Chapter 8

Air quality

Air quality

SUMMARY

Overview

Calculated PM_{10} emissions in Christchurch have declined. However, solid fuel burning from home heating remains a major contributor to poor air quality in Christchurch and other urban centres in Canterbury. Concentrations of suspended particulate (PM_{10}) exceed national guidelines during winter months in seven towns, most frequently in Christchurch and Timaru. The number of open fires in the city has fallen significantly and the number of solid fuel burners is predicted to decrease.

Resources

Canterbury's cold winters, in combination with houses that are often poorly insulated, mean that a lot of energy is required for home heating. Stand-alone solid fuel appliances are a traditionally-accepted means of home heating, and large numbers are installed throughout the region.

Solid fuel burners contribute to poor air quality on many winter nights in a number of urban areas. Meteorological conditions, including low wind and temperature inversions, limit the dispersion of contaminants, contributing to the development of concentrations which exceed guidelines.

Over time, the number of solid fuel burners in urban areas of Canterbury is predicted to decrease, as households replace older appliances with electric heat pumps, and gas and oil-burning appliances.

Some operators of larger industrial/commercial boilers have invested in pollution abatement techniques or switched away from using solid fuel. Future economic growth in the industrial sector, however, is likely to exert demand for an increasing share of air sheds which are already over-allocated.

While improvements in fuel efficiency and emission performance have reduced the pollution impacts of individual motor vehicles, vehicle use is steadily increasing and this trend is likely to continue.

Demands on energy and fossil fuel resources are increasing, and the prices of these commodities are volatile.

Processes

Wood and, to a lesser extent, coal are widely-used fuels for home heating in Canterbury. In Timaru, for example, 66% of households heated their homes by burning solid fuel in 2001.

Many industries use combustion in their processing and for space heating. The latter use is also important for institutions such as schools and hospitals. Motor vehicles also contribute to a number of air quality impacts including smoke nuisance, benzene, carbon monoxide (CO) and nitrogen oxide (NOx) emissions.

In Christchurch, emissions of particulate (PM_{10}) per night during winter in 2002 contributed by each sector were: home heating: 6.5 tonnes; industry: 1.0 t; and motor vehicles: 1.0 t.

In Timaru, during the 2001 winter, the respective contributions were home heating: 1.0 t; industry: 0.05 t; and motor vehicles: 0.07 t per night. In other Canterbury towns (Waimate, Ashburton, Kaiapoi and Rangiora), most of the PM_{10} emissions are from home heating.

Outdoor burning, particularly of stubble, continues to be a common farming practice.

Outcomes

Air quality in many urban areas in Canterbury is degraded during winter. The contaminant of most concern is suspended particulate (PM_{10}), which includes all particles in the air less than 10 microns in diameter. Adverse health effects associated with exposure to PM_{10} are well documented.

Seven towns in the region currently breach the National Environmental Standard for PM_{10}, ranging from a few days a year in smaller towns like Geraldine (two in 2007) to 30 or more days in the larger settlements of Timaru (36 in 2007) and Christchurch (32 in 2006).

Air quality is worst in Christchurch where a concentration of PM_{10} over four times the guideline value (50 µg/m^3) has been recorded in the report period (214 µg/m^3 in 2002).

Hazardous air pollutants, including both volatile and semi-volatile organic compounds, have been measured in Christchurch. While volatile organic compounds do not exceed current health-based guidelines, calculated average annual concentrations of semi-volatile organic compounds, particularly the poly-aromatic hydrocarbon benzo(a)pyrene (3 ng/m^3 in 2003/4), are well over the guideline of 0.3 ng/m^3.

Rural smoke, dust and odour continue to create occasional nuisance effects. Smoke from rural burning also sometimes impacts on urban air quality.

The trend of replacing solid fuel burners has implications for regional energy, as electricity demand for home heating will increase during the winter months. A related outcome is the consequence of this trend for the region's carbon footprint from replacing wood fuel, which is largely considered to be carbon neutral.

Response

Environment Canterbury is addressing these issues through the following activities:

- Establishing and operating air pollutant and meteorology monitoring networks throughout the region. Emission inventories have been developed for Christchurch, Timaru, Rangiora, Kaiapoi, Ashburton and Waimate. Air quality modelling has also been undertaken
- Working with urban communities, through the Clean Heat Project, to provide incentives for householders to change from heating their homes with high-emitting solid fuel burners to cleaner options
- Providing a series of measures, both regulatory and non-regulatory, for addressing the impacts of emissions from all sectors on air quality, primarily in Christchurch. These are set out in Chapter 3 of the Proposed Canterbury Natural Resources Regional Plan
- Working with district councils and local communities to establish how air quality may be managed in other urban areas, primarily Waimate, Timaru, Geraldine, Ashburton, Kaiapoi and Rangiora
- Undertaking public education and social marketing campaigns in the main urban areas to increase public awareness of air quality issues and their resolution
- Using the consent process and compliance monitoring of industrial

processes to control the level of industrial emissions. Environment Canterbury also enforces rules relating to other sources (including home heating and outdoor burning) and responds to complaints received via the 24-hour Pollution Hotline

Central Government also has a role in responding to air quality issues:

- The Government, through the National Environmental Standard for Air Quality (NESAQ), has imposed numerical standards for a range of air contaminants and has prescribed the way air sheds, in which the PM_{10} standard is breached, are to be managed
- The Government has also recently adopted policies to reduce emissions from motor vehicles, including emission standards for new and used vehicles

Key trends

PM_{10} concentrations in Christchurch, Timaru, and other urban centres, and CO concentrations in Christchurch, continue to exceed ambient air quality guidelines and the NESAQ frequently during the winter months.

PM_{10} concentrations in Christchurch have declined relative to 1996 levels when the impact of weather is taken into account.

There are far fewer exceedences of CO guidelines in Christchurch than 10 years ago: there were nine days when the eight-hour average guideline was exceeded in Christchurch (St Albans) in 1999 compared to two days in 2006.

Benzene concentrations in Christchurch are declining, from 20 µg/m^3 for an annual average measured at Riccarton Road in 1996/97 to nine µg/m^3 in 2004/05.

There are as yet insufficient data to detect trends in the annual average concentrations of benzo(a)pyrene, although it is likely that these will decrease, particularly as a result of reductions in emissions from home heating appliances.

The calculated PM_{10} emissions from home heating declined by 15% between 1999 and 2002 in metropolitan Christchurch. Emissions increased by 4% in Timaru from 1996 to 2005 due to a 16% increase in solid fuel burners, from 5270 to 6100 appliances. All types of solid fuel burner numbers decreased, with the exception of logburners which increased by 37%, from 3452 to 4737 appliances. Substantial decreases in emissions from home heating have occurred from 1997 to 2004 in Waimate (30%), Ashburton (19%), Kaiapoi (23%) and Rangiora (31%).

The calculated PM_{10} emissions from motor vehicles (a minor proportion of total PM_{10}) declined by 16% between 1999 and 2002 in metropolitan Christchurch, and decreased by 16% in Timaru from 2001 to 2005.

Between 1999 and 2002, open fire numbers in metropolitan Christchurch reduced from 17,300 to 9400, a decrease of 46%. No significant decline was evident in the number of households using wood burners.

Key indicators

The main indicators that are monitored for assessing air quality outcomes (the state of air quality) and the effectiveness of responses to degraded air quality in the urban environment are concentrations of:

- particulate (PM_{10})
- carbon monoxide (CO)
- sulphur dioxide (SO_2)
- nitrogen dioxide (NO_2)
- ozone (O_3)
- volatile organic compounds (VOCs) including benzene, and polycyclic aromatic hydrocarbons (PAHs), including benzo(a)-pyrene (BaP)

The main indicators that are measured to assess pressures on air quality are the emissions of:

- PM_{10}
- CO
- SO_2
- nitrogen oxides (NOx) and
- VOCs from domestic, industrial and motor vehicle sources

THE IMPORTANCE OF AIR QUALITY

Good air quality is important because it benefits the health of communities, as well as having visual and aesthetic values. People with existing respiratory or cardiac disorders, and the very young and elderly, are particularly prone to adverse health effects from poor air quality. Some air pollutants are also carcinogenic at low concentrations.

Air quality is measured and managed with reference to guidelines or standards that typically contain both maximum values, beyond which concentrations of contaminants should not occur, and averaging periods which determine the time span over which measurements are calculated.

Environmental results sought by the community in relation to air quality are summarised in Table 8.1.

Table 8.1 Anticipated environmental results for air quality in Canterbury

Reference	Anticipated Environmental Outcomes
The Long Term Council Community Plan (LTCCP) 2006-2016	
Air quality	• Air, beaches and ocean and land are all in a healthy condition • Business and farming activities do not harm the environment
The Regional Policy Statement 1998	
Chapter 13.4 (1)	• Effects of emissions on human health and the environment are reduced
Chapter 13.4 (2)	• Discharges into air meet the conditions and standards and terms for consents and permitted activities
Chapter 13.4 (3)	• Ambient air quality meets the standards set by Environment Canterbury
Proposed Natural Resources Regional Plan 2004	
AQL1	• Air management outcomes are consistent with the values held by Tangata Whenua as kaitiaki
AQL2	• Ambient air quality is not further degraded, and by 2020 remains within the Regional Council Air Quality targets
AQL3	• Risks from discharges of hazardous air pollutants are reduced to a level where there are no more than minor adverse effects
AQL12	• Within the Christchurch Clean Air Zone 1, the benefits of achieving the 50 $\mu g/m^3$ target for PM_{10} with one annual exceedence include reduced numbers of deaths, hospitalisations, restricted activity days, lost work days, medication use, and nuisance effects, and improved perception of Christchurch as a clean and healthy city
AQL13	• Within the Christchurch Clean Air Zone 1, there is consistent achievement of the 24-hour PM_{10} target of 50 $\mu g/m^3$ (with one annual exceedence averaged over three years) by 2012
AQL13	• Within the Christchurch Clean Air Zone 1 the Clean Air and Energy Efficiency Incentives and Assistance programme is effective in ensuring that fewer people live in inadequately heated homes

Health and Air Pollution in New Zealand (HAPINZ)

A major study into the health effects of air pollution was published in 2007. The Health and Air Pollution in New Zealand (HAPINZ) Christchurch pilot study in 2005 and the 2007 final report, were funded under a joint initiative of the Health Research Council, the Ministry for the Environment and the Ministry of Transport (Fisher et al., 2007). The aim of the study was to identify the effects of air pollution throughout New Zealand, to link these effects to the various sources of air pollution and to provide an economic impact assessment and information to help formulate policies to improve the health of New Zealanders.

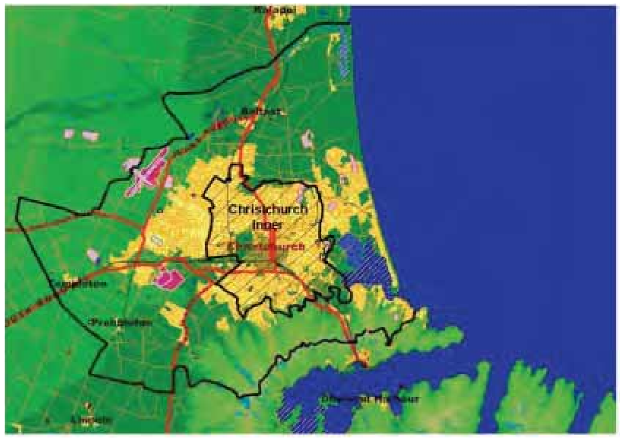
The report used epidemiological studies, carried out in Christchurch and Auckland, to provide information on the short and long-term effects on mortality and illness due to exposure to air pollution. The report notes that previous research identifies particulate matter (PM_{10}) as the primary air pollutant that affects health. Epidemiological results showed that PM_{10} levels were consistently associated with an increase in the daily mortality for people over 65 years of age, with an approximately 1% increase in mortality for each daily increase of PM_{10} by 10 µg/m³. The Christchurch and Auckland studies were used to confirm the long-term increase in mortality appropriate to be applied nationally; a 4.3% increase in mortality was used for each increase of 10 µg/m³ in the annual PM_{10} for people over 30 years of age. The report indicated that there is growing evidence for the use of a higher risk coefficient, which could be as high as 8% for each 10 µg/m³ increase of annual average PM_{10}.

The study went on to develop a national exposure model. This model, validated against monitoring and published dose-response relationships, was used to assess the impact of air pollution on the health of the population in 67 urban areas.

The Canterbury towns included in the study were Ashburton, Christchurch, Geraldine, Kaiapoi, Kaikoura, Rangiora, Timaru and Waimate. By focusing on identified urban areas, the study covered 2.7 million people nationwide — some 73% of the 2001 census population.

For each of the 67 areas the exposure model quantified the annual premature mortality due to air pollution, the incidence of extra cases of respiratory illnesses, as well as the indirect implications of air pollution for society in the form of the number of restricted activity days. Christchurch Inner City (Figure 8.1) was second highest in the national table for the number of annual premature mortalities, at 88, with Auckland City the highest. The results for Canterbury are summarised in Table 8.2, along with the national figures. The air pollution burden is generally higher than the national average in South Island towns due to the use of solid fuel burning for home heating. The number of restricted activity days for the population of each area was also calculated; the national average was about one day per person of the 2.7 million people covered by the study. The report concluded that, nationally, one in 20 people die earlier than they would have because of air pollution, while in Christchurch Inner city this could be as high as one in nine.

The report confirms the results of previous studies on the effects of air pollution in New Zealand, and corroborates evidence from overseas on the short and long-term effects on mortality. The report concludes that the greatest effect occurs due to premature mortality associated with long-term exposure to fine particulates from combustion sources. The economic impact of air pollution in New Zealand was estimated to be of the order of at least $1139 million per year, or $421 per person per year.



Christchurch Inner and Outer Areas

Figure 8.1 Areas shown within thick black lines are referred to as Christchurch Inner and Outer for HAPINZ study

Table 8.2 Annual mortality and restricted activity days due to PM_{10} (extract from HAPINZ study, appendix 1)

Area (2001 population)	Total annual premature mortality (excluding background)	Annual average/1000 premature mortality (excluding background)	Total restricted activity days (including background)
Ashburton (14,202)	7.9	0.56	15,157
Christchurch Inner (132,706)	87.7	0.66	181,144
Christchurch Outer (183,512)	58.4	0.32	180,356
Geraldine (2205)	1.0	0.44	2068
Kaiapoi (9258)	5.8	0.63	11,849
Kaikoura (2106)	0.3	0.16	2399
Rangiora (8607)	5.7	0.66	9245
Timaru (24,732)	13.0	0.53	28,657
Waimate (2757)	1.4	0.50	2556
New Zealand (67 urban areas 2,726,679)	914.6	0.34	2,395,693

8. Air quality

RESOURCES

The principal resource factors relevant to air quality are sources of emissions. The number and type of sources present at any given time dictate the emissions that will occur. Changes in the numbers will have a consequential effect on emissions, and are, therefore, a useful indicator. In turn, the mix of sources of emissions present in an urban area, until government regulation was introduced, has largely been driven by economic factors such as comparative fuel prices, vehicle prices and general economic well-being.

The impact of these emissions is dependent on the atmosphere they are discharged into. In Canterbury during winter, low temperatures are experienced, and wind speed is lower than in other seasons. During anticyclonic conditions, sunset triggers the cooling of the earth, creating a temperature inversion and a decrease in wind speed through the evening. These combined effects limit the dispersion of contaminants, contributing to an increase in concentrations. When these concentrations are high over the relevant guideline period, exceedences may occur. During the longer nights of mid-winter, the timing of the stable weather conditions generally coincides with residents' homeward journeys and the lighting of home fires.

Canterbury's economy has strengthened since the mid-1990s. Most urban centres have undergone population increases during this time, and industrial bases have also increased (see Table 8.3). Overall and per-capita energy consumption in the region have both increased steadily since 1991, per capita consumption increasing from 101 gigajoules per year (GJ/y) in 1991, to 125 GJ/y in 2004 (Environment Canterbury, 2006c). At the same time, New Zealand's existing capacity to generate electricity and its domestic supply of natural gas both appear to be reaching their upper limits, and most currently available energy sources, particularly imported hydrocarbons, are subject to price fluctuation and uncertainty of supply. Wood and coal are notable exceptions, with wood being a readily-available and relatively cost-effective fuel for domestic use, and coal likewise for industrial purposes.

Other factors also act on the extent of the emissions resource, particularly in the case of home heating. Many older Canterbury homes are poorly insulated and require substantial amounts of energy to heat. Free firewood is commonly used, and many people are reluctant to forego this convenience and cost saving. The aesthetic impact of solid fuel combustion, particularly the type of light and heat produced by a flame, is also often advanced as an argument against switching to an alternative heat source.

The total number of solid fuel burners in urban areas of Canterbury is predicted to decrease with time, as some households will naturally replace their older appliances with electric heat pumps, oil or gas burning appliances (Table 8.4). The rate of replacement may increase in the future, particularly as the relative convenience of heat pump technology becomes more well known.

While growth in the industrial sector exerts further pressure on the air sheds, the effects are mitigated to an extent by investments in pollution abatement technologies or by fuel switching away from solid fuel. More innovative strategies are also available to industrial and commercial sites, such as offsetting emissions by funding pollution abatement technologies or fuel switching from other sources within the same air shed.

In other sectors, motor vehicles continue to be relatively inexpensive to purchase and run, and imported diesel-engine vehicles make up a substantial proportion of the regional fleet (it is also recognised that a large proportion of these diesel vehicles are for agricultural purposes in the Canterbury context.) In addition, freight movement is dominated by road transport (Figure 8.2).

As a result, vehicle use continues to increase in some areas as indicated by total vehicle kilometres travelled (Table 8.5). However, the effects of this increase in use on emissions are mitigated by improvements in fuel efficiency and emission performance for individual vehicles.

The Government has introduced new emissions standards for newly-imported new and used petrol and diesel cars and light vehicles. It is a matter of some speculation whether the new standards, effective from early 2008, will have a significant impact on emissions; some interest groups have suggested that the increased cost of replacement vehicles will cause people to hold on to higher-emission cars for longer.

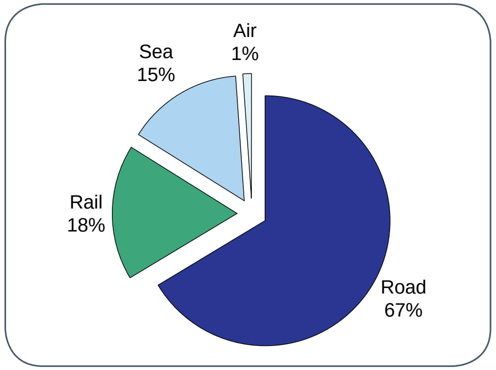


Figure 8.2 Share of goods transported per kilometre by mode, 2002 (source: Bolland et al., 2005)

Table 8.3 Active resource consents for discharges to air

	1995	2000	2005
Waimate	0	0	3
Timaru	27	36	46
Geraldine	0	1	1
Ashburton	13	18	20
Christchurch	132	684	1189
Kaiapoi	0	1	4
Rangiora	2	4	5
Kaikoura	1	1	2

Table 8.4 Numbers of solid fuel-fired home heating appliances

	1996 inventory	1999 inventory	2002 inventory
Suburban Christchurch	42,966	51,942	46,234
	1998 inventory	2001 inventory	2005 inventory
Timaru	5270	6171	6100
	1997 inventory	2004 inventory	
Waimate	950	989	
Ashburton	3661	3627	
Kaiapoi	2117	1512	
Rangiora	2667	2597	

Table 8.5 Total vehicle kilometres travelled (VKT) in selected urban areas

		2001 inventory	2005 inventory
Timaru		348,742	346,058
	1996 inventory	1999 inventory	2002 inventory
Christchurch	5,113,940	5,404,437	5,692,258

PROCESSES

Christchurch

For many years, poor air quality in Christchurch has been attributed to the effects of solid fuel burning for home heating. It is only in recent times, however, that the contribution of home heating to emissions has been quantified. The primary method for obtaining information on the quantity and sources of air contaminants discharged to an air shed is through emission inventories, which quantify the total contaminant loading from, and relative contribution of, different sources of emissions.

Improved understanding of sources assists in identifying appropriate management options, and quantification of emissions helps track both changes in pressure on air quality and the way the community is responding to management interventions. Inventories have been carried out for Christchurch in 1996, 1999 and 2002 (Fisher et al., 1998a; Wilton, 2001a; Scott and Gunatilaka, 2004). A summary of the results is shown in Figure 8.3.

Emission inventories consistently identify home heating as the main source of wintertime PM_{10} emissions in metropolitan Christchurch. Emissions of NO_x, and to a lesser extent CO, are dominated by motor vehicles, and those of sulphur oxides (SO_x) are dominated by industrial sources.

Reductions in home heating emissions from 1996 to 2002 may be attributed to an increase in the use of gas and electricity for heating, and a decline in the use of coal. Replacement of older wood burners with newer models has also reduced emissions, because emission standards for solid fuel burners have become more stringent over time. Decreases in motor vehicle emissions are largely due to an increasing infiltration of cleaner-operating vehicles into the motor vehicle fleet. Increasing emissions of $S0_x$, meanwhile, can be attributed to greater fuel consumption and rising numbers of diesel vehicles. While trends in industrial emissions could not be determined because of methodological differences[1] between inventory years, a nominal increase in emissions is likely.

Recently, a new technique has been applied in Christchurch to address some of the limitations associated with emission inventories. This is known as source apportionment, and was conducted using the Positive Matrix Factorisation (PMF) receptor model, which involves chemical analysis of particles. The PMF model can track changes in particulate over time, and calculates the relative source contributions to concentrations on a day-to-day basis. Speciated concentrations were measured at a receptor site and the model works in reverse to

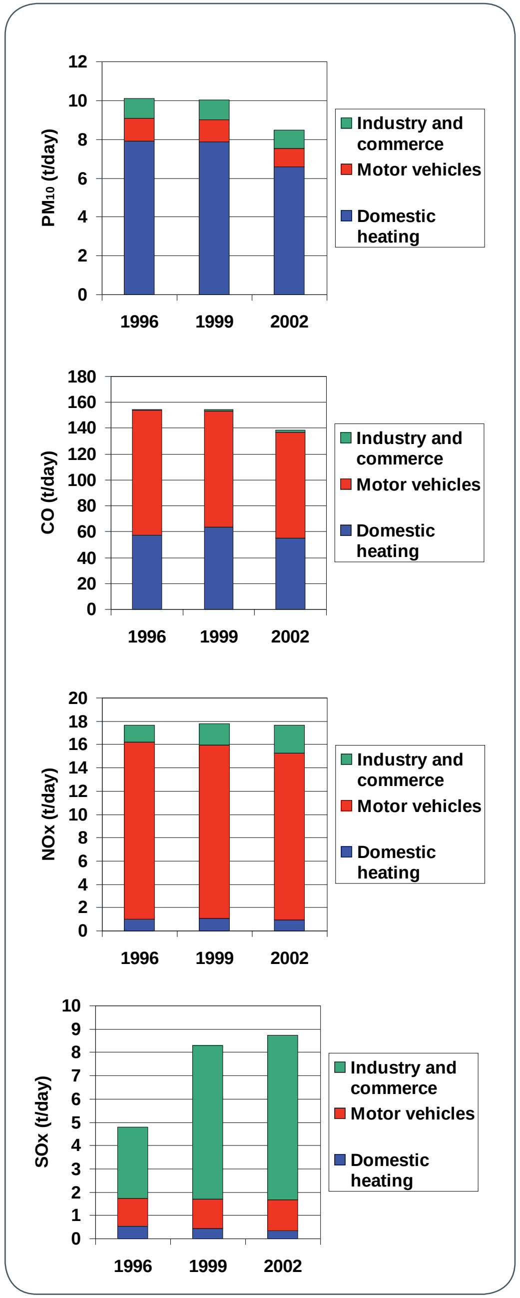


Figure 8.3 Changes in emissions and source contribution (t/day), Christchurch

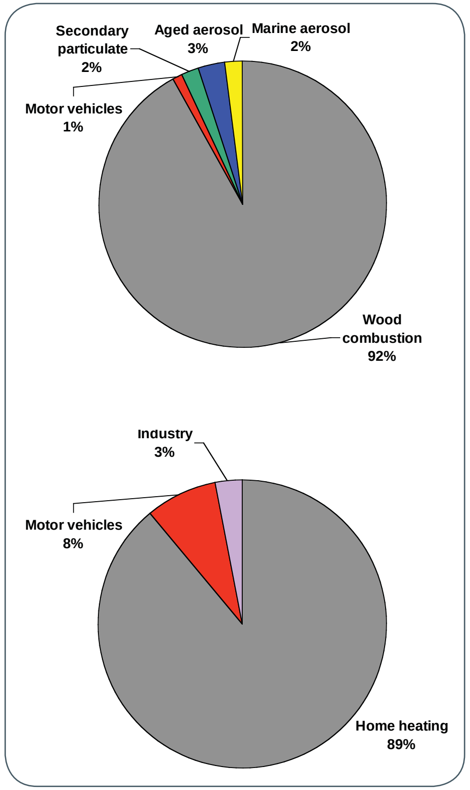


Figure 8.4 Relative contributions to peak $PM_{2.5}$ in Christchurch as determined by (a) the PMF receptor model and (b) box-modelled emission inventory data (2002) (Scott, 2004).

[1]More specific information was sought directly from industries via a questionnaire in the 2002 inventory, whereas, previous inventories used resource consent files exclusively.

determine the relative contributions to predicted concentrations. Unlike emission inventories, it provides seasonal information and determines the contribution of secondary particulate and natural sources (Scott, 2004).

The study was conducted in 2001/2 and five sources were resolved including wood combustion, motor vehicles, marine aerosol, secondary particulate and aged aerosol (a long-range transport/secondary particulate source). The model's ability to determine the main sources of $PM_{2.5}$ was evaluated by comparing the results with box-modelled emission inventory data. The emission inventory data required modelling to determine relative contributions to concentrations rather than emissions. The results are presented in Figure 8.4.

Differences between the methods were evident in the number and type of sources identified, and minor variations in the relative contributions from wood combustion/home heating and motor vehicles. The emissions inventory only quantified discharges from primary anthropogenic sources (home heating, motor vehicles and industry), while the receptor model resolved a broader wood combustion source, including outdoor burning and industrial wood-fired boilers, as well as secondary (secondary particulate and aged aerosol) and natural sources (marine aerosol). Although the receptor-modelled wood combustion source also included contributions from outdoor burning and wood-fired boilers, these were unlikely to be significant contributors to peak $PM_{2.5}$. Despite these differences, both methods clearly identified wood combustion/home heating as being by far the main source of wintertime $PM_{2.5}$.

Receptor modelling source apportionment analysis for Christchurch thus far shows strong agreement with emission inventory results. As air quality policies take effect in the region's towns, the relative contribution of different sources will change, and it will be important to ensure that tracking methods are sufficiently relevant and sensitive to accurately quantify those changes.

Other towns

Emission inventories have been made for Timaru in 1996, 2001 and 2005 (Fisher et al., 1998b; Wilton, 2001b; Smithson et al., 2006), and the towns of Waimate, Ashburton, Kaiapoi and Rangiora in 1997 and 2004 (Foster and Wood, 1998 a, b, c and d, McCauley and Scott, 2005). In all cases except Washdyke (a discrete sub-area of Timaru) PM_{10} emissions are dominated by those from home heating.

Land use in Washdyke is dominated by industrial activities, and as a result, PM_{10} emissions there are predominantly derived from those sources. Emissions of other contaminants in Timaru and the other four towns are from a mixture of sources, with SOx emissions typically derived from industry, CO from a mixture of domestic and vehicle emissions, and NO_x from industry or vehicles. In Timaru (including Washdyke) the 2001 inventory indicates slight increases in PM_{10} and SO_x emissions from 1998, and slight decreases in CO and NO_x emissions. Industrial PM_{10} and NO_x emissions, while small in comparison to other sources, show the greatest proportional increases, nearly double earlier levels.

In the other four towns, the 2006 inventory (for the 2004 calendar year) indicates general decreases in home heating emissions in all towns, and increases in industrial emissions in Ashburton and Kaiapoi (and in Rangiora, if some figures are corrected[2]). Vehicle emissions can only be compared in Ashburton and Waimate. Those in Waimate do not display any consistent trend, but an overall decrease is indicated in Ashburton.

Pressures on rural air quality

In the rural environment, emissions and smoke from the burning of vegetative material, odours from animal waste disposal, and agrichemical spray drift can adversely affect local air quality. When these issues arise, they are typically dealt with by Environment Canterbury's Pollution Hotline and enforcement staff.

[2]Activity data were over-estimated for one source in 1997. Although correct data are not available for that source in 1997, a more realistic figure can be used than the original over-estimation.

OUTCOMES

Figure 8.5 shows the locations where air quality monitoring has been undertaken in Canterbury. Not all individual sites are shown. For example, monitoring has been undertaken at numerous locations within Christchurch (Figure 8.10), and at Washdyke as well as Timaru.

During the period from 1995 to 2005 air quality was monitored in many towns in Canterbury. Continuous year-round monitoring commenced in Christchurch in 1988, in Timaru in 1997 and in Kaiapoi in 2001. Monitoring continues in these areas where concentrations of PM_{10} have regularly exceeded national guidelines during winter, with the worst day recording concentrations 2.5 to four times greater than 50 µg/m^3 (Aberkane et al., 2006). In other towns monitoring was carried out for two winters on a rotational basis, to assess the air quality, as shown in Figure 8.4. While PM_{10} is the main issue in all towns, this section will summarise all concentrations measured and compare these to national guidelines.

With the introduction of the National Environmental Standards for Air Quality (NESAQ) in September 2005 (MfE, 2004), Environment Canterbury changed its monitoring strategy to permanently monitor in areas defined as air sheds for the NESAQ. These air sheds are where the NESAQ for PM_{10} has been breached or is expected to be breached (Christchurch, Timaru, Kaiapoi, Rangiora, Ashburton, Waimate and Geraldine) and management is required to achieve the NESAQ.

Table 8.6 shows the 2002 national guidelines for the main contaminants (MfE/MoH, 2002) and those that are also National Environmental Standards.

Figure 8.5 Location of air quality monitoring sites in the Canterbury region, 1995-2005

Table 8.6 Ministry for the Environment, 2002: Ambient air quality guidelines 2002 update

Contaminant	Averaging period	MfE Guidelines (2002)	Number of permissible exceedences per year NESAQ (MfE, 2004)
PM_{10}	24 hour	50 µg/m^3	1
CO	1 hour	30 mg/m^3	
CO	8 hour	10 mg/m^3	1
SO_2	1 hour	350 µg/m^3	9
SO_2	1 hour	570 µg/m^3	0
SO_2	24 hour	120 µg/m^3	
NO_2	1 hour	200 µg/m^3	9
NO_2	24 hour	100 µg/m^3	
O_3	1 hour	150 µg/m^3	0
O_3	8 hour	100 µg/m^3	
Benzene	Annual	3.6 µg/m^3	
BaP	Annual	0.3 ng/m^3	

The guideline values above have been used to define the indicator categories shown in Table 8.7. Table 8.8 outlines how Canterbury performs against these indicators when considering the highest concentration measured at each site.

8. Air quality

Table 8.7 National ambient air quality categories used for indicators (MfE, 2002)

Category	Maximum measured value	Comment
Action	Exceeds the guideline value	Exceedences of the guideline are a cause for concern and warrant action, particularly if they occur on a regular basis
Alert	Between 66% and 100% of the guideline value	This is a warning level, which can lead to exceedences if trends are not curbed
Acceptable	Between 33% and 66% of the guideline value	This is a broad category, where maximum values might be of concern in some sensitive locations, but generally at a level which does not warrant urgent action
Good	Between 10% and 33% of the guideline value	Peak measurements in this range are unlikely to affect air quality
Excellent	Less than 10% of the guideline value	Of little concern: if maximum values are less than one-tenth of the guideline, average values are likely to be much less

Table 8.8 MfE indicator summary for maximum concentrations measured, 1995 to 2005

1995-2005	24-hr PM_{10}	8-hr CO	1-hr CO	24-hr SO_2	1-hr SO_2	24-hr NO_2	1-hr NO_2	Benzene	BaP
Waimate	Action	Good	Good	Excellent	Good	-	-	-	-
Timaru	Action	Acceptable	Acceptable	Good	Acceptable	Acceptable	Good	-	-
Washdyke	Action	Good	Excellent	Good	Acceptable	-	-	-	-
Geraldine	Action	Good	Good	Excellent	Excellent	-	-	-	-
Ashburton	Action	Acceptable	Good	Excellent	Good	-	-	-	-
Christchurch (St Albans)	Action	Action	Alert	Good	Acceptable	Acceptable	Alert	Alert	Action
Kaiapoi	Action	Alert	Acceptable	Excellent	Good	-	-		
Rangiora	Action	Acceptable	Good	Excellent	Good	-	-	-	-
Kaikoura	Action	Good	Excellent	Excellent	Excellent	-	-	-	-
- = not measured									

The contaminant requiring action in all these Canterbury locations is PM_{10}. High concentrations of CO and BaP in Christchurch are associated with high PM_{10} concentrations. The seasonal variation in PM_{10} concentrations is shown in Figure 8.6. This shows the highest daily concentration measured each month during the last decade. In most places the highest concentrations occurred during the winter, typically on still, clear nights when dispersion was restricted. These concentrations regularly exceeded 50 µg/m^3 (averaged over 24 hours) in Christchurch, Kaiapoi and Timaru, but less often in smaller towns like Ashburton, Rangiora, Waimate and Geraldine. The number of exceedences varied from year to year depending on the weather.

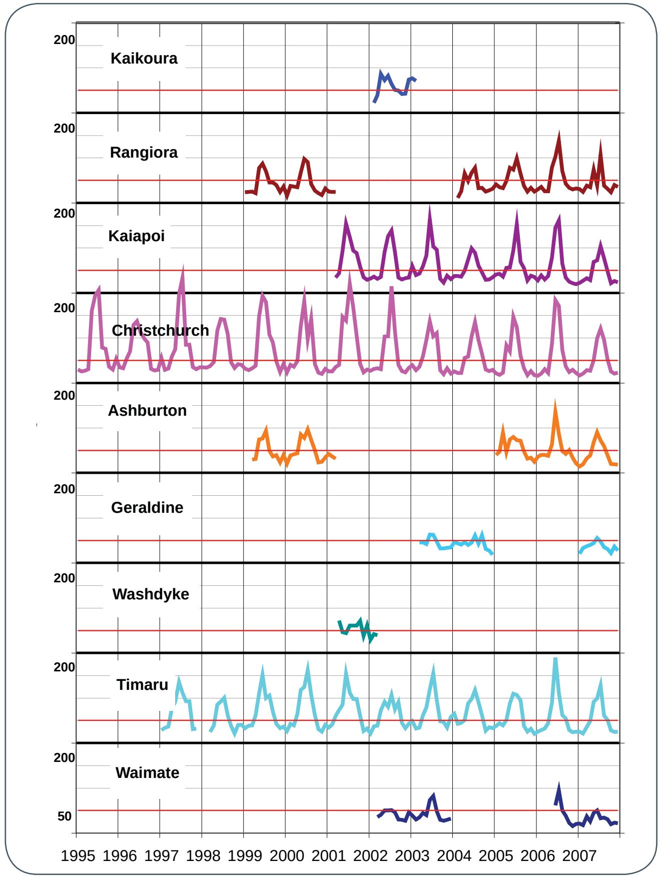


Figure 8.6 Maximum 24-hour average PM_{10} concentrations each month in Canterbury (scale is to 0-200 µg/m³ for each series and the red line is the guideline of 50)

The NESAQ sets a target for reducing PM_{10} concentrations by 2013, with a progressive path to follow from 2005. Areas for management are defined as air sheds, and regional councils are required to monitor in the worst place in the air shed, ensuring management will protect the people living in those areas. Figure 8.7 shows the number of days when daily PM_{10} concentrations exceeded 50 µg/m³ in each year of monitoring, and the target in 2013. Another way of expressing the NESAQ target, which allows one day greater than 50 µg/m³ each year, is that the second-highest concentration must be 50 µg/m³ or less by 1 September 2013. The second-highest concentrations measured each year are also shown in Figure 8.7.

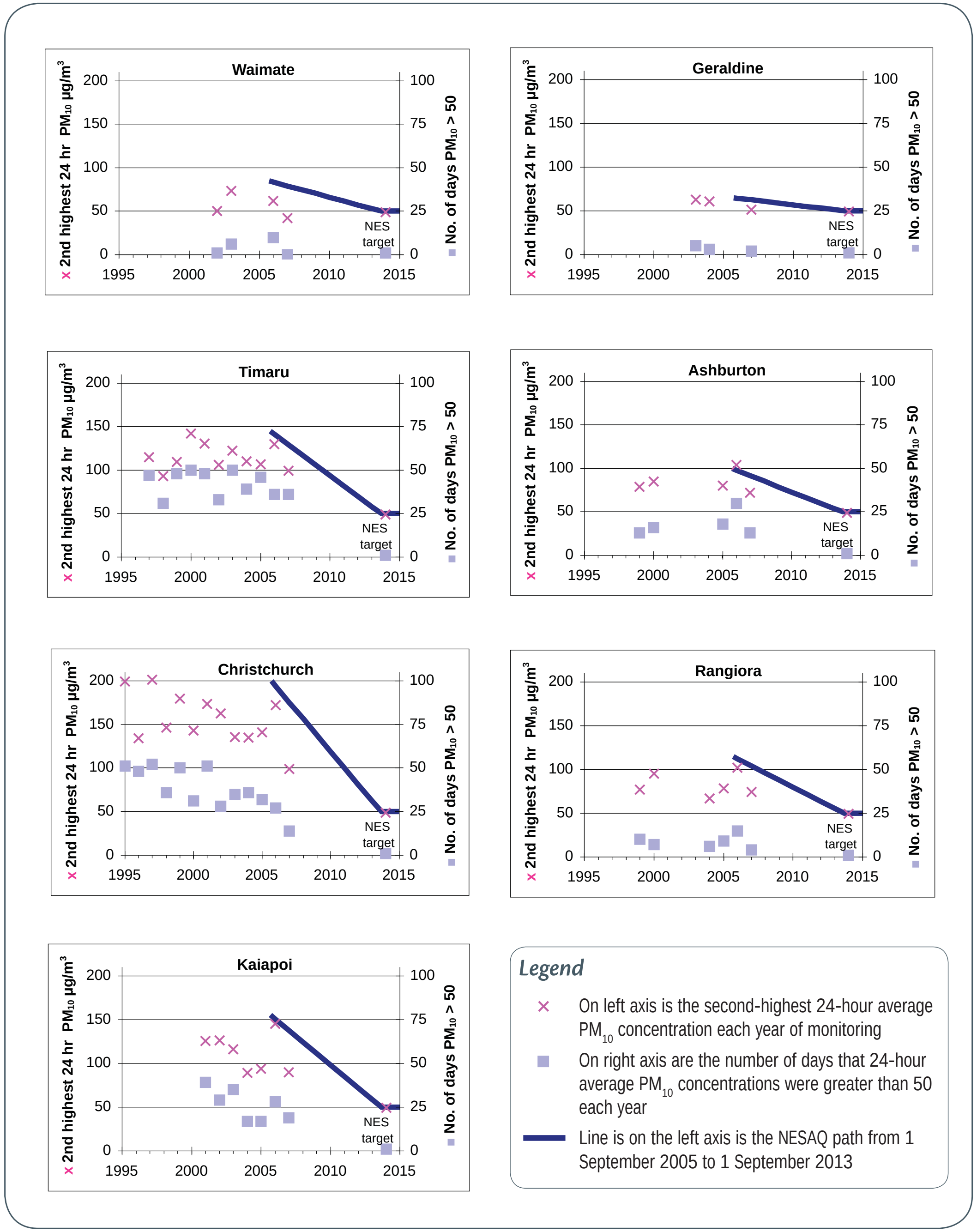


Figure 8.7 Meeting the NESAQ targets in Canterbury air sheds

Are PM_{10} concentrations declining in Christchurch?

Taking the weather out of air quality data

There are a number of ways to report on concentrations of PM_{10}, including maximum and second-highest daily concentrations and the number of days greater than 50 µg/m³. These values are dependent on weather, either on a particular evening (for the highest days) or during the months from April to September (for the number of days). The weather conditions conducive to high air pollution are anticyclones bringing clear skies, cold temperatures, low wind speed and a temperature inversion during the evening.

An alternative measure of air quality, that attempts to correct for meteorological conditions, was proposed by Canesis Networks Ltd in 2004 to assess trends in home heating (Marsh and Wilkins, 2004). This measure averages the PM_{10} concentrations that occurred between 6 pm and midnight when the temperature was less than 9°C, wind speed was less than two metres per second (m/s) and there was a temperature inversion. These were then further normalised with respect to the wind speed and ground temperature.

As indicated earlier in this chapter, emissions inventories carried out for Christchurch in 1996, 1999 and 2002 indicate a decrease in total PM_{10} emissions in metropolitan Christchurch by 13% from 1999. A decrease in normalised PM_{10} concentrations of about 15% between 1999 and 2002 is evident in Figure 8.8 from the slope of the trend line.

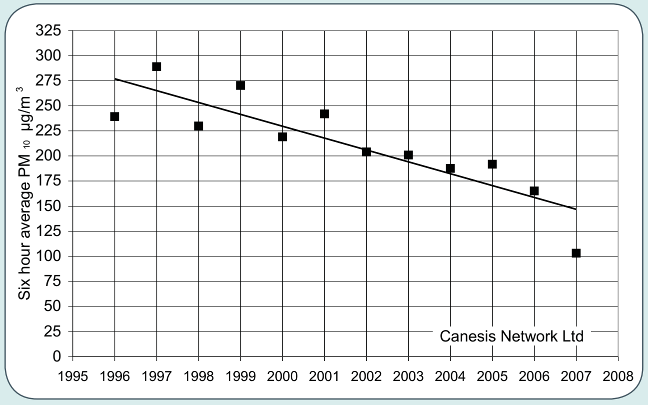


Figure 8.8 The average of PM_{10} concentrations on still, winter evenings

A number of other studies assessing trends have used the Christchurch dataset from 1999 to 2006. These have been combined into a report (Bluett et al., 2007). Each of the studies suggests that there has been a reduction in PM_{10} emissions over the period, particularly since 2001. Although not a statistically strong result, it can be inferred from the studies that a reduction in emissions has averaged about 3% to 4% per year from 1999 to 2006.

Other issues for Christchurch

Monitoring in residential areas

Generally, monitoring sites are chosen in residential areas to measure concentrations which people are likely to be exposed to in areas where they spend most of their time. In Christchurch, because of the city's size, monitoring has been carried out in a number of suburbs, with the longest record in the St Albans area.

While information from the St Albans monitoring sites can be used for assessing trends, monitoring in other suburbs indicates how concentrations vary across the city. To provide comparison between concentrations measured in different suburbs, the highest daily concentration of PM_{10} measured each month is shown in Figure 8.9, and the location of the monitoring sites is shown in Figure 8.10.

While peak hourly PM_{10} concentrations during a polluted night are similar throughout the city, the length of time the concentrations are high over a 24-hour period differs, depending on the sources in the surrounding area. This results in different 24-hour concentrations throughout the city on any given day.

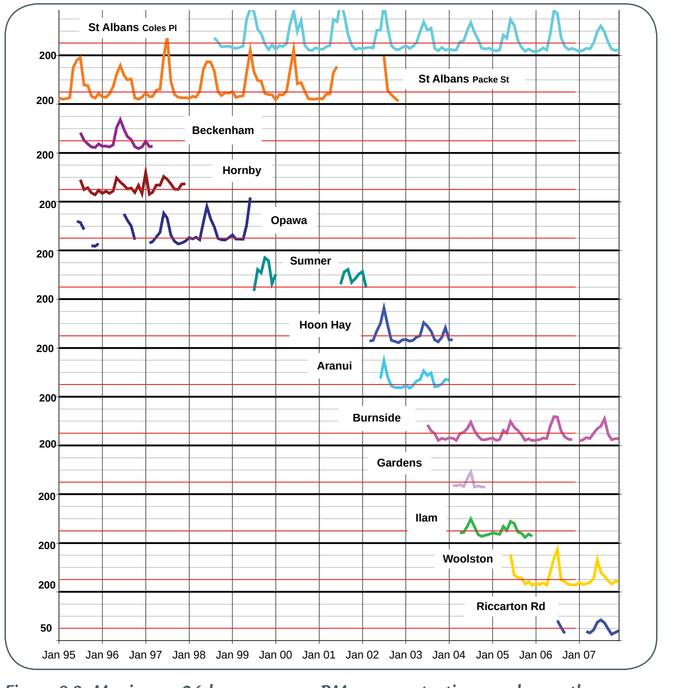


Figure 8.9 Maximum 24-hour average PM_{10} concentrations each month in Christchurch (scale is 0-200 µg/m³ for each series and the red line is the guideline of 50)

Figure 8.10 PM$_{10}$ monitoring sites in Christchurch, 1995-2005

Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbon (PAH) concentrations have been measured in Christchurch on several occasions since the mid-1990s. The most recent monitoring, during 2003 and 2004, was also the most comprehensive, taking place every six days over the course of a year at Environment Canterbury's St Albans air monitoring site (McCauley, 2005a).

Each study has indicated that benzo(a)pyrene (BaP), a known carcinogen, would exceed its annual average guideline value by a considerable amount, the 2003-2004 data showing a ten-fold exceedence. No trend can be identified with the data available, but a very strong seasonal variation can be seen in the 2003-2004 data, suggesting a close link to wintertime PM$_{10}$ concentrations and sources. Figure 8.11 shows the distribution of BaP and PM$_{10}$ concentrations on the days when sampling occurred.

Roadside air quality

In Christchurch, roadside monitoring has been carried out every few years to assess trends in carbon monoxide (CO) concentrations. The main sources of CO during the winter are home heating fires and motor vehicles. In residential areas, the concentrations are highest when PM$_{10}$ concentrations are high overnight, though there are not as many breaches of the NESAQ for CO (Table 8.8, Figure 8.12).

The highest CO concentrations occurring each year appear to have declined in Christchurch and there were no breaches of the NESAQ eight-hour average threshold of 10 mg/m^3 in 2003, 2004 or 2005 in St Albans. Total CO emissions have declined by 10% since 1999, with the greatest reductions occurring in the motor vehicle sector, reduced by 8%, and the home heating sector, down by 13% (Scott and Gunatilaka, 2004).

Roadside monitoring of CO has been carried out in Riccarton Road in 1993, 1996, and 2001; in Papanui Road at Merivale in 1997; and in the city at the Cashel and Colombo Street corner in 1997. The highest eight-hour average concentration measured at these sites is shown in Figure 8.12, in comparison to the highest measured at the St Albans monitoring site. Although the concentrations measured at roadside appear to have decreased over this period, the location of the monitoring site was different each year making it difficult to assess trends.

A permanent monitoring site was established in Riccarton Road in 2006 and concentrations from this site will enable trends in roadside concentrations to be identified more easily. These are expected to decrease with improvements in emission control technology and improved fuel for motor vehicles. Roadside monitoring includes PM$_{10}$, NO_2, and SO_2, as well as CO concentrations.

Volatile organic compounds (VOCs)

Concentrations of the VOCs benzene, ethylbenzene, toluene and xylene (BTEX) have been monitored regularly in Christchurch since the mid-1990s, and are typically much higher at busy roadside sites, compared with residential areas. Concentrations of all four contaminants show a decreasing trend, and those of benzene are represented in Figure 8.13.

Benzene is a key contaminant, given its known properties as a carcinogen. The Ministry for the Environment guideline is a staged value that decreases in 2010. The most recent measurements indicate compliance with the existing guideline but not the 2010 value (as shown by the lower red line in Figure 8.13) (McCauley, 2005b).

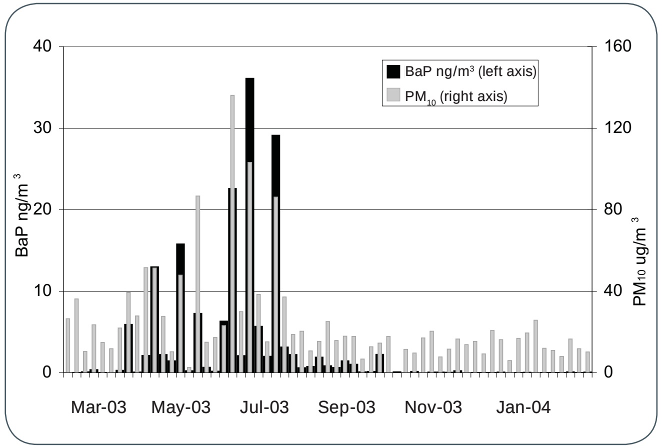


Figure 8.11 BaP and PM$_{10}$ concentrations, 24-hour averages 2003-2004

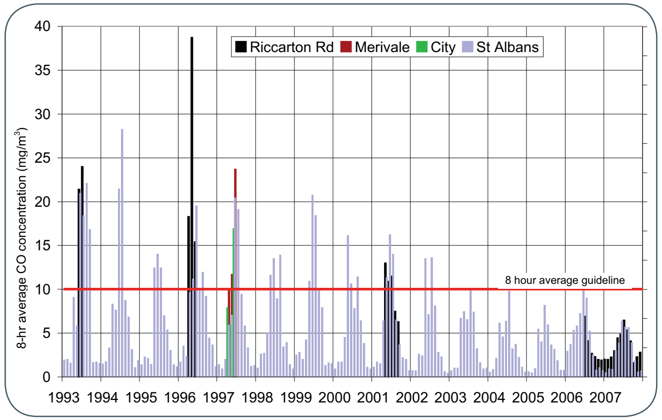


Figure 8.12 Maximum 8-hour average CO concentrations measured each month in Christchurch

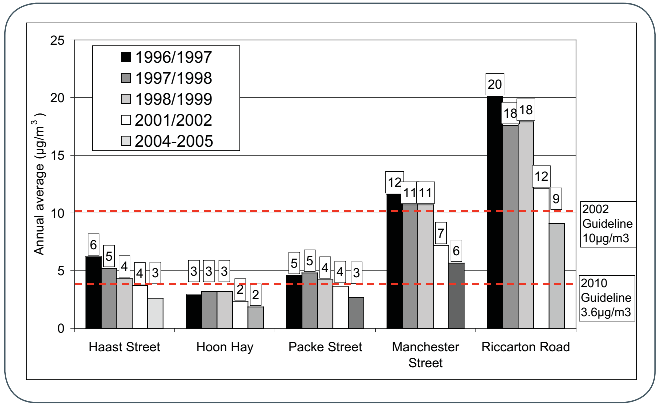


Figure 8.13 Chnages in benzene concentrations with time. Numbers above bars are annual averages (µg/m³)

Concentrations of SO_2

Figure 8.14 shows the highest one-hour SO_2 concentration each month in Christchurch measured at the St Albans, Hornby, Opawa and Woolston monitoring sites. Seasonal variations are evident in the SO_2 concentrations measured at the residential site in St Albans, as is a reduction in the wintertime peaks over this period.

These concentrations were well below the NESAQ, which allows no more than nine hours greater than 350 µg/m³ each year, with none over 570 µg/m³. Concentrations measured in Hornby, Opawa and Woolston were much higher, without the winter time peaks, indicating the added influence of industrial discharges in these areas.

These concentrations have not breached the NESAQ (one hour over 350 µg/m³ measured in Hornby in 2003, three hours in Woolston in 2005, four hours in 2006 and two hours in 2007), but have come very close in Woolston in 2005 with one hour at 570 µg/m³.

Emissions of total SOx increased by 1% from 1999 to 2002. The increases occurred in the motor vehicle (5%) and industrial sectors (2%). Conversely, home heating SOx decreased by 22%.

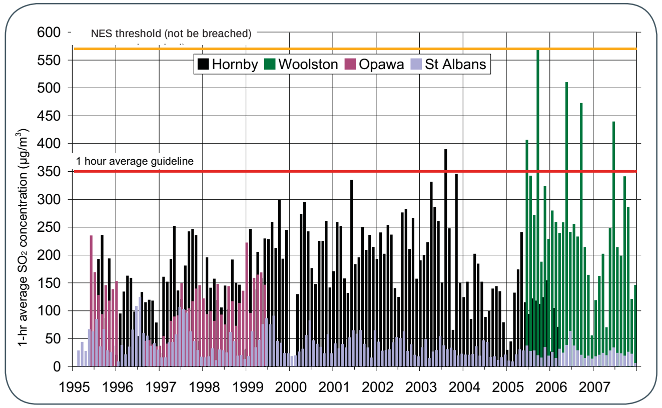


Figure 8.14 Maximum 1-hour average SO_2 concentrations measured each month in Christchurch

Wider implications

The replacement of some solid fuel burners with electricity, oil, and gas may have implications for the regional energy supply, as electricity demand for home heating will increase during the winter months.

Additionally, as some households switch from wood fuel, which is largely considered to be carbon neutral, to electricity, gas or oil, there may be implications for the carbon footprint of the region.

The magnitude of this effect will depend on a number of factors, including the energy balance between the replaced appliance and the new appliance and the proportion of electricity supplied to the region that is generated from renewable sources.

Allocation mechanisms

It was estimated in 2005 that NESAQ attainment could only occur if daily emissions from home heating were reduced from 6.5 t in 2002 to 1 t in 2013, motor vehicle emissions from 0.94 t to 0.42 t and industrial emissions capped at 1.2 t (up from 0.95 t in 2002).

Home heating emissions are addressed by rules contained in Chapter 3 of the Proposed Natural Resources Regional Plan - Air. Motor vehicle emissions are addressed at the central government level. Industrial and commercial emissions are addressed through the resource consenting process, where a limited increase in consented discharges of PM_{10} is allowed for each year (20 kg/day in suburban Christchurch).

Staff track how much of this increase has been allocated, and for new consent applications decision makers are advised how much of the allocation is available. Over recent years, there has been a small decrease in the industrial total, mainly resulting from school coal boilers being replaced with pellet burners or heat pumps, and very few new substantial industrial discharges.

Figure 8.15 shows emissions by sector for 2002 and as estimated in the target year of 2013. Emission inventories, compiled on a three-yearly basis, assist in determining progress towards these targets (as in Figure 8.3).

Number of homes in Christchurch converted through the Clean Heat Project

The Clean Heat Project has enabled many households in Christchurch to change to cleaner heating methods. The number of homes converted each month is shown in Figure 8.16 below. The project is funded for 26,464 conversions by 2013 and the estimated and actual number of conversions for each financial year are shown in Figure 8.17 below.

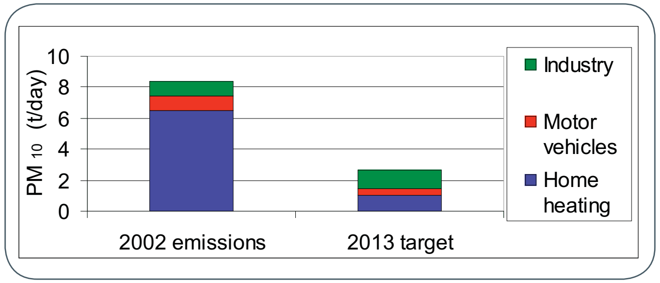


Figure 8.15 Emissions by sector, 2002, and target, 2013

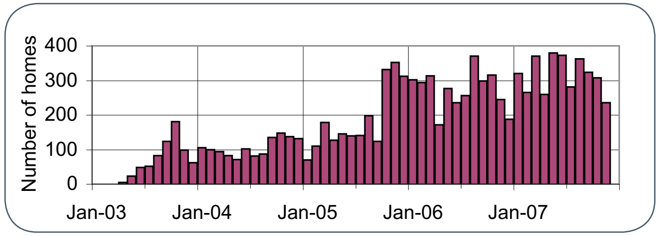


Figure 8.16 Clean Heat Project conversions by month

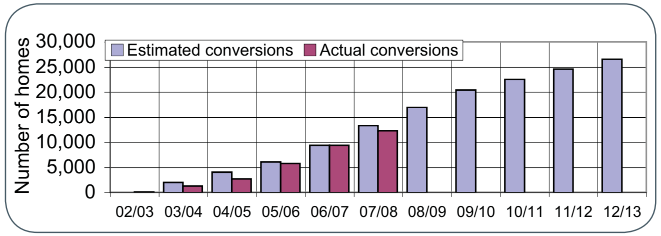


Figure 8.17 Total number of Clean Heat Project conversions each year

Public awareness campaigns

Environment Canterbury's annual public awareness survey (Sigma Group Ltd, 2007) has shown a continuing growth in public approval of its performance in its key functions and in the value of its use of ratepayers' funds. The survey is conducted by telephone on a sample of 500 people across the region aged 18 and over, with basic demographics matched to census data. The 2008 survey was conducted in April - May.

One of the questions asked was how respondents rated Environment Canterbury's performance in several areas, one of which was improving air quality in Canterbury. The responses were:

Very good	Quite good	Quite poor	Very poor	Don't know
11%	61%	16%	3%	9%

Overall, 72% of respondents rated Environment Canterbury as quite good or very good compared to 70% in 2006. In the north of Canterbury, 71% rated performance as quite good or very good at improving air quality, 73% in central Canterbury and 73% in south Canterbury.

Respondents were also asked what types of activities they thought Environment Canterbury was involved in. The following table shows the percentage of respondents that have indicated an awareness that Environment Canterbury is involved in clean air/smog reduction/fire restrictions/air pollution control, over the past six surveys.

2001	2002	2003	2004	2006	2007
25%	24%	36%	28%	38%	44%

A city-wide advertising campaign has been conducted for the Clean Heat Project during the winter months each year since 2005, with research undertaken by Opinions Market Research Ltd pre and post-winter in 2005, 2006 and 2007 to measure the awareness and impact of the project among the Christchurch public.

Results (Opinions, 2007) indicate that 73% were aware of the Clean Heat Project in 2007 (a slight increase from previous years) and the majority knew it was about converting to non-polluting heating (72%), with the remainder of responses mentioning subsidies for changing heating, replacing open fires and log burners, doing something about air pollution and the like.

Outdoor burning

Environment Canterbury enforces an outdoor fire ban in Christchurch from 1 May to 31 August each year. Chapter 3 of the Proposed Natural Resources Regional Plan has proposed a ban on outdoor fires without a resource consent in all residential areas in Canterbury year-round, while Variations 11 and 12 to Chapter 3 have proposed a ban on outdoor fires without a resource consent in Rangiora and Kaiapoi Clean Air Zones 1 and 2 from 1 May to 31 September. The two proposed bans will come into force when they are beyond any legal challenge.

Complaints to the 24-hour Pollution Hotline

Air quality complaints made up 65% of all complaints received by Environment Canterbury's Pollution Hotline during the financial years ending June 2005 and June 2006. A large number of these concerned smoke from house chimneys or outside fires in Christchurch, as shown in Figure 8.18 below. The other air complaints were for a variety of reasons, eg discharge from a stack, spray painting, or fumes from an industrial process.

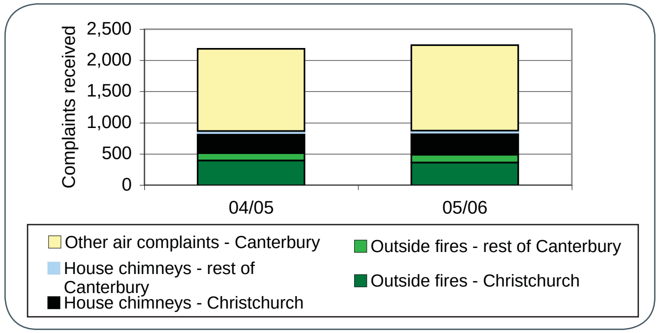


Figure 8.18 24-hour Pollution Hotline complaints

RESPONSE

Actions undertaken by Environment Canterbury to resolve the issues identified in this chapter, and to achieve the results the community seeks for the resource, take a number of forms. These include:

- the regulation of activities through resource consents
- the development and implementation of a strategic planning framework for air quality management
- the provision of information
- investigations to improve understanding of the resource
- advocacy and incentive programmes to encourage behavioural change

Responses to air quality issues in the region are summarised in Table 8.9 following.

Table 8.9 Responses to pressures on air quality

Issue	Investigations & Monitoring	Policy & Planning	Regulation & Enforcement	Incentives	Advocating & Education
Exceedence of the NESAQ for PM_{10} in urban parts of Canterbury	Air quality monitoring networks Emission inventories and source apportionment Air shed modelling Emissions testing from wood burners Allocation mechanisms	PNRRP Chapter 3 - Apply ambient air quality standards (Policy AQL9) - Set emission standards for enclosed burners (Policy AQL11) - Set emission standards for large-scale fuel burning devices (Policy AQL12) - Prohibit open fires (Christchurch) (Policy AQL14) - Phase out older style burners (Christchurch) (Policy AQL15) - Restrict out-door burning (Policies AQL4 and AQL21) Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxin, and Other Toxics) Regulations 2004 - Set ambient air quality standard - Restrict the granting of consents in compromised air sheds - Development of predetermined paths for PM10 reduction in urban air sheds National programmes to reduce emissions from motor vehicles ('10-second rule' for smoky vehicles)	Applications for discharges of PM_{10} are assessed against the requirements set out in council policy and government regulation Breaches of consent conditions and plan rules are enforced	Clean Heat project provides financial incentives for Christchurch households to convert to clean forms of home heating, and to improve insulation	Home heating advice provided over winter Air quality education programmes are available to schools Public awareness campaigns
Exceedence of guidelines for hazardous air pollutants (Note: measures targeting PM_{10} reductions are expected to impact also on HAP concentrations)	Surveillance monitoring for BTEX and PAHs Source characterisation	PNRRP Chapter 3 - Prohibit combustion of specified materials (Policy AQL1) - Apply precautionary principle to hazardous air pollutants (Policy AQL10) Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxin, and Other Toxics) Regulations 2004 - Prohibit combustion of specified materials	Consent assessments considered with reference to ground level concentration limits Breaches of consent conditions and plan rules are enforced		Information is available about hazardous air pollutants
Nuisance effects of other emissions, including outdoor burning, odour, dust and spray drift	Air quality monitoring networks	PNRRP Chapter 3 - Prohibit combustion of specified materials (Policy AQL1) - Avoid odour nuisance (Policy AQL5) - Avoid dust nuisance (Policy AQL6) - Avoid agrichemical spray drift (Policy AQL7) - Control all other discharges to air (Policies AQL4, AQL8 and AQL21)	Breaches of outdoor burning and other relevant rules are enforced Response to complaints to the 24-hour Pollution Hotline		Information is available on the relevant rules controlling these activities

CASE STUDY 8.1

Gelita New Zealand Limited: An old industry struggling with compliance

GELITA NZ Ltd (previously Davis Gelatine) was established in Christchurch in the early 1920s and has been operating the same site in Woolston since that time. GELITA is a manufacturer of gelatine, a food ingredient derived from the collagen in cattle hides and produced by treating the hide in alkali, acid and then extraction by heating before purifying and drying. The gelatine produced at this site is used in many applications, from the clarification of wine and fruit juices to pharmaceutical gelatine and powder gelatine for the catering industry and household use.

GELITA has proven to be a responsible entity and is working closely with Environment Canterbury to initiate a number of pollution-reducing measures that minimise the impact of its processes.

In 2005, GELITA was refused consent by Environment Canterbury commissioners for a new coal-fired boiler because the proposed new boiler operation had the potential to double existing contaminant emissions into the local air shed. The commissioners noted that the resulting increase in pollution would have been contrary to the purpose of the Resource Management Act.

It would also have been contrary to the aims of the Christchurch Air Plan and the NESAQ. The application was referred to the Environment Court with subsequent mediation between the company and Environment Canterbury, and the consent and conditions were signed off in the Environment Court in 2006.

The consent restricts emissions from the new boiler during the four months of winter and only allows the company's two old coal-fired boilers to be used when the new boiler is undergoing maintenance checks or for no more than two weeks in any year. The consent requires that GELITA changes the fuel of its two light fuel oil (LFO) boilers to liquid petroleum gas (LPG). This was undertaken in 2006, effectively stopping the emissions of SO_2 and PM_{10} from these sources.

In 2005 'spikes' of SO_2 were measured at Environment Canterbury's Woolston air quality monitoring station. After investigations and consultation with GELITA it was agreed that a number of stages within their process were additional sources of SO_2.

In addition to combustion processes on site there are a number of steps in the gelatine extraction process that can release SO_2 into the air shed. The gelatine extraction process requires sulphurous acid (H_2SO_3) which can be converted to SO_2 and discharged to air in a diffuse manner.

GELITA was proactive in implementing a number of control measures and procedures to control the amount of SO_2 being released and as at the end of 2007 the one hour NESAQ had not been exceeded. Environment Canterbury chooses to report SO_2 data back to GELITA and since this commenced the recorded ambient trend is downwards due to corrective action and improved operational management on site. The GELITA factory represents a very complex odour environment. When the factory was established in the early 1920s the area was predominantly heavy industry and has remained largely industrial until very recently. The demand need for ever more-affordable residential housing has seen the factory surrounded by commercial and residential activities.

The process of extracting gelatine requires the storing of large quantities of hide, alkaline conditioning, acid conditioning (washing), and cooking of the conditioned hides and processing of the waste stream – at each of these processes a potential for odour problems arises. Over the years, GELITA has co-operated with Environment Canterbury and has shown a great willingness to improve its process.

Apart from significant capital expenditure by GELITA, it has also, at Environment Canterbury's request, contracted leading experts in odour source identification and control, biofiltration and ambient odour sampling. However, odour from GELITA leaving the site and adversely effecting people living in the vicinity of the factory continues to be an issue.

CASE STUDY 8.2

New Zealand Dairies Limited consent

Under the NESAQ there exists the opportunity for industrial consented processes to offset any additional or new PM_{10} they wish to discharge by cleaning up existing emitters. This regime was included under the NESAQ legislation to allow new emitters to enter an air shed that may already be exceeding the Standards. The provision applies until 2013 at which time, if an air shed is exceeding the NESAQ, new resource consents must be declined.

The New Zealand Dairies Limited consent was granted in 2007 allowing the discharge to air from two 12 Megawatt boilers at Studholme for a new milk powder drying plant. The site is six kilometres east of Waimate township and the Waimate air shed. Air quality monitoring of PM_{10} has been carried out at Waimate and, in four years of records, the town has recorded up to 10 exceedences per year of the NESAQ and an absolute maximum concentration nearly twice the guideline value of the NESAQ. In common with other Canterbury air sheds, poor air quality is almost exclusively from winter time home heating. Whilst the Studholme plant is outside of the air shed its emission may occasionally impact on Waimate in easterly winds and, conversely, the Waimate air shed itself may produce locally poor air quality at Studholme in westerly winds.

The consent application included the proposal for the consent holder to replace open fires or wood burners more than 10 years old in 36 homes in Waimate. The replacements were to be carried out before the site was operational and confirmed to Environment Canterbury as part of the conditions of the consent. The application outlined that this level of replacement was more than sufficient to offset the air quality impacts of the new plant.

This is an example of a new consent, which embraces the concept of offsets: several domestic discharges of PM_{10} were removed from the Waimate air shed in order to counter a new large source with the potential to impact on that air shed. It demonstrates that industrial and, therefore, economic development can continue while looking after air quality for the community.