Ministry for the Environment
Manatū Mō Te Taiao

Amenity effects of PM_{10} and TSP concentrations in New Zealand

Prepared by Environet Limited for the Ministry for the Environment

August 2003

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Foreword

Particles emitted into the air from sources such as vehicles, industries and domestic fires, can affect the amenity value of our environment. Larger particles (total suspended particulate or TSP) may cause nuisance effects such as soiling of property, while smaller particles such as PM_{10} can degrade the environment by forming unsightly smog and haze over towns and cities.

This technical background report reviews the **amenity effects of particles** (TSP and PM_{10}) in New Zealand and examines their significance. It has been prepared to assist with the development of national environmental standards for air quality under the Resource Management Act 1991. The information contained in this report has been released for information only. It forms part of the section 32 analysis required for standards development. Four other technical background reports on particles are also available covering: emission inventory results, monitoring results and health effects.

I would like to thank all those councils who contributed data and information to the preparation of this report.

Barry Carbon
Chief Executive

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Executive Summary

Amenity impacts of PM_{10} in New Zealand include visibility degradation, smoke and odour nuisance associated with combustion activities and dust nuisance. The nuisance impacts associated with smoke, odour and dust include soiling, a reduced enjoyment of the environment, odour nuisance and eye, nose and throat irritation. More severe health impacts may also be associated with localised discharges resulting in nuisance effects.

Common sources of nuisance effects associated with PM_{10} concentrations in New Zealand include backyard burning, domestic home heating, industrial activities, wind blown dusts and pollens, unpaved roads and construction sites. Effects from the latter four sources include impacts of both PM_{10} and Total Suspended Particulate (TSP). Sources of visibility degradation include both localised discharges such as those previously described as well as high concentrations of particles associated with the cumulative effects from all sources. It is the finer particles (less than 1 µm in diameter) that have the greatest impact on visibility.

Visibility degradation is a significant amenity effect, caused by light scattering and absorption by particles. Visibility standards have been proposed for New Zealand based on a visual range and colour criterion, which indicates an 'action' level for visibility of a combination of 8 kilometres of visibility and some 'off' colour. A visibility risk assessment for New Zealand indicates excellent visibility conditions across most of the country with the potential for unacceptable levels of haze in a small number of urban centres.

Complaint registers compiled by regional councils indicate that complaints relating to both dusts and smoke are common. In some areas (e.g. Canterbury, Wellington and Northland), smoke concerns comprise the majority of complaints. Dust issues are a concern in most locations.

The costs associated with amenity impacts from particles include the potential impact on tourism, the cleaning of soiled materials, crop damage and potential devaluation of real estate. However these potential costs are likely to be minor relative to those associated with health impacts such as premature mortality and restricted activity days.

1 Introduction

Amenity effects associated with particle concentrations in New Zealand include visibility degradation (PM_{10}), smoke and odour nuisance (PM_{10}), dust nuisance (PM_{10} and Total Suspended Particulate (TSP)) and soiling and corrosion (PM_{10} and TSP). Measurements of the extent and frequency of these types of impacts are limited to visibility monitoring in a few areas and registers of complaints held by most regional councils. The latter system is limited as an indicator of extent and frequency of impact as many external factors (e.g. awareness or relationships with those responsible), may contribute to a person's desire to complain. A household survey is a more appropriate method of quantifying the extent of amenity impact of particles in any area. However, these data have not typically been collected to date.

This technical report comprises a review of the amenity impacts (types and extent) of PM_{10} and TSP concentrations in New Zealand.

2 Visibility Degradation

One of the most noticed impacts of concentrations of particles in the air is visibility degradation or haze. Haze typically refers to the ambient air quality visual impact of concentrations of particles, which are either uniformly distributed both horizontally and vertically to a height well above the lowest terrain or stratified in a layer near to the surface. The latter type of haze is common when temperature inversion conditions restrict the dispersion of pollution. This is also referred to as a surface layer haze, and is characterised by a distinct line at the top edge of the pollution layer. An elevated haze layer is another type of stratified ambient air haze that occurs when the pollution distribution is not in contact with the ground.

Figure 2.1 illustrates both uniform and stratified haze in Christchurch. The stratified surface layer haze is very common in Christchurch during winter mornings because of the frequency of temperature inversion conditions. These inversions typically last until around 10 am by which time the heat from the sun has typically warmed the air sufficiently to allow vertical mixing of air contaminants. This can result in the appearance of a uniform haze, although this is typically of short duration.

Figure 2.1: Uniform (left) and stratified (right) haze in Christchurch

Photos supplied by Environment Canterbury.

As well as the ambient air quality impact of haze, adverse amenity effects are associated with localised issues such as a visible smoke or dust plume. Examples of situations where a smoke plume may cause localised visibility degradation include tailpipe exhaust emissions from a smoky motor vehicle, boiler emissions from a train or boat, industrial combustion processes and backyard burning. Examples of localised dust sources that may result in visibility degradation include industrial activities (e.g. sandblasting, unsealed roads, construction sites, land tilling and stockpiling of materials). In the case of dust related sources, a large proportion of the particulate is likely to be in the larger TSP size fraction.

Figures 2.2 to 2.6 show some examples of the impacts of smoke plumes from different sources within New Zealand. The impact of the smoke plume in the Milford Sound (Figure 2.2) is particularly noteworthy as it illustrates the adverse impact of human activities on an otherwise pristine and highly valued area.

Figure 2.2: Smoke plume from a boat in the Milford Sound

Photo by Russell Winter, SRC.

Figure 2.3 shows the effect of the visible discharge of smoke from an industrial boiler on the West Coast of the South Island. Visible emissions of smoke from industrial processes are generally controlled within New Zealand for industrial processes that require resource consents. Typically, consent conditions might relate to the presence of visible smoke for a specified duration.

Figure 2.3: Smoke plume from a boiler on the West Coast

Photo supplied by Chris Pullen, WCRC.

Backyard burning emissions in New Zealand typically result in both smoke nuisance and visibility impacts. In Figure 2.4 however, the extreme vertical and minimal horizontal dispersion of the plume means that the most significant impact of this burning episode is visual.

While outdoor burning practices are very common in rural New Zealand, overseas studies indicate a higher value is placed on visibility in rural scenes than in urban areas, suggesting a lower tolerance for visibility degradation in these areas.[1]

The amenity impacts of outdoor burning or other sources of particles in any location will depend on meteorological conditions as well as the value placed on the scene by those observing the discharge. Even a relatively small outdoor rubbish fire can have a significant impact on visibility if meteorological conditions are conducive to elevated pollution. Figure 2.5 shows the visual impact of a relatively small rubbish fire in the Lyttelton Harbour.

Figure 2.4: Smoke plume from backyard burning in Marlborough

Photo by Peter Hamill.

[1] Pryor S (2002) *Particles and Visibility*. Keynote paper presented at the 16th International Clean Air and Environment Conference of the Clean Air Society of Australia and New Zealand.

Figure 2.5: Impacts of meteorology on outdoor burning emissions in the Lyttelton Harbour

Emissions of particles from domestic chimneys can also result in a visible plume, particularly if the burner is being poorly operated or inappropriate fuel is burnt (Figure 2.6). The extent to which the visual impact of a domestic home fire is regarded as an adverse amenity impact in New Zealand is unknown, although regional councils receive numerous complaints about them, both in terms of nuisance and amenity.

Figure 2.6: Smoke emissions from a solid fuel burner in Lyttelton Harbour

2.1 How do particles affect visibility?

Particles and gases in the air degrade visibility by scattering and absorbing light. These processes impact on the visibility of an object in the distance by reducing the amount of light transmitted from a source (e.g. the sun and reflected off the object). Other factors that impact on how the object is viewed include characteristics of the observer, optical illumination such as sun angle and cloud cover and characteristics of the object (e.g. colour, texture and contrast).

Of the impact of particles and gases in the intervening atmosphere, the impact of gases in visibility degradation is generally minimal. Light scattering by gases is a constant referred to as Rayleigh Scattering and doesn't vary with increasing concentrations. Light absorption by gases in the air is effectively limited to NO_2. Measurements of this component in Christchurch indicate it is not a significant contributor to daytime haze episodes.

Thus the primary cause of haze is light scattering and absorption by particles. Typically light scattering is the dominant cause with particles in the size range 0.3–0.7 microns scattering light most effectively. Light absorption by particles depends on composition and tends to be governed by elemental carbon in most urban environments.

Sources of visibility degradation in New Zealand also include fog and low cloud (although these meteorological events are natural and are unlikely to constitute an adverse amenity impact), sea spray, dusts and anthropogenic sources such as combustion emissions and industrial processes. It is also likely that emissions from vegetation could contribute to visibility degradation in some locations.

2.2 Visibility guidelines in New Zealand

While no visibility standards currently exist for New Zealand, the Ministry for the Environment has signalled an interest in establishing a criterion to protect visibility and has developed visibility degradation categories. A series of reports were prepared[2] which provide guidance on visibility measurement methods, amenity values and management and a risk assessment of visibility in New Zealand. Actions required to protect and enhance visibility in New Zealand were recommended as follows:

- Develop and implement guidelines and indicators for visibility protection.
- Fully integrate visibility as an objective in Air Plans.
- Raise awareness in the public, educational, industry and political sectors.
- Develop and recommend monitoring methods.
- Define national goals for visibility, relevant for different types of regions within New Zealand.
- Continue research on air shed modelling, with an emphasis on understanding key causes of visibility degradation.

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[2] Ministry for the Environment (1999) *Visibility in New Zealand: Guidance on measurement methods.* Wellington: Ministry for the Environment.

Ministry for the Environment (1999) *Visibility in New Zealand: Amenity value and management.* Wellington: Ministry for the Environment.

Ministry for the Environment (1999) *Visibility in New Zealand: National risk assessment.* Wellington: Ministry for the Environment.

While no specific guideline value for visibility is recommended, a proposed visibility indicator is included with which to assess visibility degradation. This is identified as preliminary with the intention that it be refined in time with regard to user comment and use. There is some flexibility in the target categories selected by councils to allow for community specific visibility objectives. A combination of both visual range and colour are proposed (Table 2.1).

Table 2.1: Proposed visibility indicators

Category	Visual range and/or appearance
Excellent	>70 km and/or no 'off' colour
Good	>20–70 km and/or no 'off' colour
Acceptable	>20–70 km and/or discernable 'off' colour
Poor	<20 km and/or discernable 'off' colour
Alert	<20 km and/or distinct 'off' colour
Action	<8 km and/or distinct 'off' colour

Source: Ministry for the Environment (1999)

2.3 Visibility perception in New Zealand

A study of visibility perception was carried out in New Zealand by NIWA in 1998.[3] The study involved household surveys in the areas of Auckland, Hawkes Bay, Hamilton City, Dunedin and Christchurch. The results of these surveys can be summarised as follows:

- In Auckland the majority of the participants thought that visibility had deteriorated and that motor vehicles were the primary cause of reduced visibility.
- Most respondents rated visibility in Hawkes Bay as excellent and there was little indication of perceived deterioration.
- In Hamilton visibility degradation was mostly attributed to natural causes such as fog and rain.
- Dunedin residents considered the standard of visibility in the area was very high and predicted that weather had the main effect on visibility. Of the anthropogenic sources domestic heating was thought to be the main contributor.
- Although Christchurch was initially included in the survey, households in Christchurch were reluctant to respond to the questionnaire. Consequently results were unable to be reported due to the small sample size (31).
- In all areas visibility was identified as an issue of importance.

Figure 2.7 shows brown haze in Auckland around the time the Auckland visibility perception survey was conducted.

[3] National Institute of Water and Atmospheric Research (1998) *Air Visibility Telephone Survey Results*. NIWA Report AK97071.

Figure 2.7: Illustration of brown haze in Auckland

Photo supplied by Jayne Metcalfe, ARC.

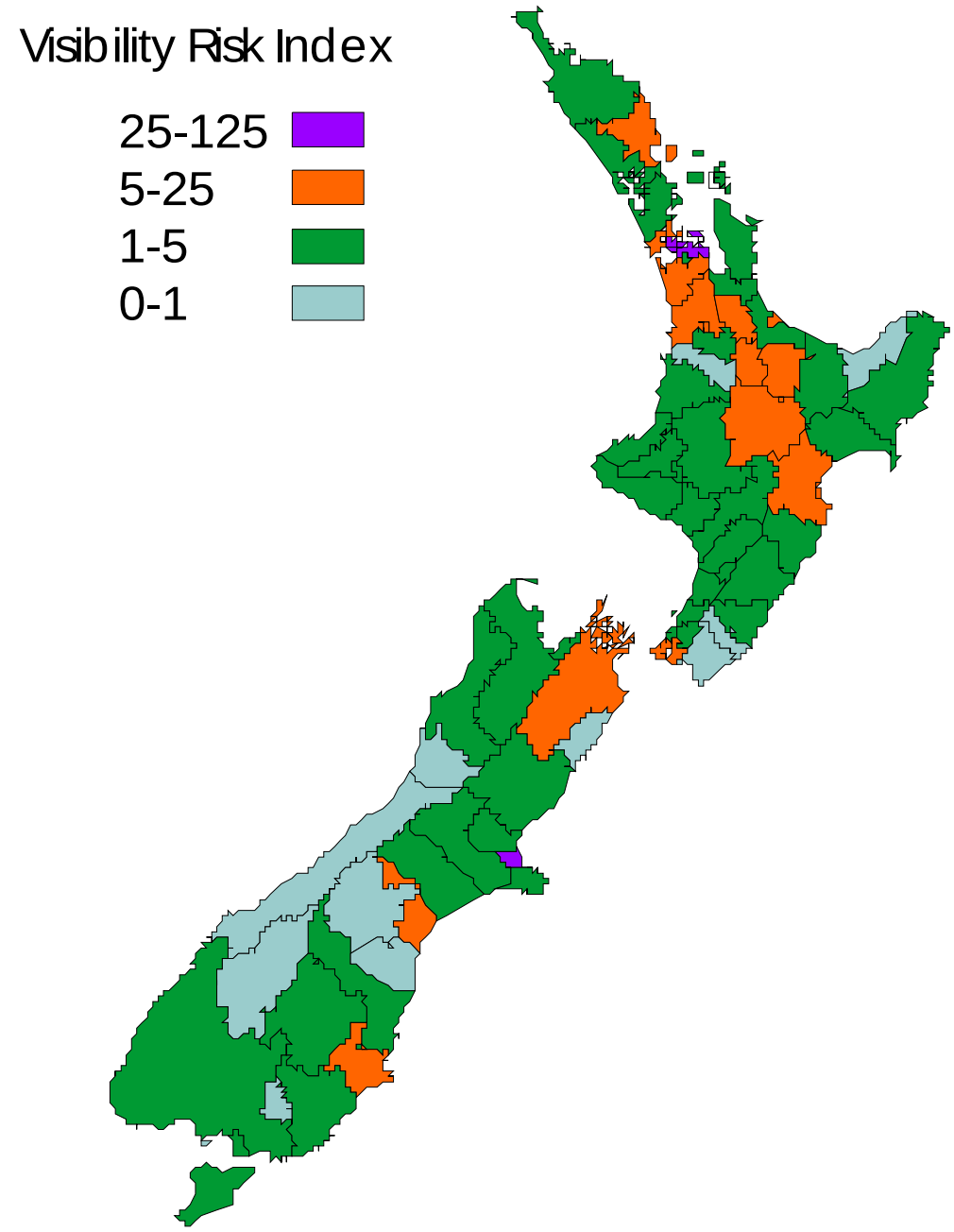
2.4 Visibility risk assessment for New Zealand

An estimate of the relative risk of poor visibility in New Zealand was assessed based on concentrations of particles and nitrogen dioxide (MfE, 1999). Table 2.2 shows the risk index that was developed for the 1999 risk assessment based on the air quality categories. An illustration of the risk of visibility degradation across New Zealand based on these data is shown in Figure 2.8. Results highlight the areas of Christchurch and Auckland as high risk areas. This is consistent with visibility observations in these areas. However, the spatial resolution of the analysis and presentation, which is based on territorial local authorities, does lead to some inconsistencies in other areas. For example, the size of the TLA areas may be too large to show the extent of visibility degradation in some small towns (e.g. Reefton). Other inconsistencies are also noted, for example, Nelson, which is known for it's visible air pollution only features as low risk.

Table 1.2: Classification of risk index into air quality categories

Risk index	Category
>125	Very high risk (action)
25–125	High risk (alert)
5–25	Medium risk (acceptable)
1–5	Low risk (good)
0-1	Very low risk (excellent)

Figure 2.8: Visibility risk index for New Zealand



Source: Ministry for the Environment (1999).

3 Smoke and Odour Nuisance

Combustion processes can also result in localised smoke and odour nuisance. Common causes of smoke and odour nuisance from combustion processes in New Zealand include backyard rubbish burning, solid fuel and rubbish burning in domestic home heating appliances, including open fires, and industrial combustion processes.

Although generally classified as a nuisance effect, exposure to high concentrations of particles associated with localised effects from combustion processes can also impact on health in the same way as ambient PM_{10} concentrations. Effects are likely to include eye irritation, increased coughs and throat irritation. It is uncertain whether more severe impacts may occur, as epidemiological studies from which the particle health relationships are derived are typically based on ambient air concentrations over a 24-hour period rather than short-term localised effects.

Other amenity impacts associated with localised smoke and odour from combustion processes include impacts on visibility, soiling of property including buildings and clothing, odour nuisance and a reduced enjoyment of the environment. Although generally associated with the smoke, the odour associated with localised combustion impacts is likely to be gaseous in nature.

In some instances, localised smoke nuisance can result in frequent and significant impacts on neighbouring properties. For example, smoke emissions from a coal burner in Christchurch resulted in such high concentrations of particles that they would regularly set off the smoke alarm within the neighbouring house.

Amenity effects associated with smoke and odour from combustion processes such as outdoor burning and emissions from domestic home heating can be regulated through Regional Air Plans. For example, some air plans include prohibitions on outdoor burning in urban areas and rules relating to visible or objectionable smoke beyond the property boundary. In the absence of such regulations, Section 17 of the RMA may be able to be used to manage smoke and odour nuisance. In some areas, nuisance effects are dealt with by local councils using Section 29 of the Health Act (1956). For example, in Timaru, outdoor burning of rubbish fires in urban areas is prohibited in the District Plan because of the nuisance impacts.

Figure 3.1 shows an example of an activity that may result in localised nuisance effects. Other sources of localised nuisance effects associated with smoke and odour include domestic home heating and industrial activities.

Figure 3.1: Smoke from the burning of green material in the Hawkes Bay region

Photo supplied by Bryce Lawrence (HBRC).

4 Dust Nuisance

Dust nuisance occurs when high concentrations of particles, typically of geological material, become suspended in the air. Dust particles resulting in nuisance effects are typically in the coarse, $PM_{10–2.5}$, and TSP size fractions, and are formed through mechanical and abrasive processes. However, some particles less than 2.5 microns in diameter may occur as a result of particular activities. Particles may become elevated as a result of natural processes such as winds or anthropogenic activities including mechanical interactions such as transportation or the tilling of land.

Examples of sources of dust nuisance in New Zealand include vehicle movement on unpaved roads, quarrying, aggregate crushing, stockpiling of materials, tilling of land, erosion of soils and riverbeds, construction sites and abrasive blasting. In some areas high levels of pollen have been reported as an air quality concern, although generally complaints relate to the deposition of material.

The Ministry for the Environment has prepared a *Good Practice Guide for Assessing and Managing the Environmental effects of Dust Emissions* (MfE, 2001). The guide includes an overview of the legal framework for managing dust emissions including regional air plans, district plans, and land use planning. Proposed management measures include conditions such as *"no dust beyond the boundary which causes an offensive or objectionable effect"*. Guidance is also given on measurement methods for dusts and dust control technologies.

The nuisance effects associated with elevated dusts include soiling of property, visual impacts, and deposition in the eyes and nose. While adverse health impacts are possible for particles in the PM_{10} size fraction, larger dust particles will be removed prior to deposition in the lungs. Figures 4.1 and 4.2 show the impact of dusts from abrasive blasting on a waterway.

Figure 4.1: Illustration of dust impacts of sandblasting a bridge in the Hawkes Bay region

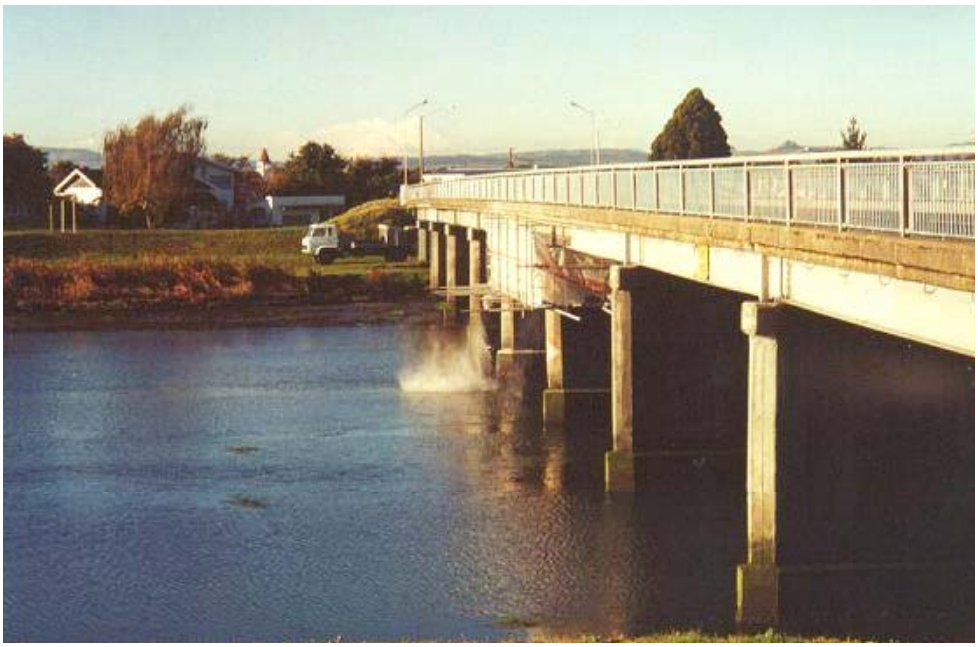


Photo supplied by Bryce Lawrence (HBRC).

Figure 4.2: Deposition of particles from sandblasting activities in the Hawkes Bay region

Photo supplied by Bryce Lawrence (HBRC).

5 Soiling and Corrosion

Soiling of property can occur as a result of dust and smoke nuisance. Typically, problems arise as a result of deposition of particles on cars, washing and vegetation, in particular flowers, ornamentals, fruit and vegetables. The presence of indoor particle deposition and soiling is of particular concern as it increases the requirement for cleaning and decreases the enjoyment of the living environment.

Soiling and corrosion of outdoor surfaces are also a concern. Soiling by particles can impact on a number of surfaces including paint, stone and fabrics and tends to be worse for carbon based particles originating from combustion sources (Watkiss et al, 2001). The impacts vary depending on the material but can range from fading and chipping of paint surfaces on buildings and cars to soiling and loss of textile strength in fabrics (WHEA, 2002).

The costs of soiling include the additional cleaning costs, loss of amenity associated with the appearance of soiled surfaces and in the case of corrosion, repair of damaged surfaces. However, corrosion of buildings tends to be associated more with sulphur dioxide than with particles.

6 Amenity Impacts of PM_{10} in New Zealand

6.1 Complaints registers

Most of the regional councils within New Zealand keep a register of complaints relating to amenity impacts associated with concentrations of particles. These are not an ideal indicator of the extent of the problem, as a number of external factors will influence the reporting of an incident. For example, factors such as awareness of the impacts and who to report to, duration of an issue and relationships with those responsible may impact on a person's tendency to make a complaint. However, the registers do provide some indication of the frequency of complaints and the types of issues for different areas. Table 6.1 summarises information supplied by regional councils on the frequency and type of complaints relating to particle pollution.

Table 6.1: Summary of data from complaints registers

	1994	1995	1996	1997	1998	1999	2000	2001
Hawkes Bay RC								
• smoke					16	27	41	35
• dust/particles					20	29	21	52
Marlborough DC								20
Environment Canterbury								
• domestic heating							277	336
• rubbish fires							428	328
• dust	39	125	138	108	75	85	103	188
Wellington RC	17	13	18	24	31	58	60	27
Taranaki RC	33	57	41	37	92	46	58	103
Northland RC								
• smoke/visibility	52	73	98	139	98	83	80	91
• dust	19	21	27	43	37	36	31	12
Environment Waikato								
• dust							51	67
• domestic burning							10	16
• rural burning							20	18
• industrial burning							38	80

In addition, the West Coast Regional Council indicated that it received 38 complaints relating to air quality from January 2000 to June 2002. These have predominantly occurred because of industrial activities, domestic emissions, school boiler emissions and coal handling. In Southland, the majority of the air discharge complaints relate to odour rather than particles, although a few smoke and dust issues have been recorded. Unsealed roads and pollen have given rise to a few dust complaints in Southland.

In Taranaki, a reduction in complaints relating to dust from abrasive blasting is associated with increased controls over emissions from this source through the resource consent process.

In Wellington the majority of the complaints reported related to smoke emissions from industrial processes, although smoke from outdoor burning and home heating were also common. A few complaints were recorded relating to mobile sources such as the Arahura Ferry and specific motor vehicles.

6.2 Economic implications

The amenity effects associated with localised and ambient concentrations of particles also have an economic cost, which is associated with reduced visibility, nuisance effects and general reduced enjoyment of the environment. While these costs could be sizeable, they are minor in comparison to the costs associated with health impacts such as mortality, morbidity and restricted activity days (Bicknell, 2001). In addition, factors such as reduced visibility could have further economic impacts if the tourism industry were affected. In particular, poor visibility could impact on New Zealand's current 'clean green' image reducing its attraction as a holiday destination. The value of this image in terms of tourism has been estimated at between $500 million and $1000 million (MfE, 2001).

An assessment of the cost associated with effects such as reduced visibility is typically carried out based on willingness to pay (WTP) surveys. While a small number of such studies have been carried out in the United States, the acceptability of visibility degradation and value placed on visibility improvements are likely to be area specific (Wilton and Spronkin Smith, 2002).

Cost estimates associated with the soiling of materials such as buildings and clothes can also be estimated using WTP data from surveys (e.g. as described in Bicknell, 2001) or based on a combination of cleaning costs and amenity costs, as described in Watkiss et al (2001). Costs associated with damage to crops will vary depending on the extent of deposition and the type of crop. Other potential costs associated with amenity impacts of particles include devaluation of real estate, for example, as a result of visibility degradation or where nuisance effects associated with smoke or dusts occur regularly.

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About the Ministry

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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