Attachment 1

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

WASTE-TO-ENERGY FACILITY AMBIENT AIR MONITORING PROGRAM ASSESSMENT

2021 - 2022 SUMMARY

MAY 27, 2024

wsp

WASTE-TO-ENERGY FACILITY AMBIENT AIR MONITORING PROGRAM ASSESSMENT

2021 - 2022 SUMMARY

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

PROJECT NO.: 211-10855-00
DATE: MAY 27, 2024

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Attention: Sarah Wellman, Senior Engineer

Dear Sarah:

Subject: WASTE-TO-ENERGY FACILITY AMBIENT AIR MONITORING PROGRAM ASSESSMENT - 2021 - 2022 SUMMARY

WSP Canada Inc. (WSP) submits this assessment report in fulfilment of the scope requirements under Greater Vancouver Sewerage and Drainage District contract No. 20-342 for the Waste-to-Energy Facility Ambient Air Monitoring Program Assessment. We trust that our report meets the project requirements and the Corporations expectations. If you have any questions or would like clarification regarding our submission, please reach out to the undersigned.

Yours sincerely,

Tyler Abel
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APPENDICES

A JURISDICTIONAL REVIEW OF AMBIENT HCL OBJECTIVES

1 EXECUTIVE SUMMARY

As a follow-up to the dispersion modelling and human health risk assessment studies conducted in 2018 in response to the requirements from the Metro Vancouver (MV) Waste-to-Energy Facility (WTEF) Operational Certificate (OC), issued December 15, 2016 by the BC Ministry of Environment and Climate Change Strategy, an ambient air monitoring station measuring NO_x, SO_2 and HCl was installed near the WTEF in 2020, and an HCl monitor was installed at Metro Vancouver Regional District's (MVRD) existing T18 – Burnaby South monitoring station. WSP Canada Inc. (WSP) prepared an assessment of the two-year monitoring program. Focusing on nitrogen oxides (NO_x), sulphur dioxide (SO_2) and hydrogen chloride (HCl) in the 2021 and 2022 calendar years, the purpose of this assessment was to evaluate the MV WTEF's contribution to ambient air quality by means of data analysis using ambient air quality data collected at two monitoring stations (S150 – MV WTEF and T18 - Burnaby South), MV WTEF emissions data, and air dispersion modelling results.

COMPARISON WITH AMBIENT AIR QUALITY OBJECTIVES

As a first step in the assessment, ambient concentrations of NO_2, SO_2, and HCl collected at the two MVRD monitoring stations during the 2021-2022 monitoring period were summarized and compared to ambient air quality objectives (AAQOs). Within the 2-year monitoring period, no exceedances of short-term nor long-term (1-hour, 24-hour, and annual) AAQOs for NO_2, SO_2, and HCl were recorded at either MVRD monitoring stations.

HCl and SO_2 concentrations were particularly low in comparison to AAQOs. For HCl, 1-hour maximum ambient air concentrations were 6% of the AAQO at the S150 – MV WTEF station and 9% of the AAQO at T18 – Burnaby South station. While the maximum concentrations of HCl monitored were low in comparison to AAQOs, in general, HCl concentrations were even lower, as 98% of the time, HCl concentrations were less than 3% of the ambient air quality objectives at both stations, highlighting that HCl was consistently low. For SO_2, 1-hour maximum ambient air concentrations were 10% of the AAQO at the S150 – MV WTEF station and 6% of the AAQO at the T18 – Burnaby South station. Similar to HCl concentrations though, 98% of the time, ambient concentrations of SO_2 were less than 2% of the AAQO at both stations.

NO_2 ambient air concentrations were higher in comparison to AAQOs than the other two pollutants analyzed., with 1-hour maximum ambient air concentrations at 76% of the AAQO at the S150 – MV WTEF station and 62% of the AAQO at the T18 – Burnaby South station. This was anticipated given that the primary contributor to NO_2 concentrations in the region are road traffic emissions. The two stations exhibited the expected trend of peak 1-hour average NO_2 concentrations during peak traffic. Slightly higher levels of NO_2 were measured at S150 – MV WTEF station compared to T18 – Burnaby South station, but both were clearly influenced primarily by traffic emissions.

WIND DATA ANALYSIS

Monitored concentrations during particular wind direction and wind speed conditions were analyzed as a tool to investigate directions and wind speeds from which contaminants may be originating from. Polar plots analyzing wind directions and wind speeds associated with monitored pollutant levels suggest the potential influence of WTEF emissions may be observable during Winter periods at the S150 – MV WTEF station, particularly during stagnant periods with low wind speeds. Seeing this relationship in the data is not unexpected given that the station was sited near the location with the highest expected ambient air concentrations identified by the WTEF dispersion modelling assessment. Although this relationship can be observed, as explained above maximum pollutant concentrations remained well below AAQOs and the levels predicted in the dispersion modelling assessment. During the Summer for S150 – MV WTEF, and at T18 – Burnaby South during the full year, measured ambient NO_2, SO_2, and HCl levels were likely associated with emissions from other sources combined with seasonal and regional meteorological patterns such as Summertime sea breezes.

RELATIONSHIP BETWEEN WTEF EMISSIONS DATA AND AMBIENT AIR MONITORING DATA

To further investigate whether the WTEF operations were impacting the levels of all three pollutants at the monitoring stations, an analysis was conducted using ambient concentrations of NO_2, SO_2, and HCl collected at S150 – MV WTEF station and T18 – Burnaby South station and continuous emissions monitoring (CEMS) data collected at MV WTEF's three boiler lines during the 2-year monitoring period. Specifically, linear regression models were utilized and determined no statistically significant linear correlation between WTEF CEMS readings and S150 and T18 ambient air quality data for all three pollutants. This suggests that there were other significant regional emission sources and meteorological factors that impact the ambient levels of NO_2, SO_2, and HCl recorded at both the S150 – MV WTEF station and T18 – Burnaby South station during the monitoring campaign.

Emissions during WTEF start up and shut down events were also evaluated as these events can result in higher emission releases. A comparison analysis determined that the ambient concentrations levels of NO_2, SO_2, and HCl recorded during different boiler unit operational statuses were very similar, and that the distributions of data were non-normal and right-skewed. Statistical analysis techniques determined that there were some statistically significant differences between ambient concentrations during different boiler operational statuses, but the differences in median concentrations for each operational status were very small. This result suggests that there were other significant regional sources and meteorological factors that had a greater impact on the S150 and T18 ambient levels of NO_2, SO_2, and HCl than the startup – shutdown status of the WTEF.

CONCLUSIONS AND RECOMMENDATIONS

The monitoring conducted at the 2 MVRD stations over the 2-year period provided insight into the near-field levels of NO_2, SO_2, and HCl within the vicinity of the WTEF. Monitored levels were confirmed to be low for SO_2 and HCl and established that NO_2 concentrations patterns did not exceed any AAQOs and that peaks were primarily linked to typical road traffic emissions patterns. Overall, the analysis of ambient air quality and CEMS data from the WTEF using spatial and statistical analysis tools did not reveal any significant correlations, trends, or patterns that suggested the WTEF is significantly impacting ambient air concentrations of NO_2, SO_2 or HCl at two ambient air monitoring stations near the facility. For all three pollutants monitored, the analysis showed that there are likely other primary drivers of ambient air concentrations at the monitoring locations. For SO_2 and NO_2, the other regional sources of emissions are well known. WSP's research of HCl emission sources and atmospheric chemistry shows that an understanding of the concentration of HCl in ambient air in a marine or coastal environment is dependent on an understanding of the contribution from the sea salt dechlorination process and the interplay with meteorological influences and anthropogenic sources. According to Crisp et al., 2013[13], in areas like Metro Vancouver meteorological and atmospheric processes related to the marine boundary layer result in the sea salt dechlorination process being a dominant influence on HCl concentrations, while biomass burning, coal combustion, and waste incineration processes are thought to be more likely influential in continental areas away from the marine boundary. Current global reactive chlorine emission inventories have estimated that greater than 80% of total tropospheric HCl stems from sea salt particle dechlorination reactions, but the understanding of the impact of chlorine catalyzed chemistry is limited due to the highly spatially variable anthropogenic HCl emissions which have not been adequately observed. Understanding that the WTEF does represent a major anthropogenic source of HCl emissions in the airshed that is not "showing up" in the ambient monitoring analysis, our discussion of the results hypothesizes that the primary driver of HCl in the near coast portion of the Lower Fraser Valley airshed (as we would characterize the location of the WTEF) is the contribution of sea salt dechlorination.

For this reason, in addition to the continuation of HCl monitoring (along with all existing parameters) at T18 – Burnaby South and NO_2, SO_2, HCl and meteorological monitoring at a station near to the WTEF to confirm monitoring results during the 2021 – 2022 period on an ongoing basis, it is also recommended that additional HCl monitoring at a minimum of two additional regional locations (one coastal and one inland). The additional monitoring is recommended to enhance understanding of the atmospheric behaviour of ambient HCl across the Lower Fraser Valley airshed.

2 INTRODUCTION

The Greater Vancouver Sewerage and Drainage District ("the Corporation") owns the Metro Vancouver (MV) Waste-to-Energy Facility (WTEF) located in Burnaby, British Columbia, which is operated under contract by Covanta Burnaby Renewable Energy, ULC. The WTEF is equipped with an air pollution control system designed to reduce emissions of nitrogen oxides (NO_x), sulphur dioxide (SO_2) and hydrogen chloride (HCl), along with a host of other air contaminants. The emissions discharge limits and performance requirements for the air pollution control equipment are laid out in the WTEF's Operational Certificate (OC), issued December 15, 2016 by the BC Ministry of Environment and Climate Change Strategy. In response to OC requirements, dispersion modelling and human health risk assessment studies were conducted in 2018. As a follow up to these studies, an ambient air monitoring station measuring NO_x, SO_2 and HCl was installed near the WTEF in 2020, and an HCl monitor was installed at Metro Vancouver Regional District's (MVRD) existing Burnaby South monitoring station, which also monitors NO_x and SO_2.

The inclusion of HCl monitoring, specifically monitoring at very low levels of HCl, makes this ambient air monitoring program unique to the Metro Vancouver region. At the time of submission of this report, we are not aware of any other Canadian regulatory agencies implementing low-level HCl monitoring. Therefore, to provide context to the HCl monitoring data presented herein, WSP have prepared a discussion of HCl atmospheric chemistry and a jurisdictional review of ambient HCl guidelines and objectives.

WSP Canada Inc. (WSP) has prepared the following report, outlining the results of the ambient air monitoring data analysis from the January 1, 2021 to December 31, 2022 period. In particular, the analysis considers ambient air quality data collected at two ambient air quality monitoring stations (S150 – WTEF and T18 – Burnaby South), emissions data and dispersion modelling results with a focus on NO_x, SO_2 and HCl.

3 HYDROGEN CHLORIDE OVERVIEW

Due to the unique nature of ambient hydrogen chloride (HCl) monitoring in the Vancouver region, a general literature review of HCl was conducted by WSP to establish a baseline understanding of HCl emission sources, atmospheric chemistry, and relevant jurisdictional regulatory air quality requirements. The following sections outline the findings of the literature review of HCl.

3.1 HCL EMISSIONS SOURCES AND ATMOSPHERIC CHEMISTRY

HCl emission sources were identified based on literature review pertaining to ambient production processes and sources of HCl, as well from the national emission reporting databases (e.g., Canada's National Pollutant Release Inventory [NPRI] and US National Emissions Inventory [NEI]). There are a total of 8 HCl emission types identified in the LFV region, which include:

- WTEF;
- Industrial Processes (industrial operations such as cement production facilities and metal finishing facilities);
- Natural Marine (resulting from the sea salt dechlorination process involving sea salt aerosols reacting with air contaminants already present in the atmosphere);
- Industrial/Agricultural Wood Boilers;
- Residential Wood Burning;
- Vehicle and Structure Fires (burning of vehicle wastes, building materials and PVC pipes);
- Cremation Emissions; and,
- Open-air Biomass Burning.

The sources of HCl are not as well inventoried as other pollutants and therefore the relative contributions to ambient HCl concentrations as more traditionally monitored pollutants such as SO_2 and NO_2. Complicating the interpretation of ambient HCl monitoring data is also the role atmospheric chemistry processes play. Therefore, the review of HCl atmospheric chemistry focused primarily on peer reviewed publications and synthesizes these results into a regionally relevant discussion of HCl chemistry. A particular area of focus was the speed of atmospheric chemical processes relating to HCl and the potential for bias in dispersion modelling results due to the lack of HCl chemistry in standard dispersion modelling approaches.

Globally, the largest source of chlorine gases to the troposphere is the mobilization of chloride (Cl^-) from sea salt aerosol (Graedel and Keen, 1995[1] and Finlayson-Pitts, 2003[2]). These gases have a wide range of implications for tropospheric chemistry, based on its potential to generate chlorine radicals, which include budgets of ozone, OH (the main tropospheric oxidant), volatile organic compounds (VOCs), nitrogen oxides, other halogens, and mercury (Saiz-Lopez and von Glasow, 2012[3]; Simpson et al., 2015[4]). Although sea salt aerosols contribute to a large chloride

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[2] Finlayson-Pitts, B. J.: The Tropospheric Chemistry of Sea Salt: A Molecular-Level View of the Chemistry of NaCl and NaBr, Chem. Rev., 103, 4801–4822, https://doi.org/10.1021/cr020653t, 2003.

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flux to the atmosphere, most of the chloride is removed rapidly through deposition (Wang et al., 2019[5]). The small fraction of remaining chloride is primarily mobilized to the gaseous phase of HCl through sea salt dechlorination. Direct emissions of gas phase HCl into the atmosphere include the combustion of chloride-containing fuels (e.g., waste incineration, biomass burning, and coal combustion), volcanic emissions, water treatment, emissions during manufacturing processes, open fires, road salt application, and fugitive dust (Keene et al., 1999[6]; Khalil et al., 1999[7]; McCulloch et al., 1999[8]; Lobert et al., 1999[9]; Sarwar et al., 2012[10]; WMO, 2014[11]; Kolesar et al., 2018[12]).

Overall, understanding of the impact of chlorine catalyzed chemistry is limited due to the highly spatially variable anthropogenic HCl emissions which have not been adequately observed (Crisp et al., 2013[13]). However, current global reactive chlorine emission inventories have estimated that greater than 80% of total tropospheric HCl stems from particle dechlorination reactions (Keene et al., 1999[6]). According to Crisp et al., 2013[13], sea salt dechlorination is dominant in the marine boundary layer, while biomass burning, coal combustion, and waste incineration processes are thought to be more likely influential in continental areas. In addition, according to Wang et al., 2019[5], the HCl mixing ratios in marine surface air are usually highest along polluted coastlines where acid displacement of sea salt aerosols is driven by large sources of HNO_3 and H_2SO_4 from anthropogenic NO_x and SO_2 emissions. On the other hand, HCl mixing ratios over the Southern Ocean are low because of the low supply of acid gases.

According to Finlayson-Pitts and Pitts, 1999[14], the lifetime of HCl in the atmosphere depends on wet and dry deposition, where dry deposition velocity in marine environments is estimated to be 1-5 cm/s. At a boundary layer height of 1 km and a deposition rate of 1 cm/s, the lifetime of HCl with respect to dry deposition is 1.2 days. On the other hand, the 24-hour average lifetime of HCl with respect to OH oxidation is approximately 15 days. In addition, Keene et al., 1990[15] and Watson et al., 1990[16] have determined that equilibrium partitioning of HCl to aerosols is pH dependent, where basic to circumneutral aerosols are expected to be a net sink for HCl. Therefore, the deposition rate of HCl is primarily controlled by HCl lifetime in the marine boundary layer and integrated Cl atom production resulting from HCl reactions with OH (Crisp et al., 2013[13]).

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3.2 HCL JURISDICTIONAL REVIEW

In the absence of HCl ambient air quality objectives in the Metro Vancouver Regional District and in the province of BC at large, the 2018 MV WTEF Dispersion Modelling Study by RWDI selected the following HCl ambient air quality objectives from other jurisdictions to evaluate the potential air quality impacts from the WTEF emissions:

- For the 1-hour averaging period, the 75 µg/m^3 from Alberta was utilized;
- For the 24-hour averaging period, the 20 µg/m^3 from Ontario was utilized; and finally,
- For the annual averaging period, the 20 µg/m^3 from US EPA was utilized.

To determine whether the above objectives are still relevant and applicable for assessing the potential air quality impacts from the WTEF, a review of the currently available HCl ambient air objectives from jurisdictions across North America was conducted by gathering and comparing objectives across jurisdictions as well evaluating their basis of criteria development. The jurisdictional review included all provinces in Canada and key US jurisdictional sources such as Texas Department of Environmental Quality (TDEQ), California Office of Environmental Health Hazard Assessment (OEHHA) and US EPA.

The summary table for the jurisdictional review of ambient HCl objectives is presented in Appendix B. There are only a few North American jurisdictions with credible HCl criteria that were well-substantiated by toxicology research and documentation for the basis of the criteria derivation – US EPA, California, and Texas. The US EPA's annual criteria of 20 µg/m^3 was adopted by many of the jurisdictions examined, including Quebec, Michigan, Oregon, and New York; hence it is still suitable for assessing the annual air quality predictions from the WTEF.

HCl objectives established for Canadian jurisdictions were observed to be either outdated or devoid of documentations for their basis. The 1-hour HCl objective of 75 µg/m^3 from Alberta is the most stringent criteria for the 1-hour averaging period among all jurisdictions assessed and this objective was indicated as being adopted from Texas. However, the current HCl criteria in Texas are higher – 190 µg/m^3 for regulatory air permitting purposes and 660 µg/m^3 as the air monitoring concentration benchmark. The basis of criteria development and associated toxicology studies are extensively documented by the TDEQ for their current objectives. However, despite the limited scientific basis or documentation for the Alberta objective, it has been retained for use in this study for consistency with the 2018 dispersion modelling study, and because it represents the most conservative 1-hour objective.

Of the jurisdictions examined, only 3 had 24-hour HCl objectives: Ontario (20 µg/m^3), Massachusetts (7 µg/m^3), and Idaho (375 µg/m^3). Although no documentations were provided by any of the 3 jurisdictions, the Massachusetts Department of Environmental Protection (MassDEP) indicated that their criteria were Threshold Effects Exposure Limits (TELs) based on non-cancer health effects (MassDEP, 2011). However, the MassDEP acknowledged that their TELs are dated in December 1995 and stated that "while a number of these values have been reviewed and updated since inception of the original TELs, many need to be re-evaluated given the newer, widely accepted methods for deriving inhalation toxicity values and availability of new primary literature since the mid-1980s" (MassDEP, 2011). The Idaho Department of Environmental Quality (IDEQ) specified that their criteria were based on occupational exposure limits expressed in terms of an Acceptable ambient concentration for a non-carcinogenic toxic air pollutant (IDEQ, 2021). The Ontario 24-hour objective has been retained for this study for consistency the 2018 dispersion modelling study, and because the Massachusetts objective was deemed to be outdated and poorly supported.

4 REGIONAL AIR QUALITY REGULATORY FRAMEWORK

4.1 AIR QUALITY OBJECTIVES

The management of air quality in Canada is accomplished primarily through federal and provincial government collaboration. At the federal level, the Canadian Council of Ministers of the Environment (CCME) acts as a forum for provincial governments to jointly undertake initiatives to address major environmental issues. Regarding air quality, the CCME approved the current air quality management system (AQMS) in 2012. The AQMS is a comprehensive approach for improving air quality in Canada and is the product of collaboration by the federal, provincial, and territorial governments and stakeholders. Each province is tasked with implementing the components of the AQMS within their respective jurisdiction.

In British Columbia, the management of air quality in the Metro Vancouver region is delegated through the Environmental Management Act (EMA) to the MVRD, a regional body governed by a board constituted of elected representatives from each municipality and electoral area within the region. Specifically, MVRD is a federation of 21 municipalities, one electoral area, and one treaty First Nation. As a result of the CCME initiatives regarding the AQMS, MVRD have adopted or updated air quality objectives for a number of air contaminants.

Air quality objectives are used to:

- Assess and provide context to current or historical air quality and trends;
- Guide decisions on the permitting of new or modified facilities;
- Guide decisions on episode management, such as air quality advisories;
- Develop long-term air quality management strategies and evaluate progress; and
- Aid in the development of new regulatory and non-regulatory initiatives.

In this assessment, ambient air quality concentrations recorded at S150 – MV WTEF station and T18 – Burnaby South station will be compared against the statistical form of the current ambient air quality objectives (AAQOs) with rules (e.g., data completeness checks) established by CCME. Ambient concentrations of nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) will be compared against MVRD AAQOs[17]. On the other hand, due to the lack of MV AAQOs for HCl (as is the case with most jurisdictions across Canada), ambient concentrations of hydrogen chloride (HCl) will be compared against objectives / criteria from other jurisdictions (Alberta Environment (AENV)[18], Ontario Ministry of Environment (Ontario MoE)[19], and US Environmental Protection Agency (US EPA[20]). Table 4-1 below outlines the list of AAQOs used in this assessment.

[17] *Metro Vancouver Ambient Air Quality Objectives (Updated January 2020):* http://www.metrovancouver.org/services/air quality/AirQualityPublications/CurrentAmbientAirQualityObjectives.pdf

[18] *Alberta Ambient Air Quality Objectives and Guidelines Summary (January 2019):* https://open.alberta.ca/dataset/0d2ad470-117e-410f-ba4f-aa352cb02d4d/resource/4ddd8097-6787-43f3-bb4a-908e20f5e8f1/download/aaqo-summary-jan2019.pdf

[19] *Ontario's Ambient Air Quality Criteria (April 2012):* http://www.airqualityontario.com/downloads/AmbientAirQualityCriteria.pdf

[20] *United States Environmental Protection Agency: Hydrogen Chloride IRIS Summary:* https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=396

It is important to note that although the statistical form of the 1-hour NO_2 AAQO is the "98th percentile of the daily maximum 1-hour concentration, averaged over three consecutive years", the data completeness criteria required to calculate the 1-hour NO_2 metric only involves two of the possible three annual 98th percentiles[21]. As such, the 2 years of ambient 1-hour average NO_2 data collected at the two monitoring stations were used to calculate the 2 year average of 98th percentile daily maximum of 1-hour concentrations for comparison against the 1-hour NO_2 AAQO.

Table 4-1 Ambient Air Quality Objectives (AAQOs)

<table>
<tr><th>AIR CONTAMINANT</th><th>AVERAGING PERIOD</th><th>STATISTICAL FORM OF OBJECTIVE</th><th>OBJECTIVE</th><th>JURISDICTION OF OBJECTIVE</th><th>OBJECTIVE TYPE</th></tr>
<tr><td rowspan="2">Nitrogen Dioxide (NO_2)</td><td>1-Hour</td><td>98th percentile of the daily maximum 1-hour concentration, averaged over three consecutive years[A]</td><td>60 ppb (113 µg/m^3)</td><td rowspan="4">Metro Vancouver Regional District (MVRD)</td><td rowspan="4">Metro Vancouver Ambient Air Quality Objective (MVAAQO)</td></tr>
<tr><td>Annual</td><td>Annual average of 1-hour concentrations</td><td>17 ppb (32 µg/m^3)</td></tr>
<tr><td rowspan="2">Sulphur Dioxide (SO_2)</td><td>1-Hour</td><td>Maximum 1-hour concentration</td><td>70 ppb (183 µg/m^3)</td></tr>
<tr><td>Annual</td><td>Annual average of 1-hour concentrations</td><td>5 ppb (13 µg/m^3)</td></tr>
<tr><td rowspan="3">Hydrogen Chloride (HCl)</td><td>1-Hour</td><td>Maximum 1-hour concentration</td><td>50 ppb (75 µg/m^3)</td><td>Alberta Environment (AENV)</td><td>Alberta Ambient Air Quality Objective (AAAQO)</td></tr>
<tr><td>24-Hour</td><td>Maximum 24-hour block average concentration</td><td>13.4 ppb (20 µg/m^3)</td><td>Ontario Ministry of Environment (Ontario MoE)</td><td>Ontario Ambient Air Quality Criteria (OAAQC)</td></tr>
<tr><td>Annual</td><td>Annual average of 1-hour concentrations</td><td>13.4 ppb (20 µg/m^3)</td><td>US Environmental Protection Agency (US EPA)</td><td>US EPA Reference Concentration for Inhalation Exposure (RfC)</td></tr>
</table>

Note: [A]Since there is only two years of ambient air quality data available for use in this assessment, the 98th percentile of the daily maximum 1-hour concentration averaged over 2-years will be compared against the 1-hour NO_2 AAQO.

21 *Canadian Council of Ministers of the Environment: Guidance Document on Achievement Determination for Canadian Ambient Air Quality Standards for Nitrogen Dioxide (2020):* https://ccme.ca/en/res/gdadforcaaqsfornitrogendioxide_en1.0.pdf

5 MONITORING STATIONS

The analysis of ambient air quality monitoring data was focused on data collected at two stations, namely the S150 – MV WTEF station and the T18 – Burnaby South station. Figure 5-1 shows the locations of the two stations relative to the MV WTEF facility. Table 5-1 provides additional details about the two stations, including exact locations and parameters monitored. In addition, on-site photos are provided in Table 5-2.

The S150 – MV WTEF station was installed in the fall of 2020 to measure NO_2, SO_2, and HCl near the location with the highest expected ambient air concentrations identified by the dispersion modelling submitted to the Ministry of Environment and Climate Change Strategy in December 2018 as per the requirements of the WTEF's Operational Certificate (issued December 15, 2016). In September 2021, a meteorological station was installed on the roof of the WTEF to provide information on local meteorological conditions and allow for comparison of measured ambient air quality concentrations to operations at the WTEF.

Metro Vancouver's existing T18 – Burnaby South station was put in place in advance of the development of the WTEF with the goal of monitoring for any potential impacts of the WTEF on air quality. The instrumentation at the station, which already included SO_2 and NO_2 monitoring, was upgraded in the fall of 2020 with the addition of an HCl monitor.

Table 5-1 Ambient Air Quality Monitoring Station Details

STATION NAME	OPERATOR	STATION TYPE	PARAMETERS MEASURED CONTINUOUSLY	LATITUDE	LONGITUDE
S150 – MV WTEF	MVRD	Air Quality	SO_2, NO_2, HCl	49.1868ºN	122.9788ºW
		Meteorology	T_{air}, W_{spd}, W_{dir}, RH	49.1862ºN	122.9777ºW
T18 – Burnaby South		Air Quality and Meteorology	SO_2, NO_2, HCl, CO, O_3, BC, PM_{10}, $PM_{2.5}$ T_{air}, W_{spd}, W_{dir}, RH, Station Pressure, Precipitation	49.2152ºN	122.9857ºW

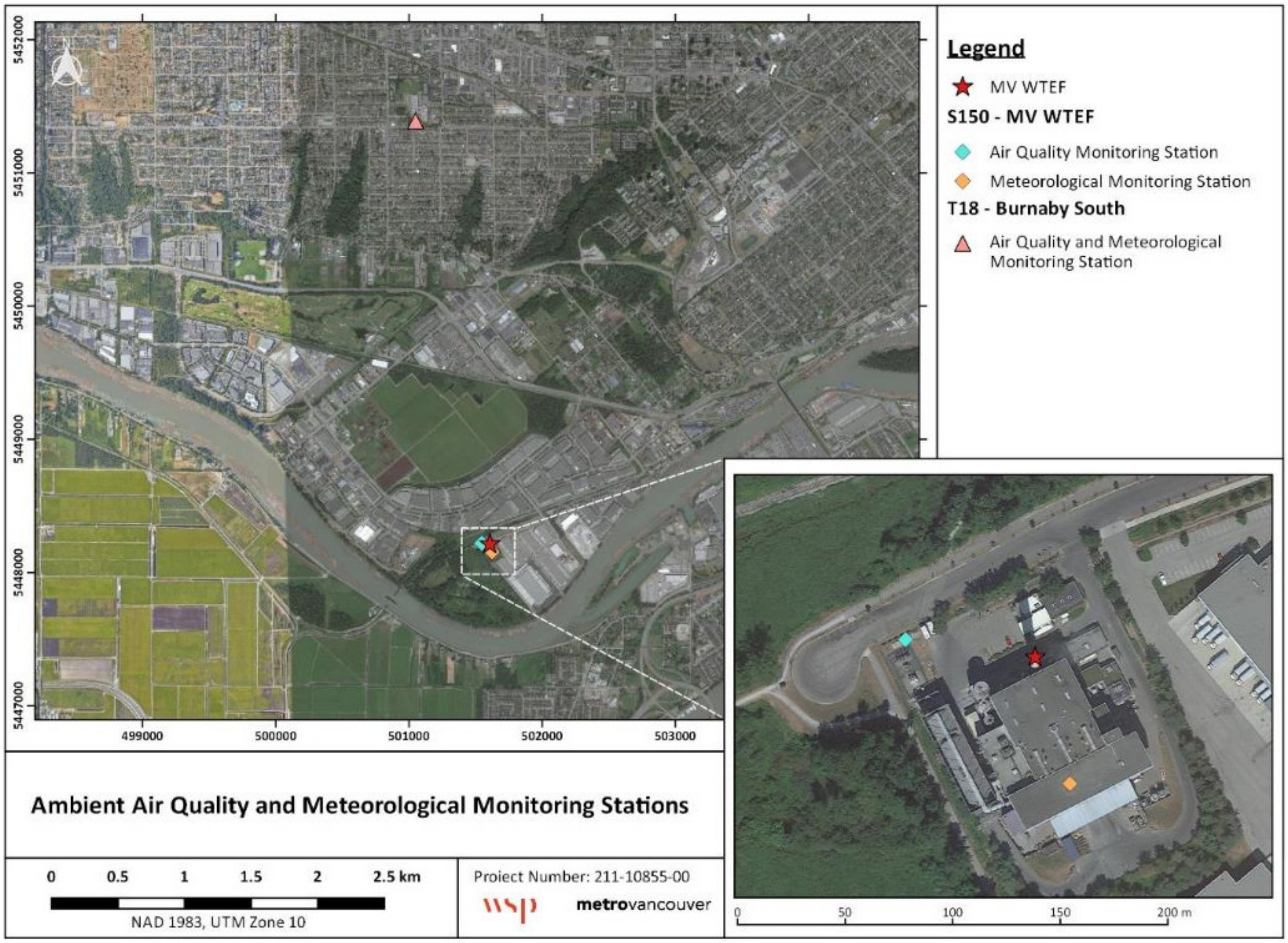


Figure 5-1 Ambient Air Quality Monitoring Station Locations

Table 5-2 Photos of the Air Quality and Meteorological Monitoring Stations

S150 – MV WTEF Air Quality Monitoring Station	
	
S150 – MV WTEF Meteorological Monitoring Station	
	

T18 – Burnaby South Air Quality and Meteorological Monitoring Station

6 METEOROLOGICAL DATA SUMMARY

The following section summarizes relevant meteorological data collected at S150 – MV WTEF station and T18 – Burnaby South station from January 1, 2021 to December 31, 2022. The hourly meteorological data summarized in this report were obtained from Metro Vancouver, where it has been thoroughly checked for quality assurance/quality control (QA/QC). It should be noted that the meteorological sensors were installed at the S150 – MV WTEF station on September 16, 2021 so the data record is limited in the 2021 calendar year.

Comparing to trends in meteorology from previous years, the higher than normal temperatures recorded at T18 – Burnaby South station in June and July 2021 are directly attributable to the heat dome event that occurred between June 25 to July 1, 2021. According to an article published by the Government of Canada[22], the 2021 heat dome event resulted in temperatures up to 20°C above normal, with more than 103 all-time heat records broken across the western provinces. Lytton, BC suffered the worst impacts, experiencing Canada's highest temperature recorded (49.6°C on June 29, 2021) and a disastrous wildfire event.

6.1 TEMPERATURE

Air temperature affects the movement and dispersion of air pollutants and has the potential to increase photochemical activity in an airshed, which in turn can increase production of secondary air pollutant such as ozone. Temperature also impacts air convection and the potential for inversions which can enhance or limit the dispersion of pollutants.

Table 6-1 and Table 6-2 summarize the 1-hour average temperature statistics recorded at S150 – MV WTEF station and T18 – Burnaby South station during the 2021 – 2022 monitoring period, respectively. Monthly boxplots of 1-hour average temperatures for each of the two stations are presented in Figure 6-1. In addition, monthly timeseries of 1-hour average temperatures recorded at the two stations are presented in Figure 6-2.

The monthly boxplots (Figure 6-1) show that the 1-hour average temperatures measured at both stations are relatively comparable, with slight differences in temperature on average by month during the 2-year monitoring period. The 1-hour timeseries (Figure 6-2) also shows that the 1-hour average temperatures measured at both stations track together fairly well. This result confirms that the S150 – MV WTEF station, which is located on the roof of the WTEF, is not significantly impacted by releases of steam or heated air from vents also located on the building roof.

Table 6-1 Monthly 1-Hour Temperature (°C) Summary at S150 – MV WTEF Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	0.0	N/A	N/A	N/A
February 2021	0.0	N/A	N/A	N/A
March 2021	0.0	N/A	N/A	N/A
April 2021	0.0	N/A	N/A	N/A
May 2021	0.0	N/A	N/A	N/A
June 2021	0.0	N/A	N/A	N/A
July 2021	0.0	N/A	N/A	N/A
August 2021	0.0	N/A	N/A	N/A
September 2021	48.3	10.3	14.4	23.5
October 2021	99.3	3.0	10.7	17.8
November 2021	100.0	1.5	8.2	14.0

[22] https://science.gc.ca/site/science/en/blogs/science-health/surviving-heat-impacts-2021-western-heat-dome-canada

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
December 2021	100.0	-12.9	1.8	12.3
January 2022	100.0	-6.2	4.6	13.4
February 2022	100.0	-4.5	5.3	12.5
March 2022	99.7	0.5	8.0	17.0
April 2022	99.2	2.0	8.9	20.2
May 2022	92.9	5.2	11.7	22.1
June 2022	99.6	10.4	16.6	32.7
July 2022	100.0	12.4	19.7	34.8
August 2022	99.3	14.3	20.8	32.7
September 2022	99.2	11.1	17.8	29.3
October 2022	99.6	5.7	13.5	26.7
November 2022	100.0	-3.1	4.8	13.1
December 2022	100.0	-11.0	1.3	12.3

Note: Due to the timing of the installation of the meteorological sensors at the S150 – MV WTEF station on September 16, 2021, the resulting data completeness for the first 9 months of 2021 (January through September) were lower than one would expect.

Table 6-2 Monthly 1-Hour Temperature (°C) Summary at T18 – Burnaby South Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	100.0	-0.6	5.2	11.0
February 2021	100.0	-5.4	2.9	10.1
March 2021	99.9	0.3	6.5	13.7
April 2021	100.0	1.6	10.7	22.6
May 2021	100.0	6.8	12.8	22.4
June 2021	98.6	8.2	18.9	39.8
July 2021	99.9	12.8	19.5	31.8
August 2021	100.0	10.9	18.8	34.9
September 2021	100.0	8.8	15.2	25.1
October 2021	98.3	4.7	9.8	17.8
November 2021	99.4	1.3	7.4	13.2
December 2021	99.7	-13.5	0.9	11.6
January 2022	100.0	-6.0	4.0	12.5
February 2022	100.0	-5.1	4.7	12.4
March 2022	100.0	0.6	7.0	13.8
April 2022	100.0	1.9	7.7	18.3
May 2022	93.4	4.5	10.7	18.8
June 2022	100.0	9.7	15.9	31.8
July 2022	100.0	12.1	19.6	34.1
August 2022	99.2	13.7	20.8	31.3
September 2022	100.0	10.8	17.8	28.4
October 2022	100.0	5.7	13.8	24.4
November 2022	100.0	-3.7	4.4	13.7
December 2022	100.0	-11.5	1.3	12.2

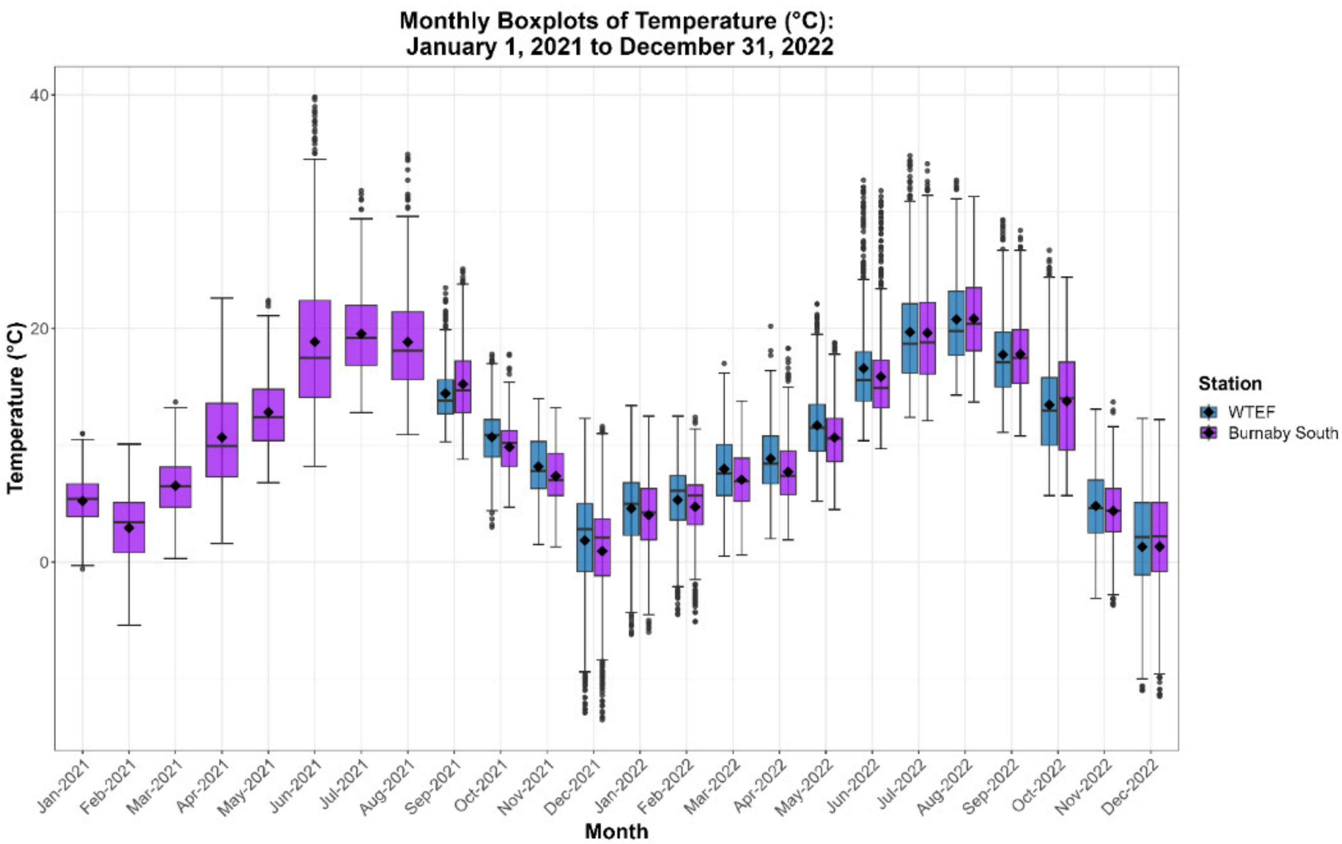


Figure 6-1 Monthly Boxplots of 1-Hour Temperature (°C) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022

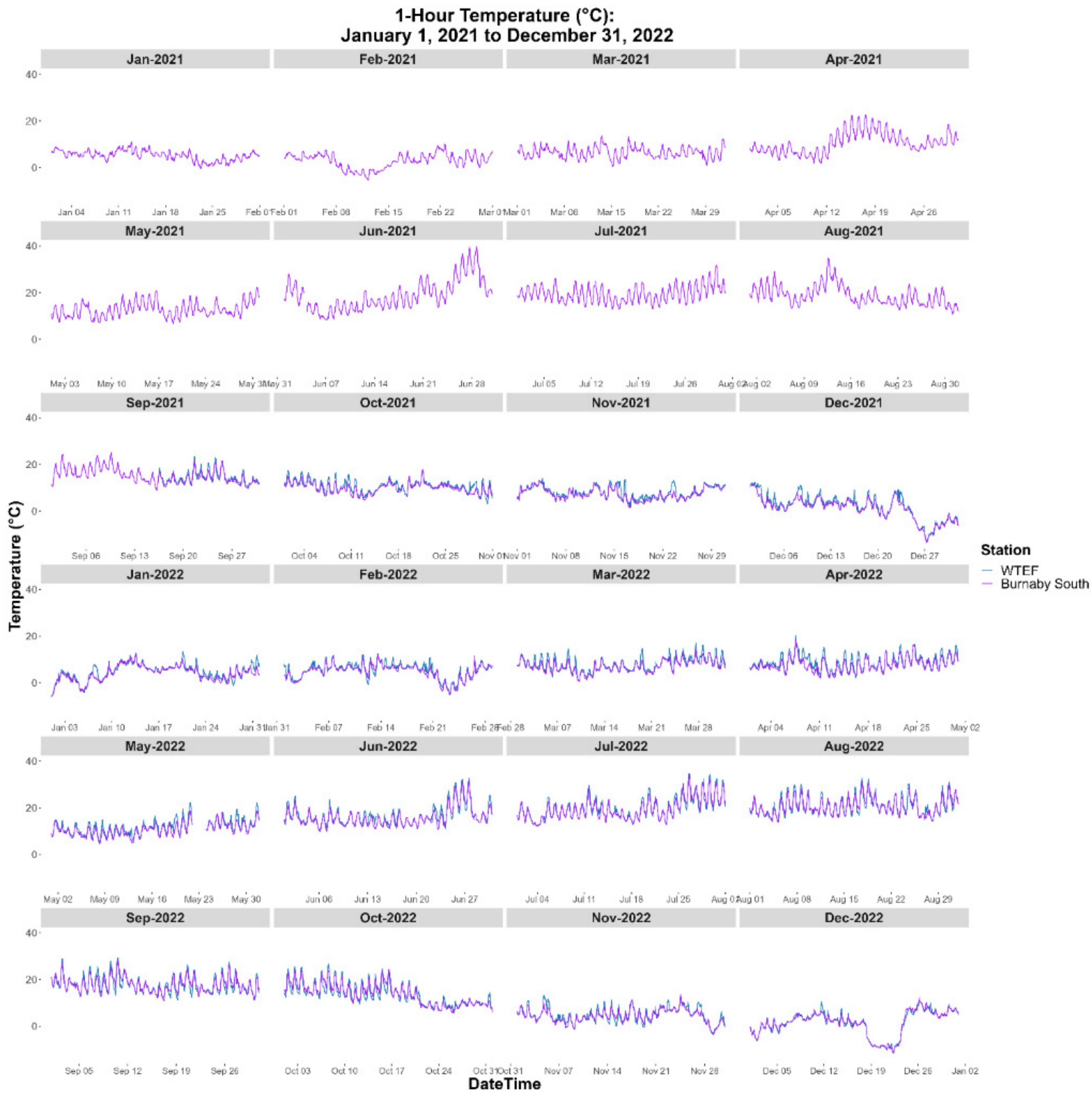


Figure 6-2 Monthly Timeseries of 1-Hour Temperature (°C) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021

6.2 WIND

Wind speed and wind direction data recorded at S150 – MV WTEF station and T18 – Burnaby South station are presented in the following section. Wind speed and wind direction are key parameters influencing the dispersion of pollutants from the MV WTEF and other local and regional sources.

Table 6-3 and Table 6-4 summarize the 1-hour average wind speed statistics recorded at S150 – MV WTEF station and T18 – Burnaby South station during the 2021 – 2022 monitoring period. Monthly timeseries of 1-hour average wind speed recorded at the two stations are presented in Figure 6-3. Both the statistics within Table 6-3 and Table 6-4 and timeseries within Figure 6-3 show that there was a slight uptick in overall peak hourly winds in the Autumn and Winter months. This is consistent with the climate normals of the Lower Mainland, when increased storm activity occurs during the Autumn and Winter months.

Figure 6-4 through Figure 6-7 show the annual and seasonal windroses from S150 – MV WTEF station and T18 – Burnaby South station during the 2021 – 2022 monitoring period. Wind roses are used to display the frequency of wind speed by wind direction, and typically show a dominant wind path dictated by the wind regime and topographical influences surrounding the station. Within this assessment, all windroses display winds blowing from a particular cardinal direction.

The annual windroses for the S150 – MV WTEF station in Figure 6-4 show that the winds were most commonly from the east and east-northeast directions for both years (2021 and 2022). This is confirmed by the seasonal windroses in Figure 6-5, which show winds from the east and east-northeast directions for all seasons (from Autumn 2021 to Winter 2022) except for Summer 2022 where the winds were most commonly from the southerly direction. This pattern is broadly indicative of easterly valley outflow influenced winds during the cooler seasons, and a strong southwesterly sea breeze during the warm Summer season.

The annual windroses for the T18 – Burnaby South station in Figure 6-6 show that highest wind speeds came from the south and south-southeast directions for both years (2021 and 2022), while the seasonal windroses (Figure 6-7) show that the proportion of dominant wind directions varied throughout the seasons. The seasonal patterns observed indicate that Winter winds were dominated by northeasterly valley outflow windows, while Summer windows were dominated by a strong southwesterly sea breeze during the warm Summer season, with shoulder seasons showing a combination of weaker valley outflows and mild sea breezes.

Calm winds, defined as less than or equal to 0.5 m/s, were recorded 0% of the time at the S150 – MV WTEF station and 1.66 % of the time at the T18 – Burnaby South station during the 2021 – 2022 monitoring period. Further breakdowns of calm wind percentages by year and season are displayed below each windrose figure (Figure 6-4 through Figure 6-7).

Table 6-3 Monthly 1-Hour Wind Speed (m/s) at S150 – MV WTEF Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	0.0	N/A	N/A	N/A
February 2021	0.0	N/A	N/A	N/A
March 2021	0.0	N/A	N/A	N/A
April 2021	0.0	N/A	N/A	N/A
May 2021	0.0	N/A	N/A	N/A
June 2021	0.0	N/A	N/A	N/A
July 2021	0.0	N/A	N/A	N/A
August 2021	0.0	N/A	N/A	N/A
September 2021	48.3	0.7	3.0	7.8
October 2021	99.3	0.6	3.2	8.6
November 2021	100.0	0.8	3.7	9.0
December 2021	100.0	0.7	3.4	9.5

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2022	100.0	0.6	3.0	8.6
February 2022	100.0	0.6	3.0	9.3
March 2022	99.7	0.7	3.1	6.1
April 2022	99.2	0.7	3.4	9.9
May 2022	92.9	0.6	3.2	7.7
June 2022	99.6	0.8	3.0	6.2
July 2022	100.0	0.6	2.6	5.0
August 2022	99.3	0.6	2.5	5.3
September 2022	99.2	0.6	2.4	6.8
October 2022	99.6	0.6	2.3	7.9
November 2022	100.0	0.6	2.9	12.3
December 2022	100.0	0.7	3.4	8.8

Note: Due to the timing of the installation of the meteorological sensors at the S150 – MV WTEF station on September 16, 2021, the resulting data completeness for the first 9 months of 2021 (January through September) were lower than one would expect.

Table 6-4 Monthly 1-Hour Wind Speed (m/s) at T18 – Burnaby South Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	100.0	0.3	2.8	10.7
February 2021	100.0	0.1	2.4	7.0
March 2021	99.9	0.6	2.6	9.8
April 2021	100.0	0.4	2.3	6.6
May 2021	100.0	0.4	2.2	5.4
June 2021	98.6	0.2	2.2	6.4
July 2021	99.9	0.0	2.1	5.7
August 2021	100.0	0.0	1.9	5.4
September 2021	100.0	0.1	2.2	8.7
October 2021	98.3	0.3	2.5	7.9
November 2021	99.9	0.0	2.9	9.6
December 2021	99.7	0.0	2.5	9.7
January 2022	100.0	0.2	2.2	8.8
February 2022	100.0	0.3	2.2	6.7
March 2022	100.0	0.1	2.4	5.6
April 2022	100.0	0.6	2.9	10.2
May 2022	93.4	0.1	2.5	7.8
June 2022	100.0	0.2	2.4	6.2
July 2022	100.0	0.1	1.9	4.3
August 2022	99.2	0.0	2.0	5.2
September 2022	100.0	0.0	1.9	4.8
October 2022	100.0	0.0	1.8	8.1
November 2022	100.0	0.2	2.2	9.3
December 2022	100.0	0.2	2.4	9.5

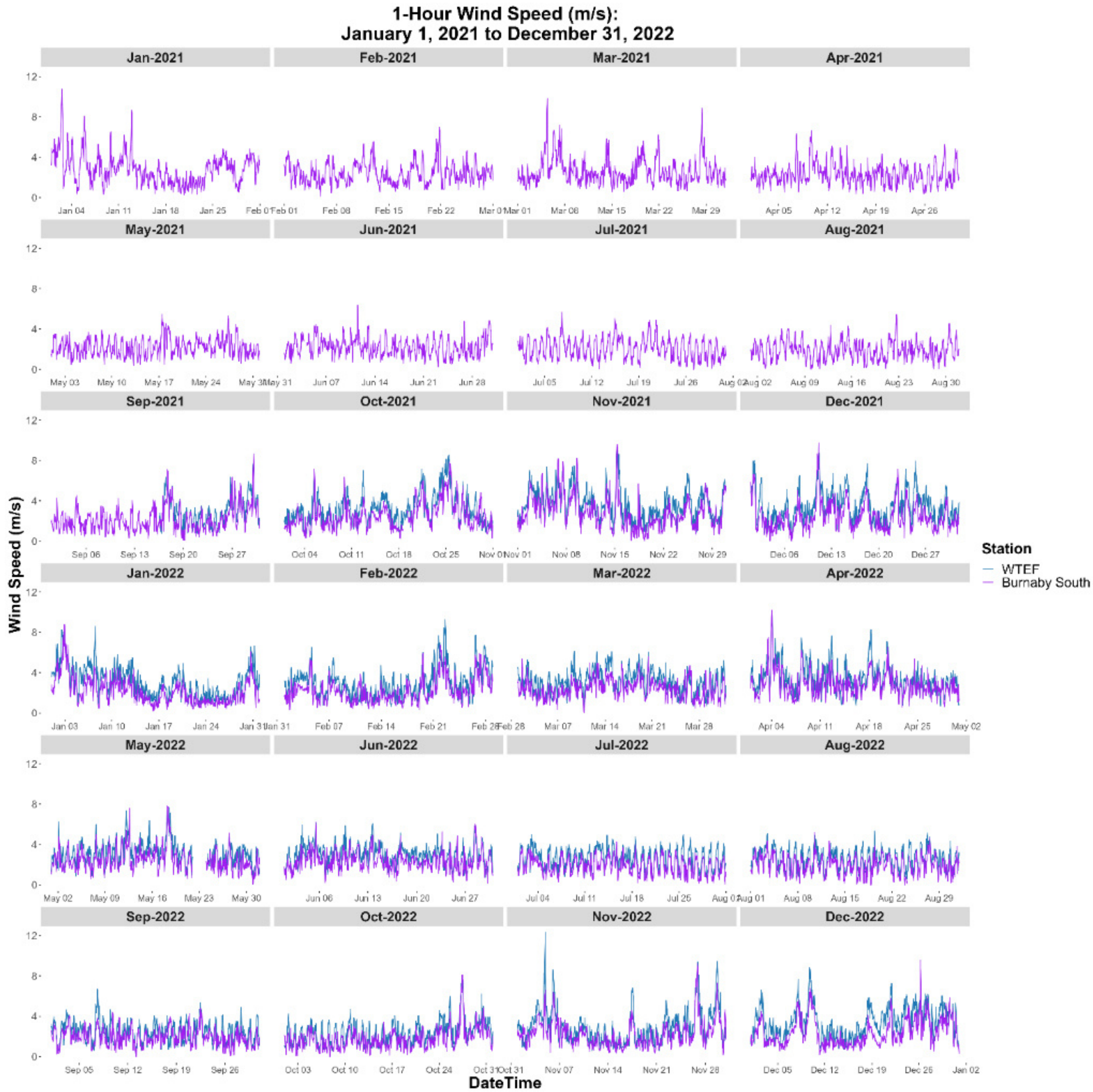
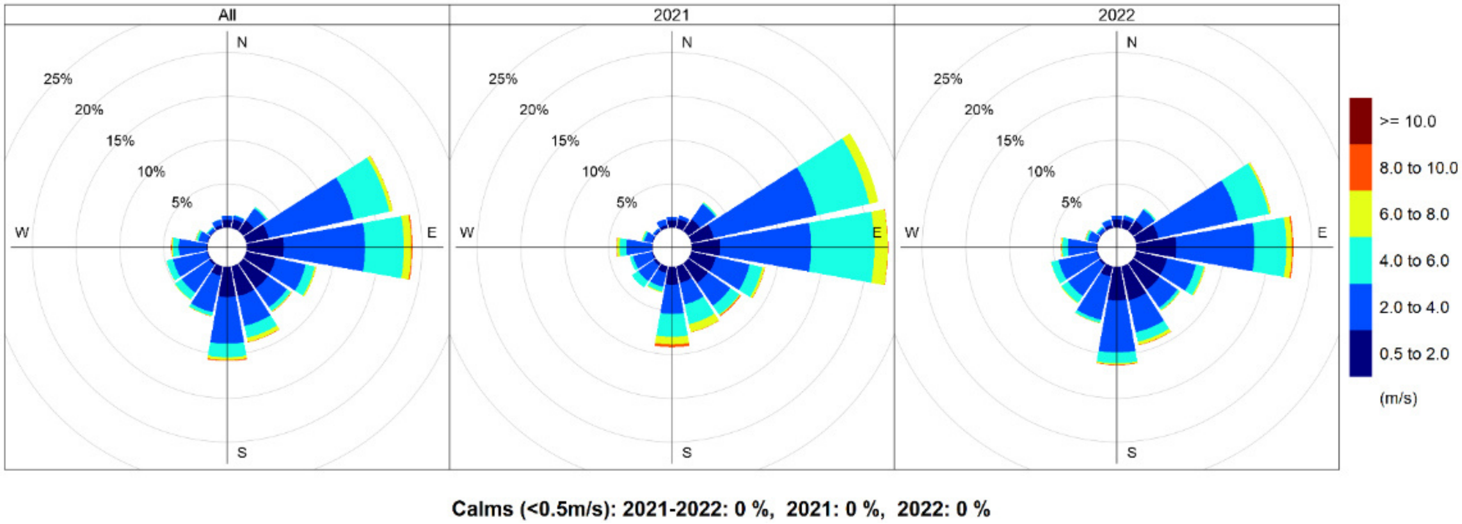
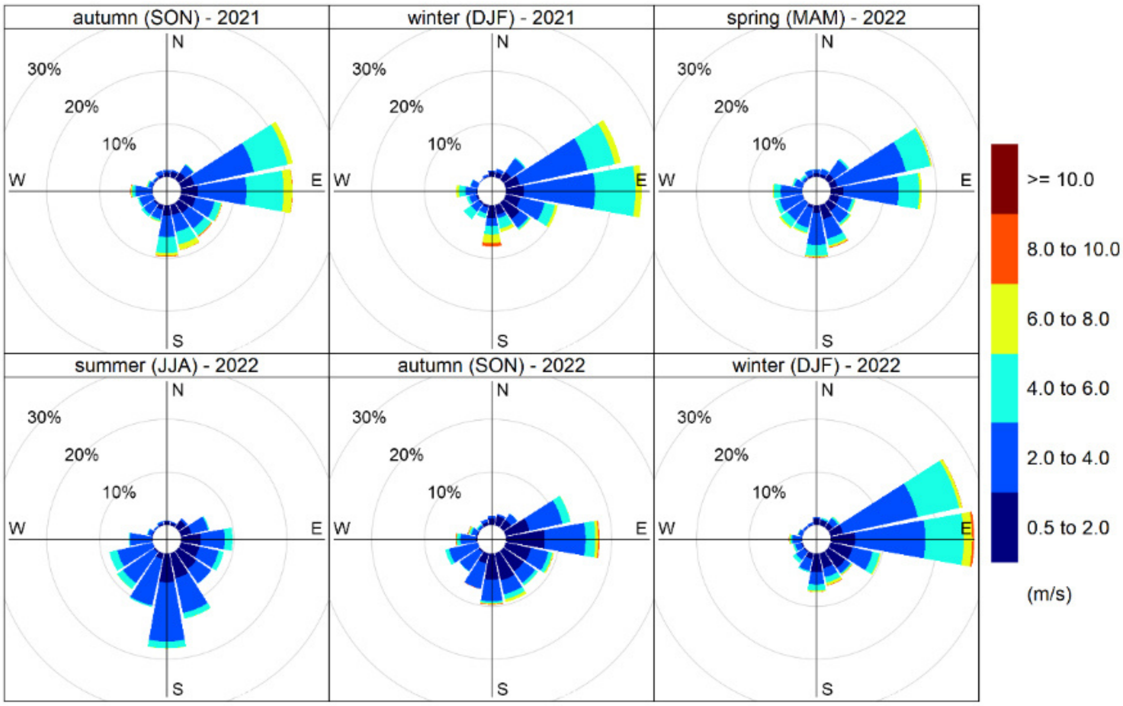


Figure 6-3 **Monthly Timeseries of 1-Hour Wind Speed (m/s) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022**



Note: Due to the timing of the installation of the meteorological sensors at the S150 – MV WTEF station on September 16, 2021, the windrose labelled "All" includes observed winds from September 16, 2021 to December 31, 2022; the windrose labelled "2021" includes observed winds from September 16, 2021 to December 31, 2021; and the windrose labelled "2022" includes observed winds from January 1, 2022 to December 31, 2022.

Figure 6-4 Annual Windroses at S150 – MV WTEF Station in 2021 and 2022



Calms (<0.5m/s): Autumn 2021: 0 %, Winter 2021: 0 %, Spring 2022: 0 %, Summer 2022: 0 %, Autumn 2022: 0 %, Winter 2022: 0 %

Note: Due to the timing of the installation of the meteorological sensors at the S150 – MV WTEF station on September 16, 2021, the windrose labelled “autumn (SON) 2021” includes observed winds from September 16, 2021 November 30, 2021.

Figure 6-5 Seasonal Windroses at S150 – MV WTEF Station in 2021 and 2022

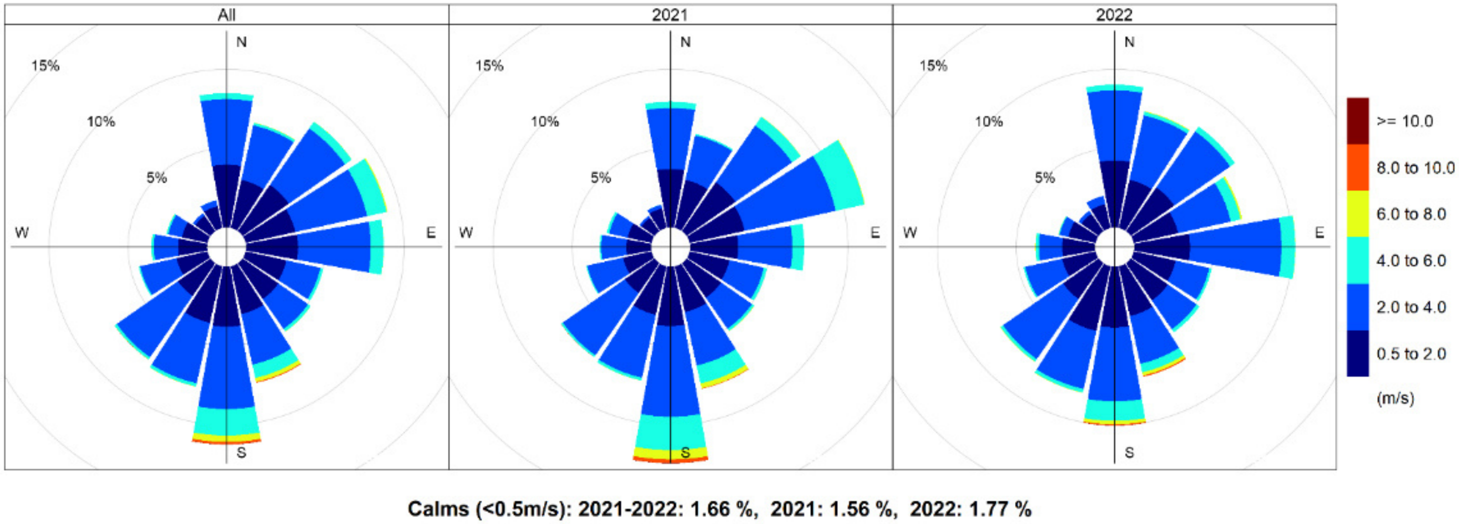
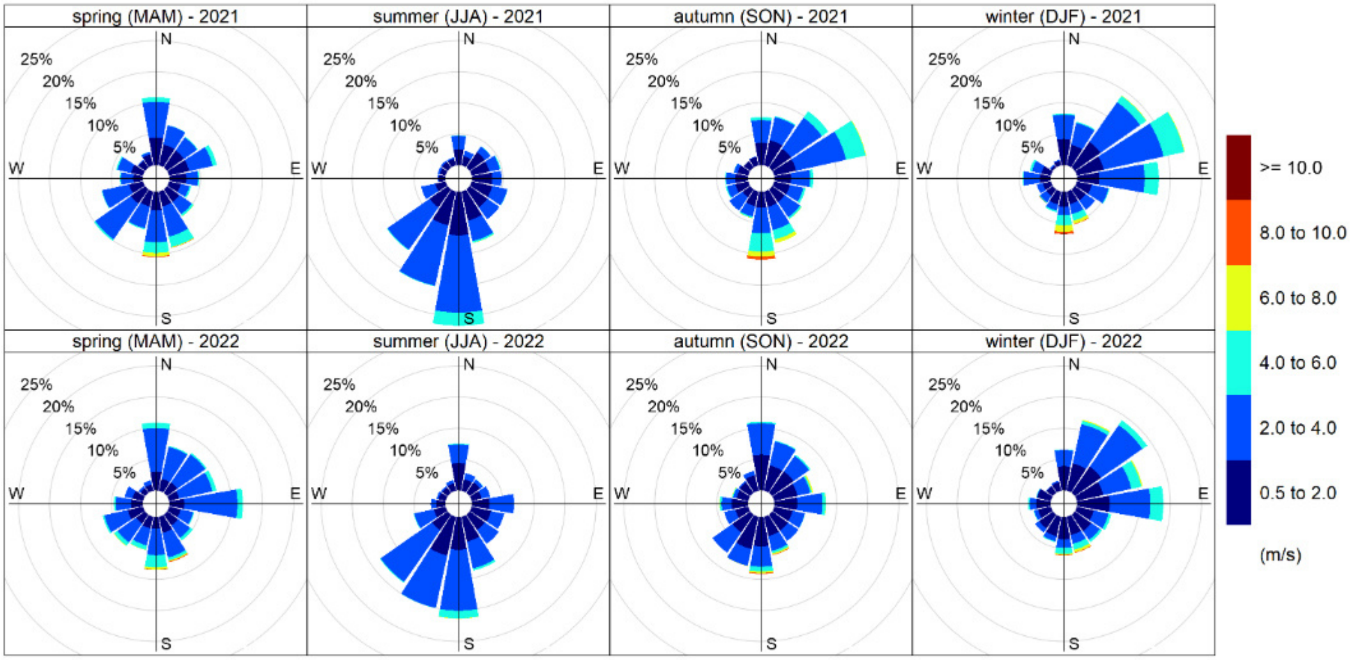


Figure 6-6 Annual Windroses at T18 – Burnaby South Station in 2021 and 2022



Calms (<0.5m/s): Spring 2021: 0.32 %, Summer 2021: 2.91 %, Autumn 2021: 1.75 %, Winter 2021: 1.25 %, Spring 2022: 0.23 %, Summer 2022: 3.09 %, Autumn 2022: 2.79 %, Winter 2022: 0.93 %

Figure 6-7 Seasonal Windroses at T18 – Burnaby South Station in 2021 and 2022

7 AMBIENT AIR MONITORING DATA SUMMARIES

The following section presents the results of the ambient air monitoring data analysis using observations recorded at S150 – MV WTEF station and T18 – Burnaby South station between January 1, 2021 and December 31, 2022. Similar to the meteorological data summary in Section 6, the hourly ambient data summarized in the following section has been obtained from Metro Vancouver, where quality assurance/quality control (QA/QC) procedures have been thoroughly applied prior to analysis. The air contaminants of interest include nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and hydrogen chloride (HCl).

7.1 COMPARISON TO AMBIENT AIR QUALITY OBJECTIVES

The following sections 7.2 through 7.4 provide details data summaries for NO_2, SO_2 and HCl, while this section provides a simple direct comparison to the AAQOs for each contaminant. The comparison of ambient air quality data against AAQOs are presented in Table 7-1, which shows that the ambient levels of NO_2, SO_2, and HCl observed at both S150 – MV WTEF station and T18 – Burnaby South station during the 2021 – 2022 monitoring period were below all the AAQOs of interest:

- **NO_2**:
  - 1-hour maximum NO_2 levels at S150 – MV WTEF station and T18 – Burnaby South station were 45.6 ppb (76% of the MVAAQO) and 37.3 ppb (62% of the MVAAQO), respectively;
  - Annual average NO_2 levels at S150 – MV WTEF station and T18 – Burnaby South station were 13.9 ppb (81% of the MVAAQO) and 11.7 ppb (69% of the MVAAQO), respectively;
- **SO_2**:
  - 1-hour maximum SO_2 levels at S150 – MV WTEF station and T18 – Burnaby South were 6.9 ppb (10% of the MVAAQO) and 4.4 ppb (6% of the MVAAQO), respectively;
  - Annual average SO_2 at S150 – MV WTEF station and T18 – Burnaby South station were 0.2 ppb (4% of the MVAAQO) and 0.3 ppb (5% of the MVAAQO), respectively;
- **HCl**:
  - 1-hour maximum HCl levels at S150 – MV WTEF station and T18 – Burnaby South station were 2.8 ppb (6% of the AAAQO) and 4.7 ppb (9% of the AAAQO), respectively;
  - 24-hour maximum HCl levels at S150 – MV WTEF station and T18 – Burnaby South station were 1.7 ppb (13% of the OAAQC) and 1.7 ppb (13% of the OAAQC), respectively; and
  - Annual average HCl levels at S150 – MV WTEF station and T18 – Burnaby South station were 0.4 ppb (3% of the US EPA RfC) and 0.4 ppb (3% of the US EPA RfC), respectively.

For short time periods compliance with AAQOs focuses on the maximum monitored values as summarized above. However, it should be noted that all other monitored values fall below these maximums. An assessment of frequency of higher values can add context to a strict AAQO comparison. In terms of frequency, the ambient air monitoring data shows that:

- For 1-hour NO_2, 95% of the time, ambient concentrations of NO_2 are 50% or less of the AAQO at both stations;
- For 1-hour SO_2, 98% of the time, ambient concentrations of SO_2 are less than 2% of the AAQO at both stations; and
- For 1-hour HCl, 98% of the time, ambient concentrations of HCl are less than 3% of the AAQO at both stations.

Table 7-1 Ambient Air Quality Objectives (AAQOs) Comparison Results

AIR CONTAMINANT	AVG PERIOD	JURISDICTION	AAQO	STATISTICAL FORM OF OBJECTIVE	S150 – MV WTEF				T18 – BURNABY SOUTH			
					VALUE: ppb ($\mu g/m^3$)			2-YR MAX[B] % OF OBJECTIVE	VALUE: ppb ($\mu g/m^3$)			2-YR MAX[B] % OF OBJECTIVE
					2021	2022	2-YR MAX[B]		2021	2022	2-YR MAX[B]	
Nitrogen Dioxide (NO_2)	1-Hour	Metro Vancouver Regional District (MVRD)	60 ppb (113 $\mu g/m^3$)	98th percentile of the daily maximum 1-hour concentration, over three consecutive years[A]	49.0 (92.1)	42.2 (79.4)	45.6 (85.7)	76%	37.5 (70.5)	37.0 (69.6)	37.3 (70.0)	62%
	Annual		17 ppb (32 $\mu g/m^3$)	Annual average of 1-hour concentrations	13.3 (25.1)	**13.9 (26.1)**	13.9 (26.1)	81%	10.6 (19.9)	**11.7 (22.1)**	11.7 (22.1)	69%
Sulphur Dioxide (SO_2)	1-Hour		70 ppb (183 $\mu g/m^3$)	Maximum 1-hour concentration	3.9 (10.2)	**6.9 (18.1)**	6.9 (18.1)	10%	**4.4 (11.5)**	3.4 (8.9)	4.4 (11.5)	6%
	Annual		5 ppb (13 $\mu g/m^3$)	Annual average of 1-hour concentrations	0.2 (0.6)	**0.2 (0.6)**	0.2 (0.6)	4%	0.2 (0.6)	**0.3 (0.7)**	0.3 (0.7)	5%
Hydrogen Chloride (HCl)	1-Hour	Alberta Environment (AENV)	50 ppb (75 $\mu g/m^3$)	Maximum 1-hour concentration	2.3 (3.4)	**2.8 (4.2)**	2.8 (4.2)	6%	3.4 (5.1)	**4.7 (7.0)**	4.7 (7.0)	9%
	24-Hour	Ontario Ministry of Environment (Ontario MoE)	13.4 ppb (20 $\mu g/m^3$)	Maximum 24-hour block average concentration	1.6 (2.4)	**1.7 (2.6)**	1.7 (2.6)	13%	1.5 (2.2)	**1.7 (2.5)**	1.7 (2.5)	13%
	Annual	US Environmental Protection Agency (US EPA)	13.4 ppb (20 $\mu g/m^3$)	Annual average of 1-hour concentrations	0.4 (0.5)	**0.4 (0.6)**	0.4 (0.6)	3%	0.4 (0.5)	**0.4 (0.6)**	0.4 (0.6)	3%

Notes: The maximum year is highlighted in **bold** where the achievement of the AAQO is based on the maximum year over the 2-year monitoring period.
[A] Since there is only two years of ambient air quality data available for use in this assessment, the 98th percentile of the daily maximum 1-hour concentration averaged over 2-years will be compared against the 1-hour NO_2 AAQO.
[B] The 2-year average is computed for ambient 1-hour NO_2 due to the required statistical form for comparison to the 1-hour AAQO level.

7.2 NITROGEN DIOXIDE (NO_2) DATA REVIEW

Nitrogen dioxide (NO_2) is a highly reactive, reddish- brown gas with a pungent and irritating odour and is partially responsible for the "brown haze" sometimes seen in the air. Nitric oxide (NO) and nitrogen dioxide (NO_2) are known collectively as nitrogen oxides (NO_x). Regional sources of nitrogen oxides include vehicles and mobile equipment that burn fossil fuels internal combustion engines, as well as industrial facilities that burn fossil fuels. Nitrogen oxides also react with other pollutants to form ground-level ozone or fine particulate matter, both of which are also harmful air pollutants.

Table 7-2 and Table 7-3 provide summaries of NO_2 measurements collected in 2021 and 2022 at S150 – MV WTEF station and T18 – Burnaby South station, respectively. Monthly timeseries of 1-hour average NO_2 at the two stations are presented in Figure 7-1.

The boxplots in Figure 7-2 and Figure 7-3 show the monthly and hourly variation in 1-hour average NO_2 concentrations at the two stations. The monthly boxplots show that, on average, there were slightly higher levels of NO_2 observed at S150 – MV WTEF station for most months of the 2-year period (with more comparable levels in the July and August months). The hourly boxplots show a similar pattern of slightly higher levels of NO_2 observed at S150 – MV WTEF station compared to the levels of NO_2 observed at T18 – Burnaby South station for most hours of the day, with the difference being most noticeable during the morning and night-time hours (00:00 to 10:00, and 20:00 to 23:00).

In addition, the time variation plots in Figure 7-4 show that, at both stations for the 2021 – 2022 monitoring period, the peak 1-hour average NO_2 concentrations occurred in the early morning on weekdays (Monday – Friday), which is indicative of a peak in traffic during the morning commute. Local waste haul trucking / vehicle activity entering and exiting the MV WTEF, where the frequency of truck deliveries is higher during weekdays compared to weekends, may have also impacted levels of 1-hour average NO_2 measured at S150 – MV WTEF station. The trends in 1-hour averaged NO_2 remained consistent at both stations between the 2 years of monitored data. As expected, Summer NO_2 levels were significantly lower at both stations, indicating higher photochemical activity causing the reaction of NO_2 with volatile organic compounds (VOC) to form ozone (O_3).

The 1-hour average NO_2 pollution roses by year and season at both stations are shown in Figure 7-5 through Figure 7-8. These pollution roses illustrate the frequency distribution of wind direction (blowing from each cardinal direction) temporally correlated with 1-hour average NO_2 concentrations observed at both stations within the 2021 – 2022 monitoring period. It is important to note that the annual and seasonal pollution roses associated with 1-hour average NO_2 concentrations collected at S150 – MV WTEF station in 2021 have not been included due to insufficient wind data collected in the 2021 year (data record begins on September 16, 2021 after the installation of the WTEF meteorological sensors). The pollution roses for S150 – MV WTEF in Figure 7-5 and Figure 7-6 show that the highest 1-hour NO_2 concentrations arose most frequently from the east and east-northeast directions for most of the 2022 year, with the exception of the Summer months. The pollution roses for T18 – Burnaby South station in Figure 7-7 and Figure 7-8 show more variation in the wind directions associated with higher concentrations of 1-hour average NO_2. Higher frequencies of elevated 1-hour NO_2 concentrations were observed during the Autumn and Winter months of 2021 and 2022 at T18 – Burnaby South station.

Alternative visualizations of 1-hour NO_2 concentrations as they relate to wind speed and wind direction are shown in the form of polar plots (Figure 7-9 through Figure 7-12), which show the concentration of NO_2 weighted by wind speed and wind direction. Each segment (10-degree by 1m/s interval) of the plot provides the percentage contribution to the total NO_2 concentration. For the S150 – MV WTEF station in 2022, Figure 7-9 shows that the highest levels of 1-hour NO_2 arose from the east and east-northeast directions with low wind speeds (2 m/s to 5 m/s). Figure 7-10 shows that the pattern seen in the annual polar plot (Figure 7-9) was primarily associated with the Spring and Winter months, with more variability in the contributions of NO_2 from different wind speeds and wind directions during the Summer and Autumn months. For the T18 – Burnaby South station, Figure 7-11 and Figure 7-12 show that there was a high level of variability in wind speed and wind direction associated with the highest levels of NO_2. There was a fairly consistent pattern between years (2021 and 2022) and within each season (e.g., Winter 2021 and Winter 2022 look similar).

Comparison of the 2021 and 2022 data measured at S150 – MV WTEF and T18 – Burnaby South with historical data up to 2021 from Metro Vancouver's monitoring network indicates that the average values and diurnal and seasonal patterns agree well with other monitoring stations in the middle western parts of the region (T13 North Delta, T17 Richmond South, T46 New Westminster), and generally higher than for stations at the eastern margins of the region (i.e., T27 Langley, T30 Maple Ridge).

Taken together, the monitoring results indicate that the S150 – MV WTEF station experienced higher NO_2 levels than T18 – Burnaby South, likely associated with its proximity to upwind NO_2 sources such as Highways 91 and 91A, Marine Way, and activity in the Riverbend and Queensborough industrials areas. The WTEF stack is also upwind of S150 (based on predominant easterly wind flows), so WTEF emissions may impact measured levels, but likely only at very low wind speeds, due to station proximity to the facility. However, because the WTEF and other major proximate NO_2 sources are aligned in the predominant upwind direction from S150, it was not possible to definitively distinguish WTEF impacts from other major sources. For T18 – Burnaby South, elevated NO_2 levels were associated with a range of different wind directions and speeds, indicating influence from many different sources. Winds from the direction of the WTEF (south-southeasterly) were not notably associated with high NO_2 levels, indicating that its influence on T18 was likely indistinguishable from background. During Winter, Spring and Autumn, the highest NO_2 levels at T18 were associated with northeasterly winds from the direction of the Kingsway corridor and Highway 1 beyond, while during the Summer, the highest NO_2 levels were associated with southwesterly windows from the direction of Highway 91, Highway 99 and the cement plants on the Fraser River in Richmond and Delta, which are the two largest NO_2 point sources in the region[23]. As indicated in Section 7.1, measured NO_2 levels at both stations remained below AAQO levels throughout the study period. In particular, with regards to 1-hour concentrations, 95% of the time, ambient concentrations of NO_2 are 50% or less of the AAQO at both stations.

Table 7-2 Monthly 1-Hour NO_2 (ppb) Summary at S150 – MV WTEF Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	95.3	1.4	19.4	51.0
February 2021	95.2	1.2	17.5	49.2
March 2021	95.8	1.1	15.7	49.0
April 2021	95.8	0.6	13.6	49.6
May 2021	99.2	0.8	9.5	38.8
June 2021	100.0	0.7	8.7	34.6
July 2021	100.0	1.0	7.4	29.8
August 2021	99.7	0.7	10.1	50.1
September 2021	99.9	1.1	11.5	34.0
October 2021	100.0	0.8	13.0	32.6
November 2021	100.0	1.1	15.2	42.4
December 2021	100.0	1.2	19.3	58.1
January 2022	100.0	1.1	18.4	45.6
February 2022	99.7	1.1	18.3	42.2
March 2022	100.0	1.0	15.7	42.5
April 2022	100.0	1.1	12.0	38.6
May 2022	99.9	0.8	9.4	35.3
June 2022	98.5	0.9	8.5	35.8
July 2022	99.5	0.8	8.0	39.9
August 2022	100.0	1.0	9.3	36.5
September 2022	100.0	1.1	12.6	52.1
October 2022	100.0	1.6	15.0	47.7
November 2022	99.4	1.0	19.1	44.9
December 2022	100.0	2.0	20.4	45.8

[23] *https://search.open.canada.ca/openmap/274ede77-27b9-46b8-96c8-4d7d4a706f08*

Table 7-3 Monthly 1-Hour NO_2 (ppb) Summary at T18 – Burnaby South Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	99.1	1.4	13.3	40.1
February 2021	99.3	1.4	13.1	34.8
March 2021	98.4	1.6	11.9	37.5
April 2021	98.6	1.4	10.1	36.6
May 2021	99.1	1.3	7.9	28.1
June 2021	98.5	1.4	7.7	26.4
July 2021	98.0	1.4	8.0	26.7
August 2021	98.3	1.3	8.7	35.4
September 2021	98.8	1.3	9.7	33.8
October 2021	99.9	1.2	9.9	32.8
November 2021	99.6	1.6	11.3	30.5
December 2021	99.7	1.9	15.4	38.9
January 2022	99.7	1.9	15.4	37.1
February 2022	98.5	1.5	14.7	37.5
March 2022	100.0	1.5	10.6	30.0
April 2022	99.4	1.2	8.1	33.2
May 2022	99.3	1.5	7.5	28.9
June 2022	98.1	0.6	6.7	22.3
July 2022	98.9	1.4	8.5	26.6
August 2022	98.1	1.2	10.1	28.7
September 2022	100.0	1.3	10.9	42.3
October 2022	100.0	1.8	16.0	49.5
November 2022	99.6	1.2	16.0	36.1
December 2022	100.0	2.3	16.4	40.2

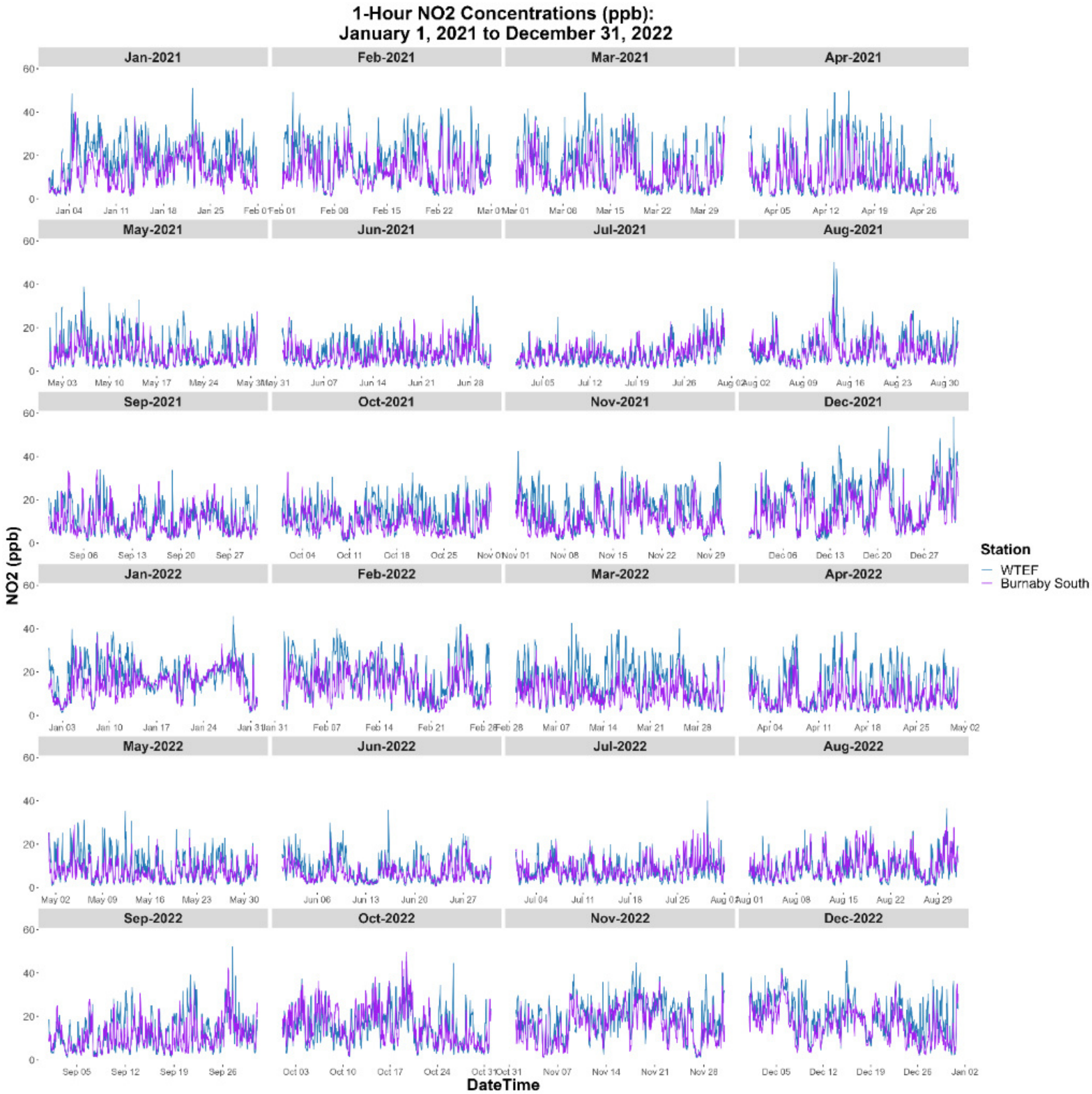


Figure 7-1 **Monthly Timeseries of 1-Hour NO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022**

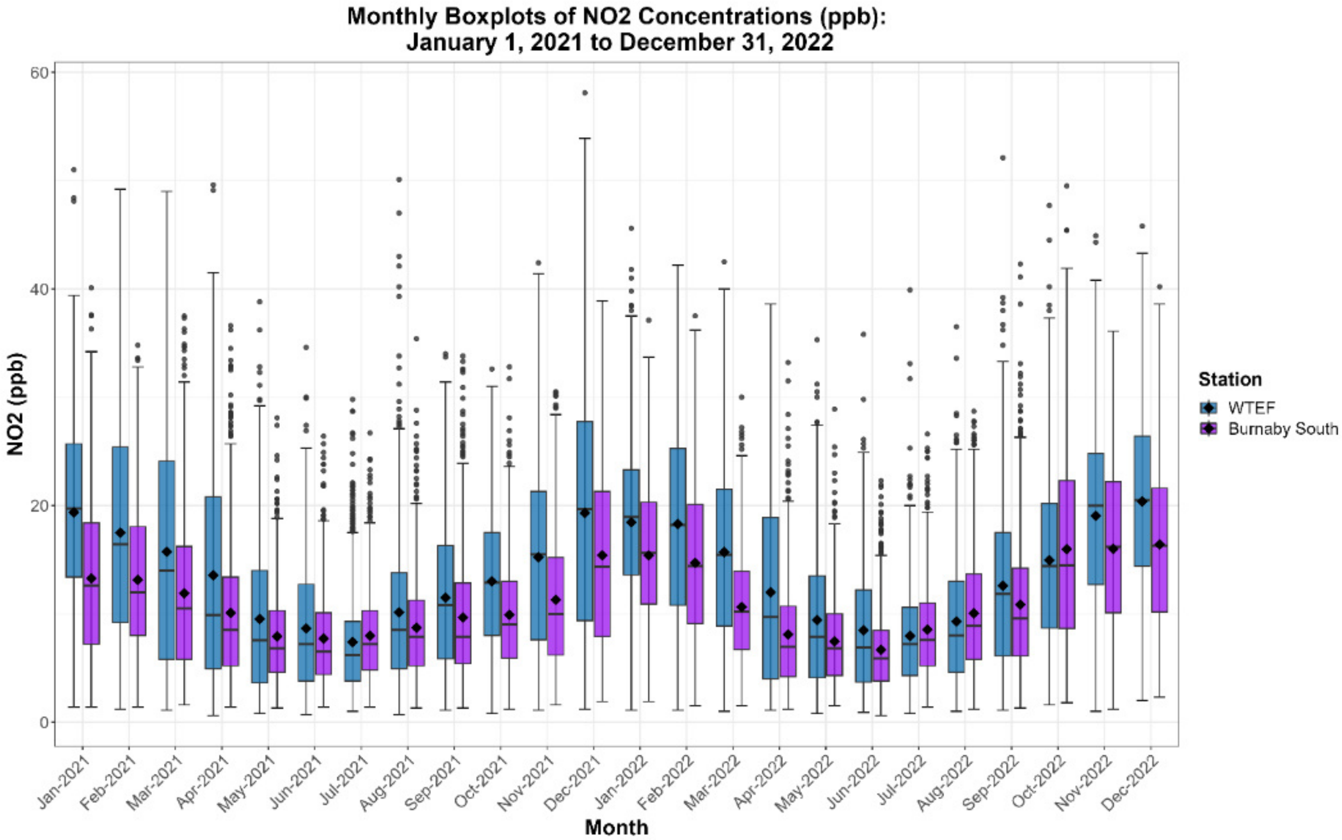


Figure 7-2 **Monthly Boxplots of 1-Hour NO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022**

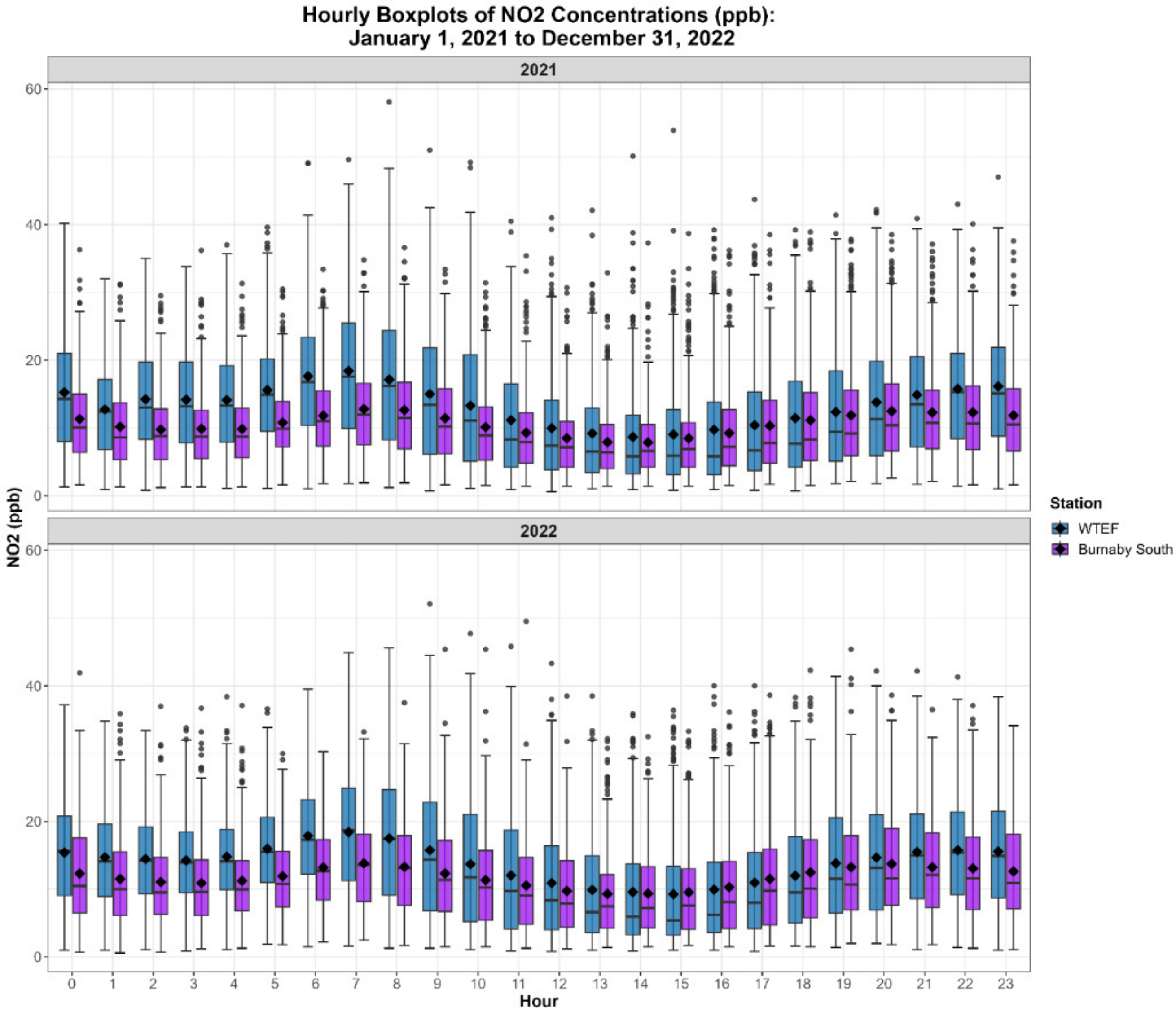


Figure 7-3 **Hourly Boxplots of 1-Hour NO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022**

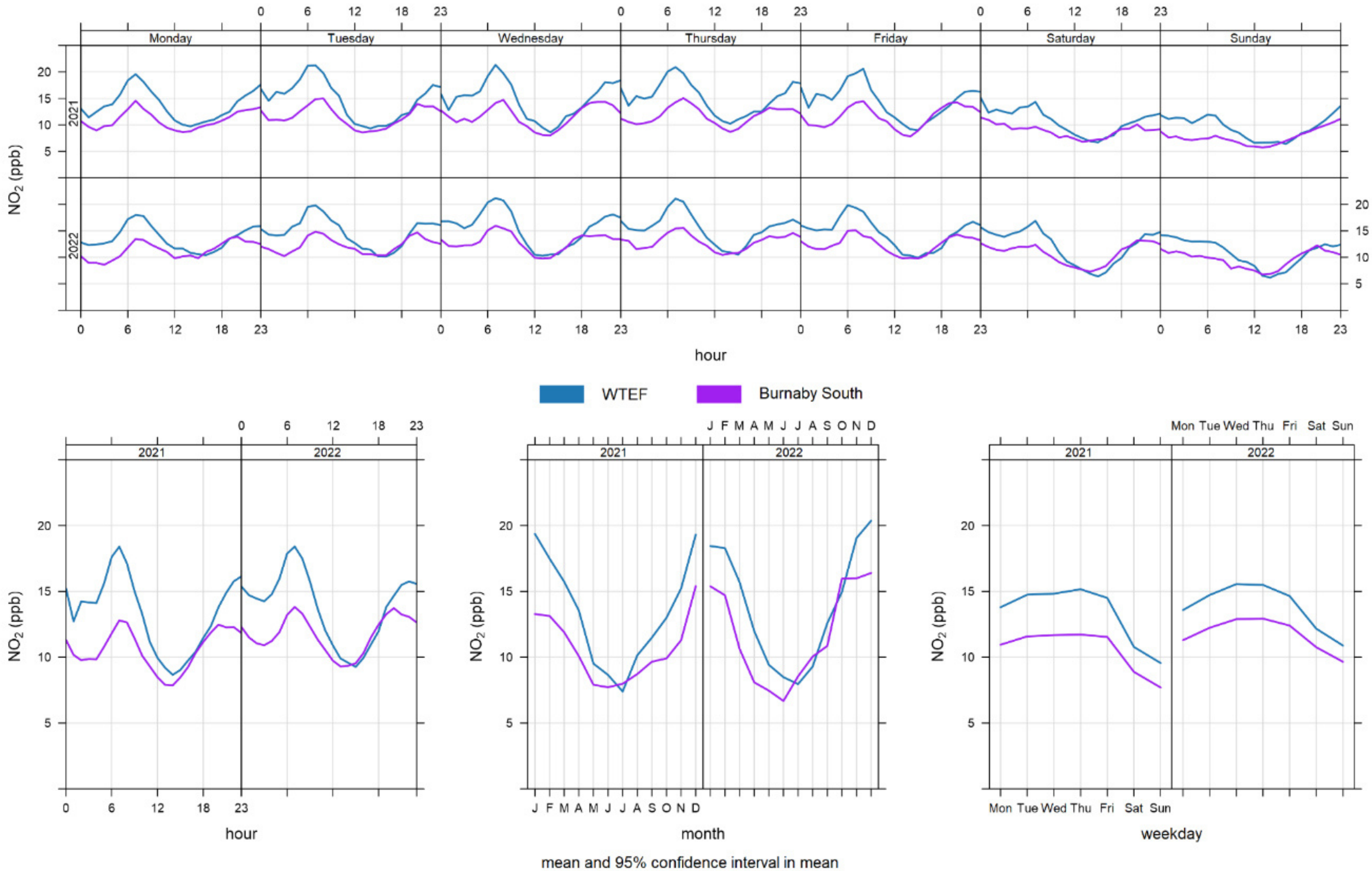


Figure 7-4 **Time Variation of 1-Hour NO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022**

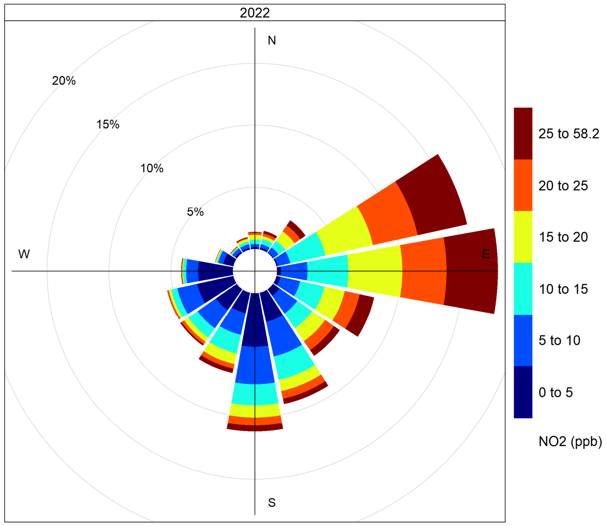


Figure 7-5 **Annual Pollution Rose of 1-hour NO_2 (ppb) at S150 – MV WTEF Station in 2022**

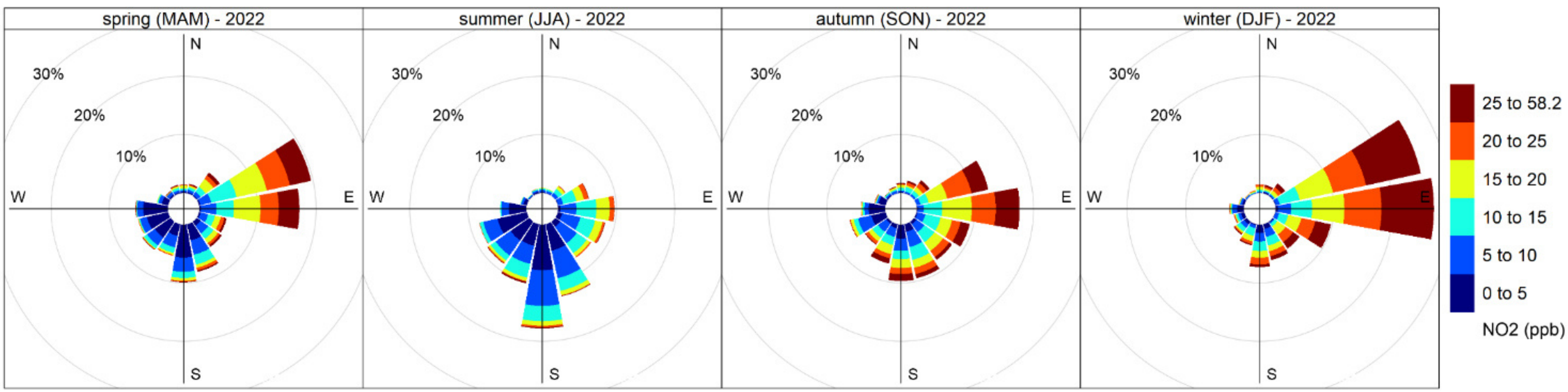


Figure 7-6 **Seasonal Pollution Roses of 1-hour NO_2 (ppb) at S150 – MV WTEF Station in 2022**

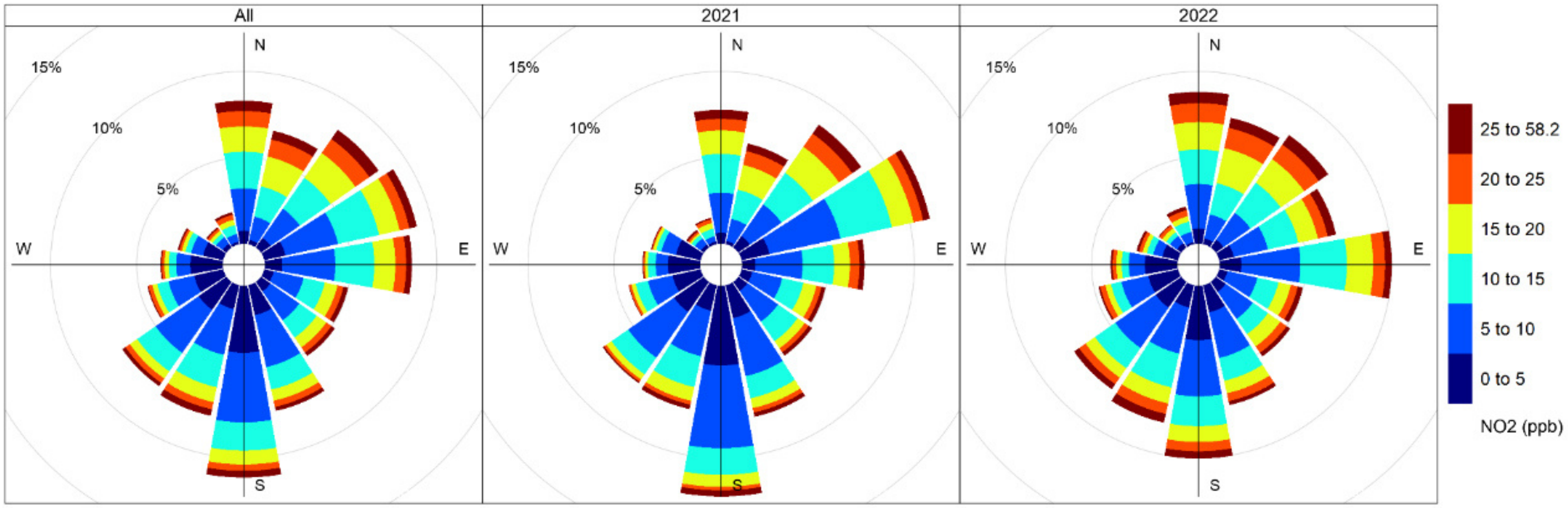


Figure 7-7 Annual Pollution Roses of 1-hour NO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

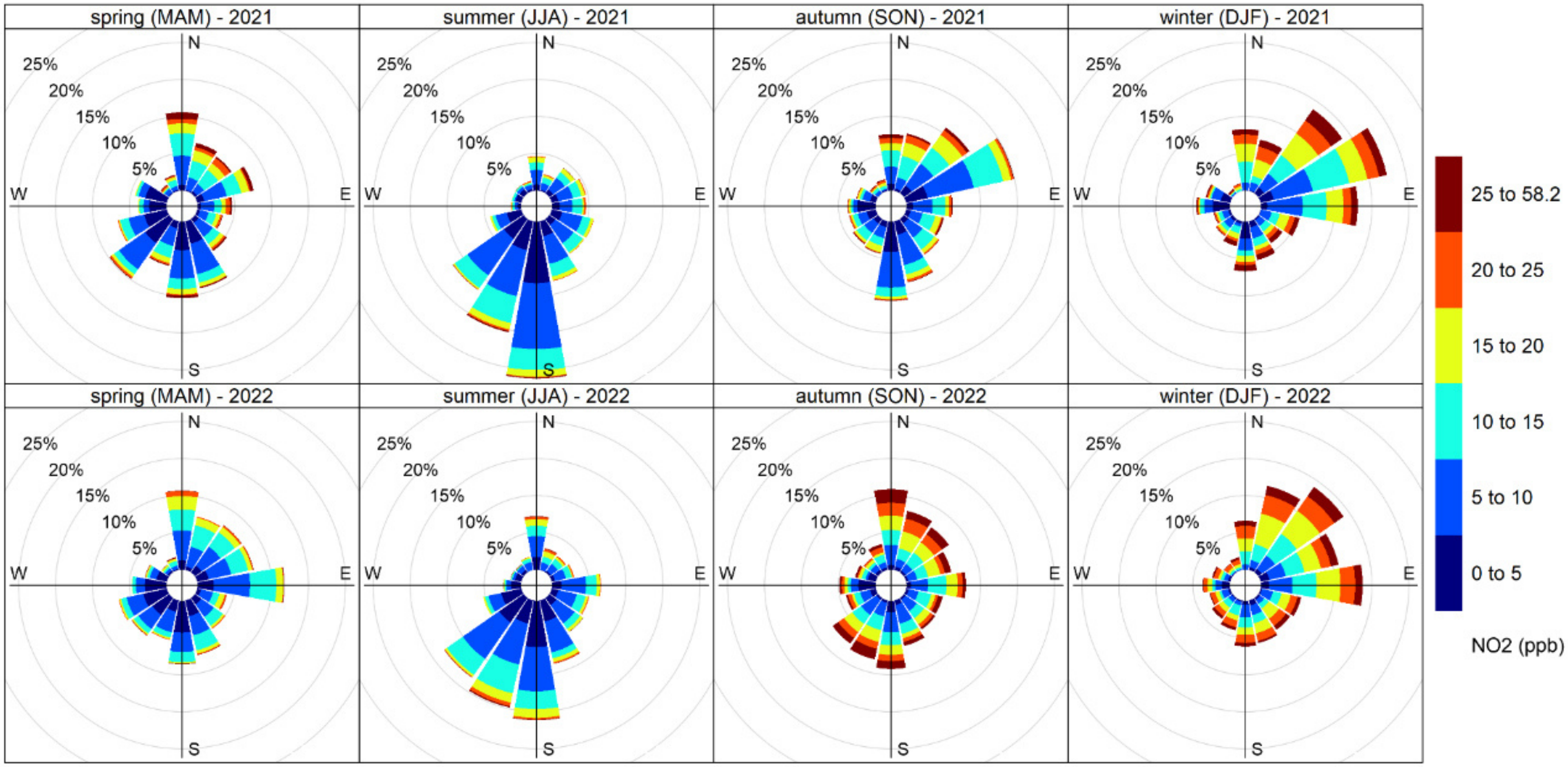


Figure 7-8 Seasonal Pollution Roses of 1-hour NO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

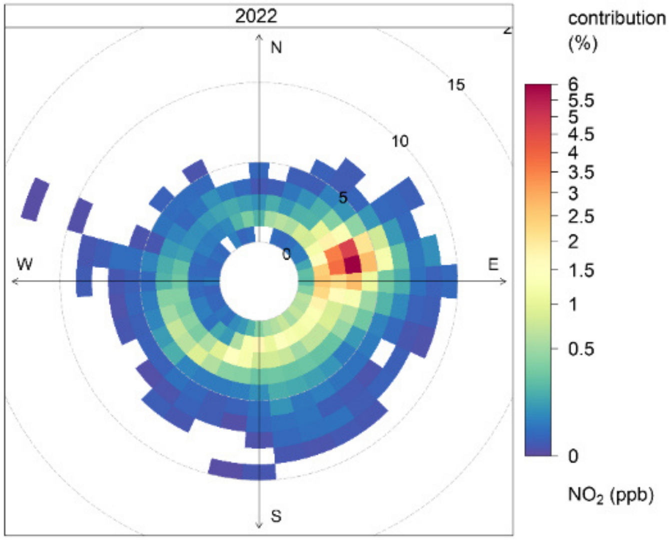


Figure 7-9 Annual Polar Plot of Percentage Contribution to Total 1-hour NO_2 (ppb) at S150 – MV WTEF Station in 2022

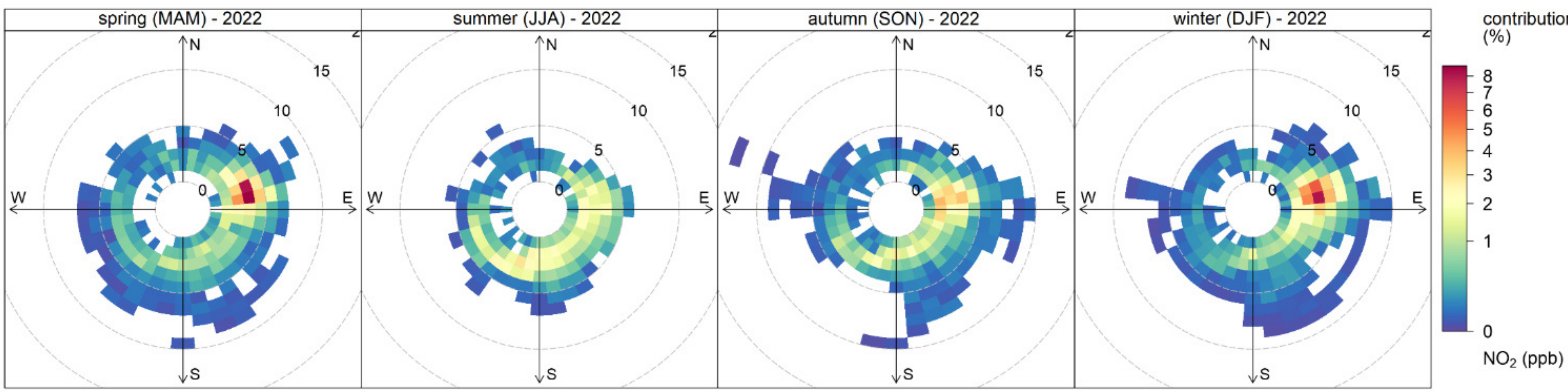


Figure 7-10 Seasonal Polar Plot of Percentage Contribution to Total 1-hour NO_2 (ppb) at S150 – MV WTEF Station in 2022

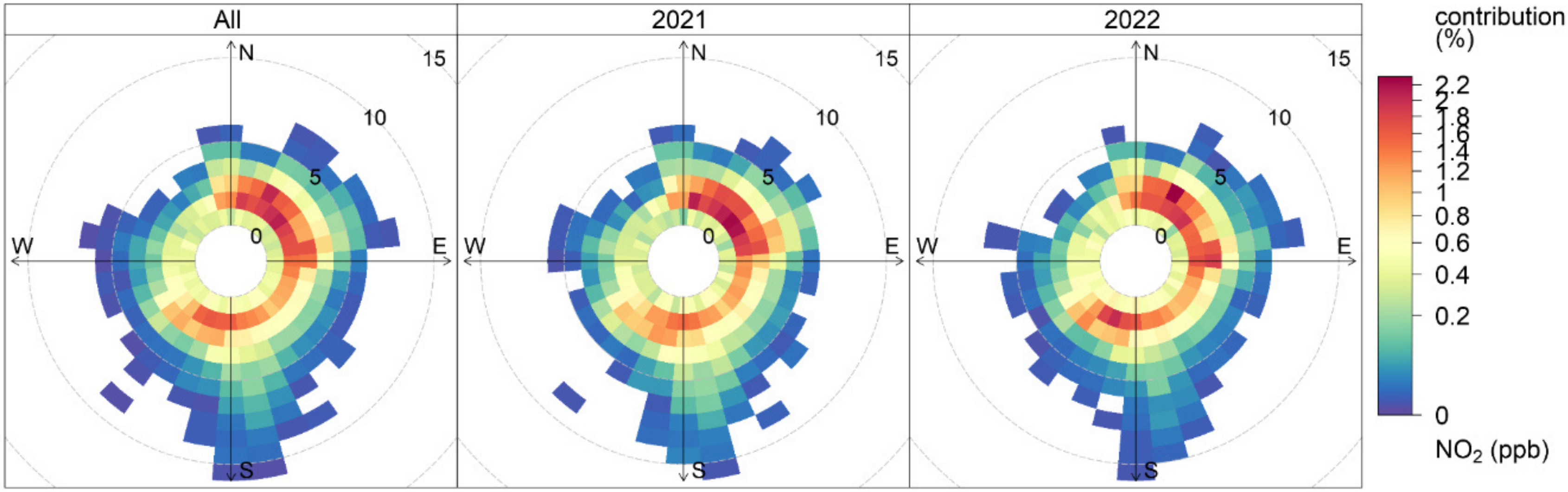


Figure 7-11 Annual Polar Plot of Percentage Contribution to Total 1-hour NO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

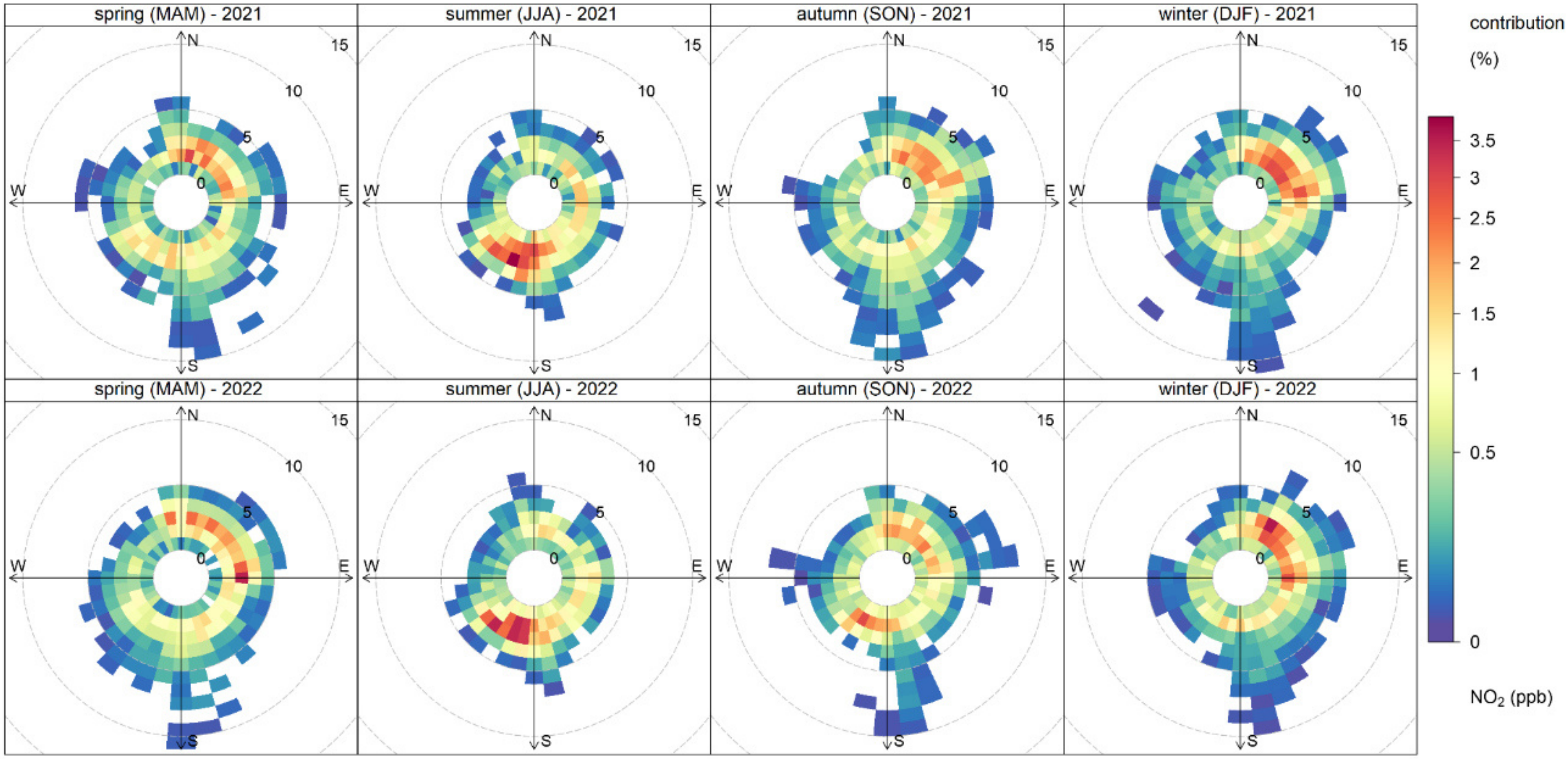


Figure 7-12 Seasonal Polar Plot of Percentage Contribution to Total 1-hour NO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

7.3 SULPHUR DIOXIDE (SO_2) DATA REVIEW

Sulphur dioxide (SO_2) is a colourless gas that smells like burnt matches. It is emitted when fossil fuels containing sulphur are burned. Sulphur dioxide can also react with other substances in the air to form particulate matter which can affect human health and create a "white haze" in the air. Regional sources of sulphur dioxide include marine vessels that burn sulphur-containing fuels, a petroleum refinery, and industrial facilities that combust solid fuels containing sulphur.

Table 7-4 and Table 7-5 provide summaries of sulphur dioxide (SO2) measurements collected in 2021 and 2022 at S150 – MV WTEF station and T18 – Burnaby South station, respectively. Monthly timeseries of 1-hour average SO2 at the two stations are presented in Figure 7-13.

The boxplots in Figure 7-14 and Figure 7-15 show the monthly and hourly variation in 1-hour average SO_2 concentrations at the two stations. In general, the boxplots show that the 1-hour average SO_2 concentrations observed at the two stations are very low, with the majority of the concentrations falling below 1 ppb. The monthly boxplots show that, on average, the levels of SO_2 observed at both stations were comparable during most of the 2-year monitoring period, with slightly higher levels observed at T18 – Burnaby South station during 2 periods (June to September 2021 and June to November 2022). The hourly boxplots show slightly higher SO_2 levels observed at T18 – Burnaby South station compared to the corresponding levels observed at S150 – MV WTEF station during the midday hours from 08:00 to 14:00 during both monitoring years.

In addition, the time variation plots in Figure 7-16 show that, at both stations, the peak 1-hour average SO_2 concentrations occurred midday on all days of the week. The trends in 1-hour averaged SO_2 also appear to stay consistent at both stations between the 2 years of monitored data.

The 1-hour average SO_2 pollution roses by year and season at both stations are shown in Figure 7-17 through Figure 7-20. These pollution roses illustrate the frequency distribution of wind direction (blowing from each cardinal direction) temporally correlated with 1-hour average SO_2 concentrations observed at both stations within the 2021 – 2022 monitoring period. It is important to note that the annual and seasonal pollution roses associated with 1-hour average SO_2 concentrations collected at S150 – MV WTEF station in 2021 have not been included due to insufficient wind data collected in the 2021 year (data record begins on September 16, 2021 after the installation of the sensor). The pollution roses for S150 – MV WTEF station in Figure 7-17 and Figure 7-18 show relatively low levels of 1-hour SO_2 (i.e., most frequently less than 1 ppb), with most observations of SO_2 arising from the east and east-northeasterly directions during the Spring, Autumn, and Winter months and most observations of SO_2 arising from the southerly direction during the Summer months. For the T18 – Burnaby South station, the pollution roses in Figure-7-19 and Figure 7-20 show that the highest 1-hour average SO_2 concentrations arose from the southerly, south-southwesterly, and southwesterly directions in the Summer months (June to August in 2021 and 2022) and the Autumn months of 2022 (September to November).

Alternative visualizations of 1-hour SO_2 concentrations as they relate to wind speed and wind direction are shown in the form of polar plots (Figure 7-21 through Figure 7-24), which show the concentration of SO_2 weighted by wind speed and wind direction. Each segment (10-degree by 1m/s interval) of the polar plot therefore provides the percentage contribution to the total SO_2 concentration. For S150 – MV WTEF station in 2022, Figure 7-21 shows that the highest levels of 1-hour SO_2 arose from the east, east-northeast, and south-southwest, southwest, and west-southwest directions with low wind speeds (2 m/s to 4 m/s). Figure 7-22 shows that there was more variability in the contributions of SO_2 from different wind speeds and wind directions, where the pattern in the Summer months of 2022 differs from the remaining 3 seasons. Annual polar plots of 1-hour SO_2 measured at T18 – Burnaby South station (Figure 7-23) show that the highest levels of 1-hour SO_2 arose from the southwest, south-southwest, and south directions during low wind speeds (2 m/s to 4 m/s) for both monitoring years. Furthermore, Figure 7-24 shows that the annual pattern of higher levels of SO_2 from the southwestern directions in the annual polar plots (Figure 7-23) was primarily driven by the SO_2 levels measured in the Summer months of 2021 and 2022.

Comparison of the 2021 and 2022 data measured at S150 – MV WTEF and T18 – Burnaby South with historical data up to 2021 from Metro Vancouver's monitoring network[24] indicates that the maximum and average SO_2 values and diurnal and seasonal patterns agree well with other monitoring stations in western parts of the region near the Salish Sea and western end of Burrard Inlet (T31 Vancouver Airport, T50 Vancouver Clarke Drive). Measured values for the study stations are generally lower than for stations near Burrard Inlet with direct influence of oil refinery emissions and marine vessel emissions (i.e., T23 Burnaby Capitol Hill, T9 Port Moody), and generally higher than for stations further east in the region (i.e., T27 Langley, T21 Pitt Meadows).

Taken together, the monitoring results indicate that the T18 – Burnaby South station experienced higher SO_2 levels than S150 – MV WTEF during the Summer, likely associated with transport of SO_2 emitted by sources to the west and southwest such as marine shipping on the Fraser River and Salish Sea and industrial sources such as the cement plants on the Fraser River in Richmond and Delta[25]. Daily Summer wind patterns associated with the switch from overnight land breezes to daytime sea breezes, along with the rising boundary layer during the morning hours likely contribute to the observed daily morning peak. The WTEF may contribute somewhat to the observed Summer morning SO_2 at T18, perhaps leading to higher peak SO_2 levels at T18 vs S150, but its location to the south-southeast of the station makes it a less likely source than those to the south west. The higher elevation of T18 may also play a role in positioning the station more directly in the SO_2 plume carried by south westerly winds. During the Winter months, the WTEF stack is upwind of S150 (based on predominant easterly Winter wind flows), so WTEF emissions may impact measured S150 levels, but likely only at very low wind speeds, due to station proximity to the facility. As indicated in Section 7.1, measured SO_2 levels at both stations remained far below AAQO levels throughout the study period. In particular, with regards to 1-hour concentrations, 98% of the time, ambient concentrations of SO_2 are less than 2% of the AAQO at both stations.

Table 7-4 Monthly 1-Hour SO_2 (ppb) Summary at S150 – MV WTEF Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	95.2	0.0	0.2	1.2
February 2021	95.5	0.0	0.2	1.0
March 2021	95.8	0.0	0.2	1.3
April 2021	95.8	0.0	0.3	3.9
May 2021	99.2	0.0	0.3	3.3
June 2021	100.0	0.0	0.3	2.1
July 2021	99.9	0.0	0.3	3.8
August 2021	99.6	0.0	0.2	3.6
September 2021	99.9	0.0	0.2	2.2
October 2021	100.0	0.0	0.2	0.8
November 2021	100.0	0.0	0.2	1.2
December 2021	100.0	0.0	0.2	0.9
January 2022	100.0	0.0	0.2	1.7
February 2022	99.7	0.0	0.2	1.7
March 2022	100.0	0.0	0.2	0.9
April 2022	100.0	0.0	0.2	1.2
May 2022	99.9	0.0	0.2	2.2
June 2022	99.0	0.0	0.2	6.9
July 2022	99.6	0.0	0.2	2.8
August 2022	100.0	0.0	0.2	2.6

[24] *https://metrovancouver.org/services/air-quality-climate-action/air-quality-reports*
[25] *https://search.open.canada.ca/openmap/274ede77-27b9-46b8-96c8-4d7d4a706f08*

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
September 2022	100.0	0.0	0.2	1.5
October 2022	100.0	0.0	0.2	1.7
November 2022	99.7	0.0	0.3	1.3
December 2022	100.0	0.1	0.3	1.6

Table 7-5 Monthly 1-Hour SO_2 (ppb) Summary at T18 – Burnaby South Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	100.0	0.0	0.2	1.5
February 2021	100.0	0.0	0.2	1.9
March 2021	99.3	0.0	0.2	1.5
April 2021	99.6	0.0	0.3	3.6
May 2021	100.0	0.0	0.2	2.2
June 2021	99.9	0.0	0.3	3.9
July 2021	99.9	0.0	0.5	4.4
August 2021	99.2	0.0	0.3	2.5
September 2021	100.0	0.0	0.3	1.7
October 2021	100.0	0.0	0.2	2.0
November 2021	99.3	0.0	0.1	2.6
December 2021	99.9	0.0	0.2	1.8
January 2022	99.9	0.0	0.2	1.1
February 2022	99.0	0.0	0.2	1.7
March 2022	100.0	0.0	0.2	2.1
April 2022	100.0	0.0	0.2	1.7
May 2022	100.0	0.0	0.2	1.2
June 2022	100.0	0.0	0.2	3.4
July 2022	100.0	0.0	0.3	2.0
August 2022	98.5	0.0	0.3	2.4
September 2022	100.0	0.0	0.4	3.2
October 2022	100.0	0.0	0.5	2.6
November 2022	99.6	0.0	0.3	1.4
December 2022	100.0	0.0	0.2	2.1

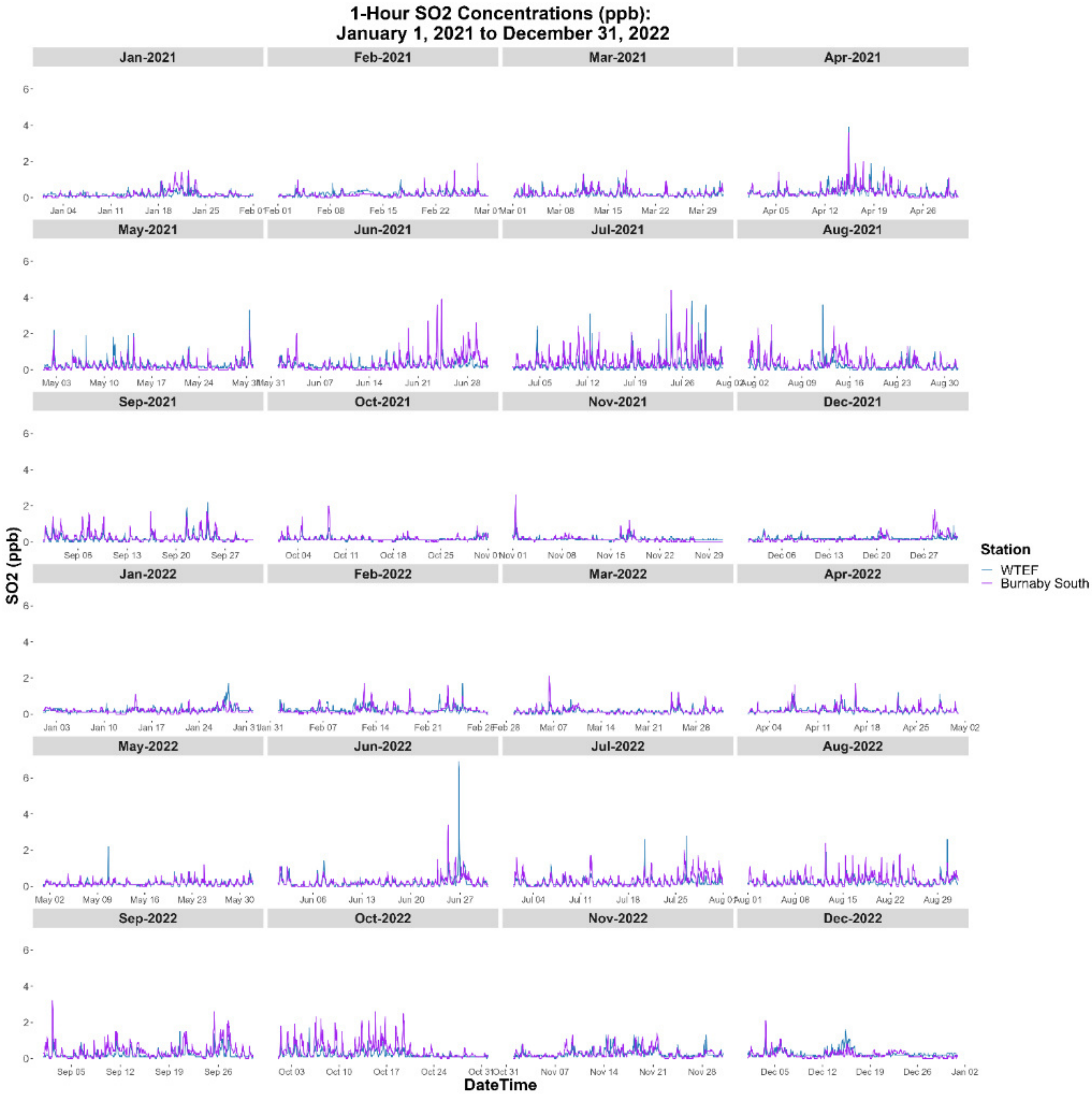


Figure 7-13 **Monthly Timeseries of 1-Hour SO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022**

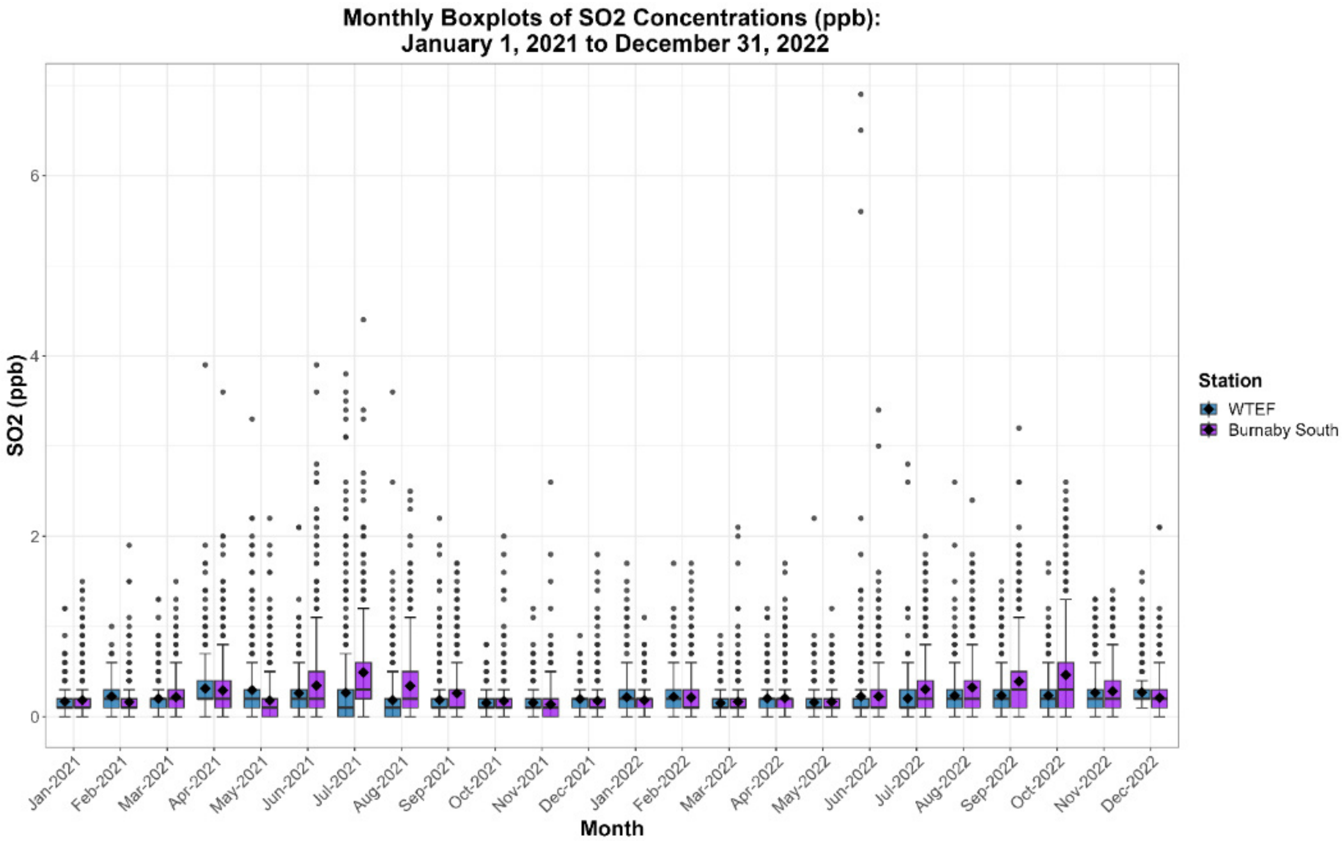


Figure 7-14 Monthly Boxplots of 1-Hour SO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022

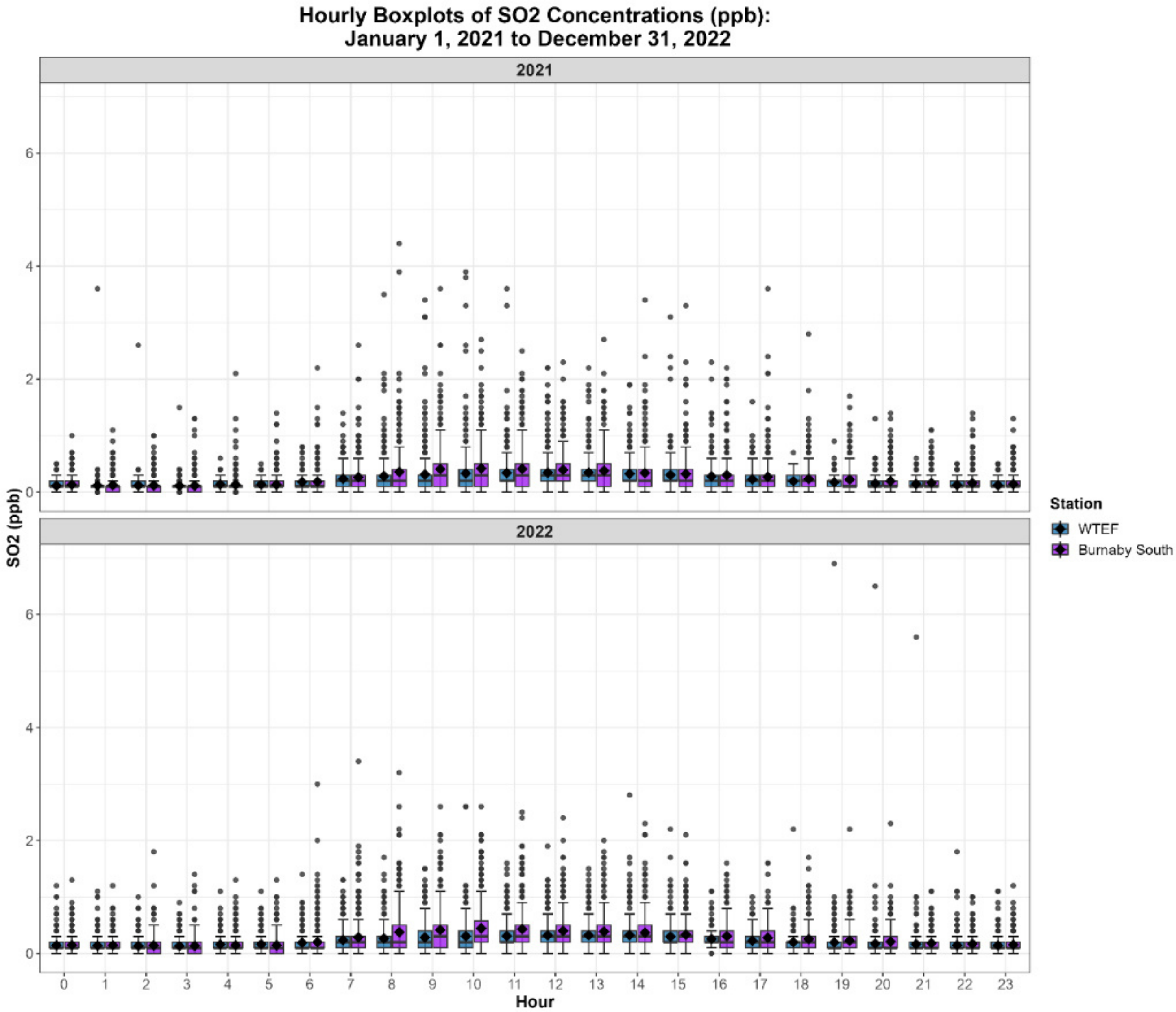


Figure 7-15 Hourly Boxplots of 1-Hour SO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022

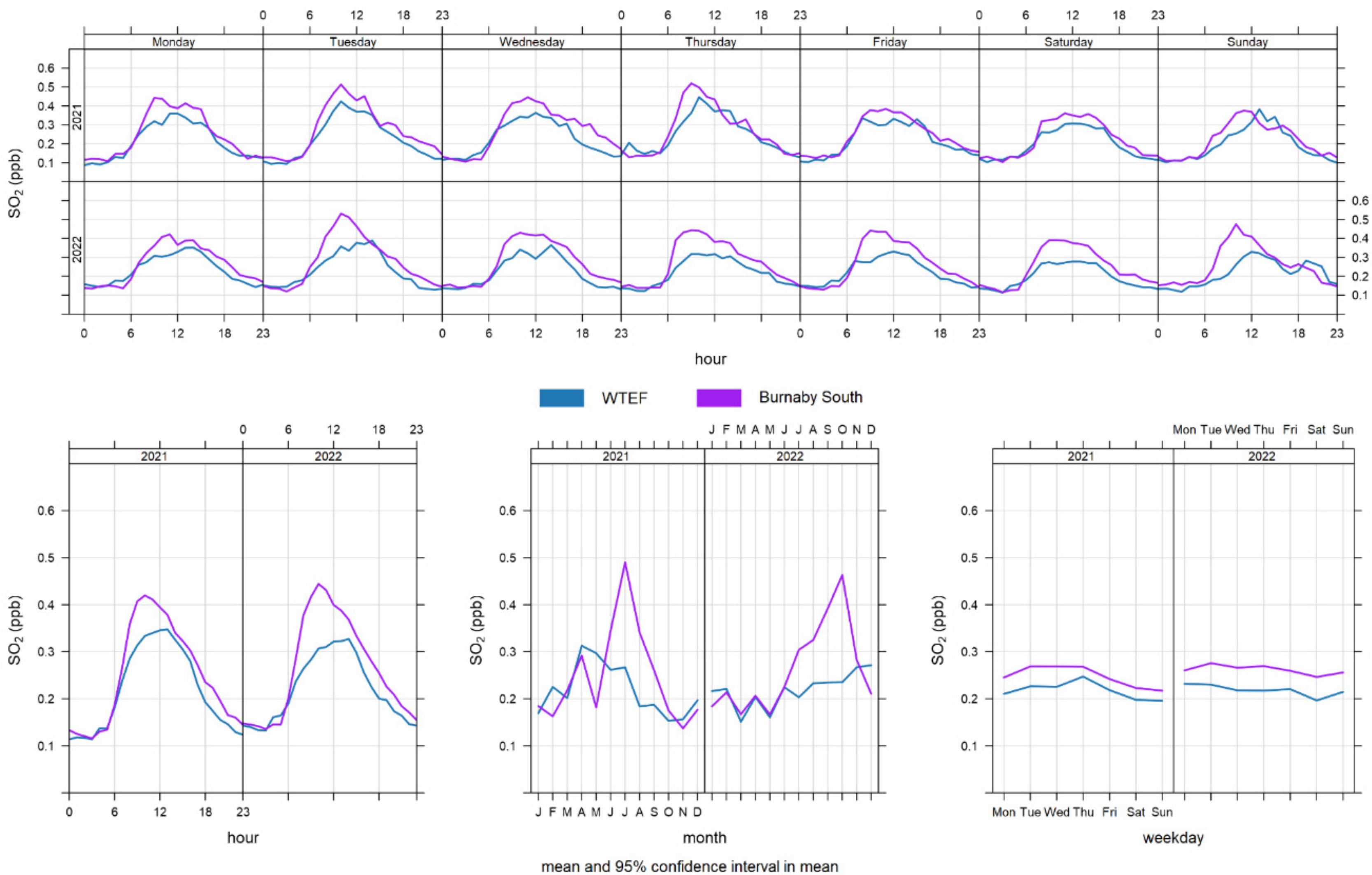


Figure 7-16 Time Variation of 1-Hour SO_2 (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022

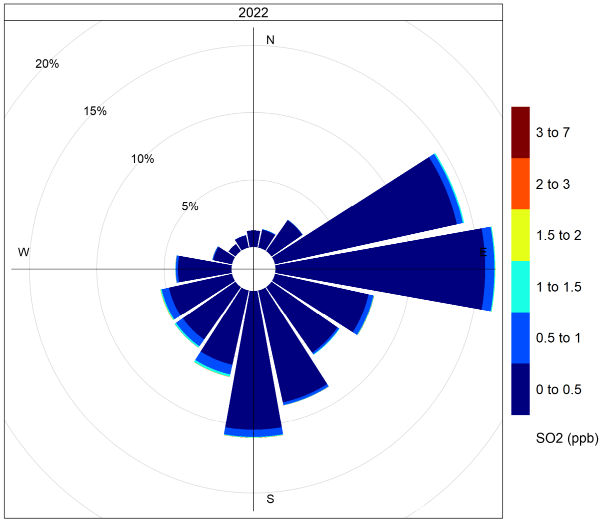


Figure 7-17 Annual Pollution Rose of 1-hour SO_2 (ppb) at S150 – MV WTEF Station in 2022

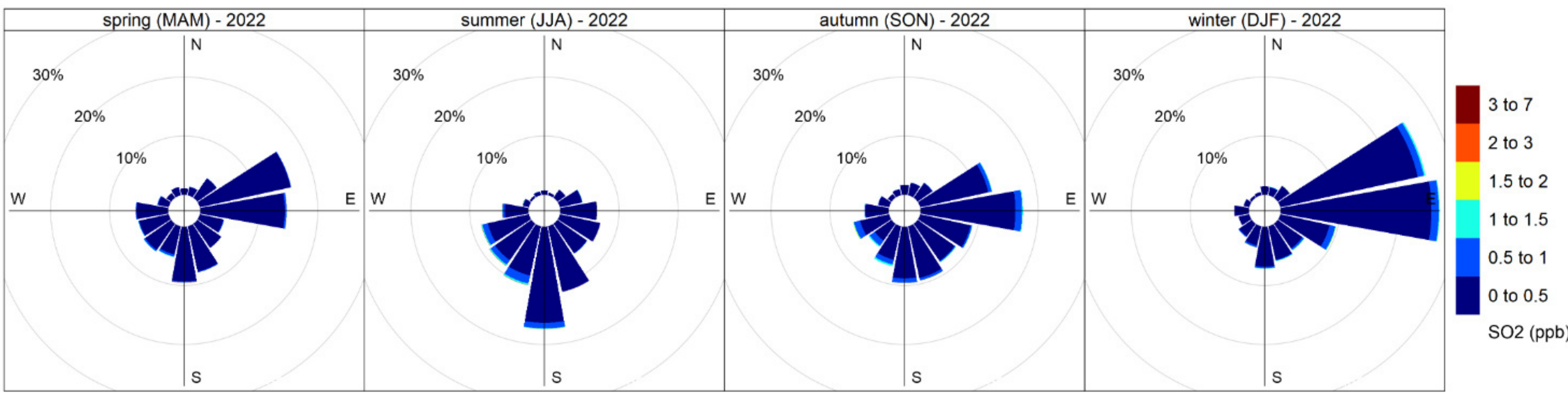


Figure 7-18 Seasonal Pollution Roses of 1-hour SO_2 (ppb) at S150 – MV WTEF Station in 2022

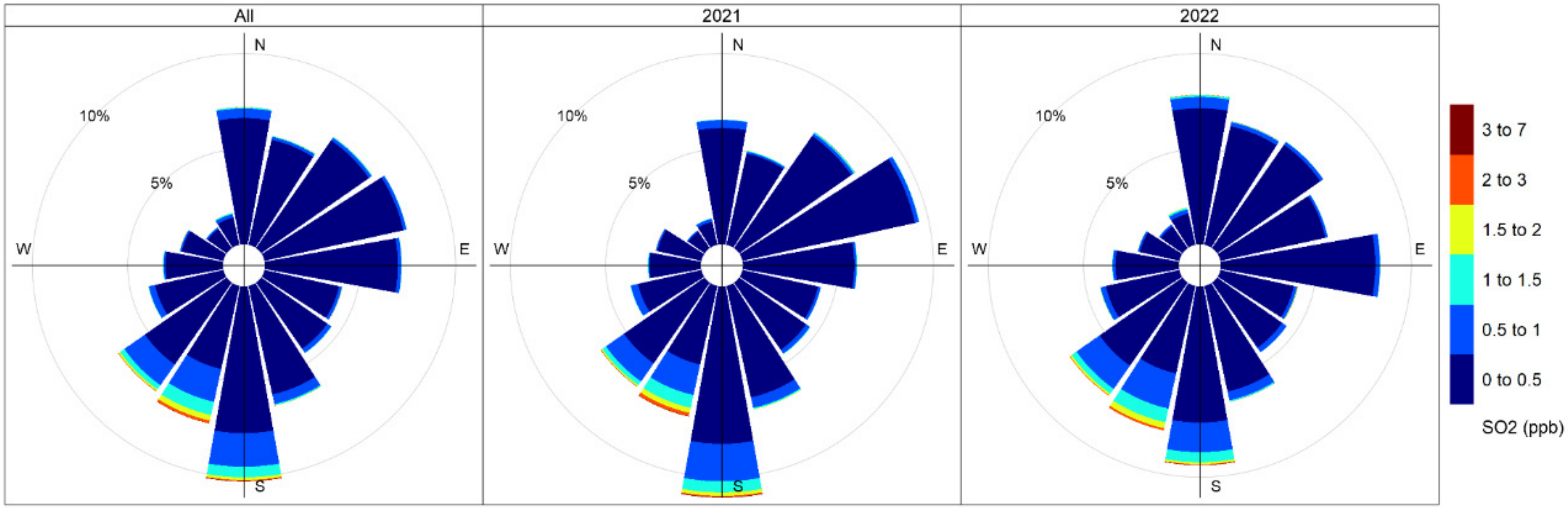


Figure-7-19 Annual Pollution Roses of 1-hour SO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

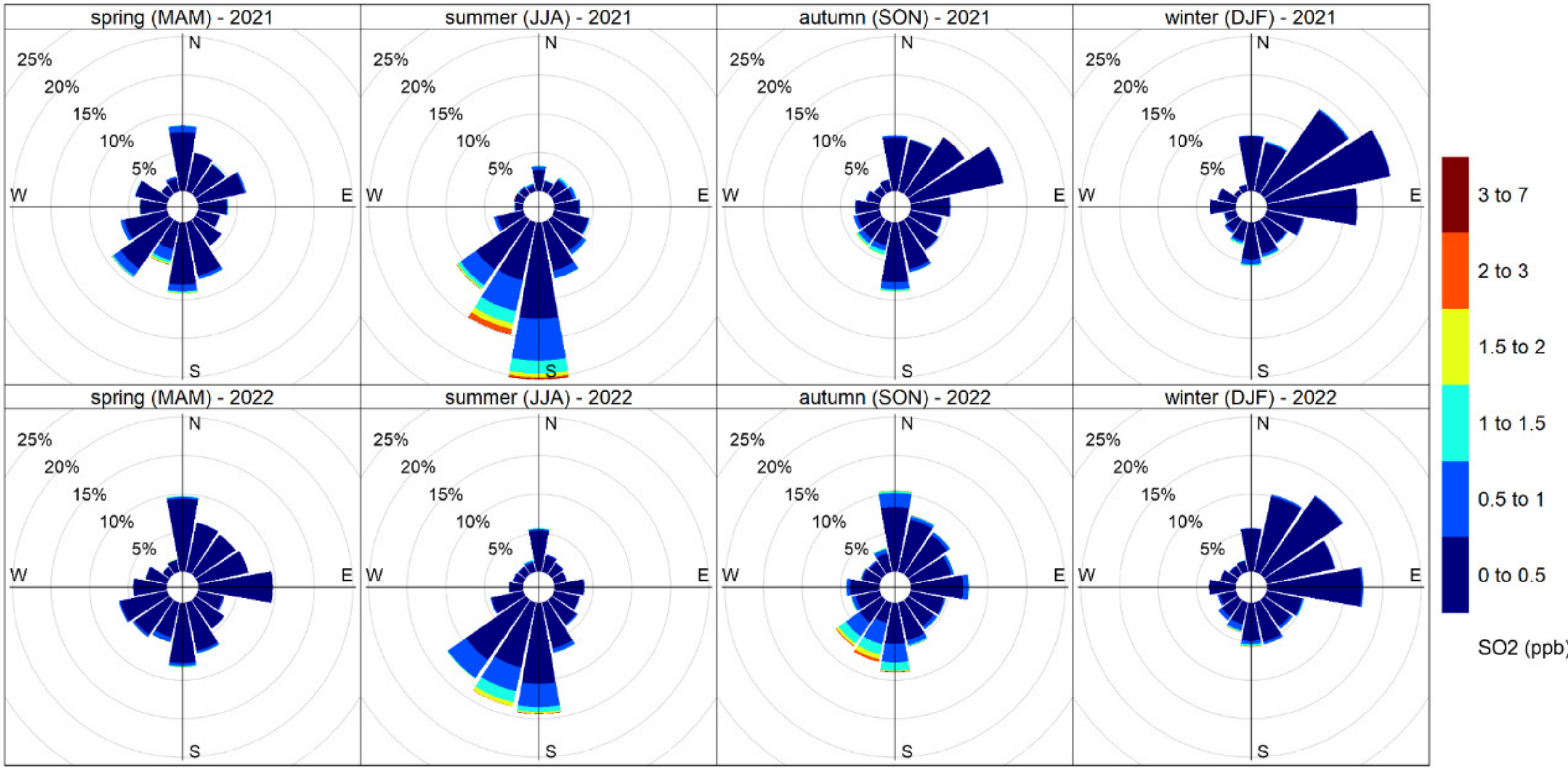


Figure 7-20 Seasonal Pollution Roses of 1-hour SO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

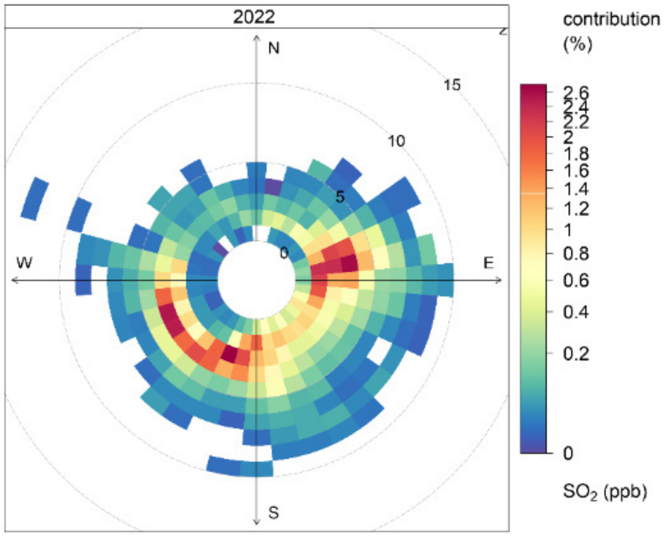


Figure 7-21 Annual Polar Plot of Percentage Contribution to Total 1-hour SO_2 (ppb) at S150 – MV WTEF Station in 2022

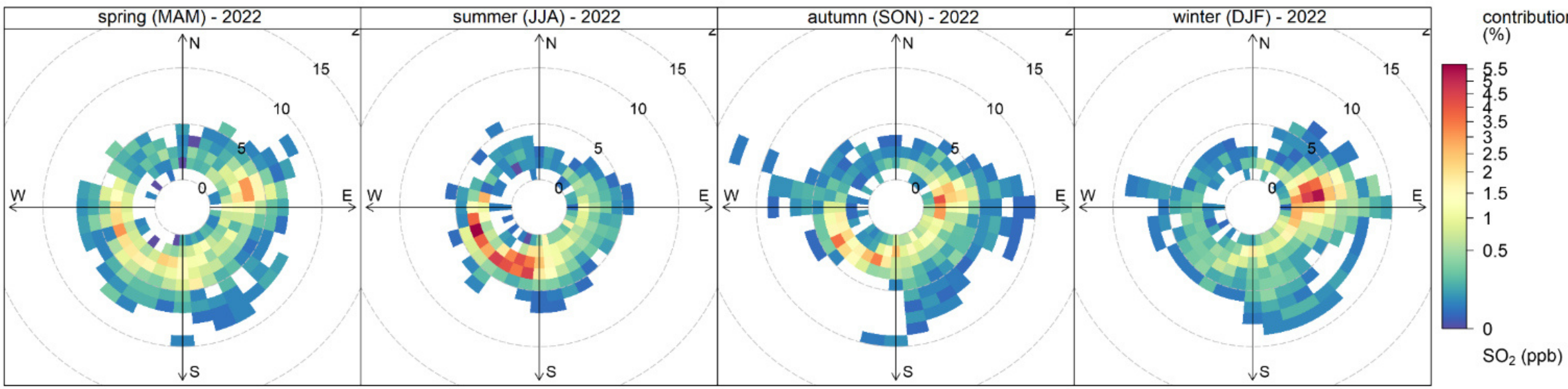


Figure 7-22 Seasonal Polar Plot of Percentage Contribution to Total 1-hour SO_2 (ppb) at S150 – MV WTEF Station in 2022

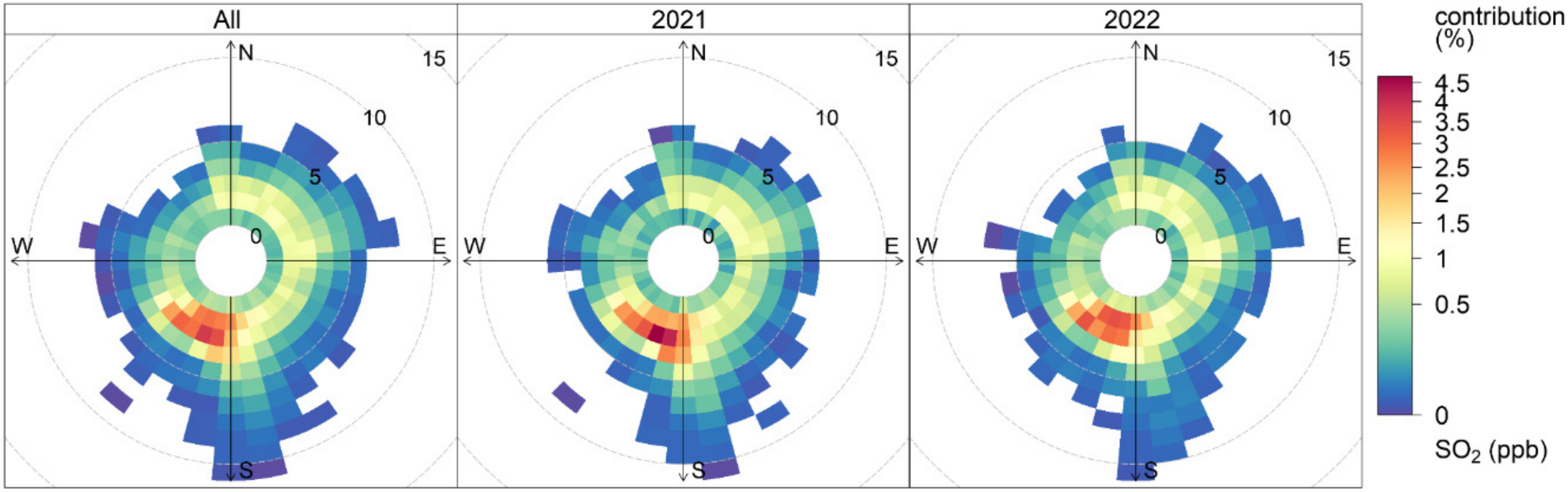


Figure 7-23 Annual Polar Plot of Percentage Contribution to Total 1-hour SO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

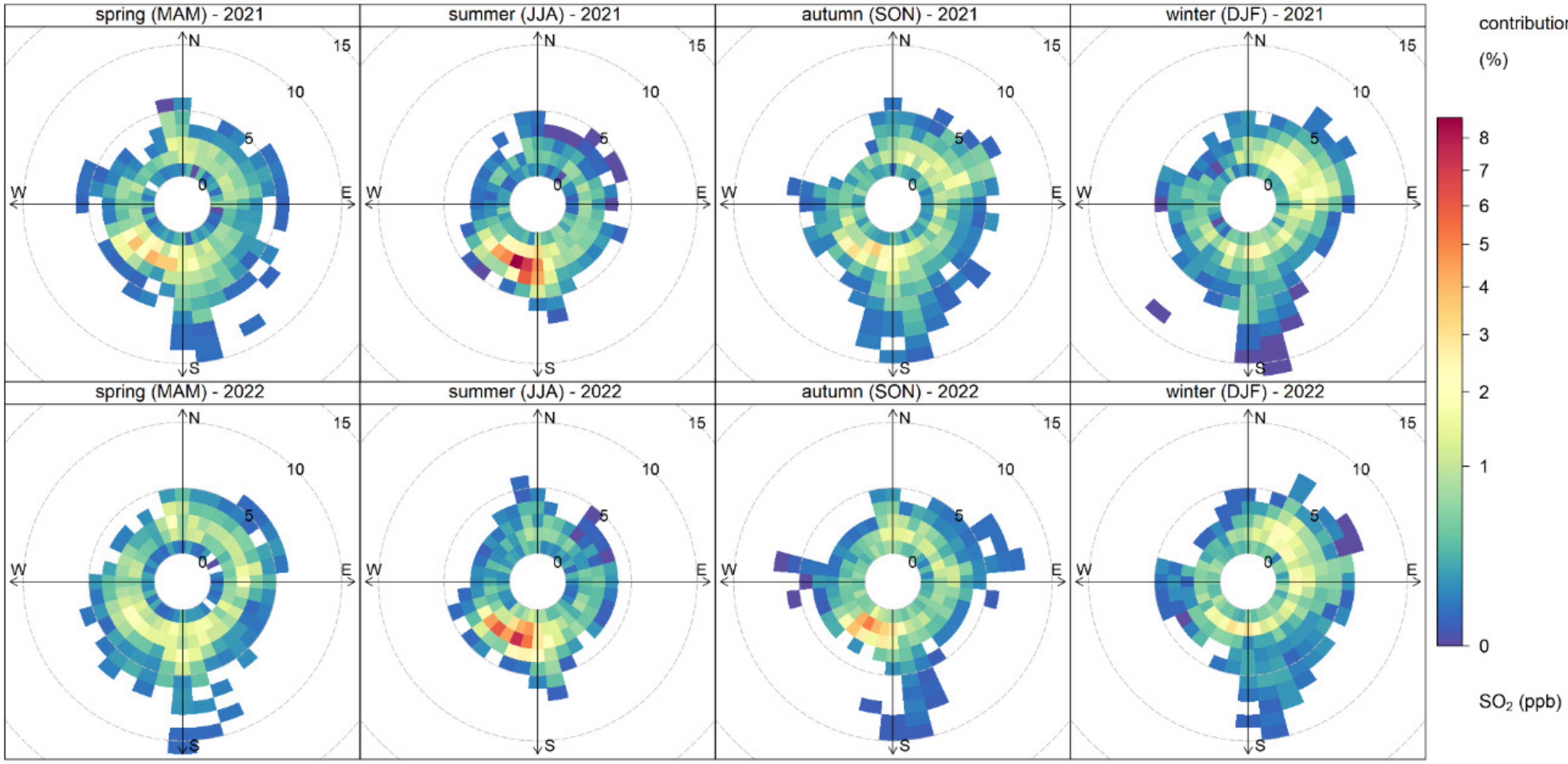


Figure 7-24 Seasonal Polar Plot of Percentage Contribution to Total 1-hour SO_2 (ppb) at T18 – Burnaby South Station in 2021 and 2022

7.4 HYDROGEN CHLORIDE (HCL) DATA REVIEW

Hydrogen chloride (HCl) is a colourless to slightly yellow gas with a pungent odour. It exists as a colourless gas at room temperature and becomes a white fume of hydrochloric acid within in the atmosphere upon contact with atmospheric water vapour. Exposure to HCl can cause irritations to the skin, nose, eyes, throat, and larynx. As detailed in Section 3, regional sources of HCl include the WTEF, industrial processes, natural marine sea salt dechlorination, industrial/agricultural wood boilers, residential wood burning, vehicle and structure fires, cremation emissions, and open-air biomass burning.

Table 7-6 and Table 7-7 provide summaries of hydrogen chloride (HCl) collected in 2021 and 2022 at S150 – MV WTEF station and T18 – Burnaby South station, respectively. Monthly timeseries of 1-hour average HCl at the two stations are presented in Figure 7-25. The timeseries show higher levels of 1-hour average HCl at T18 during the Spring months (March and April) and Summer in both monitoring years, while HCl levels at S150 were typically higher during the Winter.

The boxplots in Figure 7-26 and Figure 7-27 show the monthly and hourly variation in 1-hour average HCl concentrations at the two stations. .In general, the boxplots show that the 1-hour average HCl concentrations observed at the two stations are very low, with the majority of the concentrations falling below 1 ppb. The monthly boxplots (Figure 7-26) show that there was a pattern of higher levels of 1-hour average HCl at T18 – Burnaby South station during the Spring and Summer months compared to the Autumn and Winter months, while there was a pattern of higher levels of 1-hour average HCl at S150 – MV WTEF station during the Winter months (January and February in both years, and November and December 2022) compared to the other seasons of the 2-year monitoring period. The hourly boxplots (Figure 7-27) show that during the 2-year monitoring period there were slightly higher 1-hour HCl concentrations measured at T18 – Burnaby South station during the afternoon hours approximately between 13:00 and 18:00.

The time variation plots in Figure 7-28 show that the peak 1-hour average HCl concentrations at both stations occurred mid-afternoon (approximately 14:00 to 15:00) on all days of the week. This pattern is most evident on weekdays at the T18 – Burnaby South station during both years in the monitoring period, and least evident at S150 – MV WTEF station in 2022. The trends in 1-hour average HCl stayed consistent between the 2 years of monitoring at T18 – Burnaby South station, but changed slightly at the S150 – MV WTEF station.

The 1-hour average HCl pollution roses by year and season at both stations are shown in Figure 7-29 through Figure 7-32. These pollution roses illustrate the frequency distribution of wind direction (blowing from each cardinal direction) temporally correlated with 1-hour average HCl concentrations observed at both stations within the 2021 – 2022 monitoring period. It is important to note that the annual and seasonal pollution roses associated with 1-hour average HCl concentrations collected at S150 – MV WTEF station in 2021 have not been included due to insufficient wind data collected in the 2021 year (data record begins on September 16, 2021 after the installation of the sensor). The pollution roses for S150 – MV WTEF station in Figure 7-29 and Figure 7-30 show that the highest 1-hour HCl concentrations arose from the east and east-northeast directions during the Autumn and Winter months of 2022. The pollution roses for T18 – Burnaby South station in Figure 7-31 and Figure 7-32 show that the highest 1-hour average HCl concentrations arose from south-west directions in the Spring months (March to May) during both years of the monitoring period.

Similar to previous sections, polar plots are shown in the following figures to visualize 1-hour HCl concentrations in relation to wind speed and wind direction (Figure 7-33 through Figure 7-36). Specifically, the polar plots show the concentration of HCl weighted by wind speed and wind direction. Each segment (10-degree by 1 m/s interval) of the polar plot therefore provides the percentage contribution to the total HCl concentration. Figure 7-33 shows that the highest levels of 1-hour HCl at S150 – MV WTEF station in 2022 arose from the east and east-northeast directions with low wind speeds (2 m/s to 5 m/s). Figure 7-34 shows that the pattern seen in the annual polar plot (Figure 7-33) is driven by the Spring, Autumn, and Winter months. The annual polar plots of 1-hour HCl measured at T18 – Burnaby South station (Figure 7-35) show that the highest levels of 1-hour HCl arose from the southwest, south-southwest, and west directions during both monitoring years. The seasonal polar plots in Figure 7-36 show that there was more variation in terms of the combinations of wind speed and wind direction that are attributed to the highest levels of HCl during each season, southwesterly winds were predominantly associated with high HCl values throughout the Spring, Summer and Autumn.

Unlike NO_2 and SO_2, no other HCl monitoring data from the region is available for comparison. Taken together, the monitoring results indicate that the T18 – Burnaby South station experienced higher HCI levels than S150 – MV WTEF during the Spring and Summer, while S150 experienced higher levels during the Winter. The Spring/Summer daytime afternoon peak at T18 is associated with both peak sea breeze intensity and peak photochemical activity, suggesting that HCl emissions associated with sea salt dechlorination occurring over the Salish Sea could be playing a role. It should also be noted that at the low levels of HCl monitored, the diurnal pattern could also be influenced by known temperature artifacts on the monitoring of HCl.

Given the predominant southwesterly wind direction associated with the peak Spring and Summer HCl levels at T18, significant contribution of the WTEF emissions to observed levels is unlikely, as it is located south southeast of the station. The fact that S150 did not experience peak HCl concentrations during similar Spring/Summer afternoon periods is puzzling, as it is affected by similar sea breeze winds, especially in the Summer The higher elevation of T18 may play a role in positioning the station more directly in the HCl plume carried by southwesterly winds or this could be related to the temperature artifacts influencing the HCl at the T18 location where a longer inlet may magnify its affects at the low concentrations of HCl that were monitored. During the Winter months, the WTEF stack is upwind of S150 (based on predominant easterly Winter wind flows), so WTEF emissions may impact measured S150 levels, but likely only at very low wind speeds, due to station proximity to the facility. As indicated in Section 7.1, measured HCl levels at both stations remained far below AAQO levels throughout the study period. In particular, with regards to 1-hour concentrations, 98% of the time, ambient concentrations of HCl are less than 3% of the AAQO at both stations.

Table 7-6 Monthly 1-Hour HCl (ppb) Summary at S150 – MV WTEF Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	91.8	0.1	0.5	1.8
February 2021	89.0	0.1	0.5	2.3
March 2021	95.8	0.1	0.3	1.1
April 2021	95.8	0.1	0.4	2.3
May 2021	99.2	0.1	0.4	1.0
June 2021	99.9	0.1	0.3	1.5
July 2021	99.9	0.1	0.4	1.3
August 2021	100.0	0.1	0.3	0.8
September 2021	88.1	0.1	0.3	1.0
October 2021	99.9	0.1	0.3	1.3
November 2021	100.0	0.1	0.3	2.1
December 2021	99.9	0.1	0.3	1.5
January 2022	100.0	0.1	0.5	2.5
February 2022	99.7	0.1	0.4	1.3
March 2022	100.0	0.1	0.3	1.7
April 2022	100.0	0.1	0.2	0.7
May 2022	99.9	0.1	0.2	0.6
June 2022	90.8	0.1	0.2	0.6
July 2022	99.6	0.1	0.3	0.9
August 2022	100.0	0.1	0.3	0.8
September 2022	99.9	0.1	0.4	1.4
October 2022	99.9	0.1	0.5	1.3
November 2022	96.8	0.1	0.7	2.5
December 2022	100.0	0.1	0.7	2.8

Table 7-7 Monthly 1-Hour HCl (ppb) Summary at T18 – Burnaby South Station in 2021 and 2022

MONTH / YEAR	DATA COMPLETENESS (%)	MINIMUM	AVERAGE	MAXIMUM
January 2021	100.0	0.1	0.2	1.3
February 2021	100.0	0.0	0.2	1.6
March 2021	99.1	0.1	0.4	3.4
April 2021	99.9	0.1	0.5	2.5
May 2021	100.0	0.1	0.4	1.5
June 2021	98.3	0.1	0.6	2.4
July 2021	98.7	0.2	0.6	1.5
August 2021	99.5	0.1	0.6	2.4
September 2021	100.0	0.1	0.4	1.1
October 2021	99.7	0.1	0.2	0.9
November 2021	100.0	0.1	0.2	0.7
December 2021	99.9	0.0	0.1	1.2
January 2022	99.7	0.1	0.2	2.2
February 2022	99.4	0.1	0.2	1.7
March 2022	100.0	0.1	0.4	3.9
April 2022	100.0	0.1	0.5	4.7
May 2022	99.9	0.1	0.5	2.3
June 2022	100.0	0.2	0.6	2.9
July 2022	99.7	0.2	0.6	2.0
August 2022	96.6	0.1	0.6	2.2
September 2022	100.0	0.1	0.5	1.3
October 2022	100.0	0.1	0.4	1.5
November 2022	94.7	0.1	0.2	1.6
December 2022	100.0	0.0	0.2	1.8

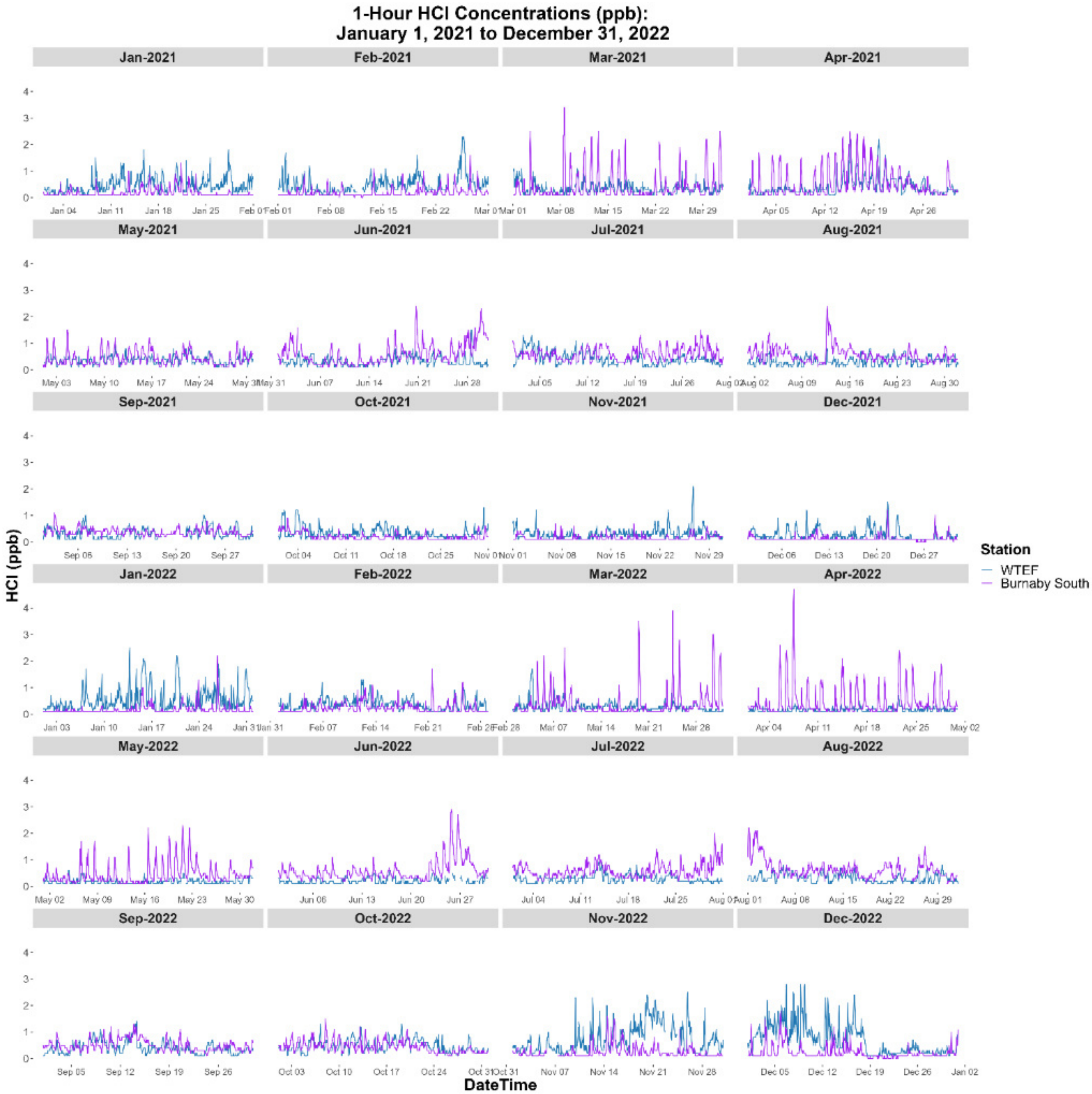


Figure 7-25 **Monthly Timeseries of 1-Hour HCl (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022**

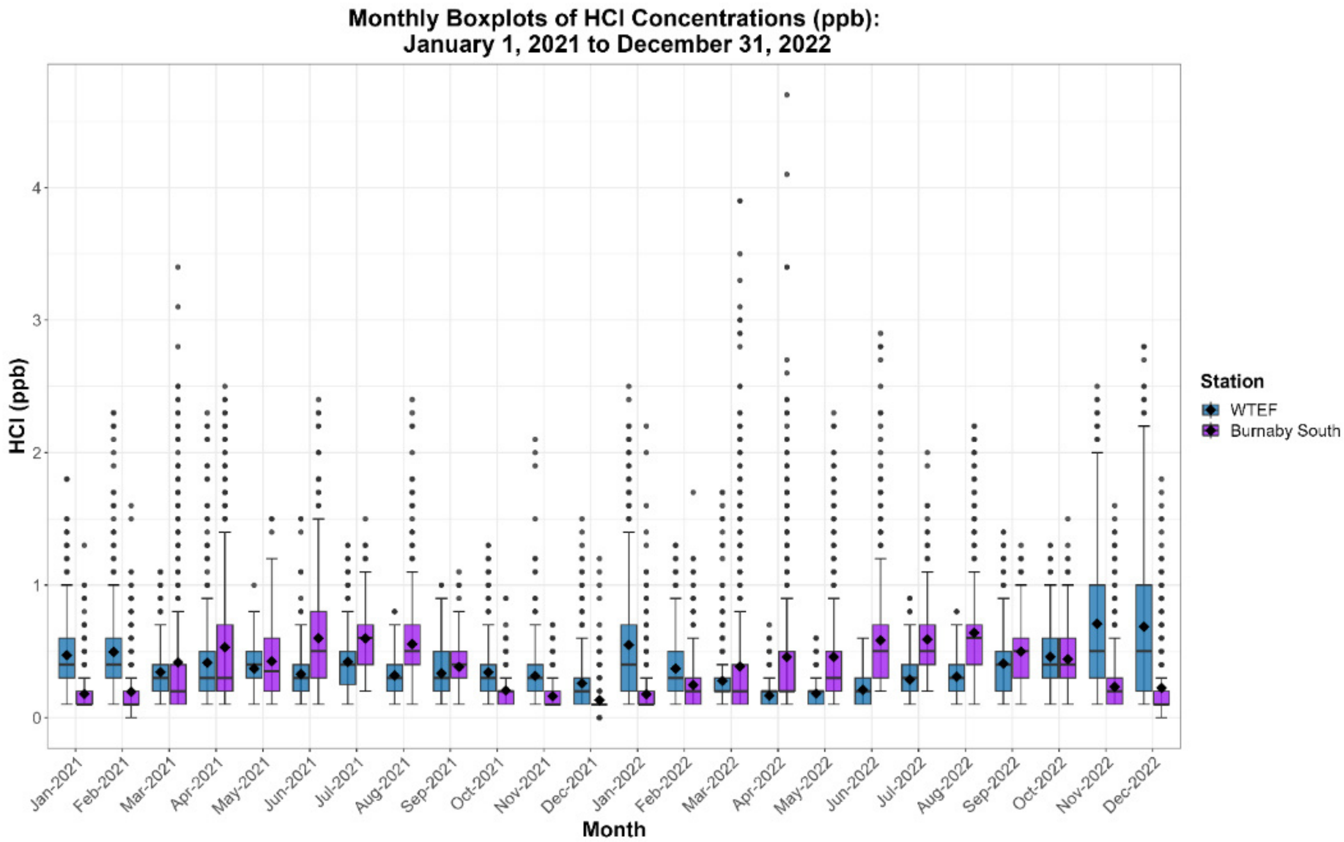


Figure 7-26 Monthly Boxplots of 1-Hour HCl (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022

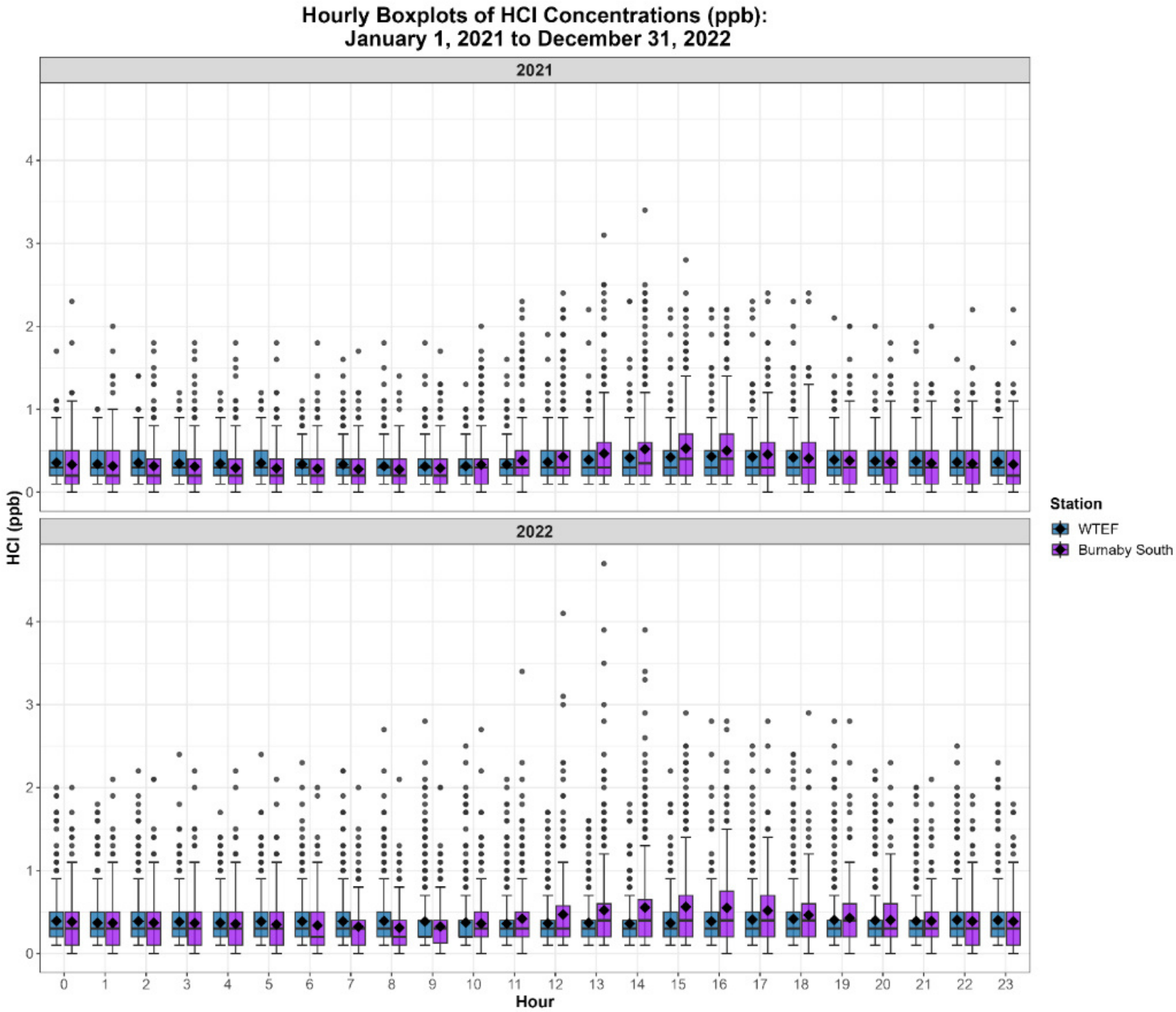


Figure 7-27 Hourly Boxplots of 1-Hour HCl (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022

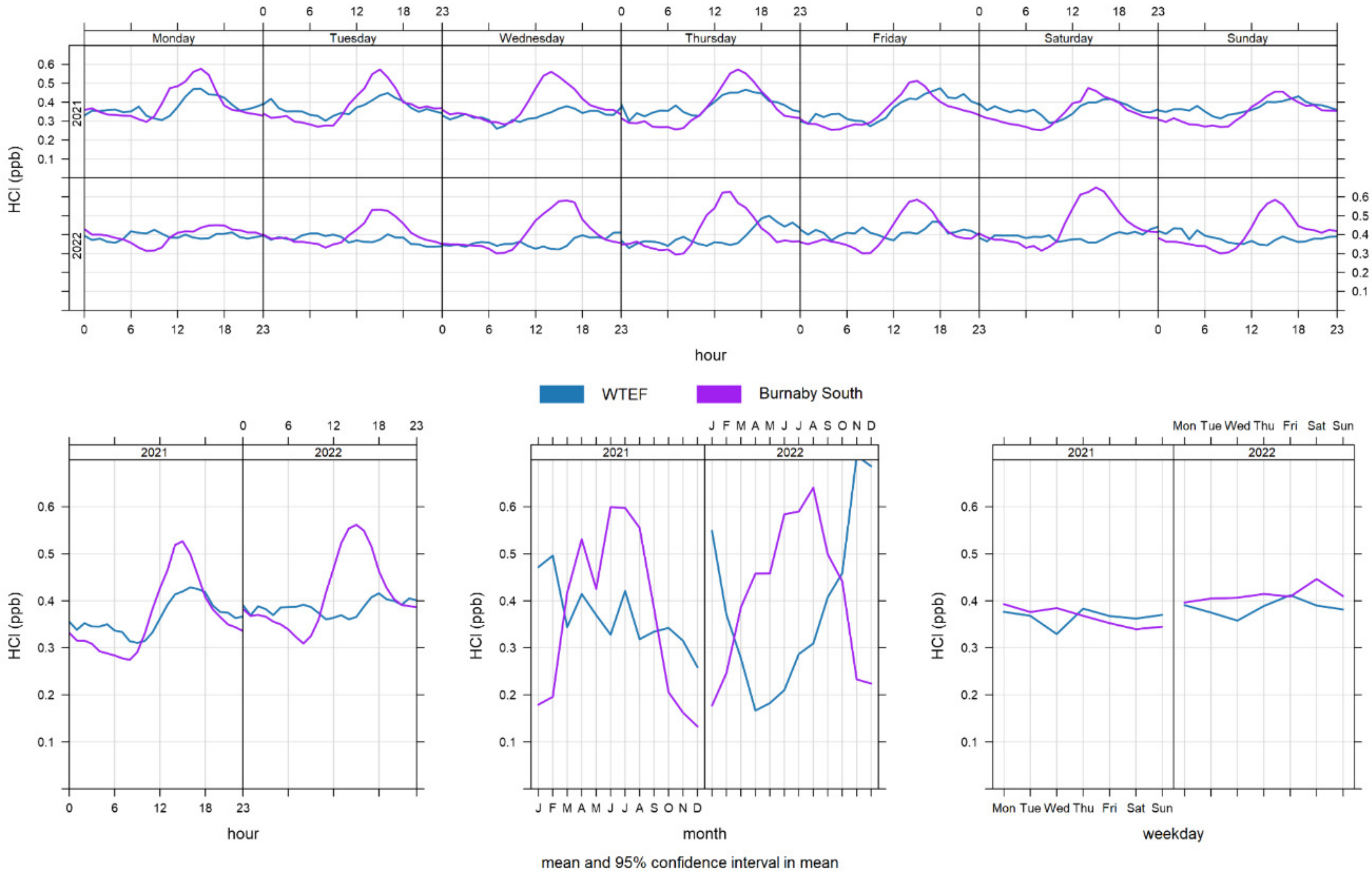


Figure 7-28 Time Variation of 1-Hour HCl (ppb) at S150 – MV WTEF Station and T18 – Burnaby South Station in 2021 and 2022

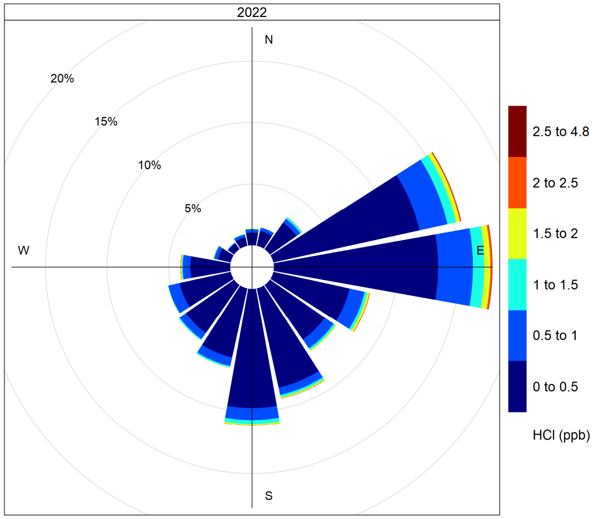


Figure 7-29 Annual Pollution Rose of 1-hour HCl (ppb) at S150 – MV WTEF Station in 2022

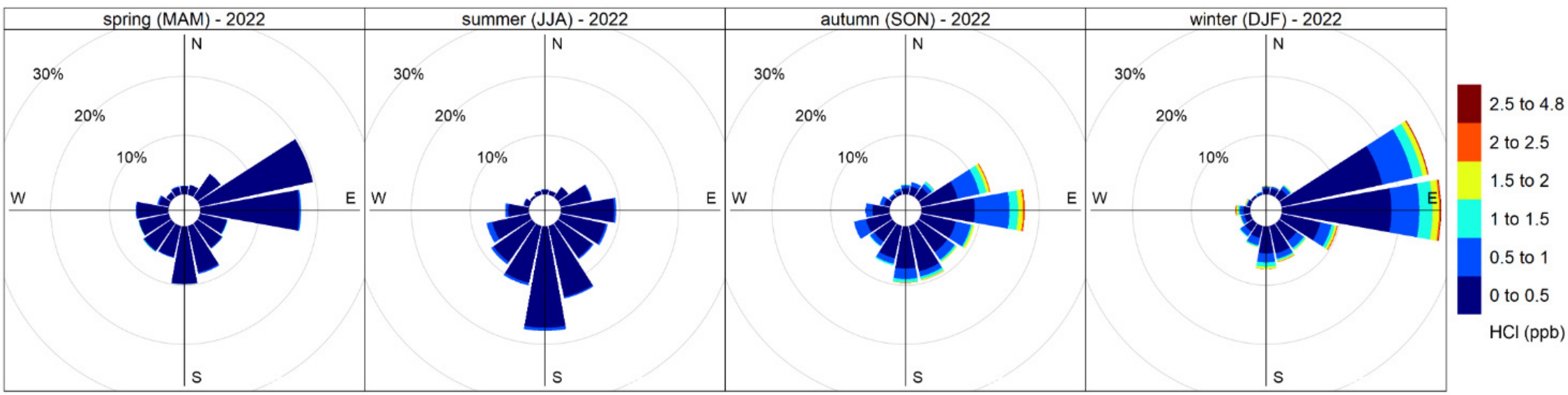


Figure 7-30 Seasonal Pollution Roses of 1-hour HCl (ppb) at S150 – MV WTEF Station in 2022

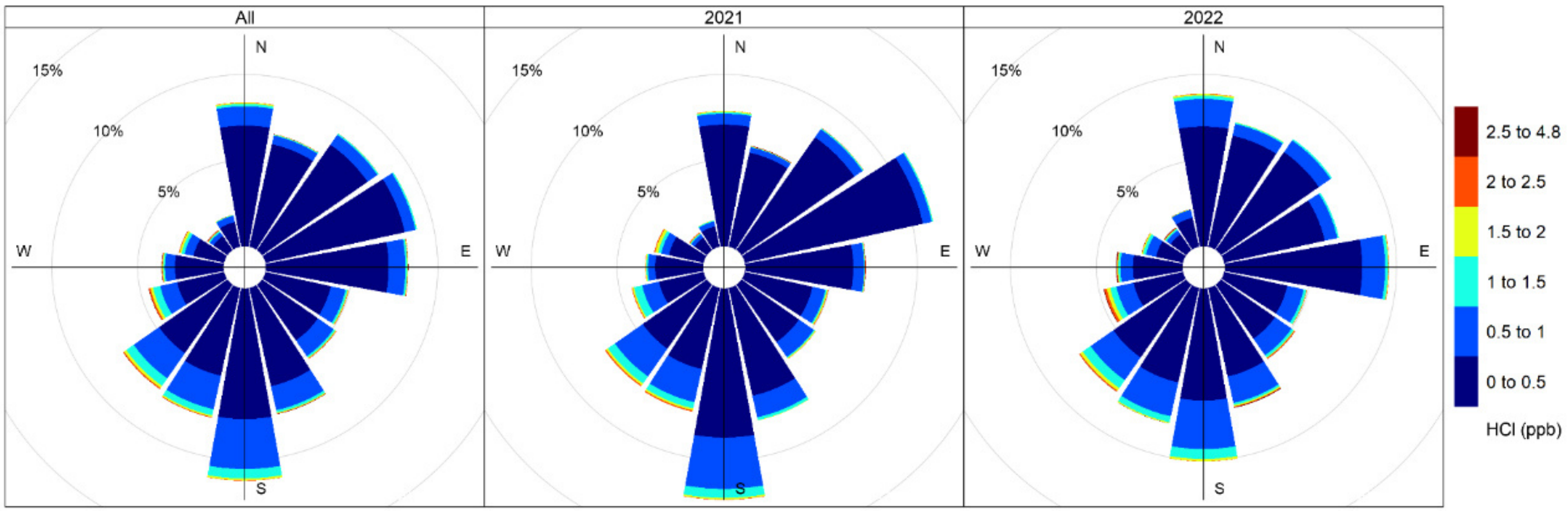


Figure 7-31 Annual Pollution Rose of 1-hour HCl (ppb) at T18 – Burnaby South Station in 2021 and 2022

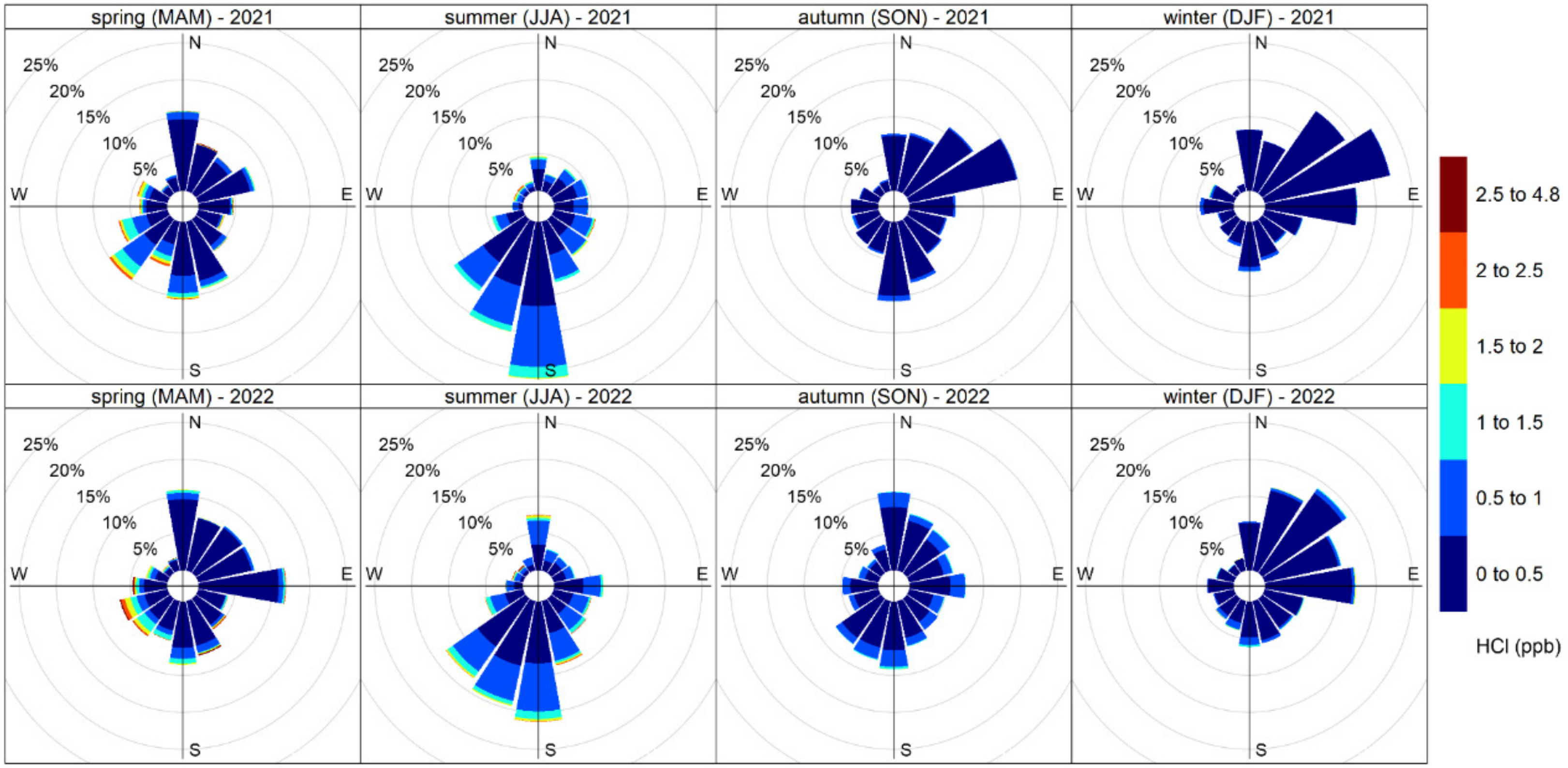


Figure 7-32 Seasonal Pollution Roses of 1-hour HCl (ppb) at T18 – Burnaby South Station in 2021 and 2022

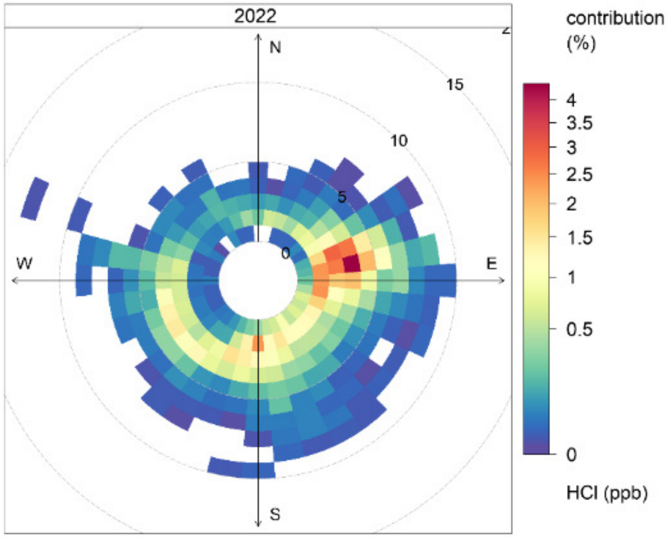


Figure 7-33 Annual Polar Plot of Percentage Contribution to Total 1-hour HCl (ppb) at S150 – MV WTEF Station in 2022

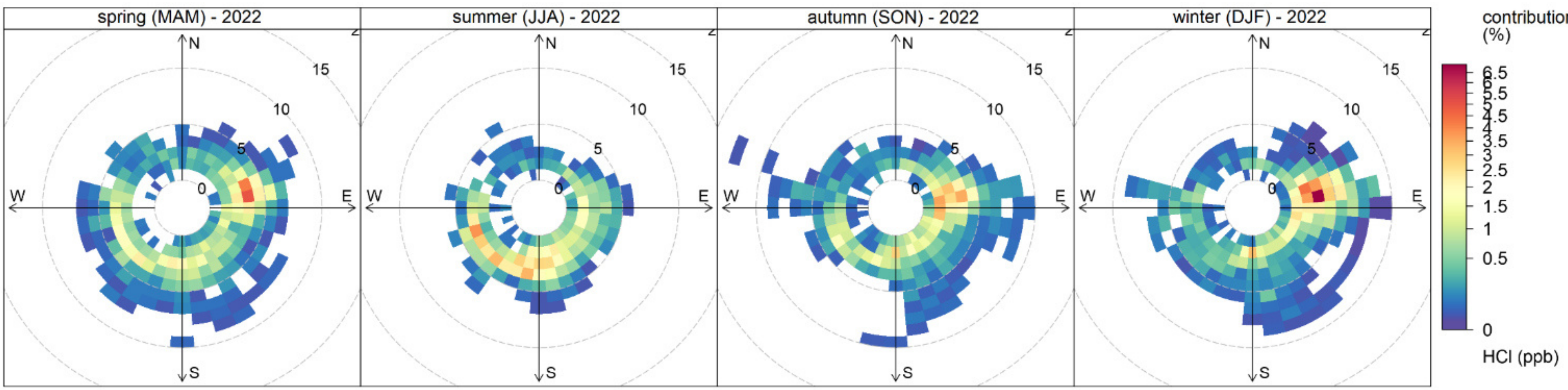


Figure 7-34 Seasonal Polar Plot of Percentage Contribution to Total 1-hour HCl (ppb) at S150 – MV WTEF Station in 2022

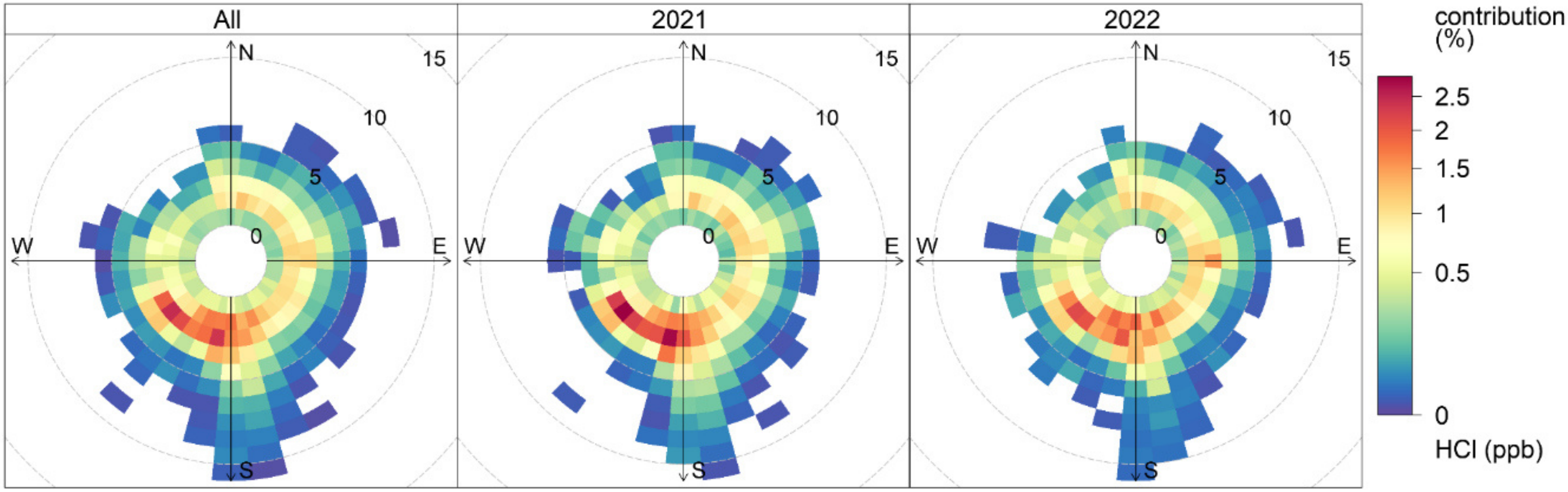


Figure 7-35 Annual Polar Plot of Percentage Contribution to Total 1-hour HCl (ppb) at T18 – Burnaby South Station in 2021 and 2022

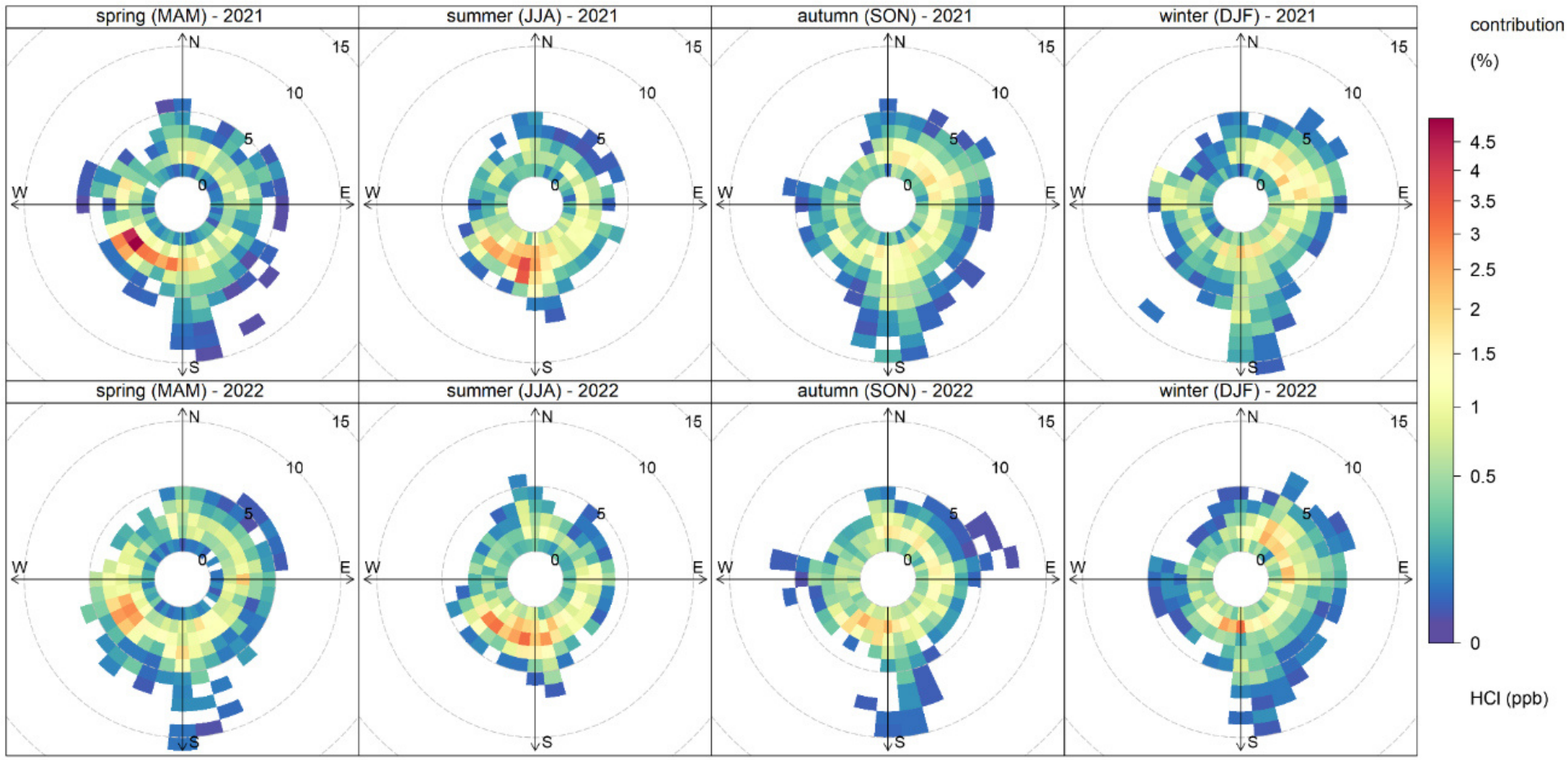


Figure 7-36 Seasonal Polar Plot of Percentage Contribution to Total 1-hour HCl (ppb) at T18 – Burnaby South Station in 2021 and 2022

8 RELATIONSHIP BETWEEN CEMS AND AMBIENT AIR MONITORING DATA

The following analysis was conducted to determine if there was any observable correlation between CEMS data collected at the 3 MV WTEF boiler units and the ambient air quality data collected at the 2 monitoring stations of interest (S150 – MV WTEF station and T18 – Burnaby South station) in the 2021 and 2022 calendar years. Due to the difference in data measurements (averaging period and units of measurement), the following conversions were applied prior to applying the correlation analysis:

- **CEMS Data**: 1-minute averaged CEMS data (at actual stack conditions) in mg/m^3 was converted into 1-hour averages in $\mu g/m^3$
  - Calculate 1-hour averages from 1-minute average data;
  - Convert mg/m^3 into $\mu g/m^3$ by multiplying by a factor of 1000;
  - Note: 100% conversion from NO_x to NO_2 was assumed in this correlation analysis to compare with the NO_2 observations at the two ambient air quality monitoring stations. It is important to recognize that this is a conservative estimate because, in reality, the quantity of NO_x converted to NO_2 in an equilibrium state is dependent on numerous factors (e.g., O_3 concentrations).
- **Ambient Air Quality Data**: 1-hour averaged data in ppb was converted into 1-hour averages in $\mu g/m^3$
  - Convert each of the NO_2, SO_2, and HCl concentrations from ppb to $\mu g/m^3$ by multiplying by the appropriate conversion factor according to the procedure outlined in Section 3.2.1.2.1 of the 2021 Guidance for NO_2 Dispersion Modelling in British Columbia document[26]

$$C\ [\mu g/m^3] = (ppb/1000) \times MW \times 40.8727$$

Where MW is the molecular weight of the pollutant in grams/mole.

Correlation between the CEMS data collected at the 3 MV WTEF boiler units and ambient air quality data collected at the S150 – MV WTEF station and T18 – Burnaby South station was determined using Pearson's correlation coefficient (r). The coefficient of determination (r^2), i.e., the proportion of variance in one variable that is "explained" by the other variable, was calculated by taking the squared value of the correlation coefficient (r). The regression of ambient air quality data on CEMS data, as represented by a linear regression equation, was then calculated to approximate the change in ambient air quality data with any given change in CEMS data.

Figure 8-1 through Figure 8-3 display the scatterplots of CEMS data collected at the 3 MV WTEF boiler units versus the ambient air quality data collected at the S150 – MV WTEF station and T18 – Burnaby South station for the 2021 and 2022 calendar years. The linear regression equations and coefficient of determination (r^2) are displayed within each scatterplot figure. It was determined that there is no statistically significant linear correlation ($r^2 \leq 0.02$) between CEMS data collected at the 3 MV WTEF boiler units and ambient air quality data collected at the S150 – MV WTEF station and T18 – Burnaby South station for NO_2, SO_2, and HCl.

As no statistically significant linear correlation between CEMS and ambient air quality data was found at both stations and all 3 air contaminants using all of the available data in both monitoring years, 4 additional linear regressions (with increasing complexity) were investigated to determine if alternative approaches to splitting the dataset could reveal any statistically significant relationships (Figure 8-4). Steps 2 through Step 4 from Figure 8-4 detail the methodology used to apply linear regressions on the total emissions from all 3 boiler units, the split of data temporally by month of year and hour of day, and the subsets of data based on wind speeds and wind directions

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[26] British Columbia Ministry of Environment & Climate Change Strategy: *Guidance for NO_2 Dispersion Modelling in British Columbia:* https://www2.gov.bc.ca/assets/gov/environment/air-land-water/air/reports-pub/modelling_guidance_nitrogen_dioxide.pdf

having the potential to result in higher levels of ambient concentrations per station location. Furthermore, a stepwise multiple linear regression approach was utilized in Step 5 whereby meteorological variables (wind speed, wind direction, and temperature) were included in the analysis to assess the impact of meteorology on ambient levels of NO_2, SO_2, and HCl. None of the additional linear regressions resulted in any detectable statistically significant linear relationship between CEMS and ambient air quality data, suggesting that there are other significant regional sources that have an impact on the ambient levels of NO_2, SO_2, and HCl recorded at both the S150 – MV WTEF station and T18 – Burnaby South station. Given the previous section's analysis, this is not an unexpected result since monitored values of SO_2 and HCl were particularly low, NO_2 levels appear primarily linked to traffic emission patterns and the potential influence of WTEF emissions observed in the polar plot analysis did not result in a corresponding observable increase in monitored concentrations. Section 10 builds on this analysis to see if particular startup or shutdown events were associated with higher pollutant concentrations.

In addition, to provide context for the result of the multiple linear regression utilized in Step 5 of the stepwise analysis (Figure 8-4), scatterplots of ambient concentrations versus each of the 3 boiler unit CEMS concentrations and the 3 meteorological variables (wind speed, wind direction, and temperature) are presented in Figure 8-5 and Figure 8-6.

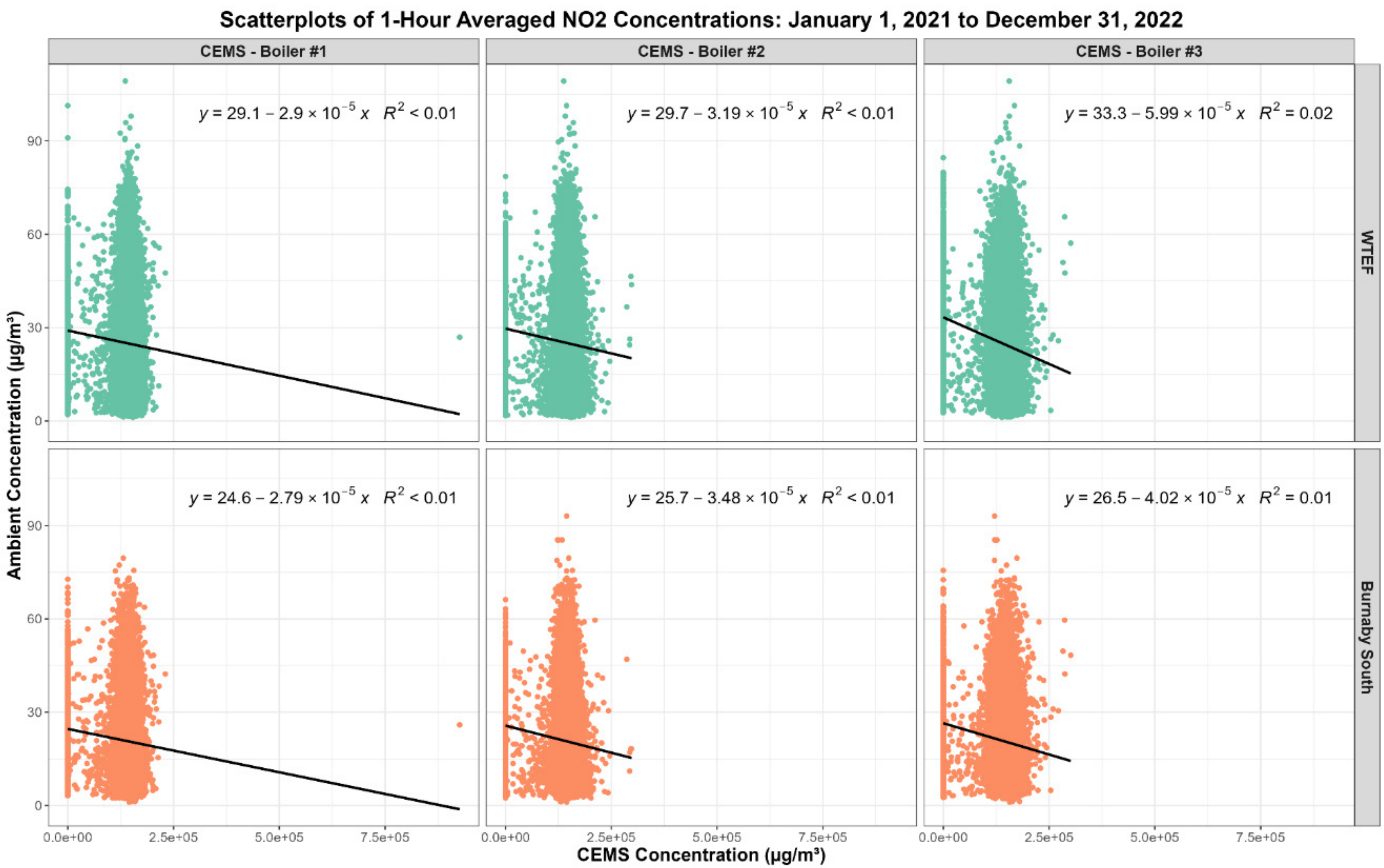

Figure 8-1 Scatterplots of 1-Hour Averaged NO_2 Concentrations in 2021 and 2022 – CEMS Data vs. Ambient Air Quality Data

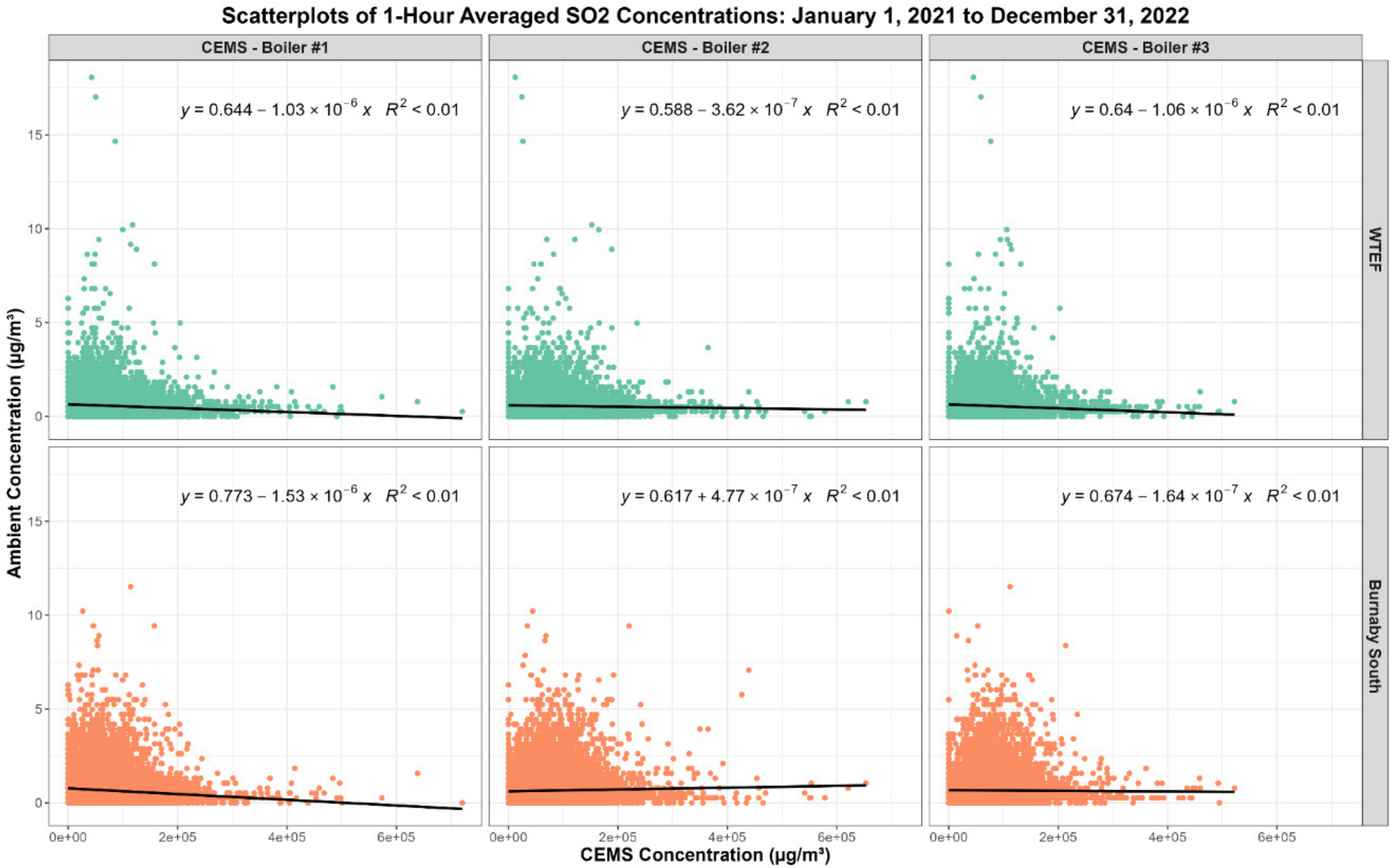

Figure 8-2 Scatterplots of 1-Hour Averaged SO_2 Concentrations in 2021 and 2022 – CEMS Data vs. Ambient Air Quality Data

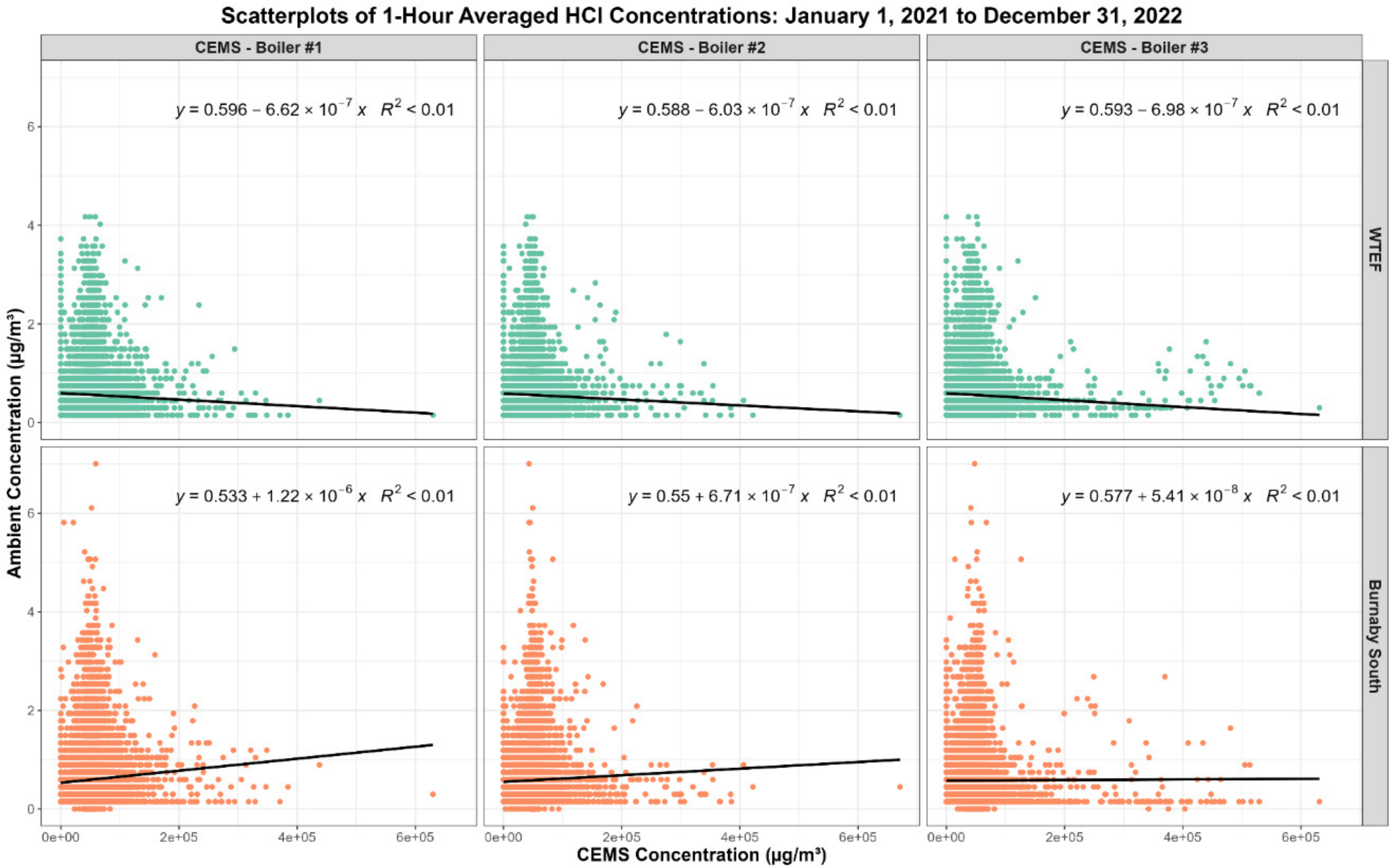

Figure 8-3 **Scatterplots of 1-Hour Averaged HCl Concentrations in 2021 and 2022 – CEMS Data vs. Ambient Air Quality Data**

Step 1

- **Method:** Simple Linear Regression
- **Formula:** Ambient ~ CEMS
- **Data Used:** Ambient and CEMS data
- **Data Period:** January 2021 to December 2022
- **Result:** No statistically significant linear correlation found

Step 2

- **Method:** Simple Linear Regression, using Total CEMS Concentrations from 3 Boilers
- **Formula:** Ambient ~ Total CEMS (Boiler Unit #1 + Boiler Unit # 2 + Boiler Unit #3)
- **Data Used:** Ambient and CEMS data
- **Data Period:** January 2021 to December 2022
- **Result:** No statistically significant linear correlation found

Step 3

- **Method:** Simple Linear Regression, subset by Month of Year and Hour of Day
- **Formula**: Ambient ~ CEMS
- **Data Used:** Ambient and CEMS data, subset by:
  - Month of Year
  - Hour of Day
- **Data Period:** January 2021 to December 2022
- **Result:** No statistically significant linear correlation found

Step 4

- **Method:** Simple Linear Regression, subset by Wind Speed and Wind Direction
- **Formula**: Ambient ~ CEMS
- **Data Used:** Ambient and CEMS data, subset by:
  - MV WTEF station: calm wind speeds
    - < 1 m/s (3.6 km/hr)
    - < 1.3888 m/s (5 km/hr)
  - Burnaby South station: wind sector associated with the direction of the MV WTEF (SE: 135° to SSW: 202.5°)
- **Data Period:** January 2021 to December 2022
- **Result:** No statistically significant linear correlation found

Step 5

- **Method:** Stepwise Multiple Linear Regression
- **Formula:**
  - Ambient ~ CEMS + Wind Speed
  - Ambient ~ CEMS + Wind Direction
  - Ambient ~ CEMS + Temperature
  - Ambient ~ CEMS + Wind Speed + Wind Direction
  - Ambient ~ CEMS + Wind Speed + Temperature
  - Ambient ~ CEMS + Wind Direction + Temperature
  - Ambient ~ CEMS + Wind Speed + Wind Direction + Temperature
- **Data Used:** Ambient, CEMS, and Meteorological data
- **Data Period:** January 2021 to December 2022
- **Result:** No statistically significant linear correlation found

Figure 8-4 Stepwise Approach of Linear Regressions

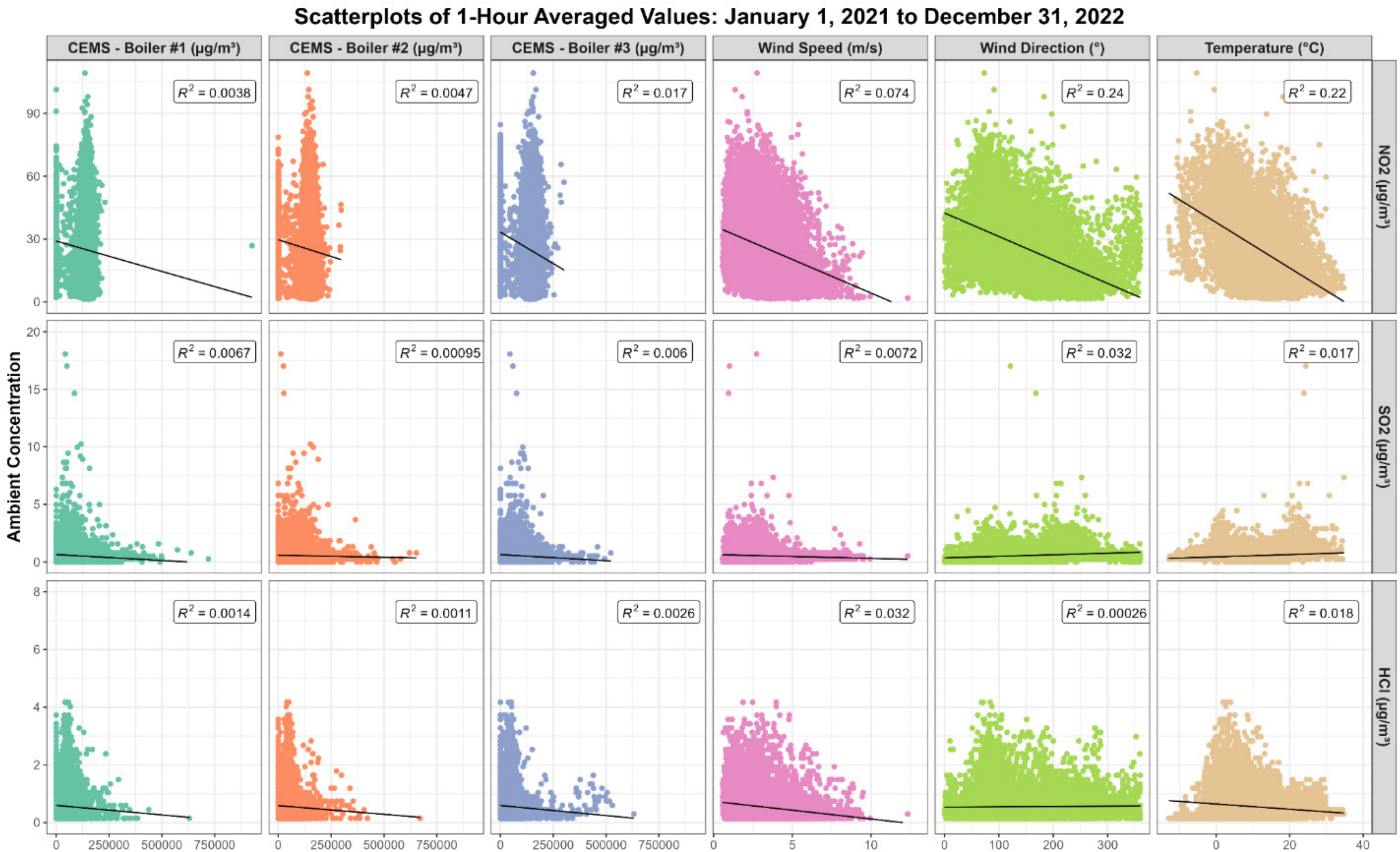

Figure 8-5 Scatterplots of 1-Hour Averaged Ambient Concentrations vs. CEMS and Meteorological Data in 2021 and 2022 at S150 – MV WTEF Station

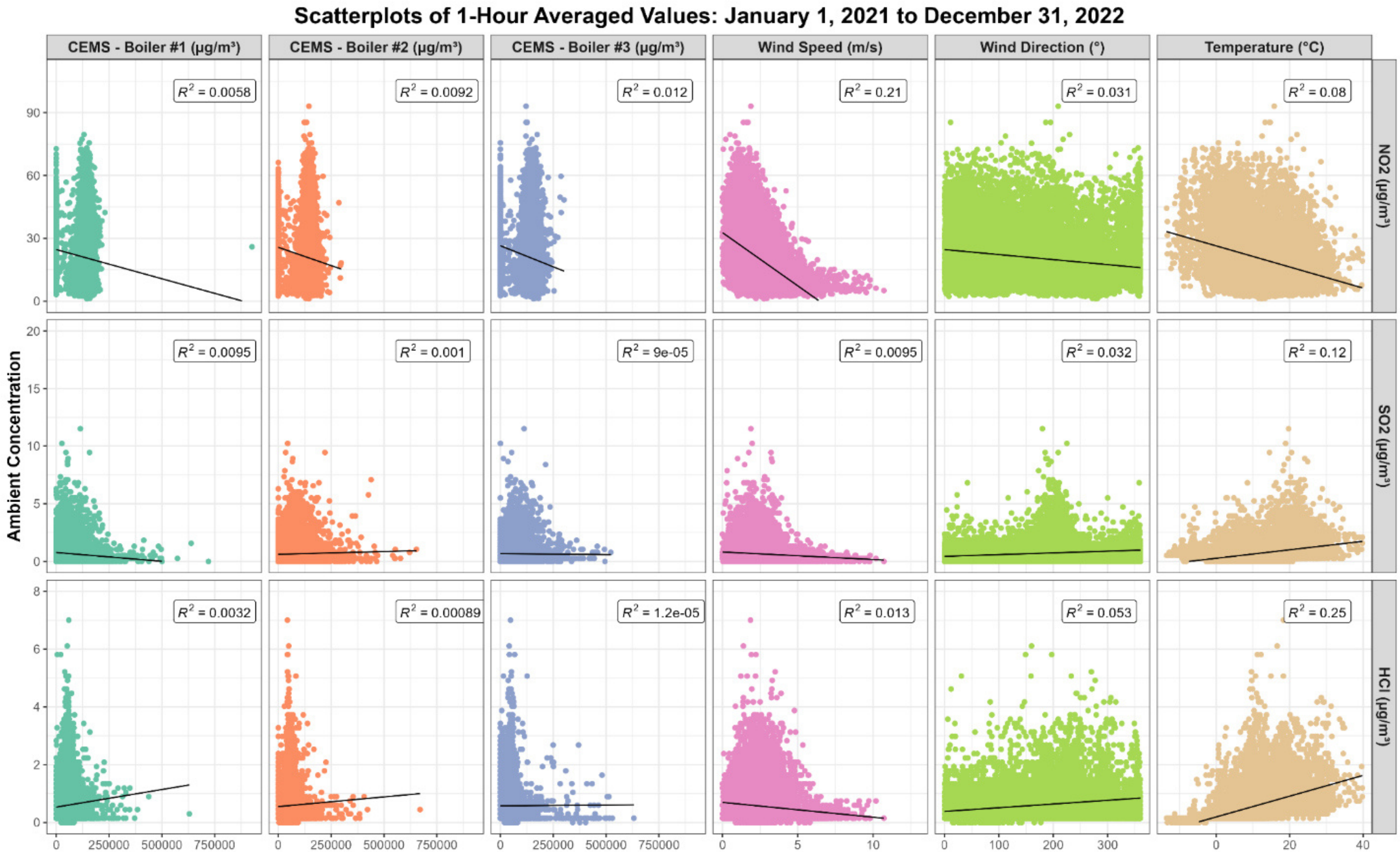

Figure 8-6 **Scatterplots of 1-Hour Averaged Ambient Concentrations vs. CEMS and Meteorological Data in 2021 and 2022 at T18 – Burnaby South Station**

9 AMBIENT AIR MONITORING DATA COMPARED TO DISPERSION MODEL PREDICTIONS

Since the S150 – MV WTEF station was installed near the location with the highest expected ambient air concentrations identified by the dispersion modelling, the following section presents the comparative results between the ambient air quality data collected at S150 – MV WTEF station and T18 – Burnaby South station against the air dispersion model predictions reported by RWDI[27] in 2018 for the "operational" model scenario.

9.1 KEY LOCATIONS FOR COMPARISON

RWDI's air dispersion model receptors were analyzed in detail, and the receptors corresponding to the locations of the S150 – MV WTEF station and T18 – Burnaby South station were selected for the comparison analysis. As there was no specific model receptor placed at the location of the S150 – MV WTEF station, the nearest 3 MV WTEF fenceline receptors were chosen to be representative of the S150 – MV WTEF station location. Table 9-1 and Figure 9-1 show the exact locations of the selected RWDI air dispersion model receptors in tabular and map formats. In the following sections, the model predictions at the 3 MV WTEF fenceline receptors will be averaged to produce one value representative of the S150 – MV WTEF station location.

Table 9-1 Key Receptor Locations from the RWDI Air Dispersion Model

REPRESENTATIVE STATION NAME	MODEL RECEPTOR TYPE	LATITUDE	LONGITUDE
T18 – Burnaby South	Discrete	49.2152ºN	122.9857ºW
S150 – MV WTEF	Fenceline	49.1866ºN	122.9788ºW
		49.1867ºN	122.9789ºW
		49.1868ºN	122.9787ºW

[27] https://metrovancouver.org/services/solid-waste/Documents/wtef-air-dispersion-modelling-study.pdf

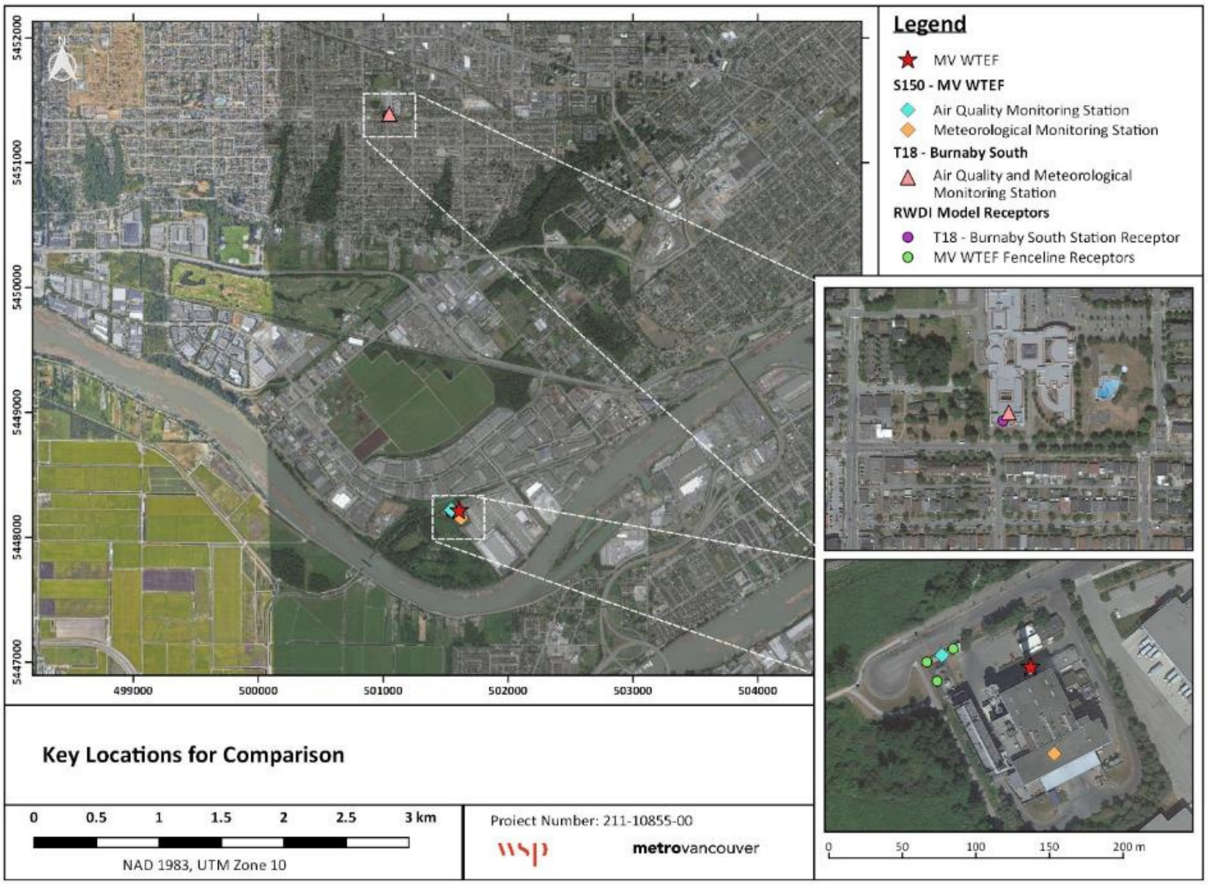

Figure 9-1 Map of Key Locations for Comparison

9.2 COMPARISON RESULTS

The ambient air quality data collected at S150 – MV WTEF station and T18 – Burnaby South station was compared against the air dispersion model predictions reported by RWDI in 2018 for the "operational" model scenario. The "operational" model scenario represents typical operations at the MV WTEF, using typical emissions from 2017 CEMS data to develop the emission rates for NO_2, SO_2, and HCl.

The maximum 1-hour concentrations for each of the 3 air contaminants (NO_2, SO_2, and HCl) were extracted from the ambient air quality data sets and the RWDI air dispersion model for the "operational" scenario at the key locations defined in Section 9.1. In all comparisons (outlined in Table 9-2), the "operational" scenario of the RWDI model predicted concentrations are above the 2021 and 2022 monitored ambient concentrations at both the S150 – MV WTEF station and T18 – Burnaby South station.

Table 9-2 Measured Ambient Air Quality Concentrations Compared to RWDI Model Predictions for the "Operational" Scenario

AIR CONTAMINANT	AVERAGING PERIOD	STATISTICAL FORM	OBJECTIVE	JURISDICTION	STATION	CONCENTRATION: ppb (µg/m³)		
						MEASURED AMBIENT AIR QUALITY[A]		RWDI "OPERATIONAL" MODEL SCENARIO (2013 – 2015)[B]
						2021	2022	
Nitrogen Dioxide (NO_2)	1-Hour	Maximum 1-hour concentration	60 ppb (113 µg/m³)[C]	Metro Vancouver Regional District (MVRD)[C]	S150 – MV WTEF	58.1 (109.3)	45.6 (85.7)	66.6 (125.3)
					T18 – Burnaby South	38.9 (73.1)	42.3 (79.5)	44.0 (82.8)
Sulphur Dioxide (SO_2)			70 ppb (183 µg/m³)	Metro Vancouver Regional District (MVRD)	S150 – MV WTEF	3.8 (10.0)	6.9 (18.1)	14.4 (37.7)
					T18 – Burnaby South	4.4 (11.5)	3.4 (8.9)	6.1 (16.0)
Hydrogen Chloride (HCl)			50 ppb (75 µg/m³)	Alberta Environment (AENV)	S150 – MV WTEF	2.3 (3.4)	2.8 (4.2)	20.4 (30.5)
					T18 – Burnaby South	3.4 (5.1)	4.7 (7.0)	6.8 (10.1)

Notes: [A] Hours corresponding to start-up and shut down events at the MV WTEF have been removed from the ambient air quality data set prior to calculating the maximum 1-hour concentrations

[B] RWDI's air dispersion model considers a 3-year period between 2013 to 2015, so the maximum 1-hour concentration have been calculated per year and the maximum of the 3-years have been presented here. In addition, baseline air quality concentrations have been accounted for in the presented values.

[C] After the removal of hours corresponding to start-up and shutdown events at the MV WTEF from the ambient air quality data set, the statistical form of the NO_2 MVRD AAQO (i.e., the 98th percentile of the daily maximum 1-hour concentrations) does not make sense to compute for comparisons. Thus, we have altered the statistical form to use the maximum 1-hour NO_2 concentrations, which does not follow the statistical form of the NO_2 MVRD AAQO.

10 START UP AND SHUT DOWN EVENTS AT THE MV WTEF

Following the analysis of potential linkages between the CEMS data at the WTEF and ambient monitoring data (Section 8), startup and shutdown events were explored to see if a statistical relationship could be found during these events that have the potential of resulting in higher emissions.

10.1 IDENTIFICATION OF START UP / SHUT DOWN EVENTS

Monthly boiler downtime summary reports generated by Covanta Burnaby Renewable Energy, ULC (the contracted operator of the MV WTEF) were shared with WSP from the Corporation. These monthly downtime summary reports were used to identify the times within the 2021 and 2022 calendar years associated with boiler shut down events. Within the monthly downtime summary reports exist brief shut down periods less than 30 minutes in duration due to minor issues at the MV WTEF. These minor shut down events (less than 30 minutes in duration) were not classified as boiler shut down events for the purposes of the assessment.

The 2018 "Start Up / Shut Down Test Report" written by HDR[28] was used as a reference to inform the identification of start up events at the MV WTEF. Although the HDR report summarizes the results of the start up and shut down testing conducted in November 2017, it serves as an example to determine the approximate duration of time prior to boiler shut downs (i.e., boiler shutting down) and after boiler shut downs (i.e., boiler starting up) to analyze. From the information made available in the HDR report, it was determined that the 4-hour period prior to a full boiler shut down would be classified as "boiler shutting down" and the 4-hour period after initial boiler start up would be classified as "boiler starting up." Furthermore, boiler shut down events generally do not occur at all 3 boiler units simultaneously, so 5 boiler unit operational statuses were created considering the events occurring at each of the 3 boiler units for each hour of the 2021 and 2022 calendar years (outlined in Table 10-1).

Table 10-1 Boiler Unit Operational Status Categories

BOILER OPERATIONAL STATUS	DESCRIPTION
Operational	All 3 boiler units are operating as normal
At least 1 boiler shutting down	One or more boiler units shutting down
1 boiler shutdown	Exactly one boiler unit shut down
At least 1 boiler starting up	One or more boiler units starting up
Multiple boilers not operational	More than one boiler unit not operating as normal (either shutting down, shut down or starting up)

[28] HDR: Start Up / Shut Down Test Report: Metro Vancouver Waste-to-Energy Facility Operational Certificate Assessment Reports (June 14, 2018).

10.2 SUMMARIES

The breakdown of the number of hours for each boiler unit operational status in 2021 and 2022 is presented in Table 10-2, while the detailed ambient air quality data summary by station and boiler unit operational status is presented in Table 10-3. To show the distribution of ambient concentrations by boiler unit operational status category, boxplots (Figure 10-1 through Figure 10-3) and histograms (Figure 10-4 through Figure 10-9) are presented to show the variation in 1-hour observations of NO_2, SO_2, and HCl per station and boiler unit operational status in 2021 and 2022. Both the boxplots and histograms show that the ambient concentrations recorded during different boiler unit operational statuses are very similar, and that the distributions of data are non-normal and right-skewed (especially skewed for SO_2 and HCl). In addition, in relation to the data summaries presented within Section 7, the histogram figures show that the observed levels of NO_2, SO_2, and HCl were well below AAQOs, with very low levels of SO_2 and HCl in particular. As noted in Section 7 It is important to note that there were no exceedances of the AAQO for any of the three air contaminants under all 5 boiler operational statuses within the 2021 – 2022 monitoring period.

Table 10-2 Summary of Hours by Boiler Unit Operational Status

BOILER OPERATIONAL STATUS	NUMBER OF HOURS		PERCENTAGE OF ANNUAL HOURS (%)	
	2021	2022	2021	2022
Operational	5697	5779	65.0	66.0
At least 1 boiler shutting down	362	321	4.1	3.7
1 boiler shutdown	2039	1975	23.3	22.5
At least 1 boiler starting up	362	321	4.1	3.7
Multiple boilers not operational	300	364	3.4	4.2
TOTAL	8760	8760	100	100

Table 10-3 Summary of Air Contaminants by Boiler Unit Operational Status

STATION	AIR CONTAMINANT	BOILER OPERATIONAL STATUS	DATA COMPLETENESS (%)		1-HOUR AVERAGE CONCENTRATION (ppb)					
					MINIMUM		AVERAGE		MAXIMUM	
			2021	2022	2021	2022	2021	2022	2021	2022
S150 – MV WTEF Station	Nitrogen Dioxide (NO_2)	Operational	98.5	99.8	0.6	0.8	12.8	13.3	58.1	45.6
		At least 1 boiler shutting down	99.2	99.4	1.1	1.2	14.7	12.5	49.2	40.1
		1 boiler shutdown	98.4	99.9	0.9	1.0	14.4	15.6	53.9	47.7
		At least 1 boiler starting up	96.7	100.0	1.3	0.8	13.8	13.0	37.4	52.1
		Multiple boilers not operational	97.7	98.9	1.1	1.8	13.5	15.4	48.4	45.8
	Sulphur Dioxide (SO_2)	Operational	98.6	99.8	0.0	0.0	0.2	0.2	3.8	6.9
		At least 1 boiler shutting down	99.2	99.4	0.0	0.0	0.2	0.3	1.8	1.3
		1 boiler shutdown	98.4	100.0	0.0	0.0	0.2	0.2	3.9	2.6
		At least 1 boiler starting up	96.4	100.0	0.0	0.0	0.2	0.2	1.7	1.3
		Multiple boilers not operational	97.3	99.5	0.0	0.0	0.2	0.2	2.4	1.9
	Hydrogen Chloride (HCl)	Operational	97.7	98.8	0.1	0.1	0.4	0.3	2.3	2.8
		At least 1 boiler shutting down	98.9	98.8	0.1	0.1	0.4	0.4	1.5	1.7
		1 boiler shutdown	95.2	99.8	0.1	0.1	0.4	0.4	2.3	2.8
		At least 1 boiler starting up	96.7	97.5	0.1	0.1	0.3	0.4	2.1	2.0
		Multiple boilers not operational	85.0	97.3	0.1	0.1	0.4	0.6	1.3	2.5
T18 – Burnaby South Station	Nitrogen Dioxide (NO_2)	Operational	98.9	99.1	1.2	0.6	10.4	11.2	38.9	42.3
		At least 1 boiler shutting down	99.4	99.7	1.9	1.5	10.9	10.7	36.0	33.7
		1 boiler shutdown	98.9	99.7	1.3	1.5	11.0	13.1	40.1	49.5
		At least 1 boiler starting up	99.4	99.7	1.6	1.2	10.6	11.6	37.6	34.5
		Multiple boilers not operational	98.7	99.5	1.4	2.3	10.1	13.3	31.2	32.8
	Sulphur Dioxide (SO_2)	Operational	99.8	99.7	0.0	0.0	0.3	0.3	4.4	3.4
		At least 1 boiler shutting down	100.0	100.0	0.0	0.0	0.2	0.3	2.3	1.6
		1 boiler shutdown	99.6	99.8	0.0	0.0	0.2	0.3	3.9	2.5
		At least 1 boiler starting up	100.0	100.0	0.0	0.0	0.2	0.3	2.0	2.1
		Multiple boilers not operational	99.7	100.0	0.0	0.0	0.3	0.3	1.7	2.4
	Hydrogen Chloride (HCl)	Operational	99.5	98.9	0.0	0.0	0.4	0.4	3.4	4.7
		At least 1 boiler shutting down	100.0	99.4	0.1	0.1	0.4	0.4	2.4	1.4
		1 boiler shutdown	99.6	99.6	0.0	0.1	0.4	0.4	2.5	3.9
		At least 1 boiler starting up	100.0	100.0	0.1	0.1	0.3	0.4	2.1	3.0
		Multiple boilers not operational	100.0	100.0	0.1	0.1	0.4	0.5	2.0	1.5

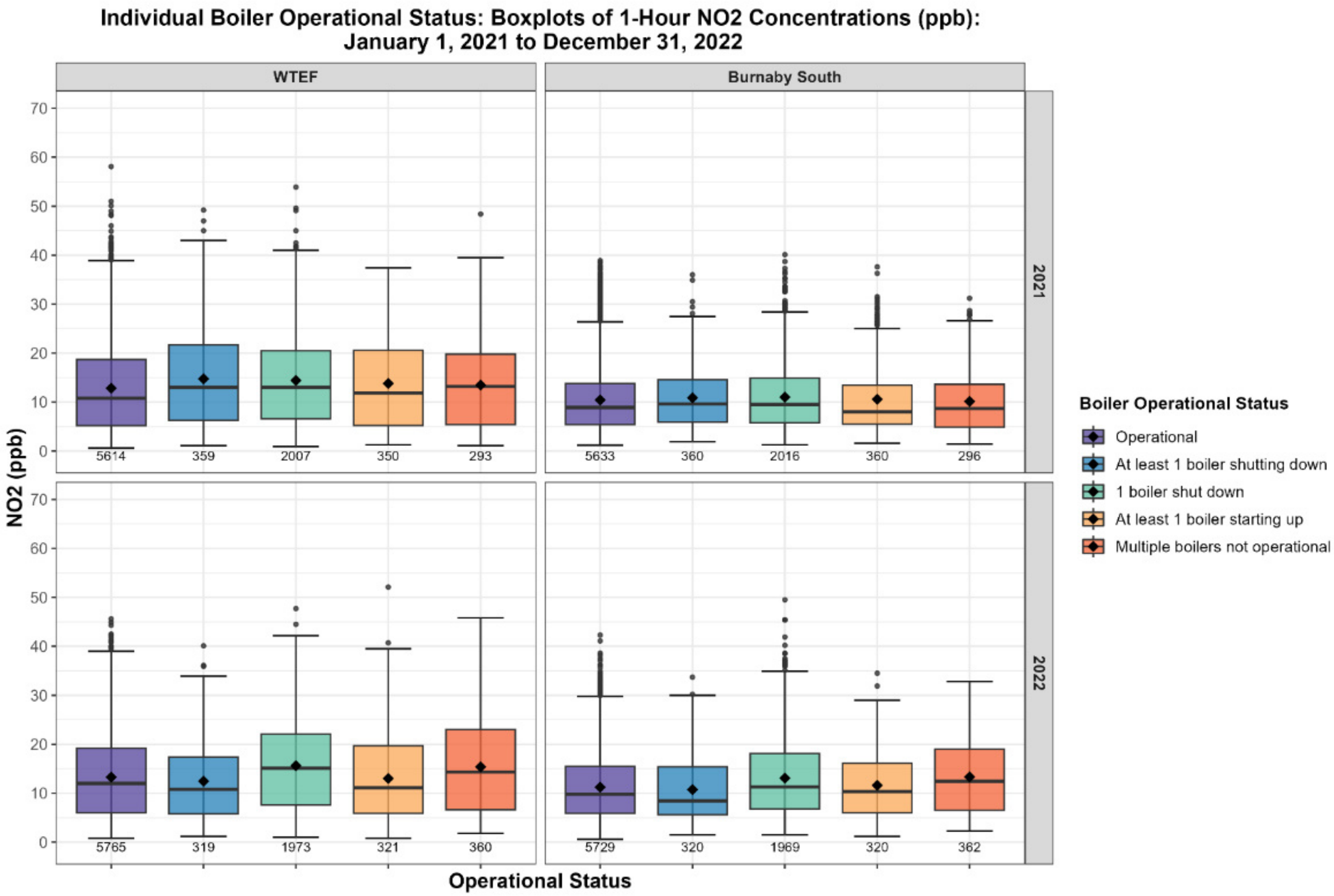

Figure 10-1 **Boxplots of 1-Hour Average NO_2 Concentrations by Operational Status at Both Stations (2021 – 2022)**

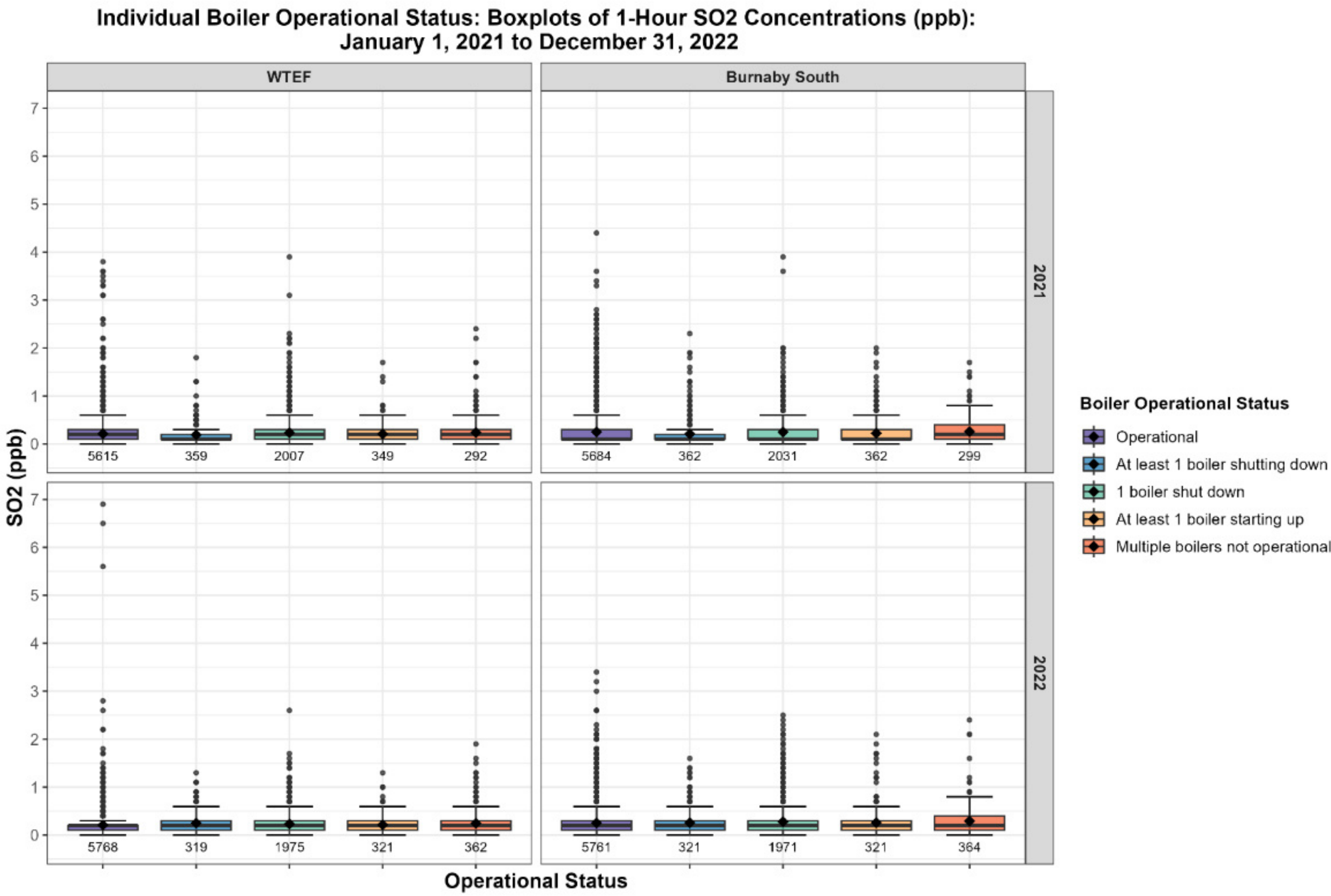

Figure 10-2 **Boxplots of 1-Hour Average SO_2 Concentrations by Operational Status at Both Stations (2021 – 2022)**

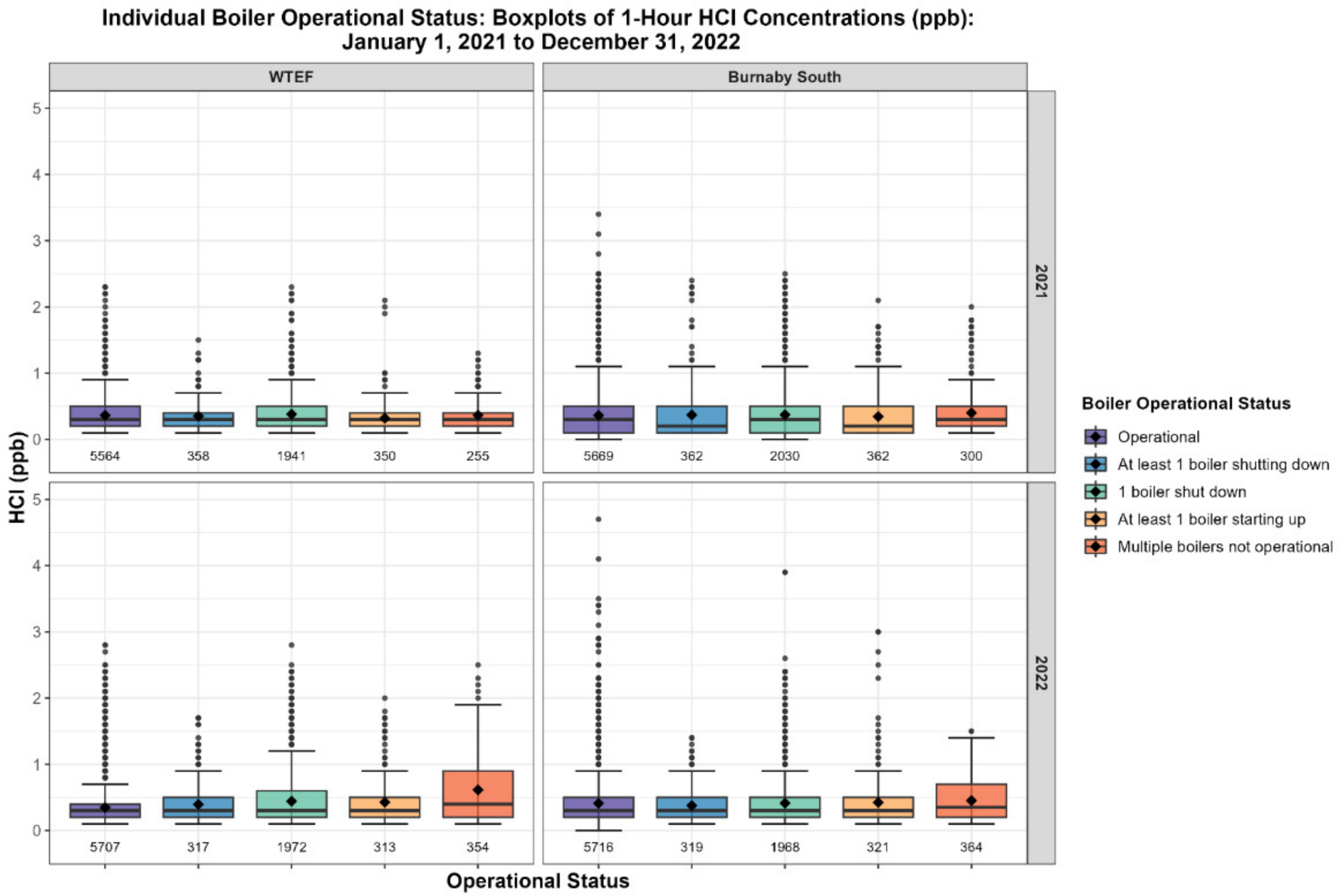

Figure 10-3 Boxplots of 1-Hour Average HCl Concentrations by Operational Status at Both Stations (2021 – 2022)

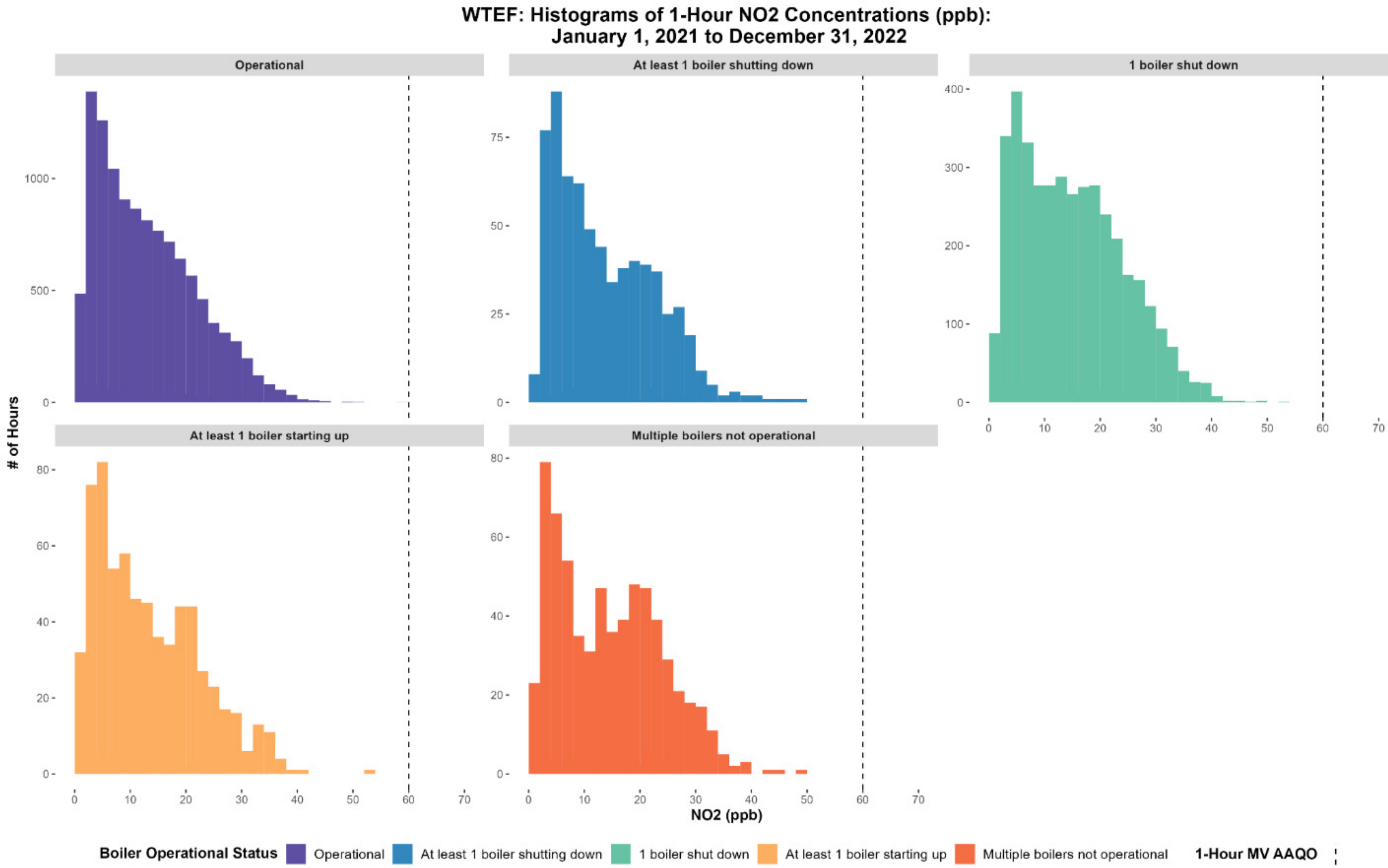

Figure 10-4 Histograms of 1-Hour Average NO_2 by Boiler Operational Status at S150 – MV WTEF Station (2021 – 2022)

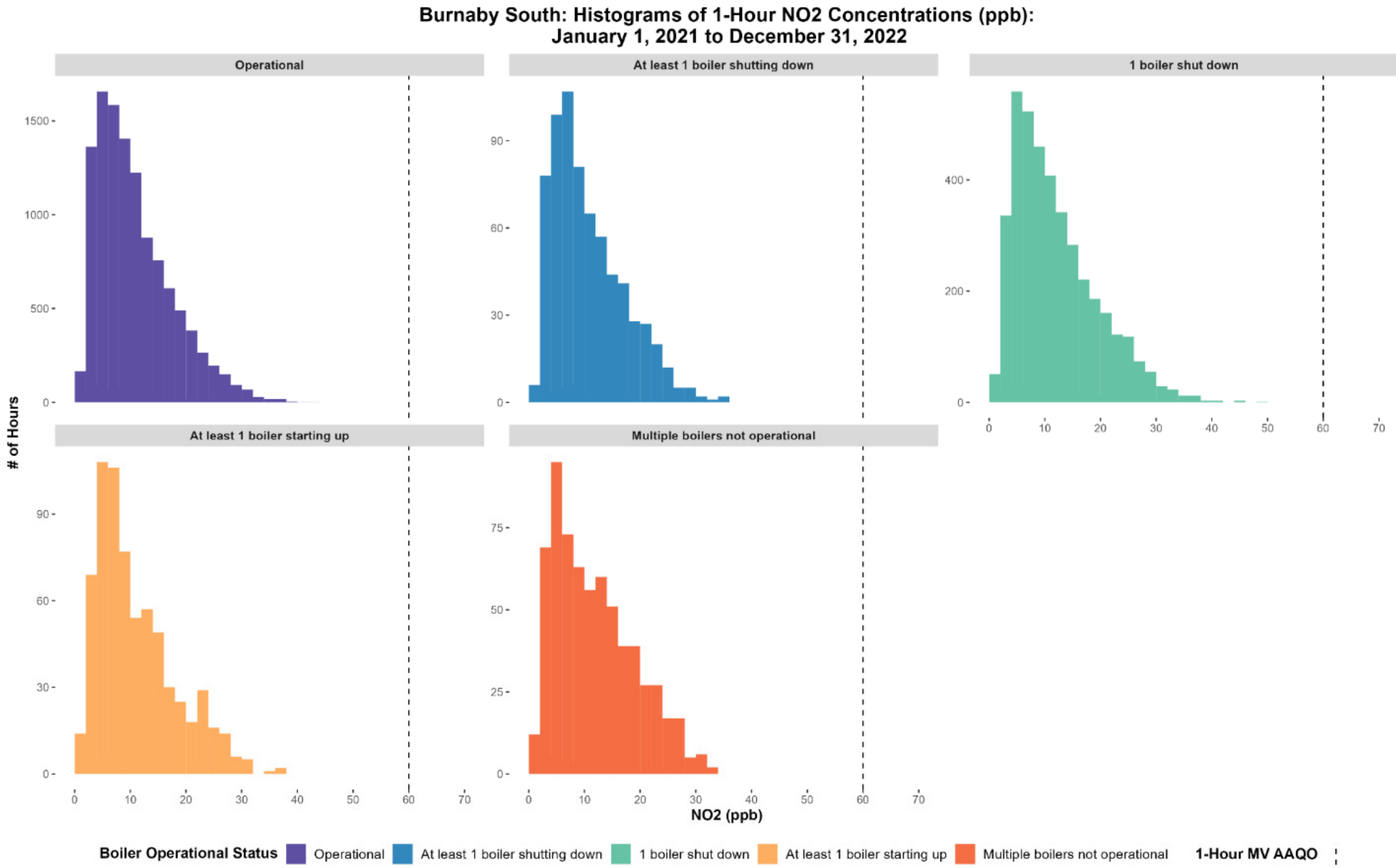

Figure 10-5 Histograms of 1-Hour Average NO_2 by Boiler Operational Status at T18 – Burnaby South Station (2021 – 2022)

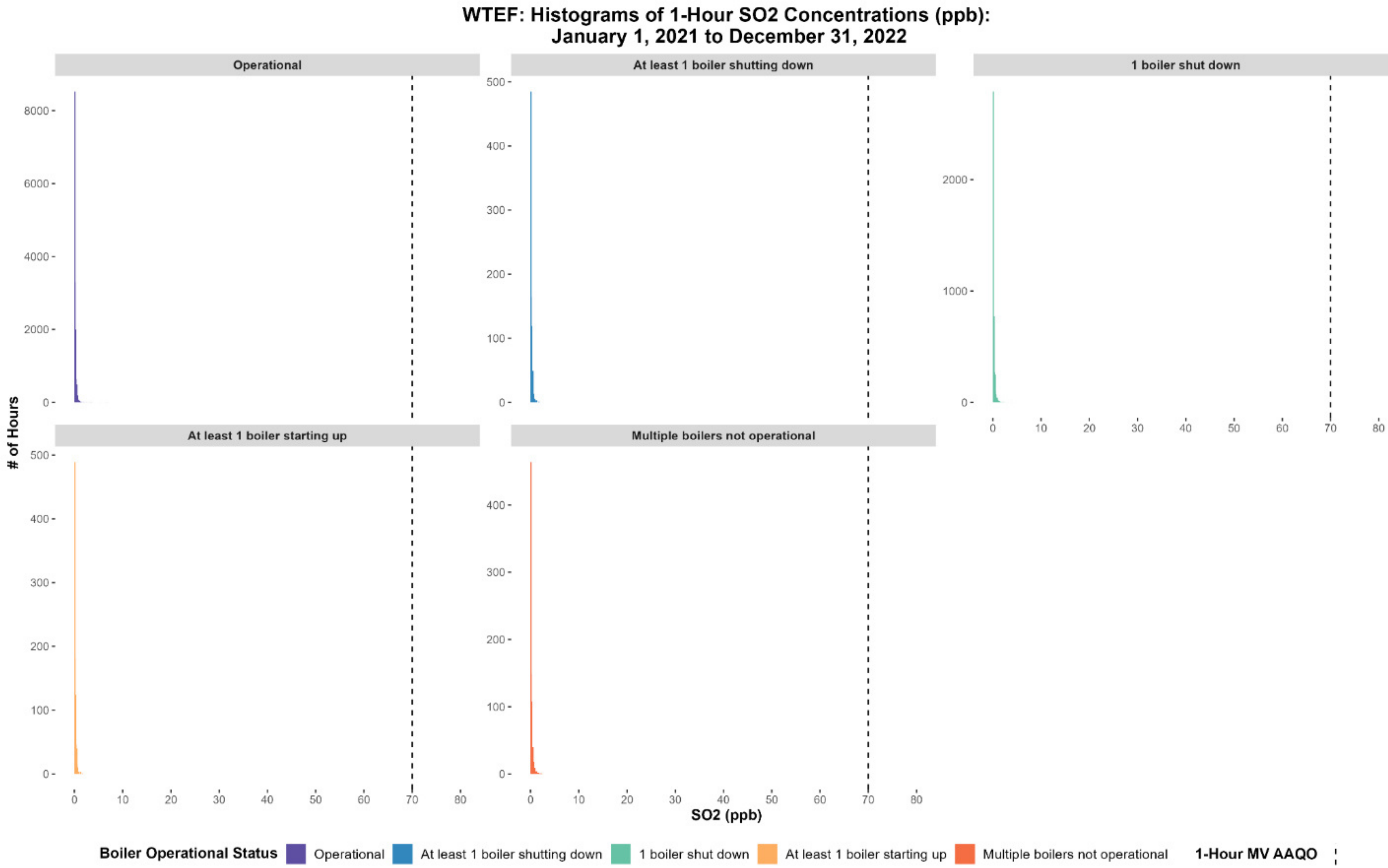

Figure 10-6 Histograms of 1-Hour Average SO_2 by Boiler Operational Status at S150 – MV WTEF Station (2021 – 2022)

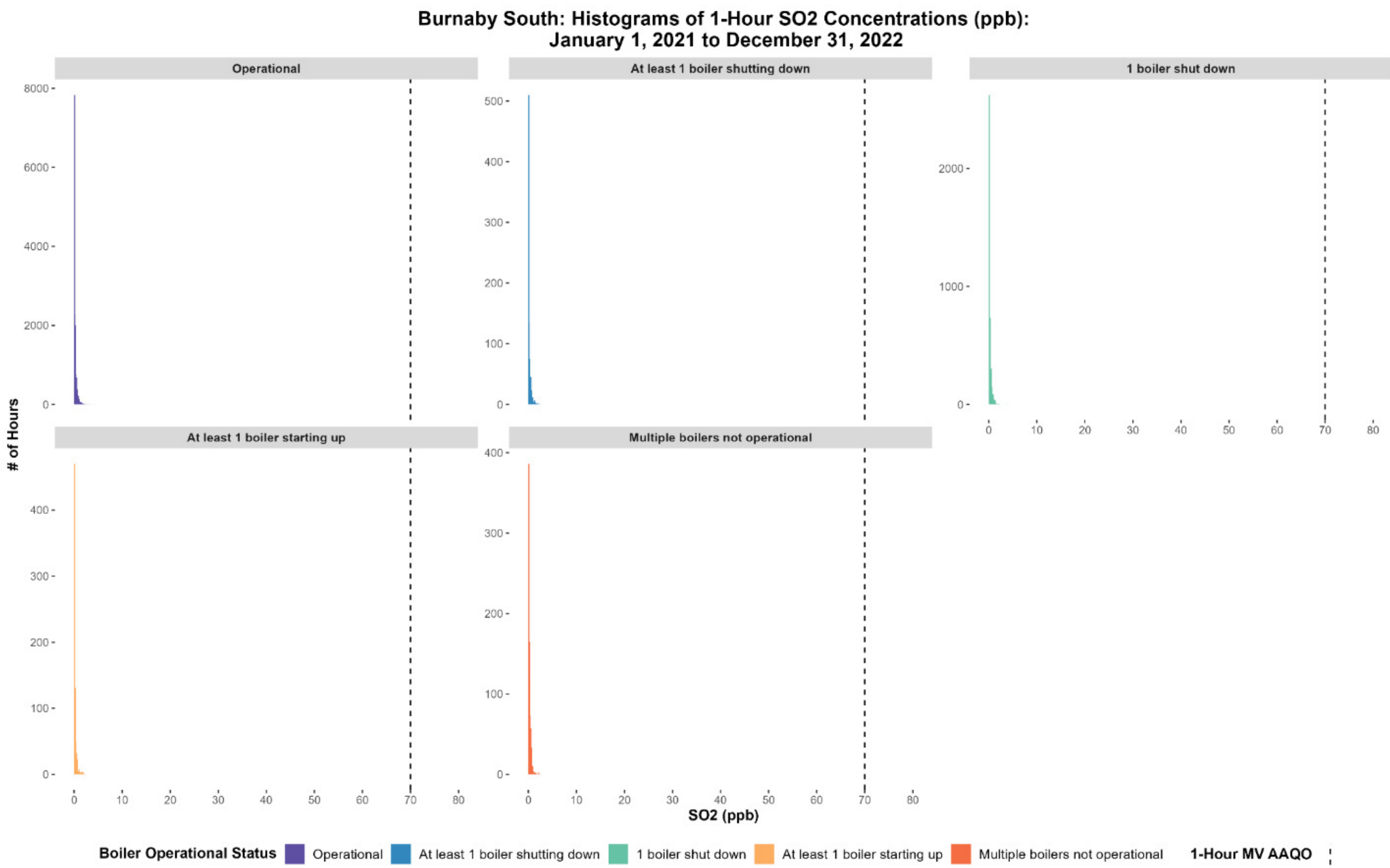

Figure 10-7 Histograms of 1-Hour Average SO_2 by Boiler Operational Status at T18 – Burnaby South Station (2021 – 2022)

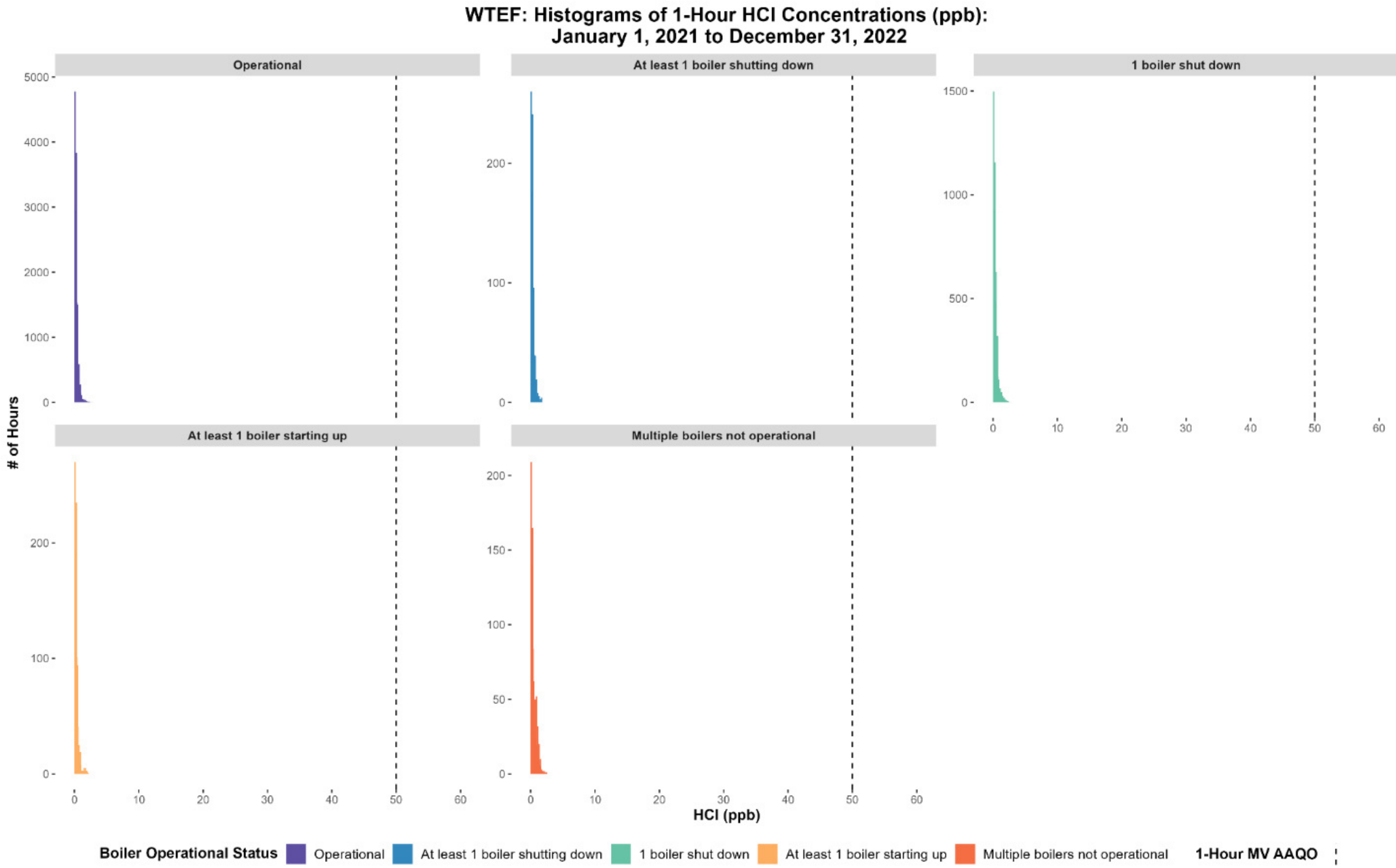

Figure 10-8 Histograms of 1-Hour Average HCl by Boiler Operational Status at S150 – MV WTEF Station (2021 – 2022)

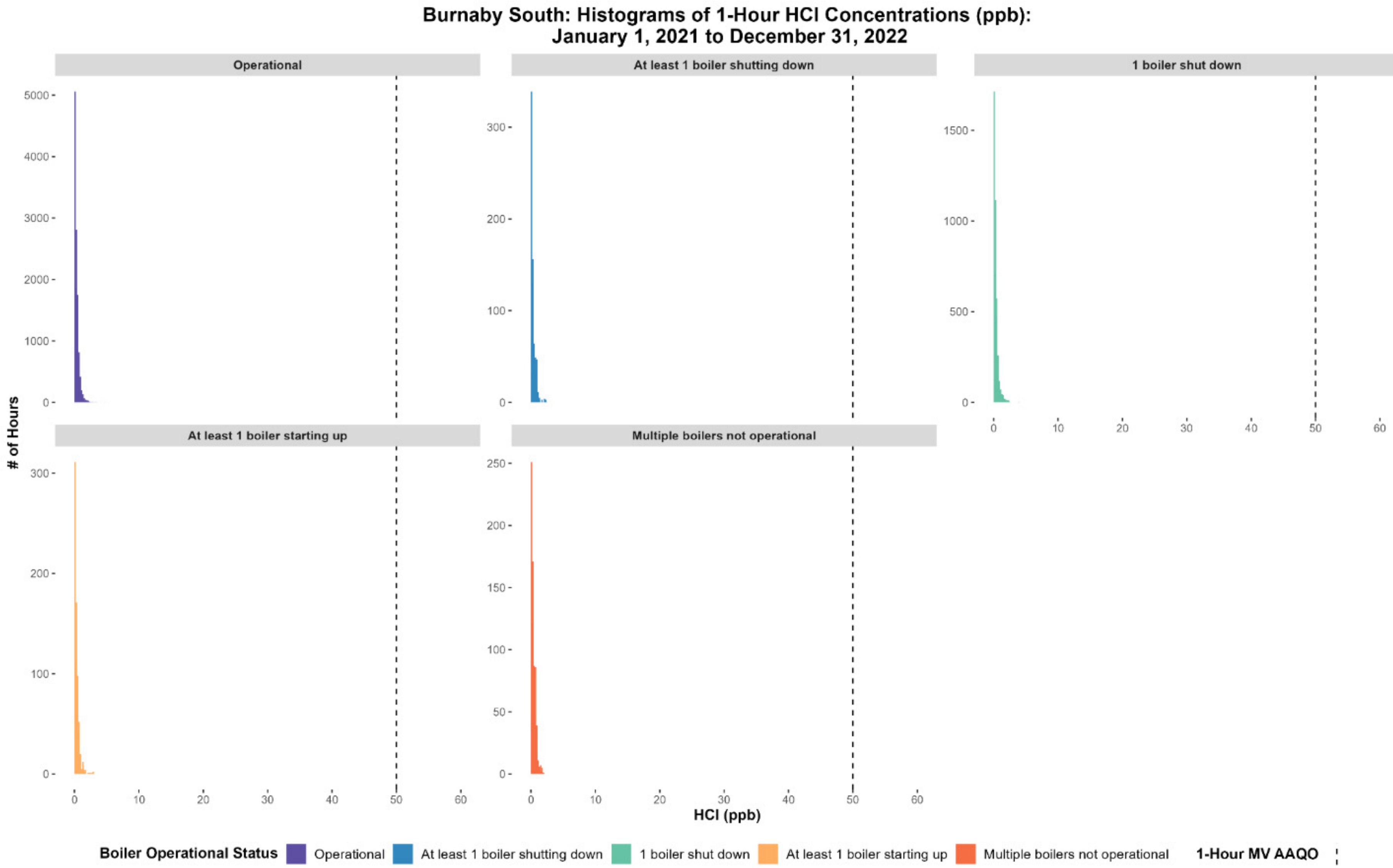

Figure 10-9 Histograms of 1-Hour Average HCl by Boiler Operational Status at T18 – Burnaby South Station (2021 – 2022)

10.3 WILCOXON RANK SUM TEST

Due to the non-normal distributions of 1-hour average NO_2, SO_2, and HCl observations at both the ambient monitoring stations (S150 – MV WTEF station and T18 – Burnaby South station) for each boiler unit operational status category, a comparison of means cannot be conducted through a standard Student's t-test. Therefore, an alternative statistical difference test, the Wilcoxon Rank Sum Test which tests whether samples are likely derived from the same population, was considered for comparison. In particular, the Wilcoxon Rank Sum Test was used to summarize the statistical difference between each of the 4 non-operational boiler unit statuses to the operational boiler unit status in terms of the median of the difference between each pair of observational samples.

The Wilcoxon Rank Sum Test is a statistical method used to determine the differences between two samples, without the need for any data distributional assumptions (i.e., no normal distribution requirement). The summary of the test is as follows:

Hypotheses:

- Null Hypothesis (H_0): The two distributions are identical.
- Alternative Hypothesis (H_A): The values in one distribution are systematically higher or lower than the values in the other distribution.
    - For similarly shaped quantitative distributions (as we have here), this test may be viewed as comparing medians.

Assumptions:

- Independence Groups Assumption: The groups must be independent of each other (i.e., the data within each group were collected independently).
- Independence Assumption: The data within each group must be independent (i.e., within each group, the individual values were collected independently from one another).

The results of the Wilcoxon Rank Sum Test are outlined in Table 10-4. With respect to NO_2, a statistically significant difference was found between two sets of boiler statuses at both stations, namely the operational vs. 1 boiler shut down statuses and the operational vs. multiple boilers not operational statuses. In terms of SO_2, a statistically significant difference between the operational vs. 1 boiler shut down statuses was found at S150 – MV WTEF station while a statistically significant difference between 3 sets of boiler operational statuses (operational vs. at least 1 boiler shutting down, operational vs. 1 boiler shut down, and operational vs. multiple boilers not operational) was found at T18 – Burnaby South station. Lastly, with respect to HCl, three sets of boiler statuses (operational vs. at least 1 boiler shutting down, operational vs. 1 boiler shut down, and operational vs. multiple boilers not operational) at S150 – MV WTEF station and two sets of boiler statuses (operational vs. at least 1 boiler shutting down and operational vs. multiple boilers not operational) at T18 – Burnaby South station were found to be statistically different from one another.

It is important to note that, where the Wilcoxon Rank Sum Test detected statistically significant differences between ambient concentrations during different boiler operational statuses, the differences in medians are very small. The accompanying histograms in Section 10.2 (Figure 10-4 through Figure 10-9) showing the distributions of ambient concentrations per boiler operational status also provide insight to similarity of ambient concentrations between operational statuses. Further, in some cases, the differences also do not align with the expected emissions from the facility; for example, the median ambient concentrations for NO_2 are higher during periods when 1 boiler is shutdown, or multiple boilers are not operational, which would mean that facility emissions are lower than normal. Thus, it is more likely that the periods when boilers are shut down are correlated with periods when regional NO_2 levels are higher due to other emissions sources or meteorological factors, than there being a negative association between WTEF shutdown periods and ambient NO_2 levels. Based on the above, its is reasonable to conclude that other regional emissions sources and prevailing meteorological patterns have a larger impact on measured NO_2, SO_2, and HCl recorded at S150 – MV WTEF station and T18 – Burnaby South stations than the operational / shutdown status of the WTEF.

Table 10-4 Summary of Results of the Wilcoxon Rank Sum Test

AIR CONTAMINANT	STATION	BOILER OPERATIONAL STATUSES COMPARED	P-VALUE	MEDIANS DIFFER?	ESTIMATED MEDIAN OF DIFFERENCE BETWEEN SAMPLES	95% CONFIDENCE INTERVAL OF ESTIMATE	MEDIAN		HOURS IN 2-YEAR MONITORING PERIOD	
							OPERATIONAL	NON-OPER-ATIONAL	OPERATIONAL	NON-OPER-ATIONAL
Nitrogen Dioxide (NO_2)	S150 – MV WTEF	Operational vs. At least 1 boiler shutting down	6.87E-02	No	-6.00E-01	(-1.20E+00, 2.23E-05)	11.5	11.7	11379	678
		Operational vs. 1 boiler shut down	2.31E-33	Yes	-1.90E+00	(-2.20E+00, -1.60E+00)		14		3980
		Operational vs. At least 1 boiler starting up	4.40E-01	No	-2.00E-01	(-9.00E-01, 4.00E-01)		11.4		671
		Operational vs. Multiple boilers not operational	1.25E-04	Yes	-1.30E+00	(-1.90E+00, -6.00E-01)		13.6		653
	T18 – Burnaby South	Operational vs. At least 1 boiler shutting down	9.02E-01	No	-2.88E-05	(-5.00E-01, 4.00E-01)	9.3	9.05	11362	680
		Operational vs. 1 boiler shut down	4.68E-17	Yes	-9.00E-01	(-1.20E+00, -7.00E-01)		10.3		3985
		Operational vs. At least 1 boiler starting up	7.85E-01	No	-1.00E-01	(-5.00E-01, 4.00E-01)		9		680
		Operational vs. Multiple boilers not operational	5.78E-04	Yes	-9.00E-01	(-1.40E+00, -4.00E-01)		10.5		658
Sulphur Dioxide (SO_2)	S150 – MV WTEF	Operational vs. At least 1 boiler shutting down	3.46E-01	No	-2.79E-05	(-4.61E-05, 5.15E-05)	0.2	0.2	11383	678
		Operational vs. 1 boiler shut down	1.33E-07	Yes	-1.54E-05	(-6.12E-05, -1.87E-05)		0.2		3982
		Operational vs. At least 1 boiler starting up	5.03E-01	No	-5.35E-05	(-2.58E-05, 3.12E-05)		0.2		670
		Operational vs. Multiple boilers not operational	2.71E-01	No	-3.15E-05	(-4.91E-05, 4.34E-05)		0.2		654
	T18 – Burnaby South	Operational vs. At least 1 boiler shutting down	1.74E-03	Yes	3.06E-05	(3.45E-05, 2.36E-05)	0.2	0.1	11445	683
		Operational vs. 1 boiler shut down	1.39E-05	Yes	-5.73E-05	(-8.59E-06, -2.89E-05)		0.2		4002
		Operational vs. At least 1 boiler starting up	1.80E-01	No	5.86E-05	(-4.19E-09, 6.17E-05)		0.1		683
		Operational vs. Multiple boilers not operational	1.78E-06	Yes	-2.70E-05	(-1.45E-05, -6.06E-05)		0.2		663

AIR CONTAMINANT	STATION	BOILER OPERATIONAL STATUSES COMPARED	P-VALUE	MEDIANS DIFFER?	ESTIMATED MEDIAN OF DIFFERENCE BETWEEN SAMPLES	95% CONFIDENCE INTERVAL OF ESTIMATE	MEDIAN		HOURS IN 2-YEAR MONITORING PERIOD	
							OPERATIONAL	NON-OPERATIONAL	OPERATIONAL	NON-OPERATIONAL
Hydrogen Chloride (HCl)	S150 – MV WTEF	Operational vs. At least 1 boiler shutting down	1.91E-02	Yes	-8.09E-06	(-1.32E-05, -6.44E-05)	0.3	0.3	11271	675
		Operational vs. 1 boiler shut down	3.14E-17	Yes	-8.25E-05	(-6.09E-06, -4.19E-05)		0.3		3913
		Operational vs. At least 1 boiler starting up	1.29E-01	No	-7.03E-05	(-7.95E-05, 2.56E-05)		0.3		663
		Operational vs. Multiple boilers not operational	1.79E-17	Yes	-1.00E-01	(-9.99E-02, -1.00E-01)		0.4		609
	T18 – Burnaby South	Operational vs. At least 1 boiler shutting down	4.81E-02	Yes	1.74E-05	(1.99E-05, 7.57E-05)	0.3	0.3	11385	681
		Operational vs. 1 boiler shut down	2.55E-01	No	-3.80E-05	(-4.30E-05, 2.66E-05)		0.3		3998
		Operational vs. At least 1 boiler starting up	4.32E-01	No	4.34E-05	(-6.30E-05, 2.98E-05)		0.3		683
		Operational vs. Multiple boilers not operational	2.96E-06	Yes	-3.68E-05	(-1.00E-01, -3.20E-05)		0.3		664

10.4 COMPARISON TO START UP / SHUTDOWN DISPERSION MODEL PREDICTIONS

The RWDI air dispersion model predictions for the “Start Up” and “Shut Down” scenarios were extracted at the same key locations outlined in Section 9.1 for comparisons against the ambient air quality observations collected at the S150 – MV WTEF station and T18 – Burnaby South station during boiler start-up and shut down events in 2021 and 2022. In particular, the RWDI air dispersion model predictions for the “Start Up” scenario were compared to ambient air quality data during hours corresponding to “at least 1 boiler starting up”, while the RWDI air dispersion model predictions for the “Shut Down” scenario were compared to ambient air quality data during hours corresponding to “1 boiler shut down”. The results presented in Table 10-5 show that in all cases except two (maximum 1-hour NO_2 concentration measured at T18 – Burnaby South in 2022 and maximum 1-hour SO_2 concentration measured at T18 – Burnaby South in 2021), the RWDI model predicted concentrations above the monitored ambient concentrations at both the S150 – MV WTEF station and T18 – Burnaby South station for all 3 air contaminants (NO_2, SO_2, and HCl). Similar to Section 9.2, only maximum 1-hour concentrations were considered within these comparisons. It is important to note that despite the monitored data exceeding the model predictions, that the monitored data during all startup / shutdown events for 2021 and 2022 remained below AAQOs.

Table 10-5 Ambient Air Quality Compared to RWDI Model Predictions for the "Start Up" and "Shut Down" Scenarios

AIR CONTAMINANT	AVERAGING PERIOD	STATISTICAL FORM	OBJECTIVE	JURISDICTION	STATION	CONCENTRATION: ppb (µg/m^3)					
						START UP SCENARIO			SHUT DOWN SCENARIO		
						AMBIENT AIR QUALITY (2021)[A]	AMBIENT AIR QUALITY (2022)[A]	RWDI MODEL (2013 – 2015)[B]	AMBIENT AIR QUALITY (2021)[A]	AMBIENT AIR QUALITY (2022)[A]	RWDI MODEL (2013 – 2015)[B]
Nitrogen Dioxide (NO_2)	1-Hour	Maximum 1-hour concentration	60 ppb (113 µg/m^3)[C]	Metro Vancouver Regional District (MVRD)[C]	S150 – MV WTEF	37.4 (70.3)	52.1 (98.0)	58.5 (110.0)	53.9 (101.4)	47.7 (89.7)	57.9 (108.9)
					T18 – Burnaby South	37.6 (70.7)	34.5 (64.9)	41.3 (77.7)	40.1 (75.4)	49.5 (93.1)	41.1 (77.4)
Sulphur Dioxide (SO_2)			70 ppb (183 µg/m^3)	Metro Vancouver Regional District (MVRD)	S150 – MV WTEF	1.7 (4.5)	1.3 (3.4)	12.5 (32.7)	3.9 (10.2)	2.6 (6.8)	5.4 (14.0)
					T18 – Burnaby South	2.0 (5.2)	2.1 (5.5)	5.5 (14.3)	3.9 (10.2)	2.5 (6.5)	3.1 (8.1)
Hydrogen Chloride (HCl)			50 ppb (75 µg/m^3)	Alberta Environment (AENV)	S150 – MV WTEF	2.1 (3.1)	2.0 (3.0)	20.5 (30.6)	2.3 (3.4)	2.8 (4.2)	20.5 (30.6)
					T18 – Burnaby South	2.1 (3.1)	3.0 (4.5)	6.8 (10.1)	2.5 (3.7)	3.9 (5.8)	6.8 (10.1)

Notes: [A] Only hours corresponding to start-up and shut down events at the MV WTEF have been included in the ambient air quality data set prior to calculating the maximum 1-hour concentrations

[B] RWDI's air dispersion model considers a 3-year period between 2013 to 2015, so the maximum 1-hour concentration have been calculated per year and the maximum of the 3-years have been presented here. In addition, baseline air quality concentrations have been accounted for in the presented values.

[C] After the removal of hours corresponding to non-start-up and non-shut down events at the MV WTEF from the ambient air quality data set, the statistical form of the NO_2 MVRD AAQO (i.e., the 98th percentile of the daily maximum 1-hour concentrations) does not make sense to compute for comparisons. Thus, we have altered the statistical form to use the maximum 1-hour NO_2 concentrations, which does not follow the statistical for of the NO_2 MVRD AAQO.

11 SUMMARY

The evaluation of MV WTEF's contribution to ambient air quality (NO_2, SO_2, and HCl) in 2021 and 2022 has been completed by means of data analysis using ambient air quality and meteorological data collected at two MVRD monitoring stations (S150 – MV WTEF and T18 - Burnaby South), MV WTEF emissions data, and air dispersion modelling results.

Prior to assessing the ambient air quality data collected, given the novel nature of regional HCl monitoring and assessment, an HCl literature review was conducted to establish a baseline understanding of HCl emission sources, atmospheric chemistry and relevant jurisdictional regulatory air quality requirements. In terms of HCl atmospheric chemistry, current global reactive chlorine emission inventories have estimated that greater than 80% of total tropospheric HCl stems from sea salt particle dechlorination reactions, but the understanding of the impact of chlorine catalyzed chemistry is limited due to the highly spatially variable anthropogenic HCl emissions which have not been adequately observed. The HCl ambient air quality objectives (AAQOs) utilized in the 2018 MV WTEF Dispersion Modelling Study by RWDI were reviewed and deemed appropriate for utilization within this assessment after a thorough jurisdictional review of HCl AAQOs was conducted.

Next, short-term and long-term ambient air quality objectives (AAQOs) were selected for comparison to the levels of ambient air quality (NO_2, SO_2, and HCl) measured at the two MVRD monitoring stations (S150 – MV WTEF and T18 - Burnaby South) within the two-year monitoring period (2021-2022). In particular, the MVRD 1-hour and annual objectives were selected for NO_2, the MVRD 1-hour and annual objectives were selected for SO_2, and a combination of different jurisdictions were selected for HCl (1-hour objective from Alberta Environment, 24-hour objective from Ontario Ministry of Environment, and annual objective from US Environmental Protection Agency).

Ambient concentrations of NO_2, SO_2, and HCl collected at the two MVRD monitoring stations during the 2021-2022 monitoring period were summarized and compared to ambient air quality objectives (AAQOs). Within the 2-year monitoring period, no exceedances of short-term nor long-term (1-hour, 24-hour, and annual) AAQOs for NO_2, SO_2, and HCl were recorded at either MVRD monitoring stations.

HCl and SO_2 concentrations were particularly low in comparison to AAQOs. For HCl, 1-hour maximum ambient air concentrations were 6% of the AAQO at the S150 – MV WTEF station and 9% of the AAQO at T18 – Burnaby South station. While the maximum concentrations of HCl monitored were low in comparison to AAQOs, in general, HCl concentrations were even lower, as 98% of the time, HCl concentrations were less than 3% of the ambient air quality objectives at both stations, highlighting that HCl was consistently low. For SO_2, 1-hour maximum ambient air concentrations were 10% of the AAQO at the S150 – MV WTEF station and 6% of the AAQO at the T18 – Burnaby South station. Similar to HCl concentrations though, 98% of the time, ambient concentrations of SO_2 were less than 2% of the AAQO at both stations.

NO_2 ambient air concentrations were higher in comparison to AAQOs than the other two pollutants analyzed., with 1-hour maximum ambient air concentrations at 76% of the AAQO at the S150 – MV WTEF station and 62% of the AAQO at the T18 – Burnaby South station. This was anticipated given that the primary contributor to NO_2 concentrations in the region are road traffic emissions. The two stations exhibited the expected trend of peak 1-hour average NO_2 concentrations during peak traffic. Slightly higher levels of NO_2 were measured at S150 – MV WTEF station compared to T18 – Burnaby South station, but both were clearly influenced primarily by traffic emissions.

Monitored concentrations during particular wind direction and wind speed conditions were analyzed as a tool to investigate directions and wind speeds from which contaminants may be originating from. Polar plots analyzing wind directions and wind speeds associated with monitored pollutant levels suggest the potential influence of WTEF emissions may be observable during Winter periods at the S150 – MV WTEF station, particularly during stagnant periods with low wind speeds. Seeing this relationship in the data is not unexpected given that the station was sited near the location with the highest expected ambient air concentrations identified by the WTEF dispersion modelling assessment. Although this relationship can be observed, as explained above maximum pollutant concentrations remained well below AAQOs and the levels predicted in the dispersion modelling assessment. During the Summer for S150 – MV WTEF, and at T18 – Burnaby South during the full year, measured ambient NO_2, SO_2, and HCl levels were likely associated with emissions from other sources combined with seasonal and regional meteorological patterns such as Summertime sea breezes.

To investigate whether the WTEF operations were impacting the levels of all three pollutants at the monitoring stations, an analysis was conducted using ambient concentrations of NO_2, SO_2, and HCl collected at S150 – MV WTEF station and T18 – Burnaby South station and continuous emissions monitoring (CEMS) data collected at MV WTEF's three boiler lines during the 2-year monitoring period. Specifically, linear regression models were utilized and determined no statistically significant linear correlation between WTEF CEMS readings and S150 and T18 ambient air quality data for all three pollutants. This suggests that there were other significant regional emission sources and meteorological factors that had an impact on the ambient levels of NO_2, SO_2, and HCl recorded at both the S150 – MV WTEF station and T18 – Burnaby South station.

Emissions during WTEF start up and shut down events were also evaluated as these events can result in higher emission releases. WTEF start up and shut down events were identified by using monthly boiler downtime summary reports generated by Covanta Burnaby Renewable Energy, ULC (the contracted operator of the MV WTEF). Five boiler unit operational statuses were determined using the summary reports and the hourly ambient dataset collected in 2021-2022 at the two MVRD monitoring stations were categorized as per the 5 statuses. A comparison analysis determined that the ambient concentrations recorded during different boiler unit operational statuses were very similar, and that the distributions of data were non-normal and right-skewed. A Wilcoxon Rank Sum Test was utilized to determined that there were some statistically significant differences between ambient concentrations during different boiler operational statuses, but the differences in medians were very small. This result suggests that there were other significant regional sources and meteorological factors that had a greater impact on the S150 and T18 ambient levels of NO_2, SO_2, and HCl than the startup – shutdown status of the WTEF.

Finally, a comparison between the ambient air quality data collected at S150 – MV WTEF station and T18 – Burnaby South station against the air dispersion model predictions reported by RWDI in 2018 for the "operational" model scenario was conducted. RWDI's model predictions at receptors corresponding to the locations of the two MVRD stations were compared to the ambient data collected during the 2-year monitoring period. The results show the conservative nature of the model predictions, where the "operational" scenario of the RWDI model predicted concentrations were consistently above the monitored ambient concentrations at both the S150 – MV WTEF station and T18 – Burnaby South station. Comparisons between ambient concentrations and RWDI dispersion model-predicted concentrations during "Start Up" and "Shut Down" events showed that, that in all cases except two (maximum 1-hour NO_2 concentration measured at T18 – Burnaby South in 2022 and maximum 1-hour SO_2 concentration measured at T18 – Burnaby South in 2021), the RWDI model predicted concentrations above the monitored ambient concentrations at both the S150 – MV WTEF station and T18 – Burnaby South station for all 3 air contaminants (NO_2, SO_2, and HCl).

The monitoring conducted at these 2 stations over the 2-year period provided insight into the near-field levels of NO_2, SO_2, and HCl within the vicinity of the WTEF. Monitored levels were confirmed to be low for SO_2 and HCl and established that NO_2 concentrations patterns did not exceed any AAQOs and that peaks were primarily linked to typical road traffic emissions patterns. Overall, the analysis of ambient air quality and CEMS data from the WTEF using spatial and statistical analysis tools did not reveal any significant correlations, trends, or patterns that suggested the WTEF is significantly impacting ambient air concentrations of NO_2, SO_2 or HCl at two ambient air monitoring stations near the facility. For all three pollutants monitored, the analysis showed that there are likely other primary drivers of ambient air concentrations at the monitoring locations. For SO_2 and NO_2, the other regional sources of emissions are well known. WSP's research of HCl emission sources and atmospheric chemistry shows that an understanding of the concentration of HCl in ambient air in a marine or coastal environment is dependent on an understanding of the contribution from the sea salt dechlorination process and the interplay with meteorological influences and anthropogenic sources. According to Crisp et al., 2013[13], in areas like Metro Vancouver meteorological and atmospheric processes related to the marine boundary layer result in the sea salt dechlorination process being a dominant influence on HCl concentrations, while biomass burning, coal combustion, and waste incineration processes are thought to be more likely influential in continental areas away from the marine boundary. Understanding that the WTEF does represent a major anthropogenic source of HCl emissions in the airshed that is not "showing up" in the ambient monitoring analysis, our discussion of the results hypothesizes that the primary driver of HCl in the near coast portion of the Lower Fraser Valley airshed (as we would characterize the location of the WTEF) is the contribution of sea salt dechlorination.

12 RECOMMENDATIONS

As a follow-up to the dispersion modelling and human health risk assessment studies conducted in 2018 in response to the requirements from the WTEF's Operational Certificate (OC), issued December 15, 2016 by the BC Ministry of Environment and Climate Change Strategy, an ambient air monitoring station measuring NO_x, SO_2 and HCl was installed near the WTEF in 2020, and an HCl monitor was installed at Metro Vancouver Regional District's (MVRD) existing T18 – Burnaby South monitoring station. Monitored levels were confirmed to be low for SO_2 and HCl and established that NO_2 concentrations patterns did not exceed any AAQOs and that peaks were primarily linked to typical road traffic emissions patterns. Both monitoring stations have not shown a significant impact from WTEF emissions.

It is recommended, however, to continue HCl monitoring (along with all existing parameters) at T18 – Burnaby South and a monitoring station near to the WTEF to confirm the trends and patterns observed to date and grow the dataset and regional understanding for this novel contaminant. It is worth noting that the initial goal of installing the T18 – Burnaby South station was to monitor for potential impacts of the WTEF on air quality. A monitoring location near to the WTEF should be re-evaluated (potentially through an updated dispersion modelling exercise) to target the maximum location of potential impacts using data from the recent on-site meteorological station installed at the WTEF and updated emissions information (as available).

Furthermore, to establish a better understanding of HCl and its variation across the Metro Vancouver region, it is recommended that Metro Vancouver consider deploying additional HCl monitors in areas that would have the potential to detect the impact of different sources of HCl on ambient air quality. Primarily, the goal of this monitoring would be to understand the atmospheric behaviour of ambient HCl in the Lower Fraser Valley airshed as conditions change from being influenced by potential sea salt dechlorination processes in the marine boundary layer near the coast to areas further inland in the Fraser Valley where this process would be less influential. Considering MVRD's extensive existing monitoring network (Figure 12-1), the most straightforward approach would be to add HCl monitors to existing regional monitoring stations. In particular, WSP recommends installing HCl monitors at the existing T39 – Tsawwassen station to capture coastal levels of HCl, and at another station, such as T27 Langley, T30 Maple Ridge, or T45 Abbotsford Airport stations to capture inland levels of HCl.

A better understanding of HCl, through the addition of HCl monitoring in the Lower Fraser Valley airshed, should provide additional insight into the levels of HCl observed at close proximity to the MV WTEF.

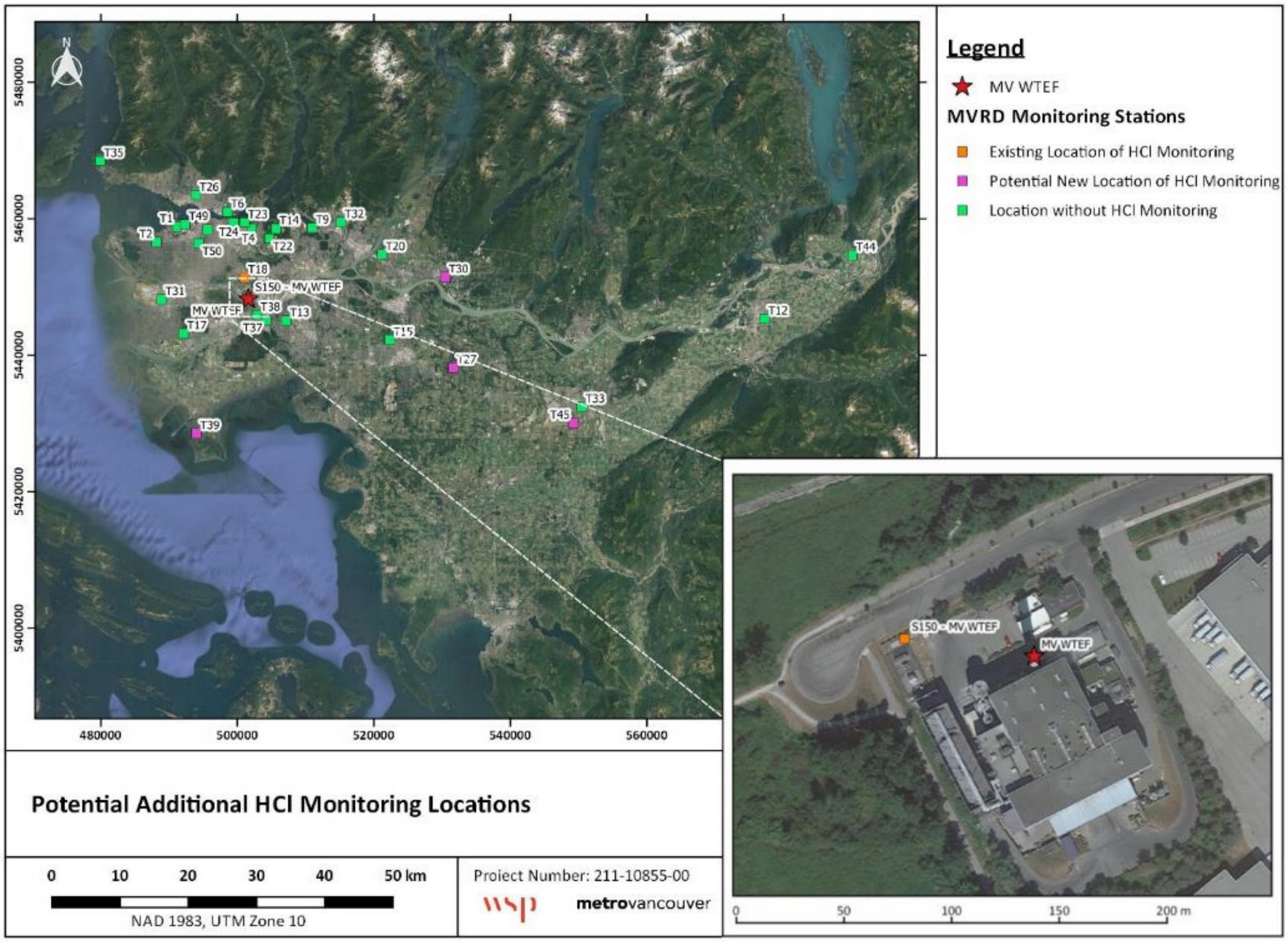

Figure 12-1 Potential New HCl Monitoring Locations using the Existing MVRD Monitoring Network

APPENDIX

A

JURISDICTIONAL REVIEW OF AMBIENT HCL OBJECTIVES

Table A-1 Jurisdictional Review of Ambient HCl Objectives

JURISDICTION	CRITERIA TYPE	AVERAGING PERIOD	CRITERIA (µG/M^3)	BASIS OF CRITERIA	DATE OF CRITERIA/	DATA SOURCE	
Alberta	Alberta Ambient Air Quality Objectives (AAAQOs)	**1-hour**	**75**	Adopted from Texas	January 2019	Table 1 Alberta Ambient Air Quality Objectives	https://open.alberta.ca/dataset/0d2ad470-117e-410f-ba4f-aa352cb02d4d/resource/4ddd8097-6787-43f3-bb4a-908e20f5e8f1/download/aaqo-summary-jan2019.pdf
Ontario	Ontario Ambient Air Quality Criteria (AAQCs)	**24-hour**	**20**	Health: Adverse health effects that could occur from short-term or long-term exposure to the contaminant in air	April 2012	Ontario's Ambient Air Quality Criteria	http://www.airqualityontario.com/downloads/AmbientAirQualityCriteria.pdf
US	Reference Concentration for Inhalation Exposure (RfC)	**Annual**	**20**	Hyperplasia of the nasal mucosa larynx and trachea	July 1, 1995	Integrated Risk Information System (IRIS)	https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=396
Manitoba	Manitoba Ambient Air Quality Criteria	**1-hour**	**100**		July 2005	Environment Management Division, 1982. Internal Tentative Guideline. Manitoba Department of Environment and Workplace Safety and Health.	https://www.gov.mb.ca/sd/envprograms/airquality/pdf/criteria_table_update_july_2005.pdf
Quebec	Norme	**4-min**	**1150**		2011	Quebec standards and criteria for atmospheric quality	https://www.environnement.gouv.qc.ca/air/criteres/Normes-criteres-qc-qualite-atmosphere.xlsx
Quebec		**Annual**	**20**		2011		
Greater Montreal	Limites	**15-min**	**100**		September 1, 2019	By-law number 2001-10 on releases to the atmosphere and the delegation of its application	https://cmm.qc.ca/wp-content/uploads/2019/11/2001-10_Codification.pdf
Texas	Acute ReV (reference value)	**Short-term**	**660**	Critical Effect: Upper respiratory symptoms (sore throat, nasal discharge) and lower respiratory symptoms (pulmonary function, cough, chest pain) in exercising asthmatics	September 14, 2015	Table 1 Air Monitoring Comparison Values (AMCVs) for Ambient Air, Short-Term Health	https://www.tceq.texas.gov/assets/public/implementation/tox/dsd/final/sept15/hydrogen_chloride.pdf
Texas	$^{acute}ESL_{odor}$	**Short-term**	**1100**	Irritating, pungent	September 14, 2015	Table 1 Air Monitoring Comparison Values (AMCVs) for Ambient Air, Odor acute odor-based Effects Screening Level	
Texas	Chronic ReV (reference value)	**Long-term**	**26**	Critical Effect: Hyperplasia of nasal mucosa, larynx, and trachea in rats	September 14, 2015	Table 1 Air Monitoring Comparison Values (AMCVs) for Ambient Air, Long-Term Health	

JURISDICTION	CRITERIA TYPE	AVERAGING PERIOD	CRITERIA (µG/M^3)	BASIS OF CRITERIA	DATE OF CRITERIA/	DATA SOURCE	
Texas	^{acute}ESL [1 h]	**1-hour**	**190**	Critical Effect: Upper respiratory symptoms (sore throat, nasal discharge) and lower respiratory symptoms (pulmonary function, cough, chest pain) in exercising asthmatics	September 14, 2015	Table 2 Air Permitting Effects Screening Levels (ESLs), Short-Term ESL for Air Permit Reviews, acute health-based Effects Screening Level for chemicals meeting minimum database requirements	
Texas	$^{chronic}ESL_{threshold(nc)}$	**Annual**	**7.9**	Critical Effect: Upper respiratory tract effects in Sprague-Dawley rats	September 14, 2015	Table 2 Air Permitting Effects Screening Levels (ESLs), Long-Term ESL for Air Permit Reviews, chronic health-based Effects Screening Level for threshold dose response noncancer effects	
California	Reference Exposure Level (REL)	**1-hour**	**2100**	Respiratory system; eyes	November 2019	Office of Environmental Health Hazard Assessment (OEHHA) Acute, 8-hour and Chronic Reference Exposure Level (REL) Note: *Exposure averaging time for acute RELs is 1 hour. Chronic RELs are designed to address continuous exposures for up to a lifetime: the exposure metric used is the annual average exposure.*	https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary
California		**Annual**	**9**	Respiratory system	November 2019		
Massachusetts	Threshold Effects Exposure Limit (TEL)	**24-hour**	**7**		1995	MassDEP Ambient Air Toxics Guidelines Note: *TELs based on non-cancer health effects. TEL is a concentration intended to protect the general population, including sensitive populations such as children, from adverse health effects over a lifetime of continuous exposure. TELs take into account the fact that people may be exposed to a chemical from other sources, including indoor air, food, soil, and water.*	https://www.mass.gov/service-details/massdep-ambient-air-toxics-guidelines https://web.archive.org/web/20110112174442/http://www.mass.gov/dep/air/aallist.pdf https://web.archive.org/web/20110318091257/http://www.mass.gov/dep/air/chem_aal_sum.pdf
Massachusetts	Allowable Ambient Limit (AAL)	**Annual**	**7**		1995		
Michigan	Initial Threshold Screening Level (ITSL)	**Annual**	**20**	Derived from US EPA.	October 28, 2009	Michigan Air Toxics System Initial Threshold Screening Level/Initial Risk Screening Level (ITSL/IRSL)	https://www.michigan.gov/documents/deq/deq-aqd-toxics-xcelitsl_411837_7.zip
Michigan		**1-hour**	**2100**	Michigan Department of Environmental Quality, Air Quality Division (AQD)	October 28, 2009		

JURISDICTION	CRITERIA TYPE	AVERAGING PERIOD	CRITERIA (µG/M^3)	BASIS OF CRITERIA	DATE OF CRITERIA/	DATA SOURCE	
Oregon	Ambient Benchmark Concentrations (ABC)	**Annual**	**20**	ABC is the 1995 US EPA IRIS RfC value. OEHHA REL is lower (9) and newer (2000). Both US EPA and OEHHA relied on the same study but used different analysis assumptions. Choice of ABC based on preference for newer US EPA toxicity information, because the ATSAC (Oregon State Air Toxics Science Advisory Committee) did not accept the uncertainty factors applied by OEHHA.	May 11, 2018	Oregon Air Toxics Benchmarks	https://www.oregon.gov/deq/FilterDocs/airtox-abc.pdf
New York	Short-term Guideline Concentration (SGC)	**1-hour**	**2100**	Derived from New York State Department of Environmental Conservation. The NYSDEC derives short-term (1-hr) and annual exposure limits (SGCs and AGCs, respectively) to protect the general population from adverse acute and long-term (months, years, or a lifetime) inhalation exposures. Some of these limits are derived independently by the NYSDEC and others are based upon the exposure data published by other agencies like California's CalEPA. The CalEPA derives many acute and chronic Reference Exposure Limits (RELs) and cancer Unit Risk Estimates (UREs) to protect the general population from adverse inhalation exposures. These values are available at: http://www.oehha.ca.gov/air.html	February 12, 2021	DAR-1 AGC/SGC Tables, Short-term Guideline Concentration (SGC)	https://www.dec.ny.gov/docs/air_pdf/dar1.pdf

JURISDICTION	CRITERIA TYPE	AVERAGING PERIOD	CRITERIA (µG/M^3)	BASIS OF CRITERIA	DATE OF CRITERIA/	DATA SOURCE	
New York	Annual Guideline Concentration (AGC)	**Annual**	**20**	Derived from US EPA. The US EPA derives both carcinogenic and non-carcinogenic annual exposure limits for use in assessing the impact from chronic exposure. RfCs are inhalation exposure limits designed to protect against adverse chronic noncarcinogenic effects. Whereas carcinogenic exposure limits are derived from the US EPA's URE values and are used to protect the public from the additional one-in-one-million excess cancer risk over a lifetime of continuous exposure. UREs and RfCs values are published on the IRIS website available at: http://www.epa.gov/iris/	February 12, 2021	DAR-1 AGC/SGC Tables, Annual Guideline Concentration (AGC)	https://www.dec.ny.gov/docs/air_pdf/dar1.pdf
Idaho	Reference Occupational Exposure Level (OEL)	**8-hour**	**750**		July 1, 2021	58.01.01 – Rules for the Control of Air Pollution in Idaho, Toxic Air Pollutants Non-Carcinogenic Increments, OEL _Note_: *Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELS) are 8-hour time weighted averages (TWAs) unless otherwise indicated: https://www.osha.gov/annotated-pels/table-z-1#notes. The AAC are 24-hour averages.*	https://adminrules.idaho.gov/rules/current/58/580101.pdf
Idaho	Acceptable Ambient Concentrations (AAC)	**24-hour**	**375**		July 1, 2021		
US	Acute Exposure Guideline Levels	**10 min**	**2700**	NOAEL in exercising asthmatic subjects (Stevens et al. 1992)	2004	Acute Exposure Guideline Levels for Selected Airborne Chemicals, Volume 4	https://www.epa.gov/sites/default/files/2014-11/documents/tsd52.pdf
US		**30 min**	**2700**		2004		
US		**1-hour**	**2700**		2004		
US		**4-hour**	**2700**		2004		
US		**8hr**	**2700**		2004		

Attachment 2

Photo: Waste-to-Energy Facility

Waste-to-Energy Facility Environmental Monitoring and Reporting – 2023 Update

Sarah Wellman, P.Eng.
Senior Engineer, Solid Waste Services

Zero Waste Committee Meeting - July 4, 2024

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CONTINUOUS EMISSIONS MONITORING SYSTEM

Stack Sampling Ports

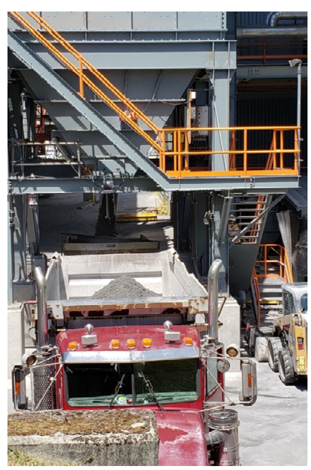
Continuous Emission Monitoring Analyzers

QUARTERLY MANUAL STACK TESTING

FLY ASH AND BOTTOM ASH MONITORING

Bottom Ash Loading

Bottom Ash Weekly Composite Samples



Loaded Fly Ash Trailers

Fly Ash Composite Samples

OPERATIONAL CERTIFICATE

All environmental reporting submitted to the Province is posted to the website:

- Monthly compliance reports
- Annual compliance reports
- Quarterly stack test results
- Semi-volatile organic compound stack test results
- Bottom ash weekly composite data
- Quarterly fly ash summary

AMBIENT MONITORING

- Temporary mobile monitoring station installed at the Waste-to-Energy Facility (2021-2023)
- Hydrogen chloride monitor added at existing station
- Study concluded that ambient levels of sulphur dioxide and hydrogen chloride are less than 10% of air quality objectives
- No statistically significant correlation between the Waste-to-Energy Facility operations and ambient air quality data
- Other sources primary drivers of observed hydrogen chloride, sulfur dioxide and nitrogen oxides
- Operational Certificate amendment application to extend timing on acid gas reduction

GREENHOUSE GAS EMISSIONS REPORTING

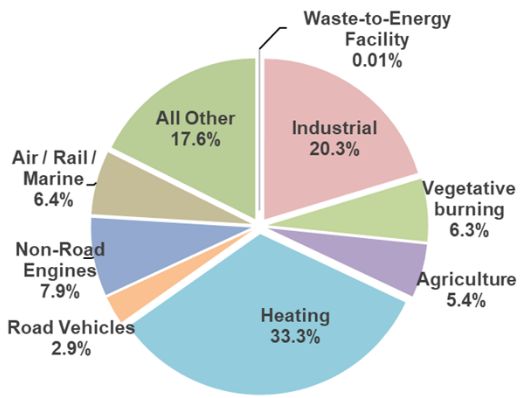
2023 Greenhouse Gas Emissions:

- Anthropogenic 124,540 tonnes (45%)
- Biogenic 153,346 tonnes (55%)
- Annual reports to provincial and federal databases

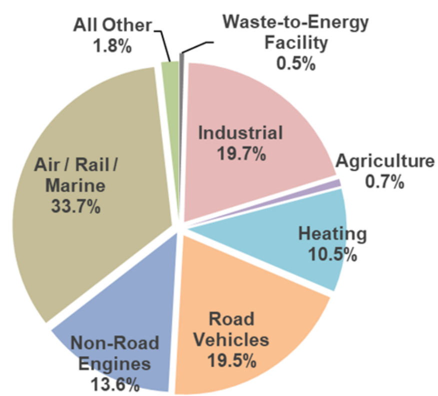
Air sample for biogenic testing

WASTE-TO-ENERGY IN A REGIONAL CONTEXT

2023 Lower Fraser Valley Fine Particle Matter (PM2.5) Emissions Sources



2023 Lower Fraser Valley Nitrogen Oxides (NOx) Emissions Sources



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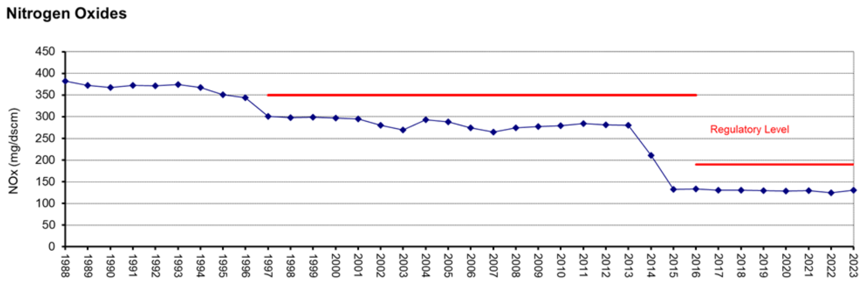

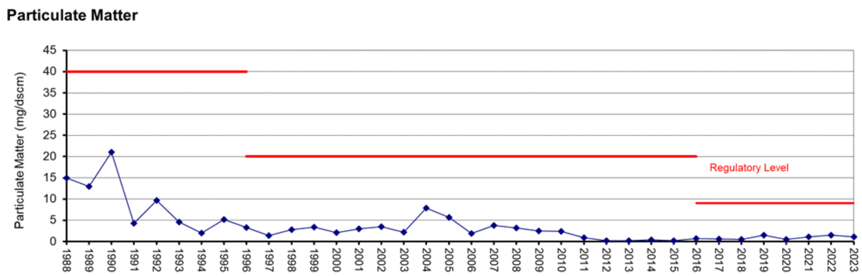

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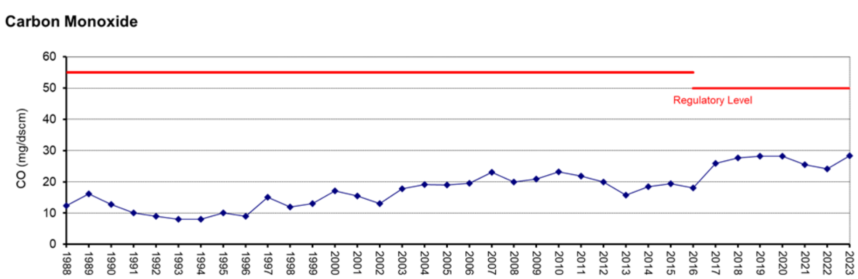

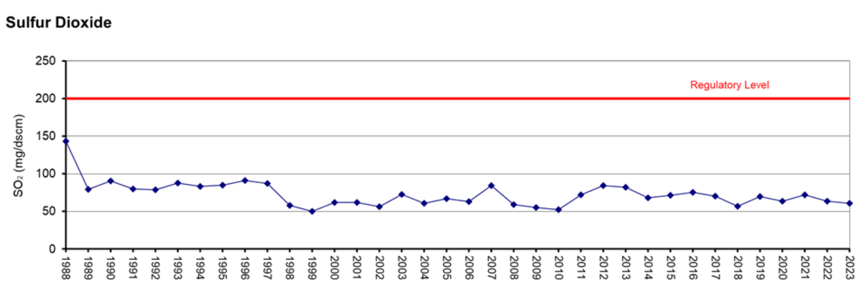

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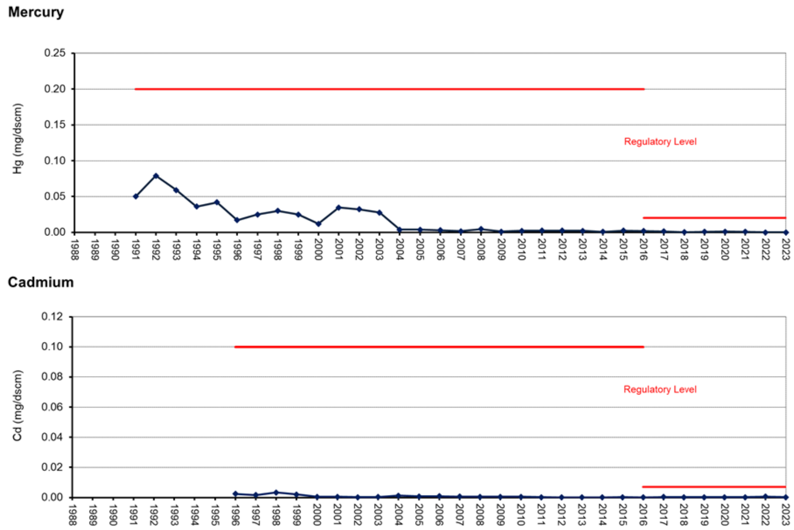

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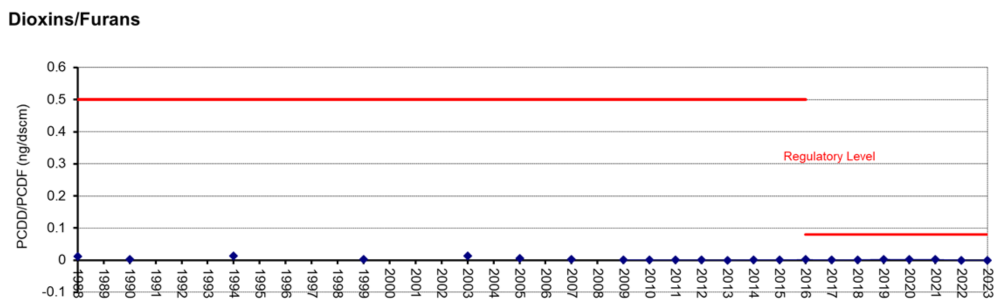

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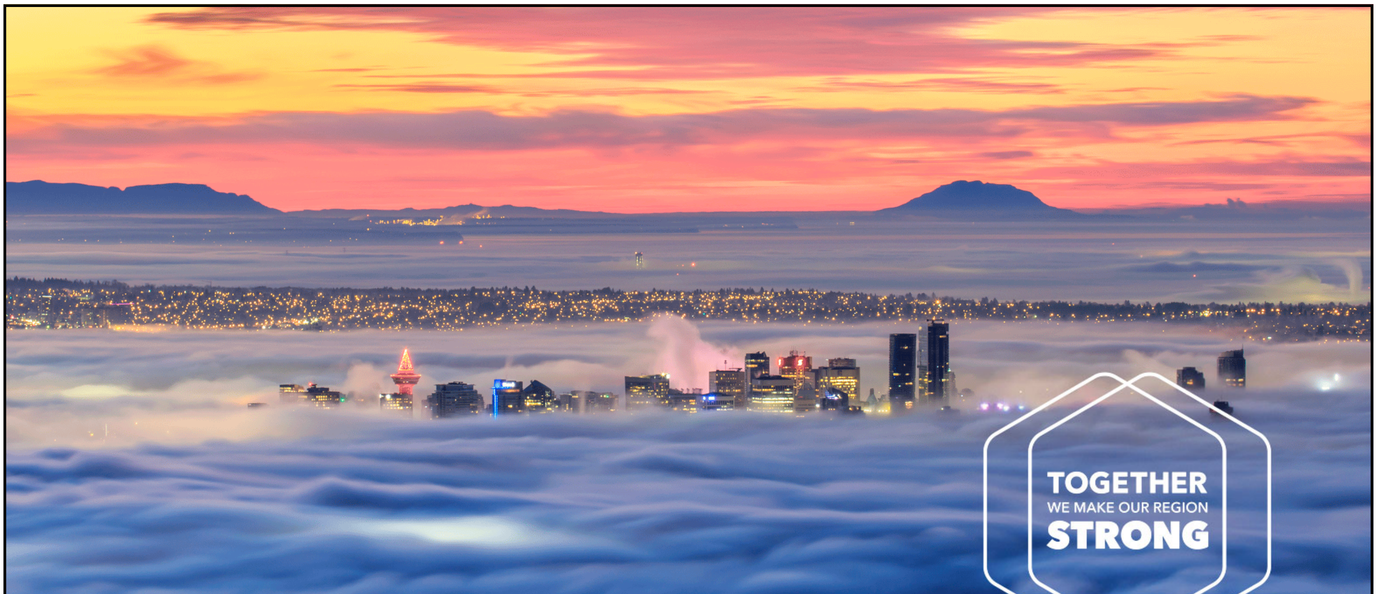

Metro Vancouver skyline

Questions?

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