# Health and Air Pollution in New Zealand

## EXECUTIVE SUMMARY

Principal Authors
G. Fisher[1], T. Kjellstrom[2], S. Kingham[3], S. Hales[4], R. Shrestha.[5]

Contributing Authors
A. Sturman[3] (Chapter 8), M. Sherman[1] (Chapter 8), C. O'Fallon[6] (Chapter 10),
J.E Cavanagh[7] and M. Durand[7] (Chapter 10).

*1. Endpoint, 2. Health and Environment International Trust, 3. University of Canterbury, 4. Wellington School of Medicine and Health Sciences, 5. Australian National University, 6. Pinnacle Research, 7. Landcare Research.*

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# Executive Summary

## Overview

The people of New Zealand are exposed to a wide range of health risks through various activities. Many of these are unavoidable, and many are due to personal choice. However, some are due to exposures to contaminants in the environment that can be reduced.

This study is concerned with identifying and quantifying the health risks due to people's exposure to air pollution. For many places, and for much of the time, New Zealand's air pollution cannot be considered poor by international standards, yet there are still measurable health effects, and there are locations and instances where air quality is poor enough to be of concern.

Measures to reduce air pollution and its effect on public health have costs. Effective management and policy therefore needs detailed information on exactly what air pollution occurs and what effects it has. The aim of this *Health and Air Pollution in New Zealand* (HAPiNZ) study is to explicitly identify the effects of air pollution throughout New Zealand, to link these effects to the various sources of air pollution, and to provide information that will help to formulate effective policy options that lead to real and measurable improvements in the health of New Zealanders.

## Methodology and scope

This study covers the whole of New Zealand. The methodology and scope of the project is large and complex. There are many different sources of air pollution, which are transported around the atmosphere by the weather in complex ways that have a wide range of health effects on the population. Effective policy analysis needs to use accurate information on just which sources have particular effects on particular sectors of the population, in some cases over many years.

The study has been funded under a joint initiative from the Health Research Council of New Zealand, the Ministry for the Environment and the Ministry of Transport, with substantial in-kind contributions from Regional Council air quality monitoring programmes. The work has been carried out by a large collaborative group, comprising several organisations and a number of New Zealand's leading researchers in air pollution, epidemiology, toxicology, environmental management and public health policy.

## Background

A large number of epidemiological studies carried out worldwide have shown associations between ambient air pollution levels and adverse health effects, including increased mortality. The short-term mortality increase in relation to daily levels of particulate matter ($PM_{10}$ or $PM_{2.5}$) is approximately 0.5–1% increase per 10 $\mu g/m^3$ $PM_{10}$ increase. A variety of statistical methods have been used, and they all come to similar conclusions. The epidemiological analysis demonstrates that the mortality effect of high air pollution lasts longer than the first day of exposure. The resulting long-term mortality increase associated with long-term exposure is substantially higher than the short-term increase. Recent advanced statistical analysis indicates that the mortality increase per 10 $\mu g/m^3$ $PM_{10}$ may be as high as 5–10%.

The exact biological mechanisms by which air pollution causes increased morbidity and mortality remain to be determined. It would seem that inflammation of the airways is a common pathway for several air pollutants, and that there are direct effects on the cardiovascular system. It is also apparent that some groups within the population are particularly susceptible to the effects of air pollution, including the elderly, people with existing respiratory and cardiovascular disease, asthmatics, young children and infants. Another issue that has not yet been resolved is whether $PM_{10}$ air pollution from different sources causes different levels of health risk. However, the conclusions from several reviews are that $PM_{10}$ from the main sources of vehicles, wood smoke and industrial sources should be considered of similar toxicity.

## General results

The results obtained from the study are wide-ranging and detailed. All the major sources are included, all the common air pollutants are included, the major effects have been quantified, the economic costs have been assessed, and some typical policy options have been identified and discussed, particularly in relation to transport and domestic heating. The following general results are clear.

- The results of previous studies on the effects of air pollution in New Zealand are broadly confirmed, but with greater detail in terms of the location and scale of these effects. In particular, the results are consistent with the 2002 study 'Health effects due to motor vehicle pollution in New Zealand', commissioned by the Ministry of Transport (Fisher et al., 2002), and with similar studies conducted overseas.
- New epidemiological studies as a part of HAPiNZ carried out in Christchurch and Auckland confirm evidence from overseas studies of short-term effects on mortality, and indicate that the dose–response relationship risk coefficients for longer-term effects are possibly greater than previously thought.
- It is estimated that effects occur throughout New Zealand – not just in the main cities. The health impact assessment in the study examines 67 urban areas throughout the country, chosen based on either their size, local activities, and/or monitoring data that shows high levels of air pollution. The study areas comprise 2.7 million people (as of the 2001 census), or 73% of the population of New Zealand.
- The greatest effect occurs due to premature mortality associated with long-term exposure to fine particulates from combustion sources. Mortality effects due to carbon monoxide (CO) and various morbidity (non-mortality illness) effects associated with various air pollutants are also identified.
- There are adverse effects from air pollution that may not have direct and obvious public health implications, but nevertheless have effects on society. These include restricted-activity days, which can affect large portions of the population on bad, or even moderate, air pollution days.
- The most sensitive portions of the population are: (a) older people, particularly over-65s; (b) infants, particularly under-ones; (c) asthmatics and people with bronchitis; (d) people with other respiratory problems; (e) people with other chronic diseases, such as heart disease.
- The effects due to various sources have been estimated. These are largely as expected: (a) home-heating solid fuel combustion; (b) industry and commercial activities; and (c) motor vehicle emissions. Some attempt has been made to attribute specific effects to specific sources. The study has included background concentrations (those largely due to natural sources), which allows for more informed policy choices.
- Mitigation options are available for new policies and actions at the government, industry and community level.

## Specific results

### *New epidemiological studies*

This study has, for the first time, provided detailed epidemiological information on both the short-term and long-term effects on mortality of exposure to urban air pollution in New Zealand. Hourly and daily levels of $PM_{10}$, CO and nitrogen dioxide ($NO_2$) from air monitoring and modelling were used in a time-series analysis of daily mortality, initially in Christchurch. The results showed that $PM_{10}$ levels were consistently associated with an increase in daily non-external mortality (excluding injuries and self-inflicted deaths) in the age groups above 65 years of age: approximately 1% increase in mortality for each increase of $PM_{10}$ by 10 $\mu g/m^3$. Distributed lag analysis of daily mortality over 40-day periods has indicated that a cumulative effect occurred, leading to greater effects. The results are similar to findings in numerous studies in overseas cities and confirm that mortality is increased by urban air pollution in New Zealand towns and cities.

The longer-term effects were studied using modelling of the spatial distribution of air pollution in Auckland ($NO_2$ and $PM_{10}$) and Christchurch ($PM_{10}$), estimating annual average exposure in each census area unit within the urban areas, and analysing the association between these exposure estimates and annual mortality adjusted for age, sex, ethnic group, smoking habits and occupational mix. The census area units comprise, on average, groups of 2,300 people, so this analysis has been conducted at a very fine scale (typically overseas studies cover entire cities of several million people agglomerated together). The results indicate higher risks than the short-term time-series studies, which is in line with results from longer-term studies overseas.

In Auckland, the non-external mortality increase (averaged for all age groups) for each 10 $\mu g/m^3$ increase of $NO_2$ was 10% (95% confidence interval: 7–13 %), and for each 10 $\mu g/m^3$ increase of $PM_{10}$ it was 6% (95% confidence interval: 1–11%). The risks for mortality from respiratory diseases were the highest. These results support the use of higher risk coefficients in health impact assessments than those produced by short-term time-series studies.

The Christchurch and Auckland studies were used to confirm the risk rates appropriate for the rest of New Zealand. Here a 4.3% mortality increase was used for each increase of $PM_{10}$ by 10 $\mu g/m^3$ in the preliminary analysis (Fisher et al., 2002). These revised New Zealand findings support the continued use of this risk coefficient for health impact assessments in New Zealand urban areas, although there is growing evidence for the use of a higher risk coefficient (i.e. resulting in potentially greater effects than are reported here).

## *Epidemiology summary*

It appears from the data presented in this report and the subsequent discussions that the 4.3% increase of mortality for people over age 30 used by Kunzli et al. (2000) for all sources of $PM_{10}$, while used here, may in future not necessarily be the best available estimate of the dose–response relationship for the purposes of health risk assessments in New Zealand. Taking the recent study by Pope et al. (2002), the HAPiNZ study by Scoggins et al. (2004), the review by Pope & Dockery (2006) and the new results presented in this report into account, it can be concluded that the true figure for annual non-external mortality increase in New Zealand could be in the range 4–8% for each 10 $\mu g/m^3$ increase of annual average $PM_{10}$. However, more evidence on any differences in toxicity between vehicle smoke and wood smoke is needed before any modifications of the dose–response relationships are made.

As a result, the health risk assessments in this report will be based on the same dose–response coefficient as in the previous assessments, and in Kunzli et al. (2000): 4.3% increase of annual mortality per 10 $\mu g/m^3$ annual $PM_{10}$ for all air pollution sources (vehicle, industry and domestic), in the age group above age 30.

This makes it possible to compare this new health impact assessment with that produced in the earlier Ministry of Transport report (Fisher et al., 2002).

## *Exposure assessment methodology*

Another significant component of this study has been the development of a new air pollution exposure model for New Zealand, represented by 67 urban areas (see Table E-1), and covering 73% of the total population. Because the study included many cities that have little or no monitoring, a new method had to be established to assess exposure. Full airshed modelling was not possible, again because of the lack of input data, but also because of the resources required to cover 67 areas.

**Table E-1. Urban areas covered in the study (listed alphabetically)**

| | | | |
|---|---|---|---|
| 1. | Alexandra | 34. | New Plymouth |
| 2. | Arrowtown | 35. | North Shore (Auckland) |
| 3. | Ashburton | 36. | Oamaru |
| 4. | Auckland | 37. | Opotiki |
| 5. | Balclutha | 38. | Orewa |
| 6. | Blenheim | 39. | Palmerston North |
| 7. | Cambridge | 40. | Papakura |
| 8. | Christchurch inner suburbs | 41. | Paraparaumu |
| 9. | Christchurch outer suburbs | 42. | Porirua |
| 10. | Clevedon | 43. | Pukekohe |
| 11. | Cromwell | 44. | Putaruru |
| 12. | Dunedin | 45. | Rangiora |
| 13. | Feilding | 46. | Reefton |
| 14. | Geraldine | 47. | Richmond |
| 15. | Gisborne | 48. | Rotorua |
| 16. | Gore | 49. | Takanini |
| 17. | Hamilton | 50. | Taupo |
| 18. | Hastings | 51. | Tauranga |
| 19. | Hawera | 52. | Te Awamutu |
| 20. | Invercargill | 53. | Te Kuiti |
| 21. | Kaiapoi | 54. | Timaru |
| 22. | Kaikoura | 55. | Tokoroa |
| 23. | Leamington | 56. | Upper Hutt |
| 24. | Levin | 57. | Waiheke Island |
| 25. | Lower Hutt | 58. | Waimate |
| 26. | Manukau | 59. | Wainuiomata |
| 27. | Masterton | 60. | Waitakere |
| 28. | Matamata | 61. | Waiuku |
| 29. | Milton | 62. | Wanganui |
| 30. | Morrinsville | 63. | Wellington |
| 31. | Mosgiel | 64. | Westport |
| 32. | Napier | 65. | Whakatane |
| 33. | Nelson | 66. | Whangarei |
| | | 67. | Winton |

The model has been validated by: (a) comparison with areas where full airshed modelling and previous studies have been carried out (mainly Auckland and Christchurch); and (b) comparison with all $PM_{10}$ monitoring available (kindly supplied by every Regional Council with a monitoring programme). The model validation shows that realistic exposures have been obtained. The model is based on $PM_{10}$, but data was also needed on other pollutants that have effects (mainly $NO_2$, CO, and benzene). Thus an additional part of the study has been to establish the relationships between $PM_{10}$ and these other pollutants.

Again the validations undertaken (and related research conducted under the Foundation for Research Science and Technology programme "Keeping New Zealand's Air Clean") show this approach to be reasonable. The model developed is not only used for the health assessment made here, but has wider applicability and interest in other sectors to evaluate and manage air pollution. In particular, it provides many Regional Councils with information on air quality in some centres that was not previously available. This information will be used in support of council policies to meet the requirements of the National Environmental Standards: Air Quality, which in some cases require aggressive measures to meet the 2013 compliance targets.

The results of the exposure analysis for each of the air pollutants considered are given in complete tables in Appendix 1 to the main report. These show that many of these areas experience degraded air quality that would not meet the standards, and this may have serious health effects on their communities.

### *Exposure assessment summary*

This study has employed a new technique to calculate the exposure to air pollution for 67 city areas in New Zealand. This had to be done because the resources and basic data were not available to make a good assessment based on either monitoring or advanced airshed modelling. All the available $PM_{10}$ monitoring data, supplied by the Regional Councils, was used in the development and validation of the new model.

The data used was basic indicators of activity that results in air pollution – vehicle flow statistics, population density, number of wood burners, location and size of industrial discharges, and an estimate of background concentrations. This data was obtained from standard sources, mainly Statistics New Zealand and the Ministry of Transport, and so the analysis year had to be 2001 – the latest year for which the required input data was available at the time of the major analysis.

The methodology has used regression methods to estimate $PM_{10}$ pollution for all urban areas of New Zealand down to the census area unit level, using these very basic data sources. The values generated accurately predict measured values in those areas where measurements were taken the correlations are similar to those achieved in other similar studies. Indeed, the agreement between the model estimates of annual concentrations and the monitoring of $PM_{10}$ was remarkable given the variability of air pollution behaviour. This agreement was not perfect (it was not expected to be), and is only applicable to the annual averages required for the study.

The results show that high pollution concentrations generally occur in towns with:

- colder climates, leading to a greater use of wood burning for heating
- easy access to wood as a resource
- poor exposure to inhibit pollution dispersion
- significant numbers and/or densities of traffic.

The higher exposures were found in Nelson, followed by Alexandra and central Christchurch. The results are much as anticipated, and are consistent with more up-to-date monitoring that has been conducted by the councils. However, here the significant advance is that the exposure has been quantified on a nationally consistent basis, and agrees with more advanced analyses in those areas where such analyses have been conducted (e.g. Christchurch and Auckland). The significance of the work is highlighted by the recent acceptance of a paper describing the work in detail in an international peer-reviewed journal (Kingham et al., 2007)

This research has estimated the contribution of the main sources of air pollution: domestic heating, vehicles, industry and natural background.

### *Health impact assessment – discussion of methods*

Any assessment of the health effects due to air pollution is extraordinarily complex. For a start, the level of air pollution is highly variable in space and time, and is affected by the weather, by what is being emitted through various activities, and by very location-specific features such as valleys and where people live and work in relation to the sources.

Although the concept that ‘dirty air’ is bad for people has been around since ancient times, it is only within the last decade that the mechanisms have started to be identified. Furthermore, a number of large-scale epidemiological studies have shown that effects can occur at quite low levels of pollution, over a wide range of people, due to a number of different exposure scenarios (e.g. which pollutant, over what time period, under which activity).

Finally, there is no one measure of ‘air pollution’. It is a common public perception that air pollution is a single thing – most people associate it with visible pollution such as smoke. However, air pollution comprises many components, not all of which are obvious or even detectable by sight or smell by people, and each of which can have different effects, as follows.

- Particulates (commonly assessed as $PM_{10}$ or $PM_{2.5}$) are very fine particles that can be visible, but are often not obvious. They are associated with increased premature mortality, and exacerbate a number of respiratory and cardiac problems.
- Carbon monoxide (CO) is a colourless gas that affects mortality slightly, but exacerbates heart disease and causes drowsiness and learning difficulties. Is strongly correlated with $PM_{10}$ in cities.
- Nitrogen dioxide ($NO_2$) is a slightly brown gas (only detectable when present over large areas) that causes breathing problems, and exacerbates asthma and other respiratory problems. It tends to be correlated with $PM_{10}$.
- Sulphur dioxide ($SO_2$) is a pungent gas that causes sore throat and eyes, and can have an effect on mortality. It is not usually present in hazardous concentrations in New Zealand.
- Ozone ($O_3$) is a colourless gas that is present naturally, but causes severe breathing problems in high concentrations. It is not presently a serious problem in New Zealand, with no measured exceedences anywhere.
- Benzene is a component of petrol (along with numerous other hydrocarbons) which can lead to cancer.
- ‘Air toxics’ refers to a whole range of other toxic compounds, including complex organic chemicals, process chemicals and heavy metals. Little is known about many of these.

In summary, while some health effects are well known, others are not, and the state of knowledge is still developing rapidly.

A particularly difficult issue that has to be dealt with is the effects of background, or natural, sources. The focus of most air quality research and assessment has been on the three main anthropogenic (human-caused) sources: domestic, vehicle and industrial. Each of these is mainly derived from combustion of some sort, and each is amenable to mitigation policies. However, the implementation of national environmental standards in New Zealand requires a rather detailed knowledge of what causes any particular airshed monitoring result to show exceedence of the standards. The ‘straight-line path’ methodology built into the regulations requires councils to mitigate various sources in order to achieve the standards, but the amount of mitigation required, by source, is variable. A proper analysis requires knowledge of the amount of background air pollution. For instance, if the amount of $PM_{10}$ due to background sources is a significant fraction of the total, then other sources may need to be mitigated more heavily, because background sources are generally beyond control.

In the health effects analysis, the effects of background sources have been explicitly included for this reason. However, it is strongly recommended that *extreme caution* be applied when attempting to sum the effects into a total effect. It is valid to assign an effect to ‘domestic emissions’, or ‘transport’ or ‘industry’, but it may not be valid to include ‘background’. The research community has not yet resolved the question of whether background sources have the same epidemiological effect as anthropogenic combustion sources. There is some evidence they do not, but on the other hand the background air pollution is included in all the epidemiological studies (after all, it is impossible to get rid of the background). Effects associated with background sources have *not* been included in the final figures reported, nor in the major conclusions.

In this study:

- domestic sources are emissions from the use of wood and coal in home-heating appliances
- vehicle sources are from internal combustion engines on the national roads, using petrol and diesel (they do not include off-road vehicles, trains, ships or aircraft)
- industrial sources include all major industries, as well as a factor for smaller commercial activities (such as painting, spraying, wood milling, fish-and-chip shops, etc).

### *Health impact assessment – results*

The health effects for all the areas studied are summarised in Table E-2. The overall total is included, but it does not include background sources that (a) cannot be mitigated and (b) may well not have the same level of effect as the emissions from the other sources.

**Table E-2. Effects of air pollution in New Zealand, by source and effect, 2001 (number of cases for the population over 30 years old)**

| Effect | Domestic | Vehicle | Industrial | Total |
|---|---|---|---|---|
| Mortality (for $PM_{10}$, $NO_2$) | 356 | 414 | 131 | **901** |
| Mortality (for CO) | 70 | 86 | 22 | **178** |
| Bronchitis and related | 887 | 541 | 116 | **1,544** |
| Acute respiratory admissions | 267 | 163 | 35 | **465** |
| Acute cardiac admissions | 137 | 83 | 18 | **238** |
| Cancer | 19 | 22 | 6 | **47** |
| Restricted-activity days | 1,105,000 | 671,000 | 145,000 | **1,921,000** |

Table E-2 shows that in the 67 urban areas studied, air pollution is associated with:

- 1,079 cases of premature mortality – that is, people dying earlier than they would have if they had not been exposed to air pollution, mostly associated with $PM_{10}$ (901), but also with CO (178)
- 1,544 extra cases of bronchitis and related illnesses
- 703 extra hospital admissions for respiratory (465) and cardiac illnesses (238)
- 1,921,000 restricted-activity days – that is, days on which people cannot do the things they might otherwise have done if air pollution was not present.

The bulk of these effects are associated with particulate pollution ($PM_{10}$), but there are also effects associated with other pollutants, such as $NO_2$, CO and volatile organic compounds.

These results can be put into context by examining how they increase the natural mortality rate. Both natural mortality rates and air pollution rates vary substantially over the country. Natural rates, with a national mean of 6.5 per 1,000 people per year, vary from a low of 5.5 in North Shore City, to a high of 8.0 in Porirua. The air pollution-related mortality rates vary from a low of 0.18 per 1,000 people per year in New Plymouth (low pollution levels due to its very exposed location) to a high of 0.74 in central Christchurch (due to its sheltered meteorology and high rate of wood burner use).

The national average increase in the base mortality rate associated with air pollution is 4.8%, ranging from 2.9% in New Plymouth to 11.8% in Christchurch. This result implies that, nationally, 1 in 20 people

(4.8%) die earlier than they would have because of air pollution. In Christchurch (and some other South Island towns with very high pollution levels) this could be as high as 1 in 9 people.

This result should not be interpreted too dramatically, although it certainly indicates a situation to be avoided by reducing air pollution. The concept of premature mortality means that some of these people may be dying a matter of days or weeks earlier than they would have otherwise. But it also means that they may be dying months or years earlier, resulting in high economic and social costs.

## *Health effects summary*

The health impact assessments shown here are based on exposures derived from modelling and validated against monitoring and published dose–response relationships. The health effects have been calculated with two overall constraining factors.

1. The study has been prioritised and based on the factors known to be associated with the greatest health effects – mainly the longer-term exposures, and the exposure to $PM_{10}$. Effects due to some other pollutants have been analysed (e.g. CO, $SO_2$, $NO_2$, and benzene), but these show diminishing effects relative to annual $PM_{10}$. The CO effects have been included because they are non-trivial. Benzene effects are also included, but these are very small relative to $PM_{10}$ and CO. Others (such as $SO_2$ and other types of air pollution) are negligible on the national scale relative to the ones included. Effects associated with $NO_2$ are non-trivial, but these are intimately associated with $PM_{10}$ effects and are not able to be identified separately. They are assumed to be included in the $PM_{10}$ effects – to avoid double counting of effects – but there is growing evidence that there may be separate and independent effects associated with $NO_2$ exposure, especially in children.

2. The dose–response relationships used for analysing the health effects are conservatively chosen from those used for a number of years in the international literature, and used by many other countries, including the USA, the European Union and Australia. There is growing evidence that some of these dose–response relationships have been underestimated, or could be applied in a more sophisticated way. However, the evidence is not yet strong enough to justify these newer methodologies in a study of this nature. The implication is that the results given here are conservative: it is likely that once new dose–response relationships are confirmed, these will show a great health burden due to atmospheric pollution in New Zealand.

The results show a number of relevant features (relevant to the 2001 population).

- The greatest health effect for all pollutants is associated with long-term exposure to elevated concentrations of $PM_{10}$ (increased premature mortality in over 30-year olds of 901 cases per year).
- Effects can occur at relatively low levels, and thus can occur to some extent in every city studied.
- Effects could also be due to background levels (i.e. $PM_{10}$ that comes from natural sources such as wind-blown dust and even sea spray). These effects have been included in the analysis because mitigation policy options need to account for them, but they should be viewed with caution because the epidemiology on this topic is incomplete.
- Effects associated with CO also show a significant level of premature mortality (178 cases per year) and illness (2,247 extra hospital admissions for respiratory and cardiac disease per year).
- These air pollution effects include premature mortality, respiratory illness, cardiac illness and restricted-activity days (1,921,000 days per year).
- The overall burden of health effects is borne by the larger urban areas, principally because of the size of the populations. These include all the greater Auckland region cities, Christchurch, greater Wellington, Hamilton, Tauranga and Dunedin. Although air pollution levels in many South Island cities are higher than in the major centres, the total number of cases of health effects is lower simply because the populations are lower. However, the proportion of the population affected will be higher in those areas with higher amounts of air pollution.

- The population within the study areas has grown by 17% from 2.73 million in 2001 to 3.20 million in 2007[1], so it is reasonable to assume that the current total health costs are also 17% greater for most of the figures derived above (although due to differences in the rates of population growth in various areas, this increase cannot be applied equally in all areas).
- Finally, a comment is required on the nature of these epidemiological results. They are long-term statistics, designed to give an indication of the effects, rather than to be a specific predictor for a particular city in a particular year. For instance, the assessment shows that there is one additional case of premature mortality in Arrowtown due to air pollution in that town. This does not mean that one extra identifiable person will die each year in Arrowtown from air pollution (for the population of around 1,600 there would be on average of 13 people dying from natural causes). It does mean that over a period of several years, taking account of the statistical variation in deaths, that on average one person a year will have died earlier than they would have otherwise because of the occurrence of air pollution.

These health effects results are complex to calculate and difficult to interpret. This executive summary, along with more detailed results in the appendices, has attempted to give a quantified indication of the total effects of air pollution in New Zealand on the health of its citizens.

## Economic impact assessment

The costs of air pollution effects can be estimated using the new statistics from this study, previous research in New Zealand, and results from overseas studies adjusted for New Zealand conditions. Table E-3 gives a summary of the specific health effects used, and their cost per case. These are not personal costs, but costs to the New Zealand health system and economy – the external costs of air pollution.

**Table E-3. Estimated costs of specific health effects used in the analysis**

| Effect | Cost per case |
|---|---|
| Mortality | $750,000 |
| Cancer | $750,000 |
| Chronic bronchitis | $75,000 |
| Admission (cardiovascular) | $3,675 |
| Admission (respiratory) | $2,700 |
| Restricted-activity day | $92 |

These figures have a degree of subjectivity, and are estimates only. There is no international, or even national, agreement on how to apply economic analysis, and the values used in various countries can differ widely. For instance, the cost of mortality is argued to be as low as $50,000 to as high as $6,000,000. The figures used here are reasonably conservative estimates, calculated for New Zealand circumstances. Different studies may apply different costs.

There are some effects that are not studied, nor explicitly costed, mainly because the research results are not available. These include asthma cases, short-term effects and toxic effects. Similarly, some effects will incur additional costs that are difficult to quantify, including costs of extra doctor's visits and medication, lower-level effects due to mild but perhaps widespread effects due to drowsiness, headaches, loss of attention and quality of life that may not be included in the restricted-activity day analysis. Finally, the general economic effect of perceptions of 'poor air quality' on tourism and recreation are not negligible, but are beyond the scope of this study.

[1] See http://www.stats.govt.nz

The total costs of health effects of air pollution can be estimated from the health effects and the cost per case of those effects. These are shown in Table E-4. By far the largest component of the 'economic health burden' is the loss of life-years as a result of premature mortality, followed by restricted-activity days and then chronic bronchitis.

**Table E-4. Annual costs ($million) of air pollution in New Zealand, by source and effect**

| Effect | Domestic | Vehicle | Industrial | Total |
|---|---|---|---|---|
| Mortality (due to $PM_{10}$, $NO_2$) | 267.0 | 310.5 | 98.3 | 675.8 |
| Mortality (due to CO) | 52.5 | 64.5 | 16.5 | 133.5 |
| Bronchitis and related | 66.5 | 40.6 | 8.7 | 115.8 |
| Respiratory/cardiac admissions | 1.2 | 0.7 | 0.2 | 2.1 |
| Cancer | 14.3 | 16.5 | 4.5 | 35.3 |
| Restricted-activity days | 101.7 | 61.7 | 13.3 | 176.7 |
| **Total** | **503.2** | **494.6** | **141.5** | **1,139.2** |

When considered across the 2.7 million people in the study areas, these amount to the following costs per person per year:

- total effects: $421 per person per year
- effects associated with domestic emissions: $186 per person per year
- effects associated with vehicle emissions: $165 per person per year
- effects associated with industrial emissions: $70 per person per year.

Although background and natural sources of air pollution (such as wind blown dust) have been included in the detailed analysis, they are not included in this cost summary.

### *Health costs summary*

Not all potential costs have been included. For instance, indirect costs, such as doctor's visits and increased use of medicine, have not been included. There is very little data on these factors, although they are not expected to be insignificant.

The total costs of air pollution in New Zealand are in the order of at least $1,139 million per year, based on 2001 statistics. Since the population within the study areas has grown by 17% from 2.73 million in 2001 to 3.20 million in 2007[2], it is reasonable to assume that the current total costs are also of the order of 17% greater, at $1,333 million.

## Policy options

A number of policy options for reducing emissions, and hence reducing health effects, have been discussed. This discussion is far from comprehensive, since new policies are being continually proposed and the environment in which they operate is constantly changing. However, the results of the study do give a quantified indication – at the level of individual cities and towns, as well as nationally – of the scale of the mitigation policy actions required.

During the time that this study has been conducted there has been a great deal of development in the transport policy arena. This has included the introduction of new fuel specifications (significantly

[2] See: http://www.stats.govt.nz

reducing the emissions of sulphur and benzene since 2001), the continuing implementation of new emissions standards for vehicles, and a series of public information and education campaigns. The overall result has no doubt been a reduction in air pollution due to vehicle emissions, although this has not been fully quantified here.

Domestic policy options have much more of a local focus – what may be highly relevant for one council may be quite inappropriate for another. In addition, the assessment of domestic heating emissions is currently the subject of active research and assessment by both the Ministry for the Environment and many councils. The importance of reducing domestic heating emissions is accepted by all branches of central and local government, and descriptions of the work being conducted in various programmes exceeds what is possible to cover here. However, a fuller discussion has been developed on some of the reduction methods being applied.

When it comes to industrial emissions, one aspect arising from the research has been that, contrary to common public perception, industries do not contribute heavily to the burden of public health associated with air pollution (of the order of 15% nationally, only exceeding this in Auckland City and Manukau, with most regions lower than 1%). They do, of course, in some areas, and the local regulating council is well aware of these in every instance. Without going into great and specific detail, there is little value that can be added beyond what councils already enact.

Despite some gaps in the comprehensiveness of the policy options, and some of them being outdated, the information produced by this study does give detailed quantitative information on the contributions from various air pollution sources throughout 67 key urban areas in New Zealand that will be valuable in assessing policy options.

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The project involved collaboration with the following named scientists. Some individual research elements of HAPiNZ have been or will be published in other forms. This report primarily covers the health impact assessment and its input data.

**Contributing scientists (in alphabetical order)**

| Name | Institution |
|---|---|
| Dr Jo-Anne Cavanagh | Landcare Research |
| Dr Tom Clarkson | National Institute of Water and Atmospheric Research (NIWA) |
| Dr Janine Clemons | Landcare Research |
| Philip Donnelly | Private Consultant |
| Dr Michael Durand | Landcare Research |
| Dr Charlie Eason | Landcare Research |
| Dr Michael Epton | Christchurch School of Medicine and Health Sciences |
| Gavin Fisher | NIWA/Endpoint |
| Dr Neil Gimson | National Institute of Water and Atmospheric Research (NIWA) |
| Dr Simon Hales | Wellington School of Medicine and Health Sciences |
| Clive Heydenrych | National Institute of Water and Atmospheric Research (NIWA) |
| Dr Simon Kingham | University of Canterbury |
| Prof. Tord Kjellstrom | Health and Environment Trust |
| Sue McLeod | University of Canterbury |
| Des O'Dea | Wellington School of Medicine and Health Sciences |
| Carolyn O'Fallon | Pinnacle Research |
| Dr Jamie Pearce | University of Canterbury |
| Amanda Scoggins | National Institute of Water and Atmospheric Research (NIWA) |
| Rupendra Shrestha | Australian National University |
| Dr Rachel Spronken-Smith | University of Canterbury |
| Prof. Andy Sturman | University of Canterbury |
| Dr Ian Town | Christchurch School of Medicine and Health Sciences |
| Dr Louis Tremblay | Landcare Research |
| Karen Trout | Landcare Research |
| Dr Jeff Wilson | University of Canterbury |
| Emily Wilton | Environet |
| Prof. Alistair Woodward | Wellington School of Medicine and Health Sciences |
| Dr Peyman Zawar-Rewa | University of Canterbury |

(Note: some of these authors have changed affiliation. This list is correct at the time of their contribution.)