Ministry for the Environment
Manatū Mō Te Taiao

Emission inventories for PM_{10} in New Zealand

Prepared by Environet Limited for the Ministry for the Environment

August 2003

Air Quality Technical Report No. 38

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Foreword

Emissions inventories provide information that is crucial to our understanding of the sources of air pollution. They assist in determining how to tailor reduction strategies to achieve the most effective improvements in air quality. While inventories provide reasonably rough quantification of PM_{10} sources, they are the best available tool. More advanced techniques such as source apportionment are showing some encouraging results, but currently require further development.

Inventory results summarised in this report indicate that home-heating fires, typically used during winter, cause the largest proportion of PM_{10} emissions in New Zealand. In some other areas and at different times, vehicles, industry and some natural sources can be more significant. Readers should be aware that some of the inventories were developed using different methods and therefore are not directly comparable to each other.

This technical report on the **sources of fine particles** (PM_{10} – particles less then 10 microns in diameter) in New Zealand will assist with the development of appropriate national environmental standards for air quality, such as ambient standards for PM_{10} and the proposed emission standard for domestic solid fuel burning appliances.

The information contained in this report is not government policy. It has been released for information only and forms part of the section 32 analysis required for standards development. It is one of four background reports on PM_{10}, with the others covering: monitoring results, amenity issues and health effects.

I'd like to thank all those councils and others who have contributed data and information for this report.

Barry Carbon
Chief Executive

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Executive Summary

Air quality monitoring throughout New Zealand indicates that concentrations of suspended particles (PM_{10}) in the air exceed the ambient air quality guideline values in many urban areas during the winter months.

Assessments to determine sources of PM_{10} emissions using the emission inventory methodology have been carried out since around 1995. At least one inventory has been carried out for the main cities as well as a number for smaller towns. All inventories have included an assessment of sources of particles with PM_{10} being the most common size fraction reported. Other common contaminants included are carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOC) and carbon dioxide (CO_2).

Differences in methodologies between inventories can make comparisons between inventories for some regions difficult. Common variations include source categorisations, the presentation of data and the quality of data collection. In some areas, data are presented as annual average contributions only, whereas in other regions data are presented as daily (typically wintertime) or daily and annual estimates. Notwithstanding these differences, a general comparison of contributions in different areas can be made.

Results indicate that the main source of PM_{10} emissions in most areas during the winter months is solid fuel burning for domestic heating, although industrial contributions may also be significant in a number of locations. Domestic home heating is also responsible for the majority of the $PM_{2.5}$ emissions in most locations as most of the PM_{10} emissions from this source are the smaller $PM_{2.5}$ size fraction. Motor vehicle emissions may also be a major source of PM_{10} and $PM_{2.5}$ in Auckland, although further work is being carried out to assess this.

Limited information is available on trends in sources of PM_{10} emissions in New Zealand owing to the relatively recent nature of the use of emission inventories. Some data for Christchurch and Timaru suggest little changes in emissions between the years 1996 and 2000. Estimated future trends in PM_{10} emissions are likely to be dominated by variations in home heating methods and growth in household numbers in most locations. Home heating methods are likely to be influenced by cost and availability of alternative sources such as electricity and gas as well as any air quality management measures. Future trends in industrial PM_{10} emissions are likely to be location dependent whereas a nationwide decrease in PM_{10} emissions from motor vehicles is predicted from 2001 to 2021 (MOT, 1998).

Another technique, which is used for assessing sources of PM_{10} in New Zealand, is source apportionment using receptor modelling. At this stage, the method has mostly been used in the Wellington region, although preliminary studies have been carried out in Auckland and Christchurch. The advantage of receptor modelling for determining sources of particles is the inclusion of natural sources such as sea spray and wind blown dusts, which are difficult to quantify using the emission inventory methodology.

1 Introduction

Air quality monitoring throughout New Zealand indicates that concentrations of suspended particles (PM_{10}) in the air exceed the ambient air quality guideline values in many urban areas during the winter months. In order to manage these emissions it is important to have a good understanding of the sources of particle pollution.

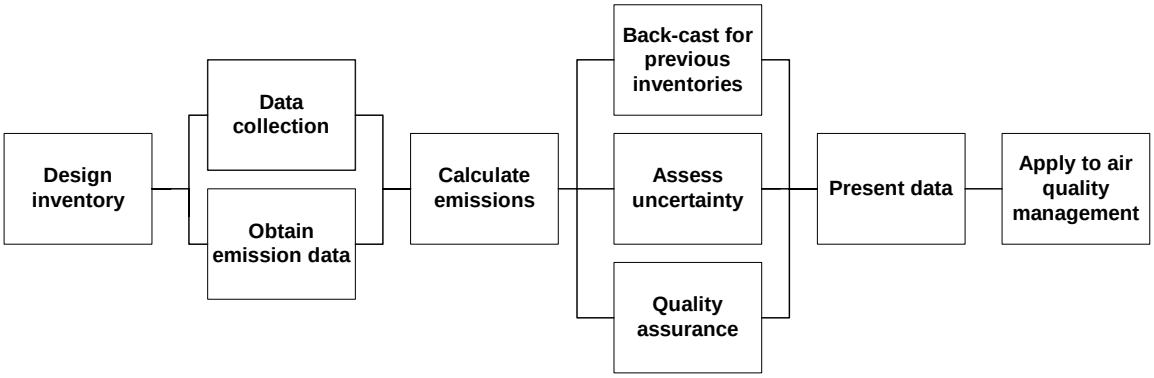
An emission inventory provides a quantitative assessment of the amount of emissions of a particular contaminant from selected sources. Estimates of emissions are based on information relating to the frequency and type of activity and the use of average emission rates or other emissions information applicable to the activity. Typical sources included in urban area inventories incorporate domestic solid fuel burning, motor vehicles and industrial emissions. In some emission inventory assessments of sources such as outdoor burning, lawn mowing, port, marine and rail activities and other activities have also been included.

This technical report comprises a review of emission inventory studies into sources of PM_{10} in urban and some rural areas of New Zealand.

Emission inventories have been successfully used in New Zealand as an air quality management tool to develop strategies to reduce ambient air concentrations of PM_{10}. Examples of the application of an emission inventory to air quality management include Christchurch (Wilton, 2001a) and Nelson (Wilton, 2002).

To assist in the preparation of quality emission inventories, the Ministry for the Environment's Sustainable Management Fund funded the preparation of the *Good Practice Guide for Preparing Emission Inventories* in New Zealand (Wilton, 2001b). The process involved in preparing an emission inventory, as described in that report are shown in Figure 1.1.

Figure 1.1: Overview of the process for preparing an emission inventory



Source: Wilton (2001b).

One of the key aspects to preparing a useful emission inventory is the design phase of the inventory and the consideration of existing air quality issues. Because concentrations of particles have been identified as the main ambient air quality issue in many urban areas, emission inventories for many urban areas of New Zealand have been designed with a focus on sources of PM_{10}.

When considering the results of emission inventory studies, it is important to note the difference between estimating contributions to emissions and determining the contribution to concentrations. There are two points that are important in this distinction. Firstly, the emission inventory estimates emissions only. The relative contribution of different sources to PM_{10} concentrations across an area will depend on the impact of meteorology, and in particular temporal and spatial variations in sources and meteorology at different times of the day. The second point is that the inventory estimates represent an average across an area. The actual contribution to concentrations at any given point within that area will vary depending on proximity to sources and local meteorology.

A further limitation to the use of emission inventories as an air quality management tool is that reliable techniques for the estimation of emissions from natural sources such as sea spray and wind blown dusts are yet to be developed. In some areas, these sources may be significant contributors to PM_{10} concentrations. In such instances, alternative methods of source determination such as receptor modelling methods may be more appropriate.

2 Emission Inventories in New Zealand

A number of emission inventories have been carried out primarily in the urban areas of New Zealand since 1995. These typically include detailed assessments of PM_{10} or TSP emissions from domestic heating, motor vehicles and industry, although emission estimates for a number of minor PM_{10} sources are also included in some of the studies. Some of the later inventories also include estimates for the $PM_{2.5}$ size fraction, although there is generally increased uncertainty surrounding the emission factors for this size fraction.

Emission estimates for PM_{10} are typically presented as daily average wintertime rates, as it is during this season that PM_{10} concentrations in most areas of New Zealand are elevated. Some inventories, in particular those employing the simpler screening type methodologies only produce annual emission estimates (Table 2.1). This report summarises the results of the emission inventories carried out in New Zealand to date for TSP, PM_{10} and $PM_{2.5}$, where available.

Table 2.1: Summary of the most recent emission inventories for New Zealand

Location	Year	Sources	Contaminants	Output	Methodology
Auckland	1993	Transport, area, vegetation, industry	Particles, CO, NOx, SO_2, CO_2	t/day	Grid square, wide range of sources, detailed data collection
Wellington	1998	Transport, industry, biogenic, domestic heating, burning and lawn mowing	PM_{10}, NOx, CO, CO_2, SO_2, NMVOC	t/day	Grid square, wide range of sources, detailed data collection
Christchurch	1999	Motor vehicles, domestic heating, industry	PM_{10}, NOx, CO, CO_2, SO_2,	kg/day	Limited spatial resolution, comprehensive data collection for major sources only
Timaru	2001	Motor vehicles, domestic heating, industry	PM_{10}, $PM_{2.5}$, CO, NOx, benzene, BaP, dioxin, SO_2, CO_2	kg/day	Comprehensive data collection for major sources only
Dunedin and 10 ORC urban areas	1999	Transport, domestic heating, industry	PM_{10}, NOx, CO, SO_2	kg/day	Detailed data collection for most sources, some limitations in motor vehicle emissions assessment
Hamilton, Tokoroa, Te Kuiti, Taupo	2001	Transport, domestic heating, industry	PM_{10}, CO, NOx, SOx, VOC, CO_2	kg/day	Detailed data collection, reliant on 1997 industry assessment
Nelson	2001	Motor vehicles, domestic heating, industry, outdoor burning	PM_{10}, $PM_{2.5}$, CO, VOC, NOx, benzene, SO_2, CO_2	kg/day	Comprehensive data collection for major sources only
Richmond	2000	Motor vehicles, domestic heating, industry, outdoor burning	PM_{10}, $PM_{2.5}$, CO, VOC, NOx, benzene, SO_2, CO_2	kg/day	Detailed data collection for most sources, some limitations in motor vehicle and outdoor burning emissions assessment
Gisborne	1996	Transport, area, industrial, agricultural, natural	TSP, SOx, NOx, VOC, CO, CO_2	t/year	Screening approach to major sources, high potential for error
Bay of Plenty	1997	Transport, industry, domestic, pollen, agriculture, geothermal	TSP, SO_2, CO, NOx, H_2S, dioxins	t/year	Screening approach to major sources, high potential for error
Northland	Non-specific	Motor vehicles, domestic heating, industry, agriculture	PM_{10}, CO, NOx, SOx, NMVOC, CO_2, N_2O, CH_4	t/year	Detailed data collection for most sources, some screening methods used
Taranaki	1998	Motor vehicles, domestic heating, industry, farm animals, vegetation	PM_{10}, $PM_{2.5}$, CO, NOx, VOC, BaP, CH_4, N_2O, NMHC	t/year	Screening approach to major sources, high potential for error

2.1 Auckland

The Victorian Environmental Protection Agency (EPA) in collaboration with NIWA carried out the first emission inventory assessment for Auckland in 1995. The Auckland Regional Council initiated a review and information update for this inventory for the year 1998, however these updates are not yet available owing to concerns with some of the existing source and emissions information.

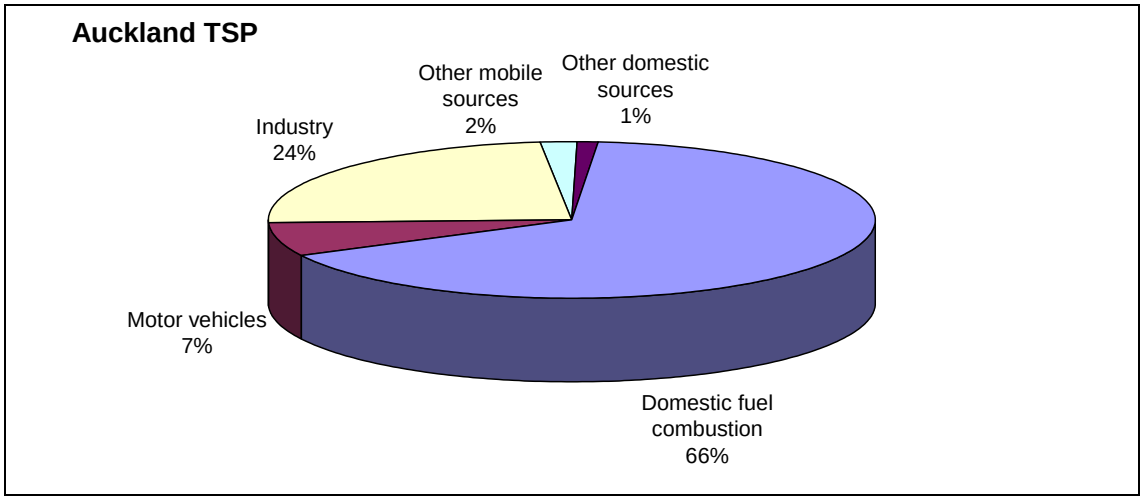
The 1995 Auckland emission inventory is comprehensive in its inclusion of sources and in its spatial distribution of the emission estimates from these sources. Table 2.2 shows the range of sources included. The spatial resolution for the inventory is an 87 km by 99 km grid, which contains in excess of 8600 km^2 divided into 957 grid cells each 3 km by 3 km.

Table 2.2: Sources included in the 1995 Auckland emission inventory

Motor vehicles	Domestic and area sources	Industry	Biogenic sources
• Motor vehicles (exhaust and evaporative) • Marine pleasure craft/ shipping • Rail • Aviation	• Surface coating and thinners • Aerosols • Service stations/ refuelling • Fuel combustion • Lawn mowing • Cutback bitumen • Natural gas leakage • Off road vehicles • Dry cleaning • Domestic waste combustion • Other unaccounted for industrial/commercial emissions	• Food manufacture • Mining and quarrying • Wood and paper products • Chemical manufacture • Textiles • Non-metallic minerals • Metal manufacture • Can coating • Fabricated metals • Printing • Power generation • Miscellaneous industries • Fuel storage	• Vegetation • Soil

The relative contributions of different sources to PM_{10} emissions across the whole of the study area from the 1995 inventory are shown in Figure 2.1. However, some concerns have been raised about the quality of some of the input data and thus the accuracy of the emissions estimates. Attempts to resolve these issues for the 1998 inventory are a current priority for the Auckland Regional Council.

Figure 2.1: Relative daily (wintertime) contribution of sources to TSP emissions in the Auckland region



The main sources of industrial TSP emissions in the Auckland region are metal manufacture and the non-metallic minerals industry, which contribute 45% and 18% of the industrial emissions respectively.

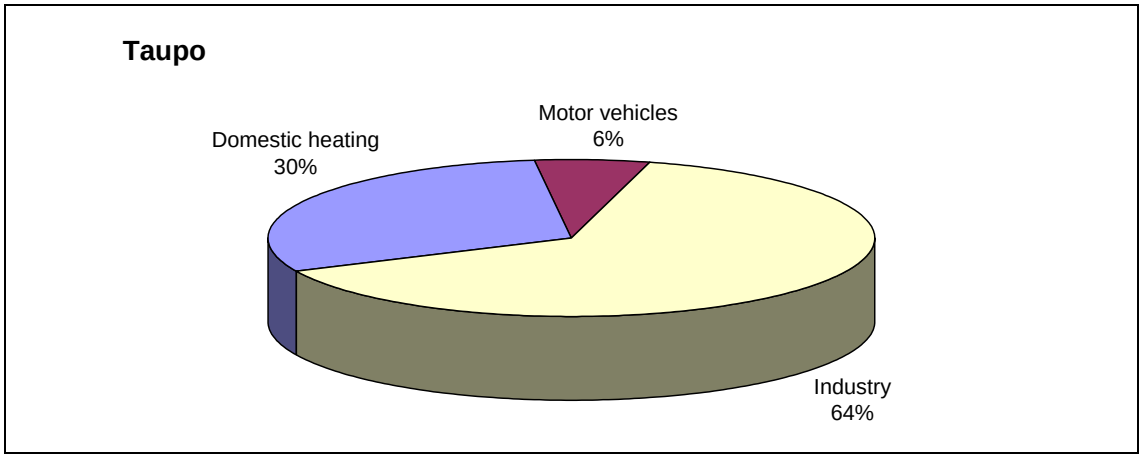
In addition to the emission inventory assessments, the Auckland Regional Council propose to identify the relative contributions of different sources to PM_{10} concentrations based on receptor modelling methodologies. Receptor modelling involves identifying the elemental composition of particles and uses statistical methods to identify sources based on the prevalence of different ratios of elements. Monitoring for this work is scheduled to commence during 2003.

2.2 Waikato region – Hamilton, Tokoroa and Te Kuiti and Taupo

An assessment of sources of PM_{10} and other contaminants in Hamilton, Tokoroa and Te Kuiti was carried out during 1997 using emission inventory methodology. The inventory was carried out in two phases: the assessment of emissions from domestic heating and motor vehicles and the assessment of emissions from industry. Results from these phases were not combined for 1997 to give an overall assessment for these areas.

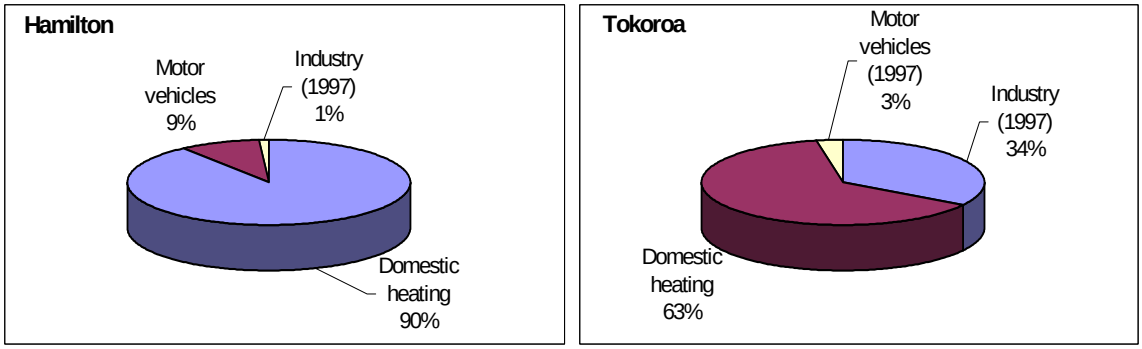
An assessment of emissions from home heating was carried out for the areas of Huntly, Matamata and Putaruru during 2000. In Taupo, both domestic heating and motor vehicle emissions were assessed for 2000. Industry information from 1997 were used to estimate the industry contribution to PM_{10} emissions in Taupo. Figure 2.2 shows the estimated relative contributions to PM_{10} emissions in Taupo. However, an assessment of PM_{10} sources in Taupo suggests that the industrial emissions component may be overestimated because of the uncertainties surrounding emission factors associated with emissions from a local wood-panelling site (Wilton, 2002a).

Figure 2.2: Relative contributions to wintertime PM_{10} emissions in Taupo in 2000



In 2001, emissions from domestic heating were reassessed for Hamilton, Tokoroa and Te Kuiti and also for motor vehicles in Hamilton. The latter data were combined with 1997 industrial emission estimates to provide an assessment of the relative contribution of domestic heating, motor vehicles and industry to PM_{10} emissions in Hamilton. Figure 2.3 shows the relative contribution of these sources to PM_{10} emissions in Hamilton and Tokoroa. The Tokoroa emission estimates exclude emissions from Kinleith, a major industrial source of emissions located about 5 kilometres from the township.

Figure 2.3: Relative contributions to wintertime PM_{10} emissions in Hamilton and Tokoroa



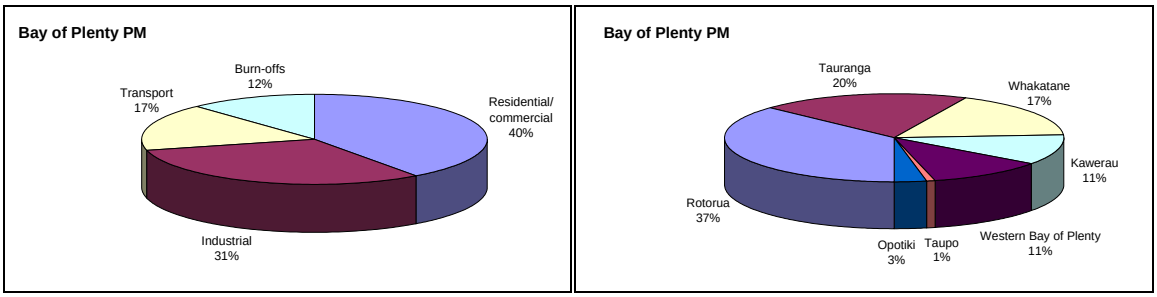
2.3 Bay of Plenty

An emission inventory encompassing the whole of the Bay of Plenty region was carried out in 1997. It is difficult to compare the results of this emission inventory with inventories from other regions in New Zealand as the inventory design and presentation precludes an assessment of daily PM_{10} emission estimates by source for the urban centres.

The focus of the Bay of Plenty inventory is on annual emission estimates for CO, SO_2, NOx and particles, which is referred to as PM and is an estimate of total suspended particles. A range of sources including on-road and marine transportation, industrial and commercial activities, domestic activities, agricultural and forestry and geothermal sources were included in the inventory. The presentation of results for particles is limited to the categories, industrial, residential/commercial, transport and burn-offs.

The inventory includes a breakdown of total emission estimates for particles for the districts Western BOP, Tauranga, Whakatane, Kawerau and Rotorua and by urban centre for Tauranga, Rotorua and Whakatane. Figure 2.4 shows the estimated annual contribution of each source to particle emissions for the whole region and a breakdown of the emissions by district.

Figure 2.4: Relative contribution to annual particle emissions in the Bay of Plenty by source and area for 1997



Although no data are provided, the report does indicate that the relative contribution of the residential and commercial sector to PM emissions does increase to 55% if just the winter data are included (Weymss, 1997). However, the methodology used in the inventory to estimate emissions from domestic home heating relies heavily on home heating methods and fuel use in other areas such as Auckland and Christchurch and results should therefore be treated with caution.

2.4 Taranaki

An emission inventory for the Taranaki region was carried out during 1998. The methodology was similar to the Bay of Plenty region in that results were presented as annual emission estimates. However, the study included both PM_{10} and $PM_{2.5}$ size fractions and incorporated more appropriate methods of assessing domestic heating emissions. Other contaminants assessed in the inventory included CO, methane (NH_4), non-methane hydrocarbons (NMHC), VOCs, nitrous oxide (N_2O), nitric oxide (NO) and nitrogen dioxide (NO_2).

Results were presented for the Taranaki region as a whole and broken down into areas representing different land uses. Figures 2.5 and 2.6 show the relative contribution of different sources to PM_{10} and $PM_{2.5}$ emissions for Taranaki and the distribution of these emissions across the different areas.

Figure 2.5: Relative contribution to annual PM_{10} and $PM_{2.5}$ emissions in Taranaki for 1998

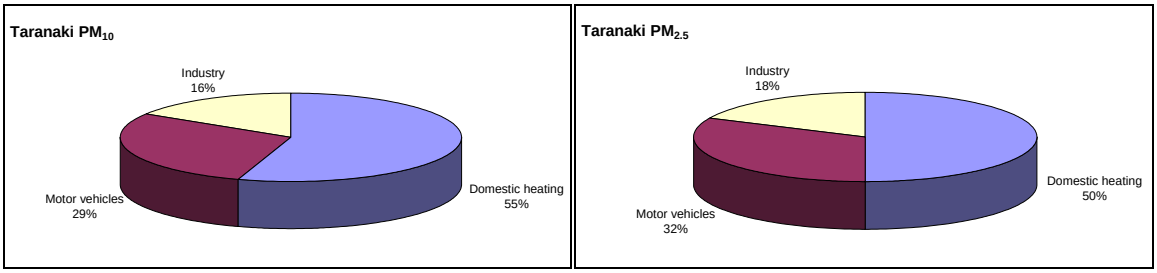
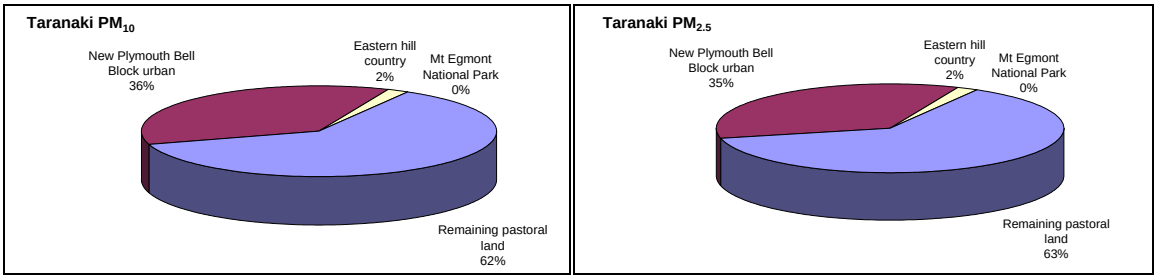


Figure 2.6: Distribution of annual PM_{10} and $PM_{2.5}$ emissions within Taranaki for 1998



2.5 Wellington

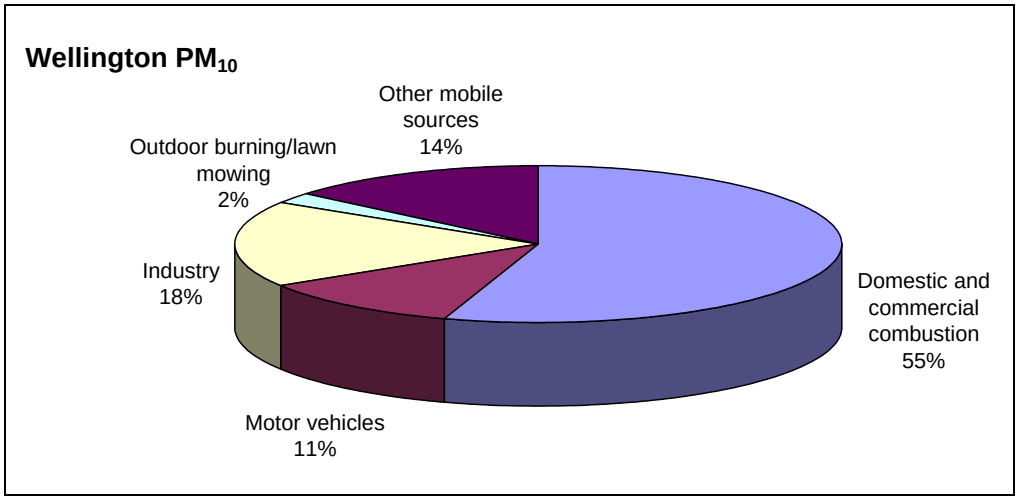
The Wellington emission inventory was carried out for the year 1998 and included three separate reports quantifying emission estimates from domestic and commercial sources, industrial and mobile sources and biogenic sources. Contaminants included were, PM_{10}, CO, NOx, SOx, NMVOC and CO_2.

The PM_{10} emissions sources included in the inventory were:

- fuel combustion (domestic and commercial)
- domestic waste burning
- lawn mowers
- marine craft
- farm-based mobile sources
- rural burn-off
- industry
- motor vehicles
- aviation.

Results for each of the inventory phases were presented as average summer and winter's day emissions for the whole region, although data were collected at a more detailed spatial distribution. Figure 2.7 shows the relative contribution to PM_{10} emissions for the Wellington region for the average winter's day.

Figure 2.7: Relative contribution to wintertime PM_{10} emissions in Wellington



Although domestic and commercial combustion is the dominant source of PM_{10} emissions, around 20% arise from industrial processes. The main contributor to industrial PM_{10} emissions in Wellington is mining and quarrying, which is estimated to produce 60% of the industrial PM_{10} emissions. The other main contributor is the wood products industry, which is responsible for around 25% of the industrial PM_{10} emissions.

2.6 Canterbury region

Emission inventories have been carried out in six of the urban towns within the Canterbury region. Emission inventories for Christchurch have been carried out during 1996 and 1999 and a third inventory for Christchurch for 2002 is currently being prepared. In Timaru inventories have been carried out for 1996 and 2001 and in Ashburton, Kaiapoi and Waimate emissions were assessed during 1997.

The Canterbury inventories focus on emissions from domestic fires, motor vehicles and industrial sources, although a number of other sources of PM_{10} are considered in the Timaru 2001 inventory.

2.6.1 Timaru

The 2001 Timaru emission inventory was primarily designed to examine sources of PM_{10}, although emission estimates for CO, NOx, SOx, CO_2, benzene, dioxins, benzo(a)pyrene and $PM_{2.5}$ were also made. The inventory encompassed the urban areas of Timaru with a further spatial breakdown provided for the following census area units:

- Washdyke
- Waimataitai (Maori Park and Waimataitai)
- Marchwiel
- Gleniti (Gleniti and Glenwood)
- Highfield
- Fraser Park
- Seaview

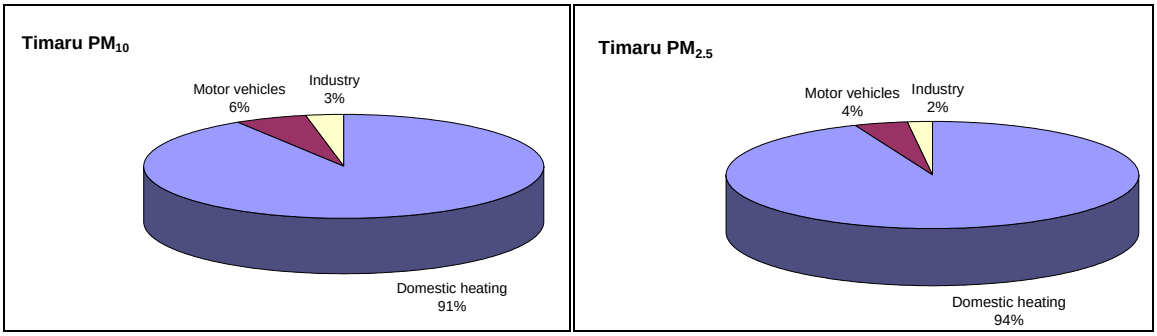
- Watlington
- Parkfield
- Kensington (Redruth and Timaru Gardens).

Results of the 2001 Timaru emission inventory indicate that solid fuel burning for domestic home heating is the main source of PM_{10} emissions in the area (Figure 2.8). Although not included in Figure 2.8, estimates of PM_{10} emissions from rail transport, dust from tilling, lawn mowers, leaf blowers and chainsaws, brakes and tyres, marine activities and cigarette smoke were also considered. They were not included in the total emissions assessment as uncertainties surrounding most of these estimates were high. However, the overall contribution of these sources was minimal at less than 50 kg/day compared to the domestic heating contribution of 1124 kg/day. Outdoor burning is prohibited in Timaru in urban areas so was not included in the assessment.

The inclusion of emission estimates for $PM_{2.5}$ in the Timaru 2001 inventory also provides a useful indication of the contribution of different sources to this size fraction. These data indicate that around 90% of domestic home heating emissions are in the $PM_{2.5}$ size fraction compared to around 60% for motor vehicles and 50% for industry. However, the 2001 inventory cautions on the use of these data as the emission factors for this size fraction are less certain and should be treated as indicative only (Wilton, 2001c).

The 2001 Timaru inventory also included an assessment of trends in sources of PM_{10} emissions since the 1996 inventory survey. After adjusting for differences in methodology it appears that PM_{10} emissions are unlikely to have changed significantly in Timaru between the years 1996 and 2000 (Wilton, 2001c).

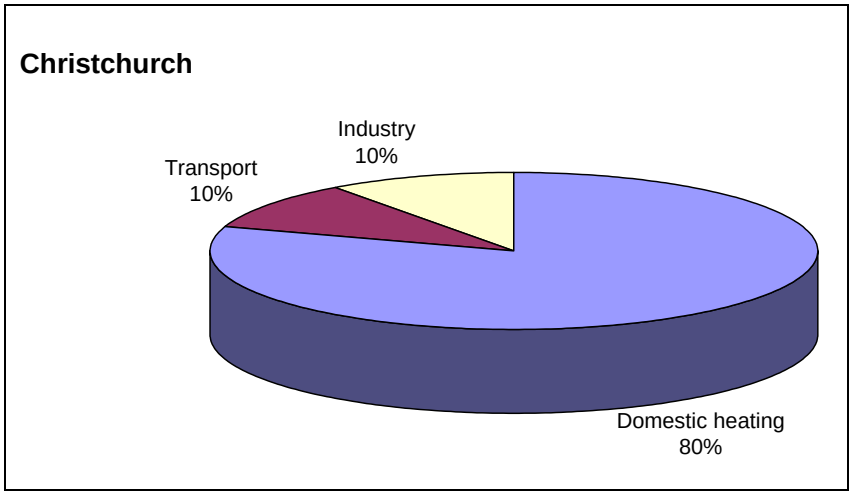
Figure 2.8: Relative contributions to wintertime PM_{10} and $PM_{2.5}$ emissions in Timaru in 2001



2.6.2 Christchurch

The most recent available emission inventory data for Christchurch is for 1999. The inventory focused on emissions of PM_{10} during the winter, as it is these months when PM_{10} concentrations in Christchurch exceed guideline values. Sources included in the assessment were domestic home heating, motor vehicles and industry. No outdoor burning sources were included as this activity is prohibited in Christchurch during the winter months. The Christchurch territorial boundary was used to define the total inventory area and breakdowns for the inner Christchurch area and the 25-suburb area used in the 1996 inventory were included.

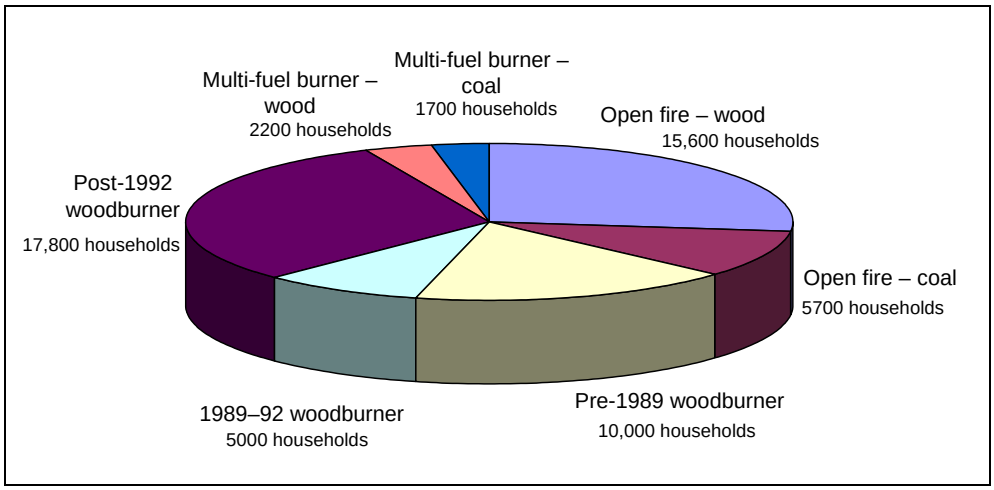
Figure 2.9: Relative contribution to wintertime PM_{10} emissions in the Christchurch 25 suburb area in 1999



Results for the 1999 emission inventory indicate that the majority of the PM_{10} emissions come from solid fuel burning for domestic home heating. Figure 2.9 shows that for the 25-suburb area, 80% of the PM_{10} emissions occur as a result emissions of domestic heating with 10% from motor vehicles and 10% from industry. Of these, over half come from open fires and pre 1989 enclosed burners (Figure 2.10). While the overall contribution from domestic heating is similar to the 1996 emission inventory, some changes in the types of heating methods contributing to the domestic heating emissions have occurred. Most notable was a decrease in the contribution from coal burning and a significant increase in the number of enclosed burners.

While no assessment of the relative contribution of different sources during the summer months has been carried out, the prevalence of summer home heating is likely to be minimal. Thus industry and motor vehicles will be more significant contributors at that time of the year. In addition, it is likely that other wind related sources such as dusts and sea spray may increase during the summer months.

Figure 2.10: Relative contribution of different heating methods to domestic heating emissions in Christchurch in 1999



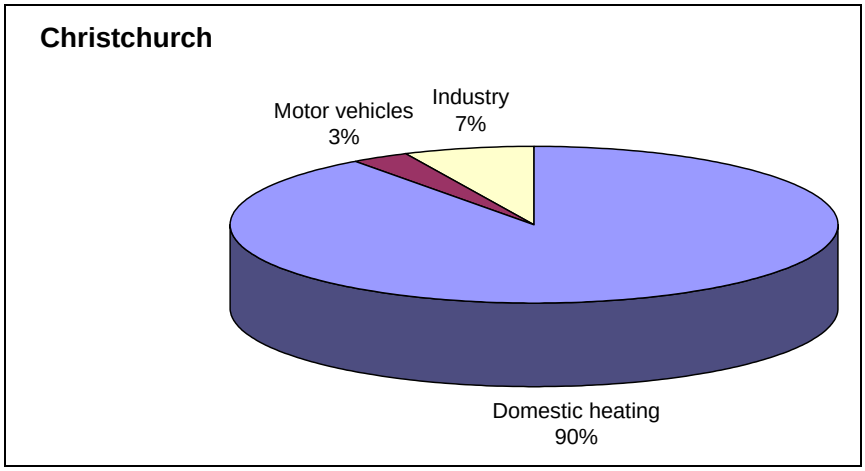
In addition to an assessment of the relative contribution of these sources to PM_{10} emissions in Christchurch, estimates have been made of the relative contribution of these sources to PM_{10} concentrations in the city. A difference between contributions to emissions and contributions to concentrations occurs because of variations in the emissions sources with time of day. Table 2.3 (from the 1999 Christchurch emission inventory) shows that the majority of domestic heating emissions occur during the evening time period (6–10 pm). This coincides with the time of the day when meteorological conditions are most conducive to pollution. Consequently, emissions that occur during this period will have a greater impact on concentrations than those that occur during the daytime when higher wind speeds result in greater dispersion.

Table 2.3: Differences in the time of day that emissions from different sources occur

	6–10 am	10 am–4 pm	4–10 pm	10 pm–6 am	PM_{10} (kg)
Domestic heating	668	1479	5720	989	8856
Motor vehicles	328	541	428	65	1361
Industry	237	497	232	214	1180
Total Christchurch	**1233**	**2518**	**6380**	**1268**	**11,397**

In Christchurch, the impact of differences in the time of day that emissions from different sources occur can be quantified using a box model developed for Christchurch by NIWA (Gimson and Fisher, 1997). The box model accounts for the impact of meteorology at different times of the day for a typical high pollution night and allows predictions of PM_{10} concentrations for variations in the timing of emissions. The outputs of the model have been used to weight the emissions from different sources relative to their contribution to 24-hour average PM_{10} concentrations (Figure 2.11). This model also indicates a linear approach to the relationship between emissions and concentrations.

Figure 2.11: Relative contribution to wintertime PM_{10} concentrations on nights of high air pollution in Christchurch for 1999

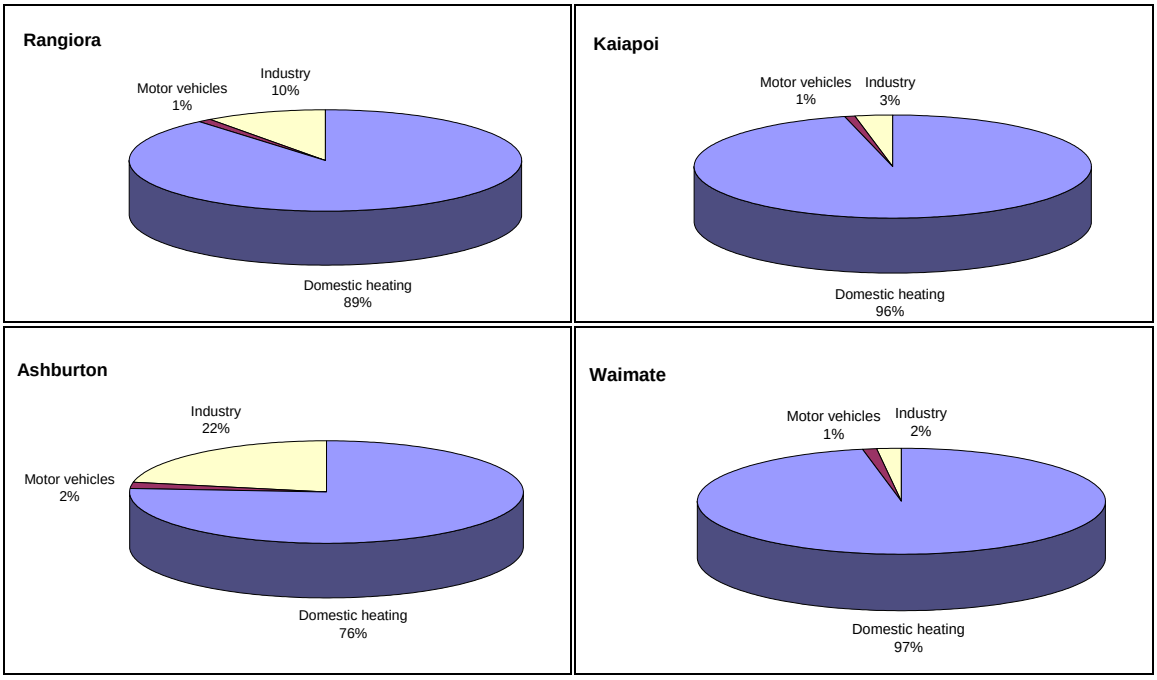


2.6.3 Ashburton, Kaiapoi, Rangiora and Waimate

Emission inventory investigations for Ashburton, Rangiora, Kaiapoi and Waimate were carried out for the year 1997. The main air quality concern in these towns was concentrations of PM_{10}, although estimates of CO, NOx, SOx, VOC and CO_2 were also included. Sources targeted included domestic home heating, motor vehicles and industry.

The main source of PM_{10} emissions in each area was domestic home heating with contributions ranging from 97% in Waimate to 76% in Ashburton (Figure 2.12). Industrial contributions were also significant in Ashburton contributing 22% of the PM_{10} emissions. In all areas the motor vehicle contribution was minor.

Figure 2.12: Relative contribution to wintertime PM_{10} emissions in Rangiora, Kaiapoi, Ashburton and Waimate in 1997



2.7 Nelson

The Nelson 2001 emission inventory was primarily designed to examine sources of PM_{10} during the winter months as PM_{10} concentrations in Nelson were found to regularly exceed ambient air quality guidelines. Emission estimates for CO, NOx, SOx, VOC, CO_2, benzene and $PM_{2.5}$ were also made. Sources examined included domestic home heating, motor vehicles including brake and tyre wear, industrial emissions and outdoor burning. Because of the undulating topography of Nelson, the area was broken down into eight separate airsheds. Results for airshed five (Toi Toi, Broads, Kirks, Bronte, Grampians and part of Britannia Heights) were of particular interest as air quality monitoring indicated PM_{10} concentrations were of greatest concern in this area.

Figures 2.13 and 2.14 show the majority of the PM_{10} and $PM_{2.5}$ emissions across Nelson and within airshed five occur as a result of solid fuel burning for domestic home heating. Outdoor burning and motor vehicles both make only a small contribution (less than 5%). The industrial contribution across the whole of Nelson is larger than in airshed five, which includes only a few coal fired boilers and some minor industrial PM_{10} sources.

About 96% of the PM_{10} emissions from domestic heating in Nelson are in the $PM_{2.5}$ size fraction. This is slightly higher than estimated for Timaru owing to the greater prevalence of the use of coal for domestic heating in Timaru. Across the whole of Nelson, about 65% of the motor vehicle and industrial PM_{10} emissions are in the $PM_{2.5}$ size fraction.

Figure 2.13: Relative contribution to wintertime PM_{10} and $PM_{2.5}$ emissions across the whole of Nelson for 2001

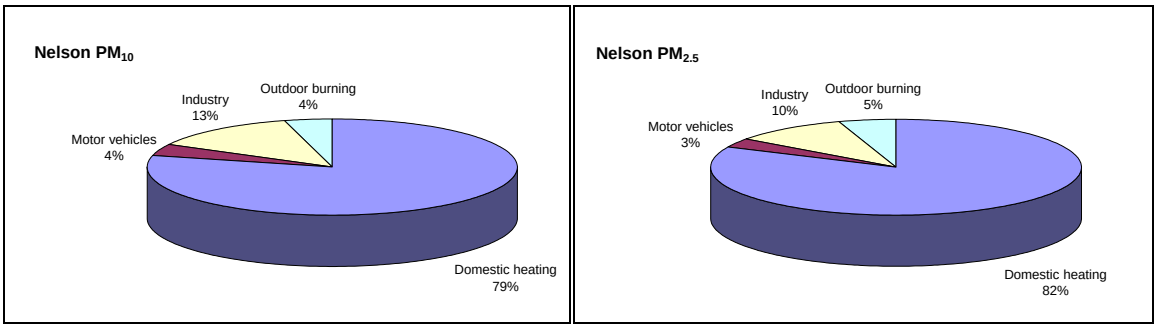
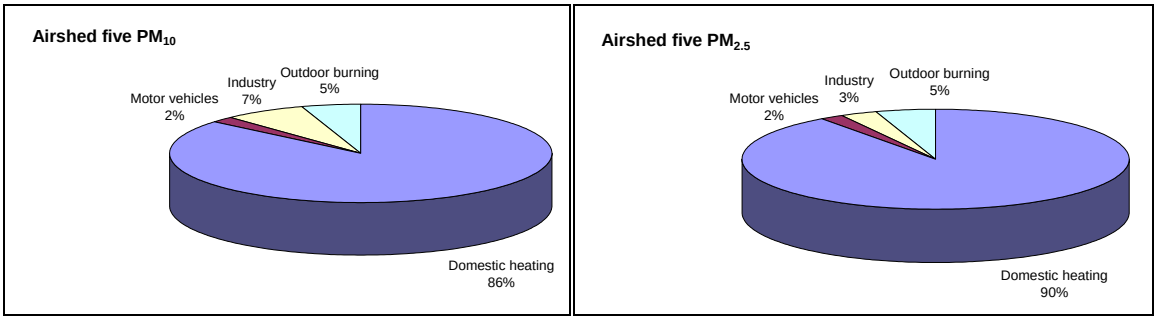


Figure 2.14: Relative contribution to wintertime PM_{10} and $PM_{2.5}$ emissions in the Nelson airshed five area for 2001



2.8 Otago

An air emissions inventory for the Otago region was carried out for the year 1999 and included an assessment of emissions from motor vehicles, domestic home heating and industry. The four contaminants assessed were PM_{10}, CO, NOx and SOx and estimates made for Dunedin as well as the following areas:

- Alexandra
- Arrowtown
- Balclutha
- Clyde
- Cromwell
- Milton
- Mosgiel
- Oamaru
- Queenstown
- Wanaka.

The area of Dunedin was broken down into a further 17 suburbs and data provided for each of these areas as well as a total for the whole Dunedin area.

Air quality monitoring has been carried out in most of the towns included in the 1999 inventory and results indicate that PM_{10} concentrations exceed the guideline value in most of these areas.

Figures 2.15 to 2.17 show the relative contribution of different sources to wintertime PM_{10} emissions in the different study areas. In this case, the domestic emissions category includes backyard burning and lawn mowing as well as home heating. The latter source is dominant, however, contributing over 99% of the PM_{10} wintertime emissions in Dunedin for example. Similarly the mobile sources include non-road sources such as marine, rail and aircraft emissions.

While domestic home heating is the dominant contributor to wintertime PM_{10} emissions in these areas, industrial PM_{10} emissions are significant in most of the towns. In particular, in Mosgiel the industrial PM_{10} contribution is estimated to be 47% and in Dunedin 37%.

Figure 2.15: Relative contribution to wintertime PM_{10} emissions in Alexandra, Arrowtown, Balclutha and Clyde for 1999

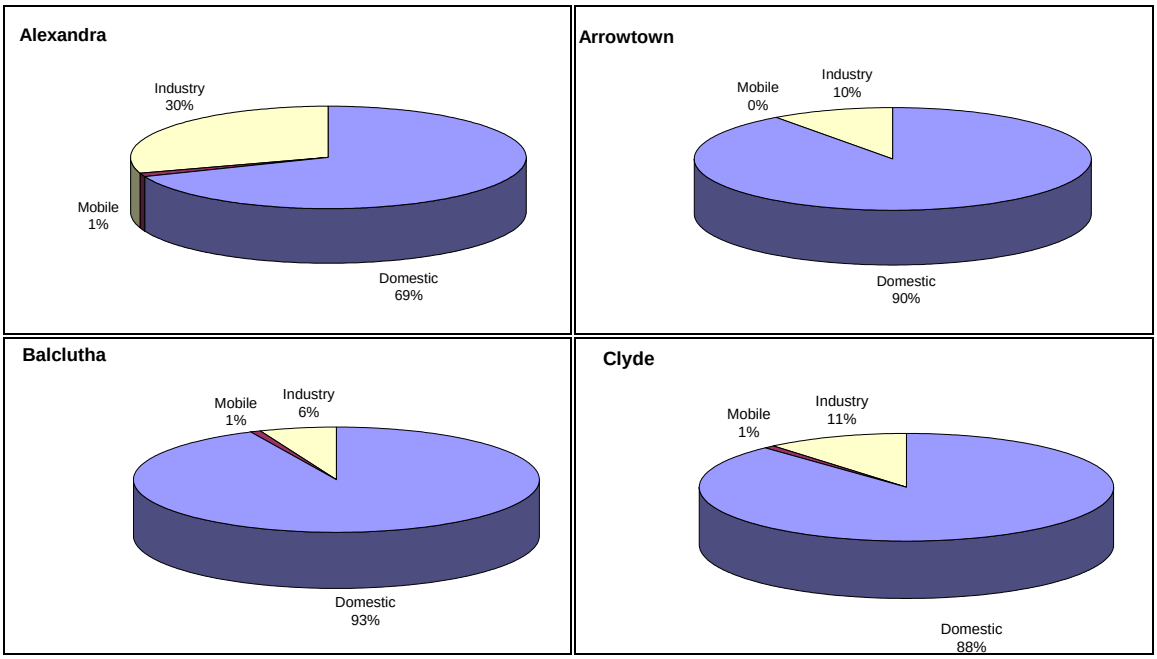


Figure 2.16: Relative contribution to wintertime PM_{10} emissions in Cromwell, Milton, Mosgiel and Oamaru during 1999

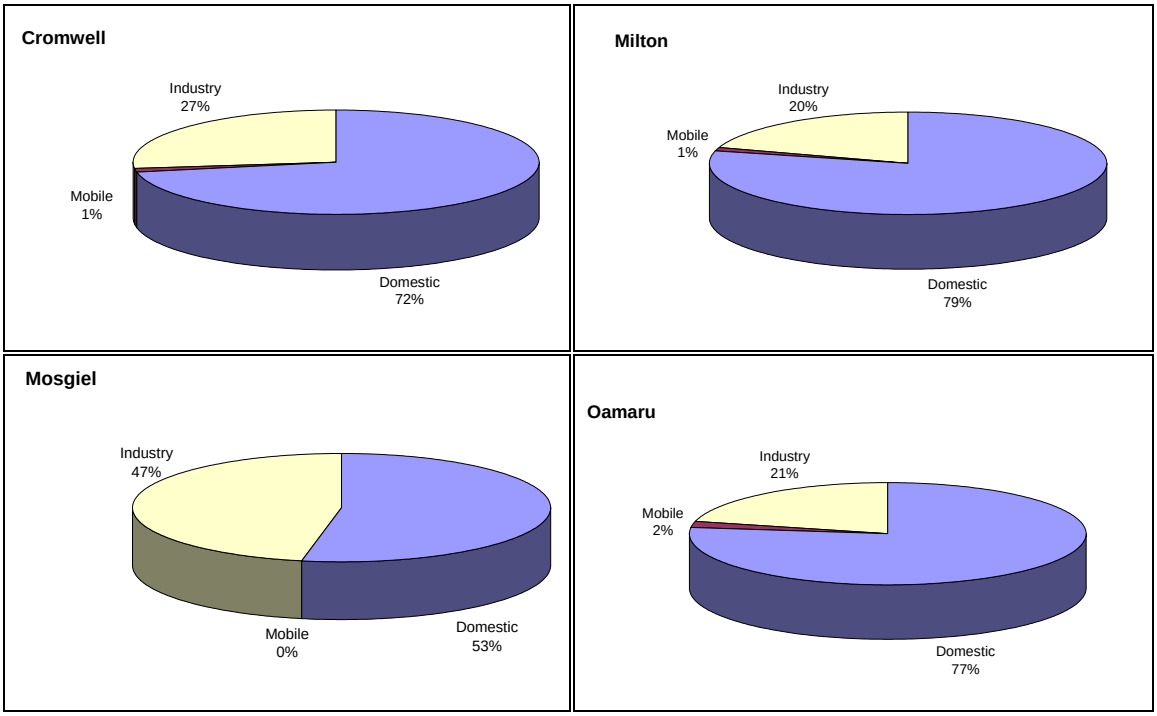
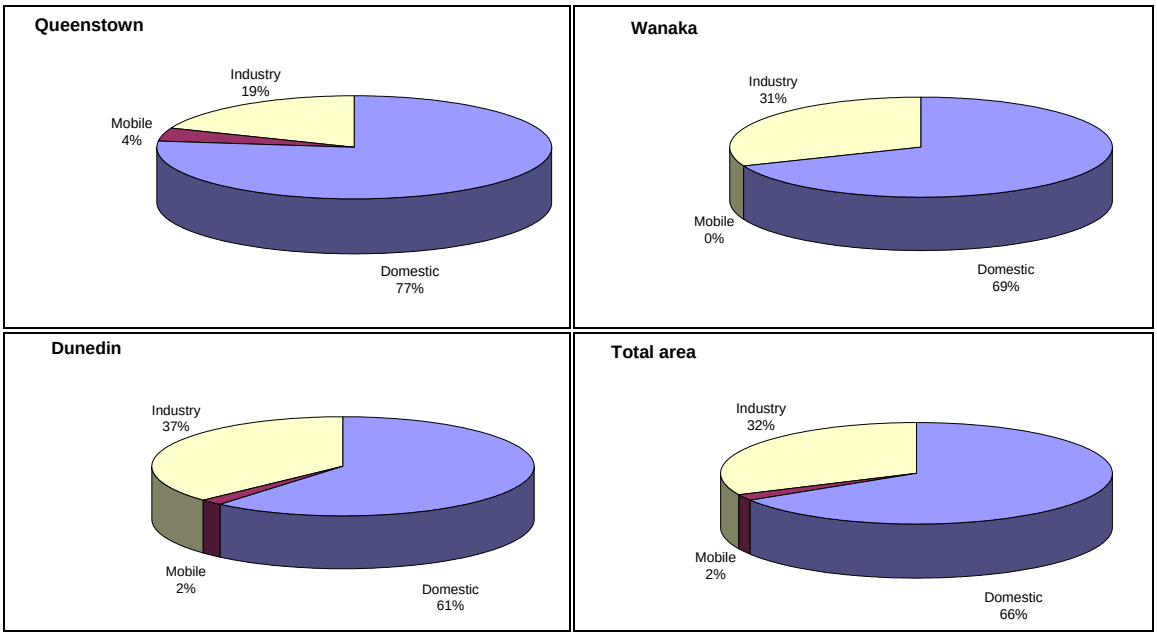


Figure 2.17: Relative contribution to wintertime PM_{10} emissions in Queenstown, Wanaka, Dunedin and across all the Otago study areas during 1999

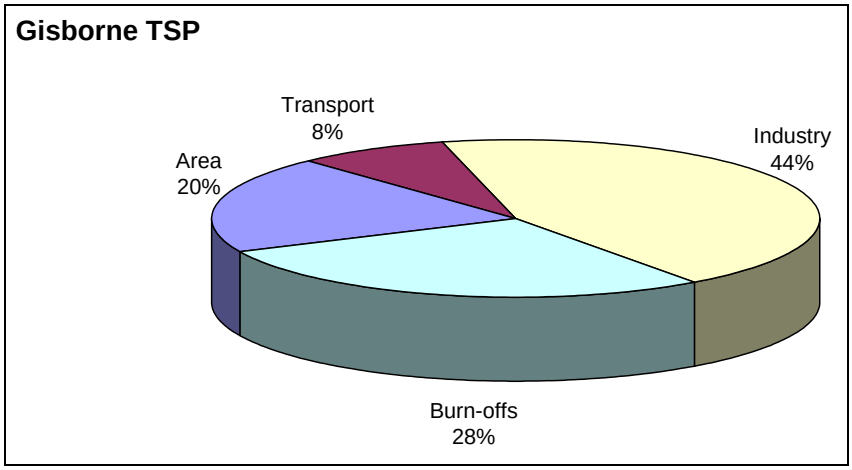


2.9 Gisborne

An emission inventory was carried out for the Gisborne area based primarily on data for 1995. Sources assessed in the inventory include transport (including motor vehicles, aircraft, rail and shipping), domestic combustion, industry, agriculture and natural emissions. Domestic combustion emissions are presented with light industrial, commercial and recreational activities and classified as area sources. Contaminants assessed included total suspended particles (TSP), although transport data were for PM_{10} estimates, CO, NOx, SOx, VOC, CH_4 and CO_2.

The methodology used was similar to the Taranaki and Bay of Plenty inventories in that data were presented as annual emission estimates. The methodology for assessing area emissions for the Gisborne region relies on a population-adjusted extrapolation from the Auckland area emissions assessment and thus results should be treated with extreme caution. Figure 2.18 shows the estimated relative contribution of different sources to annual TSP emissions in Gisborne (Wright, 1996).

Figure 2.18: Relative contribution of sources to annual TSP emissions in Gisborne



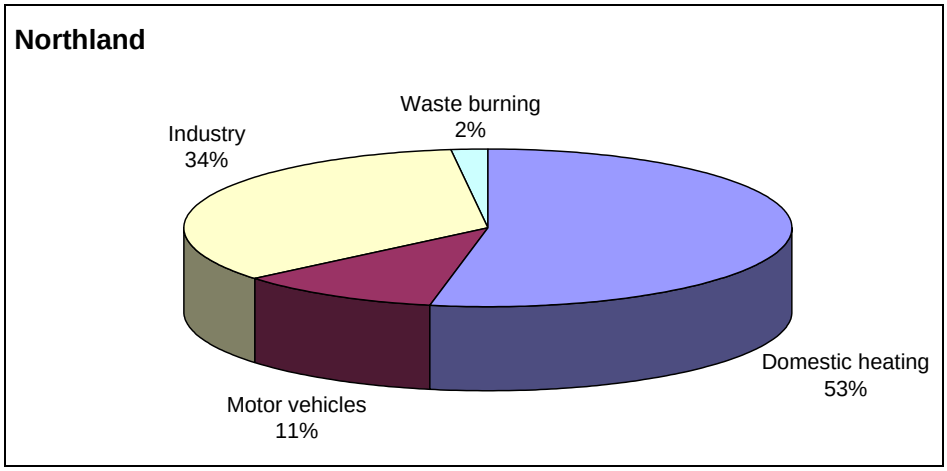
2.10 Northland

An emission inventory for Northland was carried out based on data for the years 1996 to 2000. Sources included in the inventory were major industrial discharges, domestic heating, waste burning and lawn mowing, motor vehicles and agricultural sources. Contaminants considered in the inventory included PM_{10}, CO, NOx, SOx, VOC, CO_2, CH_4 and N_2O. The latter three contaminants were considered in the context of greenhouse gas emissions.

The methodology included Northland specific statistics as well as extrapolation of data from other areas (e.g. Wellington). Data were presented as contributions to annual average emissions as well as daily emission estimates for the winter period. Industrial emissions assessments were limited to the top 10 industrial dischargers within the Northland region.

The main source of PM_{10} for a day during the winter was domestic home heating contributing around 50% of the PM_{10} emissions in the Northland area (Figure 2.19). The industrial contribution was also significant with around 30% of the PM_{10} from this source.

Figure 2.19: Relative contribution of sources to winter daytime PM_{10} emissions in Northland



2.11 Total emissions inventory for New Zealand

An assessment of the amount of PM_{10} from different sources across the whole of New Zealand was carried out by NIWA in 1998 (NIWA, 1998). Sources included in the national emission inventory were broken down into the following categories: area based emissions (predominantly domestic home heating, small scale boilers, lawn mowing, off-road vehicles, open burning), transport, industry and natural emissions. The methodology was less complex than the majority of the regional emissions assessments, with estimates based on broader assumptions. For example, emissions from domestic home heating were assessed based on the results from existing inventories (Auckland and Christchurch for the North and South Islands respectively) and scaled based on population for each area.

The transport emissions assessment in the *Total Emission Inventory for New Zealand* estimates annual PM_{10} motor vehicle emissions of 197, 694, 317, 71, 146, 225 and 368 t/year for North Shore City, Auckland City, Manukau City, Wellington and Christchurch respectively. Collectively, estimates for the Auckland area (excluding Rodney District and Franklin) total 1425 t/year or around 3.9 t/day, compared to around two tonnes per day in the 1996 Auckland Regional Emission Inventory (includes parts of Franklin and Rodney). Results from the national inventory assessment for Wellington (around 0.6 t/day) were relatively low compared to the regional estimates for 1997 of 1.2 tonnes. For Christchurch estimates were a bit closer with around 1 t/day for the 1996 national assessment compared to around 0.8 t/day for the 1996 motor vehicles assessment.

The comparability of the total PM_{10} emission estimates in the national emission inventory assessments to the regional assessments varies with area. In Wellington estimates of around 2500 tonnes per year for the national emission inventory compare to around 1500 tonnes in the Wellington region emission inventory.

In Hamilton annual estimates of around 590 tonnes of PM_{10} from the regional assessment compare to around 578 in the national emissions inventory. In Taupo, regional assessments indicate around 400 tonnes of PM_{10} are likely to compare to an estimated 249 tonnes in the national inventory assessment. In Auckland, the regional assessment for 1993 indicates annual emissions for TSP of less than 6000 tonnes per year. This is similar to the national inventory assessment when the areas of Franklin and Rodney are excluded from the assessment. However, if these areas are included, the national assessment indicates around 9000 tonnes of PM_{10} per year. The regional data includes parts of these areas.

For Christchurch, the national emissions inventory estimate of 3086 tonnes of PM_{10} per year is greater than around 2000 estimated based on the Christchurch emission inventory 1996 back-cast. A better comparison is observed in Nelson with regional estimates of around 300 tonnes per year compared to 455 in the national emissions inventory.

3 Other Methods for Assessing Sources of Particles

An alternative method for assessing sources of PM_{10} that is increasing in popularity in New Zealand is the use of receptor modelling. This source apportionment method involves the analysis of the composition of the particles collected on a filter and the subsequent statistical assessment of sources based on the relative clustering of elements on the filters.

Typical filter measurements include elements of molecular weight greater than sodium, elemental and in some cases organic carbon, and inorganic ions such as nitrates and sulphates. The elemental analysis in New Zealand is typically done using proton induced x-ray emission (PIXE), the elemental carbon using light absorption methods and ion chromatography is used to measure inorganic ions.

One of the advantages of receptor modelling methods is that they allow for the assessment of natural sources such as sea spray, which may contribute to measured particle concentrations, but is unlikely to be adequately estimated using emission inventory methods. It provides estimates of daily variations in sources contributing to particle concentrations, for example with wind direction or other daily variations in source emissions or meteorology.

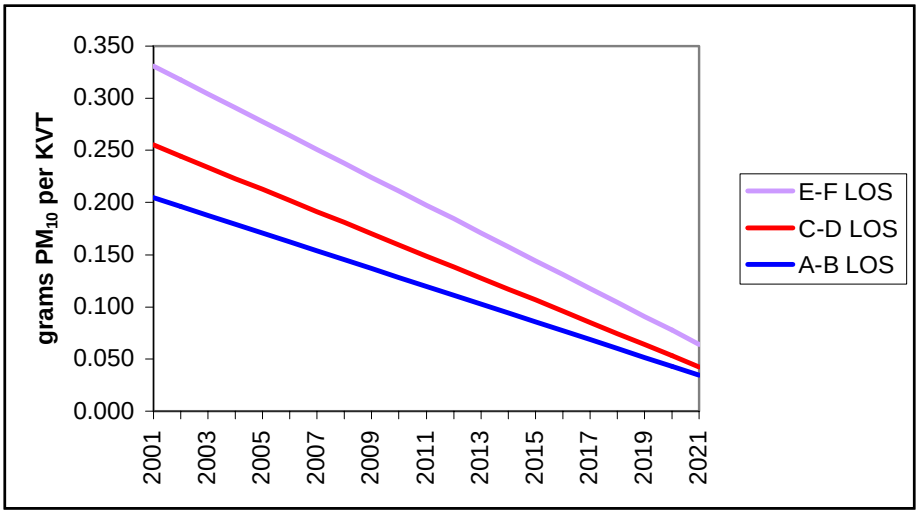
Limitations of receptor modelling methods are that a large numbers of filter samples are required and it is not always possible to distinguish between sources. In particular, combustion processes emit similar ratios of elements making it difficult to assess the motor vehicle contribution relative to the domestic fire contribution. It is probable that existing source information for New Zealand will improve as more studies are carried out and that more advanced techniques will assist in improving the outputs from this source apportionment method.

4 Trends in PM_{10} Emissions in New Zealand

Because emission inventory studies have only been carried out in New Zealand in the last seven years, limited information is available on trends in sources of emissions. Domestic home heating is the dominant source of wintertime particle emissions and therefore changes in home heating methods will play a key role in determining trends in most areas. These changes are likely to be area specific, although factors such as increases in electricity prices or concerns regarding supply could have nationwide implications.

Changes in emissions from motor vehicles will also impact on overall trends in PM_{10} emissions, although to a lesser degree in most areas. The New Zealand Transport Emission Rate model (NZTER) produced by the Ministry of Transport as a part of the vehicle fleet emission control strategy indicates a reduction in particle emissions from this source with time. The reductions are primarily associated with improved vehicle technology and are illustrated in Figure 4.1. The three levels of service (LOS) categories represent emission rates for different levels of congestion.

Figure 4.1: Predicted trends in PM_{10} emissions from motor vehicles



Source: From NZTER for the New Zealand vehicle fleet profile.

Notes: A–B shows free flow, C–D interrupted flow and E–F congested flow.

Future trends in other sources of other emissions are difficult to assess. Growth in industrial activities and changes in existing emissions from these processes are likely to be area specific and may depend on the extent of existing regulation. Trends in domestic home heating emissions will be influenced by changes in solid fuel burner technology and any standards placed on the installation of new appliances. In some areas, management measures relating to solid fuel burning are likely to impact on future emissions from this source.

Existing trend information from emission inventory studies is limited to an assessment for Timaru comparing 1996 and 2000 and for Christchurch comparing 1996 and 1999. While the latter area shows trends in home heating methods, with an increase in the number of households using solid fuel burning and a decrease in the use of coal, changes in emissions are minimal. This is because of the reduction in emissions associated with the decreased coal use and the conversion of older solid fuel burners to low emission burners is outweighed by the overall increase in the number of solid fuel burners (Wilton, 2001c). No significant changes in home heating trends or emissions were apparent in the 1996 and 2000 Timaru emission inventory comparison.

5 Sources of PM_{10} in New Zealand

The results of the emission inventory investigations into sources of particles in New Zealand are shown in Figure 5.1. With the exception of Bay of Plenty, Taranaki and Gisborne, these data represent average wintertime emission sources. The main limitation with the assessment is the exclusion of sea spray emissions, as these may be a significant contributor in some of the coastal locations. Variations in the inclusion of some of the smaller emission sources are unlikely to significantly impact on results as all inventories include an assessment of the main anthropogenic contributors, domestic fires, motor vehicles and industrial emissions.

In Figure 5.1, results are presented for the main urban areas within the different regions. For areas such as Canterbury and Otago results are also available for many of the smaller urban towns (see Sections 2.6 and 2.8 and Table 5.1). In these smaller areas domestic fires are generally more dominant than for the larger cities of Christchurch and Dunedin. In contrast, results for some of the smaller north island areas (e.g. Tokoroa and Taupo), show a stronger industry component.

Table 5.1 shows estimates of PM_{10} and TSP discharges to air from different sources in kilograms per day and tonnes for per year. For the larger cities, PM_{10} emissions of around four to 30 tonnes per day are estimated, compared to around one tonne or less for most of the smaller urban areas. In Auckland, just less than 19 tonnes of PM_{10} is estimated from domestic heating per day compared to around eight tonnes for Christchurch and six tonnes for Wellington.

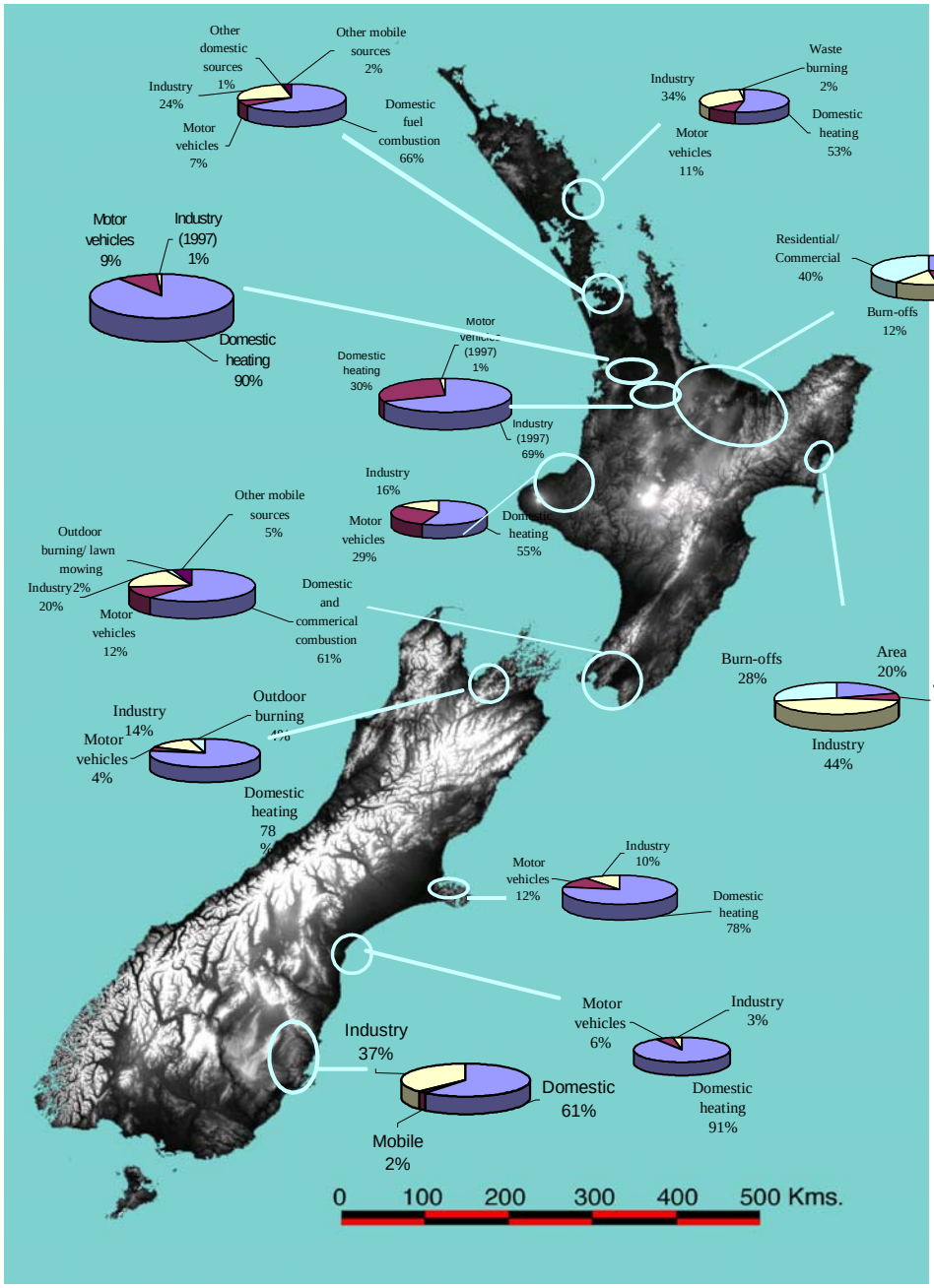
The relative contributions to PM_{10} emissions illustrated in Figure 5.1 and Table 5.1 are based on assumptions relating to emission rates and fuel use and contain some degree of uncertainty. There is some variation from area to area in the approach taken and the subsequent confidence in the results. The potential contribution of sea spray combined with concerns regarding methodological issues suggests that estimates of the relative contribution for Auckland illustrated in Figure 5.1 may not be appropriate.

The main source of particles within the urban areas of New Zealand is solid fuel burning for domestic home heating. However, industrial emissions also have the potential to be a significant contributor in a number of locations.

Table 5.1: Comparison of emissions estimates for different regions of New Zealand

	Domestic kg/day	Mobile sources kg/day	Industry kg/day			Total kg/day
Alexandra	264	4	114			382
Arrowtown	120	0.5	14			135
Balclutha	250	4	17			271
Clyde	63	0.5	8			72
Cromwell	127	1	48			176
Milton	174	2	43			219
Mosgiel	325	3	290			618
Oamaru	870	17	236			1123
Queenstown	586	31	143			760
Wanaka	147	1	68			216
Dunedin	3174	101	1933			5208
	Domestic heating kg/day	**Motor vehicles kg/day**	**Industry kg/day**	**Other domestic kg/day**	**Other mobile kg/day**	**Total kg/day**
Christchurch	7929	991	1027			9947
Rangiora	543	8	61			612
Kaiapoi	334	12	5			351
Ashburton	897	18	106			1021
Waimate	285	1	6			292
Timaru	1124	61	41			1226
Hamilton	3600	371	39			4010
Taupo	409	77	866			1352
Tokoroa	1232	58	2866			4156
Nelson	1486	78	264	85		1912
Northland	3028	633	1915	103		5679
Auckland	18,900	2000	7100	300	700	29,000
	Domestic/ commercial heating kg/day	**Motor vehicles kg/day**	**Industry kg/day**	**Other domestic kg/day**	**Other mobile kg/day**	**Total kg/day**
Wellington	6160	1200	2000	180	490	10,030
	Domestic t/year	**Mobile sources t/year**	**Industry t/year**	**Burn-offs t/year**		**Total t/year**
Taranaki	490	251	138			879
BOP	1110	455	849	323		2737
Gisborne	151	58	340	210		759

Figure 5.1: Relative contribution of sources of particles within New Zealand



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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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