4.0

State of the environment and biodiversity

Part 3 discussed the pressures that are put on the environment in the Auckland region and what the ARC is doing to respond to those pressures.

This part discusses how those pressures are impacting different aspects of the natural environment and the present state of the air, land, freshwater and marine environments in the Auckland region, as well as terrestrial biodiversity.

It also discusses the ARC's responses to the pressures.

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4.1

State of the environment and biodiversity – Air

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4.1

Air

Introduction

Clean air is a precious, natural resource that is essential to life. New Zealand's isolated position in the South Pacific means that air arriving at the coastline is relatively pure and fresh (Figure 1). However, it is rapidly degraded by many daily activities that release chemicals and particulates into the air as pollutants. These air pollutants can damage human health, cause unpleasant smells and produce hazy days that reduce air clarity.

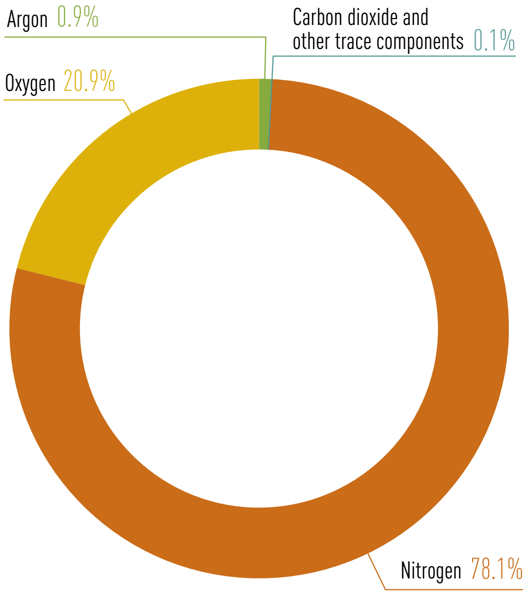


FIGURE 1 Composition of clean air arriving at New Zealand. (Source: NIWA).

Urban areas tend to experience a higher level of air pollution because many air pollutants originate from concentrated sources such as motor vehicles, urban, and industrial activities. The major sources of air pollution in the Auckland region include the combustion of fuels such as wood, gas, oil; diesel and petrol in vehicles, domestic fires and industrial processes.

The cleanliness of the air is measured by the ambient air quality, which depends on:

- the amount of pollution released into the air by human and natural activities,
- the amount of dispersion due to wind and weather,
- complex chemical reactions that can occur between pollutants.

On average, everyone in the Auckland region breathes 11,000 litres of air each day (based on a typical resting breathing rate of 7.5 litres per minute); a huge volume when compared to the two to three litres of water that each person drinks. The breathing rate rises to about 30 litres per minute when walking, and can reach 80 litres per minute during strenuous exercise, so an active person may require more than 14,000 litres of air each day.

Key findings

- The transport sector is the predominant contributor to air pollution but domestic fires are also a significant source of air pollutants during winter.
- The PM_{10} and $PM_{2.5}$ particulate concentrations exceed air quality standards and guidelines. Annual PM_{10} particulate concentrations showed a generally decreasing trend but this has levelled off in recent years. The trend for $PM_{2.5}$ particulates is not so clear.
- NO_2 concentrations at peak traffic sites exceed air quality standards and guidelines.
- Levels of CO, SO_2, ozone, benzene and lead currently comply with air quality standards and guidelines.
- Air pollution costs at least $547 million each year in health costs. The levels of PM_{10} particulates are of the most concern and cause the worst health problems, particularly those from diesel combustion.
- Emissions of PM_{10} and $PM_{2.5}$ particulates and NO_2 all need to be reduced substantially.

Air quality monitoring programme

The ARC is responsible for ensuring that the outdoor air in the Auckland region is clean and healthy to breathe. Therefore, it needs to have a sound scientific understanding of the current pollutant levels, any long-term trends and the sources of the pollutants so that the ARC can manage the air quality effectively and help reduce the level of pollutants in our air.

The ARC monitors the main air pollutants, which are PM_{10} and $PM_{2.5}$ particulates, nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3).

Air quality monitoring has been undertaken for many years within the Auckland region. This means that the ARC can use the annual averages, seasonal trends and spatial trends to indicate how concentrations of different pollutants are changing over time and to detect any long-term trends.

There are some limitations to our monitoring programme – the ARC cannot monitor every air pollutant. A range of different pollutants are released into the air and the main pollutants monitored are only a subset of this range.

Other limitations include:

- pollutants may undergo chemical reactions in the air, producing other types of pollutants that may be more harmful to human health,
- any synergistic effects on human health from two or more pollutants are not considered,
- monitoring is carried out only at 'typical' locations that are chosen to best represent the whole Auckland region and therefore may not cover other locations where people are exposed to relatively high levels of air pollution.

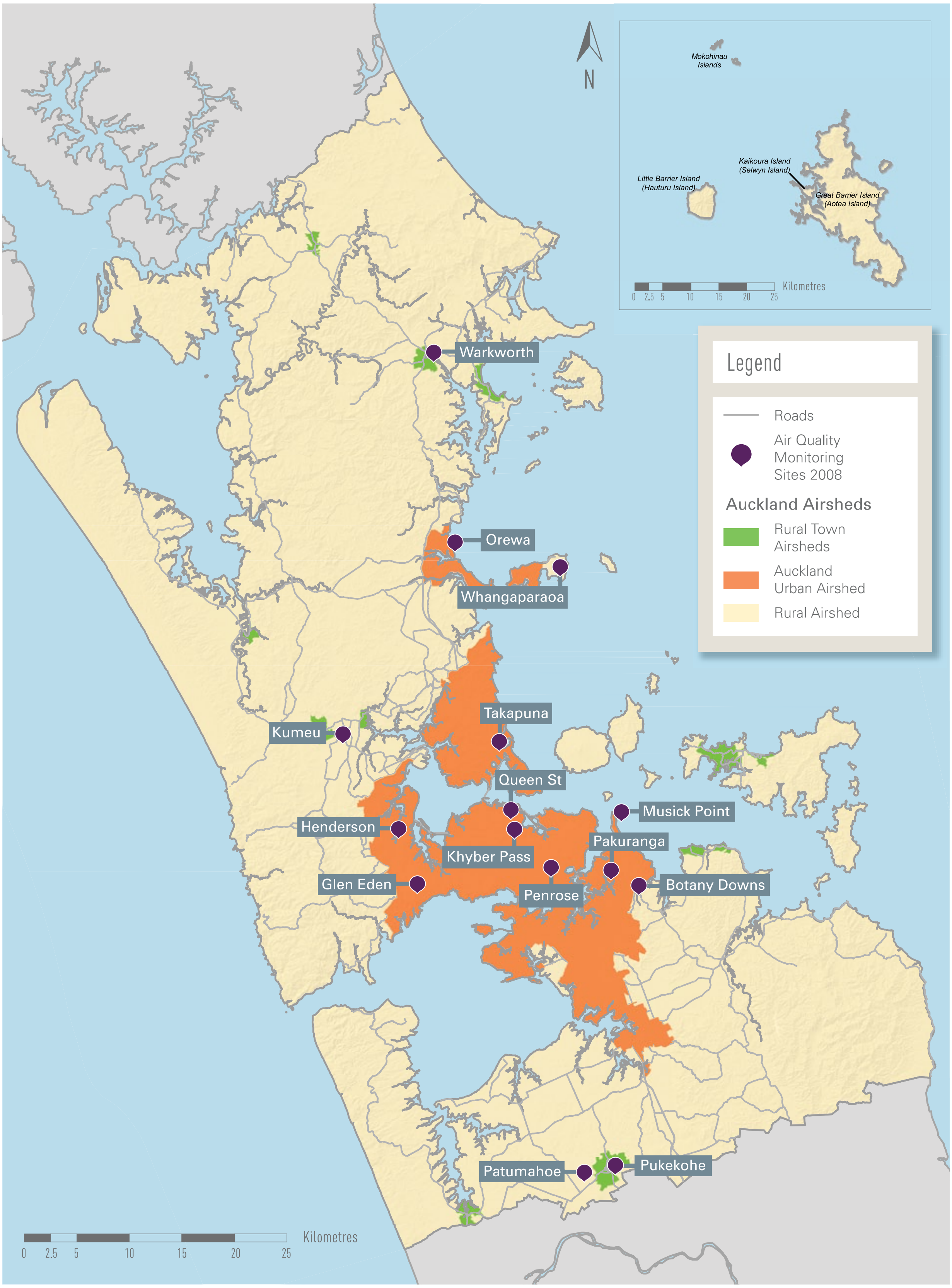


FIGURE 2 Location of the ARC air quality monitoring sites, and airsheds, in the Auckland region in 2008. (Source: ARC).

4.1

Air

Monitoring sites

The ARC continuously monitors several air pollutants at 15 sites spread across the Auckland region, ranging from Pukekohe to Warkworth, and Henderson to Botany Downs (Figure 2). MfE shares funding at two sites. These sites are selected to represent a variety of pollutant sources and exposures.

Peak traffic monitoring sites are located 2 to 3m from the roadside. These monitoring sites provide the ARC with an indication of the level of pollution that pedestrians and people who work close to busy roads are exposed to.

Urban or suburban residential area monitoring sites are located at least 10m from the roadside to represent areas where people live, work, study or play.

Industrial monitoring sites are located in industrial areas.

Rural areas are also monitored because they can be affected by air pollution from urban areas and because some rural activities can lead to air pollution.

The ARC also undertakes passive sampling of some particular air pollutants from time to time. This involves exposing passive samplers, e.g. an activated filter paper, to the air for a period of time and analysing them later to see how much of the pollutant was in the air. The pollutants measured this way nitrogen dioxide (NO_2), sulphur dioxide (SO_2), benzene, toluene, ethylbenzene and xylene.

Passive sampling is a useful survey method that can be used to show spatial distributions and long-term trends, but the results are not measured against the air quality standards and guidelines.

Air quality guidelines and standards

The Ministry for the Environment (MfE) has published air quality guidelines under the RMA. These identified the maximum acceptable concentrations for specified air pollutants in order to protect both human health and the environment, and were based on recommended guidelines from the World Health Organisation (WHO).

These guidelines were updated in 2002 and include the following air pollutants:

- nitrogen dioxide (NO_2)*
- PM_{10} and $PM_{2.5}$ particulates*
- carbon monoxide (CO)*
- sulphur dioxide (SO_2)*
- hydrogen sulphide (H_2S)
- ozone (O_3)*
- benzene*
- 1-3 butadiene*
- benzo(a)pyrene
- formaldehyde
- acetaldehyde
- lead*
- chromium (VI, III and Cr metal)
- mercury (organic and inorganic)
- arsenic (inorganic)
- arsine.

Target levels for all of these air pollutants are included in the Proposed Auckland Regional Plan: Air, Land and Water and those marked* are monitored in the Auckland region.

Box 1 National Environmental Standards (NES) for air quality

The National Environmental Standards (NES) for air quality were introduced by the Government in 2004 and then amended in 2005. They contain 14 individual standards or regulations that apply to all of New Zealand.

Seven of these standards ban activities that discharge unacceptable levels of dioxins and other toxic substances into the air. Prohibited activities include open burning of tyres, coated wire, oil, bitumen (for road maintenance) and waste at any landfill, as well as new school or healthcare incinerators (unless a resource consent is obtained) or any new high-temperature incinerators for hazardous waste.

Five of the standards impose ambient air quality standards for:

- carbon monoxide (CO)
- PM_{10} particulates
- nitrogen dioxide (NO_2)
- sulphur dioxide (SO_2)
- ozone (O_3).

The NES ambient standards define the permissible concentrations of contaminants in the air over a specified time and the number of annual allowable exceedences. There are also NES for new small-scale domestic wood burners and MfE has since identified a list of compliant appliances. MfE prohibits discharges from non-compliant wood burners from sections of two hectares or less (although discharges from open fires and other forms of burners are not prohibited).

Another standard prohibits the release of gas from large landfills unless the landfill has a system that can collect this gas and has been designed to meet specified requirements.

In 2004, MfE also introduced National Environmental Standards (NES) to improve air quality and protect the health of the general population (Box 1). These standards are regulations issued under sections 43 and 44 of the RMA and were effective from 1 September 2005. They apply to ambient (outside) air everywhere.

The NES use only one averaging period for each of the five specified air pollutants and include a number of exceedences that are allowed per year.

An exceedence occurs when the concentration of an air pollutant exceeds the permitted level in the standard or guideline. When the number of exceedences in a year is more than that allowed by the standard, this is known as a breach of the standard.

Airsheds

The ARC has also identified areas where the air quality is already known to exceed – or is likely to exceed – the air quality standards, either now or in future. These areas are designated as separate airsheds (by notice in the New Zealand Gazette, the official newspaper of the Government of New Zealand) and are the focus of our air quality management programmes.

The Auckland region has 12 gazetted airsheds (Figure 2):

- → The urban airshed covers most of urban Auckland and was formalised on 1 September 2005.
- → Eleven rural town airsheds cover the urban areas of the larger rural and coastal settlements in the Auckland region and were formalised on 1 July 2007.

The remainder of the Auckland region forms the Auckland rural airshed.

Air quality

The following pollutants have been chosen to indicate the quality of the air in the Auckland region and to identify long-term trends:

- → PM_{10} and $PM_{2.5}$ particulates
- → nitrogen dioxide (NO_2)
- → carbon monoxide (CO)
- → ozone (O_3)
- → sulphur dioxide (SO_2).

Benzene, lead and 1-3 butadiene are also measured on a long-term basis at one or more sites in Auckland.

All of these air pollutants are monitored because they are known to endanger human health and well-being and their levels can be compared to the air quality standards and guidelines.

Visibility can also be used as a subjective indicator of air quality.

Daily trends also reveal how concentrations of some air pollutants vary during the day, depending on the weather and the sources of pollution.

Fine particulates (PM_{10} and $PM_{2.5}$)

PM_{10} and $PM_{2.5}$ particulates are tiny solid and liquid particles that are suspended in the air but are invisible to the human eye.

They can be produced from natural sources such as pollen, bushfires, sea spray, windblown dust and secondary particulates, which are formed in the air by chemical reactions. They are also produced by human sources such as domestic fires, industrial activities, motor vehicle emissions, tyre and brake wear and from re-suspended road dust.

PM_{10} particulates are less than 10 micrometres (10^{-6}m or μm) in diameter, about one fifth the width of a human hair. PM_{10} particulates can stay suspended in the air for over a month and can affect visibility by creating a haze over large areas. They can also contribute towards the soiling and corrosion of buildings.

PM_{10} particulates can be inhaled easily. They lodge in the lungs and can adversely affect human health, especially for people who are asthmatic or have heart or lung disease. They can contribute towards heart attacks, strokes, respiratory diseases and can reduce lung function leading to premature deaths, hospitalisation, increased medication and days off work or school. PM_{10} particulates can also carry carcinogenic materials into the lungs.

$PM_{2.5}$ particulates are a smaller fraction of the larger PM_{10} particulates, with a diameter under 2.5 micrometres. They have the same effects as PM_{10} particulates but, because they are much smaller, can penetrate more deeply into the tiny air sacs in the lungs so their adverse health effects are greater.

4.1

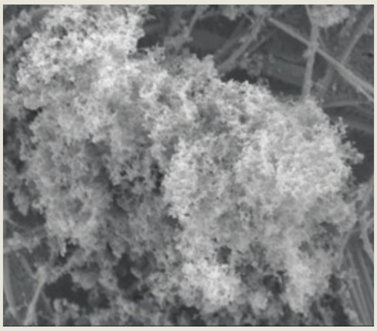
Air

Box 2 What do the particulates look like?

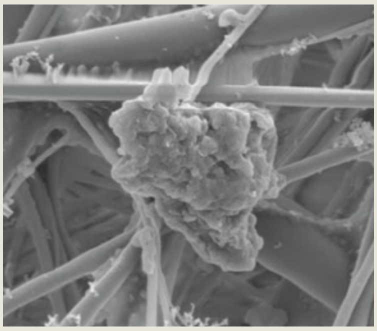
PM_{10} particulates (less than 10 micrometres) and $PM_{2.5}$ particulates (less than 2.5 micrometres) are mixtures of different particulates that have many shapes and sizes. The particulates also have different compositions depending on their origin. The types of particulates that the ARC has found on our filters included:

- combustion particulates
- salt crystals (sodium chloride)
- mineral material (e.g. soil, silt, clay dust)
- other crystals – possibly calcium sulphate (gypsum)
- seeds, spores and pollen (mainly basidiospores from fungi).

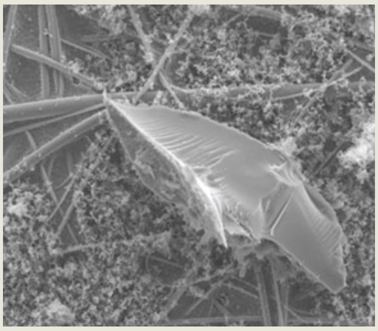
PM_{10} and $PM_{2.5}$ particulates are so small that they are invisible to the human eye. Some magnified examples are shown here:



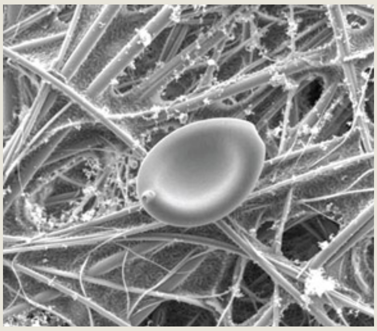
Combustion particle at Takapuna



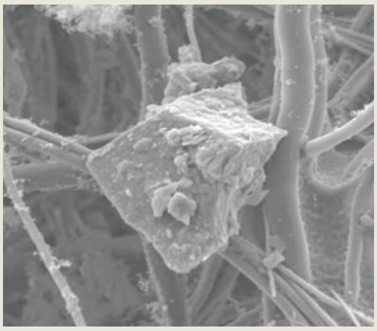
Mineral material at Kingsland



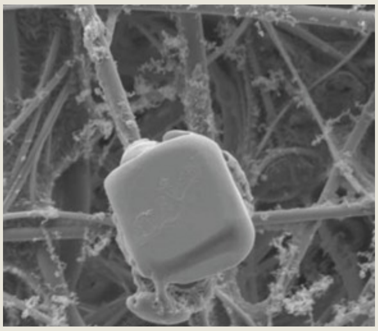
Glass fragment at Khyber Pass Road



Fungal spore at Khyber Pass Road



Mineral material at Takapuna



Salt crystal at Khyber Pass Road

The PM_{10} standard for the 24-hour average is 50 µg/m^3 with one allowable exceedence per year.

The PM_{10} guideline for the annual average is 20 µg/m^3.

The $PM_{2.5}$ monitoring guideline for the 24-hour average is 25 µg/m^3.

Safe levels of PM_{10} or $PM_{2.5}$ particulates have not been identified but adverse effects can occur at only 25 per cent of the levels given in the standards and guidelines, therefore people may be affected at much lower concentrations.

Diesel particulates are carcinogenic. They are the most toxic of all the PM_{10} and $PM_{2.5}$ particulates.

Sources of fine particulates

As discussed earlier, fine particulates can come from both natural and anthropogenic sources. The air emissions inventory (see Sources of air pollution in Part 3) can give the ARC information on the amount of particulates in the air generated by human activities (anthropogenic emissions) but does not give the ARC information on the amount of natural particulates. The ARC needs to understand this so that it can establish the reductions required to protect human health. Therefore, an extensive study has been undertaken on the composition of particulates in order to provide further information on both natural and anthropogenic sources, including their origin, variability and proportion of total particulate concentrations.

Figure 3 shows the average contributions overall from natural and anthropogenic sources to PM_{10} and $PM_{2.5}$ during summer and winter. Wood burning, motor vehicle emissions and sea salt were the most common sources of $PM_{2.5}$ particulates and PM_{10} particulates. Natural sources typically form a greater proportion of PM_{10} particulates than of $PM_{2.5}$ particulates. During winter, concentrations are usually higher and anthropogenic sources such as domestic heating and vehicle emissions contribute to a far greater proportion of the PM_{10} and $PM_{2.5}$ particulates.

The total sulphate contribution to PM_{10} particulates was similar to $PM_{2.5}$ particulates at around 10 per cent.

Dust was also present as a minor source at all monitoring sites, except at Penrose, where the dust included contributions from nearby industrial activities. Industry sources contributed minor quantities to PM_{10} and $PM_{2.5}$ particulates at Penrose and Takapuna (around 4-6 per cent of the total PM_{10}.)

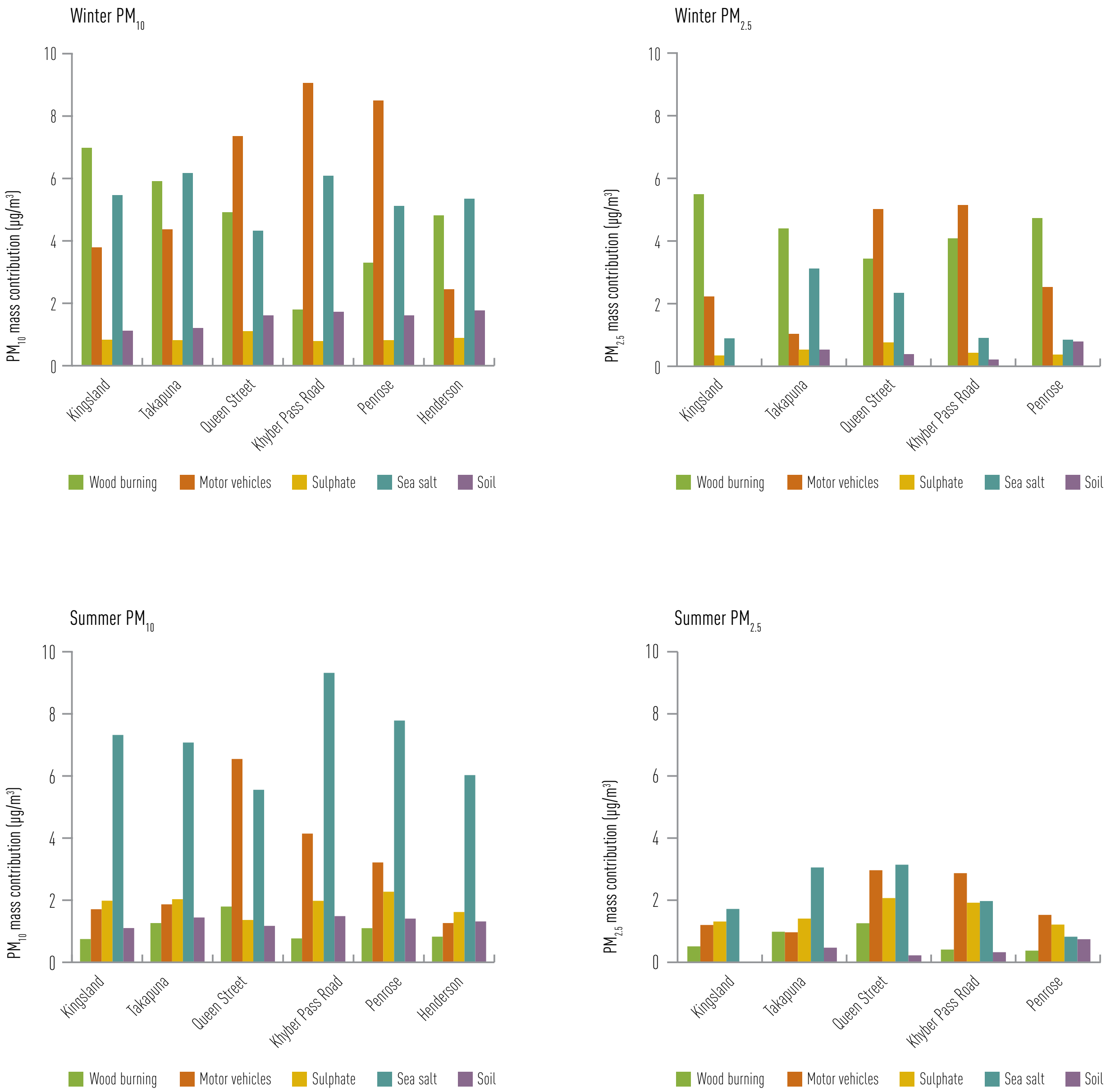


FIGURE 3 Average winter and summer contributions to PM_{10} and $PM_{2.5}$ at air quality sites in Auckland (excludes minor industry sources).

Air

Indicator 1: Concentrations of fine particulates

The PM_{10} and $PM_{2.5}$ particulate concentrations measured in the Auckland region exceed the air quality standards and guidelines.

Annual averages of fine particulates

Annual PM_{10} particulate concentrations at the Khyber Pass and Queen Street monitoring sites showed a generally decreasing trend but this has levelled off in recent years. Other sites have remained relatively static over the ten year period to 2008 (Figure 4).

Vehicle emissions and domestic fires are known to be the main sources of fine particulates in the Auckland region and, over recent years, significant improvements in both vehicle and fuel technology have been achieved. In addition, both new and used vehicles entering New Zealand now have to conform to minimum emissions standards that are becoming progressively tighter over time. This combination of factors will result in a gradual reduction of fine particulate emissions per motor vehicle in the near future. Unfortunately this reduction has been offset over the last few years (and will continue to be offset) by the growth in vehicle numbers, an increased number of kilometres driven and increasing age of the vehicle fleet (see Pressures: Transport, pg 75).

The use of solid fuels (wood and coal) for domestic fires in winter has been declining slowly but, due to the large number of residential domestic fires, solid fuels remain a significant source of particulate emissions.

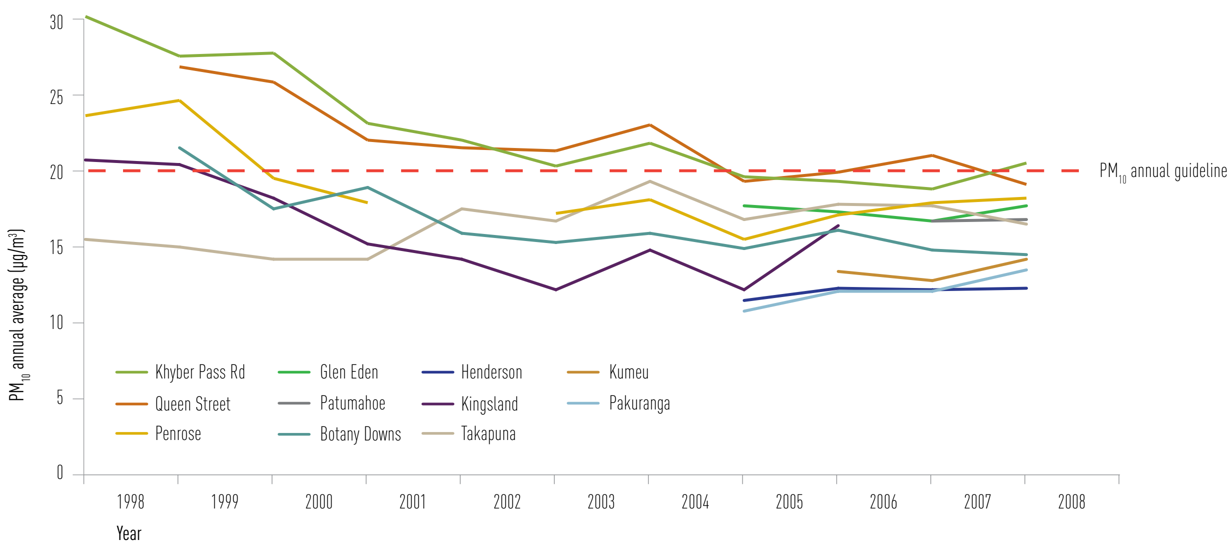


FIGURE 4 Annual averages of PM_{10} particulates in air, 1998-2008. The Kumeu site is in a rural town airshed, Patumahoe is in the rural airshed and the remaining sites are in the Auckland urban airshed. (Source: ARC).

Seasonal trends of fine particulates

PM_{10} and $PM_{2.5}$ particulate concentrations can be higher at some sites during winter, depending on the local sources of the particulates. However, it is also possible to get high PM_{10} particulate concentrations during summer and exceedences of the 24-hour standard can occur in any season.

In winter, wood burning and motor vehicle emissions were the primary sources of PM_{10} particulates at all the monitoring sites. Motor vehicle emissions dominated the roadside monitoring locations at Queen Street and Khyber Pass Road and wood burning was the primary source at the residential monitoring location in Takapuna.

During the other seasons, dust and sea salt were more likely to be found in the larger size fraction of PM_{10} particulates, particularly sea salt which is the dominant source at times.

Figure 5 shows the seasonal variations in natural and anthropogenic sources of PM_{10} particulates at the monitoring sites. Figure 6 shows the seasonal variations in natural and anthropogenic sources of $PM_{2.5}$ particulates in the monitoring sites.

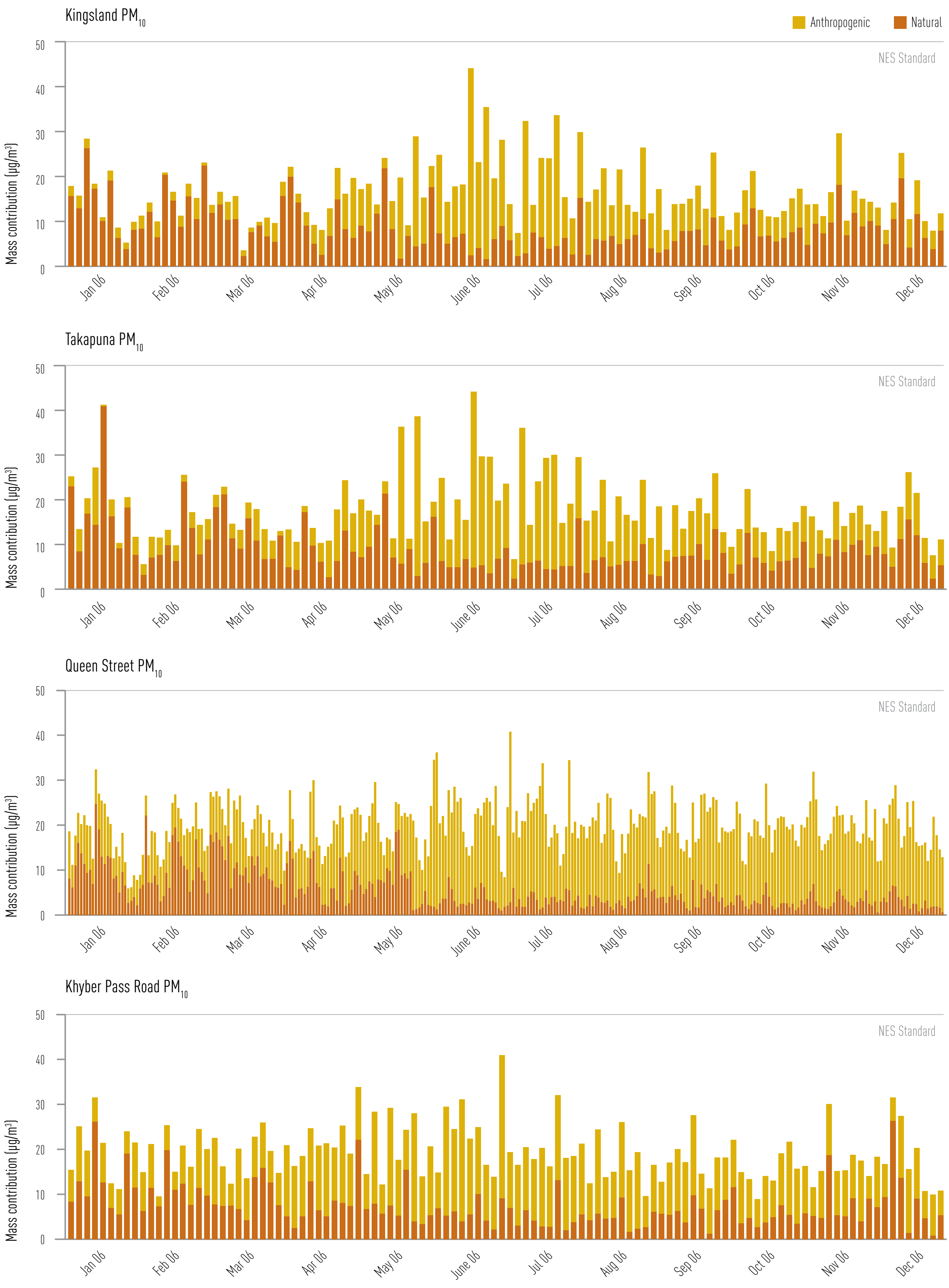


FIGURE 5 Seasonal variations in natural and anthropogenic sources of PM_{10} particulates at monitoring sites in 2006. (Source: ARC).

FIGURE 6 Seasonal variations in natural and anthropogenic sources of $PM_{2.5}$ particulates at monitoring sites in 2006. (Source: ARC).

Overall, domestic heating was shown to be the main contributor to both PM_{10} and $PM_{2.5}$ particulates at residential sites during winter.

Transport is the main contributor to both PM_{10} and $PM_{2.5}$ particulates at Queen Street and Khyber Pass Road in winter. In other seasons, transport is the main source of $PM_{2.5}$ particulates at Queen Street and Khyber Pass Road but not of PM_{10} particulates.

Motor vehicle emissions were the main source of $PM_{2.5}$ particulates during all the other seasons at all monitoring sites.

Sulphate and sea salt concentrations were highest during the summer at all monitoring sites.

The combination of a range of contributing sources results in less obvious seasonal trends for fine particulates in the Auckland region. This means that if particulate concentrations are to be reduced, measures that will reduce emissions from all sources (motor vehicles, domestic fires and industrial activities) need to be considered.

Nitrogen dioxide (NO_2)

Nitrogen dioxide is a brown, pungent, acidic gas which is mainly formed from the reaction of nitric oxide (NO) with ozone (O_3) in the air. These compounds may also react in the air for several days to form nitric acid as well as nitrate and nitrite particulates that form part of the $PM_{2.5}$ particulates.

NO and NO_2 are together referred to as nitrogen oxides (NO_x). Nitrogen oxides are formed by the combustion of fossil fuels (coal, oil and gas). Motor vehicles are a large source of NO_x in urban areas, mostly emitted as NO with some NO_2.

NO_2 can irritate the lungs and increase susceptibility to, and severity of, asthma and lower resistance to infections such as influenza. Long-term exposure to low levels of NO_2 can affect lung function growth in children and cause damage to some plants.

High levels of NO_2 can significantly affect visibility by contributing to the formation of haze and smog.

The NO_2 standard for the 1-hour average is 200 µg/m³ with nine allowable exceedences per year.

The NO_2 guideline for the 24-hour average is 100 µg/m³. The annual average guideline for protecting vegetation is 30 µg/m³.

Indicator 2: Concentrations of nitrogen dioxide

Vehicle emissions are the main source of nitrogen oxides (NO and NO_2). NO then reacts with ozone and some volatile organic compounds (VOCs) (together referred to as oxidants) to form NO_2. Consequently, measured NO_2 concentrations at peak traffic sites exceed the standards and guidelines.

Annual averages of nitrogen dioxide

Annual average NO_2 concentrations have decreased at some sites but increased at others (Figure7). The annual average NO_2 concentrations are largely controlled by the oxidant (O_3) concentrations which have changed little over the years.

As a result, the average NO_2 concentrations have not shown significant changes within the Auckland region although reductions at the peak traffic sites reflect local changes in traffic patterns and profiles.

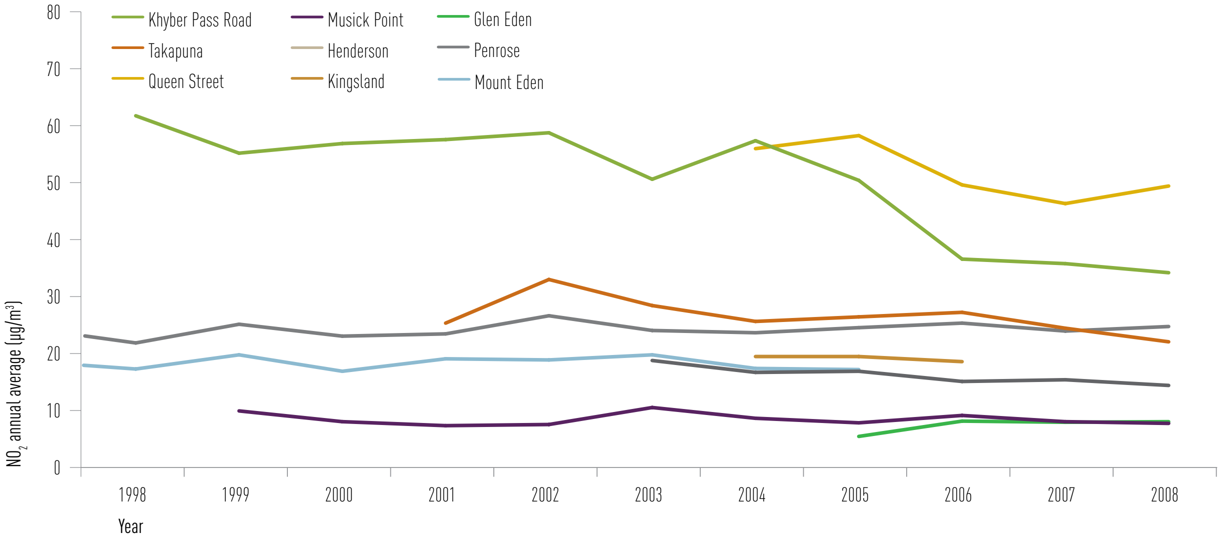


FIGURE 7 Annual averages of nitrogen dioxide in air, 1998-2008. Note, the Warkworth and Pukekohe sites are in rural town airsheds, Patumahoe is in the rural airshed and the remaining sites are in the Auckland urban airshed. (Source: ARC, MfE).

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Factors that influence the annual averages are the rapid growth in both the number and frequency of use of light and heavy duty diesel vehicles. These two factors have offset the benefits of reduced NO_2 emissions from vehicles with improved engine technology because diesel vehicles produce more NO_2 than petrol vehicles.

Seasonal trends of nitrogen dioxide

Concentrations of NO_2 are usually higher in winter than in summer. NO_2 is formed mainly from the reaction of NO with oxidants so the higher NO_2 levels in winter are due to increased oxidant levels and poor dispersion conditions, rather than due to an increase in NO_2 emissions during that season.

Figure 8 shows the seasonal trends of NO_2 concentrations in the Auckland region. Concentrations in winter are about twice as high as those in summer.

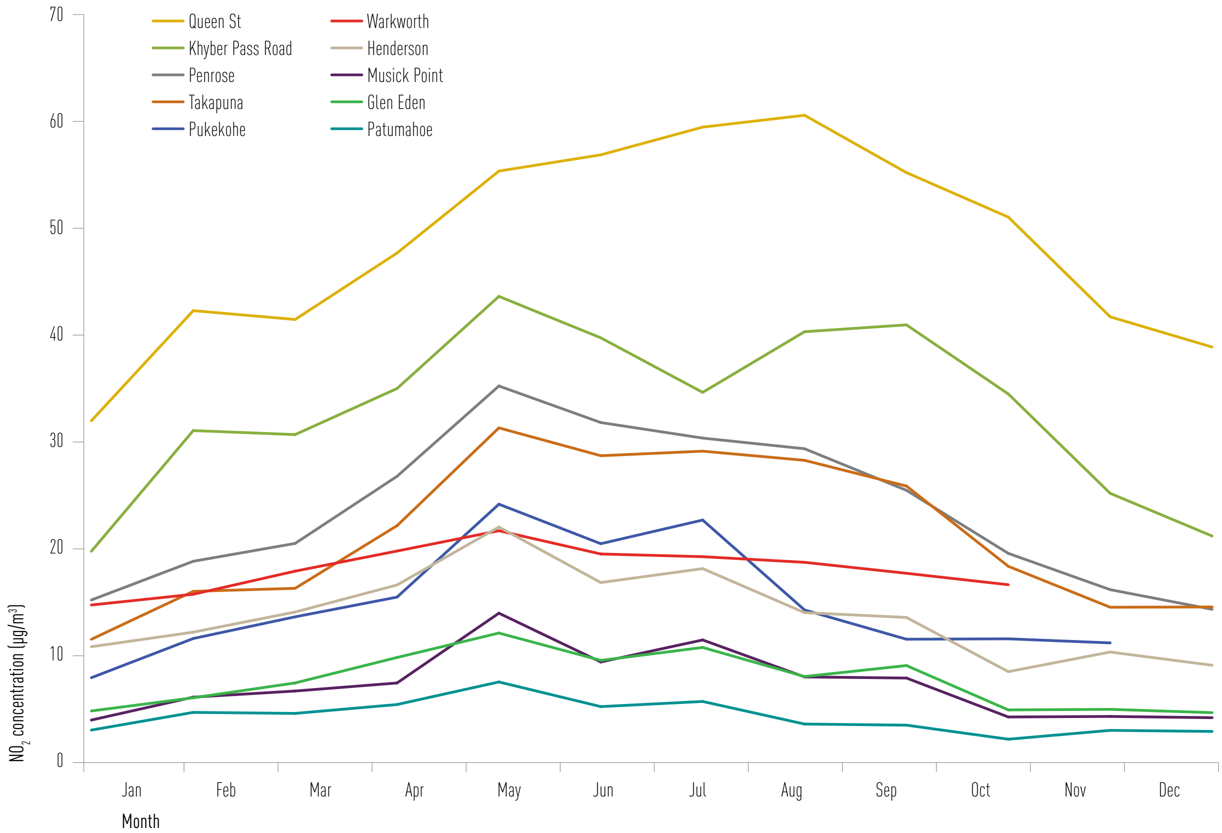

FIGURE 8 Monthly NO_2 concentrations in air, 2008. The Warkworth and Pukekohe sites are in rural town airsheds, Patumahoe is in the rural airshed and the remaining sites are in the Auckland urban airshed. (Source: ARC).

Carbon monoxide (CO)

Carbon monoxide is a colourless, odourless, tasteless and relatively inert gas which slowly converts to carbon dioxide (CO_2) in about a month. It is formed by natural processes such as volcanic activity and by human activities, primarily motor vehicle emissions.

CO is produced from the partial combustion of carbon-based fuels in air. If there is sufficient oxygen for complete combustion, CO is transformed into CO_2. Concentrations of CO are usually higher in winter than in summer. Emissions from domestic heating and poor dispersion conditions are the reasons for higher CO levels in winter.

CO interferes with the blood's ability to absorb and circulate oxygen. Low CO levels can adversely affect people with heart conditions such as angina and clogged arteries. High CO levels can cause dizziness, nausea, drowsiness and impair co-ordination and attention. Extremely high CO levels can cause death.

The CO standard for the 8-hour running average is 10mg/m^3 with one allowable exceedence per year.

The CO guideline for the 1-hour average is 30mg/m^3.

Indicator 3: Concentrations of carbon monoxide

Vehicle emissions, particularly those from petrol vehicles, are the most significant source of CO in the Auckland region. Improving vehicle technology and the increasing proportion of vehicles that are fitted with catalytic converters have reduced CO levels significantly over the past ten years, particularly at the peak traffic sites. Consequently, CO levels in the Auckland region now usually comply with air quality standards and guidelines (Figure 9).

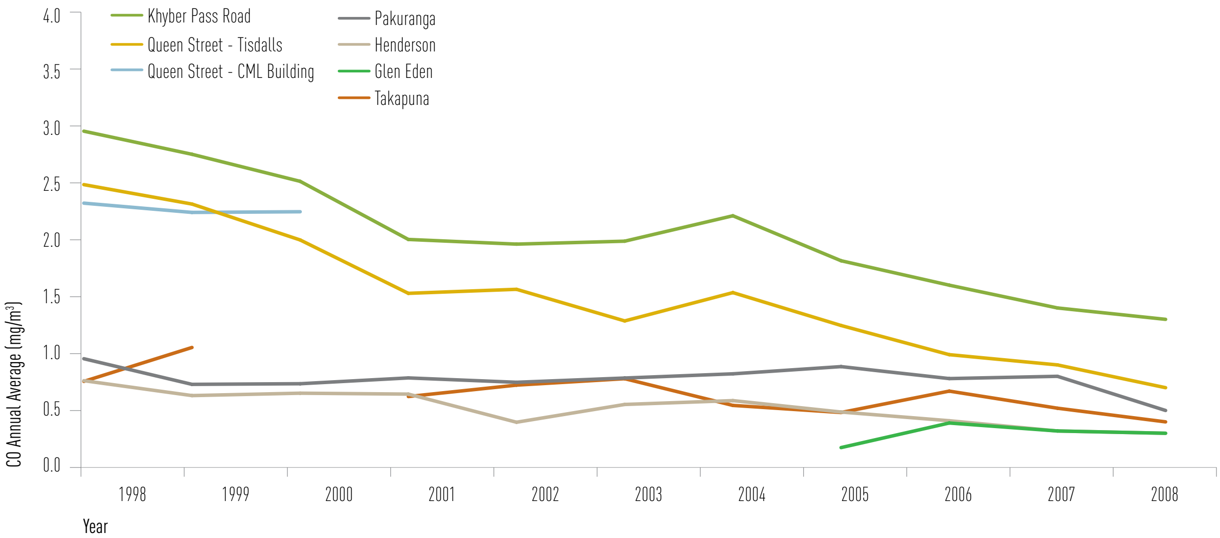

FIGURE 9 Annual averages of carbon monoxide in air, 1998-2008. (Source: ARC).

Sulphur dioxide (SO_2)

Sulphur dioxide is a colourless, pungent, acidic gas which readily reacts in the air to form sulphuric acid and other compounds. SO_2 is usually oxidised in the air within a few days.

SO_2 is mainly produced by the combustion of fossil fuels that contain sulphur (such as coal and diesel) and by industrial processes. It also comes from natural emissions such as volcanic eruptions or emissions from phytoplankton in the sea. SO_2 reacts to form sulphate particulates (part of the $PM_{2.5}$ particulates) and also forms acid rain. Although acid rain is a problem in the northern hemisphere, it is not usually a problem in New Zealand.

Exposure to SO_2 irritates the lungs causing coughing, wheezing or breathlessness. Asthmatics are particularly sensitive and may suffer breathing problems. Long-term exposure to high SO_2 levels and particulates can aggravate heart disease and cause respiratory illness.

SO_2 is toxic to some plants and is corrosive to some building surfaces and metals in moist conditions.

The SO_2 standard for the 1-hour average is 350 µg/m³ with nine allowable exceedences per year. The standard is 570 µg/m³ for the 1-hour average with no allowable exceedences per year.

The SO_2 guideline for the 24-hour average is 120 µg/m³. The guideline also includes levels for protecting agricultural crops, forest and natural vegetation, and lichen.

In 2006 the WHO updated the SO_2 guideline for the 24-hour average from 125 µg/m³ to 20 µg/m³ because the previous guidelines were considered insufficient, due to new evidence about health effects. This change is not yet reflected in New Zealand's guidelines and standards. The WHO SO_2 guideline for the 10-minute average remains at 125 µg/m³.

Indicator 4: Concentrations of sulphur dioxide

SO_2 levels decreased in the 1970s and 1980s due to reduced use of coal in industrial areas, but rose again between 1995 and 1999 due to the import of used diesel vehicles (Figure 10). However, the levels of sulphur in diesel fuel have fallen dramatically in recent years, producing another reduction in SO_2 levels.

Measured SO_2 concentrations typically meet air quality standards and guidelines. However, the introduction of the new SO_2 guideline by the WHO (that reduces the 24-hour average from 125 to 20 µg/m³) means that it is necessary to continue monitoring SO_2 levels.

It is possible that some parts of the Auckland region will not comply with this new guideline.

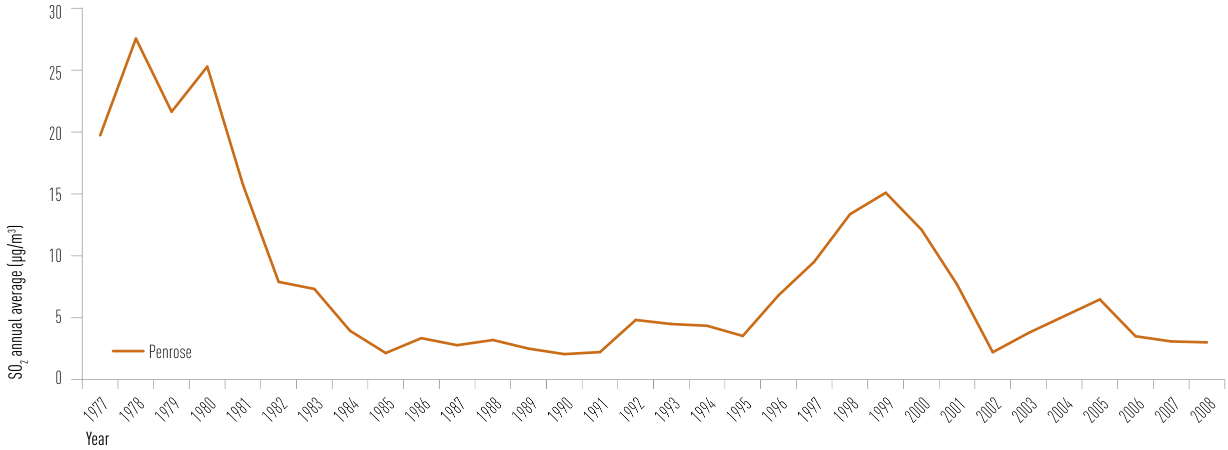

FIGURE 10 Annual averages of sulphur dioxide in air at Penrose, 1977-2008. (Source: Ministry for the Environment).

Benzene

Benzene is a colourless, flammable gas with a sweet petrol-like odour. It is a volatile organic compound (VOC) and is emitted from a range of sources including motor vehicle emissions, evaporation of petrol, petrol lawn mowers, cigarette smoke and domestic fires.

Short-term inhalation of benzene may cause drowsiness, dizziness and headaches as well as irritation to the eyes, skin and respiratory tract. At high levels it can cause unconsciousness. Long-term exposures have caused blood disorders and reproductive effects have been reported at high levels.

Benzene is classified as a human carcinogen and is associated with an increased incidence of human leukemia and adverse foetal development in animals.

The benzene guideline is 10 µg/m³ for the annual average until 2010. This drops to 3.6 µg/m³ from 2010 onwards.

Benzene and 1-3 butadiene are the two VOCs that are considered to be most hazardous to human health.

Indicator 5: Annual averages of benzene and 1-3 butadiene

Figure 11 shows the monthly benzene concentrations at Khyber Pass Road, obtained by passive sampling. Government specifications that required the level of benzene in petrol to be reduced in stages (from 4 to 3 per cent in 2004, then down to a maximum of 1 per cent in January 2006) are indicated by vertical dotted lines.

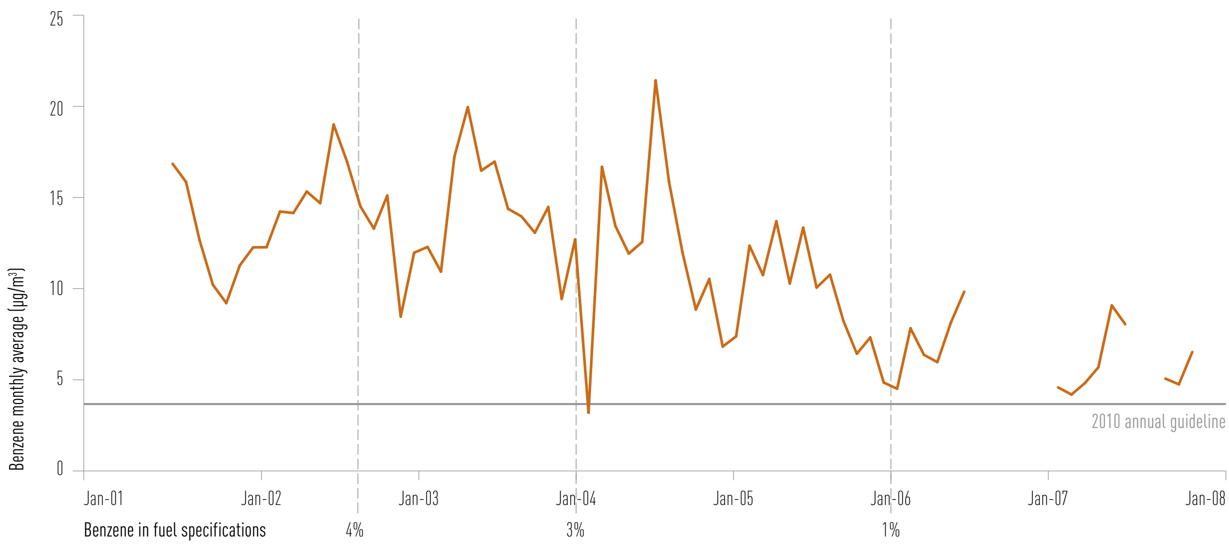

FIGURE 11 Monthly average benzene in air at Khyber Pass Road. (Source: ARC). Note: gaps indicate periods where no sampling took place.

As a result of these mandatory requirements, benzene concentrations have shown a long-term decline and have reduced significantly over recent years.

Benzene concentrations in the Auckland region now comply with current air quality guidelines. However, the guideline value will be reduced in 2010 and exceedences of this new guideline may occur at busy roadsides in the future.

1-3 butadiene concentrations in the Auckland region comply with the guideline but could increase as a result of an increase in traffic.

Lead

Lead is a heavy metal which can be absorbed by humans through the air, water and soil. High lead exposure can affect the nervous system, brain, kidneys, metabolic processes and reproductive systems.

The major source of lead in the air used to be the combustion of petrol containing lead which was added to boost the octane rating and to prevent engine knock. However, lead levels in petrol in New Zealand began to be reduced in 1986 and lead additives were completely removed in 1996.

Lead in contaminated road dust can re-enter the air due to vehicle movements and wind. Another source of airborne lead is the restoration of old houses coated with lead-based paints, particularly if dry sanding is used to remove the paint. Industrial sources include battery manufacture and small secondary smelting operations such as solder and sinker manufacture.

The lead guideline for a 3-month moving average is 0.2 µg/m³.

Indicator 6: Concentrations of lead

In 1996 lead was eliminated from petrol. Consequently, there has been a significant long-term decline in the amount of lead in the air (Figure 12) and lead levels in the Auckland region are now well below the air quality guideline.

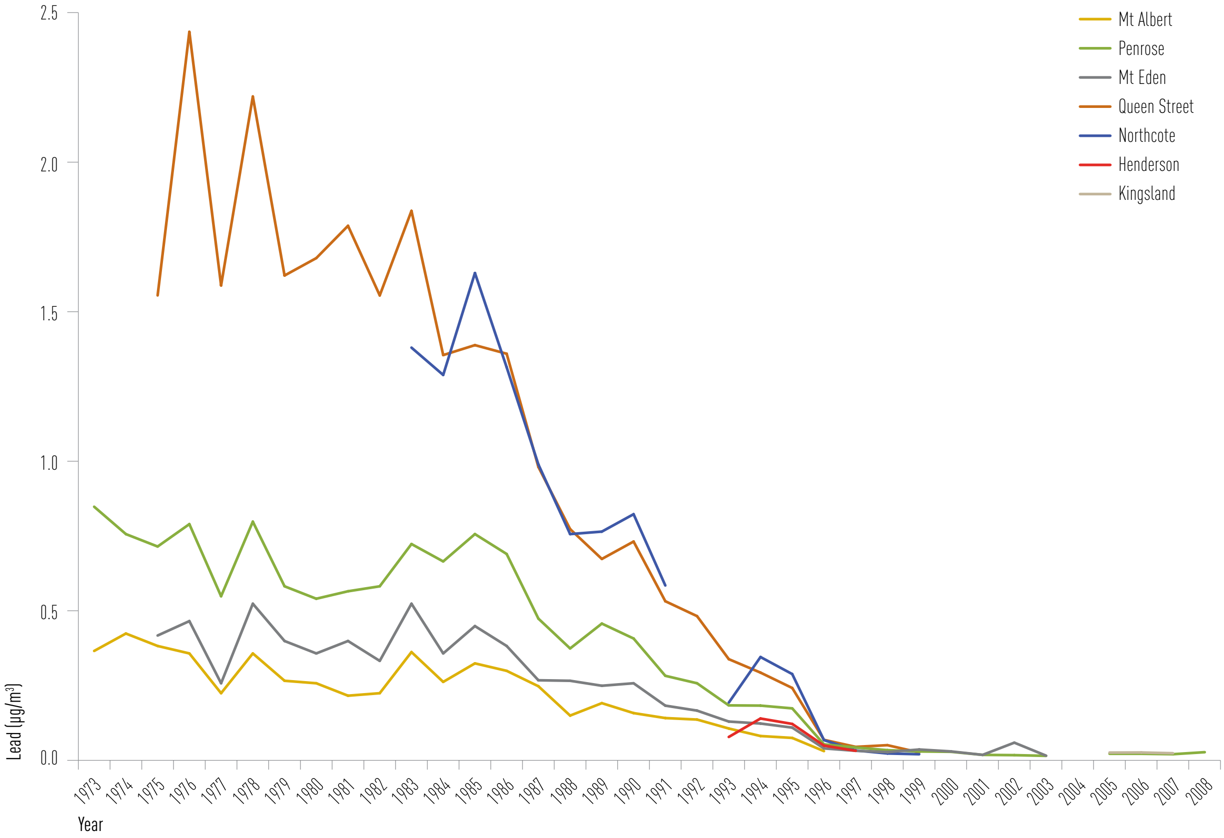

FIGURE 12 Annual average lead in air, 1973-2008. (Source: Ministry for the Environment).

Air

Ozone (O_3)

Ozone (O_3) is a colourless, highly reactive gas with a distinctive odour. It forms naturally in the air and is a vital component of the upper atmosphere where it protects the earth from ultraviolet (UV) radiation from the sun.

However, ozone at ground level is one of the main components of photochemical smog that can seriously reduce visibility, e.g. photochemical smogs in California mean that it is often almost impossible for tourists to see the Grand Canyon. It also causes deterioration of materials such as rubber and paints, and damages sensitive plants.

At ground level, ozone can form under certain conditions when nitrogen oxides and VOCs from motor vehicle emissions and industrial activities react in the presence of sunlight.

Ozone causes runny eyes, irritation of the nose and throat and breathing difficulties, especially in asthmatics. It can also cause lung damage that reduces lung capacity and lowers resistance to respiratory illnesses, particularly in infants and the elderly.

The ozone standard is 150 μg/m³ for the 1-hour average with no allowable exceedences per year.

The ozone guideline is 100 μg/m³ for the 8-hour average. The guideline also includes levels for protecting forests, semi-natural vegetation and crops.

Indicator 7: Concentrations of ozone

Ozone levels in the Auckland region are determined by two factors:

→ the natural background concentration

→ ozone that is produced locally as a result of photochemical reactions.

Measured ozone levels generally meet the air quality standards and guidelines.

Annual averages of ozone

The natural background concentration is the main factor that influences the annual average levels. Consequently, there has been little change in these levels over the past ten years (Figure 13).

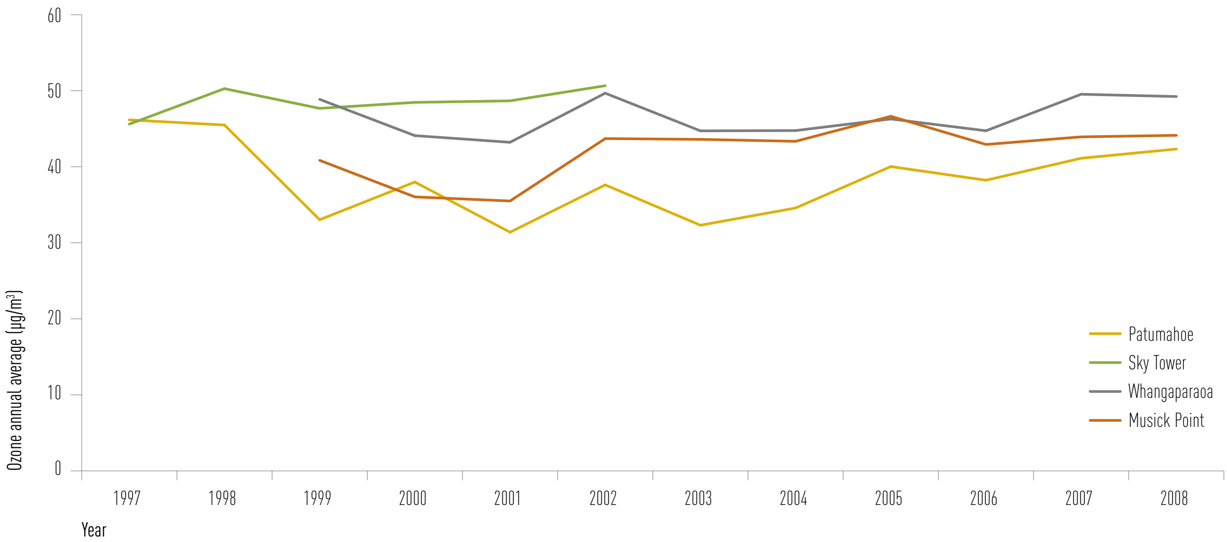

FIGURE 13 Annual averages of ozone in air, 1997-2008. (Source: ARC).

Seasonal trends of ozone

The natural background level of ozone is higher in winter than in summer in New Zealand but high, short-term, concentrations of ozone can occur in summer when sunlight and warm temperatures lead to photochemical reactions in the polluted air. This may result in photochemical smog.

Figure 14 shows an example of elevated ozone concentrations typical of photochemical reactions in summer. The high ozone concentrations at both Musick Point and Whangaparaoa occurred on 13 February 2008 – a warm and sunny day. The temperature reached 24.2°C at 3pm on that particular day at Musick Point.

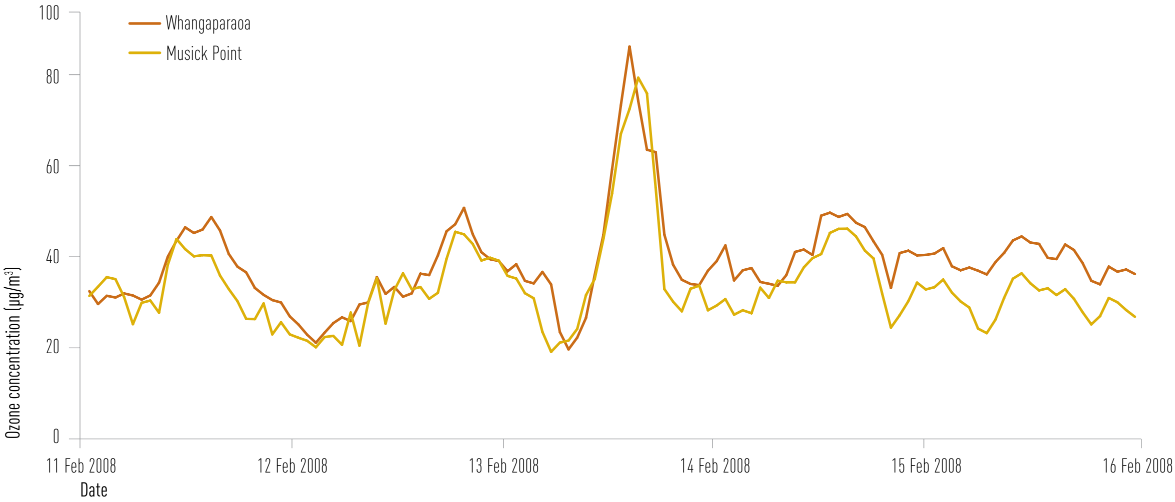

FIGURE 14 The 1-hour average ozone concentrations in the Auckland region, with high concentrations at Musick Point and Whangaparaoa 11-16 February 2008. (Source: ARC).

Exceedences of standards and guidelines

Exceedences of the PM_{10} and $PM_{2.5}$ particulate standards and guidelines have occurred in the Auckland region due to:

- → vehicle emissions
- → domestic fires
- → road works
- → special events (e.g. Guy Fawkes, Christmas in the Park, rural burning of onion skins)
- → natural sources.

Exceedences at the peak traffic monitoring sites located at Khyber Pass Road and Queen Street are due usually to vehicle emissions, while exceedences at other sites may be due mostly to domestic fires (or a combination of both). Domestic fires are the usual cause of PM_{10} and $PM_{2.5}$ particulate exceedences during winter.

NO_2 exceedences at monitoring sites located close to busy roadsides are due to motor vehicle emissions. The number of exceedences of air quality standards and guidelines has decreased at Khyber Pass Road and Queen Street in recent years, probably due to localised changes in traffic flows and fleet composition.

Emissions of PM_{10} and $PM_{2.5}$ particulates and NO_2 all need to be substantially reduced, particularly those from motor vehicles and domestic fires, in order to meet the air quality standards and guidelines.

Guidelines for other contaminants have also been exceeded occasionally in the Auckland region. For example, two exceedences of the air quality guideline were recorded at Musick Point in 2002 and all of the air quality monitoring sites have recorded ozone peaks that are close to exceedence levels.

Benzene levels have exceeded the annual guideline in the past but are lower at present due to improved fuel quality as a result of government regulations.

Over the past ten years there has been a significant trend showing a reduction in the number of CO exceedences, largely as a result of improvements in vehicle technology. Trends for other pollutants are less apparent and are likely to mirror the weather conditions of the Auckland region, rather than any changes in emissions.

The number of exceedences in any one year depends on the pollutant sources and the weather. When there is a lot of wind or rain, pollution levels are frequently lower compared to it is calm and fine weather.

Indicator 8: Number of exceedences of standards and guidelines

Air in the Auckland region frequently exceeds the standards and guidelines for PM_{10} and $PM_{2.5}$ particulates and NO_2 (Figure 15 and Table 1).

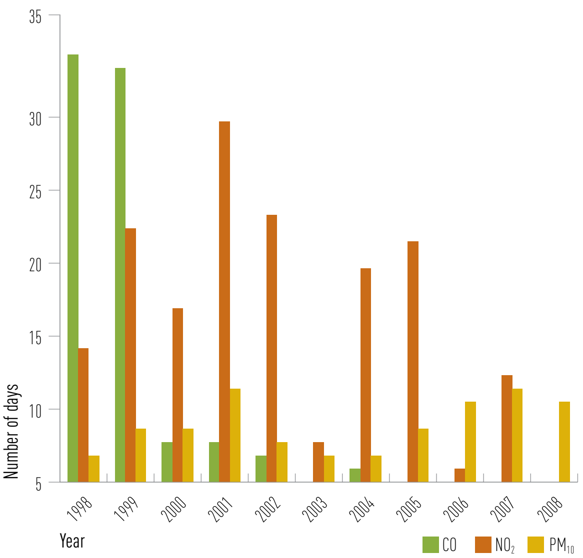

FIGURE 15 The number of days on which the air quality standards have been exceeded 1998-2008. (Source: ARC).

4.1

Air

TABLE 1 The number of days on which the air quality standards and guidelines have been exceeded* 1998-2008. (Source: ARC).

Year	Carbon monoxide		Nitrogen dioxide		PM_{10} **	$PM_{2.5}$ **	Total ***
	1 hour	8 hour	1 hour	24 hour	24 hour	24 hour	
1998	0	32	10	18	2	6	53
1999	1	31	19	15	4	3	57
2000	0	3	13	21	4	3	33
2001	0	3	27	18	7	4	46
2002	0	2	20	21	3	1	36
2003	0	0	3	6	2	6	15
2004	0	1	16	20	2	5	37
2005	0	0	18	16	4	2	31
2006	0	0	1	0	6	5	8
2007	0	0	8	0	7	9	21
2008	0	0	0	0	6	5	8

* An exceedence day of the ozone guideline was recorded in 2002.
** PM_{10} or $PM_{2.5}$ at some sites were sampled on every third day, therefore, the actual number of their exceedence days could be up to three times higher.
*** Total may not be the sum of individual pollutants as the exceedence days may overlap.

Visibility

Visibility is a measure of how far the human eye can see through the air.

Air pollution can lead to poor visibility, therefore visibility is widely used to indicate the air quality and amenity value.

Photographs of the Auckland skyline provide a useful indication of the amount of discolouration of the air and a rough indication of air clarity. The following photographs compare the Auckland skyline on a clear and a polluted day.

Figure 16 The Auckland skyline on a clear day, 22 December 2006. (Source: ARC).

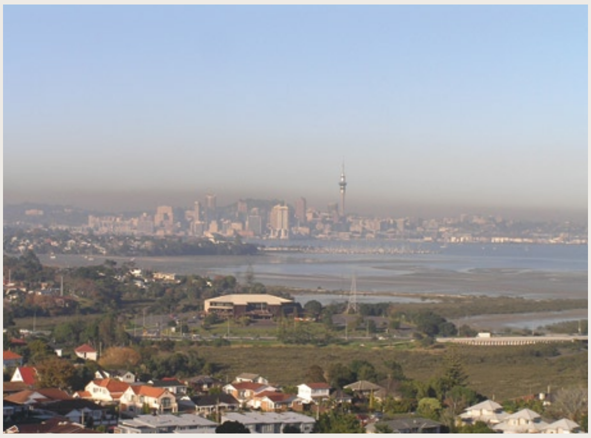

Figure 17 The Auckland skyline on a hazy day, 3 June 2009. (Source: ARC).

During the winter months, usually between May and October, a brown haze caused by air pollution can form over Auckland and reduce visibility. It usually disappears by about 1pm but occasionally lasts all day. The frequency of these brown hazes depends on pollutant sources and weather conditions.

Indicator 9: Annual number of brown haze days

Auckland experiences degraded visibility from air pollution for roughly 30 days per year. Between 2001 and 2006, the number of brown haze days ranged from 16 days in 2006 to 47 days in 2001.

Daily trends

Higher levels of air pollutants such as CO and NO_2 occur during rush hour because their main source is vehicle emissions (Figure 18).

Concentrations of fine particulates can be high in the winter evenings when people light domestic fires (Figure 19).

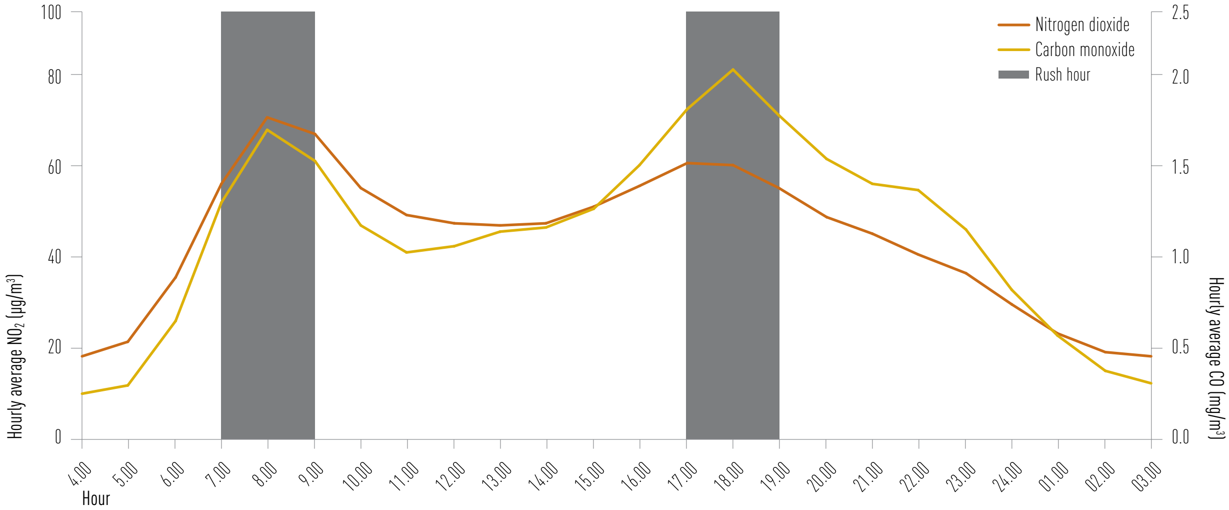

FIGURE 18 Average daily variation of CO and NO_2 concentrations at Khyber Pass Road, 2008. (Source: ARC).

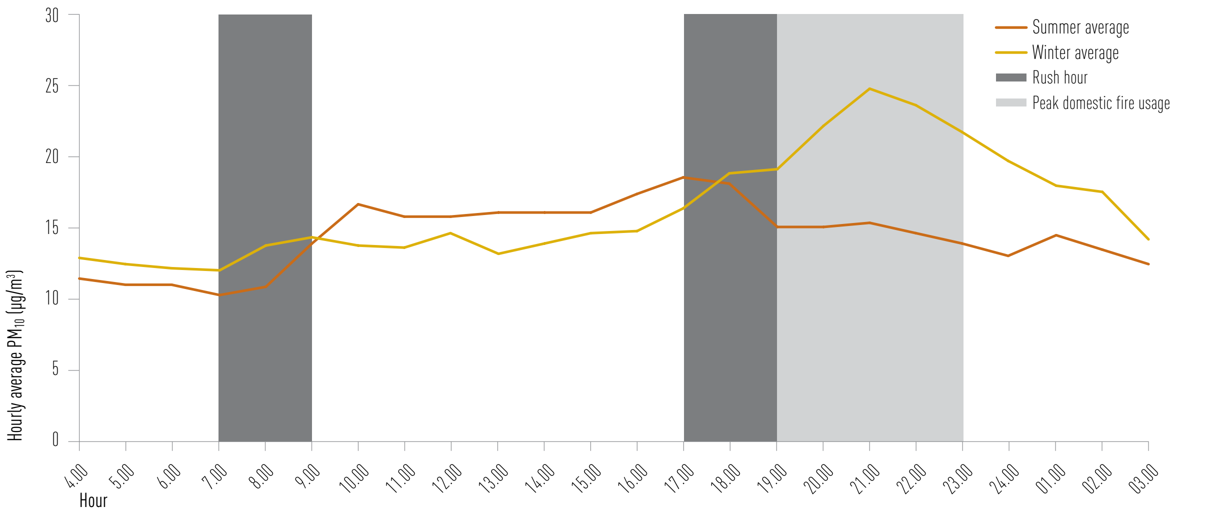

FIGURE 19 Average daily variation of PM_{10} concentrations at Khyber Pass Road, 2008. (Source: ARC).

Air

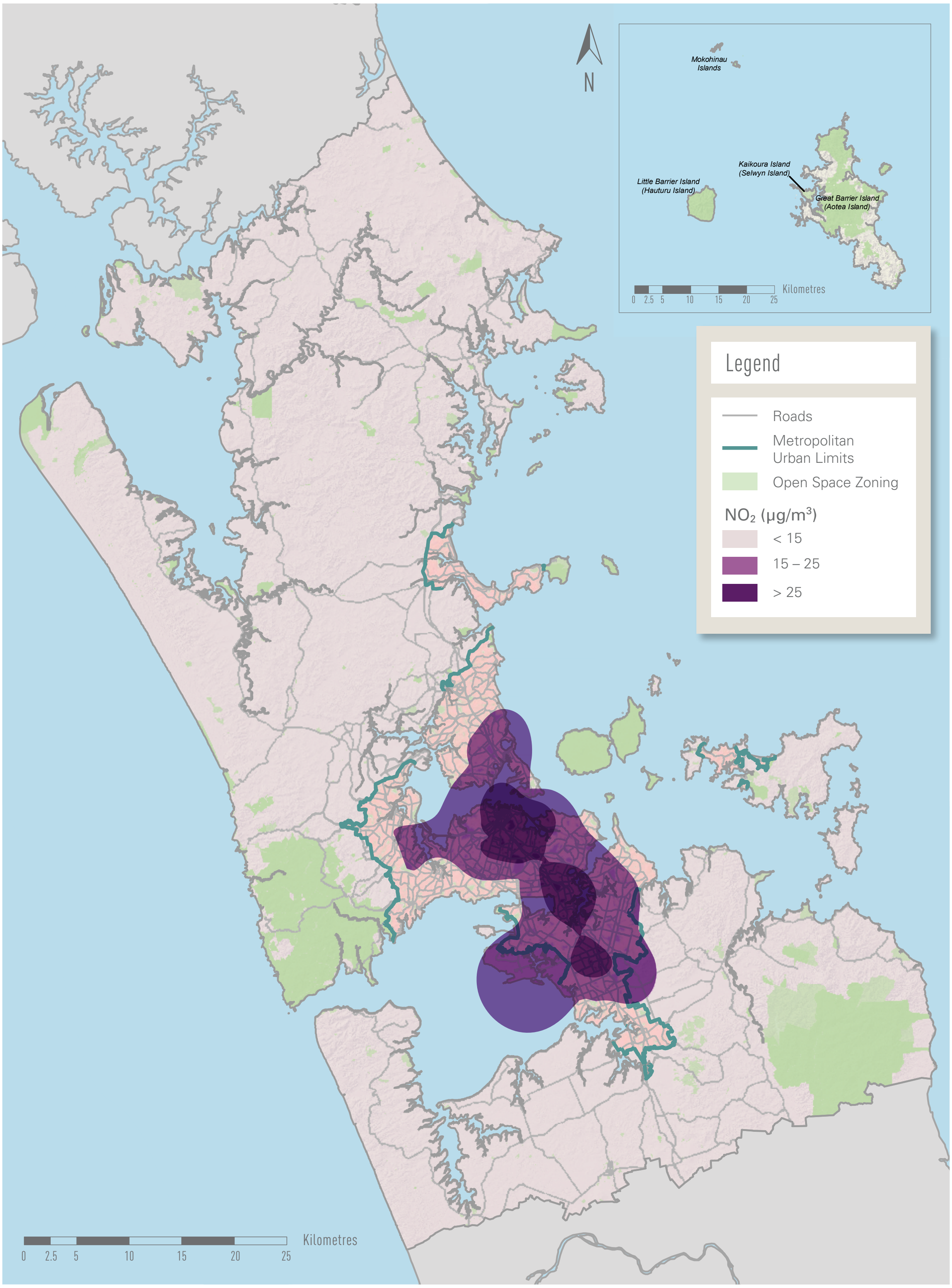

FIGURE 20 Spatial distribution of NO_2 concentrations in Auckland (three-month means) July-September 2006. (Source: ARC)

Stable weather conditions and low wind speeds can limit dispersal of air pollutants and contribute to high CO and NO_2 levels in the morning and high particulate levels at night.

Some sites, such as Khyber Pass Road, have similar traffic levels and pollutant emission levels through the day, although concentrations are usually lower at midday because there is more wind.

Spatial trends

Fine particulate (both PM_{10} and $PM_{2.5}$) levels at busy roadsides are higher on average than those at urban and residential sites due to emissions from motor vehicles, particularly diesel vehicles. However, because fine particulates stay suspended in the air for up to 30 days, their distribution is relatively uniform, with all the residential sites having an annual average within the range of 12 to 18 μg/m^3.

NO_2 and CO levels are highest at roadside sites because motor vehicle emissions are the major source of these air pollutants.

Benzene levels close to busy roadsides are significantly higher than levels in urban or industrial areas due to emissions from petrol vehicles and evaporation of petrol.

A comprehensive passive sampling programme was carried out at 78 locations around the Auckland region during the winter of 2006 to investigate where higher levels of NO_2 occur. The results showed that relatively high concentrations of NO_2 were broadly aligned along the south-east to north-west route of State Highway 1. The highest concentrations occurred in the CBD and Newmarket areas (Figure 20).

The high NO_2 concentrations found close to motorways generally decline as distance from the motorway increases, although the concentrations can remain elevated at distances of 300m from the motorway.

A passive sampling programme was carried out at 17 locations around the Auckland region during the winter of 2007 to investigate where higher levels of SO_2 occur.

The results showed elevated concentrations around the port of Auckland and the Penrose site compared with all the other sampling locations. This is due to the environmental impact of shipping and industrial activities. Ships use high sulphur fuels which emit SO_2 during combustion. An analysis of the composition of airborne particulates in the Auckland region also suggests that SO_2 emissions around the port of Auckland and Penrose contribute to the measured secondary sulphate (a fine particulate formed from chemical reactions in the air that involve SO_2).

Ozone concentrations tend to be the highest at sites away from the city because, in the time taken for the NO_2 emissions to react and form the ozone, these two pollutants have been shifted by the prevailing winds. Compared to other air pollutants, concentrations of ozone across the Auckland region tend to be more uniformly distributed because of the mixing and reaction times needed.

Implications of poor air quality

In the Auckland region, the levels of PM_{10} particulates are of the most concern and cause the worst health problems, particularly when they originate from diesel combustion. About 6000 tonnes of PM_{10} are emitted each year in the Auckland region. Annually about 50 per cent of the emissions in the region come from motor vehicle emissions, 40 per cent from domestic fires and 10 per cent from industry. This changes in winter when domestic fires account for 65 per cent, motor vehicles for 25 per cent and industry for 10 per cent of the overall PM_{10}

Estimates based on updates to the 2007 study on health and air pollution in New Zealand suggest that fine particulates contribute to more than 600 premature deaths each year in the Auckland region.

However, the overall health impact is much greater. One in six adult New Zealanders and 27 per cent of six to seven year olds suffer from asthma. Fine particulates and NO_2 are not a proven cause of asthma but are known to be an irritant for people with asthma, which leads to an increased likelihood and severity of asthma attacks.

Children are very sensitive to air pollution because their lungs are not fully developed until they are about six years old. They breathe 50 per cent more air than adults (by body weight), their immune system is immature and they have a higher exposure to air pollutants as they spend more time outside and exercising.

Table 2 shows that the estimated 'restricted activity days' per year include 1.1 million days when asthmatics or those with heart or lung disease cannot function normally.

TABLE 2 Impacts of air pollution in the Auckland region. (Source: ARC, based on Fisher et al. (2007) but updated with Statistics New Zealand 2006 census data).

Indicator	Auckland region	New Zealand
Premature fatalities	> 600	> 1,400
Restricted activity days	> 1,100,000	> 2,400,000
Health costs	> $547 million	> $1.14 billion

The figures in Table 2 are based on effects on New Zealanders over 30 years of age and do not account for the effects of air pollution on children's mortality and morbidity, such as impaired lung development and asthma.

The total economic cost of air pollution in New Zealand, including health costs from both premature deaths and adverse health impacts, is estimated to be $1.3 billion per year.

Although most of the health problems are associated with fine particulates, other pollutants such as NO_2, CO and VOCs also cause problems.

4.1

Air

Conclusions on the state of the air

Air quality in the Auckland region is generally good in comparison to many cities in the world.

Motor vehicles are the main cause of the air pollution problem in the Auckland region. The second highest source of air pollution is domestic fires, which in winter produce 65 per cent of the PM_{10}.

Policies and regulations for cleaner fuel have significantly improved the air quality in the Auckland region. Lead levels in petrol were reduced after 1986 and were eliminated in 1996. As a result, lead levels in the air have decreased dramatically, particularly at roadside sites, and are now well below the air quality guideline. Sulphur dioxide (SO_2) concentrations have also fallen substantially in response to the dramatic reduction in permitted sulphur levels in diesel and petrol since early 2000. The reduced benzene levels that are permitted in petrol have also resulted in lower benzene concentrations in the air since early 2000, although it is not yet clear whether this reduction will be enough to meet the new 2010 guideline.

Vehicle technology has improved significantly over the years. Exhaust emissions standards have been introduced recently for new and used vehicles entering New Zealand and these standards get progressively tighter over time. As a result, there has been a gradual reduction in the concentrations of carbon monoxide (CO) and fine particulates emitted from motor vehicles.

However, the improvements in air pollution that have resulted from better fuel, new vehicle technology and tighter emissions standards have been offset by the growth in vehicle numbers, kilometres travelled and the ageing vehicle fleet.

Although the use of solid fuels for domestic fires is declining slowly, the population is growing. Consequently, the levels of PM_{10} and $PM_{2.5}$ particulates have levelled off in recent years but are still at levels that can cause significant adverse health effects. Concentrations of fine particulates and nitrogen dioxide (NO_2) in the region currently exceed air quality standards and guidelines. Emissions of fine particulates and nitrogen oxides (NO_x) from motor vehicles and domestic fires need to be reduced in order to meet the standards and guidelines and to protect human health.

Annual average ozone levels in the region are mainly determined by the natural background levels. As a result, annual average ozone levels have changed little over the past ten years. However, there is continuing evidence of photochemical reactions occurring in the region and elevated levels of ozone could occur during summer, leading to exceedences of the standards and guidelines.

The average NO_2 concentrations are strongly affected by the availability of oxidants, which have changed little over the years. Subsequently, average NO_2 concentrations have not shown significant changes within the region, although they are increasing slowly at some sites and have decreased at the peak traffic sites. These trends are probably due to changes in local traffic emissions, with lower traffic volumes and fewer heavy-duty vehicles at the peak sites.

Air pollution costs the region at least $547m each year in health costs, therefore the potential benefit of reducing the levels of pollutant emissions from the Auckland vehicle fleet and domestic fires would be significant for the region, both in terms of improved health and in the associated reduced costs.

The ARC is close to meeting the ambient standard values, but these do not ensure protection of human health. The stated health effects and costs are based on current long-term exposure of the population.

The World Health Organisation Guideline: Global Update 2005 (pages 7 and 9) states,

"... as research has not identified thresholds below which adverse effects do not occur, it must be stressed that the guideline values provided here cannot fully protect human health.

Rather than standard-setting, process needs to aim at achieving the lowest concentrations possible in the context of local constraints ..."

Case Study: On-road vehicle emissions – monitoring to support policy

Vehicle emissions are a major contributor to air pollution in Auckland's urban area. Fortunately, improvements have been made to vehicle emission technologies and fuel quality in recent years. This means that, in theory, as old vehicles leave the fleet and are replaced by new ones, the amount of pollution from vehicles overall should be reducing – but are we seeing this in practice? Understanding how emissions are changing over time highlights whether additional strategies and policies might be required to meet reduction targets.

This case study describes how our measurement campaigns for real-world emissions have been used both to influence the development of policy and to see whether that policy is having an effect.

How did we measure on-road vehicle emissions?

To date, three on-road studies have investigated emissions from the Auckland fleet – initially in 2003, then later in 2005 and 2009[1]. Using a technique known as remote sensing (Figure 1) tailpipe emissions were sampled for carbon monoxide (CO), nitric oxide (NO), unburned hydrocarbons (HC) and opacity (smokiness) as an indicator of fine particulates. To find out which factors influenced emissions most, particularly for those vehicles known as 'gross emitters' (the most polluting vehicles in the fleet), the measurements were matched to vehicle characteristics such as mileage, fuel type and year of manufacture.

FIGURE 1 On road monitoring equipment and smart sign in the background (Source: NIWA). Emissions are calculated by measuring the changes in (UV and IR) light as it passes through the emissions from a vehicle's tailpipe.

A smart sign was also erected in 2003 and 2005 (Figure 2) to raise driver awareness and give motorists an immediate indication of their vehicle's emissions – good, fair or poor.

In 2005, remote sensing was combined with a broader education initiative known as the 'Big Clean Up – Tune Your Car' campaign, which used billboards and radio advertising to encourage drivers to get their vehicles checked and regularly serviced. Drivers were offered discounts at certain garages.

FIGURE 2 Smart sign display when a vehicle passes by with high emissions (Source: NIWA).

[1] The ARC funded on-road testing in April 2003 and was involved in jointly-funded programmes with NIWA and NZTA in May/June 2005 and May 2009.

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What have the measurements told us?

- Most vehicles (83 per cent) have good emissions
- 10 per cent of vehicles create 50 per cent of the air pollution
- New vehicles generally emit less pollution than old vehicles
- Older vehicles that are well-maintained produce less pollution than poorly maintained new vehicles
- Diesel vehicles produce higher emissions of smoke, but petrol vehicles are worse for NO and CO emissions
- Japanese used imports generally discharge less pollution than New Zealand new vehicles of the same age.

TABLE 1 Emissions from vehicles for 2003, 2005 and 2009 (Source: ARC/NIWA).

Pollutant	Average concentration in exhaust plume					
	Petrol vehicles			Diesel vehicles		
	2003	2005	2009	2003	2005	2009
Carbon monoxide (%)	0.84	0.65	0.46	0.12	0.05	0.03
Nitric oxide (ppm)	703	649	494	415	519	476
Hydrocarbons (ppm)	354	245	149	162	108	97
Smoke (uV)	0.41	0.07	0.05	1.00	0.20	0.16

Looking at the trends in Table 1, vehicle emissions have shown the following improvements since 2003:

- Average emissions of CO, NO, HC and smoke from petrol vehicles have decreased
- Average emissions of CO, HC and smoke from diesel vehicles have decreased
- The trends for average emissions of NO from diesel vehicles are inconclusive.

Has this work helped to reduce vehicle emissions?

The results provide valuable information on the state of Auckland's fleet, and has been used by the ARC to encourage the government to take further action on addressing vehicle emissions. Recent legislative milestones include on-going fuel quality improvements, banning the tampering or removal of emissions control technologies and requiring both used and new vehicles entering the fleet to meet minimum emissions standards (discussed in more detail in Chapter 4). In addition, minimum emissions standards for buses used in public transport have been developed for Auckland and the rest of New Zealand.

Public awareness and education campaigns undertaken by the ARC and the Ministry of Transport have increased understanding of the harmful effects of vehicle emissions and have encouraged more drivers to correctly maintain their vehicles.

Data from remote sensing campaigns and information from the ARC air quality monitoring sites confirm that emissions from the vehicle fleet have indeed been reduced. We are currently trying to establish whether those reductions will be sufficient to meet air quality standards in future.

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