1997 - 2004

Ambient Air Quality in Otago

Nitrogen dioxide, Sulphur dioxide and Carbon monoxide

AIR

Otago Regional Council

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Carbon monoxide

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Foreword

If you were asked to grade the quality of the air in Otago, most people would put it in the first class category. In fact, it's true that Otago air quality is usually very good, however, there are times, especially during the winter, when some urban areas can suffer from high levels of pollution. This is because, in addition to industrial discharges, we tend to use a lot of solid fuel, such as coal and wood, to heat our houses, which creates high levels of smoke in the air. To make matters worse, calm and cold winter nights can create a smoke trapping inversion layer, making some areas particularly prone to high levels of pollution.

The effect of this air pollution is not just a local amenity problem but it can cause significant health problems as well. The health effects are particularly noticeable within the elderly and other vulnerable groups such as those suffering from respiratory problems.

The Otago Regional Council is committed to help make the air of Otago clean and create a healthier environment. The Regional Policy Statement provides for the sustainable management of the air resource and the Regional Plan: Air sets out objectives, policies and rules the Council uses for maintaining or enhancing air quality. Industrial emissions are controlled through resource consents.

National environmental standards (NES) for ambient air quality in New Zealand were introduced by the Ministry for the Environment in September 2005. Some of the contaminants covered by the NES include small particulates (PM_{10}), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO). The Otago Regional Council has had monitoring equipment in several locations across the region to see whether these levels are exceeded.

This report provides a summary of the Otago Regional Council air quality monitoring programme for NO_2, SO_2 and CO, which has been in operation since 1997 (PM_{10} are the subject of a separate report). Reassuringly, the results show that Otago urban areas do not currently have a significant problem with these pollutants. However, future signs of changes in air quality will be investigated and action taken if necessary to ensure that communities are given cleaner and healthier air.

Executive Summary

The quality of the air that surrounds us is determined by climate, and the cumulative impacts of discharges from human activity, including domestic, industrial, commercial and transport sources. Air quality in Otago is generally considered to be very good. However, to establish what the levels of various pollutants are, the Otago Regional Council began an air quality monitoring programme in 1997, which has included measurements of Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2) and Carbon monoxide (CO).

The Otago Regional Council Regional Plan: Air sets guideline limits for average NO_2 and SO_2 levels over one hour and 24 hour periods. 24 hour average data was collected at the Albany Street site in North Dunedin between 1997 and 2000. These samples were generally less than half the ORC guideline values, and no exceedances were recorded. One hour average SO_2 data was collected at Albany Street in winter 1999, and 99.9% of samples were below the guideline value.

Other NO_2 and SO_2 sampling has been in the form of monthly average values from passive samplers. There is no guideline value for monthly averages in the Regional Air Plan, but comparisons were made with the World Health Organisation (WHO) annual average level. None of the monthly average readings for either contaminant exceeded the WHO guideline level, and levels in most Otago towns were generally less than half of the recommended annual average value.

The highest monthly average data has been recorded at Albany Street, where SO_2 levels peaked at 48 micrograms per cubic metre of air ($\mu g/m^3$), still below the WHO annual average guideline level of 50 $\mu g/m^3$.

It should be emphasised that the various measurement methods used to monitor NO_2 and SO_2 do not fully comply with existing recommended monitoring methods. The results reported here are therefore likely to be indicative only, but can be used to give a general indication of contaminant levels at the sites monitored.

CO measurements were taken at three sites in Dunedin and Mosgiel between December 1997 and March 2003. There were almost no exceedances of the one-hour average Otago guideline value for CO during that time. The majority of the one-hour samples at all three sites were in the excellent range. Mosgiel had the lowest one-hour average CO measurements, followed by Cumberland Street and George Street.

Exceedances of the Otago eight-hour average CO guideline level were also rare. In Dunedin, the George Street and Cumberland Street sites exceeded the guideline level just 3% of the time, while less than 1% of the readings from Mosgiel exceeded the guideline level. The Otago Regional Plan: Air sets considerably more stringent levels for eight-hour average CO levels than the National Environmental Standard Regulations, further signifying that CO levels in the busiest areas of Dunedin and Mosgiel are very low.

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1. Introduction

1.1 Air quality in Otago

Ambient air quality is the general quality of the air that surrounds us. The quality of the ambient air is determined by the interaction between climate and the cumulative impacts of discharges from human activity, including domestic, industrial, commercial and transport sources. Ambient air quality in Otago is generally considered to be very good. However, in order to establish what the actual levels of various pollutants are, the Otago Regional Council began an air quality monitoring programme in 1997, which has included measurements of Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2) and Carbon monoxide (CO). This report presents the results of NO_2, SO_2 and CO monitoring throughout the Otago region. Results from all permanent and temporary sites are presented.

1.2 National and local standards for air quality

A National Environmental Standard (NES) for Air Quality was passed into legislation under the Resource Management Act in 2004. This standard sets the maximum allowable concentration for Nitrogen dioxide at 200 micrograms per cubic metre of air ($\mu g/m^3$), expressed as a 1-hour mean, with 9 exceedances allowable in any 12 month period.

The NES sets the maximum allowable concentration for Sulphur dioxide at 350 $\mu g/m^3$, expressed as a 1-hour mean, with 9 exceedances allowable in any 12 month period. The Otago Regional Council Air Plan sets the maximum allowable concentration for Sulphur dioxide at 230 $\mu g/m^3$, expressed as a 1-hour mean (Table 3.1), and this lower level is the one which applies in Otago.

The Otago guideline values for CO are also more stringent than those set by the NES (Table 3.2). The Otago guideline value for one-hour average CO levels is $20mg/m^3$, while the eight-hour average level is $6mg/m^3$. Further information on the ambient air quality targets for Otago is provided in Chapter 3.

The NES Regulation came into force on 1 September 2005. After this date, regional authorities, such as the Otago Regional Council must decline any new resource consents for discharge of NO_2, SO_2 and CO in a particular airshed if the discharge from that consent is likely to cause the level of that gas to exceed the NES guideline value.

2. Monitoring sites and instrumentation

Figure 2.1 shows the location of NO_2, SO_2 and CO monitoring sites across Otago between 1997 and 2004. Eight different sites (including Mosgiel) have measured for the above contaminants in the Dunedin area, while NO_2 and SO_2 information has been collected at five and seven different Otago towns respectively.

Figure 2.1 NO_2, SO_2 and CO monitoring sites in Otago

2.1 NO_2 and SO_2 monitoring sites

The majority of NO_2 and SO_2 monitoring undertaken by the ORC has been monthly average values from passive samplers. This is a low-cost method that consists of a special filter approximately 30mm wide (Figure 2.2). The pollutant of interest accumulates over a long period of time by diffusing into and reacting with material on the filter. A total of 13 sites across Otago have had NO_2 and/or SO_2 data collected using this method, including:

- North East Valley (Dunedin)
- Albany Street (Dunedin)
- Mosgiel
- Alexandra
- Green Island (Dunedin)
- South Dunedin
- Balclutha
- Milton
- Arrowtown
- Cromwell
- Wanaka
- Palmerston
- Kaikorai Valley (Dunedin)

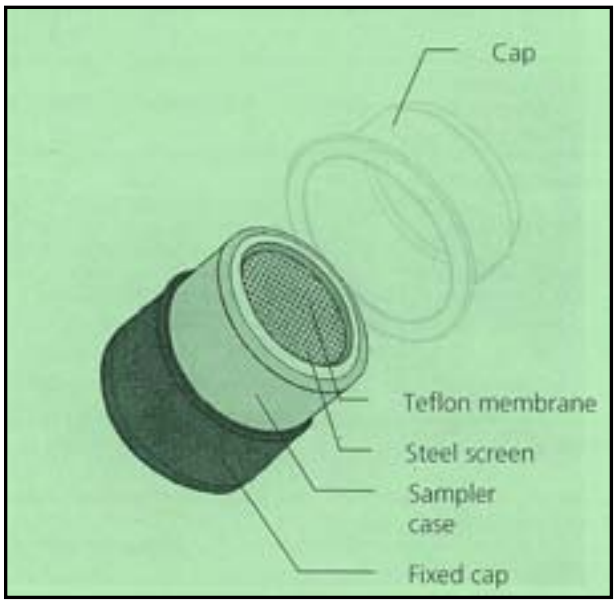


Figure 2.2 Sample filter used for monthly NO_2 and SO_2 measurements

Twenty-four-hour measurements of NO_2 and SO_2 were obtained using wet chemistry methods at Albany Street in North Dunedin from 1997 to 1999. An ultra violet fluorescence instrument was used at Albany Street in 1999 to continuously measure ten-minute and one-hour average concentrations through the winter months. This also produced 24-hour measurements, and allowed for a comparison with the wet chemistry technique. Neither of the above methods fully comply with international standards, although they have been used widely throughout New Zealand and overseas.

2.2 CO monitoring sites

Carbon monoxide monitoring has been undertaken at commercial premises on George Street, Dunedin, Gordon Road in central Mosgiel, and at the former Big Fresh supermarket building on Cumberland Street, Dunedin. These sites were chosen as they are representative of busy retail areas, with plenty of pedestrian and vehicle traffic. A gas filter correlation carbon monoxide analyser was used at both sites. This provides continuous measurements of roadside CO, and conforms to Australian Standard AS 2695-1984.

Carbon monoxide monitoring took place on the corner of George Street and Moray Place from December 1997 to January 1999, with a period of missing record in June 1998. The analyser was then shifted to the Bank of New Zealand building on Gordon Road, Mosgiel where it ran from May 1999 to April 2001, with a period of missing record in June 2000. The analyser then collected CO measurements at the Cumberland Street site from February 2002 to March 2003.

3. Ambient air quality targets

The ambient air quality standards for NO_2 and SO_2 that apply in Otago are summarised in Table 3.1. The Otago guideline values are sourced from the Regional Plan: Air (ORC 2003), while the MfE levels come from the National Environmental Standard (NES) Regulation (Ministry for the Environment, 2004).

World Health Organisation (WHO) and Otago guideline values for annual, daily and hourly average NO_2 and SO_2 levels are shown in Table 3.1. There is no local or national guideline value for monthly average levels of NO_2 and SO_2. The monthly results can be conservatively compared to the World Health Organisation (WHO) annual average guideline however.

Table 3.1 NO_2 and SO_2 air quality guidelines

Indicator	Otago Goal Levels	MfE Levels	WHO guideline level	Averaging Time
NO_2	200 µg/m^3	200µg/m^3 **(1)**		1 hour
	60 µg/m^3			24 hours
			40 µg/m^3	Annual mean
SO_2	330 µg/m^3			10 mins
	230 µg/m^3	350µg/m^3 **(2)**		1 hour
	80 µg/m^3			24 hours
			50 µg/m^3	Annual mean

Note 1: The permissible excess of this level is 9 hours in a 12 month period.
Note 2: The permissible excess of this level is 9 hours in a 12 month period, with no exceedances of 570 µg/m^3 over a 1 hour period.

The ambient air quality standards for CO are shown in Table 3.2. The Otago guideline values are sourced from the Regional Plan: Air (ORC 2003), while the MfE levels come from the NES Regulation. The Otago guideline value for eight hour average CO levels is lower than that set by the NES. The Otago guidelines also set a one hour average, whilst the NES does not specify one. The stricter of the guideline levels are the ones that apply in Otago, and in the case of CO, it is the Otago goal levels that apply.

Table 3.2 CO air quality guidelines

Indicator	Otago Goal Levels	MfE Levels	Averaging Time
CO	20 mg/m^3		1 hour
	6 mg/m^3	10 mg/m^3	8 hours

Note:
µg/m^3 = micrograms per cubic metre
mg/m^3 = milligrams per cubic metre

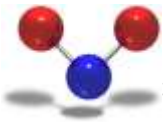
4. Quality assurance

All monitoring sites have been operated by the Otago Regional Council since 1997. Council staff are responsible for manual sample collection, routine maintenance and some calibration of equipment. External testing laboratories undertake specialist calibration and maintenance. Procedures for the management of NO_2 and SO_2 monitoring sites are outlined in the Air Quality Manual (Otago Regional Council, 2003). Additional procedures are outlined in The Air Pollution Measurement Manual (CASANZ, 2000). Policies and quality management procedures of the Otago Regional Council Resource Science Section are outlined in the Quality Manual (ORC, 2005).

As stated above, the methods used to monitor NO_2 and SO_2 do not comply with existing recommended monitoring methods, and all results in this report are likely to be indicative only. In addition, there is no New Zealand or ORC standard for monthly average data. The only data that can be compared against a New Zealand standard is the ten-minute, hourly, and 24-hourly average data from Albany Street. Guideline values from the World Health Organisation and European Union for annual average NO_2 and SO_2 levels have been included in Table 3.1 to give some comparison against the monthly average data.

The method used to monitor CO conforms to Australian Standard AS 2695-1984.

5. Nitrogen dioxide fact sheet (Source: www.mfe.govt.nz)



5.1 Chemical formula and description

The chemical formula for nitrogen dioxide is NO_2. Nitrogen dioxide is a reddish-brown, pungent, acidic gas that is corrosive and strongly oxidising.

5.2 Sources

Nitrogen dioxide is not usually released directly into the air. Nitrogen dioxide forms when nitrogen oxide (NO) and other nitrogen oxides (NO_x) react with other chemicals in the air to form nitrogen dioxide.

The main source of nitrogen dioxide resulting from human activities is the combustion of fossil fuels (coal, gas and oil), especially petrol used in cars. In cities, cars contribute about 80% of ambient nitrogen dioxide. Nitrogen oxide is also produced from making nitric acid, welding and using explosives. Other sources of nitrogen dioxide include the refining of petrol and metals, commercial manufacturing, and food manufacturing.

5.3 Effects on health

The main health effect of nitrogen dioxide is on the respiratory system. Inhalation of nitrogen dioxide by children increases their risk of respiratory infection and may lead to poorer lung function in later life. There is also an association between nitrogen dioxide concentrations in the air and increases in daily mortality and hospital admissions for respiratory disease. Nitrogen dioxide can decrease the lungs' defences against bacteria, making them more susceptible to infections, and can also aggravate asthma.

5.4 Groups most sensitive to nitrogen dioxide

Young children, asthmatics of all ages (but especially children), and adults with heart and respiratory disorders are all particularly sensitive to nitrogen dioxide.

5.5 Effects on ecosystems

Nitrogen dioxide is toxic to plants in short-term concentrations of 120 µg/m3. It reduces plant growth. When sulphur dioxide and ozone are also present, the effects on vegetation are worse. Along with sulphur dioxide, nitrogen dioxide can also cause acid rain. However, acid rain is not a problem in New Zealand.

5.6 Effects on buildings

Nitrogen dioxide forms acids in the presence of moisture and these can be corrosive to building materials at high concentrations.

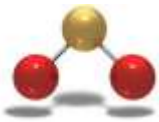
5.7 Effects on visibility

Nitrogen dioxide can form secondary particles called nitrates that cause haze and reduce visibility. Nitrogen dioxide is the gas that makes summer smog look brownish in colour.

5.8 Usual levels in New Zealand

The one hour guideline value is occasionally breached in some areas in Auckland and this problem seems to have been increasing over recent years. In most other places, including Otago, nitrogen dioxide levels are normally below the guideline values.

6. Sulphur dioxide fact sheet (Source: www.mfe.govt.nz)



6.1 Chemical formula and description

The chemical formula for sulphur dioxide is SO2. Sulphur dioxide is a colourless, soluble gas with a characteristic pungent smell, which forms sulphuric acid when combined with water.

6.2 Sources

Sulphur dioxide is produced mainly from the combustion of fossil fuels that contain sulphur, such as coal and oil (for example, coal being burnt in a home fireplace for heating and diesel-powered vehicles). Sulphur dioxide is also produced from some industrial processes, such as fertiliser manufacturing, aluminium smelting and steel making. Natural sources of sulphur dioxide include geothermal activity.

6.3 Effects on health

Sulphur dioxide can cause respiratory problems, such as bronchitis, and it can irritate your nose, throat and lungs. It may cause coughing, wheezing, phlegm and asthma attacks. The effects are worse when you are exercising.

6.4 Groups most sensitive to sulphur dioxide

Healthy children, adults with lung disease and asthmatics are all sensitive to sulphur dioxide.

6.5 Effects on ecosystems

Sulphur dioxide can cause acid rain that seriously affects ecosystems. Acid rain is a major problem in the northern hemisphere, where trees and whole forests have been affected. Acid rain does not occur in New Zealand. However, sulphur dioxide deposition can affect vegetation around industrial discharges and in cities. Lichens are good bio-indicators of pollution and do not like to grow where there is sulphur dioxide in the air.

6.6 Effects on visibility

Sulphur dioxide can form secondary particles (sulphates) that cause haze and reduce visibility.

6.7 Usual levels in New Zealand

Sulphur dioxide levels in urban areas have decreased since the 1970s. In Auckland, levels are around 5 $\mu g/m^3$ or less, with daily peaks of 20-30 $\mu g/m^3$. In Christchurch, levels have reduced from around 15-30 $\mu g/m^3$ (24-hour average) in the 1970s to 3-7 $\mu g/m^3$ (24-hour average) in the 90s, with peaks up to 30 $\mu g/m^3$ (24-hour average). The guideline value was breached in Greymouth during monitoring in 1994, and there may be some local problems caused by sulphur dioxide discharge by industrial activities. Studies show that levels of sulphur dioxide may be increasing around busy roads because of the increased use of diesel vehicles. Levels of sulphur in diesel will gradually decrease however as cleaner fuels are introduced.

7. Carbon monoxide fact sheet (Source: www.mfe.govt.nz)

7.1 Chemical formula and description

The chemical formula for carbon monoxide is CO. Carbon monoxide is a colourless, odourless and tasteless gas.

7.2 Sources

Carbon monoxide is produced both by natural processes (for example, from volcanoes, fires and metabolism of organisms) and by human activities (for example, the incomplete combustion of carbon-containing fuels and industrial processes). The most common sources of carbon monoxide are human activities. These include large amounts of carbon monoxide produced from the incomplete combustion of fossil fuels such as petrol used by cars, and from wood and coal, which is commonly burnt in fires for home heating. Tobacco smoke and indoor gas fires are also common sources of carbon monoxide.

7.3 Effects on health

When you breathe in carbon monoxide, it attaches to the haemoglobin molecules in your bloodstream, which carry oxygen around your body to your tissues. Carbon monoxide reduces the amount of oxygen that your body tissues receive, which is particularly bad for your brain and heart and your general health. Low exposure to carbon monoxide can make you feel dizzy, weak, nauseous, confused and disoriented, and can also reduce your performance while doing exercise. The higher the level of carbon monoxide in your blood stream, the worse the effects. So at very high levels, coma, collapse, loss of consciousness and death can occur.

7.4 Groups most sensitive to carbon monoxide

Middle-aged and elderly people with heart disease, and foetuses of pregnant mothers.

7.5 Usual levels in New Zealand

Carbon monoxide levels are generally highest in urban areas along or close to busy roads. It is not uncommon in some more congested traffic centres in New Zealand for carbon monoxide levels to breach the eight-hour guideline value in still conditions. Further information on levels can be found on the Ministry for the Environment website (www.mfe.govt.nz)

7.6 Areas where carbon monoxide may affect health

Carbon monoxide can be both a local problem around congested roads and an urban-wide problem where winter smog traps carbon monoxide discharged from domestic fires and vehicles causing high concentrations during temperature inversion conditions.

8. NO_2 results

This section summarises NO_2 data collected from permanent sites at North Dunedin and North East Valley, as well as data from 9 temporary sites around Otago.

8.1 Permanent NO_2 sites

NO_2 has been measured continuously at North East Valley (North Road) and North Dunedin (Albany Street) since May 1997. Data from these sites are one month averages, with the passive samplers changed at the end of each month. Winter sampling is defined as the period June to August.

8.1.1 North East Valley

Table 8.1 summarises NO_2 results from North East Valley. An annual average figure is not available for 1997 as the monitor was not running for the entire year. Table 8.1 shows that maximum monthly NO_2 levels for each year have varied from 13.9 to 22 µg/m^3. Figure 8.1 shows all monthly values recorded at North East Valley with a distinctive seasonal trend shown at this site. The highest NO_2 concentrations generally occur in winter when discharges are highest as a result of increased fossil fuel use, and when dispersion is more likely to be suppressed.

Table 8.1 Summary of monthly average NO_2 concentrations from North East Valley using passive samplers

Year	Annual Average NO_2 (µg/m^3)	Winter Average NO_2 (µg/m^3)	Max recorded NO_2 (µg/m^3)
1997	Insufficient data	18.3	21.0
1998	11.4	16.0	18.0
1999	12.7	15.3	20.0
2000	12.2	15.7	22.0
2001	11.0	13.0	14.5
2002	8.2	10.1	13.9
2003	11.2	15.0	17.1
2004	10.3	14.4	15.7
Average	**11**	**14.7**	

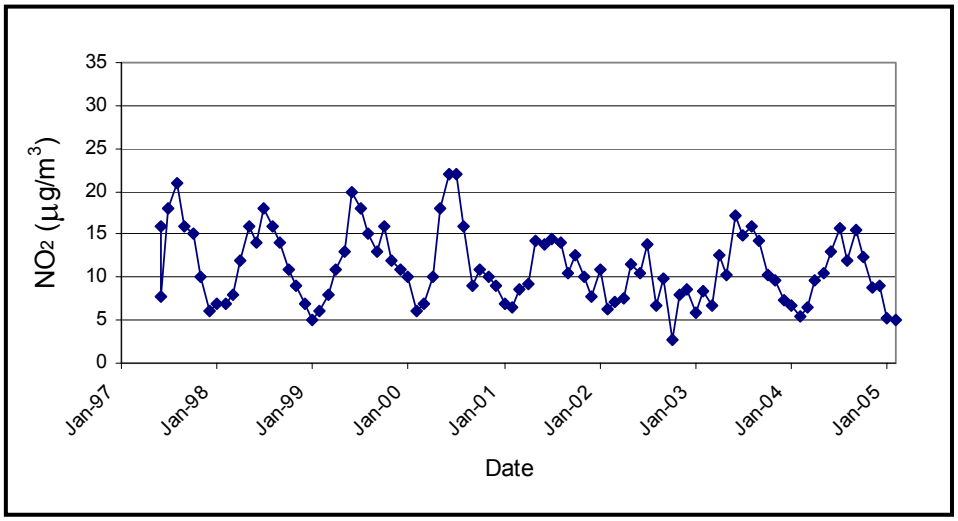


Figure 8.1 Monthly average NO_2 values for North East Valley, 1997 – 2004

8.1.2 Albany Street

Table 8.2 summarises NO_2 results from Albany Street in North Dunedin. An annual average figure is not available for 1997 as the monitor was not running for the entire year. Maximum monthly NO_2 levels at Albany Street are generally higher than at North East Valley, and range from 18 to 29 µg/m^3. Figure 8.2 shows all monthly values recorded at Albany Street. The same seasonal trend that is apparent in North East Valley is also shown at the Albany Street site.

Table 8.2 Summary of monthly average NO_2 concentrations from Albany Street using passive samplers

Year	Annual Average NO_2 (µg/m^3)	Winter Average NO_2 (µg/m^3)	Maximum recorded NO_2 (µg/m^3)
1997	Insufficient data	22.7	29.0
1998	15.0	21.3	23.0
1999	17.2	19.7	26.0
2000	13.2	16.3	18.0
2001	13.6	13.1	23.9
2002	12.5	16.6	20.4
2003	13.6	11.7	28.4
2004	15.3	18.5	23.9
Average	**14.3**	**17.5**	

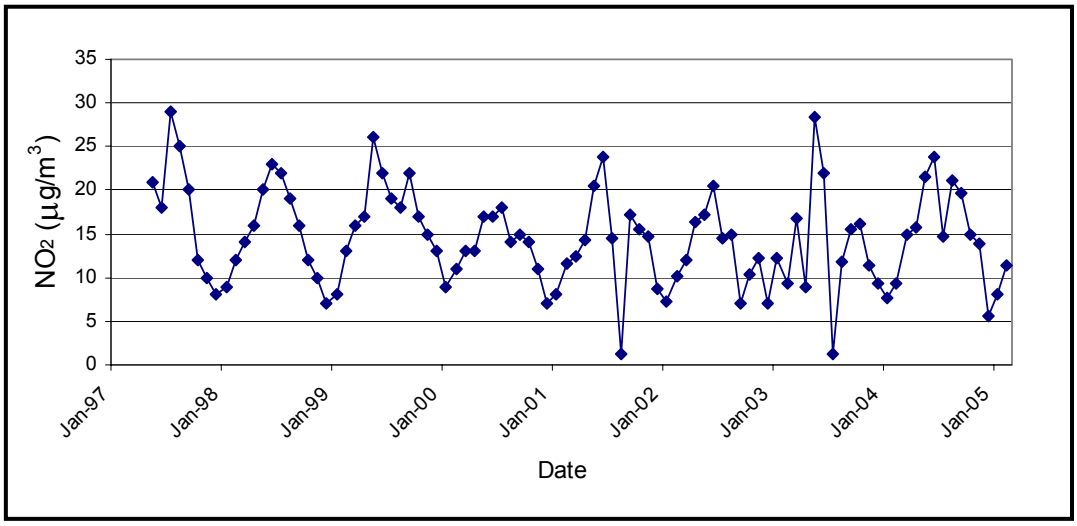


Figure 8.2 Monthly average NO_2 values for Albany Street, 1997 – 2004

A small number of 24-hour samples have been measured at Albany Street using wet chemical methods. Table 8.3 shows the results of this monitoring, which was carried out from 1997 to 1999. Figure 8.3 shows that on the days monitored, NO_2 concentrations were much less than the ORC 24-hour average guideline value of 60 µg/m^3.

Table 8.3 24 hour concentrations of NO_2 measured at Albany Street

1997	µgm^3	1998	µgm^3	1999	µgm^3
05 June 1997	11	12 June 1998	30	01 June 1999	17
11 June 1997	2	18 June 1998	23	07 June 1999	21
17 June 1997	6	24 June 1998	20	19 June 1999	25
11 July 1997	11	30 June 1998	30	25 June 1999	20
17 July 1997	20	06 July 1998	18	01 July 1999	25
23 July 1997	11	18 July 1998	15	07 July 1999	25
29 July 1997	3	24 July 1998	18	13 July 1999	20
04 August 1997	8	30 July 1998	24	19 July 1999	23
10 August 1997	5	05 August 1998	27	25 July 1999	20
22 August 1997	1	11 August 1998	25	31 July 1999	12
		17 August 1998	12	06 August 1999	21
		23 August 1998	14	12 August 1999	29
				18 August 1999	23
				24 August 1999	10
				30 August 1999	24

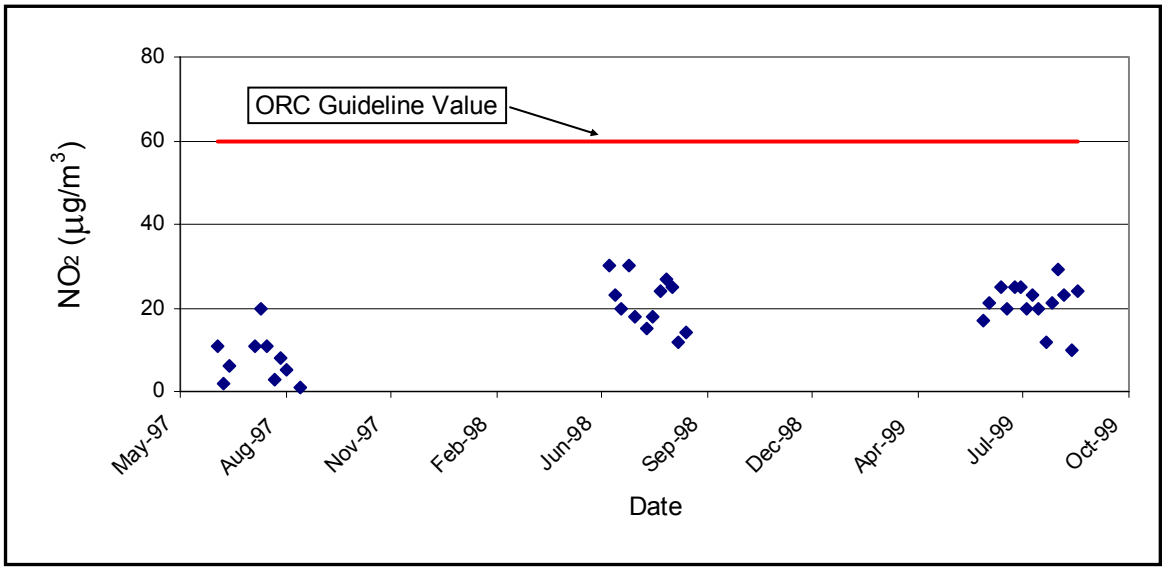


Figure 8.3 Average 24 Hour NO_2 values for Albany Street, 1997 – 1999

8.2 Temporary NO_2 sites

Results from winter monitoring undertaken at temporary NO_2 sites in Otago are presented in Table 8.4. The data for these sites is an average of the three winter monthly readings, taken from passive samplers. Winter is defined as the period June to August. Winter monitoring has been undertaken for six years at Mosgiel and Green Island, four years at Milton, two years for South Dunedin and Arrowtown, and one year each for Cromwell, Wanaka, Palmerston and Kaikorai Valley. The highest recorded monthly average NO_2 reading from these temporary sites was 29 $\mu g/m^3$, measured at Green Island during July 1997. The lowest monthly average NO_2 value recorded is 2.9 $\mu g/m^3$, at South Dunedin in June 2001.

Table 8.4 Summary of monthly average NO_2 concentrations from temporary sites using passive samplers

	Year							
Site	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Milton	13.3	10.3	8.3	14.3				
Mosgiel	15.3	14.3	12	13	11.9	12		
Green Is.	21.7	19	9	18.3	21.7	20		
Sth. Dunedin					10.5	13.2		
Wanaka							5.5	
Palmerston							12.1	
Arrowtown							9.2	12.4
Cromwell								8.8
Kaikorai								15.9

9. SO_2 results

This section summarises SO_2 data collected from permanent sites at North Dunedin and North East Valley, as well as data from nine other temporary sites around Otago. SO_2 has been measured continuously at North East Valley (North Road) and North Dunedin (Albany Street) since May 1997. Data from these sites are one month averages, with the passive samplers changed at the end of each month. Winter sampling is defined as the period June to August.

9.1 North East Valley

Table 9.1 summarises SO_2 results from North East Valley. An annual average figure is not available for 1997 as the monitor was not running for the entire year. Table 9.1 shows that maximum monthly SO_2 levels for each year have varied from 5.8 to 15 µg/m3. Figure 9.1 shows all monthly values recorded at North East Valley, with a seasonal trend in SO_2 often shown at this site. The highest readings generally occurred during winter when discharges are high as a result of increased fossil fuel use, and when dispersion is more likely to be suppressed. There were also a number of winter months where SO_2 levels declined however.

Table 9.1 Summary of monthly average SO_2 concentrations from North East Valley using passive samplers

Year	Annual Average SO_2 ($\mu g/m^3$)	Winter Average SO_2 ($\mu g/m^3$)	Max recorded SO_2 ($\mu g/m^3$)
1997	Insufficient data	6.7	7.0
1998	6.3	11.3	15.0
1999	8.4	9.3	12.0
2000	8.8	8.7	15.0
2001	5.5	5.2	9.6
2002	4.4	6.5	9.7
2003	5.4	9.4	10.4
2004	3.2	4.3	5.8
Average	**6.0**	**7.7**	

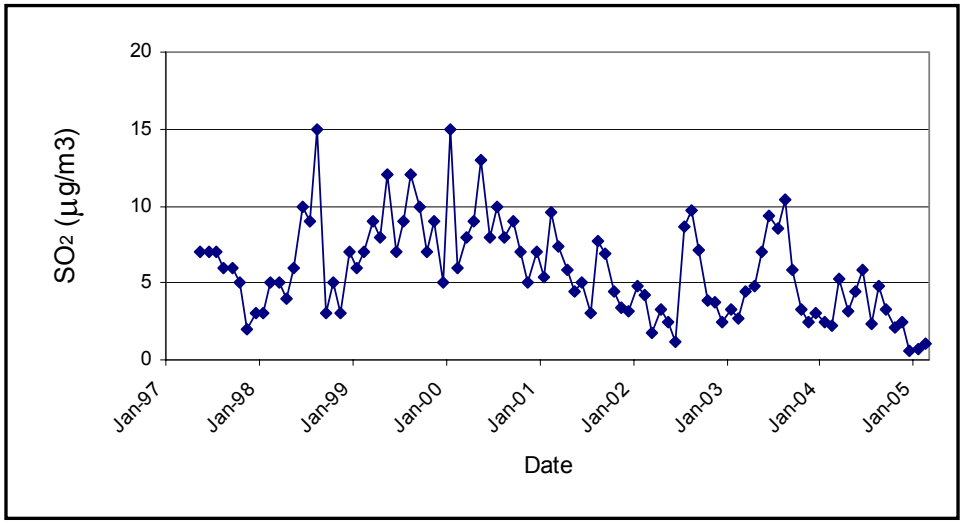


Figure 9.1 Monthly average SO_2 values for North East Valley, 1997 – 2004

9.2 Albany Street

9.2.1 Albany Street passive sampler results

Table 9.2 summarises SO_2 results from Albany Street in North Dunedin. An annual average figure is not available for 1997 as the monitor was not running for the entire year. Maximum monthly SO_2 levels at Albany Street are significantly higher than at North East Valley, and range from 18 to 48 µg/m^3. Figure 9.2 shows all monthly values recorded at Albany Street. As at North East Valley, there is a slight seasonal trend shown at the Albany Street site, with higher SO_2 readings during the winter.

Table 9.2 Summary of monthly average SO_2 concentrations from Albany Street using passive samplers

Year	Annual Average SO_2 (µg/m^3)	Winter Average SO_2 (µg/m^3)	Maximum recorded SO_2 (µg/m^3)
1997	Insufficient data	15.7	18.0
1998	16.4	23.7	30.0
1999	21.4	21.3	31.0
2000	25.4	24.3	45.0
2001	22.4	19.4	48.0
2002	18.6	18.0	44.5
2003	18.1	22.5	25.7
2004	16.1	17.9	24.9
Average	**19.8**	**20.4**	

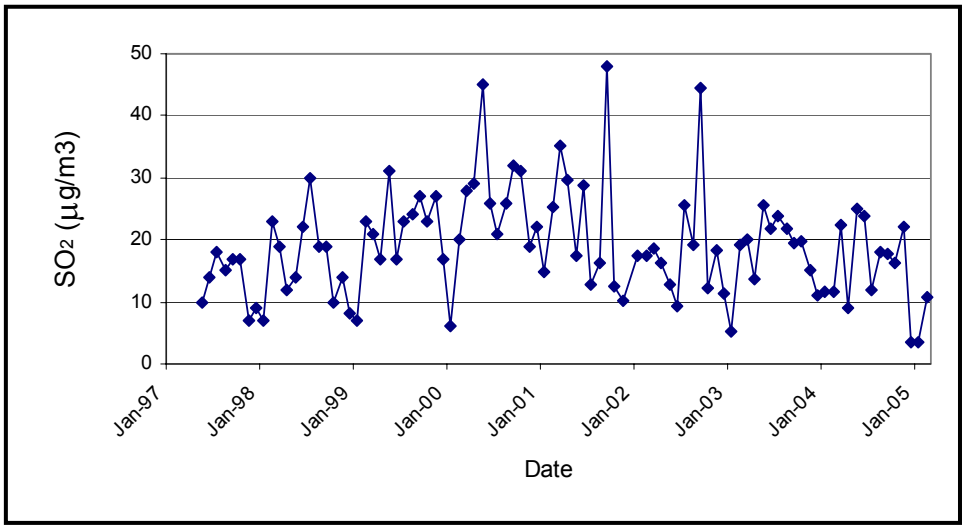


Figure 9.2 Monthly average SO_2 values for Albany Street, 1997 – 2004

9.2.2 Albany Street wet chemistry results

A number of 24-hour samples have been measured at Albany Street using wet chemical methods. Figure 9.3 shows the results of this monitoring, which was carried out from 1997 to 2000. Figure 9.3 shows that, apart from on two occasions in winter 1997, SO_2 concentrations were less than half the 24-hour average SO_2 guideline value of 80 µg/m^3 (ORC Regional Plan: Air, 2003).

Table 9.3 24 hour concentrations of SO_2 measured at Albany Street

1997/98	µgm^3	1999	µgm^3	2000	µgm^3
29 July 1997	17	07 July 1999	7	01 June 2000	11
04 August 1997	80	13 July 1999	9	07 June 2000	12
10 August 1997	8	19 July 1999	15	13 June 2000	12
16 August 1997	41	31 July 1999	22	19 June 2000	15
22 August 1997	19	06 August 1999	20	25 June 2000	20
28 August 1997	9	12 August 1999	20	07 July 2000	25
8 Sept 1997	9	18 August 1999	30	13 July 2000	18
12 June 1998	11	24 August 1999	26	19 July 2000	11
18 June 1998	14	30 August 1999	35	25 July 2000	15
24 June 1998	20	05 Sept 1999	20	31 July 2000	10
		07 Sept 1999	26	06 August 2000	6
		23 Sept 1999	29	12 August 2000	9
		29 Sept 1999	25	18 August 2000	11
				24 August 2000	9
				30 August 2000	8

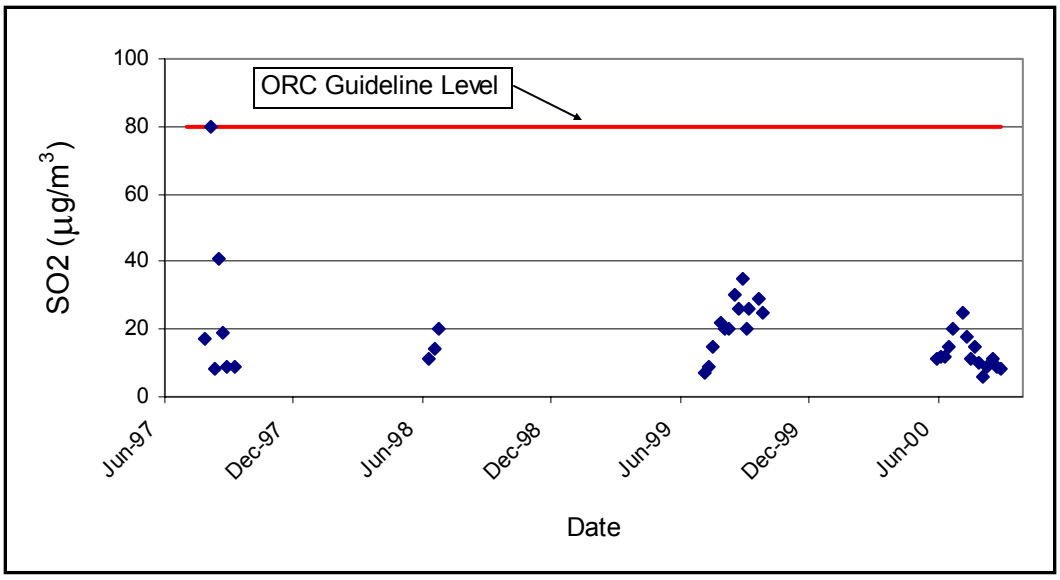


Figure 9.3 Average 24 hour SO_2 values for Albany Street, 1997 – 2000

9.2.3 Albany Street instrumental results

An ultra violet fluorescence instrument was used at Albany Street in 1999 to continuously measure ten-minute and one-hour average concentrations through the winter months. This also produced 24-hour measurements, and allowed for a comparison with the wet chemistry technique.

More than 99.9 percent of both one-hour and ten-minute average SO_2 concentrations were below their respective Otago goals. Considering that these measurements were taken during the winter months when concentrations are expected to be at their highest, it indicates that short-term sulphur dioxide concentrations are not a concern.

Figure 9.4 shows sulphur dioxide results classified according to a set of five criteria proposed by the Ministry for the Environment. The criteria considered appropriate for use as environmental performance indicators by the Ministry are listed in Table 9.4.

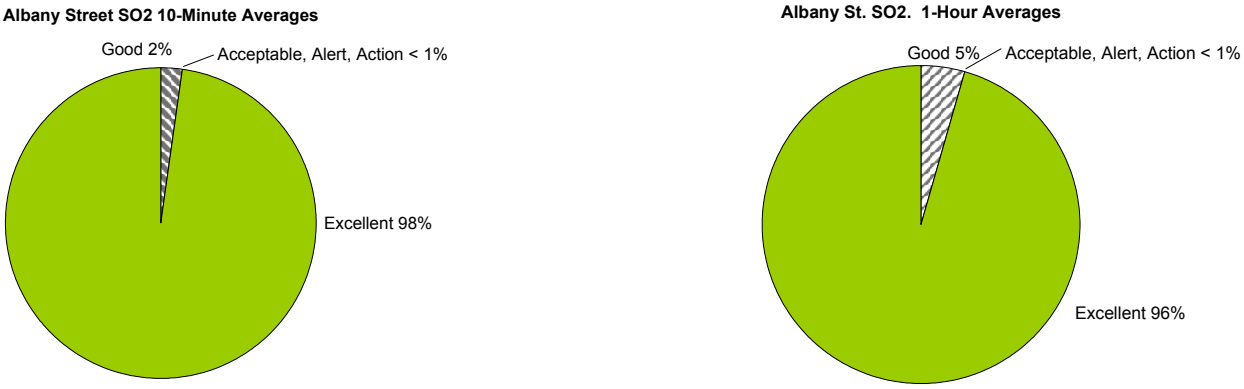


Figure 9.4 SO_2 results at Albany Street classified according to the air quality indicators criteria

Table 9.4 Air quality indicators criteria for SO_2

Criteria	Concentration Range ($\mu g/m^3$)	
	1-hour Averages	10-minute Averages
Action	> 350	> 500
Alert	230 – 350	330 – 500
Acceptable	115 – 230	165 – 330
Good	35 – 115	50 – 165
Excellent	< 35	< 50

Figure 9.4 shows one-hour averages in Albany Street can be classified as excellent for 96% of the time, while ten-minute averages were within the excellent category 98% of the time. In fact, most results were below the acceptable detection limit for the monitoring method, which is specified in the Australian Standard (AS 3580.4.1) as 30 $\mu g/m^3$.

24-hour average results from the instrumental measurements are presented in Figure 9.5. This also shows a comparison with the wet chemistry results. Instrumental 24-

hour results are much lower than the wet chemistry results, which is expected considering the wet chemistry method measures total acidity rather than being specific to sulphur dioxide. The comparison was very poor on some occasions however, and the most likely explanation for the poor agreement is the fact that concentrations were low in relation to the reliable detection limit for both methods.

It must also be recognised that the instrument was not located in an air-conditioned housing, which means the monitoring did not strictly comply with the Australian or USEPA standards. The instrument was housed in a building, with a pipe passing through to an inlet on the outside. With this arrangement it is possible that measured concentrations were influenced by changes in room temperature, particularly during the early mornings when people arrived in the building and began to heat rooms. This may have been significant when the concentrations were low, but it will not influence the general conclusions that short-term concentrations were well below guidelines for the large majority of the time.

These results demonstrate that short-term concentrations of sulphur dioxide are very low and, as such, further monitoring at this site with expensive instrumental equipment is not justified.

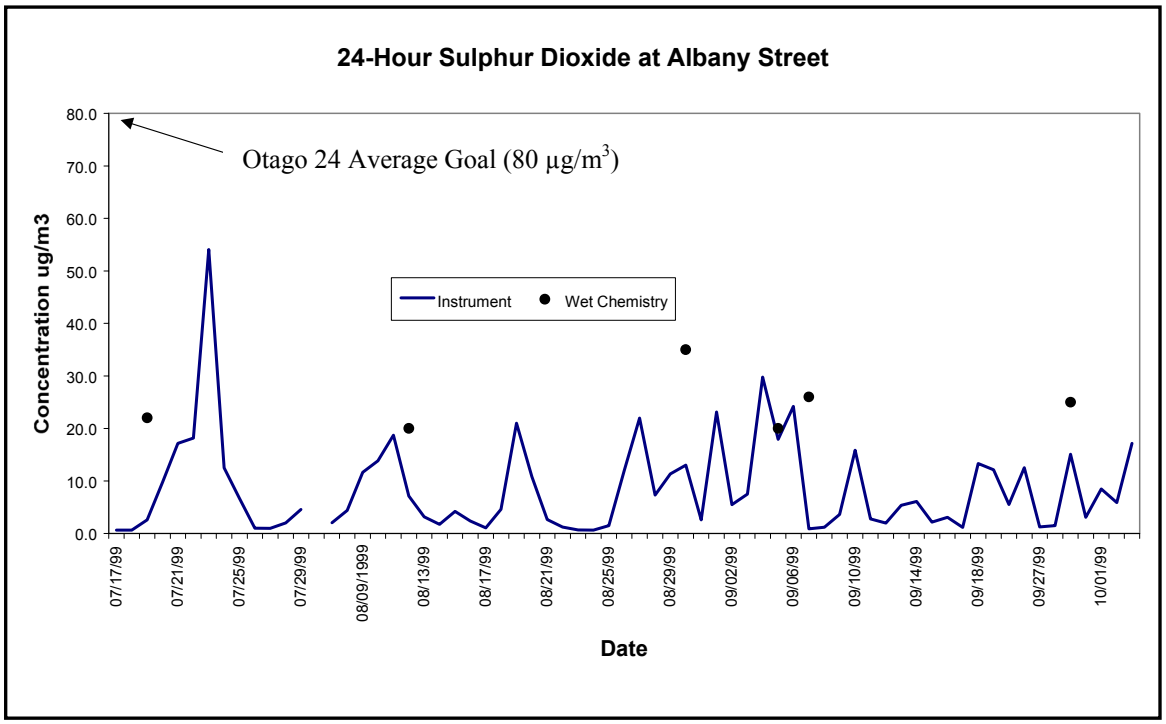


Figure 9.5 24-hour sulphur dioxide at Albany Street showing the instrument and wet chemistry results

9.3 Temporary SO_2 sites

Results from winter monitoring undertaken at temporary SO_2 sites in Otago are presented in Table 9.5. The data for these sites is an average of the three winter monthly readings, taken from passive samplers. Winter is defined as the period June to August. Winter monitoring has been undertaken for six years at Mosgiel and Green Island, four years at Alexandra and Milton, two years for South Dunedin and Arrowtown, and one year each for Balclutha, Cromwell, Wanaka, Palmerston and Kaikorai Valley. The highest recorded monthly average SO_2 reading from these temporary sites was 30 $\mu g/m^3$, measured at Green Island during August 2001. Very low monthly SO_2 readings of just one or two $\mu g/m^3$ have been recorded at all sites except Balclutha and Milton.

Table 9.5 Summary of monthly average SO_2 concentrations from temporary sites using passive samplers

	Year							
Site	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Alexandra	1	1	1	2				
Milton	12	16	14	19				
Mosgiel	3.7	4.3	4.3	5.7	5.1	3.1		
Green Island	12.3	16.3	7.7	15.3	22	6.9		
Balclutha				11.7				
Sth Dunedin					7	6.2		
Wanaka							1.1	
Palmerston							1.6	
Arrowtown							1.3	1.1
Cromwell								1.1
Kaikorai								4

10. CO results

10.1 George Street CO results

For more than 99.9 percent of the time, one-hour average concentrations of CO were below the Otago guideline level of 20 mg/m^3, while eight-hour averages were below the Otago guideline level of 6 mg/m^3 97% of the time.

Figure 10.1 shows pie charts of CO data categorised according to five criteria as proposed by the Ministry for the Environment, (MfE, 1997) for use as environmental performance indicators. The criteria have been amended to use Otago Regional Council guideline values, and are listed in Table 10.1.

Figure 10.1 Carbon monoxide results for George Street characterised according to five environmental indicator criteria

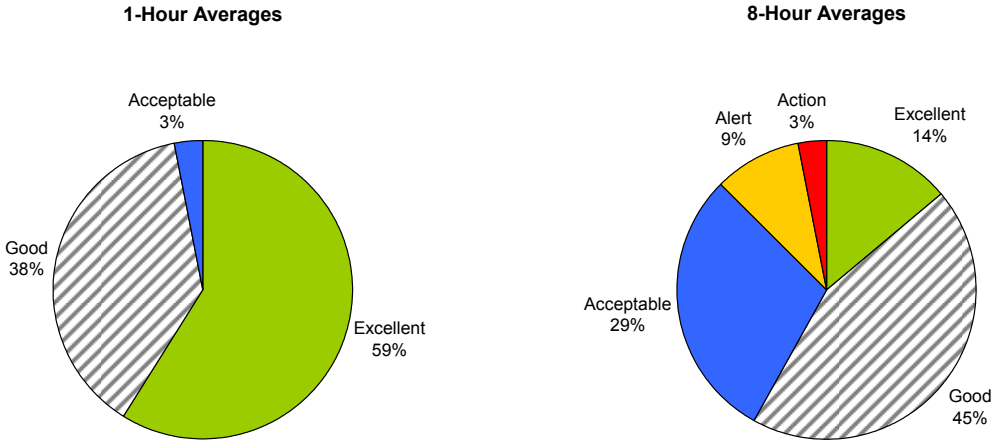


Table 10.1 Air quality indicators criteria for Carbon monoxide

Criteria	% of ORC guideline value	Concentration Range (mg/m^3)	
		1-hour Averages	8-hour Averages
Action	> 100%	> 20	> 6
Alert	66 - 100%	13 – 20	4-6
Acceptable	33 - 66%	7 – 13	2-4
Good	10 - 33%	2 – 7	0.6 – 2
Excellent	< 10%	< 2	< 0.6

The pie charts show one-hour averages could be classified as excellent for 59% of the time, while eight-hour averages were within the excellent category only 14% of the time. In this respect the eight-hour results are a more sensitive measure of air quality at this site.

The highest CO concentrations occurred in the winter months and Figure 10.2 illustrates a strong seasonal pattern of concentrations for eight-hour averages for the monitoring period. There were 30 exceedances of the Otago Regional Council eight-hour average guideline value of six mg/m^3, while the NES value was only breached twice.

Unfortunately no results were obtained during June 1998. The instrument failed and was sent to Australia for repair during this month.

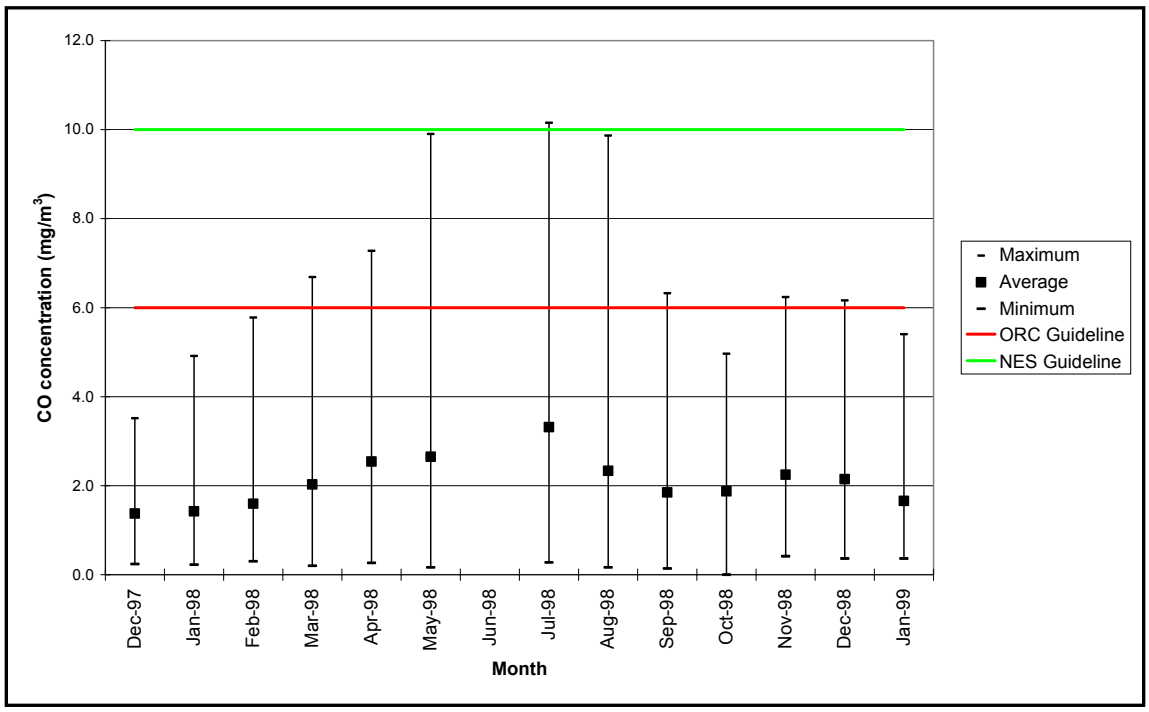


Figure 10.2 Box and whisker plot for eight-hour average carbon monoxide levels at George Street

10.2 Mosgiel CO results

One-hour average concentrations of CO were below the Otago guideline value of 20 mg/m^3 for more than 99.9% of the time, while eight-hour averages were below the Otago guideline level of six mg/m^3 99% of the time.

Figure 10.2 shows pie charts of CO data categorised according to five criteria as proposed by the Ministry for the Environment, (MfE, 1997) for use as environmental performance indicators. The criteria have been amended to use Otago Regional Council guideline values, and are listed in Table 10.1.

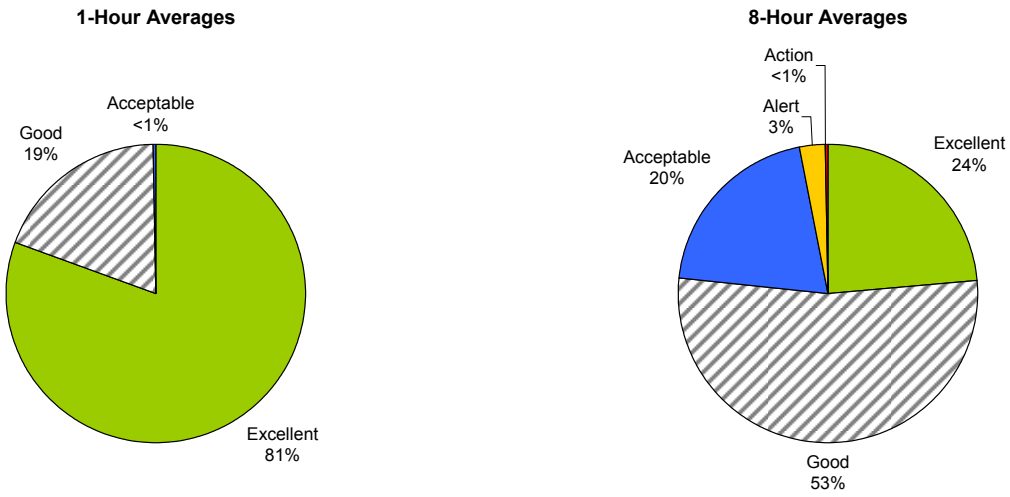


Figure 10.3 Carbon monoxide results for Mosgiel characterised according to five environmental indicator criteria

The pie charts show one-hour averages could be classified as excellent for 81% of the time, while eight-hour averages were within the excellent category only 24% of the time.

The highest CO concentrations occurred in the winter months and Figure 10.4 illustrates a strong seasonal pattern of concentrations for eight-hour averages for the monitoring period. There were five exceedances of the Otago Regional Council eight-hour average guideline value of six mg/m^3, while the NES value was only breached once.

Unfortunately no results were obtained during June 2000. The instrument failed and was sent to Australia for repair during this month.

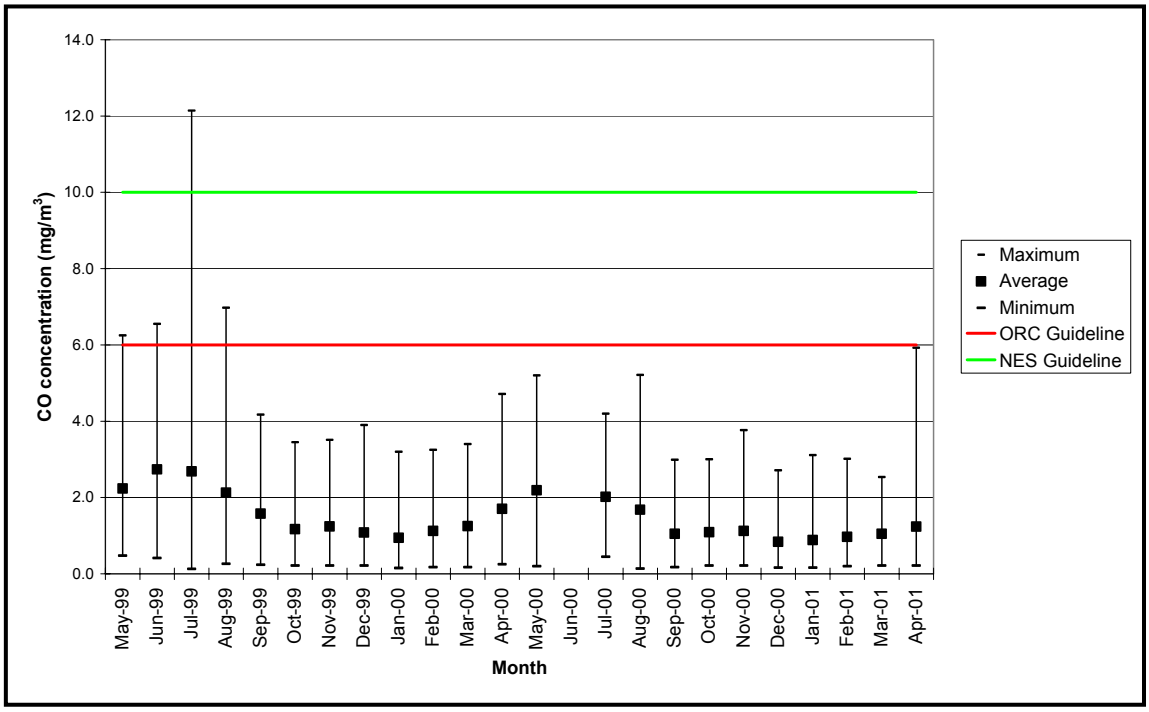


Figure 10.4 Box and whisker plot for eight-hour average carbon monoxide levels at Mosgiel

10.3 Cumberland Street data

One-hour average concentrations of CO were below the Otago guideline value of 20 mg/m^3 for all of the study period, while eight-hour averages were below the Otago guideline level of six mg/m^3 97% of the time.

Figure 10.5 shows pie charts of CO data categorised according to five criteria as proposed by the Ministry for the Environment, (MfE, 1997) for use as environmental performance indicators. The criteria have been amended to use Otago Regional Council guideline values, and are listed in Table 10.1.

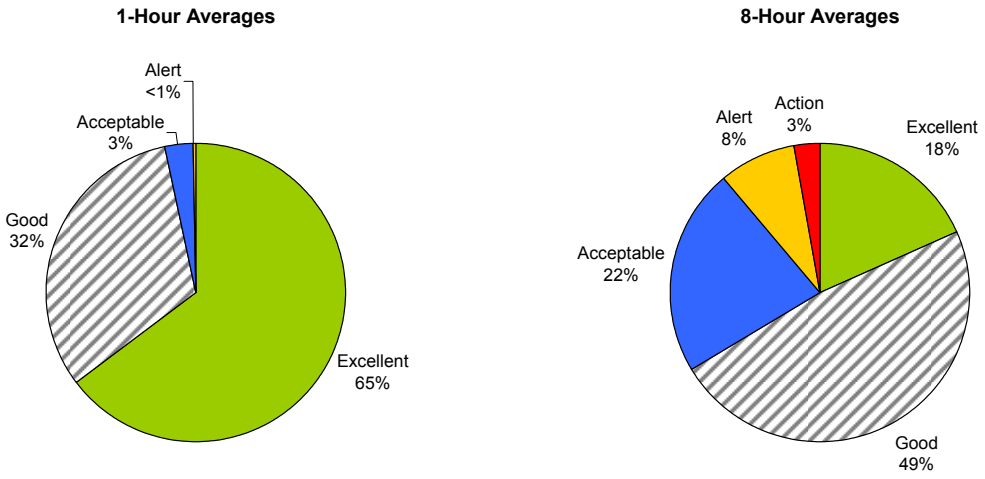


Figure 10.5 Carbon monoxide results for Cumberland Street characterised according to five environmental indicator criteria

The pie charts show one-hour averages could be classified as excellent for 65% of the time, while eight-hour averages were within the excellent category only 18% of the time.

The highest CO concentrations occurred in the winter months and Figure 10.6 illustrates a strong seasonal pattern of concentrations for eight-hour averages for the monitoring period. There were 30 exceedances of the Otago Regional Council eight-hour average guideline value of six mg/m^3, while the NES value was breached five times.

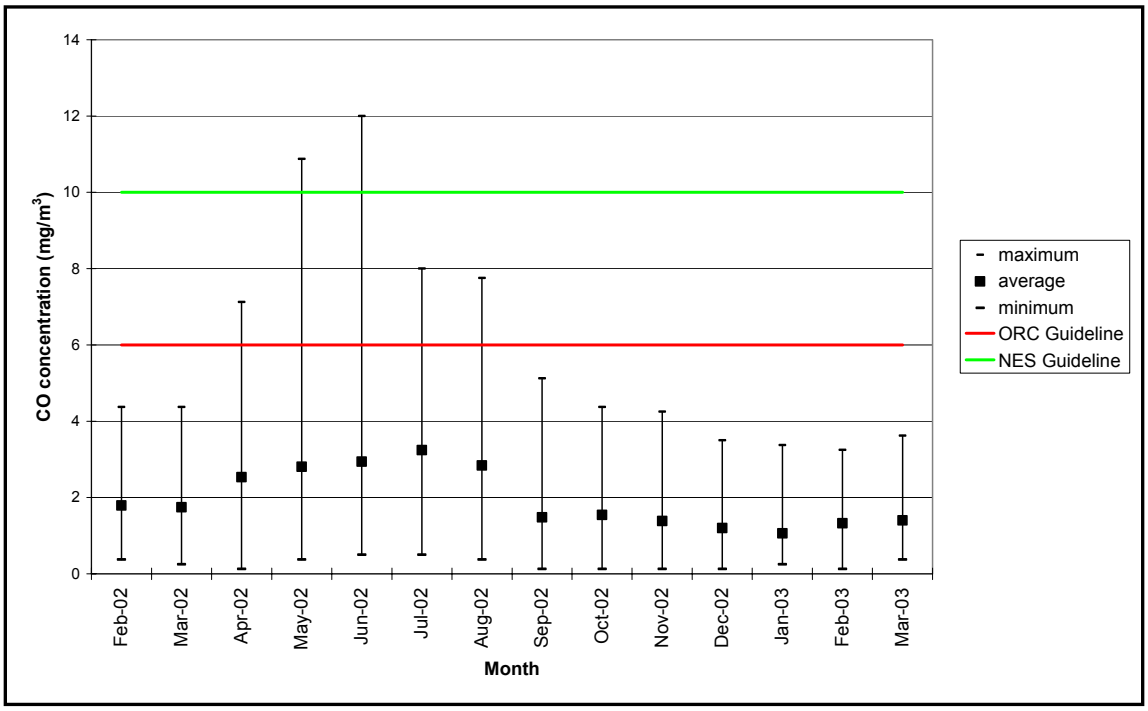


Figure 10.6 Box and whisker plot for eight-hour average carbon monoxide levels at Cumberland Street

There were several periods of missing record from the Cumberland Street monitor, in particular several weeks in late August and early September 2002, as well as in January 2003.

11. Conclusions

Otago Regional Council monitoring of NO_2, SO_2 and CO from sample sites around Otago between 1997 and 2004, shows that the levels of these contaminants were generally low, and were well below the relevant guideline levels for most of the time sampling was undertaken.

11.1 Nitrogen dioxide

Annual average NO_2 levels at the two long-term sites (North East Valley, and Albany Street) are 11 and 14 $\mu g/m^3$ respectively, well below the World Health Organisation (WHO) guideline of 40$\mu g/m^3$. The maximum monthly average NO_2 reading from any monitoring site is 29 $\mu g/m^3$, which is still below the guideline value.

The 24 hour average NO_2 data collected from Albany Street during the winters of 1997, 1998 and 1999 is also well below the ORC guideline of 60 $\mu g/m^3$. The highest 24 hour average sample was 30 $\mu g/m^3$. No hourly average NO_2 data have been collected by the Otago Regional Council, so a comparison with the Ministry for Environment guideline is not possible.

Results of winter NO_2 monitoring at other sites around Otago did not show any levels above the WHO annual average guideline value, and most sites regularly recorded monthly averages of less than 15 $\mu g/m^3$. The highest monthly average levels were recorded in Green Island, where a maximum of 29 $\mu g/m^3$ was measured during July 1997.

11.2 Sulphur dioxide

The annual average SO_2 level at North East Valley from 1997 to 2004 is six $\mu g/m^3$, while at Albany Street the annual average is 20 $\mu g/m^3$. Both these readings are well below the WHO annual average guideline of 50 $\mu g/m^3$.

Some reasonably high monthly average readings have been recorded at Albany Street, up to 48 $\mu g/m^3$. Unfortunately there is no New Zealand standard for average monthly SO_2 levels to compare these readings against. The 24 hour average readings taken from this site did not breach the Otago Regional Council guideline of 80 $\mu g/m^3$, although one sample did equal it. All other 24 hour readings were less than half the guideline value.

Ten-minute and one-hour average concentrations of SO_2 in Albany Street in 1999 were below the respective proposed Otago goal levels for a large majority of the time. More than 99.9 percent of both ten-minute and one-hour averages were below the goals of 330 and 230 $\mu g/m^3$ respectively.

Results of winter SO_2 monitoring at other sites around Otago did not show any particularly high levels, and most sites regularly recorded monthly averages of less than ten $\mu g/m^3$. Slightly elevated readings were noted at Milton and Balclutha, but these were generally below 20 $\mu g/m^3$.

Neither of the measurement methods used to monitor NO_2 and SO_2 comply with existing recommended monitoring methods. The results reported here are therefore

likely to be indicative only, but can be used to give a general indication of contaminant levels at the sites monitored.

11.3 Carbon monoxide

CO measurements were taken at three sites in Dunedin and Mosgiel between December 1997 and March 2003. There were almost no exceedances of the one-hour average Otago guideline value for CO of 20 mg/m^3 during that time. The majority of the one-hour samples at all three sites were in the excellent range (<10% of the guideline value). Mosgiel had the lowest one-hour average CO measurements, with 81% in the excellent range, followed by Cumberland Street (65%) and George Street (59%).

Exceedances of the Otago eight-hour average CO guideline level were also rare. In Dunedin, the George Street and Cumberland Street sites both exceeded the guideline level just 3% of the time. The majority of eight-hour average readings at the two Dunedin sites were in the good – to acceptable range. Mosgiel had the lowest eight-hour average CO measurements with 24% in the excellent range, and less than 1% exceeding the Otago guideline level.

The Otago guideline value for eight-hour average CO is considerably lower than that set in the National Environmental Standard Regulations (Table 3.2), further signifying that CO levels in the busiest areas of Dunedin and Mosgiel are very low.

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