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Subject: Annual Air Quality Report 2021

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PURPOSE

[1] This annual report discusses the results of the State of the Environment (SoE) monitoring for air quality for the year 2021. Also included are details on the recent updates of the World Health Organisation's air quality guidelines. The data corrections for the new instruments of the SOE network upgrade and the high concentration of particulate matter recorded in Central Dunedin are also discussed.

EXECUTIVE SUMMARY

[2] Monitoring of PM_{10} (particulate matter with a diameter of less than 10 micrometres) was undertaken in the Alexandra, Arrowtown, Central Dunedin, Cromwell, Milton and Mosgiel airsheds during 2021. All sites recorded exceedances of the NESAQ (National Environmental Standards for Air Quality, the limit for PM_{10} is 50 µg/m³ over a 24-hour average) during the winter months.

[3] Of the 64 exceedances that occurred, 23 were recorded at the Arrowtown site. Twenty occurred in Cromwell, 13 in Milton, four in Mosgiel, three in Alexandra and one in Central Dunedin. The annual averages recorded were compliant with the annual guideline of 20 µg/m³.

BACKGROUND

[4] Otago has several towns where air quality is considered degraded during winter, namely Alexandra, Arrowtown, Clyde, Cromwell and Milton. Under the Resource Management Act (RMA, 1991) regional councils are required to monitor and improve air quality where necessary. The main pollutant of concern is particulate matter, PM_{10} and $PM_{2.5}$, which are products of combustion. In Otago the main source of PM_{10} is home heating emissions in winter (Wilton, 2019). Long term exposure to PM_{10} and $PM_{2.5}$ (particulate matter with a diameter of less than 2.5 micrometres) contribute to the risks of developing and exacerbating existing cardiovascular and respiratory conditions, which makes fine particulates a serious threat to human health (WHO, 2005). Furthermore, recent research provides evidence that air pollution is dangerous at lower concentrations than previously thought, and supports the lowering of existing guidelines (WHO, 2021).

[5] ORC has an SOE monitoring network to monitor PM_{10} and report exceedances of the NESAQ (50 µg/m³, 24-hour average). This network is currently being upgraded to include monitoring for $PM_{2.5}$. The upgrade process includes a period of co-location and subsequent equivalence testing of the new instruments compared to the existing ones. Details and status of the network upgrade have previously been described to the Strategy & Planning Committee (2021a), and further monitoring is still required to be able to correct for the new instruments and accurately report some of their data.

[6] In the past, ORC has implemented a work programme as part of the Air Quality Strategy 2018 to help Otago residents meet the Regional Air Plan rules in order to improve air quality in targeted towns. This has led to the long-term reduction in concentrations in Alexandra, Arrowtown, Cromwell, Clyde, and Milton (ORC, 2021b). Significant reductions in emissions are still required to meet the NESAQ for PM_{10}.

AIR QUALITY ASSESSMENT FRAMEWORK

[7] Under the RMA, councils are required to monitor air quality and work towards meeting the standards of the NESAQ. The NESAQ is currently being updated to include limits for $PM_{2.5}$, and proposed limits were released in 2020. The relevant standards and guidelines are given below (Table 1).

[8] Table 1 Standards and guidelines for PM_{10} and $PM_{2.5}$

Pollutant	Averaging Time	NESAQ Standard 2004		Proposed NESAQ Standard 2020	
		Value (µg/m³)	Allowable exceedances	Value (µg/m³)	Allowable exceedances
PM_{10}	24-hour	50	1 per year	50	1 per year
	Annual	20*	NA*	NA	NA
$PM_{2.5}$	24-hour			25	3 per year
	Annual			10	NA

*AAQG limit and NESAQ guideline

[9] The air quality results can also be categorised according to the MfE (Ministry for Environment) Environmental Performance Indicators (EPI), outlined in the AAQG (2002). The EPI categories indicate an appropriate action according to the concentrations (Table 2).

[10] Table 2 MfE Environmental Performance Indicators for air quality

Category	Monitoring result compared to guideline	Description
Action	Exceeds the guideline	Unacceptable and action is required to reduce emissions
Alert	66-100%	Warning level which could lead to exceedances if trends are not curbed
Acceptable	33-66%	Maximum values might be a concern in sensitive locations, urgent action is not warranted
Good	10-33%	Peak measurements not likely to affect air quality
Excellent	0-10%	Not recommended for PM_{10} monitoring, PM_{10} in this range is classified as good instead

WORLD HEALTH ORGANISATION UPDATE

[11] In September 2021 the World Health Organisation released updated Air Quality Guidelines (AQG) which recommend new, and often stricter limits for the classical[1] pollutants for the protection of human health. This was the output of a systematic review of the evidence that had accumulated since the release of the 2005 guidelines. The advances in health evidence since 2005 include:

- Health effects of air pollution have now been studied in most of regions the world.
- More health conditions that are negatively impacted by air pollution have been identified.
- It has been identified that primary combustion particles[2] and secondary inorganic and organic particles[3] should be the main focus of toxicity studies.
- Collaborations between countries and continents have emerged which has strengthened and standardised the health evidence; methods of assessment have become more refined.

[12] Of particular importance to Otago is the recommendation that the 24-hour average guidelines for PM_{10} and $PM_{2.5}$ have decreased from 50 to 45 µg/m³ and 25 to 15 µg/m³ respectively. Likewise, the annual limits were reduced for both pollutants (Table 3, WHO, 2021).

[13] Table 3 WHO guidelines 2021 compared to WHO guidelines 2005 and NESAQ

Pollutant	Averaging time	NESAQ/AAQG (µg/m³)	WHO 2005 (µg/m³)	WHO 2021 (µg/m³)
PM_{10}	24-hr [a]	50	50	45
	annual	20	20	15
$PM_{2.5}$	24-hr [a]	25	25	15
	annual	-	10	5
Nitrogen dioxide (NO_2)	24-hr [a]	100	-	25
	Annual	-	40	10
Ozone (O_3)	8-hr	100	100	100
	Peak [b]	-	-	60
Carbon monoxide [c] (CO)	24-hr [a]	-	-	4
Sulfur dioxide (SO_2)	24-hr [a]	120	20	40

[a] 99th percentile, means there will be some allowable exceedances per year
[b] calculated using 8-hour means during the highest six-month running average
[c] mg/m³

[1] Classical pollutants refer to PM, SO_2, CO, NO_x and ozone
[2] Primary pollutants are emitted directly from the source
[3] Secondary pollutants form in the atmosphere via chemical reactions

NATIONAL UPDATES

[14] In December 2021 the MfE and Stats NZ released the air quality report, Our Air 2021. This will be followed up by the updated results of the Health and Air Pollution New Zealand (HAPINZ) model later this year. The Our Air 2021 report notes that the New Zealand town with the greatest number of PM_{10} exceedances of the air quality standards during the 2017-2020 period was Arrowtown, with 30 days on average (MfE & Stats NZ, 2021). The towns with the second-greatest number of exceedances were Invercargill and Timaru with 12 days on average each.

[15] In July 2020 the ORC made a submission to MfE on the proposed NESAQ update. The updated NESAQ has not yet been released and may be subject to further changes due to the WHO AQG updates.

SOE MONITORING RESULTS

[16] PM_{10} was monitored at six sites across the region in 2021: Alexandra, Arrowtown, Central Dunedin, Cromwell, Milton and Mosgiel. A summary of the key PM_{10} monitoring indicators for 2021 are given in Table 4. The highest frequency of exceedances occurred in Arrowtown, with 23. Arrowtown also had the highest winter mean of 33 µg/m³ as well as the highest recorded daily concentration of 109 µg/m³. Cromwell and Milton had 20 and 13 exceedances respectively, and similar winter means (27 and 28 µg/m³), however Milton had the second highest maximum concentration of 104 µg/m³. The recorded annual means for Alexandra, Central Dunedin and Mosgiel were compliant with the AAQG, however Mosgiel exceeded the WHO guideline of 15 µg/m³, with an annual concentration of 17 µg/m³.

[17] Figure 1 compares the 24-hour average PM_{10} data for all sites with the NESAQ and the WHO guidelines. This graph shows it is possible to have more frequent exceedances of the WHO guideline of 45 µg/m³ than the NESAQ, and this is shown in the Arrowtown, Milton and Cromwell sites especially. All sites have a seasonal pattern of high winter concentrations indicating a typical home-heating signature source of emissions except for Central Dunedin (Figure 1).

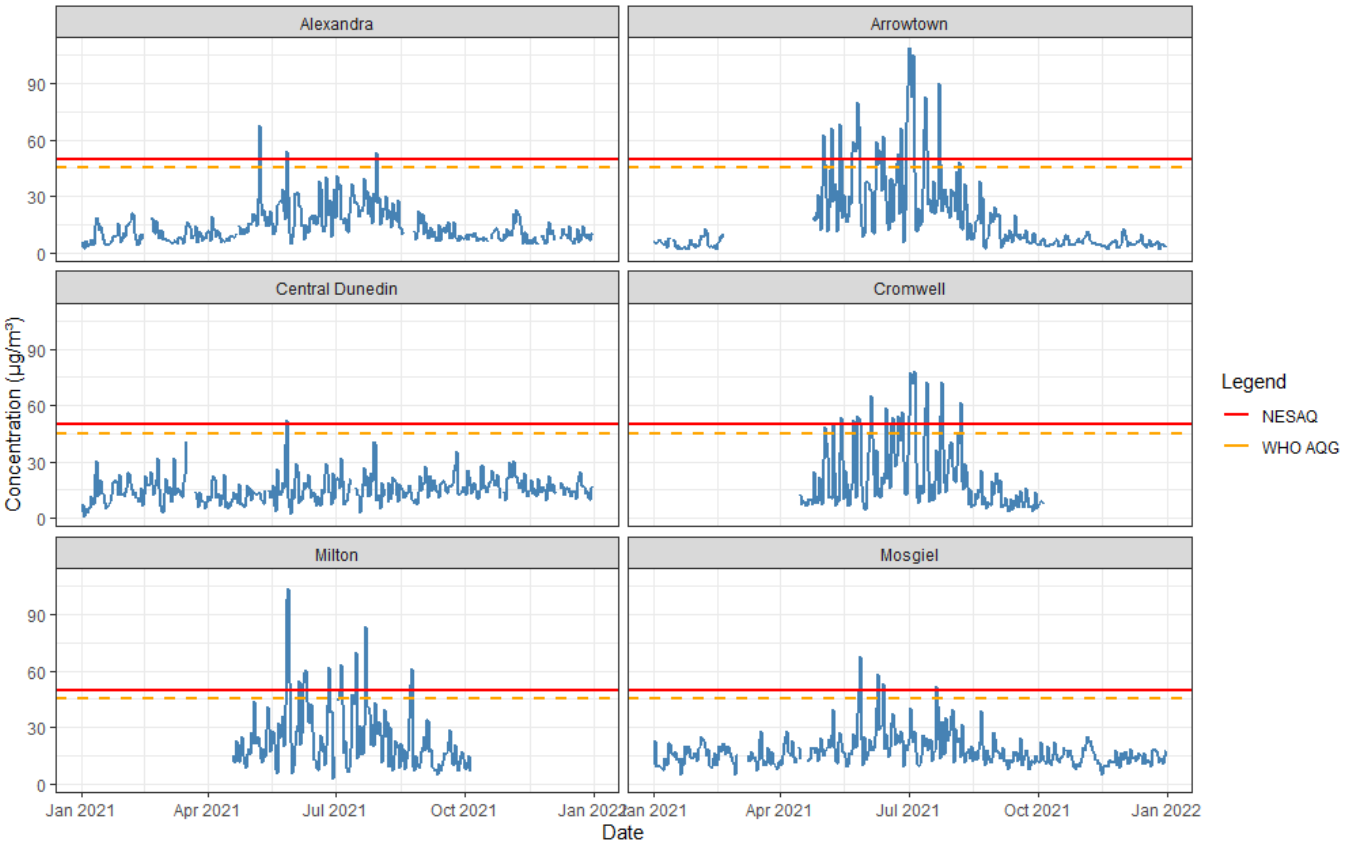
[18] Table 4 Key PM_{10} indicators for 2021

Site	Annual mean (µg/m³)	Winter mean (µg/m³)	Maximum daily concentration (µg/m³)	2nd highest daily concentration (µg/m³)	Number of NESAQ exceedances
Alexandra	14	22	68	54	3
Arrowtown	- [2]	33	109	106	23
Central Dunedin	15	15	52	41	1
Cromwell[1]	NA	27	79	78	20
Milton[1]	NA	28	104	98	13
Mosgiel	17	23	68	58	4

[1] Cromwell and Milton were monitored only during the winter months of May – September

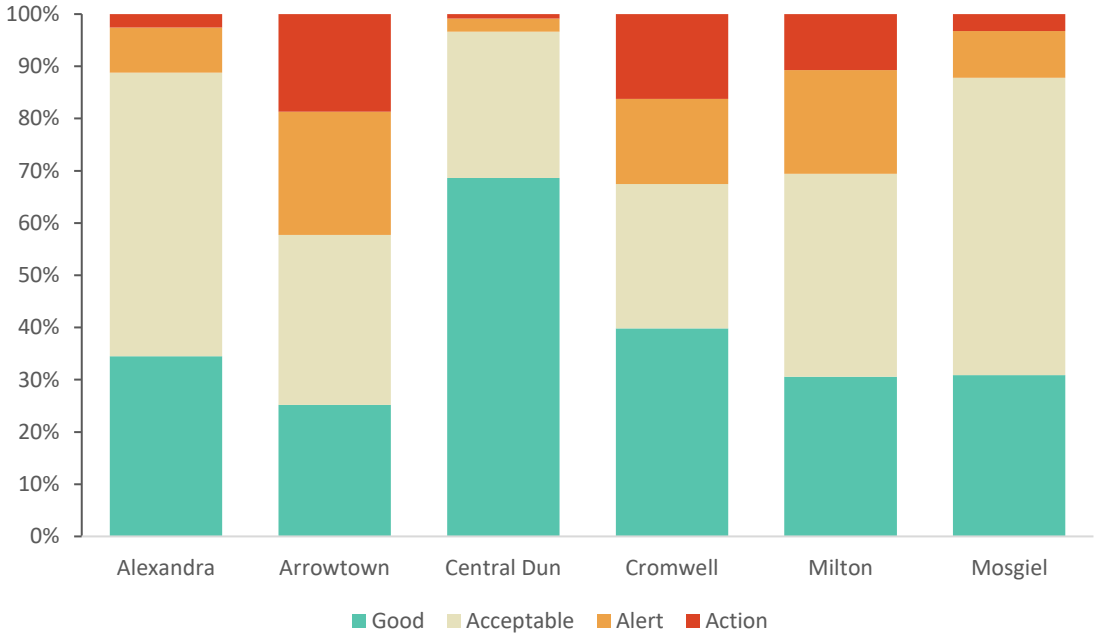
[2] Due to the site upgrade data capture for Arrowtown was 81%

[19] **Figure 1 PM_{10} concentrations for Otago towns 2021 (24-hour average)**



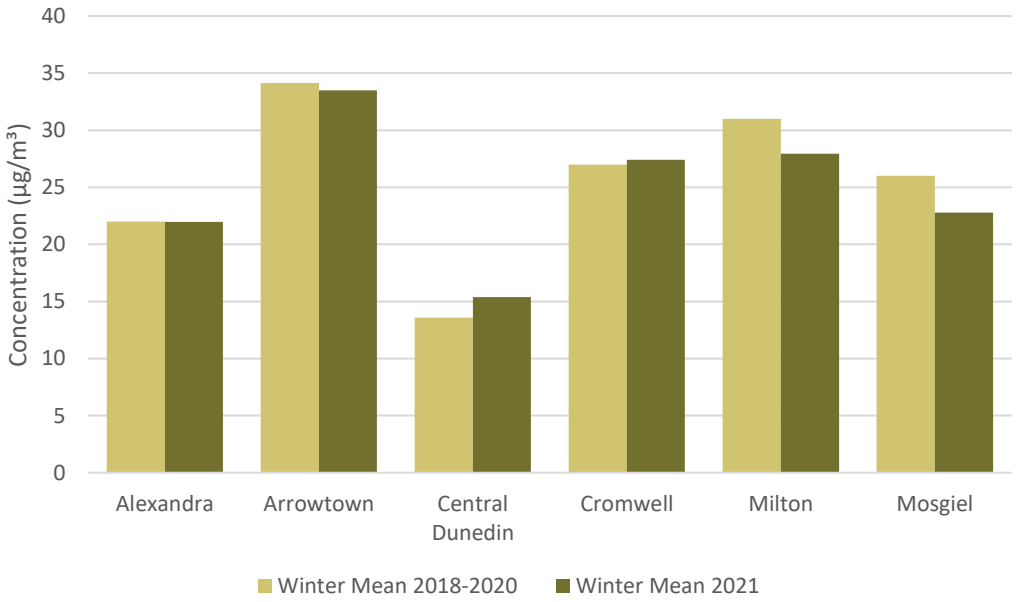
[20] The data for winter 2021, as categorised into MfE air quality indicator categories is shown in Figure 2. Alexandra, Central Dunedin and Mosgiel have high (>85%) of their winter concentrations within the "good" (under 17 µg/m³) and "acceptable" (between 17 and 33 µg/m³) categories for 2021. For Arrowtown, Cromwell and Milton between 30-40% of data is in the "alert" (between 33 and 50 µg/m³) or "action" (over 50 µg/m³) categories. This graph highlights Central Dunedin as having the best air quality in winter, with over 60% within the "good" category.

[21] **Figure 2 PM_{10} winter 2021 concentrations relative to air quality indicator categories**

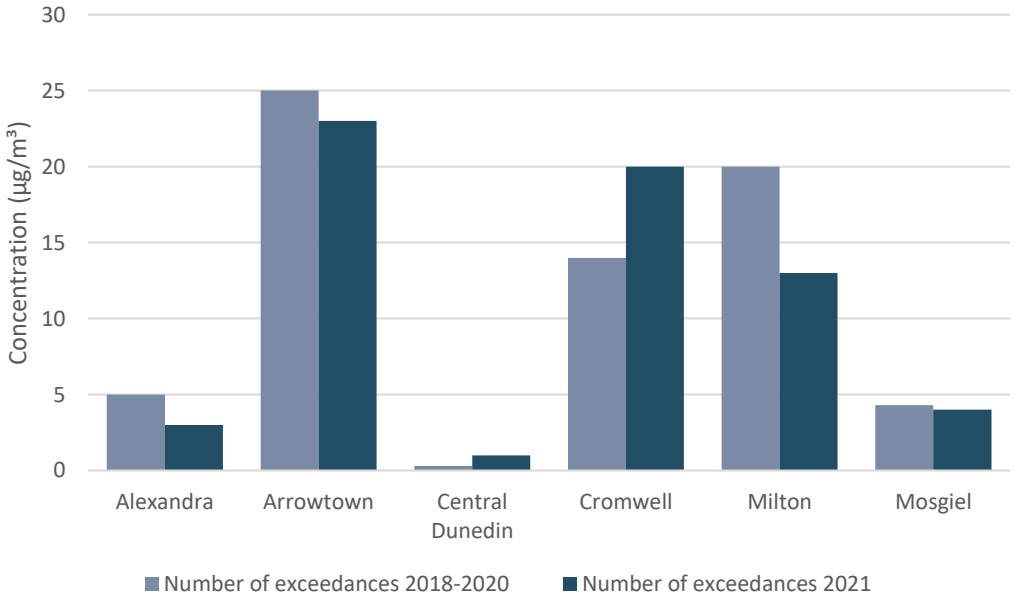


[22] When comparing the data to previous years, the winter mean is used as a more appropriate indicator as exceedances only occur in winter. The below graphs show how 2021 compares to the average of the previous three years in terms of winter mean and number of exceedances (Figures 3 and 4). Winter means are lower in comparison to the previous three years for Milton and Mosgiel, and are similar for the other sites, or higher in the case of Central Dunedin. The number of exceedances is less frequent for 2021 compared to the previous years for all sites except for Cromwell and Central Dunedin.

[23] **Figure 3 Winter means of 2021 compared to 2018-2020**



[24] **Figure 4 Number of exceedances of 2021 compared to 2018-2020**



[25] The NIWA Climate summary for 2021 (NIWA, 2022) reports that 2021 was the warmest year on record, with several months within the year the warmest months on record for much of the country. While Otago experienced a near average (within -0.5°C to +0.5°C of average) annual temperature, it experienced comparatively warm winter months. Despite this Alexandra experienced over 30 days where hourly temperatures were below 0°C for several hours. Rainfall was variable across Otago during winter, and there were periods of high snowfall in June and August in the Central Otago and Queenstown Lakes Districts.

NEW INSTRUMENT DATA CORRECTION

[26] Air quality monitoring methods and instrument types vary, which can produce different results when they are compared to each other. When replacing an instrument or upgrading a monitoring site, this issue can be addressed by obtaining a site-specific adjustment factor via the co-location of two instruments. Robust adjustment factors require at least one year of co-location data (Bluett *et al*., 2007).

[27] Two types of new instruments have been installed in Otago so far: Arrowtown and Central Dunedin have a T640x, and Clyde, Cromwell and Milton have an ES642. The T640x is considered an equivalent method[1], however, results from studies undertaken in Australia and New Zealand have indicated that the T640x instruments read higher concentrations than other monitoring methods for both $PM_{2.5}$ and PM_{10}. These differences increase at higher concentrations; however, they are systematic and can be corrected for. One study recommends an appropriate correction factor for the T640x PM_{10} is the 24-hour concentration divided by 1.35, which produces a gravimetric[2]-equivalent concentration (Coulson *et al*., 2021).

[28] The network upgrade in Arrowtown commenced in late February 2021, however due to instrument failure of our existing instrument we were unable to begin the co-location at that time. The new T640x has been successfully installed and recorded data from April onwards. The co-location monitoring will now run until November 2022, after which the relationship between the BAM1020 (existing instrument) and the T640x will be determined. This will allow us to apply a correction to the T640x data, allowing for the continuity of data; that is, the ability to compare different years and undertake long term trend analyses across this transition.

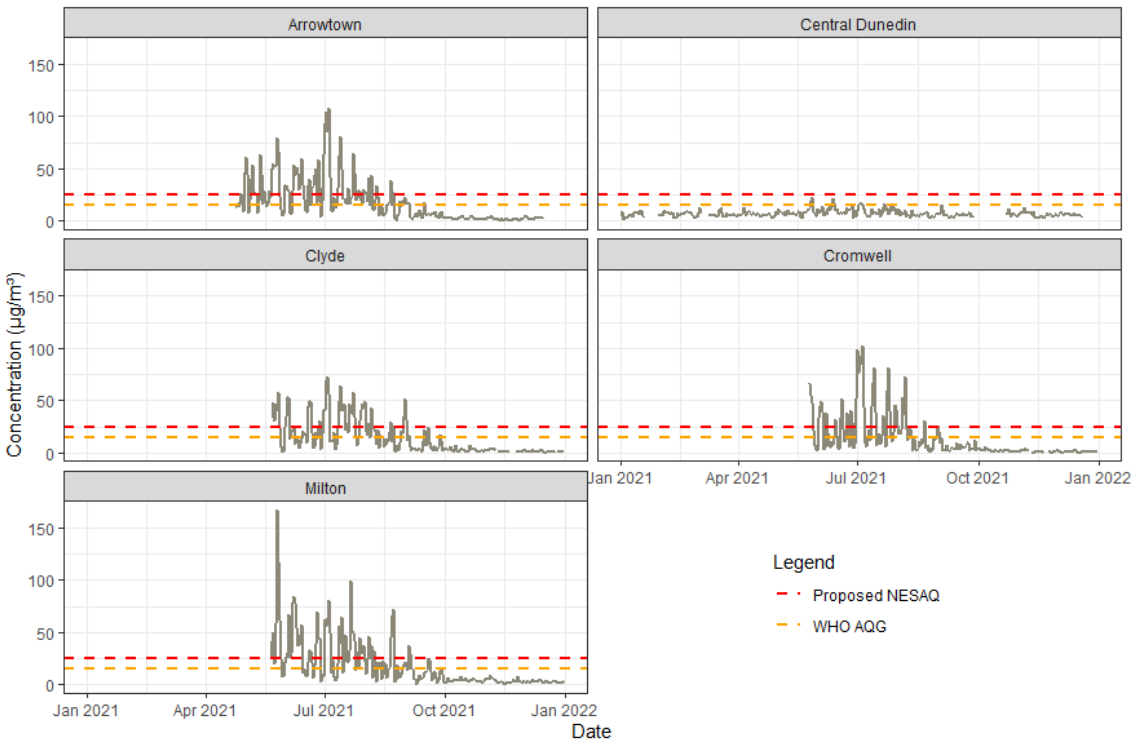
[29] To provide the interim statistics for the annual report for 2021, the correction factor from Coulson *et al*. (2021) was applied to the Arrowtown T640x data. This correction factor was derived from a co-location study undertaken in Reefton and is similar to a correction factor obtained in Timaru. These towns have similar emission compositions to Arrowtown (home-heating based), therefore at this time, this correction factor is the best we have on hand.

[30] The $PM_{2.5}$ data recorded by the ES642s at Clyde, Cromwell and Milton do not yet have correction factors. Instrument comparisons undertaken during 2022 will result in the applications of appropriate correction factors for reporting at a later date. The provisional $PM_{2.5}$ data recorded for 2021 is shown below in Figure 5, and plotted with the proposed NESAQ limit of 25 µg/m³ and the WHO guideline of 15 µg/m³.

[1] The NESAQ requires that PM_{10} is monitored in accordance with the relevant ASNZS standard. The standard for PM_{10} specifies that the US EPA designation of instruments is appropriate for monitoring in New Zealand. The Teledyne T640x was deemed by the US EPA as an equivalent method and is therefore compliant with the ASNZS standards.

[2] Reference method for PM_{10}

[31] **Figure 5 $PM_{2.5}$ concentrations for Otago towns 2021 (24-hour average)**



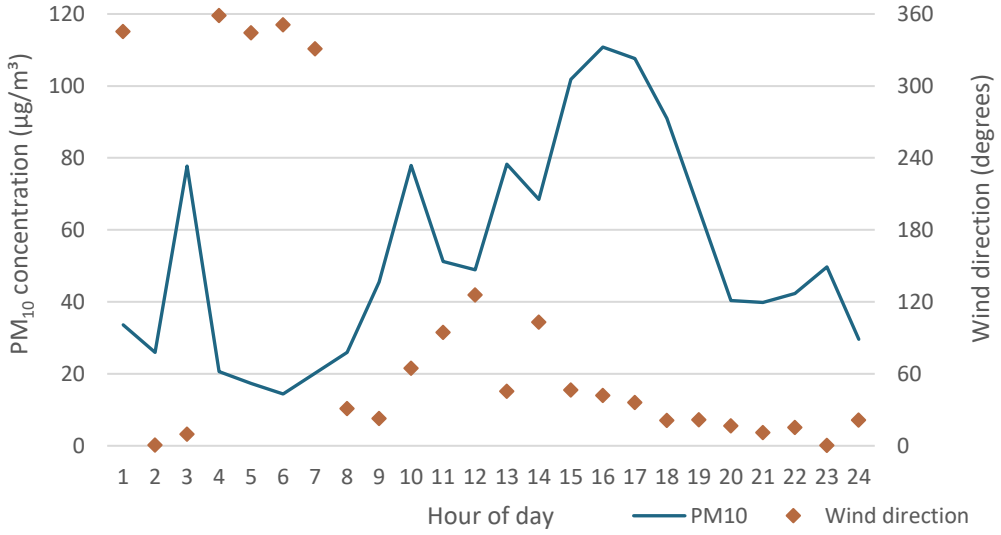
HIGH CONCENTRATION IN CENTRAL DUNEDIN

[32] On 27 May 2021 the Central Dunedin site recorded a PM_{10} concentration of 52 µg/m³. The potential source of this exceedance was investigated and is described below. The last exceedance (51 µg/m³) occurred on 18 July 2018.

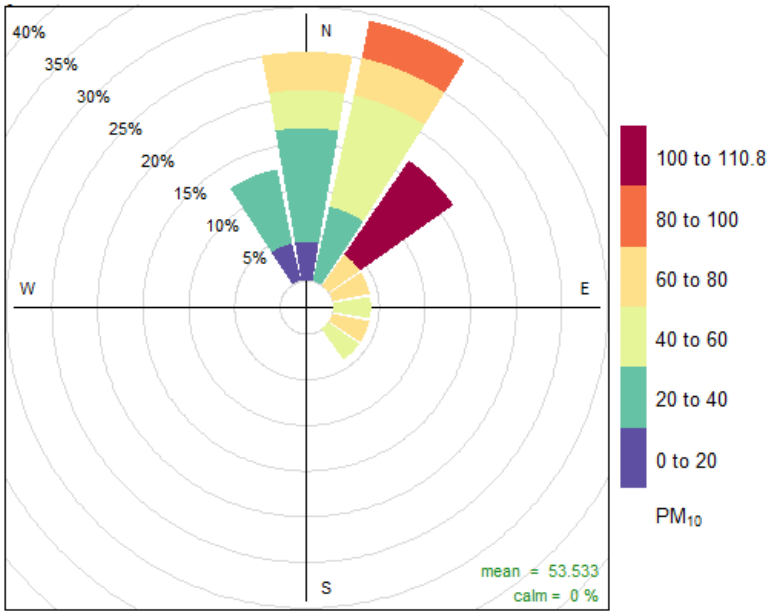
[33] The Central Dunedin monitor is located within an area of significant urban development. Construction is currently occurring on the property adjacent to the site and for this reason a new location for the monitor has been secured and is due for commissioning during 2022.

[34] The amount of rainfall (9.6 mm) during the week prior to the high concentration meant that ground conditions were not particularly dry or conducive to excessive entrainment of dust, nor were there any exceptional emissions events. The neighbouring construction site manager and the local discharge to air permit holders were contacted but nothing out of the ordinary was reported. On 27 May wind speeds were low (majority below 1 m/s), and the wind directions were mostly north-easterly. Elevated PM_{10} concentrations (>80 µg/m³) occurred during the hours of 15:00 to 18:00 (Figure 6). The pollution rose indicates these concentrations were coming from the north-northeast and northeast directions (Figure 7).

[35] **Figure 6** **Central Dunedin PM_{10} and wind direction for 27 May 2021**



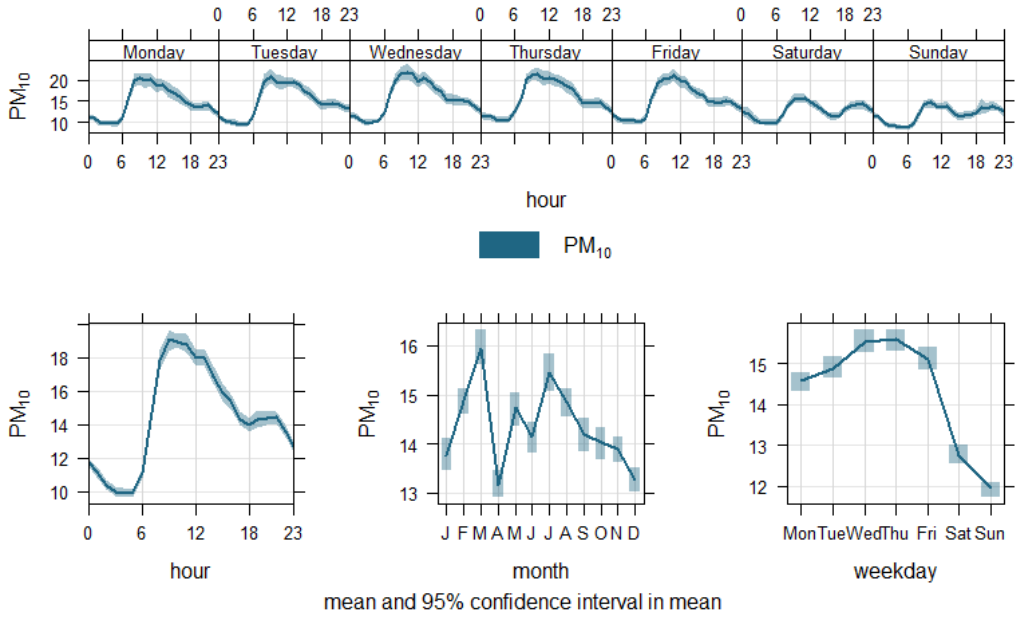
[36] **Figure 7** **Central Dunedin pollution rose for 27 May 2021**



Frequency of counts by wind direction (%)

[37] Analysis of data for the previous seven years indicates that higher PM_{10} concentrations occur during the weekdays and are lowest on Sundays. On a daily basis, PM_{10} becomes elevated in the morning and declines during the evenings. Both these patterns indicate that the PM_{10} sources are from human activity, including traffic and industrial emissions. (Figure 8).

[38] **Figure 8 Time variation for Central Dunedin PM_{10}**



[39] The percentages of the fine ($PM_{2.5}$) and coarse ($PM_{10\text{-}2.5}$) particulate matter for 27 May were 39% and 61% respectively. This is slightly lower than the average, which is about 44% fine and 56% coarse. This means the high concentrations were unlikely to be related to a combustion source, and more likely to be soil and/or dust related sources and/or sea salt. Significantly, both the harbour (source of sea salt) and the closest discharge to air activities lie to the north-east of the monitoring site.

[40] Further work to investigate Dunedin's emission sources should include a source apportionment study, which would identify the main sources of the fine and coarse PM, as well as the relative influence of each source. The last source apportionment study was undertaken in 2011, during a period of significant construction in the area and when emissions from industry were higher than present. It would be beneficial to update this study to further understand the current sources of PM in Central Dunedin.

REFERENCES

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APPENDIX

Exceedance table 2021

Site	Alexandra	Arrowtown	Central Dunedin	Cromwell	Milton	Mosgiel
Date	Concentration (µg/m³) 24-hour average					
2/05/2021		63				
7/05/2021		66				
8/05/2021	68			51		
13/05/2021		68				
14/05/2021				53		
22/05/2021		53				
23/05/2021		59		52		
24/05/2021		54				
25/05/2021		55				
26/05/2021		80		54		
27/05/2021	54	68	52	53	98	
28/05/2021					104	68
29/05/2021					54	
4/06/2021				65		
5/06/2021					55	
8/06/2021		59			53	
9/06/2021					59	58
10/06/2021		55			60	
13/06/2021		62				54
14/06/2021						
15/06/2021				59		
20/06/2021				54		
24/06/2021		53		54		
26/06/2021		66			62	
27/06/2021				57		
30/06/2021		69				
1/07/2021		109		54		
2/07/2021		106		78		
3/07/2021		83		74		
4/07/2021		106		72		
5/07/2021				79	63	
12/07/2021		66				
13/07/2021		83		58		
14/07/2021		55		72		
15/07/2021					70	
21/07/2021						52
22/07/2021					83	
23/07/2021		90				
24/07/2021				55		
25/07/2021				73		
30/07/2021	53					
7/08/2021				62		
23/08/2021					53	
24/08/2021					61	
Total number of exceedances	3	23	1	20	13	4