Chapter 5

The Atmosphere

Thunderstorm cloud near Pt Lookout, NSW.

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Introduction

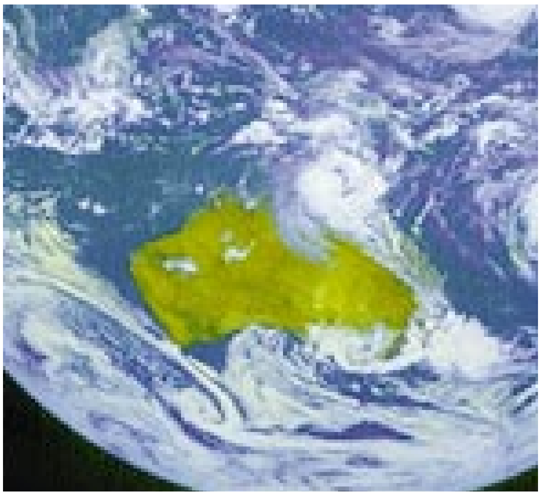
'On a clear day you can see for ever...' While not strictly true, this phrase nevertheless sums up the sense of well-being that clean, fresh air can give us.

Air is essential for most organisms. Its existence and composition also affect many other parts of the environment. The unique composition of the atmosphere helps to maintain our planet in its present form and make it habitable. 'Atmosphere' is defined as the air environment on all physical scales — from the gaseous envelope surrounding the planet to the air inside a house — and on time-scales ranging from minutes to decades.

This chapter focuses on those aspects of the atmospheric environment where human activities have a detectable effect. The natural processes that operate within the atmosphere need to be understood in order to assess the impact of human activities (see Table 5.1 and Fig. 5.1). The state of Australia's air environment depends on the country's weather and climate as well as on the various human-induced pressures on the natural environment.

The chapter considers the impact of human activities on the atmosphere on three spatial scales — global, regional and local. Although it is convenient to use these scales for this report, in practice, they overlap.

Global-scale impacts encompass the effects of long-lived gases and particles on the global atmosphere.

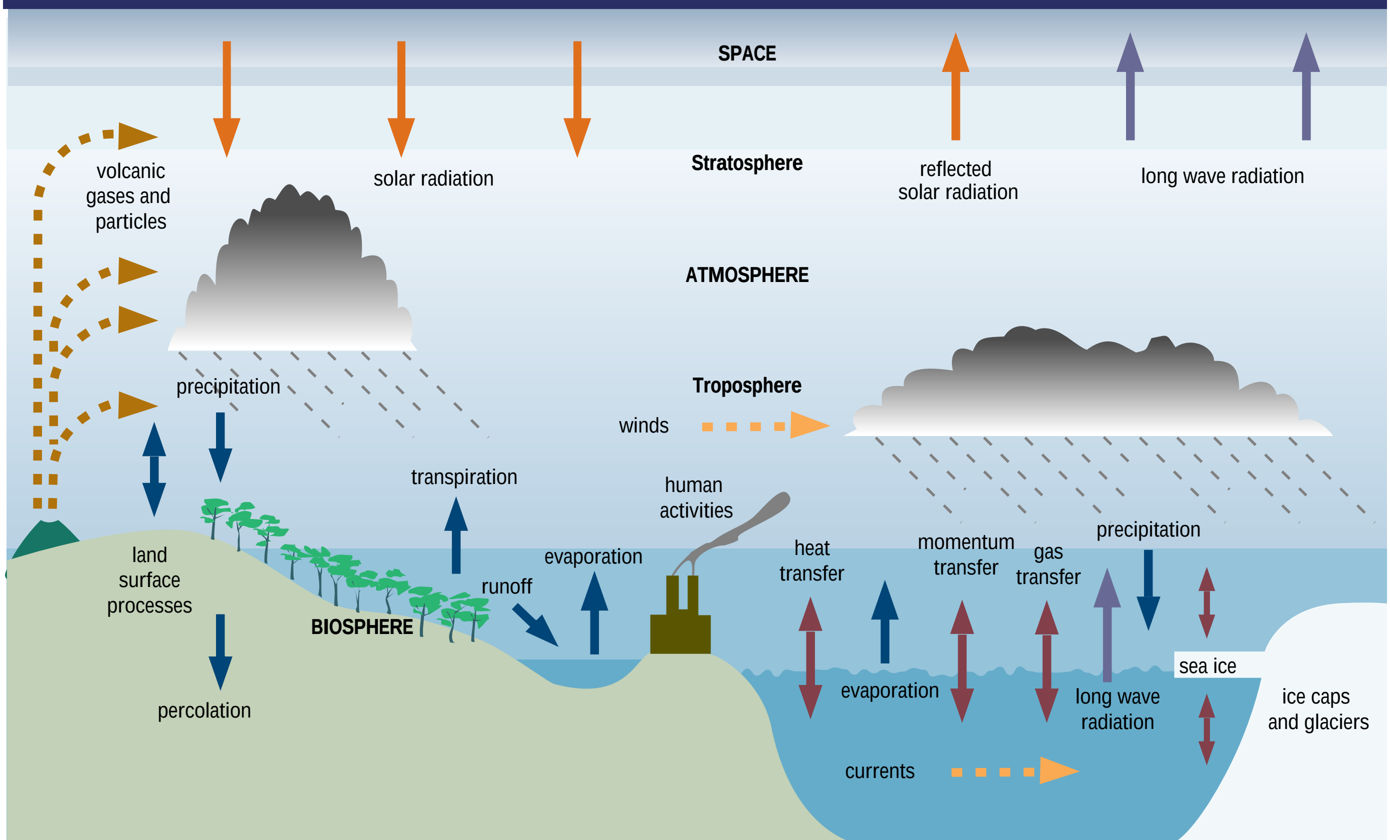


The enhanced greenhouse effect and stratospheric ozone depletion are examples of phenomena on this scale.

Regional-scale effects involve the dispersion of pollutants within the airshed in which they were emitted and their transport downwind. Examples include motor vehicle emissions in cities and emissions from large industrial plants and power generation.

Local-scale refers to pollutants that are dispersed or inactivated without travelling far from their source or are contained within confined areas — for example, indoor air pollution.

Figure 5.1 The components of the global climate system



Source: Bureau of Meteorology

Table 5.1 Composition of the lower atmosphere

Gas	Symbol	Percent by volume
Constant Components		
Nitrogen	N_2	78.08
Oxygen	O_2	20.95
Argon	Ar	0.93
Neon	Ne	0.0018
Helium	He	0.0005
Hydrogen	H_2	0.00005
Xenon	Xe	0.000009
Variable Components		
Water vapour	H_2O	0 to 4
Carbon dioxide	CO_2	0.036
Methane	CH_4	0.00017
Ozone	O_3	0.000004*
Carbon monoxide	CO	0.00002*
Sulphur dioxide	SO_2	0.000001*
Nitrogen dioxide	NO_2	0.000001*
Particles (dust etc.)		0.0001*

*Typical value in polluted air

Source: after Crowder, 1995.

Climate of Australia

Our part of the world — the southern hemisphere — enjoys relatively clean air and clear skies. It is mainly ocean, and has a smaller population and consequently a lower level of human emissions than does the northern hemisphere. Australia has the added advantage of being an isolated island, and so is not directly subjected to emissions from neighbouring countries.

We experience a climate quite different from that in Europe and North America. Many distinctive features of Australia make comparisons with other countries difficult (see Chapter 2).

Australia is a fairly flat, sparsely populated island continent located on the western rim of the Pacific in the largely oceanic southern hemisphere. Its geographic location and size mean that it experiences many climate zones. These range from tropical climates in its northern third to temperate ones in Tasmania and the southern parts of the mainland (with a small alpine region occurring in the south-east of the continent and in central Tasmania) to Mediterranean in the south-west and south-central areas. More than 75 per cent of the continent is classified as arid or semi-arid.

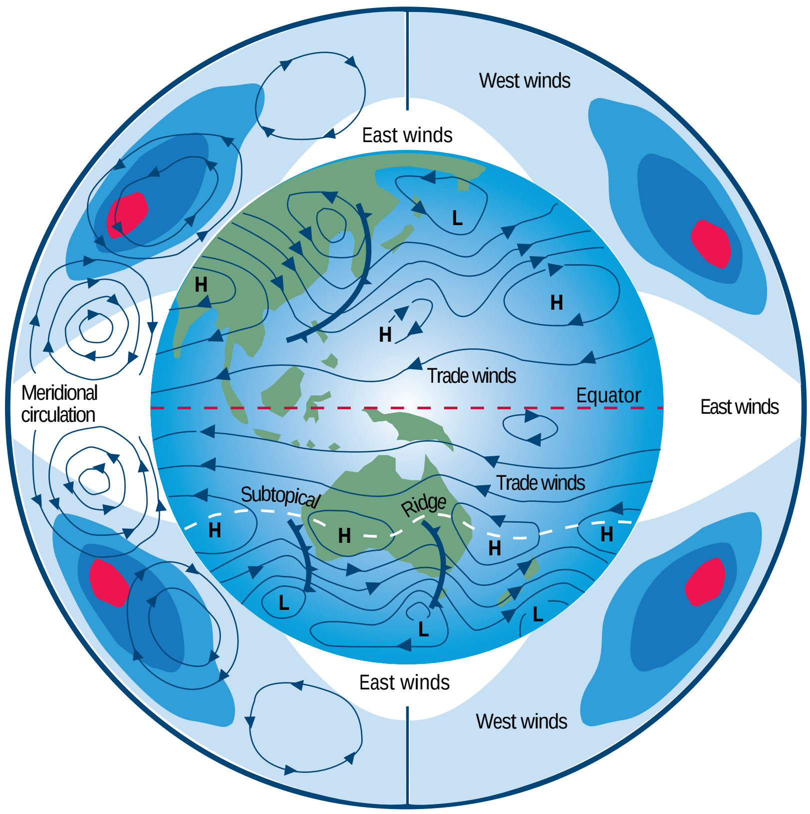
Most of the country comes under the influence of the subtropical ridge of high atmospheric pressure. The air above the ridge is in the descending branch of a large 'cell' of air circulation that links the tropics and the middle latitudes (see Fig. 5.2). The air movement of the cell is driven by the temperature contrast between the warm tropical ocean to the north of Australia (the warmest ocean on the planet) and the cold of the Antarctic regions. The other global-scale atmospheric feature exerting a particular influence is the east–west air circulation (the Walker Circulation), with air ascending over the warm western Pacific and descending over the colder waters off the west coast of South America (see Chapter 2).

Australia's generally low terrain provides little obstruction to the global circulation systems. High pressure cells that travel from west to east dominate the weather and climate over much of the country. In summer they are at a latitude well south of the landmass, and during winter they move northward to become centred over the continent. The high pressure systems ensure stable atmospheric conditions, typically with clear skies, much sunshine, light winds and little precipitation (conditions that favour the build-up of pollution).

In the cooler half of the year (May to October), the high pressure systems pass slowly across the continent, often remaining stationary for several days. Northern Australia is influenced by mild, dry south-east trade winds, while southern areas experience cooler, moist westerly flows. Frontal systems in the westerlies can cause periods of intense rain and abrupt temperature changes, and even snowfalls in the southern higher areas. The coldest temperature ever recorded in Australia was -23°C at Charlotte Pass, New South Wales, on 29 June 1994.

In the warm half of the year (November to April), the highs become centred well to the south. Easterly winds predominate and most of southern Australia experiences fine, warm — often heat-wave — conditions. Marble Bar, in north-west Western Australia, recorded 161 consecutive days above 37.8°C (100°F) between 30 October 1923

Figure 5.2 Large-scale atmospheric circulations affecting our climate



Source: Bureau of Meteorology.

and 7 April 1924. At this time of year northern Australia is influenced by the monsoon lows associated with the southward movement of warm, moist tropical air.

Australia receives less rain than any other continent except Antarctica, and no continent has less run-off from its rivers. Despite its high proportion of arid land, it has a less extreme climate than deserts such as the Sahara. The major features of its climate are: the highly irregular rainfall (see Fig. 5.3), which is closely linked to the El Niño–Southern Oscillation (ENSO) phenomenon (see Chapter 2); the extreme rate of evaporation of available water; and the large temperature ranges.

Between November and April, tropical cyclones develop over the seas to the north of the continent. Both the number of cyclones and their tracks vary greatly from season to season and are related to the ENSO phenomenon. On average, about six cyclones each season affect northern coastal areas, often producing a great deal of rain and strong winds. Some bring widespread heavy rains inland.

Pressure

Human activities exert pressures that may change the state of the earth's natural systems. A 'pressure' does not inevitably cause an environmental or other 'problem'. Whether it does or not depends on the capacity of the system to absorb the pressure — sometimes referred to as the system's assimilative capacity. This may vary in time and place, as well as with the extent of other pressures. Within the air environment, pressures come about mainly through emitted substances. However, it is also possible to create a pressure by altering the assimilative capacity of natural systems (for example, through changing land use) and thereby reducing the capacity of the 'sinks' — the processes or places that remove pollutants from the atmosphere.

Emitted substances may be gases or particulates (fine particles), both of which can remain airborne for considerable periods. Some emitted substances may interact with each other. In this way, or through atmospheric chemical processes and the influence of sunlight, the primary emissions may turn into new, sometimes unwanted, secondary substances. A good example of this is the formation of photochemical smog, which contains ozone, in sunny city air. The ozone is described as a secondary pollutant: it arises almost entirely from the interactions of emitted substances under the influence of sunlight.

However, not all secondary substances are harmful. Chemical reactions in the atmosphere and elsewhere can also change emissions into forms that are less damaging to the environment or to human health. Thus, many emitted substances are degraded and then absorbed by natural systems. Continuous cycles remove many substances — especially naturally occurring ones — from the atmosphere. However, humans may generate a greater volume of emissions than the system can remove.

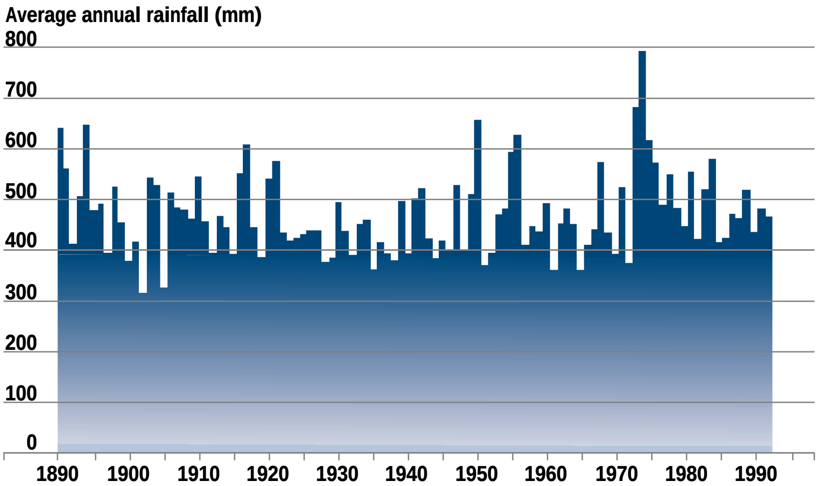
The period for which a substance remains in its active form in air is called its residence time. Certain emitted compounds, such as chlorofluorocarbons (CFCs), do not occur naturally. They are chemically non-reactive and have a very long residence time. In general, these long-lived emissions are responsible for regional and global pressures, while the short-lived reactive ones lead to local pressures.

How much pressure an emitted substance exerts depends on the type of environment it enters. For example, if emissions are concentrated because of particular air-flow patterns (natural or engineered) in a region or building, concentrations can build up and have an effect that may appear out of proportion to the absolute quantity emitted. Conversely, the atmosphere can also disperse emissions and transport them from one place to another — or even right around the planet. As well, high levels of humidity and frequent rain may 'wash out' particles and certain soluble gases before long-range transport occurs. Sunlight promotes the formation of photochemical smog and so the smog precursors — which are largely emitted from vehicles in urban areas — will create more ozone in sunny weather, and particularly when the winds are light.

How and where a substance is emitted into the atmosphere may also affect its fate. For example, emissions from tall stacks usually travel further than those arising at ground level. Chemical reactions can vary depending on the height within the atmosphere, because factors such as temperature, radiation from the sun, moisture and other gas concentrations vary with height. Air stability also affects the dispersion of emissions.

Pressures on the atmosphere that do not arise from emissions are even harder to characterise accurately. A good example concerns those aspects of the enhanced greenhouse effect that do not involve direct greenhouse gas emissions. In this case, human-induced changes that alter the planet's cover of vegetation may make it harder for the environment to remove additional carbon dioxide emitted by human activity (see Fig. 5.4).

Figure 5.3 Annual rainfall variability over Australia (1890–1990)



Source: Bureau of Meteorology.

Emissions

Many substances are emitted into the atmosphere from human activities and from natural sources. Outdoors, the main gases and particulates that are emitted, and that have particular environmental impacts, are:

- carbon dioxide (CO_2)
- carbon monoxide (CO)
- halocarbons, such as halons (used in fire protection), chlorofluorocarbons (of various chemical formulae and known collectively as CFCs) and their replacement products such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs)
- lead (Pb)
- methane (CH_4)
- oxides of nitrogen (NOx) including nitrogen dioxide (NO_2), nitric oxide (NO) and the greenhouse gas nitrous oxide (N_2O)
- particles of various compositions and sizes
- sulfur dioxide (SO_2)
- volatile organic compounds (VOCs) other than methane

Emitted gases and aerosols (suspensions of droplets or particles in the air) may contribute towards the greenhouse effect (see the box on page 5-16), the depletion of the stratospheric ozone layer (see the box on page 5-11), the phenomenon of acid deposition, the generation of photochemical smog and, on a local scale, the contamination of air, which then becomes less healthy for humans to breathe. In some cases, the same gases may contribute in different ways to a range of effects. For example, although small concentrations of ozone in photochemical smog in the lower atmosphere are damaging to most living things, small concentrations of ozone in the upper atmosphere all around the globe are necessary for life on earth because that ozone shields the surface from harmful ultraviolet (UV) radiation.

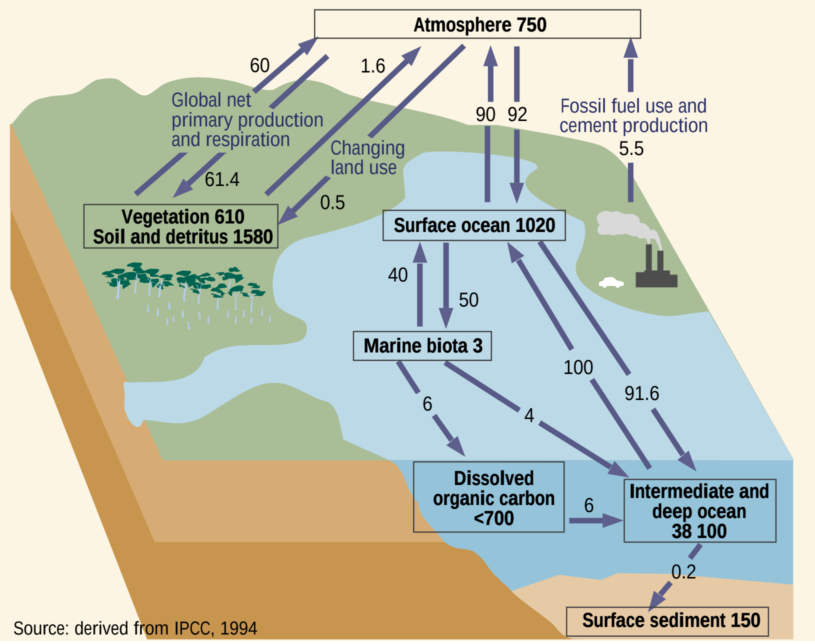
Indoor air is mainly contaminated by emissions generated indoors rather than emissions from outdoors (see Table 5.12).

Sources of emissions

The burning of carbon-containing fossil fuels powers most of Australia's transport and electricity generation and is responsible for a large part of our atmospheric emissions. Many domestic, commercial and industrial processes also emit waste gases. CFCs and halons can 'escape' into the atmosphere by leakage or by the destruction of manufactured items containing them. Agriculture can also be responsible for emissions and for changes to vegetation cover.

Aspects of Australia's society (such as its economy, demography and the lifestyle of its people) underlie pressures on the atmosphere (see Chapter 3). The country has abundant fossil-fuel energy resources, especially coal and natural gas, and is a major energy exporter. The scale of the energy industry is such that it creates considerable pressures on the

Figure 5.4 The global carbon cycle showing reservoirs (boxed) and annual exchanges of carbon in gigatonnes (Gt)



Source: derived from IPCC, 1994

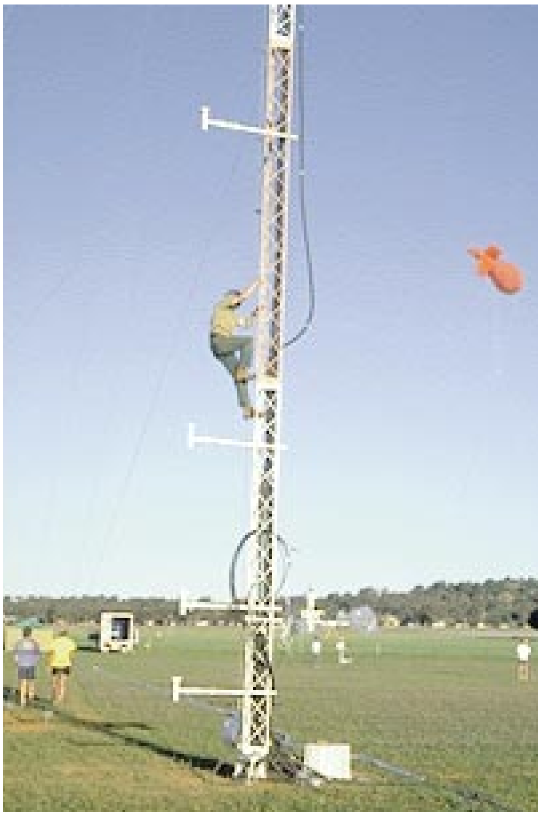
atmosphere. The main sources of fossil-fuel-derived emissions are thermal power generation, road transport and the use of energy in industrial processes.

Coal is used to generate most electric power. The process produces ash particles, acid gases such as oxides of nitrogen (NOx) and sulfur dioxide (SO_2), as well as carbon dioxide, which contributes to the greenhouse effect. In Australia the amount of SO_2 emitted per unit of energy generated is low by world standards because our coal generally has a relatively low sulfur content. We have a further advantage in that most large power-generating plants are located outside our main cities.

The demand for power is affected by our increasing population, economic growth and, among other factors, the energy-intensive nature of certain major industries such as aluminium production. At present, we have few economically viable alternatives to fossil fuels as our primary energy source. There is no nuclear power generation in Australia, and only a limited capacity for hydro-electricity in certain areas, such as Tasmania and southern New South Wales.

As well as coal, Australia contains rich mineral deposits of iron ore, bauxite, silver, lead, zinc and gold. The country has well-developed minerals, manufacturing and agricultural industries, and a large services sector. Much of its industry is export-orientated — especially the mining and mineral processing sectors, which are important to the national economy. However, the treatment of mineral ores can be a major source of emissions — often of SO_2, but also of other gases, depending on the ore and the type of treatment. Mining and ore-processing are concentrated in small areas, often wherever a suitable ore deposit may be, and these operations are generally remote from major population centres.

Greenhouse gas emissions from a field outside Wagga Wagga, NSW are being measured as part of a collaborative project involving universities and CSIRO. Measurements like this help to quantify Australian greenhouse emissions and are an essential first step in designing strategies for emission reduction.



In urban areas, motor vehicles are the main source of emissions and therefore the main contributors to outdoor air pollution. The design of Australian cities has promoted a high rate of motor vehicle ownership and use. (Our cities have low population densities compared with urban areas elsewhere and are often described as 'sprawling'.) Motor vehicle exhaust contains NOx, carbon monoxide (CO) and volatile organic compounds (VOCs). Together these are responsible for many local air pollution problems. Lead particles from leaded fuel are also present, although the use of such fuel is now declining. Particulate emissions come especially from diesel vehicles, but we have proportionately fewer of these than other countries.

The day-time brown haze that sometimes forms over our major cities is caused by particles and NOx from exhaust fumes. Less obvious forms of urban air pollution also occur. Under the influence of sunlight, NOx and VOCs may react together to form photochemical smog (see the box on page 5-25), containing the invisible gas ozone, a potentially greater threat to human health. In addition, of course, vehicles emit the greenhouse gas CO_2.

Important —but less direct — factors influencing pressures on the atmosphere are the size of the human population, its growth rate and the pattern of consumption of each individual. Australia's population of 18 million lives in relative affluence and is increasing at a rate of about 1.6 per cent per year, a rate higher than in most OECD countries. Expected economic growth and the continued growth of the population mean that the country's demand for energy is also likely to continue to increase.

Global-scale pressures

Enhanced greenhouse effect

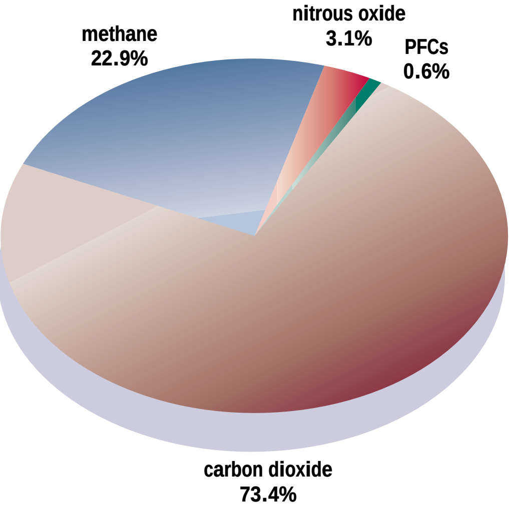
The enhanced greenhouse effect is explained in the box on page 5-16. In terms of how human activity affects the global climate system, the pressures that give rise to the effect need to be considered on a global scale. Global pressures are the sum of the smaller pressures coming from individual countries and people.

'Anthropogenic' — a word often used in discussions of environmental topics — means 'brought about by humans'. In the case of the enhanced greenhouse effect, anthropogenic emissions of greenhouse gases are those emissions that enter the atmosphere as a result of human activity — even though some of the gases may occur naturally in the atmosphere.

Human activity has not only caused an increased emission of naturally occurring greenhouse gases such as CO_2, CH_4 and N_2O, but has also released other gases that contribute to the greenhouse effect — such as CFCs and photochemically derived ozone in the lower atmosphere. To assess the impact of anthropogenic emissions from pre-industrial times until the present we need to know the source and characteristics of these emissions.

Because of its particular properties, quantity emitted and long life-time, carbon dioxide (released mainly by burning fossil fuels, changes in land-use and cement production) is the most important anthropogenic greenhouse gas. However, others also make an important contribution. Methane largely derives from the biosphere (for example, livestock, rice cultivation, organic waste and land fills), and from fossil fuels (oil and gas exploration, gas distribution and coal-mining). Ozone in the lower atmosphere is mostly formed from pollutants in urban air. It does not remain for long and is not distributed uniformly — particularly in the southern hemisphere where few

Figure 5.5 Australia's national greenhouse gas emissions inventory by component for 1990



Note: This inventory excludes gases controlled by the Montreal Protocol

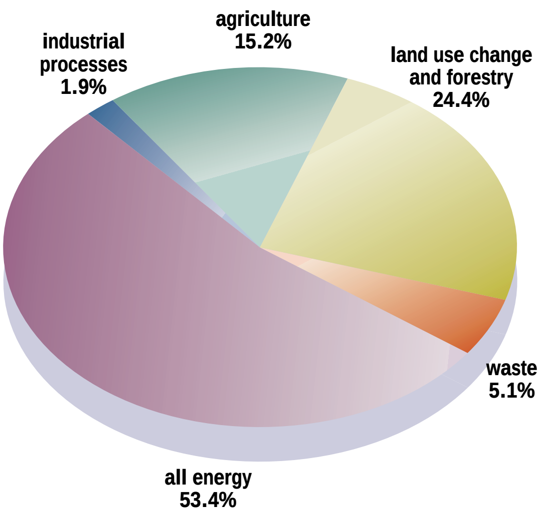
Source: National Greenhouse Gas Inventory Committee, 1994.

sources occur. Nitrous oxide from agriculture and some industrial processes, and the long-lived halocarbons (such as CFCs and carbon tetrachloride) contribute as well. CFCs have two opposing effects. While they absorb infra-red radiation in the same wave-bands as the naturally occurring greenhouse gases, they also bring about the destruction of stratospheric ozone, a naturally occurring greenhouse gas. In fact, the warming effect of CFCs is reduced by over one-half because of the cooling brought about by their depletion of stratospheric ozone. Because of the impacts of CFCs and some of their replacements, their production is now controlled on a global scale by the Montreal Protocol of the Vienna Convention for the Protection of the Ozone Layer.

As part of its obligations under the United Nations Framework Convention on Climate Change, Australia is required to compile an inventory of its greenhouse gas emissions and sinks (except for gases, such as the CFCs, controlled by the Montreal Protocol) (see Figs 5.5 and 5.6).

Carbon dioxide is by far the most significant anthropogenic greenhouse gas emitted here (see Table 5.2), accounting for about 75 per cent of our total emissions. The main sources of CO_2 are fossil-fuel combustion and fugitive emissions from the energy sector. (Fugitive emissions include leaks, losses of naturally accumulated gases during fuel extraction and emissions from burning a gas or oil ‘flare’ at drilling rigs.) Slightly more than 30 per cent of net CO_2 emissions are estimated to come from forestry and changes to land use (mainly related to land clearing for agriculture), but this figure is very uncertain. Methane comes mainly from agriculture, waste decomposition (almost entirely landfill) and fugitive emissions from the energy sector, and accounts for about 23 per cent of total Australian greenhouse gas emissions. The remainder are mainly emissions of nitrous oxide from agriculture.

Figure 5.6 Australia’s national greenhouse gas emissions inventory by sector, 1990



Note: This inventory excludes gases controlled by the Montreal Protocol

Source: National Greenhouse Gas Inventory Committee, 1994.

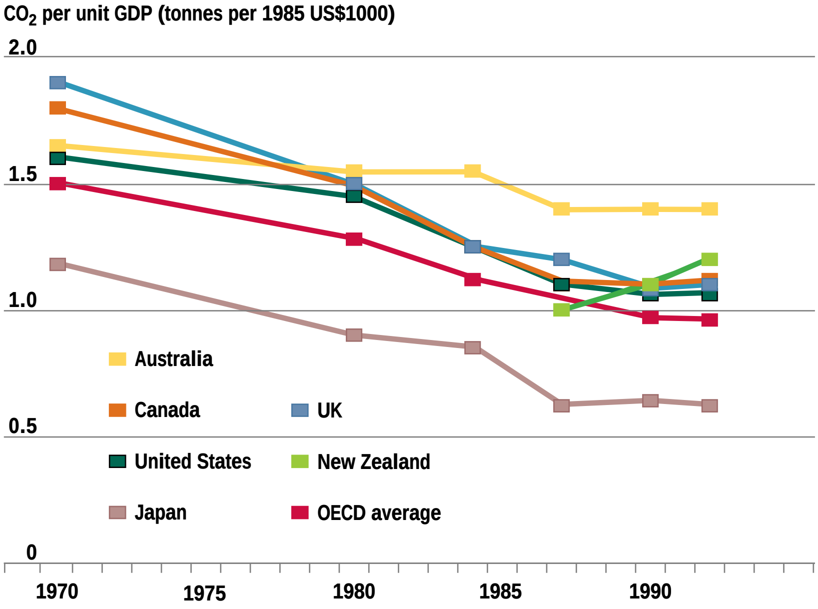
Table 5.2 Greenhouse gas emissions in Australia, 1990

Gas	Emissions (Mt)	Conversion factors (GWP)*	CO_2 equivalent (Mt)	Percent of total emissions
Carbon dioxide (CO_2)	419 807	1	419 807	73.4
Methane (CH_4)	6 243	21	131 115	22.9
Nitrous oxide (N_2O)	60	290	17 444	3.1
Perfluorocarbons (CF_4) and (C_2F_6)	1	(5 100) (10 000)	3 358	0.6
Total			**571 724**	**100.0**

* Global Warming Potentials (GWPs) are conversion factors used to express the relative warming effects of the various greenhouse gases in terms of the carbon dioxide equivalent, IPCC (1990).

Source: National Greenhouse Gas Inventory Committee, 1994.

Figure 5.7 Energy-related carbon dioxide emissions per unit GDP for selected OECD countries, 1970–92



Source: derived from IEA (1994).

Australia’s gross greenhouse gas emissions contribute 1–2 per cent of total global emissions.

Based on some criteria, Australia has very high emissions of greenhouse gases relative to other OECD countries. For example, over the period 1987–92, our energy-related CO_2 emissions per unit of GDP declined more slowly than the OECD average (see Fig. 5.7). These emissions have grown over the last 30 years principally because of population growth, industrialisation and continuing electrification (IEA, 1994).
In contrast, in other OECD countries, where economic growth was also high, the effect on emissions was offset by large falls in fossil-fuel consumption per unit of output. Australia has a higher proportion of energy-intensive industry than most of those countries because of its strong natural resource base and competitive prices.
On the other hand, as shown in Fig. 5.8, it has a smaller proportion of CO_2 emissions from the chemicals industry.

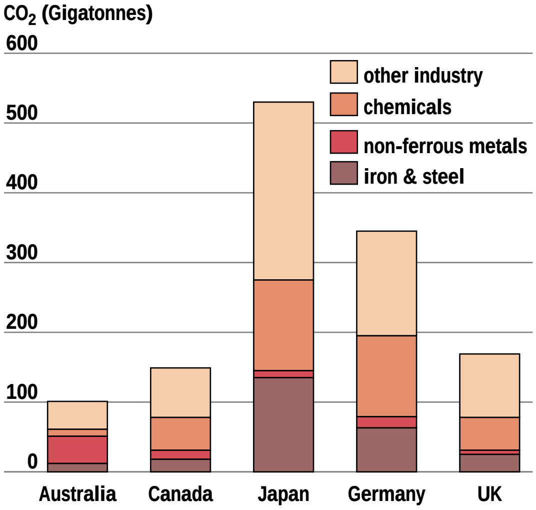
In 1992 the transport sector accounted for 24 per cent of total CO_2 emissions from energy (just above the OECD average of 22 per cent), industry contributed 18 per cent and electricity generation, using coal as its main fuel, 47 per cent. No other OECD country has such a large fraction of its energy-related emissions accounted for by electricity (IEA, 1994). Additional contributing factors to our high output of greenhouse gases are the level of CO_2 emissions associated with land-clearing and methane emissions from livestock.

Stratospheric ozone loss

The box on page 5-11 summarises what we know about stratospheric ozone depletion. Chlorofluorocarbons (CFCs) are now known to be the main source of anthropogenic chlorine in the stratosphere, and therefore to carry most of the responsibility for ozone destruction (WMO, 1995). Being chemically stable in the lower atmosphere, and not toxic or corrosive, CFCs have a wide variety of industrial and commercial applications. Since their initial synthesis in the 1930s they have been used as refrigerants, aerosol propellants, foam-blowing agents and industrial cleaning solvents. Because they are so chemically stable (part of their initial attractiveness) and do not degrade in the lower atmosphere, they remain airborne for many decades. They are dispersed globally from the point of their release and eventually reach the stratosphere, where exposure to high levels of UV radiation breaks down the molecules, releasing the chlorine that, through a complex series of reactions, causes ozone destruction. A decline in the concentration of global stratospheric ozone has been measured since the late 1970s.

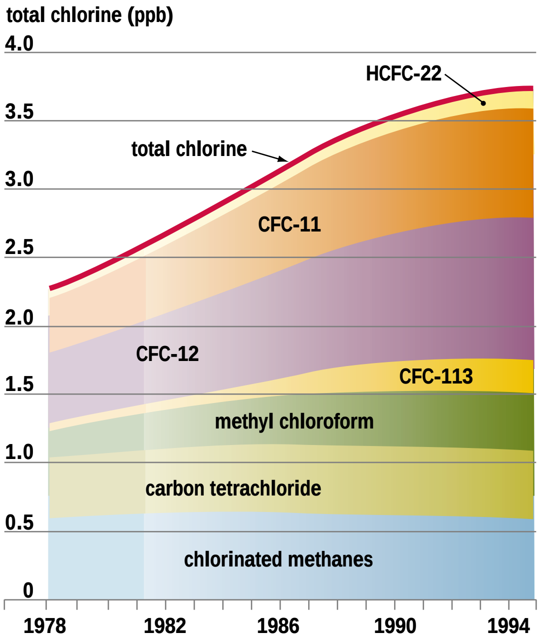
But CFCs are not the only ozone-depleting substances. The fire-fighting chemicals known as halons, which are a class of bromine-containing chemicals, and compounds such as carbon tetrachloride also have this effect. Methyl bromide,

Figure 5.8 Industry-related CO_2 emissions by sub-sector for selected OECD countries, 1992



Source: IEA, 1994.

Figure 5.9 Total chlorine in the atmosphere based on Cape Grim data



Source: CSIRO and Cape Grim Baseline Air Pollution Station.

used in Australia and elsewhere as a pest-fumigant, has recently been listed as an ozone-depleting substance, as has methyl chloroform, used as a solvent. (Unlike CFCs, methyl bromide also occurs naturally.)

At the beginning of this decade, concentrations of CFCs were rising at the rate of four to 10 per cent a year, depending on the type. The monitoring station at Cape Grim, Tasmania, has recorded a steady increase in the amount of total atmospheric chlorine (see Fig. 5.9). However, the rate of increase in CFC concentration has now declined, attributable to global action in reducing the emission of ozone-depleting substances.

Regional-scale pressures

On the regional scale, a number of factors affect air quality. These include emissions from human activity and natural sources; the lifetimes of the emitted substances and their interaction with atmospheric chemical processes; and meteorological factors and topographical features. The result may be the transformation, dispersion and/or accumulation of the emissions. The important point to note is that identical amounts of an emission do not always have the same effect, because local conditions play such an important role. Atmospheric scientists usually use the term ‘airshed’ to describe a body of air marked out by clearly defined geographic features in which a contaminant, once emitted, is contained.

Most of Australia’s population is concentrated within a very small proportion of the land area that occurs within about 100 km of the coast. Many human-induced pressures are therefore not distributed evenly across the country but rather are concentrated in major urban areas, making it hard to define and quantify the pressures on the air environment on a national scale. As well as established centres of high population density, other locations are potential or actual 'hotspots' in terms of air quality, either because of their rapid population growth or because of specific local emission sources.

As mentioned previously, most emissions in Australia derive either directly or indirectly from the use of fossil fuels. A further important source of mainly regional emissions is the metals-processing industry. Processing of ore concentrates containing sulfur produces significant volumes of SO_2 and NOx, and quantities of airborne heavy metals.

Urban airsheds

The Australian Environment Council (AEC) Report of 1988, contains the only national set of published data on urban emissions. It is based on emission inventories up to 1985. Some State government authorities are currently updating capital city inventories.

Based on 1985 data, vehicles emit about 75 per cent of the oxides of nitrogen (NOx) and about 45 per cent of anthropogenic volatile organic compounds (VOCs) in the major Australian urban areas. Vegetation is an important natural source of VOCs, especially in hot weather. Domestic activities, such as house-heating or cooking with solid fuels, oil and gas, can also produce NOx and particles. Both NOx and VOCs are important in the formation of photochemical smog (see page 5-25). Motor vehicles are significant sources of carbon monoxide, particulate matter and lead, and also emit small amounts of a range of other pollutants known as air toxics. These include benzene, 1,3-butadiene, formaldehyde and polycyclic aromatic hydrocarbons (PAH).

More recent data have been published for Melbourne, Perth and Sydney (Carnovale *et al.*, 1991; Weir and Muriale, 1994; EPA NSW, 1995) on the proportion of motor vehicle emissions (see Tables 5.3, 5.4 and 5.5). Motor vehicles remain the major source of NOx and CO and a significant source of VOCs. In Melbourne, vehicles emit about 46 per cent of the particles in summer, but this drops to only 10 per cent in winter when smoke from wood fires dominates (80 per cent).

Most urban airsheds are associated with industrial activities. Industries contributing substantial quantities of emissions include petroleum refineries, chemical and petrochemical plants, solvent-based industries (for example, dry cleaning, degreasing, use of paints and coatings) and mineral-product industries (glass, brick and tile, cement and lime production). In future, the siting of small energy-efficient power stations (local sources of NOx) within urban areas may have detrimental effects on air quality (Cope *et al.*, 1992) but will at the same time contribute to a reduction in carbon dioxide emissions (an improvement from an enhanced greenhouse perspective).

Stratospheric ozone loss

About 15 to 50 km above the earth's surface is the part of the atmosphere called the stratosphere. In the stratosphere — unlike the lower atmosphere (the troposphere) — temperatures increase with height. As a result, it is more stable and does not have the same amount of vertical mixing of air as the troposphere. From the point of view of life on earth, the most important fact about the stratosphere is its concentration of ozone which, although low, is much higher than that in the troposphere.

Ozone is produced when short-wavelength ultraviolet (UV) radiation from the sun acts upon oxygen molecules. Once formed, ozone absorbs UV. But ozone is an unstable molecule, and for every molecule formed in the stratosphere, another breaks down. Thus, the ozone layer is the result of natural processes that both produce and destroy the gas, and its concentration depends on the balance between these processes.

Chlorine, bromine and oxides of nitrogen, in their reactive forms, can catalyse the breakdown of ozone in the stratosphere. They are part of the natural ozone destruction cycle. Human activities — domestic, industrial and agricultural — produce emissions that increase the concentration of these chemicals and accelerate the destruction of ozone. This destruction by anthropogenic chemicals is particularly efficient over Antarctica in spring, as a result of the presence of ozone-depleting substances in the stratosphere combined with the unique temperature, structure and circulation of the Antarctic stratosphere during the long polar night. The seasonal reduction in ozone is referred to as the ozone 'hole', which is a shorthand description signifying that over a large area the stratospheric ozone concentration has fallen below normal (see Figs 5.17 and 5.18). The ozone is replenished at the end of spring, when ozone-rich air from the rest of the stratosphere moves over Antarctica and brings ozone levels almost back to normal.

It is important to note that ozone decline is not just a polar phenomenon — all regions apart from the tropics have shown a decline in stratospheric ozone over the last decade, although not as severe as that over the poles.

Ozone in the stratosphere reduces the amount of damaging UV radiation that reaches the earth's surface. Without the 'ozone layer' life on land would be exposed to such dangerous levels of UV radiation that few life forms would survive. It is because of the ozone layer's essential protective role that any reduction in its concentration gives rise to such serious concern. In general, a fall of one per cent in atmospheric ozone has been calculated to be equivalent to an increase of between one and two per cent in UV radiation at ground level. In humans, exposure to UV can cause sunburn, eye damage, skin cancer and damage to the immune system in susceptible individuals. Fair-skinned people are most at risk. Many other organisms, including plants, are also at risk from increased UV radiation. Too much ultraviolet irradiation reduces plant growth, the sensitivity varying between different species. Whereas humans can avoid exposure, it is more difficult for flora and fauna to do so, although some species can protect themselves by producing UV-absorbing pigments in greater quantities following exposure.

While the existence of stratospheric ozone is so important, increases in ozone in the lower atmosphere (the troposphere) are of concern. Tropospheric ozone has a limited atmospheric lifetime and is not transported to the stratosphere to any significant degree.

Table 5.3 Percentage contributions of major sources to total daily airshed emissions for Melbourne, 1990

	Motor vehicles		Industrial/Commercial point sources		Other sources	
	S	**W**	**S**	**W**	**S**	**W**
Nitrogen oxides (NOx)	78	73	17	16	5	11
Volatile organic compounds (VOCs)	50	40	20	16	30	44
Carbon monoxide (CO)	91	70	2	1	7	29
Sulfur dioxide (SO_2)	11	11	86	84	3	5
Particles	46	10	29	6	25	84

Note: **S** — summer week day; **W** — winter week day

Source: Carnovale *et al*, 1991.

Table 5.4 Percentage contributions of major sources to total daily airshed emissions for Perth, 1992

	Motor vehicles		Industrial/Commercial point sources		Other sources	
	S	**W**	**S**	**W**	**S**	**W**
Nitrogen oxides (NOx)	50.5	51.4	45.9	43.5	3.5	5.1
Volatile organic compounds (VOCs)	47.0	46.1	27.2	12.3	25.8	41.7
Carbon monoxide (CO)	93.4	73.1	2.2	1.7	4.4	25.2
Sulfur dioxide (SO_2)	2.7	2.7	96.4	95.5	0.9	1.9
Particles	40.7	9.0	53.1	11.7	6.2	79.2

Note: **S** — summer week day; **W** — winter week day

Source: Weir and Muriale, 1994.

Table 5.5 Percentage contributions of major sources to annual airshed emissions for Sydney and the greater Metropolitan Air Quality Study (MAQS) area, 1992

	Motor vehicles		Industrial/commercial activity		Domestic/ commercial activity	
	Sydney	**Greater MAQS**	**Sydney**	**Greater MAQS**	**Sydney**	**Greater MAQS**
Nitrogen oxides (NOx)	82	45	13	52	5	3
Volatile organic compounds (VOCs)	49	49	10	10	41	41
Carbon monoxide (CO)	91	69	2	23	7	8
Sulfur dioxide (SO_2)	14	2	64	96	22	2
Particles	31	16	36	68	33	16

Note: Greater MAQS area includes Newcastle and the Hunter Valley to the north of Sydney and Wollongong to the south.

Source: EPA NSW, 1995.

Regional airsheds

This chapter will refer to monitored airsheds outside major cities — most of which contain power stations — as 'regional airsheds'. Australian electricity consumption has more than doubled during the past two decades, with most of the power being generated by thermal power stations located near coalfields and away from urban areas. All emit relatively large quantities of NOx. As coal-burning power stations also emit sulfur dioxide, particulate matter and small quantities of toxic organic compounds, monitoring programs have been developed in power-generating regions such as the Latrobe and Hunter Valley airsheds.

The other major emitters to regional airsheds are: mineral-processing operations (for example, copper, lead, aluminium, gold, nickel, iron and steel production); paper and pulp manufacture; extractive industries (mining and quarrying); food processing; and intensive agriculture. Other activities associated with agriculture can also be significant sources. For example, vegetation removal may lead to soil erosion and hence airborne dust. Agricultural burning, bushfires, fuel-reduction burns and aerial spraying can all emit a range of substances, including particles and VOCs. In general, the impact of these activities is poorly known.

Local-scale pressures

Outdoor sources

People's perceptions of air quality are strongly influenced by local emissions, even though these may make only a relatively minor contribution.

Local outdoor pressures can include odours and smoke. The emissions are usually intermittent rather than continuous, with the areas affected often determined by wind direction and atmospheric stability. Important sources of local pressures include traffic, intensive agriculture such as chicken and pig farms, wood stoves, backyard incinerators, spray-painting and even cooking.

Indoor sources

Many pollutants have been investigated in Australian homes and office buildings, but not always in great detail. Few have been studied enough to determine either the existing exposure levels for Australian populations or the most appropriate strategies to reduce exposures. The following factors, alone and interacting with each other, exert pressures on indoor air quality:

- sources of chemical and biological contamination, such as building materials, furnishings or unflued heaters
- combinations of particular levels of moisture and temperature
- building design, ventilation and maintenance
- inflow of outdoor air
- building occupants.

The major pollutants are thought to be tobacco smoke, house dust mites and nitrogen dioxide.

Respirable suspended particles, certain microbes and VOCs may occur at high concentrations but have not been investigated thoroughly. Added to this lack of objective data is the problem of subjectivity — some aspects can be measured but, in the end, results often depend on the perception or symptoms of the individual, and people differ in their sensitivities.

State

Natural variability

A significant feature of the Australian climate is its large year-to-year variability.

Australia's climatic variability comes about partly because the continent lies near the 'centre of action' of the so-called Southern Oscillation. The oscillation, which occurs about once every two to seven years, is a large disturbance in the atmospheric circulation. Every few years the surface waters in the central and eastern Pacific undergo a remarkable warming, known as an El Niño, which leads to substantial changes in the atmospheric circulation throughout the entire Asia–Pacific region. The generic term El Niño–Southern Oscillation (ENSO) is often used to refer to a suite of events that occurs at the time of an El Niño (see Chapter 2).

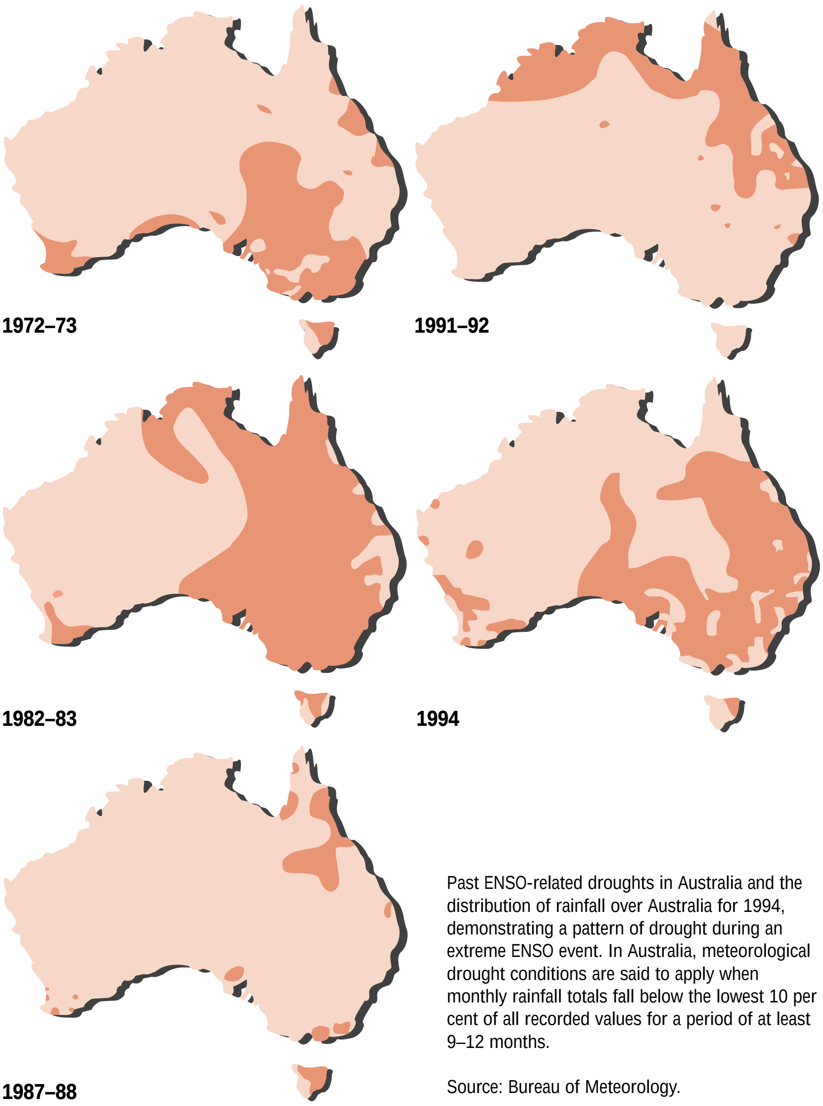
During ENSO, the area of strongest ascent of air in the Walker Cell moves eastward from Australian longitudes to the central Pacific. It is replaced by a stronger than usual descent of air and accompanying drought conditions over Papua New Guinea and eastern Australia. At the other extreme of the ENSO cycle, the ascent of air over the western Pacific is enhanced and the Australian region is more than usually subject to tropical cyclones and other flood-producing weather systems.

The most widely used indicator of the state of the Southern Oscillation and the strength of the Walker Circulation is the Southern Oscillation Index (SOI). The SOI is derived from the difference in surface air pressure between Tahiti and Darwin. A positive SOI occurs when pressures are higher than normal at Tahiti and lower than normal in Darwin, with above-average rain over eastern Australia. A negative SOI occurs at the other extreme of the ENSO cycle, with drought conditions over much of eastern Australia.

The ENSO phenomenon can be detected in the continuous records of nearly all climatic variables, but has its greatest impact on rainfall and air temperature. The most pronounced variability in the Australian region occurs over the eastern two-thirds of the continent, where the ENSO accounts for 30 to 40 per cent of the variance (a measure of variability) of rainfall. The ENSO is also detectable to some extent in the variability of air quality measurements between years, particularly the measurements of tropospheric ozone.

As well as the ENSO, variations in the sea-surface temperature in the Indian Ocean contribute to climatic variability by their effect on the passage of north-west rain-bearing cloud bands. In some seasons, these cloud bands bring increased winter rainfall to southern and western parts of the continent.

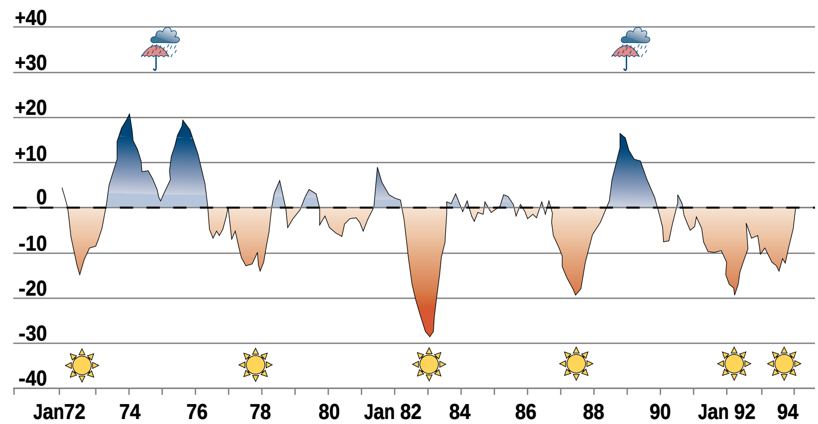
Figure 5.10 Major drought areas during ENSO years since 1972



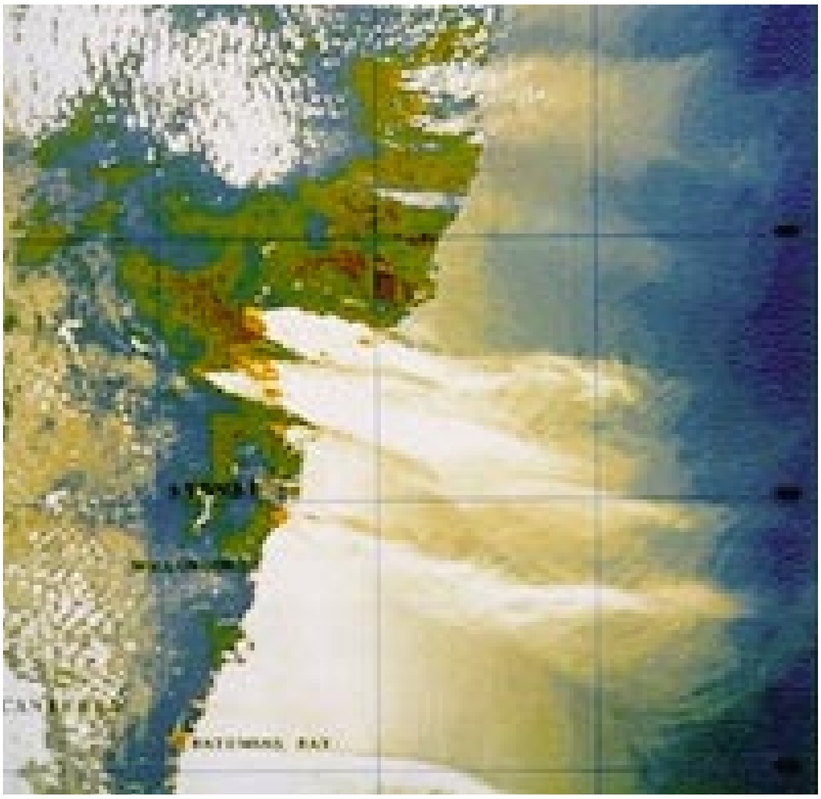
Past ENSO-related droughts in Australia and the distribution of rainfall over Australia for 1994, demonstrating a pattern of drought during an extreme ENSO event. In Australia, meteorological drought conditions are said to apply when monthly rainfall totals fall below the lowest 10 per cent of all recorded values for a period of at least 9–12 months.

Source: Bureau of Meteorology.

Figure 5.11 Fluctuations in the SOI since 1972



Source: Bureau of Meteorology.



Long range transport of smoke from the 1994 bushfires in NSW during a prolonged El Niño event.

The cycle of wet periods followed rapidly by dry ones, increases the risk of fires caused by natural conditions (such as dry thunderstorms) and by human activities. Vast areas of the interior are subjected to bushfires during extended dry periods. The major ENSO-related drought of 1982–83 was marked by severe bushfires in south-eastern Australia; similarly, in January 1994 fires devastated areas of New South Wales. Smoke haze and aerosols from fires can affect large areas downwind.

Highly variable rainfall and extremes in wind can also lead to severe soil erosion and blowing dust. When heavy drought-breaking rains fall on bare soils, further soil erosion may occur.

As well as climate variability linked to the ENSO, longer-term fluctuations can occur. Some studies (Salinger *et al.*, in press) have investigated changes in circulation patterns, particularly in the mid to high latitudes of the southern hemisphere, over the past 100–120 years. Results show that patterns during the periods 1870–1900 and 1950–1990 resembled one another more closely than they did between 1900 and 1950. In particular, the strength of the high pressure systems in the subtropical ridge has increased since the 1950s.

In the period 1951–93, mean temperatures across Australia showed a consistent warming in the range of 0.1 to 0.2°C per decade and above 0.2°C per decade for a broad zone across the country (see Fig. 5.12). By contrast, a cooling trend was observed earlier in the century (1910–51). The observed warming over the past few decades is mainly due to an increase in night-time air temperatures. Thus the diurnal temperature range (the difference between the daytime maximum and the overnight minimum temperatures) decreased over Australia during 1951–1993, with the largest decrease — of about 0.4°C per decade — occurring in the north-east interior. The trend towards night-time warming is consistent with land temperature trends worldwide. Records show an increase in cloudiness over Australia, which is also consistent with a similar trend occurring in North America, Europe and India. After detailed analysis of long-term climate records, Salinger *et al.*, (in press) concluded 'there is a longer-term climate warming trend which is not inconsistent with the enhanced greenhouse effect, and is not directly related to ENSO'.

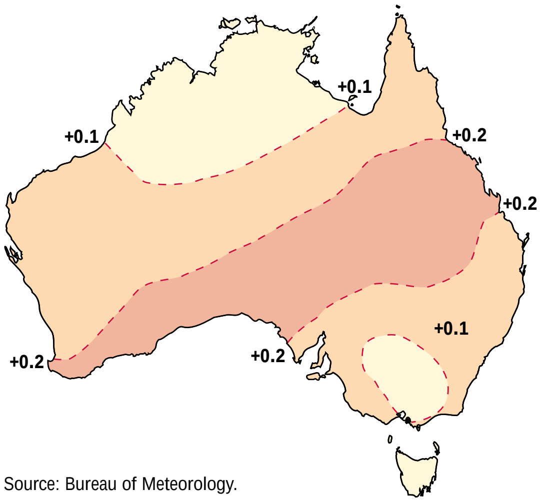
Atmospheric dispersion and transport

Atmospheric stability is the major meteorological factor controlling the vertical mixing of air pollutants. When conditions are 'unstable', gases and smoke in the atmosphere are quickly mixed (especially in the vertical plane), and so pollutants soon disperse. Such conditions of strong vertical mixing are typical of warm to hot sunny days.

By contrast, vertical mixing is reduced under stable conditions. In some circumstances, the temperature of a layer of air can actually increase with height, rather than decrease as would happen normally. This situation, known as a temperature inversion, generally occurs overnight under conditions of light winds and clear skies when the earth's surface cools rapidly. As very little vertical mixing of polluted air takes place in an inversion layer, pollution accumulates under or within the stable layer of air.

The prevailing wind speed and direction also influence the dispersion of emissions. The greater the wind speed becomes, the greater the volume occupied by the emissions and the greater their dilution. Increased wind speeds also promote increased turbulence and greater vertical mixing. The wind direction determines the shape of a plume and the path it follows. (The term 'plume' covers emissions from a variety of sources, whether backyard incinerators, vehicle exhausts, elevated

Figure 5.12 Trends in annual mean temperature (°C) over Australia for the period 1951 to 1992



Source: Bureau of Meteorology.

single sources such as industrial chimneys or an entire city.)

In urban areas, assuming no rain falls, the concentration of the urban plume will be determined by the rate of emission of pollutants (from all sources) and the volume of air into which they are emitted. This volume in turn is determined by the average wind speed and the stability of the atmosphere.

Airsheds

In addition to the weather patterns briefly discussed earlier, Australia's long coastline and the large temperature difference between land and sea can greatly influence the patterns of local air circulations and thus air quality.

One of the features experienced to some degree along the entire coastal fringe is a phenomenon known as the sea-breeze/land-breeze regime. During day-time, and under conditions of light or favourable winds, a temperature contrast builds up between the land and the cooler ocean, resulting in a regular onshore sea-breeze. These sea-breeze circulations usually extend about 500–1000 metres vertically.

During the night, stable conditions, light winds and clear skies aid the rapid cooling of the land surfaces. Air in contact with the ground cools faster than the air in the free atmosphere, so cooler (and therefore denser) air near the surface flows down any slope towards lower ground, where it may combine with other cold air flows. Because circulations of this type are typically confined to the lowest 300–500 metres, even relatively low-level terrain can produce such drainage flows of air (see Fig. 5.13). The ways in which these flows interact is what determines the extent of an airshed. In Australia, the regional airsheds around each major city are discrete and widely separated.

Sometimes, areas along the coastal fringe experience a daily reversal in the direction of air flow (see Fig. 5.14). This usually happens under conditions of a stable atmosphere and light winds. Studies show that, under these circumstances, air carried inland by the afternoon sea-breeze can recirculate in overnight drainage flows. This cycle can continue for some time — up to three days in summer. Pollutants released into the airsheds are trapped within the circulation and concentrations may build up in the lower levels. Some pollutants, mainly those emitted by motor vehicles, can undergo chemical reactions in the presence of sunlight to form photochemical smog (see the box on page 5-25).

By world standards, Australia receives a lot of sunshine. Most of the country experiences, on average, about six hours a day, with some areas receiving more than 10 hours. As a result, the potential for photochemical smog formation is high in all our cities in the summer, and remains so in the winter in northern cities such as Brisbane.

Recirculation of air within urban coastal airsheds is one of the most important events linked to the formation of photochemical smog and ozone episodes monitored over urban areas (Manins *et al.*, 1994). At certain times, major population centres, including the capital cities of Sydney, Brisbane, Perth and Melbourne, are subjected to recirculation and with it, photochemical smog formation (see Fig. 5. 31).

Figure 5.13 Formation of valley wind, drainage flows within an airshed

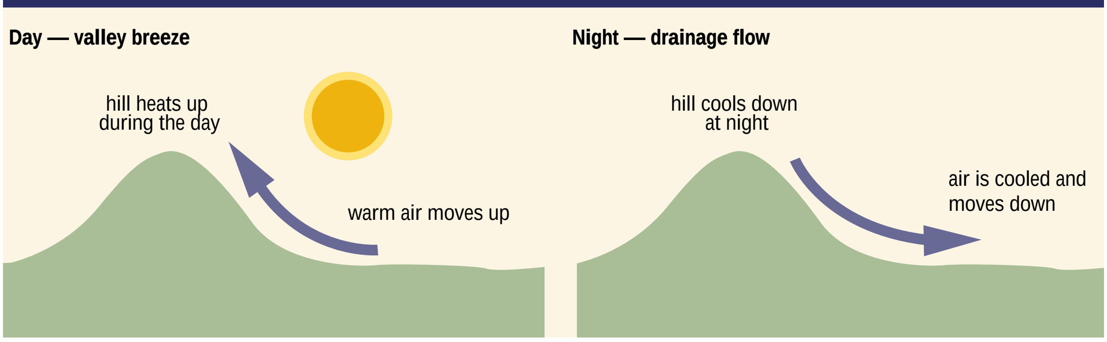
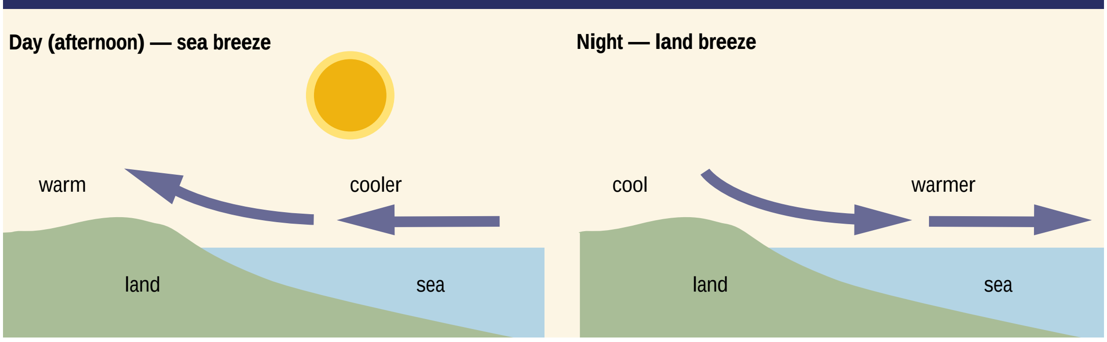


Figure 5.14 Formation of land and sea breezes



The enhanced greenhouse effect

Nitrogen and oxygen — the main components of the earth's atmosphere — are almost completely transparent to the sun's rays. The clouds, the oceans, land, snow and ice reflect about one-third of the incoming solar (short-wave) radiation. The earth absorbs the remaining two-thirds of the solar energy, mainly in the tropics, from where large-scale circulations in the oceans and the atmosphere redistribute it. Ultimately, it is re-radiated back to space as infra-red (long-wave) radiation, thus maintaining a balance with the absorbed solar radiation.

Water vapour, carbon dioxide and other trace gases absorb infra-red radiation emitted by the earth's surface and, as a result, have a major impact on this radiation balance. The absorbed radiation is not retained but re-emitted in all directions, thus increasing the temperature of the earth's surface. This warming effect, long recognised as a major element of the climate system, is known as the greenhouse effect. Without clouds, water vapour and these other so-called greenhouse gases (but with no change in the amount of solar radiation reflected back to space) the global surface temperature would average –18°C rather than the present 15–16°C.

We now know that human activity has led, and is still leading, to increased atmospheric concentrations of existing greenhouse gases (carbon dioxide, methane, nitrous oxide and ozone), as well as to the presence of new greenhouse gases such as CFCs. Most of these gases, once released into the atmosphere, persist for tens to hundreds of years, with an associated long-term impact on the background atmospheric levels. Using an understanding of the processes that govern the climate system, and applying this knowledge in computer climate models, scientists consider that the presence of additional greenhouse gases will affect the radiation balance of the atmosphere and lead to a warming at the earth's surface. This is now generally referred to as the enhanced greenhouse effect.

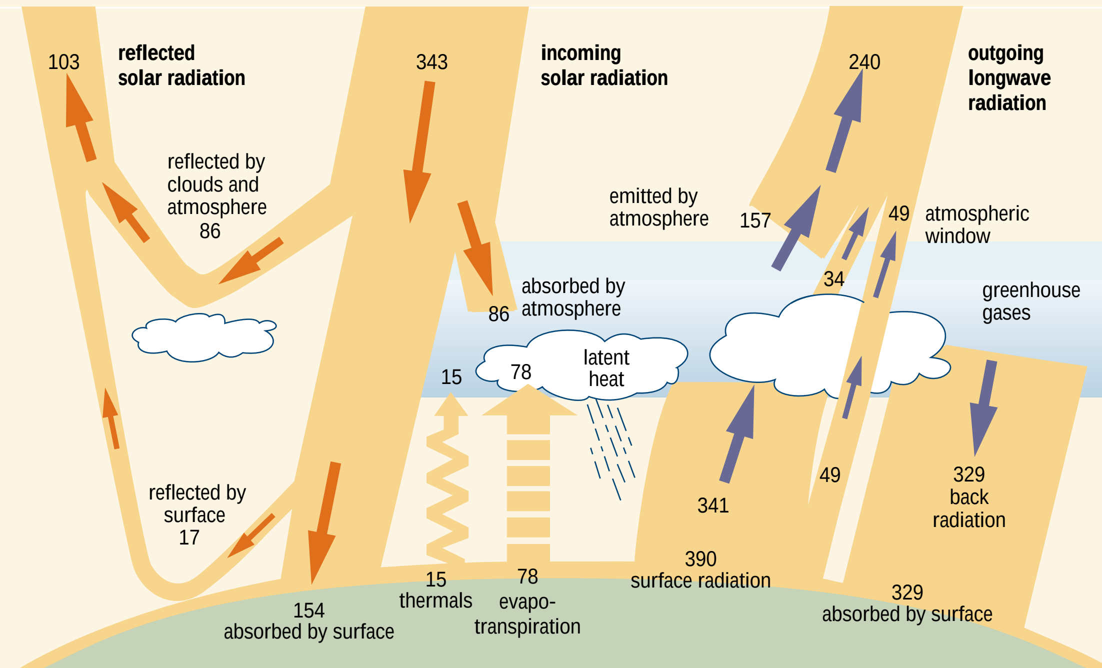
The actual impact on global climate is likely to be complex and involve changes in atmospheric and oceanic circulations, accompanied by possible changes in sea level, diurnal temperatures, rainfall and other climatic variables. While climate model simulations already offer predictions of the global impact of the enhanced greenhouse effect, only broad indications of potential change on a regional scale are currently available.

A further complicating factor has emerged in recent years. This is the realisation that, in addition to raising greenhouse gas levels, human activity is also leading to an increase of aerosols in the lower atmosphere. The most significant are sulfate aerosols that come from sulfur dioxide emissions from power generation and ore processing (see page 5-29). Carbon-based aerosols produced by burning biomass are also important. Aerosols can reflect sunlight as well as change the amount, type and radiative behaviour of clouds, resulting in a lowering of surface temperatures. Due to their short lifetime (days/weeks), their cooling effects are temporary and regional, but for some regions, particularly in the northern hemisphere, the cooling is estimated to be about the same as the warming effects of CO_2.

Since the 1990 Intergovernmental Panel on Climate Change (IPCC) First Assessment Report, considerable progress has been made to distinguish between natural and anthropogenic influences on climate. In its Second Assessment Report (IPCC, 1995) the IPCC concludes that despite uncertainties in key factors, 'the balance of evidence suggests that there is a discernible human influence on global climate'.

IPCC (1995) projects an increase in global mean surface temperature relative to 1990 of about 2°C by 2100 and a corresponding increase in sea level of about 50 cm.

The earth/atmosphere energy balance (watts per square metre)



About half the sun's incoming radiation reaches the earth's surface where some is reflected and absorbed. The atmosphere is not nearly as transparent to the long-wave radiation from the earth. Only a small amount of this radiation is lost directly to space. The remainder is absorbed by the atmposphere and the clouds with enough re-emitted upwards and out to space to maintain the total radiation balance.

Source: IPCC, 1994.

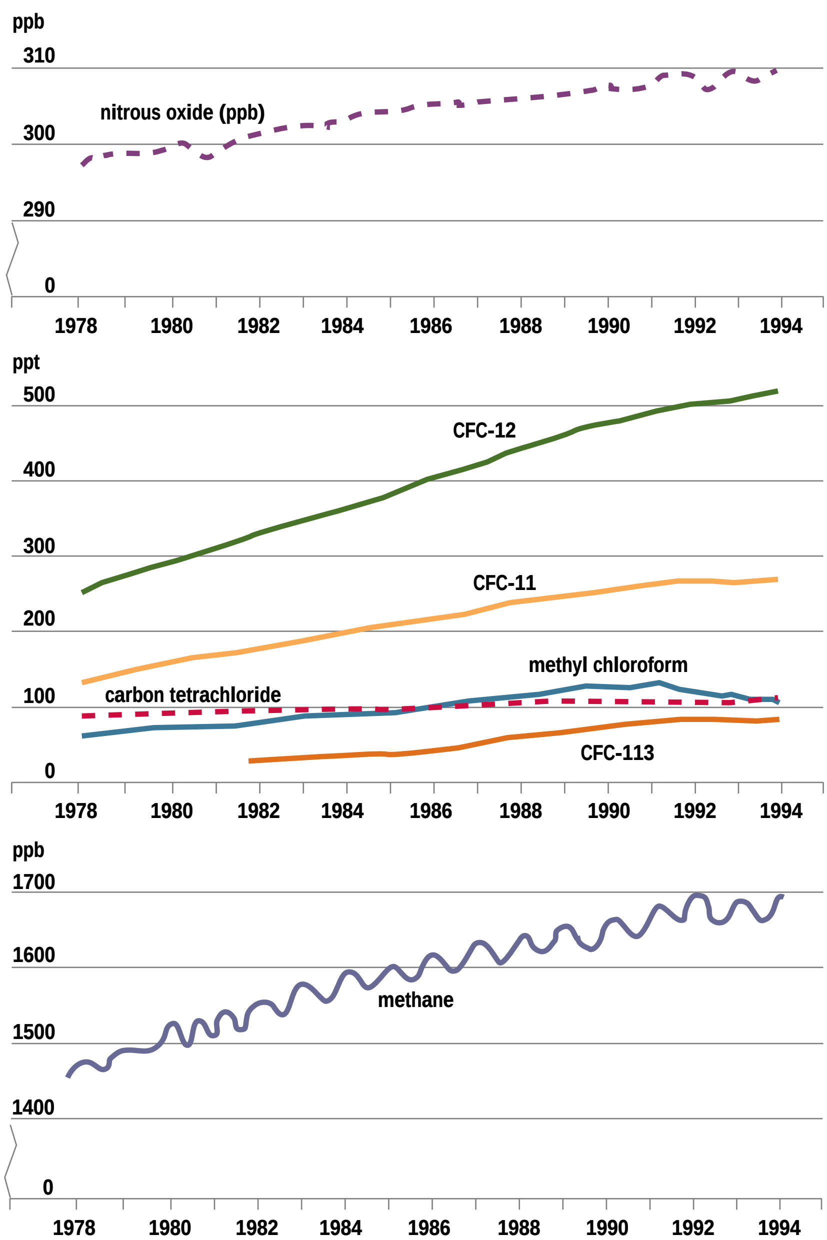
Enhanced greenhouse effect

The major scientific conclusions of the Intergovernmental Panel on Climate Change (IPCC) are that emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases carbon dioxide, methane, tropospheric ozone, nitrous oxide and CFCs. Since the time of the Industrial Revolution (about 200 years ago), the atmospheric concentration of carbon dioxide has increased by more than 30 per cent, that of methane by more than 145 per cent and that of nitrous oxide by about 15 per cent (IPCC, 1995). Climate models indicate that the sensitivity of global surface temperature to a doubling of carbon dioxide is likely to be an increase in the range of 1.5 to 4.5°C. The Panel identified many uncertainties, particularly with regard to the timing, magnitude and regional patterns of climate change. (See the discussion of the enhanced greenhouse opposite). Nevertheless, the IPCC Second Assessment Report (1995) concluded that 'the balance of evidence suggests that there is a discernible human influence on global climate'.

A global network of monitoring stations provides information on the current concentrations of greenhouse gases in the atmosphere. Australia participates in this network through Tasmania's Cape Grim (see Fig. 5.15). Analysis of Antarctic ice cores dating back to the 1300s, collected and analysed by the Australian Antarctic Division and CSIRO, clearly demonstrates the dramatic increase in the atmospheric concentrations of CO_2 since the early 1800s (see Fig. 5.16).

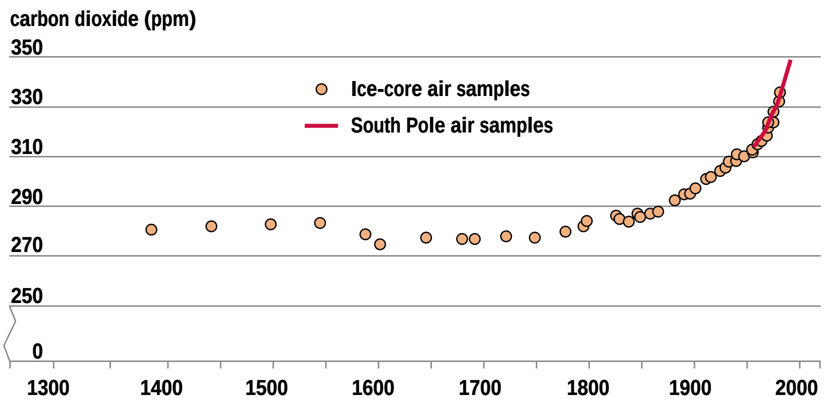
The Cape Grim data, representing the state over much of the southern hemisphere, help us piece together a better global picture, as well as helping us understand the differences between the two hemispheres. The records have made an important contribution towards understanding the science of the atmosphere. It is clear from the measurements that, unless large reductions in emissions occur, the concentrations of most greenhouse gases will continue to rise well into the next century. Indeed, the IPCC (1994, 1995) has reported that, according to a range of models, the atmospheric concentration of CO_2 will more than double unless global emissions are reduced substantially below 1990 levels.

Figure 5.15 Greenhouse gas concentrations at Cape Grim since 1978



Source: CSIRO and Cape Grim Baseline Air Pollution Station.

Figure 5.16 Atmospheric carbon dioxide concentrations since 1300 determined from Antarctic ice cores



Source: CSIRO and Australian Antarctic Division.

Stratospheric ozone loss

The ozone layer in the stratosphere protects life on the earth's surface from damaging quantities of UV radiation (see the box on page 5-11). Since the late 1980s, seasonal ozone losses above Antarctica have been severe, with more than 60 per cent of the total ozone being destroyed in spring over a region covering most of the continent as shown by satellite measurements (see Fig. 5.17).

The concentration of ozone in a column of air stretching up from the earth's surface is reported in Dobson Units (DU).

During the middle of an average year in the 1990s, ozone values over Antarctica are about 300–320 Dobson units (DU) (compared with 330 to 350 DU in the early '80s). During spring 1994, total ozone fell to a low of 90 DU in the last week of September, a value similar to the 1993 ozone minimum. Typically, the area of the ozone 'hole' in the 1990s is from 20 to 24 million sq km.

The long term decline in springtime ozone levels over the polar region is also evident from complementary ground-based measurements at Halley Bay in Antarctica (see Fig. 5.18).

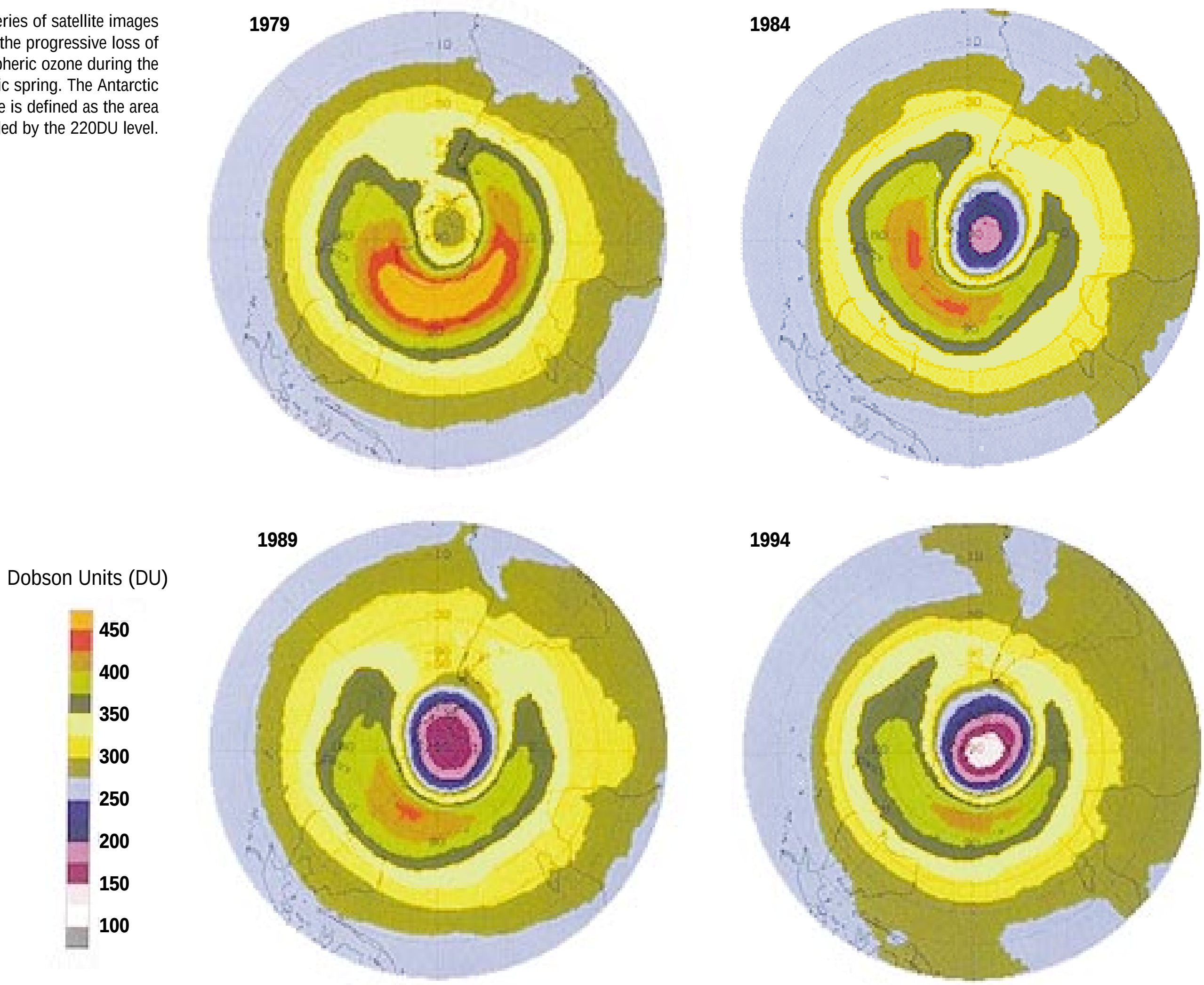
Ozone depletion is not just a polar phenomenon. Losses in stratospheric ozone of between two and four per cent per decade have been detected in mid latitudes, including over Australia (WMO, 1995).

The Bureau of Meteorology carries out stratospheric ozone monitoring at five sites in the Australian region. Their results show that ozone depletion now occurs over the most populated parts of Australia all year round (see Fig. 5.19). The occasional passage of ozone-depleted air moving across the south of the country in late spring, following the break-up of the Antarctic ozone hole, may exacerbate the situation.

Stratospheric ozone loss results in an increase in ground-level UV. A few locations worldwide (particularly Antarctica) have recorded an increase in UV-B, the most damaging waveband. The extent of the UV increase correlates well with the measured stratospheric ozone depletion at the relevant latitude (Basher *et al*., 1994). Accurate

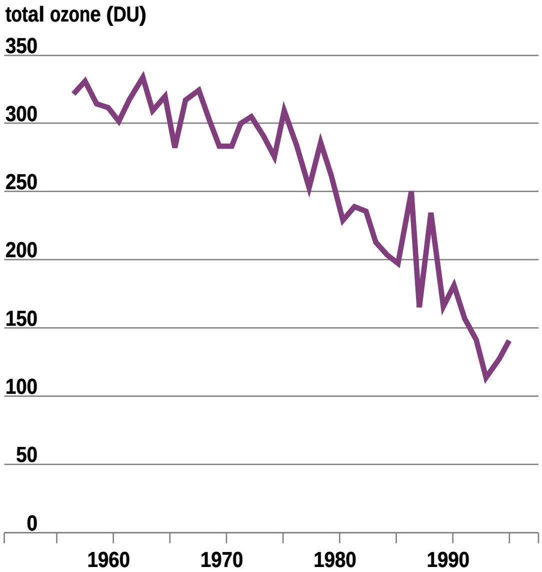
Figure 5.17 Stratospheric ozone levels over the Southern Hemisphere during October for selected years

This series of satellite images shows the progressive loss of stratospheric ozone during the Antarctic spring. The Antarctic ozone hole is defined as the area bounded by the 220DU level.



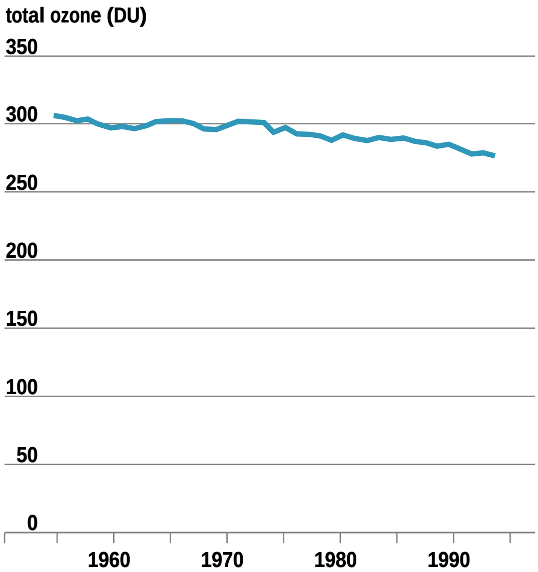
Source: satellite imagery by courtesy of NASA.

Figure 5.18 Total ozone during October over Halley Bay, Antarctica



Source: British Antarctic Survey.

Figure 5.19 Total ozone depletion during January in the air column over Melbourne

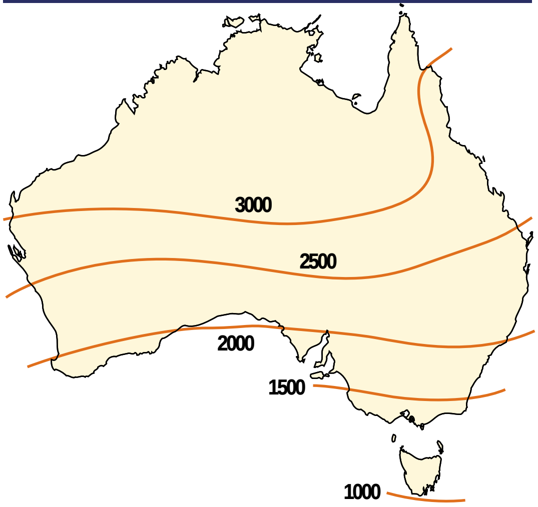


Source: Bureau of Meteorology.

monitoring of UV-B radiation is technically difficult. No country has carried out reliable long-term UV monitoring, but Australia and other countries have recently started taking regular measurements. The greatest UV increases in Australia (in percentage terms) are estimated to have occurred in the most southerly (that is, higher) latitudes (Fraser and Bouma, 1990). However, higher-latitude regions, being further from the equator, naturally receive the least amount of total solar radiation (see Fig. 5.20). Although their exposure to UV has increased proportionally the most, southern regions still receive much less UV radiation in total than places nearer the equator.

There is no precise correlation between increased ground-level UV irradiation and human health problems, but there is a clear link between exposure and a range of disorders — for example, the incidence of skin cancer is higher in Queensland than in Tasmania (Marks, 1989). However, recent changes in human behaviour to avoid exposure, brought about by greater public awareness of the issue, make predictions difficult. Information about UV levels is now presented during television weather reports, although this provides broad guidance only. Potential reductions in the yields of some crops, and effects on oceanic plankton, need further research.

Figure 5.20 Sunburning radiation levels

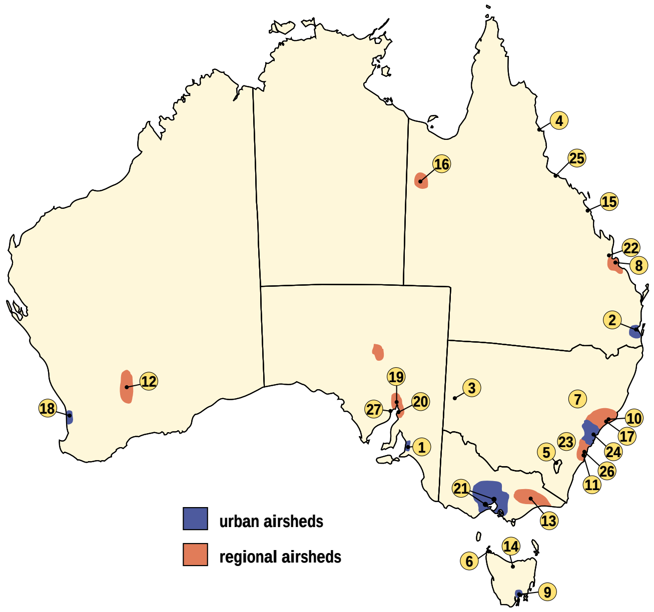


Note: The calculated average daily dose of the 'sunburning' component of sunlight is measured in erythemal dosage units. Calculations for the above figure include the effects of cloud cover.

Source: Paltridge and Barton, 1978.

Cape Grim Baseline Air Pollution Station, north-west Tasmania, is part of a global network for monitoring background atmosphere.

Figure 5.21 Australian urban and regional airsheds with ambient air-quality monitoring



Note: The numbers refer to the table below

National ambient air quality monitoring

While our perception of air 'quality' is often based on how far we can see, the Australian guidelines have largely been based on considerations of what is optimal for human health.

The primary responsibility for environmental management, and thus for the monitoring of air quality, rests with individual States and Territories. Most jurisdictions have implemented some form of routine monitoring program with the goal of assessing the impacts of ambient air quality on human health. Since the late '70s, Sydney, Melbourne and Brisbane (representing a combined population of some eight million people) have had reliable air quality data. Some other jurisdictions have long records for certain selected parameters. Routine monitoring by State and Territory agencies is limited to:

- the major metropolitan areas surrounding most capital cities (except Hobart and Darwin) — areas referred to as 'urban airsheds'
- selected regional areas such as the Latrobe and Hunter Valleys, which contain major thermal power-generating stations linked to coal deposits,

Table 5.6 Number of sites at which air quality indicators are routinely monitored and for which quality assured data are publicly available as at June 1995

Location	O_3	CO	NO_2	SO_2	Visibility	TSP	Pb	Dust	PM10	PM2.5	F	PAH	VOCs	Airtrak
1. Adelaide	2	1	2	1	2	9	9	-	-	-	-	-	-	-
2. Brisbane	8	1	9	3	4	-	5	11	-	-	-	-	-	2
3. Broken Hill	-	-	-	-	-	3	3	27	-	-	-	-	-	-
4. Cairns	-	-	-	-	-	1	-	-	-	-	-	-	-	-
5. Canberra	2	2	2	-	2	5	5	-	-	-	-	-	-	-
6. Cape Grim	1	1	-	1	-	-	1	-	1	1	-	-	-	-
7. Central Tablelands	-	-	-	-	-	2	-	10	-	-	-	-	-	-
8. Gladstone	-	-	3	2	2	-	-	-	2	-	-	-	-	-
9. Hobart	-	-	-	-	-	✓	✓	-	-	-	-	-	-	-
10. Hunter Valley	-	-	-	4	-	20	-	194	-	-	14	-	-	-
11. Illawarra	-	-	-	8	-	9	2	60	-	-	-	16	-	-
12. Kalgoorlie	-	-	-	11	-	-	-	-	-	-	-	-	-	-
13. Latrobe Valley	2	-	2	2	2	-	-	-	-	-	-	-	-	-
14. Launceston	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-
15. Mackay	-	-	-	-	1	-	-	-	-	-	-	-	-	-
16. Mt Isa	-	-	-	1	-	-	-	-	-	-	-	-	-	-
17. Newcastle	2	1	11	10	-	9	7	15	2	-	12	18	-	-
18. Perth (incl. Kwinana)	9	3	11	6	6	3	3	-	4	6	-	-	2	2
19. Port Augusta	-	-	-	✓	-	✓	-	-	-	-	-	-	-	-
20. Port Pirie	-	-	-	✓	-	✓	✓		✓	-	-	-	-	-
21. Port Phillip Region	11	5	9	7	10	5	5	-	1	-	-	-	3	-
22. Rockhampton	-	-	-	-	-	2	-	-	-	-	-	-	-	-
23. Southern Tablelands	-	-	-	-	-	-	-	11	-	-	-	-	-	-
24. Sydney	13	8	11	4	8	4	4	10	6	-	-	-	-	1
25. Townsville	-	-	-	-	-	-	-	6	2	-	-	-	-	-
26. Wollongong	2	4	2	2	2	4	5	17	1	-	-	3	-	-
27. Whyalla	-	-	-	-	-	✓	✓	-	-	-	-	-	-	-

Source: Based on Ormerod, in press.

✓ = monitored but number of monitors not specified.

and a few other major industrial centres, referred to as 'regional airsheds'

- some isolated areas around individual large sources of emissions referred to as 'hot spots'

Consequently, we cannot adequately assess ambient air quality over much of Australia because of a lack of data.

Monitored areas

Monitoring covers only about five per cent of the country by area (see Fig. 5.21 and Table 5.6). Although the reporting standards applied to air quality data differ slightly between State and Territory agencies, they are generally subject to well-defined quality control and assurance procedures. The design of the monitoring network and the parameters monitored are a compromise between scientific needs and available resources. With increased knowledge, particularly about the formation of photochemical smog, some monitoring programs, especially in the greater Sydney airshed (Hyde and Johnson, 1990) have been re-evaluated and refocused. The New South Wales government provided substantial resources for the Metropolitan Air Quality Study which has been completed recently. In Victoria, work has started on optimising the design of networks (EPAV, 1994; Ahmet and van Dijk, 1994).

As well as monitoring by government agencies, certain industrial locations undertake extensive self-monitoring. However, the quality of the data in these cases is often unknown and the data themselves are often not in the public domain.

Traditionally, the focus of concern has been on some or all of the general indicators of air quality (SO_2, CO, NOx, ozone, particulates, lead). Recently, however, it has become apparent that some of the more common toxic air pollutants, such as benzene, are present in sufficient concentrations to warrant closer monitoring. So far, investigations have been limited to several discrete surveys rather than long-term programs. Hence the indicators to be routinely monitored should be re-evaluated.

The jurisdictions and organisations that undertake air quality monitoring archive the data themselves. Consequently, no national air quality data set exists.

For the assessment of national ambient (outdoor) air quality, the National Health and Medical Research Council (NH&MRC) and the Australian and New Zealand Environment and Conservation Council (ANZECC) have jointly recommended guidelines that could be used as a basis for comparison across the nation (see Table 5.7). However, some differences occur between agencies in the monitoring, reporting and adoption of these guidelines. As well, some State government bodies have traditionally granted exemptions to specific licensed emitters.

As national ambient air quality guidelines are not uniformly applied, it is difficult to make comparisons between jurisdictions and any such comparisons should only be considered as 'indicative'.

Table 5.7 Ambient Air Quality Guidelines(a) recommended by NH&MRC/ANZECC as at June 1995

Pollutant	Averaging Time	Concentration
Ozone	1 hour	0.12 ppm(b) (under review)
Nitrogen dioxide	1 hour	0.16 ppm(c)
Sulfur dioxide	10 minutes 1 hour 1 year	0.5 ppm 0.25 ppm(b) 0.02 ppm
Carbon monoxide	8 hours	9 ppm(b)
Total suspended particulate matter	1 year	90 µg/m^3
Lead	3 months running mean	1.5 µg/m^3
Fluoride (General Land Use)	12 hours 1 day 7 days 30 days 90 days	3.7 µg/m^3 2.9 µg/m^3 1.7 µg/m^3 0.84 µg/m^3 0.5 µg/m^3
(Special Land Use)	12 hours 1 day 7 days 30 days 90 days	1.8 µg/m^3 1.5 µg/m^3 0.8 µg/m^3 0.4 µg/m^3 0.25 µg/m^3
Sulfates	1 year	15 µg/m^3(d)

Note:
(a) With the exception of fluoride (where the guideline was established to protect vegetation), all these guidelines are based on protecting human health
(b) not to be exceeded more than once per year
(c) not to be exceeded more than once per month
(d) read in conjunction with TSP

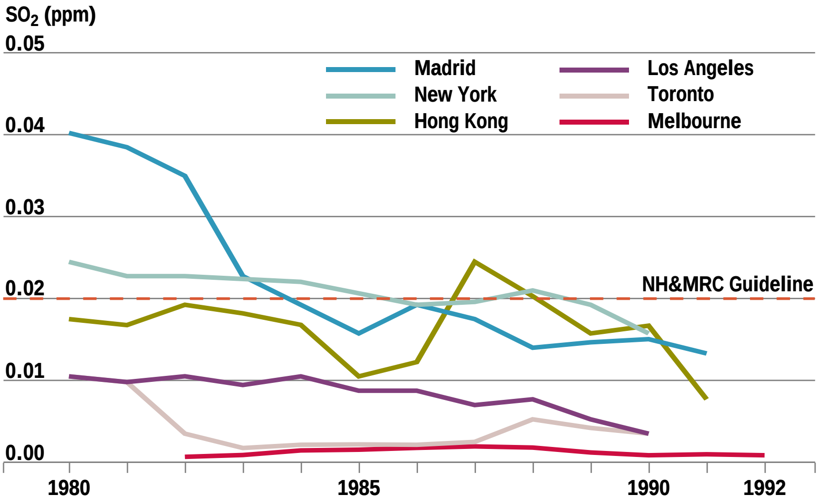
Areas not monitored

For the 95 per cent of Australia not covered by routine monitoring, it is believed that the following issues are of major concern:

- sulfur dioxide from industrial point sources, such as coal-fired power stations and major ore-processing plants
- heavy metals (including lead) from ore processing
- particulates from forestry and agricultural activities such as controlled burning, bushfires and the erosion and transport of fine topsoil by strong winds
- pesticides from aerial spraying
- emissions caused by heavy traffic along some roads in rural areas

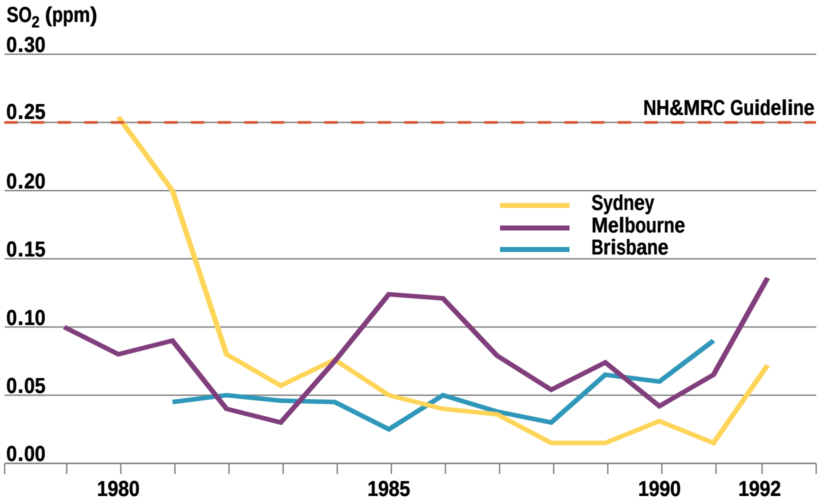
Although our knowledge about the actual levels of these pollutants and their dispersion is incomplete, it is likely that in the more remote areas of Australia, where there is little human activity, air quality is good (that is, within the guidelines) most of the time. Few studies have been undertaken on the impact that emissions, photochemical smog and ozone may have on vegetation in urban areas.

Figure 5.22 Annual average concentrations of sulfur dioxide for selected international cities



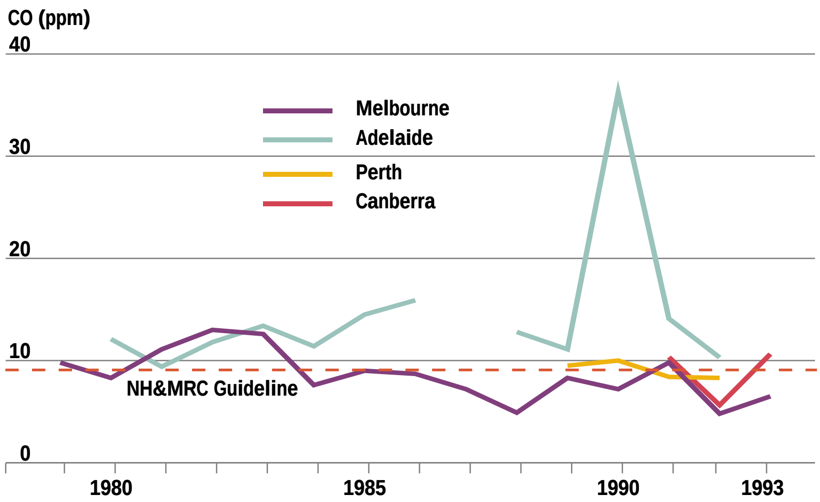
Source: Various.

Figure 5.23 Highest one-hour concentrations of sulfur dioxide for selected Australian cities



Source: State environmental authorities.

Figure 5.24 Highest eight-hour carbon monoxide concentrations for selected Australian cities



Source: State and Territory environmental authorities.

Urban air quality

Motor vehicles are the main source of emissions in urban areas, although industrial sources also contribute. As most power stations are located near coalfields and outside urban areas, their emissions do not generally affect urban air quality.

Sulfur dioxide

By and large, Australian cities do not have a sulfur dioxide (SO_2) problem, primarily because fuels used are low in sulfur and also because power stations are not located in urban areas. Some industrial sources of SO_2 do exist, such as oil refineries on the outskirts of urban areas, and these can pose local problems.

Annual SO_2 averages in Melbourne and Sydney are substantially below the 0.02 ppm guideline. Melbourne's average for the period 1980–84 was 0.002 ppm, which compares well with, for example, Tokyo's average of 0.01 ppm in 1988–89 or New York's of 0.015 ppm in 1986–87 (see Fig. 5.22). Highest annual one-hour SO_2 concentrations measured in most Australian capital cities are also well below the NH&MRC guideline (see Fig. 5.23).

Carbon monoxide

A product of incomplete combustion, carbon monoxide (CO), is found in the exhaust emissions of all motor vehicles. As an air quality issue, concern is mainly confined to inner city regions with high traffic density. High winter-time concentrations of CO in some suburban areas can be related to the use of wood fires and combustion stoves. However, recorded values are strongly dependent on the precise siting of the measuring instruments. It is therefore difficult to carry out true comparisons between cities because instruments in some are located very close to high-density traffic flows. In the past ten years, Sydney, Perth, Adelaide and Canberra have all exceeded the NH&MRC eight-hour CO guideline (nine ppm) in locations close to high traffic flows (see Fig. 5.24).

Lead

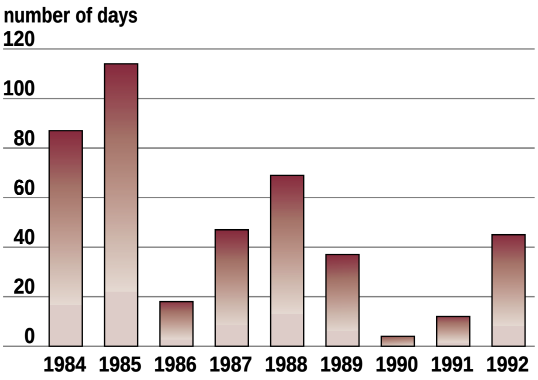
The major source of airborne lead in Australian urban areas is still from leaded fuel used in motor vehicles. However, the emissions from this source have declined considerably in all cities over the past decade because of the introduction of unleaded fuel for cars fitted with catalytic converters and a reduction in the lead content of leaded fuel (see Fig. 5.35).

Odour

Many of the gases and aerosols responsible for unpleasant odours are volatile organic and sulfur-containing compounds. The extreme sensitivity of the human nose to some of these chemicals means that some people can smell them even at very low concentrations. The fact that certain odours are mixtures, makes it hard to quantify and regulate them.

Industries such as petroleum refining, food processing and tallow rendering can all produce

Figure 5.25 Number of days in Sydney when eight-hour carbon monoxide exceeded NH&MRC guideline



Source: EPA NSW.

odours. Other sources are sewage and waste-water treatments, various metal processing and manufacturing industries, and some types of intensive agriculture.

'Bad smells' are an important issue with the public. Available data suggest that from 30 to 60 per cent of all air quality complaints received by State environmental agencies relate to odours.

Air toxics

Air toxics are defined as pollutants present at very low concentrations which are known to cause or are suspected of causing long-term health effects in humans. In the United States, 189 of some 2000 synthetic chemicals emitted to the atmosphere have been identified as air toxics and are regulated by the EPA. Many air toxics are either volatile organic compounds or metallic compounds that could affect health following long-term exposure at very low concentrations.

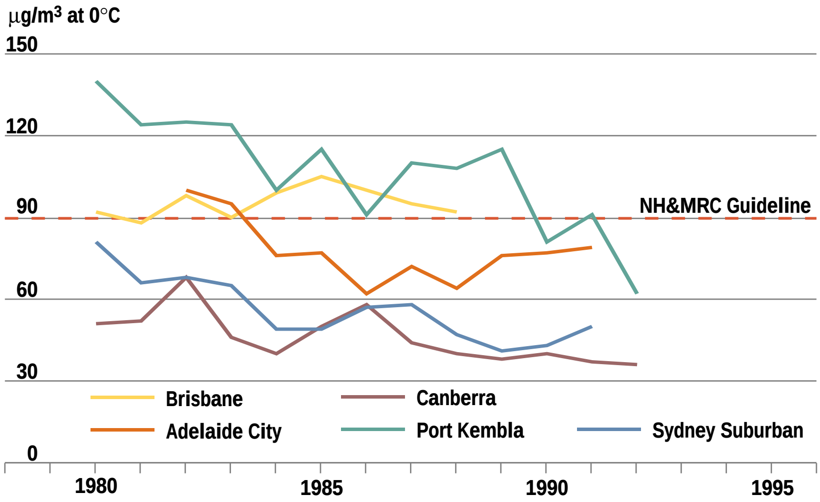
As yet, Australia has no list of air toxic emissions, but a national pollutant inventory now being developed will include them. The EPA in Victoria has recently carried out studies of air toxic emissions from motor vehicles in Melbourne and from petrochemical industries in the suburb of Altona. Other measurements have shown that Sydney city air contains common air toxics at concentrations similar to those observed in major US cities (Nelson and Duffy, 1994).

Particles

Particles of various sizes are suspended in the air and can reduce its clarity. In Australian cities these particles include: sea salt; sulfate from sea salt and from SO_2 emissions; carbon from combustion processes; silica from soil; and pollen. Lead and other contaminants may also be involved.

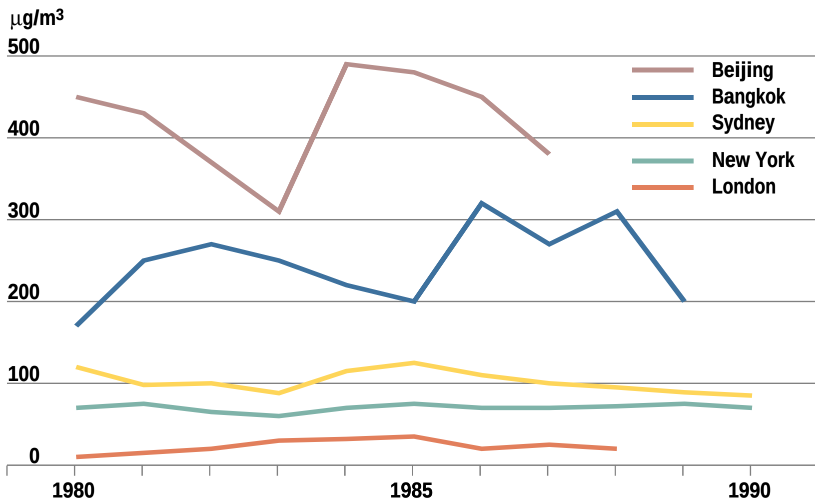
Particles are monitored and reported in size-related categories. Total suspended particles (TSP) include all particles from the smallest up to 50µm in diameter: within this range are sub-categories of those less than 10µm in diameter, known as PM10, and those smaller than 2.5µm known as PM2.5.

Figure 5.26 Annual average concentrations of total suspended particles (TSP) for selected Australian cities



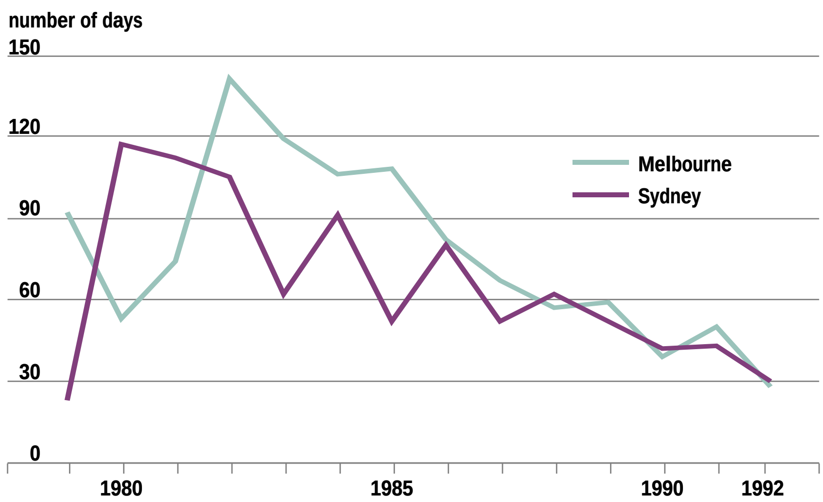
Source: State and Territory environmental authorities.

Figure 5.27 Annual average TSP concentrations in selected international cities



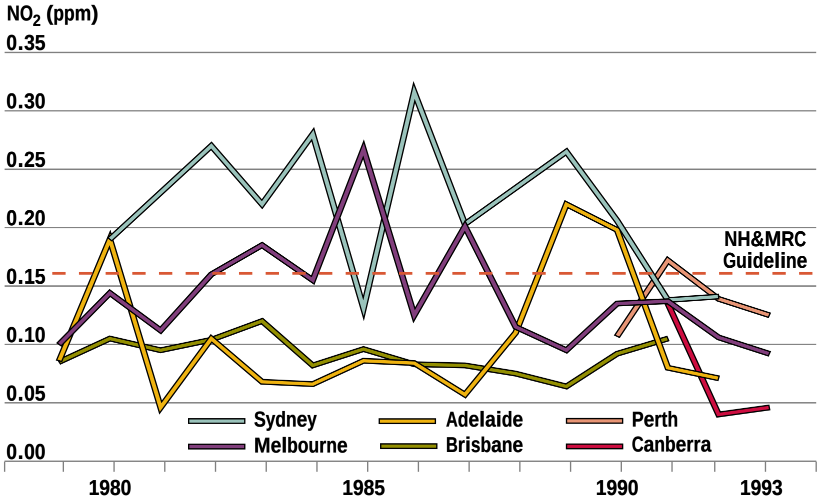
Source: Various.

Figure 5.28 Number of days in Sydney and Melbourne with visibility less than 20 km



Source: EPA NSW and EPA Victoria.

Figure 5.29 Highest one-hour nitrogen dioxide concentrations for selected Australian cities



Source: State and Territory environmental authorities.

Associated problems include:

- health effects: PM10 and PM2.5 are of most concern to human health because particles up to about 10µm in size can travel deep into the lungs and become lodged there; pollen (which varies in size) can provoke an allergic response in some people
- visibility reduction from particles in the PM2.5 range
- soiling by particles settling on surfaces

For about the last decade, urban airsheds in Australia have recorded falling levels of total suspended particulates. While levels in Sydney are not as high as those of some cities in less-developed countries, they are similar to those of other major cities in developed countries (see Figs 5.26 and 5.27).

The trend in recent years has moved away from monitoring TSP and towards monitoring PM10. The different types of measurement used, and the fact that not all capital cities measure the full range of categories, make it difficult to compare cities.

Under certain weather conditions smoke from bushfires can reduce visibility for several days.

The NH&MRC does not have a guideline for PM10. Available data indicate that average annual levels have been generally below 40 µg per cubic metre (as recommended for Victoria by Streeton, 1990), but that levels at some sites on some days in Sydney, Brisbane, Wollongong and Newcastle would have exceeded the Victorian recommended 24-hour level of 120 µg per cubic metre. However, it is impossible to discern trends, as the data have been collected for too short a time.

Only limited data are available on the concentration of PM2.5. However, their presence is indicated by a reduction in visibility. Existing data suggest that Sydney and Melbourne have experienced the most severe occurrences of urban haze, but improvements have occurred since the early 1980s due partly to tighter controls on industrial and vehicle emissions and to the banning of backyard burning. Monitoring shows that visibility in major cities has improved over the past decade (see Fig. 5.28).

Bushfires and controlled burns

Smoke from bushfires or fuel-reduction burns in the hinterland may drift into major urban airsheds, and under certain weather conditions can reduce visibility for several days. Some of the major air pollution episodes recorded in capital city airsheds have occurred when smoke from controlled burning was trapped during periods of air recirculation.

Photochemical smog and its precursors

When oxides of nitrogen (NOx) and reactive volatile organic compounds (VOCs) are present in the air in sufficient quantities, in the presence of sunlight, chemical reactions give rise to a type of smog. Because these reactions are stimulated by light, it is known as photochemical smog. Both NOx and reactive VOCs are necessary precursors for the production of smog. Ozone is a major product of this photochemical oxidation process (see the box on page 5-25).

The term 'oxides of nitrogen' (NOx) includes nitric oxide (NO) and nitrogen dioxide (NO_2). Motor vehicles are the main sources of NOx in urban airsheds. Nitrogen dioxide — the one of most concern to human health — is also a component of 'brown haze', a visible feature of severe urban air pollution. Current ambient levels in Australian urban airsheds are acceptable, but in the past in some cities have exceeded the NH&MRC one-hour guideline of 0.16 ppm (see Fig. 5.29).

About half the reactive VOCs emitted in Australian urban airsheds come from motor vehicles. Other sources include industrial and commercial plants. As mentioned earlier, vegetation also naturally emits VOCs, especially during hot, dry weather. Native vegetation is probably responsible for most of this. On a typical summer day in the Melbourne airshed, natural emissions of just one common VOC (isoprene) are about the equivalent of 10 per cent of the total anthropogenic VOC emissions (Carnovale *et al.*, 1991).

Ozone is a major constituent of photochemical smog and is the indicator for its presence. As a pollutant, ozone is not emitted directly to the atmosphere, but rather results from natural photochemical processes involving the precursor pollutants NOx and reactive VOCs in the presence of sunlight.

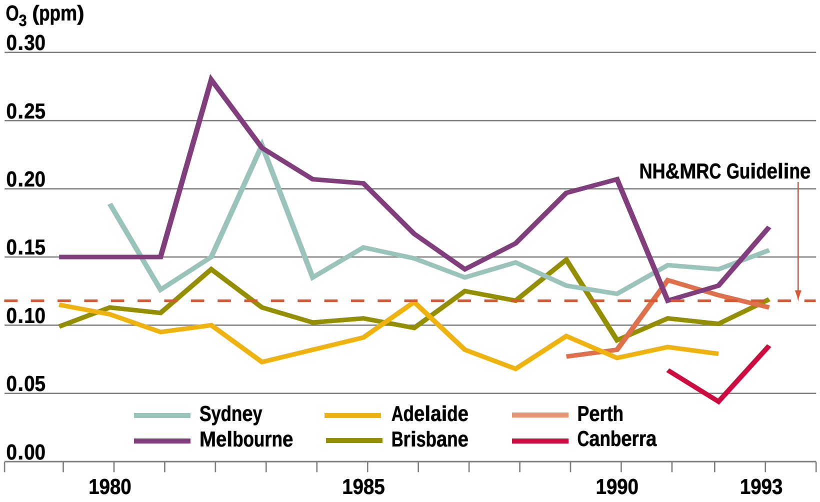
Reported ozone values are affected by the configuration of each monitoring network in our major urban airsheds. The networks are now being reassessed to ensure that they are portraying a true picture of the extent of photochemical smog.

The existing monitoring networks have reported occasional breaches of the NH&MRC ozone guideline over the past decade (see Figs 5.30 and 5.32). The NH&MRC was reviewing this guideline in 1995 and had before it a recommendation for a one-hour average guideline of 0.08 ppm. Standards close to 0.08 ppm have already been adopted in some parts of the world such as California and Japan.

The level of smog experienced in and around major cities depends on the balance between the speed of ozone production and the rate at which the polluted air is diluted by clean surrounding air. The rate of smog production is therefore an important consideration when developing control strategies.

An Australian device, the CSIRO-designed Airtrak, measures the rate of smog formation. The Airtrak samples the air and determines the rate at which the reactive VOCs present can generate smog. By giving a continuous read-out on the parameters controlling air quality, this instrument enables authorities to determine the preferred pollution-control strategies. These data are important because the mechanism controlling ozone episodes (that is, whether it is light-limited or NOx-limited) is often not clear. The diagrams in Figure 5.31 illustrate that, at the same time as the chemical reactions are taking place within the air parcels, the wind is transporting the parcels considerable distances from the source of the original emissions.

Figure 5.30 Highest one-hour ozone concentrations recorded at individual monitoring sites for selected Australian cities



Source: State and Territory environmental authorities.

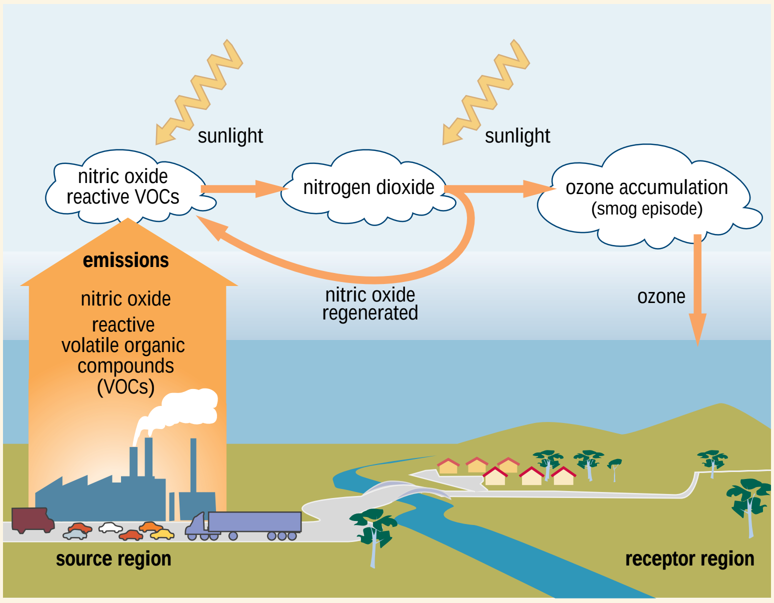
Photochemical smog

Photochemical smog is essentially the result of oxidation of nitrogen oxides in the atmosphere. Ozone is the major constituent of photochemical smog.

As air comprises about 20 per cent oxygen, it is not surprising that oxidation is the major chemical reaction occurring in the atmosphere. However, at the temperature range of the atmosphere, oxygen does not react directly with most emissions. In fact, the driving force for most atmospheric chemistry is energy provided by sunlight. (The breaking of chemical bonds by light is known as photolysis.)

The essential ingredients for the formation of photochemical smog are nitrogen oxides, reactive VOCs and sunlight.

Production of photochemical smog



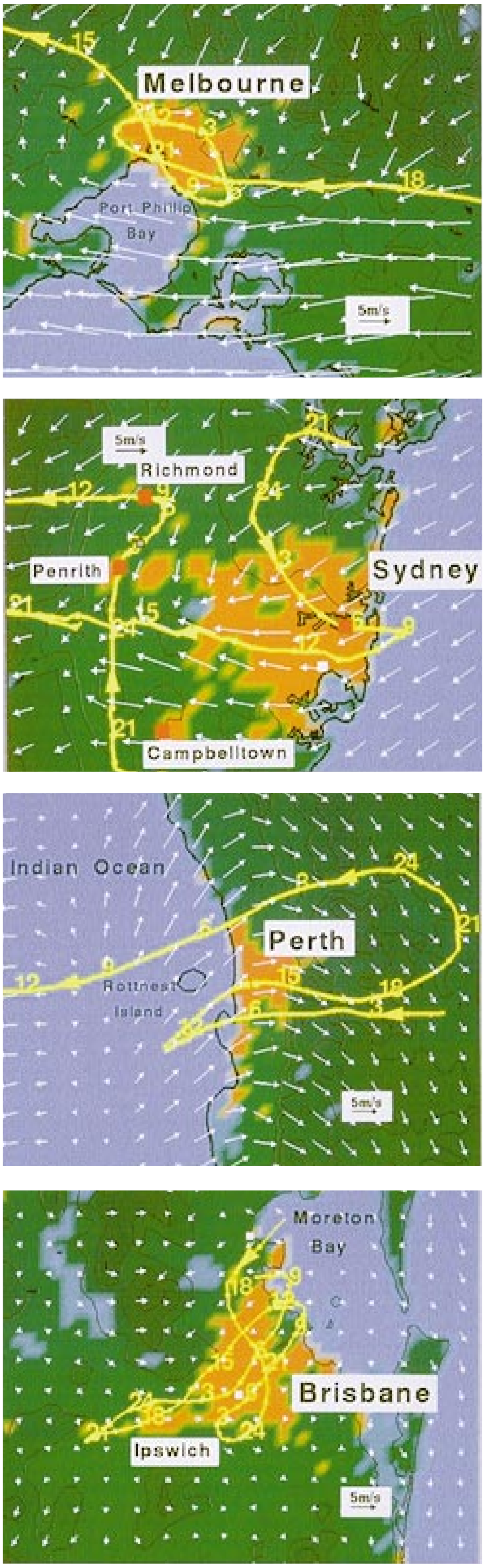
Two factors determine the speed at which smog is formed: the concentration of reactive VOCs in the air and the intensity of sunlight available to drive their breakdown.

The process of ozone formation continues as long as both sunlight and nitrogen oxides are available. Nitrogen dioxide also undergoes other oxidising reactions that convert it to nitric acid and organic nitrates, thus effectively removing nitric oxide from the reaction system and ending the production of smog.

Thus, smog formation can be seen as a two-stage process. In the first stage, temperature and radiation are the controlling factors. In the second, the amount of NOx emissions available to take part in the process determines the peak ozone concentration at some distance downwind (Johnson *et al.*, 1990).

These two stages are referred to as 'light limited' and 'NOx limited' respectively.

Figure 5.31 Recirculation in Australian airsheds



Early morning winds over Melbourne on a typical 'smog alert' day. The calculated air trajectory shows how polluted air is trapped and recirculated as the day progresses. The calculations closely match available observations.

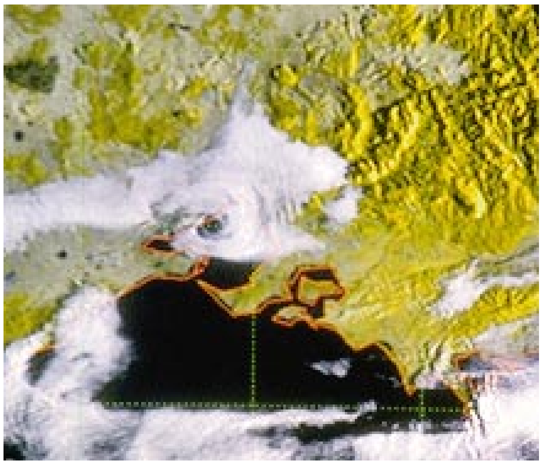
Surface winds at 3 pm: air trajectories over Sydney on high pollution-index days. One trajectory shows how the sea-breeze sends polluted air towards the western suburbs by the late afternoon.

Winds at 2.30 pm, and an air trajectory showing how on days of easterly winds, polluted air is returned from off-shore to the Perth area by the afternoon sea breeze. Overnight the same air is again returned from inland when the land breeze is re-established.

Midday winds on a typical winter's day in Brisbane. The air trajectory highlights how polluted air is trapped and remains over the metropolitan area, allowing emissions to accumulate and photochemical smog to develop.

CSIRO computer model simulations of local winds at 100m (white arrows) and associated air trajectories (yellow lines), with time of day marked.

An early morning satellite photograph. The Melbourne Eddy (see text) is marked by the cloud over the northern part of Port Phillip Bay



Recirculation in urban airsheds

The recirculation of pollutants over Australia's major capital cities is important for determining pollution levels. Photochemical smog formation under such conditions poses the biggest single threat to clean air in urban Australia.

An important concept when considering the overall air quality of an airshed is its 'assimilative capacity'. This means the degree to which it can 'deal with' emitted pollutants through natural dilution, dispersion and chemical transformation. The build-up of pollutants over the major cities during recirculation episodes often exceeds the assimilative capacity. A proper assessment of air quality requires a knowledge of both the pollution sources and the assimilative capacity of the airshed in which the city is located.

In Australia, only in the last 20 years has attention been focused on the possible role of geographical and meteorological factors in the formation of photochemical smog and its impact on populated areas. Before this, pollutants were usually monitored over central urban areas. However, we now know that where emissions of nitrogen oxides (NOx) from car exhausts are high we expect ozone levels to be relatively low. With the exception of Melbourne, monitoring has rarely been done at locations several hours downwind of the source region, where ozone formation takes place and levels are likely to be higher, although major new studies in Sydney, Brisbane and Perth are addressing this problem.

A new approach to air quality management was needed to mitigate ozone pollution in capital city airsheds. The development of forecasting systems that model the complex air flows within the airsheds, coupled with the development of new photochemical analysis techniques for air sampling (such as the CSIRO Airtrak monitoring stations) have been key factors in increasing our understanding of the major urban airsheds and in the development of new air quality management policies and strategies. The results of recirculation models for major urban airsheds are discussed briefly below (see also Fig. 5.31).

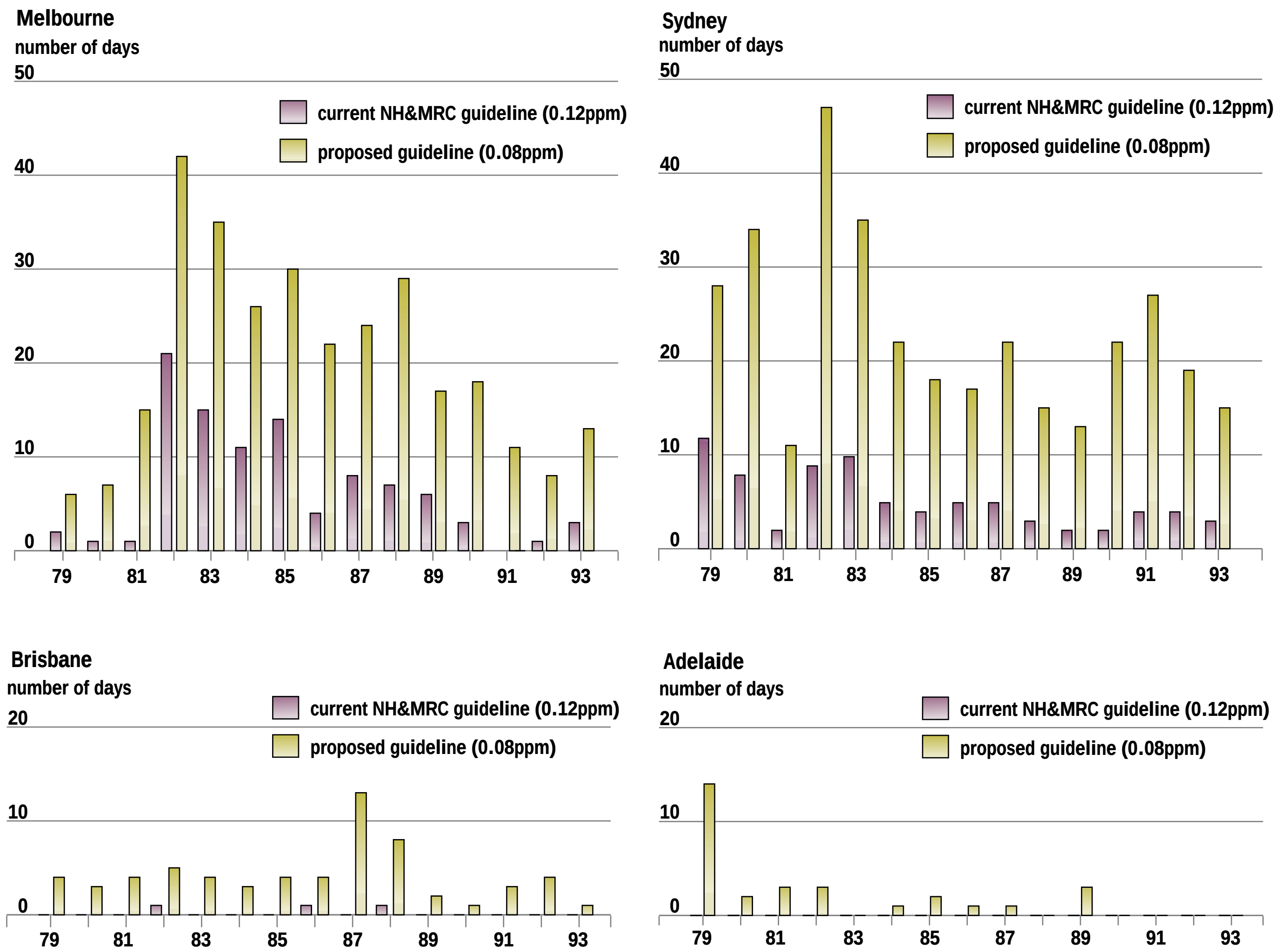
The 'Melbourne Eddy' is a deep, slow, clockwise wind circulation responsible for keeping polluted air over the Melbourne area on some summer days. On days of weak easterly winds and with a low-level inversion, the eddy develops in the lee of the Victorian Alps (to the east of Melbourne), trapping urban emissions. Computer models simulating the Melbourne Eddy have shown that a similar pattern more frequently occurs due to the daily cycle of land- and sea-breezes.

On typical summer days of high pollution in Sydney, night-time air flows from the mountain slopes move cold air to the north towards Richmond in the lee of the Blue Mountains and to the east towards the centre of the city. This latter flow accumulates pollutants as it travels over densely settled and industrial areas in the western suburbs. The air then flows out to sea during the morning. With the onset of the sea-breeze the same air is frequently returned, travelling westward and reaching the Hawkesbury Basin near Penrith or Campbelltown in the afternoon. Under some circumstances air parcels enter the Sydney basin overnight from the Hunter Valley and are caught up in the sea-breeze/land-breeze circulation, which may carry the air parcel out to sea and down the coast towards Wollongong the next day.

Perth lies on a coastal plain between the Indian Ocean and the 300-metre-high Darling Scarp rising to the east. On summer days of high smog, surface winds are generally easterly. Pollutants from Perth and the southern industrial areas are carried out to sea in the morning, but return as smog in the early afternoon with the onset of a strong sea-breeze.

Mountain ranges rise to the west of Brisbane and extend well to the north and south, while to the east Moreton and North Stradbroke Islands lie less than 20 km from the shore. At midday on a winter's day in Brisbane in light northerly winds, the local winds are also light and very variable in direction. The simulated trajectory of pollutant-laden air parcels near the surface is very confused. The model predicts that the air parcel crosses and recrosses the Brisbane urban area several times, in both the morning and the evening. By the end of the event the whole region will probably have been affected by increased smog levels in the form of ozone, nitrogen oxides or aerosols as the parcels accumulate pollutants and these are changed photochemically to smog.

Figure 5.32 Number of days on which peak hourly ozone concentrations exceeded 0.12 ppm and would have exceeded the proposed 0.08 ppm NH&MRC guideline (as at June 1995) in selected capital cities



Source: Atmosphere Reference Group.

Urban air quality trends

In general, the annual mean concentrations of common pollutants within the major Australian urban airsheds are below NH&MRC guidelines, and low by world standards. This is particularly evident for sulfur dioxide. With an increase in the proportion of vehicles using catalytic converters and unleaded fuel, levels of carbon monoxide and lead are likely to decline further. In the short term, a similar trend is expected in smog levels, but this may be counteracted by increasing vehicle usage (brought about both by a larger population and by features of urban design), and the deterioration of existing fitted catalytic converters. Computer models indicate that, based on current trends, the relative contribution by vehicles to the concentration of volatile organic compounds (VOCs) will decline and commercial and industrial sources will instead dominate VOC emissions in established urban airsheds. However, in areas of rapid urban growth (for example, south-east Queensland, Perth, western Sydney) motor vehicle emissions are likely to remain the major concern.

While the annual averages may be low, air pollution levels in Sydney and Melbourne, particularly for ozone, can occasionally approach those in New York or Tokyo. Such air pollution episodes are often associated with recirculation patterns within the urban coastal airsheds. Similar episodes have been recorded in Perth and Brisbane (see Fig. 5.31).

Nevertheless, it is generally agreed that over the past 10 years some aspects of the air quality in major cities such as Melbourne and Sydney have improved following the introduction of stricter controls on motor vehicles, especially the use of catalytic converters on all new cars since 1986 and the simultaneous introduction of unleaded petrol. Whether this improvement will continue is uncertain. Future air-quality trends may be influenced by:

- the revision of Australian Design Rule (ADR) 37 by the Advisory Committee on Vehicle Emission and Noise (ACVEN)
- a study of the emissions performance of vehicles by type and age, including the deterioration of catalytic converters being carried out by the Federal Office of Road Safety
- long-term projections of vehicle emissions by the Bureau of Transport and Communication Economics.
- responses to the Sydney Metropolitan Air Quality Study with respect to transport and land use planning.

One of the major goals of any air quality monitoring program is the detection of changes or trends in pollution over time. This is essential for assessing the effectiveness of pollution-control strategies and for developing appropriate air-quality management plans, and requires a continuous record of measurements over many years. Data fluctuations in the levels are the result of many factors, including possible trends in the emissions themselves, monitoring programs and any expansions of networks with time. The inherent variability in Australian weather patterns can mask or distort any analysis of trends in air quality.

Assessments of air quality are often based on analyses of extreme or peak events, such as daily maxima or the number of times concentrations exceed hourly guidelines.

In 1995 the NH&MRC was reviewing the ozone guideline of 0.12 ppm with a view to introducing a more stringent guideline. Figure 5.32, based on the re-evaluation of records in four capital cities,

Table 5.8 Summary of Australian urban and regional air quality

Pollutant	Areas of most significance	Measured levels	Trends	Other comments
Ozone	Primarily Melbourne and Sydney	Occasional breaches of guidelines	Signs of improvement may be the result of meteorological variability	A growing problem in Brisbane and Perth as populations increase rapidly
Nitrogen dioxide	Near heavy traffic	Occasional breaches in large cities	No clear trends	
Sulfur dioxide	Near metal ore processing sites	Substantial breaches of guidelines near some sites	Some improvements due to better controls for specific plant	
Carbon monoxide	Areas with heavy traffic, wood fires	Some breaches	Improvements in most cities	Measured levels sensitive to monitor siting
Total suspended particles (TSP or PM10)	Areas with heavy traffic, mining and industrial areas; biomass burning (including wood fires)	Some breaches	General improvements	TSP not as well related to health effects as PM10 or PM2.5
Lead	Near point sources and major roads	Some substantial breaches	Steady improvement in urban areas	Motor vehicles as lead sources declining in importance
Fluoride	Near aluminium smelters and ceramics works	Breaches, often in buffer zones	General gradual improvements	Effects on vegetation are the concern

shows the impact of lowering the guideline to 0.08 ppm. In this case, excess concentrations would have occurred on more days per year in both Melbourne and Sydney and would have been detected consistently in Brisbane and intermittently in Adelaide. The longest consecutive period for which data are available for these cities is 1979–93. (Comparable data for Perth are not available.)

Air quality data show a wide year-to-year variability, reflecting the influence of meteorological factors. In various airsheds researchers have tried to remove the influence of meteorology from the analyses of trends. But this has proved difficult; the results are not always conclusive and appear very dependent on the time interval chosen.

For example, in a detailed study of photochemical smog in the Brisbane region, researchers concluded that, for a few hours per year, the photochemical smog potential was high because of the air recirculation between land and sea (Lunney *et al.*, 1994a; 1994b). The study found few apparent trends, as the inter-annual variability of the weather tended to obscure them.

In Sydney, an apparent decrease in the number of pollution events reported in the late 1980s to early ’90s corresponds to an extended period of fast-moving weather systems (Leighton and Spark, 1995), which may explain this trend.

Air quality in regional airsheds

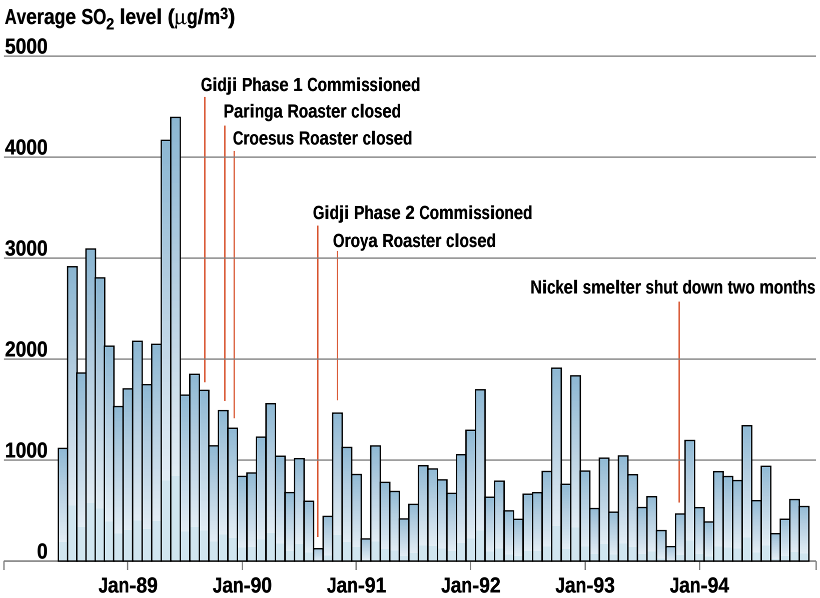
The term ‘regional airshed’ is used here to describe those areas defined by the local terrain, where monitored emissions come primarily from industrial activity and major thermal power stations, even though some of these areas may contain urban populations. Although there have been few regional airshed studies in Australia, one particularly notable one was the Latrobe Valley Study (Manins, 1988), which ran for a decade from the late 1970s. This study pioneered the development of integrated airshed modelling in Australia.

Regional airsheds are defined both by the characteristics of the source — either ground-level emissions or elevated plumes from industrial stacks — and by the surrounding topography and local wind flows. At times of stable meteorological conditions periodic reductions in dispersion can occur. The key pollutants in Australian regional airsheds are sulfur dioxide, oxides of nitrogen, lead and other heavy metals and fluoride.

Sulfur dioxide

Sulfur dioxide is an important air pollutant in regional airsheds. Both coal-burning power stations and oil refineries emit sulfur compounds. In most cases the SO_2 is emitted from elevated stacks, which may reduce ground-level concentrations near the source but also have the potential to affect areas some distance downwind. High SO_2 levels may also be associated with copper, lead and nickel

Figure 5.33 Kalgoorlie (hospital) maximum average hourly sulfur dioxide levels for the month



Source: WA Department of Environmental Protection.

smelters and gold-ore roasters, where SO_2 emissions result from the burning of sulfur compounds in the ore feed-stock. In Kalgoorlie, a general reduction in SO_2 levels has occurred following closure of the town roasters and the commissioning of new roasters at Gidji, some 15 km to the north (see Fig. 5.33) although some problems remain. An inventory of major point sources of SO_2 can be found in Steer and Heiskanen (1993).

Nitrogen oxides

The levels of oxides of nitrogen are monitored in some regional airsheds, but other pollutants, such as sulfur oxides and particulates, are usually of greater concern. A comprehensive network of NOx monitors is set up in the Latrobe Valley in Victoria, designed to assess the impact of plumes from the coal-fired power stations, and also around Gladstone, Queensland, to assess the impact of industrial NOx emissions. Data from both networks show that levels are well below the NH&MRC guideline.

Lead

Smelters emit lead and other heavy metal compounds into the air. Industrial areas of major concern are Port Kembla, Broken Hill and Boolaroo in New South Wales and Port Pirie in South Australia.

In the Port Kembla area of New South Wales, airborne lead from a smelter has been a major source of pollution. Monitoring results from three locations indicate that ambient levels near the plant often exceeded the NH&MRC guideline (EPA NSW, 1993). The smelter closed in 1994.

Port Pirie, a city of some 15 000 people, is the site of the world's largest pyrometallurgical lead smelter, in operation since the 1890s. Despite substantial reductions in process emissions since the 1970s, ambient monitoring indicates that lead levels still regularly exceed the NH&MRC guideline in areas close to the works and the wharf stockpiles (South Australia, Department of Environment and Land Management, 1993).

Fluoride

Hydrogen fluoride causes damage to plants at concentrations about 1000 times lower than those that cause detectable human health effects. Certain plants, such as grapevines, are particularly sensitive. Aluminium smelters, power stations and brick and ceramics works are major sources of fluoride, but there is no comprehensive inventory of fluoride emissions for Australia. The NH&MRC and ANZECC have jointly recommended environmental guidelines (based on damage to plants) for fluorides (see Table 5.7).

Limited measurements indicate that fluoride levels are of concern near some industrial sources. Several aluminium smelters have created buffer zones within a distance of about one kilometre, where the concentrations of hydrogen fluoride are likely to be high enough to cause plant damage. In general, brick and ceramics works have a more limited area of impact (Doley and Moller, 1994; Cameron and Rye, 1992).

In the Hunter Valley, New South Wales, some localised seasonal emissions exceeding the ANZECC environmental guideline have been reported near the smelter at Kurri Kurri. The Boyne Island smelter near Gladstone, Queensland, complies with the guideline in nearby residential areas but not in the buffer zone surrounding the plant.

Long-range transport and acid deposition

Apart from global phenomena such as the enhanced greenhouse effect and depletion of the ozone layer, several other processes produce emissions that can survive long enough to be transported many hundreds of kilometres downwind. Unlike many countries in the northern hemisphere, where emissions generated in one country may affect another's air quality, Australia is not currently subject to significant incoming air pollution. (However, this would have occurred during the 1950s and '60s when atmospheric testing of nuclear weapons resulted in worldwide dispersion of radioactivity.) Material injected into the atmosphere from volcanic eruptions may also be carried a great distance, especially if it reaches the stratosphere (for example, the eruptions of Mt Pinatubo and Mt Hudson in 1991).

Some industrial sources (such as ore-smelters and coal-fired power stations) in remote or rural areas of Australia may emit enough acid gases from tall chimneys to justify evaluating the effects of long-range transport. Their major air emissions are SO_2 and NOx. The two isolated locations of Mt Isa and Kalgoorlie, where emissions arise from several ore smelters, account for more than 60 per cent of total national SO_2 emissions.

Assessment of the impact at ground level of long-range pollution transport must include consideration of three major factors: plume dispersion, chemical transformations in the atmosphere and deposition processes — either dry or wet deposition.

It is difficult to assess impacts from large, remote sources as no routine long-distance monitoring takes place downwind of either Mt Isa or Kalgoorlie. Since the early 1980s, CSIRO has conducted a series of experiments, using a specially instrumented aircraft, to investigate the plume characteristics and trajectories from most major sources.

In the arid interior and in the absence of rain, dry deposition of SO_2 is the dominant process. It determines the way in which the emitted pollutants have an effect at ground level. Particles formed by chemical transformations are of lesser significance, although small amounts can be absorbed at the land surface. In the presence of sunlight, NOx is more quickly removed than SO_2.

For remote inland sources, simple assumptions can be made about dispersion meteorology. Using the annual average wind-rose data, researchers can estimate annual average ground-level concentrations and dry deposition rates for distances up to about 300 km downwind from the source. For emissions such as those from Kalgoorlie or Mount Isa and for uniformly distributed winds, it has been calculated that the impacts from the dry deposition of SO_2 are confined to an area about 30 to 40 km downwind from the source. Beyond this, the rate of deposition of sulfur is estimated to decrease to levels similar to those from natural sources (Williams, in press).

The impact of dry deposition on the ecosystems in remote inland areas is essentially unknown.

It is hard to quantify the extent to which rainfall removes both gases and particles from the atmosphere. These processes are more important in the coastal regions than in the drier inland areas.

Any national assessment of the impact of acid deposition must involve quantitative determination of both total deposition (wet acid deposition plus dry acid deposition) and the critical loads for affected areas.

Before 1988, some studies of the composition of Australian rainwater included measurements of rainwater acidity. However, none of them included an assessment of dry deposition and many were conducted for unrelated scientific purposes in regions remote from the major sources. Bridgman (1989) summarised pre-1988 rainwater composition work in Australia while Ayers and Gillett (1988) reviewed what was known about atmospheric acidity and acid deposition in tropical Australia at the time. The Australian Environment

Council (1989) prepared a preliminary national assessment. Several more rainwater composition studies have since been published, but none of these focused explicitly on acid deposition assessment either, or included measurement of dry deposition or evaluations of critical loads. Currently, and contrary to some earlier claims, no evidence suggests that sulfate emanating from the Mt Isa smelters has been detected in rainfall around Jabiru in the Northern Territory, where the composition of the rain has been extensively studied (Noller *et al*., 1990; Gillett *et al*., 1990). Most of the sulfate detected there came from natural sources such as vegetation and fires.

One rainwater composition study was carried out specifically to assess acid deposition in the Latrobe Valley, Victoria, between February 1990 and February 1992, but its results are not yet available. Again, it did not include measurement of dry deposition or determination of regional critical loads. A similar rainwater composition study was carried out at several sites in the Hunter Valley, New South Wales, in two phases between 1984 and 1990, following earlier work in Sydney. Dry deposition and critical loads were not determined in this study either. Two studies that do address the question of dry as well as wet deposition started in New South Wales in 1992, but are not yet complete. The air flows within the airsheds are complicated by day-time sea-breeze effects and night-time valley drainage flows, which invalidate the simple dispersion assumptions described above for remote areas. The prediction of pollution impacts requires the use of complex computer models incorporating terrain and simulated wind fields and the estimation of regional critical loads.

Dry and wet acid deposition

Gases such as SO_2 and NOx are emitted naturally. They are transformed by natural chemical processes in the lower atmosphere into trace levels of sulfuric and nitric acids. These chemicals can be further transformed into small particles known as aerosols. The acids, the gases and their aerosol products are returned to the earth's surface in two main ways:

- through wet deposition in rain or snow (often called 'acid rain')
- through dry deposition, in which atmospheric particles and gases are deposited directly on water, soil, vegetation or other surfaces.

The natural emission, atmospheric transformation, transport and deposition of sulfur and nitrogen are integral and natural parts of the global nutrient cycle.

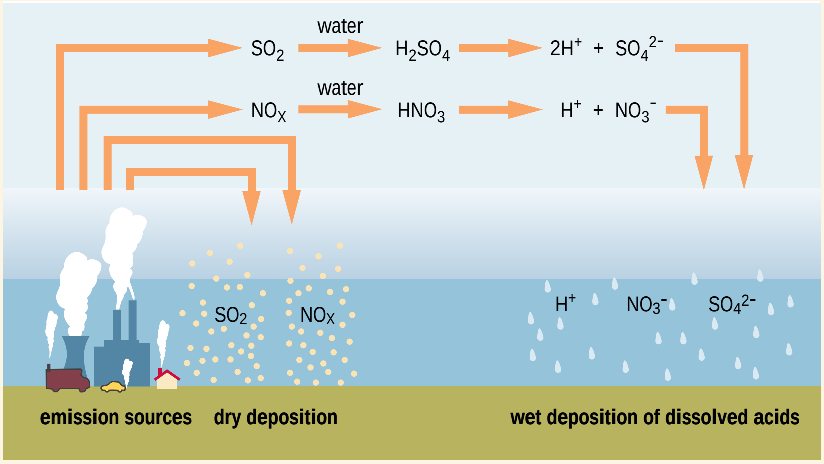
'Acid deposition' occurs when anthropogenic (human-derived) emissions of acid precursors overwhelm the natural cycles. Anthropogenic activities that emit acid-precursor gases include the combustion of fossil fuels for electricity generation and transport, and industrial processes such as smelting sulfide ores (see figure below). The major gases emitted are SO_2 and NOx. Globally, anthropogenic emissions now dwarf natural emissions three to one.

However, because acids and their precursors typically have atmospheric lifetimes of only a few days, the anthropogenic emissions are not dispersed globally but rather tend to be deposited within some hundreds of kilometres of the source. Acid deposition (mainly in the form of 'acid rain') is high in regions surrounding urban and industrial centres in the mid latitudes of the northern hemisphere, where it has caused environmental problems. In Europe, the long-range transport of acid gases is recognised as a serious transboundary pollution issue. Aerosols also play a key role in the enhanced greenhouse effect.

At present, Australia does not experience long-range transport of acid pollutants from neighbouring countries.

Environmental damage from acid deposition can occur when the extra acid added to surface soil or water exceeds the capacity of these ecosystems to accommodate it. Although arguments persist about the exact causes of damage attributed to acid rain, it is generally accepted that acidification in lakes and streams can cause loss of aquatic life, while on land it can damage leaves and reduce plant growth — most noticeable in the case of trees. In the northern hemisphere the major effects generally arise after some years (typically one or more decades) of excess acid deposition.

The chemistry of acid deposition



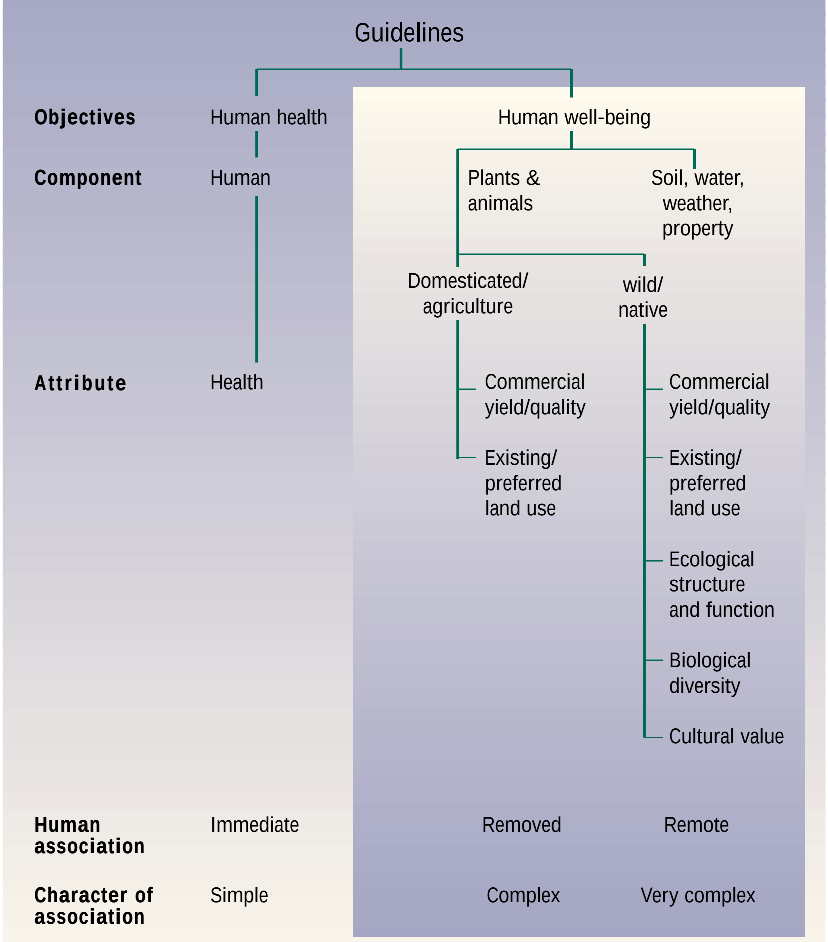
It is possible to determine the 'critical load' for a soil or surface water ecosystem below which significant harmful effects on specified elements of the environment do not occur. When total acid deposition (wet plus dry deposition) exceeds the critical load it may start to alter the structure and function of the local ecosystem. As each soil or surface water system has its own critical load, any assessments of acid deposition must include data on the critical load as well as on the rate of deposition. From the limited studies that have been carried out on acid deposition (primarily wet deposition) in Australia, it does not appear to be a serious or widespread problem in this country.

In addition, on certain occasions, the interaction of emissions from power stations with those from nearby cities (such as with the Hunter Valley and Sydney) may occur, bringing the possibility of an extra source of NOx to the urban photochemical smog system, and thereby affecting the distribution and intensity of ozone.

The situation in 1995 has not changed greatly from that presented by the Australian Environment Council (1989), and may be summarised as follows.

- Acid deposition is not a widespread problem here, as sources are generally geographically isolated from each other.
- Unlike many European countries, Australia is not subjected to transboundary transport of emissions from neighbouring countries.
- The major deposition process here is dry deposition of SO_2.
- Nevertheless, Australia has some significant individual sources and regional sources of acid-precursor emissions, and excessive acid deposition in the regions surrounding these sources is a possibility.
- There may be small areas of poorly buffered soils in Australia that could be easily acidified.

Extending guidelines to human well-being



Source: based on Doley and McCune, 1993.

Air quality and the environment

Air pollution's potential to damage human health is clearly a major concern, but other effects are also important. These include the possible decline in productivity of agricultural and forestry land (through the impact on trees, pastures, crops and livestock) and the cost of cleaning, repair and maintenance of affected property. In Australia, these effects have only been studied to a limited extent. In Sydney, the annual cost of pollution in terms of cleaning stone buildings was estimated at about $13 million (Mansfield, 1990). The presence of acidic gases in the atmosphere can accelerate corrosion of steel and aluminium (although natural effects due to the action of sea salt can be more important close to the coastline).

The term 'human well-being' has been coined to refer to areas other than human health that pollution could affect (Doley and McCune, 1993), although human health is the basis of most air quality guidelines. However, for nearly all the common air pollutants, the natural environment is more sensitive to damage than human health (Murray *et al.*, 1992). So human health guidelines alone may not be sufficient to protect the broader concept of human 'well-being'. In other developed countries, guidelines have been developed to protect against impacts such as:

- damage to agriculture and forestry
- disruption to natural ecosystems
- impacts on flora and fauna
- damage to materials, property and buildings
- deterioration of aesthetic aspects of the environment such as landscapes and urban views

Most commonly, people express concern about the potential effects of fluoride, sulfur dioxide and ozone. Although work in Australia has been limited, future guidelines should be based on scientific criteria developed for our conditions. Simply extrapolating from air quality guidelines developed in the major industrial countries of the northern hemisphere is not likely to be valid here (Doley and McCune, 1993).

For instance, some environmental impact assessments for major development projects have assumed, in the absence of suitable data, that eucalypt forests behave like coniferous forests in northern Europe or North America. Similarly, the Australian wheat belt has been modelled on the results of studies in the Canadian prairies (Murray *et al.*, 1992).

We know little about the sensitivity to sulfur dioxide of Australia's 18 000 or so plant species; likewise the effects of any air pollutants on native animals have received little attention. Urban nature parks may need particular study.

The limited work that has been done confirms that many plant and animal species — already naturally restricted in their spread — vary greatly in their response to air pollutants. A range of climatic and management conditions exists for growing any single crop variety, and the responses to airborne pollution are unlikely to be identical for all varieties in all locations.

Sulfur dioxide

Although sulfur dioxide is not monitored widely, it seems from our knowledge of its long-range transport and isolated point sources in remote areas (see page 5-30) that its ground-level concentrations must vary greatly across the country.

Sulfur is an essential element for plant growth. In Australia, the low natural sulfur content of the soils (resulting in crop sulfur deficiency being reported in some regions) means that some plants may actually benefit from airborne sulfur compounds released by human activity (Murray and Wilson, 1989). However, too much exposure can damage plants. As they adapt to other environmental conditions, such as water shortage, their sensitivities to sulfur dioxide may change. However, we know little about the concentrations of sulfur dioxide that would produce adverse responses across the range of Australian native vegetation. According to Murray *et al*. (1992), 'much of the native vegetation in semi-arid areas appears to survive sulfur dioxide concentrations which would devastate the vegetation of more humid areas.'

Until the late 1980s, little attention was paid to the relationship between sulfur dioxide concentrations and effects on important crop varieties and Australian native plants growing under our climatic conditions. In fact, some researchers claim that more work has been conducted on the effects of sulfur dioxide on eucalypts in North America than in Australia (Murray and Wilson, 1989).

Some limited studies (where plants were exposed to SO_2 in open-top chambers in the field) have been carried out on crop species of major economic value — wheat, barley, lucerne, clovers, soybean and peanuts — and on some eucalypt species from native forests near Australia's major coal-fired power stations. Scientists have also studied effects on the major softwood plantation species, *Pinus radiata*. As expected, the results show that individual species have varied and complex responses to SO_2 exposures. Eucalypt species in particular vary greatly in their responses (Murray *et al*., 1992).

Fluorides

Overseas, the use of fluoride-sensitive plants to monitor the effects of industrial emissions is widely practised. However, in general the Australian environment is too harsh for these methods to be effective (Doley, 1992). An alternative, used for some years in Australia (particularly around several aluminium smelters), involves measuring growth and the appearance of visible injury in the natural vegetation nearby. For gaseous fluoride, the most common visible injury symptoms are yellowing and death around the edges of the leaves. For each species the plant progressively deteriorates with increasing exposure, so we can infer the fluoride dose at various locations around an isolated source from the injury patterns. Despite uncertainties related to both different site conditions and vegetation patterns, it is possible to monitor trends in vegetation condition over time. However, the effects of the pollutants may be masked by:

- seasonal factors, such as the occurrence of drought, variability of rainfall, growth patterns and bushfires
- site factors such as hydrology and mineral nutrition
- salinity.

This masking occurs in the buffer zones that surround industrial point sources, thus complicating the assessment of fluoride impacts.

Photochemical smog

Nobody has assessed the effects of ozone and photochemical smog precursors (such as NOx) on street trees, urban nature reserves and vegetable and fruit production within urban airsheds in Australia. Limited work on the effects of urban ozone on Australian native vegetation (Monk, 1994) has shown great differences in the reactions of various species to ozone exposure.

Indoor air quality

No universal definition describes indoor air quality. The NH&MRC has defined indoor air as 'air within a building occupied for at least one hour by people of varying states of health'. Buildings covered by this definition include homes, schools, restaurants, public buildings, residential institutions and offices — but not workplaces covered by occupational health standards, which are set by the National Occupational Health and Safety Council. (This definition does not include air within vehicles.) The NH&MRC did not define indoor air quality. While many definitions have been proposed, this report uses the following: 'the totality of attributes of indoor air that affect a person's health and well-being'. Under this definition, the chapter uses indicators to determine how well indoor air satisfies thermal and respiratory requirements, prevents unhealthy accumulation of pollutants and enables a sense of well-being.

Many people may be surprised to learn that the quality of indoor air is often poorer than that outdoors. Most Australians spend about 90 per cent of their time indoors (EPAV, 1993) and yet there is little monitoring of indoor air pollutants in homes or recording of individuals' differing exposures to indoor pollutants. Some caravans have been monitored and occasional monitoring in commercial buildings does occur, mainly in response to worker complaints.

Without a systematic program of measurements, it is hard to develop a clear picture of Australia's indoor air quality. Factors affecting it, such as methods of construction and types of building, differ across the nation. Building codes, which specify material used in construction and the ventilation rates of buildings, also differ and have changed significantly over time. National codes have been developed but are not always implemented. Further difficulties can arise if buildings are operated at variance from the original design.

Given the amount of time spent inside, indoor air quality is probably an important environmental factor affecting human health.

In the past, the 'leakiness' of Australian homes, compared with those in the cooler climates of Europe and North America, meant indoor air quality was not a concern. However, changes to building practices that are aimed at improving energy efficiency have substantially reduced ventilation rates, and have probably increased levels of indoor air pollutants. Ventilation rates in our commercial buildings are essentially the same as those in the developed countries of the northern hemisphere.

Major indoor air pollutants can occur inside buildings at much higher concentrations than they are found outdoors. Some are completely different from those found outdoors. Whether a pollution source causes an indoor air quality problem depends on: the nature of the contaminant; the rate of emission from the source; and the ventilation rate of the building.

The following pages provide a perspective on indoor pollutant concentrations found in Australian buildings, including a summary of the major pollutants and possible responses to them. Where possible, measurements are compared with interim indoor air guidelines recommended by the NH&MRC (Brown, in press).

Smoke

Environmental tobacco smoke (ETS) is the term used to describe a complex airborne mixture of gases and particles that tobacco smoking produces. Most measurements of ETS components in Australia have been made in recreational buildings, where smoking is still commonly allowed. Results often showed high levels of ETS pollutants even when ventilation rates satisfied existing guidelines. Further investigation is needed for other building types, to remedy the lack of available information.

Authorities have not determined an exposure standard for ETS because of the complex nature of the mixture, but have used measurements of several components as markers. The most frequently used marker is combustion-derived particulate matter, since it contains a high proportion of respirable size. Such particles are known as respirable suspended particulates (RSP).

In Australia, there appear to be no measurements of typical background levels of RSP in buildings where the occupants do not smoke. Recent measurements of RSP concentrations in Perth buildings with smokers ranged from 150 to 225 µg per cubic metre. and RSP concentrations in the Adelaide casino during peak occupancy ranged from 110 to 430 µg per cubic metre.

In homes, fuel-based heaters and stoves emit RSPs, although their impact on indoor air quality has not yet been well described. Ferrari *et al*. (1988) found an average RSP concentration of 86 µg per cubic metre in eight Sydney homes with wood fires compared with 28 µg per cubic metre in four homes without them.

Legionnaire's disease

Low numbers of the disease-causing (pathogenic) Legionella bacteria are commonly found in soil and water. However, they can multiply rapidly in warm, moist environments such as cooling towers in air-conditioning plants. Inhalation of droplet aerosols containing Legionella bacteria can cause Legionnaire's disease, a pneumonia with a relatively high mortality rate that represents one per cent of pneumonia cases in Australia.

Most Australian outbreaks of Legionnaire's disease have been traced to cooling towers (especially small units) and, to a lesser extent, spa baths. This differs from overseas experience, where large hot-water systems in hotels and the like have been the major sources of the bacteria. Disease outbreaks can be significant and are notifiable in all States and Territories (see Table 5.9).

Table 5.9 Number of notifications (and incidences per 100 000 population) of Legionnaire's disease for each State and Territory from 1991 to 1994

State/Territory	Number of notifications	Incidence per 100 000 population
New South Wales	251	4.2
ACT	1	0.3
Victoria	149	3.3
Queensland	104	3.4
South Australia	84	5.8
Western Australia	73	4.4
Northern Territory	7	4.1
Tasmania	3	0.6

Source: Brown, in press.

House dust mites

As their name suggests, house dust mites live mainly in houses — especially in mattresses and carpets — where they feed off human skin flakes and other products. These mites are a major source of the allergy-causing substances (allergens) commonly found in house dust. The main species in Australia is *Dermatophagoides pteronyssinus* (Tovey, 1992), although other species may occur in some buildings. Most of the allergens are found in mite faeces, which easily become airborne when dust deposits are disturbed — for example, during cleaning. It is not easy to measure exposure to house dust mites directly. Instead, indirect methods are used to indicate people's levels of exposure. These involve measuring concentrations of a known allergen from the mites or counting the number of mites in accumulated dust (vacuumed from carpets or furniture). Allergen levels above 2 µg per gram of fine dust (equivalent to 100 mites per gram) may increase the risk of sensitisation and of symptoms, while levels above 10 µg per g (500 mites per gram) increase the risk of acute or severe asthma attacks.

As mites require humidities above 40–50 per cent for survival at normal indoor temperatures, the level of mite allergens in very dry or cold regions is generally low (less than 2 µg per g) whereas in regions with one season suitable for growth the mean level is between 2 and 15 µg per g. Coastal areas of Australia, where the climate is suitable for mites for most of the year, have allergen levels of 10 to 40 µg per gram. These data are only broadly indicative, since variations in measuring techniques can lead to two- to five-fold variations in results. Mite allergen levels appear to be highest in coastal regions, become lower inland and are virtually at zero in central Australia. Mites may present a particular health problem in parts of coastal Australia.

Other biological contaminants

Other biological contaminants include microbiological matter such as viruses, bacteria, fungi, protozoa, insect faeces and pollen. The impact of these contaminants on indoor air quality in Australia has received little attention.

Asbestos fibres

Many commercial and industrial buildings in Australia have used sprayed asbestos insulation products that can be a major source of asbestos fibre if they are damaged or deteriorate. The risk of exposure to fibres is particularly high during building maintenance or renovations. Between 1968 and 1979, unbound asbestos 'fluff' was installed as ceiling-space insulation in about 110 houses in the Australian Capital Territory and in some 100 houses in nearby New South Wales towns. In 1988, the Commonwealth Government decided to remove the asbestos fluff from the ACT houses through a $100 million program, which operated from 1989 to 1993.

Asbestos building products have also been widely used in Australia and many of these remain in place. The major items were asbestos cement sheet products for interior and exterior cladding, flooring products (high density underlay sheets, vinyl–asbestos floor tiles and cushion vinyl flooring) and fire, thermal or acoustic insulation products. An estimated 1300 million square metres of asbestos cement building sheets were produced before manufacture ceased in 1983. About half of this product, if still present in buildings, is now more than 30 years old. Emissions of asbestos fibres are greater from those products that are outdoors (particularly roofing), because of surface degradation. Nevertheless, studies have found that asbestos concentrations around such buildings are generally very low and vary little from ambient levels in other urban areas.

Nitrogen dioxide

Although indoor combustion sources produce both nitrogen dioxide (NO_2) and nitric oxide (NO), nitrogen dioxide is of principal health concern, as it is known to cause lung damage at relatively high concentrations. Australian investigations show that its major sources in indoor air are unflued gas heaters and, probably, unflued gas cooking appliances.

Investigations in homes and schools in Australia — particularly in New South Wales where unflued natural gas heaters have been widely used — show high concentrations of NO_2 in many of these buildings. New South Wales government schools are carrying out an extensive program to address the issue, but it is believed that similar concentrations may occur in many buildings in other States that have not yet been investigated.

Volatile organic compounds

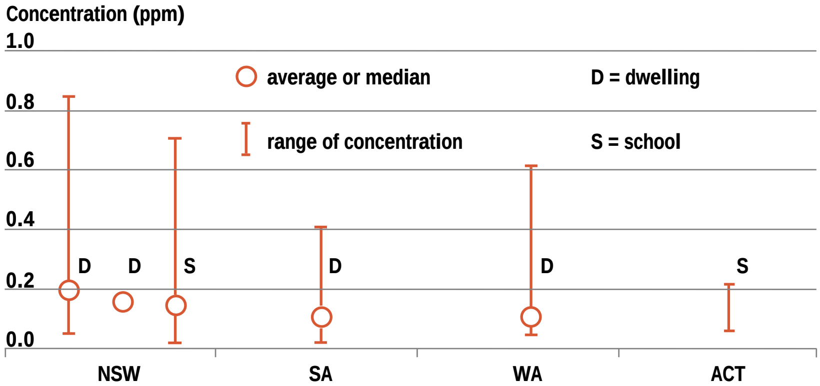
VOCs (volatile organic compounds including formaldehyde and pesticides) are organic compounds with boiling points between 50°C and 260°C which are emitted from many materials, equipment and products used in buildings. Generally, the sensitive analytical methods now available can detect from 50 to 150 such compounds in any single building.

Table 5.10 Proportion of private dwellings in each State and Territory in 1981 with asbestos–cement sheet external walls

State/Territory	% of dwellings
New South Wales	19
ACT	1
Victoria	5
Queensland	15
South Australia	9
Western Australia	18
Northern Territory	13
Tasmania	5

Source: Brown, in press.

Figure 5.34 NO_2 concentrations measured in Australian buildings with unflued natural gas heaters during winter



Source: Brown, in press.

The VOCs can irritate the respiratory tract, eyes and nose. They may play a part in 'sick building syndrome' but a clear causal link has not been established.

The major sources of VOCs in indoor air are believed to be wet construction products (paints, adhesives and sealants) in new buildings, and a mixture of wet household products and other materials, such as carpets and soft furnishings, in established buildings.

In Australian buildings — in contrast to those in other countries — VOCs have received very little investigation of any type. Despite this lack of data, the NH&MRC has established an indoor 'level of concern' for VOCs, although it is unknown whether Australian buildings comply with or exceed this level. Further investigation is urgently needed. CSIRO is carrying out a project to characterise VOC concentrations in buildings.

Formaldehyde, an irritating gas with a pungent odour, is one example of a VOC. Its major industrial application is in the production of different resins widely used in indoor materials and in consumer products (particularly pressed-wood and building products such as particleboard and medium-density fibreboard). Small amounts of formaldehyde are also emitted by gas appliances and in tobacco smoke. The NH&MRC guideline for formaldehyde is 0.1 ppm.

Formaldehyde concentrations are low in homes and offices but exceed the guideline in caravans and mobile homes up to five years old, where the high content of pressed-wood products and low ventilation rates appear to increase levels. Concentrations have also exceeded the guideline in homes recently insulated with urea formaldehyde foam insulation, although after several months, when the foam has dried, they generally fall to below the guideline. New or renovated buildings have received little investigation, but Table 5.11 summarises some findings for Australian buildings.

Overall, formaldehyde concentrations in conventional Australian buildings appear somewhat lower than those reported in North America while those in mobile buildings are similar.

Table 5.11 Formaldehyde concentrations in Australian buildings

Building Type	No. of buildings	Formaldehyde concentration (ppb)	
		Range	Mean
Conventional home	100	0-97	26
	40	3-73	23
	39	10-33	26
Caravan	20	20-280	90
Caravan/mobile home	24	80-1200	310
Conventional office	3	15-70	21
	4	20-120	66
	8	10-80	40
Mobile office	12	420-830	710

Note: NH&MRC guideline for formaldehyde is 0.1 ppm (=100 ppb)

Source: Brown, in press.

In addition, VOCs include pesticides, some of which are widely used in many parts of Australia to protect buildings against termite attack. In homes, people are probably most exposed to pesticides through the use of commercial pesticide products and the infiltration of termiticides from house foundations. Misuse of pesticides is considered to provide the greatest potential for exposure, which can occur by inhalation (including inhalation of previously contaminated house dusts) and by absorption through the skin after contact with treated surfaces. So airborne concentrations are not the only indicators for occupant exposure.

Australia has no guideline for indoor air pesticide concentration. However, concentrations have been investigated recently in small samples of Australian homes treated with termiticides. Studies both here and overseas indicate that homes treated after construction or those with 'leaky' floors have greater indoor air termiticide concentrations. The compounds in termiticides that are of most concern are the organochlorines chlordane and heptachlor. The National Registration Authority recently banned the use of these compounds in the southern States after mid 1995. No investigation appears to have addressed other pesticide sources.

Carbon monoxide

This colourless, odourless gas is produced by incomplete combustion of carbon-containing material. It is a fast-acting poison, as it combines with the oxygen-carrying pigment haemoglobin in the blood, reducing the blood's capacity to transport oxygen. Accidental deaths from CO poisoning have occurred in Australia.

The main indoor sources of carbon monoxide are smoking; unflued gas heating appliances in homes; and vehicles in enclosed car parks in commercial buildings.

In general, indoor CO concentrations are expected to follow outdoor levels except where combustion sources occur in buildings without adequate ventilation. The NH&MRC indoor air guideline for CO is 9 ppm (eight-hour average).

Ozone

A strongly oxidising gas and an irritant, ozone affects the mucous membranes, lung tissues and lung function. Potential indoor sources include electrostatic photocopiers, laser printers, electrostatic precipitators for air cleaning, ionisers and ozone-based sterilisers. Little research into ozone exposure in modern office buildings appears to have been carried out in Australia.

Lead

In residential areas close to some lead-based industries, lead particles may find their way into houses and accumulate in ceiling dust. In general, however, lead in old house paint presents the main health risks to occupants, especially children, due to flaking and chalking of the paint. People are more likely to be exposed during renovations.

Radon

Radon is an inert radioactive gas, given off naturally from most soils and rocks but at widely different rates. The major source of radon in indoor air is therefore the ground under buildings. Radon gives off alpha particles, a very damaging form of radiation. However, alpha-radiation has little penetrating power, so the effects of inhaled radon are generally confined to the lungs. Radon levels in Australian buildings have been widely investigated and found to be well below accepted indoor air guidelines in nearly all locations. This is in marked contrast to some areas in the United States and the United Kingdom, where large numbers of buildings exceed radon guidelines. This difference is believed to result from differences in soil and building designs (such as the more-common use of cellars and basements overseas).

In 1988, the Australian Radiation Laboratory carried out a nationwide survey of radon levels in 3413 homes, and found a measured annual average radon concentration of 12 Becquerel per cubic metre (Bq/m^3)(Langroo *et al*, 1990). The survey estimated that 2000 to 3000 homes nationwide may exceed the NH&MRC recommended level of 200 Becquerel per cubic metre. A subsequent survey in Western Australia reported similar results.

'Sick building syndrome'

Overseas studies have established the existence of a range of building-related illnesses, many with identifiable but diverse causes. The main symptoms are: irritated eyes; irritated, runny or blocked nose; dry or sore throat; dryness, itching or irritation of the skin; and poorly defined feelings such as headache, irritability and poor concentration.

The World Health Organization has termed this cluster of symptoms the 'sick building syndrome'. The symptoms are believed to arise from many causes that, while not clearly understood, are associated mainly with air-conditioned office buildings.

The potential causes include: inadequate ventilation; airborne chemical pollution — with many pollutants probably contributing; micro-organisms and particulates, especially dust from poorly maintained air-conditioning systems and from furnishings; temperatures above 21°C and extremes of relative humidity — both high and low humidities (less than 30 per cent) exacerbate the problem; poor lighting, flicker from fluorescent tubes and absence of windows; and personal and organisational factors.

Assessment of building-related illnesses in Australia has been very limited but research so far suggests a dissatisfaction with office air environments. One study of 228 suburban low-rise office buildings in Melbourne reported that 62 per cent experienced unacceptably stuffy, drowsy conditions, while 82 per cent failed to meet current ventilation guidelines (mainly because of changes in these guidelines after the buildings were constructed). A similar pattern of incidence has been observed for inadequate ventilation in commercial buildings in Perth.

Within Australian buildings several pollutants have been investigated at varying levels of detail. In general, it is considered that most of these pollutants have not been sufficiently studied to determine either the existing exposure levels for the Australian population or the most appropriate strategies to reduce exposure. In contrast to ambient (outdoor) environments, no regulations have been developed specifically for indoors except for workplaces.

Air quality and human health

Researchers in many countries have studied the health effects of the most common air pollutants for some years. These studies were stimulated first by the London smogs of the 1950s, and later by the Los Angeles photochemical smogs. However, as people in different countries rarely experience the same level of exposure to the same set and levels of contaminants, international data are not enough to assess the likely importance of air quality to human health in Australia.

'Proof that air quality has a harmful effect on health depends on showing that deliberately changing the quality of the air leads to an improvement in health' (Peach, in press).

In practice, researchers usually gather data by:

- longitudinal studies, that follow a group of people for many years and compare their history and likely exposure with their patterns of disease
- panel studies, that attempt to monitor the exposure of selected individuals all the time
- epidemiological studies that investigate correlations between exposure and diseases or deaths within a large population
- chamber studies, in which informed, consenting volunteers are exposed to low levels of pollutants for a short time in controlled conditions
- animal studies.

Some Australian studies have found relationships between the levels of pollutants in the air and death rates, attendances at hospital emergency departments or hospital admissions. These relationships are difficult to interpret because the studies failed to exclude the possibility that the people exposed to the pollutants might have had higher death rates, hospital attendances, etc. for other reasons — such as lower socio-economic status or the inclusion of a greater proportion of smokers in the group.

Overseas studies have found a relationship between the levels of several pollutants in the air and death rates or signs of sickness (such as hospital admissions or use of medication for respiratory disease). Some related an increase in signs of poor health with increased levels of sulfur dioxide and total suspended particulates in the air. The levels of many airborne pollutants are generally lower in Australia than in many overseas countries but, despite this, the finding of a possible relationship between the level of total suspended particulates or sulfur dioxide and certain health effects may still have implications for Australia. A detailed critical review of the current state of knowledge of the effects of air quality on human health is provided in Peach (in press).

More knowledge is needed before any clear statements can be made about the impact of air quality on the health of Australians.

Response

In its definition of the responsibilities of government, the Australian Constitution does not refer explicitly to the environment. This has caused difficulties and has encouraged a fragmented approach to those environmental matters — including the air environment — that cross jurisdictional boundaries.

Under the *Meteorology Act 1955*, the Commonwealth Bureau of Meteorology is responsible for monitoring and forecasting the 'state of the atmosphere'. While the Bureau of Meteorology deals with global baseline monitoring (at Cape Grim) and stratospheric ozone measurements, government decisions in the 1970s gave primary responsibility for air quality to the States.

The Intergovernmental Agreement on the Environment (IGAE), signed in May 1992 by the three levels of government — Commonwealth, State and local — offers the potential for a national approach. Schedule 4 of this Agreement outlines two basic goals regarding national environment protection measures. The first is that people enjoy the benefit of equivalent protection from air, water and soil pollution and from noise, wherever they live. The second is that decisions by business are not distorted and markets are not fragmented by variations between jurisdictions in relation to the adoption or implementation of major environment protection measures. The IGAE has been implemented through legislation which has resulted in the establishment of the National Environment Protection Council (NEPC), a statutory Ministerial Council.

Other basic principles embodied in both the IGAE and the Strategy for Ecologically Sustainable Development (ESD) also form a fundamental part of this national approach. One such, the precautionary principle, has been stated in various ways. In the context of the atmosphere, the principle is as quoted in the IGAE:

'Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.'

The air environment

Ambient (outdoor) air

The primary responsibility for managing the air environment rests with the individual States and Territories. Clean Air Acts were introduced in most States in the 1960s, with an emphasis on the control of visible emissions from stationary sources. Some States have a record of routine continuous air monitoring dating back to the early 1970s. In 1970, Victoria introduced the first Environment Protection Act followed by a Statewide environment protection policy in 1981.

In recent years, most States have reviewed legislation and regulations to encompass both changing approaches to air quality management and new issues. For example, in Queensland the *Clean Air Act 1963* and Clean Air Regulations (1982) were repealed by the *Environmental Protection Act 1994*.

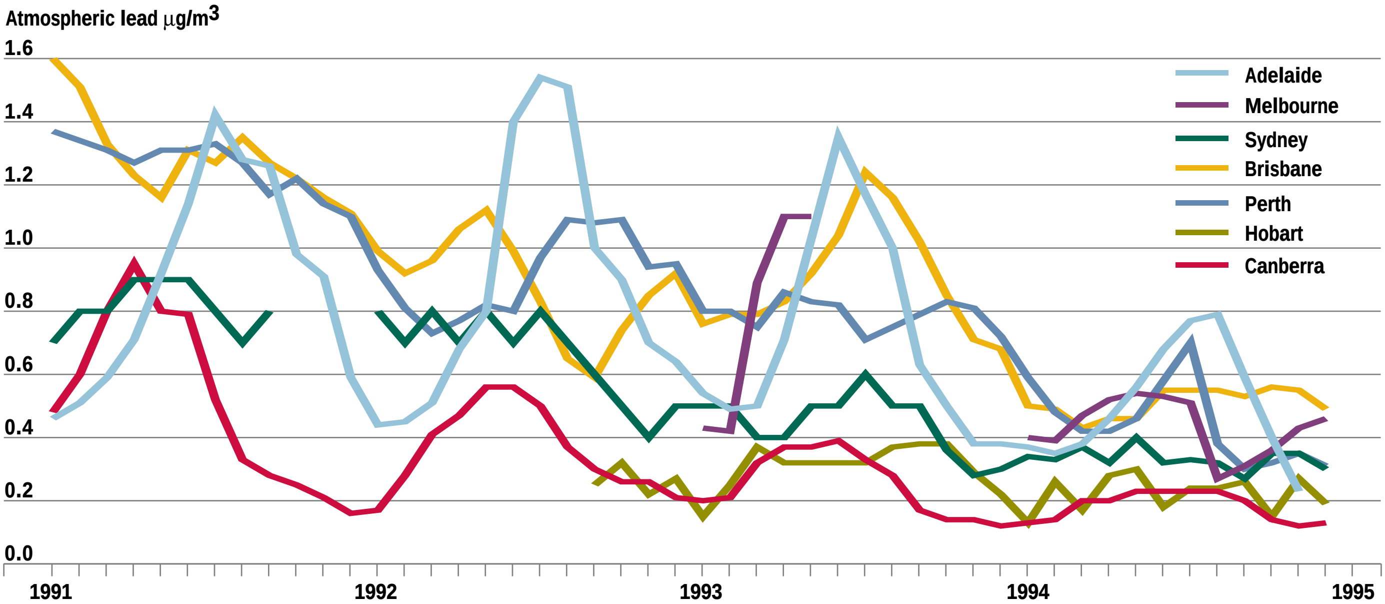
Although air quality is a State and Territory responsibility, the Commonwealth is involved through joint ministerial councils such as the Australian and New Zealand Environment and Conservation Council (ANZECC). This council of Commonwealth, State and Territory environment ministers provides a national approach to environmental matters. However, its decisions are not binding.

One area where a consistent national approach has been implemented is the setting of national standards for new vehicle emissions. The Advisory Committee on Vehicle Emissions and Noise prepares Australian Design Rules (ADRs) and draft regulations to help control motor vehicle emissions and noise. Before 1989, ADRs were advisory recommendations only; in order to become mandatory requirements they had to be recognised under State and Territory legislation. The introduction of the *Motor Vehicles Standards Act 1989*, administered by the Commonwealth Department of Transport, effectively made ADRs national standards for new vehicles. Australian urban air quality has undoubtedly improved as a result. However, emissions from vehicles already in use remain the responsibility of States and Territories and are less uniformly regulated.

In order to meet the emission requirements of ADR 37, the motor vehicle industry decided that, from 1986, new vehicles would be fitted with catalytic converters, which required the use of unleaded petrol (see Fig. 5.35). A recent further national initiative has successfully encouraged people to use unleaded petrol in older vehicles. This initiative — the 'Lead Round Table' — came about through voluntary agreements between Commonwealth, States and Territories and industry and was coordinated by the Commonwealth. The price differential between leaded and unleaded petrol (in effect since 1 February 1994), the voluntary reduction by industry of the lead content in leaded fuel to 0.3 g per litre (one company offering 'half-leaded' fuel with a concentration of 0.125 g per litre), a further reduction in 1996 and the public-awareness campaign about the lead issue have combined to give significant reductions in airborne lead. Nationally, the use of leaded petrol dropped below that of unleaded for the first time in January 1995.

Under the Constitution, the Commonwealth is responsible for signing and implementing international agreements. In relation to air quality, Australia actively contributes to several international atmospheric monitoring programs, carrying out measurements and interpreting data. The major programs are coordinated by UNEP and WMO (for baseline or clean air monitoring and a rural monitoring network) in conjunction with WHO (for urban air quality — the Global Environment Monitoring System). Australia also provides data on air quality for the OECD State of the Environment reporting process.

Figure 5.35 Levels of airborne lead in selected capital cities showing significant reductions in recent years



Source: State and Territory environmental authorities.

Within Australia, the NH&MRC used to have sole responsibility for developing guidelines for the protection of human health. Recently, this body has linked with ANZECC to provide joint recommendations covering both human health and the natural environment. However, the States and Territories are not obliged to adopt any of the recommendations. As a result, guidelines vary between each jurisdiction, making comparisons difficult. The establishment of the National Environment Protection Council provides a mechanism to resolve these problems in the future.

Air quality

All three levels of government have in place responses to air quality issues and pressures. Industry and community organisations also carry out some initiatives. The States provide the greatest number of individual responses dealing with air quality. These can be brought about through legislation, regulation, cooperative/voluntary agreements, monitoring, research and education. Some of the approaches to environmental management are listed below.

Regulation

Most States regulate emissions from stationary sources and have inspection and enforcement programs in place. In some cases, responsibility has been devolved to local governments. Environmental agencies can conduct monitoring or it may be required as part of the licence for industrial premises to operate.

Examples of responses by regulation are:

- licensing of emissions from scheduled industrial premises
- setting emission limits
- assessing emissions by testing stacks
- developing technology standards for industry that are either regulated or advised
- enforcing policy standards for major pollutants
- the limited monitoring of vehicles as part of routine vehicle inspections in some States

Cooperation

For many years industry and various State and Commonwealth government agencies have successfully maintained voluntary agreements on air quality management issues. Examples include:

- reducing lead in petrol through a national cooperative program, and the introduction by the petrol industry of half-lead petrol
- voluntary codes of practice developed by industry associations in collaboration with regulators
- voluntary emission reductions of VOCs by some major industries
- the recent move to voluntary cleaner production processes
- the ‘Responsible Care program’ introduced by the chemicals industry

Prevention

Australian environment protection agencies are changing the emphasis from one of controlling or regulating emissions at the ‘end-of-pipe’ to one of preventing emissions at their source. While this has potential to provide future savings to industry, it is still largely at the demonstration stage. Examples include:

- voluntary or regulated reductions in emissions through better processes and by minimising waste-producing parts of processes or technologies

- grants and incentive schemes for cleaner production technology
- reductions in licence fees for plants with reduced emissions
- co-generation of power from waste heat (steam)
- power generation from landfill gas (methane) — also a benefit for greenhouse gas reductions
- application of the 'polluter pays' principle
- fuel substitution — through liquefied petroleum gas (LPG) in some taxis, compressed natural gas (CNG), trials of alcohol–diesel mixtures for some buses and petrol–alcohol mixtures for cars in some parts of the country
- use of alternative energy sources such as solar and wind power

Land-use planning

Some land-use planning initiatives can reduce emissions, particularly from road transport, which in turn improves urban air quality. However, as emission reductions and improved air quality are only two of the many aspects considered in land-use planning and decision-making, other initiatives may have the opposite effect. Planning strategies implemented so far include:

- traffic management programs — for example, traffic 'calming' and traffic restriction in city centres
- greater emphasis on, and improved provision of, public transport — for example, the city loop in Melbourne or the eastern suburbs railway in Sydney (the advantages may be partly offset by freeway-building programs, cuts in expenditure on public transport and rises in fares)
- use of buffer zones to protect sensitive areas (may suffer from lack of enforcement in planning schemes)
- the Better Cities Program and urban village projects (scale is too small to prevent continuing urban sprawl)

Monitoring, research, education and information

Education and information programs are common and potentially useful responses. Most of them focus on encouraging waste minimisation or recycling, generally with the aim of changing the behaviour of householders and industry. Programs include:

- reporting air quality data on a daily basis
- air pollution forecasts ('smog alerts')
- airshed studies (including modelling studies)
- 'smoky' vehicle campaigns
- reports of prosecutions in court cases involving air pollution
- research reports on health or ecosystem effects of pollution
- the development of the National Pollutant Inventory

Individual action

Households and individual householders can also contribute to improving air quality by:

- increasing energy efficiency within the home — for example, by using energy-efficient appliances
- minimising vehicle emissions —by using public transport, by car pooling, cycling or walking or by using telecommunications to work from home if feasible
- recycling paper, glass, plastic and cans
- composting rather than burning rubbish

Local governments

Local councils are responsible for several matters that can affect local air quality —backyard incineration control, the management of tips and sewage farms, recycling and community education. They can also have responsibility for broader issues, such as land-use management, traffic management and controlled burning, and may often have sole responsibility for odour control. State and Territory governments may devolve various other responsibilities to local governments.

Commonwealth initiatives

The Commonwealth has only limited powers to respond through legislation and regulation. However, it funds strategic research by CSIRO, universities and Cooperative Research Centres (CRCs). Relevant Commonwealth departments and agencies may be responsible for programs on environmental assessment, on environmental policy and standards, on motor vehicle emissions, on waste management and on environmental protection partnerships. The Commonwealth EPA coordinates and, in some cases, regulates the use of ozone-depleting substances. The Commonwealth can coordinate voluntary initiatives (such as lead reduction in petrol and the National Pollutant Inventory) and, where appropriate, may educate the community and special-interest groups through publications and announcements. It is also responsible for the OECD State of the Environment reporting process.

Indoor air

No single government authority in any jurisdiction has responsibility for indoor air quality. Despite this, a range of responses related to indoor air in Australia is in place. These include State and Territory Government activities, the development of interim guidelines, changes to national ventilation codes, improved building design and community education.

In contrast to workplace and ambient air environments, no regulations have been developed specifically for indoor air (non-workplace) environments, a situation also common overseas. Possible reasons are that:

- the public regards private indoor environments, such as homes, as sacrosanct and therefore not subject to government control
- in practice, it would be impossible to enforce regulations on air quality within homes

- indoor air quality reflects a complex set of factors, including: the effects of building and ventilation system design, construction, operation and maintenance; outdoor climate and pollutant sources; a range and mixture of pollutants and their sources; diverse health effects; and protection of a wide range of people and their sensitivities.

State and Territory government activities

Government departments are responsible for health and environmental regulations in Australia. These departments may also undertake advisory and public education roles.

Environmental protection authorities have probably been the most active in addressing indoor air quality issues. For example, the former New South Wales State Pollution Control Commission carried out research into indoor air quality. However, the Commission was later subsumed by the Environmental Protection Authority, which no longer has this responsibility. The Victorian EPA has responsibility under the State Environment Protection Policy for the ambient (outdoor) environment but has reviewed indoor air quality in residential buildings. Also in Victoria, the Office of the Commissioner for the Environment (OCE) was established in 1986 to identify key environmental indicators and to produce State of the Environment reports. (The OCE has since been disbanded.) The report 'A Review of Air Quality Indicators and Monitoring Procedures in Victoria' addressed both indoor and outdoor pollution.

Standards and guidelines

The boundary between goals for indoor air and occupational exposure standards has became blurred in buildings that act as one person's workplace and another's public place (for example, shopping malls). Indoor-air goals must consider somewhat different factors and risk levels from those in the work environment.

The NH&MRC advises the Commonwealth Government on matters relating to health and also directs research funding. In 1990, ANZEC produced a discussion paper on indoor air quality, which concluded that the issue was not being addressed adequately in Australia and recommended a strategy consisting of three broad approaches: community education and awareness; control of sources of indoor air pollutants; and reduction of the potential for indoor air pollution problems in the future.

Ventilation codes

Australia has no specifications for minimum ventilation (infiltration) rates in residential buildings. In fact, the removal of requirements for fixed wall vents (which occurred in Victoria in 1984 and in New South Wales somewhat earlier), the improvement of construction methods and materials, the use of sheet and concrete slab flooring and the move to improve energy conservation in buildings all appear to have reduced minimum ventilation rates to levels that are in the lower range of those recommended for countries with colder climates than Australia.

The ventilation standard under the Building Code of Australia (1990) is unlikely to be revised for some years. By contrast, ventilation codes overseas are being revised and strengthened with a view to improving indoor air quality. In the Commission of European Communities 'Guidelines for ventilation requirements in buildings' it was acknowledged that not only occupants and their activities but even the buildings themselves could be major sources of pollutants, and that ventilation must be proportional to the total pollutant load. Likewise, the revised United States Ventilation Standard will emphasise the control of indoor air pollution sources. The revision may require 'additional ventilation rates' to be added to the current minimum rates if the building designer does not minimise pollutant sources in the building. The aim of this approach is to encourage the use of low-emission materials rather than increase the level of ventilation.

Reduction of indoor sources

Many indoor air pollutants have clearly identifiable sources. It is now widely accepted overseas that controlling emissions is the most important strategy for achieving improved indoor air quality. In Australia, ANZECC (1990) and NH&MRC (1993) have also recommended this approach. Future Australian Standards for pressed-wood products will probably include formaldehyde-emission limits. The CSIRO Division of Building, Construction and Engineering has recently developed environmental chambers and analytical facilities for research into formaldehyde and other VOC emissions from indoor materials. The gas industry's voluntary initiatives have reduced nitrogen dioxide emissions from new unflued gas heaters.

Public education

Public education is an important tool for improving indoor air quality, especially in homes. Education programs should be based on information from research that identifies potential problem areas, their causes and how to remedy them.

Key issues in air quality assessment

It is impossible to provide a comprehensive, quantitative assessment of national air quality. Some of the difficulties, and possible ways of dealing with them, are detailed below.

Equivalent protection for individuals

Given the lack of data for some 95 per cent of the country, it is impossible to assess whether all people enjoy the benefit of equivalent protection from air pollution — a fundamental goal of the Intergovernmental Agreement on the Environment (IGAE).

Lack of a national approach to the adoption of guidelines recommended by the NH&MRC and

ANZECC has resulted in inconsistencies between States and Territories. Thus, in practice, the current system does not provide, or even attempt to provide, equivalent protection for the 10 million or so Australians whose urban environment is monitored. A consistent national set of ambient air quality standards would be the first step.

The IGAE has the potential to provide a national approach on environment protection matters — particularly air quality. The Agreement includes the formation of a national body — now called the National Environment Protection Council — comprising Ministers representing all signatories to the IGAE. Decisions made by the Council will be binding on all members. However, progress has been slow with the last State, Western Australia, agreeing to join in late 1995. After three years, legislation has been passed in all States, with Queensland the first to enact the necessary legislation in late 1994. When established, the Council will be able to prepare and implement national environment protection measures, including national air quality standards, and so provide the basis for equivalent protection for all individuals. The first meeting of the Council was expected to be held in June 1996.

Monitoring coverage in monitored areas

The current monitoring programs are mainly restricted to the capital cities of Melbourne, Sydney, Brisbane, Perth, Adelaide and Canberra. Recent research, particularly about the formation of photochemical smog under typical Australian conditions, has highlighted deficiencies in monitoring.

Given a reliable emissions inventory, accurate knowledge of pollutant dispersion and a sophisticated representation of air chemistry, studies undertaken by organisations such as CSIRO can be used to forecast the distribution of primary emissions and the formation of secondary

Table 5.12 The main indoor air pollutants and possible response actions

Pollutant*	Typical Concentration Range	Major Sources	Responses
Asbestos fibres	less than 0.002 fibres per millilitre	friable asbestos products	risk management, removal
Synthetic mineral fibres	not characterised	insulation products	unknown
Radon	less than 200 Bq/m^3 per year (the NH&MRC guideline) found 99.9% of time in conventional homes	soil under building	siting of building improved underfloor ventilation
	less than 200 Bq/m^3 per year 91% of time found in earth-constructed homes	earth walls	material selection
Environmental tobacco smoke (ETS)	high in recreational buildings	smoking	prohibition, well-ventilated designated smoking areas, education
Respirable suspended particulates (RSP)	poorly characterised	ETS, cooking fuel combustion	improve ventilation
Legionella spp.	30% of population potentially exposed	water cooling towers	maintenance, siting, regulation
House-dust mites	10-40 µg of mite allergen marker protein per gram of dust in coastal areas.	bedding, carpet, furniture	removal/control of habitat (humidity control)
Microbial	range from hundreds of colony-forming units/m^3 to 18 000 colony forming units/m^3	moist/damp surfaces	control moisture/ mould
Formaldehyde	less than 100 ppb (the NH&MRC guideline) in conventional homes 100 to 1000 ppb in mobile buildings	pressed-wood products	source emission control, ventilation
Volatile organic compounds (VOCs)	poorly characterised	wet synthetic materials	source emission control
Pesticides	median value smaller than 5 mg/m^3. (limited data)	pest control	floor structure, inspection, clean-up, protocols for safe application
Nitrogen dioxide	up to 1 ppm	unflued gas heaters	source emission control, flued systems, improved ventilation
Carbon monoxide	about 10% exceed 9 ppm (the NH&MRC guideline)	incomplete combustion	as for nitrogen dioxide above
Carbon dioxide	poorly characterised	exhaled air	outdoor air ventilation
Lead	poorly characterised	lead paint, the fallout of accumulated roof space dust	clean-up, education
Ozone	poorly characterised	some office equipment	source emission control, ventilation

*Note: no order of priority is implied in the listing of pollutants.
In contrast to ambient (outdoor) environments, there have been no regulations developed specifically for indoors except for workplaces.

pollutants like those found in photochemical smog (see Fig. 5.31). Such studies help in assessing the most appropriate indicators for monitoring programs and for deciding the best sites for monitors.

The Metropolitan Air Quality Study (a study of the greater Sydney airshed) is a recent initiative that includes extending the city's monitoring network. It shows that transport of pollutants can occur between the city and the major industrial areas centred on Newcastle to the north and Wollongong to the south. New, extensive monitoring programs are also under way in the Perth and Brisbane airsheds, and work is scheduled to start in Adelaide soon.

During the next five years, as the population in Australian urban areas increases and city limits extend, motor vehicle usage will almost certainly increase. Vehicles will thus continue to be the major source of urban emissions. Research will continue to focus on understanding the production of photochemical smog and ozone, and policy measures will focus on limiting nitrogen oxides or VOCs. We can also expect an increased emphasis on the need to start routine monitoring of air toxics. This may be underlined by the establishment of the National Pollutant Inventory by the Commonwealth EPA.

In most Australian urban airsheds, authorities may need to reassess the requirement to monitor for sulfur dioxide and carbon monoxide, with a possible change in emphasis to ozone and air toxics.

Current conditions are likely to continue unless a major change in Australian lifestyles occurs. A reduction in motor vehicle use, and thus emissions, is possible. This would be a response partly to urban air-quality problems and partly to the identified need to increase population densities and change transportation modes to minimise our contribution to the enhanced greenhouse effect.

Monitoring for populations outside metropolitan areas

Some remote industrial centres such as Mount Isa, Kalgoorlie and Port Pirie have monitoring programs. In recent years the Queensland government has started monitoring in smaller population centres like Gladstone, Mackay and Townsville. The Melbourne airshed monitoring program has been extended to cover Geelong. Nevertheless, eight million people live outside monitored metropolitan areas.

Some major urban centres, such as the two capital cities Hobart and Darwin and Albury/Wodonga (on the Victoria/New South Wales border), have little data available, which makes it impossible to assess the extent of peoples' exposure to air pollution in those areas. As discussed above, air-quality modelling can be used to identify which population centres need to be monitored and which indicators should receive attention.

National access to air quality data

Although data exist, they are dispersed across different industries and different government agencies responsible for environmental management. This problem has been recognised for some time but remains unresolved. In 1990, a report to the Prime Minister by the Australian Science and Technology Council (ASTEC) stated that 'Australia lacks an integrated national system for measurement of environmental quality, a national database of sufficient calibre to assess and manage environmental quality and appropriate national baseline data to evaluate effectiveness of strategies' (ASTEC, 1990). Initiatives already in place — such as the IGAE Schedule 1, which calls for a national approach to data collection and handling, and the National Pollution Inventory — may provide a more satisfactory situation if fully implemented. A minimum requirement for future SoE reports should be a national inventory of the various data holdings in the States and within industry.

Data quality is also an issue. If industry is expected to monitor emissions — as is currently the case — it is essential that measurements be made using reliable methods, and also that data are independently vetted. In many cases, current practices of collecting and storing data fail to satisfy regulatory goals adequately and may actually prevent industry providing credible evidence of appropriate environmental management.

Geographical coverage of air quality monitoring

Although about 95 per cent of Australia is not regularly monitored for air quality, existing guidelines are probably satisfied over most areas, most of the time. More attention should be given to obtaining data about environmental exposure from major emission sources located in remote areas.

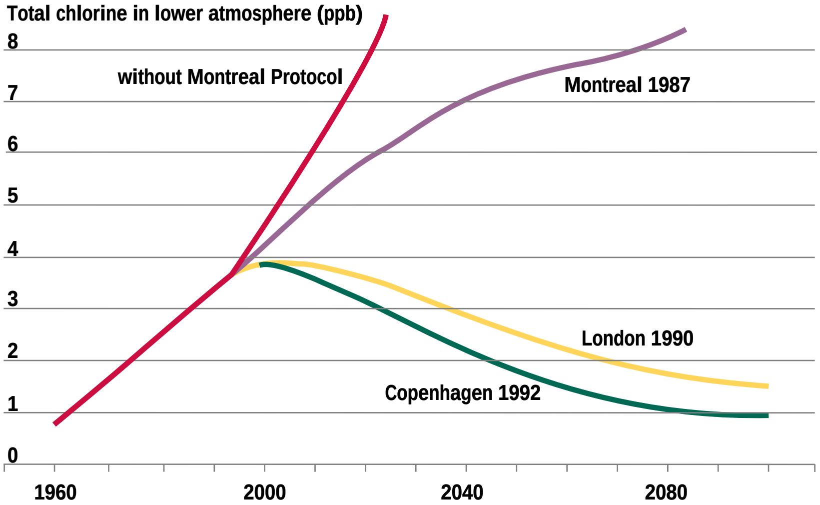
The development of a truly national picture of ambient air quality requires a network specifically designed for this purpose. Such a network would need to include:

- adequate spatial coverage — a sparsely inhabited region probably requires less-dense monitoring than the urban environment
- appropriate choice of well-characterised measurements
- data on the costs and impacts of the pollutants at the concentrations involved
- a pragmatic compromise between ideal scientific standards and the available resources
- coordination with meteorological observing networks.

A design needs to be developed for a representative, up-to-date and cost-effective network.

One possible first step towards a national assessment would be the design of a network to measure appropriate indicators for remote areas — the main ones probably being sulfur dioxide and particulates. This design process would have to

Figure 5.36 Measured chlorine-equivalent concentrations in the atmosphere since 1960 and projections according to the various measures to phase out ozone-depleting substances



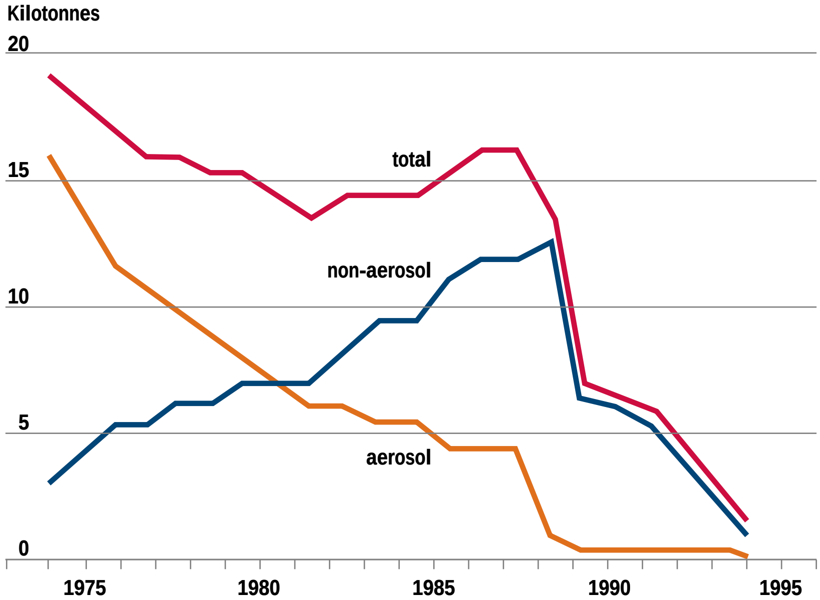
Source: derived from Albritton, WMO, 1995.

evolve as we develop our understanding of the interaction between the atmosphere and the rest of the environment (including ecosystems in remote areas) and as we improve our estimates of the cost of impacts of pollutants to society.

Understanding Australian conditions

Overseas researchers have extensively studied air quality and the effect of contaminants on the natural environment. Australia is very different — in weather and climate as well as in soils and ecosystems — from northern hemisphere countries. It is therefore not always appropriate to apply overseas findings here. In our case, it may be appropriate to set more than one standard to accommodate the sensitivities of different species, different combinations of species and environments and different exposures (so allowing for a range of land uses). However, little research is taking place in Australia and further study of our unique situation would be desirable.

Figure 5.37 Australian consumption of CFCs over the past 20 years



Source: Fraser, CSIRO, pers. comm.

Effects of air quality on flora and fauna

Even though some researchers have studied the effects of air quality on flora and fauna in Australia, the wide variations in climate and soils and the localised ranges of many plants means that their results are rarely applicable nationally. In future, we should aim to acquire more data about the effects of certain contaminants on Australian species. Interdisciplinary studies are important here. Only one research establishment in Australia is conducting controlled open-top chamber experiments to simulate the impact of air pollution under tropical, temperate and arid environmental conditions. Europe and the United States maintain much larger programs, measuring variations across the different zones of those continents.

Relationship between air quality and human health

Clearly, more epidemiological studies — properly coordinated and overseen — need to be done. Protocols should be standardised and agreed nationally, along with agreement on confounding factors and how to measure them. More and better longitudinal studies (tracking a group of people and their exposure for many years) are needed, as well as studies on the costs and benefits of changing air quality. Epidemiologists and air-quality experts could be more closely linked and emerging issues — such as levels of air toxics — should receive further investigation.

Indoor air quality and human health

Nobody is adequately addressing this important issue or developing appropriate response strategies. So far, both the measurement of indoor air quality and the assessment of impacts on human health have been fragmented. This undesirable situation will continue until a single body coordinates responsibility for management of indoor air quality.

Stratospheric ozone responses

Depletion of the ozone layer is a global problem that has attracted international attention. By the mid-1980s unusual seasonal reductions in total ozone levels over Antarctica were evident. Scientists believed that these reductions might be caused by the presence of CFCs. In 1985, worldwide concern about ozone depletion led to the Vienna Convention for the Protection of the Ozone Layer, followed in 1987 by the Montreal Protocol on Substances that Deplete the Ozone Layer. By then it had been established that CFCs were not the only industrially produced chemicals that could lead to ozone depletion. Others, such as the fire-fighting chemicals known as halons, were found to exhibit similar activity.

The 1987 Montreal Protocol introduced a series of measures, including a timetable for action to reduce the release of CFCs into the environment. Australia, the European Community and 32 other countries signed the Protocol. Together the signatory nations were responsible for more than 80 per cent of global CFC usage. The Protocol was amended in 1990 and again in 1992, both times with more stringent controls and the inclusion of more substances recognised for their ability to deplete stratospheric ozone (see Table 5.13). It now has 148 countries as signatories. Figure 5.36 shows the effect of the agreements on slowing the rate of increase of CFCs.

In 1989 — as part of its responsibilities under the Montreal Protocol — Australia adopted a Strategy for Ozone Protection, which was revised and updated in 1994. ANZECC established the Ozone Protection Consultative Committee, chaired by the Commonwealth Government and with representatives from all States and Territories and New Zealand, as well as from industry, science, conservation and community groups.

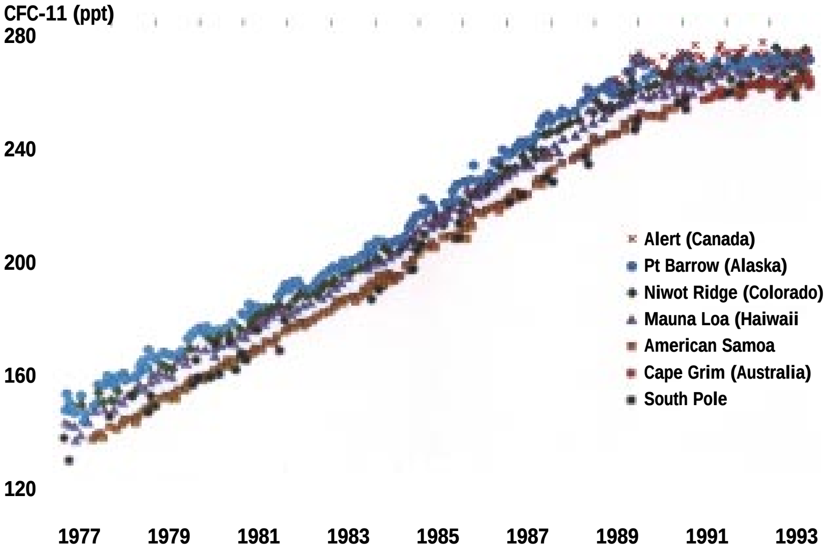
In Australia, halons were phased out at the end of 1992, a year earlier than the Protocol required. The use of CFCs, methyl chloroform and carbon tetrachloride was due to end by the end of 1995, consistent with the Protocol schedule. The Australian Strategy aims at reducing the consumption of controlled ozone-depleting substances (ODSs) by 95 per cent by the end of 1995; by the end of 1997, all further consumption should have ceased. Figure 5.37 shows the Australian consumption of CFCs over the past 20 years.

The Australian government's approach to restricting ODS consumption is to liaise with the relevant industries and encourage practical responses, backed up with economic incentives where possible. The goal is to change the behaviour of the end-users of the substance, and inform them of alternatives and the means to switch to these wherever possible. States and Territories have addressed usage, emission control and, where necessary, product and equipment bans.

Since 1989 — with the exception of essential uses such as asthma sprays — no aerosol spray cans sold in Australia have contained CFCs. Hydrochlorofluorocarbons (HCFCs) — used as temporary substitutes for CFCs — are to be controlled at a rate ahead of Protocol requirements. Atmospheric monitoring around the world has shown that the previous steady increase in the background atmospheric concentration of several ODSs, particularly CFC-11 (also a greenhouse gas), has levelled off (see Fig. 5.38).

These international measures are aimed at limiting, and ultimately reversing, the most critical impact of stratospheric ozone depletion — that is, the increase in harmful ultraviolet radiation at the earth's surface. The link between UV exposure and a range of human health problems is well established and studies have also demonstrated the UV sensitivity of other biological systems.

Figure 5.38 Atmospheric concentrations of CFC-11 from 1977 to 1993 from several observation sites



Source: IPCC, 1994.

Unfortunately, because of the long atmospheric residence time of most of the ODSs, it will take several decades to restore the natural balance between ozone production and destruction. Meanwhile, a large part of the earth will probably be subjected to increased ultraviolet radiation.

Greenhouse responses

The enhanced greenhouse effect is a global problem that requires global responses. Effective global responses will only be achieved by international agreements, such as the United Nations Framework Convention on Climate Change (FCCC), supported by effective national emission reduction and other response programs. Although Australia only produces one to two per cent of total world emissions, we need to play our part in solving the problem.

Interim planning target

Australia has acknowledged the potential impact of climate change resulting from an enhanced greenhouse effect on the nation's natural, social and working environment as well as on the global community. In October 1990, the Commonwealth Government adopted an interim planning target for the emission of greenhouse gases not controlled by the Montreal Protocol. Accordingly, Australia aims to: 'stabilise greenhouse gas emissions (not controlled by the Montreal Protocol on substances that deplete the ozone layer) based on 1988 levels by the year 2000 and to reduce these emissions by 20 per cent by the year 2005....subject to Australia not implementing response measures that would have net adverse economic impacts nationally or on Australia's trade competitiveness, in the absence of similar action by major greenhouse gas producing countries' (Commonwealth of Australia, 1992).

The target is not legally binding but acts as a guideline for action and a standard against which to measure progress (see Fig. 5.39).

National Greenhouse Response Strategy

Late in 1990, the Government recognised that measures to control greenhouse gas emissions should become an integral component of the national Ecologically Sustainable Development process then under way. The interim planning target subsequently formed the basis of the National Greenhouse Response Strategy. In 1992, the Commonwealth, State and Territory governments agreed to the Strategy, which was also endorsed by the Australian Local Government Association. The Strategy recommended a phased approach. First-phase responses will be those of a 'no-regrets' nature — that is: 'a measure that has other net benefits (or at least no net cost) besides limiting greenhouse gas emissions or conserving or enhancing greenhouse gas sinks' (Commonwealth of Australia, 1992).

Many energy-saving measures — such as improved house insulation — are examples of 'no-regrets' actions. The Strategy includes provision for public involvement, a requirement for auditing and reporting and recognition of the need to consider adapting to the impacts (both positive and negative) of climate change. The need for research and analysis to improve knowledge and understanding of the enhanced greenhouse effect is another essential element.

Table 5.13 The 1987 Montreal Protocol* and the 1990 London and 1992 Copenhagen amendments

Ozone Depleting Substances	Montreal (1987)[2]	Control Measures[1] London (1990)[2,3]	Copenhagen (1992)[4]
CFC-11, CFC-12, CFC-113, CFC-114, CFC-115	• freeze at 1986 levels by 1989 • reduce by 20% by 1 July 1993 • reduce by a further 30% by July 1998	• reduce by 50% by 1995 (from 1986 levels) • reduce by 85% by 1997 • total phase-out by 2000	• reduce by 75% by 1994 (from 1986 levels) • total phase-out by 1996
Halon-1211, Halon-1301, Halon-2402	• freeze at 1986 levels by 1992	• reduce by 50% by 1995 (from 1986 levels) • total phase-out by 2000	• total phase-out by 1994 (recycling encouraged)
Other CFCs	not included	• reduce by 20% by 1993 (from 1989 levels) • reduce by 85% by 1997 • total phase-out by 2000	• reduce by 20% by 1993 (from 1989 levels) • reduce by 75% by 1994 • total phase-out by 1996
CCl_4 (carbon tetrachloride)	not included	• reduce by 85% by 1995 (from 1989 levels) • total phase-out by 2000	• reduce by 85% by 1995 (from 1989 levels) • total phase-out by 1996
CH_3CCl_3 (methyl chloroform)	not included	• freeze at 1989 levels • reduce by 30% by 1995 • reduce by 70% by 2000 • total phase-out by 2005	• reduce by 50% by 1994 (from 1989 levels) • total phase-out by 1996
HCFCs	not included	not included, but to be reviewed in 1992	• freeze by 1996(5) • reduce by 35% by 2004 • reduce by 65% by 2010 • reduce by 90% by 2015 • reduce by 99.5% by 2020 • total phase-out by 2030
HBFCs	not included	not included	• total phase-out by 1996
CH_3Br (methyl bromide)	not included	not included	• freeze by 1995(6) (1991 base year) • further study requested • decision on cuts in 1995

Notes:
1. Control measures commence on January 1 of the year indicated.
2. A ten year grace period is allowed for developing nations provided their annual consumption is less than 0.3 kg per capita.
3. Agreement was reached to set up a special fund to provide financial and technical assistance to developing nations to enable them to comply with the Protocol.
4. The special fund was made permanent, but the application of the Copenhagen phase-out dates (plus the ten-year grace period for developing nations) will not be considered until 1995.
5. Based on 1989 HCFC consumption with an extra allowance (ODP weighted) equal to 3.1% of 1989 CFC consumption.
6. Quarantine and pre-shipment treatment is exempt.

* The timetable set by the Montreal Protocol is for bulk consumption of ozone-depleting substances (ODSs) in developed countries (this does not include references to manufactured products containing ODSs. Consumption is defined as the quantities manufactured or imported less those quantities exported in any given year. Percentage reductions relate to the base year for the substance. The Protocol does not forbid the use of recycled controlled substances beyond the phase-out dates.

Source: ANZECC, 1994.

United Nations Framework Convention on Climate Change

More than 150 countries signed the Framework Convention on Climate Change at the 1992 Rio Earth Summit. It came into force in March 1994. At the time of the first session of the Conference of the Parties (March 1995), 127 countries had ratified it. In December 1992, Australia (an Annex I (developed) country under the Convention) became the ninth nation to ratify. The stated aim of the Convention is to achieve:

'...stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.'

The Convention recognises that developed countries must take the lead in reducing greenhouse gas emissions.

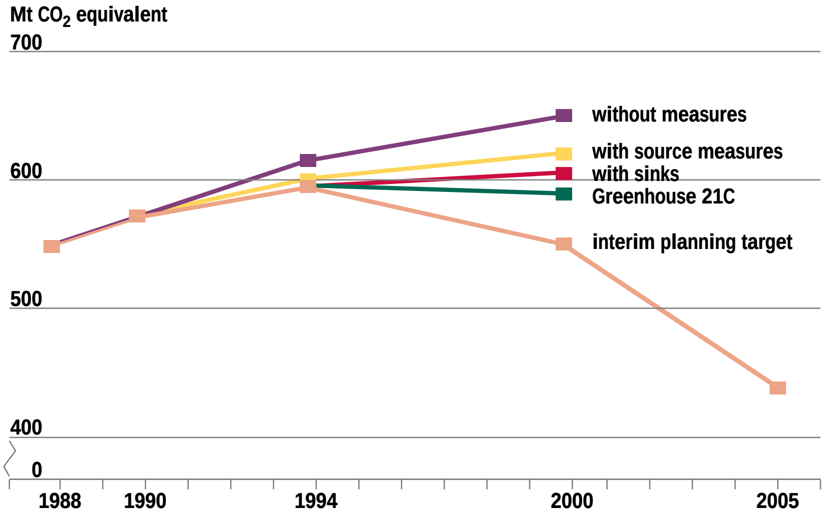
Under its obligations as an Annex I country, Australia provided its national report to the Convention in September 1994 (Commonwealth of Australia, 1994). The greenhouse gas inventory (see Figs 5.5, 5.6 and Table 5.2) forms part of these obligations. The report also outlined the range of policy measures in place to limit emissions, and provided a forward projection of Australia's greenhouse gas emissions for the year 2000 (see Fig. 5.39). However, despite measures in place in 1994 for both emission reductions from sources and increased uptake by sinks, a considerable gap remained between the projections and stabilisation at 1990 levels by the year 2000. Based on current measures, the likelihood of reaching the 2005 interim planning target is quite remote.

Assessment of first phase measures

Several measures identified in the National Greenhouse Response Strategy as satisfying a 'no-regrets' requirement have not been implemented. Mechanisms are in place to address a number of these deficiencies, but only limited progress has been made. However, some companies are using environmental management systems and cleaner production initiatives to reduce energy and commodity consumption with consequent gains. The Government considered, but did not proceed with, the introduction of a small carbon tax (environment levy) on emissions.

Australia's responses are based on, and determined by, our conditions — our high dependence on fossil fuels (particularly for power generation) and the large agricultural sector. The latter contributes significantly to CO_2 emissions from land-use changes and to methane emissions from our large livestock population. Therefore, measures must range across all sectors of the economy; government, industry, agricultural enterprises and individual householders all have a role to play.

Figure 5.39 Interim planning target and projected greenhouse gas emissions to the year 2000 — these figures indicate that considerable further reductions will be required to meet the interim planning target



Source: adapted from data in Commonwealth of Australia 1992, 1994; DEST, 1995.

A recent joint report of the Australian Academy of Technological Sciences and Engineering, Australian Academy of Science and the Academy of the Social Sciences in Australia compared this country with others in the OECD. It found:

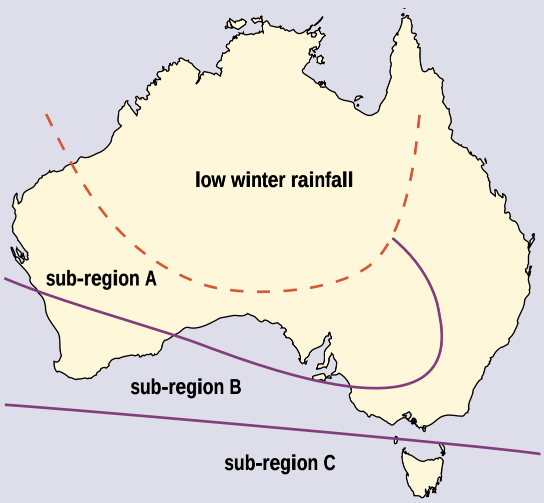
'Australia's relatively high carbon dioxide emissions have become much higher in the last two decades. From 1987 to 1992 energy-related carbon dioxide emissions grew much faster than the OECD average: more than 13 per cent compared with less than five per cent. Australia has had greater increases in population than other OECD countries, but other OECD countries have had greater increases in gross domestic product. Both increasing population and increasing gross domestic product could have been expected to increase greenhouse gas emissions, but carbon dioxide emissions in OECD countries have increased in line with population and gross domestic product while in Australia the rate of emission increase has been significantly higher than the rate of increase in gross domestic product and population.' (Steering Committee of Climate Change Study, 1995).

Our relatively high dependence on fossil fuels (compared with other OECD countries), the lack of nuclear power and the limited opportunities for hydro-electricity generation all restrict the available options to reduce CO_2 emissions. However, we have large reserves of natural gas — the least carbon-intensive of the three main fossil fuels (coal, oil and gas). There is potential for substituting natural gas for coal in some applications. As well, Australia's climate provides abundant supplies of renewable energy sources such as solar and wind power, although their development and use have so far been limited. The conversion of domestic water heating to solar power is one immediate opportunity to achieve worthwhile savings in greenhouse emissions (Commonwealth of

Table 5.14 Scenarios of rainfall change for locations in Australia

Season	Region	Response per degree of global warming	Change in 2030	Change in 2070
Summer half-year (Nov. to April)	Any location	0 – +10%	0 – +20%	0 – +40%
Winter half-year (May to Oct.)	Locations in sub-region A	0 – -5%	0 – -10%	0 – -20%
	Locations in sub-region B	-5% – +5%	-10% – +10%	-20% – +20%
	Locations in sub-region C	0 – +5%	0 – +10%	0 – +20%

Note: Sub-regions are defined in the map below. Values for the years 2030 and 2070 are rounded to the nearest 10%.



Source: CSIRO, 1992

Australia, Senate, 1991). The contribution of urban transport to greenhouse gas emissions and energy use can also be potentially reduced.

Although all governments had adopted the National Strategy for Ecologically Sustainable Development, by mid-1995, there has been no indication that they paid close attention to the application of its basic principles in major initiatives such as the operation of the national electricity grid and the extension of reticulated electricity grids to remote areas. Governments appear reluctant to account adequately for environmental costs in the decision-making process when new power stations are constructed.

Greenhouse 21C

In March 1995, the Commonwealth Government announced a package of further measures, entitled ‘Greenhouse 21C’, which included three main initiatives:

- cooperative agreements between government and industry for reductions in net greenhouse gas emissions
- renewable energy initiatives, including the Commonwealth commitment to establish a Cooperative Research Centre on renewable-energy technology
- continuing emphasis on economic reform in the energy sector, with a greater focus on gas reform and delivery of energy efficiency and renewable-energy programs

Greenhouse 21C also covers: a greenhouse information network to support action by all sections of society; enhanced cooperation with the States and Territories to address issues such as land management and energy-sector reforms; expansion of tree-planting programs to provide greenhouse sinks; and an emphasis on environmental best practice in the Commonwealth Government’s own operations.

To date, most effort has been on developing mitigation measures, with particular emphasis on voluntary agreements with industry sectors. Projections in Greenhouse 21C indicate that emission levels in 2000 will be about three per cent above those needed for stabilisation at 1990 levels (see Fig. 5.39). Strong action will be needed in all sectors to achieve these emission reductions. Substantially larger reductions will be needed to achieve the Interim Planning Target for the year 2005. In mid 1995, it was still too soon to judge the likely success of these particular measures.

Climate change research

Australia has made a considerable investment in climate change research and has built up a strong body of scientific expertise both for the country and the region. Australian scientists have also played a major role in the international research effort on the enhanced greenhouse effect, providing a unique southern hemisphere perspective. Research has covered areas such as: the analysis of Antarctic ice-core data; analysis of the global carbon cycle; research in atmospheric chemistry including analysis of long-term background data from the Cape Grim baseline station; climate modelling and validation exercises; impact assessment; and studies of climate variability.

Clearly, a good understanding of the science of climate change should underpin the policy-making process. However, the current uncertainty in the science means that there are no reliable regional predictions of possible climate change over the Australian continent. A precautionary approach is justified in the face of this level of uncertainty. For planning purposes a range of future scenarios has been developed (CSIRO, 1992). Table 5.14 shows an example of a broad scenario designed to help in long-range decision-making, developed by CSIRO for Australian conditions. Such scenarios can help assess vulnerability and develop options for responses (for example, assessing potential costs and benefits, or enhancing the processes that take up greenhouse gases — that is, sinks) and for adaptations (for example, actions to cope with adverse changes and/or take advantage of beneficial changes). In addition, research work designed to help implement adaptation policies will also contribute to our efforts to cope more effectively with the impacts of climate variability, which is an important feature of Australia.

Table 5.15 Summary

Element of the environment/Key issue	State	Adequate Info.	Response	Effectiveness of response
Climate Natural climate variability	Australia's climate displays a high natural variability. In 1994/95 large areas of eastern and northern Australia suffered severe drought linked to a highly abnormal long-lived El Niño episode. Rainfalls in some areas were the lowest on record.	✓✓	An active research program into climate variability is underway.	Seasonal and interannual predictions are available.
Enhanced Greenhouse Effect Global atmospheric concentrations of major greenhouse gases.	Observations at the Cape Grim Baseline Station (Tasmania) show continuing annual increases in global concentrations of all major greenhouse gases.	✓✓✓	Negotiation of the UN Framework Convention on Climate Change (FCCC) including an implied target of developed countries returning emissions to 1990 levels by 2000. Australia has signed and ratified the FCCC. Negotiations continue on the Berlin Mandate.	The first Conference of the Parties of the FCCC, held in Berlin in March 1995, agreed that the global response was inadequate.
Australia's contribution to global emissions.	Australia contributes 1-2% of current global emissions. The NGGI shows that Australia's relatively high contribution to global emissions is mainly due to high fossil fuel use, vegetation clearing and agriculture.	✓✓	1990 : Interim Planning Target - stabilisation at 1988 levels by 2000, 20% reduction by 2005; 1992 : Governments agreed to the NGRS based on a 1995 : Greenhouse 21C including voluntary Industry agreements	Early initiatives will not achieve stabilisation by 2000.It is too soon to judge the success of responses under Greenhouse 21C.
Stratospheric ozone Stratospheric ozone loss	The Antarctic ozone hole has increased in depth and extent since the early 1980s. A decline in stratospheric ozone and a decrease in total column ozone have been monitored over Australia in the past decade.	✓✓✓	Negotiation of the Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol, London and Copenhagen Amendments. Australia is a Party to the Convention and its protocol and amendments.	The ozone hole will persist but conditions are expected to improve within the next five years, with some expectation that global ozone levels will also begin to increase.
Atmospheric concentrations of CFC-11 & CFC-12	Measurements at Cape Grim (Tasmania) show levels of CFC concentrations are stabilising.	✓✓✓	Australia is meeting all Montreal Protocol obligations ahead of schedule, eg total phase-out of halon imports and use in new equipment, phase-out of CFC production before the end of 1995, most air conditioning units in new vehicles are CFC-free.	Concentrations of several major CFCs are expected to decline globally in the next few years.
Urban air quality Sulfur dioxide (SO_2)	SO_2 levels in major urban airsheds are generally well below levels of concern. Major sources such as power stations are located outside urban areas.	✓✓✓	Low levels result from low sulfur content of Australian fuels.	Effective.
Ozone	Tropospheric ozone concentrations in urban areas result from the chemical interaction of NOx and VOC emissions in the presence of sunlight. Amblent levels are generally low. Episodic high values in Sydney, Melbourne and increases in Perth are of concern.	✓✓	Nationwide introduction of catalytic converters in new vehicles in 1986 reduced emissions of VOCs with a smaller reduction in NOx. Future responses will need to be made in the light of a number of studies currently underway.	Trends are difficult to assess. Increases in new vehicles may be offset by other factors eg Increase in the number of vehicles & the distance travelled. In-service vehicle standards are needed. In future further controls on NOx emissions will be necessary,
Lead	Airborne lead levels have fallen over the past decade.	✓✓✓	Increased use of unleaded petrol following mandatory controls on vehicle emissions (1986) and the installation of catalytic converters in new vehicles. A more recent campaign to encourage increased use of unleaded petrol	Further reductions in lead levels are expected to occur as the number of pre-1986 vehicles decreases.
Toxics	A number of toxic substances have been identified in urban air sheds. However to date only local isolated measurement programs have been undertaken.	✓	Recognition of potential concern. Proposals for a National Pollutant Inventory are under consideration.	Further research is required.

Table 5.15 Summary (continued)				
Element of the environment/Key issue	**State**	**Adequate Info.**	**Response**	**Effectiveness of response**
Particles	Seasonal episodic high values are reported from all major capital cities. Sources include domestic wood fires, backyard incinerators, vehicles (particularly diesel), control burns and bushfires.	✓✓	Elimination or restrictions on the use of backyard incinerators. Improved management of control burns in rural regions upwind or major urban areas; and new emission limits on diesel vehicles.	Improvement in visibility within cities however the lack of controls on domestic wood burning poses a significant problem in some urban areas. Diesel emission standards require further update.
Health Effects	A number of Australian studies have sought to determine whether relationships exist between levels of pollutants in ambient air health/morbidity/mortality but results have been inconclusive.	✓	NH&MRC guidelines for the protection of human health are agreed for a range of individual pollutants but the guidelines are not implemented nationally. A limited number of studies of health effects have been undertaken.	Currently no nationally implemented guidelines. There is a need for more epidemiological studies with standard protocols and agreement on confounding factors. Few longitudinal studies are available.
Regional air quality Sulfur dioxide (SO_2)	A number of major point sources are located in remote inland areas. SO_2 emissions are removed downwind mainly by dry deposition processes. There is no evidence of significant acid (wet) deposition in Australia.	✓	Airshed management of emissions from major sources is used to control ground level concentration mainly for health protection.	Some high levels are occasionally recorded in vulnerable areas. Improved management strategies are being implemented. Effects on native vegetation are generally unknown.
Fluoride	Levels are locally high in the vicinity of aluminium smelters, brickworks, ceramic kilns etc.	✓✓	Buffer zones protect areas adjacent to smelters.	Overall the use of buffer zones is effective however improved emission reduction technology is available.
Indoor air quality Environmental Tobacco Smoke (ETS)	Unknown. Few direct measurements are available.	✓	Designation of non-smoking areas in public buildings. However there are few controls on emissions in private homes.	Non-smoking policies for public buildings are selectively applied.
House Dust Mites (HDM)	Elevated levels are reported in the warm moist coastal areas of Australia.	✓	Nil	Reduced ventilation requirements for energy efficiency may lead to an increase in the concentration of HDMs in private homes.
Legionella	Isolated outbreaks have occurred in mainland Australia with fatal outbreaks linked mainly to poor maintenance of cooling towers.	✓✓✓	Legionella is a notifiable disease. Building codes and NH&MRC guidelines have been developed for the maintenance of cooling towers.	High standards of maintenance must be ensured.
Asbestos	Asbestos has been used extensively as a construction material and for insulation. Asbestos is still present in many old buildings in Australia. The major risk of exposure is linked to disturbances such as renovations and removal.	✓✓	A code of practice for removal has been developed.	The adequacy of the current responses is unknown.
Radon	Levels are generally low in Australian homes.	✓	NH&MRC has defined a guideline.	Effective.
Volatile Organic Compounds (VOCs)	Concentrations can be high in new buildings and caravans. VOCs, particularly formaldehyde, are released by furnishings, carpet and particle board. Concentrations decrease with time.	✓	Apart from ventilation requirements in building codes there are few controls on emissions in private homes.	Ventilation requirements have weakened with the move to increase energy efficiency thus increasing the potential for high concentrations of VOCs indoors.
Health effects and personal exposure.	Limited studies show Australians spend 90% of time indoors where the range of pollutants and personal exposure times are often greater than outdoors.	✓	Small numbers of targeted public education programs.	Limited progress in some aspects but ineffective in regard to many others.

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