Our air 2024

Tō tātou hau takiwā

New Zealand's
Environmental Reporting Series

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Message to readers

Tēnā koutou katoa

Aotearoa New Zealand’s isolation in the Pacific Ocean and strong prevailing westerlies mean that our overall air quality is among the best in the world. Our large areas of clean air and smog-free skies provide many benefits for New Zealanders and are a major drawcard for international visitors.

Many monitoring sites across the country have shown improving air quality since the last *Our air* report, largely because emissions from transport and home heating have reduced. However, our air quality is not good everywhere. In cities and urban areas, where most of us live, air pollution is often above national standards and international guidelines. Some regions are worse affected than others, and the level of air pollution varies between seasons and times of day. This is important as it’s becoming clear that for most air pollutants, there are significant health impacts.

We are continually learning more about the effects of poor air quality on our health and environment, but we still need more and better data to inform high-quality decision making. Most of Aotearoa New Zealand’s monitoring network is located in urban areas, and as a result we know little about the effects of air pollution on our native species and ecosystems. We also lack sufficient data on some emerging pollutants, as well as on other aspects of air quality such as pollen, light pollution and noise pollution.

A strong evidence base is crucial for informing decisions about the natural and built environments and ensuring we continue to meet the social and economic needs of people, now and in the future. This report provides valuable context on the challenges we face with air quality in Aotearoa, as well as where things are getting better.

James Palmer
Secretary for the Environment

Mark Sowden
Government Statistician

Introduction

The air we breathe plays an important role in both our health and our quality of life. In Aotearoa New Zealand, air quality is generally good compared with many other countries. Many monitoring sites across our country have shown improvements in recent years. But air pollution remains an important public health issue. At particular times and places, and under certain conditions, our air quality can result in harm.

While we cannot see the air, its presence is made visible by its impacts on people and the environment. If the air is not healthy, we will see impacts on human and environmental health and our connections to the environment (see *Environment Aotearoa 2022*).

In te reo Māori (Māori language), the word hau can mean air or wind, and can also refer to the vital essence or vitality of a person, place or object. The origins of these words recognise that our hauora (health) and the health of hau takiwā (air) are interlinked. In te ao Māori (Māori world view), the human and non-human worlds are indivisible. All things are interconnected, and whakapapa (genealogy) relationships connect people with the environment, including the air, in a multitude of ways.

For many Māori, air is a taonga (treasure). This view is reflected in Māori creation stories where the separation of Ranginui (Sky Father) and Papatūānuku (Earth Mother) allowed light and air into the world. Light and air link all components of Earth and the atmosphere, and reflect cultural connections to te taiao (the environment).

Aspects of air quality that affect our lives include emissions of pollutants as well as light pollution, noise pollution, and odour. The main sources of air pollution in Aotearoa are transport and home heating. Other human activities including agriculture, construction, and industry also put pressure on our air quality through a range of air pollutants.

Some of the pressures on our air quality have been decreasing in recent years, with declining emissions of most pollutants. However, increasing urbanisation can mean that more people are at risk of exposure to polluted air.

What's changed since *Our air 2021*

Since *Our air 2021* our understanding of the health impacts of fine particulate matter ($PM_{2.5}$) and nitrogen dioxide has increased. As a result, concentrations of $PM_{2.5}$ and nitrogen dioxide have been monitored at more sites, with implications for the way we produce and update environmental indicators. *Our air 2024* builds on updates of six air quality indicators, and reports for the first time on the indicator of health impacts of $PM_{2.5}$ and nitrogen dioxide.

Transport, in particular motor vehicle emissions, remain a large source of air pollutants, including $PM_{2.5}$ and nitrogen dioxide. Transport emissions were lower for all monitored pollutants except sulphur dioxide in 2019 than 2012. Motor vehicle engine and fuel improvements continue to contribute to reductions. This is despite increases in the total number of kilometres travelled in a year, vehicle fleet numbers, and proportion of diesel vehicles. In 2022 we reached the largest fleet size to date, with the largest percentage of diesel vehicles (21 percent).

Burning wood for home heating also continues to be a major source of $PM_{2.5}$. According to the 2018 Census data, fewer homes are burning wood for home heating, and the use of heat pumps continues to increase. There was a 32 percent increase in the sales of heat pump units from 2020 to 2021 and further increases in 2022 and 2023.

Particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide, and sulphur dioxide concentrations continue to improve at most monitoring sites. However, many sites have still been reaching levels above World Health Organisation (WHO) guidelines (see Guidelines and standards we report against).

Evidence in recent years has shown that air pollution has greater health impacts in Aotearoa than previously thought. The health impacts in this report are therefore much higher than those reported in *Our air 2021*, largely due to an increase in our understanding of nitrogen dioxide exposure. These impacts come with significant social costs, with these costs falling disproportionately on already disadvantaged communities. Our understanding of the health impacts of air pollution will improve as we monitor and investigate both existing and emerging pollutants.

About *Our air 2024*

Our air 2024 is the latest in a series of environmental reports produced by the Ministry for the Environment and Stats NZ. It is the fourth report in the series dedicated to our air, following the 2014, 2018 and 2021 reports. It is part of the third cycle of reports released under the Environmental Reporting Act 2015.

Our air 2024 builds on previous reporting and contributes further information while we progress the fundamental changes needed to improve the reporting system in line with recommendations from the Parliamentary Commissioner for the Environment (PCE) (PCE, 2019). The primary focus of this report is on updating recent indicators and scientific evidence about air. *Our air 2024* updates some of the indicators reported on in previous years and brings those indicators together with what we know from past reports and insights from the research literature.

Report structure

As required by the Environmental Reporting Act 2015, this report uses the concepts of pressure, state and impact to report on the environment and these concepts form the basis for the report's structure. The logic of the framework is that pressures can cause changes to the state of the environment, and these changes may have impacts on air and associated human values. The report also includes future outlook assessments. The evaluation of specific policies is out of scope for environmental reporting releases under the Environmental Reporting Act 2015, and therefore is not included here.

The data used in this report, some of which is monitored, and some of which is modelled, came from many sources including data from Crown research institutes and central and local government (see the Acknowledgements). This report uses modelling outputs from the Health and Air Pollution in New Zealand (HAPINZ) 3.0 study. Two sources have been used through the report:

- the Human health impacts of $PM_{2.5}$ and NO_2 indicator from Stats NZ using data from 2016
- a more recent study (Metcalfe and Kuschel, 2023) commissioned by the Ministry of Health and Crown research institute ESR using data from 2019.

For the indicators related to our air and the date when each one was last updated, see the Stats NZ indicator web pages (see Environmental indicators). See appendix A for details of the monitoring sites presented in this report.

A 'body of evidence' approach provided further supporting information. This body of evidence includes peer-reviewed, published literature, as well as mātauranga Māori (Māori knowledge) and observational tools used to identify changes in our air. All data used in this report, including references to scientific literature, were corroborated and were checked for consistency with the original source. A team of analysts and scientists from within and outside the Ministry for the Environment and Stats NZ produced the report. In addition, a panel of independent experts reviewed it.

Guidelines and standards we report against

This report evaluates monitored data against two primary air quality standards or guidelines – one national and one international – to indicate potential impacts on human health.

Nationally, the Resource Management National Environmental Standards for Air Quality (NESAQ) Regulations 2004 set legally binding levels of air pollution that must not be exceeded.[1] The levels of these standards are set based on international research and guidelines available at the time (eg, the WHO guidelines – see below). Where no NESAQ standard exists, as is the case for fine particulate matter ($PM_{2.5}$), for example, the WHO guidelines can provide guidance directly.

In contrast to the NESAQ Regulations 2004, the *WHO Global Air Quality Guidelines (particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide)* (WHO, 2021) (WHO guidelines) are based on an evaluation of the most recent science on health impacts from air pollution and identify air pollution levels above which there are significant risks to human health. This is the only consideration used for setting the guideline levels, although the WHO guidelines also discuss how growing evidence indicates that for most pollutants there is no safe level. They are intended to inform air quality management but, as international guidelines, they are not legally binding. The WHO guideline values apply to the 99th percentile – that is, they allow three to four days above the guideline per year (WHO, 2021).

Table 1 summarises the guidelines and standards we report against from each of these sources.

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1 See https://www.legislation.govt.nz/regulation/public/2004/0309/latest/DLM286835.html.

Table 1: National Environmental Standards for Air Quality (NESAQ) and World Health Organization (WHO) air quality guidelines for particulate matter ($PM_{2.5}$, PM_{10}), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide

Air pollutant	NESAQ			WHO air quality guidelines	
	Time period	**Concentration**	**Number of exceedances allowed**	**Time period**	**Concentration**
Particulate matter (PM_{10})	24-hour	50 µg/m³	1 in a 12-month period	24-hour[a]	45 µg/m³
				Annual	15 µg/m³
Fine particulate matter ($PM_{2.5}$)	No standard	No standard	No standard	24-hour[a]	15 µg/m³
				Annual	5 µg/m³
Nitrogen dioxide (NO_2)	1-hour	200 µg/m³	9 in a 12-month period	24-hour[a]	25 µg/m³
				Annual	10 µg/m³
Sulphur dioxide (SO_2)	1-hour	350 µg/m³	9 in a 12-month period	24-hour[a]	40 µg/m³
	1-hour	570 µg/m³	None		
Ozone (O_3)	1-hour	150 µg/m³	None	8-hour[a]	100 µg/m³
				Peak season[b]	60 µg/m³
Carbon monoxide (CO)	8-hour	10 mg/m³	1 in a 12-month period	24-hour[a]	4 mg/m³

Note

a. 99th percentile (ie, 3–4 exceedance days per year).

b. Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

µg/m³: micrograms per cubic metre.

mg/m³: milligrams per cubic metre.

Our air 2024

Across Aotearoa New Zealand as a whole, air quality is good compared to many other countries. However, poor air quality exists at particular places and times which has negative health impacts for people living there.

Air quality is improving in most places where it is monitored.

87%

of NZTA sites had **improving NO_2 concentrations** between 2014 and 2023.

75%

of sites had **improving $PM_{2.5}$ concentrations** between 2016 and 2023.

Particulate matter and nitrogen dioxide (NO_2) are key pollutants that contribute to poor air quality.

39% of emissions of nitrogen oxides (NO_x) were from **road vehicles** in 2019.

30% of emissions of fine particulate matter ($PM_{2.5}$) were from **home heating** in 2019.

Despite improvements in air quality at monitored sites, our growing understanding of health impacts shows that most air pollutants have no safe level.

Modelling indicates

3,239

premature adult deaths were associated with air pollution in 2019.

This was almost 10% of total deaths in Aotearoa.

Modelling indicates in 2019 the annual social cost of air pollution was estimated at

$15.3 billion.

69% of costs attributed to motor vehicles emissions.

Pressures on our air

Human activities and natural phenomena affect the quality of the air we breathe. We are a remote island nation far from sources of pollution in other countries, and so almost all our air pollution is generated locally. Home heating and transport are major human sources of air pollution in Aotearoa. Other contributing human activities are agriculture, construction and industry. Natural sources can also affect air quality, such as where small particles of salt from sea spray are suspended in the air.

Pressures on air quality vary across Aotearoa. For example, air pollution is greater in urban areas with a lot of traffic or in areas where more people use wood burners to heat their homes. The time of day or year can also make a difference. For instance, more people use wood burners in the evening and in winter. Another factor affecting the level of air pollution is the environment into which we emit pollutants: local geography and weather patterns influence how much pollutants either disperse or build up. All these variables influence air quality and, combined with how close we are and our level of exposure, impact how much pollution we breathe in.

Pollutant emissions are not the only influences on the quality of the air we experience. Light, noise and odour pollution contribute, putting pressure on our health, quality of life and connection with the wider environment.

This section looks in more detail at the diverse factors that influence our air quality.

Air pollutants can be either gases or particulate matter

- **Particulate matter (PM)** refers to tiny solid particles and liquid droplets suspended in the air. It can include substances such as heavy metals and microplastics (Fan et al, 2022; Semadeni-Davies et al, 2021). In Aotearoa, we measure two categories of particulate matter. PM_{10} refers to airborne particles that are less than 10 micrometres in diameter, while $PM_{2.5}$ is fine particulate matter, a subset of PM_{10}, referring to airborne particles less than 2.5 micrometres in diameter (LAWA, 2023).
- **Gas pollutants** are potentially harmful substances that exist as gases in the air. Many gas pollutants are often present in our air. Air quality standards in Aotearoa require monitoring of four gas pollutants: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and ground-level ozone (O_3) (LAWA, 2021).
- Pollutants emitted directly into the air are known as **primary pollutants**. Primary pollutants can then react in the air to form **secondary pollutants**. Some pollutants such as NO_2 and particulate matter can be both primary and secondary pollutants, as they can be emitted directly and also produced from the reaction of other pollutants in the air.

- Data on NO_2 emissions are grouped with a similar gas, nitric oxide (NO), and reported together as nitrogen oxides (NO_x), which are mainly emitted from the combustion of fossil fuels. Meanwhile, air quality monitoring sites report concentrations of specific pollutants in the air, including NO_2 (see State of our air section).
- In Aotearoa, total emissions of four out of five monitored pollutants ($PM_{2.5}$, NO_x, SO_2 and CO) were lower in 2019 than in 2012, but not PM_{10} (see Indicator: Air pollutant emissions).
- Ground-level ozone is a secondary pollutant that forms when NO_x combine with volatile organic compounds (generated by sources such as motor vehicles and industrial processes). This process requires sunlight, so concentrations are typically higher on hot sunny days and over warmer months (EPA, 2024).
- Reactions that produce secondary pollutants such as ozone and fine particulate matter speed up with higher temperatures, so could be affected by climate change (Coates et al, 2016; NIWA, nd; Silva et al, 2017).

Road transport continues to be the main source of nitrogen oxides in Aotearoa

- Transport emissions (including from road, aviation, shipping and rail) were lower in 2019 than in 2012 for all monitored pollutants except SO_2. Emissions of CO were down 47 percent (over 85,000 tonnes) and NO_x emissions were down 12 percent (over 8,000 tonnes) (see Indicator: Air pollutant emissions).
- Road vehicles contribute significantly to different types of air pollution. They were the largest source of NO_x (39 percent) in 2019, with the greatest contribution coming from diesel vehicles. Vehicle fuel combustion, particularly diesel, is also a significant source of $PM_{2.5}$, while wear of brake pads and tyres, and road surface dust are a major source of PM_{10} (LAWA, 2023; Semadeni-Davies et al, 2021; see Indicator: Air pollutant emissions).
- Vehicle ownership per person in Aotearoa is among the highest in the world. Vehicle numbers increased steadily over the decade to 2022, reaching the largest fleet size to date and the largest percentage of diesel vehicles (21 percent) in that year (MOT, nd-a).
- The total number of vehicle kilometres travelled in a year has increased over recent decades (MOT, 2022, nd-a).
- Air pollutants from motor vehicle exhaust emissions are reducing per kilometre travelled due to vehicle emissions standards, lower-emissions vehicles, and improvements in engine technology and fuel quality (Boamponsem et al, 2024; Metcalfe & Kuschel, 2022).
- Domestic shipping is a significant source of SO_2 (contributing 16 percent of all SO_2 emissions in 2019), although an international treaty now limits the level of sulphur in ship fuel (MOT, nd-b). However, most ships use relatively low-quality fuel so even modern engines produce high emissions of other pollutants. This affects coastal air quality nearby, such as the air close to Picton Harbour, the Port of Auckland and Hauraki Gulf shipping lanes (Boamponsem et al, 2024; NIWA, 2021; Talbot & Reid, 2017; Wilton, 2022) (see Indicator: Air pollutant emissions).

Burning wood for home heating continues to be a major source of $PM_{2.5}$ in Aotearoa

- In 2019, the majority of particulate matter emissions in the residential energy sector consisted of $PM_{2.5}$. The residential energy sector accounted for 30 percent of $PM_{2.5}$ and 41 percent of CO emissions, primarily from wood burning for home heating (see Indicator: Air pollutant emissions).

- Heat pumps and electric heaters were the most common types of heating used in houses in 2018. Over time, a smaller proportion of homes have been burning wood and coal, but wood burning remains a common heating method. In 2018 one-third of houses still relied on wood or pellet burners and the proportion was higher in the South Island. Just over 1 percent of houses used coal burners (EHINZ, 2015, 2020; Stats NZ, 2018).
- The use of wood and coal varies between regions due to their differences in regulations, winter conditions, the affordability of alternative heating options, and personal preferences (Boamponsem et al, 2024; Dale et al, 2021; EHINZ, 2020; Tunno et al, 2019).
- The level of pollutant emissions from wood burners depends on factors such as the type and age of the burners and the way they are used, as well as the moisture content of wood used (Coulson et al, 2015; Metcalfe et al, 2018). Efforts to improve wood burner efficiency and reduce emissions have reduced particulate matter emissions over time (MfE, 2020).
- Climate conditions and topography have a significant influence on air pollution from wood burners. For example, towns and cities in valleys and basins often face air quality problems during cooler months when home heating emissions are high. This occurs especially during calm weather and temperature inversions, where temperature increases with height, trapping pollutants close to the ground (Fiddes et al, 2016; see *Our air 2018*).

Human activities – including agriculture, construction and industry – emit a range of air pollutants

- Agriculture can be a major source of particulate matter, including through tillage, burning vegetation and crop harvesting. Intensification of livestock farming in recent decades continues to increase ammonia emissions from animal waste and fertiliser, which also contributes to secondary particulate matter (Metcalfe et al, 2022; Parfitt et al, 2012; see *Our air 2018*).
- Dust from unsealed roads was the largest source of PM_{10} (28 percent) in Aotearoa in 2019, less than 10 percent of which was $PM_{2.5}$ (see Indicator: Air pollutant emissions).
- Construction of infrastructure and buildings is a source of air pollutants, including particulate matter and NO_x. These pollutants come from processes such as using heavy machinery, transportation, combustion, demolition and removing earth (Cheriyan & Choi, 2020; Kunak, 2023; Yan et al, 2023).
- Air pollutants are released from burning materials such as wood, coal, gas and diesel for heating commercial and public buildings, as well as industrial processes. The air pollutants released include $PM_{2.5}$, PM_{10}, CO, SO_2, benzene and NO_2 (LAWA, nd).
- Burning coal was a major source of SO_2 emissions (41 percent), primarily from manufacturing, construction, and public electricity generation and heat production. Aluminium production (13 percent) was another significant source of SO_2 (see Indicator: Air pollutant emissions).
- Emissions from public electricity generation and heat production were lower in 2019 than in 2012 for all pollutants. Sulphur dioxide emissions were down 40 percent (over 5,000 tonnes) due to lower emissions from coal burning (see Indicator: Air pollutant emissions).
- Industrial sources of air pollution include steel mills, chemical plants and coal-fired power plants. The most common pollutants from such activities are SO_2, particulate matter and NO_x (EHINZ, nd).

Natural sources of particulate matter in Aotearoa are influenced by climate conditions including wind patterns

- Particulate matter can come from natural sources. Sea salt is the largest natural source of particulate matter in urban areas of Aotearoa and the level is strongly influenced by local wind direction and wind speed over the ocean (Boamponsem et al, 2024; Davy et al, 2024; Revell et al, 2024). In Auckland, sea salt is a major source of PM_{10} during summer because the wind conditions favour it (Boamponsem et al, 2024; Davy et al, 2017).
- Secondary sulphate, from oceans and volcanos, is the dominant natural component of secondary particulate matter (Davy et al, 2024).
- Volcanoes and geothermal activity are natural sources of ash and gases, including SO_2 (Stewart et al, 2022a). Eruptions can affect air quality over a large area. For example, SO_2 emissions from a future eruption in the Auckland area could lead to poor air quality under conditions that make dispersal more difficult (Brody-Heine et al, 2024).
- Natural sources of wind-blown dust include exposed topsoil, dry riverbeds, sand dunes, plant pollen and volcanic eruptions (Hawke's Bay Regional Council, nd; MfE, 2016; Otago Regional Council, 2023).

Aotearoa faces growing pressure from light and noise pollution, and some nuisance odours could intensify

- Compared with many countries, Aotearoa has a low level of light pollution. However, the use of artificial light at night has expanded and intensified over the past decades, putting increasing pressure on our natural environment (Cieraad & Farnworth, 2023).
- The transition from traditional incandescent bulbs to brighter light-emitting diodes (LEDs) in public lighting may have accelerated the trend towards increasing artificial light at night. As of January 2023, LEDs make up 84 percent of our public street lighting. However, the recent use of shielding is helping to limit this source of light pollution (Cieraad & Farnworth, 2023).
- The number of objects in outer space and orbiting Earth is also on the rise. These objects can be much brighter than other parts of the night sky, which puts people's ability to engage with it at risk (Lawrence et al, 2022; Zielinska-Dabkowska & Xavia, 2021). As of June 2024, there was reported to be over 10,000 active satellites orbiting Earth (Spacewatch, 2024). More than 100,000 satellites could orbit our planet by 2030 (Lawrence et al, 2022).
- Noise pollution is a growing environmental problem globally and has effects on our quality of life in Aotearoa. It particularly affects urban environments, given common sources of noise are transport, industry and commercial activities (Longley et al, 2014; Shepherd et al, 2016; UNEP, 2022; WHO, 2022). Urban noise and recreational sources of noise such as helicopters are expected to increase in the future due to urbanisation and increased human presence in the natural environment (Sordello et al, 2020; Watts et al, 2020).
- Undesirable odours contribute to concerns about air quality and can affect our quality of life. Odour emissions come from diverse natural sources (eg, geothermal activities) and human sources such as industry, wastewater treatment plants, and landfills (Bay of Plenty Regional Council, 2010; Bokowa et al, 2021; Environment Canterbury & Christchurch City Council, 2020; Waikato Regional Council, nd). Some nuisance odours, such as those from wastewater, are expected to intensify in parts of Aotearoa as our climate changes. These could contribute to loss of cultural identity and poorer mental health (Hughes et al, 2021).

State of our air

The most recent data show that, in relation to both particulate matter and gas pollutants, air quality is improving at many of the monitoring sites around Aotearoa. However, some sites show worsening quality, and even in many of the improving sites these pollutants are still at levels that are above (that is, worse than) WHO guidelines. More than that, for most air pollutants, no level may be safe, so while levels may be improving or within guidelines, reduced air quality can still impact people's health.

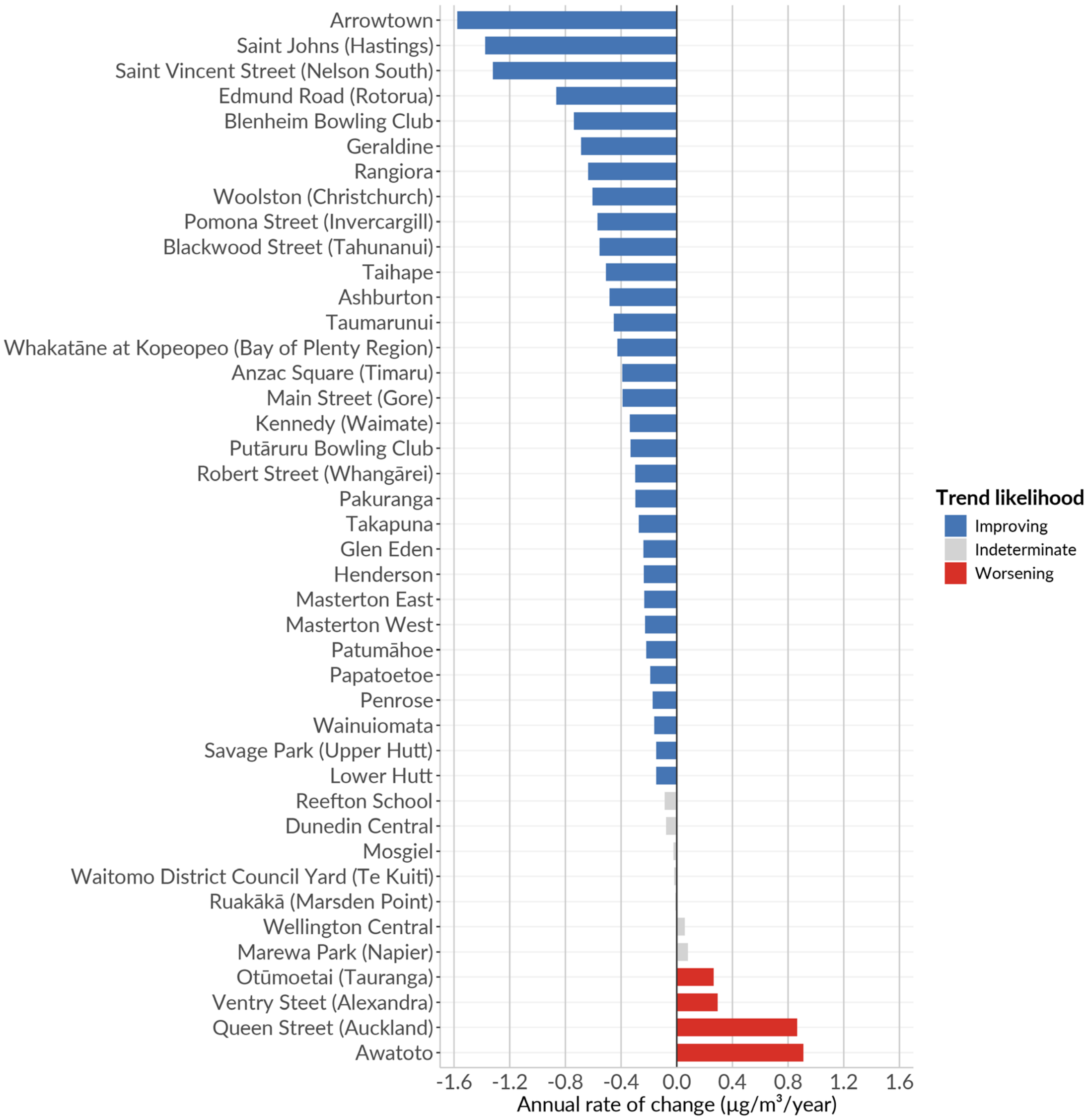
Monitoring of air quality generally takes place in areas where we expect air pollution to be highest and where people are exposed. Typically, then, it focuses on urban areas, where the major sources of air pollutants tend to be concentrated and where we therefore expect the impacts on people to be highest. Our monitoring network covers a large proportion of the population but a relatively small part of our land area. While this approach captures data relevant to many people at risk from poor air quality, we generally do not have air quality data for rural or less-populated areas of the country. For more information on monitoring sites presented in this report, see appendix A.

This section presents an overview of the most recent air quality data from monitoring sites across the country.

PM_{10} concentrations continue to improve at many sites, but 66 percent of sites were above the 24-hour WHO guideline between 2020 and 2023

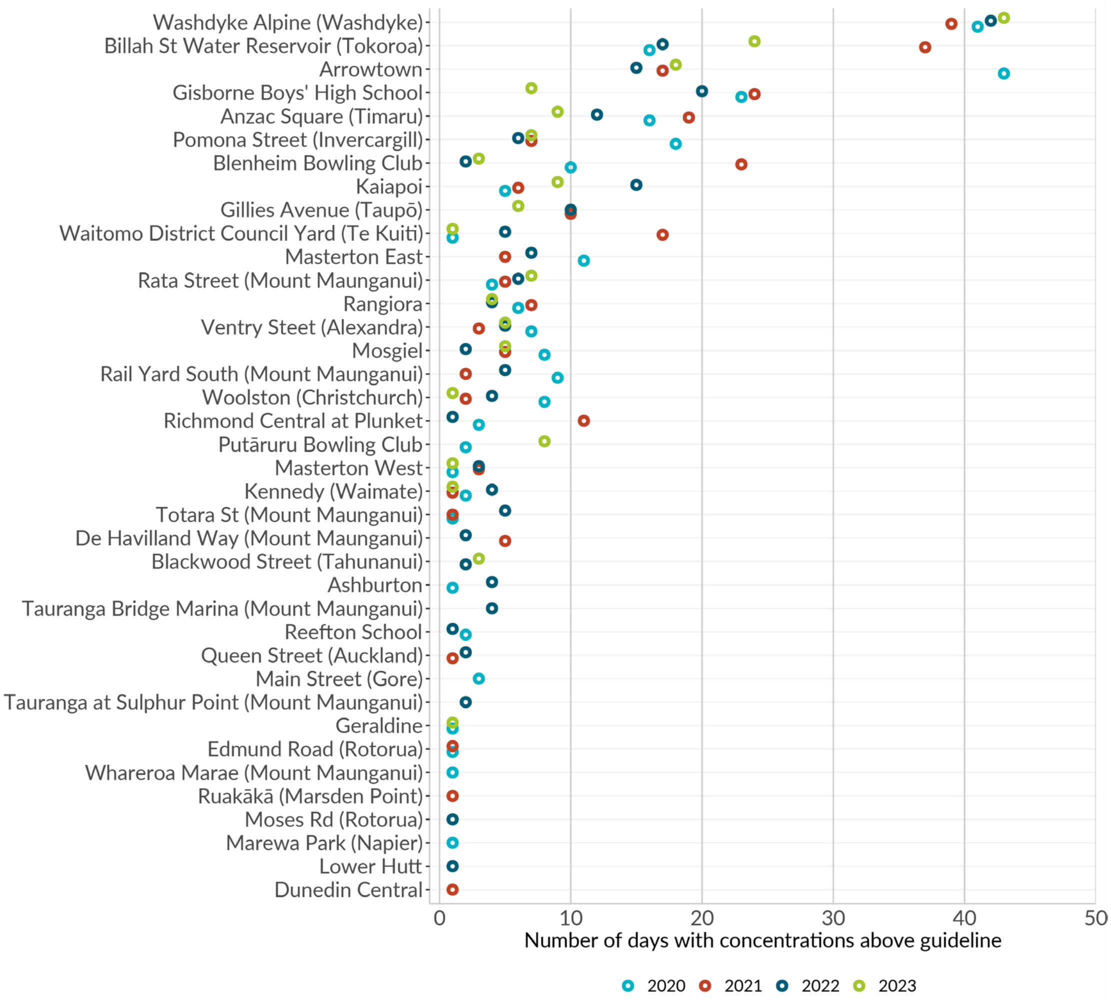
- Between 2016 and 2023, trends in annual average PM_{10} concentrations improved at 31 of 41 sites (73 percent) where trends could be assessed (see figure 1).
- Between 2020 and 2023, 24-hour PM_{10} measurements could be assessed at 58 sites across the country. At 21 of these 58 sites (36 percent), PM_{10} levels exceeded the 24-hour NESAQ standard for PM_{10} (50 micrograms per cubic metre ($\mu g/m^3$)) on two or more days in at least one of these years.
- Between 2020 and 2023, at least once every year 38 sites (66 percent) were above the more stringent WHO guideline based on a 24-hour average (45 $\mu g/m^3$) (see figure 2).
- Most concentrations above the NESAQ and WHO thresholds were at sites classified as residential, which is defined as a suburban area that has a relatively high population density but is not close to a busy road or industry. Washdyke Alpine, Arrowtown and SWDC Billah St Water Reservoir (Tokoroa) had the highest number of days on average per year above the thresholds.
- Twenty-seven of 58 sites (47 percent) were above the annual average WHO guideline for PM_{10} (15 $\mu g/m^3$) at least once between 2020 and 2023. Nine of these sites were above the guideline every year. Washdyke Alpine had the highest average concentration of PM_{10} during this period (see Indicator: PM_{10} concentrations (air quality): Data to 2023).

Figure 1: Trends in PM_{10} levels, by monitoring site in Aotearoa, 2016–23



Data source: Regional councils and unitary authorities

Figure 2: Days above 24-hour 2021 World Health Organization air quality guideline for PM_{10}, by monitoring site in Aotearoa, 2020–23

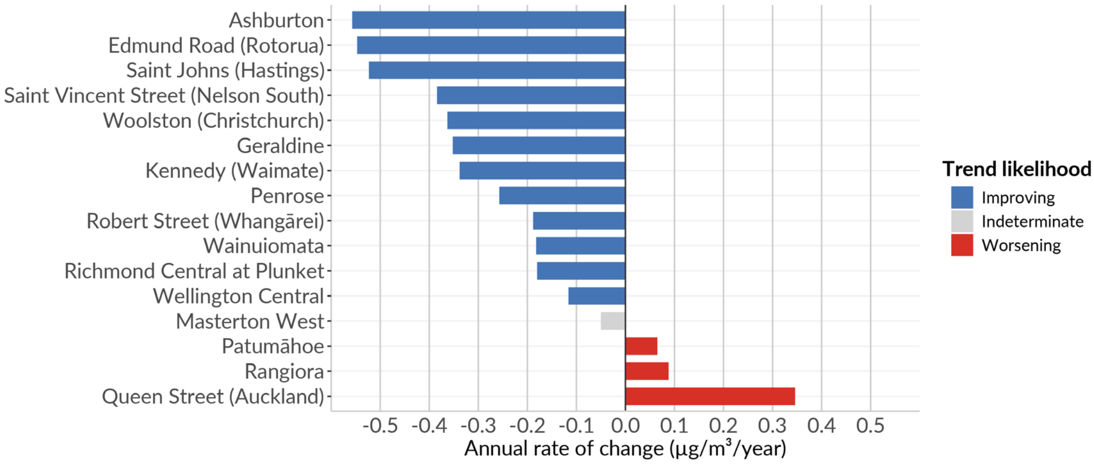


Data source: Regional councils and unitary authorities

$PM_{2.5}$ concentrations continue to improve at most sites, but all sites were above the 24-hour WHO guideline between 2020 and 2023

- Between 2016 and 2023, trends of annual average $PM_{2.5}$ concentrations improved at 12 of the 16 sites (75 percent) where trends could be assessed (see figure 3).
- Of the 31 sites that could be assessed, all sites were above the 24-hour average WHO guideline for $PM_{2.5}$ (15 µg/m^3) at least once every year between 2020 and 2023 (see figure 4). Most of these sites are classified as residential. The sites with the highest average number of days above the guideline per year during the same period were Reefton Area School (85 days), SWDC Billah St Water Reservoir (Tokoroa) (80 days) and Timaru Anzac Square (74 days).
- Out of 31 sites, 28 (90 percent) were above the annual average WHO guideline for $PM_{2.5}$ (5 µg/m^3) at least once between 2020 and 2023, and 18 sites were above the guideline every year (see Indicator: $PM_{2.5}$ concentrations (air quality): Data to 2023).

Figure 3: PM2.5 trends, by monitoring site in Aotearoa, 2016–23



Data source: Regional councils and unitary authorities

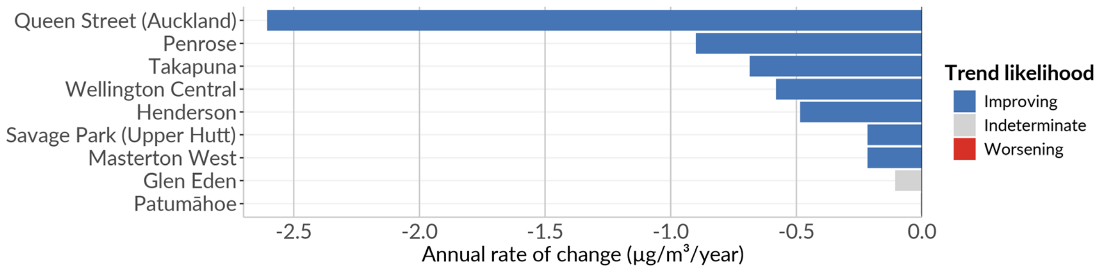
Figure 4: Days above 24-hour 2021 World Health Organization air quality guideline for PM2.5, by monitoring site, 2020–23

Data source: Regional councils and unitary authorities

Nitrogen dioxide concentrations continue to improve at most sites, but 60 percent of sites were above the 24-hour WHO guideline between 2020 and 2023

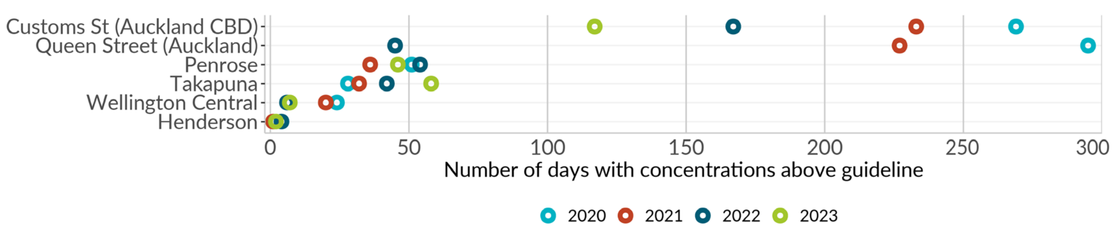
- Regional councils and unitary authorities, as well as the New Zealand Transport Agency|Waka Kotahi (NZTA), monitor NO_2 concentrations. Trends in annual average NO_2 concentrations improved at 87 percent of sites in the NZTA monitoring network (99 of 114) between 2014 and 2023, and worsened at no sites. Of the nine other sites that could be assessed, NO_2 concentrations improved at seven sites between 2016 and 2023, while the trend at the other two was indeterminate (see figure 5).
- Nitrogen dioxide concentrations at regional council and unitary authority monitoring sites were worst (highest) in winter (June, July, August) between 2020 and 2023.
- Of the 10 sites that could be assessed, one site, Customs Street (Auckland CBD), exceeded the one-hour NESAQ standard for NO_2 (200 µg/m^3) at least once between 2020 and 2023.
- Six of 10 sites (60 percent) were above the 24-hour WHO guideline for NO_2 (25 µg/m^3) between 2020 and 2023. Most of the monitoring sites exceeding the guideline were located near busy roads (see figure 6). The sites with the highest number of days above the guideline per year were Customs Street (Auckland CBD) (196 days), Queen Street (Auckland CBD) (189 days) and Penrose (47 days).
- Five of 10 sites were above the annual WHO guideline for NO_2 (10 µg/m^3) at least once between 2020 and 2023. Customs Street (Auckland CBD) had the highest annual average NO_2 concentration (31.5 µg/m^3). Three sites were above the guideline every year during this period: Customs Street (Auckland CBD), Penrose and Takapuna (see Indicator: Nitrogen dioxide concentrations: Data to 2023).

Figure 5: Nitrogen dioxide trends, by monitoring site in Aotearoa, 2016–23



Data source: Regional councils and unitary authorities

Figure 6: Days above 24-hour World Health Organization air quality guideline for nitrogen dioxide, by monitoring site in Aotearoa, 2020–23



Data source: Regional councils and unitary authorities

Sulphur dioxide concentrations continue to improve at most sites, but two of nine sites were above the 24-hour WHO guideline between 2020 and 2023

- Between 2016 and 2023, trends in annual average SO_2 concentrations improved at three of four sites where trends could be assessed.
- None of the nine sites that could be assessed exceeded the more stringent one-hour NESAQ lower standard for SO_2 (350 $\mu g/m^3$) or the upper standard (570 $\mu g/m^3$) between 2020 and 2023.
- Two sites were above the 24-hour WHO guideline for SO_2 (40 $\mu g/m^3$) between 2020 and 2023. These sites were classified as industrial (close to industry, including heavy commercial and processing factories). Of these two sites, Tauranga Bridge Marina (Mount Maunganui) exceeded the guideline for three days and Whareroa Marae (Mount Maunganui) exceeded it for one day on average per year.
- Sulphur dioxide concentrations were worst (highest) in February to April on average between 2020 and 2023 (see Indicator: Sulphur dioxide concentrations: Data to 2023).

Ground-level ozone continues to be within WHO guidelines at Patumāhoe (Auckland) and Wellington Central between 2020 and 2023

- Between 2016 and 2023, trends in annual average ground-level ozone concentrations decreased at Patumāhoe (Auckland) and increased at Wellington Central.
- Neither of the two monitored sites, Patumāhoe and Wellington Central, exceeded the one-hour average NESAQ standard for ground-level ozone (150 $\mu g/m^3$) between 2020 and 2023.
- These two sites were also below the eight-hour average WHO guideline for ground-level ozone (100 $\mu g/m^3$) and the peak season average (60 $\mu g/m^3$) between 2020 and 2023. The daily maximum eight-hour mean for the peak season in Patumāhoe was 57.1 $\mu g/m^3$ in 2023, falling just within the WHO guideline.
- Ground-level ozone concentrations were worst (highest) during the mid-afternoon at both sites between 2020 and 2023 (see Indicator: Ground-level ozone concentrations: Data to 2023).

Carbon monoxide concentrations continue to improve at one of three sites, with no sites above the WHO guidelines between 2020 and 2023

- Carbon monoxide is monitored at sites in the Wellington and Canterbury regions. Between 2016 and 2023, trends in annual average CO concentrations improved at one of the three sites where trends could be assessed. The trends at the other two sites were indeterminate.
- Peak concentrations of CO occurred during morning and evening hours, between 2020 and 2023.
- Carbon monoxide concentrations were worst (highest) in winter (June, July, August) across the monitored sites between 2020 and 2023.
- Of the four sites that could be assessed, no site exceeded the eight-hour average NESAQ standard for CO (10 milligrams per cubic metre (mg/m^3)) between 2020 and 2023.
- No site was above the one-hour average WHO guideline for CO (35 mg/m^3), or the 24-hour average (4 mg/m^3) between 2020 and 2023 (see Indicator: Carbon monoxide concentrations: Data to 2023).

Artificial light at night is increasing in both extent and brightness in Aotearoa, despite the growing number of certified dark sky places

- Between 2012 and 2021, the lit surface area of the country increased by 37.4 percent (from 3.0 percent to 4.2 percent), even though 95 percent of the country had no direct emissions of artificial light at night. The expansion of artificial light at night was concentrated in rural areas (Cieraad & Farnworth, 2023).
- Between 2012 and 2021, brightness intensity increased in 4,694 square kilometres of the country (median increase of 87 percent), while it decreased in 886 square kilometres of Aotearoa (median decrease of 33 percent). Most of the decreases were observed in urban centres, but their brightness levels remained high relative to levels in rural areas (Cieraad & Farnworth, 2023).
- Globally, the visibility of stars, which is an indicator of the level of light pollution, decreased between 7 and 10 percent per year from 2011 to 2022 (Kyba et al, 2023). The visibility of the night sky in Aotearoa appears to be following a similar trend. Satellites that are visible could soon outnumber the stars visible from Aotearoa and worldwide (Zielinska-Dabkowska & Xavia, 2021).
- Aotearoa has seven internationally certified dark sky places that preserve and protect dark sites. Two of these have been designated in the last two years: the Wairarapa Dark Sky Reserve (3,665 square kilometres) in 2023 and the Oxford Forest Conservation Area (113.5 square kilometres) in 2024 (DarkSky International, 2023).

Impacts on people and nature

Air quality directly affects our health and our quality of life. Air pollution plays a part in the premature deaths of thousands of New Zealanders every year. It contributes to hospitalisations and other health impacts, and results in billions of dollars in social costs. Our improved understanding of both the health effects and associated costs has helped us establish that these health and economic impacts are higher than previously reported.

The impacts of air pollution are not spread evenly across the population. Some groups are more likely to be affected, including Māori, Pacific peoples, children, the elderly and those living in the most deprived areas.

Air pollution also impacts the wider environment, as the air is interconnected with the land, freshwater and marine environments. While evidence is limited in Aotearoa, air pollutants as well as light pollution can cause harm to species and ecosystems.

This section looks at the health, economic and cultural impacts of different types of air pollution, and the evidence around how it impacts the environment more broadly.

The impacts of air pollution from motor vehicles are much higher than previously understood, causing health issues for thousands of people each year along with substantial social costs

- In 2019, human-made air pollution in the form of $PM_{2.5}$ and NO_2 was associated with 3,239 premature deaths, 13,237 hospitalisations, 12,653 cases of childhood asthma and over 1.771 million restricted activity days, when symptoms were sufficient to prevent usual activities, such as work or study (based on updated data from 2019 using the Health and Air Pollution New Zealand (HAPINZ) model, Metcalfe & Kuschel, 2023; see appendix A). For more information on how these air pollutants can lead to these health impacts, see *Our air 2018*.
- Premature deaths associated with air pollution represented almost ten percent of all 34,260 deaths in Aotearoa in 2019 (based on updated data from 2019 using the HAPINZ model, Metcalfe & Kuschel, 2023; Stats NZ, nd).
- Among all hospitalisations and premature deaths associated with air pollution, air pollution from motor vehicles alone accounted for 71 percent of the estimated total hospitalizations (nearly 9,400 cases) and 68 percent of total premature deaths (2,247 cases) in 2019 (based on updated data from 2019 using the HAPINZ model, Metcalfe & Kuschel, 2023).

- The estimated health impacts associated with human-made air pollution increased between 2006 and 2016 due to population growth and rising NO_2 exposure. This period saw a 28 percent increase in premature deaths and a 39 percent increase in hospitalisations attributed to motor vehicle emissions. Over the same period, health impacts from $PM_{2.5}$ exposure decreased, likely due to reduced emissions from domestic fires between 2006 and 2016 (see Indicator: Human health impacts of $PM_{2.5}$ and NO_2).
- Annual social costs from air pollution were estimated at $15.3 billion in 2019. Air pollution from motor vehicles accounted for 69 percent ($10.5 billion) of these costs (based on updated data from 2019 using the HAPINZ model, Metcalfe & Kuschel, 2023). Most of the remaining costs were attributed to domestic fires (Kuschel et al, 2022).
- The health impacts and social costs from human-made air pollution are higher than previously thought, based on a better understanding of the extensive health and social damage caused by motor vehicle pollution (Kuschel et al, 2022).
- Since the cost estimates presented in this report were calculated, NZTA has increased the statistical value of a human life by more than two-and-a-half times, from $4.5 million to $12.5 million (Kuschel et al, 2022; NZTA, 2024). This means that future estimates will be even higher than those reported here.
- Poor outdoor air quality can influence air quality indoors, where we spend most of our time. The extent to which this impact increases our exposure to air pollutants is highly variable, depending on factors such as geographic location and housing type (BRANZ, 2017; Longley, 2020).
- International research has linked other pollutants such as SO_2 and ground-level O_3 to negative health impacts but their impacts have not been well studied in Aotearoa (Kuschel, 2022; Orellano et al, 2021; see *Our air 2018*).

The burden of the health impacts of air pollution is greater for some areas and population groups than for others

- In 2016, 81 percent of the population of Aotearoa as a whole lived in areas where $PM_{2.5}$ levels were above the WHO guidelines, compared with 94 percent of Pacific peoples. Similarly, while 31 percent of the general population lived in areas where NO_2 levels were above the WHO guidelines, the percentage was much higher for Pacific peoples, at 54 percent (see Indicator: Human health impacts of $PM_{2.5}$ and NO_2).
- The health costs of air pollution are distributed unevenly across the country. The Auckland region, with its large population, experienced an estimated 939 premature deaths related to air pollution in 2016. Taking population size into account, Invercargill is the centre where air pollution had the highest impact in 2016 (219 premature deaths per 100,000 people aged 30+ years), followed by Christchurch (206 per 100,000) (see Indicator: Human health impacts of $PM_{2.5}$ and NO_2).
- Some groups are more vulnerable to the impacts of air pollution than others, including children, elderly, pregnant people, and people with pre-existing cardiovascular disease and/or respiratory disease (Peled, 2011). Māori and Pacific populations have a higher prevalence of underlying respiratory conditions (Hales et al, 2021).
- People who live in the most socio-economically deprived areas are exposed to more air pollution and suffer greater health impacts than those in the least deprived areas. For example, they experience higher rates of premature mortality and of respiratory and cardiovascular hospitalisation related to air pollution, and prevalence of asthma is higher among children in these areas (Telfar-Barnard & Zhang, 2021; Wickham et al., 2023).

- Children who are regularly exposed to traffic pollution, which is a major source of NO_2, are at higher risk of asthma, respiratory infections and organ damage. Among respiratory hospital admissions due to NO_2 exposure in 2016, 13 percent of the cases occurred in children aged 0 to 18 years presenting with asthma or wheeze (Kuschel et al, 2022).

Light, odour and noise pollution can be a major nuisance, cause risks to health and reduce quality of life

- Odours are the most common reason for air pollution complaints in Aotearoa (Bokowa et al, 2021). Unpleasant, persistent odours can reduce the enjoyment of the outdoors and quality of life, and cause sickness such as nausea and headaches for those who live and work around the source (Piccardo et al, 2022; Waikato Regional Council, nd; see *Our air 2018*).
- Exposure to artificial light at night has been linked to a range of health issues such as sleep disturbance, mood disorders, obesity and cancer (Bożejko et al, 2023; Wang et al, 2023). In 2014, 97 percent of our population lived under light-polluted skies (Cieraad & Farnworth, 2023).
- Long-term exposure to environmental noise affects daily life, reduces quality of life, can cause hearing issues, sleep disorders, anxiety and cardiovascular issues, and can affect mood. People living near motorways and busy roads are more likely to report instances of annoyance due to air and noise pollution (Shepherd et al, 2016).
- Air pollution, including odour, can affect people living near places of cultural significance. For example, air pollution at Whareroa Marae in Mount Maunganui is affecting the quality of life of those living near the marae, and community members are concerned about its effects on their cultural practices (Bay of Plenty Regional Council, nd; ESR, 2023).
- Our natural landscapes and a lack of pollution draw visitors to Aotearoa. Yet noise pollution can diminish the natural quiet and isolation of the wilderness experience that people value (Booth, 2022; One Picture, 2023; Watts et al, 2020).
- Engaging with the night sky is important for cultural practices, astrotourism and astronomical research but light pollution puts that at risk. The creation of dark sky reserves is helping to protect areas from light pollution. Dark sky reserves are popular tourist destinations and foster economic, social and cultural growth by preserving night sky views and providing educational opportunities (Patterson, 2023; South Wairarapa District Council, nd; Tapada et al, 2021; Zielinska-Dabkowska & Xavia, 2021).
- Many Māori cultural practices are based on astronomical knowledge, including those related to growing crops and fishing. Reduced visibility of the night sky forces changes to these practices (Hikuroa, 2017; Matamua, 2017; see *Environment Aotearoa 2022*).

Air and light pollution can harm the health of plants and animals, but we have limited data and evidence on these impacts in Aotearoa

- Air pollution particles, such as nitrogen and sulphur compounds, microplastics and trace metals, can settle from the air onto land and water bodies. This can affect the natural environment, cause damage to vegetation and impair the health of animals, though evidence for these impacts in Aotearoa is limited (Auckland Council, 2023; Aves et al, 2024; Parfitt et al, 2006; Wright et al, 2018).
- Particulate matter containing hazardous substances can bioaccumulate in organisms; that is, it builds up in animals that are at higher levels of the food chain. This can have toxic effects on animals, including taonga (treasured) species and those important to mahinga kai (traditional food gathering practices) (see *Our air 2018*).

- International research indicates that gaseous ammonia emissions, which lead nitrogen to be deposited in the environment, can harm biodiversity across land, freshwater and marine ecosystems. Whether such emissions create ecological risks in Aotearoa is unknown (Deshpande et al, 2024; Gauss et al, 2021; Liang et al, 2020; Parfitt et al, 2006).
- Global studies find that birds exposed to air pollution are often negatively impacted, including through respiratory problems, behaviour change and reproductive challenges (Barton et al, 2023; Sanderfoot & Holloway, 2017).
- Evidence of the impact of air pollution on plants and animals is limited. However, growing (while still limited) evidence indicates that light pollution negatively impacts some species in Aotearoa, including natives (Schofield, 2021; Cieraad & Farnworth, 2023; Sterup, 2024).
- Light pollution is particularly disturbing for native bats, wētā and seabirds, disrupting their mating and foraging habits. It can also affect the abundance, interactions and survival of a species (Cieraad & Farnworth, 2023; Falcón et al, 2020; McNaughton et al, 2022; Meeuwen-Dijkgraaf, 2021). These negative impacts could become worse as light pollution further reduces Aotearoa New Zealand's natural darkness (Cieraad & Farnworth, 2023).

The outlook for our air quality

In this section, we provide an assessment of how we think the air quality of Aotearoa may change out to 2050. Assessments are not statements of fact, but rather use evidence from peer-reviewed literature, statistical data, input from experts and other credible sources to indicate what may happen based on our current pathway and what we know now. For more information on the probabilistic and analytical language we use in these assessments, see appendix B.

To support outlook assessments in this report, we make the following set of baseline assumptions about the future across a spectrum of issues.

- Transport and home heating will continue to be the significant sources of air pollution in Aotearoa.
- Current international and national policies that seek to reduce air pollutant emissions – such as through standards and regulations for vehicle efficiency, wood burners, and shipping – will generally continue to follow trends of tightening over time.
- Technological advances in transport and electric heating will continue to improve efficiency and reduce costs for users, contributing to improvements in air quality.
- The population in Aotearoa will continue to grow and age. Much of the population increase will occur in our urban centres, which will in turn increase the number of people who are vulnerable and exposed to air pollution.
- Urban sprawl will continue in many urban centres and encourage private vehicle use.
- Our climate will continue to get warmer and our weather patterns will change, including with an increase in the frequency and severity of extreme weather events.
- The health impacts of poor air quality will continue to be spread unevenly across the country because of people's varying proximity to pollution sources and underlying health conditions.

Critical uncertainties remain, however. The direction of change is unclear in areas such as:

- long-term transport, housing and environmental policy
- trends in remote working
- the cost of electricity compared with the cost of solid-fuel heating
- step-changes in technological advances (eg, smart traffic systems) and their deployment (Munir et al, 2022)

- the pace of uptake of electric vehicles and active transport compared with the uptake of other modes.

In addition, evidence is insufficient to estimate how air pollution might impact public health in future (see the Knowledge gaps section).

Volcanic eruptions can affect air quality over a large area but, given the unpredictable nature of volcanic activity, we cannot reflect it in our assessments of how air quality might change in future. The same is true for other rapid onset events such as the COVID-19 pandemic, where our response to the event can have a substantial effect on air quality.

Although use of electric heating is likely to increase, the resulting improvement in air quality will be gradual because people will continue to use the existing stock of wood burners for many years (*moderate confidence*)

- A range of factors will continue to influence the use of wood and coal burning for home heating, which is a major source of $PM_{2.5}$ in Aotearoa. These factors include national policies, local regulations, winter conditions, housing type and quality, heating costs, technological advances and personal preferences. All these factors influence regional variations in exposure to $PM_{2.5}$ and will continue to do so (Boamponsem et al, 2024; Dale et al, 2021; EHINZ, 2020; Tunno et al, 2019).
- Heat pump use in Aotearoa has steadily increased over recent decades. There was a 32 percent increase in the sales of heat pump units from 2020 to 2021 and further increases in 2022 and 2023 (EECA, 2023; Genesis Energy, 2022). As the cost of electricity continues to increase (Commerce Commission, 2023), how that cost will compare with the cost of solid-fuel heating is a key uncertainty in predicting future uptake and use of heat pumps.
- People will continue to use wood burners that have already been installed in homes, but they could use them less over time. In Auckland, for example, solid-fuel fire use fell by 8.3 percent from 2012 to 2018 despite the city's growing population. The number of council-issued consents for new fireplaces in Auckland has been relatively stable since 2017 (Auckland Council, 2022).
- A substantial proportion (30 to 95 percent) of new housing stock in major urban centres is expected to be medium-high density and within existing urban footprints (PCE, 2023). For this reason, wood burners are less likely to be installed in new houses.
- Health impacts and social costs from $PM_{2.5}$ exposure decreased from 2006 to 2016, likely due to reduced emissions from domestic fires (Kuschel et al, 2022; see Indicator: Human health impacts of $PM_{2.5}$ and NO_2). These costs remained stable between 2016 and 2019. If the future trend is to increasingly prefer electric heating over solid-fuel heating, this would reduce health impacts. However, cumulative impacts to populations that have already been exposed to poor air quality will remain (Kim et al, 2020; Wolf et al, 2021; Zanobetti et al, 2024).
- By 2048, it is projected that people aged 65 years and over will make up 21–25 percent of our population (Stats NZ, 2022). Our ageing population will be more sensitive to air pollution because older people experience higher rates of chronic disease and comorbidities (EHINZ, 2020; Simoni et al, 2015). While lower solid-fuel use per person may help to reduce these health impacts, the overall reduction in health impacts may be limited by the effects of a growing and ageing population.

It’s highly likely that some natural particulate matter and aeroallergens will increase because of climate change *(moderate confidence)*

- Climate conditions influence the amount and types of particulate matter and gases in the air. Stable weather allows pollutants to accumulate, while wind and rain can disperse them (Talbot, 2019; UCAR Center for Science Education, nd; Waikato Regional Council, nd).
- As wind and rain patterns alter with climate change, they will affect the extent to which particulate matter disperses and is removed from the air. The north and east of Aotearoa are expected to become drier, and it is possible wind patterns will become more north-easterly in summer and westerlies more intense in winter (Bodeker et al, 2022; see *Our atmosphere and climate 2023*).
- Areas with drier conditions and more frequent drought could experience worsening air quality due to lower rainfall, higher fire risks and more windblown dust (Bolton, 2018). In Aotearoa, our changing climate is increasing the frequency and severity of wildfires and escalating their risks (Langer et al, 2021, 2022). In addition, Australian wildfires are already likely to have caused high levels of particulate matter in Aotearoa and are projected to become more frequent (Akdemir et al, 2022; Davy & Trompetter, 2022; Dowdy et al, 2019). Smoke from land fires has adverse physical and mental health effects, which children in general and people with asthma are particularly vulnerable to (Aguilera et al, 2021; McDonald et al, 2023).
- While projections involve some uncertainty, some projections show particulate matter from sea salt, and possibly dust transported from Australia could increase over Aotearoa due to climate change (Davy et al, 2024). Sea salt is expected to remain a significant contributor to particulate matter in coastal urban areas (Revell et al, 2024).
- It is highly unlikely that projected increases in natural particulates will alone cause exceedances of WHO guidelines or NESAQ standards. However, they will increase the baseline to which human sources are then added. Human activities will continue to be the largest source of air pollution and contribute the most to health impacts (Davy et al, 2024).
- An important emerging issue is the impact of climate change on pollen levels and the potential flow-on effects on health. Allergic rhinitis, or hay fever, is commonly caused by wind-borne pollen. It affects 35 to 40 percent of those aged 20–44 years in Aotearoa, and the number of people affected is increasing (Newnham, 2017, 2021).
- Warmer temperatures and higher carbon dioxide concentrations could increase the suitable growing areas of major pollen-producing species and enable plants to produce more pollen for longer (Damialis et al, 2021; Newnham, 2021). Recent monitoring and research in Aotearoa indicate that our high pollen count days have increased by 75 percent over the last three decades (RNZ, 2024).
- Thunderstorm asthma events occur when a thunderstorm coincides with a significant amount of pollen in the air and causes immediate asthma flare-ups. Emerging evidence indicates that thunderstorm asthma events are likely to increase because of climate change (D’Amato et al, 2021) and could possibly occur in Aotearoa (Asthma Foundation NZ, 2021; Sabih et al, 2020; Stewart et al, 2022b).
- An increasing prevalence of high pollen events is likely to increase social costs, but evidence to date is limited (Newnham, 2021).

It’s highly likely that air pollutants from vehicle exhaust emissions will continue to reduce, while other non-exhaust air pollutant emissions (tyre and road wear) will continue to increase. How air pollution from transport will evolve and impact public health is uncertain (moderate confidence)

- Air pollutants from vehicle fleet exhaust are declining in Aotearoa. It’s expected that this downward trend will continue through time as more people move to lower-emissions vehicles (Metcalfe & Kuschel, 2022; NZTA, 2023).
- The reduction in air pollutants from this source is likely to only gradually affect air quality because of the long length of time that vehicles are used for in New Zealand. The average age of our vehicle fleet was 14.6 years old in 2022, and older vehicles tend to be less efficient. A high proportion of less efficient vehicles will remain in the fleet for many years (EHINZ, 2021; MOT, nd-a).
- In 2021, 21 percent of vehicles were diesel-powered and they contribute disproportionately to the health impacts from air pollution (Metcalfe & Kuschel, 2023; MOT, 2022). The proportion of diesel vehicles has been growing steadily (EHINZ, 2023), and shows no sign of slowing in the near future.
- Used diesel vehicles entering the fleet in 2020 that did not meet new efficiency standards included 30 percent of diesel heavy commercial vehicles, 8 percent of diesel light commercial vehicles and 27 percent of diesel passenger cars (Metcalfe & Kuschel, 2022).
- How much electric vehicle uptake will affect the composition of the national fleet is uncertain. The uptake of electric vehicles has been shown to be sensitive to financial incentives and the availability of charging infrastructure (Sierzchula et al, 2014). Currently less than 2.5 percent of vehicles in Aotearoa are electric (EVDB, 2024).
- Non-exhaust pollution from vehicles includes brake and tyre wear, and road dust. Factors such as the national fleet size and vehicle kilometres travelled have a significant impact on non-exhaust pollution. Data show these factors are increasing and are expected to continue to do so out to 2050 (Davy & Trompetter, 2021; MOT, 2019; Semadeni-Davies et al, 2021). The composition of the fleet and how vehicles are used (such as in congested areas or rural open roads) are other influential factors in how much air pollution vehicles produce (Semadeni-Davies et al, 2021).
- Public transport use is projected to increase significantly, especially in Auckland. This will likely have only a marginal impact on air quality, as the overall share of trips made on public transport will remain small (below 10 percent; MOT, 2017).
- Road freight activity has grown year-on-year over the last 10 years (NZTA, 2022). This growth is anticipated to continue for at least the next three decades (MOT, 2020), which will contribute to both exhaust and non-exhaust air pollutants.
- Population growth and urbanisation contribute to increasing health impacts from exposure to air pollution (OECD, 2012). Moreover, cumulative effects of long-term exposure can remain even after air quality has improved (Kim et al, 2020; Krzyzanowski, 2023). Health impacts from transport are unlikely to reduce significantly even while some improvements to air quality are possible.

Knowledge gaps

Air pollution monitoring in Aotearoa focuses on a few pollutants in high-risk locations. While this approach gives us a good picture of the impacts on the most-affected populations, it results in significant gaps in our knowledge of the wider effects of air pollution on people and nature. We need our monitoring to reflect our emerging understanding of different types of pollutants and their impacts, and our projections need to take account of climate change and shifting demographics. Here we highlight five key knowledge gaps that became apparent when we were compiling this report.

Improving the spatial coverage of air quality monitoring

We generally only monitor air pollutants in areas that we know are at risk of poor air quality and where people are exposed. As a result, we do not have a full national picture of air quality in Aotearoa, and we may not be aware of poor air quality that could exist in some areas. Rural areas generally do not have air quality monitoring, and many communities in these areas also have less access to healthcare.

Important ways to improve monitoring include expanding NO_2 monitoring beyond main centres and continuing to expand the $PM_{2.5}$ monitoring network alongside PM_{10} monitoring. Other means of expanding air quality monitoring beyond current monitoring stations can also be investigated, including the use of satellite data, artificial intelligence-enabled forecasting and citizen science initiatives.

Increasing monitoring and research related to important and emerging pollutants and their impacts

Air quality monitoring in Aotearoa focuses on a few pollutants, which has given us a good understanding of their risks. This means that we lack a full understanding of air quality more generally, including localised and emerging pollutants, and what makes up our particulate matter. It is therefore likely that current and projected health impacts are underestimated. Improving our data and understanding in these areas can help with conducting risk assessments and quantifying associated costs. Important pollutants for which we have limited data include black carbon, airborne pollen, airborne microplastics, ultrafine particulate matter and persistent organic pollutants.

Two examples illustrate how such data can support our understanding of air pollution. First, black carbon is a type of particulate matter produced from combustion, and when monitored alongside other pollutants can provide data that help us to determine the sources of pollution. The WHO air quality guidelines recommend monitoring black carbon but currently this only occurs regularly in Aotearoa at three locations and we have no national monitoring standard.

Second, airborne pollen data for Aotearoa is fragmented and outdated. Given the prediction that the already significant health impacts of pollen in Aotearoa are predicted to increase with climate change, it is important to have comprehensive information on airborne pollen distribution.

Our understanding of the physical and biological mechanisms through which air pollution impacts human health is continually improving, but there remains more to learn. We have significant knowledge gaps around cumulative impacts and emerging pollutants, such as ultrafine particles, which are the subject of a growing area of research.

Modelling future human exposure to air pollution and associated health impacts

Projecting how air pollution might impact public health in future is important so that we can plan for and manage health impacts and associated social costs. A more strategic network for air quality monitoring could better support modelling and predictions of future air quality and associated health and economic impacts. Integrating air pollution data with climate change and extreme weather projections will strengthen our understanding of future air quality and health impacts. This knowledge can then help inform actions to address both air quality and climate change.

Strengthening te ao Māori perspectives and building a richer understanding of connections between domains

Our physical health is only one component of health. We lack data about how air quality is impacting cultural health, ways of life and traditional practices. Such gaps are particularly clear in relation to impacts on te ao Māori (Māori worldview). While some aspects of air quality disproportionately impact Māori, we have little documented evidence of impacts beyond physical health statistics. More generally, there is a lack of reporting on air quality issues from a Māori perspective.

Strengthening our understanding in this area requires enhancing our mātauranga Māori (Māori knowledge) evidence base and improving the resourcing of Māori research and access to ngā tohu o te taiao (environmental indicators) that draw from mātauranga Māori. In te ao Māori, te taiao (the environment) is seen as a whole rather than as separate parts. This perspective can be challenging for our national reporting system, which divides the environment into domains. But emphasising the connections between different parts of the environment helps build a richer understanding of the whole. For air, this could mean, for example, looking more closely at cumulative and legacy impacts of poor air quality on land and water, and how these impacts affect mahinga kai (traditional food gathering practices) and taonga (treasured) species and subsequently customary practices related to these species.

Understanding the impacts of air pollution on the natural environment

We have limited evidence of how air pollution is impacting the natural environment in Aotearoa. Non-populated locations are not monitored, so we lack understanding of the pollutants that our natural environment and many of our taonga species are being exposed to.

We can look to more well established and robust international studies to get an idea of impacts that could be happening in Aotearoa but are not documented. However, as we are a remote island nation with unique ecosystems, the shortage of specific evidence for Aotearoa makes it challenging to understand how our ecosystems might respond to air pollution and how sensitive they are to damage. For example, we do not monitor airborne nitrogen deposition in freshwater and terrestrial environments. We therefore have no information on the scale of this issue or how sensitive our taonga species and mahinga kai practices are to it.

Appendix A: Environmental indicators – site descriptions, body of evidence updates, and trend assessments

Site numbers and geographic spread of indicators updated for this report

Observed coarse particulate matter (PM_{10}) concentrations are reported from 58 monitoring sites across Aotearoa. Daily exceedances, along with 24-hour and annual average PM_{10}, are reported for state between 2020 and 2023. Annual average daily concentrations are also available. Annual trends are reported for 41 sites between 2016 and 2023.

Observed fine particulate matter ($PM_{2.5}$) concentrations are reported from 31 monitoring sites across Aotearoa. Annual average and 24-hour $PM_{2.5}$ are reported for state, as well as annual average daily concentrations, between 2020 and 2023. Annual trends are reported for 16 sites between 2016 and 2023.

Observed nitrogen dioxide (NO_2) concentrations are reported from two data sources: 10 monitoring sites from regional councils and unitary authorities, and 114 monitoring sites from NZTA's monitoring network. For the regional council and unitary authority monitoring network, state is monitored hourly at 10 sites, and is reported as 24-hour and annual averages against environmental standards between 2020 and 2023. Annual trends are reported for 9 sites between 2020 and 2023. For the NZTA network, annual trends are presented for 114 sites between 2014 and 2023.

Observed sulphur dioxide (SO_2) concentrations are reported from 8 monitoring sites across Aotearoa. Hourly exceedances and 24-hour SO_2 are reported against environmental standards between 2020 and 2023. Annual average daily concentrations are also reported. Annual trends are reported for 4 sites between 2016 and 2023.

Observed carbon monoxide (CO) concentrations are reported from 12 monitoring sites across the Auckland and Greater Wellington regions. State is reported at 4 sites between 2020 and 2023, and trends across 3 sites for the period between 2016 and 2023.

Observed ground-level ozone (O_3) concentrations are reported from 2 monitoring sites: Patumāhoe and Wellington Central. State is monitored hourly, and reported as eight-hour averages against environmental standards between 2020 and 2023. Eight-year trends from 2016 to 2023 are reported.

Trends

For sites where trends could be determined, trends are classified as determinate when the probability of an increasing or decreasing trend is above 95 percent. The term 'indeterminate' is used when there is not enough statistical certainty to determine trend direction (less than 95 percent certainty). Trends were only analysed for sites where both sampling location and instrumentation were consistent for the considered period. For more information, see the indicators.

Body of evidence updating indicator information

Evidence supported by the Indicator: Human health impacts of $PM_{2.5}$ and NO_2 has been updated with information from the latest Health and Air Pollution in New Zealand (HAPINZ) release, with data up to 2019 (Metcalfe & Kuschel, 2023) (see table 2).

Table 2: Estimated human health impacts per year from $PM_{2.5}$ and NO_2 air pollution in 2016 and 2019

	2016 (See Indicator: Human health impacts of $PM_{2.5}$ and NO_2)	2019 (Metcalfe & Kuschel, 2023)
Cases due to $PM_{2.5}$		
Premature deaths (30+ years)	1,292	1,275
Cardiovascular hospitalisations (all ages)	2,639	2,746
Respiratory hospitalisations (all ages)	1,985	2,041
Restricted activity days (all ages)	1,745,354	1,771,197
Cases due to NO_2		
Premature deaths (all adults)	2,025	1,964
Cardiovascular hospitalisations (all ages)	1,987	2,010
Respiratory hospitalisations (all ages)	6,544	6,440
Asthma prevalence (0–18 years)	13,229	12,653

Metcalfe and Kuschel (2023) also estimated the social costs from $PM_{2.5}$ and NO_2 as $15,613 million in 2016 and $15,267 million in 2019.

Evidence previously supported by the Indicator: Artificial night sky brightness has been updated with information from peer-reviewed literature, using data up to 2021 (Cieraad & Farnworth, 2023).

Appendix B: Probabilistic and analytical confidence language used in the outlook assessments in this report

Expressions of likelihood are underlined in each outlook assessment. Expressions of confidence are presented in italics in brackets at the end of each assessment.

Probabilistic language	Associated numeric probability
Almost certain	>90%
Highly likely / Very probable	75–85%
Probable / Likely	55–70%
Realistic possibility	25–50%
Improbable / Unlikely	15–20%
Remote / Highly unlikely	<10%

Analytic confidence

High confidence	Assessments are based on high-quality information, and/or the nature of the issue makes it possible to give a solid judgement. A 'high confidence' judgement is not a fact, however, and still carries a risk of being incorrect.
Moderate confidence	Assessments are based on credibly sourced and plausible information, but are not of sufficient quality or are not sufficiently corroborated to warrant a higher level of confidence.
Low confidence	Assessments are based on questionable or implausible information, the information is too fragmented or too poorly corroborated to make solid analytic inferences, or significant concerns or problems with sources exist.

Outlook assessments contained in this report should not be read as statements of fact and may be based on a variety of sources that differ in their reliability. Certain words in this report are used to convey the probability of analytical assessments. These words are underlined to clearly identify assessments. The probability terms are used in conjunction with expressions of confidence, which indicate the reliability and level of corroboration of sources used in an assessment. The language and probability ranges are the same as those other government agencies use, to maintain consistency and support effective cross-agency decision-making.

Additional information

Environmental indicators

Listed below are the environmental indicators incorporated in this report, including seven indicators updated since the last release in bold:

- Air pollutant emissions
- **Carbon monoxide concentrations: Data to 2023**
- **Ground-level ozone concentrations: Data to 2023**
- **Human health impacts of $PM_{2.5}$ and NO_2**
- **Nitrogen dioxide concentrations: Data to 2023**
- **PM_{10} concentrations (air quality): Data to 2023**
- **$PM_{2.5}$ concentrations (air quality): Data to 2023**
- **Sulphur dioxide concentrations: Data to 2023**.

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HAPINZ 3.0 (Human health impacts of $PM_{2.5}$ and NO_2)

Regional councils (PM_{10} concentrations, $PM_{2.5}$ concentrations, NO_2 concentrations, SO_2 concentrations, ground-level ozone concentrations, CO concentrations, Human health impacts of $PM_{2.5}$ and NO_2)

Stats NZ (air pollutant emissions)

Unitary authorities (PM_{10} concentrations, $PM_{2.5}$ concentrations, NO_2 concentrations, SO_2 concentrations, ground-level ozone concentrations, CO concentrations)

New Zealand Transport Agency | Waka Kotahi (NO_2 concentrations, Human health impacts of $PM_{2.5}$ and NO_2).

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Infographic

The summary of key findings on page 10 was created by Studio C.

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