Ambient Air Quality Guidelines

2002 Update

Air Quality Report No 32

Prepared by the Ministry for the Environment and the Ministry of Health

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Ministry for the Environment
Manatu Mō Te Taiao

Foreword

Air pollution is harming our health and that of our children and parents. The young and old are particularly vulnerable to the effects of air pollution. A recent study estimates that around 970 premature deaths are caused every year in New Zealand by inhaling air pollution from sources such as vehicles, home-heating fires and industries. Premature deaths are just the 'tip of the iceberg'. Air pollution causes many harmful effects, ranging from premature death, to headaches, coughing and asthma attacks.

The air resource is not a rubbish dump for the harmful particles and gases we emit as we drive our cars, heat our homes and run our factories. But it is easy to forget that as we put our foot down on the accelerator, or throw another log on the fire, potentially harmful pollutants spew out of the tailpipe or chimney. We tend to think pollutants simply blow away, but under some conditions they may be inhaled, minutes or hours later, by someone who suffers as a consequence. Or worse, we think that our small contribution is insignificant – 'my actions do not affect air quality'.

To reduce the health and environmental effects of air pollution and ensure that our air is clean for future generations, we need to reduce emissions of pollutants into the air we breathe.

Regional councils develop regional air plans and education programmes aimed at reducing pollution, and central government is developing vehicle emissions standards, national environmental standards and new fuel regulations. While these actions should improve air quality, we need to encourage everyone to think about how they contribute as individuals to air pollution, and to change their daily activities as a result. This is the real challenge, but there are small, manageable changes that everyone can make that will improve air quality.

These revised 2002 *Ambient Air Quality Guidelines* set guidelines values that we must achieve and, where possible improve upon, to ensure our air is clean and healthy to breathe. The Ministry will encourage all those responsible for managing air quality to use the 2002 Guidelines to develop reduction strategies that achieve sustainable air quality.

Finally, I would like to thank those who commented on the proposals released in December 2000. It has taken a long time to produce these new Guidelines, but I think the input of so many people is reflected in their quality and usefulness.

Marian L. Hobbs

Hon Marian L Hobbs
Minister for the Environment

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Contents

1 Introduction

1.1 Purpose

This report contains new ambient air quality guideline values for New Zealand, and updated guidance on how they should be used to manage air quality under the Resource Management Act 1991 (RMA). The new guideline values replace those first published by the Ministry for the Environment in 1994. The 2002 Guidelines follow the previous guidelines in applying only to ambient air outside buildings or structures, and not to indoor air or air in the workplace.

The primary purpose of national ambient air quality guidelines is to promote sustainable management of the air resource in New Zealand.

Guideline values are the minimum requirements that outdoor air quality should meet in order to protect human health and the environment. Where air pollution levels breach guideline values, emission reduction strategies should be implemented to improve air quality. Where levels do not breach the values, efforts should be made to maintain air quality and, if possible, reduce emissions. This is particularly important for those pollutants, such as particles less than 10 microns in diameter (PM_{10}), for which the guideline value cannot be based on a 'no observable adverse effects level'.

Guideline values should not be used as limits to pollute up to. If pollution approaches the guideline value, then air quality is comparatively poor and has been degraded from its background state.

Updated advice on how to apply the guideline values to assess air quality and prepare emission reduction strategies is provided in Chapter 3. Only limited advice is given on how to – and, in particular, how not to – apply the guideline values to assess discharges to air. Further guidance on assessing discharges to air from point, area and line sources will be provided in a separate report available for comment by the end of 2002.

As well as providing updated values for the contaminants covered in the 1994 Guidelines, the 2002 Guidelines include new priority contaminants:

- benzene
- 1,3 butadiene
- formaldehyde
- acetaldehyde
- benzo(a)pyrene
- mercury
- chromium
- arsenic.

They also provide guidance on assessing the potential impacts of air pollution on ecosystems.

The 2002 Guidelines were developed as part of the Ministry's Air Quality Management Programme. The Programme develops well-debated national guidance for councils, industries and communities involved in managing air quality, and investigates, develops and implements appropriate national policy tools to improve air quality.

The document is structured as follows.

- Chapter 1 (this chapter) describes the process involved in developing the guidelines, briefly covers the legal framework under which air quality is managed in New Zealand, and explains the status of the guideline values and how they will be reviewed.
- Chapter 2 contains the guideline values, along with descriptions of the health effects of each contaminant and reasons for the chosen guideline value.
- Chapter 3 discusses the framework for air quality management and how guideline values can be used to determine the state of the air environment, devise regional criteria, set reduction targets and develop reduction strategies for both regional and national planning processes.
- Chapter 4 introduces an approach to assessing and managing the impacts of air pollution on ecosystems using critical levels.

1.2 Background

The development process

The new and revised guideline values and guidance on how to use them are derived from:

- comprehensive reviews of research on the health and environmental effects of the priority contaminants (see below)
- a review of how the 1994 guideline values were applied to managing air quality in New Zealand (Ministry for the Environment, 2000c, Chapter 2)
- consideration of current air pollution levels in New Zealand (Ministry for the Environment, 1998c; Chiodo and Rolfe, 2000)
- discussions in expert working groups and 17 consultation meetings
- submissions on the discussion document *Proposals for Revised and New Air Quality Guidelines – Discussion Document* (Ministry for the Environment, 2000c)
- submissions on the *Summary of Submissions Received on the Discussion Document and Proposals for Amendments* (Ministry for the Environment, 2001c)
- developments through the Ministry's Environmental Performance Indicators Programme.

The reviews of environmental and health research used to determine the new guideline values are written up in several technical reports prepared for the Ministry for the Environment:

- *Health Effects of Five Air Contaminants and Recommended Protective Ranges*. Air Quality Technical Report 12. L Denison, K Rolfe, and B Graham, 2000.
- *Health Effects of Eleven Hazardous Air Contaminants and Recommended Evaluation Criteria*. Air Quality Technical Report 13. J Chiodo and K Rolfe, 2000.
- *Preliminary Review of Strategies for Managing Air Quality*. Air Quality Technical Report 14. T A'Hearn, W Robins and K Rolfe, 2000.
- *Effects of Air Contaminants on Ecosystems and Recommended Critical Levels and Critical Loads.* Air Quality Technical Report 15. C Stevenson, V Hally, and M Noonan, 2000.

The Ministry has also prepared a pamphlet seeking input from Maori, and discussed the proposals at several hui throughout New Zealand. Potential issues of concern for Maori are discussed later.

What the Guidelines don't cover

The Guidelines *do not* cover:

- the potential synergistic effects of different contaminants – if synergies are a potential issue they should be considered on a case-by-case basis, using up-to-date research on the cause-and-effect relationships
- the effects of spray drift arising from agrichemical application – these are managed by regional air quality plans and the Hazardous Substances and New Organisms Act 1996 (HSNO), and will be subject to requirements imposed by the Environmental Risk Management Authority (ERMA)
- organochlorines – the Ministry's Organochlorines Programme has recently released a draft *Action Plan for Reducing Discharges of Dioxins to Air* (Ministry for the Environment, 2001d) addressing the generation, transport and fate of these compounds in the general environment (see Appendix 1)
- management of odour, dust nuisance and degraded visibility – these are addressed as separate projects within the Ministry's Air Quality Management Programme; reports and good-practice guides on these issues can be downloaded from the Ministry's web site at: http://www.mfe.govt.nz/monitoring/epi/airqualtech.htm.

1.3 Legal and policy framework

The legal and policy framework for environmental management in New Zealand directs how air quality is managed in New Zealand. This information is generally well known, so this section only briefly covers the key points.

Regional air quality management

Under the RMA, regional councils and unitary authorities are responsible for managing discharges into the air and therefore for managing the quality of the outdoor air that we breathe. The purpose of the RMA is to promote the sustainable management of natural and physical resources, including air.

Sections 5 to 8 of the RMA outline the key principles and purpose of the RMA. Section 5 provides that the purpose of the Act is to promote the sustainable management of natural and physical resources including safeguarding the life supporting capacity of the air, while sections 6 to 8 describe other matters (including the Treaty of Waitangi) which must be considered when making decisions. Of particular relevance for air quality management is section 7(f), which states that persons exercising powers under the Act must have particular regard to the:

> *(f) Maintenance and enhancement of the quality of the environment.*

Section 30 of the RMA specifies the functions of regional councils and unitary authorities, which include controlling the discharge of contaminants into the air. Councils are also responsible for gathering sufficient information about the state of the environment to enable them to carry out their functions (section 35). To manage the environment, councils can prepare regional policy statements or regional plans specifying objectives, policies and rules to address any issues of concern (sections 63 to 70).

The costs and benefits of measures to improve air quality through regional policy statements and regional plans must be analysed in accordance with section 32 of the RMA. The options must be discussed with, and take into account the views of, the local community before being implemented.

Further information on establishing air quality management plans under the RMA will be available in the Quality Planning web site at www.qualityplanning.org.nz.

National policy development

The Government's key goal for public sector policy and performance relating to the environment is to:

> *Protect and enhance the environment – treasure and nurture our environment with protection for ecosystems so that New Zealand maintains a clean, green environment and rebuilds our reputation as a world leader in environmental issues.*

The Minister for the Environment is responsible for the Government's environment portfolio and for achieving this key goal. The Ministry for the Environment advises the Minister, on whose behalf it carries out Ministerial duties under various laws, such as the RMA. These duties include promoting and developing national tools to achieve sustainable air quality management (see Appendix 1).

The Ministers and Ministries of Health, Transport, and Economic Development are also involved in developing policies and legislation that influence discharges to air, particularly where national solutions are required. The Ministry works closely with these departments to develop and implement national strategies for improving air quality.

1.4 Maori and air quality

Air and air quality can be described as both a taonga and a part of the traditional kainga.

The Crown is responsible under article two of the Treaty of Waitangi to actively protect Maori Treaty rights. The Ministry is committed to honouring the Treaty of Waitangi and obligations to Maori outlined in the RMA. We aim to incorporate Maori values into the development of environmental guidelines so that they recognise both Western science and Maori views.

In 1999 the Ministry discussed environmental issues concerning Maori at a number of hui around the country. Discussions highlighted the need for the Ministry to integrate its programmes on guidelines and standards to reflect the holistic view of the environment traditionally held by Maori. To focus discussion on the proposed air quality guidelines, the Ministry prepared a pamphlet entitled *Review of the Ambient Air Quality Guidelines: Seeking comment from Maori*, and attended several further hui in 2001 to discuss the guidelines as well as other Ministry programmes.

General discussions at these hui emphasised the need to minimise discharges to air by applying the best practicable option, support for national environmental standards to protect the air, the importance of recognising Maori values in making decisions about air discharges (especially around areas such as marae and waahi tapu), and the involvement of Maori in local planning processes.

The Ministry's work on the pamphlet highlighted the following issues for Maori in terms of the potential effects of air pollution on their health.

- Maori are more likely than non-Maori to be hospitalised for asthma. Although Maori asthma rates decreased in the early 1990s, rates have increased recently.
- Cancer is one of the leading causes of death for Maori and non-Maori, but the incidence of cancer remains higher among Maori.
- Maori experience far more cases of respiratory illness (such as asthma and emphysema) and heart disease than non-Maori.

Other issues of significance and interest to Maori include:

- deposition of air pollutants onto mahinga kai, waahi tapu, waterways and marae
- reduction of visibility
- increases in airborne smell
- the impact of contaminants on important or valued sites; for example, discharge material from the flue of a crematorium can be blown over puna wairoa or mahinga kai.

In developing the air quality guidelines and the Air Quality Management Programme, the Ministry has attempted to take these concerns into account, and to develop an approach that is consistent with section 6(1), 7(e) and 8 of the RMA. In particular we have considered:

- that Maori represent one of the sensitive groups the health protection guideline values are aiming to protect
- the wider impacts of air quality on plants, animals and other materials, including water and soil, in developing the guidance on assessing and managing the impacts of air pollutants on ecosystems
- how to improve the ability and opportunity for Maori to effectively control, manage and regulate air quality within their rohe (boundaries) and according to their own cultural preferences.

1.5 Status of the Guidelines

Guideline values and advice on how to apply them are not legislative requirements under the RMA or any other legislation.

However, the process and consultation involved in preparing the Guidelines mean that they reflect well-debated, expert, national and international best practice and knowledge. They contain sound, consistent and good-quality advice. As such they should be afforded considerable weight in decision-making on air quality management. The new guidance on how to apply the Guidelines aims to eliminate inconsistencies and confusion about applying them in the past.

Regional councils and unitary authorities need to determine the extent to which they will apply the new guideline values and guidance. Monitoring programmes, rules in regional air quality plans, emissions inventories, existing resource consents, and applications for consents may need to be amended or revised. Councils will also need to assess the costs and benefits of measures required to achieve the revised Guidelines (as required by section 32 of the RMA), and to discuss these options with their local communities through the regional planning process.

Through submissions on plans and workshops the Ministry will encourage councils to incorporate the revised Guidelines and guidance into planning documents and monitoring programmes as soon as practicable.

1.6 Reviews

Developing and applying guideline values is an iterative process. New research findings regularly enhance our understanding of health effects of pollutants and ways in which emissions can be reduced.

Because of the rapid rate at which research on air quality develops, the Ministry intends to review and update the air quality guidelines and their application on at least a five-yearly basis. Some contaminants will be reviewed sooner, including carbon monoxide, particles ($PM_{2.5}$) and hydrogen sulphide. Reviews for these contaminants will commence in 2002 and will be completed by 2004. Other guideline values may be reviewed sooner than the five-year cycle if new international or national research suggests that the values need changing.

The reviews will examine research on the health and environmental effects of the particular contaminant, the recommended monitoring method, and the effectiveness of the guideline value in achieving sustainable air quality management. Data compiled for the Environmental Performance Indicators (EPI) Programme will be used to determine the effectiveness of the Guidelines and other policies towards achieving sustainable air quality management.

2 Health-based Guideline Values

2.1 Introduction

The revised and new guideline values listed in Table 1 should be used to direct air-shed management and evaluate ambient air quality monitoring results. Guidance on how to apply the guideline values is given in Chapter 3.

The health-based guideline values aim to protect people's health and well-being. They are generally designed to protect those who are most susceptible to experiencing health effects when a particular contaminant is inhaled. All the values are based on health effects, except the one for hydrogen sulphide, which is based on odour nuisance. They have been derived from epidemiological studies, international guidelines and, in some cases, laboratory research. The economic benefits and costs associated with achieving the values have not been taken into account. These must be considered when specific reduction strategies are developed (discussed further in section 3.3).

Potential health effects caused by inhaling contaminants range from relatively minor impacts, such as respiratory irritation, headaches and cough, to more serious health impacts, including asthma, cancer and advanced mortality in those already suffering serious illness. The following sections contain only brief descriptions of the human health effects of each contaminant (as opposed to the results of animal or laboratory research) and limited references. The reader is strongly advised to seek more detailed information and references in Chiodo and Rolfe (2000) and Denison et al. (2000).

The new contaminants (also referred to as 'hazardous air pollutants') were selected by prioritising those that are of greatest concern, are most likely to exist in New Zealand, and that should be monitored, assessed and, where necessary, reduced. The ranking method considered each contaminant's hazard to human health, toxicity, likelihood of being discharged, potential to cause public exposure, and ultimate fate in the environment (Chiodo and Rolfe, 2000).

In most cases the guideline value is based on the 'no observable adverse effect level' or 'lowest observable adverse effect level' of the contaminant, as determined through research studies. A safety factor may also be applied. Where research has been unable to determine such a threshold, a judgement has been made as to what constitutes an 'acceptable' health risk, taking into account the level of uncertainty in our understanding of the health effects caused by the contaminant. Given these different considerations, the result is inevitably a range of risk values, which are specified in Appendix 4.

Fluoride guideline values are now covered under Chapter 4 on ecosystem protection.

Table 1: Guideline values and the key health effects

Contaminant	Guideline values[a]		Key health effects
	Value	Averaging time	
Carbon monoxide	30 mg/m^3 10 mg/m^3	1-hour 8-hour	Reduced birth weight (non-smoking mothers), decreased work capacity, increased duration of angina (for those with ischaemic heart disease), decrease in visual perception, decreased manual dexterity, and decreased ability to learn.
Fine particles (PM_{10})	**50 μg/m^3** **20 μg/m^3**	24-hour Annual	Mortality, morbidity, hospitalisation, work-affected days, increased use of medication. There is no evidence of a threshold below which adverse health effects will not be observed.
Nitrogen dioxide	**200 μg/m^3** 100 μg/m^3	1-hour 24-hour	Apparent contribution to morbidity and mortality, especially in susceptible subgroups, including young children, asthmatics and those with chronic inflammatory airway disease.
Sulphur dioxide[b]	350 μg/m^3 **120 μg/m^3**	1-hour 24-hour	Daily mortality, hospital admissions and emergency room attendances for respiratory and cardiovascular disease, increases in respiratory symptoms and decreases in lung function.
Ozone	150 μg/m^3 100 μg/m^3	1-hour 8-hour	Increased daily mortality, respiratory and cardiovascular disease; decreases in lung function; increases in hospitalisations, and in respiratory illnesses such as cough, phlegm and wheeze.
Hydrogen sulphide[c]	7 μg/m^3	1-hour	Nuisance and unpleasant odour – sensitivity is reduced through continuous exposure. Higher concentrations lead to eye irritation, eye damage, and over-stimulation of the nervous system, causing rapid breathing, cessation of breathing, convulsions and unconsciousness.
Lead[d]	**0.2 μg/m^3**	3-month moving average, calculated monthly	At low levels: impairment of hearing, effects on intelligence, effects on CNS, reductions in nerve condition.
Benzene (year 2002) Benzene (year 2010)	**10 μg/m^3** **3.6 μg/m^3**	Annual Annual	Decreased white blood cell counts, genotoxic and carcinogenic (group 1 carcinogen). Short-term exposure to high levels causes drowsiness, dizziness, headaches and unconsciousness.
1,3-Butadiene	**2.4 μg/m^3**	Annual	Carcinogenic effects on humans. Acute exposure causes: irritation of eyes, throat, lungs and nasal passages; blurred vision; fatigue; headache and vertigo.
Formaldehyde	**100 μg/m^3**	30 minutes	Eye, nose and throat irritation; coughing, wheezing, chest pains and bronchitis.
Acetaldehyde	**30 μg/m^3**	Annual	Odour; eye, nose and throat irritation; coughing. Carcinogen of low potency.
Benzo(a)pyrene	**0.0003 μg/m^3**	Annual	At high levels: dermatitis, photosensitisation, eye irritation and cataracts. Animal studies note effects on blood and liver. Potential increases in lung cancer.
Mercury (inorganic)[d] Mercury (organic)	**0.33 μg/m^3** **0.13 μg/m^3**	Annual Annual	CNS effects such as hallucinations, delirium and suicidal tendencies; gastrointestinal effects, and respiratory effects such as chest pains, cough, pulmonary function impairment.
Chromium VI[d] Chromium metal and chromium III[d]	**0.0011 μg/m^3** **0.11 μg/m^3**	Annual Annual	High levels cause coughing and wheezing and gastrointestinal and neurological effects; chronic inhalation causes effects on the respiratory tract, such as bronchitis, pneumonia, asthma and nasal itching; and potentially effects on the liver, kidney, and gastrointestinal and immune systems.
Arsenic (inorganic)[d] Arsine[d]	**0.0055 μg/m^3** **0.055 μg/m^3**	Annual Annual	May cause gastrointestinal effects, haemolysis, and CNS disorders. High levels lead to kidney failure.

Notes:

[a] All values apply to the gas measured at standard conditions of temperature (0º C) and pressure (1 atmosphere).

[b] The sulphur dioxide guideline values do not apply to sulphur acid mist.

[c] The hydrogen sulphide value is based on odour nuisance and may be unsuitable for use in geothermal areas.

[d] The guideline values for metals are for inhalation exposure only; they do not include exposure from other routes such as ingestion. These other routes should be considered in assessments where appropriate.

2.2 Carbon monoxide

2.2.1 Guideline values

The guideline values are 30 mg/m^3 (1-hour average) and 10 mg/m^3 (8-hour average).

The guideline values aim to ensure that nobody will be exposed to levels of ambient carbon monoxide (CO) that would result in blood carboxyhaemoglobin (COHb) levels greater than 2.5%, at any level of physical activity. They are set to protect the more susceptible population sub-groups, including those with ischaemic heart disease, other forms of cardiac disease (including cyanotic heart disease), hypoxaemic lung disease, cerebrovascular disease, peripheral vascular disease, those with anaemia and haemoglobin abnormalities, children, and developing foetuses.

2.2.2 Health effects

When inhaled, CO combines with haemoglobin (Hb), the blood's oxygen-carrying protein, to form COHb. In this state the Hb is unable to carry oxygen (O_2). It takes about 4 to 12 hours for CO concentrations in the blood to reach equilibrium with the CO concentration in air, so any fluctuations in the ambient CO concentrations are only slowly reflected in the COHb levels in humans.

High exposures to CO can cause acute poisoning, with coma and collapse occurring at COHb levels of over 40%. Ambient exposures to CO are several orders of magnitude lower than those associated with acute poisoning. However, some exposures in urban settings have been shown to adversely affect the heart, brain and central nervous system.

Adverse cardiovascular effects of CO inhalation include decreased O_2 uptake and decreased work capacity. Those with angina may suffer decreased exercise capacity at onset of angina, and increased duration of angina. Adverse neurobehavioural effects of CO include a decrease in vigilance, visual perception, manual dexterity, ability to learn and perform complex sensorimotor tasks in healthy individuals, and reduced birth weight in non-smoking mothers.

Recent epidemiological studies have found effects in susceptible groups at levels lower than previously thought to be of concern. The Ministry therefore intends to review the CO guideline values within the next two years.

2.2.3 Description and sources

CO is a colourless, odourless and tasteless gas. It is a trace constituent of the atmosphere, with background levels normally ranging between 0.01 and 0.2 mg/m^3. CO is formed from burning fuels, especially during incomplete combustion. It is produced both by natural processes (for example, from volcanoes) and by human activities (for example, the incomplete combustion of carbon-containing fuels, especially from motor vehicles). Industrial processes may also produce CO.

2.3 Particles (PM_{10} and $PM_{2.5}$)

2.3.1 Guideline values

The PM_{10} guideline values are 50 μg/m^3 (24-hour average) and 20 μg/m^3 (annual average).

Research has been unable to determine a threshold for PM_{10} below which there are no adverse effects (WHO, 1999). Consequently, these guideline values are associated with a higher level of health risks than for many of the other contaminants. The values for PM_{10} are designed to be the first step in reducing the health effects caused by particles in areas where concentrations breach the guideline values. Where PM_{10} levels are within the guideline values, efforts should still be made to maintain and, where possible, further reduce levels (see also discussion in section 3.3).

The 1994 24-hour average guideline value of 120 μg/m^3 is no longer appropriate given recent evidence of the acute (short-term) health effects of PM_{10}, and the annual average value has been amended to take account of recent evidence of the chronic (long-term) health effects of PM_{10}. The values are consistent with several current international guideline values and standards.

Recent research has shown that particles less than 2.5 microns in diameter ($PM_{2.5}$) may responsible for specific health effects caused by fine particles. We therefore need to increase our understanding of $PM_{2.5}$ in New Zealand and to promote monitoring and source assessments. A monitoring value of 25 μg/m^3 (24-hour average) can be used for assessing monitoring results and to judge whether further investigations are needed to quantify $PM_{2.5}$ sources. In suggesting this value, the Ministry aims to promote $PM_{2.5}$ monitoring and assessment. It is premature to use $PM_{2.5}$ as a target for air-shed management until further research can accurately determine its specific health effects and its sources. The Ministry will commence an investigation into $PM_{2.5}$ in 2002 with the aim of establishing an appropriate guideline value by 2004.

2.3.2 Health effects

The major health effects from airborne particles are:

- increased mortality
- aggravation of existing respiratory and cardiovascular disease
- hospital admissions and emergency department visits
- school absences
- lost work days
- restricted activity days.

People most susceptible to the effects of particles include the elderly; those with existing respiratory disease such as asthma, chronic obstructive pulmonary disease and bronchitis; those with cardiovascular disease; those with infections such as pneumonia; and children. As discussed above, the results of epidemiological studies have provided no evidence for the existence of a threshold value below which no adverse health effects are observed.

2.3.3 Description and sources

Particles are diverse in their chemical and physical characteristics and can span several orders of magnitude in size. Particles derive from many sources, including motor vehicles (especially diesels), solid-fuel burning for domestic heating, industry, photochemical processes, and natural sources such as dust, pollens and sea spray.

2.4 Nitrogen dioxide

2.4.1 Guideline values

The nitrogen dioxide guideline values are 200 $\mu g/m^3$ (1-hour average) and 100 $\mu g/m^3$ (24-hour average).

The guideline values are based on a safety factor of 50% applied to the lowest observable adverse effect level in order to ensure adequate protection of the more vulnerable sub-groups in the population, including children, asthmatics of all ages (but especially children), and compromised adults with chronic respiratory and cardiac disorders. This value is consistent with the WHO guideline value of 200 $\mu g/m^3$ (1-hour average) and the 1994 New Zealand 24-hour guideline value of 100 $\mu g/m^3$.

2.4.2 Health effects

Exposure to nitrogen dioxide (NO_2) has been shown to cause reversible effects on lung function and airway responsiveness. It may also increase reactivity to natural allergens. Inhalation of NO_2 by children increases their risk of respiratory infection and may lead to poorer lung function in later life. Recent epidemiological studies have shown an association between ambient NO_2 exposure and increases in daily mortality and hospital admissions for respiratory disease. NO_2 has also been shown to potentiate the effects of exposure to other known irritants, such as ozone and respirable particles.

There is some evidence that acute exposure to NO_2 may cause an increase in airway responsiveness in asthmatic individuals. This response has been observed only at relatively low NO_2 concentrations, mostly in the range of 400–600 $\mu g/m^3$. However, the findings of both clinical and epidemiological studies do not provide any clear quantitative conclusions about the health effects of short-term exposures to NO_2. The adverse health effects at low levels of NO_2 remain equivocal, with conflicting patterns of results obtained in both controlled exposure studies and in epidemiological studies. The contribution of NO_2 as one of a mixture of pollutants in the ambient environment has yet to be clearly defined.

2.4.3 Description and sources

NO_2 is a pungent, acidic gas. Corrosive and strongly oxidising, it is one of several oxides of nitrogen (NO_x) that can be produced as a result of combustion processes. Combustion of fossil fuels converts atmospheric nitrogen and any nitrogen in the fuel into its oxides, mainly nitric oxide (NO) but with small amounts (5–10%) of NO_2. NO slowly oxidises to NO_2 in the atmosphere. This reaction is catalysed in the presence of O_3. In the presence of sunlight, NOx, including NO_2, react with volatile organic compounds to form photochemical smog.

The main source of NO_2 resulting from human activities is the combustion of fossil fuels (coal, gas and oil). In cities, about 80% of ambient NO_2 comes from motor vehicles. Other sources include the refining of petrol and metals, commercial manufacturing, and food manufacturing. Electricity generation using fossil fuels can also produce significant amounts.

2.5 Sulphur dioxide

2.5.1 Guideline values

The guideline values for sulphur dioxide are 350 μg/m^3 (1-hour average) and 120 μg/m^3 (24-hour average).

These values are set to provide protection of lung function and prevent other respiratory symptoms of vulnerable sub-groups in the population, including asthmatics and those with chronic obstructive lung disease. They are in line with current international guideline values and standards. The annual guideline value for sulphur dioxide is now discussed in Chapter 4 on ecosystem-based guidelines. The short-term guideline value has been removed, as it is not appropriate for managing air quality in large air sheds, however, shorter-term criteria for sulphur dioxide may be appropriate for assessing industrial discharges.

2.5.2 Health effects

Sulphur dioxide (SO_2) is a potent respiratory irritant when inhaled. Asthmatics are particularly susceptible. SO_2 acts directly on the upper airways (nose, throat, trachea and major bronchi), producing rapid responses within minutes. It achieves maximum effect in 10 to 15 minutes, particularly in individuals with significant airway reactivity, such as asthmatics and those suffering similar bronchospastic conditions.

The symptoms of SO_2 inhalation may include wheezing, chest tightness, shortness of breath or coughing, which are related to reductions in ventilatory capacity (for example, reduction in forced expiratory volume in one second, or FEV_1), and increased specific airway resistance. If exposure occurs during exercise, the observed response may be accentuated because of an increased breathing rate associated with exercise. A wide range of sensitivity is evident in both healthy individuals and more susceptible people, such as asthmatics, the latter being the most sensitive to irritants.

Epidemiological studies have shown significant associations between daily average SO_2 levels and mortality from respiratory and cardiovascular causes. Increases in hospital admissions and emergency room visits for asthma, COPD and respiratory disease have also been associated with ambient SO_2 levels. These associations were observed with up to a two-day lag period. Long-term exposure to SO_2 and fine particle sulphates (SO_4^{2-}) has been associated with an increase in mortality from lung cancer and development of asthma and cardio-pulmonary obstructive disease. Increases in respiratory symptoms have also been associated with SO_2 levels.

2.5.3 Description and sources

SO_2 is a colourless, soluble gas with a characteristic pungent smell. It is mainly produced by the combustion of fossil fuels containing sulphur and some industrial processes.

2.6 Ozone

2.6.1 Guideline values

The guideline values for ozone are 150 $\mu g/m^3$ (1-hour average) and 100 $\mu g/m^3$ (8-hour average).

Recent epidemiological studies demonstrate that there is no apparent threshold concentration for ozone (O_3) below which adverse health effects will not be observed. The proposed guideline values aim to provide reasonable protection for human health by protecting respiratory function in vulnerable sub-groups of the population, including those with asthma and chronic lung diseases, healthy young adults undertaking active outdoor exercise over extended periods, and the elderly, especially those with cardiovascular disease.

Guidelines to protect vegetation from the impacts of O_3 are provided in Chapter 4.

2.6.2 Health effects

Epidemiological evidence indicates that a wide variety of health outcomes are possible from exposure to O_3, including short-term effects on mortality, hospital admissions and emergency room attendances, respiratory symptoms and lung function. Experimental evidence has demonstrated short-term physiological and pathological changes in the respiratory system of humans. Although potentially more important, there is little evidence of long-term effects. Recently, ozone has been found to cause asthma, particularly in young children exercising in areas with higher ozone levels.

The health effects associated with exposure to ozone can be summarised as follows:

- increase in daily mortality, respiratory and cardiovascular disease
- increase in hospital admissions and emergency room visits
- increase in respiratory and cardiovascular disease

- decrease in lung function
- increase in symptoms of respiratory illness such as cough, phlegm and wheeze
- increase in bronchodilator usage.

These effects are observed in sensitive sub-populations, although effects on lung function have also been observed in the healthy normal population.

2.6.3 Description and sources

O_3 is a secondary air pollutant formed by reactions of primary pollutants – oxides of nitrogen (NO_x) and hydrocarbons – in the presence of sunlight. These primary pollutants arise mainly from motor-vehicle emissions, stationary combustion sources and industrial and domestic use of solvents and coatings.

O_3 is only one of a group of chemicals known as photochemical oxidants (commonly referred to as photochemical smog), but it is the predominant one. Also present in photochemical smog are formaldehyde, other aldehydes, and peroxyacetyl nitrate. Most epidemiological studies relate to O_3 plus the other oxidants, though it is usually only the former that is measured as an indicator of photochemical oxidants.

2.7 Lead

2.7.1 Guideline value

The guideline value for lead in PM_{10} is 0.2 μg/m^3 (3-month moving average, calculated monthly).

This value aims to protect people from the health effects of inhaling lead – especially its effects on developing foetuses and on children's health, such as decreased intelligence and performance. With no apparent threshold for lead it is appropriate to have the ambient air quality guidelines for lead as low as possible.

The guideline value is reasonably consistent with the UK long-term objective of 0.25 μg/m^3 (annual average) to be achieved by 2008, and the recommendation of their Expert Panel on Air Quality Standards (EPAQS), which concluded that the effects on the health of children at this level would be so small as to be negligible. The guideline value is more precautionary than that recommended by WHO (1999) of 0.5 μg/m^3 (annual average).

This guideline value does not take account of other routes of exposure to lead, such as by eating contaminated food. Where other routes may be significant, they should also be considered when assessing the impacts of lead. Alternative sources of information and deposition criteria to use when considering exposure routes can be sourced from WHO (1999).

2.7.2 Health effects

The health effects of lead are related to the level of lead in human blood. Although there are some differences in the bio-availability of different lead compounds, the health effects caused by increased blood lead levels are the same, regardless of the lead compounds causing the exposure.

One of the most widely recognised effects of lead exposure is a decrease in intelligence and general academic performance in children, especially when exposed to lead within the first two to three years of life. The sub-groups most vulnerable to lead are young children and developing foetuses. There is now clear epidemiological evidence of a close causal relationship between prenatal exposure to lead and early mental development indices, and it has not been possible to identify a clear threshold for its effects.

Where there is the likelihood of ingestion from deposited lead, this must be taken into account in conjunction with inhalation exposure when considering the total body burden. This is especially so when assessing potential health effects on children living in an area where lead may be inhaled and/or ingested.

2.7.3 Description and sources

Lead is a bluish or silvery-grey soft metal. With the significant reduction in the amount of lead allowed in petrol in New Zealand (current specifications allow a maximum of 13 mg/l) there is now very little lead in vehicle emissions. However, residual lead from historical vehicle emissions may still be present in the environment, although this is unlikely to be a concern for lead inhalation.

Airborne lead can also be found around some industrial discharges, such as at metal smelters, and houses or other structures where lead-based paint is being, or has been, removed without the proper safety precautions. Exposure for both adults and children can arise from inhaling fine lead particles in the air, or by ingesting soils or crops contaminated by lead deposition. In these cases, contaminated soils and dusts act as a continuous source of lead.

2.8 Hydrogen sulphide

2.8.1 Guideline value

The guideline value for hydrogen sulphide is 7 $\mu g/m^3$ (1-hour average).

Unlike other guideline values, the value for hydrogen sulphide (H_2S) is based on preventing odour annoyance and the resulting impacts on well-being rather than specific health effects. The guideline value may not be suitable for geothermal areas.

More recent work on odour has suggested that alternative management and assessment methods may be more appropriate. These will be considered in a forthcoming review of *Odour Management under the Resource Management Act* (Ministry for the Environment, 1995a).

Further monitoring and research is required to develop a guideline value for long-term exposure to hydrogen sulphide where natural background concentrations from geothermal activities occur above the odour-based guideline value. H_2S will be reviewed at the same time as $PM_{2.5}$ and CO.

2.8.2 Health effects

H_2S is a colourless gas with a distinctive odour at low concentrations. Humans detect it at levels of 0.2–2.0 μg/m^3, depending on its purity. This is the odour threshold, which is defined as the concentration at which 50% of a group of people can detect an odour. At about three to four times this concentration range it smells like rotten eggs.

H_2S causes nuisance effects because of its unpleasant odour at concentrations well below those that cause health effects. Continuous exposure to H_2S reduces sensitivity to it.

In acute exposures H_2S acts on the nervous system to cause a range of symptoms characterised as H_2S intoxication. At levels above 15 mg/m^3 it causes eye irritation, and above 70 mg/m^3 it causes permanent eye damage. Above 225 mg/m^3 it paralyses olfactory perception so that the odour is no longer a warning signal of the gas's presence. At concentrations above 400 ug/m^3 there is a risk of pulmonary oedemea, and above 750 mg/m^3 it over-stimulates the central nervous system, causing rapid breathing, cessation of breathing, convulsions, and unconsciousness. At 1400 mg/m^3 it is lethal.

Adverse effects have been observed in occupationally exposed populations at an average concentration of 1.5–3.0 mg/m^3. Symptoms include restlessness, lack of vigour, and frequent illness. In occupationally exposed groups, at levels of 30 mg/m^3 or more 70% complained of fatigue, headache, irritability, poor memory, anxiety, dizziness and eye irritation.

2.8.3 Description and sources

H_2S occurs naturally in geothermal areas. It also forms under anaerobic conditions where organic material and sulphate are present. Human activities can release naturally occurring H_2S, such as when natural gas is extracted or when heat is extracted from geothermal waters. H_2S is also produced in industrial processes where sulphur and organic materials combine in oxygen-deprived environments. These include pulp and paper manufacturing, oil refining, tanning of animal hides, and wastewater treatment.

2.9 Acetaldehyde

2.9.1 Guideline value

The guideline value for acetaldehyde is 30 μg/m^3 (annual average).

This value aims to protect people from adverse health effects of acetaldehyde inhalation rather than its odour nuisance effects. It is based on the WHO upper risk level of 9 x 10^{-7} per μg/m^3, and an acceptable carcinogenic risk of between 1 in 10,000 and 1 in 100,000. The chosen value of 30 μg/m^3 takes a reasonably precautionary approach as it comes from the lower end of the range of 12–120 μg/m^3 derived from the WHO risk level and acceptable carcinogenic risk.

2.9.2 Health effects

The major route for exposure to acetaldehyde in humans is inhalation. The major toxic effects for acute exposure are eye, nose, skin and respiratory tract irritation; erythema; coughing; pulmonary oedema; and necrosis. Extremely high concentrations can cause respiratory paralysis and death. Depressed respiratory rates and elevated blood pressure have been observed in animals exposed to high concentrations of acetaldehyde. Chronic intoxication of acetaldehyde in humans can produce symptoms resembling alcoholism.

Human data regarding the carcinogenic potential of acetaldehyde are inadequate, but an increased incidence of nasal tumours in rats and laryngeal tumours in hamsters has been observed following acetaldehyde inhalation exposure (US EPA, 1998).

Acetaldehyde has been classified as a Group B2 carcinogen of low potency by the US EPA, and a Group 2B carcinogen by IARC (IARC, 1998).

2.9.3 Description and sources

Acetaldehyde, like formaldehyde, is very reactive and is important in photochemical smog reactions. Major sources of acetaldehyde are motor vehicle exhaust and domestic solid-fuel combustion. It is also released from some industrial processes.

2.10 Benzene

2.10.1 Guideline values

The guideline value for benzene is 10 μg/m^3 (annual average), with a guideline value of 3.6 μg/m^3 (annual average) to be achieved by 2010.

These values are based on a combination of the European Council and UK approaches and the need to set reducing, precautionary guideline values for a carcinogen such as this.

2.10.2 Health effects

The most significant chronic adverse effects from prolonged exposure to benzene are haemotoxicity, genotoxicity and carcinogenicity (WHO, 1996). Haemotological effects of varying severity have occurred in workers occupationally exposed to high levels of benzene. Decreased red and white blood cell counts in humans have been reported above median levels of approximately 120 mg/m^3. There is only weak evidence for effects below 32 mg/m^3, and no reported effects at 0.03–4.5 mg/m^3.

Data from animal and human exposures indicate that benzene is both mutagenic and carcinogenic. Increased mortality from leukaemia has been demonstrated in occupationally exposed workers. Benzene has been classified as a Group A carcinogen of medium potency by the US EPA, and a Group 1 carcinogen by IARC (see Appendix 3).

2.10.3 Description and sources

Benzene (C_6H_6) is a colourless, clear liquid with a density of 0.87 g/cm^3 (at 20^{o}C) and a boiling point of 80.1^{o}C. Chemically it is fairly stable but it undergoes substitution and addition reactions.

Motor vehicles and household fires are significant sources of benzene in New Zealand's air. There are also some industrial activities that use and discharge benzene. Motor vehicle exhaust emissions of benzene are thought to derive partly from unburnt benzene in the fuel, and partly from the dealkylation of other aromatic hydrocarbons. Other sources of benzene that may impact locally include oil refining, petrochemical production, and synthetic rubber manufacture.

2.11 1,3-Butadiene

2.11.1 Guideline value

The guideline value for 1,3-butadiene is 2.4 μg/m^3 (annual average).

This guideline value is designed to reduce ambient concentrations to as low a level as reasonably practicable such that 1,3 butadiene inhalation represents an exceedingly small risk to human health. The value is consistent with the UK's Air Quality Objective to be achieved by 2003. The evidence that 1,3-butadiene is a genotoxic carcinogen is ambivalent, but has been accepted by expert panels in the UK and in the US, and by IARC. A precautionary approach in setting the ambient guideline value for New Zealand has therefore been taken.

2.11.2 Health effects

The main route for 1,3-butadiene exposure in humans is inhalation. Adverse health effects from acute exposure include irritation of the eyes, throat, lungs and nasal passages, and neurological effects such as blurred vision, fatigue, headache and vertigo. Chronic non-cancer effects in exposed humans include cardiovascular and blood diseases.

The US EPA classifies 1,3-butadiene as a Group B2 carcinogen of medium potency. The IARC classification is Group 2A (IARC, 1998). The UK Expert Panel accepts that 1,3-butadiene is a genotoxic carcinogen (UK Expert Panel on Air Quality Standards, 1998).

WHO considers that the uncertainties in current estimates of carcinogenic risks to humans do not allow a specific guideline value to be recommended. Given that there is some equivocal evidence of carcinogenicity, they recommend prudence in developing ambient air quality guidelines/standards.

The UK EPAQS (1998) recommended a 1,3-butadiene standard of an annual running average of 2.4 $\mu g/m^3$. The panel concluded that on the basis of current data, the increased risks of lymphomas and leukaemias would be unlikely to be detectable by any practicable means in workers from a lifetime exposure to 2,400 $\mu g/m^3$ of 1,3-butadiene. The recommended standard was arrived at by applying a safety factor of 100 to account for differences in chronological and working life, and in susceptibility). The panel believed that standards for genotoxic carcinogens should be set as low as practicable. Since ambient levels in the UK on current data have not exceeded 2.4 $\mu g/m^3$, the panel has recommended this level as the standard, implying an additional safety factor of 10.

2.11.3 Description and sources

1,3-butadiene (C_4H_6) is a colourless, highly reactive gas, with a mild aromatic odour. Emission sources include motor vehicle exhausts, and production of synthetic rubber, latex and resin. The atmospheric half-life of 1,3-butadiene is quite short (several hours) compared to benzene (several days).

2.12 Formaldehyde

2.12.1 Guideline value

The ambient guideline value for formaldehyde is 100 $\mu g/m^3$ (30-minute average).

This guideline value is based on the WHO value and is designed to protect most individuals. However, some people may be (or have become) hypersensitive to formaldehyde, so it is important to consider whether there are such people in the population, particularly in areas where formaldehyde levels may be elevated. If so, full health risk assessments should be carried out.

2.12.2 Health effects

The major route for exposure to formaldehyde in humans is inhalation. The main toxic effects for acute exposure are eye, nose and throat irritation and effects on the nasal cavity. Other effects include coughing, wheezing, chest pains and bronchitis. Chronic exposure has also been associated with respiratory symptoms and eye, throat and nose irritation.

WHO notes that there is substantial inter-individual variability in human formaldehyde responses. Significant increases in signs of irritation occur at levels above 0.1 mg/m^3 in healthy subjects, and a progression of symptoms occur above 1.2 mg/m^3. No lung function alterations were noted in healthy non-smokers and asthmatics exposed to formaldehyde levels up to 3.7 mg/m^3, leading to the conclusion that the observed effects were related more to peak than to mean concentrations (WHO, 1996).

Formaldehyde is classified as a Group B1 carcinogen of medium potency by the US EPA, and as a Group 2A carcinogen by IARC (1998).

The WHO ambient air quality guideline value is 100 μg/m^3, 30-minute average, for protection of the general population. This is based on a no observable adverse effects level of 100 μg/m^3 and an uncertainty factor of 1. WHO also recommend that for groups within the general population that show hypersensitivity reactions without immunological signs, the formaldehyde concentration should be kept to a minimum and not exceed 10 μg/m^3 (30-minute average).

2.12.3 Description and sources

Formaldehyde (HCHO) is the simplest and most common aldehyde found in the environment. At normal temperatures it is a colourless gas with a pungent odour, and is soluble in water.

Motor vehicles and domestic solid-fuel combustion are major sources of formaldehyde in the urban environment. Industrial sources can be locally important, and include the manufacture of particleboard, plywood, fabrics and furnishings. Formaldehyde emissions from furnishings and fittings can be important for indoor air quality.

The atmospheric half-life is quite short (a few hours), so the main impacts are relatively close to the source. However, formaldehyde is highly reactive and is an important contaminant in widespread photochemical smog formation.

2.13 Benzo(a)pyrene

2.13.1 Guideline value

The guideline value for benzo(a)pyrene (as an indicator of polyaromatic hydrocarbons) is 0.0003 μg/m^3 (annual average).

This is based on an acceptable risk to the community of between 1 in 10,000 and 1 in 100,000 which has been applied to the WHO unit risk values to provide an annual average guideline value for benzo(a)pyrene in the range 0.00012–0.0012 μg/m^3.

The Ministry intends to review this guideline in five years to work towards a toxic equivalency scheme for polyaromatic hydrocarbons (PAHs) similar to that for organochlorines.

2.13.2 Health effects

There are no human data on the effects of acute exposure to benzo(a)pyrene (BaP) and other PAHs. Chronic exposure to BaP in humans has resulted in dermatitis, photosensitisation, eye irritation, and cataracts. Epidemiological studies have reported increases in lung cancer in humans from exposure to coke-oven and roof-tar emissions and cigarette smoke, all of which contain a number of PAHs.

WHO notes that the carcinogenicity of PAH mixtures may be influenced by other compounds emitted with PAHs during incomplete combustion, and also points out the poor quality of available data sets from which to derive a risk assessment for BaP (WHO, 1996).

WHO has determined an inhalation unit risk of 8.7 x 10^{-2} per $\mu g/m^3$ BaP, based on interpolation from risk estimates for PAHs in coke-oven emissions. WHO has also determined an inhalation unit risk from studies of animals exposed to complex mixtures of PAHs of 2 x 10^{-5} per $\mu g/m^3$ BaP 10^{-5} per ng/m^3 (WHO, 1996). They recommend that unit risks be used to set ambient air quality guidelines.

The US EPA has classified BaP as a Group B2 carcinogen of medium potency. The IARC classification is Group 2A (IARC, 1998). The US EPA has not determined an inhalation unit risk for BaP.

The UK has proposed a new objective for BaP of 0.00025 $\mu g/m^3$ (annual average at 20^oC) to be achieved by the end of 2010.

2.13.3 Description and sources

PAHs are a large group of organic compounds with two or more benzene rings. They are semi-volatile compounds that occur in both the gaseous phase or attached to particles. PAHs with low vapour pressures are almost totally adsorbed onto particles. BaP is an indicator species for PAHs. Although a relatively minor component of PAHs, BaP is extremely important because of its highly toxic and carcinogenic properties and, as discussed above, most guideline values are based on BaP.

PAHs arise from incomplete combustion of solid and liquid fuels. Main sources of PAHs in New Zealand include vehicles, home-heating fires and some industrial processes.

2.14 Mercury

2.14.1 Guideline values

The guideline values for mercury are 0.33 μg/m^3 (annual average) for inorganic mercury and 0.13 μg/m^3 for organic mercury (annual average).

The guideline values aim to protect people from adverse health effects caused by inhaling mercury fumes or particles.

The value for inorganic mercury is derived from the occupational health standards for inorganic mercury and the US EPA reference concentration (RfC) and the Californian Air Resources Board's reference exposure level (REL) values (Chiodo and Rolfe, 2000). The value for organic mercury is derived from the value for inorganic mercury by scaling according to the occupational health standards.

The above levels should be viewed as applicable where exposure to mercury is mainly through inhalation. They will need to be adjusted downwards where dietary intake is significant.

2.14.2 Health effects

The effects of chronic exposure to elemental mercury include central nervous system (CNS) effects (such as erethism, irritability, insomnia), severe salivation, gingivitis and tremor, kidney effects (including proteinuria), and acrodynia in children. The primary effect of chronic exposure to methyl mercury is CNS damage, while chronic exposure to inorganic mercury induces kidney damage (US EPA, 1998). Acute inhalation exposure to high levels of elemental mercury in humans results in CNS effects such as hallucinations, delirium and suicidal tendencies; gastrointestinal effects; and respiratory effects such as chest pains, dyspnoea, cough, pulmonary function impairment, and interstitial pneumonitis. Acute exposure to high levels of methyl mercury also results in CNS effects, including blindness, deafness, impaired level of consciousness and death.

Studies of the effects on human reproduction and development from exposure to inorganic mercury are ambivalent. There is no information on reproductive and developmental effects on humans, but animal studies have reported effects including testicular changes and developmental abnormalities. Studies on the carcinogenic effects of elemental mercury on humans are inconclusive. No studies are available on the carcinogenic effects of methyl mercury on humans.

The US EPA has classified inorganic and methyl mercury as Group C carcinogens, and elemental mercury as Group D (unclassifiable). IARC has classified methyl mercury compounds as a Group 2B carcinogen, and mercury and inorganic compounds as Group 3 (unclassifiable) (IARC, 1998).

No unit risk factors are available for mercury and mercury compounds. Their status as carcinogens is ambivalent. WHO recommends a guideline for inorganic mercury of 1 μg/m^3 as an annual average. This is based on a lowest observable adverse effects level for renal tubular effects on humans of 20 μg/m^3 and an uncertainty factor of 20.

The US EPA RfC for elemental mercury is 0.3 μg/m^3, and the reference dose (RfD) for methyl mercury is 0.3 μg/kg/day (US EPA, 1993). The California Air Resources Board (CARB) RELs are as follows:

- elemental mercury 0.3 μg/m^3 (chronic REL)
- inorganic mercury and mercury compounds 30 μg/m^3 (acute REL)
- methyl mercury 1 μg/m^3 (chronic REL).

The acute REL for inorganic mercury is under review, and a draft value of 1.8 μg/m^3 is to be reviewed by the Scientific Review Panel on Toxic Air Contaminants.

2.14.3 Description and sources

Elemental mercury exists almost totally in the gas phase in the atmosphere, as does methyl mercury, while inorganic mercury compounds are usually particle-bound (CARB, 1998).

Volcanic and geothermal activities are the most important sources of mercury in New Zealand. Specific sources include fossil fuel combustion such as vehicles, trucks and power stations. Other sources are crematoria, waste incinerators, gold-recovery plants and chlor-alkali plants.

2.15 Chromium

2.15.1 Guideline values

The guideline value for chromium VI is 0.0011 μg/m^3 (annual average) and for other chromium (chromium III and chromium metal) it is 0.11 μg/m^3 (annual average).

The guideline value for chromium VI recognises that it is a human carcinogen of high potency, and that a risk level of 1 in 100,000 (which is at the lower end of the range considered acceptable by the US EPA) is appropriate for New Zealand. This guideline value for chromium VI is at the top end of WHO values but lower than the US value.

For chromium metal and III compounds, concentrations 100 times larger than those for chromium VI is appropriate on the basis of their much lower toxicity and non-carcinogenicity.

As is the case for mercury, these values may need to be adjusted downwards if dietary intake is significant.

2.15.2 Health effects

Chromium VI compounds are more toxic than chromium III. The respiratory tract is the major target organ for acute inhalation exposure to chromium VI. Dyspnoea, coughing, and wheezing in humans have been reported following exposure to very high levels. Gastrointestinal and neurological effects have also been reported. Chronic inhalation exposure has been associated with effects on the respiratory tract. Perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, asthma, and nasal itching and soreness have also been reported in humans following exposure. Other effects of chronic inhalation exposure have been reported on the liver, kidney, gastrointestinal and immune systems, and possibly the blood.

Complications during pregnancy and childbirth in humans have been reported following inhalation exposure. Reproductive effects have not been reported in animal studies, but oral exposure has been reported to cause severe developmental effects in mice. Epidemiological studies of workers have established that inhaled chromium is a human carcinogen, resulting in increased risk of lung cancer, although the studies were unable to differentiate between chromium VI and chromium III compounds.

The US EPA has classified chromium VI as a Group A carcinogen of high potency, and chromium III as not classifiable (Group D). IARC has classified chromium VI as a Group 1 carcinogen, and chromium III as Group 3 (unclassifiable) (IARC, 1998).

Unit risk factors for chromium VI compounds for inhalation exposure adopted by various groups are as follows: 1.2×10^{-3} per $\mu g/m^3$ (US EPA, 1998), 1.5×10^{-1} per $\mu g/m^3$ (CARB, 1998) and $1.1–13 \times 10^{-2}$ per $\mu g/m^3$ (WHO, 1996).

Because chromium VI is considered a human carcinogen, WHO has not specified a guideline for ambient air quality, but recommends that unit risk factors be applied.

The US EPA specifies an RfD for chromium VI of 5 μg/kg/day, and 1000 μg/kg/day for chromium III (US EPA, 1993). RfCs for both groups of compounds are under review.

CARB specifies a non-cancer chronic REL of 2×10^{-3} $\mu g/m^3$ for chromium VI, considering effects on the respiratory tract, kidney, and gastrointestinal system as the toxicological targets. An REL has not been established for chromium III.

2.15.3 Description and sources

Chromium (Cr) is a grey, hard metal most commonly found in the trivalent state in nature, but hexavalent compounds are found in small quantities.

Emissions of chromium in New Zealand are mostly associated with particles emitted when burning fossil fuels, which includes power stations, cars and trucks. The emissions largely depend on the chromium content of the fuel, which varies with both the fuel type and source. Specific sources of chromium include metal smelting and foundries, cement production, pulp and paper mills, chrome plating, timber treatment using copper/chrome/arsenic preservatives, cooling towers and leather tanning.

2.16 Arsenic

2.16.1 Guideline values

The guideline value for inorganic arsenic is 0.0055 μg/m^3 (annual average). For arsine the guideline value is 0.055 μg/m^3 the (annual average).

The ambient guideline value for inorganic arsenic is based on an acceptable risk value of 1 in 100,000 for a high-potency carcinogen.

As is the case for mercury and chromium, these values may need to be adjusted downwards if dietary intake is significant. Contaminated soils may be a significant source of exposure for children.

2.16.2 Health effects

Acute inhalation exposure to inorganic arsenic may result in gastrointestinal effects, haemolysis, and central and peripheral nervous system disorders in humans. Effects of acute exposure to arsine (a gaseous compound of arsenic) include haemolytic anaemia, haemoglobinuria and jaundice, and can lead to kidney failure. Acute inhalation exposure to arsine can lead to death: it has been reported that exposure to 87–170 mg/m^3 arsine for half an hour can be lethal.

Chronic inhalation exposure to, and contact with, inorganic arsenic is associated with irritation of the skin and mucous membranes, including dermatitis, conjunctivitis, pharyngitis and rhinitis. Several studies of women working or living near metal smelters, and in the electronics industry, have associated exposure to arsenic and arsine gas with an increased incidence of spontaneous abortions and lower birth weights. However, the studies have limitations due to simultaneous exposure to other pollutants, and small numbers in some studies. Human inhalation studies have reported that inorganic arsenic exposure is strongly associated with lung cancer. Human exposure by ingestion has also been associated with an increased risk of skin, bladder, liver and lung cancer (US EPA, 1998).

The US EPA has classified inorganic arsenic as a Group A carcinogen of high potency, but it has not classified arsine. IARC has not classified either inorganic arsenic or arsine.

Unit risk factors for inorganic arsenic for inhalation exposure adopted by various groups are as follows: 4.3 x 10^{-3} per μg/m^3 (US EPA, 1998), 3.3 x 10^{-3} per μg/m^3 (CARB, 1998) and 1.5 x 10^{3} per μg/m^3 (WHO, 1996).

Since inorganic arsenic is considered a human carcinogen, WHO has not specified a guideline for ambient air quality, but recommends that unit risk factors be applied.

The US EPA specifies an RfD of 0.3 μg/kg/day for inorganic arsenic, but it has not established an RfC. For arsine, the US EPA has not established an RfD, but it does specify a non-cancer RfC of 0.055 μg/m^3 (US EPA, 1993).

CARB specifies a non-cancer chronic REL of 0.55 $\mu g/m^3$ for inorganic arsenic, considering blood disorders as the toxicological endpoint, and a non-cancer chronic REL of 140 $\mu g/m^3$ for arsine, for which the toxicological endpoints are considered to be the respiratory system, the central and peripheral nervous systems, and the skin (CARB, 1998).

2.16.3 Description and sources

Arsenic and its compounds are ubiquitous in the environment and exhibit both metallic and non-metallic properties. The trivalent and pentavalent forms are the most common oxidation states. At least six groups are present in the environment, with inorganic forms (such as arsenic trioxide and arsenic pentoxide) and gaseous inorganic and organic arsenic compounds (for example, arsine) being the most important for air quality.

Specific sources of arsenic include timber treatment using copper/chrome/arsenic preservatives, and previous pesticide application. Emissions are largely to land or water. Arsine can be released into the air from old chemical landfill sites. The burning of treated timber releases volatile arsenic oxides, either in the gaseous form or associated with particle emissions. Health and environmental guidelines for selected timber treatment chemicals are available (Ministry for the Environment, 1997b).

3 Applying the Guideline Values to Air Shed Management

3.1 Introduction

The Guidelines deal with managing outdoor air quality over an area or region typically referred to as an 'air shed'. An air shed is a volume of air, bounded by geographical and/or meteorological constraints, within which activities discharge contaminants. Air sheds can vary in size from relatively small areas within valleys, to urban-wide and even region-wide air sheds where the effects of urban air pollution (such as ozone) may extend over many kilometres. Within an air shed there may be areas where pollution levels are elevated because of a particular discharge or group of discharges, such as around one or two industries or around a busy, congested intersection. These may be referred to as 'bubble' areas or 'hotspots'.

Pollution levels within an air shed are influenced by complex interactions between the pollution sources, contaminants discharged into the air, meteorology, and topography. Information about all of these is required to understand the factors affecting pollution levels in an air shed, how they change over time and space, and the adverse effects they are having on people and the environment. Once this information is collected, effective strategies to improve or maintain air quality can be developed, discussed with communities and implemented.

Tools such as emissions inventories, air quality monitoring, atmospheric dispersion modelling, and predictions of trends in emissions and pollution levels should be used to obtain information for effective air quality management. While all these techniques are important, they are covered in other guidance documents, and will not be discussed in detail here. Instead this chapter focuses on how guideline values are used to understand the state of air quality, to determine particular air quality issues in a region, and to direct actions to manage it.

Developing and implementing an air quality management plan under the RMA or a reduction strategy generally occurs in five stages.

1. Determine the state of the air and pressures on it and how these will change over time.
2. Use monitoring data and national guideline values to establish regional criteria and reduction targets, where necessary.
3. Devise management or reduction strategies and assess their costs and benefits.
4. Refine strategies through community consultation and implement them.
5. Evaluate the effectiveness of reduction strategies by assessing changes in the pressures on, and state of, the air environment and refine strategies if necessary.

The term 'reduction strategies' has been used broadly to include a range of options that can be implemented to manage air quality, including policies and rules in regional policy statements and plans, education programmes, national policies and regulations, and incentive schemes.

Guidance on using the guideline values in each of these stages is discussed in the following sections. The guidance builds on information in the 1994 Guidelines and takes into account the review of how the 1994 Guidelines have been applied. A summary of the guidance is contained in Appendix 2. Issues for Maori and use of guideline values in assessing individual discharges to air are also briefly discussed in sections 3.6 and 3.7 respectively.

3.2 The state of air quality and pressures on it

Clearly, information about the air resource is important for effective air quality management. There is no point in developing measurable air quality guideline values or criteria if no sensible measurements and assessments are going to be made.

To determine the state of air quality and its effects on people's health, pollution levels must be monitored and compared with the guideline values, and, if necessary, detailed air shed modelling and health impact assessments should also be carried out. In this way it is possible to determine whether the air quality is good or bad, whether improvements are required, or whether it is already in a good state and should be maintained. It is also important to work out where the pollution is coming from – the pressures – and to use an emissions inventory to predict how these are changing over time.

Under section 35 of the RMA, councils are responsible for implementing air quality monitoring programmes. The extent of monitoring and the methods used will depend on the air quality issues facing each council. Many factors influence the monitoring needs of a region, such as resources and other environmental priorities. General guidance on establishing monitoring programmes is contained in the *Good-practice Guide for Air Quality Monitoring and Data Management* (Ministry for the Environment, 2000a).

The discussion below focuses on how to use the guideline values to make decisions about monitoring and to assess monitoring results.

In general, where contaminant levels exceed the guideline values, more detailed assessments of the health risks should be carried out and taken into account in planning activities.

3.2.1 Where do the guideline values apply?

The guideline values apply to outdoor air wherever a person might reasonably be expected to be exposed to the contaminant over the relevant averaging period.

Where the guideline value applies therefore depends on the specific contaminant, the relevant averaging period, and the spatial extent over which the guideline is likely to be breached. This is a precautionary approach, because if pollution levels at a peak site where someone may be affected are within the guideline value, then it is expected that pollution levels at other sites will also be within the guideline value.

For example, a contaminant with an annual average guideline value should be measured at a location where people are likely to spend a significant amount of time outdoors, such as a residential site. On the other hand, a one-hour average should be measured where a person may be exposed for around one hour. This includes peak sites such as traffic hotspots.

3.2.2 Amount and location of monitoring

Obviously it is impossible to monitor at every location where a person may be exposed to a particular contaminant. It is therefore necessary to select a number of representative sites, ranging from hot spots to background sites, to provide sufficient data with which to estimate the spatial and temporal variability in pollution levels and people's exposure. Where necessary, monitoring data can be supplemented with air shed modelling to create a map illustrating how exposures vary over time and weather conditions.

Urban areas in New Zealand differ widely in their geography, population, regulatory approaches and emissions characteristics. Consequently they have varying air quality issues, and a prescriptive national approach to monitoring is not appropriate. The following sections suggest the amount and type of monitoring for towns according to population in order to gauge compliance with the guideline values. Further guidance on selecting monitoring sites and monitoring methods for air-shed management can be found in Ministry for the Environment (2000a), and for industrial management in *Compliance Monitoring and Emissions Testing of Discharges to Air* (Ministry for the Environment, 1998a).

Areas with populations less than 25,000

In small urban areas (population less than 25,000) it may be impracticable to install permanent monitoring stations, mainly because of resource limitations. However, a short-term programme, possibly using screening monitoring methods, should be undertaken. If potentially elevated levels are found through the initial monitoring, more accurate monitoring methods can then be installed. Emission inventory data and a desktop evaluation of complaints, local meteorology and topography should be used to indicate where there are problem areas.

It is likely that the principal contaminant of concern for small urban centres will be PM_{10}, or possibly $PM_{2.5}$. The problem could be more wide ranging if there are significant industrial emissions (where a range of contaminants may be of concern), or there is a highway or roadway through a town or forestry/rural settlement (in which case roadside carbon monoxide and PM_{10} may be an issue). There are a number of small- to medium-sized towns in both the North and South Islands where PM_{10} concentrations could be high during the winter months, and it is important that these areas are properly assessed. Sulphur dioxide may also need to be monitored where there is significant coal burning.

It may be possible to make well-researched comparisons with other similar small urban areas that have been monitored, although this needs to be done carefully. Councils are encouraged to communicate and share information and possibly equipment; for example, through the EPI Programme and Air Quality Working Group. This will ensure efficient use of monitoring resources and avoid unnecessary duplication.

Areas with populations of 25,000–100,000

For large towns (population between 25,000 and 50,000) the minimum level of monitoring should include representative short-term surveys, certainly of PM_{10} or $PM_{2.5}$ and carbon monoxide. Nitrogen dioxide should be measured where there is significant traffic congestion, and sulphur dioxide should be investigated in areas with significant coal or oil burning. If the results of the short-term programme show that ambient air concentrations breach – or are likely to breach – 66% of the guideline value, then at least one permanent monitoring site with the recommended measurement methods should be installed.

Areas with populations above 100,000

Monitoring in the main urban centres (including Auckland, Hamilton, Wellington, Christchurch and Dunedin) should involve extensive monitoring programmes using permanent and temporary sites, monitoring a range of contaminants. The monitoring data should be supported by regional air-shed modelling to develop a picture of the spatial and temporal variation in air pollution levels. Monitoring programmes in such areas have been developed by regional councils and are being evaluated through the Environmental Performance Indicators Programme.

Monitoring new contaminants

Councils and the Ministry, through its GEMS monitoring programme, will need to prioritise which of the new hazardous air contaminants to monitor and which methods to use. This can be done by considering the results of updated emission inventories including the new contaminants, and by checking existing monitoring data for contaminants that may be associated with the new contaminants. For example, high levels of PM_{10} from domestic fires may indicate high levels of benzo(a)pyrene.

Initial screening monitoring with simple methods such as passive samplers can be used to determine whether more accurate monitoring is required (see Table 2 below for recommended methods).

3.2.3 Recommended monitoring methods

Consistent monitoring methods should be used in New Zealand to ensure:

- good-quality data is collected
- data can be compared with both New Zealand and overseas data
- data can be used in epidemiological studies
- the effectiveness of different policy responses can be evaluated.

The recommended monitoring methods to determine compliance with the guideline values are listed in Table 2. Changes to 1994 monitoring methods are in given in bold. US EPA ‘equivalent methods’ are also recommended. These methods are derived from the review of potential methods in Air Quality Technical Reports 12 and 13 (Denison et al, 2000; Chiodo and Rolfe, 2000).

Table 2: Recommended monitoring methods

Contaminant	Revised or new method
Carbon monoxide	**AS3580.7.1 – 1992**
Particles (PM_{10})*	**US 40 CFR Part 50, Appendix J**
Particles ($PM_{2.5}$)*	**US 40 CFR Part 50, Appendix L**
Nitrogen dioxide	AS3580.5.1 – 1993
Sulphur dioxide	AS3580.4.1 – 1990
Ozone	AS3580.6.1 – 1990
Hydrogen sulphide	**AS3580.4.1 – 1990, coupled with a hydrogen sulphide to sulphur dioxide converter**
Lead content of PM_{10}	**US 40 CFR Part 50, Appendix J** **US 40 CFR Part 50, Appendix G**
Benzene and 1,3-butadiene	**US EPA method TO-1**
Formaldehyde and acetaldehyde	**US EPA method TO-11A**
Benzo(a)pyrene	**US EPA method TO-13A**
Mercury, chromium, arsenic as particulates	**PM_{10} sampling in accordance with 40 CFR Part 50, Appendix J, followed by analysis using atomic absorption spectroscopy or an equivalent method. For Mercury – Method IO-5 (Sampling and Analysis for Vapour and Particle Phase Mercury in Ambient Air Utilising Cold Vapour Atomic Fluoresce Spectrometry).**

* Where a tapered elemental oscillating microbalance (TEOM®) is used to monitor PM_{10} and $PM_{2.5}$, another recommended monitoring method should be co-located at the site for at least one year to calculate an appropriate adjustment factor.

Screening methods (such as passive sampling) can be used where a detailed programme is not warranted, or as an adjunct to a comprehensive programme to assess spatial variability. However, it is inappropriate to use screening methods to determine whether an air shed complies with the guideline values.

Approving alternative and new monitoring methods

There may be methods that do not have US EPA equivalency but collect sufficiently accurate results that can be compared with guideline values. The person or organisation intending to use or develop a method can apply to the Ministry to seek its consideration for inclusion in Table 2.

Once an application is received, the Ministry will convene an expert working group to consider the method and any studies of its accuracy. The expert working group will recommend whether to add the method to the list in Table 2 and the list will be re-issued via the Ministry's web pages.

3.2.4 Comparing monitoring data to guideline values

Many factors affect pollution levels measured at a particular site, including:

- proximity and type of emissions sources
- background or natural concentrations
- monitoring method used
- meteorology
- quality assurance checks
- atmospheric reactions
- topography.

Careful analysis of how these factors interact and influence pollution levels is required to understand and interpret the data collected at a site.

The first stage is usually to determine whether the contaminant concentrations recorded comply with the guideline values. This usually focuses on the magnitude and frequency of peak monitoring results. As part of the quality assurance process, the reasons for the peak values must be investigated. Some peaks may not be valid results (for example, due to equipment failure), or they may be valid but occur because of unusual events (for example, Guy Fawke's night or a diesel generator parked nearby).

It is difficult to develop a general national approach that takes into account different guideline averaging times, site characteristics and monitoring result variability. However, where there is insufficient information about the reasons for peak results, the Ministry has recommended a set of percentiles that can be used for analysing the data.

For 24-hour guideline values where daily data are collected, the Ministry recommends using the annual 99.5 percentile to judge compliance with the guideline value. This allows for two 24-hour averages collected over a year to be excluded from determining whether pollution levels at the site meet the guideline value. For 1-hour and 8-hour averages, the annual 99.9 percentile can be used. Percentile limits can only be applied when there are a large amount of data, and are therefore more appropriate where substantial continuous monitoring of short-term concentrations (hourly or less) has been carried out.

If, on the other hand, there is sufficient information to say that the peak values occur relatively frequently (on the basis of several years of data) and that they are not anomalous or invalid, it would be appropriate to use them to judge compliance.

Probably the most common ambient-monitoring method used in New Zealand at permanent monitoring sites is 24-hour measurement of PM_{10} by manual gravimetric methods on a 1-day-in-6 cycle. With this method there is insufficient data collected over a year to apply a sensible annual percentile limit, so the peak results should be used. The peaks should also be used for longer-term measurements, such as 7-day measurements, monthly means and annual averages.

3.2.5 Emission inventories

Emission inventories are an integral part of air quality management. They are used to understand the 'pressures' on air quality in an air shed – contributions from different emissions sources, and how emissions may change over time and space. They are also important in determining potential background or natural sources of pollution, especially for contaminants such as PM_{10}, whose background concentrations from natural sources may be significant. Most regional councils have prepared and used inventories in their regional planning, although the inventories vary in detail and complexity.

Emissions inventory data enables strategies to be tailored to address emission sources in order of their contribution to the pollution problem. In this way, the major sources can be targeted and the biggest improvements achieved. Inventory models can also be used to assess and compare the effectiveness of potential reduction measures.

Although emissions from a particular source are often proportional to its contribution to ambient air concentrations, this cannot automatically be assumed and should be carefully analysed. Other factors affecting pollution levels monitored at a site, such as meteorology and time of day of the emission, need to be carefully examined and, where appropriate, air shed modelling should be used to estimate the relationship between emissions and concentrations.

Guidance on preparing and interpreting inventories is available from the Sustainable Management Fund web site (Wilton, 2001) and will not be provided here. Suffice to say an inventory is crucial for effective air quality management.

Once there is sufficient information about the level of air pollution, the factors affecting it and the pollution sources, it is then possible to develop regional criteria, set emission reduction targets and devise emission reduction strategies.

3.3 Regional criteria and reduction targets

Through regional plan development under the RMA some clear steps for developing regional criteria and reduction targets have evolved. The guidance below summarises this experience, and aims to improve national consistency while enabling sufficient flexibility for councils to address regional circumstances and community aspirations. The approach described is therefore not intended to be unduly prescriptive.

3.3.1 Regional air quality criteria

The national guideline values can be used to set quantifiable region-specific criteria (a concentration-based goal for air quality) based on local monitoring results and community consultation.

The main goal for sustainable air quality is to maintain air quality where it is good and to improve air quality where it has been degraded and is affecting people's health. When it comes to guideline values, this means that where pollution levels breach a guideline value, emissions into the air shed should be reduced so that breaches do not occur; where possible, further improvements should also be made (particularly for those contaminants with no threshold level for adverse effects). It also means that where air quality does not breach the guideline values but looks like it might worsen over time (based on emissions inventory predictions), action should be taken to prevent it from breaching the guideline value. This is particularly important because measures required to reduce emissions may take some time to be implemented and become effective.

A framework for directing this process and establishing regional criteria using air quality 'categories' has been developed through the Environmental Performance Indicators (EPI) Programme. Table 3 lists five air quality categories. While these values are somewhat arbitrary, they have been widely used in planning processes since their introduction in 1997.

Table 3 shows that pollution levels recorded above 66% of any national guideline value fall within the 'alert' category, as defined by the EPI Programme. This warning level indicates that the guideline value could be exceeded if upward trends are not curbed. In a sense, this provides a definition of degraded air because it implies that 66% of the guideline is the threshold above which it is necessary to consider taking action to maintain or reduce emissions into the air shed. In this situation it may be necessary to develop policies aimed at curbing a potential upward trend, or at enhancing air quality – depending on the circumstances, local community aspirations and the costs and benefits of the actions required.

Table 3: EPI programme air quality categories

Category	Measured value	Comment
Action	Exceeds the guideline value	Exceedances of the guideline are a cause for concern and warrant action, particularly if they occur on a regular basis.
Alert	Between 66% and 100% of the guideline value	This is a warning level, which can lead to exceedances if trends are not curbed.
Acceptable	Between 33% and 66% of the guideline value	This is a broad category, where maximum values might be of concern in some sensitive locations, but are generally at a level that does not warrant urgent action.
Good	Between 10% and 33% of the guideline value	Peak measurements in this range are unlikely to affect air quality.
Excellent*	Less than 10% of the guideline value	Of little concern: if maximum values are less than a 10th of the guideline, average values are likely to be much less.

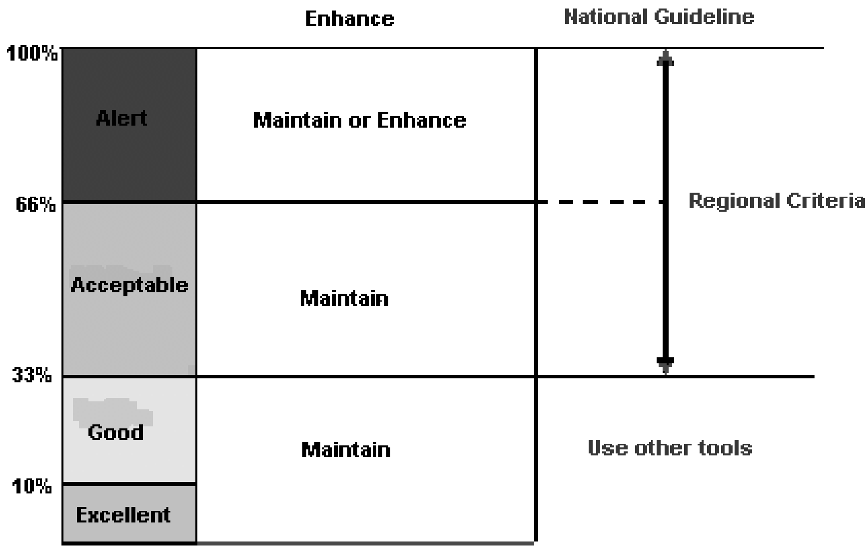
* The 'excellent' category should not be applied to PM_{10} because the level of detection of most monitoring methods is not accurate enough.

Regional criteria should be based on monitoring data indicating current air quality and community aspirations for the level of air quality desired in an area or region. They can have a spatial extent, such as a particular city area, receiving environment or monitoring site type. Regional criteria should not be less stringent than national guideline values.

In general, the top of the acceptable category range is appropriate to maintain and protect air quality in most areas of New Zealand where, although there is limited information, the air quality is generally clean and there are no specific issues. Typically, this would apply to rural areas or small- to medium-sized urban areas without too many problems.

Figure 1 illustrates the range of potential values considered appropriate for region-specific criteria.

Figure 1: Potential range of values for regional criteria based on the EPI categories



Areas that are pristine or of special sensitivity should fall within the 'good' or 'excellent' categories listed in Table 3. However, it is not usually practicable to use the lower values to manage emissions in these areas. Any measure of performance against numerical guideline values relies on traditional ambient air monitoring techniques, and these are often unable to provide a sensitive enough measure when the air is very clean. In any case, most authorities would not monitor areas where air quality is this good because they tend to be remote pristine areas.

For those areas considered pristine or of special significance, one or more of the following management tools should be considered:

- criteria based on visibility degradation (Ministry for the Environment, 2001b)
- specific ecosystem criteria based on critical levels, or a biological monitoring criterion (see Chapter 4)
- broad site limitations for certain activities in sensitive areas (guidance on these will be available in the guide to assessing discharges to air).

3.3.2 Emission reduction targets

Once information is available about the state of air quality and the pressures on it, and regional criteria have been determined, it is then possible to quantify the emission reductions required from different sources to achieve the criteria or guideline value. Reduction targets are the percentage amount by which emissions into the air shed should be reduced from each source. For example, *a 50% reduction in PM_{10} emissions from domestic fires is required to ensure that the PM_{10} guideline value of 50 $\mu g/m^3$ (24 hours average) is not exceeded*. The reduction target can be used to evaluate the effectiveness of different options for reducing emissions.

Reduction targets are usually based on peak monitoring results, emission inventory information, the guideline value (or regional criteria), any air-shed modelling, and investigations determining the relationship between emissions and concentrations measured at a monitoring site. The following need to be taken into account:

- whether monitoring data from the site are representative of pollution levels in the air shed, including peak values
- the accuracy of monitoring results
- any health effects assessments highlighting particular areas or contaminants of concern
- atmospheric dispersion modelling that explains the relationship between emissions and ambient concentrations
- community aspirations for emissions reductions
- the emission sources requiring greatest control, estimated through an emissions inventory and, where necessary, atmospheric dispersion modelling.

To determine reduction targets, councils should also consider the following:

- Do the peak values represent relatively frequent pollution events that are likely to cause health effects?
- Were there any unusual circumstances when the peak values were monitored (for example, bonfire night, diesel generator parked nearby)?
- Have the peak values occurred relatively frequently over the past few years?
- How accurate is the monitoring method?

If the peak values represent relatively frequent pollution levels and are not anomalous, then it is appropriate to base the reduction target on the peak results (possibly averaged over a number of years). If there is reason to believe that the peak results are not representative of typical peak pollution levels, then the monitoring results should be considered carefully. If one or more peak results are determined to be anomalous or do not occur on a regular basis, they should not be used to calculate the reduction target. If it is not possible to confirm whether the peak results are anomalous or otherwise, the 99.5 percentile should be used for 24-hour averages and the 99.9 percentile for 1-hour and 8-hour averages.

As a policy decision, councils can opt for a staged approach whereby the strategy or plan aims to reduce emissions based on one breach by a certain date, followed by an increase in measures to ensure there are no breaches of the guideline value by a subsequent date. Alternatively, councils can commit to reviewing the plan by a specific date and to changing the measures according to new monitoring data and analysis.

3.4 Reduction strategies

Reduction strategies include a range of options that can be implemented to manage air quality, including regional air quality plans, education strategies, national regulations and incentive schemes. A discussion on each of these is beyond the scope of this document, but it is important to note that any strategy and individual measures within a strategy should aim to achieve the reduction targets by a certain date (target date). Their development must include community consultation and an analysis of the costs and benefits of the chosen measures.

In summary, strategies for improving air quality should include sound policies based on the following information:

- a permanent ambient air monitoring programme, representative of the areas in question
- emission inventory studies to identify key sources and how they change over space and time – both short term and long term
- analysis and projection of trends in emissions, influencing factors and air pollution levels
- where possible, atmospheric dispersion modelling studies and exposure assessments to determine the spatial extent and frequency of areas where pollution levels exceed the guideline value, and their impacts
- analysis of the options for improving air quality and their cost effectiveness
- community views on the desirable level of air quality and options required to improve it
- analysis of potential other causes, such as one-off events (for example, volcanoes) and large-scale weather/climate influences (for example, El Nino).

Human health surveys, exposure assessments, risk assessments or biological monitoring studies may also be appropriate in some circumstances to determine the actual health effects of pollution and to refine reduction strategies. Such studies must be based on rigorous research techniques.

3.4.1 Assessing costs and benefits

Section 32 of the RMA requires any persons responsible for achieving its purpose to consider the costs and benefits of any objective, policy or rule, and to consider potential alternatives that could be pursued. Other matters that should be considered by councils include indirect effects that occur as a consequence of implementing the measure.

More detailed guidance on how to undertaken a full section 32 analysis is contained within the *What Are the Options? A guide to using Section 32 of the Resource Management Act* (MfE, 2000d).

The guideline values in this report do not negate the need for councils to undertake full cost–benefit assessments in accordance with section 32 when developing regional plans.

National policies and regulations must also be accompanied by a full regulatory impact assessment that includes consideration of costs and benefits of implementing policies or particular regulations.

3.4.2 Community consultation

Consultation with the community is also an integral part of regional air quality management and plan development under the RMA, and for national policy development.

Councils and central government agencies should ensure that the community is kept informed about air quality (especially where it does not meet the guideline values), the main pollution sources, and their potential effects on people's health and well-being. Adequate information is particularly important when discussing the potential cost of improvement options and when asking the community to make decisions on the actions required to improve air quality.

Methods for presenting air quality monitoring information are being developed by councils, the media and the Ministry. The *Good-practice Guide to Air Quality Monitoring and Data Management* (Ministry for the Environment, 2000a) the Ministry's *The Air We Breathe* web pages, regional state of the environment reports and the EPI Programme all have useful examples and guidance on how to present and interpret monitoring data, and how to communicate monitoring results to the general public.

3.5 Evaluating reduction strategies

Once reduction strategies and actions are implemented, their effectiveness needs to be assessed over time by ongoing air quality monitoring and analysis of the pressures.

Assumptions used to predict the effectiveness of different measures should be checked. For example, if an emission inventory model was used to predict the reductions associated with a particular policy, the assumptions used in the model should be periodically checked and re-evaluated.

Likewise, air quality monitoring can be used to check predicted improvements in air quality, taking into account the influence on meteorology. Given the factors affecting air quality it may take a number of years before a clear trend can be determined.

If evaluation shows that the predictions were inaccurate and the rate of anticipated improvements is not being achieved, plans and policies should be reviewed and revised. The same applies if improvements are faster than anticipated and particular rules or policies are perhaps not needed as urgently.

3.6 Involving Maori

Traditionally Maori have had a close relationship with the environment, of which air quality is an important part. Iwi and mana whenua have traditionally exercised their roles as kaitiakitanga, and this role differs in each area.

The way in which Ngai Tahu may choose to exercise their role of kaitiaki in Christchurch might be different from the way it is done in Kawerau by Tuwharetoa-ki-Kawerau. And clearly, for urban Maori this could again be markedly different from the practise of Maori living in rural areas.

The practice of kaitiakitanga will be largely influenced by the nature of the influence in their geographical area. Iwi and mana whenua may seek to employ a vast range of differing tools both traditional and modern in order to meet these responsibilities.

In developing guidelines the Ministry has aimed to provide flexibility so that local regional approaches can be tailored to local circumstances. The recommended approach of applying guidelines and developing management options at a regional level under the RMA will enable Maori to be better placed to establish regional measures that are consistent with the tikanga, history and present expectations of that region.

For this to work effectively, there needs to be a good relationship between local iwi and regional councils. The Ministry has produced guidance on how to build relationships with local iwi: *Talking Constructively: A practical guide for building agreements between iwi, hapu and whanau and local authorities,* and *Iwi and Local Government Interaction under the Resource Management Act 1991: Examples of good practice*. Both of these are available from the Ministry's publications department, or they can be downloaded from: http://www.mfe.govt.nz/about/publications/rma/rma.htm.

3.7 Assessing individual discharges to air

As was stated in the 1994 Guidelines, the ambient guideline values are not designed to be used to assess the environmental and health impacts of individual discharges to air as required by the RMA, or a regional or district plan. Individual discharges include point, area or line sources from activities such as industries, roads and sewage-treatment plants.

We recognise, however, that in the absence of alternative guidance the guideline values will be used in such assessments and have, at times, been applied inappropriately. National advice on how they should and should not be applied to individual discharges is therefore needed to improve the quality and consistency of assessments.

The Ministry suggested several options for national guidance on assessing individual discharges in the discussion document (Ministry for the Environment, 2000c). A number of submissions requested more detailed investigation into the options and suggested a separate guidance document to cover issues such as: national assessment criteria (modelling design concentrations), effective consent conditions, tailoring assessments to the scale and significance of the discharge, notification procedures and mitigation options.

A draft of the new assessment guide will be available for comment by the end of 2002. It will be consistent with the *Guide to Atmospheric Dispersion Modelling* due to be released for comment in mid-2002.

However, it is useful to briefly look at how the ambient guideline values should *not* be used to assess individual discharges, and to highlight key issues that must be taken into account in assessing the environmental impacts of individual discharges through the resource consent and plan processes.

In general, guideline values:

- *should not* usually be used as limits to pollute up to by one industry
- *should not* be applied without taking into account the sensitivity of the receiving environment
- *should not* be applied without considering background concentrations and potential cumulative effects
- *should only* be used as part of a full assessment of environmental effects as required under the RMA.

Other factors that should be considered include:

- the best practicable option for reducing emissions
- the accuracy of atmospheric dispersion modelling results
- community views
- the need for a full health risk assessment
- any other RMA or regional plan requirements.

In many cases other criteria such as shorter-term ‘modelling design concentrations’ developed specifically for the hot spot or bubble area, or the type of individual discharge, may be more suitable. In addition, ambient guideline values, such as PM_{10}, may not be suitable for assessing certain discharges, such as nuisance dust from dust generating activities. Guidance on assessing and managing dusty activities is contained in the *Good-practice Guide for Assessing and Managing the Environmental Effects of Dust Emissions* (Ministry for the Environment, 2001a).

4 Ecosystem-based Guidance

4.1 Introduction

The RMA requires consideration of the potential and actual effects of air pollutants on ecosystems as well as human health. This chapter presents new guidance for assessing the effects of air pollution on ecosystems. It must be read in conjunction with *Effects of Air Contaminants on Ecosystems and Recommended Critical Levels and Critical Loads* (Stevenson et al, 2000). The guidance is designed to encourage councils and others to investigate the potential impacts of air quality on ecosystems. However, the advice should be applied cautiously and flexibly as it is based on northern hemisphere research that may not be wholly applicable to New Zealand. It must also only be applied where areas of potentially sensitive ecosystems exist.

For the purposes of this discussion, an ecosystem is considered to include all the living organisms within natural and semi-natural systems and the environments in which they live and on which they depend. This specifically excludes the direct effects of pollutants when people inhale them, which are covered in the health-based guideline values.

On the basis of current scientific evidence it was only possible to assess a fraction of the organisms and impact pathways, and a limited number of common contaminants. Even for the various impacts that have been documented in the technical report (Stevenson et al, 2000), there is still a high degree of uncertainty, particularly when compared with human health-effects studies.

As a general principle, protecting the fundamental components of an ecosystem protects the ecosystem as a whole. The most fundamental components are climate and hydrology, and the physical and chemical characteristics of the soils and substrata. As the primary photosynthetic producers, plants are the next most fundamental component. To a large extent plants determine and exemplify the nature, diversity and health of ecosystems. Accordingly, if the characteristics of the fundamental components are protected, and substantially unaltered conditions for plant growth are assured, the health and quality of the ecosystem are also assured.

Animals are likely to be protected from the direct toxic effects of air pollutants by standards or guidelines established to protect human health. However, the possibility of some exceptionally sensitive species being adversely affected at such levels cannot be ruled out.

The discharge of toxic components such as heavy metals or persistent organic toxins into the environment can adversely affect animals in an ecosystem without adversely affecting plants. Toxic components are therefore a possible exception to the general principle that protecting the fundamental ecosystem components protects all plants and animals.

4.2 Recent research

There has been considerable research done in Europe and North America on developing guideline values to protect ecosystems. These are aimed at a variety of natural and semi-natural ecosystems and species, and are typically referred to as *critical levels* and *critical loads*.

Critical levels relate to the toxic effects of ambient air pollutants on plants. They are available for sulphur dioxide, oxides of nitrogen, ozone and ammonia. Critical loads relate to the toxic effects of deposition of air pollutants into ecosystems. These are available for acidity (the acidifying effect of sulphur and nitrogen air pollutants on ecosystems, particularly on soil/plant systems and natural waters), and nitrogen (the effects of nutrient enrichment).

The United Nations Economic Commission for Europe (UNECE) has developed the most comprehensive approach to ecosystem management as part of the Convention on Long Range Transboundary Air Pollution. The UNECE has used critical levels and critical loads for protecting natural and semi-natural ecosystems, which it defines as follows:

> ***Critical levels:***
> *The concentrations of pollutants in the atmosphere above which direct adverse effects on receptors such as plants, ecosystems or materials, may occur according to present knowledge.*
>
> ***Critical loads:***
> *A quantitative estimate of an exposure, in the form of deposition, to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.*

Generally, critical levels are based on relatively short-term (hours to a year) effects of a single pollutant species (for example, oxides of nitrogen, sulphur dioxide or ozone). Critical loads involve assessing the effect of several different pollutants over longer time periods (one year to decades). UNECE has defined critical loading for acidity deposition and nitrogen deposition. Both critical loads and critical levels vary from traditional air quality guideline values established for the protection of human health in several ways:

- critical loads/levels are developed to protect both single organisms and ecosystems
- critical loads/levels are established as close to the threshold point as possible with little or no margin of safety
- critical loads/levels consider both direct and indirect impact mechanisms: they are effects-based approaches to environmental management
- both critical loads and critical levels are defined in terms of their environment (for example, ecotype).

The critical load/critical level concept has subsequently been adopted by the World Health Organization (WHO, 1996). Due to their comprehensiveness and international acceptance, this approach seems to be a valid method for New Zealand to use as a management tool.

It is important, however, to recognise that the UNECE/WHO (1996) guidelines are based on central and northern European conditions. Therefore, in the absence of detailed specific New Zealand research, particularly for native species, it is difficult to gauge their applicability here. European ecosystems have developed with human influences at varying degrees of intensity over many centuries, and have almost certainly adapted to this situation to a certain degree. On the other hand, most New Zealand ecosystems have developed under conditions of low nitrogen supply, for example, and have only been subject to increased nitrogen supply over about the last century or less.

The guidelines should therefore be applied cautiously and users must review the more detailed discussions in Stevenson et al (2000). Where more specific information is available for New Zealand conditions, this should be used in preference to the guidelines given below.

4.3 Guidance for New Zealand

4.3.1 Critical levels

Critical levels for different airborne pollutants are presented in Table 4. They are based on the UNECE/WHO (1996) and Australia and New Zealand Environment and Conservation Council (ANZECC) guideline values. The fluoride guidelines presented with Table 6 are the same as those in the 1994 Guidelines.

Table 4: Critical levels for protecting ecosystems

Contaminant and land use	Critical level	Averaging period	Additional requirements
Sulphur dioxide:			
• agricultural crops	30 μg/m^3	Annual and winter average	
• forest and natural vegetation	20 μg/m^3	Annual and winter average	
• lichen	10 μg/m^3	Annual	
Sulphate particulate:			
• forests	1.0 μg/m^3	Annual	Where ground-level cloud present > 10% of time
Nitrogen dioxide	30 μg/m^3	Annual	
Ammonia	8 μg/m^3	Annual	
Ozone:			
• forests	21,400 μg/m^3-h	6-month	
• semi-natural vegetation	6420 μg/m^3-h	3-month	
• crops (yield)	6420 μg/m^3-h	3-month	
• crops (visible injury)	428 μg/m^3-h	5-day	Mean daytime vpd below 1.5 kPa
	1070 μg/m^3-h	5-day	Mean daytime vpd above 1.5 kPa

Contaminant and land use	Critical level	Averaging period	Additional requirements
Fluoride:			
• special land use	1.8 μg/m^3	12-hour	
	1.5 μg/m^3	24-hour	
	0.8 μg/m^3	7-day	
	0.4 μg/m^3		
	0.25 μg/m^3	90-day	
• general land use	3.7 μg/m^3	12-hour	
	2.9 μg/m^3	24-hour	
	1.7 μg/m^3	7-day	
	0.84 μg/m^3	30-day	
	0.5 μg/m^3	90-day	
• conservation areas	0.1 μg/m^3	90-day	

Notes: Critical levels for nitrogen dioxide assume that either O_3 or SO_2 are also present at near guideline levels. Critical levels for ozone are expressed as a cumulative exposure over a concentration threshold referred to as AOT40 values (accumulative exposure over a threshold of 85.6 μg/m^3, at 0^oC), calculated as the sum of the difference between hourly ambient ozone concentrations and 85.6 μg/m^3, when ozone concentrations exceed 85.6μg/m^3). Ozone is only measured during daylight hours with a clear global radiation of 50 Wm^{-2} or greater; vpd = vapour pressure deficit.

In general, areas where sensitive ecosystems are located (rural and forest environments) are unlikely to experience pollution levels that breach these critical levels. There may be cause for concern if valued ecosystems are located near large individual sources or urban environments. It is difficult to make this same broad statement with regard to ammonia, since emission sources, emission rates and ambient concentrations in New Zealand are generally not well known. Intensive agriculture is a potentially significant ammonia source in rural areas, where sensitive ecosystems may also be located (although the little information available suggests that the critical level for ammonia is unlikely to be exceeded).

Of particular interest is the high sensitivity of forests and lichen to long exposures to sulphur dioxide. It is also important to note that the critical levels adopted by WHO (1996) are much lower than the 1994 guideline value for human health protection of 50 μg/m^3 (annual average).

4.3.2 Critical loads

Critical loads for acidity are defined in terms of the acid-neutralising capacity of the soil, which depends on the nature of the parent material and the texture of the soil.

The probable critical loads for acidity for a range of New Zealand catchments are estimated in Technical Report 15 (Stevenson et al, 2000). They indicate that problems of soil/ecosystem acidification are unlikely to occur here in New Zealand, making it unnecessary to provide national guidelines for critical loads. However, where the area requiring protection is likely to be sensitive to acid deposition, as indicated by very low levels of alkalinity in water draining from the area (for example, less than 10 mg/l as calcium carbonate), or from other information, investigations of potential effects should be undertaken.

Where the potential effects of acid deposition and nitrogen enrichment need assessment, acid deposition and nitrogen enrichment can be estimated using approximate relationships between ambient air concentrations and their deposition rates for the pollutants of concern. In this way, ambient air monitoring data (modelled or monitored) can be used to estimate the worst-case deposition scenario. The results can then be compared with the critical load for the appropriate ecosystem. If the ambient air concentrations suggest that there may be problems from acid deposition or nitrogen enrichment (using the specified relationships), further investigations may be required, such as measuring actual deposition rates and the soil's acid-neutralising capacity.

Because of the low probability of significant soil acidification in New Zealand and the uncertainties about the nitrogen sensitivities of New Zealand ecosystems, the Ministry has not developed critical loads for use in New Zealand. However, councils are advised to identify valuable ecosystems and determine whether existing or predicted ambient air quality has the potential to affect them via nitrogen loads. Such assessments should ideally be undertaken as part of the assessment of environmental effects for consent applications for discharges to air.

Further local investigations need to be undertaken to refine the relationships between ambient air concentrations of nitrogen and sulphur compounds and deposition rates of acidity and nitrogen.

4.3.3 Applying ecosystem-based guideline values

As for the health-based guideline values, the critical levels provided above are mostly for investigating the potential region-wide effects of air pollution levels on ecosystems. With the exception of fluoride, they are not designed to assess individual discharges to air, and the same caveats as those given in section 3.6 apply to their use.

When they are applied, the following factors must be taken into account:

- the potential for effects to occur on more sensitive sub-groups within an ecosystem
- the inter-dependency between various species in an ecosystem
- the value placed on the flora and fauna within an ecosystem (whether it is native or introduced and, if introduced, whether or not it is a pest species)
- any key ecosystem role that sensitive at-risk species may have.

Further guidance on considering the impacts of individual discharges on ecosystems will be contained in guidance on assessing discharges to air.

Appendix 1: Relationships to other Ministry and government programmes

Air Quality Management Programme

The Ministry's Air Quality Management Programme develops national tools and guidance to promote sustainable local air quality management. It aims to improve the quality, consistency and cost-effectiveness of monitoring and managing air quality in New Zealand. The Ministry works collaboratively with other government departments, councils and other stakeholders.

Current projects include:

- development of guides on atmospheric dispersion modelling and assessing discharges to air
- reviewing the Ministry's 1995 *Guide to Odour Management under the RMA*
- preparation of a Particle Action Plan to address emissions of particles from all sources, but especially domestic fires, which may include a national environmental standard
- consideration of indoor air quality – its likely impacts on people's health and responsibilities for its management.

Completed projects published by the Ministry include:

- *Good Practice Guide to Assessing and Managing the Environmental Effects of Dust Emissions* (2001a)
- *Good Practice Guide to Monitoring and Managing Visibility in New Zealand* (2001b)
- *Good-practice Guide for Ambient Air Quality Monitoring and Data Management* (2000a)
- *Emissions Testing and Compliance Monitoring of Discharges to Air* (1998c).

Organochlorines Programme

The Ministry's Organochlorines Programme recently sought comment on a draft *Action Plan for Reducing Discharges of Dioxin to Air* that includes a proposed national environmental standard for dioxin emissions. A large-scale monitoring programme was implemented in the early stages of this Programme to ascertain the level of dioxins and furans in different environments.

Hazardous Waste Management Programme

These 2002 Guidelines include air contaminants arising from the management of hazardous waste. The guideline values and Dioxin Action Plan will be taken into account in developing the Ministry's Hazardous Waste Management Programme.

Climate change policy

In general, both the ambient air quality guidelines and climate change policies aim to manage and, where appropriate, reduce the emissions of contaminants into the air. The Ministry aims to ensure that these programmes are complementary.

Government action on energy efficiency and renewable energy

Energy efficiency is at the heart of the Government's energy policy. The Energy Efficiency and Conservation Authority (EECA) is responsible for achieving the Government's energy policy goals and, specifically, energy efficiency and renewable energy policy. EECA also supports and complements other Government actions to improve the nation's environmental and economic performance, with emphasis on the housing, transport, business, industrial and other sectors with significant energy use.

EECA's focus is on developing and implementing a diverse range of operational energy efficiency, renewable energy and energy conservation programmes. EECA was recently designated a Crown entity role under the Energy Efficiency and Conservation Act 2000. The Act has put EECA in a position to lead the Government's charge to engage all sectors of the economy in the drive towards greater energy efficiency and renewable energy uptake.

Many energy-efficiency improvements and greater uptake of renewable energy have direct benefits in terms of reducing air emissions. The links between reducing air pollution and undertaking energy efficiency measures will be examined on an ongoing basis.

Reducing vehicle emissions

The Ministry of Transport leads the development of policies to reduce vehicle emissions. It is currently implementing initiatives in the Vehicle Fleet Emissions Control Strategy (VFECS), and exploring additional measures.

The VFECS package includes:

- developing a rule to formalise an emissions standards regime for vehicles entering the national fleet
- providing information and tools to enable the use of environmental capacity analysis and local traffic management techniques to tackle local air quality problems
- reviewing the automotive petroleum fuel specifications (led by the Ministry of Economic Development)
- amending the Traffic Regulations to enable the police to enable drivers of excessively smoky vehicles to be fined more easily
- reviewing the *Ambient Air Quality Guidelines* and air quality monitoring methods (led by the Ministry for the Environment).

Hazardous Substances and New Organisms Act

A number of the new air contaminants covered in this document are used (in liquid or other form) in manufacturing and other processes. As a result, their use – and to some extent their disposal – come under the provisions of the HSNO Act. However, ERMA may take some time to evaluate the chemicals and determine specific environmental criteria and conditions of use. Once this has been done, these regulations and requirements will have greater weight than the air quality guideline values.

Environmental Performance Indicators Programme

The EPI Programme develops and uses indicators to measure and report on how well we are looking after our environment. The Ministry is currently collating data and sorting out data management arrangements with monitoring agencies for the Stage 1 air indicators (see Table A1).

Table A1: Air indicators

Indicator	Stage
Carbon monoxide	1
Particles (PM_{10})	1
Nitrogen dioxide	1
Sulphur dioxide	1
Ozone	1
Visibility	2
Particles ($PM_{2.5}$)	2
Benzene	2
Lichen coverage and diversity	2

Appendix 2: Summary table of actions required, by air quality category

	Action	Alert	Acceptable	Good/Excellent
Definition	Above the guideline	66–100% of the guideline	33–66% of the guideline	Good: 10–33% of the guideline Excellent: 0–10% of the guideline
EPI category description	Exceedances of the guideline value are a cause for concern and warrant action, particularly if they occur on a regular basis	This is a warning levels, which can lead to exceedences if trends are not curbed.	This is a broad category, where maximum values might be of concern in some sensitive locations but are generally at a level that does not warrant dramatic action.	Good – Peak measurements are unlikely to affect air quality Excellent – of little concern: if maximum values are less than 10th of the guideline, average values are likely to be much less.
Action required	Achieve guideline value within shortest possible timeframe; investigate and monitor comprehensively	Reduce further, where practicable, and monitor	Maintain, reduce where practicable and monitor periodically	Maintain and monitor occasionally
Recommended monitoring/ investigations	Set up comprehensive continuous monitoring Compile detailed emissions inventory Investigate how emissions are likely to change over time Determine potential spatial extent of exceedances Carry out meteorological monitoring	Set up continuous monitoring Compile a detailed emission inventory Investigate how the situation may change over time Investigate the location and cause of maximum results Check location of monitoring sites and their representativeness Undertake meteorological monitoring	Consider regular monitoring to check for any trends Compile basic emissions inventory Examine cause of maximum results Investigate how emissions/air quality is likely to change over time	Carry out periodic monitoring using survey techniques Check siting of monitors
Management issues	Establish and implement management options to ensure pollution levels are reduced within the shortest time frame possible Alert public to location, severity and extent of guideline breaches	If the situation is likely to worsen with peaks entering the alert category: establish and implement management options to ensure pollution levels do not worsen If situation is likely to remain the same: implement measures to ensure emissions do not increase	Where increases in emissions are unlikely: consider management options to maintain ambient air quality If emissions are likely to increase: instigate management options to address these potential increases	Examine desired state/uses/ values of the air resource and potential future uses Establish management techniques accordingly If the air is in or near to pristine environments (e.g. national parks, protected national areas), strict controls may be required
Special investigations	Examine population exposure to air with high pollution levels Determine potential health effects on population exposed Consider monitoring of hazardous air contaminants	Investigate the spatial extent of the pollution concern	None	None

Appendix 3: Background information on hazardous air contaminants

Contaminant	Health effects	Classification		Unit risk x 10^{-6}			Various guidelines ($\mu g/m^3$) (annual averages unless otherwise stated)				
		IARC*	US EPA* (potency)	WHO	US EPA	CARB	UK	EC	TWA/ 100	WHO	US
Benzene	Haemotoxic; genotoxic; carcinogenic	1	A (medium)	4.4–7.5	8.3	29	18 (now) 3.6 (goal)	10 (now) 5 (2010)	18	–	–
1,3-Butadiene	Neurological; irritation of eyes, throat, lungs and nose; mutagenic; carcinogenic (?)	2A	B2 (medium)	–	280	170	2.4	–	24	–	–
Formaldehyde	Irritation of eyes, throat, nose and respiratory symptoms; nasal cancer	2A	B1 (medium)	Very low	13	6	–	–	9.2	100 normal 10 hypersensitive (30-min)	–
Acetaldehyde	Irritation of eyes, throat, nose and respiratory system; nasal cancer	2B	B2 (low)	15–90	2.2	2.7	–	–	3600	2400 (24-hour)	9 (RfC)
Benzo(a)pyrene	Dermatitis; photosensitisation; eye irritation; cataracts; lung cancer (?)	1	B2 (medium)	87,000	–	–	–	–	–	–	–
Mercury**	CNS; gastrointestinal; respiratory system; kidney	2B(m) 3(I)	C (medium) D (low)	–	–	–	–	–	0.1(al) 0 25(I) 1.0(ar)	1(I)	0.3(I) (RfC) 0.3(I) (REL)
Chromium VI	Respiratory; gastrointestinal; liver; kidney; immune system; blood	1	A (high)	11,000–130,000	1200	150,000	–	–	0.1–0.5	–	0.0023
Chromium III and metal		3	D	–	–	–	–	–	5.0	–	–
Arsenic (inorganic)	Gastrointestinal; haemolysis; central and peripheral NS; eyes; skin; mucous membrane	1	A (high)	1500	4300	1500	–	–	0.1	–	0.41 (REL)
Arsine									1.7	–	0.055 (RfC)

* IARC classes and US EPA equivalents are as follows.

IARC	Descriptor	USEPA
1	The agent (mixture) is carcinogenic to humans. The exposure circumstances entail exposures that are carcinogenic to humans.	A
2A	The agent (mixture) is probably carcinogenic to humans. The exposure circumstances entail exposures that are probably carcinogenic to humans.	B1
2B	The agent (mixture) is possibly carcinogenic to humans. The exposure circumstances entail exposures that are possibly carcinogenic to humans.	B2, C
3	The agent (mixture or exposure circumstances) is not classifiable for humans.	D
4	The agent (or mixture) is probably not carcinogenic to humans.	E

** Abbreviations for mercury: Organic (o) = [methyl (m), aryl (ar), alkyl(al)]; Inorganic (I) = elemental and other inorganic compounds.

For more information about these contaminants, please read Air Quality Technical Report 13.

Appendix 4: Basis for the guideline values for the new air contaminants

Contaminant	Guideline values (μg/m³)		Implied risk (per 10^6)	Levels for risk of 1 in 10^6 (μg/m³)	Ambient levels (annual average, or as specified)	Comment
	Ambient (annual average)	Basis				
Benzene	10 (now) 3.6 (2010)	EC (now) UK (long-term goal)	44–75 (WHO) 16 (WHO)	0.13–0.23	~ 7 (urban) 20+ (traffic)	
1,3-Butadiene	2.4	UK	17–72 (RIVM) 670 (US EPA)	0.03–0.14 0.0036	~ 1 (24-hour)	
Formaldehyde	15	WHO (health) converted	196 (US EPA)	0.077	12 (17-day) ~ 30 (1-hour)	
Acetaldehyde	30	WHO (health) converted	450–2700 (WHO) 66 (US EPA)	0.001–0.067 0.45	No NZ data US ~ (2–4)	
Benzo(a)pyrene	0.0003	Risk of 2–3 in 10^5 assumed acceptable	26 (US EPA)	0.00001	7–72 (24-hour)	
Mercury (organic)	0.13	TWA/100	–	–	No urban data	
Mercury (inorganic)	0.33	TWA/100	–	–	< 50 (7-day)	
Chromium (VI)	0.0011	Assume risk of 1 in 10^5 is acceptable (between WHO and US EPA)	12–140 (WHO)	0.000007–0.00009	No NZ data	Ignores dietary intakes
Chromium (metal and III)	0.11	100 x Cr (VI)	1.3 (US EPA)	0.00083		
Arsenic (inorganic)	0.0055	Risk of 1 in 10^5 assumed acceptable (between WHO and US EPA)	8.3 (WHO)	0.00067	No NZ data	
Arsine	0.055	RfC (US EPA)	24 (US EPA)	0.00023		

Glossary

Ambient air	The air outside buildings and structures. This does not refer to indoor air, air in the workplace, or contaminated air discharged from a source.
Critical level	The concentration in ambient air above which adverse effects may occur to vegetation.
Critical load	An exposure, in the form of deposition, to one or more pollutants, below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.
Dispersion modelling	A computer modelling technique used to predict downwind concentrations of air contaminants from a known discharge rate, height and temperature.
Emission	The discharge of contaminants into the air.
Guideline value	A concentration value, and averaging period over which it applies, for assessing and managing ambient air quality.
Hui	Gathering to speak and share ideas and thoughts.
Indicator	A contaminant that can be used as an indicator of other contaminants.
Kainga	Home area, including dwelling and gardens.
Kaitiakitanga	Means the exercise of guardianship; and, in relation to a resource includes the ethic of stewardship based on the nature of the resource itself (section 2 RMA).
Mahinga kai	Food gathering, processing or preparation site.
Marae	Significant gathering area of whanua, hapu or Iwi-connected usually with an Ancestor
Maximum Design Concentration	A value specifying a concentration and averaging time that is used to assess the results of atmospheric dispersion modelling.
Percentile	A statistical value that represents a distribution of data – in this case of ambient air concentrations. For example, the 99.9 percentile represents the ninth-highest result from a years worth of one-hour monitoring data.
Reduction strategy	One or more measures implemented through: regional air plans, policy statements, education programmes, incentive schemes, national regulations or national policies, to reduce emissions and manage air quality.
Reduction target	A percentage reduction in emissions required from different sources to achieve a guideline value or regional criteria.
Regional criteria	Region- or air shed-specific, concentration-based criteria specified in regional air quality plans or policy statements.
Rohe	Geographical boundary and the land, features and people within it.

Target date	Date by which a council or other agency aims to achieve a specific regional criterion or guideline value.
Taonga	Prized possession, treasure.
Waahi tapu	Sacred or significant site applying to various types of area. Iwi determines the use of the word.

Abbreviations

ANZECC	Australia and New Zealand Environment and Conservation Council
BaP	Benzo(a)pyrene
C_4H_6	1,3 Butadiene
C_6H_6	Benzene
CARB	Californian Air Resources Board
CNS	Central nervous system
CO	Carbon monoxide
COHb	Carboxyhaemoglobin
COPD	Cardio-pulmonary obstructive disease
Cr	Chromium
EECA	Energy Efficiency and Conservation Authority
EPAQS	Expert Panel on Air Quality Standards (UK)
EPI	Environmental Performance Indicator
ERMA	Environmental Risk Management Authority
FEV_1	Forced expiratory volume in one second
H_2S	Hydrogen sulphide
Hb	Haemoglobin
HCHO	Formaldehyde
HSNO	Hazardous Substances and New Organisms Act 1996
IARC	International Agency for Research on Cancer
LOAEL	Lowest observable adverse effects level
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
O_2	Oxygen
O_3	Ozone
PAH	Polyaromatic hydrocarbon
$PM_{2.5}$	Particulate matter with diameter less than 2.5 μgm^{-3}
PM_{10}	Particulate matter with diameter less than 10 μgm^{-3}
REL	Reference exposure level
RfC	Reference concentration
RfD	Reference dose
RMA	Resource Management Act 1991
SO_2	Sulphur dioxide
UNECE	United Nations Economic Commission for Europe
US EPA	United States Environmental Protection Agency
VFECS	Vehicle Fleet Emission Control Strategy
WHO	World Health Organization

References

A'Hearn T, Robins W, Rolfe K. 2000. *Preliminary Review of Strategies for Managing Air Quality*. Air Quality Technical Report 14. Prepared for the Ministry for the Environment, Wellington.

Bullen S, Jacobsen V, Palmer G, Scrimgeour F. 2000. *The Use of Economic Instruments for the Control of Air Quality in Auckland: A scoping study*. Prepared for the Auckland Regional Council, Auckland.

California Air Resources Board. 1998. *Toxic Air Contaminants Fact Sheets.*

Chiodo J, Rolfe K. 2000. *Health Effects of Eleven Hazardous Air Contaminants and Recommended Evaluation Criteria*. Air Quality Technical Report 13. Prepared for the Ministry for the Environment, Wellington.

Denison L, Rolfe K, Graham B. 2000. *Health Effects of Five Air Contaminants and Recommended Protective Ranges*. Air Quality Technical Report 12. Prepared for the Ministry for the Environment, Wellington.

Environment Protection Authority Victoria. 1985. *Plume Calculation Procedure: An approved procedure under schedule e of the state environment protection policy (The Air Environment).* EPAV publication No. 210. Melbourne, Australia.

Fisher G, Austwick C, Bird M, Rolfe K, Kerschel G, Simpson J. 1998. *The Use of the Ministry for the Environment's Ambient Air Quality Guidelines for Air Quality Management in New Zealand.* Unpublished report prepared for the Ministry for the Environment, Wellington.

International Agency for Research on Cancer (IARC). 1998. *List of IARC Evaluations.*

Ministry for the Environment. 1994. *Ambient Air Quality Guidelines.* Ministry for the Environment, Wellington.

Ministry for the Environment. 1995a. *Odour Management Under the Resource Management Act.* Ministry for the Environment, Wellington.

Ministry for the Environment. 1995b. *Principles and Processes for Developing Guidelines and Standards*. A position paper, October 1995. Ministry for the Environment, Wellington.

Ministry for the Environment. 1997a. *Environmental Performance Indicators: Proposals for air, freshwater and land. Signposts for Sustainability*. Ministry for the Environment, Wellington.

Ministry for the Environment. 1997b. *Health and Environmental Guidelines for Selected Timber Treatment Chemicals.* Ministry for the Environment, Wellington.

Ministry for the Environment. 1998a. *Compliance Monitoring and Emissions Testing of Discharges to Air.* Ministry for the Environment, Wellington.

Ministry for the Environment. 1998b. *Emissions Testing and Compliance Monitoring of Discharges to Air.* Ministry for the Environment, Wellington.

Ministry for the Environment. 1998c. *State of New Zealand's Environment Report*. Ministry for the Environment. Wellington.

Ministry for the Environment. 1999a. *A Guide to Preparing a Basic AEE.* Ministry for the Environment, Wellington.

Ministry for the Environment. 1999b. *Auditing Assessments of Environmental Effects: A good-practice guide.* Ministry for the Environment, Wellington.

Ministry for the Environment. 1999c. *Climate Change: Domestic policy options statement*. Ministry for the Environment, Wellington.

Ministry for the Environment. 1999d. *Environmental Education: A guide for programme providers – how to develop, implement and evaluate strategies and programmes*. A Sustainable Management Fund project. Ministry for the Environment, Wellington.

Ministry for the Environment. 2000a. *Good-practice Guide for Ambient Air Quality Monitoring and Data Management.* Air Quality Technical Report 10. Ministry for the Environment, Wellington.

Ministry for the Environment. 2000b. *Meeting Notes and Analysis of Reviewers' Comments.* Air Quality Technical Report 22. Ministry for the Environment, Wellington.

Ministry for the Environment. 2000c. *Proposals for Revised and New Ambient Air Quality Guidelines.* Discussion document. Air Quality Technical Report 16. Ministry for the Environment, Wellington.

Ministry for the Environment. 2000d. *What Are the Options? A guide to using Section 32 of the Resource Management Act.* Ministry for the Environment, Wellington.

Ministry for the Environment. 2001a. *Good Practice Guide for Assessing and Managing the Environmental Effects of Dust Emissions.* Air Quality Technical Report 21. Ministry for the Environment, Wellington.

Ministry for the Environment. 2001b. *Good Practice Guide for Monitoring and Management of Visibility in New Zealand.* Air Quality Technical Report 31. Ministry for the Environment, Wellington.

Ministry for the Environment. 2001c. *Summary of Submissions Received on the Discussion Document and Proposals for Amendments.* Ministry for the Environment, Wellington.

Ministry for the Environment. 2001d. *An Action Plan for Reducing Discharges of Dioxin to Air*. Ministry for the Environment, Wellington.

Ministry of Transport. 1998. *Local Air Quality Management: Impacts from the road transport sector. Vehicle Fleet Emissions Control Strategy – final report.* Prepared by the Ministry of Transport with technical assistance from Fuels and Energy Management Group, Wellington.

NIWA. 1997. *Guidelines for the Use of Dispersion Models*. Prepared for the Sustainable Management Fund administered by the Ministry for the Environment, Wellington.

Rolfe K. 2000a. *Meeting Notes and Analysis of Reviewers' Comments*. Air Quality Technical Report 22. Prepared for the Ministry for the Environment, Wellington.

Rolfe K. 2000b. *Recommended Amendments to the Ambient Air Quality Guidelines 1994*. Air Quality Technical Report 23. Prepared for the Ministry for the Environment, Wellington.

Stevenson C, Hally V, Noonan M. 2000. *Effects of Air Contaminants on Ecosystems and Recommended Critical Levels and Critical Loads.* Air Quality Technical Report 15. Prepared for the Ministry for the Environment, Wellington.

Sullivan R, Beudeker B. 1999. New directions in air quality impact assessment in Australia. *Clean Air* 33: 3.

UK Expert Panel on Air Quality Standards. 1998. *Recommendation for a United Kingdom Air Quality Standard for 1,3-Butadiene.* Department of the Environment, Transport and Regions, United Kingdom.

US Code of Federal Regulations, 40 CFR Part 58 – Ambient Air Quality Surveillance.

US Code of Federal Regulations, Appendix W to CFR Part 40.

US Environmental Protection Agency. 1993. *Reference Dose (RfD): Description and Use in Health Risk Assessments.* Integrated Risk Information System.

US Environmental Protection Agency. 1998. *Draft Integrated Urban Air Toxics Strategy.* Federal Register: 63 FR 49239-49258.

World Health Organization. 1996. *Proposed Air Quality Guidelines for Europe.* World Health Organization Regional Office for Europe, Copenhagen.

World Health Organization. 1999. *Guidelines for Air Quality.* United Nations Environment Programme, International Labour Organisation and World Health Organization, Geneva.

Wilton E. 2001. *Good Practice Guide for Preparing Emission Inventories*. Prepared for the Minister for the Environment for the Sustainable Management Fund, Wellington. smf.govt.nz

About the Ministry for the Environment

The Ministry for the Environment works with others to identify New Zealand's environmental problems and get action on solutions. Our focus is on the effects people's everyday activities have on the environment, so our work programmes cover both the natural world and the places where people live and work.

We advise the Government on New Zealand's environmental laws, policies, standards and guidelines, monitor how they are working in practice, and take any action needed to improve them. Through reporting on the state of our environment, we help raise community awareness and provide the information needed by decision makers. We also play our part in international action on global environmental issues.

On behalf of the Minister for the Environment, who has duties under various laws, we report on local government performance on environmental matters and on the work of the Environmental Risk Management Authority and the Energy Efficiency and Conservation Authority.

Besides the Environment Act 1986 under which it was set up, the Ministry is responsible for administering the Soil Conservation and Rivers Control Act 1941, the Resource Management Act 1991, the Ozone Layer Protection Act 1996, and the Hazardous Substances and New Organisms Act 1996.

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