Ministry for the Environment
Manatū Mō Te Taiao

The Effects of Air Pollution on New Zealand Ecosystems

Summary of Findings and Priorities for Investigation

Prepared by Environmental Science & Research Limited in collaboration with the University of Waikato, Hort Research, the University of Queensland, Pacific Air and Environment and the Ministry for the Environment

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Air Quality Technical Report No. 4

Request for Comments

Maintaining New Zealand's biodiversity and healthy ecosystems, both natural and modified, are important goals for many New Zealanders and the New Zealand Government. Although major threats such as pests, weeds and deforestation pose the most immediate and widespread threats to New Zealand's ecosystems, the impacts of contaminants in the air should not be overlooked.

At this stage, research indicates that there are localised impacts of air pollution on ecosystems in and around large scale discharges of contaminants to air, and that the distribution of some sensitive species across cities is affected by the level of air quality. There is relatively little information about the significance of potential region-wide contaminants such as ozone and about the potential sensitivity of New Zealand species to air pollutants. This lack of information and expected increase in emissions of contaminants with the potential to affect ecosystems, such as nitrogen dioxide, emphasise the need to investigate these issues.

This is the fourth report in a series of reports by Environmental Science Research Limited (ESR) into the effects of air pollution on ecosystems in New Zealand. The reports also include a review of information, discussion of the situation in New Zealand and notes from a focus group meeting. They provide a comprehensive starting point for stimulating debate and discussion on how to manage the potential effects of air quality on New Zealand's ecosystems. It is expected that the outcomes of this project will be used in the Ministry's review of the ambient air quality guidelines.

The Ministry for the Environment is seeking your comments and views on:

- the interim conclusions drawn by ESR about the current situation in New Zealand, and
- the recommended priorities for further investigations and tool development for air quality managers.

Although the Ministry sees the priority for this project as being the development of national policy it should be possible, and is indeed necessary, to promote and facilitate further scientific research and to develop useful tools to assist industry and councils in assessing environmental effects and monitoring programmes.

Feedback is especially sought on the desirable nature and form of "tools". Tools can include guidance on bio-monitoring, techniques for estimating contaminant deposition and recommended sampling methodologies etc. The detailed research investigations recommended as Priorities 3 and 4 in this report are seen as important by the Ministry, however, they are beyond the scope of the current Ministry's work programme. The identification and prioritisation of these scientific investigations will be useful for

organisations responsible for considering research priorities such as the Ministry of Research, Science and Technology.

If you are interested in receiving all the reports please contact Caroline Austwick via email on caroline.austwick@mfe.govt.nz or telephone (04) 917-7475 or facsimile (04) 917-7523. The reports are available either as a hard copy or electronically. They can also be down loaded from the Ministry for the Environment's Website at www.mfe.govt.nz.

Please provide comments by 1 May 1999.

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1 Introduction

Assessing the environmental effects of a discharge of contaminants into the air commonly focuses on determining the potential and actual human health or amenity effects. There is often little consideration of the potential adverse effects on ecosystems, including sensitive plant and animal species.

Consideration of the effects on ecosystems may be missing from decisions about air quality for a number of reasons:

- there is a sparse amount of readily accessible information on ecosystem impacts
- effects on ecosystems are not seen as a priority, particularly in urban environments, where potential effects on human health are considered most important
- the impacts are difficult to assess
- there is a lack of guidance and information on what constitutes a "significant" adverse effect of air pollutants on an ecosystem.

The Ministry's 1994 *Ambient Air Quality Guidelines* did not discuss ecosystem effects of the pollutants to any great extent. The exception to this was the guideline value for fluoride which was based on its effects on plants.

There is a growing body of evidence that suggests plants and delicately balanced ecosystems, are affected by levels of contaminants below those that cause human health effects. The relevant period of exposure may also be quite different for plants than for humans. Consequently, managing the air in accordance with the current Ambient Air Quality Guidelines for contaminants such as sulphur dioxide, ozone and nitrogen dioxide may not be sufficient to prevent adverse effects on sensitive plant life and fragile soil chemistry.

The Ministry aims to promote consideration of potential effects of discharges on ecosystems by developing and facilitating the uptake of useful information, guidance, and effective tools for air quality managers.

In summary, this project aims to:

- determine whether and where air pollution in New Zealand has the potential to cause adverse effects on ecosystems
- provide advice for air quality managers on how to assess air pollution effects on ecosystems and
- consider whether any air quality guidelines can be produced which will protect ecosystems.

The review, discussion and recommendations for further work in the next stage of the project have been developed by Institute of Environmental Science & Research (ESR) in collaboration with the Universities of Waikato and Queensland, Hort Research,

Pacific Air and Environment, and the Ministry for the Environment, air quality practitioners and interested parties from around New Zealand. So far, the project has involved the running of a workshop in Auckland and the preparation of four documents:

- *Review of National and International Research*
- *Interim Conclusions and Recommended Investigations*
- *Focus Group Meeting Notes*
- *Summary of Findings and Priorities for Investigation* (this report)

The first report is a review of several national and overseas studies on the effects of air contaminants on ecosystems. The second outlines what are considered to be the main issues for New Zealand, the role of air quality management, potential guidelines to protect ecosystems and options for further work. The third provides a summary of discussions at the focus group meeting held in Auckland. And finally, this fourth report prioritises further work and requests comments from air quality managers and scientists on the work so far and on future priorities.

This initial review and prioritising exercise takes a relatively wide approach. Ecosystems to be considered in the review include modified ecosystems, such as urban parks and agricultural crops, and natural ecosystems such as national forests. ESR were also asked whether it was possible to identify particular species that may be sensitive to the effects of air pollutants and whether any New Zealand native species would be especially sensitive, especially given the pristine environment in which they have evolved.

The work does not include a detailed assessment of the potential effects of agrichemical spray drift, although further investigation of spray drift effects is recommended. The assessment and management of agrichemicals is currently the focus of new regulations under the Hazardous Substances and New Organisms Act. Their use and management in New Zealand will come under the control of the Environmental Risk Management Authority in April 1999. The effects of ozone layer depletion or climate change on ecosystems was also not a priority for investigation in this project.

The project does not examine issues concerning air pollution and its effects on Maori values of fauna and flora, and ecosystems. An investigation of Maori values and air quality, and how to incorporate Maori views and consultation into the review of the air quality guidelines is being pursued as part of the Review of the Ambient Air Quality Guidelines.

2 Effects of Air Quality on Ecosystems in New Zealand

The most critical factors involved in air pollution effects on ecosystems in New Zealand are described in the reports prepared by ESR and the summary of discussions at the focus group meeting. They can be conveniently divided into whether the state of air quality in New Zealand is bad enough to affect ecosystems, and to what extent New Zealand ecosystems, including native species, are sensitive to air pollutants and have already been affected. Each of these will be discussed briefly. The third part of this section discusses the current development of ambient air quality guidelines to protect ecosystems.

2.1 The state of New Zealand's air quality

The air quality situation in New Zealand is significantly different from other northern hemisphere countries that experience, or have experienced, severe impacts of air pollution on ecosystems. These differences must be taken into account when deriving conclusions from overseas research about effects and possible policy options for New Zealand. The main differences are as follows:

- New Zealand has a small population and lack of major heavy industry resulting in air pollution levels that are generally lower than more populated parts of the world. For example, urban background sites in New Zealand typically measure levels that are similar or less than rural background sites in the United Kingdom.

- Compared to Europe and North America, New Zealand has a short history of adverse air quality effects, due to the (historically, anyway) lower vehicle usage and relatively recent development of heavy industry.

- The isolated location, shape and size of New Zealand prohibits the long-term, cross-boundary transport of air pollution plumes, often responsible for acid deposition seen over large continents.

- With the exception of ground level ozone, most air pollution effects will be limited to within 10-20kms of major sources, such as large cities (e.g. Auckland and Christchurch) and large-scale industrial discharges.

- In New Zealand, generally low pollution levels combined with, for the most part, relatively undisturbed and good buffering capacity of soils, reduces the risk of significant chemical imbalances (caused by acid deposition) and its consequent flow-on effects on ecosystems that are seen in Europe.

- Plants in Europe, particularly trees, are most severely affected by high levels of NO_x and SO_2 in winter months when they are not actively growing. These high levels result in a higher potential for plant damage and because they are not actively metabolising, they cannot repair any damage suffered. While similar climatic

conditions exist in New Zealand, they do not appear to coincide with high levels of air pollution and acid deposition.

In summary, ecosystems which may be affected by air pollution include:

- ecosystems in urban areas such as residential gardens, urban parks, and environments around industrial discharges.
- ecosystems such as World Heritage Areas, National and Regional Parks and agricultural land that lie downwind from large scale discharges and urban areas
- any ecosystems which possess an inherent "fragility", such as acid soils that are near to pollution sources, and
- ecosystems downwind from geothermal areas or volcanic eruptions.

The reports note that the contaminants of highest regional concern include ozone and nitrogen species, including ammonia. Whereas, locally around one or two major discharges, sulphur dioxide, fluoride, heavy metals, boron and other hazardous air pollutants have the potential to cause significant adverse effects. Ecosystems down wind from geothermal areas and volcanic eruptions were also highlighted as potentially impacted by hydrogen sulphide. Although where they exist near long term geothermal areas they are likely to be adapted to the contaminated air environment.

Wet deposition (commonly called acid rain) is unlikely to occur in sufficient amounts in New Zealand to cause adverse effects. Generally sulphur dioxide emissions and concentrations are low and by the time sulphur dioxide in the air converts to sulphuric acid it has probably been well dispersed and transported out to sea. However, there may be some acid deposition when high pollution levels coincide with periods of high rainfall or fog. Areas where this could occur include the Hunua Ranges near Auckland and the Port Hills in Christchurch.

Dry deposition of sulphur on plants and soils can cause adverse effects. Dry deposition covers both deposition of particulate contaminants on plants and soils and uptake of gaseous constituents from the air. Sulphur is estimated to be 2 - 2.6 times more phytotoxic than nitrogen dioxide. Ecosystems surrounding large industrial discharges of SO_2, such as oil and coal-fired power stations and fertiliser plants, have the potential to be affected by dry deposition.

Measured and predicted ozone concentrations in Auckland and Christchurch can reach levels several times a year that are sufficient to affect sensitive plant species (based on international guidelines for ozone). However, there is insufficient information about ozone formation and its spatial distribution around major urban areas to undertake a proper assessment of potential ecosystem effects at this stage.

This lack of information available points towards the need for more studies into the *direct effects* of air pollution on New Zealand's ecosystems. However, it should be recognised that the levels of pollution in New Zealand, for the most part, will not be high enough to cause visible injury. As noted previously, the exceptions to this on a

regional scale are ozone and to a lesser extent nitrogen oxides, and locally, sulphur dioxide, fluoride, boron and other hazardous air pollutants.

2.2 The sensitivity of ecosystems in New Zealand

Ecosystems are highly complex entities. The vast array of interdependent interactions between organisms, climate, terrain, soil type and many other factors make them very difficult to investigate and understand. In terms of potential effects on New Zealand ecosystems, the review of overseas studies found that effects on plant species are more critical that those on animals. As a general rule, animals are affected either at higher levels than plants, or as a result of flow-on or accumulation effects within the ecosystem. Unlike plants, animals can escape from uncomfortable environments.

Plants are sessile and often long-lived organisms. They must possess sufficient genetic potential to enable them to adapt in order to survive any disturbance to the environment in which they live. Their structure means they are also a significant interceptor of air contaminants. Contaminants adversely affect plants via the following mechanisms:

- disruption to plant metabolism caused by the need to cope with increased intake of NO_x or SO_2.
- reproduction failure, e.g. flowering and seed-set, which may affect crop production
- regeneration failure, e.g. germination and re-establishment
- foliar damage, e.g. from ozone resulting in loss of productivity
- reduction in functional leaf area and vegetative growth
- potential acidification of the soil medium as a result of plant survival strategies
- the potential fertiliser effects to both the plant and the ecosystem, of all nitrogen species, including ammonia
- the potential for chemical imbalance effects resulting from increased loadings of contaminants on fragile ecosystems

With the exception of fluoride, there is little information on the effects of air pollution on New Zealand native species. And while there is quite substantial information on the effects on many crop and exotic plants grown in New Zealand, it is not known whether these plants are more sensitive to air contaminants than their northern hemisphere counterparts. For example, some plant species in the northern hemisphere have adapted to polluted environments.

Compared to those in the northern hemisphere, most plants in New Zealand are exposed to better growing conditions of high light levels accompanied by high soil moisture. Consequently they tend to grow very well. These different growing conditions can affect sensitivity to air contaminants.

Investigations into the effects of fluoride in New Zealand on around 60 plant species deduced that the following plant characteristics influence sensitivity:

- small-leaved plants are often more tolerant than large-leaved
- slow-growing plants are often more tolerant that fast-growing plants
- salt-tolerant species are more fluoride tolerant.

The study also found that fluoride levels in foliage were not directly associated with visible signs of injury. Using these general conclusions, other research and information on plant physiology could be used to identify species likely to be susceptible to other pollutants such as SO_2. However, projects such as this tend to be very expensive and limited to only one or two species, which may not be very useful when trying to determine the range of potential effects on an ecosystem as whole.

Soil characteristics, particularly its chemical balance, also influence an ecosystem's sensitivity to deposited contaminants. Some soils can buffer contamination such as acid deposition better than others without resulting in damage to the plants living in it. In New Zealand there may be some soils with low buffering capacity e.g. pakahi soils in northern kauri forests, that will be especially sensitive to the deposition of acid gases.

There is also relatively little information in New Zealand about the pathways along which contaminants enter and travel through the environment. For example, it is not clear what proportion of contaminants in an estuary are derived from vehicle exhaust emissions compared to other sources such as leaking oil and fuel tanks, industrial sites etc. Understanding such pathways can:

- enable pollution sources to be ranked in order of their percentage contribution
- assist in developing options for managing contaminants once they are released
- assist in developing appropriate ways to prevent contaminants from becoming an environmental concern.

Combining information on where air quality has the "potential" to cause ecosystem effects and on which plants/organisms are most likely to be affected can provide a suitable approach to understanding the level of potential problems and the need for management in New Zealand.

2.3 Potential Air Quality Guidelines

The findings of ESR's review closely agrees with the draft 1996 World Health Organisation's (WHO) guidelines that consider effects on ecosystems, rather than individual plant species. These draft guidelines recommend a critical loadings approach to assessing ecosystem sensitivity and potential effects of pollution. This is particularly the case for nitrogen and sulphur. Unfortunately, at this time only summary information is available from the WHO, and it is desirable to evaluate their supporting documentation.

ESR have made contacts at the WHO in Holland, who are aware of the interest in their supporting documentation in New Zealand. As soon as this information is public, its relevance to the New Zealand situation can be assessed.

In terms of revising the current New Zealand *Ambient Air Quality Guidelines*, ESR recommend that the revised 1996 WHO guidelines be used as a guide (when they become available) until more specific New Zealand-based investigations are completed.

Such guidelines and guidance material on how they should be used in decision-making, also provide valuable tools for councils and others responsible for air quality management. They will indicate when a level of a contaminants in the environmental poses a significant risk and the discharge should not be allowed to continue or mitigation is required. Although the use of international guidelines is not ideal, it may be the best approach given that it may take a number of years before appropriate New Zealand specific information is available.

3 Current work in New Zealand

This section will briefly outline recent and current work into the effects of air quality on ecosystems in New Zealand.

Landcare Research (funded by the Minister for the Environment's Sustainable Management Fund) recently completed a study on the use of bio-indicators in environmental monitoring. They investigated the effects of air pollution on lichens and some other organisms in New Zealand. They found several areas around industrial sites referred to as "lichen deserts". These areas contained virtually no lichen on trees and rocks, although one particular algae species was prevalent. With distance away from the discharge, lichen biodiversity and coverage gradually increased, roughly mirroring the prevailing wind conditions. They also found that lichen biodiversity and coverage patterns roughly mirrored contaminant levels across Auckland and Christchurch.

Lichens are useful bio-indicators of air quality, however, other influencing factors, such as light, growing surface and climatic conditions, need to be taken into account when drawing conclusions about how they indicate air pollution levels.

Based on Landcare's work, lichen biodiversity and coverage is proposed as a Stage 2 indicator of air quality for the Environmental Performance Indicators Programme. It is proposed as a Stage 2 indicator because further work is required to:

- refine the monitoring methods
- understand the physiological mechanisms causing the lichen reactions
- correlate ambient contaminant concentrations with observed effects and
- determine the "significance" of potential impacts.

There are several large-scale industrial sites in the Taranaki Region. For some time now the Taranaki Regional Council has required bio-monitoring as a condition of resource consents for discharges from these sites. They include gas-fired thermal power stations, an agrochemical formulations plant, several petrochemical sites, and a metals re-smelting plant. The bio-monitoring required by consent conditions includes lichen surveys and vegetation and soil sampling for certain contaminants at both potential impact zones and control sites. This information is used to:

- assess whether there are any ecological effects (cf 2 (c), fourth schedule RMA),
- track changes in the environment over time caused by the discharge or,
- identify improvements following addition of abatement systems.

If trending towards an adverse effect, the bio-monitoring results can be used to initiate a review of consent conditions. Some other regional councils, including Northland Regional Council, also require bio-monitoring using lichens and Southland Regional Council requires sampling of fluoride concentrations in fauna and flora around an aluminium smelter.

Bio-monitoring can demonstrate trends over time and indicate that there an "effect" is occurring. However, we need to develop consistent monitoring methods and to consider what constitutes a "significant" effect and therefore whether there is a problem that needs to be dealt with. To do this, the results must be compared to some form of guideline value. For this reason, potential guideline development is a focus of this project and will be discussed later in more detail.

Contaminant pathways are currently being investigated by the National Institute of Water and Atmospheric Research (NIWA) as part of a project entitled "Mitigating Contaminant Effects in Urban Aquatic Habitats" for the Public Good Science Fund. Part of this project aims to develop a model to predict the fate of transport-generated contaminants in the environment (looking at exhaust emissions, tyre wear, oil leaks and brake lining wear etc) and to investigate the pathways along which contaminants enter and move through the environment.

As discussed earlier, there has been little work on the relative sensitivity of New Zealand species compared to those overseas. Some preliminary work at the University of Waikato (Allen Green personal communication with ESR) found that New Zealand lichens may be more sensitive to air contaminants than similar lichens in Europe. However, this needs to be clarified through controlled exposure experiments and further investigation of the actual physiological mechanisms affecting lichen growth and colonisation. There does not appear to be any current projects investigating the sensitivities of plants growing in New Zealand (where they have been exposed to low, if any, levels of air pollution) compared to those growing in the heavily industrialised countries of the northern hemisphere.

Auckland Regional Council is undertaking further monitoring of ozone levels and this work should determine whether ozone is an issue in and around Auckland.
However, more monitoring and possibly modelling is needed to determine whether ozone poses a significant risk to ecosystems in New Zealand.

4 Main Information Gaps

The review has identified many areas that need to be investigated to get a better understanding of ecosystem effects of air quality. The discussions have mainly centred on two different approaches to prioritise further work.

Broadly, we could treat species as individual indicators of the effects of air quality, in which case the following work should be undertaken:

- identify locations where effects-causing levels of pollution occur
- identify native New Zealand plants that may be affected by pollutant exposure and test their responses
- identify crops that may be at risk and test their responses
- identify exotics species and test their responses.

Or, preferably, we can take the approach that the ecosystem as a whole becomes the indicator. In this case we need to:

- clearly identify locations where effects-causing levels of pollution occur
- identify and rank specific ecosystems to their sensitivity to air pollutants
- calculate existing inputs of air pollutants, e.g. NO_x, NH_4, SO_2
- calculate input tolerance levels for each ecosystem "type".

Gaining a holistic picture of the functioning of the ecosystems will provide the best management tool and will ultimately be the most cost-effective approach. However, it is still important to improve our understanding of the reactions of certain plants to pollution exposure in New Zealand, particularly with regard to ozone exposure.

It makes sense to make expedient use of the most efficient management tool, the ecosystem, as the indicator of adverse effects. This approach is particularly valuable when dealing with risks from deposition of potential nutrients, in particular, nitrogen and sulphur. It does not, however, provide the best approach to minimising damage caused by ozone or other hazardous air pollutants. Further work on investigating ozone levels and their spatial distribution is under way and, when sufficient data is available, it could be used to assess potential impacts. However, more information on background and potential impact site levels is required, along with an assessment of key species sensitivities.

In terms of management of nitrogen and sulphur deposition, research priorities should include:

- classifying ecosystems based on nutrient status
- classifying soil types with regard to buffering capacity

- integrating the two above to identify ecosystems at risk
- identifying the processes which incur the risks
- identifying those ecosystems most at risk from atmospheric disturbance.

It is proposed that a major priority for this project should be the development of tools and techniques required to undertake the above assessments and classifications.

The management of damage to plants caused by ozone exposure is far less predictable. Since very little is known of ozone "episodes" in New Zealand, modelling and measurement of this potential needs to be undertaken in order to provide real information on the potential risk. Also, since nothing is known of the response by plants growing in New Zealand conditions to ozone exposure, a carefully considered research programme to investigate levels of tolerance is required.

Possibly one of the most important gaps is the lack of consideration of effects on ecosystems in the current *Ambient Air Quality Guidelines*. As noted previously, the main focus of this work is to address this major gap and also recognise other issues that require further investigation.

5 Recommended Investigations in Priority Order

Priority One

National Policy Development

1(a) Assess the applicability of the draft WHO guidelines and supporting studies for New Zealand to provide input into the Ministry's review of the *Ambient Air Quality Guidelines.*

1(b) Provide guidance on how WHO guidelines could be used regional plan development, assessing effects and making decisions about resource consents.

Priority Two

Develop Tools/Methods for Assessing Effects of Discharges on Ecosystems

Develop information, guidance and tools to assist councils to assess the local impacts of air quality on ecosystems, particularly for point sources discharges. Recommended work includes:

2(a) Review methodologies for estimating nitrogen and sulphur loadings to ecosystems.

2(b) Evaluate options and recommend the best approach to assessing the potential adverse effects of priority contaminants in different ecosystems.

2(c) Evaluate and/or develop convenient and reliable inexpensive sampling/analysis methods for measuring air concentrations and ecosystem uptake of contaminants, including bio-monitoring.

2(d) Develop methods for assessing existing sources, cycles and sinks.

2(e) Review methods for measuring long-term concentrations of nutrient and acid gases and particles, with assessments of possible ecosystems inputs and impacts.

2(f) Review available information on nutrient and alkaline ion catchments (water quality information) discharges to define potential sensitivities in ecosystems.

2(g) Define air composition, deposition mechanisms, deposition modelling for specific ecosystems.

2(h) Review effective settling velocities, with reference to varying meteorological conditions, to define simple approaches.

2(i) Assess ways to measure cycling and accumulation in specific ecosystems.

2(j) Review the impact of agrichemical spray drift on ecosystems and review methods for assessing the impacts of spray drift.

Priority Three

Research Objectives

To understand the potential for contaminant concentrations in New Zealand to affect ecosystems and plants, the following research is recommended:

3(a) A comprehensive review of all ozone monitoring or modelling done in New Zealand

3(b) An evaluation of the best methodology for predicting ozone impact

3(c) Identification of major ozone precursor sources

3(d) Plan ambient monitoring sites according to the above predictions

3(e) Include indicator plants at the above sites, to assist in evaluation of ozone damage to existing plant communities

3(f) Identify key plants and undertake exposure trials to determine tolerance levels.

Priority Four

Investigate Plant Sensitivities

To investigate the mechanisms that cause plant or ecosystem damage and to identify potentially sensitive species, the following work is recommended:

4(a) Divide plants into classes based on their utilisation, e.g. commercial crop species, ornamental and native species, and using available information (literature, personal knowledge), rank species according to expected vulnerability and potential for exposure to pollution. Use this as a guide to select test species.

4(b) Plan controlled exposure experiments to determine species sensitivities

4 (c) Undertake an investigation to determine suitable plant indicators

ESR consider that all work identified above can be carried out in New Zealand. Experience in the design and operation of controlled exposure trials can be accessed in Australia, or other overseas countries.