Port Otago air quality screening study 2023

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Otago Regional Council

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Executive summary

Spatial monitoring for SO_2 was undertaken at and around Port Otago operational areas between 6 December 2022 and 3 August 2023. Many of the results were below the laboratory's limit of detection. The sites that most consistently recorded valid results were the Central Dunedin control site, followed by the T&U Berth. The highest concentration occurred at the T&U Berth (10.3 µg/m³ in December 2022).

The results indicate that SO_2 is generally quite low in the Port Otago area and there was not enough information to identify any seasonal trends at many of the sites. Further monitoring of SO_2 is not recommended in the near future but $PM_{2.5}$ monitoring and/or source apportionment analysis may be useful.

1. Introduction

Sulphur dioxide (SO_2) is produced by the combustion of sulphur-containing fuels such as coal and diesel. It is also produced by industries such as fertiliser and steel manufacture, and by natural sources such as geothermal activity. SO_2 is a pollutant of concern in New Zealand, especially around ports and industrial activities. The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI sought to limit air pollution from ships while in port. From 1 January 2020, international ships coming to New Zealand and New Zealand ships travelling internationally were required to comply with Annex VI (Ministry of Transport, 2020). Annex VI requires that the limit for the sulphur content of fuel is reduced from 3.5% to 0.5%, either by using scrubbers to reduce emissions or by using higher grade fuel. New Zealand signed up to Annex VI in 2021 and compliance was implemented from the first quarter of 2022.

In recent years public concern for shipping emissions has increased in New Zealand. Cruise ships are just one source of emissions that occur at New Zealand ports, other sources include emissions from cargo ships and other vehicles such as trucks that transport cargo.

Previous monitoring of SO_2 undertaken by ORC in the late 1990's and early 2000's recorded annual averages of between 3 and 9 µg/m³ at North East Valley and between 16 and 26 µg/m³ at Central Dunedin (ORC, 2005). A three-month study in 2021[1] resulted in SO_2 monthly averages of between 5.7 and 7.0 µg/m³ at the Central Dunedin monitoring site (ORC, 2023). Table 1 shows the current relevant standards and guidelines for SO_2.

[1] Sampling was conducted using a continuous analyser as per AS 3580.4.1 – 2008 Determination of oxides of sulfur dioxide – Direct reading instrumental method.

Table 1 SO_2 limits and guidelines

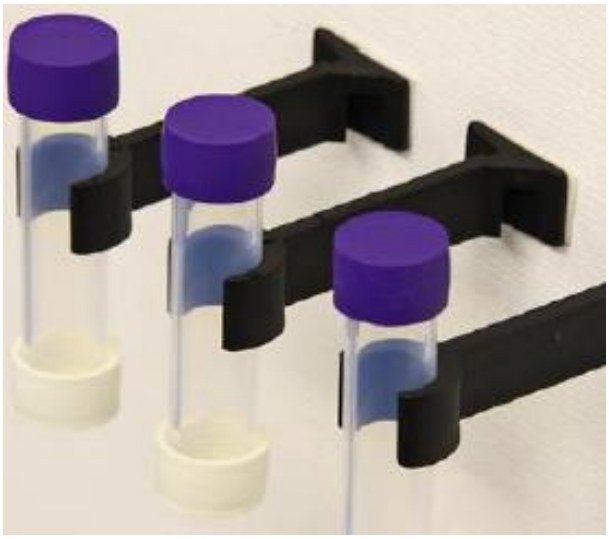
Averaging time	NESAQ 2004		AAQG 2002		WHO 2021	
	Limit	Allowable exceedances	Limit	Allowable exceedances	Limit	Allowable exceedances
1-hour	350	9				
1-hour	570	NA				
24-hours			120	NA	40	3-4*

*99th percentile

2. Methods

SO_2 was monitored using passive diffusion tubes[2] which were provided by Gradko Environmental in the UK and sent back for analysis. The tubes were made of plastic and are 7 cm long and 1.5 cm wide. They operate by the diffusion of pollutant molecules from the high-concentration ambient air into the low-concentration tube, where they were collected by an absorbent – a metal disc coated with an absorbent chemical reagent. The concentration of sulphate ions were determined by ion chromatography and the SO_2 concentration was accordingly calculated using this data, the rate of uptake and the exposure time. The tubes were attached to structures 2-3m above ground level and were exposed for monthly periods in duplicates. Field and travel blanks[3] were also undertaken each month. The laboratory provided the data in parts per billion (ppb) which were then blank corrected and converted into µg/m³ at 0° as per the New Zealand conversion factor (MfE, 2009).

Figure 1 Diffusion tubes for SO_2. Source, Gradko Environmental. The absorbent is located in the purple cap at the top of the tube, while the white cap contains a one-micron porosity filter to prevent particulates from entering the tube.



[2] Diffusion tubes are considered a low-cost option for monitoring and are best for spatial or temporal comparisons.

[3] A travel blank is a sealed tube that travels to and from the lab with the others but is never deployed. A field blank is a sealed tube that is deployed but not exposed to ambient air.

Figure 2 shows the locations of the monitoring sites. Four sites were located within the property boundary of Port Otago and were mounted on light towers (LT7, LT12 and LT16), and one was located at the T&U Berth in the Otago Harbour. Three additional locations were monitored around Port Chalmers - two sites on George Street, which is the main street southwest of the port, and one at Careys Bay to the northwest. One site served as a control site and was located in Central Dunedin at the permanent air quality station.

Figure 2 Map of SO_2 sampling locations

Figure 3 Site photos of SO_2 samplers

A Central Dunedin
B LT7
C LT12
D LT 16

Figure 3 continued **Site photos of SO_2 samplers**

E T&U Berth
F 2 George Street
G 38 George Street
H Careys Bay

3. Results

The dominant wind direction for most months during the sampling period was east-northeast at both high and low windspeeds. During the non-summer months, the west north-west is the next most frequent wind direction and this was the dominant direction during July 2023. Wind speeds were generally low, being under 6 m/s most of the time. It is possible that the wind was slightly different at different places within the Otago Harbour. The weather station at the Port is partially obstructed and therefore only provides a partial wind direction record. These data were not used in this study, so data was taken from the Central Dunedin air quality monitoring station instead.

Figure 4 **Wind roses showing wind speeds and direction at Central Dunedin for each month**

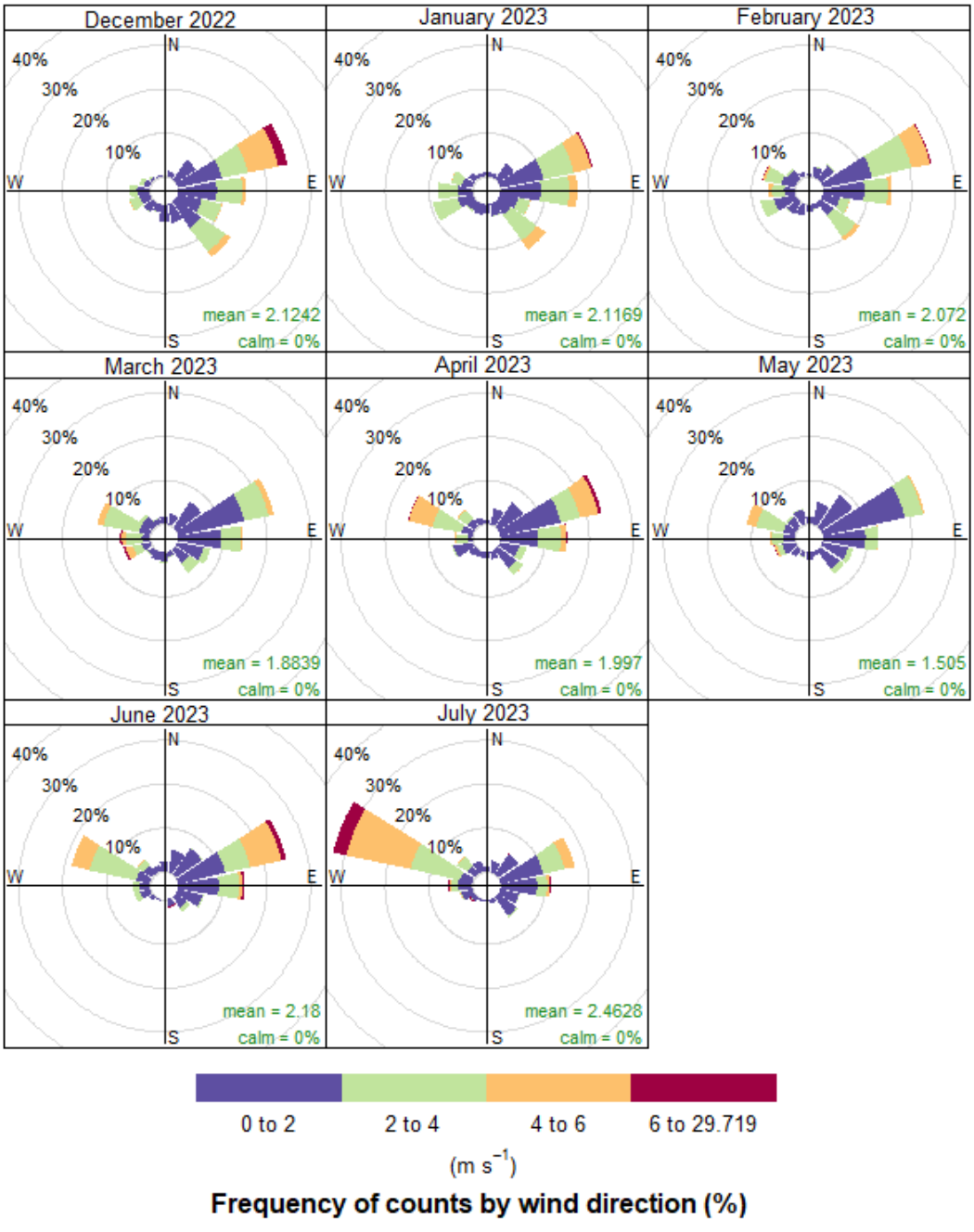


Table 2 displays the results of the averaged duplicates, including the inconclusive results. The results may be considered inconclusive if one of the duplicates is less than the limit of detection (<LOD) or if the difference between two duplicates exceeds 30%. One of the results for the T&U site was quite spurious and very high compared to its duplicate and all other results. Sometimes the laboratory noted that the sample tubes were dirty on the outside which may have influenced some results. In this case it is unknown why this result was spurious.

Table 2 Monthly SO_2 results (µg/m³)

	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23
Central Dunedin	2.7	2.7	1.9	<LOD	3.4	2.6	2.6	<LOD
LT7	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
LT12	6.7[a]	<LOD	<LOD	<LOD	1.6	2.0	<LOD	<LOD
LT16	30.5[a]	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
T&U	4.5	10.3	6.5	2.1	7.2[b]	3.7	274.8[b]	<LOD[c]
2 George Street	<LOD	N/A[d]	2.1[a]	<LOD	2.3	<LOD	<LOD	<LOD
38 George Street	4.2[a]	1.5[a]	1.8	<LOD	2.2	<LOD	<LOD	<LOD
Careys Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

[a] One of the duplicates is less than the limit of detection <LOD

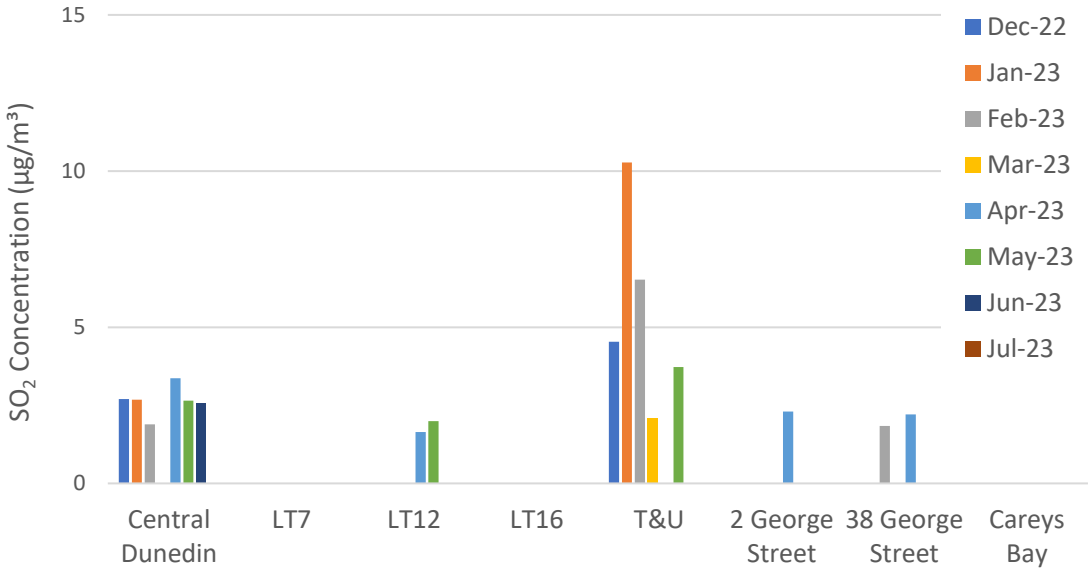
[b] The duplicates have a percentage difference greater than 30%

[c] One duplicate could not be tested

[d] Both tubes went missing due to road works and removal of the lamppost they were on

The majority of the results came back as lower than the limit of detection, most notably at LT7 within the Port boundary, and at Careys Bay to the northwest. The highest concentrations were recorded at the T&U berth. The highest valid result was 10.3 µg/m³ for the month of January, followed by 6.5 µg/m³ for February, both at the T&U Berth. The other site with consistent detectable results was Central Dunedin, with the highest concentration of 3.4 µg/m³ occurring in April. Figure 5 below displays the valid results.

Figure 5 Valid monthly SO_2 results



4. Discussion

This study identified that the T&U Berth had the highest concentration of SO_2, which occurred in January 2023. There is not enough data to identify any seasonal or spatial trends. As these SO_2 samples are measured as a monthly average, they do not provide information on the hourly or daily concentrations of SO_2, consequently they cannot be compared to current standards or guidelines. However, the monthly results are very low, which indicates that the standards are likely to be met. The results for Central Dunedin are a bit lower than those recorded in 2021, but within the same ballpark (1.9 to 3.6 µg/m³ compared to 5.7 to 7.0 µg/m³). The difference in results may be attributable to the difference in methods.

As this is the first SO_2 monitoring project to be undertaken at Port Otago, it is unknown whether changes to shipping emissions under MARPOL Annex VI has had an impact on the ambient air quality, but SO_2 monitoring undertaken at Port Tauranga has shown significant decreases from January 2020, after the adoption of Annex VI by international ships (BPRC, 2023).

It may be beneficial to further investigate sources of PM within the Port Chalmers airshed. It is known that elevated $PM_{2.5}$ concentrations occur in winter due to home heating (ORC, 2022); there may also be influences from Port activities or related vehicles such as cargo trucks, as has been found at CentrePort in Wellington (Mitchell, 2022).

5. References

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6. Appendix

SO_2 duplicate results (µg/m³)

	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23
Central Dunedin	3.0	2.5	1.8	<LOD	2.9	2.7	2.4	<LOD
Central Dunedin	2.4	2.8	2.0	<LOD	3.9	2.6	2.7	<LOD
LT7	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
LT7	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
LT12	<LOD	<LOD	<LOD	<LOD	1.7	2.0	<LOD	<LOD
LT12	6.7	<LOD	<LOD	<LOD	1.6	2.0	<LOD	<LOD
LT16	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
LT16	30.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
T&U	4.3	8.6	6.2	2.1	3.4	3.6	545.7	<LOD
T&U	4.8	11.9	6.9	<LOD	11.0	3.9	3.9	NA
2 George Street	<LOD	Missing	2.2	<LOD	2.4	<LOD	<LOD	<LOD
2 George Street	<LOD	Missing	1.9	<LOD	2.2	<LOD	<LOD	<LOD
38 George Street	4.2	1.5	1.8	<LOD	2.3	<LOD	<LOD	<LOD
38 George Street	<LOD	<LOD	1.8	<LOD	2.2	<LOD	<LOD	<LOD
Careys Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Careys Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD