Environmental Indicators

For National State of the Environment Reporting

the atmosphere

Australia: State of the Environment
Environmental Indicator Report

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Preface

The Commonwealth State of the Environment Reporting system supports the *National Strategy for Ecologically Sustainable Development* and helps Australia meet its international obligations, such as those under *Agenda 21* and the OECD environmental performance reviews. The first independent and comprehensive assessment of Australia's environment, *Australia: State of the Environment 1996* was released by the Commonwealth Environment Minister in September of that year.

The next step in the evolution of the reporting system is to develop a set of environmental indicators that, properly monitored, will help us track the condition of Australia's environment and the human activities that affect it. To help develop these indicators, Environment Australia has commissioned reports recommending indicators for each of the seven major themes around which Commonwealth state of the environment reporting is based. The themes are:

- human settlements
- biodiversity
- the atmosphere
- the land
- inland waters
- estuaries and the sea
- natural and cultural heritage.

Clearly, none of these themes is independent of the others. The consultants worked together to promote consistent treatment of common issues. In many places issues relevant to more than one theme receive detailed treatment in one report, with cross-referencing to other reports.

Report authors were asked to recommend a comprehensive set of indicators, and were not to be constrained by current environmental monitoring. One consequence of this approach is that many recommendations will not be practical to implement in the short term. They are, however, a scientific basis for longer term planning of environmental monitoring and related activities.

An eighth report, deals with the use of the recommended indicators by local or regional environmental managers and with the role of the community in indicator work. It is the result of a pilot study carried out by the Australian Local Government Association and Environment Australia.

These reports are advice to Environment Australia and have been peer reviewed to ensure scientific and technical credibility. They are not necessarily the views of the Commonwealth of Australia.

The advice embodied in these reports is being used to advance state of the environment reporting in Australia, and as an input to other initiatives, such as the National Land and Water Resources Audit and the Australian Local Government Association's Regional Environmental Strategies.

Summary

A key set of 60 environmental indicators for the atmosphere is recommended for Australian state of the environment reporting. Of these, 16 relate to climate variability and change, 9 to stratospheric ozone, 19 to urban air quality, and 16 to regional air quality. A further 5 potential key indicators for climate variability and change are also identified. Indicators for indoor air quality are fully described in a report by Newton *et al.* (in prep.) on environmental indicators for human settlements, but are also listed in an appendix to this report.

Aims of the study

- present a key set of environmental indicators for the atmosphere for national state of the environment reporting;
- ensure that the list of indicators adequately covers all major environmental themes and issues;
- examine each indicator in detail to ensure that it is rigorously defined and measurable and in an interpretive framework;
- identify suitable monitoring strategies for each indicator – including measurement techniques, appropriate temporal and spatial scales for measurement and reporting, data storage and presentation techniques, and the appropriate geographical extent of monitoring;
- identify relevant data sources for each indicator, if these are available;
- define the baseline information that is needed to properly interpret the behaviour of the indicators.

Table of Contents

Background

Commonwealth State of the Environment Reporting

In 1992 Australia's *National Strategy for Ecologically Sustainable Development* (Council of Australian Governments 1992) was endorsed by the Commonwealth, all State and Territory Governments and Local Government. The objectives of this strategy are:

- to enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- to provide for equity within and between generations; and
- to protect biological diversity and maintain essential ecological processes and life-support systems.

The strategy called for the introduction of regular state of the environment (SoE) reporting at the national level to enhance the quality, accessibility and relevance of data relating to ecologically sustainable development.

The broad objectives of state of the environment reporting for Australia are:

- to regularly provide the Australian public, managers and policy makers with accurate, timely and accessible information about the condition of and prospects for the Australian environment;
- to increase public understanding of the Australian environment, its conditions and prospects;
- to facilitate the development of, and review and report on, an agreed set of national environmental indicators;
- to provide an early warning of potential problems;
- to report on the effectiveness of policies and programs designed to respond to environmental change, including progress towards achieving environmental standards and targets;
- to contribute to the assessment of Australia's progress towards achieving ecological sustainability;
- to contribute to the assessment of Australia's progress in protecting ecosystems and maintaining ecological processes and systems;
- to create a mechanism for integrating environmental information with social and economic information, thus providing a basis for incorporating environmental considerations in the development of long-term, ecologically sustainable economic and social policies;
- to identify gaps in Australia's knowledge of environmental conditions and trends and recommend strategies for research and monitoring to fill these gaps;
- to help fulfil Australia's international environmental reporting obligations; and
- to help decision makers make informed judgements about the broad environmental consequences of social, economic and environmental policies and plans.

The first major product of this process was *Australia: State of the Environment 1996* (State of the Environment Advisory Council 1996) - an independent, nation-wide assessment of the status of Australia's environment, presented in seven major themes: atmosphere; biodiversity; estuaries and the sea; human settlements; inland waters; land resources; and natural and cultural heritage.

In *Australia: State of the Environment 1996*, each theme is presented in a chapter that follows the Organisation for Economic Co-operation and Development's (OECD) (1993) Pressure-State-Response model (see also DEST 1994). The OECD P-S-R model describes, respectively, the anthropogenic pressures on the environment, conditions or states of valued elements of the environment, and human responses to changes in environmental pressures and conditions.

Australia: State of the Environment 1996 is the first stage of an ongoing evaluation of how Australia is managing its environment and meeting its international commitments in relation to the environment. Subsequent state of the environment reports will assess how the environment, or elements of it, have changed over time, and the efficacy of the responses to the pressures on the environment. The next national SoE report is due in 2001, consistent with the regular reporting cycle of four to five years. In order to assess changes in the environment over time it is necessary to have indicators against which environmental performance may be reviewed. As pointed out in *Australia: State of the Environment 1996*:

"In many important areas, Australia does not have the data, the analytical tools or the scientific understanding that would allow us to say whether current patterns of change to the natural environment are sustainable. We are effectively driving a car without an up-to-date map, so we cannot be sure where we are. Improving our view of the road ahead by enhancing the environmental data base is a very high priority. Our intended destination is a sustainable pattern of development, but it is not always clear which direction we need to take to get there".

The development of a nationally agreed set of indicators is the next stage of the state of the environment reporting system. This report recommends environmental indicators for the atmosphere. Indicators for the land (Hamblin 1998), biodiversity (Saunders *et al.* 1998), estuaries and the sea (Ward *et al.* 1998), inland waters (Fairweather and Napier 1998), human settlements (Newton *et al.* in prep.), and natural and cultural heritage (Pearson *et al.* in prep.) have been developed in consultancies overlapping with the development of indicators for the atmosphere.

Environmental indicators

Environmental indicators are physical, chemical, biological or socio-economic measures that best represent the key elements of a complex ecosystem or environmental issue. An indicator is embedded in a well-developed interpretive framework and has meaning beyond the measure that it represents.

Repeated measurements of the variable in various places and times, and in a defined way, comprise the monitoring program for that indicator. Comparison of this repeated set of measurements with a benchmark set of condition provides the basis for identifying natural variability and detecting change. Over time, in the case of a Condition indicator, this change can be matched to particular Pressure and Response indicators to assess both the nature of the effects of particular Pressures, and the efficacy of our management responses to key environmental issues. The scale at which the information is needed for management purposes dictates the scales (spatial and temporal) at which the monitoring program must resolve changes in each indicator. (We note that the OECD uses the term "State" rather than "Condition". The present nomenclature is used to avoid confusion from the different meanings of "State".)

The key set of indicators is defined as the minimum set which, if properly monitored, provides rigorous data describing the major trends in, and impacts on, the Australian atmosphere. The key set should include:

- indicators that describe the condition of all important elements of the atmospheric environment;
- the extent of the major human activities that affect these elements (pressures); and
- indicators of societal and governmental responses to either the condition or changes in the condition of the atmospheric environment.

It is important that the set of condition indicators provides a basis for the identification of the inherent natural variability of the climate system, so that an accurate assessment can be made of human impacts and responses to policy measures.

The selection criteria for national environmental indicators are listed below (from DEST 1994); the set of key indicators should meet as many of these as possible.

Each indicator should:

- serve as a robust indicator of environmental change;
- reflect a fundamental or highly-valued aspect of the environment;
- be either national in scope or applicable to regional environmental issues of national significance;
- provide an early warning of potential problems;
- be capable of being monitored to provide statistically verifiable and reproducible data that show trends over time and, preferably, apply to a broad range of environmental regions;
- be scientifically credible;
- be easy to understand;
- be monitored regularly with relative ease;
- be cost-effective;

- have relevance to policy and management needs;
- contribute to monitoring of progress towards implementing commitments in nationally significant environmental policies;
- where possible and appropriate, facilitate community involvement;
- contribute to the fulfilment of reporting obligations under international agreements;
- where possible and appropriate use existing commercial and managerial indicators; and
- where possible and appropriate, be consistent and comparable with other countries' and State and Territory indicators.

Existing processes

There are some existing processes that are relevant to developing environmental indicators for the atmosphere for state of the environment reporting. The OECD requirement for national reporting based on a set of environmental indicators provides an international framework for the present study, while the continuing work of the National Environment Protection Council (NEPC) should lead to a mechanism for implementation of long-term nationally-consistent monitoring of air quality parameters needed for state of the environment reporting. The Academy of Technological Sciences and Engineering (ATSE) has recently completed an Inquiry into Urban Air Pollution in Australia which, with the National Environment Protection Measure (NEPM) studies, yields further material to assist the development of air quality indicators. The development of indicators related to the enhanced greenhouse effect benefits from activities under the National Greenhouse Response Strategy (NGRS). Each of these processes is briefly discussed below.

OECD environmental indicators

The OECD has developed a set of environmental indicators, including indicators for the atmosphere. These are listed in the publication *Environmental Indicators: OECD Core Set* (OECD 1994). The OECD uses the Pressure-State-Response model, which is increasingly being followed, with modifications, around the world.

The OECD atmosphere indicators are generally more relevant to Australia than those for the other major themes. Even so, the OECD atmosphere indicators must be carefully scrutinised for applicability to Australia, especially in view of the large interannual variations in meteorological factors that influence our climate and air quality.

The OECD Group on State of the Environment Reporting is further developing OECD indicators. This group has started to recognise that the indicators need to account for variations across regions of the world, and it is taking some steps toward addressing the issue.

National Environment Protection Measures

The National Environment Protection Council (NEPC) is a Ministerial Council with law-making powers that was established as a result of the Intergovernmental Agreement on the Environment (1992). One of the primary functions of the NEPC is to make National Environmental Protection Measures (NEPMs).

NEPMs are broad framework-setting statutory instruments that outline agreed national objectives for protecting particular aspects of the environment. NEPMs may consist of a combination of goals, standards, protocols and guidelines. A NEPM will become a national standard, recognised through an associated law in each jurisdiction once it is passed by the NEPC, unless it is disallowed by either House of the Commonwealth Parliament. A two-thirds majority is required for the NEPC to pass a NEPM. Implementation of NEPMs is the responsibility of each participating jurisdiction.

In June 1996, the NEPC decided to set in train a process to develop a NEPM for ambient air quality. This NEPM will have the goal of protecting human health and well-being, and will entail establishing ambient air quality standards and monitoring and reporting protocols for carbon monoxide, sulphur dioxide, nitrogen dioxide, photochemical oxidant (as ozone), lead and particulate matter.

The Commonwealth Government, in co-operation with State and Territory Governments, established a process in 1992 to develop a National Pollutant Inventory (NPI). This activity is part of the NEPC process, providing information on pollutants released into the atmosphere and their related risks. The NPI NEPM was adopted by NEPC on 27 February 1998.

Both environmental indicators for state of the environment reporting and the NEPM are at relatively early stages of development, and there is ample opportunity for each process to influence the other. It has been agreed that parties should work together to ensure that the indicators and the NEPM are consistent and complementary.

Inquiry into Urban Air Pollution in Australia

The Inquiry into Urban Air Pollution in Australia was carried out by the Academy of Technological Sciences and Engineering for the Commonwealth Government. Its terms of reference include the words ". . . briefly identify current trends, scale and likely future sources of carbon monoxide, sulphur dioxide, nitrogen dioxide, lead particulates and photochemical oxidants (as ozone) including ozone precursors (hydrocarbons) which adversely affect air quality."

The summary results of the study became available in November 1997 (ATSE, 1997). The study involved seven task groups covering the present context, stationary sources, domestic or local sources, transport vehicles, transport logistics, urban infrastructure, and environmental economics and cost benefit. Separate reports were prepared by each task group, as supplementary information to the study.

Performance Indicators for the National Greenhouse Strategy (NGS)

Australia is one of the first countries in the world to develop a set of primary performance indicators to evaluate progress of its National Greenhouse Strategy (NGS). Australia's agreed primary performance indicators include macro indicators to provide a measurement of overall national performance (e.g. emissions and emissions per unit of output); sectoral indicators reflecting sectoral objectives and measures; and diagnostic indicators for strategic industries or policy areas.

Work on developing secondary indicators and measuring specific performance indicators will proceed as part of the development of a new National Greenhouse Strategy, due for release in mid 1998. The agreed primary performance indicators may need to be amended or changed, subject to the outcome of the National Greenhouse Strategy development.

Overview of atmospheric indicators

For most people the state of the atmosphere is the primary indicator of the state of the environment. Our physical climate affects the flora and fauna of Australia, as well as the economic, social and medical well-being of our society. Air quality is determined by the chemical composition of the atmosphere which impacts on human health and aesthetic values, as well as ecological systems.

The focus of the atmospheric indicators is on human health, rather than atmospheric impacts on ecological systems. Indeed many condition indicators of the atmosphere will appear as pressure indicators for biodiversity, inland waters, and coastal systems. However, there are some indicators for air quality (e.g. fluoride) which are primarily related to ecological systems.

As with most environmental issues, the pressures on the state of the atmosphere are closely related to human population and activity. Because Australia is an island continent, relatively isolated in the southern hemisphere, and with a low population, some of these pressures are not as great as in countries in the northern hemisphere. However, there are global-scale pressures on the atmosphere that impact on the whole world.

We can separate indicators of the state of the atmosphere into measures of climate, driven by large-scale forces, and measures of air quality, driven by regional or local factors. A major difference between the large-scale and local forces is the life-time of the atmospheric pollutants that lead to pressures on associated systems. Pollutants with large-scale impacts have life-times of years to centuries in the atmosphere (e.g. carbon dioxide and chlorofluorocarbons (CFCs)), while local impacts are caused by short-lived pollutants such as sulphur dioxide and lead.

Each type of indicator requires a different approach to monitoring and interpretation. Where pressures occur on a global scale, it is necessary to ensure that our monitoring and response strategies are co-ordinated with the relevant international activities. Similarly, in order to determine nationally-consistent indicators of regional issues, we must ensure that the activities of State and Commonwealth agencies are well co-ordinated.

There are two global-scale meteorological issues that have attracted considerable scientific and political interest over the last few decades. These issues are the potential for global climate change due to the enhanced greenhouse effect and the potential for the depletion of the stratospheric ozone layer due to the addition of human-made chemicals into the atmosphere. In attempting to interpret indicators of these anthropogenic pressures, we must take into account the high natural variability of climate. That is, we must recognise that the anthropogenic signal of climate change and trends is embedded in a background of noise due to the natural fluctuations in the climate system. Our climate is also affected by external influences, such as the eruption of volcanoes and variations in the intensity of the Sun, which are essentially random in nature.

On regional and local scales, the state of the atmosphere is judged by society on the chemical and aesthetic quality of the air. Because variations in air quality are closely linked to human activities and because the Australian population tends to be clustered in distinct regions, air quality tends to be a regional issue, with monitoring and response strategies being conducted by State agencies. In developing national environmental indicators, the impact of our clustered population must be taken into account. Thus the primary measures of air quality should be obtained in the major urban areas of the country, while other (regional) air-sheds containing significant industrial sources of air pollutants should also be monitored on an individual basis. The selection of indicators is also linked to the air NEPM process where the standards are set to protect human health and well-being.

Because most people spend a substantial fraction of their time indoors, the quality of indoor air is at least as important as that of the air out-of-doors. The assessment of national air quality therefore needs to have a substantial emphasis on indicators of the indoor environment. For logistical reasons, this issue is not fully considered in the present report, but it is taken up in the human settlements report (Newton *et al.* in prep.) in this series. It is expected that indoor air quality will be included appropriately in the category of atmospheric indicators for formal reporting on the state of the environment in the future, as occurred for the 1996 SoE report (State of the Environment Advisory Council 1996). A list of recommended indicators for indoor air quality is provided in Appendix 1. A full description of those indicators is given in Newton *et al.* (in prep.).

Following the OECD model, the atmospheric indicators are developed to provide measures of the condition of the atmosphere, of the external pressures acting on it due to human activity, and of the response of government and society to alleviate the impacts of those pressures.

The following tables contain all the recommended indicators for each of the four atmospheric issues considered in this report.

Issue 1: Climate Variability and Change

Number	Title	Type
1.1	Southern Oscillation Index	Condition
1.2	Average sea surface temperatures	Condition
1.3	Average sea level	Condition
1.4	Average daily rainfall	Condition
1.5	Average maximum and minimum temperatures	Condition
1.6	Occurrence of rainfall extremes	Condition
1.7	Occurrence of temperature extremes	Condition
1.8	Occurrence of tropical cyclones	Condition
1.9	Temperature of the free atmosphere	Condition
1.10	Greenhouse gas atmospheric concentrations	Condition
1.11	Annual total greenhouse gas emissions	Pressure
1.12	Greenhouse gas emissions by sector of the economy	Pressure
1.13	Insurance losses due to extreme weather events	Response
1.14	Cost of drought to Government	Response
1.15	National crop yield	Response
1.16	Government expenditure on climate related activities	Response

In addition to the recommended indicators for Issue 1, it is suggested that the following five indicators should be considered as potential indicators which should be valuable but which require further research before they can be suitably quantified. (It is noted that some of the recommended indicators could be refined by further research.)

Number	Title	Type
1.17	Rainfall intensity	Condition
1.18	Average evaporation rate	Condition
1.19	Average aerosol loading	Condition
1.20	Development of carbon sinks	Response
1.21	National involvement in international processes on climate variability and change	Response

Issue 2: Stratospheric Ozone

Number	Title	Type
2.1	Concentration of ozone depleting substances in the atmosphere	Condition
2.2	Stratospheric ozone concentrations across Australia	Condition
2.3	Ultra-violet radiation flux at the surface	Condition
2.4	Magnitude of Antarctic spring-time ozone hole	Condition
2.5	National emission of ozone depleting substances	Pressure
2.6	Fulfilment of national responsibilities under the Montreal Protocol and associated agreements	Response
2.7	Public behaviour modification to protect against ultra-violet radiation	Response
2.8	Health effects linked to ultra-violet exposure	Response
2.9	Destruction of ozone depleting substances	Response

Issue 3: Urban Air Quality

Number	Title	Type
3.1	Concentration of carbon monoxide in urban areas	Condition
3.2	Concentration of ozone in urban areas	Condition
3.3	Concentration of lead in urban areas	Condition
3.4	Concentration of nitrogen dioxide in urban areas	Condition
3.5	Concentration of sulphur dioxide in urban areas	Condition
3.6	Concentration of particles in urban areas	Condition
3.7	Concentration of benzene in urban areas	Condition
3.8	Haze in urban areas	Condition
3.9	Pollen levels in urban areas	Condition
3.10	Toxic dosage of air pollutants	Condition
3.11	Meteorological conditions that exacerbate air quality problems	Condition
3.12	Emission of air pollutants in urban areas	Pressure
3.13	Number of people covered by air quality monitoring	Response
3.14	Quality of national monitoring system	Response
3.15	Uniform government actions to monitor and reduce urban air pollutants	Response
3.16	Compliance with government legislation and regulations	Response
3.17	Motor vehicle use	Response
3.18	Use of unleaded petrol	Response
3.19	Hospital admissions for respiratory conditions	Response

Issue 4: Regional Air Quality

Number	Title	Type
4.1	Concentration of sulphur dioxide across regional air-sheds	Condition
4.2	Concentration of particles across regional air-sheds	Condition
4.3	Concentration of lead across regional air-sheds	Condition
4.4	Concentration of carbon monoxide across regional air-sheds	Condition
4.5	Concentration of ozone across regional air-sheds	Condition
4.6	Concentration of nitrogen dioxide across regional air-sheds	Condition
4.7	Concentration of fluoride across regional air-sheds	Condition
4.8	Deposition of dust across regional air-sheds	Condition
4.9	Concentration of benzene across regional air-sheds	Condition
4.10	Meteorological conditions that exacerbate air quality problems	Condition
4.11	Toxic dosage of air pollutants	Condition
4.12	Occurrence of haze	Condition
4.13	Occurrence of smoke and fire	Condition
4.14	Emission of regional air pollutants	Pressure
4.15	Area of national air-sheds monitored for state of the environment reporting	Response
4.16	Number of local government bodies which have programs to monitor and regulate air quality	Response

Issue 1: Climate variability and change

Background

Any changes in the global climate induced by human activities occur against a background of natural variability. The high variability of Australian climate is due to the impact of the El Niño - Southern Oscillation (ENSO) phenomenon which is the largest source of interannual variation in the global climate system. Human-induced (or anthropogenic) climate trends or changes will be difficult to detect against this background variability. It is therefore necessary for consistent long-term observations to be established and maintained in order to have the capability to detect anthropogenic climate change.

For more than a century, it has been recognised that the burning of fossil fuels leads to increased concentrations of carbon dioxide in the atmosphere and that, as carbon dioxide is a greenhouse gas, the natural greenhouse effect is consequently enhanced (Arrhenius, 1896). The increasing emission of greenhouse gases into the atmosphere over the last few decades has led to increased scientific and political activity to investigate the potential impacts of the enhanced greenhouse effect on the global climate.

Monitoring strategy

The high natural variability of Australian rainfall has a significant impact on the sustainability of agriculture in some parts of the country. In order to adapt our agricultural practices to our climate, it is necessary to have long-term records of the regional variations of rainfall, temperature and other meteorological variables. The meridional and zonal extent of Australia cause the climate to have large geographical variations, from a classical monsoon climate in the north to a Mediterranean climate in the south west. These geographical variations need to be monitored and analysed.

Meteorology is inherently an international activity, and so a world-wide network of meteorological instrumentation has been established under the auspices of the World Meteorological Organization (WMO). In Australia, these functions are carried out by the Bureau of Meteorology operating under the *Meteorology Act 1955.* An international focus for the enhancement and maintenance of long-term climate observations is provided by the Global Climate Observing System (GCOS), which is jointly sponsored by WMO, the Inter-governmental Oceanographic Commission (IOC) and the United Nations Environment Programme (UNEP). The aims and activities of GCOS are well documented in Karl (1996).

International coordination is needed in monitoring not only the physical aspects of climate but also the chemical composition of the atmosphere. To monitor the global concentration of greenhouse and other gases, the WMO established the Background Air Pollution Monitoring Network (BAPMoN) in 1972. At Cape Grim in North Western Tasmania, Australia maintains one of the key stations of that Network. The station is funded and managed by the Bureau of Meteorology, which jointly supervises the scientific program with the Commonwealth Scientific Industrial Research Organisation (CSIRO) Division of Atmospheric Research. The station is known internationally for the quality and extent of its observation program, and it will remain a key element in the Australian program to monitor climate and climate change (e.g. Francey *et al.*, 1996).

For many of the climate indicators, it is important to compare the Australian data with those from other countries and with global data. In this way, we can establish benchmark data for some condition indicators and attempt to estimate world best-practice levels for some pressure and response indicators.

Use of models

We note that some jurisdictions report climate change scenarios as indicators of the state of the environment. Such parameters are not seen in this report as appropriate indicators for the state of the environment. The environmental indicators need to be based on actual observations of the current state of the atmosphere. Models can be used to provide a theoretical framework to explain the physical basis of observed trends; for example, this technique is reported in the Second Assessment Report of the IPCC as the means to detect an anthropogenic signal in the observed climate record. Such fingerprint detection methods continue to be developed (e.g. Hegerl *et al.*, 1997), and they depend upon careful comparisons of observed data with model results.

Model results can be seen as adjuncts to observation-based indicators. Thus some jurisdictions may use them as justification for some response strategies associated with greenhouse gas emissions. However, in using models for this purpose, it is important to recognise the continuing uncertainties that remain (and are inherent) in the prediction of climate on regional scales. The Intergovernmental Panel on Climate Change (IPCC, 1996) notes that, while the results of model simulations are the basis of the global concern about the enhanced greenhouse effect, the prediction of climate variations on regional scales has several sources of uncertainty. Some of these uncertainties are related to limitations in models, some arise from our lack of knowledge of the future rates of emissions of greenhouse gases and sulphate aerosols, and some are due to the inherently chaotic nature of the climate system.

Recommended indicators

The following pages contain background on indicators of climate variability and change for which data either are readily available or could be obtained from known sources. Thus these indicators are recommended for immediate use in SoE reporting. In the next section, we consider potential indicators that would require further research to clarify issues associated with data availability or interpretation.

The first ten indicators describe the condition of the atmosphere, and they are:

- Southern Oscillation Index (SOI)
- Average sea-surface temperatures (SSTs)
- Average sea level
- Average daily rainfall
- Average maximum and minimum temperatures
- Occurrence of rainfall extremes
- Occurrence of temperature extremes
- Occurrence of tropical cyclones
- Temperature of the free atmosphere
- Greenhouse gas atmospheric concentrations

The SOI and the SST distribution represent large-scale influences on Australian climate. The sea level responds to these forces, but it is also an indicator of the enhanced greenhouse effect as the upper ocean expands due to increasing temperatures. The next four indicators provide a broad description of the Australian climate, with a focus on the occurrence of extreme climate events. These indicators relate to conditions at the surface, and so we consider two other indicators of the state of the free atmosphere which is the bulk of the atmosphere not directly influenced by the earth's surface. Trends in the temperature of the free atmosphere have been studied extensively for evidence of climate change in recent decades. Finally the atmospheric concentration of greenhouse gases is an important indicator of the condition of the atmosphere due to the emission of these trace gases arising from human activities.

Pressures on the atmosphere are measured by two indicators:

- Annual total greenhouse gas emissions
- Greenhouse gas emissions by sector of the economy

These indicators relate to the emission of greenhouse gases due to human activities. They are now monitored under the United Nations Framework Convention on Climate Change (UNFCCC), and they allow the national emissions to be compared with those of other countries.

Policy responses to climate change and natural climate variability in Australia are monitored through the following indicators:

- Insurance losses due to extreme weather events
- Cost of drought to Government
- National crop yield
- Government expenditure on climate-related activities

Because of the difficulty in distinguishing climatic impacts due to natural variability from those due to the enhanced greenhouse effect, these response indicators are aimed at covering both aspects together.

Indicator 1.1 Southern Oscillation Index

Description

Annual and seasonal averages of the Southern Oscillation Index (SOI) would be reported. Formally the SOI is ten times the difference in the mean anomaly of surface pressure in Tahiti minus the anomaly in Darwin, normalised by the standard deviation of the difference. Thus a SOI change of 10 corresponds to a variation of the pressure difference of one standard deviation.

Rationale

For decades (e.g. Walker, 1910) it has been recognised that the broad-scale climate of Australia is affected by a coupled ocean-atmosphere phenomenon called the El Niño-Southern Oscillation (ENSO). The atmospheric component of ENSO is represented by see-saw variations in the pressure pattern across the Pacific Ocean. In normal conditions, the surface atmospheric pressure in the equatorial region north of Australia tends to be low compared with the pressure in the eastern Pacific. This pressure pattern leads to the convergence of moist air in the Indonesian archipelago which supports very active cumulus convection. During an ENSO event, this large-scale pressure pattern is weakened, the storminess north of Australia is reduced, and the rainfall across much of northern and eastern Australia is below normal. A measure of this pressure pattern is the Southern Oscillation Index which is the normalised surface pressure difference between Tahiti and Darwin. Thus the SOI is a measure of a large-scale atmospheric circulation that impacts on Australian climate and consequently on a range of biological and societal activities (Nicholls, 1988).

Interpretation and analysis

Sustained values of the SOI below -10 indicates an ENSO event, which generally corresponds to wide-spread drought across Australia. When the SOI has sustained values above 10, the rainfall across much of Australia tends to be above normal, corresponding to an anti-ENSO event.

Monitoring

Spatial Scale: Point measurements at Darwin and Tahiti

Frequency: Daily

Measurement Technique: Barometer

Data sources

Data Archive: National Climate Centre, Bureau of Meteorology

Data Quality Control: National Climate Centre, Bureau of Meteorology and research community

Current Status of Data: Records extend back to the 19th century

Contact: National Climate Centre, Bureau of Meteorology

Reference

Troup (1967) defines the SOI.

Research Needs

Continuing research is needed to refine the interpretation of the SOI and its links to Australian climate. A significant issue is the decadal-scale variability of the SOI.

Indicator 1.2 Average sea-surface temperatures

Description

The annual average amplitudes of the 10 main Sea Surface Temperature (SST) principal components are recorded.

Rationale

While the El Niño-Southern Oscillation represents the largest interannual variation in the coupled ocean-atmosphere climate system, there are other large-scale influences acting on Australian climate. Nicholls (1989) has shown that rainfall across Australia can be related to particular patterns of sea surface temperature (SST) in the Indian and Pacific Oceans. Later studies have confirmed that the interannual variability of seasonal rainfall and temperature in Australia can be related to variations in SST patterns. Thus the SST distribution in the oceans around Australia provides information on the large-scale forcing on our climate, additional to that provided by the Southern Oscillation Index.

Interpretation and analysis

The main patterns of variation in the SST field in the Indian and Pacific Oceans are represented statistically by the principal components (Drosdowsky and Chambers, 1997). It is found that the main variations in rainfall and temperature across Australia can be statistically related to the first 10 principal components. The first principal component represents the SST pattern in the Pacific Ocean associated with the El Niño phenomenon. The second principal component represents the dipole SST pattern in the Indian Ocean associated with north-west cloud-bands that bring rain across Australia (Nicholls 1989). The other principal components are found to contribute statistically to representation of the regional rainfall and temperature patterns in Australia. The amplitude of each principal component indicates the strength of each SST pattern, and hence its impact on Australian climate.

Monitoring

Spatial Scale: Observations are available from ships and satellites at varying densities

Frequency: Observations are taken several times each day from ships, buoys and satellites

Measurement Technique: Thermometers on ships and buoys; Infrared radiance from satellites. Observations are blended through an objective analysis technique (Smith, 1995).

Data sources

Data Archive: National Climate Centre, Bureau of Meteorology

Data Quality Control: National Climate Centre, Bureau of Meteorology

Current Status of Data: Analyses at reasonable quality are available in the Bureau since 1950

Contact: National Climate Centre, Bureau of Meteorology

Reference

Drosdowsky and Chambers (1997) describe the procedure for calculating the principal components of SST.

Research Needs

Continuing research will refine our capability to analyse and interpret the global SST patterns, and these improvements in understanding will need to be reflected in the SoE reports in future.

Indicator 1.3 Average sea level

Description

The key parameter is the deviation of the annual average sea level from the long-term national mean. The time series of these measurements would be analysed for long-term trends, which would be compared with global sea level trends. The observations at 16 individual sites monitored by the National Tidal Facility (NTF) can also be used to provide regional information to support indicators of the coastal and marine environment. The NTF also has routine sea level data from harbours around the Australian coast.

Rationale

The climate of Australia is affected by complex interactions between the atmosphere and the ocean. The sea level is determined by these interactions, as well as by tidal forcings. The enhanced greenhouse effect is expected to lead to a global increase in sea level, as the upper ocean expands and land ice melts due to global warming. By carefully observing the sea level around

Australia, we can detect trends and attempt to identify their causes. The observed trends around Australia need to be compared with global values in order to separate local and large-scale features.

Interpretation and analysis

The NTF calculates annual sea level trends at each of the 16 sites around Australia. A simple average of the 15 mainland sites provides an indication of average sea level rise around Australia. Current estimates of global sea level rise due to the enhanced greenhouse effect are about 1 to 2 millimetres per year. Robust estimates of such trends will require observations over several decades.

The NTF also provides information on the monthly sea level anomalies at each site. These anomalies are defined as deviations from the long-term monthly mean value. Given the known linkages between the atmosphere and ocean, seasonal and annual variations in these anomalies can sometimes be linked to large-scale climate variations.

Monitoring

Spatial Scale: The NTF undertakes the Australian Baseline Sea Level Monitoring Project, aimed at identifying long-term sea-level changes around Australia. Measurements are taken at 15 sites around the Australian coast, together with an observation at Cocos Island in the Indian Ocean.

Frequency: Data are continuously monitored in real time by the NTF.

Measurement Technique: The NTF uses Sea-level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) at the 16 tidal stations, where meteorological observations are also taken.

Data sources

Data Archive: National Tidal Facility, Flinders University

Data Quality Control: National Tidal Facility, Flinders University of South Australia.

Current Status of Data: Data from the 16 NTF sites are available since about 1992

Contact: National Tidal Facility, Flinders University of South Australia

Reference

http://www.ntf.flinders.edu.au/TEXT/PRJS/BASE/base.html

Research Needs

The NTF sites are maintained through a range of project grants, including the National Greenhouse Research Program. Thus long-term support is not guaranteed.

Indicator 1.4 Average daily rainfall

Description

Annual and seasonal average daily rainfall for the nation and each state would be reported. Maps are also available across the nation at a resolution of about 25 km.

Rationale

Because of the influence of the El Niño-Southern Oscillation (ENSO) phenomenon on our climate, Australia's rainfall variability is extremely high by global standards. This high variability leads to substantial impacts on the natural ecosystems, as well as human activities, in Australia. Water is a limiting factor in agricultural and other biological systems. The average daily rainfall is therefore a very important parameter for SoE reporting.

Interpretation and analysis

Water is a limiting factor in many activities in Australia, thus it is useful to report on the annual rainfall and to highlight the variations in the daily distribution by reporting the 1st and 9th decile values, as well as the mean, for each year. Because the rain in parts of the country varies seasonally, the seasonal average values should also be reported.

The mean values should be compared with the long-term deciles. Drought conditions occur when rainfall amounts fall to the 1st (long-term) decile level or below.

Monitoring

Spatial Scale: Varies across the country; average separation is about 80 km

Frequency: Daily

Measurement Technique: Raingauge observations are analysed each day onto a national grid on a scale of about 25 km. This scale should be adequate to calculate information required for SoE reporting on inland waters and land environments.

Data sources

Data Archive: National Climate Centre, Bureau of Meteorology

Data Quality Control: National Climate Centre, Bureau of Meteorology

Current Status of Data: National analyses available for this century

Contact: National Climate Centre, Bureau of Meteorology

Reference

Mills *et al.* (1997) describes the analysis system for rainfall in the Bureau. Gibbs and Maher (1967) explains the use of long-term deciles to define drought.

Research Needs

There may also be an interest in analysing trends in the intensity of daily rainfall. Such an indicator can be readily calculated (Nicholls and Kariko 1993).

Indicator 1.5 Average maximum and minimum temperatures

Description

Average maximum and minimum temperatures would be reported. In order to highlight interannual variations in the daily temperature distribution, the mean, 1st decile and 9th decile annual values would be reported. Both annual and seasonal values should be given.

Rationale

Because of the potential for global warming due to the enhanced greenhouse effect, there is much interest in reporting the annual surface temperature across Australia. There is some suggestion that the maximum and minimum temperatures will not necessarily change at the same rate. It is therefore appropriate to report on both the maximum and overnight minimum temperatures. Because of the impact of frost on many crops, the interannual variability of the minimum temperature is of great interest to agriculture. Nicholls (1997) suggests that recent trends in overnight temperatures have affected the Australian crop yield.

Interpretation and analysis

Trends in the mean and decile values would be analysed and compared with global values and with values in neighbouring countries like New Zealand. The differences between maximum and minimum temperature trends would be noted.

Monitoring

Spatial Scale: Varies across the country

Frequency: Basic data are daily readings

Measurement Technique: Thermometry

Data sources

Data Archive: National Climate Centre, Bureau of Meteorology

Data Quality Control: National Climate Centre, Bureau of Meteorology

Current Status of Data: Bureau of Meteorology data archive in computer-compatible form back to 1957. (Actually, monthly data exist back to 19th century. However, corrections (for site changes etc.) are needed. Such corrections have been made for annual figures, but not seasonal ones).

Contact: National Climate Centre

Reference

Torok and Nicholls (1996) describe the quality control and analysis of Australian temperature data.

Research Needs

There is continuing comment on the expected bias in national temperature trends due to the inclusion of observations from cities, where the "heat island" effect tends to lead to temperatures above those in the surrounding country-side. The national temperature trends are computed by ignoring city-based measurements. However, it may be appropriate to include in the national SoE report a measure of the average heat-island effect in the major population centres across the country. Some research would be needed to determine the feasibility of such an indicator.

Indicator 1.6 Occurrence of rainfall extremes

Description

Reports would be provided on the

(a) areal average of the percentage of annual rainfall falling on days with rainfall above the daily long–term 95th percentile

(b) percentage of the area of the country with annual rainfall below decile 1 or above decile 9

Rationale

A key issue, arising from interest in the enhanced greenhouse effect, is the extent to which climate on both global and regional scales is changing. It is recognised that changes in the occurrence and frequency of extreme weather events are likely to have the most impact on society. Australian rainfall is naturally highly variable due to the El Niño-Southern Oscillation (ENSO) phenomenon. In order to monitor both the interannual variability and any trends or changes in extreme rainfall events, it is appropriate to monitor variations in a number of parameters that are being developed under the auspices of the Global Climate Observing System (GCOS). By monitoring the selected parameters, we will be able to compare the variations in Australian rainfall with those of other countries.

Interpretation and analysis

These parameters will be plotted as annual values, and their long-term trends analysed. Their variations can also be compared with their behaviour in other countries where they are computed under the international GCOS program. The parameters can be evaluated for individual States, as well as for the whole country.

(a) This parameter provides an indication of interannual variability in the occurrence of extreme rainfall events. The rainfall on any given day at a specific location will normally be above percentile 95 for 5% of the time. (The rainfall thresholds for percentiles are based on a standard period, such as 1960 to 1990.) If, for example, there is an upward trend in the occurrence of high-intensity storms across the country then this indicator would be expected to increase with time.

(b) A region is experiencing drought conditions when the annual rainfall is below decile 1. Conversely a region with rainfall above decile 9 will be experiencing high rainfall conditions. By monitoring the variations in the fraction of the country with rainfall experiencing these extremes, we can determine whether we are moving to periods of more drought and floods. There have been some suggestions that such conditions could become apparent under an enhanced greenhouse effect.

Monitoring

Spatial Scale: Daily rainfall is analysed across the country on a grid scale of about 25 km

Frequency: Indicators are based on daily station data

Measurement Technique: Raingauge

Data sources

Data Archive: National Climate Centre, Bureau of Meteorology

Data Quality Control: National Climate Centre, Bureau of Meteorology

Current Status of Data: Data available for this century

Contact: National Climate Centre, Bureau of Meteorology

Reference

This indicator was developed at an international workshop held in June 1997 in Asheville, NC, USA under the auspices of GCOS and the World Climate Research Programme–Climate Variability and Predictability Programme (WCRP-CLIVAR).

Research Needs

The development and analysis of indicators of extreme weather trends will continue to be studied by GCOS and WCRP, with a focus on indicators to be used in Intergovernmental Panel on Climate Change (IPCC) assessments.

Indicator 1.7 Occurrence of temperature extremes

Description

The indicators to monitor are:

(a) percentage of the area of the country with annual average temperature above percentile 90

(b) percentage of the area of the country with annual average temperature below percentile 10

Rationale

A key issue, arising from interest in the enhanced greenhouse effect, is the extent to which climate on both global and regional scales is changing. It is recognised that changes in the occurrence and frequency of extreme weather events are likely to have the most impact on society. In order to monitor both the interannual variability and any trends or changes in extreme temperature events, it is appropriate to monitor variations in a number of parameters that are being developed under the auspices of the Global Climate Observing System (GCOS). By monitoring the temperature indicators above, we will be able to compare the variations in Australian temperature with those of other countries.

Interpretation and analysis

These parameters provide an indication of the interannual variability in the occurrence of extreme temperature events. There is some suggestion that extreme temperature events could become more common under enhanced greenhouse conditions.

These parameters will be plotted as annual values, and their long-term trends analysed. Their variations can also be compared with their behaviour in other countries where they are computed under the international GCOS program. The parameters can be evaluated for individual States, as well as for the whole country.

(a) A region will normally have an average temperature above decile 9 on 1 year in 10. (The temperature thresholds for deciles are based on a standard period, such as 1960 to 1990.) If there were an upward trend in the occurrence of heat waves then this parameter would increase with time.

(b) A region will normally have an average temperature below decile 1 on 1 year in 10. (The temperature thresholds for deciles are based on a standard period, such as 1960 to 1990.) If there were an upward trend in the occurrence of cold conditions then this parameter would increase with time.

Monitoring

Spatial Scale: Daily average temperature is analysed across the country on a grid scale of about 100 km

Frequency: Indicators are based on daily station data

Measurement Technique: Thermometry

Data sources

Data Archive: National Climate Centre, Bureau of Meteorology

Data Quality Control: National Climate Centre, Bureau of Meteorology

Current Status of Data: Data available for this century

Contact: National Climate Centre, Bureau of Meteorology

Reference

This indicator was developed at an international workshop held in June 1997 in Asheville, NC, USA under the auspices of GCOS and World Climate Research Programme–Climate Variability and Predictability Programme (WCRP-CLIVAR).

Research Needs

The development and analysis of indicators of extreme weather trends will continue to be studied by GCOS and WCRP, with a focus on indicators to be used in Intergovernmental Panel on Climate Change (IPCC) assessments.

While the emphasis here is on analysis of the average temperature, there would also be interest in a similar analysis applied to both the maximum and minimum daily temperatures.

Indicator 1.8 Occurrence of tropical cyclones

Description

The total number of tropical cyclones and the number of intense tropical cyclones in the Australian region would be reported annually.

Rationale

Tropical cyclones (TCs) cause major disruption to commercial and societal activities across northern Australia. Their occurrence is correlated with the SOI (Nicholls 1992), and there have been suggestions that their frequency and intensity could vary under enhanced greenhouse conditions. Recent analyses have indicated that the frequency of intense TCs and that of all TCs can vary differently in various regions of the world. In order to monitor their long-term behaviour, the total number and the number of intense TCs should be recorded.

Interpretation

There is significant interannual variability in the TC frequency, and so care will be needed in analysing the data for long-term trends.

Monitoring

Spatial Scale: All Australian TC regions, as defined by the Bureau of Meteorology, should be included

Frequency: Annual totals over the TC season from October to March

Measurement Technique: Summation of numbers of tropical cyclones (based upon October to March data) in the Australian region. A tropical cyclone (TC) is formally named by the Bureau of Meteorology when a tropical depression has wind speeds of more than 63 km/hr: An intense TC occurs when the intensity of a TC falls below 970 hPa which corresponds to the TC having a discernible eye. Although records have been maintained for more than a century, the number of tropical cyclones was underestimated prior to the mid 1960s, when satellite observations commenced.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: Records are updated each year and they are readily available

Contact: Bureau of Meteorology

Reference

Nicholls (1995) describes some of the problems in analysing TC data for long-term trends.

Research Needs

Continuing research is expected on the refinement of the analysis of past data and on the interpretation of all TC data. There is also an interest in information on the variation of TC intensity with time. While these records are even more uncertain than those on the basic frequency of TCs, it may be appropriate to commence the inclusion of average TC intensity for future SoE reporting.

INDICATOR 1.9 TEMPERATURE OF THE FREE ATMOSPHERE

Description

Effective temperatures for the lower troposphere and the lower stratosphere averaged over the Australian region would be reported, as described in Parker *et al.* (1997). Annual average values would be calculated, based on the data from radiosondes which are instruments attached to meteorological balloons for routine sounding of the atmosphere.

Rationale

Indicators of climate variability tend to be focused at the surface of the earth. However, the climate of a region is also characterised by the structure of the free atmosphere above the surface. Williams (1987) shows that the troposphere temperatures in the Australian region tend to vary with the Southern Oscillation Index.

In the investigation of trends potentially associated with the enhanced greenhouse effect, there is increasing emphasis on variations in the free atmosphere. In particular, trends in the troposphere and lower stratosphere measured from radiosondes have been compared with trends measured from satellites (e.g. Hurrell and Trenberth 1997). Moreover, comparison of observed variations in the temperature structure of the atmosphere with model simulations is the basis of the fingerprint technique for detecting climate change (e.g. Hegerl *et al.* 1997).

Interpretation and analysis

Because of the general interest in satellite observations, it is appropriate to use the radiosonde data to simulate two of the microwave radiance channels of the satellite Microwave Sounding Unit (MSU). Following Parker *et al.* (1997), estimates of the MSU-2R and MSU-4 effective temperatures can be calculated. The first channel corresponds to an average temperature weighted towards the lower troposphere, while the second channel corresponds to an average temperature in the lower stratosphere.

The interannual variability and long-term trends in these two temperatures averaged over the Australian region would be analysed. The enhanced greenhouse effect would tend to increase the tropospheric temperature and decrease the stratospheric temperature in the long term.

Monitoring

Spatial Scale: Radiosonde measurements are taken at about 50 sites across Australia. Radiance measurements from satellites have a resolution of about 100 km.

Frequency: The radiosonde observations need to be taken at least daily. The satellite observations, while there are two National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites, occur every six hours.

Measurement Technique: Parker *et al.* (1997) describe an appropriate technique for analysing radiosonde data for temperature trends. In particular, they show how satellite data can be used to remove biases associated with instrument changes in the radiosonde records. On the other hand, the work of Hurrell and Trenberth (1997) suggests that care must be taken in this analysis, because the satellite data also suffer from biases due to instrument changes.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: Radiosonde data are available since the 1950s, but satellite data are generally available since about 1979.

Contact: Bureau of Meteorology

Reference

Parker *et al.* (1997).

Research Needs

As reported by Parker *et al.* (1997) and Hurrell and Trenberth (1997), continuing research is needed to refine both the radiosonde and satellite records.

INDICATOR 1.10 GREENHOUSE GAS ATMOSPHERIC CONCENTRATIONS

Description

Annual average values for the primary well-mixed greenhouse gases would be reported. The gases are carbon dioxide, methane, nitrous oxide, halocarbons, and substitute halocarbons.

Rationale

Over the last century the concentration of greenhouse gases has risen in the atmosphere. This rise is largely due to human activities, especially the burning of fossil fuel. Thus observations of the concentration of these gases provides a measure of anthropogenic greenhouse forcing in the atmosphere.

Interpretation and analysis

Because all these gases have long lifetimes in the atmosphere, the baseline measurements at Cape Grim are representative of global values (bearing in mind seasonal differences and transport between hemispheres). Trends in these gases would be recorded and compared with emission rates. The values should also be compared with pre-industrial levels.

Because Australia does not have the concentration of industrial complexes found in the northern hemisphere, aerosols and tropospheric ozone do not contribute significantly to the national greenhouse budget. However, the National Greenhouse Gas Inventory (NGGI) includes sulphur dioxide, which is the main source of anthropogenic aerosols.

Monitoring

Spatial Scale: Point values at Cape Grim Baseline Air Pollution Station

Frequency: Annual averages

Measurement Technique: Various chemical sampling techniques (Francey *et al.* 1996).

Data sources

Data Archive: CSIRO, Division of Atmospheric Research (DAR)

Data Quality Control: CSIRO DAR

Current Status of Data: Observations of atmospheric constituents commenced at Cape Grim in 1976. Records have been maintained since that time. Moreover an archive of Cape Grim air has been kept since 1978 (Langenfelds *et al.* 1996)

Contact: CSIRO, DAR

Research Needs

The measurements at Cape Grim continue to be refined. To extend the record back in time, observations are being taken from air trapped in Antarctic ice (e.g. Etheridge *et al.* 1996).

Reference

Observations at Cape Grim are described by Steele *et al.* (1996) for carbon dioxide, methane, nitrous oxide, and by Fraser *et al.* (1996) for halocarbons.

INDICATOR 1.11 ANNUAL TOTAL GREENHOUSE GAS EMISSIONS

Description

Annual equivalent CO_2 emissions (tonnes) in absolute terms and as a fraction of global emissions should be reported. The total emission of each direct greenhouse gas (i.e. carbon dioxide, methane, nitrous oxide, and perfluorocarbons) should also be reported. The emissions of the indirect greenhouse gases tend to be accounted for in the air quality indicators.

Rationale

The steady increase in anthropogenic emissions of greenhouse gases is increasing the radiative forcing in the global atmosphere such that the surface of the earth tends to be warmed. This enhanced greenhouse effect tends to change the earth's climate on global and regional scales.

Each reported greenhouse gas is important. However, the relative contribution of each gas can be calculated using the theoretically-based Global Warming Potential (GWP). Using the GWP for each gas, the net emission of greenhouse gases can be computed in terms of carbon dioxide.

Interpretation and analysis

The report should be given in raw terms so that normalisation against societal or economic parameters (e.g. Gross Domestic Product (GDP)) can be done independently. However, care should be used when applying any normalisation to ensure that the process properly highlights cause and effect relationships.

Raw values can be monitored for trends. If there are international targets or standards then these should be reported also. The human settlements report (Newton *et al.* in prep.) will consider detailed analysis of energy use and efficiency measures.

Monitoring

Spatial Scale: State and national inventories should be reported

Frequency: Annual

Measurement Technique: Intergovernmental Panel on Climate Change methodology is used by the National Greenhouse Gas Inventory (NGGI) to accumulate the emissions from individual sectors, based on agreed GWPs for normalisation. The methodology does not include ozone depleting substances that are being phased out under the Montreal Protocol.

Data sources

Data Archive: National Greenhouse Gas Inventory (NGGI)

Data Quality Control: NGGI

Current Status of Data: Analyses available annually since 1988

Contact: National Greenhouse Gas Inventory Committee (NGGIC)

Reference

NGGIC (1997) gives the inventory for 1995.

Research Needs

Uncertainties exist, especially with respect to land clearing (NGGIC, 1997).

Indicator 1.12 Greenhouse gas emissions by sector of the economy

Description

Percentage of total national emissions attributed to each sector. Following the National Greenhouse Gas Inventory (NGGI), the sectors are:

- stationary energy
- transport
- fugitive emissions from fuel
- industrial processes
- solvents
- agriculture
- land use change and forestry
- waste

Rationale

By considering the sectoral break-down of emissions, one can better identify the sources of greenhouse gases. In this way, the success of focused policy initiatives to limit greenhouse gas emissions can be analysed.

The sectors used in the national report follow those recommended by the Intergovernmental Panel on Climate Change (IPCC) except that the IPCC energy sector is split into the sub-categories of stationery energy, transport, and fugitive emissions from fuel. This approach allows the national emissions to be broken down into nationally relevant sectors, while international comparisons are made simply by aggregation of the sub-categories.

Interpretation and analysis

As for "annual total greenhouse gas emissions". The sectoral break-up also provides information to monitor the relative performance of each sector in Australia. If the sectoral emissions are normalised then the normalisation factor should represent the sector control. For example, it could be misleading simply to normalise each sectoral emission by the total population.

Analysis of energy use and sources is covered in more detail in the human settlements report (Newton *et al.* in prep.) of this series.

Monitoring

Spatial Scale: National

Frequency: Annual

Measurement Technique: As for "annual total greenhouse gas emissions", using the Global Warming Potential (GWP) to normalise the relative contribution of each gas.

Data sources

Data Archive: NGGI

Data Quality Control: NGGI

Current Status of Data: Analyses available annually since 1988

Contact: National Greenhouse Gas Inventory Committee (NGGIC)

Reference

NGGIC (1997) describes the inventory process.

Research Needs

Uncertainties exist, especially with respect to land clearing (NGGIC, 1997). Research on the remote sensing of agricultural land cover change by CSIRO Earth Observation Centre and the Bureau of Resource Science should reduce the uncertainties associated with land cover change. Continuing work will be needed to document the rates of clearing over a 20 year period to meet IPCC inventory requirements. Significant improvements in biomass data are also needed to estimate more accurately the emissions due to clearing of above-ground biomass.

INDICATOR 1.13 INSURANCE LOSSES DUE TO EXTREME WEATHER EVENTS

Description

Insurance losses (in constant-year dollars) due to weather events would be reported.

Rationale

These losses provide a measure of the impact of climate variability on human activity. In particular, the cost is a measure of the vulnerability of the nation to climate extremes.

Interpretation and analysis

A careful analysis of the statistics on extreme weather events in Australia is provided by Ryan (1993).

International comparisons would need to account for differences in insurance and reporting policies. For example, unlike Australia, other countries support insurance against flooding.

Monitoring

Spatial Scale: National and by State

Frequency: Annual

Measurement Technique: Total insurance claims on weather-related events

Data sources

Data Archive: The Insurance Council of Australia (ICA) maintains figures for insurance losses due to extreme weather

Data Quality Control: ICA

Current Status of Data: Data since 1967 are available from ICA

Contact: Mr Les Lester, ICA (03-9614 1077)

Reference

Insurance Council of Australia (1997) gives data on losses since 1967.

Research Needs

There would be some interest in also reporting the cost losses normalised against the total value of insured infrastructure. This process may help identify the effective losses due to weather variations, by factoring out the changes in infrastructure. However, a careful analysis of the available data would be needed before this process is accepted.

Indicator 1.14 Cost of drought to Government

Description

Total government expenditure (Commonwealth and State) in normalised dollars should be reported. The Rural Adjustment Scheme (RAS) is a government mechanism for supporting farmers in "drought exceptional circumstances". The annual total funding on exceptional circumstances would be a measure of this indicator.

Rationale

This indicator is a measure of the impact of climate variability on agriculture. In particular, it provides a measure of Government policy on the management of drought.

Interpretation and analysis

The total government expenditure on drought is a measure of the extent to which the community is able to cope with climate variability.

Monitoring

Spatial Scale: Total national costs, and costs for each state

Frequency: Annual values

Measurement Technique: Sum of federal and state government expenditure on drought relief

Data sources

Data Archive: Department of Primary Industries and Energy (DPIE)

Data Quality Control: DPIE

Current Status of Data: The Rural Adjustment Scheme Advisory Council (RASAC) was established in 1992.

Contact: DPIE

Reference

RASAC (1997) gives figures on Rural Adjustment Scheme funding.

Research Needs

The RASAC spending is a robust indicator only while the RAS remains in place. However, it is expected that any alternative scheme would allow a comparable measure to be determined.

Indicator 1.15 National crop yield

Description

The total annual crop (particularly wheat) yield for Australia would be reported.

Rationale

It is found that there is a strong correlation between interannual fluctuations in the national crop production and the Southern Oscillation Index (SOI), which is a measure of the large-scale climate variation across Australia. Moreover, recent work (Nicholls 1997) suggests that part of the increase in Australian crop yields can be related to trends in climate over the last few decades.

Interpretation and analysis

Much of Australian agriculture is maintained in marginal climatic conditions, with water availability being a major limitation on growth. It is therefore found that much of the interannual variation in crop yield is linked to variations and trends in our climate. The annual crop yield can provide an indicator of the response of the agricultural system to climate forcings.

Careful analysis would be required to estimate the climate signal associated with crop yield, bearing in mind the economic and social influences at both national and international levels.

Monitoring

Spatial Scale: National

Frequency: Annual

Measurement Technique: Total crop yield data are available from the DPIE

Data sources

Data Archive: DPIE

Data Quality Control: DPIE

Research Needs

Continuing research would be needed to ensure that this indicator remains a valid measure of agricultural response to climate.

INDICATOR 1.16 GOVERNMENT EXPENDITURE ON CLIMATE-RELATED ACTIVITIES

Description

Annual figures on the total Commonwealth direct expenditure on climate-related activities should be recorded.

Rationale

The capability of the Australian community to respond to the impacts of climate change and variability depends upon the level of support to relevant activities. As climate is a national issue, the level of funding by the Commonwealth to climate-related activities is a measure of the national commitment to the issue.

Interpretation and analysis

Climate variability and change have impacts across the whole Australian community. Moreover the issues are largely global, and so governments need to lead the national effort. The extent of and changes in government funding for these activities provide a measure of the importance given to managing climate variability and change in a scientific fashion.

Monitoring

Spatial Scale: National

Frequency: Annual

Measurement Technique: It is very difficult to get estimates of the government expenditure on specific aspects of climate, such as research. For example, "climate" tends to be included in government figures on "environmental" research. In order to obtain a feasible measure of support for climate activities, it is recommended that the figures provided biennially by the Bureau of Meteorology (e.g. Bureau of Meteorology, 1995) should be used. These figures are for the Commonwealth expenditure on climate-related activities, including research and response activities. The Bureau report includes both direct and indirect spending. Because the indirect figures include costs incurred where climate is not necessarily the main objective (e.g. the Bureau's observing networks serve several purposes), the SoE report should use the direct expenditure figures.

The Bureau of Meteorology report lists State government activities, but it does not provide funding estimates. Because of the difficulty in identifying specific expenditure on climate-related activities in the States, it is recommended that the SoE report should be limited to Commonwealth expenditure at this time.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: The Bureau of Meteorology reports are available with these figures since 1993

Contact: Bureau of Meteorology

Research Needs

While the data for the expenditure of the Commonwealth Government are available, the State figures are not easy to obtain at present. However, the indicator would be much more useful if it included State Government expenditure. Care would be needed to ensure that double-counting did not occur across Governments.

POTENTIAL INDICATORS

The following is some background information on indicators of climate variability and change which could potentially be useful in SoE reporting. However, it is believed that it would be premature to introduce these indicators into formal SoE reporting, without further research being conducted to clarify remaining issues on interpretation or data availability.

Additional indicators of the condition of the atmosphere are given by:

- Rainfall intensity
- Average evaporation rate
- Average aerosol loading

Data for the first two indicators are available from the Bureau of Meteorology, but they have not undergone the detailed quality control that the daily temperature and rainfall records have in recent times. On the other hand, there is no large-scale monitoring of total aerosol loading, but international projects are now being started on the issue.

Additional response indicators are:

- Development of carbon sinks
- National involvement in international processes on climate variability and change

The first response indicator should be included in the primary indicator of greenhouse gas emissions (as a sink), but it may be appropriate to highlight this aspect of the greenhouse gas inventory. At this stage, it is difficult to quantify the second indicator and so it may not be regarded as a true indicator.

INDICATOR 1.17 RAINFALL INTENSITY

Description

As with the primary indicator of extreme rainfall, the indicator would be reported by the behaviour of percentile 95 in the one hour rainfall.

Rationale

Heavy short-term rainfall can lead to local soil erosion and flooding, and so it can have significant impacts on the biodiversity and land cover of the country. There is also some evidence that heavy rainfall events have become more frequent in Australia (Suppiah and Hennessy 1996).

Interpretation and analysis

The primary rainfall indicators use daily rainfall observations to estimate the variability of extreme rainfall events. However, there is interest in the occurrence of short-term (e.g. one hour) heavy rainfall events associated with individual storms. This indicator would therefore supplement the primary one by identifying trends or changes in storm-scale events.

Monitoring

Spatial Scale: The nature of short-term rainfall means that the scale of each observation is local, but observations would be used from across the country.

Frequency: The indicator would be based on 10 minute data

Measurement Technique: The Bureau of Meteorology maintains a substantial number of recording pluviographs around the country; these could be analysed to estimate the distribution of 10 minute average rainfall.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: The primary indicators of rainfall are based on daily measurements, which have been carefully quality controlled. It would be appropriate to have a similar analysis of existing pluviograph data, so that trends and variability in heavy rainfall events could be examined.

Contact: Bureau of Meteorology

Research Needs

Some research would be needed to determine the adequacy of the current and past pluviograph data to support national estimates of rainfall intensity that can be related to soil erosion and local flooding.

We note that an alternative indicator of rainfall intensity can be found from the daily rainfall observations (Nicholls and Kariko 1993), which are readily available.

INDICATOR 1.18 AVERAGE EVAPORATION RATE

Description

Annual and seasonal maps of evaporation across the country should be provided. The interannual variability and trends in the annual values would also be reported.

Rationale

The growth of vegetation in Australia is often limited by the availability of water, which is very dependent upon the balance between rainfall and evaporation. This information is regarded as a pressure indicator for biodiversity and land use reporting on the environment.

Interpretation and analysis

An indicator of the annual-average evaporation across the country would complement the annual-average rainfall in the list of primary indicators. The difference between annual rainfall and evaporation measures the increase in ground-water storage offset by run-off to the ocean.

Monitoring

Spatial Scale: National

Frequency: Daily

Measurement Technique: While the Bureau of Meteorology carries out some direct measurements of evaporation at specific sites, some research would be necessary to ensure that the data are adequate to detect long-term trends and changes on a national scale.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: While there are direct measurements of potential evaporation at specific sites across the country, those data have not been quality controlled to the same extent as the primary rainfall and temperature data

Contact: Bureau of Meteorology

Research Needs

It is likely that the most effective and accurate estimate of evaporation on national and State scales will be obtained through the data assimilation process of the operational numerical weather prediction (NWP) system of the Bureau of Meteorology. Evaporation (and other surface fluxes) is a variable in the operational NWP system, which yields estimates of variables uniformly across the country in a dynamically consistent fashion, using all the relevant meteorological data as input. Some research would be needed to establish the validity of this technique and to determine benchmark observation sites for continuing direct calibration of the model-based estimates.

INDICATOR 1.19 AVERAGE AEROSOL LOADING

Description

If national coverage can be obtained then a map of the annual-average optical depth of aerosol would be useful, together with a time series of the area-average annual values.

Rationale

It is recognised that aerosols (especially sulphate aerosols generated by human activities) increase the effective albedo or reflectivity of the planet. In this way, aerosols can partly offset the global warming arising from the anthropogenic increase in greenhouse gases in the atmosphere. Because of Australia's low population and relative isolation in the southern hemisphere, the aerosol loading in our atmosphere is not large. However, there would be some value in establishing routine reporting of the average aerosol loading to provide a benchmark for future levels and for comparison with other countries.

Interpretation

The essentially global coverage of aerosols now affects the global radiation balance, and so it is appropriate to monitor trends and variability in the aerosol loading across Australia.

Monitoring

Spatial Scale: National

Frequency: Observations would need to be collected on at least a daily basis

Measurement Technique: The effective aerosol loading can be estimated from surface radiation measurements at specific sites. However, a combination of satellite and ground-based observations with transport modelling is expected to yield a national (or global) analysis and prediction system.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Contact: Bureau of Meteorology

Research Needs

It is not clear that it is necessary to monitor the national aerosol loading. Before establishing it as a national indicator, it would be appropriate to conduct some studies to determine the most representative measurement and to establish the interannual variability and significance of the measurement.

Programmes are commencing in USA and Europe to use a combination of Advanced Very High Resolution Radiometer (AVHRR) satellite data and transport modelling to estimate the global aerosol distribution. Using the transport modelling capability of the Bureau of Meteorology and the analysis system for smoke developed in CSIRO Earth Observation Centre (EOC) (Indicator 4.13), it would be feasible and valuable to develop a similar aerosol analysis and prediction system in Australia to focus on southern hemisphere issues.

An alternative to reporting the aerosol loading may be to use an estimation of the solar radiation reaching the surface across Australia. A system using satellite data is run routinely by the Bureau of Meteorology to estimate daily solar irradiance. The system does not account for detailed variations in aerosol loading.

INDICATOR 1.20 DEVELOPMENT OF CARBON SINKS

Description

The annual mass of carbon taken up by reafforestation programs would be recorded.

Rationale

This indicator is a measure of government response to reducing greenhouse gas concentrations by increasing carbon sinks through reafforestation. This indicator is implicitly included in the "greenhouse gas emissions by sector of the economy" indicator. However, there may be some value to highlight this issue, as it is a major component of government policy.

Interpretation and analysis

The Commonwealth Government has a policy of actions to increase carbon sinks, and this indicator could be used to measure the success of the policy.

It is noted that this indicator is linked to the Land SoE report (indicator 5.8 "estimated success of programs to reduce land carbon loss and increase sequestration, by landcover region" (Hamblin 1998).

Monitoring

Spatial Scale: National

Frequency: Annual

Measurement Technique: The mass of carbon absorbed due to reafforestation programs would be calculated from the National Greenhouse Gas Inventory (NGGI) annual audit.

Data sources

Data Archive: NGGI

Data Quality Control: NGGI

Current Status of Data: An inventory has been maintained annually since 1988.

Reference

NGGI

Research Needs

Given that the impact of this measure is included in the greenhouse emissions indicator, it would need to be established as a significant policy indicator in its own right to justify it being used as a national indicator.

INDICATOR 1.21 NATIONAL INVOLVEMENT IN INTERNATIONAL PROCESSES ON CLIMATE VARIABILITY AND CHANGE

Description

Activities would be listed, with a break-down into monitoring, research, impacts, and policy activities. For each activity, the objective and progress towards the objective should be reported. Particular activities to be recorded are:

Global Climate Observing System (GCOS), covering climate monitoring;

World Climate Research Programme (WCRP), covering climate research;

Intergovernmental Panel on Climate Change (IPCC), covering the assessment of climate change science, its impacts and societal responses;

The UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP), covering intergovernmental policy responses to climate change issues, such as Joint Implementation Projects.

Rationale

This indicator gives a measure of our commitment to maintain international best practice and to benefit from overseas experience.

Interpretation and analysis

Climate variability and change are global-scale issues, and so a nation needs to ensure that it has effective international links. Such links would allow Australia to benefit from overseas experience and to influence the international decision-making process. A simplistic interpretation of this indicator is to assume that these impacts are measured by the number of activities in the list. A degree of effectiveness would be obtained by checking that the activities are in the mainstream of international affairs.

Monitoring

Spatial Scale: National

Frequency: Annual

Measurement Technique: The indicator would be "measured" through a listing of relevant activities.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Reference

Much of the required material is contained in the biennial report on climate activities in Australia by the Bureau of Meteorology; e.g. Bureau of Meteorology (1995)

Research Needs

This list is not a true (quantifiable) indicator in its present form. It could be quantified by specifying the expenditure associated with each activity. As Government policy develops, this indicator could be linked to activities associated with the need to meet international obligations under agreements, such as the UNFCCC.

Issue 2: Stratospheric ozone

Background

Ozone in the stratosphere plays a vital role in the physical and biological systems of the earth. Through the absorption of ultra-violet (UV) and other radiation, ozone in the stratosphere affects the thermodynamic and dynamic balance of the general circulation of the atmosphere (e.g. Karoly, 1997). A property of UV radiation is its ability to break down living matter at the molecular level. Thus, by filtering out UV radiation, stratospheric ozone helps to maintain life on earth (e.g. Armstrong, 1997).

In the early 1970s, the potential was recognised for human-made chemicals (such as chlorofluorocarbons (CFCs) developed for industrial purposes) to diffuse from the surface of the earth into the stratosphere, where they could deplete the ozone layer. The validity of those theories has since been demonstrated (e.g. Fraser 1997), and co-ordinated international action under the Montreal Protocol and subsequent agreements is leading to a phasing out of ozone depleting substances (ODSs). The SoE report needs to reflect the fact that substitute chemicals are being used in place of the major ODSs phased out under the Montreal Protocol.

It is important to distinguish indicators of stratospheric ozone from those of surface ozone. The latter are generally associated with regional air quality issues, and so they are treated in later sections.

Indicators

The following four indicators can be used to monitor the condition of atmospheric processes associated with stratospheric ozone:

- Concentration of ozone depleting substances in the atmosphere
- Stratospheric ozone concentrations across Australia
- Ultra-violet (UV) radiation flux at the surface
- Magnitude of Antarctic spring-time ozone hole

The first indicator measures the concentrations of trace gases in the atmosphere that tend to deplete stratospheric ozone, while the others relate to measures of the amount of ozone. The flux of UV radiation at the surface is seen as an indicator that impacts on human health.

The major indicator of pressure on stratospheric ozone is:

- National emission of ozone depleting substances

Indicators of policy responses to the stratospheric ozone issue are:

- Fulfilment of national responsibilities under the Montreal Protocol and associated agreements
- Public behaviour modification to protect against UV radiation
- Health effects linked to UV exposure
- Destruction of ozone depleting substances

The first and last of these four indicators relate to the national response to the control of ozone-depleting substances. The other two indicators measure responses to exposure to UV radiation, which is modulated by stratospheric ozone.

Indicator 2.1 Concentration of ozone depleting substances in the atmosphere

Description

Annual mean concentrations of ozone depleting substances (ODSs) and hydrofluorocarbons (HFCs); e.g. CFC-11, CFC-12, CFC-113, methylchloroform, carbon tetrachloride, halons, HCFC-22, HCFC-141b, HCFC-142b, and HFC-134a.

Rationale

It is now well established that the depletion of stratospheric ozone is linked to the presence of reactive chlorine and bromine, transported from the surface in the form of chlorofluorocarbons (CFCs), chlorinated solvents and halons (Fraser 1997). These ozone depleting substances have very long life-times in the atmosphere, and so they are well mixed. Although they are also greenhouse gases, their impact is not accounted for in formal budgets of the greenhouse effect because their supply is being phased out under the Montreal Protocol.

To expedite the phase-out of the supply of CFCs and other ODSs, the chemical industries have developed replacement gases. In the short term, HCFCs are replacing the CFCs. However, the HCFCs still contain chlorine, and so they will eventually be replaced by hydrofluorocarbons. The HFCs contain no chlorine or bromine, and they are expected to replace most of the ODSs by 2020.

Interpretation

The annual mean concentrations of the major ODSs, including HCFCs, should be reported and compared with the expectations of the Montreal Protocol. The levels of HFCs should also be reported, as their increase compensates for the expected decreases in ODSs.

The time series of these annual values indicates the effectiveness of global policies to limit ODSs.

Monitoring

Spatial Scale: Point measurements at Cape Grim Baseline Air Pollution Station

Frequency: Continuous

Measurement Technique: These gases are measured systematically at the Cape Grim Baseline Air Pollution Station. For example, Fraser *et al.* (1996) describe the measurements of CFC-11, CFC-12, CFC-113, methylchloroform, and carbon tetrachloride. Oram *et al.* (1995) give measurements of HCFCs at Cape Grim.

Data sources

Data Archive: Cape Grim Baseline Air Pollution Station

Data Quality Control: Cape Grim Baseline Air Pollution Station

Current Status of Data: Using the air archives from Cape Grim, concentrations of ODSs can be traced back to 1978. The rapid growth in HCFCs and HFCs, essentially from zero, can be observed (e.g. Fraser, 1997).

Contact: CSIRO Division of Atmospheric Research

Reference

Fraser *et al.* (1996) describes the observations at Cape Grim.

Research Needs

The specific HCFCs and HFCs to be reported are expected to evolve with time as industrial applications change. The gradual phasing out of methyl bromide in agriculture should also be monitored. However, the air archive at Cape Grim (Langenfelds *et al.* 1996) means that analyses of the atmospheric concentrations of ODSs can be done retrospectively.

Indicator 2.2 Stratospheric ozone concentration across Australia

Description

One possible measure is the mean annual ozone concentration across Australia in two latitude bands: one north of 22°S and one south of 22°S. This representation, based on the daily analyses, would separate trends in the tropics from those in the sub-tropics. A more robust measure of ozone levels at our latitudes would be to take the average value around zonal belts from 10°S to 22°S and from 22°S to 45°S. These large-scale values could be complemented by the annual average ozone levels at the five Bureau of Meteorology sites of Darwin, Brisbane, Perth, Melbourne and Macquarie Island.

Rationale

Ozone filters ultra-violet (UV) radiation from the Sun and affects the dynamics of the stratosphere and the overall atmospheric radiation balance.

Interpretation and analysis

There is clearly a public interest in reporting on changes in ozone concentrations across Australia. Because the stratospheric ozone across Australia at any time is determined largely by meteorological transport forcing conditions (rather than by chemistry constraints), this indicator is expected to have substantial interannual variability, and care is needed in its interpretation. It would be useful to report the annual global concentration of stratospheric ozone together with the national levels.

Trends in ozone will be analysed for signs of the success of the Montreal Protocol in phasing out ozone depleting substances (ODSs). However, the life-time of ODSs in the atmosphere is in the order of decades, and so the global concentration of ozone is expected to continue to fall until the turn of century. Full recovery of the ozone layer will require some decades beyond the time that the supply and emission of ODSs is stopped (Fraser 1997). Trends at specific sites or averaged across Australia will need to be interpreted carefully because local ozone levels are substantially affected by general meteorological conditions, as mentioned earlier.

Monitoring

Spatial Scale: Satellite data provide high-resolution data, with *in situ* calibration points at major centres across Australia.

Frequency: Annual

Measurement Technique: Global-scale daily analyses are produced by the Bureau of Meteorology on a 2.5 - degree latitude by 2.5 - degree longitude grid, using satellite data. *In situ* Dobson spectrophotometer measurements at major centres in Australia provide benchmark and calibration data of total-column ozone.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: The daily ozone analyses have been archived routinely since January 1997. The *in situ* measurements have been available for some decades.

Contact: Bureau of Meteorology

Research Needs

The quality control on the early Dobson data requires further work.

INDICATOR 2.3 ULTRA-VIOLET RADIATION FLUX AT THE SURFACE

Description

In order to relate the ultra-violet (UV) flux measurements to human health, it is common to report in units of the minimal erythemal dose (MED). This unit accounts for the erythemal response to different wavelengths of UV radiation, and it effectively integrates in time to estimate the total exposure required to induce a perceptible erythemal response in people with a particular skin type (e.g. Roy *et al.* 1997)

Rationale

The level of UV radiation reaching the ground from the Sun is controlled largely by the level of stratospheric ozone. (Clouds play a substantial role in modulating the UV flux at any particular time.) The UV radiation can damage living matter, and so it affects all biological systems. The focus of the SoE indicator is on human health, where UV radiation is found to be linked to the incidence of skin cancer, cataract eye disease, and even immune system suppression (Armstrong 1997).

Interpretation and analysis

For quality-controlled data, the trends in UV can be analysed and compared with those in ozone. The interannual variability due to variations in ozone and cloudiness needs to be accounted for.

Monitoring

Spatial Scale: Broad-band *in situ* observations are taken at 18 sites around the country by the Australian Radiation Laboratory.

Frequency: Continuous measurements

Measurement Technique: Broad band UV spectrometry (use of biometer)

Data sources

Data Archive: Australian Radiation Laboratory (ARL), Melbourne

Data Quality Control: ARL, Melbourne

Current Status of Data: Some data are available since the early 1980s. In general, data quality is not uniform.

Reference

Roy *et al.* (1997) describes the ARL network, and Manton (1997) describes the UV systems of the Bureau of Meteorology.

Research Needs

A need exists for a comprehensive monitoring network of broad-band measurements, complemented by a small baseline network of precision spectral measurements across the nation. Such a network is being planned by the Bureau of Meteorology to link directly with the basic national meteorological observations.

The Bureau of Meteorology runs each day a system to analyse the UV radiation at the surface of the globe (Rikus 1997). The UV system runs in conjunction with the ozone analysis system. It is likely that the most effective and accurate means to estimate the UV radiation flux across Australia is through this UV analysis system, with baseline *in situ* observations for calibration.

INDICATOR 2.4 MAGNITUDE OF ANTARCTIC SPRING-TIME OZONE HOLE

Description

Peak and average areal extent (km^2) and depth (Dobson Units) of the Antarctic spring-time ozone hole during the last week in September and first week in October each year.

Rationale

The most dramatic phenomenon associated with the stratospheric ozone layer over recent decades has been the rapid growth in the region of ozone depletion in the Antarctic during the spring-time break-down of the polar vortex. Theoretical and observational studies have demonstrated that the decrease in ozone is largely associated with the effects of ozone depleting substances (ODSs). By routinely monitoring the size of the annual ozone hole, we can estimate the long-term trends in the impacts of ODSs as they are phased out.

Interpretation and analysis

While the size of the ozone hole is strongly influenced by the presence of ODSs, there is a natural reduction in ozone associated with the break-down of the polar vortex each spring. In order to interpret the measurements of the size of the ozone hole, it is important to consider the interannual variability associated with natural forces. The long-term trends in the variation in the ozone hole can be interpreted against the observed concentrations of ODSs in the atmosphere and the estimated emissions of ODSs in past years.

Monitoring

Spatial Scale: 1 degree latitude by 1.25 degree longitude gridded Total Ozone Mapping Spectrometer (TOMS) data.

Frequency: Daily observations

Measurement Technique: Daily analyses are prepared from the TOMS instruments on various satellites. The international meteorological community is ensuring that these observations will be continued into the next century. The ozone hole is defined by the World Meteorological Organization (WMO) as the region with ozone concentration below 220 Dobson units.

Data sources

Data Archive: National Aeronautics and Space Administration (NASA) maintains an archive of TOMS data, for the following satellites: Nimbus-7 (1979-93), Meteor-3 (1993-94), and Earth Probe (1996 onwards)

Data Quality Control: NASA Goddard Space Flight Center TOMS Processing Team

Current Status of Data: TOMS data are available with some gaps since 1979

Contact: Bureau of Meteorology

Indicator 2.5 National emission of ozone depleting substances

Description

The net trade (consumption) in ozone depleting substances (ODSs) in Australia each year could be reported.

Rationale

The emission of ODSs leads to atmospheric concentrations of gases that are transported to the stratosphere where they can react with ultra-violet (UV) radiation to reduce the ozone concentration.

Interpretation and analysis

The net trade (consumption) in ODSs is an indicator of the change in total ODSs in Australia. Any increase in ODSs would lead to future emissions or future destruction operations.

Monitoring

Spatial Scale: Annual

Frequency: National

Measurement Technique: There is little reliable or complete data on emissions of ODSs available from the State and Territory authorities that authorise the sale and use of these substances. However, the manufacture, import and export of chlorofluorocarbons (CFCs), halons, methylchloroform and carbon tetrachloride has been controlled since 1989 in Australia, in line with our international obligations under the Montreal Protocol. These activities are now banned. Since 1996 the manufacture, import and export of methylbromide and hydrochlorofluorocarbons (HCFCs) have also been controlled at the Commonwealth level. The sale, purchase and use of ODSs is controlled under State legislation. While the manufacture, import and export of ODSs is controlled, the release of existing ODSs cannot be fully accounted for. Until all the ODSs are phased out, it would be useful to report on the net trade (consumption) in them, i.e. any manufacture plus import minus any export. This surrogate measure is not of the current emissions, but of the potential for future emissions in Australia.

Data sources

Data Archive: Environment Australia and State Environment Protection Authorities (EPAs)

Data Quality Control: Environment Australia and State EPAs

Current Status of Data: Data on manufacture, import and export are available from 1989.

Contact: Environment Australia

Reference

Australian and New Zealand Environment and Conservation Council (ANZECC 1994).

Research Needs

It would be useful to find a robust measure of the actual emissions.

Indicator 2.6 Fulfilment of national responsibilities under the Montreal Protocol and associated agreements

Description

Australia's achievements under the Montreal Protocol and contributions to the Multilateral Fund would be reported.

Rationale

Under the Montreal Protocol and associated agreements, Australia is required to phase out ozone depleting substances (ODSs) in line with the international timetable. It is appropriate to report on our success at reaching each of the milestones in the Protocol.

Interpretation and analysis

Australia has been a leader in achieving the Montreal Protocol milestones. These achievements should continue to be reported. As there is some concern about developing countries being able to contribute to the phase-out of ODSs, Australia's participation in regional projects through the Multilateral Fund is a measure of our helping with this global problem.

Monitoring

Spatial Scale: National

Frequency: Annual

Measurement Technique: The Montreal target for the phase-out of each ODS would be reported against the date at which Australia meets that milestone.

Australia is also involved in the Multilateral Fund, which aims to assist developing countries in phasing out ODSs. The annual funding provided to the Fund, and the achievements of the funding should be reported.

Data sources

Data Archive: Environment Australia

Data Quality Control: Environment Australia

Current Status of Data: Data are available from 1989

Contact: Environment Australia

Reference: Australian and New Zealand Environment and Conservation Council (ANZECC 1994).

Indicator 2.7 Public behaviour modification to protect against ultra-violet radiation

Description

Key results from the Sun Surveys should be reported annually. For example, the fraction of the population who believe that "close family think that a suntan is good" has dropped in Victoria from 50% in 1988 to 19% in 1995; and the fraction who "wore a wide brimmed hat between 11 am and 3 pm on the previous Sunday" has increased from 9% in 1988 to 20% in 1995 (Hill and Boulter 1996). These values could be reported each year from summer-time surveys in capital cities.

Rationale

While the Australian climate is conducive to sunburn and medical problems, such as melanoma, the overall impact of these climatic conditions is determined by human behaviour. Borland (1996) discusses the scientific methods for estimating the human risk factors and responses associated with Sun exposure. It is appropriate to include a SoE indicator which measures changes in human behaviour with time aimed at reducing these risks.

Interpretation and analysis

The change in behaviour and attitude of the population would be reported. Given the national campaigns that are routinely run to educate the community, it is expected that both behaviour and attitude should continue to change with time.

Monitoring

Spatial Scale: Major population centres

Frequency: Annually

Measurement Technique: Population surveys have been conducted annually in Victoria since 1989 under the Sun Survey program (Hill and Boulter 1996). These studies have involved unobtrusive observation of people in parks etc., and household surveys. Behaviour (e.g. percentage of people wearing hats) and attitudes (e.g. percentage of people who believe that suntan is healthy and necessary) are measured.

Data sources

Data Archive: The Anti-Cancer Council of Victoria (ACCV) is a source of much national data on this issue.

Data Quality Control: Surveys inevitably have some uncertainty, but good design can improve their accuracy

Current Status of Data: Information from the Sun Survey program is available.

Contact: ACCV.

Reference

Hill and Boulter (1996) describe some of the results of the Sun Surveys.

Research Needs

The survey program would need to be continued in Victoria and extended to other States to provide national statistics.

INDICATOR 2.8 HEALTH EFFECTS LINKED TO ULTRA-VIOLET EXPOSURE

Description

The national and State incidence of melanoma mortality should be reported each year.

Rationale

Skin cancer is the major type of cancer occurring in Australia, and the mortality from it has increased this century in fair-skinned populations around the world including Australia (Giles and Thursfield 1996). The increasing incidence of skin cancer started long before any depletion of the ozone layer began, and so it is associated primarily with human behaviour and attitudes in a climate that is conducive to out-door living. The issue has been highlighted in recent years through publicity about the depletion of the ozone layer. However, skin cancer is significant in Australia independently of ozone depletion. Indeed, our improved capability at early detection of cancers is leading to a gradual decline in melanoma mortality over recent decades.

Taylor and McCarty (1996) point out that the incidence of cataract is clearly linked to exposure to ultra-violet (UV) radiation, and that other ocular diseases are also associated with exposure to the Sun. While there are other risk factors for cataracts, there is strong experimental evidence of the importance of UV exposure. Given that cataract is the main cause of blindness around the world and given the out-door mode of living in Australia, it would be informative to include a measure of cataract incidence in the SoE report.

Interpretation and analysis

Australia's climate and Australians' behaviour lead to our having a high incidence of melanoma, which is largely associated with exposure to UV radiation. Owing to improved techniques for detecting and treating cancers and to improved human behaviour, melanoma mortality should continue to decline in the future. Any increase in UV radiation due to a reduction in stratospheric ozone may increase the incidence of melanoma, if human behaviour did not change. In assessing links between UV exposure and the incidence of skin cancers, it is necessary to account for the time lag between exposure and the appearance of cancers, such as melanoma.

Monitoring

Spatial Scale: National

Frequency: Annual records

Measurement Technique: The registration of cancer incidence has been carried out in all jurisdictions since the 1980s, and the Australian Bureau of Statistics (ABS) is now collating the data. Non-melanocytic skin cancers (NMSCs) are not included in all State registers. Data on mortality from malignant melanoma are the most complete, but Giles and Thursfield (1996) explain that mortality data do not provide a full picture of the incidence of cancer.

Data sources

Data Archive: State cancer registries and ABS

Data Quality Control: State cancer registries

Current Status of Data: National cancer records available since the 1980s

Contact: State registries

Reference

Giles and Thursfield (1996) analyse national melanoma mortality and other indicators of cancer incidence in Australia.

Research Needs

In addition to data on melanoma mortality, it would be informative to have national data on NMSC and on the incidence of skin cancers.

Another indicator of disease incidence, independent of human behaviour, would be the incidence of UV-related disease in animals, such as skin cancer in cattle.

While one survey has been conducted in Melbourne to estimate the incidence of cataract in the community (Taylor and McCarty 1996), it would be useful to establish more routine methods of estimating the incidence of cataract in the Australian community. Such routine observations would be needed to support the reporting of a SoE indicator.

Indicator 2.9 Destruction of ozone depleting substances

Description

The cumulative amount of ozone depleting substances (ODSs) collected, recycled, banked and destroyed would be reported each year.

Rationale

Under the Montreal Protocol, the supply of new ODSs is being phased out. While supply of some substances, such as chlorofluorocarbons (CFCs) and halons, have already been phased out, others, such as hydrochlorofluorocarbons (HCFCs), will be phased out over the next few decades. Alternatives to ODSs are being developed for most applications, and ODSs are being collected from existing equipment for recycling or destruction. A measure of government and industry action to assist this process is the establishment of programs to destroy ODSs.

Interpretation and analysis

The continuing collection, recycling, banking and destruction of ODSs indicate the community commitment to the phasing out of these substances. In addition to reporting the amount destroyed, it would be useful to normalise the amount collected by the estimated initial total amount in the community. This normalised value would indicate the relative success of the program.

Monitoring

Spatial Scale: National

Frequency: Annual

Measurement Technique: There are several available technologies for the recycling or destruction of ODSs. For example, Refrigerant Reclaim Australia co-ordinates the destruction or recycling of contaminated refrigerants. Similarly the National Halon Bank, managed by DASCEM Holdings Pty Ltd, has collected and stored halon-1211 and halon-1301 pending destruction or for servicing essential halon fire protection systems in Australia.

Data sources

Data Archive: Environment Australia

Data Quality Control: DASCEM Holdings, Refrigerant Reclaim Australia, and Environment Australia

Contact: Environment Australia

Research Needs

It would be useful to establish a national halon bank management system where annual usage and projected future needs of essential users are determined.

Issue 3: Urban air quality

Background

Australia has a highly urbanised population, with more than 90 percent of the population located along the coastal fringe of the country. By international standards, the population density of our urban areas is not especially high. On the other hand, our climate is such that we receive a relatively high amount of direct sunshine, and so our urban areas are susceptible to photochemical smog.

Because of the relatively low population density across Australia, it is necessary to identify specific urban areas to be monitored for their air quality. Two alternative approaches could be taken in defining urban areas. One is to take a threshold population of about 1 million. This criterion, representing the threshold at which photochemical smog becomes a significant issue due to the number of motor vehicles, would mean that Sydney, Melbourne, Brisbane, Perth and Adelaide (with populations varying from about 3.7 million down to 1.1 million) would be included in the process. Hobart, with a population of about 200,000, and Canberra, with about 300,000 people, are not near the threshold, but they could be reported through the regional air quality indicators.

The second alternative is to take a population threshold of 25,000 as the criterion for monitoring urban areas. This threshold is specified in the draft Air National Environmental Protection Measure (NEPM), so that monitoring is not required in towns with populations below 25,000. This criterion is recommended for SoE reporting, because it directly aligns the SoE process with the National Environmental Protection Council (NEPC) process, from which monitoring infrastructure should be established and maintained on a nationally consistent basis. Thus national SoE reporting would be a further justification for NEPM monitoring.

While the draft Air NEPM provides a basic framework, it would be appropriate for the national SoE reporting system to extend beyond the NEPM and to anticipate potential air quality issues. Thus the SoE process should encourage background reporting of indicators that may not be included in a NEPM at a particular time. Any decision to commence routine SoE reporting would be justified by earlier research results. In this way, the SoE process, in co-operation with the States, can provide the long-term background information that can support informed decisions by the NEPC.

Just as reporting on a variable should commence as soon as it has been identified as being scientifically significant, reporting should continue on variables even when the air quality problem appears to be improving. For example, government and industry action has caused the amount of lead in the air to be greatly reduced over the last decade. Nonetheless it is important to continue to report on lead levels, so that the success of the current response strategy is clear and so that any unexpected increase in lead levels in the future will be well recorded.

Data analysis

Under the Meteorology Act, the Bureau of Meteorology has the national responsibility to maintain a national network to obtain consistent long-term observations of the physical parameters relating to weather and climate. However, legislation in the 1970s has led to the monitoring of air quality becoming a State responsibility. Thus air quality data are collected and archived by State agencies. One means of encouraging quality control and national consistency of data is to ensure that they are readily accessible to the research community. Such national access would allow the data to be readily intercompared and analysed to enhance our understanding of the variations of our environment across the nation. Access is also needed to ensure compliance of jurisdictions with the Air NEPM. While quality control can be time-consuming, it is expected that raw data should be processed promptly so that the air quality data are available for timely analysis.

In addition to direct air quality data, it is essential that meta-data are maintained and available for all SoE reporting sites. The meta-data give information on the history of each site, including the siting conditions, instrument changes and quality control procedures. Differences in siting conditions particularly can lead to significant differences in the interpretation of air quality observations. The monitoring protocol being developed under the Air NEPM process should address these issues.

To analyse and interpret the national air quality data, it will be important to ensure that the direct observations, the meta-data, and related meteorological data are all readily available. This function may be optimised through the establishment of a national reporting centre, as recommended under the OECD (Organisation of Economic Co-operation and Development) country review (OECD 1998).

A particular issue, requiring continuing research and analysis, is the detection of significant trends in air quality data. It is well known that air quality data, such as ozone concentrations in an urban area, have substantial variability on time scales extending from minutes to decades. Much of this variability is associated with meteorological conditions, which always exhibit large fluctuations. Specialised statistical techniques have been developed to account for the external sources of variability, and so to identify statistically significant trends in basic air quality (e.g. Chock 1984; Comrie 1992). The refinement of these techniques will require open access to all the relevant air quality and meteorological data.

In reporting concentrations of air pollutants, there is usually an emphasis on analysis of the tails of frequency distributions of the data so that extreme values are highlighted. On the other hand, it is important to record the range of concentrations that occurs on most days. The Academy of Technological Sciences and Engineering (ATSE 1997) study demonstrates that a single diagram can show time-histories of the maximum, minimum, 10th percentile, 90th percentile, and median value of a pollutant for each year. In order to estimate the dominant effects across an air-shed, the study also uses data from the peak value at a given time period from any station in the air-shed. This strategy should be used for national SoE reporting. Going into even more detail, the OECD has recently recommended the use of box plot analysis techniques and the calculation of the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles, in addition to the maximum values. Analysis by season may also be useful, particularly for ozone, to assess the effects of meteorological variability.

For each pollutant included in the draft air NEPM, the number of days per year on which the NEPM standard is exceeded should also be reported as an SoE indicator. Although this measure represents national compliance with the draft Air NEPM, its interannual variability is expected to be too high for trends to be detected readily.

The density of air quality measuring sites is invariably low, and it is difficult to capture the full spatial variability of each air pollutant. Indeed, for the draft Air NEPM, the density of sites is determined by population density rather than the variability of pollutants. This limitation means that each site tends to represent an area of varying pollutant concentration. Basic indicators, such as pollutant concentration, should be determined directly from observed data. However, some integrative indicators, such as toxic loading across the population, depend upon reasonable estimates of the spatial distribution of pollutant which in turn depend upon the mesoscale flow patterns across an air-shed. For these cases, appropriate statistical or mathematical techniques should be used to develop the estimates (e.g. Manins 1995).

In order to obtain an optimal estimate of the distribution of each pollutant across an air-shed, it would be appropriate to employ the techniques of data analysis used in meteorology (e.g. Seaman 1989). The step beyond direct analysis of pollutant data is the employment of data assimilation techniques, which use a physically-based model to assimilate observed data to obtain a consistent spatial analysis. This model-based technique is somewhat different from the use of models with emission data alone to predict the distribution of pollutants. The application of these techniques to air quality data is still at an early stage of development, but future research should lead to effective means for estimating the spatial distribution of pollutants across air-sheds using a combination of models and observations. The modelling of chaotic processes like meteorology is always critically dependent upon direct observations.

Monitoring strategy

The draft Air NEPM recommends the use of performance monitoring stations, which are sited "so as to be representative of the air quality to which the population of that region is generally exposed". Thus peak sites, at which expected maximum values are observed, are excluded from NEPM reporting. The draft Air NEPM also recommends that instrumentation should be maintained at the same location for at least five years.

For SoE reporting, it is appropriate to use data from all observing sites, and the benefits of maintaining sites for long periods should be recognised so that trends can be determined as accurately as possible. The density of performance monitoring sites for the draft Air NEPM is determined by the population density of the urban area. However, the focus of SoE reporting needs to be on the analysis of the variations of the atmospheric pollutants; i.e. the density of observations should be determined by the variations in pollutant concentration. The recent study on urban air pollution (ATSE 1997) notes the current lack of standardisation in measurement, data management and data access across the various jurisdictions in Australia. The monitoring protocol, being developed under the draft Air NEPM, should address some of these issues.

In order to obtain accurate estimates of trends in air quality, it is important that the monitoring sites maintain data recovery rates as high as possible. A recovery rate of 95% is desirable, but a more feasible aim is 90%. Given current resources and priorities, it is likely that levels of only 80% recovery will be achieved. Even a recovery rate of 95% would mean that true monthly average values would be difficult to obtain, because each observation site may lose data for about one day each month.

Indicators

The following indicators are used to quantify the condition of urban air quality:

- Concentration of carbon monoxide in urban areas
- Concentration of ozone in urban areas
- Concentration of lead in urban areas
- Concentration of nitrogen dioxide in urban areas
- Concentration of sulphur dioxide in urban areas
- Concentration of particles in urban areas
- Concentration of benzene in urban areas
- Haze in urban areas
- Pollen levels in urban areas
- Toxic dosage of air pollutants
- Meteorological conditions that exacerbate air quality problems

The first six indicators of the condition of the atmosphere correspond to the six pollutants considered under the draft Air NEPM. Because of the increasing interest in the potential impacts of toxics, benzene should be monitored. Haze and pollen have a significant impact on the urban environment, and so they are included. In order to estimate the impact of air pollutants on health, it is recommended that a measure of the toxic dosage of pollutants should be recorded. Extreme pollution events are usually associated with specific meteorological conditions, and so these conditions should be monitored in order to help explain variations and trends in air quality.

The pressure on urban air quality is provided by:

- Emission of air pollutants in urban areas

The following indicators represent a range of activities that are related to policy responses by the community:

- Number of people covered by air quality monitoring
- Quality of the national monitoring system
- Uniform government actions to monitor and reduce urban air pollutants
- Compliance with government legislation and regulations
- Motor vehicle use
- Use of unleaded petrol
- Hospital admissions for respiratory conditions

The indicators associated with motor vehicles are listed in the response (rather than pressure) category because the extent and scope of the use of vehicles are determined by the community; the emissions from the vehicles are the pressure indicators. The indicator on hospital admissions is included as a significant measure, although it is recognised that respiratory conditions are exacerbated by other factors than weather and air quality.

INDICATOR 3.1 CONCENTRATION OF CARBON MONOXIDE IN URBAN AREAS

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard of 9 ppm for 8 hour average data is exceeded would be reported. The draft Air NEPM allows 1 day per year.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each urban area should be reported, based on 8 hour average data.

Rationale

Background levels of carbon monoxide (CO) are about 0.01 to 0.2 ppm, but values of several ppm can occur in urban areas from motor vehicle exhaust. In the major urban areas of Australia, about 80% of CO arises from motor vehicles.

Health effects depend upon exposure time and CO concentration. Impacts are related to carboxyhaemoglobin in blood which interferes with the carriage of oxygen to organs in the body. Exposure at low levels can lead to increased occurrence of cardiovascular disease symptoms.

Interpretation and analysis

As motor vehicle exhaust emissions are reduced further and traffic management is improved, the CO levels in major urban areas should fall. However, interannual variability and long-term trends in meteorological conditions could mask trends associated with policy changes. The impacts of policy changes to reduce emissions from each vehicle could also be masked by increases in the total number of vehicles.

In some urban areas, wood-burning stoves are a significant source of CO in winter.

Monitoring

Spatial Scale: Point values across major urban areas, resolving gradients in concentration

Frequency: Continuous

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM: Direct reading instrumental method (AS3580.7.1, 1992)

Data sources

Data Archive: State Environment Protection Authorities

Data Quality Control: The development and implementation of a national monitoring protocol under the NEPC process should ensure that consistent high-quality data are collected in future.

Current Status of Data: The number of CO monitoring sites in each urban area varies; for example, the figures at 30 June 1995 were (Australian Bureau of Statistics, 1997a):

Adelaide	1
Brisbane	1
Perth	3
Melbourne	5
Sydney	8

However, the number of sites alone does not give the full picture on the adequacy of a network to resolve the variations in concentration in a given region. For example, the only site in Adelaide is outside a fast food outlet so that it records peak values. Thus Adelaide appears to have a greater problem with CO when compared with other Australian cities that do not monitor peak values (NEPC 1997).

Contact: National Environment Protection Council (NEPC).

Reference

NEPC (1997) provides background on CO.

Indicator 3.2 Concentration of ozone in urban areas

Description

Nature of Report: The number of days per year on which the draft Air NEPM standard of 0.1 ppm for 1 hour average data is exceeded would be reported. The draft Air NEPM allows 1 day per year. Similarly, the number of days on which the 4 hour average of 0.08 ppm is exceeded would also be reported.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each urban area should be reported, based on 1 hour average data.

Rationale

Ozone forms in the lower atmosphere as a product of reactions among various precursor pollutants, such as oxides of nitrogen and reactive hydrocarbons arising from motor vehicle use and other sources in urban areas. These reactions are generally driven by ultra-violet (UV) radiation from the Sun, and so there is a strong dependence upon meteorological conditions leading to smog. Indeed the peak ozone values usually occur some distance downwind of the original pollutant sources. There is a natural background level of ozone of about 0.02 ppm, also maintained through photochemical processes (Ayers *et al.* 1992).

The health effects of ozone vary with exposure from minor changes in lung function to respiratory and cardiovascular disease.

Interpretation and analysis

Trends and interannual variability in the number of days on which the National Environmental Protection Measure (NEPM) standards are exceeded would be analysed. It is noted that the World Health Organization (WHO) includes a standard of 0.06 ppm based on 8 hour average data. Trends in the distribution of 1 hour data would also be analysed, accounting for interannual variability. Long-term trends in the 90th percentile and the median would provide a measure of the success of policy initiatives to reduce pollution levels.

Because of the seasonal cycle in ozone, it may be useful to report the seasonal values, in addition to the annual distribution.

Monitoring

Spatial Scale: Point values across major urban areas, resolving gradients in concentration

Frequency: Continuous

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM: Direct reading instrumental method (AS3580.6.1, 1990)

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of ozone monitoring sites in each urban area varies; for example, the figures at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Adelaide	2
Brisbane	8
Perth	9
Melbourne	11
Sydney	13

However, the number of sites alone does not give the full picture on the adequacy of a network to resolve the variations in concentration in a given region. Moreover jurisdictions tend to change sites from time to time.

The maximum concentrations of ozone tend to occur downwind of the source of primary pollutants, and Australian coastal air-sheds are subject to the recirculation of pollutants. In order to resolve the variations in ozone across an air-shed, it is therefore necessary for the monitoring networks to account for the meteorological circulations as well as the distribution of population.

Contact: State EPAs

Reference

National Environmental Protection Council (NEPC 1997).

Research Needs

The level of ozone in the atmosphere is determined largely by the amount of oxides of nitrogen (NO_x) emitted (mainly from motor vehicles) and by the meteorological conditions (containing the pollutants and providing UV radiation). Further research is needed to determine whether NO_x emissions can and should be monitored for SoE reporting, as an indicator of the precursor conditions for photochemical smog in urban areas. It is also noted that new sources of NO_x, such as co-generation plants in urban air-sheds, may alter the spatial distribution of peak ozone levels.

Indicator 3.3 Concentration of lead in urban areas

Description

The draft Air NEPM standard is exceeded if the annual average loading of lead is greater than 0.50 ug/m^3.

The peak 3 month average level for each urban area would be reported for trend analysis and to record seasonal variations.

Rationale

Background levels of lead in the atmosphere are generally less than 0.01 ug/m^3. In urban areas the main anthropogenic source of airborne lead is motor vehicle emissions from the use of leaded petrol.

The health impacts of lead depend upon the level and duration of exposure. The effects vary from the inhibition of enzymes to the production of morphological changes (including liver, kidney and neurological damage) and death.

Interpretation and analysis

Owing to the implementation of government policy, the level of lead in the atmosphere has been substantially reduced over the last two decades (ATSE 1997). To record this success and to identify any new and unexpected sources in the future, monitoring of lead levels should continue.

Monitoring

Spatial Scale: Point values across major urban areas, resolving gradients in concentration

Frequency: Intermittent sampling

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM: High volume sampler of gravimetric method (AS2800, 1985).

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of lead monitoring sites in each urban area varies; for example, the figures at 30 June 1995 were (Australian Bureau of Statistics, 1997a):

Adelaide	9
Brisbane	5
Perth	3
Melbourne	5
Sydney	4

However, the number of sites alone does not give the full picture on the adequacy of a network to resolve the variations in concentration in a given region. Moreover jurisdictions tend to change sites from time to time. For example, the network was enhanced in major urban air-sheds to assess the impact of policy measures under the Lead Round Table Initiative. As a significant decrease in airborne lead levels was recorded between 1991 and 1996, the number of monitoring sites is likely to decrease in future.

Contact: State EPAs

Reference

NEPC (1997).

Indicator 3.4 Concentration of nitrogen dioxide in urban areas

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard for NO_2 of 0.12 ppm for 1 hour average data is exceeded would be reported. The draft Air NEPM allows for 1 day per year to be above the standard. Similarly, a report would be made if the annual average exceeded the draft Air NEPM standard of 0.03 ppm.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each urban area should be reported, based on 1 hour average data. The average annual level would also be reported.

Rationale

Nitrogen dioxide results from the combustion of fossil fuels, associated with motor vehicles, refining and manufacturing. It is an important contributor to photochemical smog in urban areas. Owing to unvented gas stoves and heaters, indoor exposure to NO_2 can greatly exceed the outdoor exposure levels.

The health effects of nitrogen dioxide include respiratory and cardiovascular disease. It can also exacerbate the effects of other pollutants such as ozone and sulphur dioxide.

Interpretation and analysis

Emissions of NO_2 from motor vehicles were not controlled prior to 1997. Trends in the peak values should be downward in response to policy changes on motor vehicle emissions, bearing in mind the interannual variability due to meteorological conditions. However, new sources of NO_2 in urban areas, such as co-generation plants, may affect the distribution of photochemical smog in the future.

Monitoring

Spatial Scale: Point values across major urban areas, resolving gradients in concentration.

Frequency: Continuous

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM: Chemiluminescence method (AS3580.5.1, 1993)

Measurements of NO_x, NO and NO_2 tend to be taken together.

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of nitrogen dioxide monitoring sites in each urban area varies; for example, the figures at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Adelaide	2
Brisbane	9
Perth	11
Melbourne	9
Sydney	11

However, the number of sites alone does not give the full picture on the adequacy of a network to resolve the variations in concentration in a given region. Moreover jurisdictions tend to change sites from time to time.

Contact State EPAs

Reference

NEPC (1997).

INDICATOR 3.5 CONCENTRATION OF SULPHUR DIOXIDE IN URBAN AREAS

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard for SO_2 of 0.2 ppm for 1 hour average data is exceeded would be reported. The draft Air NEPM allows for 1 day per year above the standard. The draft Air NEPM also allows for 1 day per year above the 24 hour standard of 0.08 ppm. Similarly, a report would be made if the annual average exceeded the draft Air NEPM standard of 0.02 ppm.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each urban area should be reported, based on 1 hour average data. The annual average level would also be reported.

Rationale

Sulphur dioxide occurs naturally in the atmosphere from volcanic and geothermal activity. It also arises naturally from bacterial and algal processes. Anthropogenic sources of sulphur dioxide are power generation and industrial operations using coal, oil or gas. It also arises from the smelting of mineral ores, oil refining and motor vehicles.

The health effects of sulphur dioxide are associated with respiratory disease and asthma.

Interpretation and analysis

Sulphur dioxide tends not to be a problem in Australian urban areas, because our coal has a relatively low sulphur content and power generation tends to be away from urban areas. Refining activities in Kwinana could continue to put pressure on SO_2 levels in the Perth region.

Monitoring

Spatial Scale: The location of monitoring sites has been determined by major point sources, such as refineries. Thus the networks are designed to detect peak levels to resolve gradients in concentration across an air-shed.

Frequency: Continuous

Measurement Technique: Use draft Air NEPM standard: Direct reading instrumental method (AS3580.4.1, 1990)

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of SO_2 monitoring sites in each urban area varies; for example, the figures at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Adelaide	1
Brisbane	3
Perth	6
Melbourne	7
Sydney	4

However, the number of sites alone does not give the full picture on the adequacy of a network to resolve the variations in concentration in a given region. Moreover jurisdictions tend to change sites from time to time.

Contact: State EPAs

Reference

NEPC (1997).

INDICATOR 3.6 CONCENTRATION OF PARTICLES IN URBAN AREAS

Description

The number of days per year on which the draft Air National Environment Protection Measure (NEPM) standard of 50 um/m^3 for 24 hour average PM10 data is exceeded would be reported. The draft Air NEPM allows for 5 days per year above the standard.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each urban area should be reported, based on 24 hour average data.

Rationale

Particles in the atmosphere vary in size from about 100 um down to a cluster of a few molecules. Background levels of particles arise from condensation from naturally occurring gases (e.g. from volcanoes) and from the mechanical transport of particles from the surface of the land and the ocean. Anthropogenic particles are emitted from power plants, industrial processes, motor vehicles, domestic burning, and fuel-reduction burning of bushland.

The health impacts of particles are associated with respiratory and cardiovascular disease; e.g. Gras (1996) suggests that particle concentrations in Perth lead to an increased daily mortality of 2-5%.

Interpretation and analysis

The PM10 data are not always collected continuously, and they often consist of 1 day samples every 6 days. With the increasing use of Tapered Element Oscillating Microbalance (TEOM) methods, data should become continuous. The control of vehicle emissions should lead to reducing trends in PM10, but bushfires and controlled burning of bushland can cause episodes of high PM10. Bearing in mind the health concerns associated with small particles, the levels of PM10 should be kept low, independently of their source. However, it is possible for a reduction in PM10 levels to be associated with an increase in the number of smaller particles.

Monitoring

Spatial Scale: Point values across major urban areas, resolving gradients in concentration

Frequency: Generally intermittent sampling

Measurement Technique: Draft NEPM: High volume sampler with size selective inlet gravimetric method (AS3580.9.6, 1990) or Dichotomous sampler with gravimetric method (AS3580.9.7, 1990)

Recent instrumentation includes the use of TEOM, which yields continuous measurements. It is now the USA EPA standard technique, although there is no Australian Standard for operation of TEOMs.

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of particle monitoring sites in each urban area varies; for example, the figures at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Adelaide	9
Brisbane	0
Perth	4
Melbourne	5
Sydney	6

However, the number of sites alone does not give the full picture on the adequacy of a network to resolve the variations in concentration in a given region. Moreover jurisdictions tend to change sites from time to time; e.g. there are now six PM10 sites in Brisbane.

Contact: State EPAs

Reference

NEPC (1997).

Research Needs

Current research suggests that the health impacts of particles are mainly due to small particles (of order 1um). Diesel engines are a significant source of such particles. There is expected to be a case for reporting of PM2.5 or even PM1 in the future. For example, USA now has a PM2.5 standard of 65 ug/m^3 over a 24 hour period. (It is noted that this PM2.5 standard is less severe than the draft Air NEPM for PM10 in Australia. The USA standard for PM10 is 150 ug/m^3 over 24 hour.s) As soon as there is scientific consensus on the appropriate standard size, SoE reporting should include fine particle observations.

Given the operating characteristics of nephelometers, it could be feasible to use light-scattering observations as a surrogate for small particle measurements such as PM2.5.

INDICATOR 3.7 CONCENTRATION OF BENZENE IN URBAN AREAS

Description

The annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each urban area should be reported, based on 24 hour average data. If hourly data become available then it will become possible to record peak events during the diurnal cycle. The annual average level would also be reported.

Rationale

Benzene is a human carcinogen, linked to non-lymphocytic leukaemia. A level of zero-risk has not been identified. It is a minor constituent of petrol, and motor vehicles are believed to be the main source in the atmosphere, with some input arising from the refining and distribution of petrol. Duffy and Nelson (1996) describe observations of significant exposure to benzene and other toxics in Australian conditions inside motor vehicles in high traffic zones.

Interpretation and analysis

Benzene is currently not included in the draft air quality National Environmental Protection Measure (NEPM) in Australia, but substantial monitoring has been carried out in the UK. The UK recommended standard is 5 ppb as a running annual mean.

Monitoring

Spatial Scale: Spot locations along busy roads in urban areas

Frequency: Hourly values

Measurement Technique: Benzene can be monitored along with other volatile organic compound (VOC) measurements, but the latter are not routinely measured by State Environment Protection Authorities (EPAs).

Data sources

Data Archive: Archive to be maintained with other air pollutants by States

Data Quality Control: State EPAs

Current Status of Data: Benzene has been measured routinely at 7 sites around Sydney for about 2 years.

Contact: State EPAs

Reference

UK SoE Report.

Research Needs

Benzene is currently not included in the draft Air NEPM air quality standards, but these standards are expected to evolve with time. The SoE report should be used to support this evolutionary process by analysing additional parameters that may become significant for the National Environmental Protection Council (NEPC) in the future. The potential health implications of background levels of benzene suggest that it should be monitored, and that continuing research should be maintained to monitor its significance.

Benzene is one of a number of toxics (e.g. Ye *et al.* 1997) that should be under continuous evaluation for inclusion in the national SoE report.

INDICATOR 3.8 HAZE IN URBAN AREAS

Description

The report would be of the number of days each year on which the visibility fell below a threshold of 20 km, as well as the annual value of the 95th percentile of the visibility distribution.

Rationale

Brown haze provides a dramatic manifestation of air pollution in urban areas. Williams *et al.* (1982) describe the properties of brown haze in Sydney. Most of the effect is caused by particles smaller than 2 μm, but oxides of nitrogen can also contribute. Gras (1996) presents a more recent analysis of haze in Perth. Because the haze is mainly due to small particles, there are health implications as well as the obvious aesthetic impact.

Interpretation and analysis

The occurrence of haze in urban areas requires appropriate meteorological conditions, as well as a threshold concentration of small aerosols and gases. Thus interannual variations in visibility would reflect variations in synoptic and local meteorological conditions, as well as the impacts of policy responses. The meteorology of a region is expected to provide a lower limit on the frequency of occurrence of haze.

Monitoring

Spatial Scale: Point measurements across air-sheds

Frequency: Continuous

Measurement Technique: The haze could be measured by two methods. First, the Bureau of Meteorology takes observations of the current weather every 3 hours at many sites, including airports. The current weather category number 05 corresponds to haze and 04 corresponds to industrial smoke haze, and so they provide a specific (although subjective) observation.

The current weather category is accompanied by an estimate of visibility.

Alternatively, Environment Protection Authorities (EPAs) maintain nephelometers at sites in urban air-sheds. As these instruments respond to the dry weight of small particles (less than about 2 um), they could be used to yield objective measurements of visibility.

Data sources

Data Archive: Bureau of Meteorology and State EPAs

Data Quality Control: Bureau of Meteorology and State EPAs

Current Status of Data: The Bureau data provide a long-term record across the country, while the EPA data are more variable in their coverage.

Contact: Bureau of Meteorology and State EPAs

Reference

Williams *et al.* (1982) describes Sydney's brown haze.

Research Needs

Some comparisons should be carried out on the available nephelometer and current weather data to determine the differences in haze occurrence and distribution from the different measurement methods.

INDICATOR 3.9 POLLEN LEVELS IN URBAN AREAS

Description

In the absence of routine sampling, it would be informative to report the average and peak concentrations of airspora (commonly called "pollen") obtained in ad-hoc surveys in urban areas, especially during the growing season. Over a number of years, the interannual variability of airspora, as well as any trends or changes, could be assessed.

Rationale

Airspora are primarily pollen grains and fungal spores, and the inhalation of airspora has been shown to cause allergic respiratory symptoms (Madelin 1994). The concentration and nature of airspora are dependent upon the local vegetation and meteorology. Some studies (e.g. Knox 1993) have suggested a link between the incidence of asthma and changes in the weather, such as the onset of thunderstorms. The concentration of fungal spores indoors has been found to be related to the concentration in outdoor air during the growing season (Burge 1990).

Interpretation and analysis

It is recognised that pollen levels are essentially independent of human activity. Nonetheless they are associated with significant health effects, and so the interannual variation and trends in their levels should be reported. Where possible, potential links between meteorological conditions and respiratory problems in the community could be considered. Different types of pollen could also lead to different impacts.

Monitoring

Spatial Scale: Point measurements in major urban centres

Frequency: Daily samples are usually taken over a one week period

Measurement Technique: Surveys, using air trapping techniques (Ogden *et al.* 1993), have been carried out in Australia in Brisbane (e.g. Rees 1964; Rutherford *et al.* 1997) and in Melbourne (Knox 1993). There is also related work in Sydney and Adelaide. The trapping technique involves the collection of airspora on strips of adhesive tape. Daily samples of the number of grains per unit volume of air are obtained.

Data sources

Data Archive: Survey data are held in laboratories in Brisbane (R. Simpson, Griffith University), Adelaide (K. Thompson, Adelaide Aerobiology Laboratory) and Melbourne (B. Knox, University of Melbourne).

Contact: Assoc. Prof. R. Simpson, Griffith University, provided background information on this indicator.

Reference

Rutherford *et al.* (1997) describes a pollen survey in Brisbane.

Research Needs

The establishment of routine surveys would provide valuable data on the inter-seasonal and interannual variability of airspora. Those data could also be more carefully analysed against meteorological conditions and the incidence of respiratory problems in the community. The links to elevated levels of other air pollutants could also be investigated.

Indicator 3.10 Toxic dosage of air pollutants

Description

Given the uncertainties in estimating toxic dosage at this time, the report should be limited to estimates of the dosage due to individual pollutants at monitoring sites. When accepted analysis techniques are developed to estimate the overall spatial and temporal distribution of each pollutant across an air-shed, this indicator could be extended to provide an indicator on the number of people exposed to air below agreed quality standards. The indicator would provide a measure of environmental equity, involving the exposure of people to air that is potentially unhealthy.

Rationale

A key indicator of air quality is the net health risk associated with exposure to the overall range of pollutants in urban areas. Some modelling studies (e.g. Manins 1995) have demonstrated the potential risks in Australian cities.

Interpretation and analysis

As policy initiatives lead to lower concentrations of pollutants, the indicators of toxic exposure should show improvements in time. However, as with concentrations, interannual variability in meteorological conditions could mask long-term trends.

The impact of CO is to combine with haemoglobin to form carboxyhaemoglobin (COHb), thus preventing the uptake of oxygen. Levels of COHb above 5% have measurable neurobehavioural effects; the level of no adverse effect is recognised as 2%. Coburn *et al.* (1965) provide an estimate of COHb against CO level.

Morgan *et al.* (1996) show an association between NO_2 levels and hospital admissions for respiratory and cardiac conditions. However, there is no accepted mathematical relationship between NO_2 exposure and health effects (NEPC 1997).

For ozone there is a monotonic relationship between concentration and health effects, with no lower threshold apparent at this time. NEPC (1997) suggests that there is an associated mortality increase of 2.5% per 0.01 ppm of ozone above 0.1 ppm over summer due to cardiovascular causes.

Exposure to sulphur dioxide produces rapid responses in the upper airways. NEPC (1997) suggests an essentially linear relationship between SO_2 concentration and reduction in forced expiratory volume over one second (FEV1) in asthmatics, for concentrations above 0.2 ppm.

Exposure to lead can cause a wide range of health effects, and lead tends to accumulate in bones over a lifetime. Health impacts have been measured against the level of lead in blood, and a threshold of 10 ug/dL for blood lead is found. There is some suggestion of a linear relationship between blood lead level and IQ decrements in children (Schwartz, 1994). Although there is no agreed relationship between atmospheric lead concentration and blood lead level, a value of 1.92 ug/dL per ug/m^3 is typically used to represent the uptake in children (NEPC 1997).

The health impacts of particles (PM10) are well documented. A daily mortality (all causes) increase of 1% is found per 10 ug/m^3 of PM10, while higher rates occur for specific diseases; e.g. a respiratory mortality increase of 3.4% per 10 ug/m^3 of PM10 (NEPC 1997).

Monitoring

Spatial Scale: Urban region

Frequency: Annual loading

Measurement Technique: Because of the uncertainties in combining the impacts of pollutants and in accounting for net exposures, the dosage should be computed for each pollutant based on peak values at specific sites across the country.

Data sources

Data Archive: State Environment Protection Authorities

Data Quality Control: State EPAs

Current Status of Data: It is recognised that there is some uncertainty in the specific impacts of pollutants on human health.

Research Needs

The effective toxic dosage of air pollutants is a key parameter in estimating the health consequences of pollutants. However, there are many uncertainties in estimating this parameter, and it is apparent that a general indicator cannot be computed at this time. The issues that need to be considered to reduce the uncertainties are (a) estimation of the dosage due to individual pollutants on an individual at a specific site, (b) estimation of the net dosage due to multiple pollutants, (c) estimation of the net effect of a single pollutant on an individual taking into account the exposure history, (d) estimation of the effective dosage for a total population, and (e) identification of the network requirements to calculate total population dosages. The exposure history of individuals needs to account for the impacts of indoor pollutants. At this time, reasonable estimates of issue (a) can be made.

For this indicator to provide a measure of overall population exposure to pollutants, it is necessary to use spatial analysis techniques to extend the point observations at monitoring sites to estimate the overall areal distribution of pollutant. This approach is more direct than the use of models to simulate the overall distribution. However, the lack of data at present means that modelling is the only feasible method for many areas.

INDICATOR 3.11 METEOROLOGICAL CONDITIONS THAT EXACERBATE AIR QUALITY PROBLEMS

Description

The number of days on which pollution-conducive conditions arise in each urban area would be reported. Following ATSE (1997), there is some useful information in reporting annual-average pollutant concentrations conditionally sampled to include only pollution-conducive days.

Rationale

The lack of ventilation in air-sheds tends to exacerbate air quality problems. Indeed meteorological conditions, associated with the local orography and topography, can lead to the re-circulation of polluted air (e.g. Manins *et al.* 1994). It is appropriate to monitor the occurrence of these conditions and to correlate them with air quality conditions.

Interpretation and analysis

Air quality, especially smog, is determined by a combination of pollutant emissions and meteorological conditions. In order to monitor the impact of policy initiatives in response to air quality issues, it is necessary to account for variations or trends in the meteorology. Because interannual and inter-decadal variations are known to occur in the synoptic weather patterns, they need to be monitored.

Monitoring

Spatial Scale: Local

Frequency: Daily

Measurement Technique: A supporting report to ATSE (1997) shows that cluster analysis can be used to estimate the meteorological conditions under which smog will develop in each urban area; i.e. pollution-conducive days. The weather categories for the occurrence of haze or high ozone levels in the major urban areas are summarised in Table 8 of ATSE (1997). These categories could be used to determine whether each day is pollution-conducive.

In the future, it is expected that more sophisticated estimates of these conditions could be analysed directly each day from the data assimilation process of the routine numerical weather prediction system of the Bureau of Meteorology.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: Bureau of Meteorology records of synoptic conditions at major centres are comprehensive.

Reference

ATSE (1997) summarises the results of the study by Katestone Scientific Pty Ltd on pollution-conducive days.

Research Needs

The weather categories computed for the ATSE (1997) study should be confirmed as appropriate for each major urban area. Further studies could be carried out to identify more specific criteria (such as boundary layer depth) that are available from the Bureau of Meteorology numerical weather prediction system.

INDICATOR 3.12 EMISSION OF AIR POLLUTANTS IN URBAN AREAS

Description

Through the National Pollutant Inventory (NPI) or other processes, each jurisdiction conducts intermittent studies on the emissions in the major urban areas. For each pollutant, the most recent inventory for each major urban area would be shown by a bar chart, showing the annual contribution (kilotonnes) of the main sources. A time-history chart would show the total annual national emission for each pollutant, with the contribution of each urban air-shed recorded. However, the intermittent nature of the inventory process means that the interpretation of emission time series can be difficult.

Rationale

The emission of pollutants into the atmosphere can lead to concentrations of gases and particles that have deleterious effects. The relationship between emissions and atmospheric concentration of pollutants is complex, because of transport and dispersion by the meteorology and of chemical reactions. However, the relationship is understood and can be modelled (e.g. Manins 1995).

Interpretation and analysis

The identification of the major sources of each pollutant indicates the sectors in which policy initiatives could be most effective. The important sectors will vary with region, but motor vehicles tend to be the main emitters in all major urban areas. The time plots can show the impacts of policy actions in each jurisdiction. In order to obtain a measure of our relative success in controlling pollutants, it is useful to compare the national emissions with those of other countries, especially the transport emissions on a per capita basis (ATSE 1997).

Monitoring

Spatial Scale: Local

Frequency: Ideally emission data should be estimated annually, so that trends can be easily monitored. In practice data are obtained intermittently. When data are collected, they should allow for the seasonal variations in emissions and they should account for each source sector.

Measurement Technique: Each jurisdiction conducts emission studies from time to time. The National Pollutant Inventory (NPI) process (NEPC 1998) should help to regularise these practices. Boyle *et al.* (1996) describe the results of trial projects aimed at providing a sound base for national reporting.

For each pollutant, the contribution of each type of source should be identified. Sources can be classified as mobile, diffuse area, industrial or biogenic. In turn, each class can be broken down, as follows:

Mobile sources

- motor vehicles
- locomotives
- aircraft
- marine pleasure craft
- commercial shipping

Diffuse area sources

- gas leakage
- gaseous and liquid fuel consumption
- solid fuel consumption
- surface coatings and thinners
- waste combustion
- aerosols and solvents
- dry cleaning
- lawn mowing
- bitumen
- service stations

Industrial sources

- chemical manufacturing
- metal processing
- metal fabrication
- non-metallic mineral processing
- fuel storage
- printing
- petroleum refining
- waste treatment
- textile manufacturing
- food and beverage manufacturing
- miscellaneous

Biogenic sources

- vegetation

Boyle *et al.* (1996) list 26 pollutants that should be included in an inventory. Consistent with the atmospheric pollutants to be used in national SoE reporting, the key emissions are:

- benzene
- carbon monoxide
- lead
- oxides on nitrogen (NO_x)
- particles (PM10 and TSP)
- sulphur dioxide
- volatile organic compounds (VOC)

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: Emission inventories are available from State EPAs for the major urban areas, and the NPI process should ensure that inventories are updated routinely.

Contact: NEPC and State EPAs

Reference

NEPC (1998).

Research Needs

The refinement of the Inventory process will continue. It will be necessary to develop uniform methods across all jurisdictions, including all the main pollutants.

INDICATOR 3.13 NUMBER OF PEOPLE COVERED BY AIR QUALITY MONITORING

Description

Total number of people and the fraction of the total population covered by air quality monitoring.

Justification

It is unnecessary and unfeasible to monitor the overall air quality across the country. However, routine monitoring does provide a means of assessing environmental equity across the nation. It is therefore appropriate to record the number of people across the country who are covered by a routine monitoring program used in SoE reporting.

Interpretation and analysis

As the fraction of the population covered by routine air quality monitoring is increased, environmental equity can be more easily assessed.

Monitoring

Spatial Scale: National and State scales

Frequency: Annual audit

Measurement Technique: The number of people covered by routine monitoring would be counted. The draft Air National Environmental Protection Measure (NEPM) formula could be used to estimate the number of people covered by each monitoring site. The count would be taken over the whole country, not just the major urban areas.

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Research Needs

The determination of which sites are included and how many people each site represents may need to be refined from time to time.

INDICATOR 3.14 QUALITY OF THE NATIONAL MONITORING SYSTEM

Description

The observing networks and data processing and access regimes in each major urban area would be reported, through parameters such as:

- number of sites for each pollutant
- average age of each site
- number of trend stations
- recovery rate for each data set
- number of sites with full meta-data
- time delay between observation date and availability of data

Rationale

While the Bureau of Meteorology has the responsibility to maintain a national network to obtain consistent long-term observations of the physical parameters relating to weather and climate, the monitoring of air quality has become a State responsibility. Thus, there is a need for mechanisms to ensure that nationally consistent data on air quality can be obtained and maintained. It is expected that the Air National Environmental Protection Measure (NEPM) process will achieve this outcome.

In order to obtain a national perspective on urban air quality, it is necessary to have a national monitoring system that has sufficient density and consistency of observations to give accurate and consistent estimates of air quality variations across the country. Moreover, the raw data from the networks need to be readily available to ensure the quality and consistency of the individual measurements.

Interpretation and analysis

As the number of observation sites increases, the national capability to monitor air quality precisely improves. Information on trends is best established from long-term sites, and so it is expected that the average age of sites would increase as would the number of trend stations. The accuracy of SoE reports will depend upon the accuracy and representativeness of the raw data, and so high recovery rates for data should be encouraged. In order to encourage analysis and to provide feedback to measuring organisations, it is important to encourage ready access to data.

Monitoring

Spatial Scale: Sufficiently dense within major urban areas to resolve gradients of each pollutant

Frequency: Continuous, as specified in draft Air NEPM

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Indicator 3.15 Uniform Government actions to monitor and reduce urban air pollutants

Description

One indicator of the recognition of air quality issues at all levels would be the number of local government authorities that have implemented air quality management plans in urban areas.

Rationale

To optimise the national impact, actions on air quality issues need to be uniform across jurisdictions. However, a first step is the acceptance of air quality issues at all levels of government in major urban areas. The Air National Environmental Protection Measure (NEPM) process should support this aim at the State level, but it is appropriate also to consider the policies of local governments.

Interpretation and analysis

Community awareness of air quality issues may be reflected in the degree and scope of local government involvement in the issue.

Monitoring

Spatial Scale: Local

Frequency: Annual report

Measurement Technique: The Australian Local Government Association (ALGA) is encouraging local governments to be aware of environmental issues. Some councils are developing SoE indicators and establishing monitoring networks. The initial indicator would be the number of local governments with air quality programs.

Data sources

Data Archive: ALGA

Contact: ALGA (02-6281 1211)

Research Needs

Some research would be needed to refine this indicator beyond the initial step of counting authorities with air quality management plans. Some measures of achieving performance targets and of uniformity of standards would be desirable. In seeking uniformity, it is clearly necessary to allow for regional differences in air quality issues. The National Environmental Protection Council (NEPC) process should ensure that uniformity develops at the State level.

Indicator 3.16 Compliance with government legislation and regulations

Description

Report on number of convictions and total fines on urban air quality legislation, as well as the number of breaches of licence agreements in each jurisdiction.

Rationale

Although governments can enact legislation and regulations, their effectiveness depends upon acceptance by the community. Air quality issues extend from the general public (e.g. limitations on wood burning) to industry (e.g. limitations on stack emissions). The degree of compliance with government policy is a measure of its effectiveness.

Interpretation and analysis

As the community concern about air quality increases, it is expected that compliance with particular regulations will increase. If there are continuing breaches of a specific regulation then further policy action may be necessary, either to educate the offenders or to change the regulation. Interannual changes in breaches could be compared with changes in the national emissions and concentrations of the relevant pollutant. It is noted that environmental laws and regulations are not uniform across jurisdictions, and so comparison between States may be difficult.

Monitoring

Spatial Scale: Each state

Frequency: Annual

Measurement Technique: Breaches of licence agreements for industry could be reported. Similarly the number of convictions relating to air quality regulations could be reported.

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Research Needs

While data on breaches and fines are available in principle, it is not expected to be straightforward to collate the data.

INDICATOR 3.17 MOTOR VEHICLE USE

Description

Report nationally and by state on the number and type of vehicles, the number of vehicle-kilometres travelled (VKT), and the average age of vehicles. The VKT should be broken down into sectors. The volume of motor fuel sold nationally and in each state should also be reported. The relative use of diesel and petrol as motor vehicle fuel would also be of interest. Sector-based VKT data may not be routinely available, but the most recent data should be used.

Rationale

A major source of air pollution in urban areas is the motor vehicle, and so it is useful to report on the number and use of vehicles. In particular, changes in the vehicle usage are often the objective of policy initiatives.

Interpretation and analysis

The total emissions from vehicles are determined by the emissions from an individual vehicle and the overall use of vehicles. The emissions from a vehicle are dependent upon the age of the vehicle and the level of maintenance. The number of vehicles and the vehicle-kilometres-travelled (VKT) provide information in the overall use of vehicles. By breaking the VKT into sectors, it is possible to identify the relative contributions of each sector of the economy.

Policy initiatives to control emissions from vehicles are generally implemented through features on new cars. Thus emission improvements tend to be linked to the rate of renewal of vehicles. The age of the Australia vehicle fleet is greater (median more than 10 years) than that of other developed countries (ATSE 1997), and so it is important to monitor the age of the fleet.

The relationship between the total volume of motor fuel sold and the number of vehicles or VKT provides an indicator on the efficiency of fuel use.

Monitoring

Spatial Scale: National and state

Frequency: Annual

Measurement Technique: The Australian Bureau of Statistics (ABS) maintains records on vehicle use and ownership.

Data sources

Data Archive: ABS has annual figures on the number of vehicles used and on the number of cars owned per 100 persons. They also have annual figures on the total kilometres travelled and the average distance travelled by vehicles.

Current Status of Data: The ABS has intermittent records of motor vehicle use since 1963.

Reference

Australian Bureau of Statistics (1997a,b)

Research Needs

These data are collected intermittently by the ABS.

Indicator 3.18 Use of unleaded petrol

Description

The volume of leaded petrol sold and the ratio of unleaded to total petrol sold in each state and nationally would be recorded each year. More specifically the mass of lead in fuel has also been reducing with time, and so the total mass of lead in petrol should be reported.

Rationale

Leaded petrol has been a major source of air-borne lead. Although the amount of lead in the air due to petrol is falling rapidly, this indicator should continue to be reported in order to demonstrate the success of policy initiatives.

Monitoring

Spatial Scale: National and state

Frequency: Annual

Measurement Technique: Annual sales of leaded and unleaded fuel would be reported. Since the amount of lead in leaded fuel has also been falling, the total amount of lead in petrol should be recorded.

Interpretation and analysis

The percentage of unleaded petrol sold in Australia has increased almost linearly since 1994, so that at August 1997 it accounts for more than 65% of the total. The volume of leaded petrol has fallen each year. The total mass of lead has also been falling.

Data sources

Data Archive: Department of Primary Industries and Energy (DPIE) and the Australian Bureau of Statistics (ABS)

Reference

DPIE (1997) is a monthly report on petroleum usage.

Research Needs

This indicator relates to the major source of lead in the air. However, it would be useful to measure directly the impact on human health of decreasing levels of air-borne lead. There should be some research to determine the availability of routine data on the levels of lead in blood. (A novel suggestion is to measure the lead levels in children's teeth after they fall out.)

Indicator 3.19 Hospital admissions for respiratory conditions

Description

Annual total number of admissions, both nationally and by state, for the category of diseases of the respiratory system, normalised by total population; e.g. the Australian Institute of Health and Welfare (AIHW 1997) has statistics for 1995-96.

The daily records should also be used to correlate the admissions with local meteorological and air quality conditions. These raw data since about 1993 are available on request from AIHW, who in turn need to seek permission from the source agencies.

Rationale

Curson (1993) notes that respiratory diseases "enjoy the reputation for being amongst the most weather/climate sensitive". It is therefore appropriate to report on the level of respiratory disease in urban communities. However, it needs to be recognised that air pollutants and climate are not the only source of respiratory diseases.

Interpretation and analysis

Australia has a high incidence of respiratory disease, and these diseases are exacerbated by weather and air quality conditions. Bearing in mind that there are other causes, trends and interannual variability in hospital admissions could be analysed against changes in air quality and climate.

Monitoring

Spatial Scale: Local

Frequency: Daily

Measurement Technique: The AIHW publishes annual reports on hospital admission statistics.

Data sources

Data Archive: AIHW

Data Quality Control: AIHW

Current Status of Data: AIHW has been publishing hospital statistics since 1985-86.

Contact: AIHW

Reference

http://www.aihw.gov.au

Issue 4: Regional air quality

Background

Australia is a large island continent, relatively isolated in the southern hemisphere, surrounded by expanses of open ocean. Unlike many countries in the northern hemisphere, we are not significantly affected by trans-national transport of air pollutants. Moreover, the overall population density of Australia is low. Thus air quality issues tend to arise only in specific air-sheds that contain major sources of air pollutants. Apart from our urban air-sheds, regions where air quality is a potential concern tend to be associated with industrial activity. Regular observations at the Cape Grim Baseline Air Pollution Station provide information on the overall background levels of air pollutants in our region (e.g. Galbally *et al.* 1996).

The large area of Australia and the isolated nature of industrial sources mean that the monitoring of regional air quality will be generally confined to specific air-sheds. These air-sheds must be identified from time to time on the basis of the potential sources of air pollutants. The range of pollutants could vary with time, but monitoring needs to be maintained in regions containing sources of sulphur dioxide, lead, fluoride, particles, ozone, nitrogen oxides, and heavy metals. The scope of monitoring in each region will need to be determined by the specific sources. However, the focus tends to be on monitoring point sources of sulphur dioxide, particles or heavy metals. In many regions, the deposition of dust of industrial origin is a significant issue.

In order to ensure that trends and changes in air quality can be detected, it is important that monitoring should commence before human-based sources of emissions begin to operate so that an appropriate background level can be determined. Moreover only 5% of the country is routinely monitored for air quality, and so gradual expansion of our networks would help us to understand the overall nature of our atmospheric environment.

With a population threshold of 25,000 for urban areas (Issue 3), many Australian regions with point sources will already be covered by the SoE reporting on urban air quality. However, SoE reporting should include all regions containing significant point sources of pollutant. Moreover some air-sheds covered by the "urban" report may also require reports on "regional" pollutants such as fluoride or dust due to the presence of particular point sources.

A further distinction between regional and urban air quality reporting is on the justification for monitoring. In urban areas, the focus is essentially on human health. However, in regional air-sheds, the overall health of ecosystems becomes an additional issue. Thus, the impacts of ozone and fluoride are primarily on ecosystems in regional air-sheds. More research is needed to clarify the effects of air pollutants on crops and native vegetation and fauna under Australian conditions. Few guidelines have been developed for the protection of agriculture and natural ecosystems in Australia. Moreover, the available studies indicate a wide range of responses, and results cannot be simply transferred from northern hemisphere studies to Australian conditions.

The 1996 state of the environment report (State of the Environment Advisory Council 1996) noted that only five percent of Australia is covered by routine monitoring and that additional pollutants could be of concern in other regional areas. For example, pesticides from aerial spraying, emissions from traffic along some roads in rural areas, and particulates from forestry and agricultural activities are potential sources of air pollution in some rural areas. These pollutants would generally be reported at a local and state level, rather than the national level.

Monitoring strategy

The monitoring strategy for regional air quality indicators should be similar to that for urban air quality (Issue 3). In general the procedures recommended by the draft Air National Environmental Protection Measure (NEPM) for monitoring air pollutants should be followed. However, the distribution of observation sites should not be entirely linked to population density. In order to monitor accurately the variations of air pollutants across the air-shed, the distribution of observation sites should be determined by the distribution of pollution sources and by the meteorological transport processes in the air-shed.

The need for observations linked to the meteorology rather than population is most clear with the monitoring of the long-range transport of pollutants. In Australia the issue of long-range transport is most significant from the smelting operations at Mt Isa and Kalgoorlie, which produce a substantial fraction of our sulphur dioxide. The impact on the environment from the long-range transport of pollutants (particularly SO_2 and NO_2, which transform to acid aerosols) is through wet and dry deposition of aerosols. Many studies on acid deposition have been carried out in Australia (e.g. Ayers *et al.* 1995; Ayers and Granek 1997). These studies indicate that dry deposition is the major process, but there is little evidence of any significant problem from acid deposition.

Indicators

The condition of regional air quality is quantified by the following indicators:

- Concentration of sulphur dioxide across regional air-sheds
- Concentration of particles across regional air-sheds
- Concentration of lead across regional air-sheds
- Concentration of carbon monoxide across regional air-sheds
- Concentration of ozone across regional air-sheds
- Concentration of nitrogen dioxide across regional air-sheds
- Concentration of fluoride across regional air-sheds
- Deposition of dust across regional air-sheds
- Concentration of benzene across regional air-sheds
- Meteorological conditions that exacerbate air quality problems
- Toxic dosage of air pollutants
- Occurrence of haze
- Occurrence of fire and smoke

The extent of the monitoring of each pollutant will vary from region to region and will depend upon regional emissions. The first six indicators are the agreed pollutants in the draft Air NEPM, and so data for them should be readily and consistently available. Fluoride and dust are produced by specific industries in regional Australia, and they should be monitored appropriately. One other indicator, not in the urban air quality list, is a measure of smoke and fire, which is a significant issue across much of Australia.

The pressure on regional air quality is measured by:

- Emission of regional air pollutants

Policy response measures for regional air quality are given by:

- Area of national air-sheds monitored for SoE reporting
- Number of local government bodies which have programs to monitor and regulate regional air quality

The last indicator provides a measure of the extent to with local governments are embracing air quality issues.

Indicator 4.1 Concentration of sulphur dioxide across regional air-sheds

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard of 0.2 ppm for 1 hour average data is exceeded would be reported. The draft Air NEPM allows for 1 day per year above the standard. The draft Air NEPM also allows for 1 day per year above the 24 hour standard of 0.08 ppm. Similarly, a report would be made if the annual average exceeded the draft Air NEPM standard of 0.02 ppm.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each relevant air-shed should be reported, based on 1 hour average data. The annual average level would also be reported.

This indicator would be linked to the “average aerosol loading” indicator (indicator 1.19).

Rationale

Sulphur dioxide occurs naturally in the atmosphere from volcanic and geothermal activity. It also arises naturally from bacterial and algal processes. Anthropogenic sources of sulphur dioxide are power generation and industrial operations using coal, oil or gas. It also arises from the smelting of mineral ores, oil refining and motor vehicles.

The health effects of sulphur dioxide are associated with respiratory disease and asthma. In industrial regions, sulphur dioxide and particles together can cause increased incidence of chronic lung disease; i.e. SO_2 can exacerbate the effects of other pollutants. There can also be adverse effects on native vegetation and crops (Murray and Wilson, 1989). However, the addition of sulphates can have a fertilising (and hence positive) effect on some Australian soils.

Interpretation and analysis

Australian fossil fuels have low sulphur content, but levels of sulphur dioxide can be high in regional air-sheds where smelting, refining or power generation occurs. The long-range transport of SO_2 from Mt Isa and Kalgoorlie particularly needs to be monitored. As industry controls are improved (e.g. through the installation of sulphuric acid plants), the peak levels of SO_2 should be contained.

Monitoring

Spatial Scale: Need to monitor across the air-shed, accounting for transport by the atmosphere and deposition processes

Frequency: Continuous

Measurement Technique: Use draft Air NEPM standard: Direct reading instrumentation method (ASA3580.4.1, 1990)

Data sources

Data Archive: State Environment Protection Authorities (EPAs) and industry

Current Status of Data: The number of SO_2 monitoring sites in each air-shed varies; e.g. the numbers at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Gladstone	2
Kalgoorlie	11
Wollongong	2

However, the number of sites alone does not give the full picture on the adequacy of the network to resolve the variations across a given air-shed. Moreover, it may not be necessary to monitor all pollutants in all air-sheds.

Reference

NEPC (1997).

Research Needs

Further research is needed to determine the effects of SO_2 on ecosystems, so that guidelines can be developed to protect sensitive flora and fauna.

Indicator 4.2 Concentration of particles across regional air-sheds

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard of 50 $\mu m/m^3$ for 24 hour average data is exceeded would be reported. The draft Air NEPM allows for 5 days per year above the standard.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each relevant air-shed should be reported, based on 24 hour average data.

Rationale

Particles in the atmosphere vary in size from about 100 μm down to a cluster of a few molecules. Background levels of particles arise from condensation from naturally occurring gases (e.g. from volcanoes) and from the mechanical transport of particles from the surface of the land and the ocean. Anthropogenic particles are emitted from power plants, industrial processes, motor vehicles, domestic burning, and fuel-reduction burning of bushland.

The health impacts of particles are associated with respiratory and cardiovascular disease. Sulphur dioxide and nitrogen dioxide emissions from isolated point sources, such as smelters, transform to acid aerosols as they are transported downwind. The wet and dry deposition of these aerosol particles can have significant effects on vegetation and ecosystems.

Interpretation and analysis

The control of vehicle and industry emissions should contain trends in PM10, but bushfires and controlled burning could lead to episodes of high PM10. Also the use of domestic wood heaters needs to be contained in regional air-sheds where pollutants are readily trapped in winter-time.

Monitoring

Spatial Scale: Need to monitor across the airshed, accounting for transport by the atmosphere and deposition processes

Frequency: Generally intermittent sampling

Measurement Technique: The draft Air NEPM standard methods are: high volume sampler with size selective inlet gravimetric method (AS3580.9.6, 1990) or dichotomous sample with gravimetric method (AS3580.9.7, 1990).

Recent instrumentation includes the use of Tapered Element Oscillating Microbalance (TEOM), which yields continuous measurements.

Data sources

Data Archive: Environment Protection Authorities (EPAs)

Data Quality Control: EPAs

Current Status of Data: The number of particle monitoring sites in each air-shed varies; e.g. the numbers at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Gladstone	2
Kalgoorlie	0
Wollongong	4

However, the number of sites alone does not give the full picture on the adequacy of the network to resolve the variations across a given air-shed. Moreover, it may not be necessary to monitor all pollutants in all air-sheds.

Reference

NEPC (1997).

Indicator 4.3 Concentration of lead across regional air-sheds

Description

The draft Air National Environmental Protection Measure (NEPM) standard is exceeded if the annual average loading of lead is greater than 0.50 $\mu g/m^3$.

The peak 3 month average level for each relevant air-shed would be reported for trend analysis and to record seasonal variations.

Rationale

Background levels of lead in the atmosphere are generally less than 0.01 $\mu g/m^3$. In regional air-sheds, the main anthropogenic sources of airborne lead are large industrial operations and motor vehicle emissions from the use of leaded petrol.

The health impacts of lead depend upon the level and duration of exposure. The effects vary from the inhibition of enzymes to the production of morphological changes and death. Lead also has the potential to affect animals and ecosystems, through limiting the availability of nutrients.

As with urban air quality, lead is covered by the draft Air NEPM and so it should be reported. However, apart from the major regional cities not included in the urban report, the reporting on lead can be restricted to air-sheds containing smelting industries.

Interpretation and analysis

In regional urban areas, airborne lead levels should continue to fall as policy on lead in petrol is implemented. At major point sources, such as Port Pirie which has the largest lead smelter in the world, the draft Air NEPM standards may continue to be exceeded.

Monitoring

Spatial Scale: Need to monitor across the air-shed, accounting for transport by the atmosphere and deposition processes

Frequency: Intermittent sampling

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM of high volume sampler of gravimetric method (AS2800, 1985).

Data sources

Data Archive: Environment Protection Authorities (EPAs)

Current Status of Data: The number of lead monitoring sites in each air-shed varies; e.g. the numbers at 30 June 1995 were (Australian Bureau of Statistics, 1997a):

Gladstone	0
Kalgoorlie	0
Wollongong	5

However, the number of sites alone does not give the full picture on the adequacy of the network to resolve the variations across a given air-shed. Moreover, it may not be necessary to monitor all pollutants in all air-sheds. The networks also evolve with time; e.g. data on lead are now available from Hobart.

Major regional sources of air-borne lead are located at Broken Hill, Boolaroo and Port Pirie, and data are available from the relevant State EPAs.

Reference

NEPC (1997).

Indicator 4.4 Concentration of carbon monoxide across regional air-sheds

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard of 9 ppm for 8 hour average data is exceeded would be reported. The draft Air NEPM allows for 1 day per year above the standard.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each relevant air-shed should be reported, based on 8 hour average data.

Rationale

Background levels of carbon monoxide (CO) are about 0.01 to 0.2 ppm, but values of several ppm can occur in urban areas from motor vehicle exhaust or from domestic burning. In regional centres, CO is produced from industrial processes such as steel making.

Health effects depend upon exposure time and CO concentration. Impacts are related to carboxyhaemoglobin in blood which interferes with the carriage of oxygen to organs in the body. Exposure at low levels can lead to increased occurrence of cardiovascular disease symptoms.

Interpretation and analysis

In urban areas, the CO levels are due mainly to motor vehicle exhaust. However, domestic burning (e.g. wood-burning heaters) are significant sources in some regions, so that the monitoring stations need to be suitably located to identify all sources and the analysis of data needs to identify diurnal variations.

Monitoring

Spatial Scale: Need to monitor across the airshed, accounting for transport by the atmosphere and deposition processes

Frequency: Continuous

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM: Direct reading instrumental method (AS3580.7.1, 1992)

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of CO monitoring sites in each air-shed varies; e.g. the numbers at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Gladstone	0
Kalgoorlie	0
Wollongong	4

However, the number of sites alone does not give the full picture on the adequacy of the network to resolve the variations across a given air-shed. Moreover, it may not be necessary to monitor all pollutants in all air-sheds.

Reference

NEPC (1997).

Indicator 4.5 Concentration of ozone across regional air-sheds

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard of 0.1 ppm for 1 hour average data is exceeded would be reported. The draft Air NEPM allows for 1 day per year above the standard. The draft Air NEPM also allows for 1 day per year above the 4 hour standard of 0.08 ppm.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each relevant air-shed should be reported, based on 1 hour average data.

Rationale

Ozone forms in the lower atmosphere as a product of reactions among various precursor pollutants, such as oxides of nitrogen and hydrocarbons. These reactions are generally driven by ultra-violet (UV) radiation from the Sun, and so there is a strong dependence upon meteorological conditions leading to smog. There is a natural background level of ozone of about 0.02 ppm, which is also maintained through photochemical processes (Ayers *et al.* 1992). The precursor pollutants are generally emitted from motor vehicles, but domestic, commercial and industrial combustion processes are also sources.

The health effects of ozone vary with exposure from minor changes in lung function to respiratory and cardiovascular disease.

Ozone is included in the draft Air NEPM. However, in most regional air-sheds, the reporting on ozone will be linked primarily to its impact on ecosystems rather than human health; e.g. Monk (1994) finds that ozone affects native vegetation. Because ozone is a phytotoxicant, there is the potential for crops and market gardens to be affected by high ozone levels in some regions.

Interpretation and analysis

Trends in the distribution of 1 hour data and days on which the NEPM standards are exceeded would be analysed. In regional areas, enhanced ozone levels can affect native vegetation and commercial crops, and so the potential impact of ozone on ecological systems would need to be considered.

Monitoring

Spatial Scale: There is a need to monitor ozone across the air-shed, accounting for transport by the atmosphere and deposition processes. Indeed it is most likely to be transported into regional air-sheds from neighbouring urban areas, and so trajectory analysis combined with modelling and intermittent observations may be an effective process for assessing its distribution.

Frequency: Continuous

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM: Direct reading instrumental method (AS3580.6.1, 1990)

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of ozone monitoring sites in each air-shed varies; e.g. the numbers at 30 June 1995 were (Australian Bureau of Statistics 1997a):

Gladstone	0
Kalgoorlie	0
Wollongong	2

However, the number of sites alone does not give the full picture on the adequacy of the network to resolve the variations across a given air-shed. Moreover, it may not be necessary to monitor all pollutants in all air-sheds.

Reference

NEPC (1997).

Research Needs

There is a need to determine the effects of ozone on native vegetation and crops, and so to establish guidelines for their protection, as required.

Indicator 4.6 Concentration of nitrogen dioxide across regional air-sheds

Description

The number of days per year on which the draft Air National Environmental Protection Measure (NEPM) standard of 0.12 ppm for 1 hour average data is exceeded would be reported. The draft Air NEPM allows for 1 day per year above the standard. Similarly, a report would be made if the annual average exceeded the draft Air NEPM standard of 0.03 ppm.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each relevant air-shed should be reported, based on 1 hour average data. The annual average level would also be reported.

Rationale

Nitrogen dioxide (NO_2) results from the combustion of fossil fuels, associated with motor vehicles, refining and manufacturing. Particular sources are thermal power generation, mineral processing, food processing, paper and pulp manufacturing, and mining. It is an important contributor to photochemical smog.

The health effects of nitrogen dioxide include respiratory and cardiovascular disease. It can exacerbate the impact of other pollutants such as ozone and sulphur dioxide. Extended exposure of plants to NO_2 can cause biochemical and physiological changes. The nitrogen balance of ecosystems can also be altered through NO_2 exposure.

Interpretation and analysis

Trends in the frequency that NEPM standards are exceeded and in extreme levels of NO_2 should be downward in response to policy initiatives. However, support for co-generation as a greenhouse policy may lead to an increase in NO_2 levels.

Monitoring

Spatial Scale: Need to monitor across the airshed, accounting for transport by the atmosphere and deposition processes

Frequency: Continuous

Measurement Technique: Use the Australian Standards method recommended in the draft Air NEPM: Chemiluminescence method (AS3580.5.1, 1993)

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The number of NO_2 monitoring sites in each air-shed varies; e.g. the numbers at 30 June 1995 were (Australian Bureau of Statistics, 1997a):

Gladstone	3
Kalgoorlie	0
Wollongong	2

However, the number of sites alone does not give the full picture on the adequacy of the network to resolve the variations across a given air-shed. Moreover, it may not be necessary to monitor all pollutants in all air-sheds.

Reference

NEPC (1997).

Research Needs

There is a lack of research on the impact of NO_2 on Australian ecosystems.

Indicator 4.7 Concentration of fluoride across regional air-sheds

Description

The Australian and New Zealand Environment and Conservation Council (ANZECC) has set standards on fluoride levels to protect vegetation. These goals are for 3.7, 2.9, 1.7, 0.84 and 0.50 $\mu g/m^3$ over sampling periods of 12 hour, 24 hour, 7 days, 30 days and 90 days respectively. The number of days on which the 12 hour and 24 hour standards is exceeded would be reported. Similarly the number of times that the other standards are exceeded would also be reported.

In order to highlight trends in the distribution, the annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each relevant air-shed should be reported, based on 12 hour average data.

Rationale

Hydrogen fluoride is emitted by some specialised industries, such as aluminium production, superphosphate manufacturing and the firing of bricks, glass and ceramics.

Fluoride irritates the skin, eyes and respiratory system. Long-term exposure to high concentrations produces fluorosis of the bones. Plants are very sensitive to fluoride, and Doley (1992) finds that fluoride exposure causes deterioration and death of leaves of plants.

Interpretation and analysis

The level of fluoride needs to be monitored in regions where there are aluminium smelters and other sources of hydrogen fluoride. Because of our unique climate, we need to conduct Australian monitoring studies on the impact of fluoride on our ecosystems.

Monitoring

Spatial Scale: Need to monitor across the airshed, accounting for transport by the atmosphere and deposition processes

Frequency: Continuous

Measurement Technique: The ANZECC standard is based on Australian Standard techniques AS2618-1 (1983) and AS2618-2 (1984).

Data sources

Data Archive State Environment Protection Authorities (EPAs) and industry

Current Status of Data: Fluoride is not routinely monitored extensively, but it should be carried out in air-sheds where emissions could be significant. There are about 14 monitoring sites in the Hunter Valley. Data are also available from Portland, Gladstone and Swan Valley.

INDICATOR 4.8 DEPOSITION OF DUST ACROSS REGIONAL AIR-SHEDS

Description

The 24 hour average values of total suspended particulates (TSP) should be analysed through reporting on the maximum, minimum, 10th and 90th percentiles, and the median value for each significant air-shed. The annual average level would also be reported.

Rationale

Dust (large particles) is carried by the wind from soil erosion and from various industrial and land development processes. There can be a particular problem with dust transported from stockpiles of iron ore and mining wastes.

The impact of dust on human health is not clear, but dust deposition does cause significant annoyance to residents. It is likely to impact on vegetation through deposition on leaves restricting evapotranspiration. The deposition of dust may also lead to contamination of land and inland waters by heavy metals.

Interpretation and analysis

The National Health and Medical Research Council (NHMRC) has a standard for TSP of 90 um/m^3 over a year. The annual levels of TSP should be compared with that standard, and the interannual variability analysed using peak values from major air-sheds. The variations and trends in the distribution of the 24 hour data should be compared with emissions trends.

Monitoring

Spatial Scale: There is a need to monitor across the air-shed, accounting for transport by the atmosphere and deposition processes

Frequency: Intermittent collection

Measurement Technique: Dust can be measured as TSP, which is equivalent to PM50, i.e. all particles smaller than 50 um.

Data sources

Data Archive: Environment Protection Authorities (EPAs)

Current Status of Data: The number of TSP monitoring sites in each air-shed varies; e.g. the numbers at 30 June 1995 were (Australian Bureau of Statistics, 1997a):

Gladstone	0
Kalgoorlie	0
Wollongong	4

However, the number of sites alone does not give the full picture on the adequacy of the network to resolve the variations across a given air-shed. Moreover, it may not be necessary to monitor all pollutants in all air-sheds. There are extensive industry monitoring networks for dust.

INDICATOR 4.9 CONCENTRATION OF BENZENE ACROSS REGIONAL AIR-SHEDS

Description

The annual values of the maximum, minimum, 10th percentile, 90th percentile and median value for each relevant air-shed should be reported, based on 24 hour average data. The annual average level would also be reported.

Rationale

Benzene is a human carcinogen, linked to non-lymphocytic leukaemia. A level of zero-risk has not been identified. It is a minor constituent of petrol, and motor vehicles are believed to be the main source in the atmosphere, with some input arising from the refining and distribution of petrol. While benzene levels are expected to be highest in urban areas, some monitoring in regional air-sheds is needed to provide background levels and to detect potential problems in the future.

Interpretation and analysis

Benzene is currently not included in the draft Air quality National Environmental Protection Measure (NEPM) in

Australia, but substantial monitoring has been carried out in UK. The UK recommended standard is 5 ppb as a running annual mean. Measurements in NSW regional air-sheds suggest that regional levels are well below those found in the major urban air-sheds. The emissions of benzene will be included under the National Pollutant Inventory (NPI).

Monitoring

Spatial Scale: Spot locations along roads

Frequency: Hourly values

Measurement Technique: Observations need to have a precision of less than 1 ppb. Benzene can be monitored along with other volatile organic compound (VOC) measurements.

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: The NSW EPA has been measuring benzene at various sites since about 1995.

Reference

UK SoE Report.

Research Needs

Benzene is currently not included in the draft Air NEPM air quality standards, but these standards are expected to evolve with time. The SoE report should be used to support this evolutionary process by monitoring additional parameters that may become significant for National Environmental Protection Council (NEPC) in the future. The potential health implications of background levels of benzene suggest that it should be monitored, and that continuing research should be maintained to monitor its significance.

INDICATOR 4.10 METEOROLOGICAL CONDITIONS THAT EXACERBATE AIR QUALITY PROBLEMS

Description

The number of days on which pollution-conducive days occur in each air-shed would be reported. The Academy of Technological Sciences and Engineering (ATSE 1997) study shows that some useful analyses can be carried out using pollution-conducive days to conditionally sample pollutant concentration data.

Rationale

The lack of ventilation in air-sheds tends to exacerbate air quality problems, and so it is appropriate to monitor the occurrence of these conditions and to correlate them with air quality conditions.

Interpretation and analysis

The concentrations of air pollutants are determined by a combination of the nature and degree of emissions and the prevailing meteorological conditions. In order to monitor the impact of policy initiatives on air quality issues, it is necessary to account for or at least be aware of variations or trends in the meteorology which could mask the impacts of policy changes.

It is noted that pollutants are often emitted from elevated stacks in regional air-sheds, and the pollutants can be more dispersed than in an urban air-shed. The simple statistical techniques used in the ATSE (1997) study may not be adequate in some cases.

Monitoring

Spatial Scale: Local

Frequency: Daily

Measurement Technique: A supporting report to ATSE (1997) shows that cluster analysis can be used to estimate the meteorological conditions under which smog will develop in each major urban area; i.e. pollution-conducive days. Similar analyses could be carried out for all air-sheds.

In the future, it is expected that estimates of pollution-conducive days for each air-shed across the country could be determined directly from the data assimilation process of the routine numerical weather prediction system of the Bureau of Meteorology.

Data sources

Data Archive: Bureau of Meteorology

Data Quality Control: Bureau of Meteorology

Current Status of Data: The Bureau of Meteorology records of synoptic conditions for the major air-sheds are comprehensive.

Reference

ASTE (1997).

Research Needs

In the first instance, statistical analyses like those described in ATSE (1997) need to be carried out of major regional air-sheds to identify conditions for pollution-conducive days. Further studies could be conducted to use more specific criteria, such as boundary-layer depth and the effective release height of pollutants, that are available routinely from the Bureau of Meteorology numerical weather prediction system.

INDICATOR 4.11 TOXIC DOSAGE OF AIR POLLUTANTS

Description

Given the uncertainties in estimating toxic dosage at this time, the report should be limited to estimates of the dosage due to individual pollutants at monitoring sites.

When accepted analysis techniques are developed to estimate the overall spatial and temporal distribution of each pollutant across an air-shed, this indicator could be extended to provide an indicator on the number of people exposed to air below agreed quality standards. The indicator would provide a measure of environmental equity, involving the exposure of people to air that is potentially unhealthy.

Our lack of knowledge on the impacts of pollutants on ecosystems means that the report should be limited to effects on humans. Results cannot be simply transferred from the northern hemisphere because of the major influence of climatic conditions on the response of flora and fauna to stresses.

Rationale

A key indicator of air quality is the net health risk associated with exposure to the overall range of pollutants in regional air-sheds. For most pollutants, there are also significant impacts on ecosystems, and the toxic dose for plants can be substantially lower than that for human health.

Carbon monoxide

The impact of carbon monoxide (CO) is to combine with haemoglobin to form carboxyhaemoglobin (COHb), thus preventing the uptake of oxygen. Levels of COHb above 5% have measurable neurobehavioural effects; the level of no adverse effect is recognised as 2%. Coburn *et al.* (1965) provide an estimate of COHb against CO level.

Nitrogen dioxide

Morgan *et al.* (1996) show an association between nitrogen dioxide (NO_2) levels and hospital admissions for respiratory and cardiac conditions. However, there is no accepted mathematical relationship between NO_2 exposure and health effects (NEPC 1997).

Ozone

For ozone there is a monotonic relationship between concentration and health effects, with no lower threshold apparent at this time. The National Environment Protection Council (NEPC 1997) suggests that there is an associated mortality increase of 2.5% per 0.01 ppm of ozone above 0.1 ppm over summer due to cardiovascular causes.

Ozone is a phytotoxicant , and so it could damage crops and native vegetation. There is some suggestion that the response of native vegetation to ozone exposure is varied (Monk 1994).

Sulphur dioxide

Exposure to sulphur dioxide (SO_2) produces rapid responses in the upper airways. NEPC (1997) suggests an essentially linear relationship between SO_2 concentration and reduction in forced expiratory volume over one second (FEV1) in asthmatics, for concentrations above 0.2 ppm.

The impact of SO_2 on ecosystems is through the deposition of acidic aerosols. In the absence of measurements, the impact of acid deposition downwind of large point sources of SO_2 in remote areas of Australia is unknown. In the northern hemisphere, long exposure of ecosystems to acid deposition has caused damage to plant life and acidification of lakes. The problem does not appear to be severe in Australia. However, the response of Australian vegetation to SO_2 appears to be quite different from that of northern hemisphere plants (Murray *et al.* 1992).

Lead

Exposure to lead can cause a wide range of health effects, and lead tends to accumulate in bones over a lifetime. Health impacts have been measured against the level of lead in blood, and a threshold of 10 μg/dL for blood lead is found. There is some suggestion of a linear relationship between blood lead level and IQ decrements in children (Schwartz, 1994). Although there is no agreed relationship between atmospheric lead concentration and blood lead level, a value of 1.92 μg/dL per $\mu g/m^3$ is typically used to represent the uptake in children (NEPC 1997).

Lead in soil can delay the decomposition process and so limit the availability of nutrients. The main focus of studies on the impact of lead in plants has been on the cumulative lead loading in humans ingesting crops grown in soils with high lead content (NEPC 1997).

Particles
The health impacts of particles (PM10) are well documented. A daily mortality (all causes) increase of 1% is found per 10 ug/m^3 of PM10, while higher rates occur for specific diseases; e.g. a respiratory mortality increase of 3.4% per 10 ug/m^3 of PM10 (NEPC, 1997).

Fluoride
Plants are about 1000 times more sensitive to fluoride than are humans (State of the Environment Advisory Council 1996). At low concentrations it can cause yellowing of leaves and reduced plant growth. The impact is dependent not only on the atmospheric concentration of fluoride but also on the time of exposure in the growing season.

Interpretation and analysis

As policy initiatives lead to lower concentrations of pollutants, the indicators of toxic exposure should show improvements in time.

Monitoring

Spatial Scale: Regional air-shed

Frequency: Annual effective loading

Measurement Technique: Because of the uncertainties in combining the impacts of pollutants and in accounting for net exposures, the dosage should be computed for each pollutant based on peak values at specific sites across the country.

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Research Needs

Much more research is needed to clarify the effects of air pollutants on crops, native vegetation, and fauna in Australian conditions. Results cannot always be simply transferred from the northern hemisphere (Doley and McCune 1993).

Indicator 4.12 Occurrence of haze

Description

At sites within each of the monitored regional areas, the number of days on which the visibility drops below 20km each year would be recorded.

Rationale

Haze can arise from both natural and anthropogenic sources. It also requires conducive meteorological conditions. However, in regions affected by significant industrial or urban activity, haze can usually be attributed to anthropogenic causes, and the community recognises the aesthetic impact as well as the potential health consequences of haze.

Interpretation and analysis

A 20km threshold for visibility is recognised as a level below which haze is noticeable. In using Bureau records for visibility, care is needed to ensure that the visibility reduction is not due to rain, fog or low cloud. It is therefore appropriate to use the occurrence of present weather category 05 (haze) and category 04 (industrial smoke haze) to identify the presence of haze.

Monitoring

Spatial Scale: Regional

Frequency: Continuous

Measurement Technique: Some State authorities operate nephelometers which provide objective measurements of visibility. However, a national observing network of relevant observations is available from the Bureau of Meteorology. Subjective measurements of visibility are taken every 3 hours at Bureau sites, especially at airports. The present weather category of 05 corresponds to haze.

Data sources

Data Archive: Bureau of Meteorology

Data Quality: Control: Bureau of Meteorology

Contact: Bureau of Meteorology

Research needs

Unlike the Bureau rainfall and temperature records, the records for visibility have not been scrutinised by researchers for errors that would affect long-term climate statistics.

Indicator 4.13 Occurrence of smoke and fire

Description

Smoke would be reported as the number of sq km days each year across the country, and fire would be reported as the total number of sq km burnt each year.

Rationale

Smoke is readily identified as an air pollutant, associated with biomass burning. In addition to the particulates, which make the smoke visible, biomass burning produces a range of gases, such as methane and carbon dioxide, that are recognised air pollutants. In particular, biomass burning contributes to the national greenhouse gas inventory.

Interpretation and analysis

Fire occurs naturally, through lightning strikes, and by human actions. The actual costs and benefits of biomass burning are not clearly known at present. By routinely monitoring the total amount of biomass burning and smoke across the country, we will have the data to understand the inter-annual variability of these processes and their causes.

This indicator is linked to Indicator 1.19 on average aerosol loading and to indicators 6 and 21 in the biodiversity report (Saunders *et al.* 1998) and indicator 2.6 in the land report (Hamblin 1998).

Monitoring

Spatial Scale: Can be monitored across the country at a resolution of about 5 km

Frequency: Monitoring can be achieved from 6 hourly Advanced Very High Resolution Radiometer (AVHRR) satellite data (while at least two National Oceanic and Atmospheric Administration (NOAA) meteorological satellites are available).

Measurement Technique: National estimates can be obtained from analysis of the multi-spectral data from AVHRR data. Ground-based spectrometer measurements at specific sites across the country by the Bureau of Meteorology can be used to calibrate the satellite estimates of aerosol loading, i.e. smoke “thickness”.

Data sources

Data Archive: Commonwealth Scientific and Industrial Research Earth Observation Centre (CSIRO EOC)

Data Quality Control: CSIRO EOC

Current Status of Data: A continental-scale archive is being developed for the period 1981-present by D. Graetz of CSIRO EOC. Completion date is late 1999.

Contact: D. Graetz, CSIRO EOC

Reference

Hsu *et al.* (1995) and Christopher *et al.* (1996) .

Research Needs

Although techniques for estimating smoke coverage from satellite data may evolve with time, it is important to maintain a consistent definition for SoE reporting so that long-term trends can be identified unambiguously. The original data also need to be retained so that different analyses can be carried out in the future as techniques are improved.

Indicator 4.14 Emission of regional air pollutants

Description

Through the National Pollutant Inventory (NPI) or other processes, each jurisdiction is expected to conduct intermittent studies on the emissions in the major urban areas. For each pollutant, the most recent inventory for each regional air-shed would be shown by a bar chart, showing the annual contribution (kilotonnes) of the main sources. A time-history chart would show the total annual national emission for each pollutant, with the contribution of each air-shed recorded.

Rationale

The emission of pollutants into the atmosphere leads to concentrations of gases and particles that have deleterious effects. The relationship between emissions and atmospheric concentration of pollutants is complex, because of transport and dispersion by the meteorology and of chemical reactions. However, the relationship is understood and can be modelled (e.g. Manins 1988).

Interpretation and analysis

The identification of the major sources of each pollutant indicates the sectors in which policy initiatives could be most effective. The important sectors will vary with region. The regional air-sheds in Australia that are monitored tend to have specific industries within them, and those industries determine the key pollutants to be monitored.

Time plots can show the impacts of policy actions in each jurisdiction. In order to obtain a measure of our relative success in controlling pollutants, it is useful to compare the national emissions with those of other countries, especially the transport emissions on a per capita basis (ATSE 1997).

Monitoring

Spatial Scale: Local

Frequency: Ideally emission data should be estimated annually, so that trends can be easily monitored. In practice data are obtained intermittently. When data are collected, they should allow for the seasonal variations in emissions and they should account for each source sector. Except for the Latrobe Valley, emissions inventories have been limited to urban air-sheds in the past.

Measurement Technique: Each jurisdiction conducts emission studies from time to time. The NPI process should help to regularise these practices. Boyle *et al.* (1996) describe the results of trial projects aimed at providing a sound base for national reporting.

For each pollutant, the contribution of each type of source should be identified. Sources can be classified as mobile, diffuse area, industrial or biogenic. In turn, each class can be broken down, as follows:

Mobile sources

- motor vehicles
- locomotives
- aircraft
- marine pleasure craft
- commercial shipping

Diffuse area sources

- gas leakage
- gaseous and liquid fuel consumption
- solid fuel consumption
- surface coatings and thinners
- waste combustion
- aerosols and solvents
- dry cleaning
- lawn mowing
- bitumen
- service stations

Industrial sources

- chemical manufacturing
- metal processing
- metal fabrication
- non-metallic mineral processing
- fuel storage
- printing
- petroleum refining
- waste treatment
- textile manufacturing
- food and beverage manufacturing
- miscellaneous

Biogenic sources

- vegetation

Boyle *et al.* (1996) list 26 pollutants that should be included in an inventory. Consistent with the atmospheric pollutants to be used in national SoE reporting, the key emissions are:

- benzene
- carbon monoxide (CO)
- lead
- oxides on nitrogen (NO_x)
- particles (PM10 and TSP)
- sulphur dioxide (SO_2)
- volatile organic compounds (VOC)

Data sources

Data Archive: State Environment Protection Authorities (EPAs) and industry

Reference

Boyle *et al.* (1996) describe trial projects for developing the NPI process. The NPI National Environmental Protection Measure (NEPM) (NEPC 1998) was made in February 1998.

Research Needs

The refinement of the inventory process will continue. It will be necessary to develop uniform methods across all jurisdictions, including all the main pollutants.

INDICATOR 4.15 AREA OF NATIONAL AIR-SHEDS MONITORED FOR SOE REPORTING

Description

Annual total number of air-sheds and the total area (km^2) would be reported.

Rationale

The low population-density of Australia means that it is unnecessary and unfeasible to monitor the overall air quality across the country. As an indicator of the scope of regional air-quality monitoring, it is appropriate to record the total area of the country that is being monitored routinely each year.

Interpretation and analysis

The magnitude of the area being monitored indicates the national scope of air quality monitoring across the country. It could also give an indication of the variation in human activity as more air-sheds are included.

Monitoring

Spatial Scale: National scale

Frequency: Annual audit

Measurement Technique: Each State (through the National Environmental Protection Council (NEPC)) would record the number of air-sheds (urban and regional) being routinely monitored and the total area of these air-sheds. The area of an air-shed is defined by the orography and meteorology, given the location of pollutant sources.

Data sources

Data Archive: State Environment Protection Authorities (EPAs)

Data Quality Control: State EPAs

Current Status of Data: Regions can be identified from the existing National Environmental Protection Measure (NEPM) process

Research Needs

The definition of a monitored air-shed may need to be refined from time to time.

Indicator 4.16 Number of local government bodies which have programs to monitor and regulate regional air quality

Description

The number of local governments with implemented air quality management programs would be recorded.

Rationale

For air quality policy to have a national impact, the issue needs to be recognised at all levels of government. The National Environmental Protection Measure (NEPM) process implies a commitment of governments at the Commonwealth and State levels. It would be useful to include an indicator of community interest and commitment at the regional level. The simplest indicator is whether local governments have relevant programs.

Interpretation and analysis

Community awareness and interest in air quality issues may be reflected in the degree and scope of local government involvement.

Monitoring

Spatial Scale: Local

Frequency: Annual

Measurement Technique: The Australian Local Government Association (ALGA) is encouraging local governments to be aware of environmental issues. Through ALGA it should be possible to determine the plans of local government authorities.

Data sources

Data Archive: ALGA

Contact: ALGA

Research Needs

It would be appropriate to refine this indicator in future, beyond simply counting authorities with plans.

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Appendix 1 Indicators for indoor air quality

Extract from human setttlements environmental indicators report (Newton *et al.* in prep.)

	INDICATOR	C-P-R
	INDOOR AIR QUALITY	
7.1	Occupant satisfaction with commercial indoor air quality	C
7.2	Mechanical ventilation rate of commercial buildings	C
7.3	Thermal comfort in commercial buildings	C
7.4	Air infiltration rates of new housing	C
7.5	Proportion of population sensitive to pollutants	C
7.6	Proportion of adult smokers with children	P
7.7	Proportion of commercial and recreational buildings with smoking prohibition	R
7.8	Quantity of asbestos products removed from work-places	P/R
7.9	Number of unflued gas heaters in residences and schools	C
7.10	Number of people housed in mobile buildings	P
7.11	Proportion of residences with high house dust mite allergen	P/C
7.12	Incidence of legionnaires disease	C
7.13	Production of low-voc emission building products	R
7.14	Exposure to indoor air (time spent in city traffic)	P/C

Appendix 2 List of indicators considered for the key set but not included

The following list is of some indicators that were considered and then rejected as key indicators of the state of the atmosphere.

Drought index

It could be argued that a specific indicator on the fraction of the country affected by meteorological drought should be a key indicator of the state of the atmosphere. However, in recent times the agricultural, economic and social aspects of drought have been emphasised more than the basic meteorological component, and so it is recommended that the key atmospheric indicators should be focused on rainfall itself, as in Indicator 1.4 (on the average rainfall) and Indicator 1.6 (on extreme rainfall events). These indicators ensure that national-scale drought is recorded.

Solar radiation

In discussion of Indicator 1.19 on the average aerosol loading, the value of reporting the average solar radiation is also noted. This indicator relates closely to primary production, and it could be derived from routine products prepared by the Bureau of Meteorology. However, the aerosol loading is seen as a more direct measure of the state of the atmosphere, affecting both short-term issues such as air quality and long-term ones such as climate change. Moreover, it is recommended that UV radiation at the surface (Indicator 2.3) should be used as an atmospheric indicator, associated with the issue of stratospheric ozone.

Rate of change of atmospheric pollutants

The rate of change of atmospheric pollutants (on both global and local scales) provides a measure of the success of environmental policies, and so appropriate indicators could be explicitly listed. However, the recommended indicators include the annual-average concentrations of atmospheric pollutants (i.e. Indicators 1.10, 2.1, 3.1-3.9 and 4.1-4.9), and these indicators should be displayed in a time-series form so that the rates of change are clear. It would therefore seem that a separate set of indicators is not necessary to provide the required information.

Precursors of urban air pollution

The recommended list of indicators of urban air quality includes ozone (Indicator 3.2) which is produced as a result of reactions among various precursor pollutants, such as oxides of nitrogen and non-methanic hydrocarbons. It could be argued that the list should include these precursor gases. However, the air quality indicators have been selected generally to coincide with the pollutants to be monitored consistently by all jurisdictions under the NEPC process. In order to balance consistency and comprehensiveness, it is recommended that the focus should remain on the agreed pollutants of the air NEPM.

Appendix 3
List of Acronyms

ABS	Australian Bureau of Statistics
ACCV	Anti-Cancer Council of Victoria
AIHW	Australian Institute of Health and Welfare
ALGA	Australian Local Government Association
ANZECC	Australian and New Zealand Environment and Conservation Council
ARL	Australian Radiation Laboratory
ATSE	Academy of Technological Sciences and Engineering
AVHRR	Advanced Very High Resolution Radiometer
BAPMoN	Baseline Air Pollution Monitoring Network
CFC	Chlorofluorocarbon
CLIVAR	Climate Variability and Predictability Programme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAR	Division of Atmospheric Research (CSIRO)
DPIE	Department of Primary Industries and Energy (Commonwealth)
ENSO	El Niño – Southern Oscillation
EOC	Earth Observation Centre
EPA	Environmental Protection Authority
GCOS	Global Climate Observing System
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
ICA	Insurance Council of Australia
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
MED	Minimal erythemal dose
NASA	National Aeronautics and Space Administration (US)
NEPC	National Environmental Protection Council
NEPM	National Environmental Protection Measure
NGGI	National Greenhouse Gas Inventory
NGGIC	National Greenhouse Gas Inventory Committee
NGRS	National Greenhouse Response Strategy
NHMRC	National Health and Medical Research Council
NMSC	Non-melanocytic skin cancer
NOAA	National Oceanic and Atmospheric Administration (US)
NPI	National Pollutant Inventory
NTF	National Tidal Facility
NWP	Numerical weather prediction

ODS	Ozone depleting substance
OECD	Organization of Economic Co-operation and Development
RASAC	Rural Adjustment Scheme Advisory Council
SoE	State of the Environment
SoEAC	State of the Environment Advisory Counci
SOI	Southern Oscillation Index
SST	Sea-surface temperature
TC	Tropical cyclone
TEOM	Tapered Element Oscillating Microbalance
TOMS	Total Ozone Mapping Spectrometer
TSP	Total Suspended Particulates
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultra-violet
VOC	Volatile Organic Compound
WCRP	World Climate Research Programme
WMO	World Meteorological Organization

List of Environmental Indicator Reports

Environmental indicator reports for national state of the environment reporting are available in seven themes. An eighth report in the series examines community and local uses of environmental indicators. Bibliographic details are as follows:

Human Settlements

Newton P., J. Flood, M. Berry, K. Bhatia, S. Brown, A. Cabelli, J. Gomboso, J. Higgins, T. Richardson and V. Ritchie (in prep.) *Environmental indicators for national state of the environment reporting – Human Settlements,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Biodiversity

Saunders D., C. Margules, & B. Hill (1998) *Environmental indicators for national state of the environment reporting – Biodiversity,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

The Atmosphere

Manton M. & J. Jasper (1998) *Environmental indicators for national state of the environment reporting – The Atmosphere,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

The Land

Hamblin A. (1998) *Environmental indicators for national state of the environment reporting – The Land,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Inland Waters

Fairweather P. & G. Napier (1998) *Environmental indicators for national state of the environment reporting – Inland Waters,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Estuaries and the Sea

Ward T., E. Butler, & B. Hill (1998) *Environmental indicators for national state of the environment reporting – Estuaries and the Sea,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Natural and Cultural Heritage

Pearson M., D. Johnston, J. Lennon, I. McBryde, D. Marshall, D. Nash, & B. Wellington (in prep.) *Environmental indicators for national state of the environment reporting – Natural and Cultural Heritage,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Local and Community Uses

Alexandra J., J. Higgins & T. White (1998) *Environmental indicators for national state of the environment reporting – Local and Community Uses,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

SoE Reporting homepage:
http://www.erin.gov.au/environment/epcg/soe.html