Ministry for the
Environment
Manatū Mō Te Taiao

The Effects of Air Pollution on New Zealand Ecosystems

Focus Group Meeting Notes

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

July 1998

Air Quality Technical Report No. 3

ESR FOCUS GROUP MEETING 30 JUNE 1998

Introduction
Caroline Austwick asked for direction and guidance in relation to the aims of the current project, namely the review of ambient air quality guidelines (AAQGs) for New Zealand, with emphasis on issues extending beyond human health, and including the notion of environmental and amenity values. Inputs from regional councils and industry were critical to this process, as these are the groups that must implement AAQGs.

Discussion Presentations

1. Air Pollution potential - Robin Ormerod
This contribution stimulated discussion on air pollution potential. Pages 5 and 6 of the discussion document referred to air pollution sources. John Hay indicated that a National Pollutant Inventory had been conducted by a student at the University of Auckland, and the results were being published by NIWA. NIWA had also indicated that work was needed on photochemical pollutant formation in Auckland, Christchurch and Hamilton. The sea breeze conditions make Auckland different from most other areas, and further modelling of the effects is recommended.

Other issues included: Local effects of pollutants in hilly country may be different from the usually modelled situations. Pollutants are released from volcanic activity, with very large quantities of SO_2 being released rarely, and much smaller quantities of H_2S being released continuously.

2. The New Zealand Air Pollution Situation - Craig Stevenson

Craig Stevenson presented a review of the data available. The general background levels of pollution in New Zealand are low, due to the relatively small populations of most cities, the short wind trajectory across the country under most common meteorological conditions, and the distribution of cities across rather than along the paths of wind movement.

One of the most polluted environments in New Zealand was indicated to be St Albans, Christchurch. Patterns of pollutant concentration were compared with AAQGs. In Auckland, about 10 days per year were identified as having ozone pollution potential as a result of the maximum one-hour ozone concentrations.

Passive samplers were discussed in relation to their use for a national monitoring network for the SO_2 and NO_x. These offer an economical means of determining long-term average concentrations, which are usually the major concern (except for ozone) for assessment of possible ecosystem effects. Sulphur dioxide concentrations other than in the vicinity of discreet sources are commonly too low to be measured either by passive samplers or instrumental monitoring. Nitrogen dioxide can be measured readily, and excellent correlations with instrumental monitoring are obtained. However, for assessment of ecosystem effects, rather than human health, nitric oxide concentrations are also of interest. ESR is currently evaluating a commercially available NO_x passive sampler, so that it may prove possible to obtain concentrations of both nitrogen dioxide and nitric oxide, using pared nitrogen dioxide and NO_x passive samplers. Alternatively, consideration of instrumental monitoring results indicates that, as the distance from the original nitrogen oxides emissions sources increases, progressive oxidation of nitric oxide to nitrogen dioxide means that, for regional surveys passive sampling for nitrogen dioxide gives a reasonable approximate estimate of NO_x, which is likely to be in the range 100-200% of the nitrogen dioxide concentration.

Reference was made to the McKendry Report on ozone potential for Auckland, Christchurch and Hamilton, and the importance of associating ozone potential contributed by meteorological and topographic conditions with the potential associated with precursors such as motor vehicles. The acid precipitation scenario was discussed, with reference to conversion of SO_2 to H_2SO_4, which in a typical NZ setting is expected to occur at a rate that would be expected to result in 10% conversion during the passage of an air stream across New Zealand, provided that the source was on the windward side of the country, and allowing for about 10 hours for passage across the country under a mean wind speed of 5 m/s.

Conversion of H_2S from geothermal sources was questioned.

3. Plant Physiological Responses - Alan Green

Plant structures and processes influencing exchange of air pollutants with plant were presented, and the importance of critical parts of the supply process were emphasised. Cuticular and stomatal transfer were considered, and the importance of the large area of absorbing surface within leaves was stressed. In addition, roots have large (possibly equally large) absorbing surfaces which exchange nutrient ions and hydrogen ion with the soil. Studies on air pollutant effects must consider the whole plant, and its relationship with the soil as well as the air, as many of the pollutant problems in Europe have been associated with perturbation of nutrient supplies, rather than direct effects of the air pollutants on metabolism of the aerial parts of plants.

One of the critical aspects of plant response is the amount of resources consumed during the process of repair of damage to existing organs (especially roots and leaves) and replacing these organs if they are damaged extensively. Under conditions where the normal growth rates or levels of reserves in the plants are limited, the additional stress imposed by an air pollutant may be inimical to plant survival. The capacity of New Zealand plant species to withstand air and soil stresses associated with air pollutants is largely unknown.

About half of the plant species occurring in New Zealand are exotic, so considerable amount of information on the sensitivity of plant species to air pollutants can be derived from overseas sources. However, the representatives of these species may not necessarily have the same sensitivities to pollutants as the populations occurring overseas. The local populations have been living in low-pollutant environments for over 100 years, and selection for pollutant resistance would not have occurred.

The importance of ecosystems in different situations was indicated. Urban ecosystems are those most threatened, agricultural and forestry ecosystems near urban areas are the next most affected, whilst those ecosystems near point sources of pollutants, ecosystems on disturbed sites, and ecosystems on acid soils may require special attention.

The assessment of effects was discussed, with attention being given to the difficulty of interpreting some physiological measurements (especially chlorophyll fluorescence as described in pages 11-14 of the Discussion Document). An important issue is the relationship between growth effects and other expressions of pollutant response. This relationship varies with pollutant, species, and accompanying environmental conditions, and these relationships need to be determined in some detail before they can be used for regulatory purposes.

4. Plant Response to Air Pollution - David Doley

Adverse effects of pollutants were discusses in relation to vegetation used for a range of purposes, and described in pages 27 and 28 of the Discussion Document. The important issue was the actions that would be required to avoid diverse effects in different situations, and also the scale of activity that would be regarded as requiring protection from adverse effects. Examples from adverse effects associated with fluoride exposure were discussed, including growth reduction, fluoride accumulation in foliage and visible injury.

Assessments of pollutant response require understanding of the baseline condition of the species or ecosystem - including the degree of variability that can be expected to occur with the passage of time or fluctuation in natural environmental conditions. The description of change could commence with the preparation of species lists for ecosystems, identification of those species for which some information on pollutant sensitivity is available, and recording of changes in vegetation structure or composition that occur over a period of time. Care must be taken to separate pollutant from non-pollutant effects. For example, the removal of grazing domestic animals from the Tiwai Peninsula has resulted in a substantial increase in the abundance of red tussock, and the increase in density of flax and shrub cover, independently of the existence of the aluminium smelter.

The training of industry personnel to recognise air pollutant injury, and to distinguish it from other environmental stresses was suggested if adverse effects assessments were to be based on visible injury symptoms. Other means of assessing adverse effects (ecological surveys, growth studies, etc.) would require more resources than visible injury assessment, but may be justified in some situations where the commercial or conservation value of an impacted ecosystem was high.

For rapidly-acting pollutants, such as ozone, the instantaneous concentration is very important, and below a threshold concentration, repair processes occur that remove the continuing impact of an air pollutant exposure. Plant response to multiple exposures depends on the magnitude of individual exposures, the time between successive exposures, and if mixed pollutants are present, the order of exposure, as well as the occurrence of stresses such as cold, drought and heat.

Accumulating pollutants, such as fluoride, affect plants differently from the labile pollutants, particularly ozone, and to a lesser extent, sulfur dioxide.

5. Assessment of Effects - Tord Kellstrom

Environmental health or performance indicators were needed, and could be modelled on those developed for human health assessment shown in Figure 1. This scheme (referred to as

DPSEEA) was preferred to the Pressure State, Response (PSR) model commonly used for environmental assessment, as it identified more clearly the processes that were affected, and the ways in which the response may be expressed.

The critical aspect is that attention is shifted from the process of regulation (Response) to the Effects on the system that is to be protected. These effects are not necessarily a simple function of the pressure, so that the condition of the object to be protected is modified under any given environmental state by the degree of exposure of the organism to that environmental state.

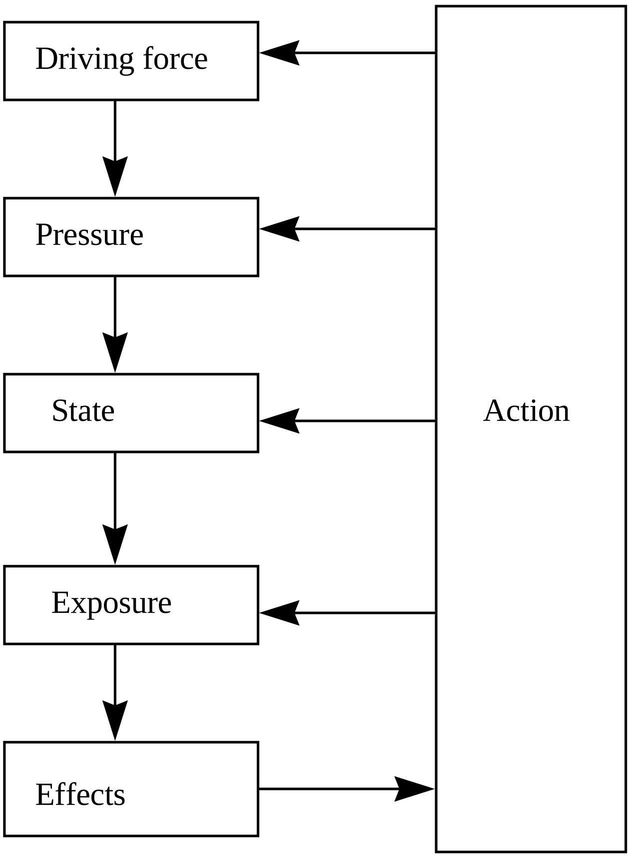

Figure 1. Relationship proposed between environmental pressures and responses to account for non-uniform environments in which target organisms may exist (from T. Kellstrom).

6. Biomonitoring/ bioindicating - Allan Green

Alan Green pointed out that biomonitoring had to deal with the fact that plant processes were buffered from the environment, and adaptive plant responses tended to minimise responses. Plant species or varieties that were particularly sensitive to a pollutant were the most useful monitors, as the purpose is to provide forewarning of injury to other organisms and/or humans.

Active monitoring, with plants introduced to an area and measured after a set exposure duration, and passive monitoring, with plants pre-existing in the area, were discussed. Passive monitoring was generally favoured, because this allowed for the variation in natural plant distributions, and did not require the same degree of attention as active monitoring.

Aspects of monitoring using different plant groups were discussed with reference to the Review Document (page 45 ff). Some work on biomonitoring existed in New Zealand, particularly in relation to distributions of lichens around point sources of pollutant. Species diversity and lichen species cover appeared to be reliable long-term indicators for sulfur dioxide and fluoride.

Different organisms are useful for different types of monitoring. For example, lichens respond relatively slowly to pollutants, because they are slow-growing, but they are very sensitive to pollutants such as sulfur dioxide and fluoride. As a result, they can indicate patterns of air pollutant distribution over a period of a decade or more, but may not be useful for monitoring on a day-to-day basis. This means that short term management decisions in industry cannot be based on lichen conditions, and even the short term air quality standards cannot be tested by this means.

On the other hand, some varieties of tobacco (notably Bel W3) are extremely sensitive to ozone, and demonstrate visible injury after exposure to concentrations of less than 0.1 ppm for less than one hour. Consequently, they can record ambient conditions on a time scale that is useful to industrial management. In the case of ozone injury to tobacco, the sources are most likely to be a very large number of motor vehicles, and their management on an hourly basis would require considerable social determination. However, their management on a daily basis is possible.

In the case of fluoride injury to sensitive plant species, responses may be rapid in some species and under some conditions. The management application of this information usually requires alteration of the processes that emit the fluoride, but since these can be identified, are usually small in number, and are under the control of industries, the management of emissions on a short-term basis is a realistic objective.

7. Ecosystem Functioning as a Biological Indicator - Craig Stevenson/Allan Green

Craig Stevenson and Alan Green presented impressions of thinking within the World Health Organization and European research groups concerning the use of ecosystem functions as criteria for the development of notions of environmental quality. That is, the ecosystem, rather than an individual species, becomes the indicator of environmental health. This approach is quite different from the notion that human health should be the cornerstone of environmental standard-setting, and even departs from the notion of assessing the pollutant sensitivity of individual species for this purpose. One of the most important shifts in perception is from the direct effects of a pollutant on various responses of individual plants, or populations of a species, to the effects of a pollutant on the flows of mass and energy in an ecosystem. In this way, species that may not be affected directly by the absorption of a pollutant from the atmosphere may be affected because of an increase or decrease in the availability of a nutrient from the soil. These changes in soil conditions have large, but commonly slowly developed or delayed effects on the relative growth rates of different species, leading to altered composition of an ecosystem. In New Zealand, one of the important effects of these nutritional changes may be to make the areas more suitable for establishment and growth of alien plants.

The essential aspect of ecosystem functioning for sulfur and nitrogen is the amount of each element that can be added to the ecosystem per year without causing deleterious changes in species functioning, and thereby species presence. The quantities of nutrients that can be added to different ecosystems without deleterious effects vary by an order of magnitude between low-nutrient native plant communities and high-nutrient agricultural ecosystems

Most attention at the Focus Group was concentrated on ecosystems that are naturally functioning at low levels of nutrient capital and input. The species in these systems are able to recycle a large proportion of their nutrients, but are commonly not competitive with species that function normally at higher levels of nutrition. In addition to these competitive effects of changed nutrient status through atmospheric additions, changes in the soil environment as a result of alteration of pH and consequently nutrient availability to the soil solution are important in determining the effects of pollutants. The changes typically have lead to increases in nitrate ion concentration in the soil solution, increasing the solubility of calcium and magnesium compounds, and resulting in the leaching of these minerals from the soil profile. The consequence of this is the appearance of nutrient deficiency disorders that are caused indirectly rather than directly by air pollution, rather than the effects of excesses of nitrogen or sulfur from the atmosphere.

The most susceptible ecosystems in Europe are heaths and bogs, in which cryptogams (mosses) and lichens are often abundant, and may be major components. It can be expected that similar ecosystems in New Zealand will also have very low nutrient turnover rates. If New Zealand were to adopt AAQGs to protect these ecosystems, it would be necessary to identify the systems clearly, and then to define in turn the critical nutrient loading rates, the associated ambient concentrations of sulfur and nitrogen, and the associated rates of emission from anthropogenic sources.

Agricultural ecosystems in New Zealand commonly require the addition of large amounts of nutrients, particularly in the form of superphosphate but also in the form of nitrogenous fertilisers, for their commercial viability under current economic conditions. The additions of nutrients to these ecosystems would exceed the rates that are acceptable for the maintenance of the naturally nutrient-poor systems such as heaths and bogs.

Clearly, the continuation of agricultural activity in New Zealand and the preservation of valuable biological entities require different environmental standards. This leads to the position that a uniform air quality standard or guideline may be inappropriate for the entire country.

8. Application of information - General Discussion

The meeting recognised that air quality had an important effect on land use in New Zealand in that certain land uses and certain ecosystems had species associated with them that are sensitive or potentially sensitive to air pollutants. The most appropriate means for protecting all or selected species in all or selected areas requires a clear path for decision making.

Pollutants of importance at a regional level are ozone and nitrogen species, including ammonia, whilst sulfur dioxide and fluoride are more restricted in their origin and impact.

Plant and lichen species are sensitive to air pollutants at concentrations that range from slightly to two orders of magnitude lower than concentrations that have adverse health effects on pollutant-sensitive humans, particularly if the most sensitive members of these plant and lichen species are considered.

For ozone, which acts very rapidly on biological structures and processes, but does not persist in living tissues, and can be metabolised to varying degrees by different tissues, the impact is dependent upon the amount of time for which ozone concentrations exceed critical or threshold levels. The threshold concentrations for the most ozone-sensitive plant species are close to the ambient concentrations reached during ozone episodes in Auckland. Different species, and different variety of some species (e.g. tobacco) vary in ozone sensitivity by a factor of about five.

Existing air quality standards (designed principally to protect human health) are unlikely to prevent adverse effects on the most pollutant-sensitive species of plants, lichens, or animals that may occur in any area.

Because of the variation in plant sensitivity to air pollutants, the application of uniform air quality standards protecting the most pollutant-sensitive plant species throughout New Zealand would result in the adoption of standards that would be very restrictive to many currently accepted rural, urban, domestic and industrial practices.

The resources required for a nationwide survey of ecosystems and the effects of air pollutants on them would be prohibitive, and it is suggested that a carefully designed series of studies on selected ecosystems will provide the information necessary to protect the most valuable and sensitive ecosystems. It is suggested that all ecosystems do not require the same degree of protection, so that a corollary of the process recommended is the establishment of air quality guidelines that are related to recognised land use categories, in a manner similar to those already adopted for fluoride. At this stage, the guidelines for ozone, sulfur dioxide and oxides of nitrogen are not specified, but the imminent World Health Organization guidelines and the following recommendations can provide a framework for developing national guidelines.

Possible Courses of Action

Option One
Because of the difficulty of assessing the sensitivity all possibly affected species to air pollutants through both direct effects and indirect, ecosystem effects, it is recommended that the primary focus in assessing possible effects of changed air quality on a particular ecosystem should be done through assessment of existing input and loss cycles for nutrients (particularly sulphur and nitrogen) and acid/base species. If the effects of the proposed air quality changes through the various forms of the deposition and uptake are restricted to a modest proportion of the existing annual cycles, there will be a good assurance of very small impacts on the ecosystem. Of course, "existing" will require definition, so that "creeping” degradation is not allowed where not intended, via multiple modest increments resulting in significant overall change.

In essence, this approach focuses strongly on the physics and chemistry of the ecosystem, on the basis that these are the factors which have controlled the biota present. If they are maintained, the ecosystem is unlikely to change.

Consideration of the more detailed information provided by WHO, in conjunction with information about New Zealand soils and fresh waters, the extent of sulphur emissions and the New Zealand geographic situation suggests that ecosystem acidification is unlikely to be a concern. Fertilisation effects, particularly from nitrogen are more likely to be significant, particularly in view of the development of much of the New Zealand flora in relatively low nitrogen conditions.

A key need is a better understanding of the sources, cycles and levels of nitrogen species in air and in ecosystems. It is likely to be much easier to develop a workable understanding of nitrogen inputs to ecosystems from air than it will be to establish rates of nitrogen loss from them, because of the complexities and inaccessibility of pathways in terrestrial systems.

Option Two
A possible course of action to establish appropriate air quality guidelines for different land uses and ecosystems with high conservation values would be to:

1. Identify land areas of high conservation significance, ranking them as being included in or suitable for inclusion in (a) World Heritage Areas, (b) National Parks, (c) Regional Parks, (d) Crown Land with public recreational value, (e) municipal land with recreational value.

2. Identify land areas of high commercial value (including urban, industrial, agricultural, forest), categorising them in terms of their profitability when managed in ways that result in currently acceptable environmental impacts.

3. Identify ecosystems in each of the conservation categories in paragraph 1 in which the natural availability and/or turnover of nutrient elements associated with air pollutants is limited. In particular, identify ecosystems in which nitrogen (as either nitrate or ammonium) and sulfur are recognised as the most limiting nutrients in this regard, although phosphorus may be a critical element in some areas adjacent to areas of intensive agriculture.

4. Conduct comprehensive ecological surveys of these areas, with reference to species

occurrence, abundance, plant and animal community structures, and indications of ecosystem stability (such as the temporal stability of the systems, success of reproduction, evidence of pollutant injury).

5. Assemble air quality data, or conduct macro- or meso-scale pollutant dispersion modelling, to indicate areas in which accessions of critical nutrient elements from air pollution may exceed the limits indicated in paragraph 3.

6. Identify ecosystems in conservation classes 1(a) and 1(b) which could be expected to be compromised by the predicted air quality conditions.

7. Compare the ecological data (cf. Paragraph 4) for these areas with data for similar areas not exposed or less exposed to air pollution.

8. Determine whether the differences in ecological condition of the selected areas can be attributed to air pollution. This determination may require carefully designed further detailed field observations and selective experimental studies.

9. Determine the amount by which air pollution must be reduced in order to remove the ecological differences between the perturbed and pristine ecosystems.

10. Identify the most likely sources of pollutant and the most appropriate measures available to reduce the pollutant emissions.

11. Determine the relative values to society of the threatened ecosystem and the activities responsible for the generation of the pollution, taking into account the costs and other benefits of pollution reduction. This analysis need not be limited to economic variables, but economic and other variables would have to be tested in an accepted manner.

12. Determine the most effective strategy to reduce the pollutant concentration to a level below that which is threatening to the ecosystem. This strategy may include multiple guidelines determined by established or preferred land use.

The adaptation of the DPSEEA model to this sequence of decisions is indicated in Figure 2, with the factors relevant to the responses of ecosystems to air pollutants.

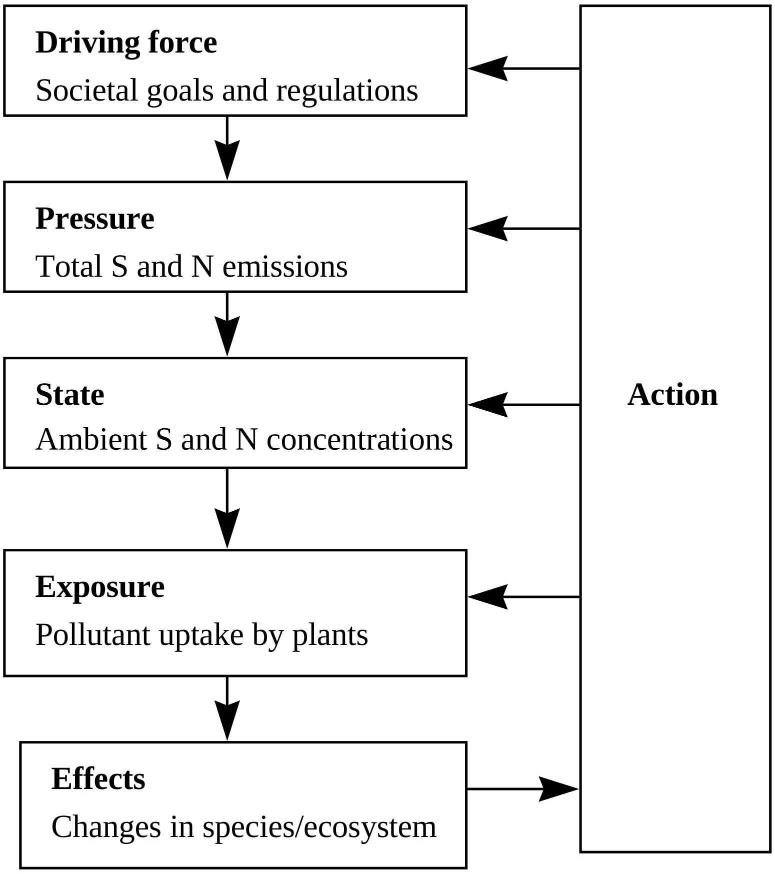

Figure 2. DPSEEA scheme adapted to indicate factors important to the protection of New Zealand ecosystems.

Appendix 1 Participants at Focus Group Meeting
Mt Albert Science Centre
Tuesday 30th June

Mr Nath Pritchard
Programme Manager Utilities
Environment Waikato
P O Box 4010
HAMILTON EAST

Mr Larry Burrows
Scientist
Landcare Lincoln
P O Box 69
LINCOLN

Ms Deborah Ryan
Resource Officer
Environment Waikato
P O Box 4010
HAMILTON EAST

Prof Tord Kellstrom
Environmental & Occupational Health
Dept of Community Health University of Auckland
Private Bag 92019
AUCKLAND

Mr David Hayden
Environmental Affair Advisor
Methanex New Zealand Ltd
Private Bag 2011
NEW PLYMOUTH

Prof John Hay
Associate Professor School of Environmental & Marine Science
University of Auckland
Private Bag 92019
AUCKLAND

Mr Leiff Pigott
Scientist Environmental Analysis & Reporting
Environment Waikato
P O Box 4010
HAMILTON EAST

Dr Ross Beever
Team Leader
Landcare Research
Private Bag 92170
AUCKLAND

Mr Philip Millichamp
Resource Officer (Air Quality)
Otago Regional Council
Private Bag
DUNEDIN

Mr John Gifford
Resource Centre Manager of Environmental Research Group
Forest Research Institute
Private Bag 3020
ROTORUA

Mr Geoff Taylor
Air Quality Management Office
Northland Regional Council
Private Bag 9021
WHANGAREI

Mr Perry Davey
Resource Scientist
Wellington Regional Council
P O Box 11646
WELLINGTON

Mr Steve Vaczi
Tasman Pulp and Paper
Private Bag
KAWERAU

COLLABORATORS:

Mr Robin Ormorod
Pacific Air and Environment
7,9 Grenier Dr
Archerfield Queensland 4108
AUSTRALIA

Prof Allan Green
Biological Sciences
University of Waikato
P O Box 3105
HAMILTON

Mr David Doley
Department of Botany
University of Queensland
Queensland 4072
AUSTRALIA

Dr David Klinac
Hort Research
Ruakura Research Centre
P O Box 3123
HAMILTON

Dr Ralph Riese
Department of Environment
Scientific Assessment Section
P O Box 155 Brisbane QLD 4002
AUSTRALIA

Dr Craig Stevenson
Senior Consultant Environmental
Chemistry
ESR Mt Eden Science Centre
17 Kelly St
Mt Eden
AUCKLAND

Vera Hally
Air Pollution Scientist
ESR Mt Eden Science Centre
17 Kelly St
Mt Eden
AUCKLAND

Caroline Austwick
Ministry for the Environment
PO BOX 10 362
WELLINGTON