NORTHCONNEX
VENTILATION OUTLET AIR QUALITY MONITORING INDEPENDENT AUDIT

Transurban

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Job Number 20071149

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NorthConnex
Ventilation Outlet Air Quality Monitoring Independent Audit

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1 INTRODUCTION

Todoroski Air Sciences have conducted an independent audit of the ventilation outlet air quality monitoring data collected for the NorthConnex Motorway (hereafter referred to as the Project). The aim of the audit it to check that the data comply with the applicable limits. This independent audit reviews the available ventilation outlet air quality data collected for the Project during 31 October 2020 to 30 April 2021. The validity of the data measurement methods, calibrations etc., is checked in the Operating Procedure and Equipment Independent Audit (**Todoroski Air Sciences, 2021c**).

The auditor has previously conducted an independent review of the NorthConnex Project Air Quality Impact Assessment report for the NSW Department of Planning and Environment and is also conducting the 6-monthly NorthConnex audits for the in-tunnel monitoring data, ambient air quality data and air quality monitoring operating procedures and equipment.

2 SCOPE OF WORK

Condition E10 of Infrastructure Approval SSI-6136 requires an audit of the ventilation outlet monitoring data collected for the Project. The relevant part of the condition reads as follows:

Ventilation Outlets - Monitoring

E10 ...

> *Auditing is to be undertaken by an independent person(s) or organisation(s) approved by the Secretary.... Monitoring shall take place in accordance with this condition throughout operation of the SSI.*

2.1 Project Requirements

Under Condition E10 of Infrastructure Approval SSI-6136, the Project is required to monitor the following ventilation outlet air quality pollutants and parameters set out in **Table 2-1** below, following the specified sampling method, units of measure, and sampling frequency.

The concentration of a pollutant discharged from the ventilation outlets must not exceed the respective limits specified for that pollutant under condition E11.

Under condition E13, should the results of monitoring show that any of the ventilation outlet limits specified in Condition E11 have been exceeded, the Project will immediately notify the Secretary, EPA and Ministry of Health.

Table 2-1: Ventilation outlet emission monitoring methodologies required under Condition E10

Pollutant/Parameter	Unit of measurement	Frequency	Method[1]
Solid particles	mg/m^3	Continuous	Special Method 1[4]
Solid particles	mg/m^3	Quarterly	TM-15
PM_{10}	mg/m^3	Quarterly	OM-5
$PM_{2.5}$	mg/m^3	Quarterly	OM-5
NO_2 or NO or both, as NO_2 equivalent	mg/m^3	Continuous	CEM-2
NO_2	mg/m^3	Continuous	CEM-2
CO	mg/m^3	Continuous	CEM-4
VOC[2]	mg/m^3	Continuous	CEM-8
Speciated VOC	mg/m^3	Annual	TM-34
PAH	$\mu g/m^3$	Annual	OM-6
Velocity	m/s	Continuous	CEM-6
Volumetric flow rate	m^3/s	Continuous	CEM-6
Moisture	%	Continuous	TM-22
Temperature	°C	Continuous	TM-2
Selection of sampling locations	N/A	N/A	TM-1

Notes

1. Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales (EPA 2007) or an alternative method approved by the Secretary in consultation with the EPA.
2. Must include, but not be limited to: Benzene, Toluene, Xylenes, 1,3-Butadiene, Formaldehyde and Acetaldehyde.
3. Must include, but not limited to; 16 USEPA priority PAHs, namely; Naphthalene, Phenanthrene, Benz(a)anthracene, Benzo(a)pyrene, Acenapthylene, Anthracene, Chrysene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Fluoranthene, Benzo(b)fluoranthene, Dibenz(a,h)anthracene, Fluorene, Pyrene, Benzo(k)fluoranhtene, Benzo(g,h,i)perylene.
4. Special Method 1 means a method approved by the Secretary in consultation with the EPA.

3 VENTILATION OUTLET MONITORING

The NorthConnex ventilation outlet air pollutants and parameters are continuously measured for the ventilation outlets located at Eaton Road, West Pennant Hills (VS01), and Woonona Avenue, Wahroonga (VS04). **Figure 3-1** presents the location of the ventilation outlets for the Project.

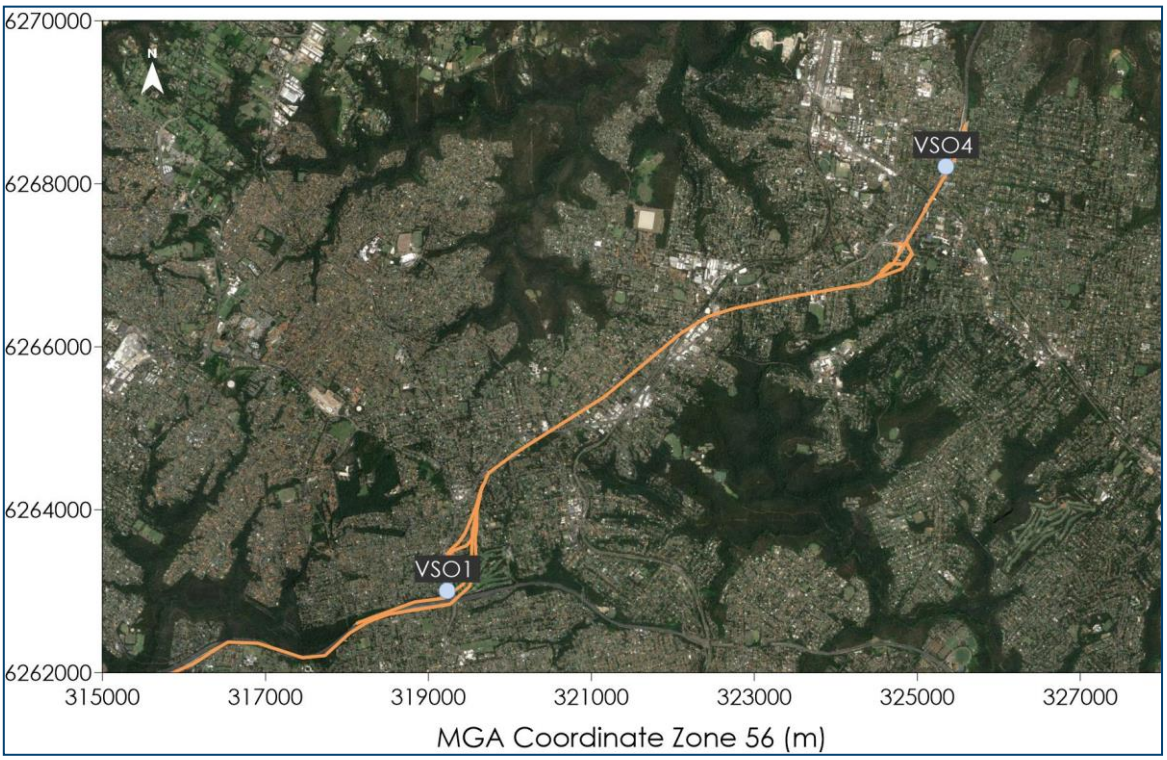

Figure 3-1: Monitoring site locations

Continuous ventilation outlet monitoring, data collection and reporting for pollutants, moisture and temperature was conducted by Norditech Pty Ltd, a NATA accredited organisation. Monthly validation reports are prepared by Norditech (**Norditech, 2020 & Norditech, 2021a-e**).

Continuous velocity and volumetric flowrate data for this review were provided by Transurban. It is noted that velocity and flowrate cannot be directly measured at the outlet itself due to its variable configuration[1], and hence velocity measurements from uniform sections of the tunnel need to be used. In-tunnel sensors ASS203 and ASS113 in conjunction with the corresponding variable outlet cross-sectional area at the time of the reading are used to calculate the flowrates and velocities for VSO1 and VSO4 respectively. However, it is noted that it has not been possible to obtain consistently reliable data from the ASS203 sensor, as such the difference in the up flow and down flow sensors in the main tunnel "S7-S8" is used. Further discussion on the measurement of ventilation outlet velocity is provided in the Operating Procedure and Equipment Independent Audit (**Todoroski Air Sciences, 2021c**).

[1] There are two divisions in the ventilation outlet, approximately 1/3 and 2/3 of the outlet in size, each of these has multiple louvers along its side that can be opened to vary the flow, on the other side of the louvers there are multiple fans to maintain the required airflow. This causes a range of varying flow conditions within the outlet structure, and there are no locations in it where a reliable reading can be made for velocity and hence that can be used to calculate the flow. (This does not apply to gasses and fine particles, which are well-mixed in the flow, and can have their concentration measured reliably at almost any point).

Quarterly ventilation outlet monitoring, data collection and reporting was conducted by Assured Environmental, a NATA accredited organisation. Quarterly reports are prepared by Norditech (**Assured Environmental, 2021a**).

4 AIR QUALITY GOALS

4.1 Particulate matter

Particulate matter consists of dust particles of varying size and composition. Two classes of particulate matter include PM_{10}, particulate matter with equivalent aerodynamic diameters of 10µm or less, and $PM_{2.5}$, particulate matter with equivalent aerodynamic diameters of 2.5µm or less.

PM_{10} particles are generated through various sources, which include but are not limited to, the abrasion or crushing of rock, the general disturbance of dusty material and from pollen generated by trees. Finer particulates, such $PM_{2.5}$, are more often generated through combustion processes such as wood burning and vehicle exhaust, or chemical processes in the atmosphere.

4.2 Nitrogen dioxide

Nitrogen dioxide (NO_2) is reddish-brown in colour (at high concentrations) with a characteristic odour and can irritate the lungs and lower resistance to respiratory infections such as influenza. NO_2 belongs to a family of reactive gases called oxides of nitrogen (NO_X). These gases form when fuel is burned at high temperatures, mainly from motor vehicles, power generators and industrial boilers (**US EPA, 2011**). It is important to note that when formed, NO_2 is generally a small fraction of the total NO_X generated in a combustion process.

4.3 Carbon monoxide

Carbon monoxide (CO) is an odourless, colourless gas. CO can be produced during incomplete combustion of carbon based materials such as fuel, coal or wood etc. It can inhibit the capacity of blood to transport oxygen in humans resulting in symptoms of headache, nausea and fatigue.

4.4 Volatile organic compounds

Volatile organic compounds (VOCs) are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure. VOCs include a variety of chemicals, some of which may have short-term and long-term adverse health effects.

4.5 NorthConnex ventilation outlet limits

Table 4-1 summarises the ventilation outlet limits set out for the Project per Condition E11.

Table 4-1: NorthConnex ventilation outlet mass pollutant concentrations

Pollutant	100 percentile limit	Units of measurement	Averaging Period	Reference conditions
Solid particles	1.1	mg/m^3	1 hour, or the minimum sampling period specified in the relevant test method, whichever is the greater	Dry, 273K, 101.3kPa
NO_2 or NO or both, as NO_2 equivalent	20	mg/m^3	1 hour block	Dry, 273K, 101.3kPa
NO_2	2.0	mg/m^3	1 hour block	Dry, 273K, 101.3kPa
CO	40	mg/m^3	1 hour rolling	Dry, 273K, 101.3kPa
VOC (as propane)	4.0	mg/m^3	1 hour rolling	Dry, 273K, 101.3kPa

Per Condition B3, the ventilation outlet exit plane must have a minimum exit velocity of:

- 13 metres per second; or
- a velocity, or variable velocity, to be determined in the Tunnel Ventilation, Incident Response and Traffic Management Systems Integration Protocol required under condition B7, but only if an equivalent or better environmental outcome than presented in the Proponent's most up to date air assessment can be demonstrated to the satisfaction of the Secretary, in consultation with the EPA.

5 CONTINUOUS MONITORING DATA

The continuous monitoring data in this report are presented as provided to Todoroski Air Sciences.

The continuous monitoring data provided to Todoroski Air Sciences are presented in graphical format in **Appendix A**.

It is noted that small negative concentration readings recorded are due to the instrument noise at low/zero concentration levels and are a normal part of the operation of gas and particulate analysers and are thus considered to be valid data for reporting purposes. A relatively large negative spike was recorded in each of the 1-minute and 5-minute VSO4 moisture data in late December 2020. These readings are not considered valid.

Table 5-1 presents a summary of the measured continuous pollutant levels occurring during the review period from 31 October 2020 to 30 April 2021 compared with the relevant concentration limits.

The data in **Table 5-1** indicates:

- The recorded solid particles, NO_x, CO and VOC levels were below the relevant air quality limits during the review period at VSO1 and VSO4.
- The NO_2 limit of 2mg/m^3 was exceeded on two occasions at VSO4.

Table 5-1: Summary of measured pollutant levels for review period (mg/m³)

Site	Solid particles	NOx	NO_2	CO	VOC
	1-hour	1-hour block	1-hour block	1-hour rolling average	1-hour rolling average
	NorthConnex Ventilation Outlet Mass Pollutant Concentration Limit				
	1.1	20	2.0	40	4.0
Maximum pollutant level					
VSO1	0.35	8.49	1.28	7.93	2.55
VSO4	0.31	12.05	**2.70**	14.92	0.45
Minimum pollutant level					
VSO1	0.00	0.02	0.02	-0.03	-0.01
VSO4	0.00	0.04	0.04	-0.26	0.02
Number of times recorded above criterion					
VSO1	0	0	0	0	0
VSO4	0	0	2	0	0
6-month average pollutant level					
VSO1	0.06	2.62	0.32	2.01	0.09
VSO4	0.03	4.80	0.58	2.69	0.13

Table 5-2 presents the percentage of data capture available over the review period. Review of the monitoring data indicates low data capture rates of solid particles for VSO1 and solid particles, CO and VOC for VSO4. The lower percentage of data capture available is reported in the in the monthly validation reports which note persistent issues with the TSP instruments at VSO1 and VSO4, and with the VOC instrument at VSO4 in the November 2020 to January 2021 reports.

The following issues were identified by the instrument supplier:

- TSPs were frequently in and out of fault mode

- VOCs were unstable with drifting spans, determined to be issues with the H3 generator.
- CO had detector faults causing instrument alarms, unstable spans and drift in data.

It is noted that flowrate and velocity is continuously calculated and used for the management and operation of the tunnel however, due to a technical issue this data was not logged during the review period. TAS has been advised that this issue has been rectified. For the purpose of this review, Transurban provided back-calculated ventilation outlet flow rates and velocities. The velocity value in brackets presents the data capture for the representative monitor.

Table 5-2: Percentage of continuous data capture available for the review period

Site	Data Capture %	
	VSO1	VSO4
Solid particles	55	52
NOx	91	89
NO_2	91	89
CO	85	67
VOC	90	48
Velocity	N/A (92)	N/A (92)
Flow rate	N/A	N/A
Moisture	100	97
Temperature	98	95

5.1 Solid particles monitoring data

Figure 5-1 presents the 1-hour average solid particles (TSP) monitoring data recorded during the review period. The data indicate that 1-hour average solid particle levels were below the respective air quality limit of 1.1mg/m^3 during the review period.

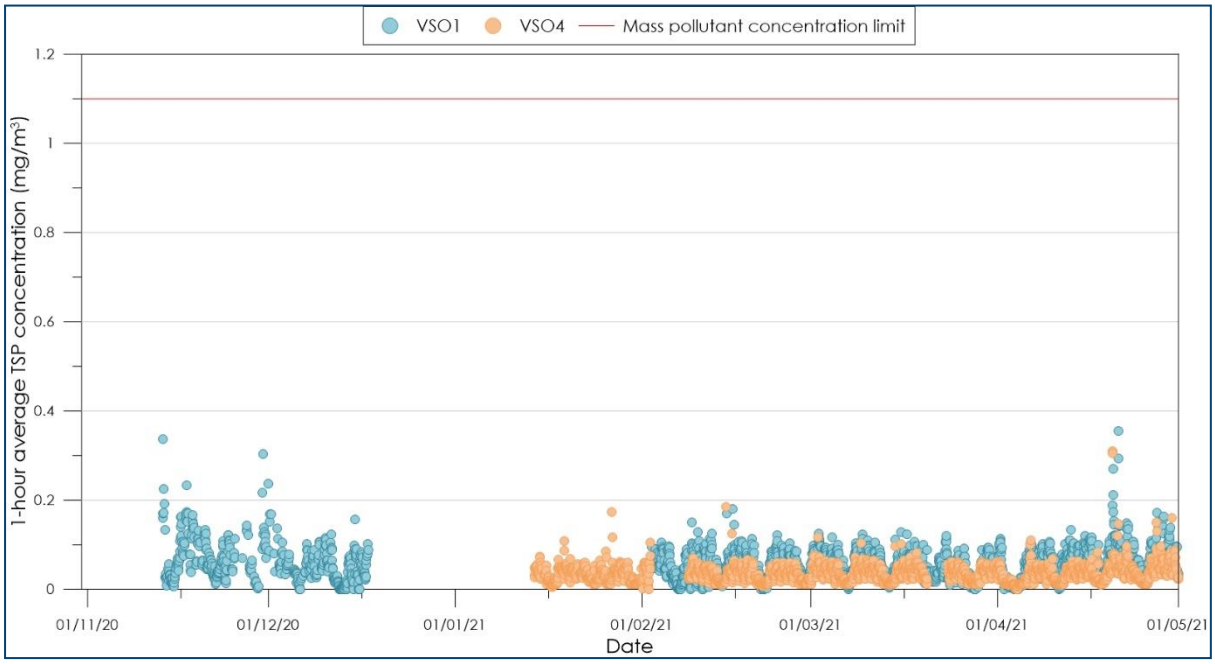

Figure 5-1: 1-hour average solid particles

5.2 NO_x monitoring data

Figure 5-2 presents the 1-hour average NO_x monitoring data recorded during the review period. The data indicate that 1-hour average solid particle levels were below the respective air quality limit of 20mg/m^3 during the review period.

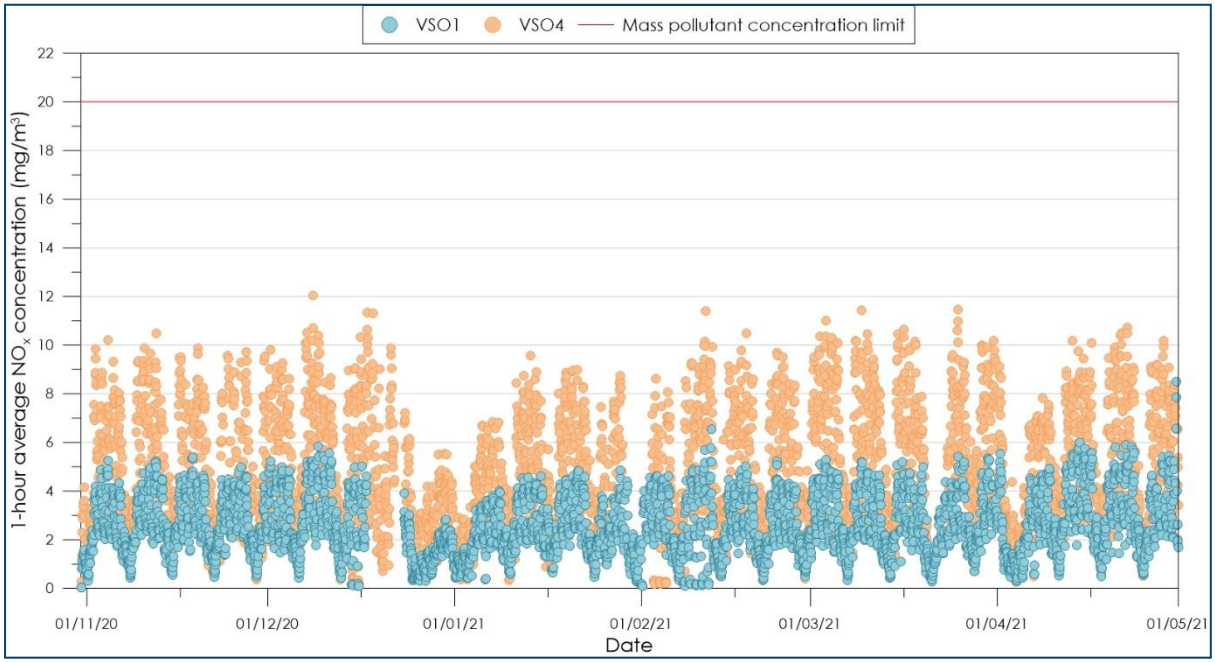

Figure 5-2: 1-hour average NO_x

5.3 NO_2 monitoring data

Figure 5-3 presents the 1-hour average NO_2 monitoring data recorded for the Project during the review period. The data indicate that on two occasions during the review period, the NO_2 levels at VSO4 were above the relevant air quality limit of 2.0mg/m^3.

The elevated results occurred on 21 December 2020 and 16 February 2021. Investigations into these exceedances were reported (**Todoroski Air Sciences, 2021a & b**). While various potential causes were investigated, the specific cause of the elevated reading could not be identified, however it is suspected that an issue with the instrument may have been the cause of the exceedance.

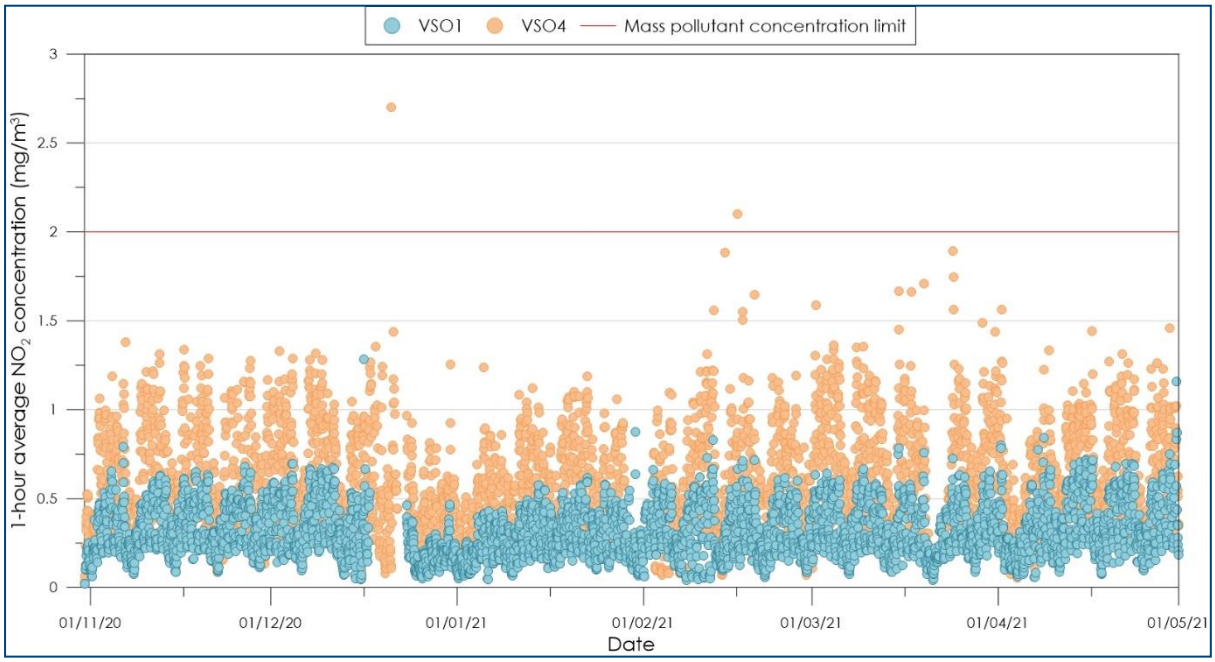

Figure 5-3: 1-hour average NO_2 levels

5.4 CO monitoring data

Figure 5-4 presents the rolling 1-hour average CO monitoring data recorded for the Project during the review period. The data indicate the CO levels were below the relevant air quality limit of 40mg/m^3 during the review period.

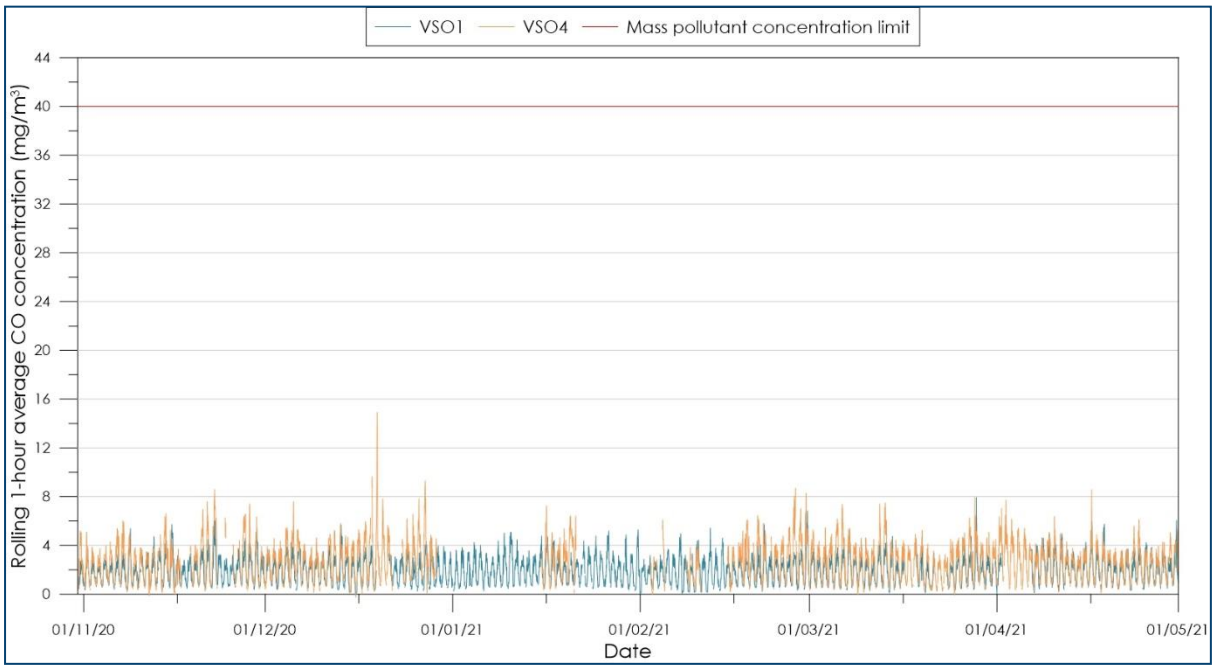

Figure 5-4: Rolling 1-hour average CO levels

5.5 VOC monitoring data

Figure 5-5 presents the rolling 1-hour average VOC monitoring data recorded for the Project during the review period. The data indicate the VOC levels were below the relevant air quality limit of 4mg/m^3 during the review period.

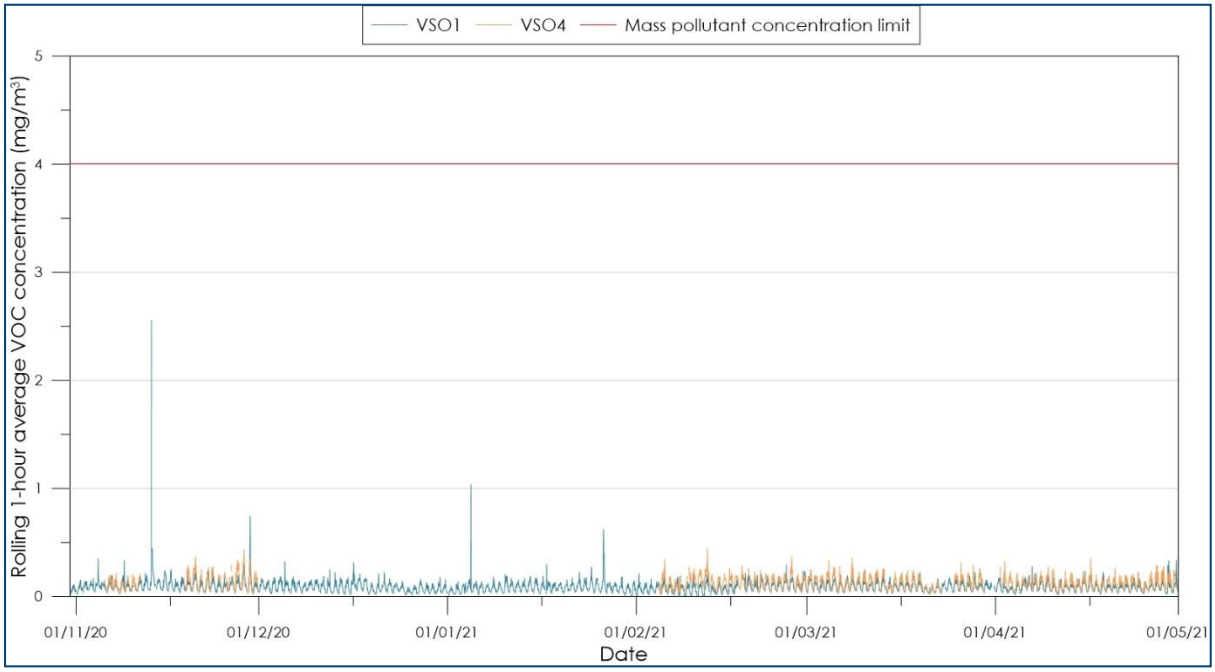

Figure 5-5: Rolling 1-hour average VOC levels

5.6 Velocity monitoring data

Figure 5-6 and **Figure 5-7** present the rolling 1-hour average velocity monitoring data calculated for VSO1 and VSO4 respectively during the review period. The data indicate that during the review period, the rolling 1-hour average velocity levels were below the minimum criterion of 13m/s for 3% of the time at VSO1 and 1% of the time at VSO4, (velocities below the minimum criterion are undesirable).

It was advised that readings near/at zero were likely due to power outages, brown outs or maintenance. It was also advised that periods of relatively narrow ranges in fluctuations compared with periods of higher fluctuation, as seen in VSO4, represent different operational modes.

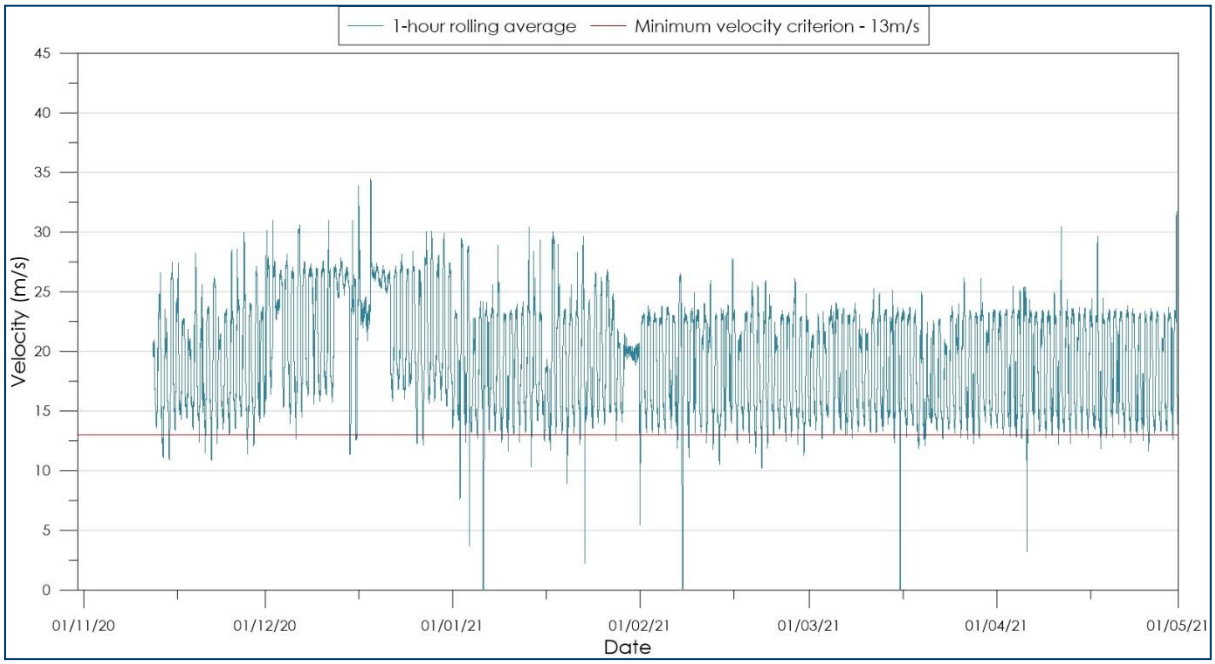

Figure 5-6: VSO1 rolling 1-hour average velocity levels

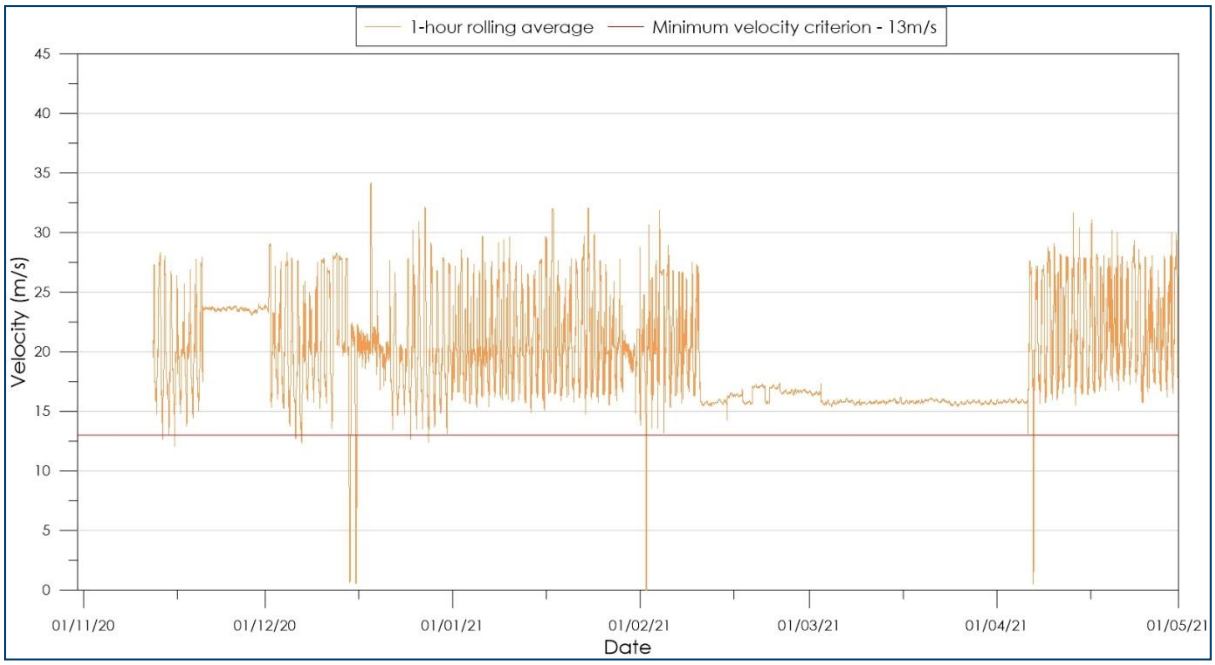

Figure 5-7: VSO4 rolling 1-hour average velocity levels

6 QUARTERLY MONITORING DATA

The quarterly monitoring data in this report are presented as provided to Todoroski Air Sciences.

Table 6-1 presents a summary of the quarterly particulate monitoring undertaken during the review period. Quarterly monitoring for solid particles (total particulate matter), PM_{10} and $PM_{2.5}$ was conducted on 8/2/2021 and 10/02/20201 for VSO1 and on 15/02/2021 and 22/02/2021 for VSO4. Note that there are no specific concentration limits for the quarterly monitoring of PM_{10} and $PM_{2.5}$.

Table 6-1: Summary of quarterly particulate monitoring undertaken during the review period

Site	Date	Stack concentration (mg/Nm^3)		
		Solid particles	PM_{10}	$PM_{2.5}$
VSO1	8/2/2021	0.311	-	-
	10/02/20201	-	0.35	0.017
VSO4	15/02/2021	-	0.64	0.282
	22/02/2021	0.694	-	-

The solid particle concentrations appear to be high in consideration of the CEMS data as presented previously in **Section 5.1** which indicate a maximum 1-hour average solid particles in February 2021 at both VSO1 and VSO4 of approximately 0.2mg/m^3. Assured Environmental provided a response (**Assured Environmental, 2021b**) indicating that the reported concentrations were lower than the CEMS and that the difference was not significant. It is noted that the available CEMS data provided to Todoroski Air Sciences does not show this and Assured Environmental appear to be referring to their concurrent CEMS monitoring at the time of the sampling.

The fraction of $PM_{2.5}$ appears to be lower than may be expected for a road tunnel ventilation outlet.

It is noted that the sampling methods specified in the consent conditions are not suitable for measuring particulate levels below 1mg, however they were the only EPA approved method available at the time the conditions were developed. As the particulate levels in the ventilation outlets should be lower than 1mg/m^3 the results of the quarterly monitoring are not considered to be particularly accurate, or suitable for verifying the CEMS results. Further discussion on the sampling methods is provided in the Operating Procedure and Equipment Independent Audit (**Todoroski Air Sciences, 2021c**).

7 ANNUAL MONITORING DATA

Annual monitoring of speciated PAH and VOC did not occur during the 6-month review period.

8 DISCUSSION

Todoroski Air Sciences have conducted an independent audit of the ventilation outlet monitoring data collected for the NorthConnex Project between 31 October 2020 and 30 April 2021.

There were some issues with the TSP, VOC and CO instruments at VSO1 and VSO4 in the first half of the six-month review leading to low data capture rates. Based on the later results, these initial issues appear to have been resolved.

The recorded ventilation pollutant monitoring data between 31 October 2020 and 30 April 2021 were generally below their respective air quality limits as outlined in **Table 4-1**.

There were two instances where the 1-hour average NO_2 limit of 2.0mg/m^3 was exceeded. Each of these instances have been assessed and reported in separate investigation reports. While various potential causes were investigated, a specific cause of the elevated reading could not be identified, and it is likely to be an issue with the instrument was the cause of the exceedance on both occasions. The data show that these brief high levels are unusual.

The 1-hour average solid particle levels, 1-hour average NO_x levels, rolling 1-hour CO levels and rolling 1-hour VOC levels during the review period were below their respective ventilation outlet air quality limits.

The back-calculated 1-minute average velocity was on occasion less than the minimum criterion of 13m/s at VSO1 and VSO4. It is understood that readings near/at zero were likely due to power outages, brown outs or maintenance.

9 REFERENCES

Assured Environmental (2021a)

"NorthConnex Quarter 1 Compliance Emissions Monitoring", prepared by Assured Environmental, July 2021

Assured Environmental (2021b)

" AE response to feedback received on the 20th of July 2021 in relation to report 13454 Q1 Compliance Report R_0 – signed", prepared by Assured Environmental, July 2021

Norditech (2020)

"DM Roads - NorthConnex Tunnel Ventilation Stack Outlet Air Quality Monitoring Validated Data Report 31 October 2020 to 30 November 2020", prepared by Norditech, December 2020

Norditech (2021a)

"DM Roads - NorthConnex Tunnel Ventilation Stack Outlet Air Quality Monitoring Validated Data Report 1 December 2020 to 31 December 2020", prepared by Norditech, January 2021

Norditech (20216)

"DM Roads - NorthConnex Tunnel Ventilation Stack Outlet Air Quality Monitoring Validated Data Report 1 January 2021 to 31 January 2021", prepared by Norditech, February 2021

Norditech (2021c)

"DM Roads - NorthConnex Tunnel Ventilation Stack Outlet Air Quality Monitoring Validated Data Report 1 February 2021 to 28 February 2021", prepared by Norditech, March 2021

Norditech (2021d)

"DM Roads - NorthConnex Tunnel Ventilation Stack Outlet Air Quality Monitoring Validated Data Report 1 March 2021 to 31 March 2021", prepared by Norditech, April 2021

Norditech (2021e)

"DM Roads - NorthConnex Tunnel Ventilation Stack Outlet Air Quality Monitoring Validated Data Report 1 April 2021 to 30 April 2021", prepared by Norditech, May 2021

Todoroski Air Sciences (2021a)

"NorthConnex Independent Air Quality Expert Review of Ventilation Outlet Limit Exceedance 21 December 2020", prepared by Todoroski Air Sciences, January 2021

Todoroski Air Sciences (2021b)

"NorthConnex Independent Air Quality Expert Review of Ventilation Outlet Limit Exceedance 16 February 2021", prepared by Todoroski Air Sciences, March 2021

Todoroski Air Sciences (2021c)

"NorthConnex Air Quality Monitoring Operating Procedure and Equipment Independent Audit", prepared by Todoroski Air Sciences, November 2021

US EPA (2011)
"Health Effects of Pollution", United States Environmental Protection Agency website http://www.epa.gov/region07/air/quality/health.htm, 2011

Appendix A

Continuous Monitoring Data (Graphical)

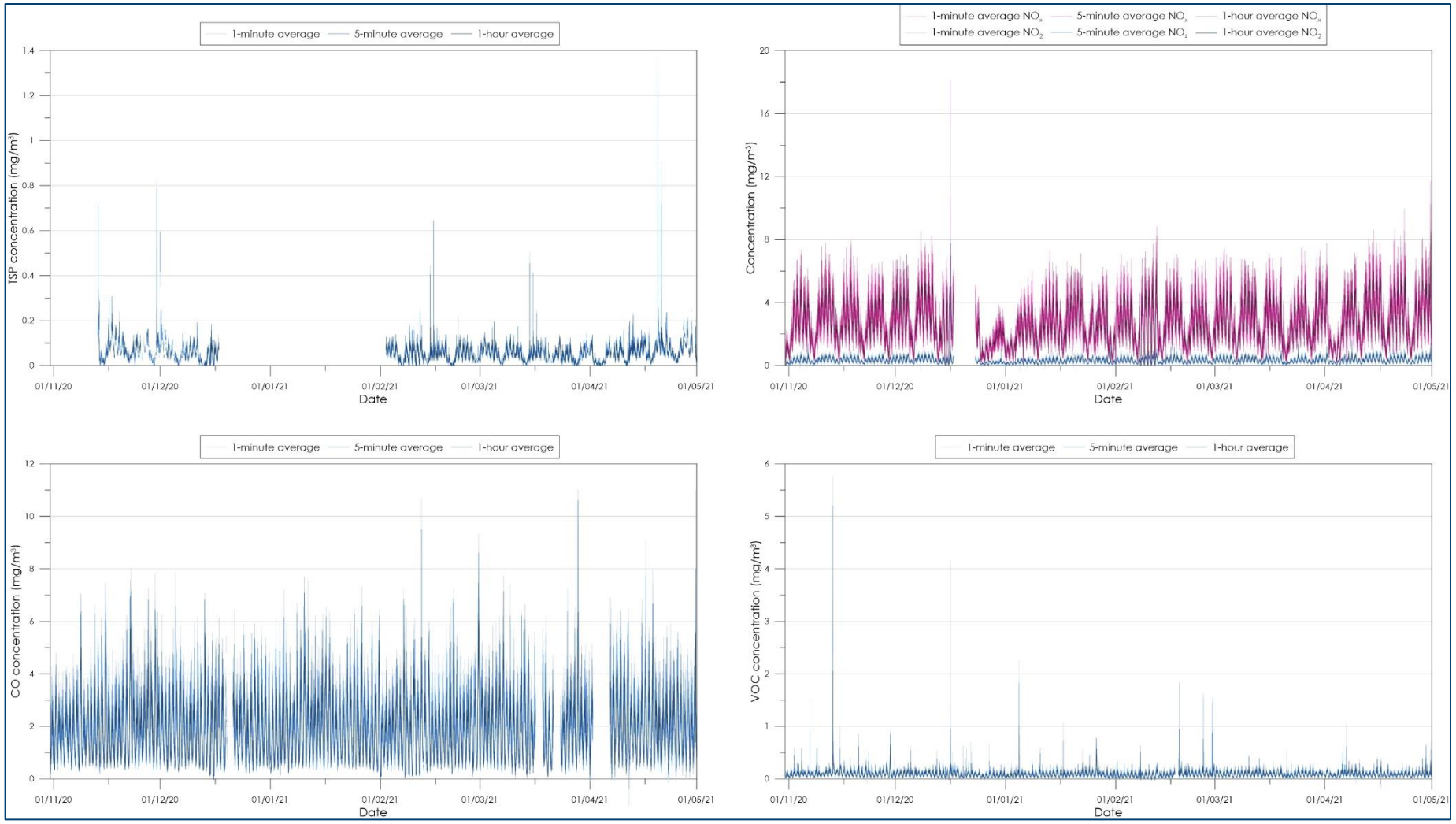

Figure A-1: VSO1 pollutant monitoring data

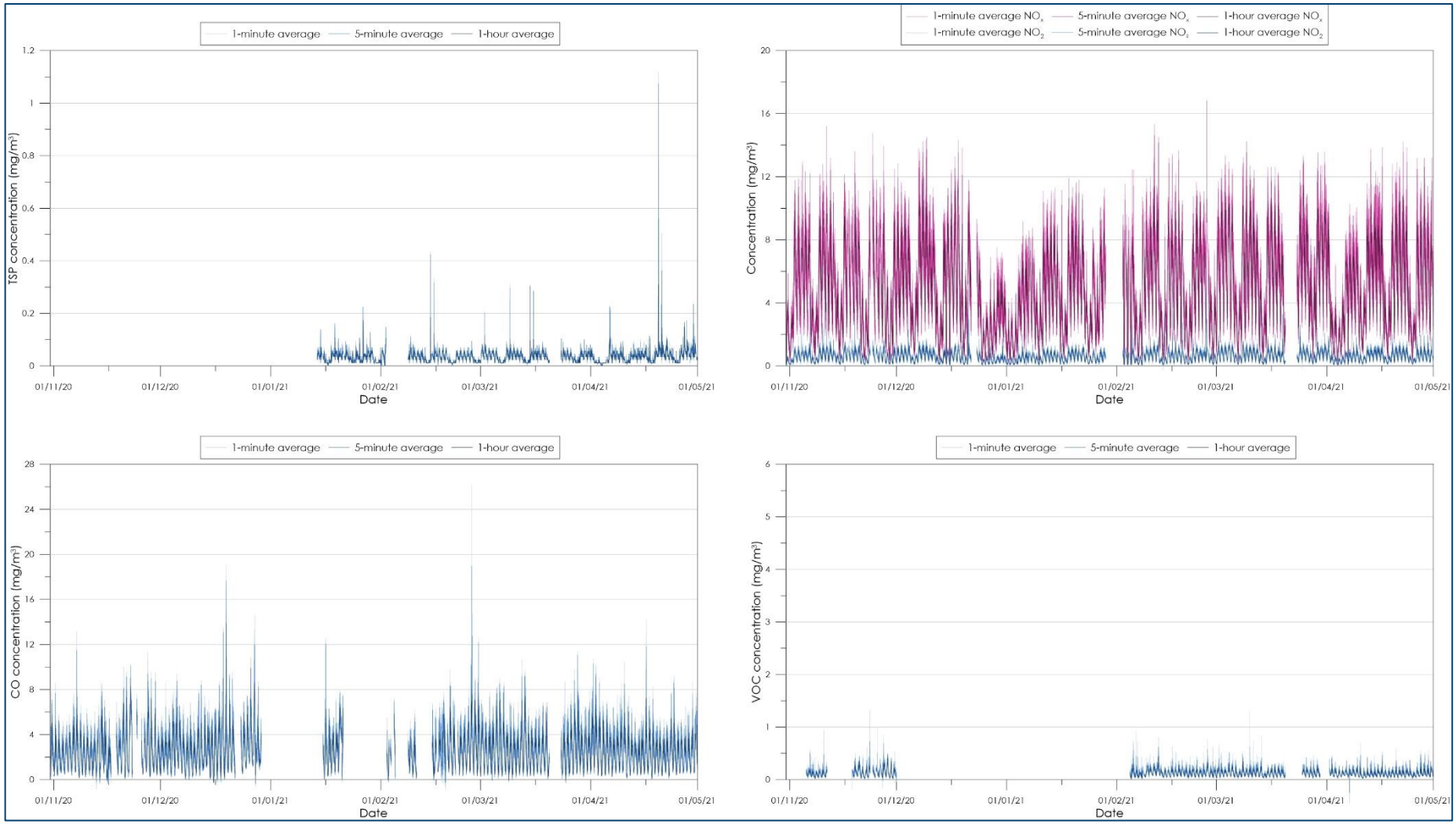

Figure A-2: VSO4 pollutant monitoring data

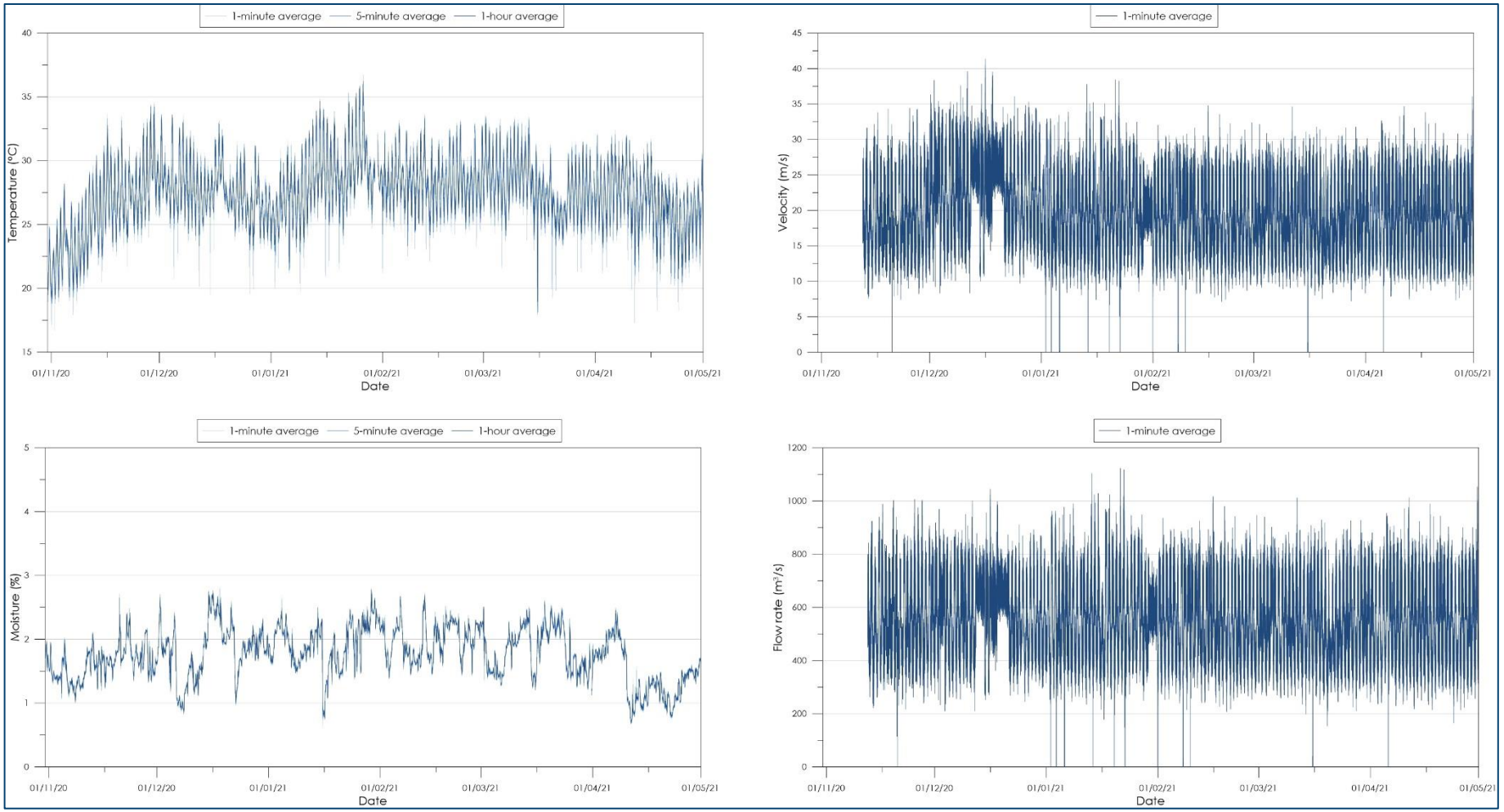

Figure A-3: VSO1 parameter monitoring data

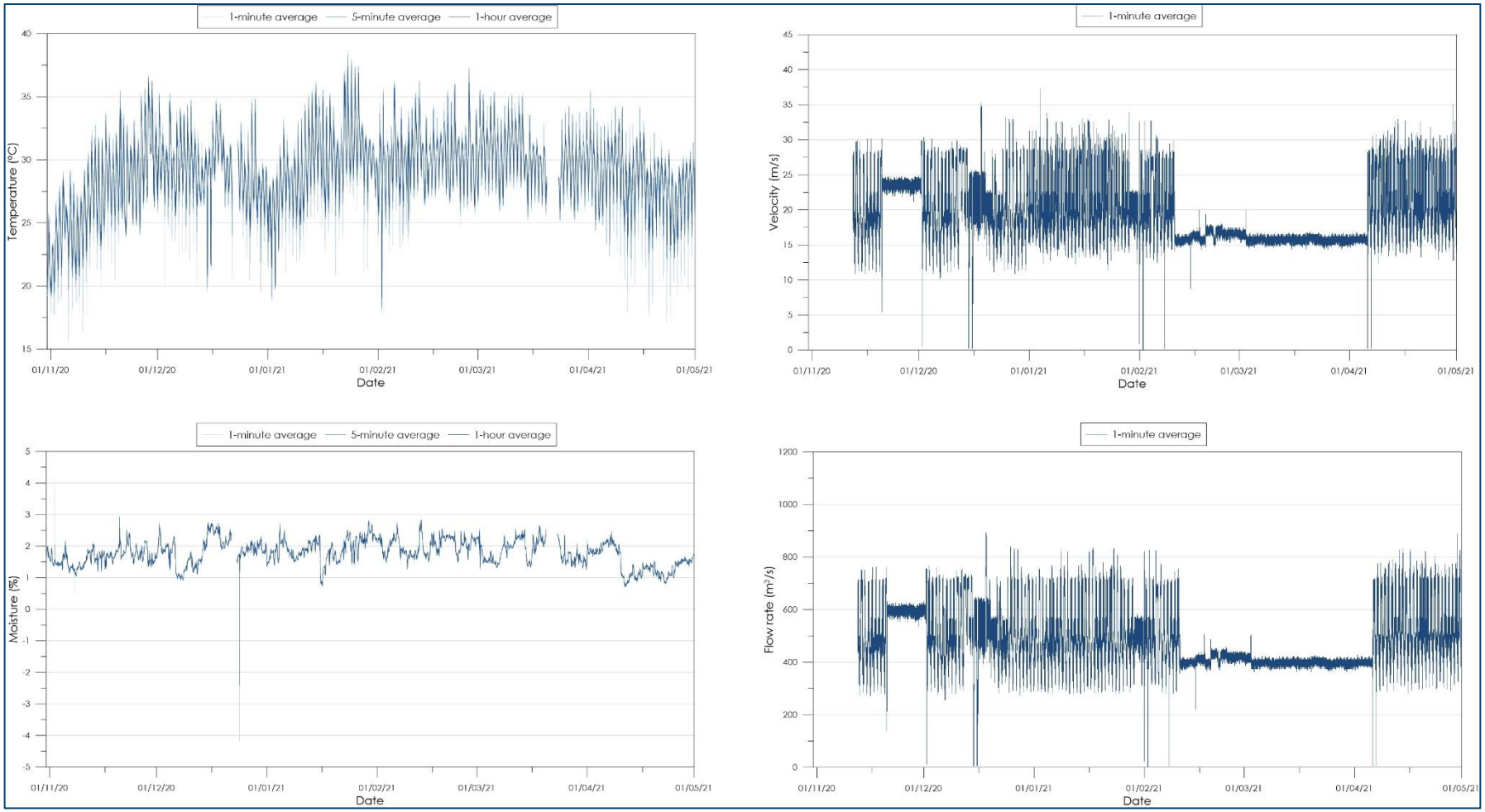

Figure A-4: VSO4 parameter monitoring data