4 Air Quality

4.1 Air Quality: Main Points

Pressures

- Air quality related incidents and issues continue to dominate the complaints received by the Regional Council. In particular smoke nuisance, offensive odours, dust and agrichemical spraydrift. More recent figures show an increasing intolerance of these.
- A small number of industries are responsible for the majority of trade discharges.

State

- Northland's air quality is dominated by the region's exposure to the prevailing southwesterly winds, which quickly disperse air pollutants.
- Dust (measured as PM_{10} - particulate matter) concentrations fluctuate on a day-to-day basis. Weather, particularly wind speed, has a significant effect on PM_{10} concentrations. Monitoring in Whangarei has shown that PM_{10} concentrations are either good or acceptable 74% of the time. At times, PM_{10} concentrations approach or exceed recommended guidelines. These exceedances are not great, and are likely to occur in the early hours of the morning under cool, winter inversion conditions.
- Carbon monoxide (CO) investigations in Whangarei have shown that at times, elevated concentrations of CO are present in the central city area. Earlier surveys revealed concentrations above recommended guideline concentrations. However, more recent monitoring showed no exceedances of the guidelines. This is likely to be more related to sampling times rather than a reduction in CO concentrations.
- Monitoring of sulphur dioxide (SO_2) in the Marsden Point industrial area has revealed relatively low concentrations. However, there are occasional results that approach the boundaries set in the National Ambient Air Quality Guidelines.

Response

- The Revised Proposed Air Quality Plan for Northland contains rules that permit, control or prohibit activities which cause discharges of pollutants to the air. This plan is almost operative.
- Additional State of the Environment monitoring programmes for air quality are planned for implementation.
- The NRC supports the use of industrial codes of practice such as those published by the Agrichemical Education Trust.

4.2 Introduction to Air Quality in Northland

Ambient air quality is the general quality of the air that surrounds us, outside buildings or structures, and is the result of climate and topography as well as the combined effects on the air of human activities (industrial, commercial and domestic) and natural sources.

Northland's air quality is dominated by the region's exposure to the prevailing southwesterly winds, which, particularly during the winter and spring, quickly disperse air pollutants. This, along with the relatively dispersed population, low vehicle density and sparse heavy industry, means that Northland enjoys a high standard of natural air quality.

However, monitoring has identified that at times pollutants approach or even exceed national air quality guidelines. These exceedances are restricted to specific locations and often occur under specific meteorological conditions.

4.3 Regional Policy Statement Objectives

The Regional Policy Statement contains objectives relating to Northland's air quality. These objectives seek to sustainably manage air quality in the Northland region.

The Regional Policy Statement objectives are:

- **The sustainable management of the air resource by avoiding, remedying, or mitigating adverse effects on the environment from the discharge of contaminants to air.**

- **The reduction of the region's discharges of ozone-depleting substances and the net emissions of greenhouse gases in line with National Policy Statements.**

4.4 Air Quality Issues

The following is a summary of the significant air quality management issues of the region:

- The effects of discharges from industrial areas.

- Discharges from various existing activities, which have localised adverse effects including nuisance and odour problems. These include rubbish burning, odour from waste treatment and disposal facilities (such as tips, waste ponds, and effluent spraying) and dust (from sandblasting, ship loading, quarries and roads).

- Agrichemical and fertiliser overuse, overspread or overspray and drift on to water bodies, neighbouring properties and non-target vegetation.

- Dust from unsealed roads affecting the use of adjacent land and buildings.

- The general lack of information on air quality management issues in Northland, including air quality measurements.

- The need for air quality management policy, standards or guidelines.

- Northland's contribution to greenhouse gas-induced climate change is due mainly to discharges of carbon dioxide from motor vehicles, industrial fossil fuel use and processes as well as methane, mainly from livestock and also from landfills, sewerage and agricultural waste treatment facilities.

- The release of ozone-depleting substances.

4.5 Pressures Affecting Air Quality

4.5.1 Pollutants

The air, like any other natural resource, can be adversely affected by pollutants. Pollutants are substances that, under certain conditions, can harm human, animal or plant life. Polluted air can also interfere with the use and enjoyment of life and property by affecting visibility, causing odour, dust or smoke problems or corroding and disfiguring materials.

Pollutants of concern such as oxides of nitrogen, reactive organic compounds, particles, lead, carbon monoxide and sulphur dioxide are released into the atmosphere from a range of human and natural sources. Important sources of these pollutants include motor vehicles, industrial activities and some domestic and commercial activities. Once in the atmosphere some pollutants can then be transported throughout the region by wind and air currents.

The air quality in Northland is primarily affected by the meteorological conditions that are prevailing at the time. Warm, windy conditions tend to promote better dispersion and hence better air quality than cool, calm conditions. Consequently, air quality in Northland tends to follow a seasonal trend with air quality improving in the summer and deteriorating during the winter months.

4.5.2 Environmental Incidents

On 1 November 1993, the Council began operating a 24 hours a day, 7 days a week toll-free hotline for the reporting of environmental incidents. The environmental incident system receives not only calls on the 0800 number, but also by letter or facsimile, as well as those reported by staff and people visiting the Council offices.

Since 1993, the Northland Regional Council has responded to more than 6000 incidents. These incidents range from minor land disturbances through to major oil spills. Figure 1 identifies the major resources affected by these incidents.

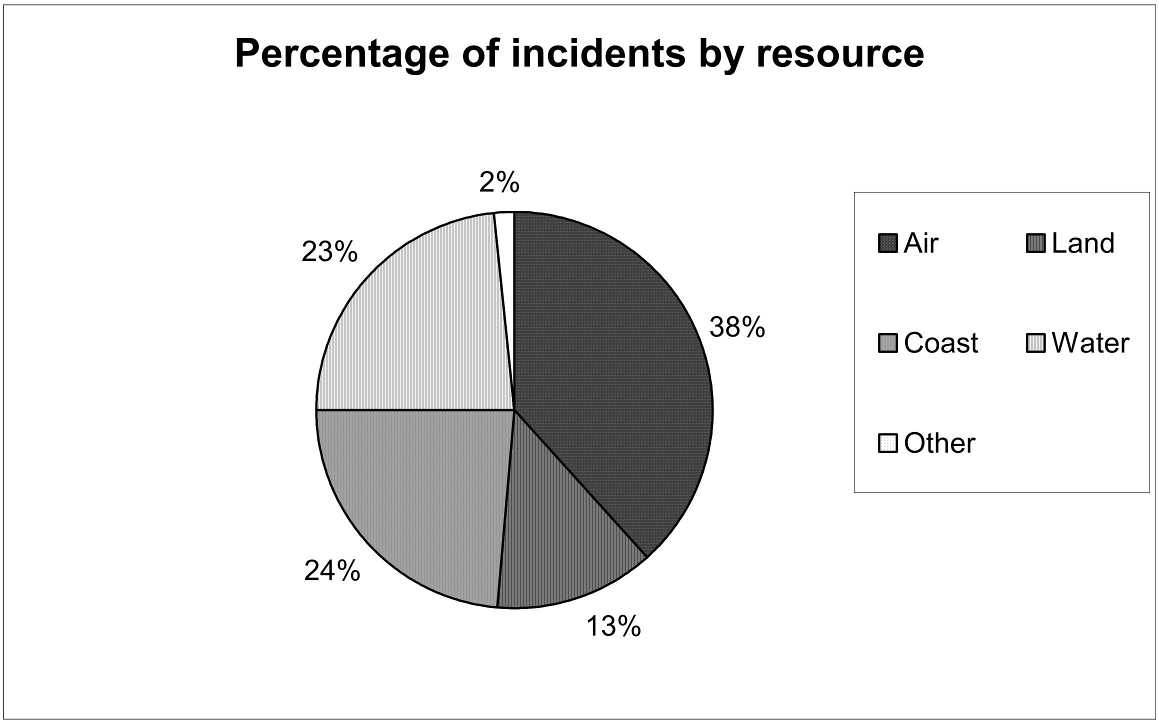


Figure 1: Percentage of environmental incidents by resource

Figure 1 identifies that more air-related incidents are received than any other resource. In any given year, air incidents comprise between one third to one half of all incidents received by the Council.

Air incidents can be divided into five main categories of burning/smoke nuisance, agrichemical spraydrift, odour, industrial emissions and dust nuisance. Figure 2 identifies the percentage of each group of air-related incidents.

From Figure 2, it is clear that there are three major groups of air-related incidents – agrichemical spraydrift, burning/smoke nuisance and odour. The trend in the past few years has been away from burning/smoke nuisance problems towards more odour-related problems. This trend is consistent with similar findings in other parts of New Zealand and overseas and seems to reflect an increasing intolerance in western societies of poor air quality, specifically offensive odours.

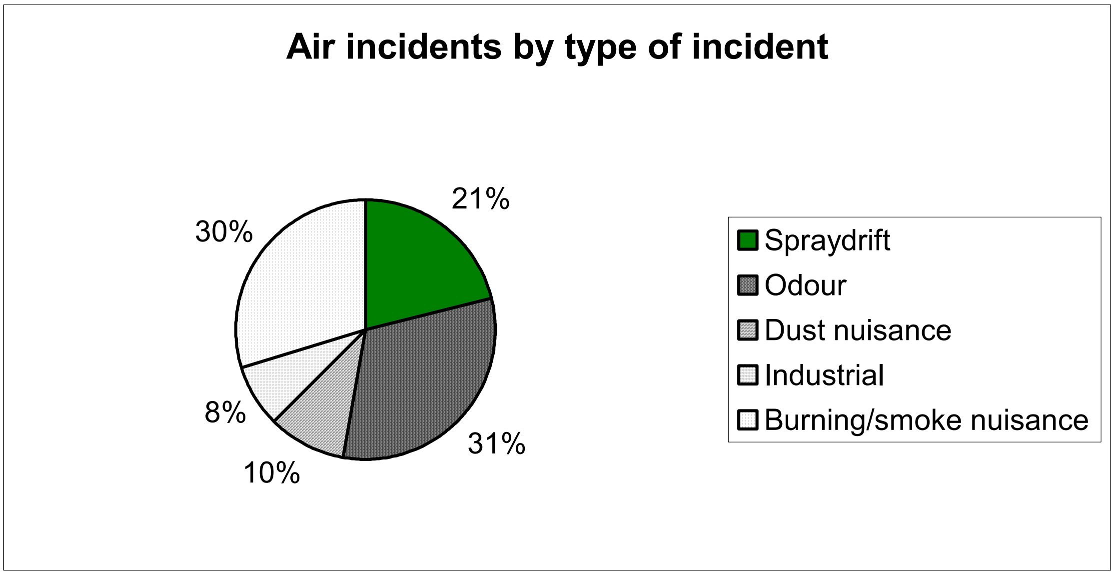


Figure 2: Air-related incidents by incident type.

Unfortunately, odour nuisance can be some of the most difficult and frustrating problems to identify and resolve and frequently require specialist skills, experience, equipment and training.

Dust sourced from roads is a common complaint

Staff from the Regional Council assist new and existing industries with technical advice, information and experience to avoid causing odour problems and to assist with resolving odour problems where they already exist.

The overall numbers of air-related incidents have reduced in recent years, particularly in the areas of agrichemical spraydrift and burning/smoke nuisance. This is attributed to a number of factors including;

- Increasing awareness and compliance with the rules in the Proposed Regional Air Quality Plan for Northland.
- Changes in the type of agrichemicals commercially available.
- Publicity associated with high profile air incidents
- Availability of "instant fines"

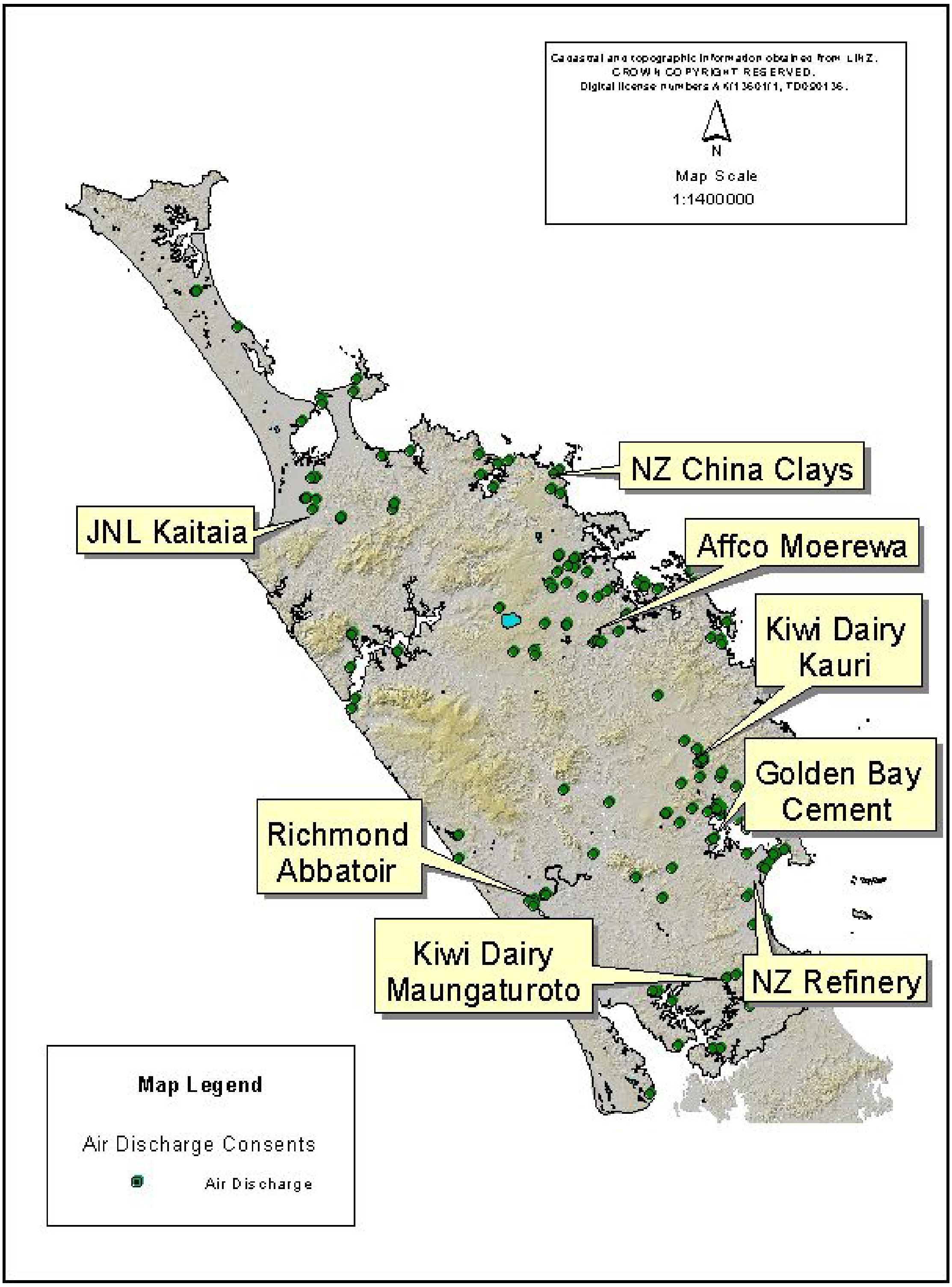
Upon completing an incident investigation, a summary is drafted which outlines the results of the investigation and any recommendations that should follow.

4.5.3 Industrial and Trade Discharges

Northland Regional Council monitors around 180 resource consents which have permits to discharge into the air. Many of these consents are for small-scale sewage treatment and disposal facilities which need appropriate controls placed on air emissions to prevent odour problems from arising.

Approximately 60 discharge to air consents are closely monitored by the Northland Regional Council to ensure that there are no significant adverse effects arising from the exercise of these consents. Major industry sites with consents to discharge to air are labelled in Map 1.

Industrial discharge



Map 1: Location of air discharges subject to air consents in Northland

A monitoring report is produced for each consent holder on a regular basis. The reports detail the results of any monitoring undertaken and the comments made during any site inspections.

At times, it is necessary to measure exactly what is being discharged from a stack or chimney. This requires specialised equipment and training and can often be difficult, challenging work. The Northland Regional Council monitors a number of industries annually as a check on their emission control equipment and to assess compliance with their consent discharge limit.

4.5.4 Emissions Inventory

Northland Regional Council is currently in the process of preparing an emissions inventory to quantify the existing air discharges from the Northland region.

4.6 State of Air Quality

Clear, clean air is essential for the health and well being of the Northland community. Poor air quality can not only impact on health, but also upon the agricultural, horticultural and tourism industries.

While the resource consent process addresses major point source discharges from industrial processes, non-point source discharges from motor vehicles or domestic fires can also collectively impact on air quality. By monitoring these pollutants in ambient air, it is possible to determine long-term trends. These trends can give advance warning of possible problems and enable effective strategies to be developed to prevent any deterioration of air quality.

Northland Regional Council currently monitors the following pollutants:

- Particulate matter or PM_{10}
- Deposited particulate
- Carbon monoxide
- Sulphur dioxide

4.6.1 PM_{10}

The term ‘Particulate matter’ covers a range of small to medium-sized particles, which exist in solid or aerosol state under normal conditions. There are a number of different types of particulate matter. PM_{10} is the name given to very small, fine suspended particles that have an aerodynamic diameter of 10 microns or less.

PM_{10} particulates are sourced from a variety of different processes. Some are generated from combustion and industrial processes, others from naturally occurring dusts and salt spray. Because of their small size these particulates can be inhaled into the lungs where they can cause a variety of adverse health effects.

In the early 1950s many residents in London were affected by what became known as the “killer fogs”. These fogs were responsible for affecting the health of a large number of residents in the central London area, in part because the concentration of fine particulate (or PM_{10}) from local coal burning exceeded safe guidelines.

Concentrations of PM_{10} are now closely monitored in most major cities around the world to ensure that they stay below concentrations that cause health effects.

PM_{10} in Northland

In March 2000, a PM_{10} high volume sampler was installed in Robert Street, Whangarei to monitor daily PM_{10} concentration. Samples are collected and analysed gravimetrically on a weekly basis in accordance with USEPA methodology. Although the sampler has only been operating since March 2000, some useful information has already been obtained.

Sample results, shown below in figure 3, reveal that the PM_{10} concentration fluctuates considerably on a day-to-day basis. This fluctuation correlates well with meteorological influences and it is likely that the weather, particularly wind speed, has a significant effect on PM_{10} concentration. Low wind speeds and cooler air temperatures result in the formation of an inversion layer which traps pollutants from domestic fires, local industry and transport close to the ground, thereby increasing particulate concentration.

The national air quality guideline is currently 120 micrograms per cubic metre of air per day. However, this guideline is currently being reassessed in line with new overseas research, and it is likely that the new national guideline will be set at 50 micrograms per cubic metre.

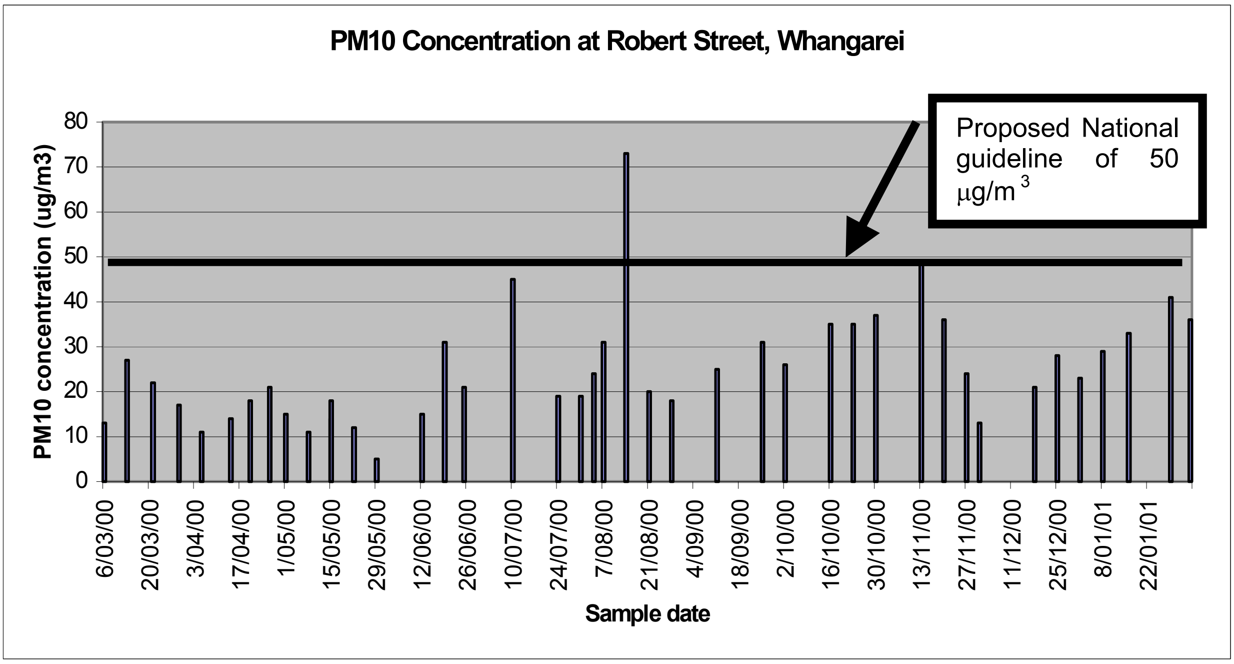


Figure 3: PM_{10} concentration measured at Robert Street, Whangarei

The general pattern of PM_{10} is fairly consistent throughout much of the year. Unlike other pollutants, such as carbon monoxide, there is no strong seasonal influence during the winter months. This suggests that much of the PM_{10} material at Robert Street is sourced from motor vehicles rather than domestic fires, which have a seasonal influence.

The value in this information comes from viewing trends over several years when it will be possible to determine whether the policies and rules in regional and district plans are gradually improving air quality.

Figure 4 shows that the PM_{10} concentration is either good or acceptable approximately 74% of the time. However, the results also indicate that, at times, the PM_{10} concentration is approaching or even exceeding recommended guidelines. These exceedances are unlikely to manifest themselves as health effects, even for sensitive individuals, given that they are relatively infrequent events and that the magnitude of the exceedance is not great. In addition, the higher PM_{10} concentrations will usually be attained during the early hours of the morning under cool, winter inversion conditions.

When compared with other regions, Northland's air quality is very good. Auckland, Waikato, Wellington and Canterbury all have regular exceedances of PM_{10}

concentration. Although the reasons for such exceedances vary, in Northland, it appears that most of the particulate is sourced from motor vehicles.

Table 1: Air quality Indicator categories

Category	Maximum measure value	Comment
Excellent	less than 10% of the guideline	Of little concern, if maximum values are less than a tenth of the guideline, average values are likely to be much less
Good	between 10% and 33% of the guideline	Peak measurements in this range are unlikely to impact air quality
Acceptable	between 33% and 66% of the guideline	a broad category, where maximum values might be of concern in some sensitive locations but generally at a level which does not warrant dramatic action
Alert	between 66% and 100% of the guideline	a warning level, which can lead to exceedances if trends are not curbed
Action	more than 100% of the guideline	exceedances of the guideline are a cause for concern and warrant action if they occur on a regular basis

Source: NIWA 2001

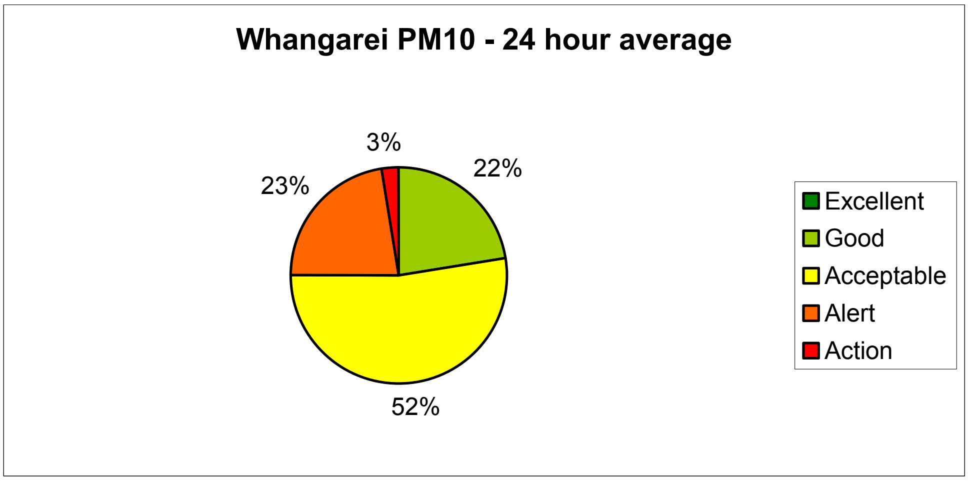


Figure 4: Percentage of time the PM10 concentrations occupied each of the five air quality categories

Despite this, it is important that both the frequency and severity of these exceedances reduce over time, in line with the policies and objectives of the Proposed Regional Air Quality Plan for Northland. With this in mind, the data from the PM_{10} programme will prove invaluable in future years to enable trends in air pollution to be tracked over time.

4.6.2 Deposited Particulate Monitoring Programme

Ongoing deposited particulate (dust) investigations are carried out at two monitoring sites. One site is located at Robert Street, Whangarei and the other site at Whangarei Airport.

Monitoring is carried out using a deposition gauge, which is essentially an elevated 'bucket' with a known surface area. The gauges are installed and a chemical solution added, after which the gauges are left for a 30-day period (± 2 days) during which time they collect particulate material (dust). The gauges are collected and taken to the laboratory for analysis. The final result is a composite of both soluble and insoluble material.

Figures 5 and 6 illustrate the Deposition Gauge results from the Whangarei City (Robert Street) and Onerahi Airport sites respectively.

Results

Figures 5 and 6 show that typical normal deposited particulate values in Whangarei range between 1 and 12 grams per square metre per 30 days depending upon the time of the year, weather, location, wind speed/direction etc. In general, higher results prevail during the summer and lower results during the winter. This is due to the dust suppression action of the wetter winter weather. Sources of deposited particulate include; bare earth, pollen and grass seed, dust from roads and industrial processes such as fertiliser silos and abrasive blasting.

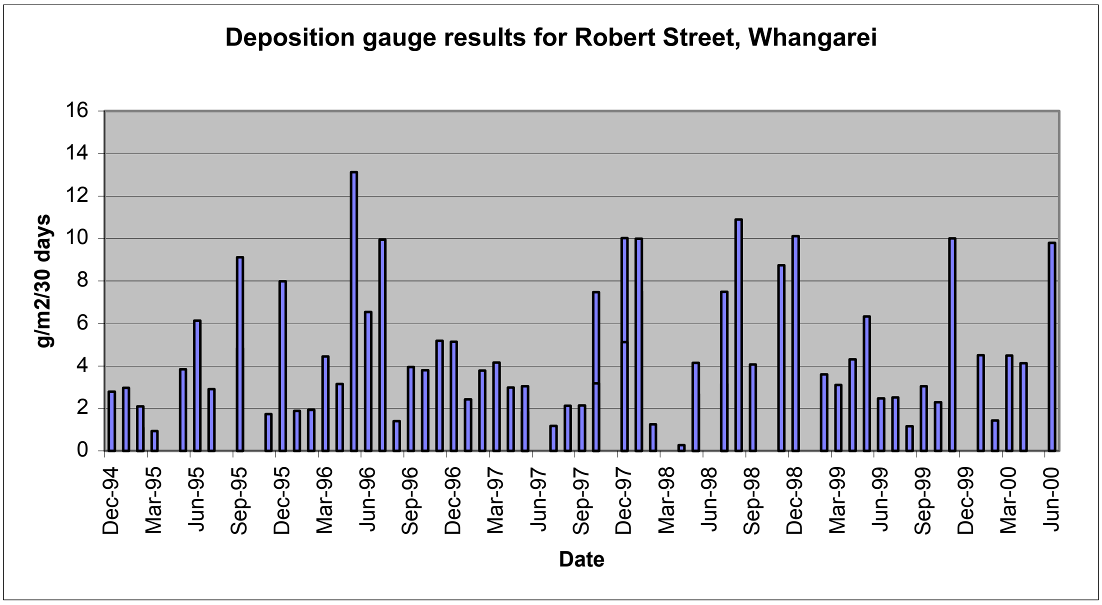


Figure 5: Deposition Gauge Results for Whangarei City (Robert Street)

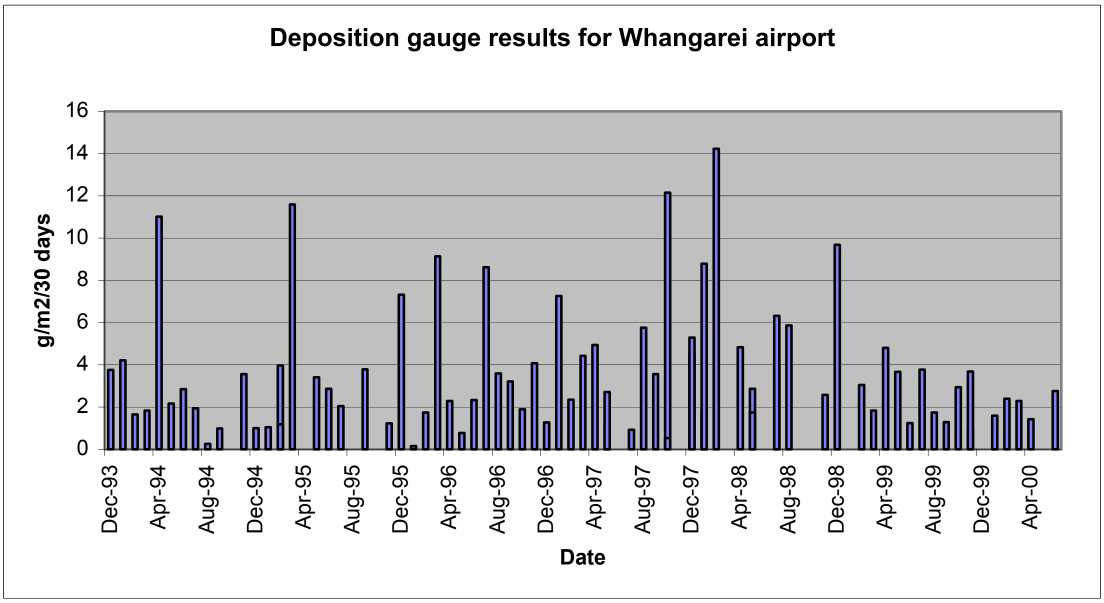


Figure 6: Deposition Gauge Results for Whangarei Airport

While there is no specific limit set for deposited particulates, the Ministry of Health previously specified a 'nuisance' guideline value of an average of 4 grams per square metre per 30 days. Values above this have been known to result in dust nuisance complaints, but they would have to be significantly higher before health effects are observed. If values were found to be significantly higher than the typical normal range of between 1 and 12 grams, then the Council would identify the source(s) and take the necessary action.

The high result measured at Onerahi airport in February 1998 resulted from foreign material entering the gauge. It is likely that the gauge was tampered with during this period.

In general the deposition gauge results suggest that dust nuisance is not a serious issue in Whangarei. While earthworks, excavation and other dust-producing activities generate localised dust nuisance problems, these issues are not widespread and are generally dealt with quickly and efficiently through the Council's hotline service.

4.6.3 Carbon Monoxide

During June, July and August 1994 the Northland Regional Council investigated the level of winter air pollution in urban Whangarei resulting from emissions from motor vehicles and domestic fires used for heating purposes.

Pollution levels are likely to be greatest in winter due to many cold, still nights when inversion conditions prevail and trap the pollutants close to the ground. A range of pollutants were investigated including carbon monoxide, nitrogen dioxide, lead and particulate matter.

In suburban Whangarei the levels of carbon monoxide, nitrogen dioxide, particulate matter (PM_{10}) and lead were all well below the air quality guidelines published by the Ministry for the Environment. (MFE, 1994)

In the central city area, the carbon monoxide levels were much higher. On average the levels exceeded the recommended air quality guidelines for approximately 5% of the monitoring period. These results suggested that at times there is the potential for health effects. (Brown, 1994)

In September 2000, the Northland Regional Council repeated the carbon monoxide monitoring that was undertaken during 1994. The objective was to determine whether the concentration of carbon monoxide had increased and if so, whether the concentrations of carbon monoxide were high enough to pose a risk to public health.

Why Measure Carbon Monoxide?

Carbon monoxide is a colourless, odourless gas that can be hazardous to humans. It is readily absorbed from the lungs into the bloodstream where, because of the stronger affinity haemoglobin has for carbon monoxide, it reduces the oxygen-carrying capacity of the blood.

Carbon monoxide is a trace constituent of the atmosphere, produced by both natural and human activities. Such human activities include vehicle use and domestic burning (where incomplete combustion takes place). Places where vehicle emissions accumulate such as traffic jams, tunnels and carparks are locations of potentially high exposure levels. Office buildings and shops located along congested motorways or below carparks can also accumulate carbon monoxide (NIWA, 1996)

The current National Ambient Air Quality Guideline for the maximum 1 hour average concentration is set at 30 mg/m^3, and 10 mg/m^3 for the maximum 8 hour concentration (MFE, 2000).

Where are the Measurements Being Taken?

The carbon monoxide monitor is situated at the Bank Street/Cameron Street intersection in Whangarei. This monitor location was chosen due to the proximity to a major intersection and the ability to house the instruments securely.

Results of the Investigation

In order to achieve the stated objectives, it was decided to monitor the carbon monoxide concentration over a three-month period in 2000. This monitoring was scheduled to commence in September and conclude in November.

Unfortunately, vandalism to the inlet during mid October resulted in serious instrumental damage to the carbon monoxide analyser. Repairs to the system were not cost effective and in any case would take several months. A replacement analyser was not available.

Despite these drawbacks, 51 days of data was collected. This compares favourably with similar datasets collected in other parts of New Zealand as part of the NIWA national carbon monoxide monitoring programme in August 1996. (NIWA, 1996)

Summary statistics from the carbon monoxide monitoring are shown in Table 2 below.

Table 2: Summary statistics from Bank St carbon monoxide monitoring

Averaging period	# days of valid data	Mean	Std dev.	National guideline	Max	90%	95%	99%
10 min	51	1.86	1.79	N/A	13.09	4.19	5.50	8.04
1 hour	51	1.85	1.62	30	9.71	4.17	5.18	7.07
8 hour	50	1.85	1.17	10	6.12	3.44	4.11	5.26

Although no national guideline has been specified, recent epidemiological investigations suggest that short-term exposure to high concentrations of carbon monoxide can result in adverse health effects. For this reason the World Health Organisation has specified 15 minute and 30 minute short-term exposure limits of 100 and 60 mg/m^3. (WHO, 1995)

The summary statistics demonstrate that the Bank Street area tends to receive moderate concentrations of carbon monoxide throughout the day. This pattern suggests that short-term exposure limits are unlikely to be significantly exceeded and the longer averaging periods such as the 8-hour guideline are more likely to be exceeded.

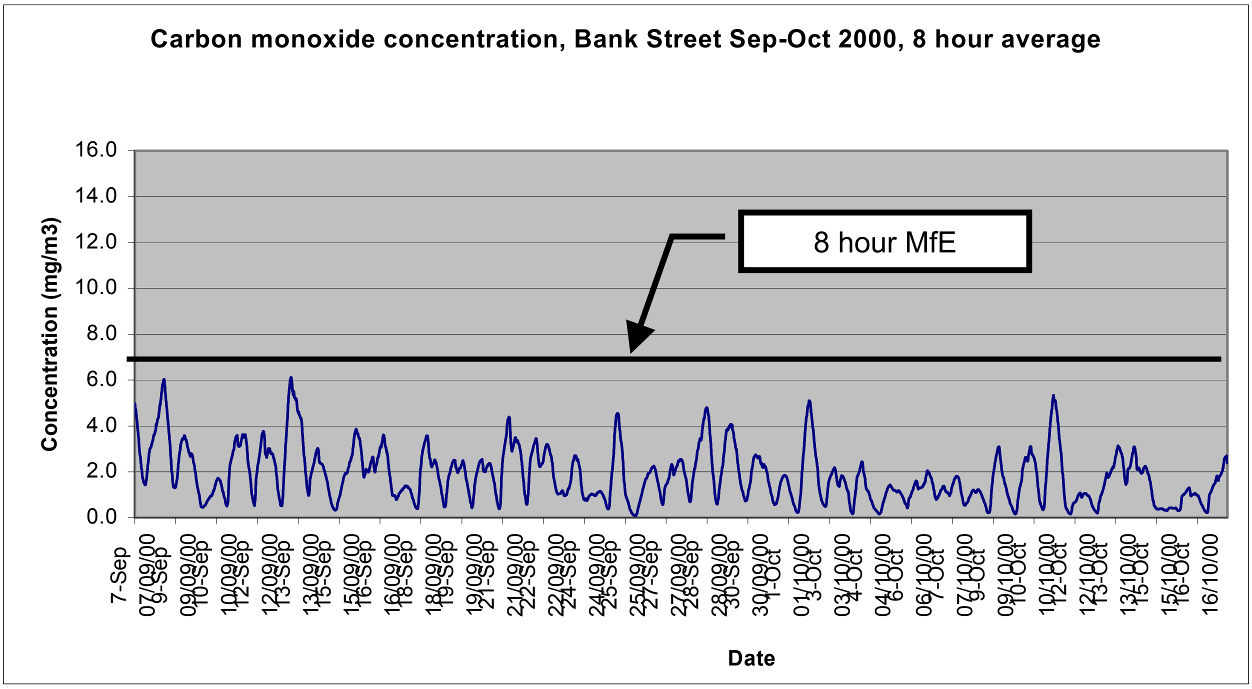


Figure 7: Carbon monoxide concentration at Bank Street Whangarei. September-October 2000 8 hour average concentration

This pattern is also reflected in the two pie charts below which are based on the Air Indicators category values as shown in Table 2. The two plots below depict the percentage of time during the monitoring period that the carbon monoxide concentration occupied each air quality category.

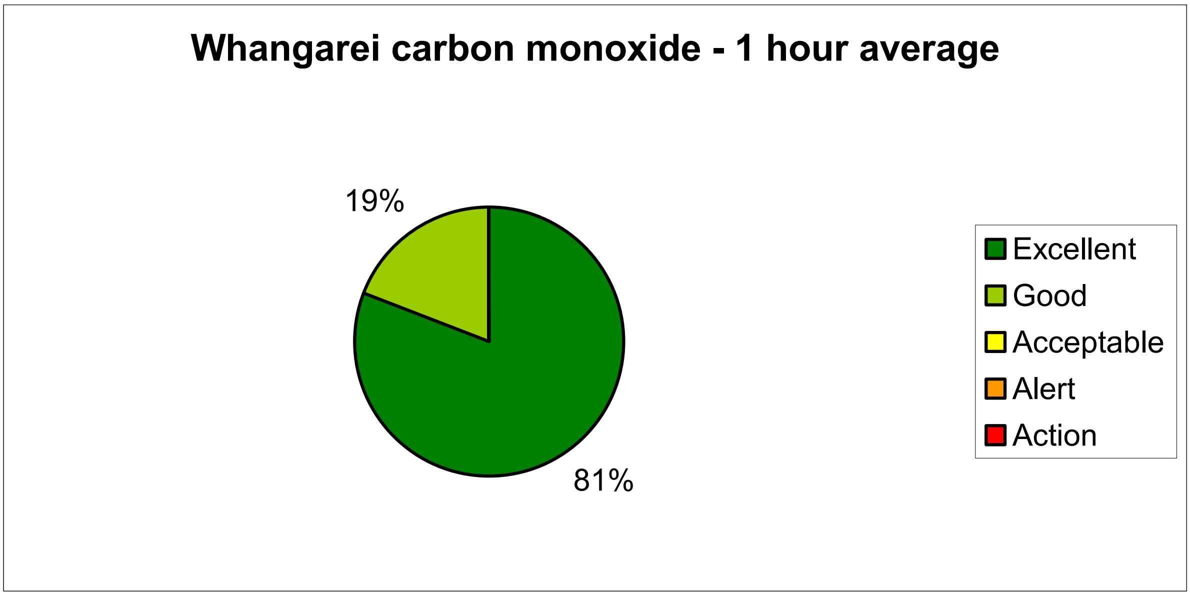


Figure 8: Percentage of time the 1-hour average carbon monoxide concentrations occupied each of the five air quality categories.

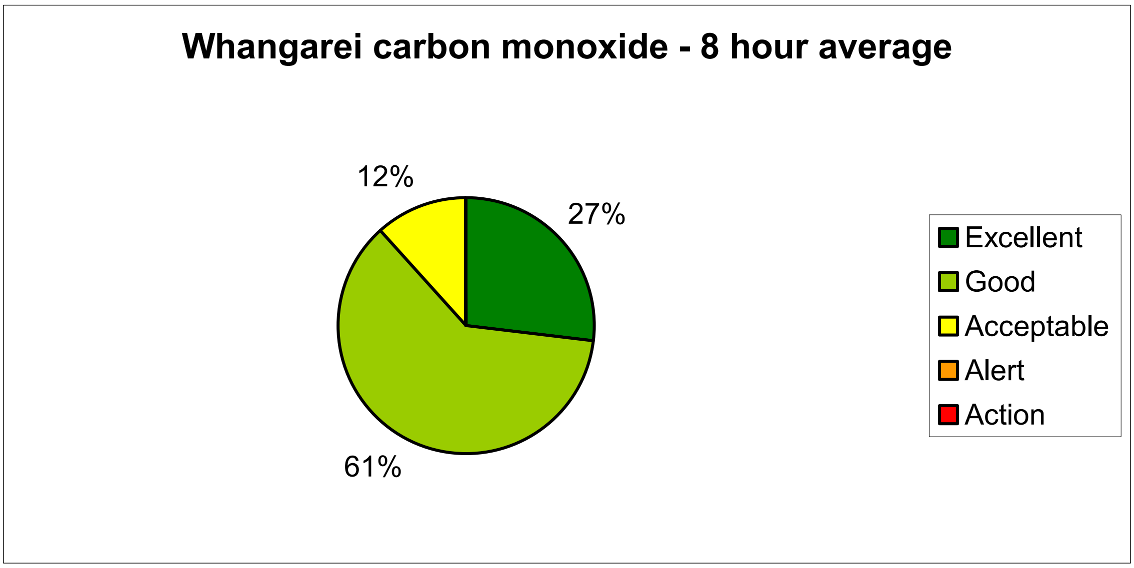


Figure 9: Percentage of time the 8-hour average carbon monoxide concentrations occupied each of the five air quality categories

Figures 8 and 9 also confirm the tendency for moderate levels of carbon monoxide to accumulate in the Bank Street/Cameron Street area. The pattern of accumulation correlates well with traffic density. The highest carbon monoxide concentrations occur during periods of peak traffic in the early morning. A later, reduced peak in the afternoon also corresponds with increased traffic flows.

The daily rise and fall of carbon monoxide concentration will be similar to other hazardous air pollutants (HAP's) and it is likely that $PM_{2.5}$, PM_{10}, and benzene will also follow the same general pattern. This normal daily pattern is depicted in Figure 10 below.

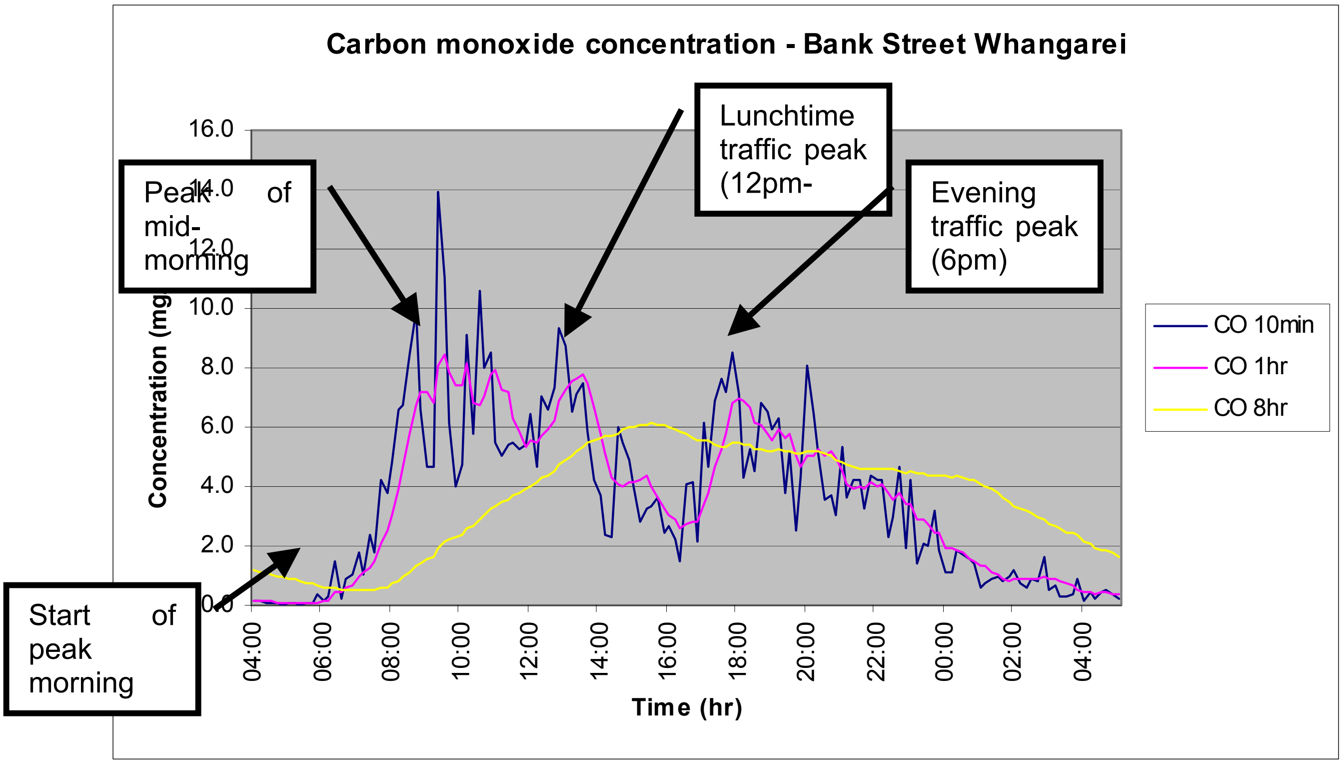


Figure 10: Carbon monoxide concentration over a 24-hour period on 13/14 September 2000. Three different time averaging periods are displayed

Comparison with Other Regions

Comparing carbon monoxide concentrations with other regions is difficult and complex due to temporal and spatial differences between sampling sites. Direct comparisons are made more difficult due to variations in traffic density and street canyoning effects.

Despite these differences, provided that allowances are made for variations between sampling sites, crude comparisons can be made with other regional centres that have undertaken similar monitoring programmes. This information is shown in Table 3 below.

Table 3: Comparison of 1 hour average carbon monoxide concentrations with other monitoring sites

Site	Mean	Std Dev	Max	No. days of data
Invercargill	1.95	2.19	15.00	31
Dunedin	3.08	2.66	18.73	36
Gore	0.49	0.4	2.1	26
Te Kuiti	0.45	0.29	1.87	5
Rotorua	2.36	1.82	11.53	23
Manurewa	1.71	2.33	13.23	28
Khyber Pass	4.29	3.91	22.81	46

Whangarei 00	**1.85**	**1.62**	**9.71**	**51**
Whangarei 94	n/a	n/a	30.5	90
Dargaville 95	n/a	n/a	8.7	62
Kaitaia 95	n/a	n/a	9.7	62

n/a: not available

(NIWA, 1996)

Sampling at the top seven sites took place between February and July which differs from the September and October sampling period used for this investigation. Despite this, the mean and maximum carbon monoxide concentration is similar to other regional centres such as Invercargill, Rotorua and Manurewa.

Table 3 also reveals significant differences between the 1994 investigation and the 2000 investigation. The different meteorological conditions which prevailed during the 1994 monitoring period were due in part to the timing of the previous monitoring which was undertaken in the relatively cooler months of June, July and August.

In addition to increased development of inversion conditions, the cooler weather also prompted more residents to utilise solid wood fuels, which in turn discharged additional carbon monoxide into the Whangarei airshed. These factors combined to result in exceedances for both the 1-hour and the 8-hour carbon monoxide guideline issued by the Ministry for the Environment.

In this most recent monitoring, the higher air temperatures and wind speeds prevented the formation of inversion conditions and also reduced the quantity of solid fuel that was burnt for home heating purposes. This in turn reduced the concentration of carbon monoxide which appears to be a seasonal problem and one which is strongly influenced by meteorology.

Findings

In summary, the investigation demonstrated that at times, the Bank Street/Cameron Street intersection is exposed to elevated concentrations of carbon monoxide. This investigation has revealed that higher carbon monoxide concentrations are associated with cool, calm conditions when strong inversion conditions prevail. These cooler conditions also retain a significant percentage of the emissions from domestic solid fuel fires during the winter.

The investigation has also determined that meteorological conditions play a major role in the accumulation of carbon monoxide in the central city area. Not only wind speed and air temperature but also wind direction due to the directional nature of the city streets.

Peak carbon monoxide concentrations occur between 8am and 11am and although elevated, are unlikely to pose a risk to public health. No excursions of either the 1-hour or the 8-hour guideline occurred during the monitoring period.

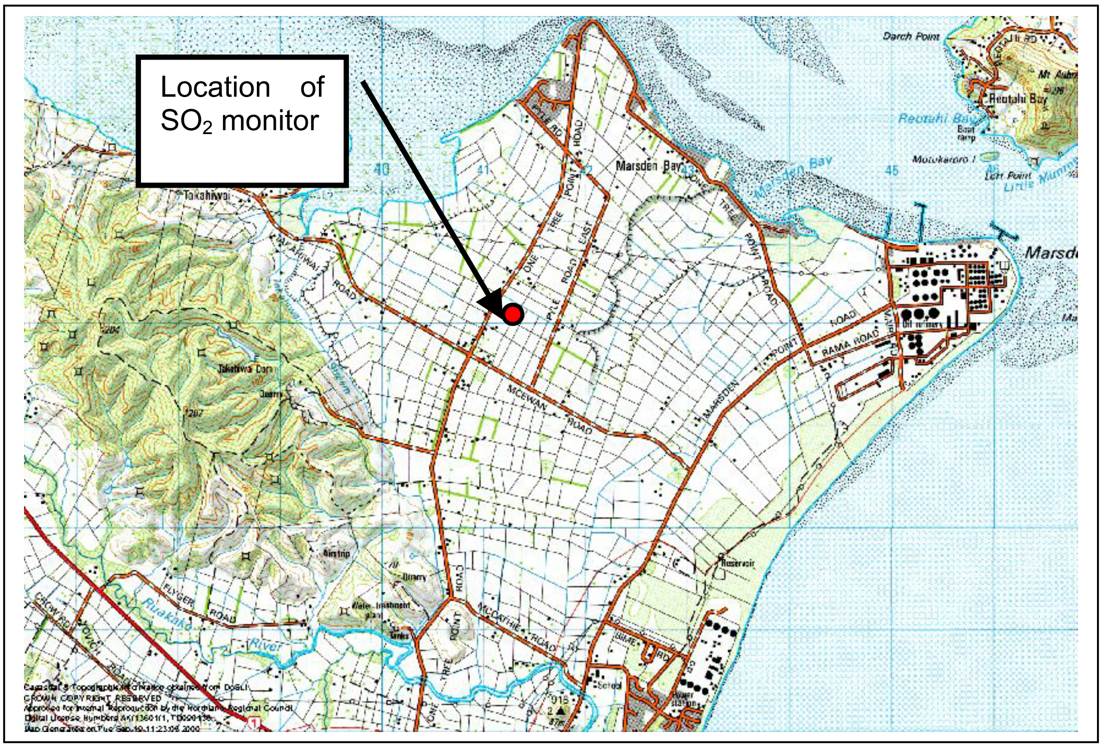
These results contrast with earlier findings which identified frequent excursions of both the 1-hour and 8-hour guideline. The previous study was undertaken during the winter and meteorological results demonstrate that both the average air temperature and wind speeds were significantly lower during the previous investigation. This suggests that the peak carbon monoxide concentrations will be confined to the winter months and that the spring and autumn periods will have peak concentrations which are within the national guidelines.

4.6.4 Sulphur Dioxide (SO_2)

Sulphur dioxide (SO_2) is a colourless gas that readily reacts with ambient moisture to generate sulphuric acid aerosols (H_2SO_4). This transformation is the major contributor to “acid rain”.

Sulphur dioxide is readily identifiable by its characteristic pungent, irritating odour. Studies have shown that sulphur dioxide in combination with particulate matter poses a greater health risk than sulphur dioxide alone. High concentrations of sulphur dioxide are known to trigger the onset of chemical bronchitis and tracheitis. However, lower concentration may trigger bronchospasm in sensitive individuals such as asthmatics.

Sulphur dioxide is produced during the combustion of fossil fuels, especially coal and oil due to the oxidation of small quantities of sulphur compounds present within the fuel. In Northland, the major sources of sulphur dioxide are from industries that use feedstocks with substantial quantities of sulphur. These include Marsden Point refinery or other industries that oxidise sulphur as part of their production process such as the Ballance Agri-Nutrients manufacturing plant.



Map 2: Location of SO_2 monitor at Takahiwai

In March 2000, the Northland Regional Council began monitoring sulphur dioxide at Takahiwai (in the vicinity of the Marsden Point industrial zone). The results reveal that the sulphur dioxide levels are relatively low. However there are occasional results that approach the National Ambient Air Quality Guidelines.

The Ministry for the Environment has specified four ambient air quality guidelines for exposure to sulphur dioxide. These guidelines have been set at different exposure times and are based on population exposure investigations undertaken by the World Health Organisation.

The four guidelines are:

- 500 μg/m3 at a 10-minute average
- 350 $\mu g/m^3$ as an hourly average of 10-minute means,
- 125 $\mu g/m^3$ as the 24 hour average and;
- 50 $\mu g/m^3$ as an annual average

The monitor at Takahiwai records the sulphur dioxide concentration at 10-minute intervals. This information is then used to derive the 1-hour and 24-hour averages which are plotted below in figures 11, 13 and 15.

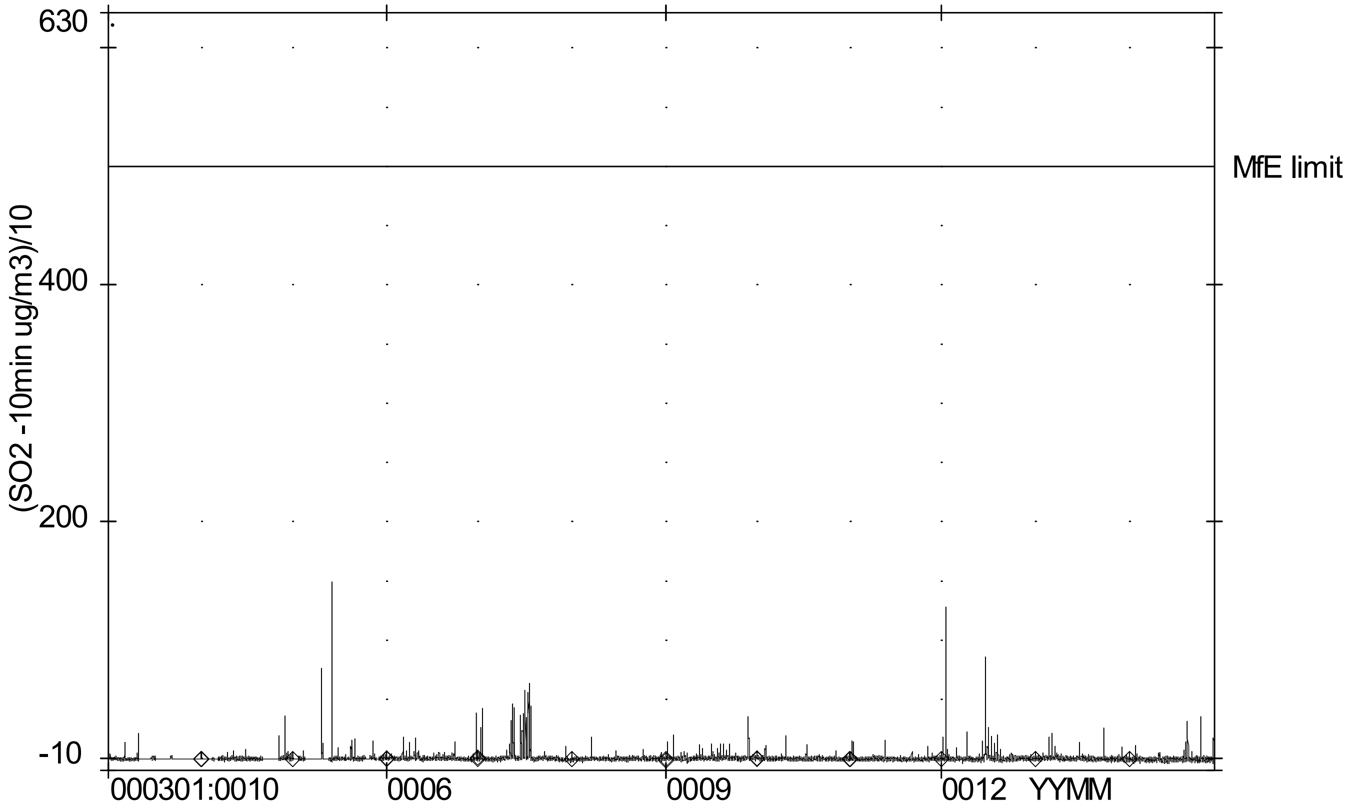


Figure 11: Sulphur dioxide monitoring results in micrograms per cubic metre from 1 January 2000 through to 28 February 2001 (10-minute average)

At Takahiwai, most of the increase in sulphur dioxide can be traced back to Marsden Point refinery. The higher peaks which can be seen in Figure 9 usually correlate with easterly winds which carry the plume towards the sulphur dioxide monitoring equipment monitor at Takahiwai. Three separate monitors are operated in the Whangarei Heads area.

Although there are occasional peaks, the 10-minute averages are well below the MfE guideline and indicate that despite some influence from local industry, sulphur dioxide levels are well within recommended guidelines. This is confirmed in Figure 10, which reveals that the sulphur dioxide concentration was excellent for 100% of the monitoring period.

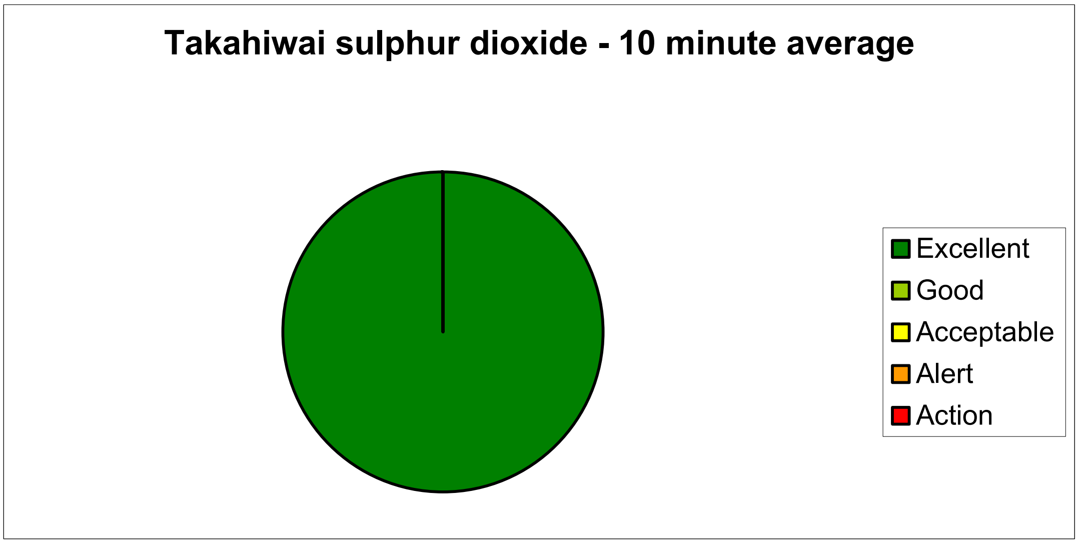


Figure 12: Percentage of time the 10-minute average sulphur dioxide concentrations occupied each of the five air quality categories

The graph below plots the sulphur dioxide results as a 1-hour average. The Ministry for the Environment guideline value of 350 $\mu g/m^3$ is also identified on the graph.

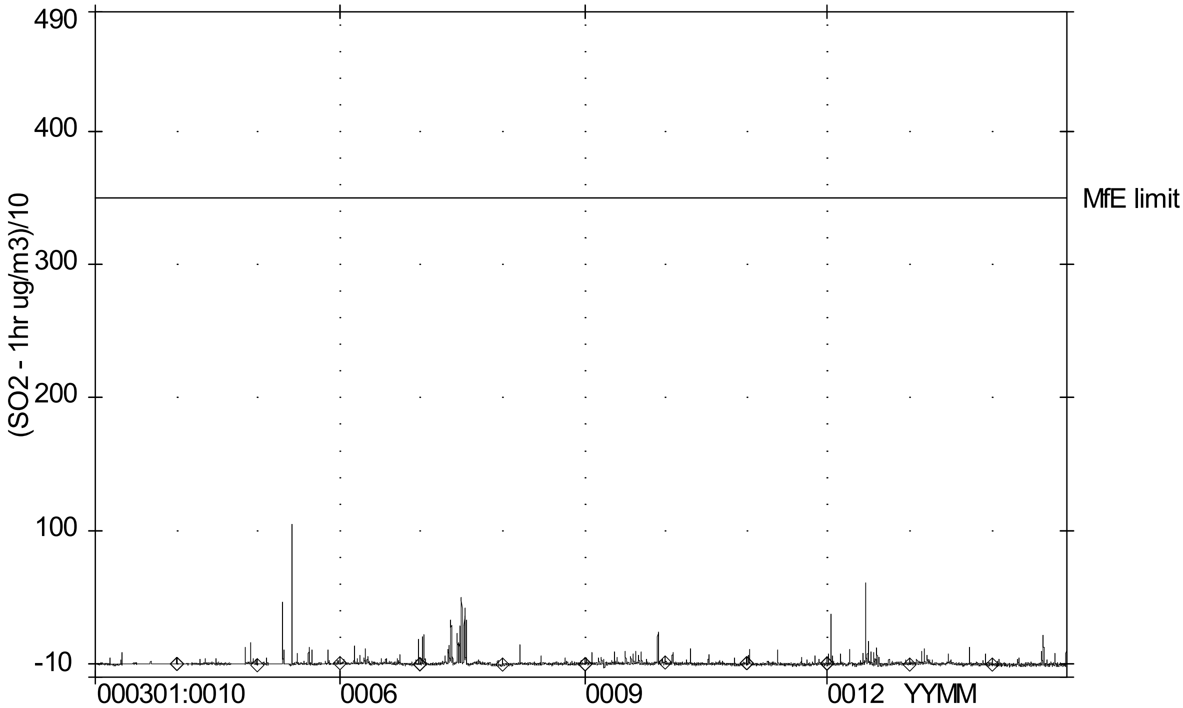


Figure 13: Sulphur dioxide monitoring results in micrograms per cubic metre from 1 January 2000 through to 28 February 2001 (1-hour average).

As with the previous guideline value, the 1-hour average is well within the Ministry for the Environment guideline value. This is shown in figure 14 below, which reveals that the sulphur dioxide concentration was excellent for 99.9% of the monitoring period.

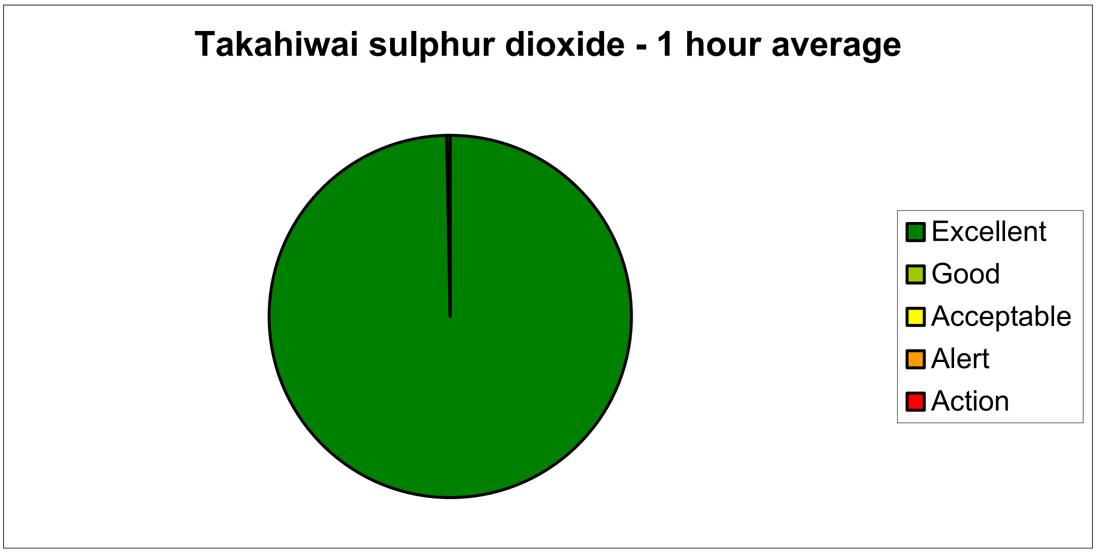


Figure 14: Percentage of time the 1-hour average sulphur dioxide concentrations occupied each of the five air quality categories.

The next graph reveals the 24-hour average of sulphur dioxide from Takahiwai.

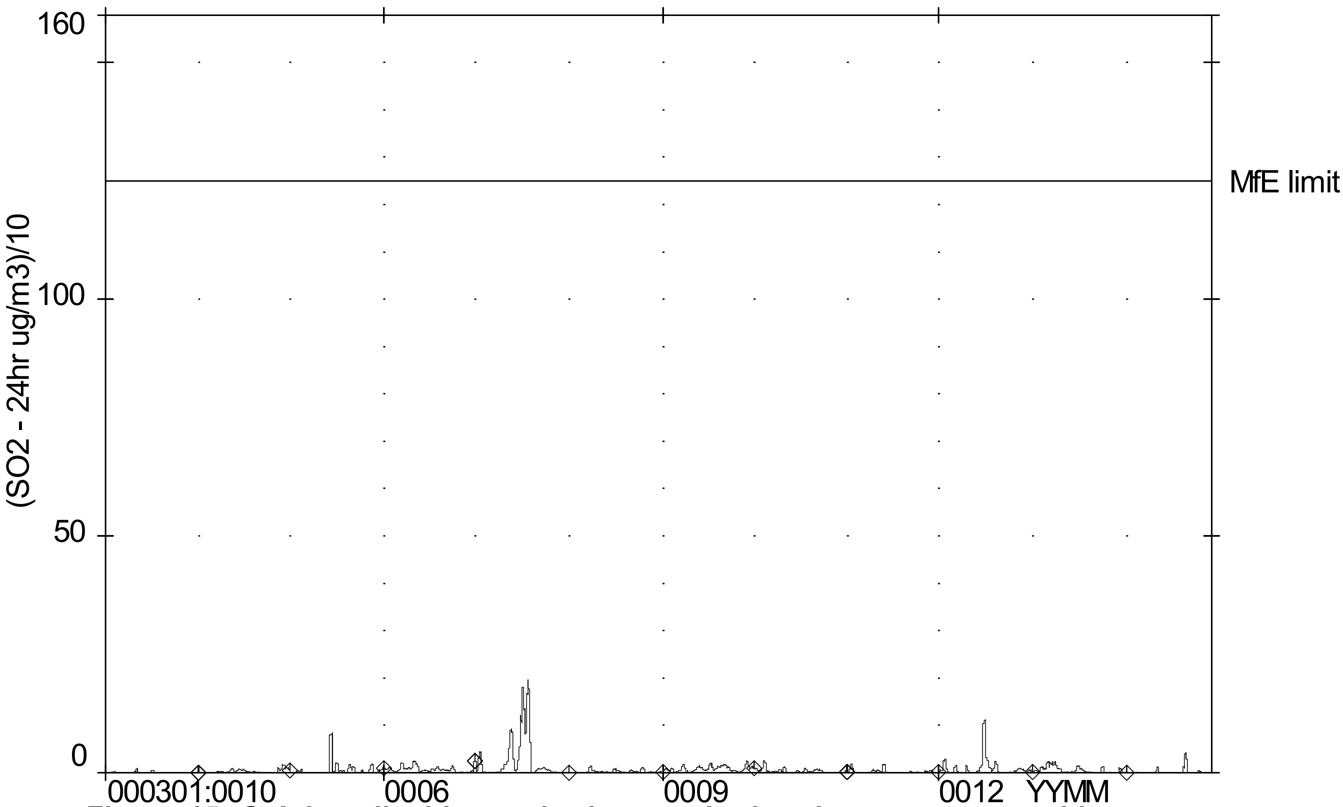


Figure 15: Sulphur dioxide monitoring results in micrograms per cubic metre from 1 January 2000 through to 28 February 2001 (24-hour average).

The graph again shows that the concentration of sulphur dioxide is well below the Ministry for the Environment guideline levels. This is reflected in the pie chart below which indicates that sulphur dioxide concentrations were excellent for 99.3% of the monitoring period and good for the remaining 0.7% of the monitoring period.

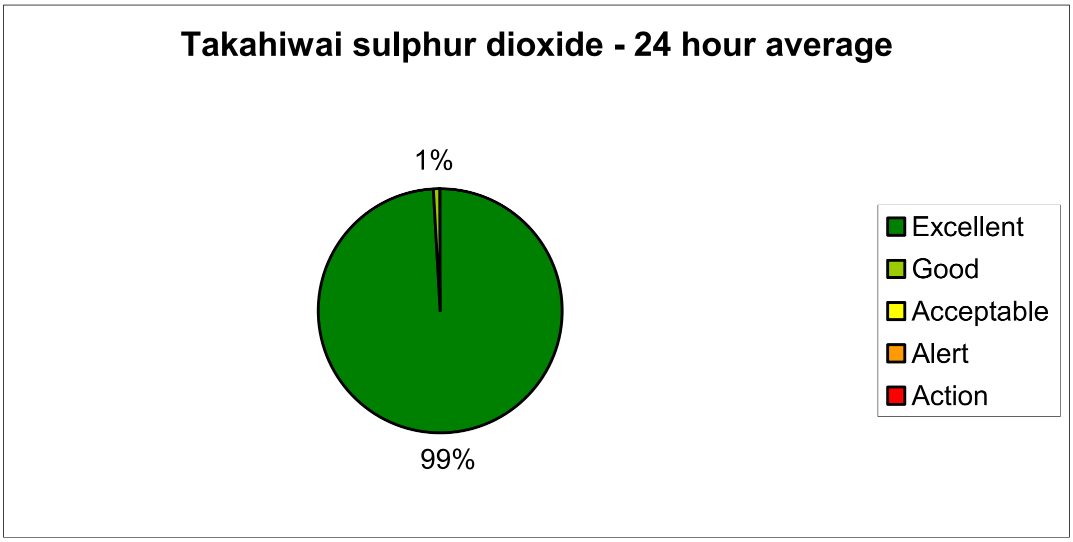


Figure 16: Percentage of time the 24-hour average sulphur dioxide concentrations occupied each of the five air quality categories.

The SO_2 monitor has been situated at Takahiwai for more than six years and the monitoring has consistently shown that sulphur dioxide concentrations are well below Ministry for the Environment guidelines.

The situation is expected to be somewhat different in Whangarei City where several major industries discharge sulphur dioxide into the Whangarei airshed. These discharges, combined with the sulphur dioxide contribution from motor vehicles and domestic home heating suggest that sulphur dioxide concentrations are likely to be much higher, particularly during the winter months.

For this reason, it is anticipated that the sulphur dioxide monitoring equipment will be relocated into Whangarei within the next twelve months.

4.7 Response to Air Quality Issues

4.7.1 Northland Regional Council

The Northland Regional Council has produced two policy documents to manage Northland's air resource. The **Regional Policy Statement** provides an overview of resource management issues in Northland, including those with regard to air quality. It contains objectives, policies and methods to achieve the integrated management of Northland's environment.

The **Revised Proposed Regional Air Quality Plan for Northland** contains rules that permit, control or prohibit activities which cause discharges of pollutants to air. Major issues covered by the plan are summarised below:

Pollution Control

In order to address the issue of pollution from both point source and non-point sources, the Regional Council has specified ambient air quality guidelines in order to protect both human health and the environment. Once guidelines levels had been set it would then be possible to measure the effects of various activities in order to ensure that they did not cause any adverse effects on the environment.

The Regional Air Quality Plan specifies ambient air quality guidelines for Northland. This plan would then also specify rules for allowing, restricting or prohibiting various discharges to air. This in turn would enable the monitoring and enforcement provisions of the Resource Management Act to be used more easily for enhancing and maintaining ambient air quality.

Use of Agrichemicals and Fertiliser

The use (or misuse) of agrichemicals was identified as a serious issue during the development of the Regional Policy Statement. It was decided that the best way to tackle this problem was to promote practices which avoided, remedied or mitigated any adverse effects on the environment that resulted from agrichemical or fertiliser application.

In practice, this is achieved by supporting the Agrichemical Education Trust, adopting relevant industry codes of practice, including appropriate rules in the Regional Air Quality Plan and having a system which reports and investigates issues of non-compliance arising from the misuse of agrichemicals or fertiliser.

Avoiding Nuisance Effects

It is recognised that a number of activities generate, or have the potential to generate, nuisance effects either through odour, smoke or dust. Many of these 'nuisances' arise from relatively minor activities and often result from ignorance or carelessness on the part of the operator.

Rather than regulate these minor activities, it is considered to be more appropriate to first educate, assist and inform operators of services and practices which could prevent nuisance effects. If these actions are unsuccessful, then it would be necessary to regulate the activity.

This has been achieved by including appropriate provisions in the Regional Air Quality Plan and encouraging the separation of incompatible land-uses in District Plans.

Consent Monitoring

Northland Regional Council monitors around 180 resource consents with permits to discharge to air. These consents range in size from local community sewage treatment plants to large, heavy industries, such as the New Zealand Refining Company at Marsden Point or Juken Nissho Ltd, triboard manufacturing plant in Kaitaia.

Compliance monitoring of industrial sites which discharge to air typically includes the following components:

- Regular inspection of emission control equipment
- Downwind sampling for airborne pollutants
- Stack emission testing
- Liaison with site manager/representative concerning any plant modifications or improvements.
- Review of complaints or site problems
- Review of compliance with consent conditions

State of the Environment Monitoring

The Council also operates a State of the Environment monitoring programme to determine ambient (background) air quality. Contaminants currently monitored include sulphur dioxide, carbon monoxide, PM_{10} and deposited particulate.

A review of the Council's air quality monitoring programme was conducted in 1999 (Baynham and Beanland, 1999). The review identified the following information needs:

1) Whangarei urban area – continuous PM10 monitoring (1999-)
2) Sulphur dioxide investigations, in the following order of priority
    a) Whangarei urban area
    b) Marsden Point industrial area
    c) Further state of environment monitoring depending on the results
3) Whangarei urban area – carbon monoxide monitoring
4) Ambient concentrations of agrichemicals
5) Emission inventory and targeted airshed studies

As of May 2001 monitoring programmes for information needs 1-3 have been implemented by the Council. Information need 4 (study into the ambient concentrations of agrichemicals) is planned for the 2002/03 financial year.

Emissions Inventory

In order to predict the impact of future developments upon the Northland airshed, it is important to quantify existing discharges so the additional atmospheric burden of future projects can be estimated. Information on existing discharges from Northland is currently being compiled into an emissions inventory. This document will estimate emissions from point sources such as local industry, as well as non-point source emissions such as particulate emissions from domestic home heating, vehicle emissions from the transport sector and agricultural emissions from livestock. This is the first attempt to quantify these emissions and as such will provide valuable information for resource planners, developers and local industry.

Traffic Study

Part of the inventory will focus on emissions from the transport sector. This is a difficult task given the wide range of vehicles used in Northland, the different types of roads that exist and also the variation in traffic movement both within and between days. In order to adequately assess these emissions, other agencies including the Whangarei District Council, Ministry of Transport and petroleum retailers are collaborating in a joint project that will develop an urban transport model for the Whangarei area. This model will estimate vehicle emissions on a virtual real-time basis which will allow resource planners to identify 'hotspots' and determine the most cost-effective solutions for resolving air pollution problems. Provision will be made in the model to allow for reduced emissions due to improvements in fuel or vehicle technology.

Particulate Emission Study

One of the issues currently facing Whangarei concerns the quantity of fine particulate present in the atmosphere, particularly during the cooler, winter months. These elevated levels occasionally exceed national guidelines and inhalation could potentially affect the health of local residents. In order to reduce the levels of fine particulate present in the atmosphere, it is important to determine the source of this material. There is no point targeting smoke from domestic wood fires if the majority of fine particulate is sourced from diesel vehicles.

As part of the emission inventory investigation, the Northland Regional Council has collected atmospheric particulates from two locations – one in downtown Whangarei and the other from Raumanga. These particulates have been sent to the Waikato University geochemical laboratory for isotopic analysis.

The fine particulate present in the air we breathe is predominantly comprised of carbon. Most of this carbon will exist as C^{12} but a small amount will be present as unstable C^{14}. Carbon 14 is unstable and breaks down over time. The rate of this breakdown is well known and can be use to determine the age of an object. This method of dating is referred to as "carbon dating". The older the carbon, the less carbon 14 will be present. Fossil fuels such as petrol and diesel contain virtually no carbon 14 as this carbon is millions of years old. Conversely, carbon present in most trees contains relatively higher proportions of carbon 14 as this carbon is much younger. So if the carbon in our atmosphere is sourced from petrol and diesel vehicles, the amount of carbon 14 would be very low. However, if the carbon in our atmosphere is sourced from wood-fueled domestic fires, we would expect the amount of carbon 14 to be much higher. This technique is a relatively simple method of determining the source of the fine particulate in our atmosphere. The technique is complicated by the fact that some households burn coal. However, this can be accounted for in calculations.

4.7.2 Regional Aspect of Global Air Quality Responsibilities

When the Northland contribution to global problems such as greenhouse gases or ozone depletion is put into perspective, it is relatively insignificant. For example, Northland contributes less than a fraction of a percent of the total global discharge of carbon dioxide. Nevertheless, we still have a part to play in addressing international issues such as global warming and ozone depletion.

To do this the Northland Regional Council uses both the Regional Policy Statement and the Regional Air Quality Plan to frame policy, which addresses global issues.

It is important to note that these documents cannot specifically require adherence to international agreements.

In practice, the Northland Regional Council is completing an emissions inventory, which will quantify the emissions of greenhouse gases such as carbon dioxide and methane in addition to identifying the quantity of ozone-depleting substances which are stored or used in Northland. This assessment will be undertaken biannually in order to assess trends in emissions of these substances.

Once this information is known, if needed, more specific policies and methods can be developed which will reduce Northland's contribution to global warming or ozone depletion.

4.8 Case Study: Odour nuisance from Juken Nissho Ltd (JNL)

Process summary

The "mill" manufactures a range of wood products including triboard, strandboard, medium density fibreboard and veneer. The various types of boards are comprised of both fibre and strands to which wax, glue and occasionally fungicide are added. Both the fibre and strand components are prepared by debarking pine logs followed by chipping or flaking to the required size and then drying. The triboard is produced by sandwiching a layer of strands between two layers of fibre, and then pressing the layers together and injecting steam to "cure" the glue. The three individual processes involved in the manufacturing of triboard, namely the production of fibre, strands and the pressing or formation of the board take place on the fibre line, strands line and the press line respectively. There are presently two presslines in operation.

Since late 1993, wood veneer has also been manufactured at the site. The process of veneer production involves placing a log on a similar device to a log lathe and shaving several sheets off the log. The sheets are then collected, stacked and then dried in a veneer oven.

Process emissions

The process at the JNL site discharges a number of contaminants into the air. These include aldehydes and other volatile organic compounds (VOCs), particulates (dusts), and products of combustion such as oxides of nitrogen and carbon and water vapour. Emissions of VOCs can give rise to both odours and blue haze which can be seen above the mill occasionally.

Visible emissions such as steam, smoke and occasionally dust and odour are the emissions that the public most frequently detect on a day-to-day basis. Of these odour is the most significant because it can impact directly on the public.

There are a variety of odour sources at the JNL plant. The processing of pinus radiata frequently results in a "pine-like" odour under normal operations. This odour is clearly evident during site visits to the plant. Other types of wood processing may result in a "singed" or "burnt or hot" wood odour which is the result of the emission of VOCs. Blue haze may be associated with the burnt or hot wood odour on some occasions.

Odour Sources

Of the various odour emission sources from the JNL plant, the strands drier has been highlighted as the most significant source of potentially objectionable odour (Juken Nissho Limited, 1996). Blue haze from the strands drier has been observed on a number of site visits.

Hot air from the energy centre is passed through the strands drier in order to dry strands of wood. During this process water vapour is driven off, as are VOCs and other contaminants. These will typically include monoturpenes (mainly β-pinene), acetic acid and resin and fatty acids (typically dehydroabietic acid). The blue haze which results from the partial pyrolysis of the strands and aldehydes (derived from the thermal decomposition of wood carbohydrates and lignins) may also be generated during this process.

Other potential sources of odour from within the JNL plant include:
- Energy centre
- Dust burner
- Fibre drier
- Board presses
- Veneer drying
- Waste water treatment plant

Odour modelling and predictions

Previous source monitoring of the strands drier had quantified the discharge of odour, in odour units, from this emission source. The maximum or worst case concentrations of odours were calculated using a ISCST3 dispersion model on the basis of emissions from the strands drier.

The model predicted that maximum values would occur on hillsides to the east of the plant and predicted that the maximum ground level concentration of odour would be 27 OU m^{-3} (1-hour average). The modelling results confirm that the emission of odour from the strands drier will, at times, cause the ground level concentration to exceed guidelines which will inevitably result in offensive and objectionable odour beyond the boundary of the mill.

Odour complaints

The diagram below shows the number of incidents registered by the Council, concerning offensive or objectionable odours from Juken Nissho. It is clear that while there have been occasional odour complaints during previous years, there has been a significant increase in the number of odour complaints within the past six months. This would suggest that either there has been some change of process at the mill which is now giving rise to offensive or objectionable emissions or, alternatively, the tolerance level of odour from the mill has reduced and local residents are no longer prepared to tolerate emissions from the mill.

It is also worthwhile pointing out that the previous resource consent issued on 13 February 1995 required the Consent Holder to undertake an independent assessment of odour control options and to adopt the best practicable option for the control of odour. The report concluded that the control of odour was not a practicable option at that time and no significant changes to control odour were made. Other than restricting odour from the veneer plant to a practicable minimum, the previous consent did not address the issue of odour from the plant.

The new consent issued on the 10 May 1999, specifically states:

The consent holder's operations shall not give rise to any discharge of odour or dust deposition, which in the opinion of an enforcement officer of the Council is offensive or objectionable at or beyond the property boundary.

This condition enables the Council to address the issue of odour from the plant and to take enforcement action if necessary.

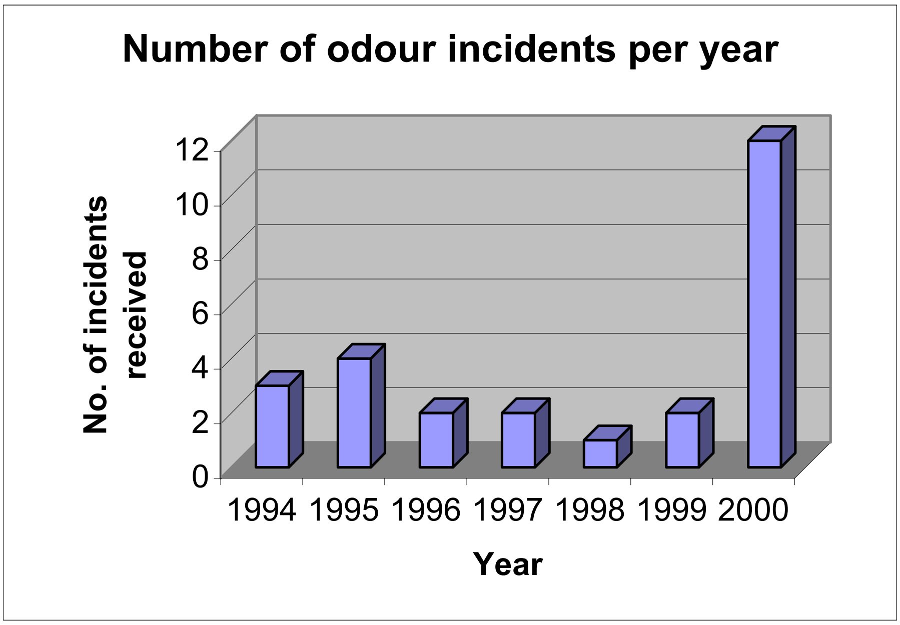


Figure 17: Plot of the number of odour incidents about JNL received per year

Although a number of local residents have registered these incidents, it appears that approximately 80% of the complaints received within the past six months have been reported by one household. Despite this, investigations by enforcement officers from the Regional Council have confirmed the presence of offensive odours downwind of the mill at the complainant's dwelling on a number of occasions.

Mill management were asked to comment in order to identify whether any process changes or recent plant upsets had contributed to an increase in odour. Comments from mill management suggested that they were aware of the odour issues and were reasonably certain that the odour discharge was sourced from the strands drier. They pointed out that this had been identified as an issue during the consent process (Assessment of Environmental Effects, 1995) and that emissions from this source are recognised as occasionally resulting in odour and visibility complaints.

Despite the assurance from mill management that the strands drier is the source of the odour complaints, there is evidence to suggest that other discharges from the mill may occasionally cause odour problems. On a number of occasions complainants have alleged that they have observed visible smoke discharging from the energy centre, dust burner and from the veneer plant which they claim to have caused the offensive odours.

Possible odour sources

The concern of local residents is that the new mill expansion will add additional odour problems to those already being experienced at present. In order to address this issue, it is important to identify which part of the mill process is generating the odours in order to assess whether or not the proposed discharges from the new plant will significantly contribute to the discharge.

Unfortunately, there is insufficient evidence to conclusively demonstrate the source of the odour problems. However, there are two strong possibilities.

Under normal operation, it is unlikely that emissions from the energy centre would give rise to odour complaints, however, there may be circumstances where “burnt wood” odour will be noticed downwind. At such times, smoke discharges may also be obvious. The main cause of odorous discharges from the wood-waste fired thermal plant is an imbalance in the air-to-fuel ratio or changes in the fuel quality (size or moisture content). This occurs because of the nature of the fuel and/or reduction in oxygen concentrations in the thermal plant furnace. Smoke and odour discharges from the energy centre have been observed on occasion. More recently emissions from the dust burner, including blue haze, have been noted by a number of residents. The recent discharge of blue haze from the dust burner has also been confirmed by enforcement officers from the Council.

The second possibility is that emissions from the veneer plant may be generating offensive or objectionable odour. During the veneer plant process two discernible fractions are released, volatiles and condensables. The volatile fraction is comprised of terpenes, pinenes and very small quantities of other organic compounds. Significant components are likely to be α & β pinene, d-limonene and a wide range of aldehydes. The condensable organic compounds consist largely of wood resins, resin acids and wood sugars which cool outside the point of emission when they mix with ambient air and combine with water vapour to form an aerosol which often has a blue tinge to it. The later blue haze and associated odours will become particularly evident if overdrying occurs at higher temperatures.

The emissions from the veneer plant have recently been ducted through to the burner. However, a higher than anticipated calorific value from the ducted gases has affected the rate of fuel consumption within the burner. Despite these setbacks, emissions from the veneer plant have reduced considerably and apart from occasional discharges, associated with power outages, emissions from the veneer plant generally appear to comply with the conditions of the resource consent.

Plant changes

Apart from ducting modifications such as those described above, there have been two major changes to plant operations recently. The first of these concerns the increase in stack height, which has raised the release height of exhaust gases from the plant. Modelling predictions based on the increased stack heights suggest that both the number and frequency of odour-related complaints should reduce as a result of these modifications.

The second modification concerns a resin change. The new resin polymeric methylene diisocyanate (PMDI) appears to have very low levels of emissions. Tests conducted to date have revealed concentrations which are at or below analytical detection limits. Consequently it is unlikely that the change in resin is resulting in odour-related complaints.

Conclusion

In summary, a spate of complaints highlighted the issue of odour discharges from the Juken Nissho mill. While these odour complaints have been occurring intermittently for some time, the frequency and location of the complaints suggests that odour is currently a serious concern for some local residents.

Investigations by enforcement officers from the Council have confirmed the presence of offensive and objectionable odours beyond the boundary of the mill on a number of occasions. These discharges do not comply with condition 6 of JNL's resource consent, which relates to offensive and objectionable odour.

In order to resolve this problem, Juken Nissho Ltd has been served with an abatement notice which requires the company to purchase, install and operate suitable air emission abatement equipment which will ensure that their discharge complies with condition 6 of their resource consent.

Recent Developments

Since the serving of an abatement notice early last year, Juken Nissho Ltd have agreed to install additional emission abatement equipment in order to address ongoing smoke and odour complaints from local residents.

Juken Nissho Ltd have engaged an American company to oversee the design and construction of the emission control equipment which will be retrofitted to the strands drier stack, a major contributor to VOC, particulate, smoke and odour discharges.

Two wet scrubbers are already used on site to reduce emissions from the fibre drier and the press room. In addition to the two wet scrubbers already used on site, a wet electro-static precipitator is to be constructed to substantially limit emissions from this source.

The emission control equipment is expected to be installed and operational by mid July 2002.

4.9 Case Study: Strong hydrogen sulphide odour, Ngawha Springs

This study investigates the hydrogen sulphide concentration within Ngawha springs township during the period from 1 October 1999 through to and including 31 March 2000. It is the intention of this investigation to determine whether the average and peak concentration of hydrogen sulphide has increased significantly from the background monitoring period January 1997 through to and including March 1998. If the investigation identifies that the hydrogen sulphide concentration has increased significantly, an attempt will be made to determine the reason for this increase.

Hydrogen Sulphide

Hydrogen sulphide is a colourless gas with a distinctive odour at low concentrations. Humans can detect hydrogen sulphide at levels as low as 0.2 to 2.0 $\mu g/m^3$, depending on its purity. This is the odour threshold, which is defined as the concentration at which 50 per cent of a population can detect an odour. At higher concentrations, typically three to four times the odour threshold, hydrogen sulphide resembles the smell from rotten eggs.

Hydrogen sulphide (H_2S) is a naturally occurring contaminant that arises from regions of geothermal activity. Hydrogen sulphide typically occurs around sulphur springs and lakes but can also form under anaerobic conditions in the presence of sulphate and organic material.

Hydrogen sulphide can also result from human activities, where sulphur and organic materials combine in oxygen-deprived industrial environments.

Adverse effects

This investigation was initiated following complaints from a local resident regarding alleged increases in the frequency and magnitude of hydrogen sulphide exceedances within Ngawha springs township. The resident alleges that the concentration of hydrogen sulphide was sufficient to induce dermal sensitisation in the eyes, ears and throat following approximately 60 minutes of exposure to the gas.

Hydrogen sulphide is known to generate an unpleasant odour at concentrations well below those that cause health effects. However, continuous exposure to hydrogen sulphide can reduce sensitivity to the gas.

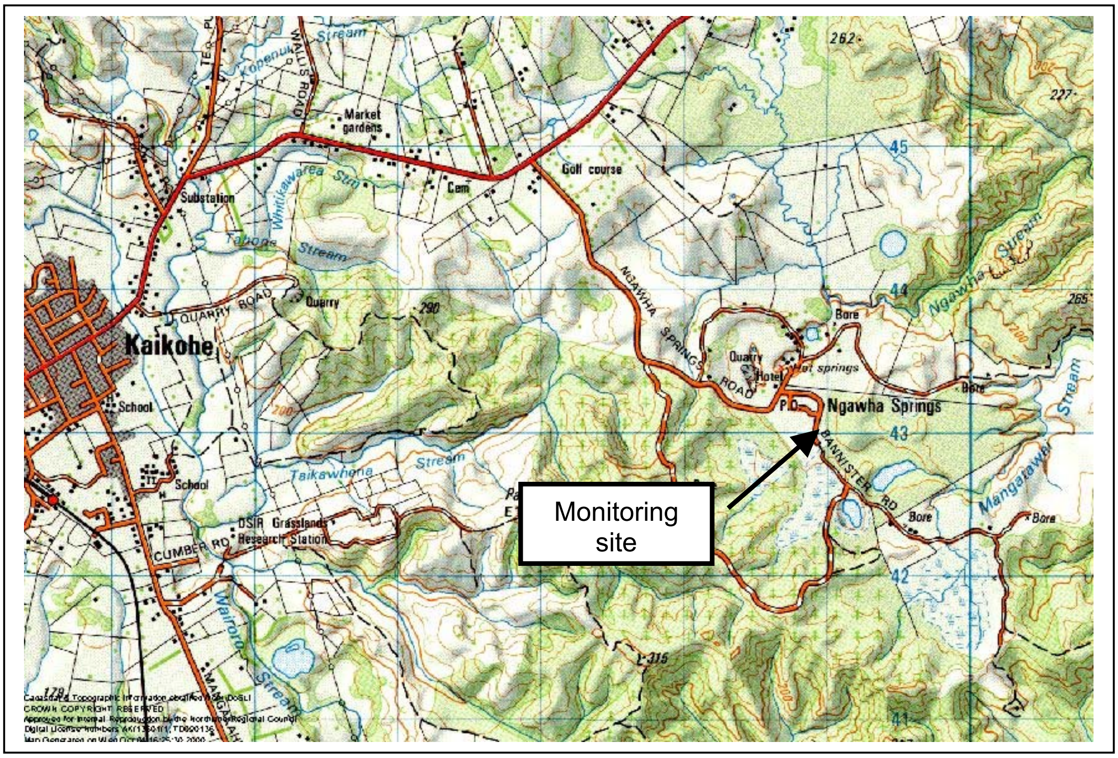
At high concentrations, hydrogen sulphide acts on the nervous system and can cause a range of symptoms characteristic of hydrogen sulphide intoxication. At concentrations over 15 mg/m^3, it can cause eye irritation. At concentrations above 70 mg/m^3 it causes permanent eye damage. At concentrations in excess of 225 mg/m^3 it paralyses the bodies olfactory perception (sense of smell) so that the odour no longer acts as a warning of the presence of the gas. At concentrations above 400 mg/m^3 there is a risk of pulmonary oedema. At concentrations in excess of 1400 mg/m^3, it is lethal.

The Ambient Air Quality Guidelines developed by the Ministry for the Environment recommends a guideline level of 7 $\mu g/m^3$ with an averaging time of 30 minutes. This level is set to prevent odour nuisance rather than health effects. The document goes on to state that areas which have naturally occurring levels of hydrogen sulphide should consider a higher level (such as 70 $\mu g/m^3$) which recognises the natural variability of emissions from such areas.

Hydrogen sulphide sampling and site selection

Hydrogen sulphide is measured continuously at Ngawha Springs using an MDA toxic gas analyser. This equipment operates by passing a known volume of air through a specially prepared filter over a 15-minute period. The tape is then passed under an optical sensor, which provides a signal output. The signal output is then stored on a data logger before being converted to hydrogen sulphide concentration. The instrument is capable of measuring hydrogen sulphide concentrations between 0 and 90 ppb.

In addition to a continuous hydrogen sulphide monitor, a meteorological monitoring station also records wind speed and wind direction, solar radiation, temperature and humidity at a height of 10 metres. The instrument is situated on a property at 54 Puia Street, Ngawha Springs, as shown in map 3. Measurements are taken every 3 seconds; these are then averaged and logged as 15-minute values for comparison with results from the hydrogen sulphide monitor. Rainfall measurements are also monitored at the site.



Map 3: Location of hydrogen sulphide and meteorological monitoring sites adjacent to Ngawha Springs.

Results

Prior to the commissioning of the Ngawha Geothermal Power Station, hydrogen sulphide monitoring data was collected along with meteorological monitoring information. The results, particularly the number and frequency of hydrogen sulphide excursions above the national ambient air quality guideline were compared with more recent data collected earlier this year and late last year.

Method

The two datasets were compared by isolating the number of exceedances in a given month, then further refining the data into categories of low (7-50 $\mu g/m^3$), medium (50 to 100 $\mu g/m^3$) and high (greater than 100 $\mu g/m^3$) exceedances. These categories were then compared statistically (at a level of 5%) to determine whether there was a statistically significant difference between the two datasets.

At a 5% level of significance, and assuming a normal distribution, we can assume that:

$$t = \frac{\chi 1 - \chi 2}{\sigma\sqrt{\frac{1}{N_1} + \frac{1}{N_2}}} \quad \text{where } \sigma = \sqrt{\frac{N_1 S_1^2 + N_2 S_2^2}{N_1 + N_2 - 2}}$$

The results from the calculations are shown in Table 4 below:

	7 to 49 μg/m³	50 to 99 μg/m³	100+ μg/m³
Limits[1] (1.71 to –1.71)	-0.29	-1.09	0.34

Table 4: Comparison of H_2S monthly results from before and after the geothermal power station commenced operation.

The results demonstrate that at a percentile level of 0.95, there is no statistically significant difference between the two sets of results, once variations in meteorological conditions have been accounted for. Both the number of excursions and the peak concentrations of hydrogen sulphide remain similar to those that occurred prior to the operation of the power plant.

However, the comparison did establish that excursions in the medium to high categories generally occur in the late evening or early hours of the morning when wind speeds are lower. This suggests that convection related dispersion has a significant effect on reducing the hydrogen sulphide concentration. The increased prevalence of hydrogen sulphide excursions during the winter months (May-August) also suggests that the development of inversion conditions is likely to significantly reduce the dispersion of relatively warm, moist gas flows resulting in increased hydrogen sulphide concentration downwind.

The elevation of the terrain may also generate preferential heating and cooling which could well be the dominant gaseous transport mechanism under inversion conditions. This could well result in the generation of preferential transport 'corridors' of hydrogen sulphide plumes under low wind speeds.

Intraseasonal and interseasonal meteorological variations may influence the frequency of excursions on an annual basis by increasing or decreasing the likelihood of inversion conditions during a given year. This may have implications for any future investigations when comparing the two datasets.

Health implications

The investigation identified that peak hydrogen sulphide concentrations of between 110 and 130 $\mu g/m^3$ (**half-hour average**) were occurring in Ngawha Springs residential community. The World Health organisation recommends a **24-hour** averaged limit of 150 $\mu g/m^3$ to prevent any possible eye injury. It should be mentioned that this value is at least 100 times lower than the concentration where eye injury is expected to occur.

When results from Ngawha Springs are converted to 24-hour averaged results, they indicate that health effects arising from acute exposure to the hydrogen sulphide within Ngawha springs township are extremely unlikely[2].

[1] Limit calculated using a 0.95 percentile value with 23 degrees of freedom.

[2] NOTE: This assumes that the H_2S concentrations local residents are exposed to are similar to those measured at the monitoring site on Puia Street.

Less information is available on the chronic effects of long-term exposure to hydrogen sulphide. Occupational studies undertaken overseas suggest that concentrations of 1500 to 3000 $\mu g/m^3$ may lead to a variety of symptoms including restlessness, lack of vigour and frequent illness. Concentrations of hydrogen sulphide in Ngawha Springs village are well below this level and based upon current information, it is unlikely that any local residents will suffer from chronic health effects resulting from exposure to hydrogen sulphide.

Conclusion

In summary, there does not appear to be any statistically significant increase in hydrogen sulphide concentration arising from the operation of the geothermal power station. The monitoring results suggest that variations on an annual basis were likely to be due to meteorological factors rather than variations in hydrogen sulphide emission rates.

In addition, the concentrations of hydrogen sulphide monitored at Ngawha Springs are unlikely to cause health effects of the kind exhibited by the incident reporter.