxide:* Averaging period: one hour; Maximum concentration: 0.12 parts per million;
Goal by 2008 (maximum exceedences): 1 day per year
Averaging period: one year; Maximum concentration: 0.03 parts per million;
Goal by 2008 (maximum exceedences): none

It is worth noting that standards for health are measured as nitrogen dioxide, whereas environmental standards emissions are measured as total oxides of nitrogen.

**Indicator A13: Ambient ozone concentration compared with National Environment Protection (Ambient Air Quality) Measure standard and goal.**

Perth's air quality is of a high standard compared to other Australian and international cities, but photochemical smog is regularly experienced over the city in summer. When compared to the NEPM standard, there has been a trend of decreasing ozone concentrations in the maximum range of one hour averages at Caversham (Figures A4.1) and Rockingham (Figure A4.2). Ozone concentrations exceeding the standard are very infrequent at South Lake (Figure A4.3). Caversham is an eastern inland Perth suburb, Rockingham is a southern coastal suburb, and South Lake is a southern inland suburb.

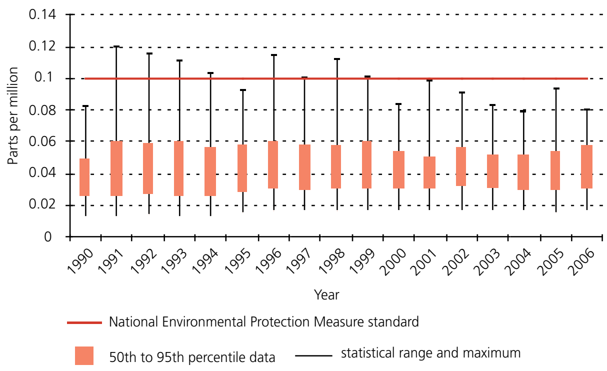



**Figure A4.1:** Ambient yearly range of ozone levels (one hour average) at Caversham air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

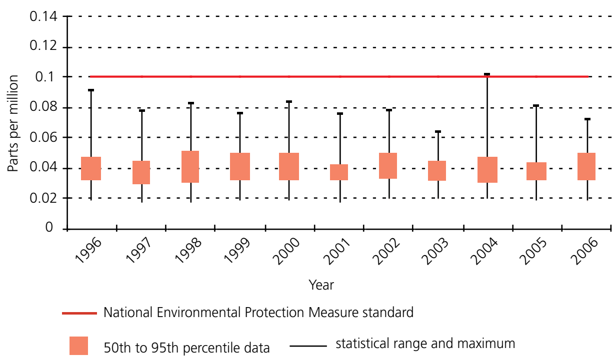



**Figure A4.2:** Ambient yearly range of ozone levels (one hour average) at Rockingham air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

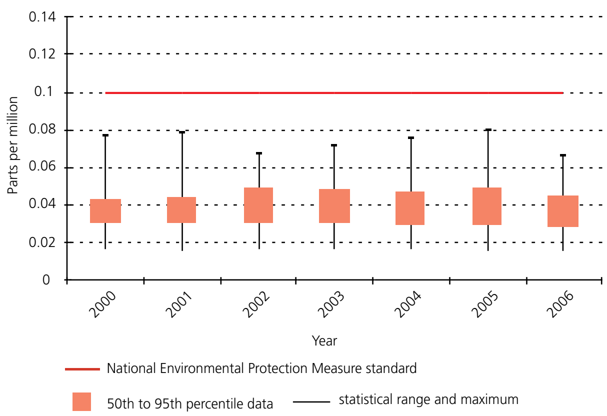



**Figure A4.3:** Ambient yearly range of ozone levels (one hour average) at South Lake air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

**Indicator A14:** Number of exceedences of the ozone National Environment Protection (Ambient Air Quality) Measure.

There were 13 exceedences of the ozone NEPM standard for metropolitan Perth from January 1998 to December 2006 and none were recorded in other monitored areas. The ambient air quality protection goal of no more than one exceedence per site per year would have allowed four exceedences over this period. While of concern, this is not high compared to other locations in Australia. For example, the Sydney, Newcastle and the Hunter Valley region of NSW had 392 exceedences of the standard at air quality monitoring sites between July 1998 and June 2006 (NSW Environment Protection Authority 1998-2006). All exceedences in Perth have occurred in January and February, due to the high summer temperatures required for smog to form. The number of exceedences of the standard for ozone has generally decreased over time, although some sites had more in 2004 than in previous years.

Ozone is also measured at Quinns Rock, Rolling Green and Swanbourne sites, where no exceedences of the ambient air quality standard have been recorded. The behaviour of ozone in the airshed contributes to hotspots in concentration, which can move according to meteorological conditions, and consequently these hotspots are not necessarily picked up by existing monitoring stations.

**Indicator A15:** Background concentration of ozone in the Perth airshed.

Even though the total number of ozone exceedences of the NEPM standard is not high (Figures A4.1, A4.2 and A4.3), a concerning trend is the increase in background ozone concentrations. A rise in background concentration means that Perth airshed is gradually moving closer to the NEPM standard, and less of a daily increase is required to exceed the standard (Figure A4.4). For example, the number of days showing moderate levels of ozone (0.03 ppm to 0.07 ppm) increased between 1992 and 2002 at Caversham – but still remains below the NEPM standard. A levelling out was seen between 2003 and 2005, but may have started rising again in 2006 (Figure A4.4).

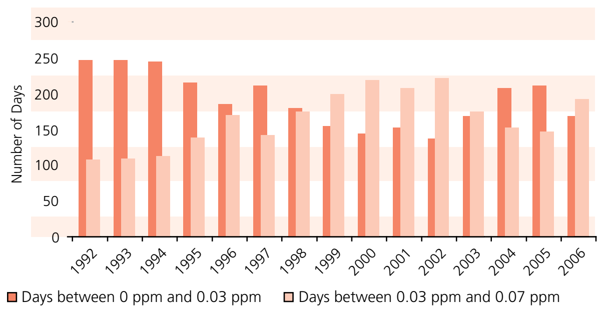



**Figure A4.4:** Number of days at Caversham air quality monitoring station where the daily maximum one-hour averaged ozone concentration was lower or higher (but below the National Environment (Ambient Air Quality) Protection Measure exceedence limit), 1992–2006.

Data source: Department of Environment and Conservation. Analysis: Department of Environment and Conservation. Note: An ozone concentration of 0 ppm to 0.03 ppm is considered low. A concentration between 0.03 ppm to 0.07 ppm is higher, but still below the NEPM exceedence limit.

**Indicator A16:** Number of exceedences of the nitrogen dioxide National Environment Protection (Ambient Air Quality) Measure.

Nitrogen dioxide levels in Perth are generally low and below the NEPM standard at all monitoring sites. Ambient nitrogen dioxide levels for most suburban sites are low (i.e. Caversham, Hope Valley, North Rockingham, Quinns Rock, Rolling Green, South Lake and Swanbourne, Duncraig) and have remained stable over time (for example, see Figure A4.5). In contrast, nitrogen dioxide levels at the Queens Building monitoring site in Perth's central business district shows some exceedences of the NEPM standard, but a general decreasing trend is observed (Figure A4.6).

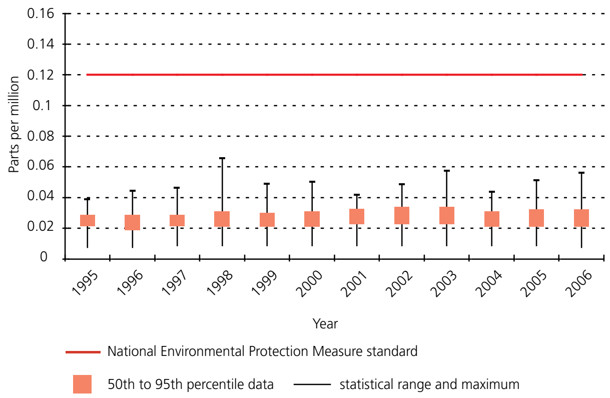



**Figure A4.5:** Ambient yearly range of nitrogen dioxide levels at Duncraig air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

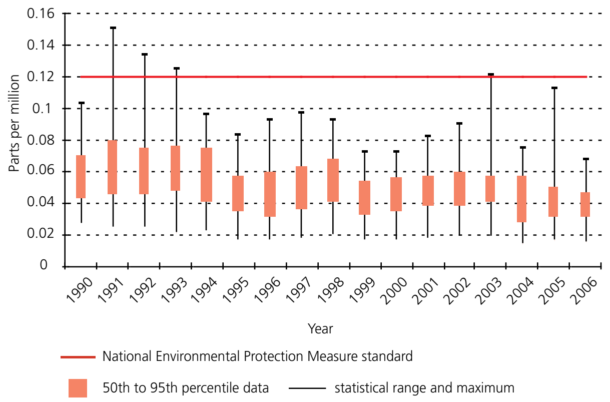



**Figure A4.6:** Ambient yearly range of nitrogen dioxide levels at Queens Building (Perth central business district) air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

**Indicator A17:** Background concentration of nitrogen dioxide.

The *Air Quality in Perth: 1992–2002* study (Department of Environmental Protection, 2003) found there had been no improvement in ambient nitrogen dioxide concentrations over the study period. Slight trends to increasing daily maximum concentrations (based on one-hour averages) were recorded at some monitoring sites. Emissions from area-based sources (e.g. commercial shipping and off-road vehicles), motor vehicles and industry have significantly increased since 1992. Increased emissions from motor vehicles are a result of increase in the number of vehicles and age of the vehicle fleet (average of 11 years) in Perth (Australian Bureau of Statistics, 1999, cited in Department of Environmental Protection, 2003).

Monitoring for nitrogen oxides has also been conducted in Dampier and Karratha for the *Pilbara Air Quality Study* (Department of Environment, 2004a), Port Hedland (BHP Billiton, 2005) and Wagerup in the South West (Alcoa Australia, 2005). Past monitoring has shown low nitrogen dioxide levels in these regions which are below the NEPM standard. However, monitoring is no longer conducted at the Pilbara study sites, and data from industry sites is not readily available, so it is not possible to be certain the standard has been met in these areas in recent years.

## Pressures

**Indicator A18:** Emissions of precursors to photochemical smog.

Oxides of nitrogen and reactive organic compounds are major precursors for the formation of photochemical smog.

Oxides of nitrogen are released from motor vehicles, and other fuel combustion and point sources. Motor vehicles and industrial emissions contribute 42% and 37%, respectively, to the oxides of nitrogen load in the Perth airshed (Department of Environmental Protection, 2002a).

Estimated oxides of nitrogen emissions in the Perth airshed have increased between 1992–93 and 1998–99 (Figure A4.7; Department of Environmental Protection, 2002b). Increases were recorded for all sources, except biogenic and natural sources which remained stable. Increases occurred in the number of cars on the road, the number of kilometres being travelled, and a greater number and/or volume of industrial and commercial emissions. The significant increase in area-based emissions results from off-road vehicles (i.e. trains, aircraft) and ships, and a change in methodology to address underestimates in earlier figures (Department of Environmental Protection, 2002b).

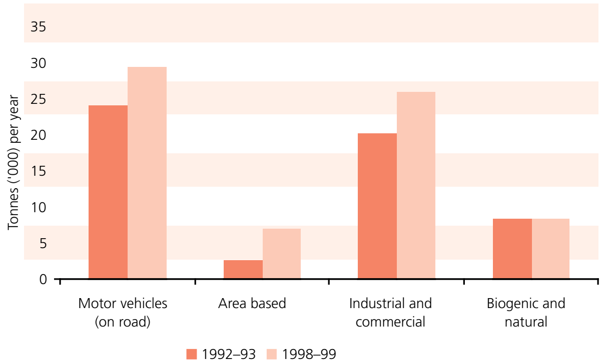



**Figure A4.7:** Change over time in estimated amount and source of emissions of oxides of nitrogen in the Perth airshed.

Data source: Department of Environmental Protection (2002b).

Reactive organic compounds were examined in the *Perth Airshed Inventory Update 1998–1999* (Department of Environmental Protection, 2002b). Total estimated emissions reduced between 1992–93 and 1998–99, and the major source changed from motor vehicles to area-based sources (Figure A4.8). Reduced motor vehicle emissions were likely to be a result of better emission controls (associated with engine design improvements) and a significant decrease in industrial emissions (primarily the result of improvement work undertaken at the BP Kwinana refinery).

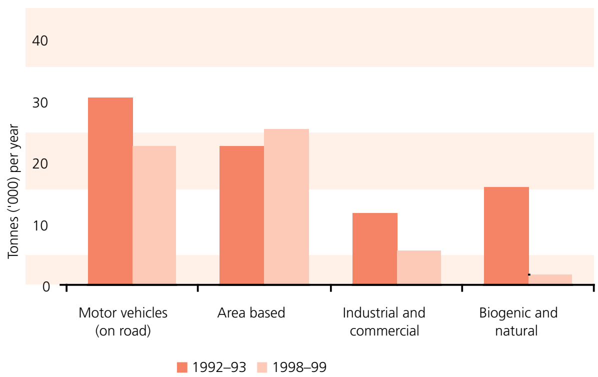



**Figure A4.8:** Change over time in estimated amount and source of reactive organic compound emissions in the Perth airshed.

Data source: Department of Environmental Protection (2002b).

Work on a third inventory of emissions into Perth's airshed is underway, however details are not yet available.

## Current responses

National Environment Protection Measures: were established in 1998 by the National Environment Protection Council to set uniform standards for ambient air quality. Amongst other pollutants, standards have been defined for ozone and nitrogen dioxide as precursors to photochemical smog. Recent reviews of the standards by the Environmental Protection and Heritage Council has shown that health effects related to ozone exposure occur in cities with low atmospheric levels of ozone as well as in cities with high levels, such as Los Angeles (Environment Protection and Heritage Council, 2005a). There is no evidence from epidemiological studies of a threshold level for adverse health effects; if there is a threshold it is below background ozone levels (Environment Protection and Heritage Council, 2005b). There is 100-fold variability in response to ozone across the Australian population. Around 10% of people are particularly sensitive, but are not necessarily asthmatic or prone to respiratory illness. Lowering the standard from 0.10 ppm to 0.08 ppm (as has been suggested by some groups) would not necessarily protect against long-term exposure effects but the full review has not yet been completed.

TravelSmart: is a community based program that encourages people to use alternatives to travelling in their private car. TravelSmart forms part of the *Metropolitan Transport Strategy* and aims to reduce car-as-driver trips of Perth residents by 35% over the next 30 years.

Conversion of vehicles to gas: Vehicle conversion to gas has a lot of potential to reduce emissions and pollution to urban airsheds. Since 2000, the Department of Planning and Infrastructure has provided a subsidy for more than 11 000 vehicle owners wishing to convert petrol cars to liquid petroleum gas or to buy factory made gas-run vehicles (Department for Planning and Infrastructure, 2005). In 2006, the subsidy was expanded by the Australian Government.

Urban planning: Although the *Network City* plan for Perth and the Peel region focuses on managing growth of the urban area, making fuller use of urban land, nurturing the environment and encouraging the use of public transport, it does have the opportunity to plan for reduced car use and consequently improve air quality (Western Australian Planning Commission & Department for Planning and Infrastructure, 2004). However, with present urban growth rates, traffic concentration and commuting distances in private vehicles continues to be of concern.

*Environmental Protection Authority Guidance Statement no. 15:* The EPA has developed a guidance statement for emissions of $NO_x$ for the installation of new gas turbines (Environmental Protection Authority, 2000). This is intended to promote installation of gas turbines that achieve Australian Environment Council and National Health and Medical Research Council guidelines (which were the predecessors of NEPM standards).

## Implications

Photochemical smog can cause a number of population health problems. Ozone and oxides of nitrogen are especially harmful for senior citizens, children, and people with heart and lung conditions such as emphysema, bronchitis, and asthma. They can irritate breathing passages (nose and throat), irritate the eyes, cause a choking sensation and shortness of breath, wheezing and coughing, and may decrease the lung's working capacity. It is known to interfere with the body's ability to fight infection, increasing susceptibility to illness. Hospital admissions and respiratory deaths increase during severe smog episodes. Native vegetation, horticultural and agricultural crops can show reduced growth and visible injury with prolonged ozone exposure, even at low concentration. Concentrations of ozone and reactive organic compounds are likely to increase into the future with increasing population, rapid economic growth, and increasing dependence on vehicles.

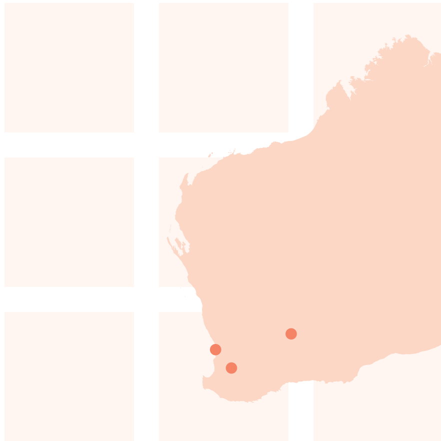
**SUGGESTED RESPONSES**

2.15 Implement the *Perth Air Quality Management Plan*. Although the plan was released in 2000 and much progress made, many parts have yet to be implemented.

2.16 Develop and implement an air quality management plan for photochemical smog in susceptible regional areas, using the *Perth Air Quality Management Plan* as a model.

Car exhaust contributes to the formation of photochemical smog over Perth (Department of Environment and Conservation)

# 2.5 SULFUR DIOXIDE



INDICATIVE EXTENT OF ISSUE

## PRIORITY RATING: 5

**KEY FINDINGS**

- Sulfur dioxide emissions have dramatically improved in Kalgoorlie and Kwinana since the early 1990s and are now meeting national emissions standards.
- The creation of additional coal-fired power stations has the potential to increase sulfur dioxide concentrations in their vicinity.

## Description

Sulfur dioxide ($SO_2$) is a colourless gas with a pungent, suffocating odour. It can be a significant air pollutant in WA, particularly around industrial areas such as Kalgoorlie, Kwinana and Collie. It is produced by the combustion of fuels like coal, oil and diesel fuel, and in smelting of metallic sulfide ores. The sulfur content of a fuel can be reduced by refining, so that less sulfur dioxide is emitted when the fuel is burned. Sulfur dioxide oxidises in air to sulfite (SO3) which, when dissolved in atmospheric water droplets, forms sulfuric acid and potentially acid rain. Acid rain issues have not been researched in WA as the problem has not been recorded as it has in parts of America and Europe. This process is accelerated in the presence of particulates, assisting with the condensation of water droplets (see '*Particulates*'). Industry uses a similar chemical process to generate sulfuric acid.

Sulfur dioxide is a dangerous air pollutant because of its toxicity and corrosive properties. Sulfur dioxide is a strong irritant to the respiratory tract, causing breathing problems in people with sensitive airways. In addition, sulfur dioxide can corrode buildings and other infrastructure, and damage aquatic systems and vegetation, including agricultural crops.

## Objectives

- To protect health, amenity and the environment by ensuring that levels of sulfur dioxide in the air meet the relevant standards.

## Condition

There are standards in place for sulfur dioxide via the *National Environment Protection (Ambient Air Quality) Measure* (NEPM) to ensure community health is not compromised. They include:

*Sulfur dioxide:*

Averaging period: one hour; Maximum concentration: 0.20 ppm;

Goal by 2008 (maximum exceedences): one day per year
Averaging period: one day; Maximum concentration: 0.08 ppm;

Goal by 2008 (maximum exceedences): one day per year
Averaging period: one year; Maximum concentration: 0.02 ppm;

Goal by 2008 (maximum exceedences): none

There is also a State policy (the *Environmental Protection (Goldfields residential areas) (sulfur dioxide) Policy 2003)* that specifies emissions standards for the Goldfields, including:

*Sulfur dioxide:*

Averaging period: one day;
Maximum concentration: 0.2 ppm.

Goal by 2008: the current number of allowable exceedence days is three per year. The goal is to progressively reduce the number of exceedences to meet the NEPM goal (one day per year) in 2008.

**Indicator A19:** Ambient levels of sulfur dioxide compared to National Environment Protection (Ambient Air Quality) Measure standards and goals.

Kalgoorlie–Boulder, Kwinana and Collie are the major settlements experiencing sulfur dioxide issues. Kalgoorlie–Boulder has had a dramatic improvement in sulfur dioxide levels over the last decade (Figure A5.1), although the environment protection policy standards are occasionally exceeded. Since 1998, the NEPM goal of no more than one exceedence per year has been met. At Kwinana, sulfur dioxide emissions have not exceeded the standard since 1993 (Figure A5.2). Collie has remained below the standard since monitoring commenced in 1995, although a cautious view needs to be taken of these results because monitoring at industry sites suggested that the location may not be representative of the local airshed (Figure A5.3). Emission reductions at both Kalgoorlie and Kwinana have been achieved due to improved regulation and best practice industry technology. Sulfur dioxide is also measured at Rockingham and Wattleup, but no exceedences of the standard have been recorded at these sites.

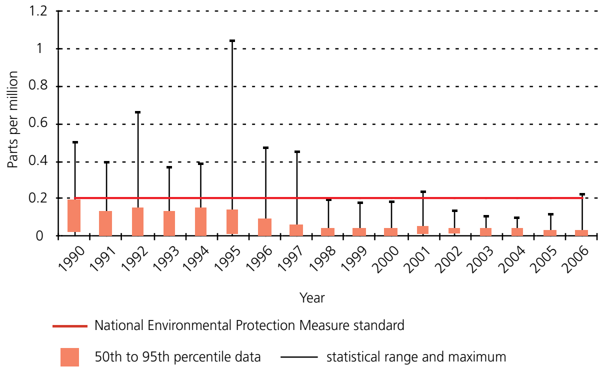



**Figure A5.1:** Ambient yearly range of sulfur dioxide levels (one-hour average) at Kalgoorlie Regional Hospital air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

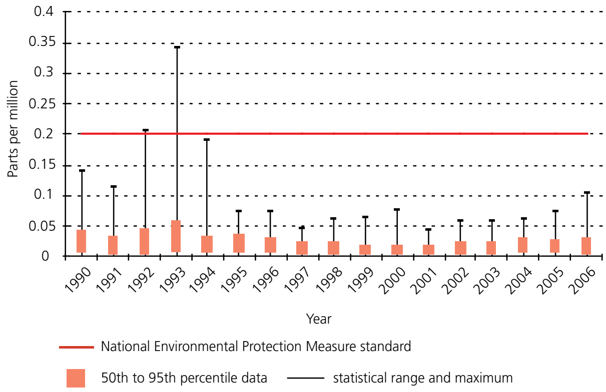



**Figure A5.2:** Ambient yearly range of sulfur dioxide levels (one-hour average) at Hope Valley air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

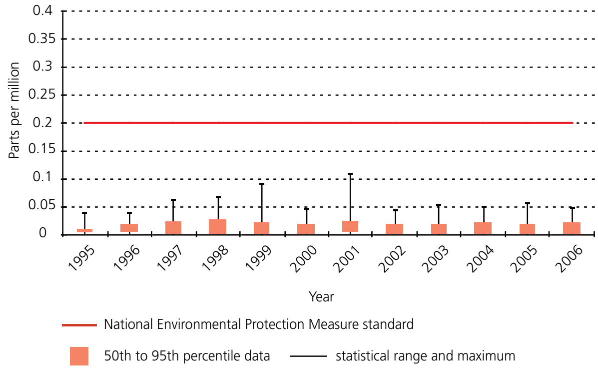



**Figure A5.3:** Ambient yearly range of sulfur dioxide levels (one-hour average) at Collie air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

**Table A5.1:** Exceedences of National Environment Protection (Ambient Air Quality) Measure standard for sulfur dioxide in Western Australia, 1998–2004.

| Location | Year | Month |
|---|---|---|
| Kurrawang | 1999 | January |
| Kurrawang | 2000 | March |
| Kalgoorlie Airport | 2000 | April |
| Coolgardie | 2000 | June |
| Hannans Golf Course | 2000 | August |
| Kalgoorlie Airport | 2000 | August |
| Kalgoorlie Council Yard | 2000 | August |
| Kalgoorlie Airport | 2000 | November |
| Kalgoorlie Council Yard | 2000 | November |
| Boulder Shire Yard | 2001 | November |
| Metals Exploration site | 2001 | May |
| Kalgoorlie Regional Hospital | 2001 | December |

Data source: Department of Environment [ver.2005]. Note: all locations are in Kalgoorlie and surrounding areas.

Kwinana industrial area (Department of Environment and Conservation)

Twelve exceedences of the NEPM standard for sulfur dioxide occurred between 1998 and 2004 (Table A5.1). With the exception of the Kalgoorlie Regional Hospital exceedence, most were recorded in the Kalgoorlie-Boulder area at industry sites. There were no exceedences recorded at monitoring sites in the Perth area (Figure A0.1).

## Pressures

**Indicator A20:** Level of sulfur dioxide emissions in Western Australia.

Ambient sulfur dioxide levels around Kalgoorlie have fallen following the installation of scrubbing equipment at the largest industrial source (metal smelters), and are expected to be successfully controlled into the future. However, National Pollutant Inventory estimates of emissions of sulfur dioxide across the State have generally been increasing (Figure A5.4) since 1999–2000 (emissions data prior to this are unreliable). However, it should be noted that many more companies and facilities reported their emissions in later years than did in earlier years, which may account for the overall increase (186 facilities from 30 industry sources in 1999-2000 compared to 279 facilities from 40 industry sources in 2005-06) (Department of the Environment and Water Resources, 2007).

Although there has been a very significant improvement in $SO_2$ levels around Kwinana, vigilance needs to be maintained because health effects can be seen at concentrations less than NEPM levels. There are now considerable pressures due to expansion of existing industries, the lack of available land for more industry and the construction of new homes in the buffer zone.

The levels of sulfur dioxide at Collie are under comparatively less pressure from emissions, but future construction of coal-fired power stations is likely to result in it becoming more of an air quality issue.

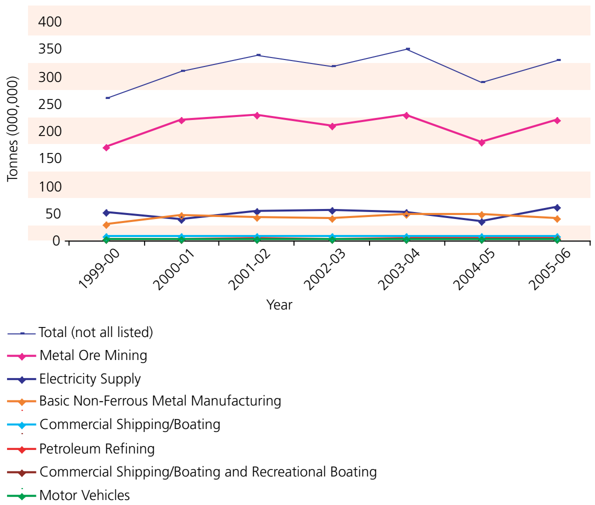



**Figure A5.4:** Estimated sulfur dioxide emissions in Western Australia from various sources.

Data source: Department of the Environment and Water Resources - National Pollutant Inventory sulfur dioxide Western Australia [ver. 2007].

The *Air Quality in Perth: 1992–2002* study (Department of Environmental Protection, 2003) found ambient sulfur dioxide levels were negligible in the Perth airshed, and had decreased from industrial sources. The gradual shift in energy sources from coal to natural gas, tighter sulfur dioxide controls and installation of sulfur recovery units at Kwinana industries are thought to have contributed to the emission decrease for Perth (Department of Environmental Protection, 2003).

## Current responses

Environmental protection policies: were established to provide regulatory standards and limits for sulfur dioxide levels for Kwinana (December 1999) and Kalgoorlie (March 2003). It should be noted that although both Kalgoorlie and Kwinana have policies in place, they have a different purpose in each location. The focus in Kwinana is controlling industrial emissions, while at Kalgoorlie it has been to limit emissions when meteorological conditions are likely to affect the local community. There has been concern about short periods of exposure to high levels of sulfur dioxide, and a review is underway to assess the practicability of introducing a 10-minute standard: currently the shortest averaging period is one hour (National Environment Protection Council, 2004b).

*Environmental Protection (Diesel and Petrol) Regulations 1999:* were introduced as a way to improve fuel quality, and therefore emissions, from existing vehicles. The regulations aim to phase out leaded petrol, limit emissions of evaporative hydrocarbons from vehicles, reduce sulfur content of petrol and diesel to improve performance of three-way catalytic converters, and other initiatives to reduce environmental impacts.

National Pollutant Inventory: The National Environment Protection (National Pollutant Inventory) Measure defines substances for which companies and governments need to report emissions. This provided the framework for the development and establishment of an internet database designed to provide publicly available information on the types and amounts of certain chemicals being emitted to the air, land, and water (Environment Protection and Heritage Council, 2006).

## Implications

The most common health symptoms resulting from inhalation of sulfur dioxide are coughing, wheezing and shortness of breath. Some people experience a burning sensation in their airways. Asthmatics are most sensitive to sulfur dioxide, usually suffering a sharp short-term decrease in lung function, but repeated exposure does not seem to worsen symptoms (Department of Environmental Protection, 2000a). In addition to human health consequences, sulfur dioxide can cause corrosive damage to buildings and other infrastructure, aquatic systems and vegetation, including crops (Department of Environment, 2003a). Australian studies indicate that crop yields can be affected by prolonged exposure to 0.05 ppm and greater concentrations, while trees suffer leaf damage at 0.08 ppm (Department of Environmental Protection, 2000a). Sulfur dioxide is known to go into solution and form acid rain in parts of Europe, Asia and America, but this has not been researched in WA.

### SUGGESTED RESPONSES

2.17 Implement the *Perth Air Quality Management Plan* and other sulfur dioxide regulations and policies: significant progress has been made with lowering emissions in problem areas, but further work is still required.

2.18 Develop and implement an air quality management plan for regional areas where significant sources of sulfur dioxide emissions exist or are planned.

# EMERGING ISSUE – OXIDES OF NITROGEN

Oxides of nitrogen is classed as an emerging issue due to its potential to cause significant impacts on human health and the atmosphere, however it is currently well below NEPM standards in areas where it is monitored. Subsequent State of the Environment reports may include it as a full issue. Some data is included in '*Photochemical smog*' as it is a significant precursor for this issue.

'Oxides of nitrogen' ($NO_x$) is a broad term used to include nitric oxide (NO), nitrogen dioxide ($NO_2$), nitrous oxide ($N_2O$), or mixtures of these compounds. They are all precursors of photochemical smog (see '*Photochemical smog*'). Nitric oxide is a colourless and odourless gas that oxidises in the atmosphere to form nitrogen dioxide, an odorous, brown, acidic and highly corrosive gas that can affect human health and the wider environment. Nitrogen dioxide is a lung irritant and may lower immunity to respiratory infections. Exposure to high levels of nitrogen dioxide causes severe lung injury and has been demonstrated to increase the effects of exposure to pollutants such as ozone, sulfur dioxide and inhalable particulates (National Environment Protection Council, 1998). At high concentrations, nitrogen dioxide can reduce plant growth and cause visible injury, including damage to foliage that can inhibit crop yield. It can also fade and discolour fabrics, react with surfaces and furnishings and reduce visibility (Environmental Protection Agency & Queensland Parks and Wildlife, 2003). Nitrous oxide is a colourless non-flammable gas with a pleasant, slightly sweet odour. It has an anaesthetic effect (commonly known as laughing gas), but is also a potent greenhouse gas.

Oxides of nitrogen are emitted by internal combustion engines, industrial and commercial boilers in power generation and from industrial combustion processes, with motor vehicle emissions being the major source in urban areas. Natural sources of nitrogen oxides are from lightning and oxidation of ammonia, but these constitute a very small proportion of overall atmospheric concentrations. Indoor sources of nitrogen dioxide include unflued gas stoves and heaters and other combustion devices.

Standards are in place for nitrogen dioxide via the *National Environment Protection (Ambient Air Quality) Measure* (NEPM) to ensure community health is not compromised. They include:

*Nitrogen dioxide:* Averaging period: one hour; Maximum concentration: 0.12 parts per million;

Goal by 2008 (maximum exceedences): one day per year
Averaging period: one year; Maximum concentration: 0.03 parts per million;
Goal by 2008 (maximum exceedences): none

Standards for health are measured as nitrogen dioxide, whereas standards for environmental emissions are measured as total oxides of nitrogen.

Nitrogen dioxide and other oxides of nitrogen are generally low in WA and below the NEPM standards. The *Air Quality in Perth: 1992–2002* study (Department of Environmental Protection, 2003) found there had been no improvement in ambient nitrogen dioxide concentrations over the study period. Slight trends to increasing daily maximum concentrations (based on one-hour averages) were recorded at some monitoring sites. Emissions from area-based sources (e.g. commercial shipping and off-road vehicles), motor vehicles and industry have significantly increased since 1992. Increased emissions from motor vehicles are a result of increase in the number of vehicles and age of the vehicle fleet (average of 11 years) in Perth (Australian Bureau of Statistics, 1999, cited in Department of Environmental Protection, 2003).

Monitoring for nitrogen oxides has also been conducted at Dampier and Karratha for the *Pilbara Air Quality Study* (Department of Environment, 2004a), Port Hedland (BHP Billiton, 2005) and Wagerup in the South West (Alcoa Australia, 2005). Past monitoring has shown low nitrogen dioxide levels in these regions, below the NEPM standard. However, monitoring is no longer conducted at the Pilbara study sites, and data from industry sites is not readily available, so it is not possible to be certain the standard has been met in these areas in recent years.

Although design changes to vehicles and higher fuel standards have been implemented in WA to reduce nitrogen oxides, it is likely that population growth will result in more vehicles and therefore more nitrogen oxide pollution in Perth and regional centres. Changes to industrial processes have incorporated low nitrogen oxide emission burners in new installations, and the technologies are now well accepted by industry. Generally, greater reliance on natural gas fired power generation may have the adverse effect of increasing emissions of nitrogen oxides, but this has to be balanced against other environmental benefits.

Design changes to car engines have reduced emissions of oxides of nitrogen since the 1970s (Department of Environment and Conservation)

# EMERGING ISSUE – INDOOR AIR

Indoor air is classed as an emerging issue due to its potential to cause significant impacts to human health, however there is currently inadequate information to report more fully on this issue.

Indoor air refers to air inside residential dwellings and vehicles. It does not include workplaces or occupational-related indoor air quality. Indoor air quality is significant as some people may spend 90% or more of their time indoors, and it is generally accepted that poor indoor air quality can result in health problems (Woodcock & Custovic, 1998; Scarborough, 2004). Unfortunately, impacts of indoor air quality on heath have not been investigated systematically in Australia.

Increasingly, buildings are becoming more sealed from the external environment, and this can lead to pollutants from indoor sources being found at higher concentrations in buildings that are not well ventilated. For example, office equipment such as photocopiers and printers has been shown to emit respirable particulates, ozone and a range of reactive organic compounds (Brown, 1996). In addition, more humid or temperature controlled environments inside buildings provide ideal conditions for spread of mould or mildew (especially in bathrooms). Fungi can be toxic to humans and pets, and result in breathing difficulties, dizziness, headaches and recurrent infections (Nelson, 2001). Substandard or old buildings can develop problems with rising damp, begin to decay, contain materials such as asbestos or lead, or allow entry of pests and vermin, all of which can lead to poor indoor air quality.

The use of gas stoves, unflued gas heaters and wood heaters can contribute a large percentage of indoor pollutants, including nitrogen dioxide and carbon dioxide. A national audit of wood heaters showed that many in use did not comply with Australian standards (Environment Australia, 2002b) and many were being operated incorrectly (Todd, 2003). The audit found more than 120 gas and aerosol species in homes, comprising various air pollutants (Environment Australia, 2002b). Environmental tobacco smoke is considered one of the main contributors to poor indoor air quality, releasing about 4000 chemicals, including carbon monoxide, nicotine, formaldehyde, ammonia and at least 43 other chemicals known to be human carcinogens (QuitWA, 2005).

Reactive organic compounds are irritants to the human respiratory tract and can invoke allergic reactions. They are found in solvents, floor adhesives, paints, cleaning products, furnishings, polishes and room fresheners. A relationship has been observed between children presenting to hospitals with asthma and exposure to elevated reactive organic compounds, such as benzene, ethylbenzene and toluene (Rumchev et al., 2004). Formaldehyde is found in many furnishings, glues and building materials, and can irritate eyes and may cause respiratory problems. Other indoor pollutants such as carbon monoxide, asbestos, pesticides, radon and lead have received limited study of their relationship to human health, but are generally present in very low concentrations indoors.

Biological contaminants such as moulds, dust mites, insect faeces, pollen, viruses, bacteria and protozoa are known to have allergenic or pathogenic effects on some people. Occurrence and health effects of some organisms are well-known (e.g. dust mites, and the bacterium *Legionella*) but there has been little investigation of the impact of other microbial contaminants on indoor air quality in Australia (Environment Australia, 2001b). Some diseases or illnesses are closely related to the indoor environment. 'Sick building syndrome' occurs when occupants experience acute health effects and discomfort that appears to be linked to time spent in a building, but where no specific illness or cause can be identified (United States Environmental Protection Agency, 1991). 'Building related illness' describes symptoms of a diagnosable illness which is identified and can be attributed directly to indoor air contaminants (United States Environmental Protection Agency, 1991). Legionnaires' disease is a serious (and sometimes fatal) type of pneumonia caused by bacteria of the genus *Legionella*. It occurs naturally in soil and water but can become concentrated in artificial environments such as showers, spas, fountains, cooling towers associated with air conditioning and industrial cooling processes, and potting mixes (State Government of Victoria, 2004).

Poor indoor air quality has significant implications for human health. This may present as physical or psychological symptoms that are very individual, complex and often poorly defined. Pollutants such as sulfur dioxide, nitrogen dioxide, ozone, inhalable particulates, and reactive organic compounds can affect lung growth. In addition, they may also cause respiratory problems and lower the immune system (Department of Environmental Protection, 2000a). Occupants of buildings with poor indoor air quality can suffer from severe effects such as asthma, allergic responses, cancer risk and illnesses or have mild and generally non-specific symptoms. Some health effects may show up years after exposure, or only after long or repeated periods of exposure, and thus can be characterised as long-term health effects. These can be severely debilitating or fatal, include respiratory diseases and cancer, and are associated with indoor air pollutants such as pathogens, radon, asbestos and environmental tobacco smoke.

**Old, inefficient wood heaters can contribute to poor indoor air quality and high particulate loads in some areas. There have been efforts by the State Government to buy and recycle them (Department of Environment and Conservation).**

## EMERGING ISSUE – AIR TOXICS

Air toxics are classed as an emerging issue due to its potential to cause significant impacts to human health, however there is currently inadequate information to report more fully on this issue.

Air toxics are gaseous, aerosol or particulate pollutants that are present in the air in low concentrations and have toxicity or persistence that is hazardous to human, plant or animal life (National Environment Protection Council, 2005). The term 'air toxics' includes a very wide variety of chemicals and compounds. While air toxics can be released from natural sources such as bushfires, the major emission sources are related to industry, motor vehicles, cigarette smoking and building products and equipment. The highest concentrations of toxic emissions originate from industrial processes and the combustion of fossil fuels for these processes. However, motor vehicles contribute the highest overall load of air toxics to the atmosphere (Tibbett, 2004).

Many air toxics are highly volatile and evaporate readily into air, allowing inhalation. While the levels that endanger public health have not been established, it is believed that long-term exposure to even very low levels could have adverse effects. Some health effects may take many years to become evident and some air toxics have synergistic effects (causing higher toxic effects in combination than individually). Cancer, pulmonary disease, neurological or gastrointestinal effects, respiratory congestion and irritation to the eyes, nose and throat are some of the serious or debilitating effects of exposure to air toxics (Tibbett, 2004). Native fauna and flora are also susceptible to toxic effects.

In Australia, some air toxics have been recognised in the National Environment Protection (Air Toxics) Measure which designates levels of pollutants at which investigation should occur (as opposed to standards set for ambient air quality) (National Environment Protection Council, 2004a). The pollutants covered by the air toxics NEPM are benzene, benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons), formaldehyde, toluene and xylenes. Through the Living Cities Air Toxics Program, the Commonwealth Government identified a group of priority pollutants as a starting point for focusing attention on the development of national strategies for the management of air toxics (Table A8 .1).

The key air toxics of concern in WA include heavy metals, benzo(a)pyrene (polycyclic aromatic hydrocarbons), volatile organic compounds, persistent organic pollutants and asbestos. Very limited data on the levels of these pollutants is available and in some cases no data is available. Heavy metal air toxics include arsenic, lead (indoor air), cadmium, mercury, chromium, nickel and their associated compounds. While lead levels in Perth were historically high, it is no longer considered to be a problem (see '*Outgoing issue – Lead*'). The *Perth Haze Study* found polycyclic aromatic hydrocarbon levels in Perth were high in Duncraig (an area impacted by wood smoke) compared to Swanbourne and Caversham (Department of Environmental Protection, 1996; Environment Australia, 1999). Volatile organic compounds include benzene, toluene, chlorofluorocarbons (CFCs), halons, carbon tetrachloride and some pesticides. Studies of airborne reactive organic compounds in Perth have shown low levels of volatile organic compounds, benzene, toluene, ethylbenzene and xylene (Department of Environmental Protection, 2000b; Environment Australia, 2003) compared to other Australian cities and the relevant standards. The *Background Air Quality (Air toxics) Study* gathers data for some air toxics at thirteen metropolitan sites and compares them to NEPM guidelines and international standards. Results have been recorded for volatile organic compounds at sites in Albany and Kalgoorlie (see former Department of Environment website), but data have not yet been analysed in detail.

**Table A8.1:** Compounds listed as air toxics under the Living Cities Air Toxics Program.

| Priority pollutants | |
|---|---|
| Acetaldehyde | Methylenebis (phenylisocyanate) (MDI) |
| Acroleina | Nickel and compounds |
| Acrylonitrile | Polycyclic aromatic hydrocarbons (PAHs) |
| Arsenic and compounds | Polychlorinated biphenyls (PCBs) |
| Benzene | Phthalates |
| 1,3–Butadiene | Polychlorinated dioxins and furans |
| Cadmium and compounds | Styrene |
| Chromium (VI) compounds | Tetrachloroethylene |
| Dichloromethane | Toluene |
| Fluoride compounds | Toluene–2,4–diisocyanate |
| Formaldehyde | Total volatile organic compounds[a] |
| Mercury and compounds | Trichloroethylene |
| Methyl ethyl ketone | Vinyl chloride (monomer) |
| Methyl isobutyl ketone | Xylenes |
| **Criteria pollutants[b] identified for consideration in the indoor context** | |
| Carbon monoxide | Oxides of nitrogen |
| Lead and lead compounds | Respirable particulate matter |

Data source: Environment Australia (2002a). Notes: (a) Volatile organic compounds are now known as reactive organic compounds. All reactive organic compounds in a sample are included, such as acrolein, acrylonitrile, benzene, methyl ethyl ketone, styrene, tetrachloroethylene, toluene, toluene–2,4–diisocyanate, trichloroethylene and xylenes.
(b) Criteria pollutants are those for which ambient air quality NEPM standards have been defined.

# OUTGOING ISSUE – LEAD

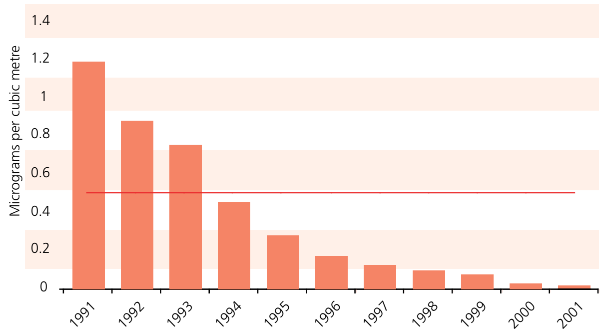



**Figure A9.1:** Lead concentration in Perth's atmosphere over time, compared with the Australian standard for exposure, 1991–2001.

Data source: Department of Environment [ver. 2005].

Atmospheric lead was addressed in the *1998 State of the Environment Report* but since then, its importance as an environmental issue has decreased. Unless environmental health experts consider that it increases in importance, it will not be considered in the subsequent reports.

Airborne lead particles are produced from a number of sources including the disturbance of lead-based paints used on exterior walls of houses, pollution from lead-producing industrial areas, and contaminated dust, soils and water bodies (Government of Western Australia, 1998). Prior to the introduction of unleaded petrol in WA, motor vehicle emissions contributed approximately 90% of the lead in the atmosphere, except for major point sources such as lead-smelting facilities (Department of the Environment and Heritage, 2004b).

High levels of lead in the atmosphere can have detrimental effects on human health. Lead is absorbed following inhalation of contaminated air. While small amounts may cause few or no symptoms, larger amounts have a range of effects on the body including cramps, nausea, anaemia, headaches and high blood pressure. Intellectual and developmental problems are possible side-effects in children. Historically, atmospheric lead was well above the standard in Perth, but has fallen steadily and is now at very low levels (Figure A9.1).

Growing concerns about the dangers of lead for human health instigated government action, including the phasing out of lead based paints in the 1970s and legislation requiring all new motor vehicles to run on unleaded petrol as of 1986 (Government of Western Australia, 1998). The lead content of leaded fuels was gradually reduced from 0.4 to 0.2 grams per litre between 1993 and 1996, and the transfer of leaded fuel to lead-replacement fuel occurred on 1 January 2000 in WA. Fuel containing lead was no longer available for sale after that date. The Commonwealth Government took the same step nation-wide two years later (Australian Institute of Petroleum, 2002).

In 1996–97 the average maximum lead level concentration in Perth's atmosphere was 0.22 micrograms per cubic metre. By 2001 this had decreased ten fold to an annual average maximum of 0.02 micrograms per cubic metre. Monitoring ceased on at the end of 2001 in response to lead levels becoming increasingly undetectable and apparently stabilised at approximately 4% of the national standard, with no exceedences (Department of Environment, 2003a). Atmospheric lead is no longer considered a problem in WA however, lead remains a significant health concern in some areas of WA (such as Esperance).

## OUTGOING ISSUE
## CARBON MONOXIDE

Carbon monoxide was identified as an issue in the *1998 State of the Environment Report* (Government of Western Australia, 1998), but is not identified as a major environmental issue for this report.

Carbon monoxide is an air pollutant produced by incomplete combustion of carbon-based fuels (e.g. petrol, diesel, oil, gas, wood or coal). Carbon monoxide (CO) is a colourless and odourless gas and is a common urban air pollutant. Carbon monoxide can have significant health effects. It is absorbed into the body via the lungs and enters the blood stream, where it reduces the blood's ability to deliver oxygen to organs and tissues. Exposure to carbon monoxide at high levels is poisonous to humans, and may result in increased incidence and duration of angina pectoris (chest pain sometimes leading to heart attack), visual impairment, reduced motor skills, poor learning ability, difficulty in performing complex tasks and low birth weight (Department of Environmental Protection, 2000a).

In Perth, 80% of all carbon monoxide emissions are from motor vehicle exhausts (Department of Environmental Protection, 2002a). The highest recorded levels of carbon monoxide are in areas of dense vehicle traffic (Government of Western Australia, 1998). Other significant sources of carbon monoxide include power generation, domestic solid fuel heaters and burning vegetation. It is also formed in the atmosphere by the oxidation of methane.

Two network monitoring stations have been selected to show concentrations of carbon monoxide monitored in the Perth airshed over time. The Duncraig monitoring station displays a strongly seasonal trend with high emissions during winter from wood heaters, but no trend from year-to-year is obvious (Figure A6.1). The Queens Building station in Perth's central business district primarily detects motor vehicle emissions (Figure A6.2), and shows that ambient CO concentration is declining. Overall, ambient carbon monoxide concentrations in the Perth airshed have been decreasing since 1992 and no exceedences of the NEPM standard has been recorded (A Grieco, Department of Environment, pers. comm.).

Carbon monoxide is a good example of positive progress arising after implementation of progressively better technologies to reduce emissions from motor vehicles. Efficiency gains from better engine technologies have resulted in a significant reduction in emissions of both carbon monoxide and oxides of nitrogen from vehicles. The decline in carbon monoxide concentration has occurred despite increases in total vehicle kilometres travelled and number of vehicles registered (see '*Transport*').

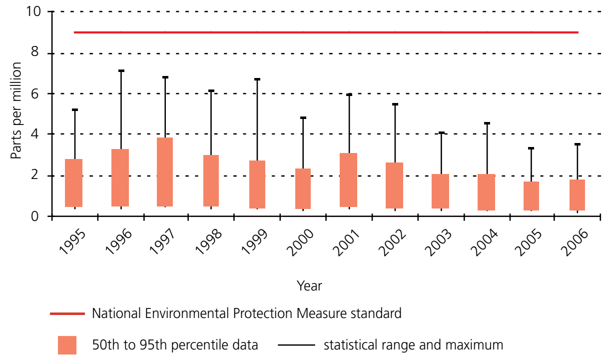



**Figure A10.1**: Ambient yearly range of carbon monoxide levels at Duncraig air quality monitoring station, compared with the Australian standard.

Data source: Department of Environment and Conservation.

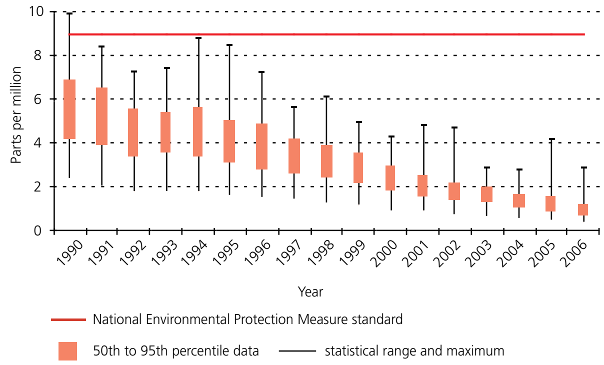



**Figure A10.2**: Ambient yearly range of carbon monoxide levels at Queens Building (Perth central business district) air quality monitoring station, compared with the Australian standard for exposure.

Data source: Department of Environment and Conservation.

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