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2017 Lower Fraser Valley Air Quality Monitoring Report

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Summary

This annual report summarizes the air quality monitoring data collected by the Lower Fraser Valley (LFV) Air Quality Monitoring Network in 2017 and describes the air quality monitoring activities and programs conducted during the year. The main focus is to report on the state of ambient (outdoor) air quality in the LFV.

LFV Air Quality Monitoring Network

The LFV Air Quality Monitoring Network includes 31 air quality monitoring stations located from Horseshoe Bay in West Vancouver to Hope. Metro Vancouver operates 25 stations in Metro Vancouver, as well as 6 stations in the Fraser Valley Regional District (FVRD) in partnership with the FVRD.

Air quality and weather data from all but one station are collected automatically on a continuous basis, transmitted to Metro Vancouver's Head Office in Burnaby, and stored in an electronic database. The data are then used to communicate air pollutant information to the public, such as through air quality health index (AQHI) values and on airmap.ca.

Air quality monitoring stations are located throughout the LFV to provide an understanding of the air quality levels that residents are exposed to most of the time. This report shows how these levels have varied throughout the region in 2017 and how these levels have changed over time. Trends in air quality measured by the Air Quality Monitoring Network are used to evaluate the effectiveness of pollutant emission reduction actions undertaken as part of Metro Vancouver's Clean Air Plan.

Specialized Air Quality Monitoring

In addition to the monitoring network stations, Metro Vancouver deploys portable air quality stations and instruments to conduct specialized monitoring studies. Specialized studies can target suspected problem areas (or "hot spots") at the local, neighbourhood or community level. Specialized studies in 2017 included continuation of a near-road monitoring study in Vancouver to assess air pollutants near a major roadway to aid in the determination of public exposure to air pollutants.

Visual Air Quality

Visual air quality (sometimes referred to as visibility or haze) can become degraded in the LFV, causing local views to become partially or fully obscured. Haze may have different characteristics depending on the underlying cause. In parts of Metro Vancouver, especially more urbanized areas to the west, haze can have a brownish appearance due to nitrogen dioxide from transportation emissions. Further east in the LFV, impaired visual air quality can be more associated with a white haze caused by small particles ($PM_{2.5}$) in the air that scatter light.

Monitoring is conducted to assess how and by how much visual air quality has become impaired. Measurements of $PM_{2.5}$, particle constituents (for example, particulate nitrate, particulate sulphate, elemental carbon and organic carbon), nitrogen dioxide and other air contaminants as well as light scattering provide important data for visual air quality management activities. Automated digital cameras operated in seven locations to record views along specific lines-of-sight. By examining photographs alongside data from monitoring equipment, visual air quality impairment can be related to pollutant concentrations and relevant emissions sources. These activities conducted through a multi-agency collaboration (BC Visibility Coordinating Committee) inform the development of policy options for improving visual air quality.

Pollutants Monitored

Pollutants are emitted to the air from a variety of human activities and natural phenomena. Once airborne, the resulting pollutant concentrations are dependent on several factors, including the weather, topography and chemical reactions in the atmosphere.

Common air contaminants, including ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter are widely monitored throughout the network. Particulate matter is composed of very small particles that remain suspended in the air. They are further distinguished by their size, which is measured in units of a millionth of a metre (or micrometre).

Particles with a diameter smaller than 10 micrometres are referred to as inhalable particulate (PM_{10}), while those smaller than 2.5 micrometres are termed fine particulate ($PM_{2.5}$). Both PM_{10} and $PM_{2.5}$ concentrations are monitored at stations throughout the LFV.

Other pollutants less widely monitored in the network include black carbon (BC), ultrafine particles (UFP), ammonia (NH_3), volatile organic compounds (VOC), and total reduced sulphur compounds (TRS).

Air Quality Health Index (AQHI)

Developed by Environment and Climate Change Canada and Health Canada, the Air Quality Health Index (AQHI) communicates the health risks associated with a mix of air pollutants to the public and provides guidance on how individuals can adjust their exposure and physical activities as air pollution levels change. The AQHI is calculated every hour using monitoring data from stations in the LFV.

Current AQHI levels in the LFV as well as the AQHI forecasts and additional information about the AQHI are available at:

www.airmap.ca
www.airhealth.ca
www.env.gov.bc.ca/epd/bcairquality/readings/aqhi-table.xml

Air Quality Objectives and Standards

Several pollutant-specific air quality objectives and standards are used as benchmarks to characterize air quality. They include Metro Vancouver and provincial ambient air quality objectives, and the federal Canadian Ambient Air Quality Standards (for ozone, particulate matter, sulphur dioxide and nitrogen dioxide).

The federal Canadian Ambient Air Quality Standards (CAAQS) have been established as objectives under the Canadian Environmental Protection Act, and replaced Canada-Wide Standards. In 2015, Metro Vancouver adopted a 1-hour interim ambient air quality objective for SO_2 of 75 parts per billion (ppb) prior to establishment of the federal SO_2 CAAQS. After establishment of the federal SO_2 CAAQS, Metro Vancouver's SO_2 objectives were revised in November 2017, with a more stringent 1-hour objective of 70 ppb not to be exceeded and an annual objective of 5 ppb.

In 2019, Metro Vancouver aligned its objectives for CO, NO_2 and O_3 with federal and provincial standards. Metro Vancouver adopted a 1-hour and annual ambient air quality objective for NO_2 that is the same as the federal 2020 CAAQS. Similarly, the 8-hour O_3 objective was made the same as the 2020 CAAQS. The 1-hour and 8-hour CO objectives were set to 13,000 ppb and 5,000 ppb respectively, to match the more stringent Provincial objectives.

Priority Pollutants

Research indicates that adverse health effects can occur at the air contaminant concentrations measured in the LFV. Health experts have identified exposure to ozone and particulate matter as being associated with the most serious health effects. Ozone is a strong oxidant that can irritate the eyes, nose and throat, and reduce lung function. $PM_{2.5}$ particles are small enough to be breathed deeply into the lungs, resulting in impacts to both respiratory and cardiovascular systems. Long-term exposure to these pollutants can aggravate existing heart and lung diseases and lead to premature mortality.

Of particular concern is $PM_{2.5}$ that is emitted from diesel fuel combustion in car, truck, marine, rail and non-road engines. These particles ("diesel PM") are carcinogenic and are believed to contribute significantly to the health effects described above. Instrumentation installed in some air quality monitoring stations in the LFV can be used to estimate the proportion of particles that originate from diesel engines.

Wildfire Impacts

Wildfire activity in the Pacific Northwest has increased in severity in recent years. Wildfire smoke can be transported long distances and impact Metro Vancouver. The wildfire season in 2017 was one of the worst in British Columbia's history and included significant smoke-related air quality impacts which occurred due to wildfires burning in the BC Interior, and the west coast of the US. These impacts led to the most air quality advisories issued in a single year by Metro Vancouver.

Air Quality Advisories

In 2017, air quality advisories were in effect for a total of nineteen days in July, August and September. Two single-day advisories were issued in July, an 11-day

advisory in August due to wildfire smoke with elevated ozone for parts of the advisory, a single day advisory for wildfire smoke at the end of August, and a 5-day advisory for wildfire smoke in September that also included one day with a combined ozone and fine particulate advisory.

The 11-day advisory in August was the longest continuous Metro Vancouver advisory on record and was caused by outflow winds that transported smoke from wildfires burning in the BC Interior. The 5-day advisory in September was the result of wildfire smoke from the interior of BC as well as wildfires burning in Washington State.

Periods of degraded air quality can occur in the LFV for several reasons, such as smoke from wildfires or summertime smog during hot weather. Air quality advisories are issued to the public when air quality has deteriorated or is predicted to deteriorate. In the last ten years, the number of days when air quality advisories were in place ranged from zero to as many as 19 days annually.

Regional Long-Term Trends

Long-term *regional* trends in air quality are the trends observed within the LFV as a whole. They are determined by averaging measurements from several stations distributed throughout the LFV.

Figures S1 to S4 show the average concentrations and the short-term peak concentrations of four common air contaminants for the last two decades. Average concentrations represent the ambient concentrations that the region experiences most of the time. Short-term peak concentrations show the relatively infrequent higher concentrations experienced for short periods (on the scale of one hour to one day). Specific locations may have experienced trends that differ slightly from the regional picture.

Improvements have been made over the last two decades for most pollutants, including carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and fine particulate matter ($PM_{2.5}$). Both short-term peak and average concentrations have declined since the mid- nineties for all these pollutants.

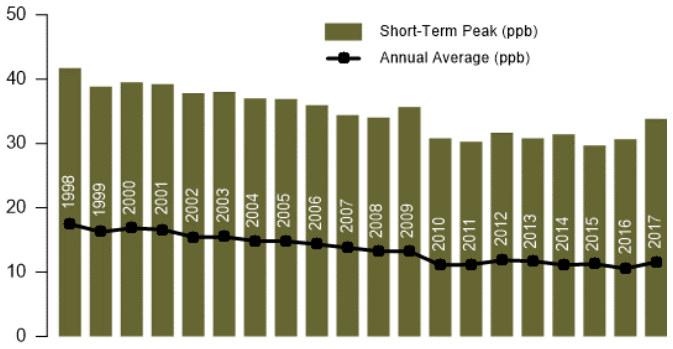


Figure S1: Nitrogen Dioxide Trend.

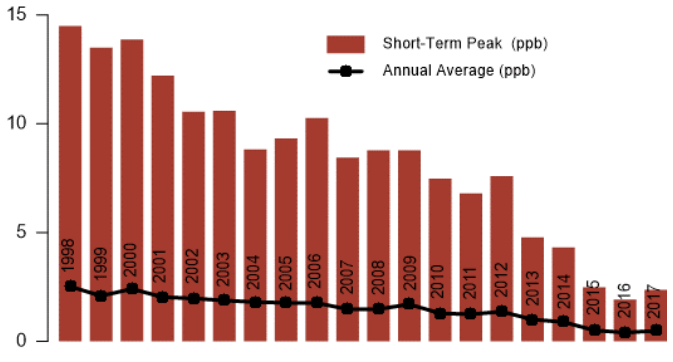


Figure S2: Sulphur Dioxide Trend.

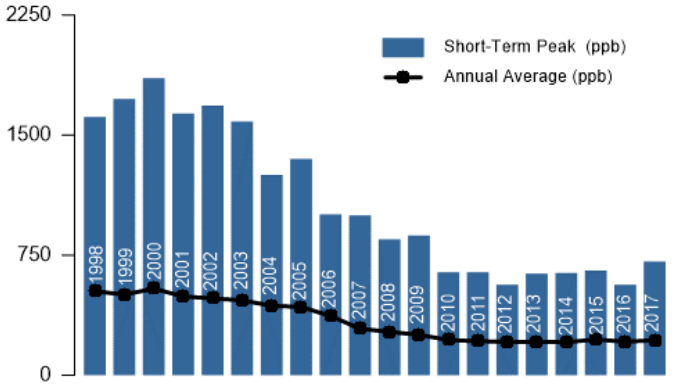


Figure S3: Carbon Monoxide Trend.

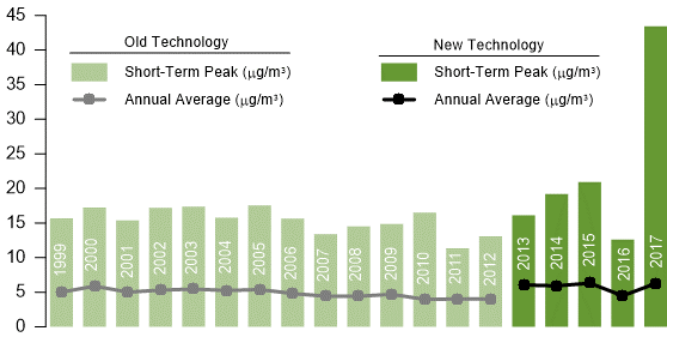


Figure S4: Fine Particulate Matter ($PM_{2.5}$) Trend.

Despite significant population growth in the region over the same time period, actions to reduce emissions across a variety of sectors have brought about these improvements in air quality. Stricter vehicle emission standards and the AirCare program are largely responsible for lower carbon monoxide (CO) and nitrogen dioxide (NO_2) levels.

Requirements for reduced sulphur content in marine, on-road and off-road fuels, and reduced emissions from the petroleum refining and cement industries have led to the considerable improvements in sulphur dioxide (SO_2) levels. Emission reductions from light duty and heavy duty vehicles, wood products sectors, and petroleum refining have contributed to the decline in $PM_{2.5}$ levels.

The regional $PM_{2.5}$ trends since 1999, when continuous $PM_{2.5}$ monitoring became prevalent throughout the LFV, are illustrated in Figure S4. Fine particulate matter monitoring technology was upgraded in 2013 to continuous particulate monitors that met the U.S. Environmental Protection Agency $PM_{2.5}$ Federal Equivalent Method (FEM). The FEM monitors have the ability to measure a portion of particulate matter not previously measured. Wildfire effects are evident in the 2017 trend.

Figure S5 shows long-term $PM_{2.5}$ trends from a single monitoring station with a long record using the same monitoring method (non-continuous filter-based monitoring) at the Port Moody station.

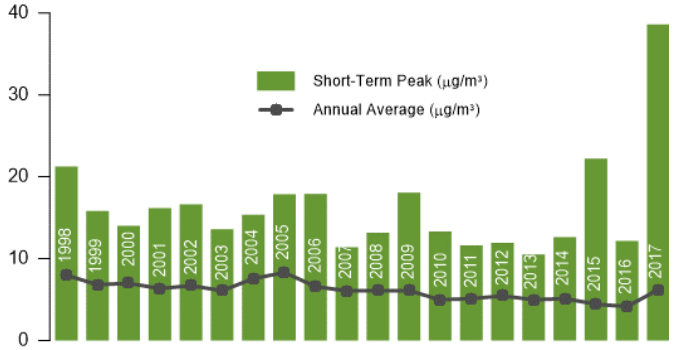


Figure S5: Port Moody $PM_{2.5}$ Trend.

For ozone, the same improvements seen for other pollutants have not been observed. In contrast, average regional ozone levels (Figure S6) have shown a slight increasing trend. Research suggests that background ozone concentrations are rising and are one reason for the observed increase in average levels.

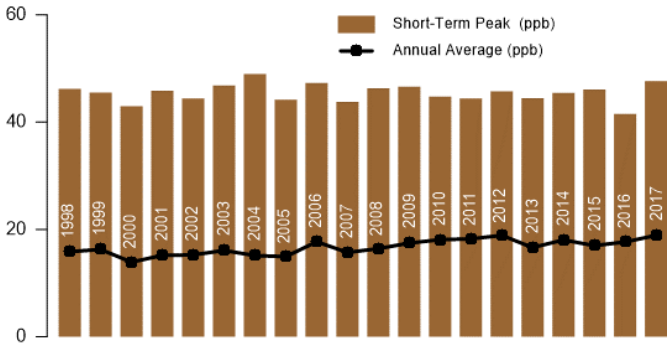


Figure S6: Ozone Trend.

Regionally averaged short-term peak ozone trends are also shown in Figure S6. The severity of peak ozone episodes greatly diminished in the 1980s, however short-term peak ozone levels have been mainly unchanged during the last two decades, despite large reductions in emissions of pollutants that contribute to ozone formation.

Metro Vancouver and the Fraser Valley Regional District adopted the Regional Ground-Level Ozone Strategy in 2014, which provides strategic policy direction for ozone management in the LFV based on local scientific research. Research indicates that a spatial understanding of the ratio of concentrations of nitrogen oxides (NO_X) and volatile organic compounds (VOC), two precursor pollutants that react to form ozone, is key to determining which precursors to reduce in order to maintain and improve air quality in our region.

Ground-Level Ozone – 2017

Monitoring results for all ozone monitoring stations with sufficient data coverage during 2017 are shown in Figure S7. The data show that peak ozone levels, as measured by the Canadian Ambient Air Quality Standard value and maximum 1-hour average, generally occurred in the eastern parts of Metro Vancouver and in the FVRD during sunny and hot weather.

In 2017, the Canadian Ambient Air Quality Standard for ozone was met at all monitoring stations with the exception of Hope. Metro Vancouver's 1-hour objective was exceeded on six days (June 25, August 2, 3, 9, 10, and 29) at a combination of eight monitoring stations. The 8-hour Metro Vancouver objective was exceeded on twelve days (June 24, 25 and 29, July 5 and 6, and August 2, 3, 7, 9, 10, 11 and 29) at a combination of 13 stations (not shown). Air quality advisories were issued due to ground-level ozone on eight days in 2017. Throughout the summer ozone production was enhanced by wildfire smoke.

Ground-level ozone is a secondary pollutant formed in the air from other contaminants such as nitrogen oxides (NO_X) and volatile organic compounds (VOC). The highest concentrations of ozone occur during hot sunny weather and can be enhanced by wildfire smoke.

NO_X emissions are dominated by transportation sources, with nearly 77% of emissions coming from cars, trucks, ships, rail, planes, and non-road engines. VOC are emitted from natural sources (e.g., trees), cars, light trucks, and solvents found in industrial, commercial and consumer products.

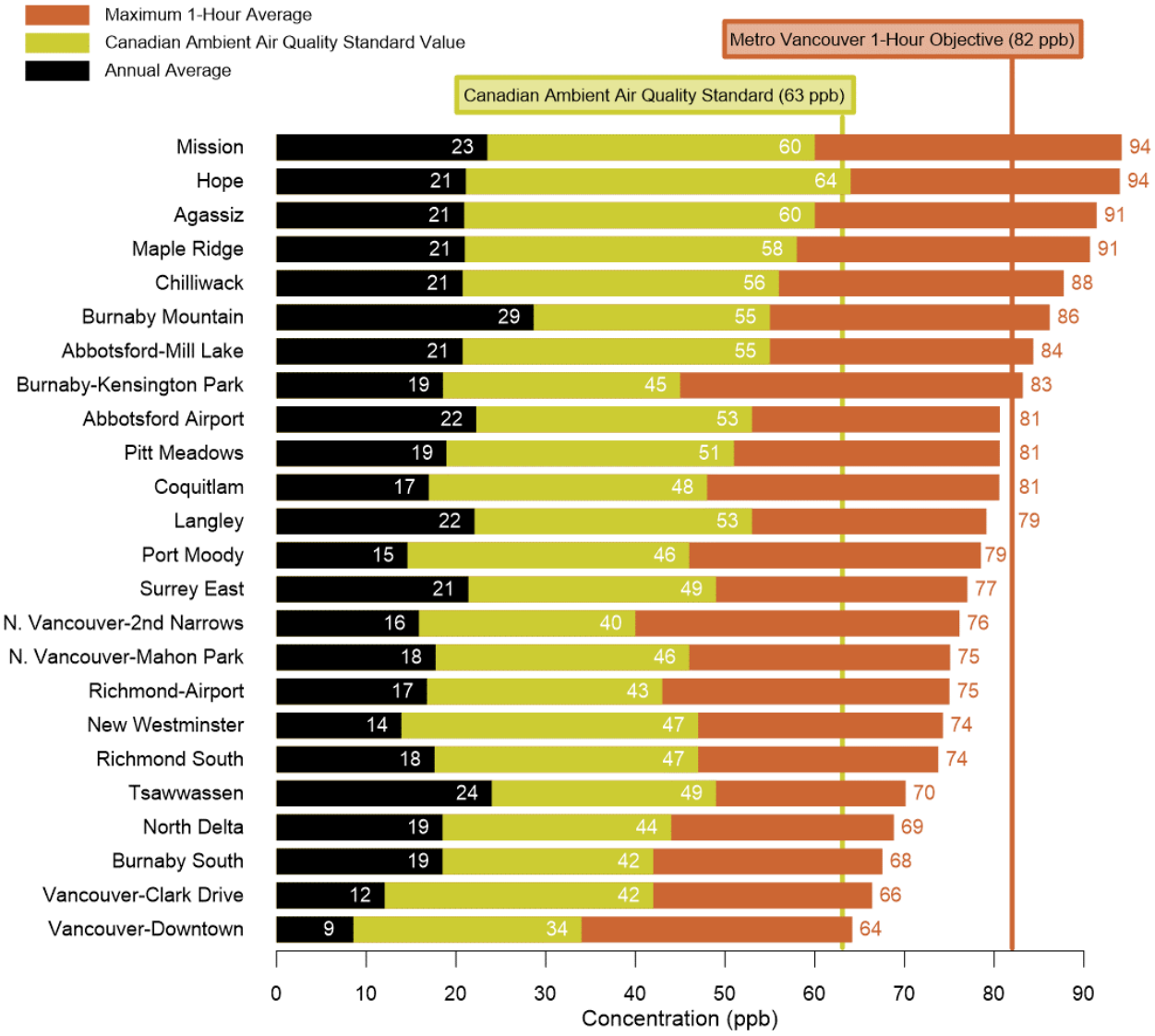


Figure S7: Ozone (O_3) 2017.

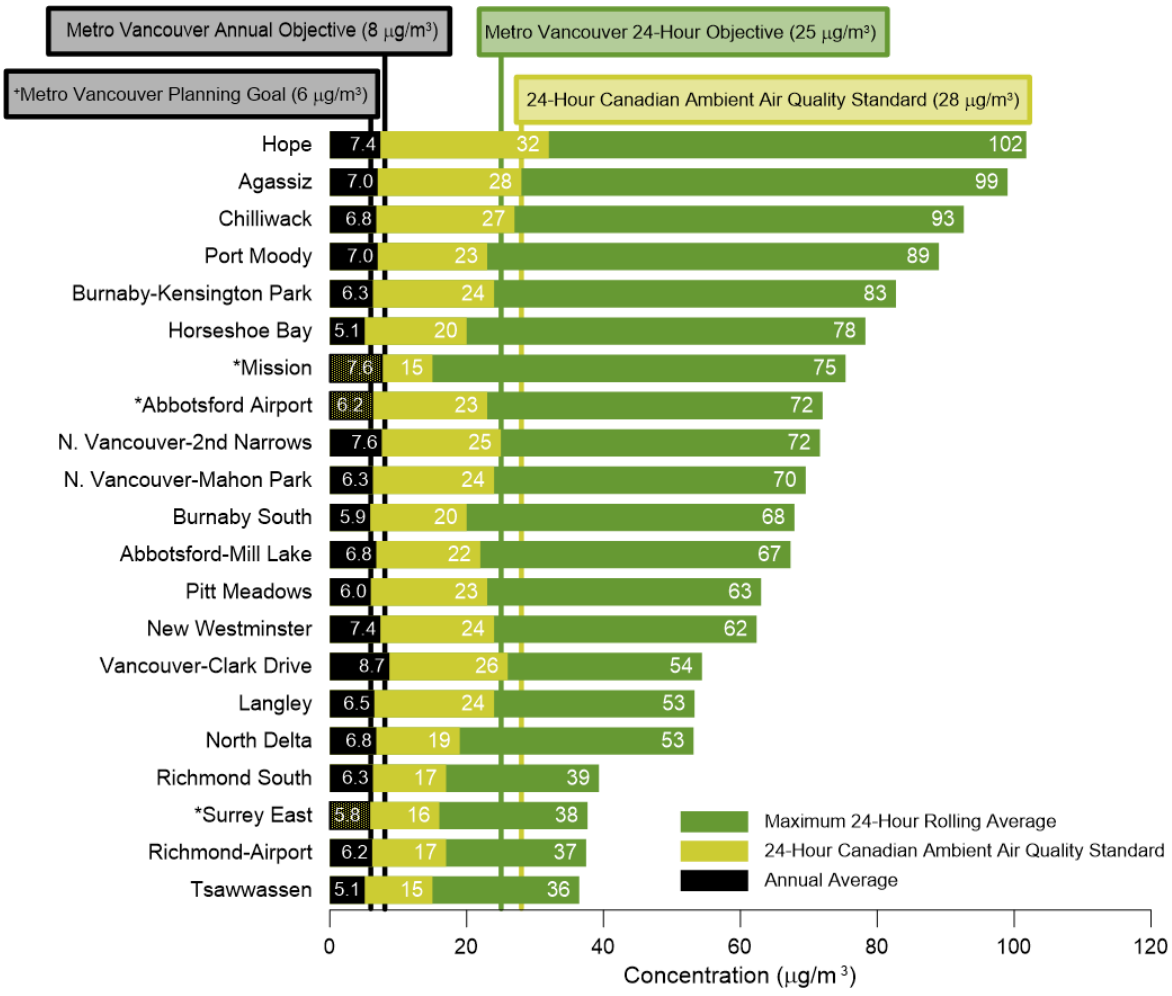
Fine Particulate Matter ($PM_{2.5}$) – 2017

Results for all $PM_{2.5}$ monitoring stations with sufficient data coverage during 2017 are shown in Figure S8. All stations were better than the Canadian Ambient Air Quality Standard for $PM_{2.5}$ with the exception of Hope. All but one station (Vancouver-Clark Drive) was below the Metro Vancouver annual objective of 8 μg/m³.

Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective were widespread in 2017. The objective was exceeded at a single station in July (July 18) and at all monitoring stations in August and September due to extensive wildfire smoke. An unprecedented eleven-day advisory was issued at the beginning of August and a single day advisory was issued near the end of August. In early September, a 5-day advisory was issued followed by a single day advisory issued mid-month. The advisories were caused by wildfire smoke primarily from the BC Interior as well as Washington, Oregon and California.

Fine particulate matter ($PM_{2.5}$) emissions are typically dominated by transportation, wood and natural gas heating, and industrial sources. In 2017 the impact of wildfires outside the region was apparent. $PM_{2.5}$ is also formed by reactions of nitrogen oxides (NO_X) and sulphur dioxide (SO_2) with ammonia in the air. $PM_{2.5}$ produced in this manner is called secondary $PM_{2.5}$ and accounts for a significant portion of $PM_{2.5}$ in summer.

In addition to wildfire influences, there were other exceedances that occurred throughout the year. Exceedances were experienced in Langley on October 28 and 29, Vancouver-Clark Drive on October 29, 31, November 1 and December 11, and in New Westminster on December 13. These exceedances were thought to be a result of a combination of Halloween fireworks, residential wood burning and/or open burning.



⁺Metro Vancouver's Planning Goal of 6 μg/m³ is a longer term aspirational target to support continuous improvement.
*Data completeness criteria were not met at these stations and the mean has been calculated with all available data.

Figure S8: Fine Particulate Matter ($PM_{2.5}$) 2017.

Nitrogen Dioxide – 2017

Results for nitrogen dioxide (NO_2) monitoring in 2017 are shown in Figure S9. All stations experienced nitrogen dioxide levels that were below Metro Vancouver's 1-hour objective. Average levels for the year were also below Metro Vancouver's annual objective with the exception of the Vancouver-Clark Drive station. In 2017, the highest average nitrogen dioxide levels were measured near major roadways, including at the Vancouver-Clark Drive and Vancouver-Downtown stations.

As nitrogen dioxide emissions are dominated by transportation sources, the highest average nitrogen dioxide concentrations are measured in the more densely trafficked areas and near busy roads. Lower concentrations are observed where these influences are less pronounced, such as the eastern parts of Metro Vancouver and in the FVRD.

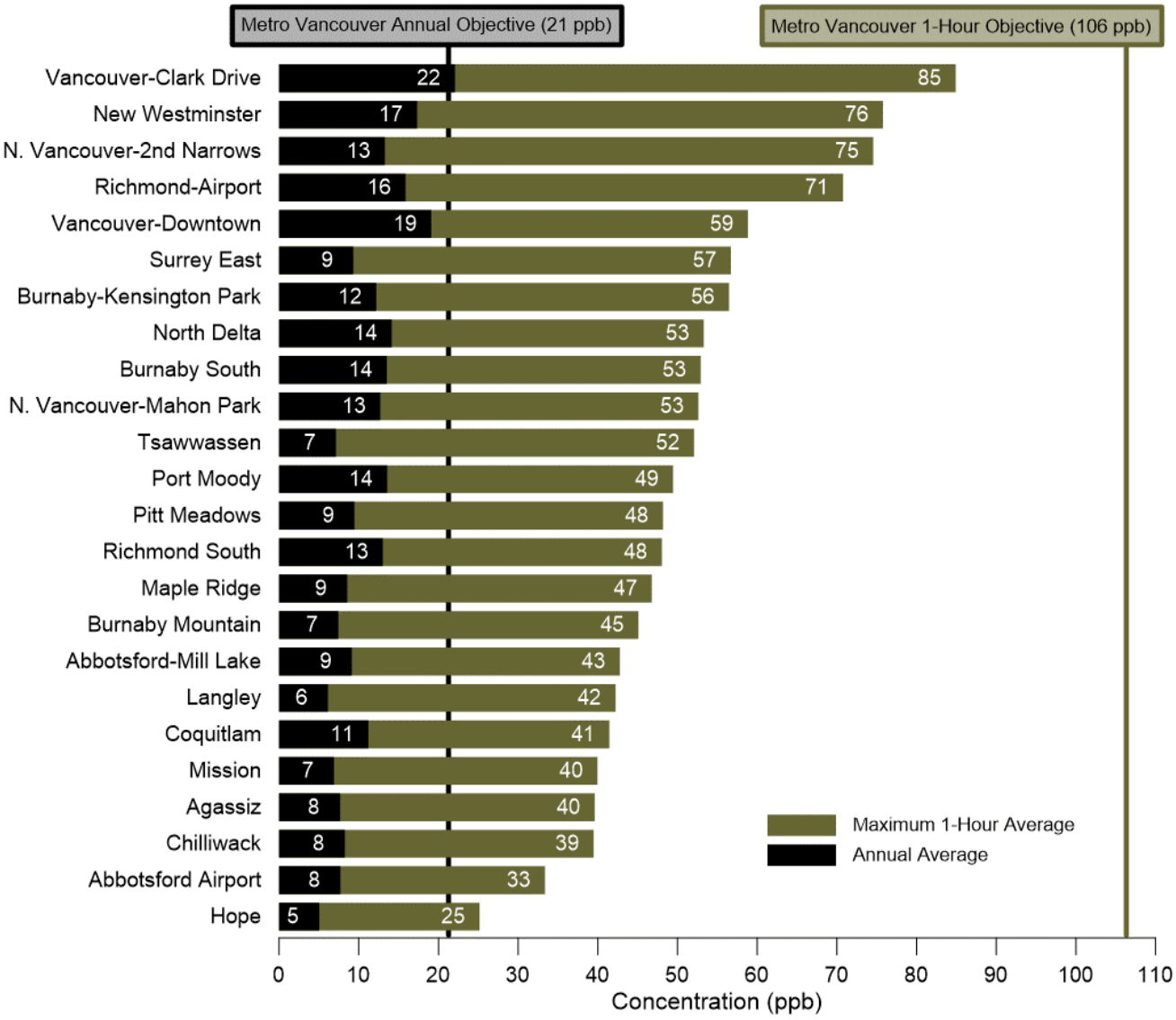


Figure S9: Nitrogen Dioxide (NO_2) 2017.

Sulphur Dioxide – 2017

Monitoring results for sulphur dioxide (SO_2) monitoring stations are shown in Figure S10. Sulphur dioxide levels were below annual objective at all stations in 2017.

Average concentrations of sulphur dioxide for 2017 stations were less than 1.3 ppb at all stations. Average levels remain low in 2017 compared with previous years which can be attributed to stricter marine fuel requirements that came into effect at the beginning of 2015.

With the exception of Burnaby-Capitol Hill all stations were below Metro Vancouver's 1-Hour objective of 70 ppb in 2017. The 1-hour objective was exceeded on four separate days at the Burnaby-Capitol Hill station in the evening of February 13, the morning and evening of March 20, the evening of October 28 and morning and evening of December 7. The exceedances were measured when winds were blowing from the direction of the petroleum refinery.

Sulphur dioxide is formed primarily by the combustion of fossil fuels containing sulphur. The largest sources in the LFV are marine vessels (mainly ocean-going vessels) and the petroleum products industry. As a result, the highest sulphur dioxide levels are typically measured near the Burrard Inlet area. Away from the Burrard Inlet area, sulphur dioxide levels are considerably lower.

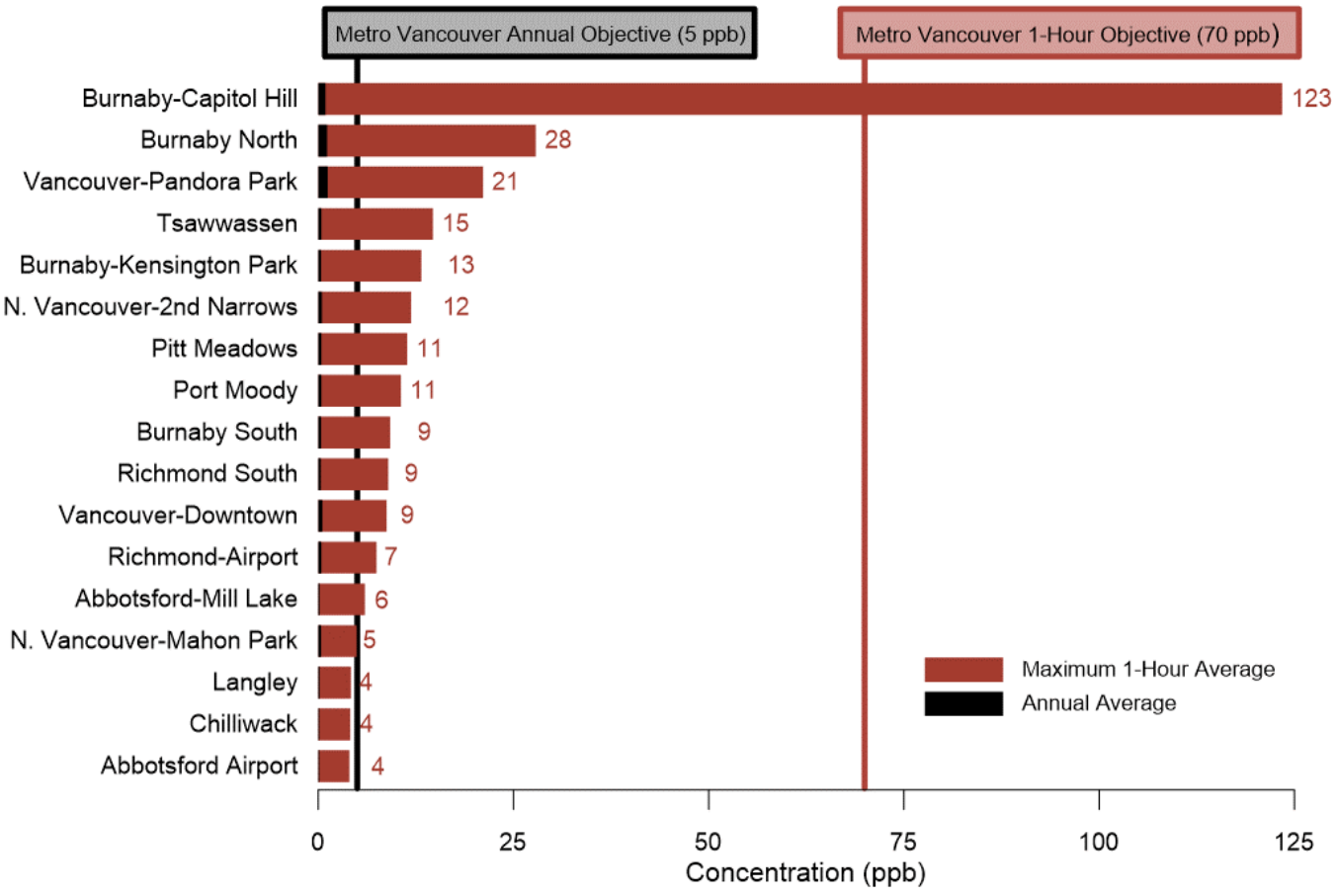
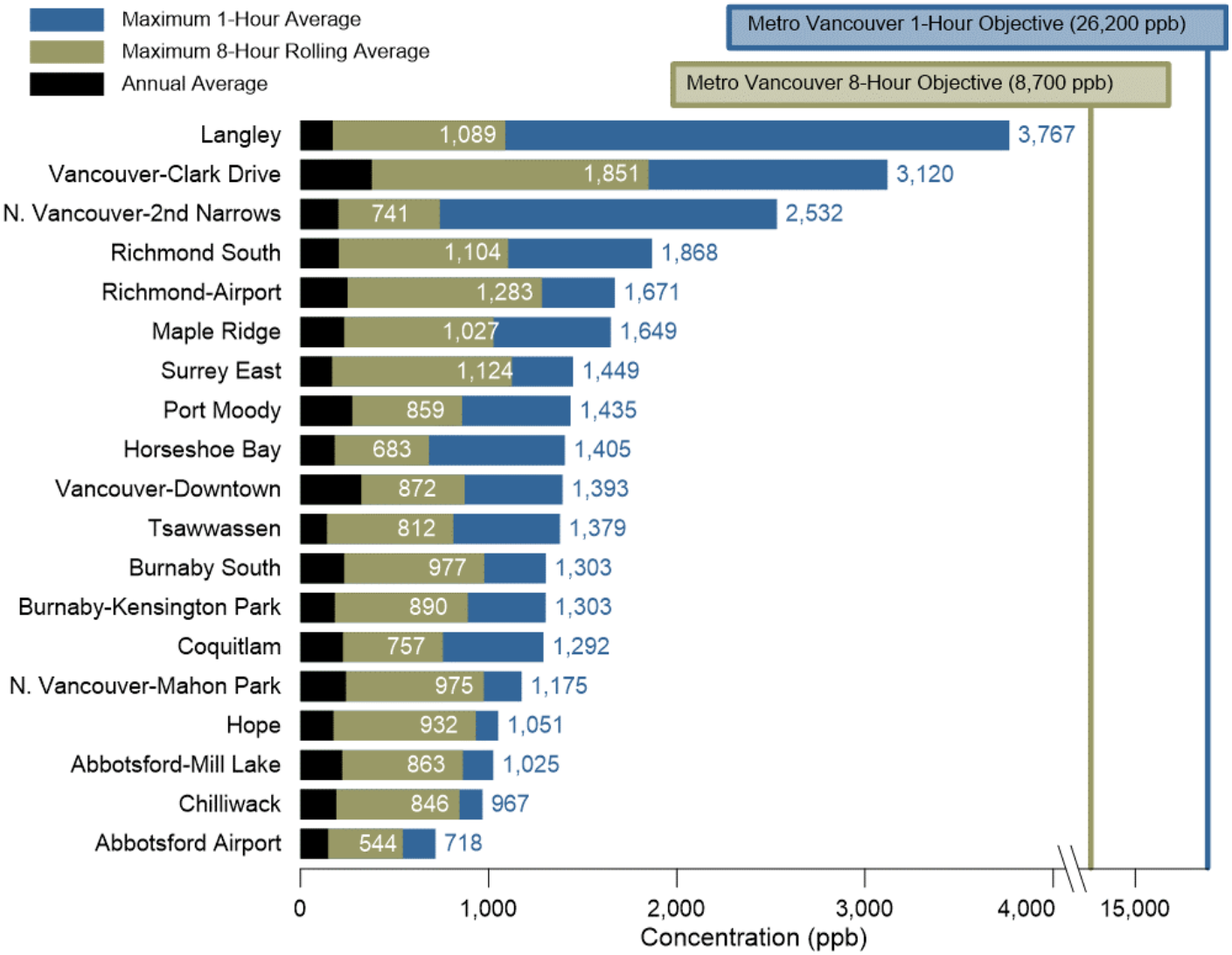


Figure S10: Sulphur Dioxide (SO_2) 2017.

Carbon Monoxide – 2017

Carbon monoxide (CO) monitoring results for 2017 are shown in Figure S11. Carbon monoxide levels were all well below the relevant Metro Vancouver air quality objectives at all stations throughout the LFV. The principal source of carbon monoxide continues to be emissions from motor vehicles.

Higher concentrations generally occur close to major roads during peak traffic periods. Like nitrogen dioxide, the highest average carbon monoxide concentrations are measured in the more densely trafficked areas and near busy roads. Lower concentrations are observed where these influences are less pronounced, such as the suburban and rural parts of Metro Vancouver and the FVRD.



Note: The scale is broken in the x-axis between 4,000 and 8,000 ppb. The highest concentrations measured are five times less than the objective.

Figure S11: Carbon Monoxide (CO) 2017.

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List of Acronyms

AQHI	Air Quality Health Index
BC	Black Carbon
BCVCC	BC Visibility Coordinating Committee
CCME	Canadian Council of Ministers of the Environment
CAAQS	Canadian Ambient Air Quality Standard
CO	Carbon Monoxide
FEM	Federal Equivalent Method
FVRD	Fraser Valley Regional District
LFV	Lower Fraser Valley
MAMU	Mobile Air Monitoring Unit
NAPS	National Air Pollution Surveillance
NO_X	Nitrogen oxides
NO_2	Nitrogen dioxide
NO	Nitric oxide
NH_3	Ammonia
O_3	Ozone
PM	Particulate matter
PM_{10}	Inhalable particulate matter (particles smaller than 10 micrometres in diameter)
$PM_{2.5}$	Fine particulate matter (particles smaller than 2.5 micrometres in diameter)
SO_X	Sulphur oxides
SO_2	Sulphur dioxide
THC	Total hydrocarbons
TRS	Total reduced sulphur compounds
UFP	Ultrafine particles
VOC	Volatile organic compounds

Section A – Introduction

This report summarizes data collected from air quality stations in the Lower Fraser Valley (LFV) Air Quality Monitoring Network in 2017 and describes the air quality monitoring activities and programs conducted during the year. The focus is to report on the state of ambient (outdoor) air quality in the LFV.

Metro Vancouver maintains one of the most comprehensive air quality networks in North America serving a population of 2.8 million with 31 air quality stations located from Horseshoe Bay in West Vancouver to Hope in 2017. Pollutants monitored by the network include both gases and particulate matter. Common air contaminants include ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter. These are all widely monitored throughout the network.

Particulate matter consists of very small solid and liquid material suspended in the air. This air pollutant is characterized by size and measured in units of a millionth of a metre, or micrometre (μm). Particles with a diameter smaller than 10 micrometres are referred to as inhalable particulate (PM_{10}), while those smaller than 2.5 micrometres are termed fine particulate ($PM_{2.5}$). Both PM_{10} and $PM_{2.5}$ concentrations are monitored throughout the LFV.

Other pollutants monitored by the network include ammonia, volatile organic compounds (VOC), black carbon, ultrafine particles (UFP) and odourous total reduced sulphur compounds (TRS). Additional information Metro Vancouver collects to help monitor air quality conditions includes weather (meteorological) data and images recording visual air quality conditions (visibility).

Priority Pollutants

Research indicates that adverse health effects can occur at air quality levels commonly measured in the LFV. Health experts have identified exposure to ozone and particulate matter as being associated with serious health effects. Ozone is a strong oxidant that can irritate the eyes, nose and throat, and reduce lung function. Fine particulate ($PM_{2.5}$) is small enough to be breathed deeply into the lungs, resulting in impacts to both respiratory and cardiovascular systems. Long-term exposure to these pollutants can aggravate existing heart and lung diseases and lead to premature mortality.

Of particular concern is $PM_{2.5}$ that is emitted from diesel fuel combustion in car, truck, marine, rail and non-road engines. These particles ("diesel PM") are carcinogenic and are believed to contribute significantly to the health effects described above. Instrumentation installed in some air quality monitoring stations in the LFV can be used to estimate the proportion of particles that originate from diesel engines.

Air Quality Trends

Improvements have been made in air quality over the last two decades for most pollutants, including nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), volatile organic compounds (VOC) and fine particulate matter ($PM_{2.5}$). Despite significant population growth in the region over the same time period, emission reductions across a variety of sectors have brought about these improvements. The population increased in Metro Vancouver and the FVRD by about 50% from 1991 to 2016, from approximately 1.8 million to 2.8 million residents.

The long-term regional trends for ground-level ozone show a different story. Long-term trends of peak ozone concentrations show levels currently lower than those experienced in the 1980s, but peak levels have been largely unchanged over the last fifteen to twenty years. However, average concentrations of ground-level ozone have increased over the same period.

Metro Vancouver and the Fraser Valley Regional District adopted the Regional Ground-Level Ozone Strategy in 2014, which provides strategic policy direction for ozone management in the LFV based on local scientific research. Research indicates that a spatial understanding of the ratio of concentrations of nitrogen oxides (NO_X) and volatile organic compounds (VOC), two precursor pollutants that react to form ozone, is key to determining which precursors to reduce in order to maintain and improve air quality in our region.

Trends in air pollutants are discussed further by pollutant in Section D.

Wildfires and Air Quality Events

In recent years, wildfires in the Pacific Northwest have increased in severity and become more widespread. Wildfires can produce considerable amounts of smoke that can be transported great distances. The 2017 wildfire season was one of the worst in British Columbia's history, with the largest area burned.

In 2017, significant and lengthy smoke-related air quality impacts occurred due to wildfires burning in the BC Interior and the west coast of the US. These impacts led to the most air quality advisories issued in a single year by Metro Vancouver.

Wildfires and other air quality events experienced in 2017 are discussed further in Section J.

Air Quality Advisories

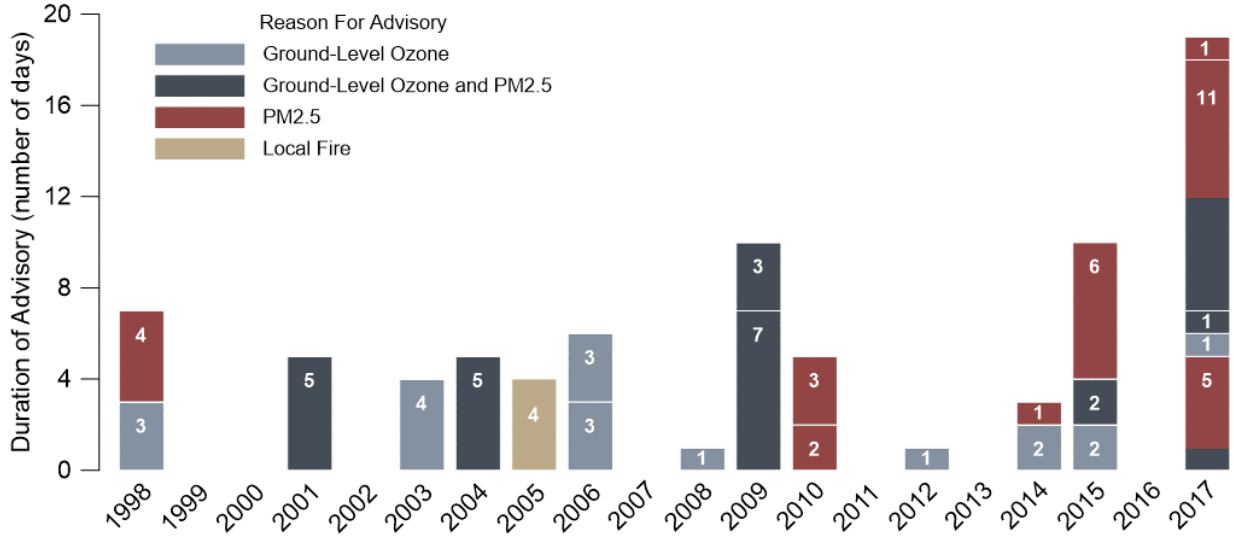
In 2017, air quality advisories were issued during five separate periods for a total of nineteen days in summer. The first advisory of the year was initiated during hot weather on July 6 due to high concentrations of ground-level ozone in the eastern parts of Metro Vancouver and the Fraser Valley. The advisory was in effect for a single day.

A one-day advisory was issued on July 18 for elevated $PM_{2.5}$ due to wildfires outside of the region. In early August an unprecedented 11-day advisory was issued (August 1) making it the longest advisory in Metro Vancouver history. During the 11-day period, $PM_{2.5}$ was elevated throughout the region on all days while O_3 was elevated for five days. The degraded air quality was the result of outflow winds that brought smoke from wildfires burning in the BC Interior.

On August 29, a one-day advisory was issued for both elevated O_3 and $PM_{2.5}$ due to wildfires burning in North California, Oregon and Washington State. In early September, a five-day advisory was initiated (September 5) which was the result of wildfire smoke from the interior of BC as well as wildfires burning in Washington State. The first day of the advisory included a ground-level ozone advisory due to elevated levels of ozone.

Periods of degraded air quality can occur in the LFV for several reasons, such as summertime smog during hot weather, smoke from forest fires and winter inversions preventing dispersion of emitted air contaminants. In cooperation with partner agencies, including the Fraser Valley Regional District, Vancouver Coastal Health Authority, Fraser Health Authority, Environment Canada and the B.C. Ministry of Environment, Metro Vancouver operates an air quality advisory program.

Air quality advisories are issued to the public when air quality has deteriorated or is forecast to deteriorate significantly within the LFV. Typically air quality advisories are issued when a pollutant exceeds or is predicted to exceed an air quality objective or standard at more than one monitoring location.



Notes:

- Criteria used for issuing advisories have changed over the years; care must be taken when interpreting advisory trends.
- The advisory in 2005 was the result of a large fire in Burns Bog.

Figure 1: Number of days of air quality advisories in the LFV.

In the last ten years, the number of days on which air quality advisories were in place has ranged from zero to nineteen days annually. Shown in Figure 1 is the historical trend of the number of days the LFV was under an advisory. The total number of advisory days is shown as a bar while the number of consecutive days of an advisory period is given by the number in white.

Air quality bulletins are used to advise the public of the occurrence of localized degraded air quality during cool weather months and actions that may be taken to reduce the emissions contributing to degraded air quality conditions.

Air Quality Health Index (AQHI)

The national health-based Air Quality Health Index (AQHI), developed by Environment Canada and Health Canada, has been in use since 2008. The AQHI communicates the health risks associated with a mix of air pollutants to the public and provides guidance on how individuals can adjust their exposure and physical activities as air pollution levels change.

The AQHI is calculated every hour using monitoring data from stations in the LFV. Current AQHI levels in the LFV, AQHI forecasts (for *today*, *tonight*, and *tomorrow*) and additional information about the AQHI are available at:

www.airmap.ca
www.airhealth.ca
www.env.gov.bc.ca/epd/bcairquality/readings/aqhi-table.xml

Environment Canada's Weather Website also publishes the AQHI.

Visual Air Quality

Degraded air quality can cause views to be partially or fully obscured by haze at times in the LFV. This is referred to as visual air quality impairment.

Throughout the LFV, the contaminant with the greatest impact on visual air quality is $PM_{2.5}$. However, the appearance of haze can be affected by the presence of a number of different air contaminants. In more urbanized areas in the west, haze may have a brownish colour. Nitrogen dioxide emissions from transportation sources contribute to this brown appearance. Further east in the LFV, a white haze can sometimes be observed as a result of small particles in the air ($PM_{2.5}$) scattering light. Secondary $PM_{2.5}$, such as that formed by reactions of NO_X and SO_2 with ammonia, as well as directly emitted (or primary) $PM_{2.5}$ contribute to this haze. Smoke, windblown dust and soil particles, as well as moisture levels in the air can affect visibility at times.

Characterization of air contaminants is being used to understand the factors contributing to visual air quality impairment in the LFV and to develop tools to evaluate visual air quality quantitatively. Data collected as part of the visual air quality monitoring program include measurements of nitrogen dioxide and $PM_{2.5}$, measurements of the constituents of particulate matter (for example particulate nitrate, particulate sulphate, elemental carbon and organic carbon) and the optical (light scattering) characteristics of ambient air samples.

In 2017, Automated digital cameras were used to record visual air quality conditions in seven locations. Images from the cameras show views along specific lines-of-sight with recognizable topographical features at known distances. The images are archived for various uses, including:

- relating air contaminant measurements to visual range and visual air quality degradation under a variety of air quality and meteorological conditions;
- assessing public perceptions of the different visual air quality conditions found in the LFV; and
- developing visual air quality measurement metrics.

Images from each of the seven monitoring locations are available online in near-real time through www.clearairbc.ca.

The monitoring data and images collected provide important input to a collaborative multi-agency initiative to develop a visual air quality management strategy for the LFV. Visual air quality is further discussed in Section F.

Air Quality Measurements

The LFV Air Quality Monitoring Network primarily employs continuous monitors which provide data in real-time every minute of the day. The network also contains specialized air quality monitors that sample the air non-continuously. Non-continuous 24-hour (daily) samples are collected on filters and/or in canisters every sixth or twelfth day depending on the site. The sampling is scheduled in accordance with the National Air Pollution Surveillance (NAPS) program. After sample collection,

filters and canisters are analyzed in a federal laboratory to determine pollutant concentrations. Non-continuous samples of volatile organic compounds (VOC) are collected at eight sites throughout the LFV. VOC refers to a group of organic chemicals. A large number of chemicals are included in this group but each individual chemical is generally present at relatively low concentrations in air compared to other common air contaminants.

Non-continuous particulate samples are collected at four monitoring stations in the LFV where pollutant concentrations are determined. A detailed analysis is conducted by the federal laboratory for three of these stations (Port Moody, Burnaby South and Abbotsford Airport).

Chemicals contained in $PM_{2.5}$ and VOC samples are identified and quantified at a federal laboratory. These data can then be used to help determine the emission sources contributing to the contaminants in the air.

Non-continuous measurements are discussed in Section E.

Section B – Air Quality Objectives and Standards

Several air quality objectives and standards are used as benchmarks to characterize air quality including the federal Canadian Ambient Air Quality Standards (CAAQS), and Metro Vancouver's ambient air quality objectives. Metro Vancouver's ambient air quality objectives are shown in Table 1. The objective or standard is achieved if the ambient concentration is at or lower than (i.e., better than) the objective.

The federal Canadian Ambient Air Quality Standards (CAAQS) have been established as objectives under the Canadian Environmental Protection Act 1999, and replaced the Canada-Wide Standards for fine particulate matter and ground-level ozone. The CAAQS were implemented in 2015 for particulate matter (PM) and ozone (O_3). In 2020, the numerical value of the CAAQS became more stringent for $PM_{2.5}$ and O_3, and nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) were also added. These set specific limits for $PM_{2.5}$, O_3, NO_2, and SO_2 based on concentrations averaged over a three-year period with the exception of the annual metric which are averaged over one year.

The CAAQS for $PM_{2.5}$ is calculated by taking an annual 98th percentile value using daily averages, averaged over three consecutive years. Achievement of the $PM_{2.5}$ CAAQS is attained when the CAAQS value is less than or equal to 27 µg/m^3.

The CAAQS for ozone is calculated by the 4th highest annual 8-hour daily maximum concentration, averaged over three consecutive years. Achievement of the ozone CAAQS is attained when the CAAQS value is less than or equal to 62 ppb.

The NO_2 CAAQS include metrics for both 1-hour and annual averages. The 1-hour CAAQS for NO_2 is calculated by taking an annual 98th percentile value using daily maximum 1-hour measurements, averaged over three consecutive years. Achievement of the 1-hour NO_2 CAAQS is attained when the CAAQS value is less than or equal to 60 ppb. The annual CAAQS for NO_2 is 17 ppb, which is compared to the average of all 1-hour concentrations collected within the year.

In 2005, as part of the Air Quality Management Plan, Metro Vancouver adopted health-based ambient air quality objectives for ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO).

In 2009 the provincial government established air quality objectives for $PM_{2.5}$. The province set an annual objective of eight micrograms per cubic metre (µg/m^3) and annual planning goal of six micrograms per cubic metre for $PM_{2.5}$.

An objective or standard is achieved if the ambient concentration is at or lower than (i.e., better than) the objective.

Metro Vancouver aligned its annual objectives for $PM_{2.5}$ in the 2011 Integrated Air Quality and Greenhouse Gas Management Plan, as well as adopting a one-hour ozone objective of 82 parts per billion.

Metro Vancouver's 24-hour $PM_{2.5}$ objective of 25 µg/m^3 is numerically the same as the province, but compliance with Metro Vancouver's objective requires that there are no exceedances and is applied as a rolling average.

In 2015, Metro Vancouver adopted a 1-hour interim ambient air quality objective for SO_2 of 75 parts per billion (ppb) prior to establishment of the federal SO_2 CAAQS. After establishment of the federal SO_2 CAAQS, Metro Vancouver's SO_2 objectives were revised in November 2017, with a more stringent 1-hour objective of 70 ppb not to be exceeded and an annual objective of 5 ppb.

In 2019, Metro Vancouver aligned its objectives for CO, NO_2 and O_3 with federal and provincial standards. Metro Vancouver adopted a 1-hour and annual ambient air quality objective for NO_2 that is the same as the federal 2020 CAAQS. Similarly, the 8-hour O_3 objective was made the same as the 2020 CAAQS. The 1-hour and 8-hour CO objectives were set to 13,000 ppb and 5,000 ppb respectively, to match the more stringent Provincial objectives.

Several of Metro Vancouver's objectives are intended to be compared with *rolling averages*. A *rolling average* is an average that is calculated by averaging the concentrations from a number of previous consecutive hours. For example, a 24-hour rolling average is calculated by averaging the concentrations measured during the previous 24 hours. A 24-hour rolling average is

calculated for each hour of the day. Similarly, an 8-hour rolling average is calculated by averaging the concentrations from the previous 8 hours.

Table 1: Metro Vancouver's ambient air quality objectives.

Air Contaminant	Averaging Period	Ambient Air Quality Objective[a]	
		µg/m³	ppb
Carbon monoxide (CO)	1-hour	30,000 (14,900*)	26,200 (13,000*)
	8-hour[b]	10,000 (5,700*)	8,700 (5,000*)
Nitrogen dioxide (NO_2)	1-hour	200 (113*[c])	106 (60*[c])
	Annual	40 (32*)	21 (17*)
Sulphur dioxide (SO_2)	1-hour	183	70
	Annual	13	5
Ozone (O_3)	1-hour	161	82
	8-hour	128[b] (122*[d])	65 (62*[d])
Inhalable particulate matter (PM_{10})	24-hour	50[b]	
	Annual	20	
Fine particulate matter ($PM_{2.5}$)	24-hour	25[b]	
	Annual	8 (6[e])	
Total reduced Sulphur (TRS)	1-hour (acceptable)	14	10
	1-hour (desirable)	7	5

*Metro Vancouver's Board adopted more stringent air quality objectives in November of 2019.

[a] Except where noted, Metro Vancouver objectives are "not to be exceeded", meaning the objective is achieved if 100% of the validated measurements are at or below the objective level.

[b] Achievement based on rolling average.

[c] Achievement based on annual 98th percentile of the daily maximum 1-hour concentration, averaged over three consecutive years.

[d] Achievement based on annual 4th highest daily maximum 8-hour average concentration, averaged over three consecutive years.

[e] Metro Vancouver's annual $PM_{2.5}$ planning goal of 6 µg/m³ is a longer term aspirational target to support continuous improvement.

Section C – Lower Fraser Valley Air Quality Monitoring Network

Metro Vancouver operates the LFV Air Quality Monitoring Network which consists of air quality monitoring sites located between Horseshoe Bay in West Vancouver and Hope. The locations of the monitoring stations operated in 2017 are shown in Figure 2 while the pollutants and meteorology measured at each station are identified in Table 2.

In 2017, there were 31 air quality monitoring stations in the network which includes 25 stations located in Metro Vancouver and 6 stations located in the FVRD. There are also 3 stations in Metro Vancouver that provide only weather data. Air quality and weather data are collected automatically on a continuous basis, transmitted to Metro Vancouver's head office in Burnaby, and stored in a database. The data are then used to provide information to the public through the AQHI, Metro Vancouver's website, the BC air quality website, and reports. At one of the stations (White Rock) particulate matter is sampled throughout the year on a defined periodic schedule. These non-continuous data are not collected automatically to the database.

Many pollutants measured are discussed in this report with a focus on common air contaminants: particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2).

Comparisons of measured levels of these air contaminants with federal, provincial and Metro Vancouver air quality objectives and standards and an assessment of regional trends are provided in Section D. The locations of SO_2, O_3, NO_2 and $PM_{2.5}$ monitoring in 2017 are shown in Figures 3 to 6.

Portable equipment was used to carry out short-term air quality monitoring studies (specialized studies) in 2017. The equipment employed in specialized studies includes Metro Vancouver's Mobile Air Monitoring Unit (MAMU) which is capable of monitoring gaseous and particulate pollutants in the same way as other monitoring stations in the network. Specialized studies and other monitoring activities undertaken are described in Sections G, H and I.

Real-time data from the LFV Air Quality Monitoring Network can be accessed on Metro Vancouver's website at: www.airmap.ca

Additional information on the LFV Air Quality Monitoring Network is available in the 2012 report "Station Information: Lower Fraser Valley Air Quality Monitoring Network". This report is available at: www.metrovancouver.org

Data completeness for the year 2017 is shown in Table 3. In Table 3 the annual completeness is provided numerically while each quarter shown as green if completeness for that quarter is greater than or equal to 75%, red if below 75% and white if no data exists.

Network Changes

There are ongoing enhancements to stations and equipment that occur throughout the air quality monitoring network.

Network improvement highlights for 2017 included completion of reconfiguration of incoming solar radiation measurement locations, addition of meteorological parameters at the North Vancouver – Second Narrows station and the Vancouver-Clark Drive near-road monitoring station became part of the network.

Changes to the network in 2017 include:

- A pyranometer was added to the Burnaby North station and removed from the N. Vancouver-Mahon Park and Coquitlam stations.
- N. Vancouver-Second Narrows station housing was changed from a one-storey building to a trailer located with several metres of the previous location.
- Air temperature, relative humidity and precipitation instrumentation was added to the N. Vancouver-Second Narrows station.
- The Vancouver-Clark Drive near-road monitoring station became part of the network, with analysis of its data included in this report and an SO_2 analyzer was added.
- The Surrey East station was temporarily relocated from its historical location at the Clayton Reservoir to a location approximately 100 metres north at a City of Surrey park.

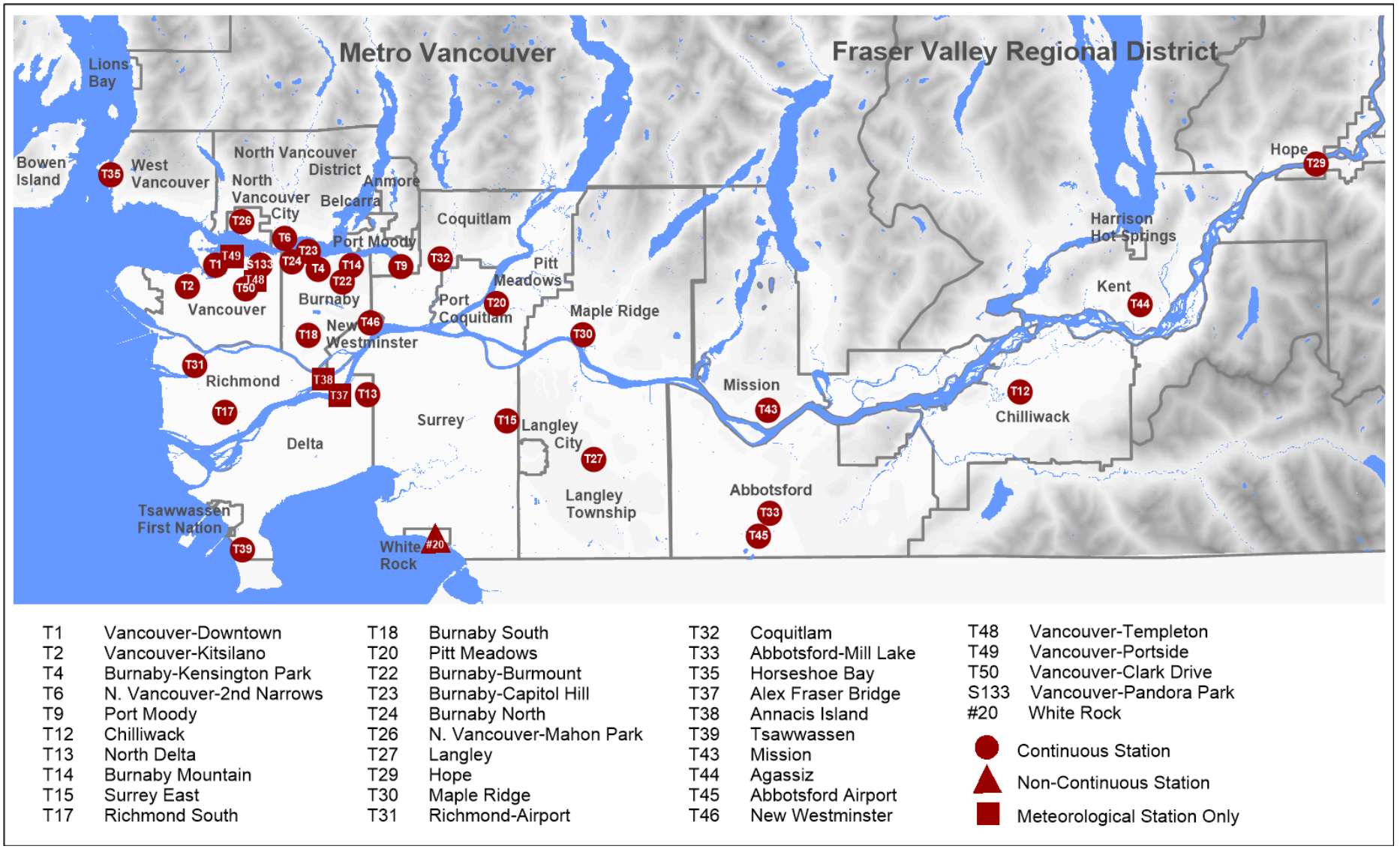


Figure 2: Lower Fraser Valley air quality monitoring network, 2017.

Table 2: Air quality monitoring network, 2017.

Stations		Air Quality Monitors														Meteorology					
		Continuous											Non-Continuous								
		Gases							Particulate Matter												
ID	Name	SO_2	TRS	NO_2	CO	O_3	THC	NH_3	PM_{10}	$PM_{2.5}$	BC	NEPH	VOC	SP	D	Wind	T_{air}	SR	RH	BP	Precip
T1	Vancouver-Downtown	√		√	√	√															
T2	Vancouver-Kitsilano	Station temporarily out of service																			
T4	Burnaby-Kensington Park	√	√	√	√	√			√	√						√	√		√		
T6	N. Vancouver-2nd Narrows	√		√	√	√				√	√					√	√		√		√
T9	Port Moody	√	√	√	√	√			√	√	√		√		√	√	√	√	√		√
T12	Chilliwack	√		√	√	√		√	√	√	√	√	√			√	√	√	√	√	√
T13	North Delta			√		√				√						√	√		√		√
T14	Burnaby Mountain			√		√										√	√		√		√
T15	Surrey East			√	√	√				√						√	√				√
T17	Richmond South	√		√	√	√				√						√	√		√		√
T18	Burnaby South	√		√	√	√			√	√	√	√	√	√	√	√	√		√	√	√
T20	Pitt Meadows	√		√		√				√	√	√				√	√		√	√	√
T22	Burnaby-Burmount		√				√						√			√	√				
T23	Burnaby-Capitol Hill	√	√													√	√		√		
T24	Burnaby North	√	√				√		√				√			√	√	√	√		√
T26	N. Vancouver-Mahon Park	√		√	√	√				√						√	√	√	√	√	√
T27	Langley	√		√	√	√			√	√						√	√		√	√	√
T29	Hope			√	√	√			√	√						√	√		√		√
T30	Maple Ridge			√	√	√										√	√		√		√
T31	Richmond-Airport	√		√	√	√			√	√	√	√	√			√	√	√	√	√	√
T32	Coquitlam			√	√	√										√	√	√	√	√	√
T33	Abbotsford-Mill Lake	√		√	√	√		√	√	√						√	√		√		√
T35	Horseshoe Bay				√					√						√	√		√		√
T37	Alex Fraser Bridge	Station temporarily out of service																			
T38	Annacis Island															√	√		√		√
T39	Tsawwassen	√		√	√	√				√						√	√		√		√
T43	Mission			√		√				√						√	√		√		√
T44	Agassiz			√		√				√						√	√		√		√
T45	Abbotsford Airport	√		√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√
T46	New Westminster			√		√				√						√					
T48	Vancouver-Templeton															√	√		√		
T49	Vancouver-Portside															√	√		√		√
T50	Vancouver-Near-Road	√		√	√	√				√	√		√	√	√	√	√		√		
S133	Vancouver-Pandora	√																			
#20	White Rock														√						
Total Monitoring Units		**18**	**5**	**24**	**19**	**24**	**2**	**3**	**10**	**21**	**8**	**5**	**8**	**3**	**5**	**30**	**29**	**7**	**27**	**8**	**24**

SO_2 = sulphur dioxide; TRS = total reduced sulphur; NO_2 = nitrogen dioxide; CO = carbon monoxide; O_3 = ozone; THC = total hydrocarbon; NH_3 = ammonia;

PM10 = inhalable particulate matter; $PM_{2.5}$ = fine particulate matter; NEPH = particulate light scattering; VOC = volatile organic compounds; SP = particulate speciation;

D = dichotomous particulate; BC = Black Carbon; Wind = wind speed and direction; T_{air} = air temperature; SR = incoming solar radiation; RH = relative humidity;

BP = barometric pressure; Precip = precipitation; √ = monitored at this location.

Table 3: Annual and quarterly data completeness, 2017.

Stations		Air Quality Monitors											Meteorology						
		Gases							Particulate Matter										
ID	Name	SO_2	TRS	NO_2	CO	O_3	THC	NH_3	PM_{10}	$PM_{2.5}$	BC	UFP	Wind Spd	Wind Dir	Tair	SR	RH	BP	Precip
T01	Vancouver-Downtown	92		96	93	96													
T02	Vancouver-Kitsilano																		
T04	Burnaby-Kensington Park	98	98	98	96	99			96	98			99	100	99		99		
T06	N. Vancouver-2nd Narrows	96		96	94	95				96	95		96	96	60		60		60
T09	Port Moody	98	98	98	97	98			99	98	91		99	99	99	99	99		99
T12	Chilliwack	97		97	95	97		97	92	99	86		98	99	100	100	99	100	100
T13	North Delta			97		97				98			99	98	99		99		99
T14	Burnaby Mountain			98		99							100	100	100		100		100
T15	Surrey East			90	90	88				90			91	92	92				91
T17	Richmond South	94		97	97	97				94			98	98	97		97		98
T18	Burnaby South	91		98	98	98			100	96	100		100	99	100		100	100	100
T20	Pitt Meadows	95		98		95				99	100		99	99	100		100	100	100
T22	Burnaby-Burmount		95				96						99	99	99				
T23	Burnaby-Capitol Hill	98	97										100	100	100		100		
T24	Burnaby North	99	98				96		100				100	100	99		99		91
T26	N. Vancouver-Mahon Park	94		98	98	98				99			100	100	100	47	100	100	100
T27	Langley	98		98	97	97			99	99			99	99	100		100	100	100
T29	Hope			97	97	96			98	98			100	100	100		100		100
T30	Maple Ridge			99	86	95							100	100	100		97		100
T31	Richmond-Airport	98		98	97	98			100	100	98		100	100	100	100	100	100	100
T32	Coquitlam			79	79	80							81	80	80	45	80	80	80
T33	Abbotsford-Mill Lake	97		97	97	97		76	97	97			98	99	99		98		99
T35	Horseshoe Bay				96					97			99	100	100		100		100
T38	Annacis Island												83	82	83		83		21
T39	Tsawwassen	97		98	96	97				96			98	98	98		98		98
T43	Mission			97		98				86			98	98	98		98		98
T44	Agassiz			98		96				99			98	98	99		99		99
T45	Abbotsford Airport	96		91	94	96		87	94	86	97		89	88	90	90	90	90	90
T46	New Westminster			96		96				97			100	100					
T48	Vancouver-Templeton												80	80	80		80		
T49	Vancouver-Portside												99	99	100		100		87
T50	Vancouver-Clark Drive	48		96	95	94				96	92	95	66	90	90		90		
S133	Vancouver-Pandora Park	91											100	100	100		100	100	

Note: Quarterly completeness ≥ 75% is shown in green, < 75% is shown in red, and no data is white, while annual completeness is shown numerically.

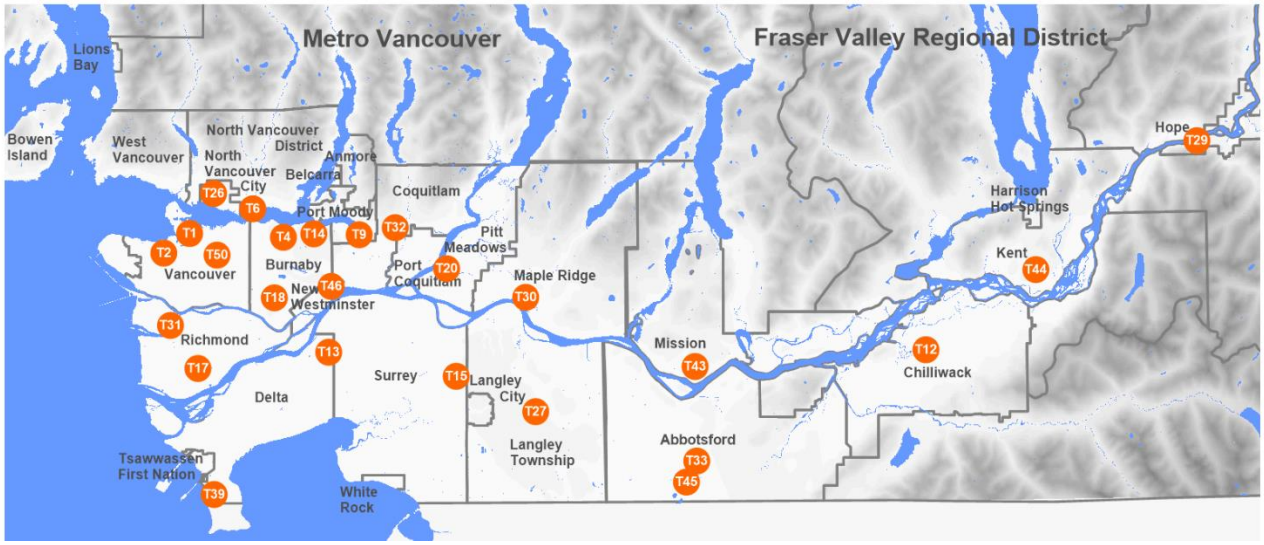


Figure 3: Ground-level ozone and nitrogen dioxide monitoring stations, 2017.

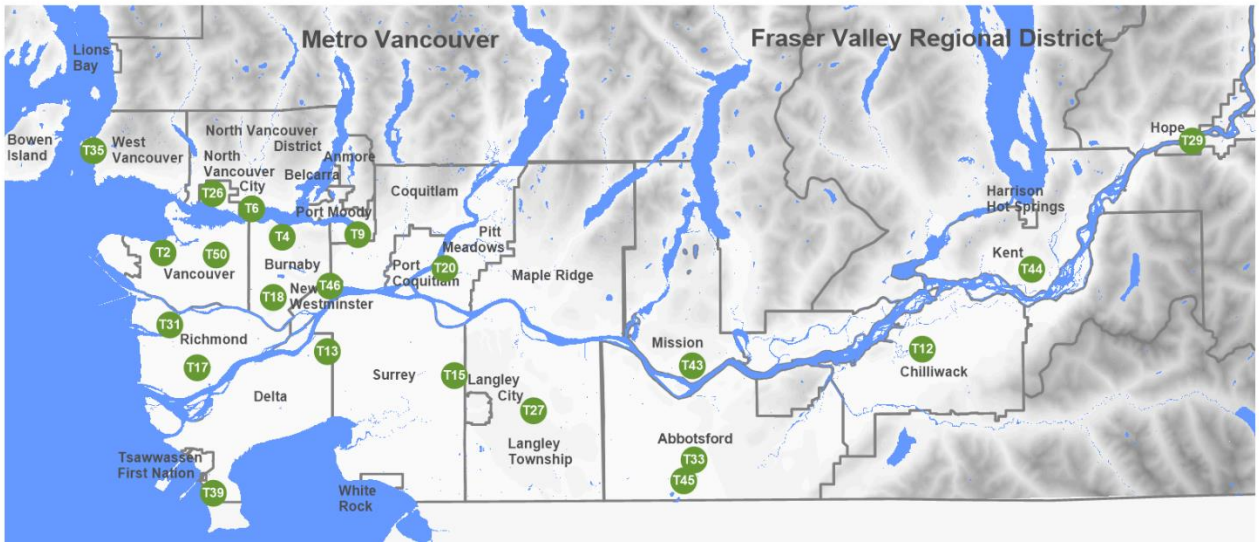


Figure 4: Fine particulate matter ($PM_{2.5}$) monitoring stations, 2017.

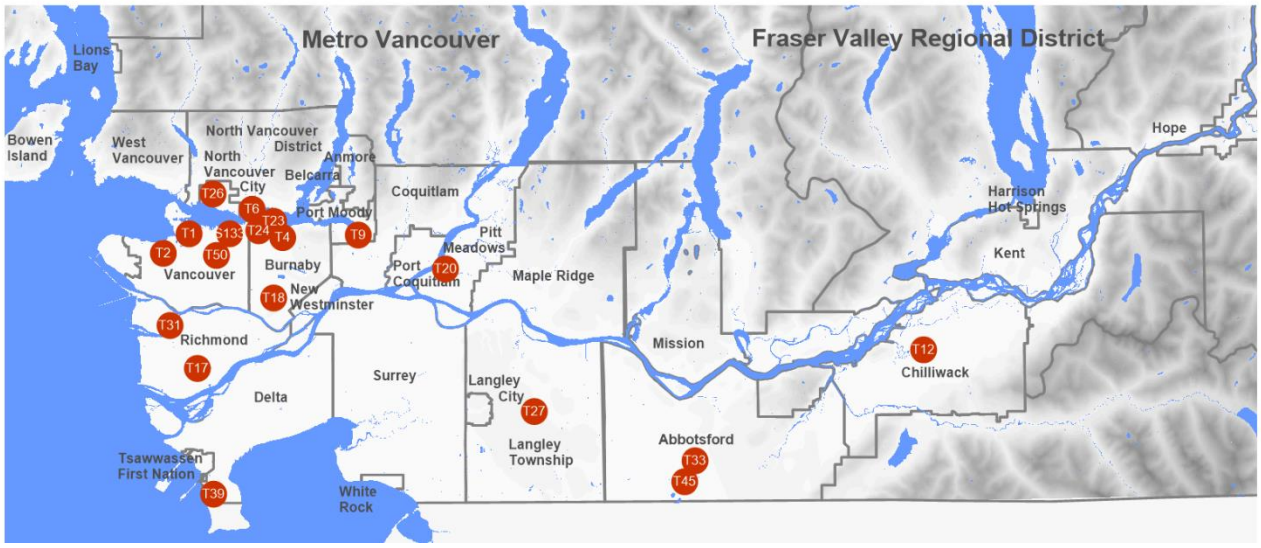


Figure 5: Sulphur dioxide monitoring stations, 2017.

Section D – Continuous Pollutant Measurements

Ozone (O_3)

Characteristics

Ozone (O_3) is a reactive form of oxygen. It is a major pollutant formed when NO_X and reactive volatile organic compounds (VOC) react chemically in the presence of heat and sunlight. Sunlight plays a significant role in O_3 production and as such, local maximum O_3 concentrations are usually experienced during the summer in the LFV.

Naturally occurring O_3 in the upper level of the atmosphere, known as the stratosphere, shields the surface from harmful ultraviolet radiation. However, at ground level, O_3 is a major environmental and health concern. Ozone is a significant oxidant and can irritate the eyes, nose and throat as well as reduce lung function. High concentrations can also increase the susceptibility to respiratory disease and reduce crop yields.

Sources

Ozone is termed a secondary pollutant because it is not usually emitted directly into the air. Instead, it is formed from chemical reactions involving pollutants identified as precursors, including NO_X and reactive VOC. The levels of O_3 measured depend on the emissions of these precursor pollutants.

Nitrogen oxide (NO_X) emissions are dominated by transportation sources. About 60% of the emissions come from cars, trucks, ships, rail and planes. Other sources include non-road engines, boilers and building heating systems.

The main contributors to VOC emissions are chemical products use (industrial, commercial and consumer products such as paints, varnishes and solvents), natural sources (trees and vegetation), cars and light trucks and non-road engines.

The formation of O_3 occurs readily during hot and sunny weather conditions with peak levels observed in the summer. Under these conditions, the highest levels generally occur downwind of major precursor emissions such as in eastern parts of Metro Vancouver and in the FVRD.

Monitoring Results

Figures S7 and 6 illustrate the results of O_3 monitoring in 2017. Figure 6 represents a bubble plot which shows three types of information: maximum 1-hour, maximum 8-hour and annual average concentrations for each ozone monitoring station. In Figure 6 the bubble position on the x-axis denotes the maximum 1-hour average, the position on the y-axis denotes the maximum 8-hour rolling average and the size of the bubble is proportional to the annual average. The Metro Vancouver 1-hour and 8-hour objectives are also provided on the plot as lines and areas of exceedance are shaded grey. The stations plotted above the 8-hour objective (65 ppb) all exceeded the objective while the stations to the right of the 1-hour objective (82 ppb) exceeded both objectives. Stations towards the top right have higher pollutant concentrations, those towards the bottom left have better air quality. The same values are represented spatially in Figures 7 to 9 while the Canadian Ambient Air Quality Standard (CAAQS) is shown in Figure 10.

In 2017, elevated levels of ground-level ozone formed during hot and sunny weather as well as some days with smoky conditions. There were exceedances of the 1-hour Metro Vancouver objective on six days and the 8-hour objective on twelve days.

In 2017, the Canadian Ambient Air Quality Standard (CAAQS) was exceeded at Hope. The CAAQS value is calculated by the annual 4th highest 8-hour daily maximum, averaged over three consecutive years. The 2017 year included two years (2015 and 2017) that had hot summers and considerable wildfire smoke. In both summers smoke from wildfires acted to enhance ozone production resulting in higher concentrations. The CAAQS calculation methodology allows for the removal

of days that are influenced by wildfire events. As such, when wildfire days are removed from the calculation, the ozone CAAQS at Hope is not in exceedance.

The Burnaby Mountain station measured the highest average ozone level which is typical given the station's high elevation on the top of Burnaby Mountain.

There were periods during the summer of 2017 when conditions were conducive for ozone formation resulting in elevated ozone levels in the LFV. The 1-hour Metro Vancouver objective was exceeded at eight stations on a combination of six days with the highest value of 94 ppb measured in both Mission and Hope. Exceedances occurred on June 25th at Maple Ridge; August 2nd at Abbotsford-Mill Lake, Chilliwack, and Agassiz; August 3rd at Mission, Chilliwack, Agassiz, and Hope; August 9th at Mission; August 10th at Mission, Chilliwack, Agassiz, and Hope; and August 29th at Burnaby-Kensington Park, Chilliwack, Burnaby Mountain, Hope, Maple Ridge, Abbotsford-Mill Lake, Mission and Agassiz. Exceedances in the western portion of Metro Vancouver (i.e., Burnaby) are not common. For example, Burnaby-Kensington Park has not exceeded the 1-hour objective since 1990 and it is thought that ozone was enhanced on August 29, 2017 due to wildfire smoke that was prevalent throughout the region.

The 8-hour Metro Vancouver objective was exceeded on twelve days including June 24, 25 and 29, July 5 and 6, and August 2, 3, 7, 9, 10, 11 and 29 at a combination of 13 stations. The highest value of 80 ppb was measured in Mission.

Air quality advisories were issued in 2017 due to a combination of elevated ozone and/or fine particulate matter. In 2017, air quality advisories were issued due to ground-level ozone on eight days. One air quality advisory was issued in July due to just ozone, while the other seven were issued due to ozone and $PM_{2.5}$ during periods of unprecedented wildfire smoke.

Results of the wildfire smoke influence are discussed further in Section J.

The highest short-term O_3 concentrations occur in the eastern parts of Metro Vancouver and in the FVRD (Figures 8, 9 and 10). The lowest annual O_3 averages (Figure 7) occur in highly urbanized areas due to O_3 scavenging. Ozone scavenging occurs in locations where higher levels of NO_x are found (e.g. urban areas or near busy roadways). In these areas, emissions containing NO_x, react quickly with O_3 to form NO_2 (nitrogen dioxide) and O_2 (oxygen) thus decreasing O_3 concentrations.

The seasonal variation evident in Figure 11 is typical of historical ozone trends in the LFV with higher values in spring and summer, and lower values during fall and winter. Since O_3 is produced by photochemical reactions there is greater production in spring and summer with the presence of sunlight and land- and sea-breeze wind patterns. Spring exhibits the highest average O_3 concentrations (Figure 11 left) while the highest short-term hourly concentrations (Figure 11 right) occur in the summer.

Figure 12 illustrates the long-term annual average O_3 trend in the LFV. Annual O_3 levels have shown an upward trend since the mid-90s. Research indicates that background ozone concentrations are rising and is one factor for observed increases in average levels.

A trend in short-term peak O_3 concentrations (Figure 12) is less apparent. Yearly differences are likely related to variability in meteorology, however there doesn't appear to be a significant trend in peak concentrations. Peak ozone levels have been mostly unchanged during the last fifteen to twenty years, despite significant reductions in ozone precursor pollutants over the same time period.

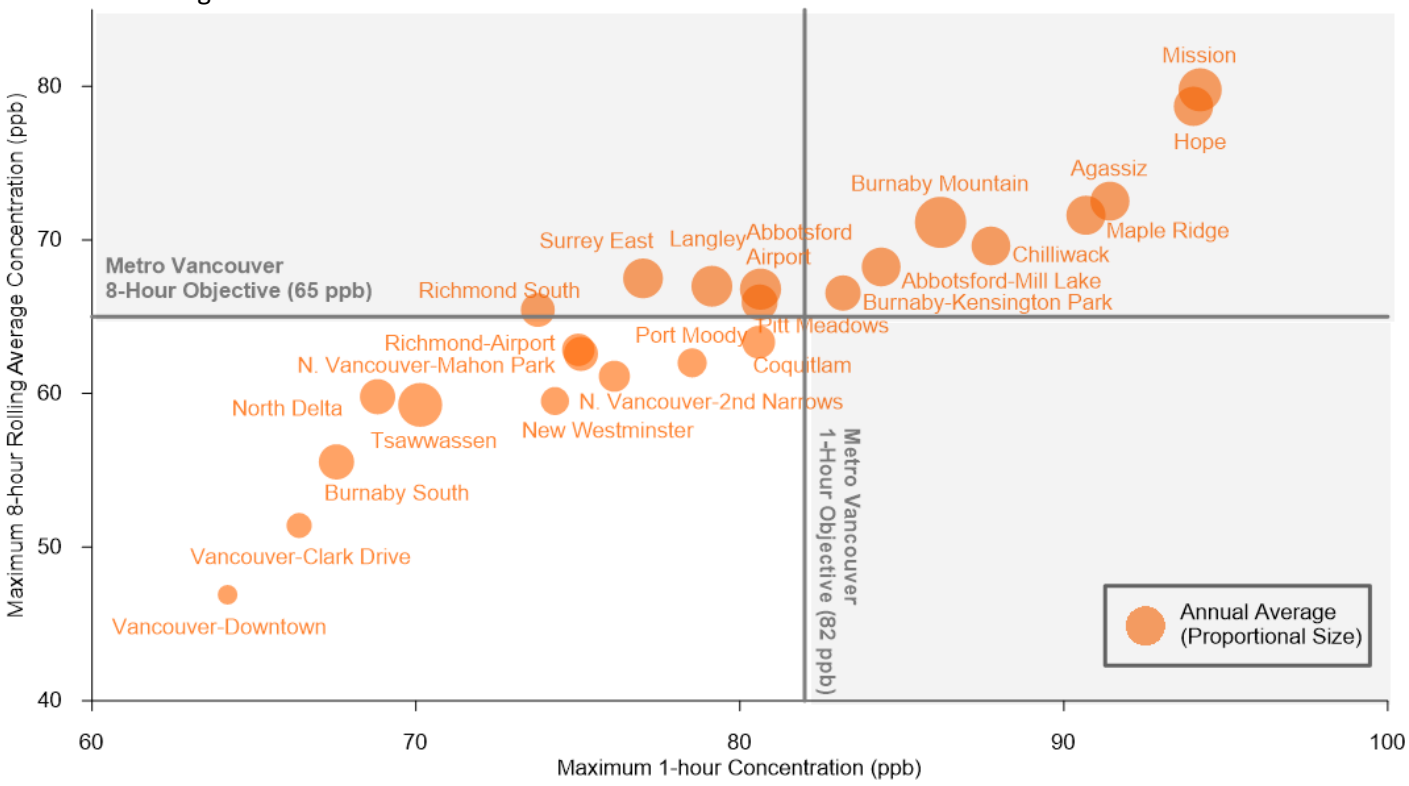
Metro Vancouver and the Fraser Valley Regional District adopted the Regional Ground-Level Ozone Strategy in 2014, which provides strategic policy direction for ozone management in the LFV based on local scientific research. Research indicates that a spatial understanding of the ratio of concentrations of nitrogen oxides (NO_X) and volatile organic compounds (VOC), two precursor pollutants that react to form ozone, is key to determining which precursors to reduce in order to maintain and improve air quality in our region.

The values in Tables 4 and 5 represent the frequency distribution (or count) of how many hourly and 8-hour rolling average measurements were in the specified ranges, respectively. The frequency distributions in these tables show how often various O_3 levels are reached. It can be seen that stations located in the eastern parts of Metro Vancouver and in the FVRD measured the greatest frequency of high O_3 concentrations.

A series of diurnal plots are shown in Figure 13 for each O_3 monitoring station. The plots illustrate the differences between weekdays and weekends along with differences between summer and winter. Most of the stations exhibit similar diurnal trends. In the summer, O_3 concentrations

are low through the night and begin increasing near sunrise with the highest (peak) concentration occurring in the afternoon. Examining the timing of the peak shows, in general, that the stations in the west peak first while the stations in the east peak a few hours later with Hope typically experiencing the latest peak in the day. Noon is marked on the figure as a black vertical line for reference.

On very hot sunny days, typically during a summertime episode, the O_3 peak occurs later in the day. Winter shows a similar trend of an afternoon peak although it is greatly attenuated compared with the summer.



Note: Stations contained within the grey area denote an exceedance of an objective.

Figure 6: Ground-level ozone monitoring, 2017.

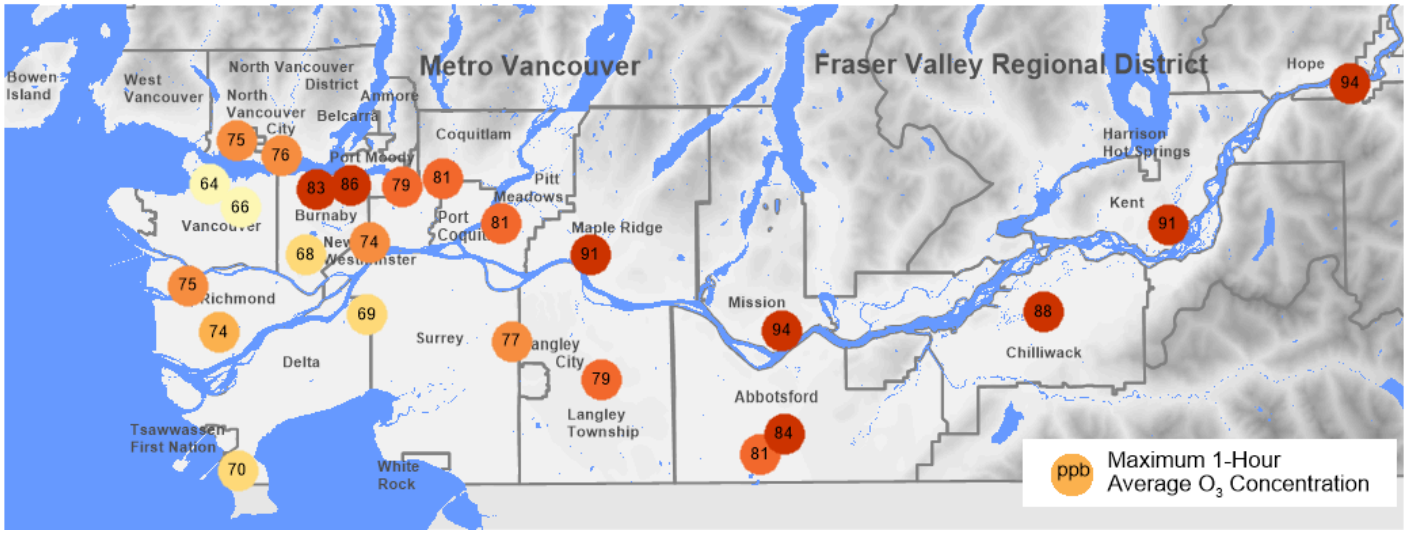


Figure 7: Short-term peak (maximum 1-hour) ozone in the LFV, 2017.

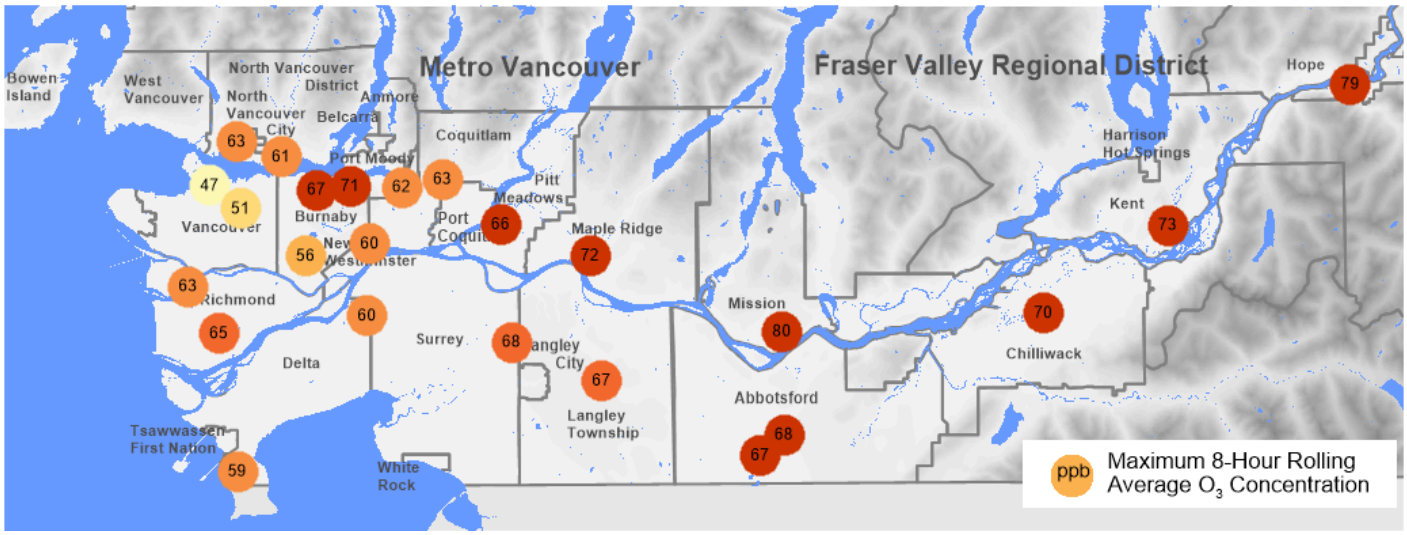


Figure 8: Short-term peak (maximum 8-hour) ozone in the LFV, 2017.

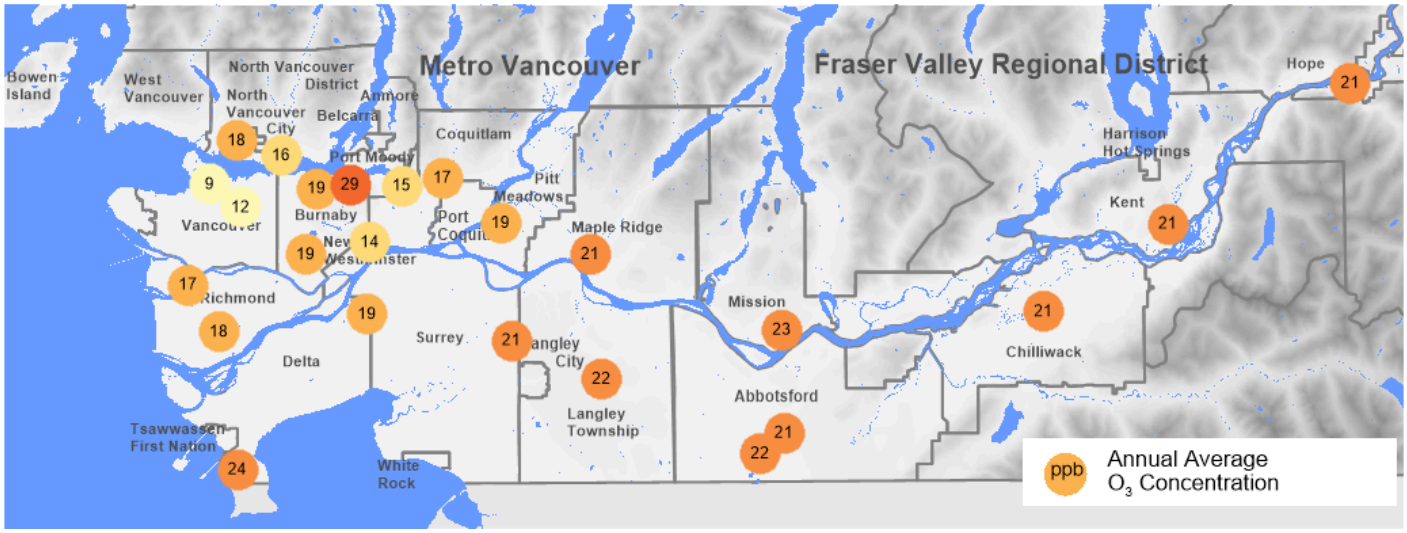


Figure 9: Annual average ozone in the LFV, 2017.

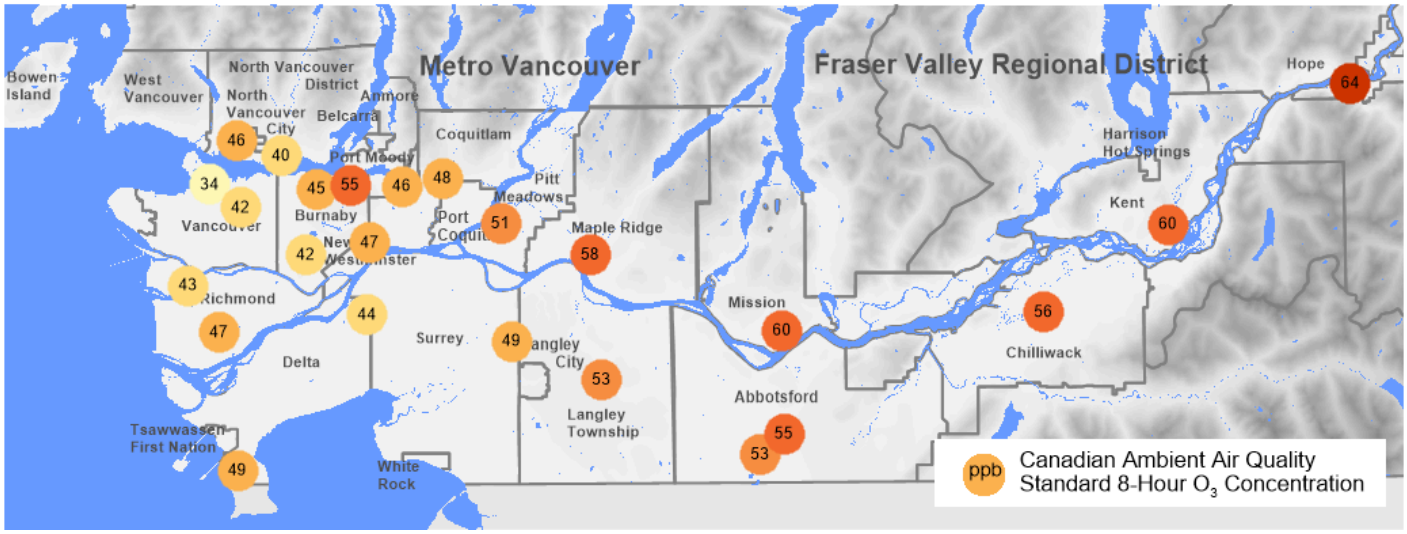


Figure 10: Canadian Ambient Air Quality Standard value for ozone in the LFV, 2017.

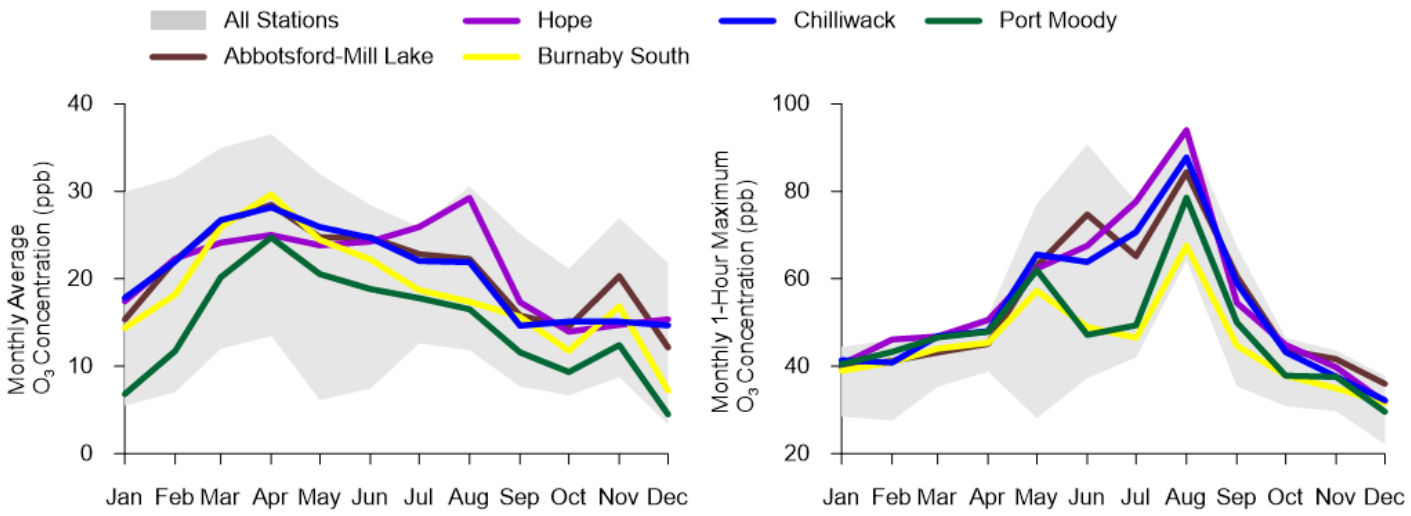


Figure 11: Monthly average (left) and short term peak (right) ozone, 2017.

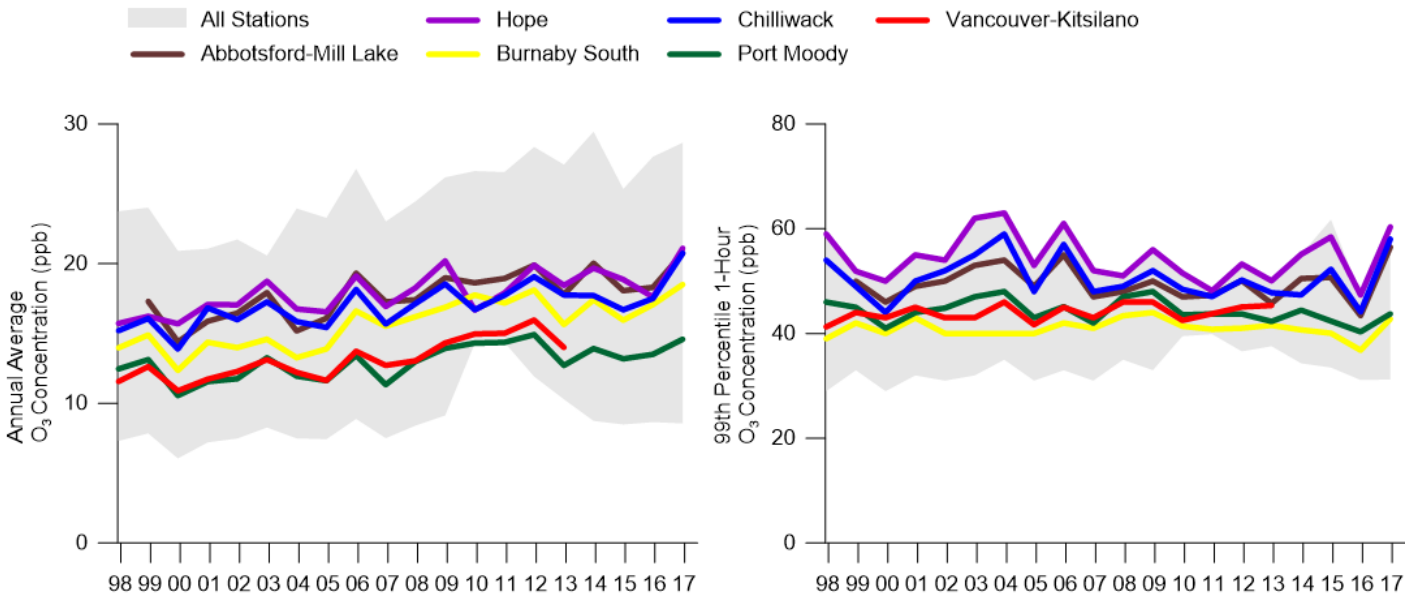


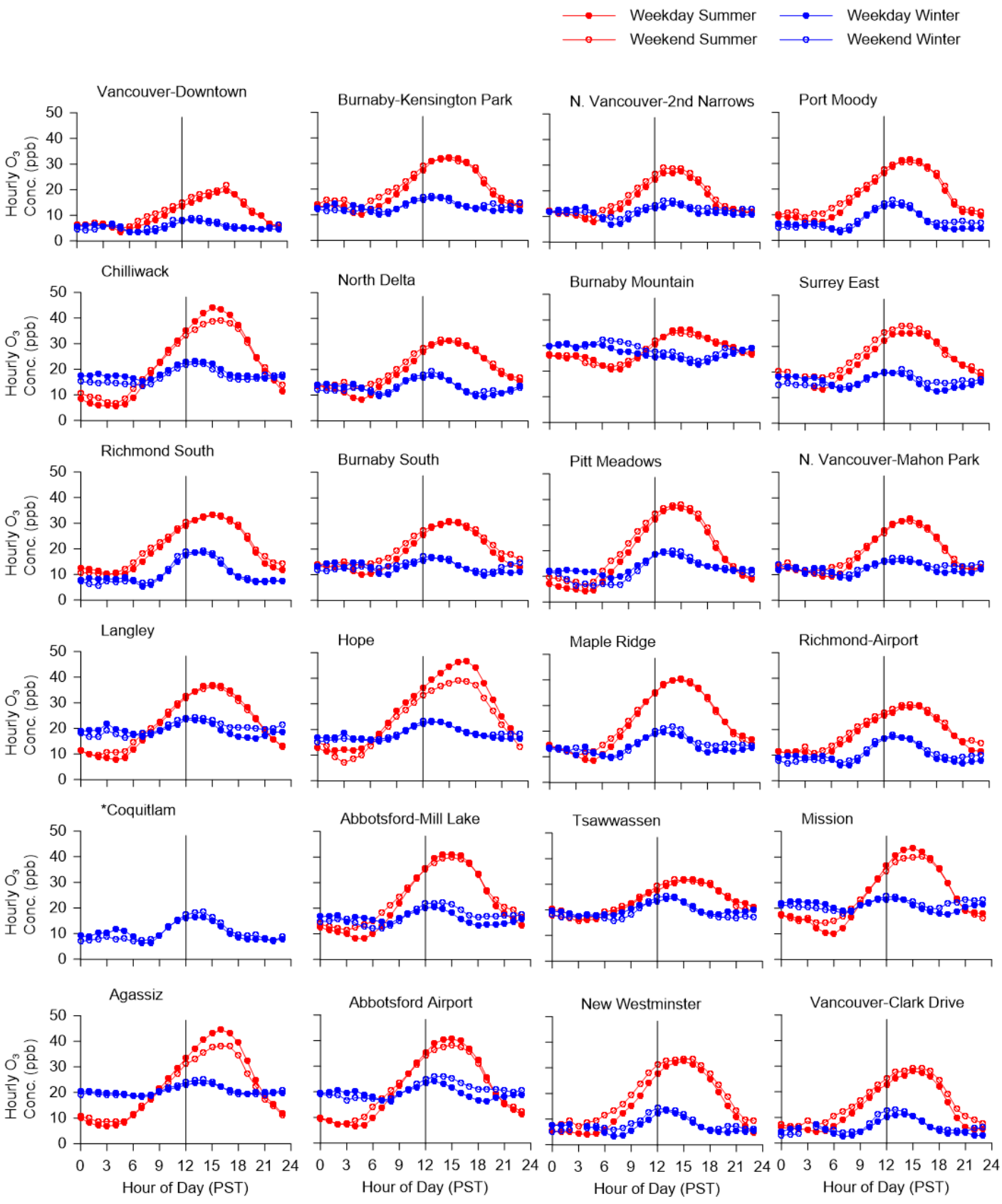
Figure 12: Annual (left) and short term peak (right) ozone trend, 1998 to 2017.

Table 4: Frequency distribution of hourly ozone, 2017.

O_3 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to 4	3145	1099	1394	2344	1190	1324	75	814	2010	997	1828	1415	1065	1165	1066	1819	1454	1034	519	543	1088	953	2621	2860
4 to 8	1638	763	1031	926	623	649	126	460	604	826	586	725	497	714	601	665	699	627	332	496	622	597	922	856
8 to 12	1250	833	964	849	688	804	220	614	632	837	556	808	473	710	715	748	687	803	474	668	730	682	780	820
12 to 16	925	1005	1028	864	821	891	405	734	773	1026	650	926	655	742	791	845	644	820	698	725	762	746	746	861
16 to 20	645	1084	1000	776	813	935	746	858	755	958	654	1069	864	768	868	1003	679	864	974	956	871	732	731	789
20 to 24	398	999	902	710	895	941	1079	942	801	1080	809	956	877	768	833	925	660	816	1085	946	875	747	656	694
24 to 28	232	943	715	688	919	967	1312	922	837	1032	812	942	1035	834	826	932	596	872	1143	1110	887	829	574	500
28 to 32	100	760	611	589	723	852	1423	904	739	783	793	778	1039	721	804	741	549	883	1113	1037	818	833	478	345
32 to 36	39	618	417	426	633	593	1277	724	576	538	666	460	931	721	709	542	483	830	918	863	654	830	397	228
36 to 40	14	290	182	229	590	338	1123	476	400	312	526	290	596	584	487	271	277	497	679	635	599	771	228	144
40 to 44	6	143	67	98	287	156	541	197	256	125	252	138	265	319	321	88	139	177	393	277	241	365	142	69
44 to 48	5	40	19	43	82	52	161	101	77	30	91	47	104	138	127	14	52	88	124	90	74	134	45	19
48 to 52		23	5	15	73	16	67	32	29	16	27	23	43	65	48	7	18	45	29	54	47	47	15	9
52 to 56	2	7	2	7	47	7	26	21	5	5	24	9	25	50	37	1	9	40	13	46	46	38	13	8
56 to 60	2	5	1	3	35	3	24	10	4	7	17	9	12	34	29	4	8	25	7	33	42	25	8	1
60 to 64	2	8	1	4	25	2	13	6	6	6	9	3	13	28	24	1	2	22	7	30	24	16	7	2
64 to 68	1	2	2	1	12	2	9	3	4	1	9	2	8	19	8	1	3	14	3	18	16	13	2	1
68 to 72		2		3	14	1	5	4	2		6	2	4	9	7	1	3	11	1	14	10	10	3	
72 to 76		2	1	3	6		4	1	3		3	4	6	12	6	2		9		6	6	9	1	
76 to 80		1	1	2	2			2			1		2	7	6			1		11	4	2		
80 to 84		2			5		4				1			4	2		1	5		5	4	2		
>=84					3		1							7	4			1		6	5			
Missing Data	346	125	411	172	273	225	119	929	240	176	435	147	234	339	434	144	1791	272	248	189	329	377	380	545
Completeness	96%	99%	95%	98%	97%	97%	99%	89%	97%	98%	95%	98%	97%	96%	95%	98%	80%	97%	97%	98%	96%	96%	96%	94%

Table 5: Frequency distribution of 8-hour rolling average ozone, 2017.

O_3 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to 4	2557	801	1041	1807	679	955	19	578	1391	711	1349	994	750	789	746	1282	1087	682	355	285	613	591	1953	2217
4 to 8	2098	751	1035	1085	754	759	68	500	817	818	698	748	531	763	637	918	713	659	322	410	757	591	1208	1190
8 to 12	1557	867	1143	1062	857	838	174	658	852	902	729	996	624	859	727	879	851	850	436	686	809	762	1073	1150
12 to 16	1094	1168	1222	1082	983	1019	360	806	936	1122	805	1108	756	876	898	1057	824	965	730	906	960	974	947	1133
16 to 20	652	1278	1153	987	1004	1152	767	932	1009	1215	842	1189	989	870	1067	1200	857	1036	1138	1091	1005	859	956	938
20 to 24	300	1177	1062	828	989	1123	1166	1087	919	1248	853	1182	1017	930	965	1064	729	978	1160	1176	1037	816	734	750
24 to 28	140	1093	760	783	936	1005	1488	985	934	1094	927	1050	1102	937	938	939	640	967	1260	1181	982	934	623	459
28 to 32	32	733	578	544	783	862	1555	989	695	810	892	752	1096	754	888	738	625	932	1173	1022	748	860	471	260
32 to 36	21	531	305	316	689	582	1385	736	537	473	596	379	917	762	727	462	396	829	940	925	668	879	296	125
36 to 40	6	206	112	140	512	236	1102	428	324	215	439	204	610	529	438	144	203	390	684	589	589	747	127	95
40 to 44	3	75	20	39	155	71	416	118	143	61	185	80	159	239	207	31	80	128	316	172	147	296	75	24
44 to 48	7	15		6	99	16	136	62	33	11	35	18	60	91	69	5	19	67	59	78	81	76	15	7
48 to 52		11	2	9	50	6	32	16	6	7	22	4	25	52	54		10	41	17	46	35	32	13	5
52 to 56		7	2	8	41	1	19	10	5	7	13	8	19	38	23	2	3	32	5	47	36	30	6	
56 to 60		7	2	5	27	4	26	10	6		11	4	10	21	17	2	4	17	3	29	17	15	5	
60 to 64		5	1	2	14		10		3		6	3	7	15	10	2	4	11		17	18	12		
64 to 68		2			9		8	4	2		3		5	15	11			12		8	7	5		
68 to 72					2		7							9	9			1		8	7			
>=72														13						8	1			
Missing Data	293	33	322	57	177	131	22	841	148	66	355	41	83	198	329	35	1715	163	162	76	243	281	258	407
Completeness	97%	100%	96%	99%	98%	99%	100%	90%	98%	99%	96%	100%	99%	98%	96%	100%	80%	98%	98%	99%	97%	97%	97%	95%



*Data completeness requirements were not met at this site in summer.

Figure 13: Diurnal trends ozone, 2017.

Fine Particulate ($PM_{2.5}$)

Characteristics

The term '$PM_{2.5}$' has been given to airborne particles with a diameter of 2.5 micrometres (μm) or less, also known as fine particulate matter. Particles of this size make up a fraction of PM_{10} (those particles with a diameter of 10 micrometres or less) which can vary with factors such as season and location. Within the LFV, emissions of $PM_{2.5}$ represent approximately one-half of the PM_{10} emissions, which is a typical value for North American urban environments.

Given the very small size of these particles, they can penetrate into the finer structures of the lungs. As with inhalable particulate (PM_{10}), exposure to fine particulate ($PM_{2.5}$) can lead to both chronic and acute human health impacts, aggravate pulmonary or cardiovascular disease, increase symptoms in asthmatics and increase mortality. Fine particulate matter is considered by health experts to be an air pollutant of serious concern because of these health effects.

Fine particulate is also effective at scattering and absorbing visible light. In this role $PM_{2.5}$ contributes to regional haze and impaired visual air quality.

Sources

Emissions of $PM_{2.5}$ are dominated by heating, transportation, industrial sources and non-road engines. In addition to these local sources, $PM_{2.5}$ can be transported long distances in the air from sources such as large forest fires in other parts of western Canada, the US or more distant.

Scientific investigations in the LFV indicate that a considerable proportion of ambient $PM_{2.5}$ is also formed by reactions of NO_X and SO_2 with ammonia in the air (mainly from agricultural sources in the LFV). Fine particulate produced in this manner is called secondary $PM_{2.5}$ and accounts for a significant percentage of $PM_{2.5}$ in summer. Therefore, emissions of precursor gases of secondary $PM_{2.5}$ are also important sources in the region.

Monitoring Results

The $PM_{2.5}$ annual average, maximum 24-hour rolling average and Canadian Ambient Air Quality Standard (CAAQS) values are shown in Figures S8 and 14 for 2017. The same values are shown spatially in Figures 15, 16 and 17, respectively.

All stations with sufficient data available to calculate a CAAQS value were found to meet or be below the Standard with the exception of Hope. Canadian Ambient Air Quality Standard values for 2017 ranged from 15 to 32 $\mu g/m^3$.

Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective were widespread in 2017 due to smoke from wildfires burning outside our region. Unprecedented levels of $PM_{2.5}$ were measured throughout the region in August and September.

All but one station (Vancouver-Clark Drive) were below the Metro Vancouver annual objective of 8 $\mu g/m^3$ and most stations were above the planning goal of 6 $\mu g/m^3$. Metro Vancouver's planning goal is a longer term aspirational target to support continuous improvement.

Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective were widespread in 2017. The objective was first exceeded on July 18 at Hope when a single day advisory was issued. In August in September the objective was exceeded at all monitoring stations throughout the region.

On August 1, an unprecedented eleven-day air quality advisory was issued due to smoke transported from wildfires burning outside the region. Smoke was transported to the region by outflow winds from wildfires burning in the BC Interior. Smoke was first detected in Hope and became widespread throughout the region by August 2nd. On August 2 and 3 the highest concentrations were experienced region-wide with the highest 24-hour concentration measured in Hope on August 4 with a value of 102 $\mu g/m^3$. The eleven-day air quality advisory was the longest advisory on record.

On August 29 and 30 exceedances were experienced at three stations and a single-day advisory was issued on August 29. The smoke was transported into the region primarily from wildfires burning in North California, Oregon and Washington.

An air quality advisory was in place for five days when $PM_{2.5}$ concentrations became elevated on September 4. The 24-hour $PM_{2.5}$ objective was exceeded at most monitoring stations during the advisory with the greatest impact in Hope. The smoke originated from wildfires in the interior of BC and Washington.

On September 17 the 24-hour $PM_{2.5}$ objective was exceeded at numerous stations due to wildfire smoke, however an air quality advisory was not issued due to the transient nature of the event.

Results of the wildfire smoke influence are discussed further in Section J.

In addition to the wildfire influences there were other exceedances that occurred throughout the year. Exceedances were experienced in Langley on October 28 and 29, Vancouver-Clark Drive on October 29, 31, November 1 and December 11, and in New Westminster on December 13. These exceedances were thought to be a result of a combination of Halloween fireworks, residential wood burning and/or open burning.

Table 6 gives the frequency distribution of $PM_{2.5}$ concentrations for the year. In 2017, Hope experienced the highest frequency of elevated $PM_{2.5}$ concentrations (> 25 $\mu g/m^3$), which occurred due to the proximity of the Fraser Canyon which experienced outflow winds transporting wildfire smoke into the region.

Seasonally, $PM_{2.5}$ levels are usually higher in the summer with the highest values typically experienced during the dry summer months (Figure 18), due to the formation of secondary $PM_{2.5}$ and smoke from wildfire activity. In 2017, the highest average and peak $PM_{2.5}$ levels were experienced in August.

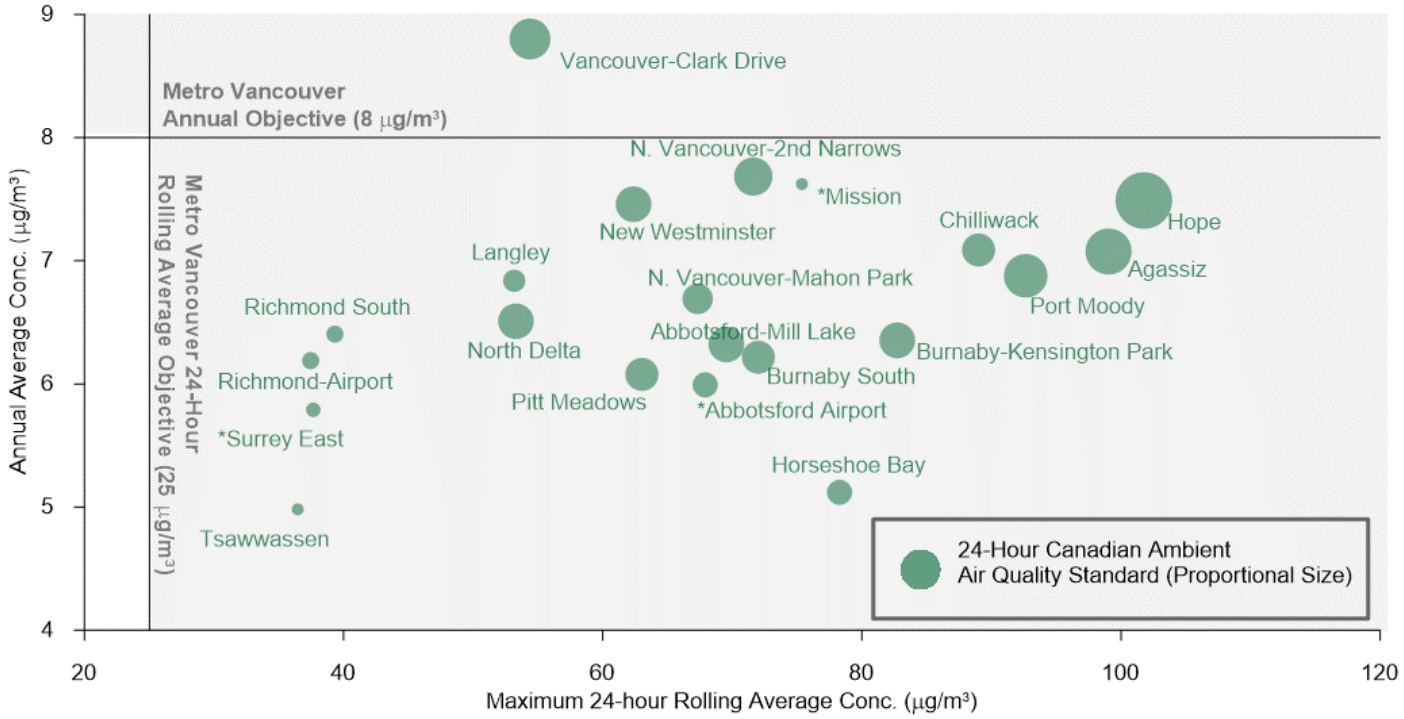
Figure 19 illustrates the long-term $PM_{2.5}$ trends in the LFV with the annual average and peak concentrations shown respectively. Monitoring technology was upgraded in 2013 to continuous particulate monitors that met the U.S. Environmental Protection Agency $PM_{2.5}$ Federal Equivalent Method (FEM). The FEM monitors have the ability to measure a portion of particulate matter not previously measured. The short-term peak concentrations reflect the highest levels that occurred, represented by the 99^{th} percentile of the 24-hour rolling average for each year. Given that it will take numerous years to establish a long-term record of $PM_{2.5}$ with the FEM monitor, both the older TEOM and newer FEM data are shown together.

In Figure 19 the TEOM data is shown as solid lines with a grey band displaying the range of values from all TEOM stations, while the FEM data is shown as dotted lines with an orange band showing the range from all FEM stations.

It is evident that the FEM monitor measures higher $PM_{2.5}$ concentrations compared to the TEOM monitor. Long-term average trends of the TEOM data show that 2015 was not appreciably different than previous years. However, the FEM data shows a step increase compared with the TEOM, which is a result of the FEM monitor's ability to measure some particles not previously measured by the TEOM monitor.

The differences in peak trends from year to year are driven by meteorological variability and wildfire activities. The long-term peak trend shows that 2017 measured much higher peak concentrations compared with other years.

A series of diurnal plots are shown in Figure 20 for each $PM_{2.5}$ monitoring station. Typically, the summer exhibits little diurnal variation while the winter displayed higher $PM_{2.5}$ concentrations in the evenings compared with the daytime. The evenings in winter were likely elevated due to reduced atmospheric mixing depths coupled with regional and local emission sources.



Note: Stations contained within the grey area denote an exceedance of an objective.

Figure 14: Fine particulate ($PM_{2.5}$), 2017.

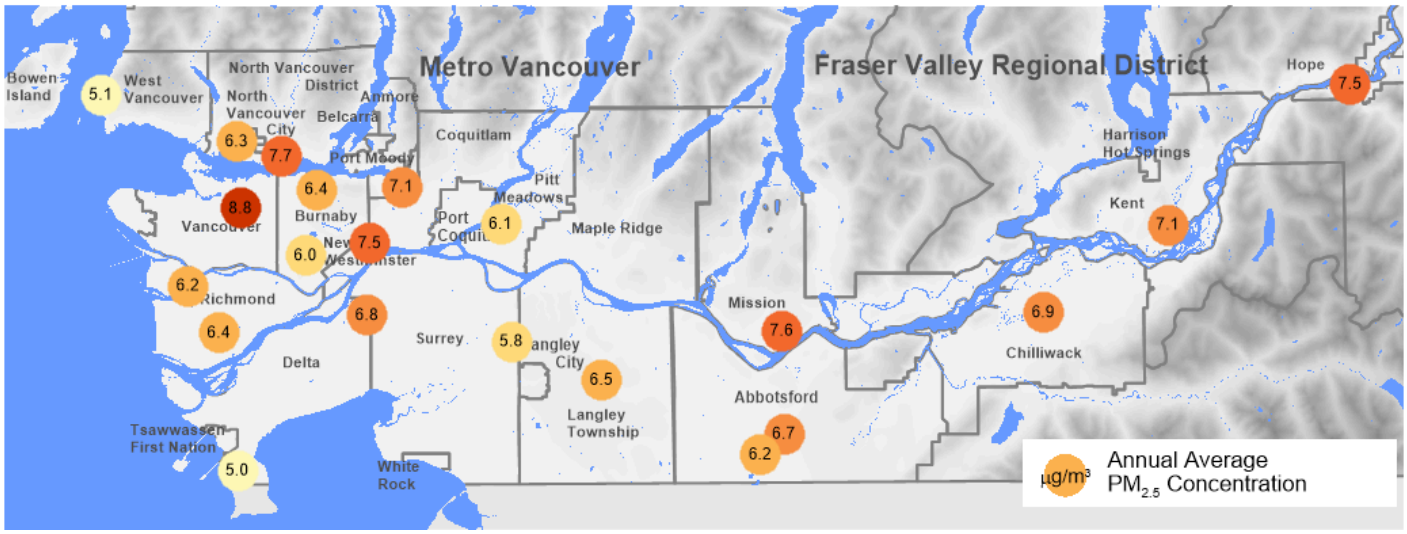


Figure 15: Annual average fine particulate ($PM_{2.5}$) in the LFV, 2017.

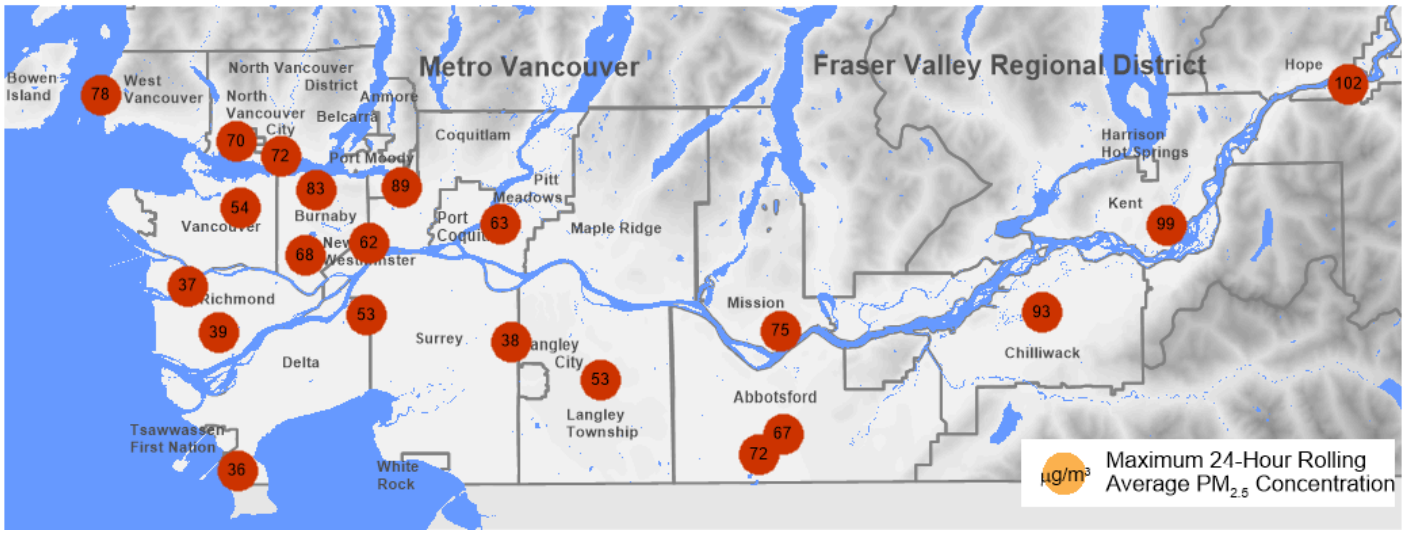


Figure 16: Short-term peak fine particulate ($PM_{2.5}$) in the LFV, 2017.

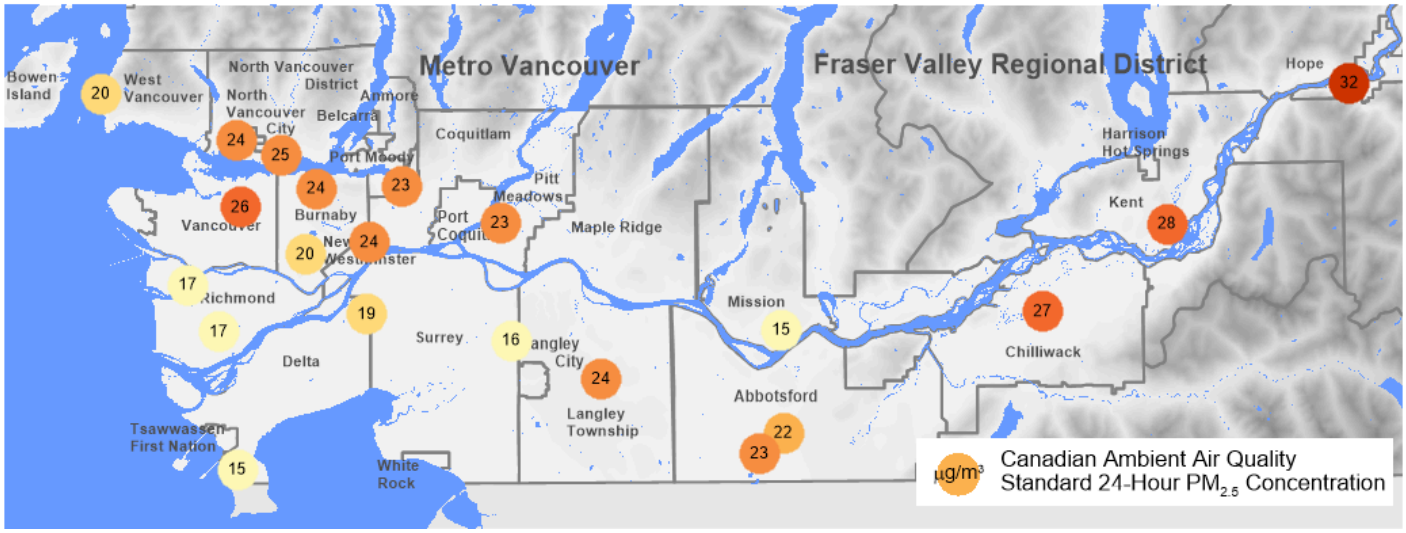


Figure 17: Canadian Ambient Air Quality Standard value for fine particulate ($PM_{2.5}$), 2017.

Table 6: Frequency distribution of 24-hour rolling average fine particulate ($PM_{2.5}$), 2017.

$PM_{2.5}$ Conc. ($\mu g/m^3$)	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Richmond-Airport	Abbotsford-Mill Lake	Horseshoe Bay	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to 5	5246	3259	4168	5029	4070	4311	4025	5186	5259	5453	4968	5077	4726	4519	6476	5907	3670	4990	4341	3431	2129
5 to 10	2594	4099	3517	2526	3369	2637	2907	2186	2226	2278	2538	2664	2815	2804	1536	1715	2516	2720	2343	3646	4447
10 to 15	344	547	556	591	599	586	767	578	649	429	585	273	653	696	89	433	792	460	473	744	850
15 to 20	55	71	46	72	191	190	276	70	162	71	228	86	300	138	54	79	169	83	78	290	375
20 to 25	34	51	22	46	67	32	63	38	49	46	68	41	100	64	32	105	46	46	61	69	236
25 to 30	15	17	15	41	68	29	27	64	27	14	48	40	50	30	14	76	31	26	46	40	96
30 to 35	23	16	21	25	63	14	40	76	28	17	56	13	57	53	28	36	32	27	52	52	60
35 to 40	28	22	29	26	71	11	39	46	60	25	52	17	18	37	71	12	31	22	48	65	55
40 to 45	47	37	41	28	49			47	63	30	63	20		46	93		25	18	53	41	46
45 to 50	57	62	47	32	7			22	64	46	49	15		53	44		54	27	5	26	36
50 to 55	80	58	58	70	10			4	8	57	12	31		10	15		67	26	5	22	42
55 to 60	33	67	54	59				4	12	78		58		24	4		31	64	8	8	
60 to 65	5	13	2	8				11	10	24		8		6	3		11	38	5	7	
65 to 70	4	6	2	8				6		19		11		4	3		10	19	15		
70 to 75	3	12	2	22								19			6		20	12	3		
75 to 80	4		2	15								44			13		2	25			
80 to 85	10		7	4								44						12			
85 to 90			7	5								32						10			
90 to 95				4								17						4			
95 to 100												16						5			
100 to 105												4									
>=105																					
Missing Data	178	423	164	149	196	950	616	422	143	173	93	230	41	276	279	397	1253	126	1224	319	388
Completeness	98%	95%	98%	98%	98%	89%	93%	95%	98%	98%	99%	97%	100%	97%	97%	96%	86%	99%	86%	96%	96%

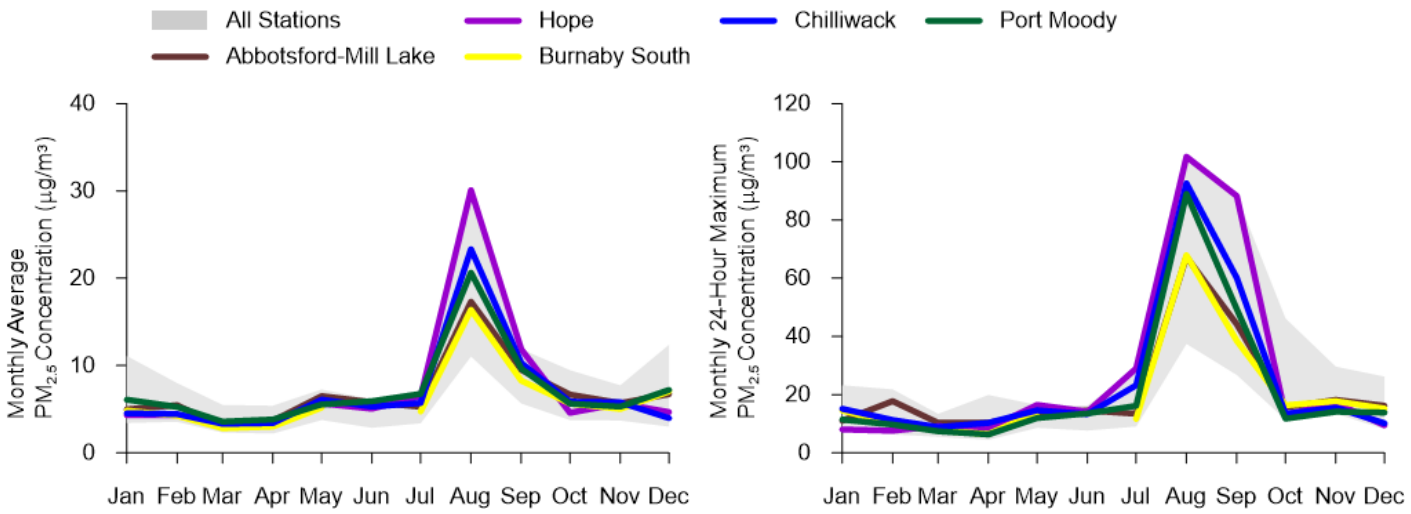


Figure 18: Monthly average (left) and short term peak (right) fine particulate ($PM_{2.5}$), 2017.

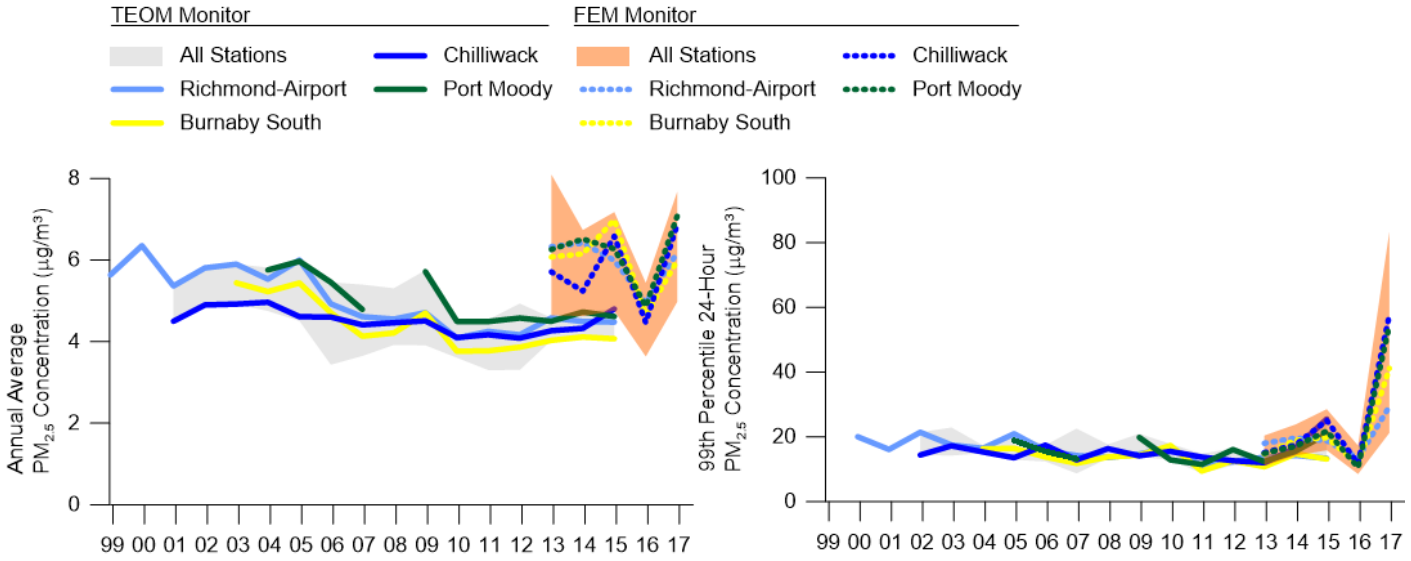
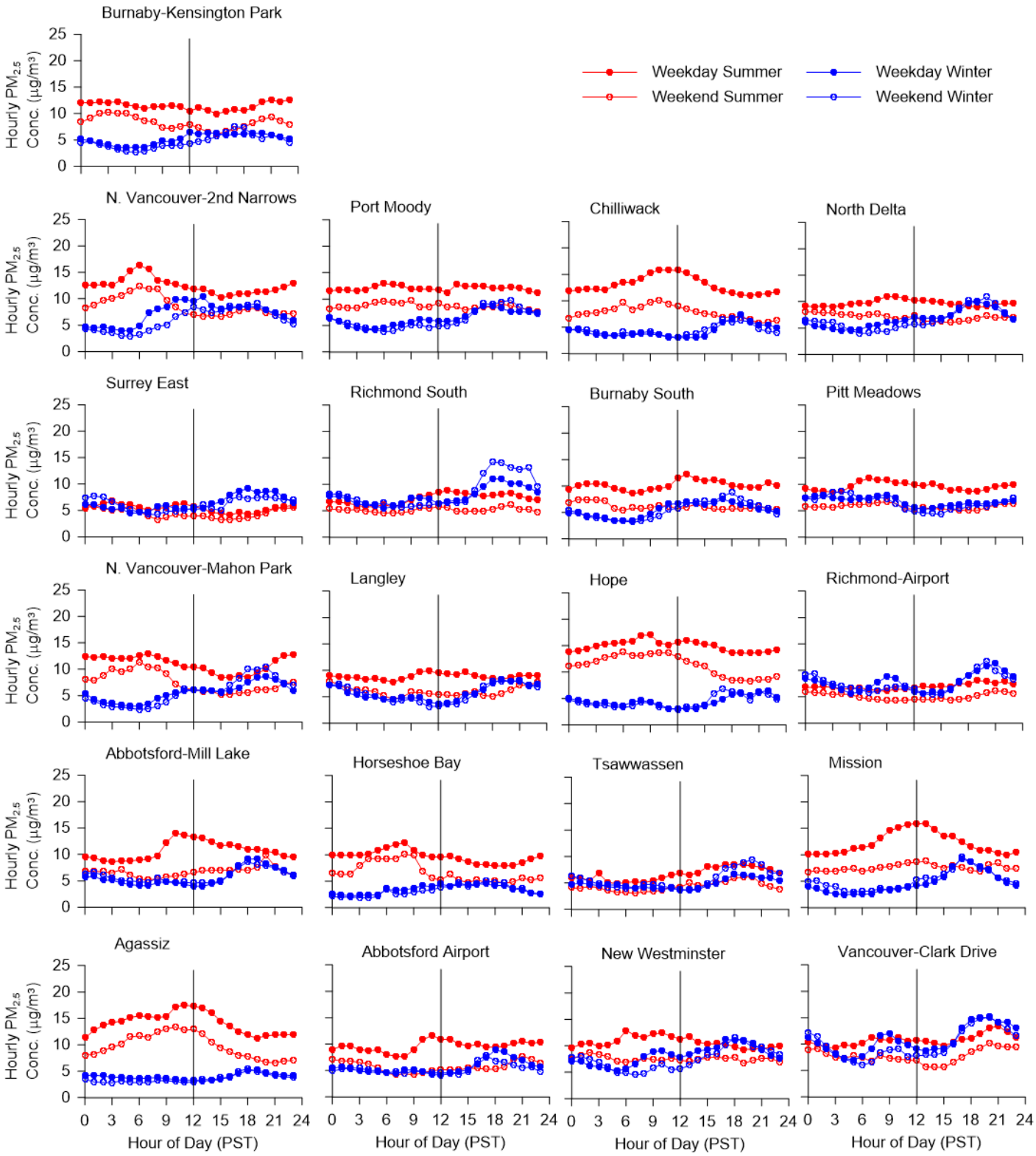


Figure 19: Annual (left) and short term peak (right) fine particulate ($PM_{2.5}$) trend, 1999 to 2017.



Note: These diurnal plots are heavily influenced by wildfire smoke events in summer and do not represent a typical annual trend.

Figure 20: Diurnal trends fine particulate ($PM_{2.5}$), 2017.

Nitrogen Dioxide (NO_2)

Characteristics

Of all the different oxides of nitrogen (NO_X), nitric oxide (NO) and nitrogen dioxide (NO_2) are of most concern in ambient air quality. Both are produced by the high temperature combustion of fossil fuels, and are collectively referred to as NO_X. Nitric oxide generally predominates in combustion emissions but rapidly undergoes chemical reactions in the atmosphere to produce NO_2.

Nitrogen dioxide is a reddish-brown gas with a pungent, irritating odour. It has been implicated in acute and chronic respiratory disease and in the creation of acid rain. It also plays a major role in ozone formation, and as a precursor to secondary particulate formation ($PM_{2.5}$), both of which can affect visual air quality in the region.

Sources

Common NO_X sources include boilers, building heating systems and internal combustion engines. In the LFV, transportation sources account for approximately 77% of NO_X emissions, with stationary and area sources contributing the remainder.

Monitoring Results

Figures S9 and 21 shows NO_2 monitoring levels in 2017, while Figures 22 and 23 shows the same values spatially. All 1-hour NO_2 concentrations continued to be below the Metro Vancouver objective at all times in 2017. Average levels for the year were also below Metro Vancouver's annual objective with the exception of the Vancouver-Clark Drive station.

The majority of nitrogen oxides are from transportation sources such as cars, trucks, rail, planes and ships. These sources play a large role in ozone formation in the summer, which can lead to an air quality advisory.

Emissions affecting NO_2 concentrations are dominated by transportation sources, which is indicated by the locations of the highest concentrations. The highest concentrations are measured in more densely trafficked areas near busy roads. Lower concentrations were observed where traffic influences were less pronounced, such as the eastern parts of Metro Vancouver and in the FVRD.

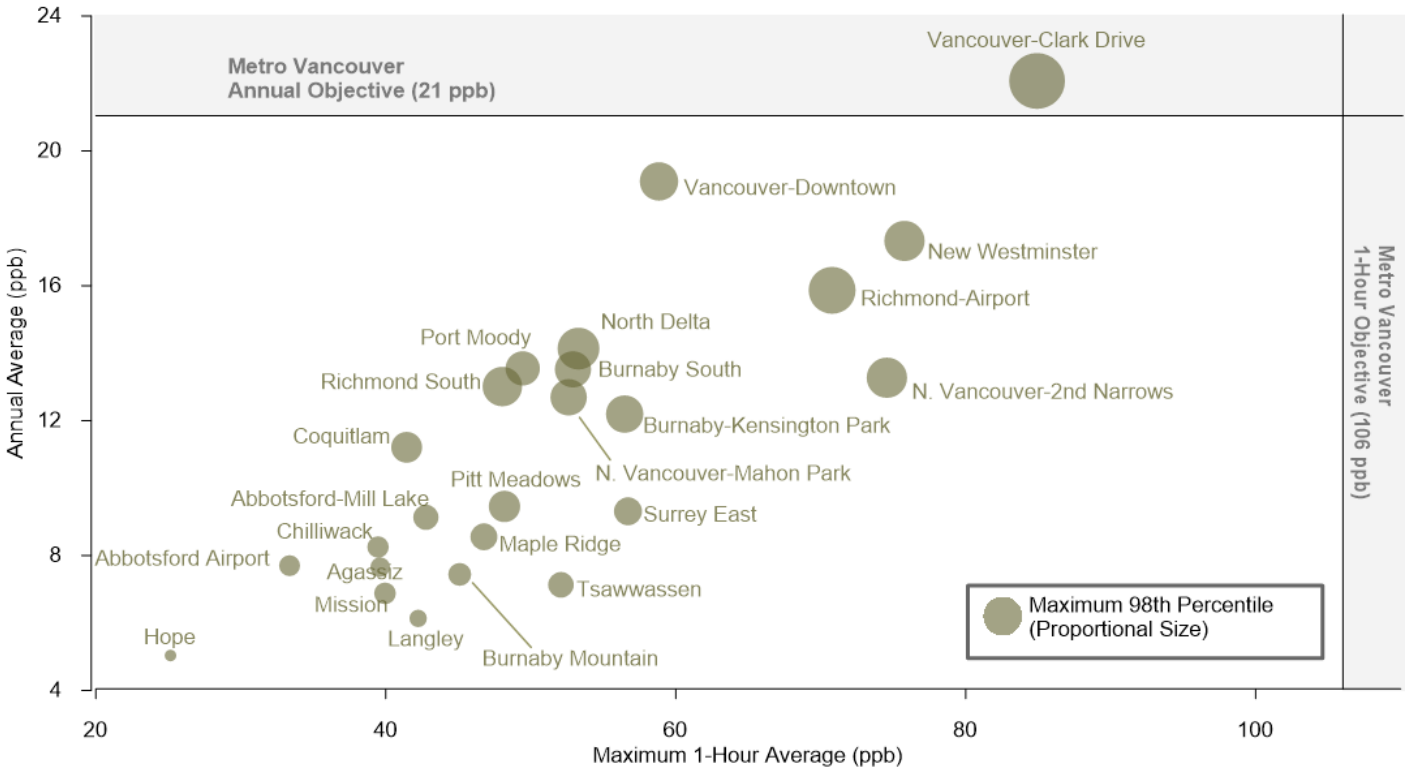
The seasonal trend for NO_2 in 2017 is shown by monthly averages and the monthly maximum 1-hour concentrations in Figure 24. On average, NO_2 concentrations were higher in the winter and lower in the summer. This seasonal trend is typical of the region and is the result of lower atmospheric mixing heights in winter along with increased residential, commercial and industrial heating.

The long-term NO_2 trends are shown in Figure 25. The annual average and short-term peak trends are provided in Figure 25 for the last two decades.

The trend for average and peak (99th percentile of 1-hour) concentrations continued to decline, showing constant improvement in NO_2 levels since the mid 1990's. Long-term changes in air quality can be attributed to changes in emissions while the yearly variation is likely attributable to meteorological variability. The improvements in the long-term trends shown here are thought to be largely due to improved vehicle emission standards and the AirCare program.

The frequency distribution of hourly concentrations measured in 2017 is given in Table 7.

A series of diurnal plots are shown in Figure 26 for each station that monitors NO_2. The plots demonstrate the differences between weekdays and weekends along with differences between summer and winter. Most stations exhibit higher concentrations on weekdays compared with weekends and show a peak in the morning along with a peak in the afternoon. Higher concentrations correspond relatively well with traffic volume patterns.



Note: Stations contained within the grey area denote an exceedance of an objective.

Figure 21: Nitrogen dioxide monitoring, 2017.

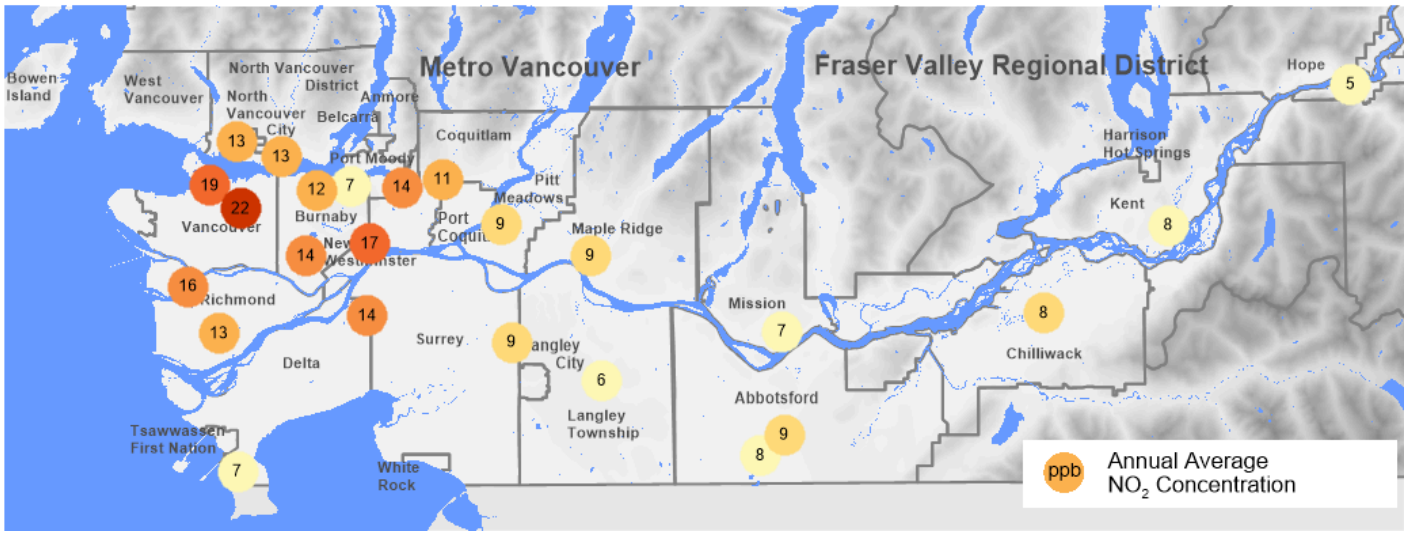


Figure 22: Annual average nitrogen dioxide in the LFV, 2017.

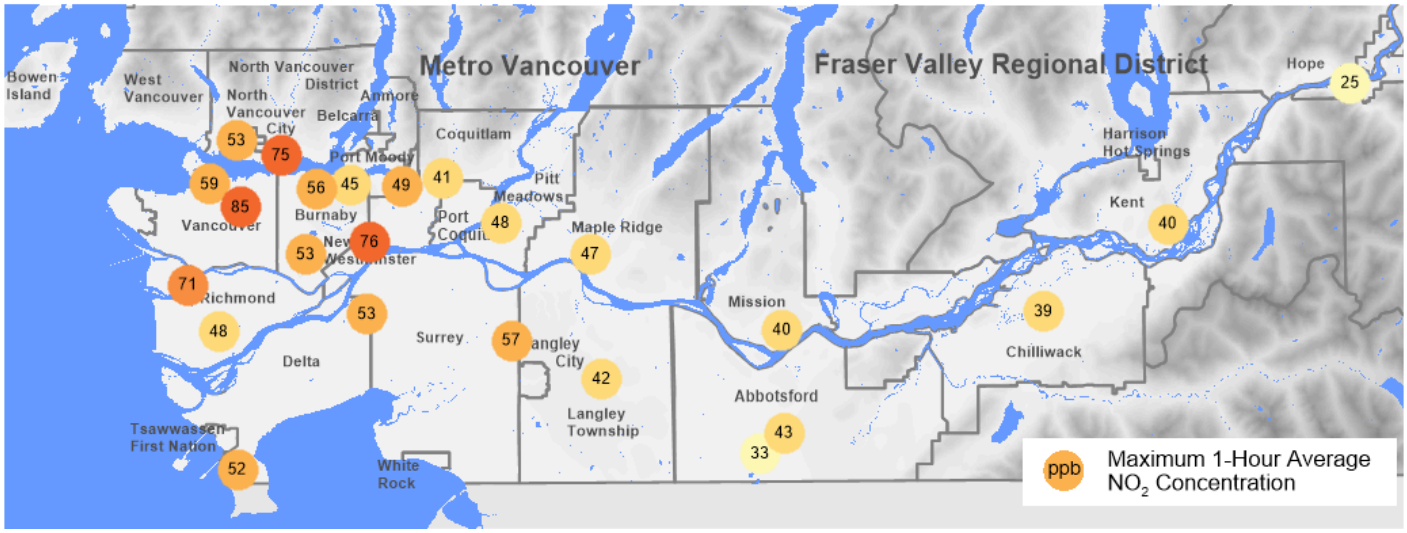


Figure 23: Short-term peak (maximum 1-hour) nitrogen dioxide in the LFV, 2017.

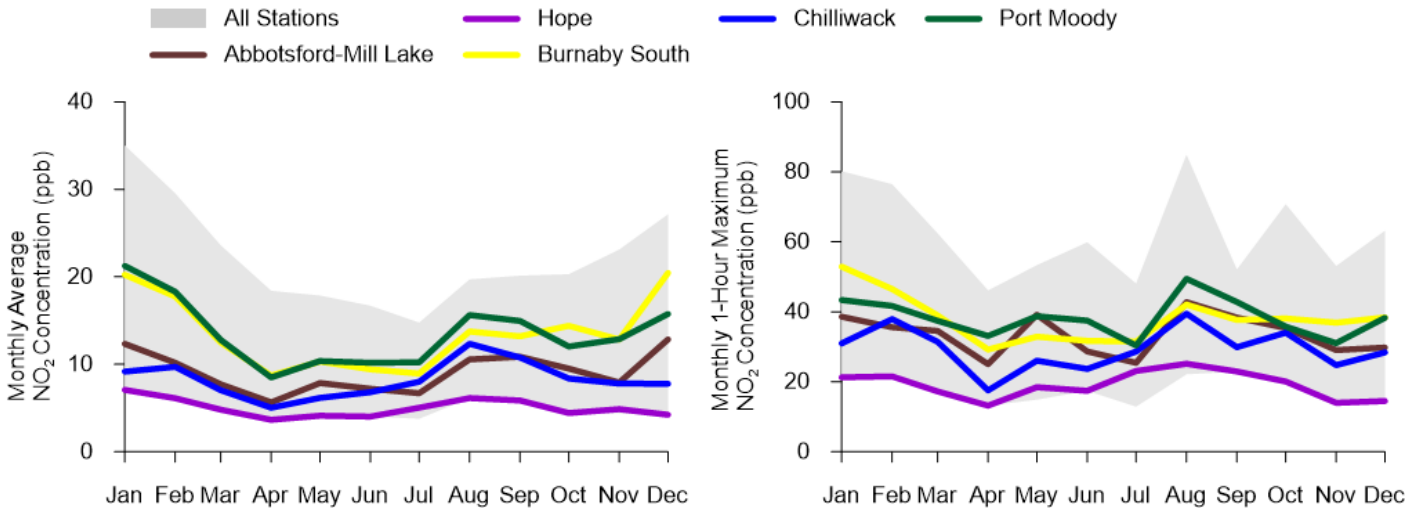


Figure 24: Monthly average (left) and short term peak (right) nitrogen dioxide, 2017.

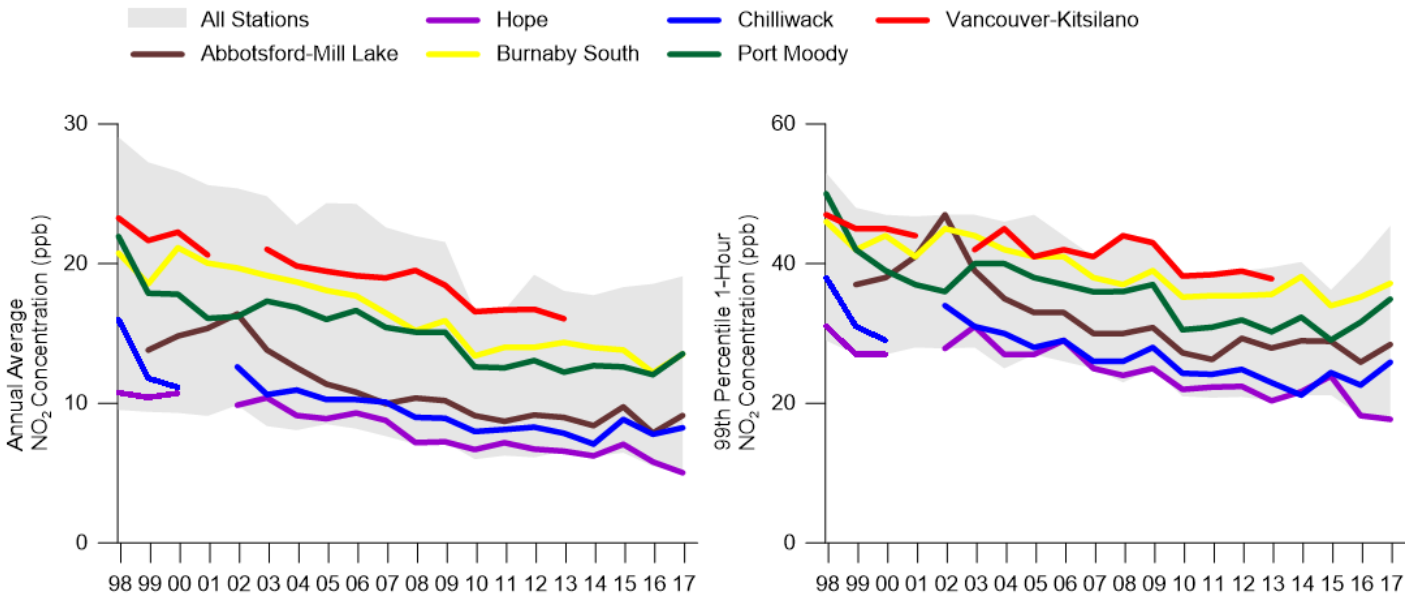
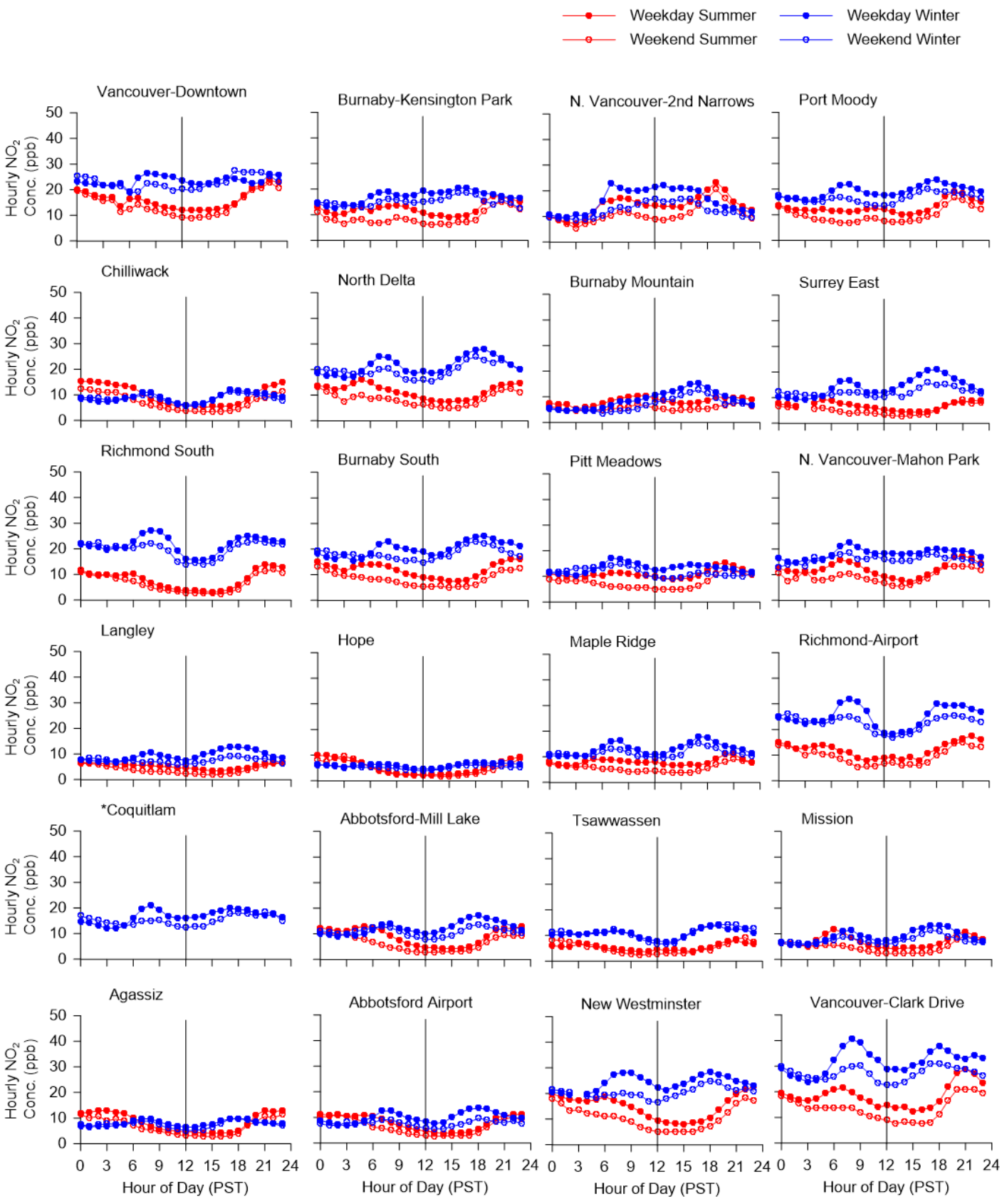


Figure 25: Annual (left) and short term peak (right) nitrogen dioxide trend, 1998 to 2017

Table 7: Frequency distribution of hourly nitrogen dioxide, 2017.

NO_2 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to 5	57	1496	1023	954	2905	1273	3366	2589	2187	984	3001	1513	4507	5185	3145	1148	1657	2739	4419	4301	3653	3359	573	302
5 to 10	937	2806	2711	2353	3047	2361	3286	2576	1846	2505	2277	2530	2591	2424	2772	1953	1999	2790	2105	2310	2526	2248	1396	939
10 to 15	1730	1887	1955	2122	1526	1653	1182	1241	1374	2037	1526	1682	965	717	1430	1526	1427	1421	1006	1047	1398	1371	1691	1168
15 to 20	2042	1038	1126	1498	706	1150	432	753	1132	1358	818	1249	358	162	709	1305	843	906	560	506	733	684	1635	1537
20 to 25	1802	651	742	852	239	832	197	407	823	918	495	813	122	35	324	1032	567	446	301	236	229	218	1411	1351
25 to 30	1126	371	377	522	68	603	79	197	532	444	242	415	35	1	154	735	314	146	110	67	44	70	945	1184
30 to 35	492	199	253	217	29	334	44	79	371	205	131	252	11		59	431	109	44	65	23	15	9	465	795
35 to 40	150	107	130	68	5	175	18	20	179	101	39	99			30	240	27	10	19	9	1		177	545
40 to 45	40	40	69	14		75	8	7	43	28	6	33	1		5	142	2	1	5				57	269
45 to 50	10	14	17	1		38	1	2	7	11	4	8			1	67							19	151
50 to 55	1	6	7			7		1		4		1				16			1				5	68
55 to 60	2	1						2								5							2	35
60 to 65			4													3								14
65 to 70																1								11
70 to 75			1													1								3
75 to 80																							1	1
>=80																								3
Missing Data	371	144	345	159	235	259	147	886	266	165	221	165	170	236	131	155	1815	257	168	261	161	801	383	384
Completeness	96%	98%	96%	98%	97%	97%	98%	90%	97%	98%	98%	98%	98%	97%	99%	98%	79%	97%	98%	97%	98%	91%	96%	96%



*Data completeness requirements were not met at this site in summer.

Figure 26: Diurnal trends nitrogen dioxide, 2017.

Sulphur Dioxide (SO_2)

Characteristics

Sulphur dioxide (SO_2) is a colourless gas with a pungent odour. It reacts in the air to form acidic substances such as sulphuric acid and sulphate particles.

Brief exposure to high concentrations of SO_2 and its by-products can irritate the upper respiratory tract and aggravate existing cardiac and respiratory disease in humans. Long-term exposure may increase the risk of developing chronic respiratory disease.

The environmental effects of SO_2 and its reactive products have been studied for many years. These compounds can cause damage to vegetation and buildings, they play a role in the formation of acid rain and they may affect the natural balance of waterways and soils. Sulphur oxides (SO_X) including SO_2 can also combine with other air contaminants to form the fine particulates ($PM_{2.5}$) that are thought to be one of the contributing factors in the degradation of visual air quality in the region.

Sources

Sulphur dioxide is emitted when fossil fuels containing sulphur are burned. The largest source of SO_2 emissions in the region is the marine sector, mostly ocean-going vessels. The major industrial source of SO_2 in this region is an oil refinery located in the Burrard Inlet area. Other significant sources contributing to the measured ambient SO_2 concentrations include non-road engines, industry, heating and transportation (motor vehicles, aircraft and trains).

Local SO_2 emissions are low relative to other cities of similar size because natural gas, rather than coal or oil, is used in almost all residential, commercial and industrial heating in the region.

Monitoring Results

Sulphur dioxide levels measured in 2017 are shown in Figures S10 and 27. Figure 27 displays the maximum 1-hour and annual average concentrations for each SO_2 monitoring location with sufficient data coverage during 2017. The same values are represented spatially in Figures 28 and 29.

Sulphur dioxide levels were below the annual objective at all stations in 2017. The annual average SO_2 levels were less than 2 ppb at all stations. Average levels remained low in 2017 compared with previous years and can be attributed to stricter marine fuel requirements that came into effect at the beginning of 2015.

Average sulphur dioxide levels have drastically improved in recent years due to stricter requirements for lower sulphur content marine fuels.

With the exception of Burnaby-Capitol Hill all stations were below Metro Vancouver's 1-Hour objective of 70 ppb in 2017. The 1-hour objective was exceeded on four separate days at the Burnaby-Capitol Hill station in the evening of February 13, the morning and evening of March 20, the evening of October 28 and morning and evening of December 7. All of the exceedances were measured when winds were blowing from the direction of the petroleum refinery.

The highest levels of SO_2 are typically measured in the northwest (Figures 28 and 29), particularly close to the dominant sources of SO_2 emissions (i.e., marine vessels, port areas and the petroleum refinery) in the Burrard Inlet area.

Figure 30 shows the seasonal trend of SO_2 based on the monthly average and highest 1-hour concentration from each month. Concentrations from selected stations are shown alongside the range of concentrations measured at all stations (shown as a grey band). There is little or no discernible trend in SO_2 concentrations throughout the year. The stations nearest to Burrard Inlet generally experienced the highest average concentrations through most of the year while the highest 1-hour measurements were recorded at Burnaby-Capitol Hill in February, March, October and December.

The long-term SO_2 trends in the LFV are shown in Figure 31. The annual average trend is given in the left plot with the short-term peak trend given in the right plot for the last two decades. Average sulphur dioxide levels have drastically improved in recent years due to stricter

requirements for lower sulphur content marine fuels. Overall, the yearly variation can be attributed in part to meteorological variability while the major long-term changes in air quality are mainly a result of changes in emissions.

Long-term trends provide information to help assess the impact of emission reduction efforts, policy changes and technology advances. For example, emissions of SO_2 declined during the early 1990s due to reduced sulphur content in on-road fuels and reduced emissions from oil refining and cement industries. In recent years, measurements of both the annual short-term peak (99th percentile of the 1-hour values) and the annual average are markedly lower than they were in the 1990s.

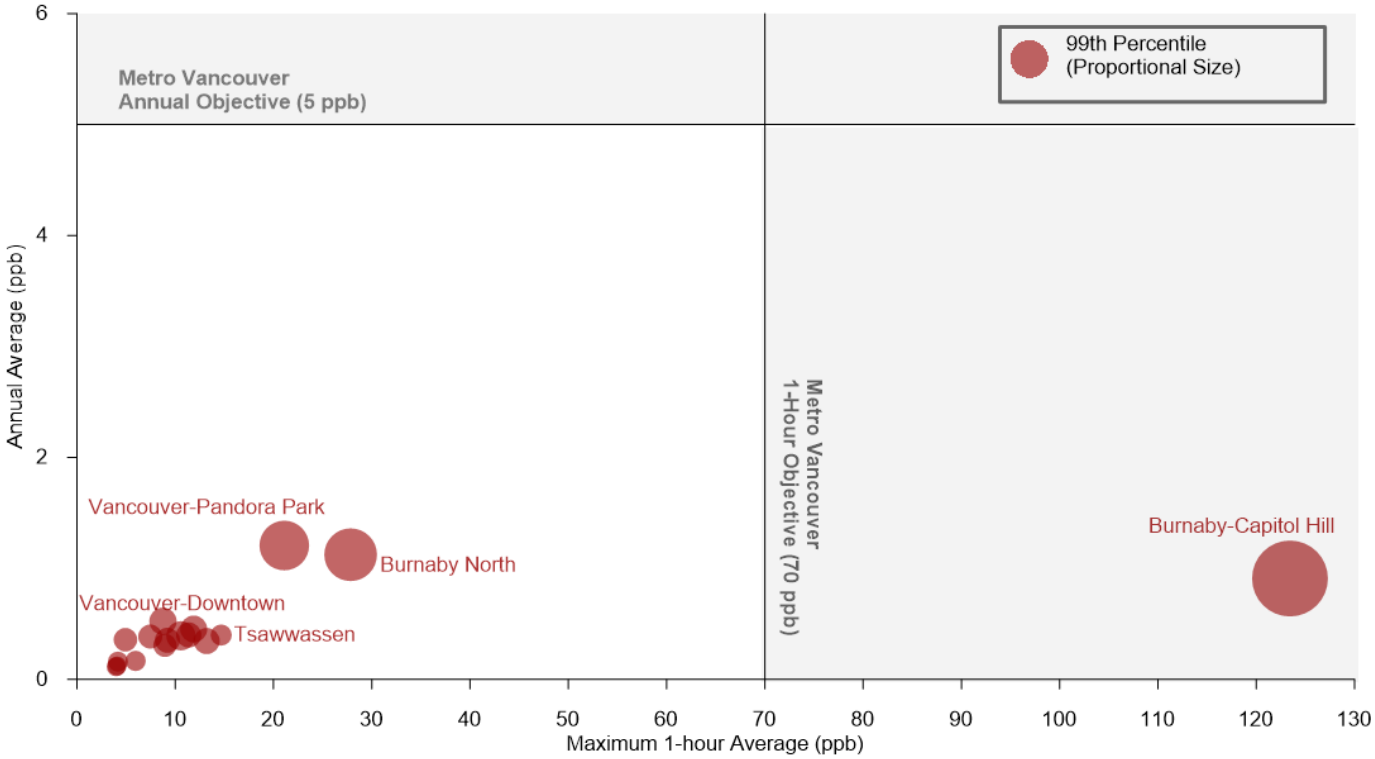
The values in Table 8 represent the frequency distribution (or count) of the number of hourly average measurements in the specified ranges. It is evident that stations located near the Burrard Inlet area experience a greater occurrence of higher concentrations compared with areas away from the Inlet.

A series of diurnal plots are shown in Figure 32 for each SO_2 monitoring station. The diurnal plots illustrate the weekday/weekend differences along with summer/winter differences. Stations located away from Burrard Inlet show little diurnal variation while stations located near the inlet show trends indicative of nearby emission sources.

The diurnal patterns of SO_2 measured near Burrard Inlet in the summer are mainly influenced by wind flow and marine and oil refinery emissions. Port Moody experiences higher concentrations during the middle of the day in summer when winds are blowing from marine areas and the oil refinery toward the station.

Stations historically influenced by marine vessel emissions such as North Vancouver-2nd Narrows and North Vancouver-Mahon Park show attenuated levels compared with previous years.

The Burnaby-Capitol Hill station and Burnaby North show diurnal variation with sporadic peak SO_2 concentrations during the morning and evening periods when mixing layer depth is reduced and dispersion is limited. Measurements of SO_2 at this station are influenced by its proximity to the oil refinery.



Notes:

- Stations contained within the grey area denote an exceedance of an objective.
- For clarity, only a few station labels have been included in the figure due to several stations clustered together.

Figure 27: Sulphur dioxide monitoring, 2017.

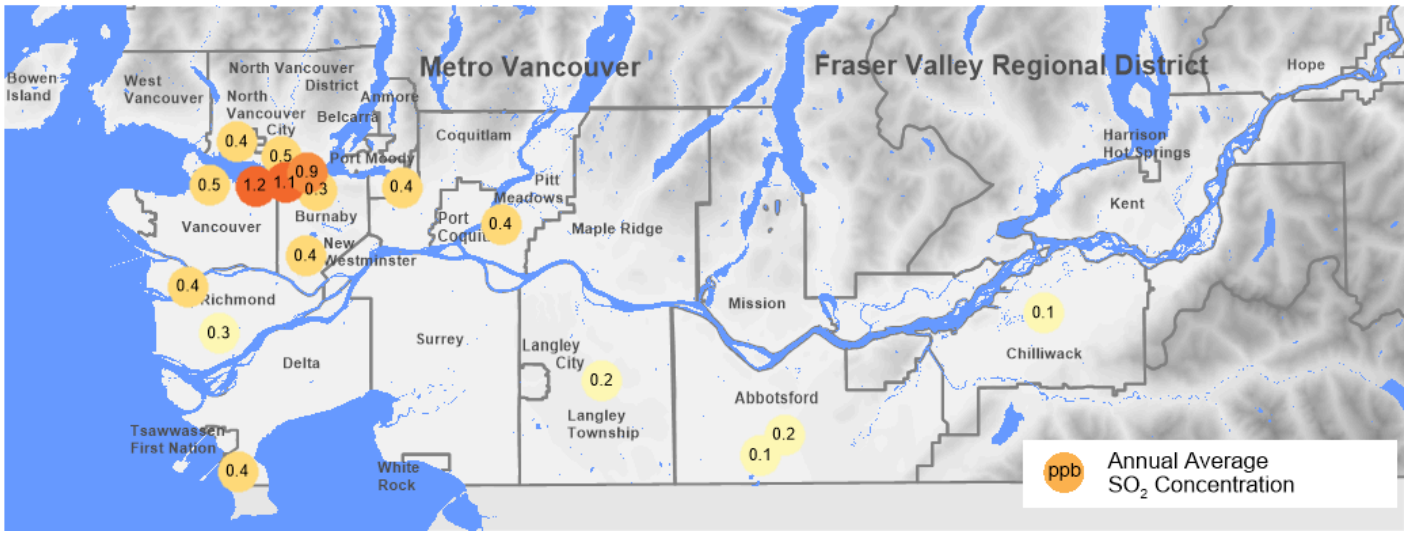


Figure 28: Annual average sulphur dioxide in the LFV, 2017.

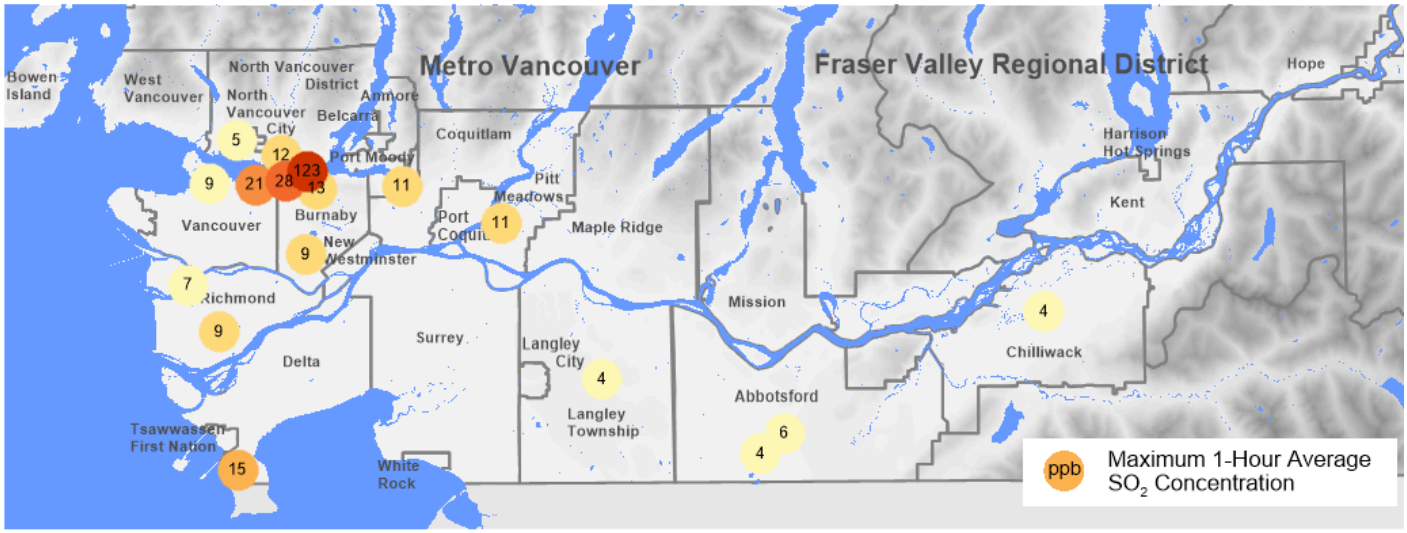


Figure 29: Short-term peak (maximum 1-hour) sulphur dioxide in the LFV, 2017.

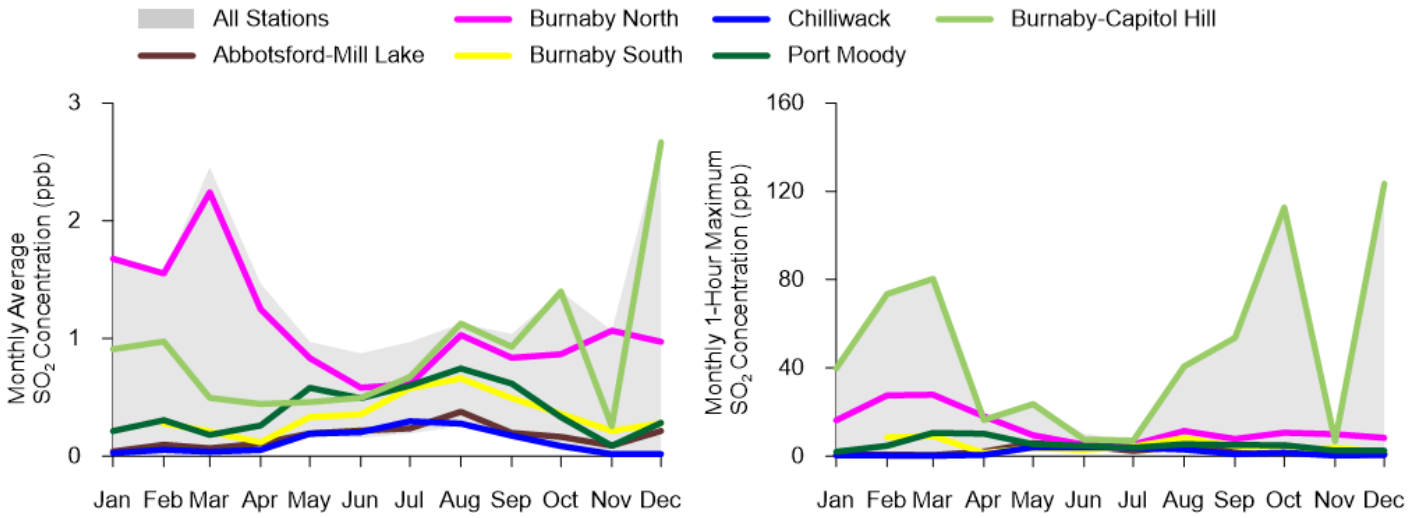


Figure 30: Monthly average (left) and short-term peak (right) sulphur dioxide, 2017.

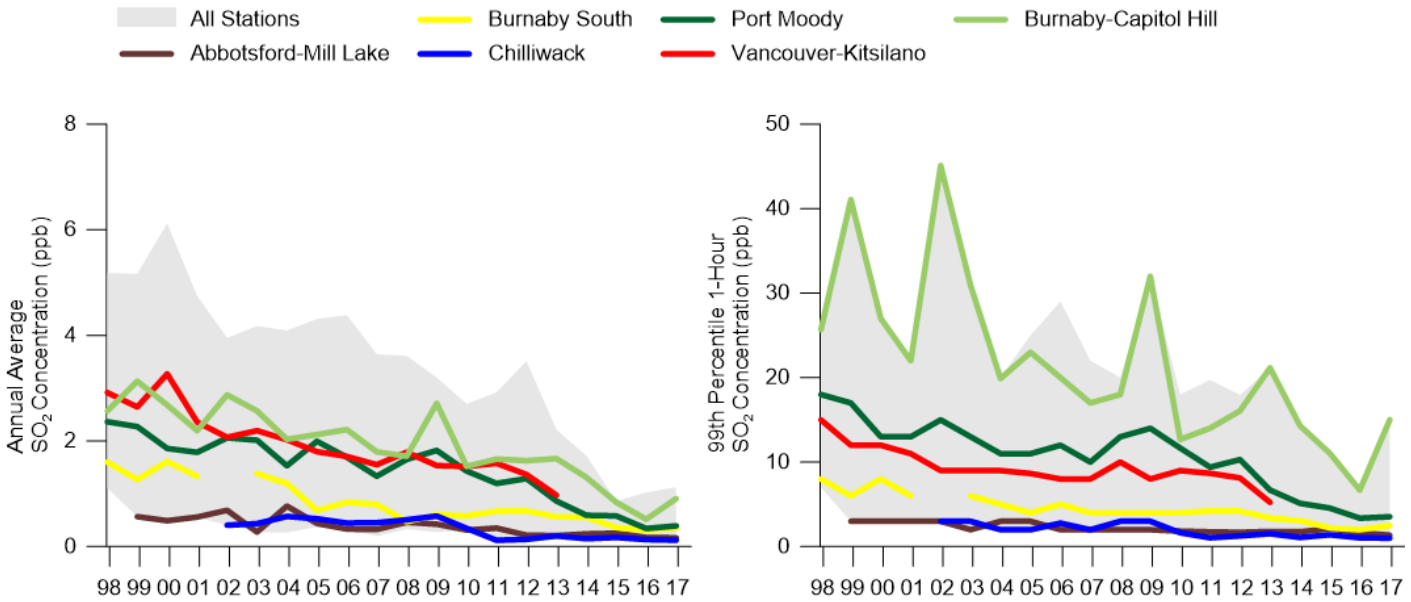
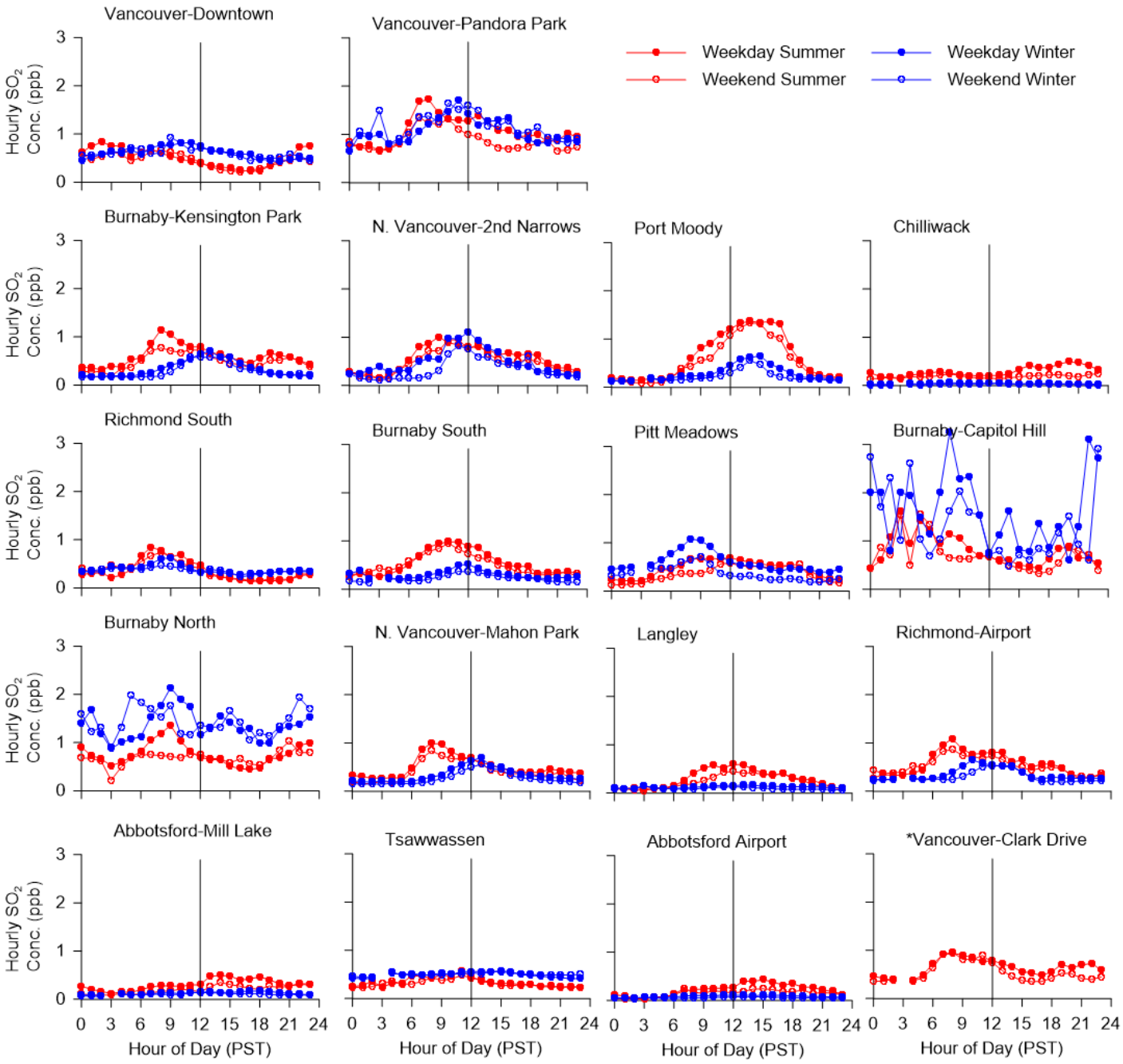


Figure 31: Annual (left) and short-term peak (right) sulphur dioxide trend, 1998 to 2017.



*Data completeness requirements were not met at this site in winter.

Figure 32: Diurnal trends sulphur dioxide, 2017.

Table 8: Frequency distribution of hourly sulphur dioxide, 2017.

SO_2 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	Richmond South	Burnaby South	Pitt Meadows	Burnaby-Capitol Hill	Burnaby North	N. Vancouver-Mahon Park	Langley	Richmond-Airport	Abbotsford-Mill Lake	Tsawwassen	Abbotsford Airport	Vancouver-Clark Drive	Vancouver-Pandora Park
0 to 5	8009	8341	8007	8305	7296	7997	7798	8209	7992	8254	8083	8535	8218	8015	8480	7233	4176	7709
5 to 10	23	10	29	11		8	10	2	119	248			3	1	6		2	180
10 to 15		2	2	2				1	43	50					2			39
15 to 20									31	15								14
20 to 25									19	2								2
25 to 30									8	2								
30 to 35									6									
35 to 40									4									
40 to 45									5									
45 to 50									2									
50 to 55									2									
55 to 60									2									
60 to 65									1									
65 to 70																		
70 to 75									1									
75 to 80									2									
80 to 85									1									
>= 85																		
Missing Data	700	155	384	220	240	518	793	410	154	134	553	207	171	291	236	359	4552	785
Completeness	92%	98%	95%	97%	97%	94%	91%	95%	98%	99%	94%	98%	98%	97%	97%	95%	48%	91%

Carbon Monoxide (CO)

Characteristics

Carbon monoxide (CO) is a colourless, odourless and tasteless gas produced by the incomplete combustion of fuels containing carbon. It has a strong affinity for haemoglobin and thus reduces the ability of blood to transport oxygen. Long-term exposure to low concentrations may cause adverse effects in people suffering from cardiovascular disease.

Sources

Carbon monoxide is the most widely distributed and commonly occurring air pollutant. The principal sources are non-road engines and motor vehicles. In the LFV, over 91% comes from mobile sources which include cars, trucks, buses, planes, trains, ships and non-road engines. Other sources contributing to measured CO levels are building heating, commercial and industrial operations, and smoke from wildfires.

Monitoring Results

Figures S11 and 33 illustrate the results of CO monitoring for 2017. Figure 33 displays the maximum 1-hour and 8-hour average as well as the annual average for each CO monitoring location. The same results are represented on maps in Figures 34, 35 and 36.

Measured carbon monoxide levels were well below Metro Vancouver's objectives at all stations throughout the LFV. Typically, the highest concentrations occur in more urbanized areas with large traffic volumes.

With the majority of CO released from cars, trucks, buses and non-road engines, dramatic improvements have occurred in the last two decades due to improved vehicle emission standards and vehicle emissions testing.

Average levels remained low throughout the LFV with the lowest readings recorded at stations away from heavily trafficked areas.

The seasonal trends for CO in 2017 are plotted as monthly average and maximum 1-hour concentrations in Figure 37. Overall, average CO concentrations were higher in the winter compared with the summer. This seasonal trend is typical of the region and is the result of lower atmospheric mixing heights in winter along with increased residential, commercial and industrial heating.

Figure 38 illustrates the long-term average and peak CO trends in the LFV. Some year-to-year variation is evident in the peak trends, however long-term changes in air quality are mainly attributed to changes in emissions. Improvements in both the average and the short-term peak concentrations (99th percentile of the 1-hour values) appear to be leveling off in recent years.

In the LFV average levels have decreased dramatically since the early nineties. Declining CO concentrations are largely due to improved vehicle emission standards and the AirCare program.

A series of diurnal plots are shown in Figure 39 for each station that monitors CO. Most stations exhibit higher winter concentrations on weekdays compared with weekends, with many stations showing a large peak in the morning that corresponds relatively well with morning traffic patterns.

Stations that appear to be strongly influenced by CO emission sources such as traffic include Vancouver-Clark Drive where a well-defined peak is evident in the mornings on weekdays during the winter.

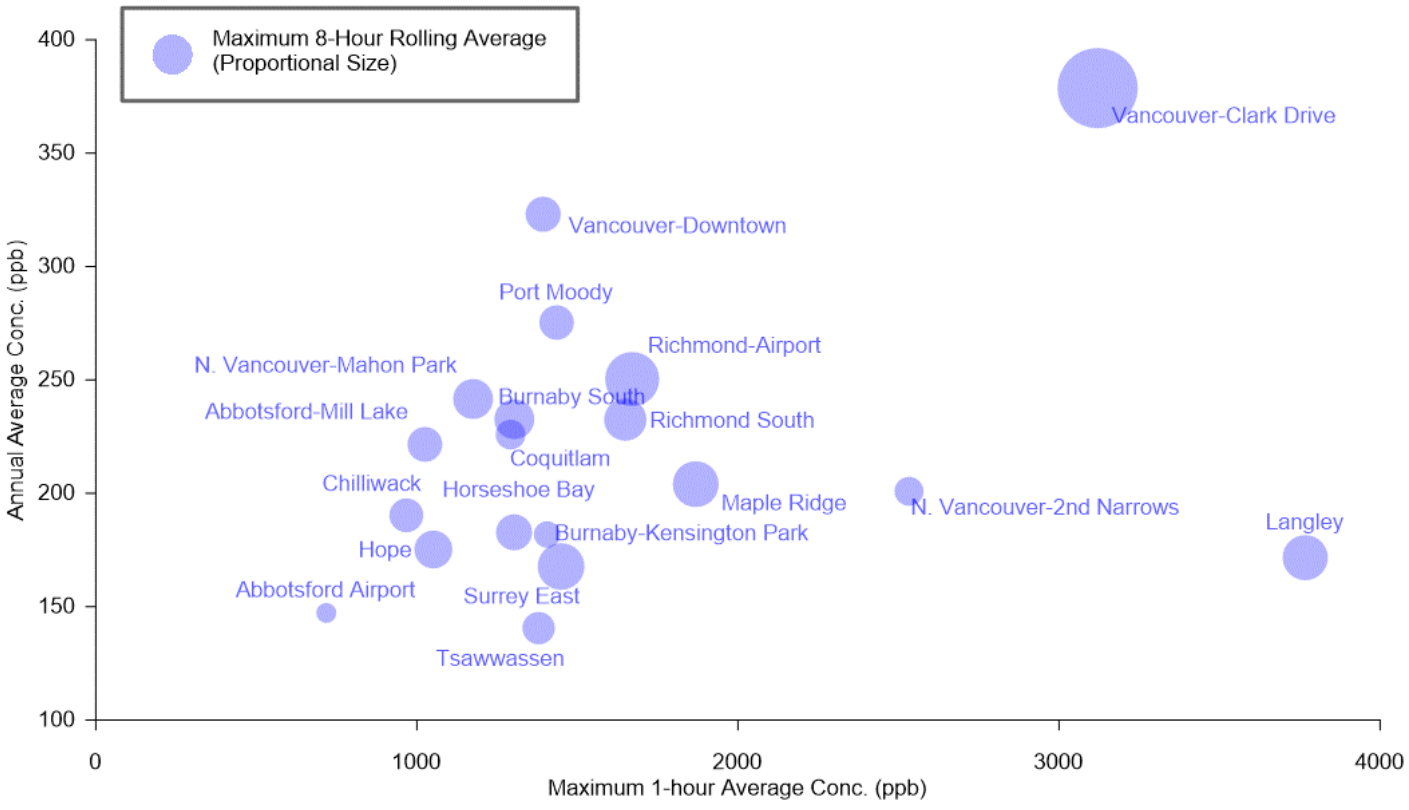


Figure 33: Carbon monoxide monitoring, 2017.

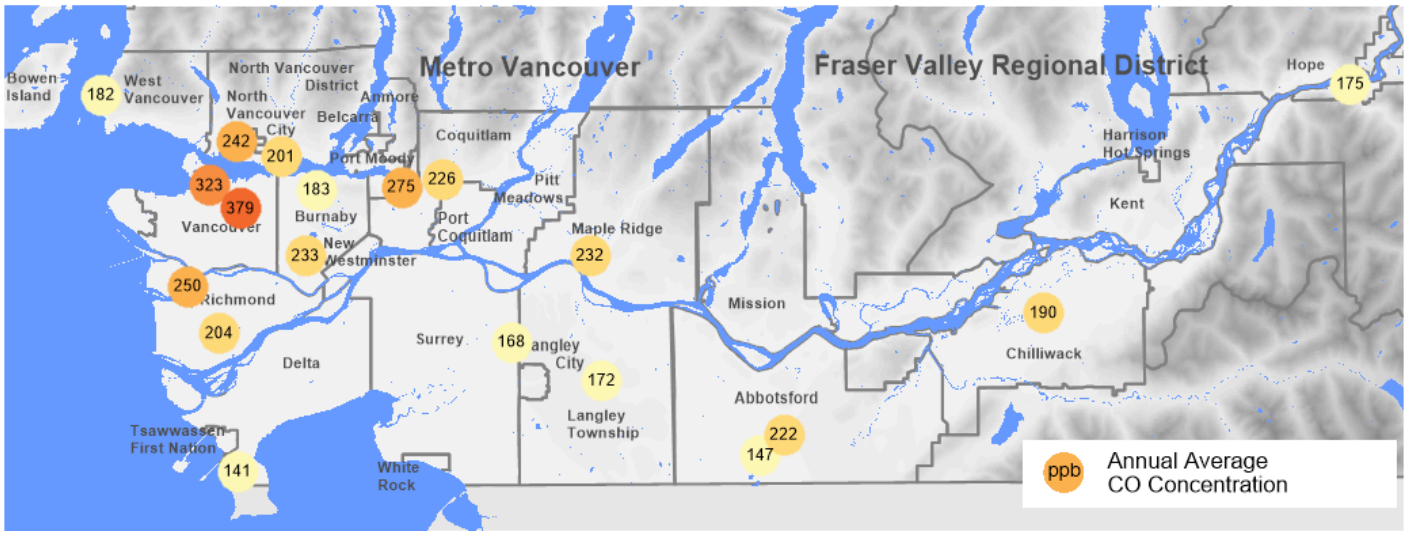


Figure 34: Annual average carbon monoxide in the LFV, 2017.

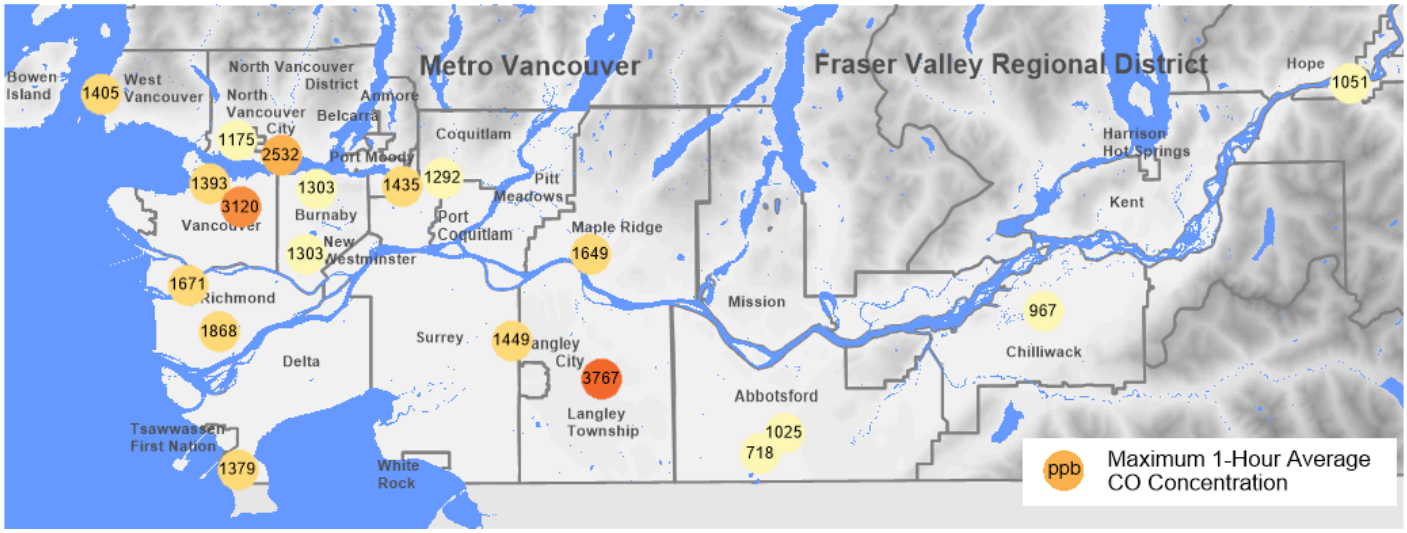


Figure 35: Short-term peak (maximum 1-hour) carbon monoxide in the LFV, 2017.

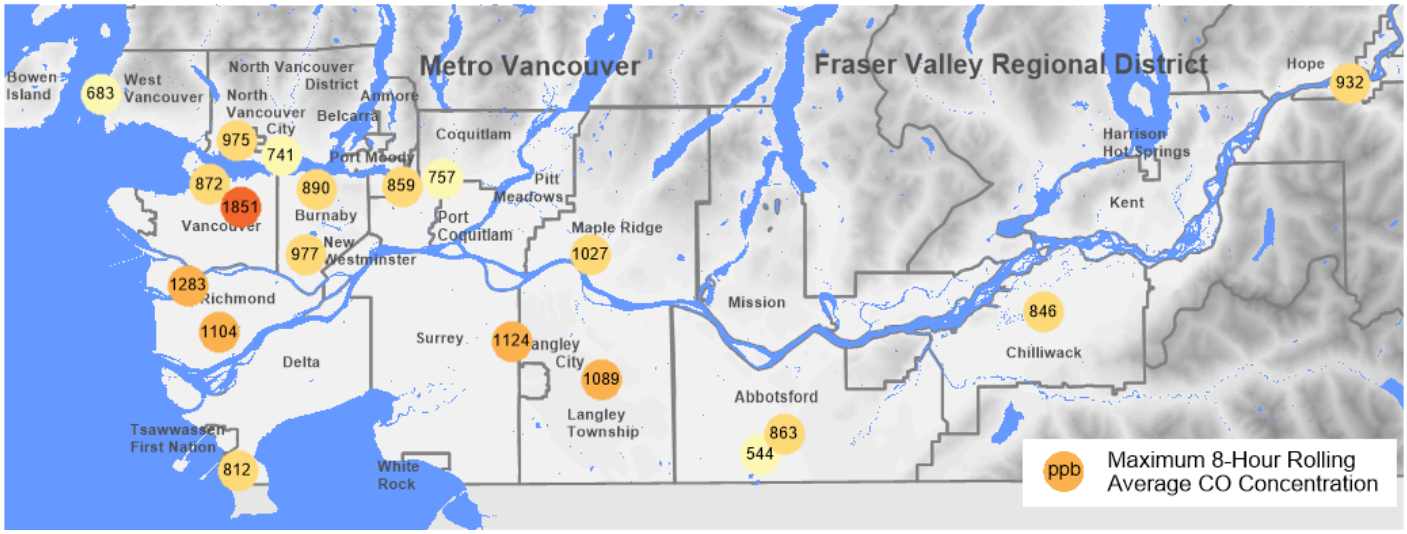


Figure 36: Short-term peak (maximum 8-hour) carbon monoxide in the LFV, 2017.

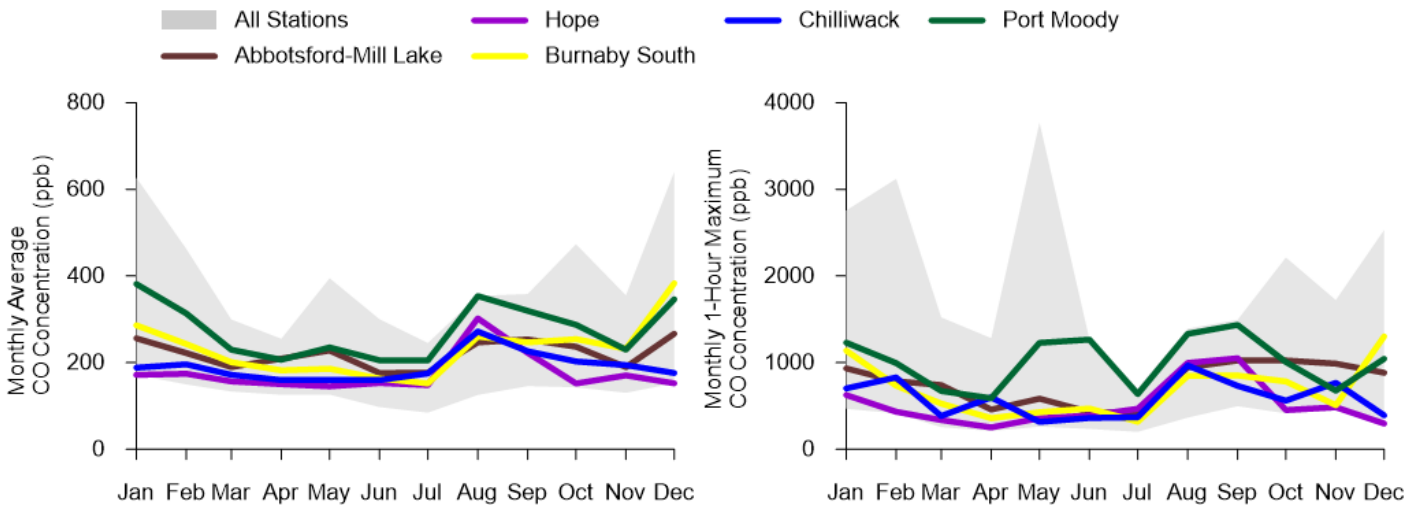


Figure 37: Monthly average (left) and short term peak (right) carbon monoxide, 2017.

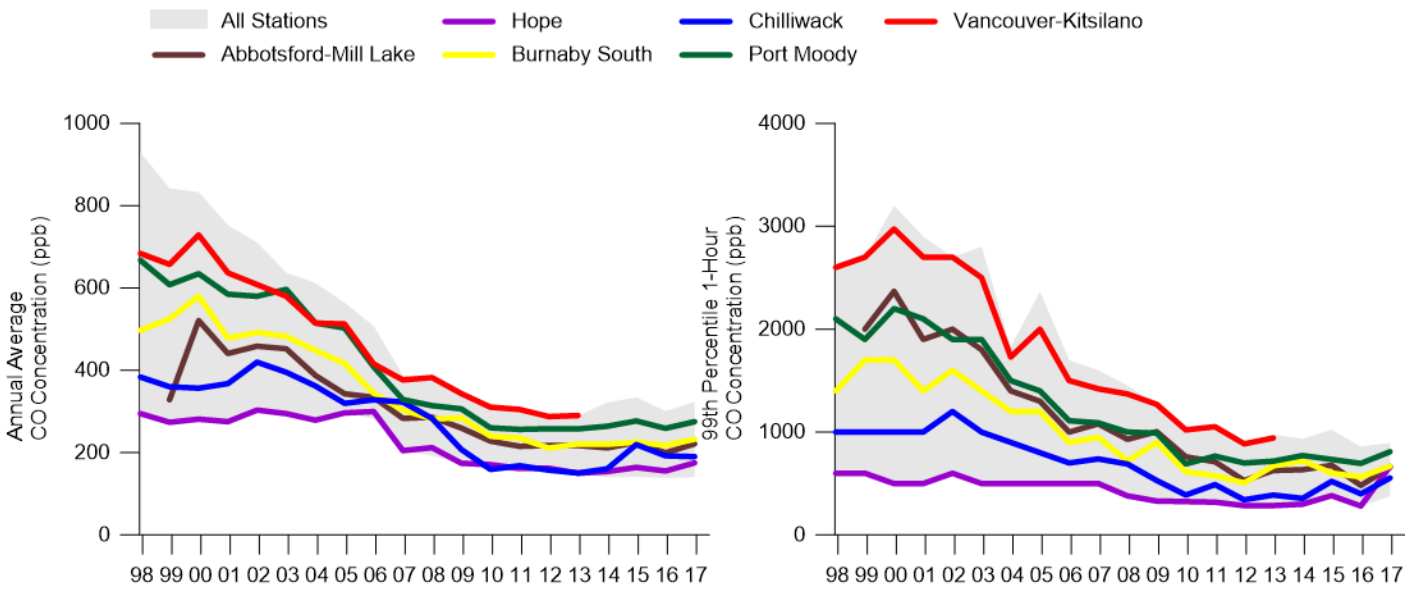
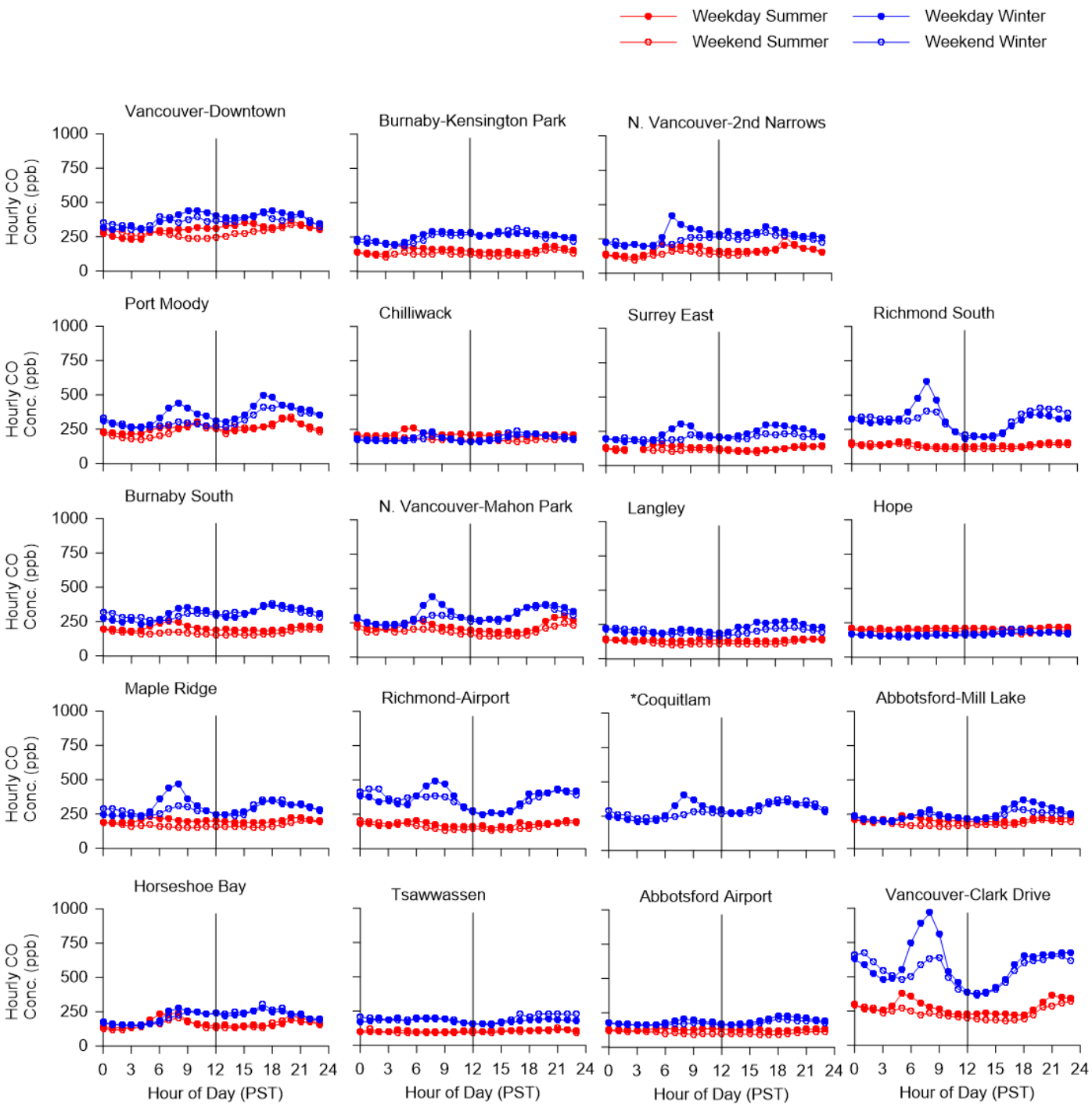


Figure 38: Annual (left) and short term peak (right) carbon monoxide trend, 1998 to 2017.



*Data completeness requirements were not met at this site in summer.

Figure 39: Diurnal trends carbon monoxide, 2017.

Inhalable Particulate (PM_{10})

Characteristics

The term 'PM_{10}' refers to airborne particles with a diameter of 10 micrometres (μm) or less. These particles are also known as inhalable particulate matter which, given their small size, can be inhaled and deposited in the lungs.

Exposure to PM_{10} can lead to both chronic and acute human health impacts, particularly pulmonary function. Inhalable particulate can aggravate existing pulmonary and cardiovascular disease, increase symptoms in asthmatics and increase mortality. High PM_{10} levels can also increase corrosion and soiling of materials, and may damage vegetation. The smaller particles also contribute to degraded visual air quality.

Sources

Inhalable particulate is emitted from a variety of sources with the largest contribution from road dust (37%). Road dust is made up of material that has been previously deposited on the road surface such as mud and dirt track-out, leaves, vehicle exhaust, tire debris, brake linings, and pavement wear. Traffic or wind re-suspends the road dust into the air. Other major contributors to PM_{10} are transportation, construction and demolition, residential wood heating, agriculture and industry. There are also natural sources of PM_{10} such as wind-blown soil, forest fires, ocean spray and volcanic activity.

Monitoring Results

Figure 40 illustrates the PM_{10} monitoring in 2017, while Figures 41 and 42 shows the same values spatially. Annual averages ranged from 6 to 14 μg/m^3 which are all below Metro Vancouver's annual PM_{10} objective.

Widespread exceedances of Metro Vancouver's 24-hour PM_{10} objective were experienced in 2017. The Metro Vancouver 24-hour objective was exceeded on August 1 at Hope and most stations August 2 to 11. Exceedances were also experienced September 5 through 8 at multiple stations. The duration of exceedances in 2017 was considerably longer than in 2015. As discussed in the $PM_{2.5}$ section, 2017 was heavily impacted by wildfire smoke from the BC Interior, Washington, Oregon and California.

While improvements in PM_{10} concentrations have occurred in the last two decades, exceedances of Metro Vancouver's 24-hour PM_{10} objective were widespread in 2017 due to smoke from wildfires burning outside our region.

Table 9 gives the frequency distribution of PM_{10} concentrations for the year. In 2017, stations in Metro Vancouver experienced the greatest frequency of high PM_{10} concentrations due to smoke transported from wildfires burning in August and September.

The seasonal trend of monthly average PM_{10} was similar to previous years with the highest concentrations occurring during hot and dry periods of the summer (Figure 43). The highest average concentrations were experienced in the month of August while the highest peak levels occurred in August and September. These trends were a result of wildfire smoke impacts to the region.

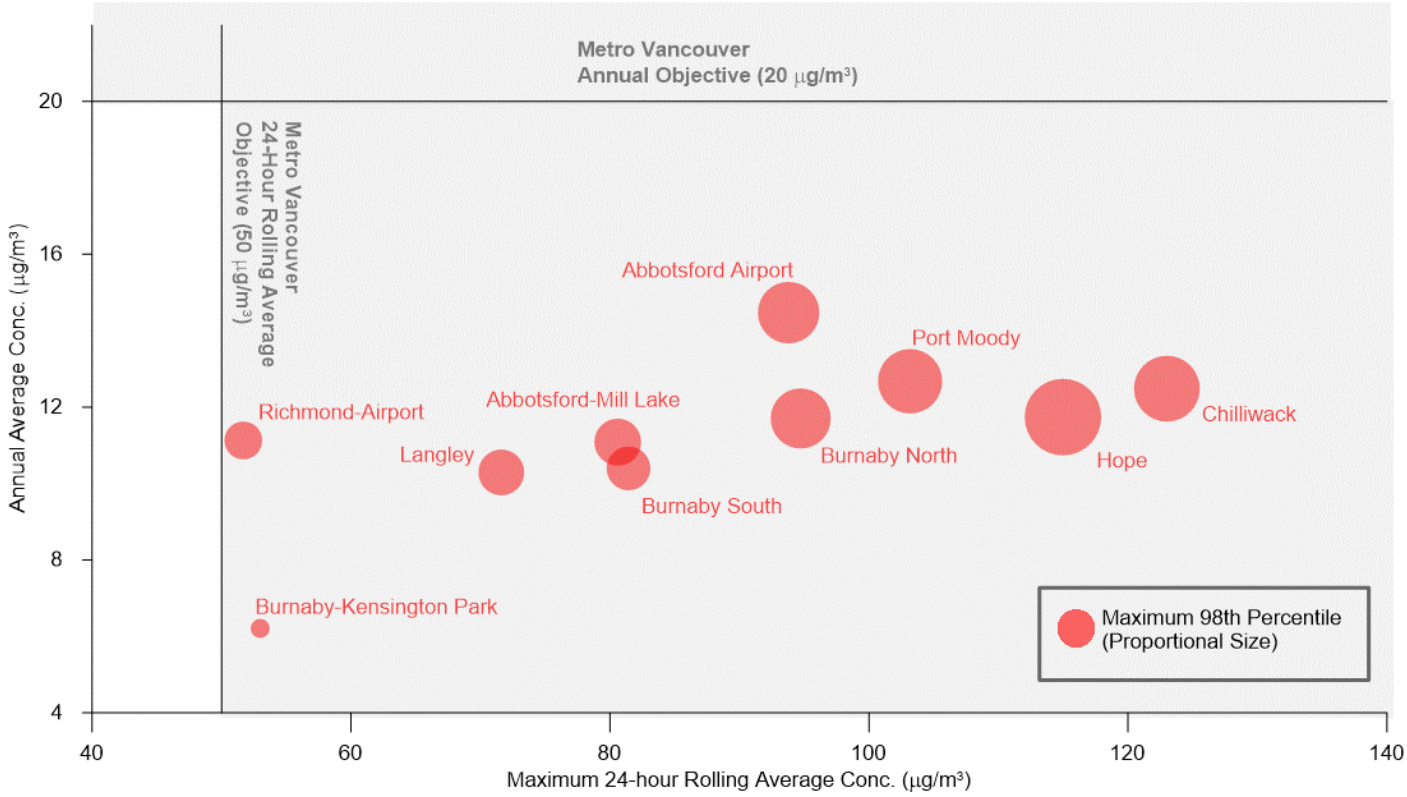
A series of diurnal plots are shown in Figure 45 for each PM_{10} monitoring station. The plots show the differences between weekdays and weekends along with differences between summer and winter.

Historically most stations exhibit higher concentrations on weekdays than weekends, likely the result of greater traffic volumes (road dust) and work related activities (outdoor burning, agricultural activities, industrial processes, etc.). In 2017 however, other factors including wildfires influenced concentrations.

Winter exhibits the least diurnal variation. The summer pattern was influenced by the wildfire events resulting in elevated levels on weekdays due to the timing of the smoke impacts.

The long-term PM_{10} trends (1998 to 2017) are shown in Figure 44 with the annual average trend provided on the left and the short-term peak trend on the right. The annual average PM_{10} trend shows a general improvement in the last 20 years. The peak trend, represented by the 99th percentile of the 24-hour rolling average also shows a slight improvement with the exception of the latest year. The year 2017 was influenced by unprecedented

wildfire smoke that covered the region. The peak measured in 1998 was attributed to a dust storm in Asia with long-range transport of airborne dust across the Pacific to the LFV. The 2005 peak was the result of a large fire in Burns Bog located in Delta. The 2015 peak was also a result of wildfire smoke that covered the region.



Note: Stations contained within the grey area denote an exceedance of an objective.

Figure 40: Inhalable particulate (PM_{10}) monitoring, 2017.

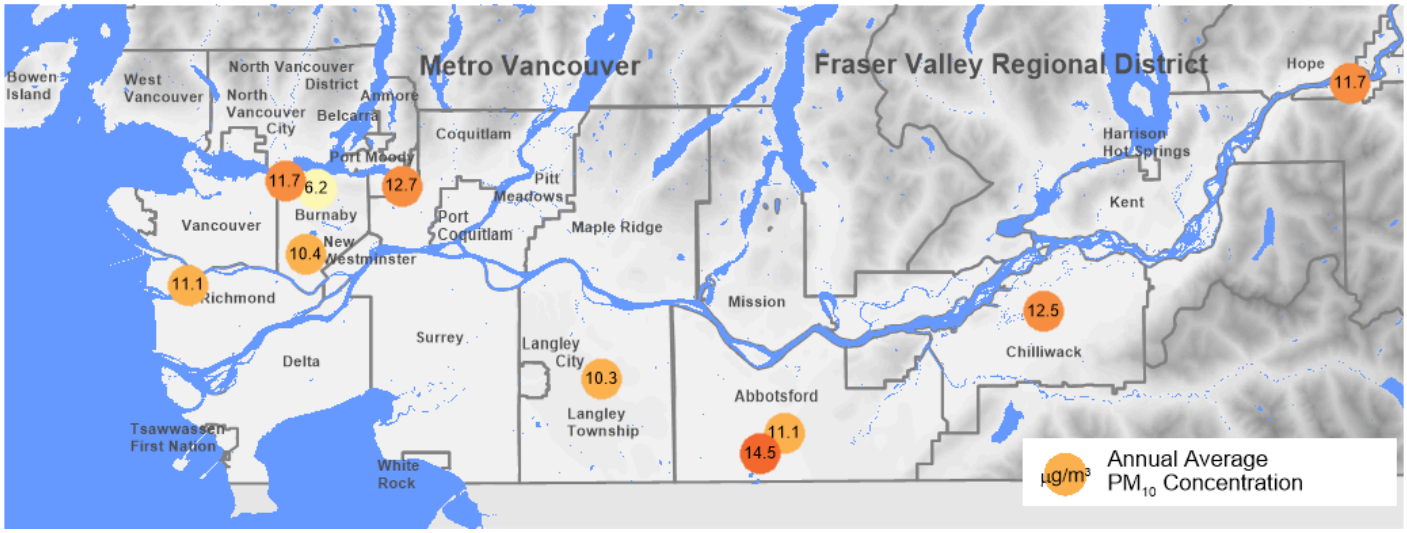


Figure 41: Annual average inhalable particulate (PM_{10}) in the LFV, 2017.

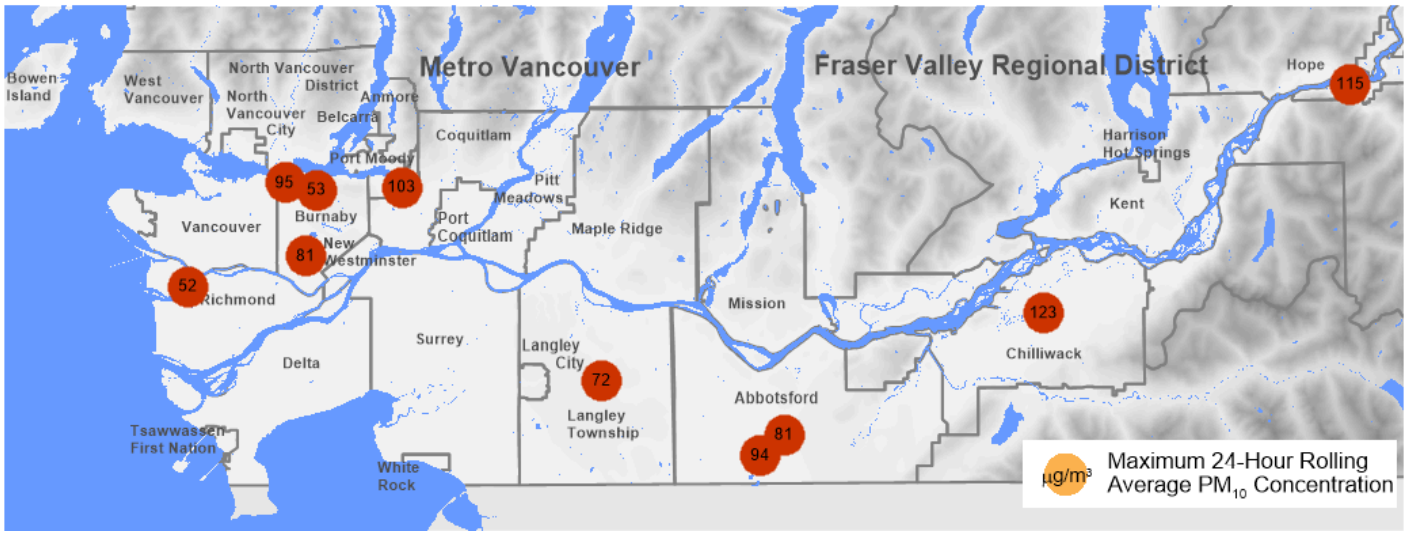


Figure 42: Short-term peak inhalable particulate (PM_{10}) in the LFV, 2017.

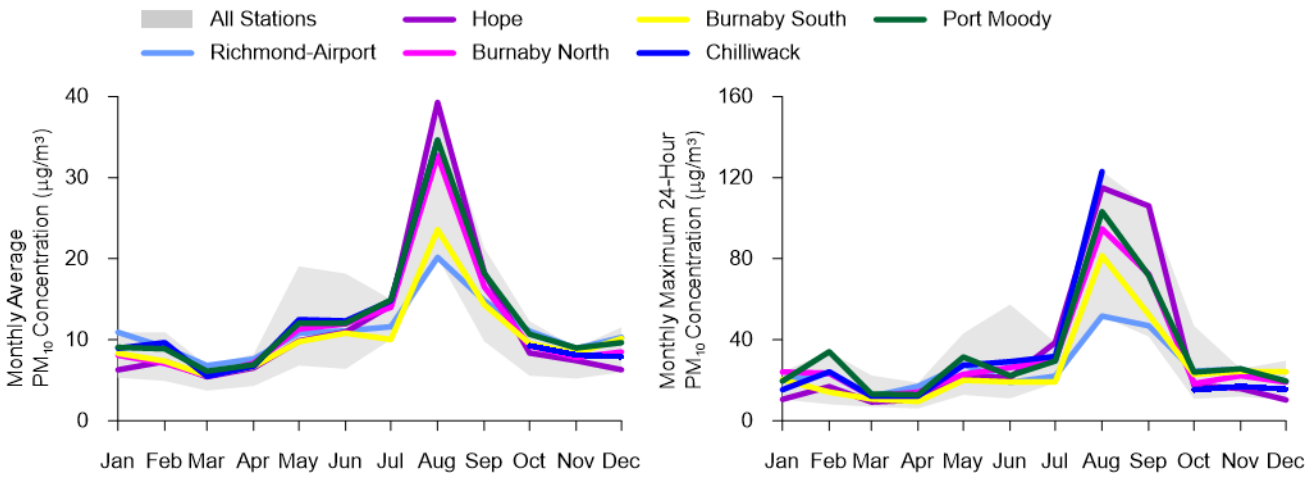


Figure 43: Monthly average (left) and short term peak (right) inhalable particulate (PM_{10}), 2017.

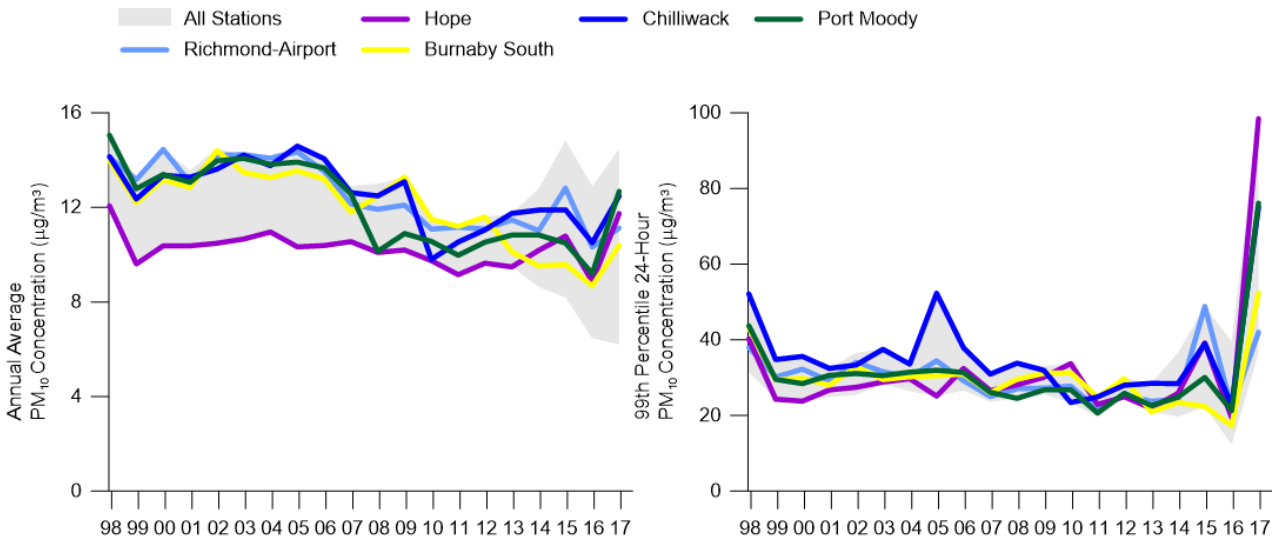
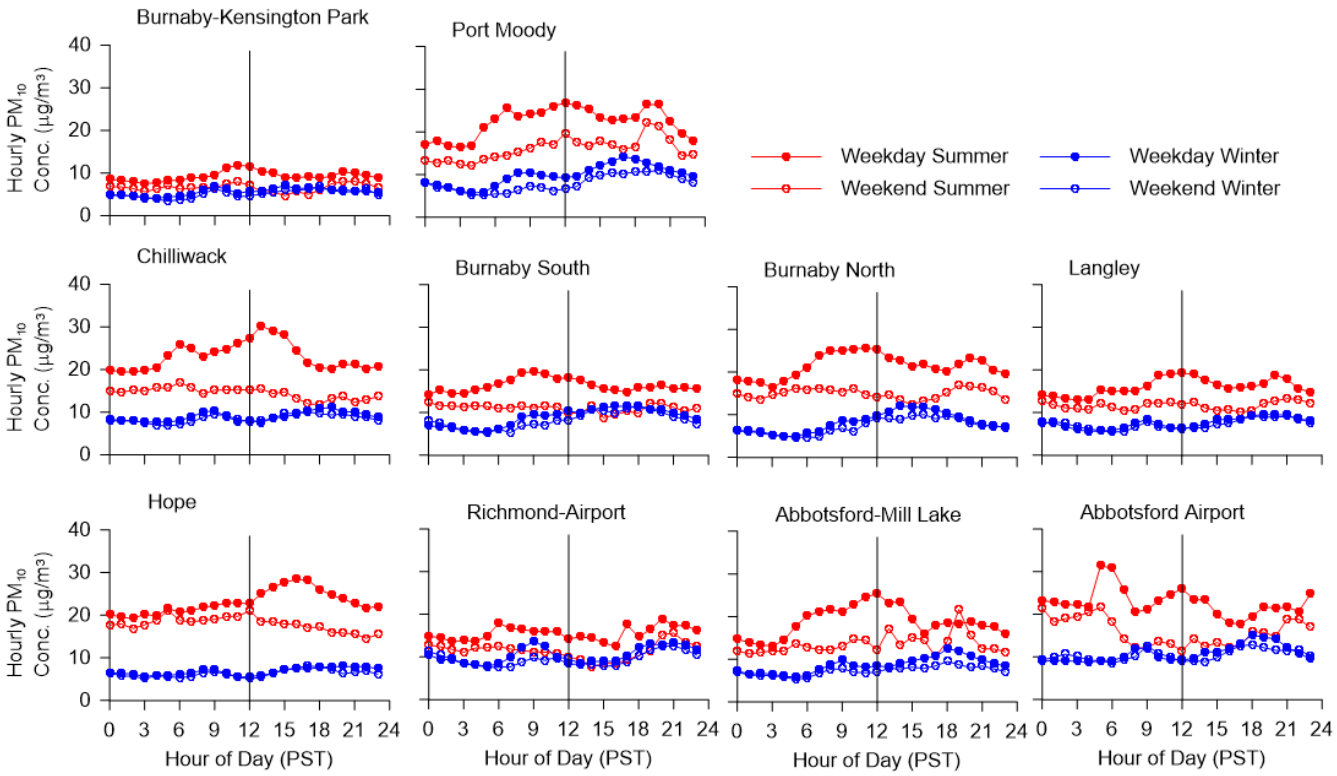


Figure 44: Annual average (left) and short term peak (right) inhalable particulate (PM_{10}) trend, 1998 to 2017

Table 9: Frequency distribution of 24-hour rolling average inhalable particulate (PM_{10}), 2017.

PM_{10} Conc. ($\mu g/m^3$)	Burnaby-Kensington Park	Port Moody	Chilliwack	Burnaby South	Burnaby North	Langley	Hope	Richmond-Airport	Abbotsford-Mill Lake	Abbotsford Airport
0 to 5	3382	911	893	945	1217	1192	1073	410	1120	586
5 to 10	3999	3667	3780	4722	3883	4469	4955	4361	4007	3192
10 to 15	260	2109	1838	2065	2075	2080	1556	2416	2046	1933
15 to 20	23	1114	767	569	907	454	388	1008	841	996
20 to 25	24	353	249	110	243	100	161	185	199	617
25 to 30	13	79	93	37	72	45	55	108	63	293
30 to 35	13	35	31	24	28	44	34	82	37	215
35 to 40	46	13	31	56	11	35	36	68	29	139
40 to 45	14	10	23	38	11	42	10	50	34	76
45 to 50	20	20	19	63	21	71	13	36	29	45
50 to 55	7	26	26	54	23	28	11	17	36	26
55 to 60		22	24	34	39	44	15		48	54
60 to 65		24	20	4	44	43	8		44	58
65 to 70		93	51	3	71	10	49		7	31
70 to 75		27	79	5	61	8	24		23	13
75 to 80		39	12	9	15		30		12	15
80 to 85		7	9	5	5		11		3	12
85 to 90		27	8		6		26			5
90 to 95		4	3		11		30			5
95 to 100		4	24				47			
100 to 105		10	7				29			
105 to 110			5				16			
110 to 115			3				23			
115 to 120			5							
120 to 125			5							
>=125										
Missing Data	959	166	755	17	17	95	160	19	182	449
Completeness	89%	98%	91%	100%	100%	99%	98%	100%	98%	95%



Note: These diurnal plots are heavily influenced by wildfire smoke events in summer and do not represent a typical annual trend.

Figure 45: Diurnal trends inhalable particulate (PM_{10}), 2017.

Black Carbon (BC)

Characteristics

Black carbon (BC) is carbonaceous material formed by the incomplete combustion of fossil fuels, biofuels, and biomass, and is emitted directly in the form of fine particles ($PM_{2.5}$). BC is a major component of "soot", a complex light-absorbing mixture that also contains some organic carbon.

The terms black carbon and soot are sometimes used interchangeably. Although BC has a very short residence time in the atmosphere (about a week), it is a strong absorber of solar radiation and can absorb much more energy than carbon dioxide (CO_2). As a result, BC is considered a "short-lived climate forcer". Black carbon contributes to the adverse impacts on human health, ecosystems, and visibility associated with fine particulate matter ($PM_{2.5}$).

Sources

Mobile sources are the largest contributors of BC emissions in the LFV, emitting over 80% of the BC emissions in the region. Non-road engines (primarily diesel fuelled), heavy duty vehicles, rail and marine vessels are significant sources of BC emissions. Other significant sources in the region are biomass burning activities, including agricultural burning, open and prescribed burning, wildfires and residential heating.

Monitoring Results

Figure 46 illustrates the results of continuous BC monitoring for 2017. Figure 46 displays the value of the maximum 1-hour and 24-hour average as well as the annual average for each station.

There are no provincial, federal or Metro Vancouver objectives for black carbon. The highest 1-hour average BC concentration occurred at Abbotsford Airport, likely due to a local emission source for a short period of time.

In Figure 47 the seasonal trends for BC shows average values higher in January, August and December with the highest peak level occurring in December.

Black carbon is generally greater on weekdays compared with weekends, shown in Figure 48. This trend is especially evident at the Vancouver-Clark Drive station where greater amounts of BC are experienced in the winter and on weekdays compared with weekends.

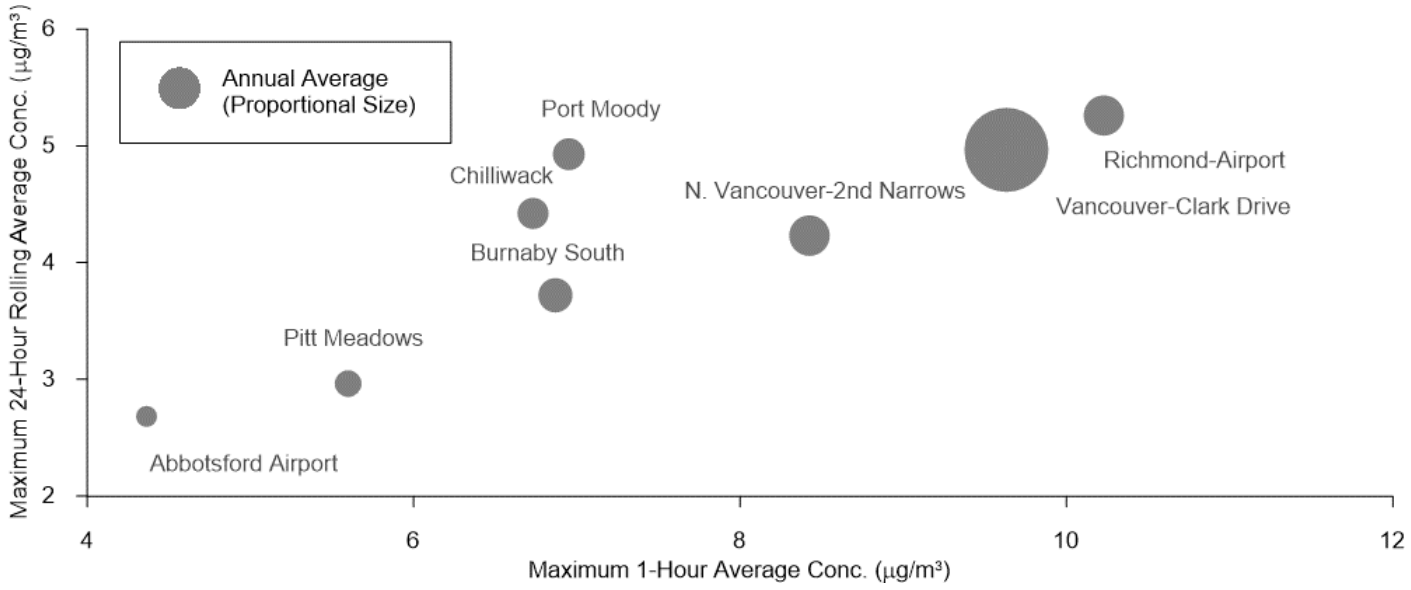


Figure 46: Black carbon monitoring, 2017.

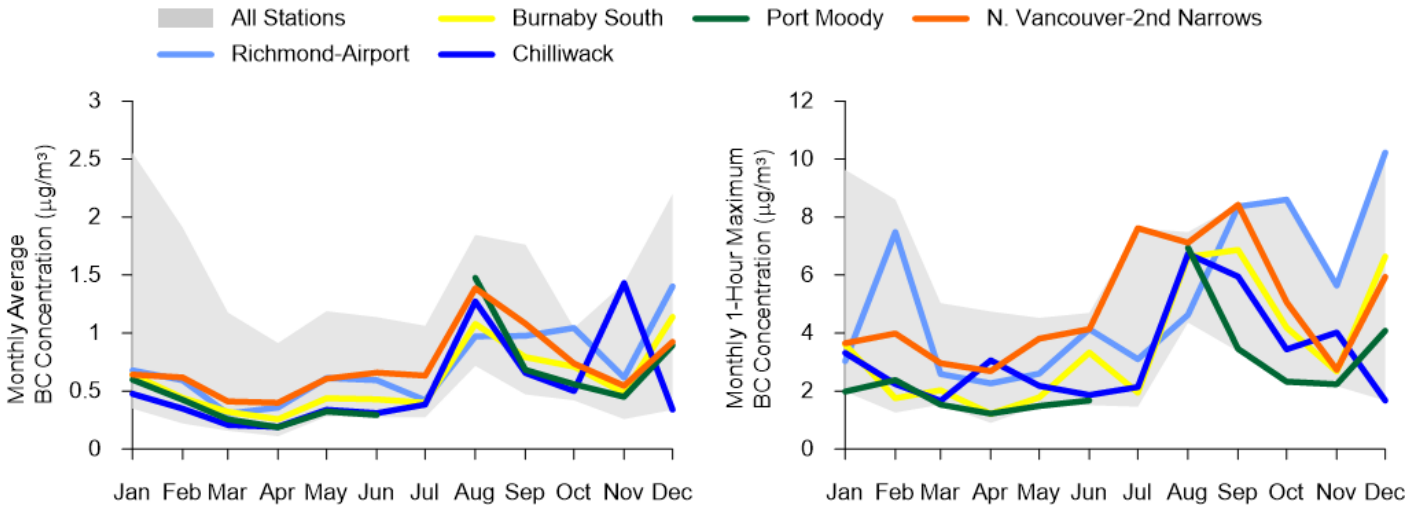


Figure 47: Monthly average (left) and short term peak (right) black carbon, 2017.

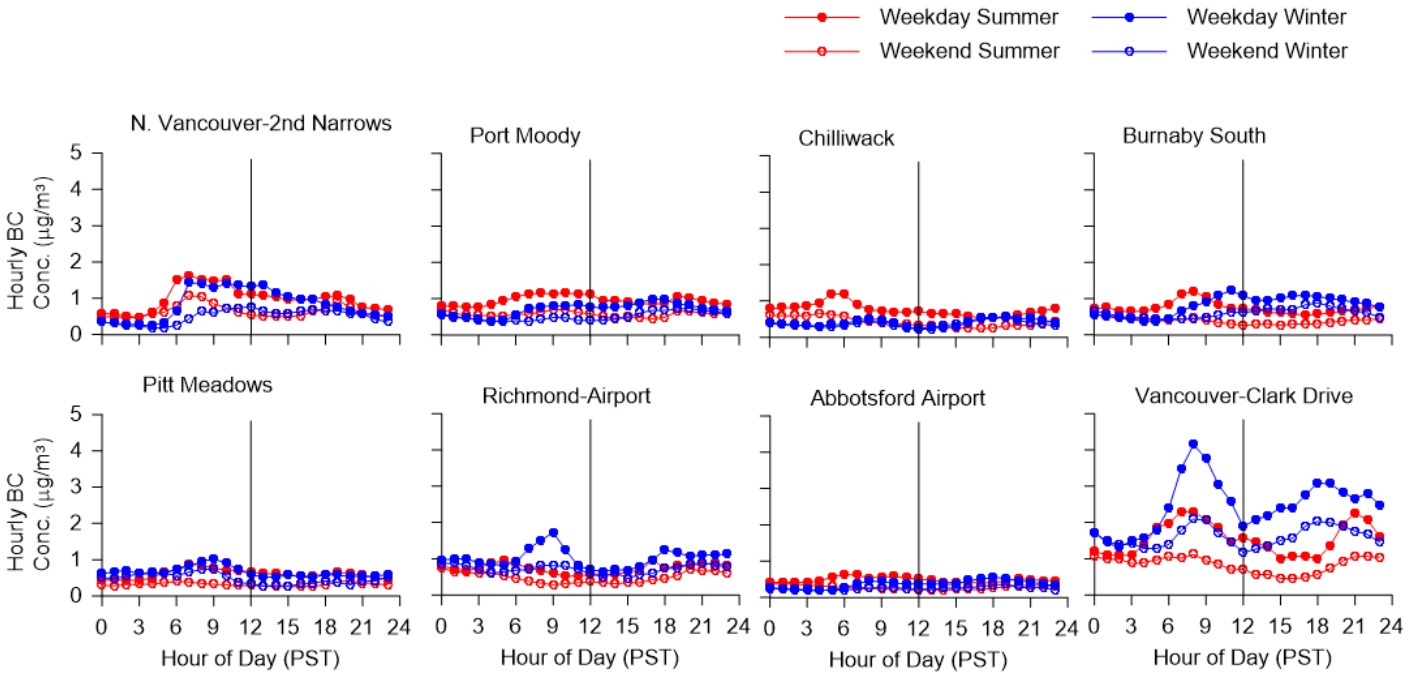


Figure 48: Diurnal trends black carbon, 2017.

Ultrafine Particles (UFP)

Characteristics

Ultrafine particles (UFP) consist of a combination of suspended solids and liquid droplets having aerodynamic diameters less than 0.1 microns (100 nanometers). These particles are measured based on their numbers (units of 10^3 #/cm^3) in the atmosphere rather than fine particulate matter that is measured based on its mass (μg/m^3).

Ultrafine particles are relatively short-lived, as compared to longer-lived $PM_{2.5}$ particles which may persist in the atmosphere for up to several weeks. The short lifetime for UFP results from their very high number concentrations upon emission. Levels may peak near strong UFP sources such as busy freeways. These exceptionally concentrated UFP rapidly agglomerate (stick together) with each other and with larger particles (e.g. $PM_{2.5}$) to yield particles with diameters larger than 0.1 microns. Agglomeration, dispersion, and advection are the dominant atmospheric processes determining the UFP spatial distribution. Deposition (settling onto surfaces) plays a minor role in the UFP spatial distribution because gravity does not have a strong influence on UFP. Typically, the UFP level decreases exponentially away from a source.

Sources

There are several sources of UFP, including manufacturing processes, combustion sources, and nucleation events. It is generally recognized that smaller particles are more harmful to human health. Unlike larger particles, UFP can penetrate pulmonary tissue, enter the bloodstream, and circulate throughout the body.

Monitoring Results

Ultrafine particle monitoring has not been conducted in the region prior to the near-road air quality monitoring study. The results from the near-road monitoring study are the first collected in the Metro Vancouver region due to availability of new monitoring technology and interest in these particles from a health perspective.

Figure 49 illustrates the results of continuous UFP monitoring for 2017. The figure displays the value of the maximum 1-hour and annual average for the single UFP station that operated in 2017. There are currently no federal, provincial or regional air quality objectives for UFP.

In Figure 50 the seasonal trends for UFP shows average values higher in the winter months with the highest peak level occurring in January.

Ultrafine particle counts are generally higher on weekdays compared with weekends. As shown in Figure 51, the winter weekday trend is the most prominent with a peak count of ultrafine particles in the morning corresponding with traffic.

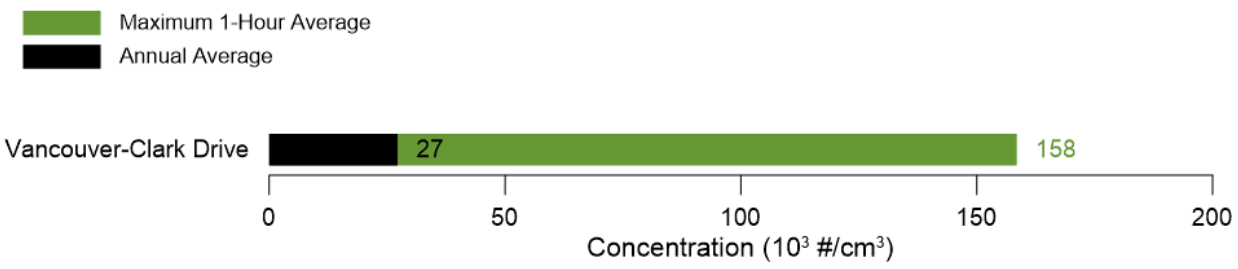


Figure 49: Ultrafine particle monitoring, 2017.

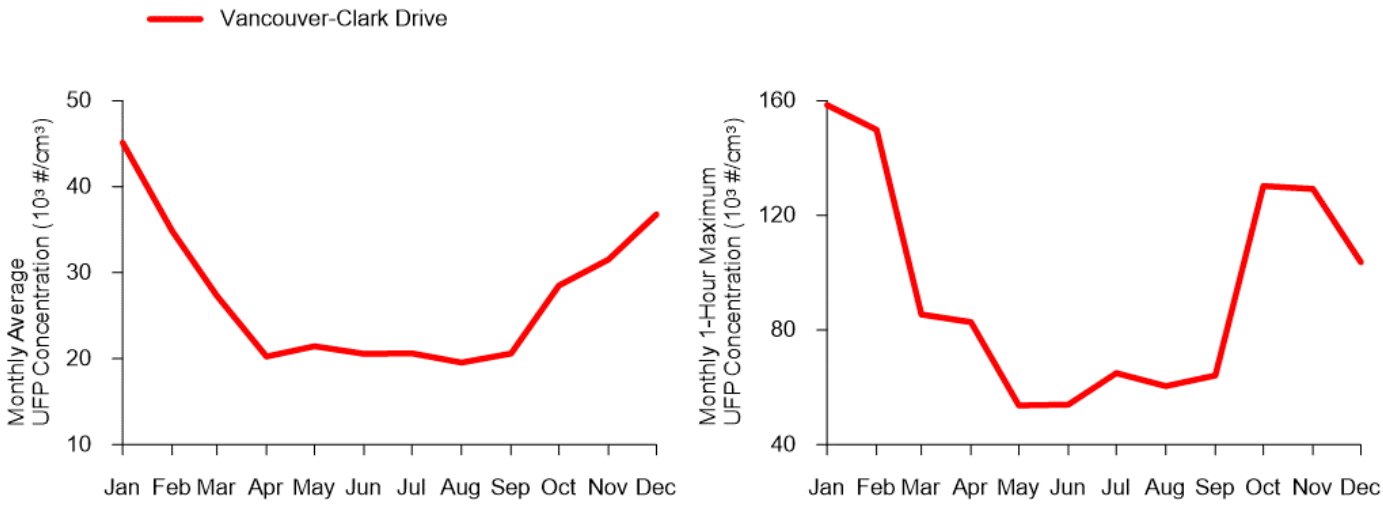


Figure 50: Monthly average (left) and short-term peak (right) ultrafine particles, 2017.

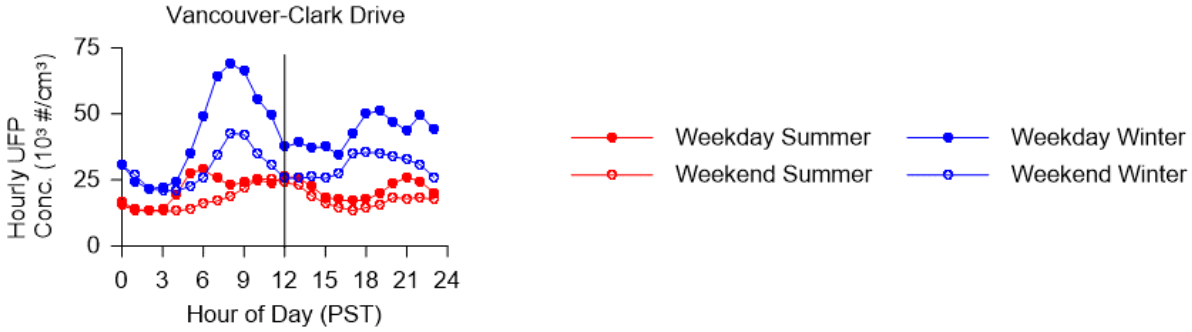


Figure 51: Diurnal trends ultrafine particles, 2017.

Total Reduced Sulphur (TRS)

Characteristics

Total reduced sulphur (TRS) compounds are a group of sulphurous compounds that occur naturally in swamps, bogs and marshes. They are also created by industrial sources such as pulp and paper mills, petroleum refineries and composting facilities. These compounds have offensive odours similar to rotten eggs or rotten cabbage, and at high concentrations can cause eye irritation and nausea in some people.

Sources

Most public complaints regarding these odours are associated with composting facilities and with the petroleum refining and distribution industry located along Burrard Inlet. A few periodic inquiries also occur as a result of natural emissions from such locations as Burns Bog in Delta.

Monitoring Results

Figure 52 illustrates the TRS measurements in 2017 for stations with sufficient data completeness. Average levels continued to be near detectable limits. Peak levels during 2017, indicated by the maximum 1-hour value, exceeded the Desirable Objective for a total of 3 hours and the Acceptable Objective for a total of 1 hour at Port Moody. The occurrences of elevated TRS are of short duration and generally during the night or early morning. The exceedances occurred in March, September and October.

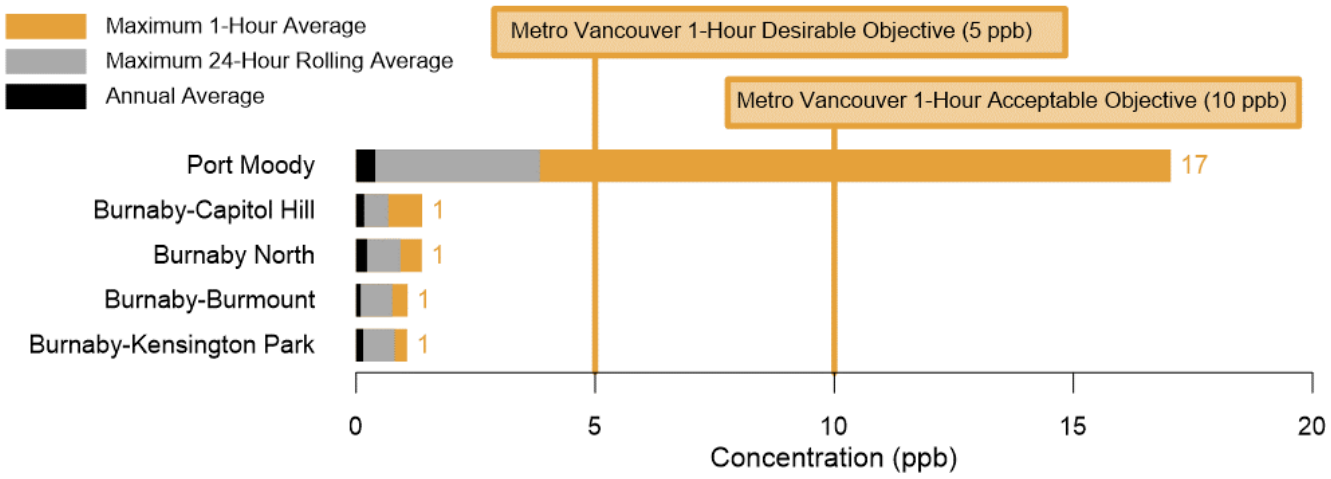


Figure 52: Total reduced sulphur monitoring, 2017.

Ammonia (NH_3)

Characteristics

Ammonia (NH_3) can contribute to the formation of fine particles when chemical reactions occur between ammonia and other gases in the atmosphere including sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). The resulting ammonium nitrate and ammonium sulphate particles are efficient at scattering light and can impair visual air quality with a white haze.

Sources

The largest contribution to ammonia in the LFV comes from the agriculture sector. The majority of ammonia emissions come from cattle, pig, and poultry housing, land spreading and storage of manure, and fertilizer application.

Monitoring Results

Continuous measurements of ammonia were made at three sites in the monitoring network in 2017. The 2017 data are presented in Figure 53, shown as the maximum 1-hour average, maximum 24-hour rolling average and annual average ammonia concentrations. There are no applicable objectives for ammonia.

Continuous measurements of ammonia began in 2005. Due to the relatively short period for which data are available, no clear long-term trend in ammonia is evident.

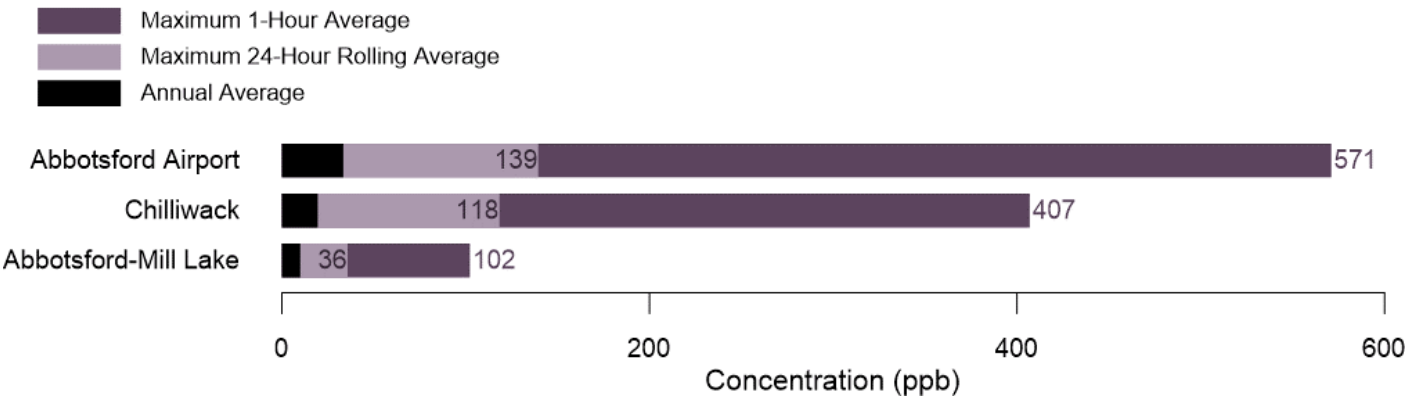


Figure 53: Ammonia monitoring, 2017.

Section E – Non-Continuous Pollutant Measurements

Non-continuous samples are collected in accordance with the National Air Pollution Surveillance (NAPS) program. After collection, samples are transported to and analyzed in a federal laboratory in Ottawa to determine pollutant concentrations.

Analysis results of non-continuous (integrated) sampling from the federal laboratory can take considerable time. Therefore, analysis of non-continuous results will be conducted when available and appended to this report.

Particulate Sampling

Non-continuous 24-hour (daily) $PM_{2.5}$ and PM_{10} samples are collected on filters every sixth day depending on the site. Non-continuous particulate samples are collected at five monitoring stations in the LFV and pollutant concentrations are determined. A detailed analysis is conducted by the federal laboratory for four of these stations (Port Moody, Burnaby South, Abbotsford Airport and Vancouver-Clark Drive).

Using specialized PM speciation instrumentation, additional detailed information about the chemical composition of $PM_{2.5}$ is obtained from three stations in the network (Burnaby South, Abbotsford Airport and Vancouver-Clark Drive) as a result of analyses carried out by the federal NAPS program. From the 24-hour samples collected at these two sites, the various compounds that form $PM_{2.5}$ are identified.

Volatile Organic Compounds (VOC)

Volatile Organic Compounds (VOC) refers to a combination of organic chemicals. A large number of chemicals are included in this group but each individual compound is generally present at relatively low concentrations in air compared to other common air contaminants. The gaseous VOC present in the air can originate from direct emissions and from volatilization (*i.e.* changing into the gas phase) of substances in the liquid or solid phase.

Locally, some VOC can be pollutants found in urban smog and are precursors of other contaminants present in smog such as ozone and fine particulates. Some materials in this class (*e.g.* carbon tetrachloride) can contribute to depletion of the stratospheric ozone layer and may contribute to climate change. Other VOC (*e.g.* benzene) can pose a human health risk.

Sources of VOC in Metro Vancouver include, but are not limited to emissions from the combustion of fossil fuels, industrial and residential solvents and paints, vegetation, agricultural activities, petroleum refineries, fuel-refilling facilities, the burning of wood and other vegetative materials, and large industrial facilities.

Under the Canadian Environmental Protection Act some VOC are included in the Toxic Substances List.

Emissions of some VOC are managed under permits and industry-specific regulations within Metro Vancouver.

Non-continuous 24-hour (daily) sampling of VOC is conducted every sixth or twelfth day on a national schedule. In 2017, VOC samples were collected at eight sites in the LFV. In cooperation with the federal National Air Pollution Surveillance (NAPS) program, canister sampling of VOC has been conducted in the LFV since 1988. Canisters sent to the federal laboratory are analyzed for up to 175 VOC. These data can then be used to help determine the emission sources contributing to contaminants in the air.

In addition to the canister sampling, continuous measurements of total hydrocarbons (THC) were made at two stations in 2017, Burnaby North and Burnaby-Burmount (results not shown). Both of these are adjacent to petroleum industry facilities.

Section F – Visual Air Quality Monitoring

Characteristics

When light between an object and the eye of an observer is scattered and/or absorbed by particles and gases in the air, views can look hazy or even be fully obscured. The term visual air quality refers to the impacts air contaminants have on our ability to see through the atmosphere, affecting the appearance of views including the distance at which the elements of a scene can be clearly seen. It does not refer to the direct effects of clouds, fog, rain or mist on a view.

Visual air quality studies conducted in the LFV have concluded that the major contributor to visual air quality impairment in the LFV is $PM_{2.5}$ and have shown that visual air quality degradation occurs at relatively low air contaminant concentrations, below Metro Vancouver's ambient air quality objectives for $PM_{2.5}$. However, the effects of visual air quality impairment can have different characteristics in different locations within the airshed due to the air contaminants present.

For example, in more urbanized areas of the western LFV, nitrogen dioxide emitted when fuels are burned contributes to the yellow-brown discolouration of the view. Further east in the LFV, visual air quality impairment usually occurs as white haze due to the presence of $PM_{2.5}$. Sources of particulate matter contributing to visual air quality impairment include anthropogenic activities as well as natural sources such as windblown dust, soil, sea salt and smoke.

Monitoring Program

To assess visual air quality in the LFV, Metro Vancouver, FVRD, and Environment and Climate Change Canada jointly established a visual air quality monitoring network. Continuous measurements of light scattering and the species responsible for light absorption are complemented by particulate speciation sampling, meteorological measurements and images of views along specific lines-of-sight. Measurements of views or both views and air contaminants are made at seven locations in the LFV (Figure 54).

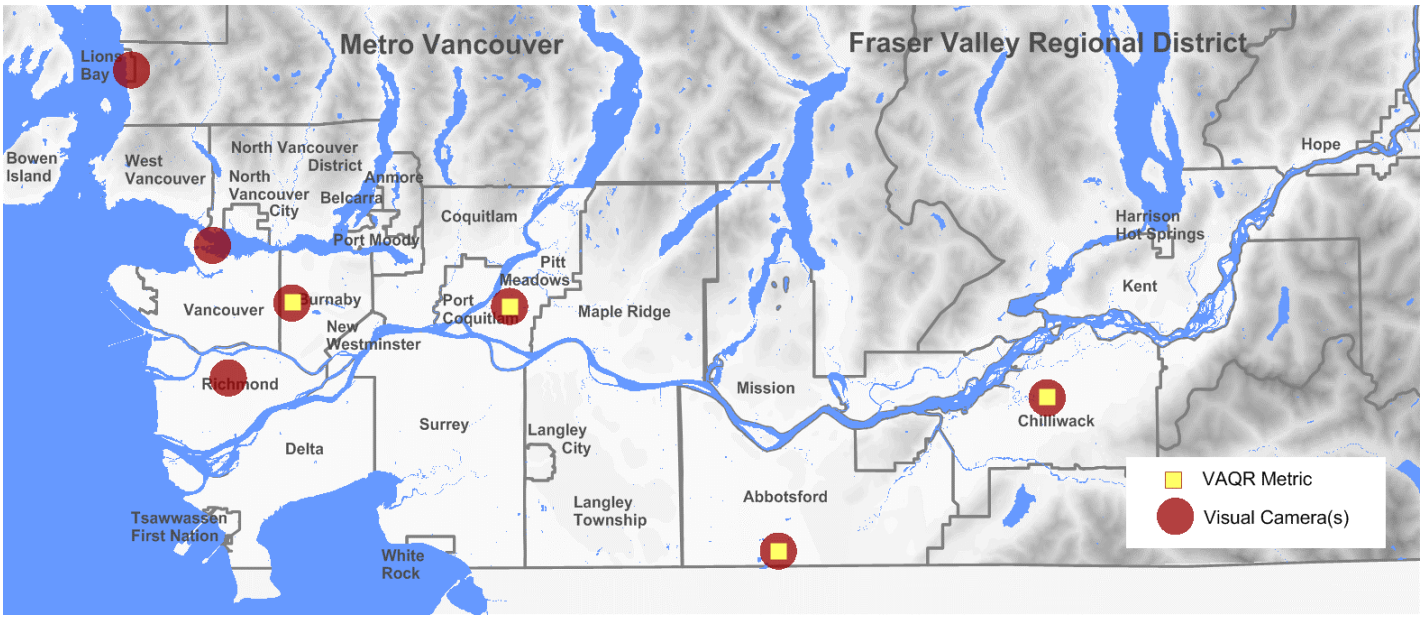


Figure 54: Visual air quality monitoring locations in the LFV, 2017.

Light scattering measurements are made for visual air quality analysis using nephelometers in five locations. Aethalometers and nitrogen dioxide analyzers are also located at these sites and are used to characterize light absorption. Analysis of monitoring data to reconstruct light extinction has indicated that scattering by particles generally has the most influence on visual air quality in the LFV. Modelling work has determined that the highest contributions to extinction, and consequently visual air quality degradation, in the LFV on the most impaired visual air quality days are from particulate nitrate and organic matter. The extent of the influence of other species, such as particulate sulphate, on visual air quality degradation is dependent on meteorological conditions.

Automated digital cameras are operated in the seven locations shown in Figure 54: Chilliwack, Abbotsford, Pitt Meadows, Burnaby, Vancouver, Richmond and Lions Bay. Images are captured at 10 or 30 minute intervals along specific lines-of-sight with recognizable topographical features at defined distances.

Visual Air Quality Pilot Project

A visual air quality pilot project was established in the LFV by the BC Visibility Coordinating Committee (BCVCC). The BCVCC was established in 2006 and is a collaborative venture between Metro Vancouver, FVRD, Environment and Climate Change Canada, Health Canada and BC Ministry of Environment and Climate Change Strategy. An objective of the pilot project is to determine the actions necessary to protect and improve visual air quality in the LFV.

Key components of the pilot project include:

- The establishment and ongoing operation of a visual air quality monitoring network;
- The development of a visual air quality reporting tool and recommendations for a visual air quality goal;
- The identification of the causes and impacts of impaired visual air quality in the LFV;
- An improvement of our understanding of the economic drivers for visual air quality management; and
- The creation of a strategy to engage and inform stakeholders and members of the public about visual air quality issues.

Visual Air Quality Rating

A visual air quality rating (VAQR), with descriptors ranging from excellent, good, fair, poor to very poor, was developed by the BCVCC, to enhance outreach about visual air quality in the LFV and to provide a metric to track changes in visual air quality. The VAQR was launched in 2015 and was reported for four sites in 2017, as shown in Figure 54.

The VAQR reflects residents' perceptions of visual air quality conditions. Images from visual air quality monitoring network cameras were used to survey residents in Metro Vancouver and FVRD to relate perceived visual air quality to measured air contaminant concentrations and the estimated resulting optical characteristics of the atmosphere along the line-of-sights to the views.

Visual air quality conditions recorded by the camera in Pitt Meadows in 2017 are shown in Figure 55. The images demonstrate the effect of wildfire smoke on visual air quality in July and August 2017.

http://www.clearairbc.ca/community

Figure 55: Images showing a range of visual air quality ratings in June, July and August, (Pitt Meadows - 2017) with 24-hour rolling average $PM_{2.5}$ concentrations of 6 µg/m3, 15 µg/m3 and 28 µg/m^3, respectively.

Section G – Meteorological Measurements

Purpose

An understanding of meteorology is integral in understanding and forecasting air quality and visual air quality patterns. The state of the atmosphere determines pollutant dispersion and the resultant ground-level concentration. Meteorology is observed at LFV air quality monitoring network stations for several purposes:

- To allow for a characterization of meteorological patterns throughout the LFV.
- To assist with the linkage between pollutant emission sources and ambient concentrations.
- To provide data to be used as input in dispersion modelling.
- To provide real-time data to numerous agencies including Environment Canada, which are used for weather and air quality forecasting in the region.

It should be noted that the LFV network's primary purpose is for the collection of air quality measurements and secondary purpose is for meteorological observation. Attempts have been made to site meteorological instruments to provide representative observation, however due to site restrictions at some stations, not all instruments are sited to capture spatially representative measurements.

Monitoring Program

Various meteorological parameters are observed as part of the LFV air quality monitoring network (see Section C Table 2). Meteorological parameters observed in the network include:

- wind speed and direction
- air temperature
- relative humidity
- precipitation
- barometric pressure
- incoming solar radiation

Wind speed and direction observations allow for the characterization of pollutant transport and dispersion and are used to understand the relationships between pollutant sources and measurements at air quality monitoring stations.

Air temperature and incoming solar radiation measurements can be used to determine the potential for ozone formation during the summer. Ozone concentrations are dependent on sunshine to cause photochemical reactions among air pollutants. Higher air temperatures are necessary for these reactions to occur.

Vancouver-Portside meteorological station.

Humidity is important in the formation and growth of visibility reducing particles, and its measurement is a key to understanding the many factors responsible for visual air quality degradation.

Precipitation can remove pollutants from the atmosphere and may help explain differences in air quality from one part of the region to another. In addition, precipitation data are used by Metro Vancouver's Wastewater Collection and Watershed Management functions.

Meteorological Observations

Figure 56 shows the annual precipitation totals for 2017 at Lower Fraser Valley air quality monitoring network stations. The greatest precipitation was observed near the local mountains. Historical 30-year climate normals (1981-2010) obtained from Environment Canada are also shown in Figure 56 for several stations. Figure 56 displays the seasonal variation as observed by the LFV air quality network stations (shown as a grey band). Historical 30-year climate normals (1981-2010) obtained from Environment Canada are also shown in Figure 54 for Vancouver International Airport, Port Moody and Chilliwack.

Compared to climate normals, monthly precipitation in 2017 was drier in January, June, July and August, and was wetter in March, April, and May.

Figure 58 illustrates the seasonal variation of air temperatures observed throughout the monitoring network stations. The hourly maximum and minimum, daily maximum and minimum, and average temperatures are given with the range in values shown as bands. Also shown in Figure 58 are the 30-year climate normals (1981-2010) for Environment Canada's Vancouver International Airport and Agassiz stations.

The data observed in 2017 indicate that average temperatures recorded in August and September were warmer than the 30-year average. During these months' higher averages and daily maximums were experienced compared with the climate normals. The highest air temperatures were measured in August. January, February, March and December was on average cooler than normal.

Table 10 provides the average temperature along with the lowest and highest hourly air temperatures observed throughout the year. Air temperatures are milder near the water and exhibit a greater range inland. The highest hourly temperature in 2017 was 37.1°C observed at Hope.

Table 11 gives the frequency distribution of hourly air temperature for the year. Stations located inland, such as those in eastern parts of Metro Vancouver and the Fraser Valley Regional District exhibit the greatest frequency of both very low and very high air temperatures.

Wind patterns vary between stations as shown by the frequency distributions in Figure 59. The distributions are shown as a "wind rose", which is a bar chart in a polar format. The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 59 shows observed annual wind roses for selected stations including (in order of west to east): Horseshoe Bay, Richmond-Airport, Burnaby North, Pitt Meadows, Abbotsford Airport, Chilliwack, and Hope. The patterns shown during 2017 reflect the predominant winds in those areas. Richmond exhibits a predominant easterly wind with a smaller component from the west, and very little wind from either the north or south. Horseshoe Bay shows wind patterns aligned with Howe Sound with a strong north-south component.

2017 started with a colder and drier than normal winter followed by wet spring and hot dry summer. Record breaking heat was experienced in August and September.

Burnaby North shows several northerly wind components along with a predominant east-north east component. This wind pattern is reflective of the North Shore mountain wind flows and drainage flow from Indian Arm. Pitt Meadows shows a somewhat similar pattern with predominant directions from the valleys of Pitt Lake and Alouette Lake. Abbotsford, Chilliwack and Hope experience similar wind flow patterns, with strong east-west components driven by the channelling of winds in the narrower portion of the Fraser Valley.

Figures 60 to 63 show wind roses for winter, summer, spring and fall, respectively. The contrast between winter and summer can be seen in Figures 60 and 61 with winds predominantly from the east in winter switching to southwest in summer. The more westerly flow seen in the summer is the development of a daytime sea breeze during anti-cyclonic (high pressure) weather.

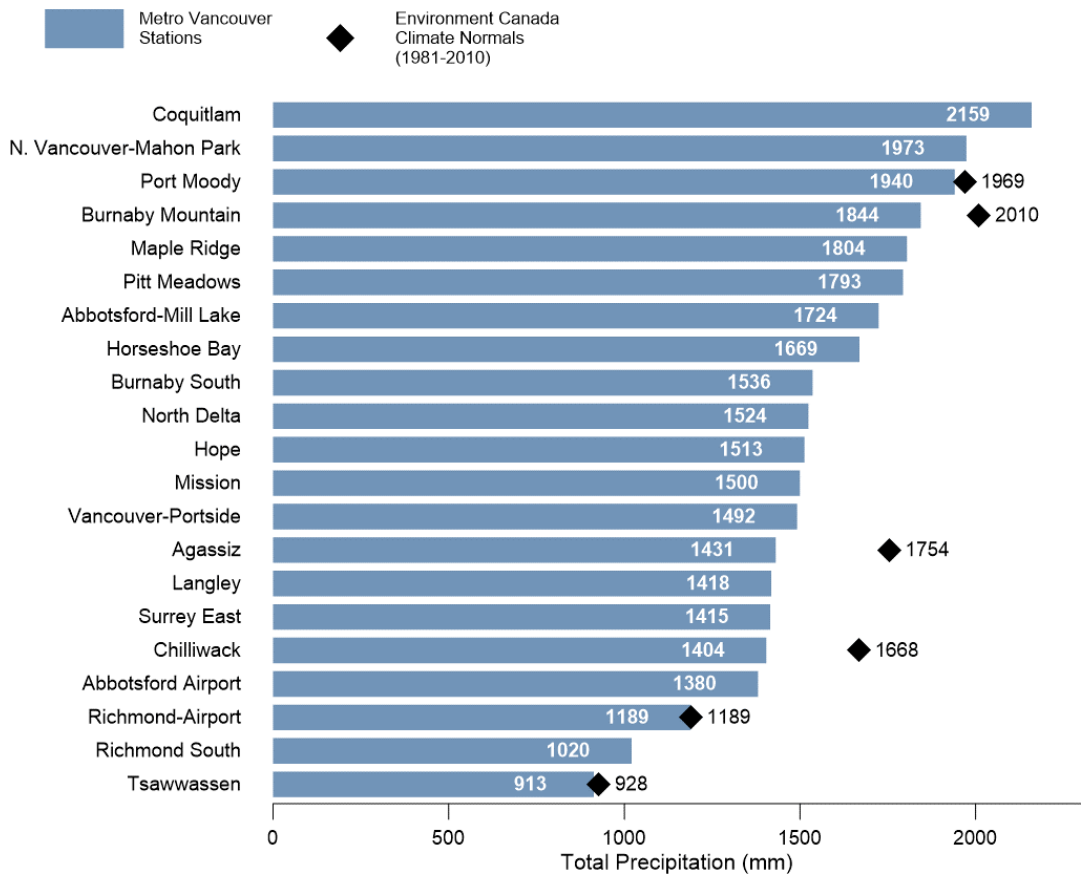
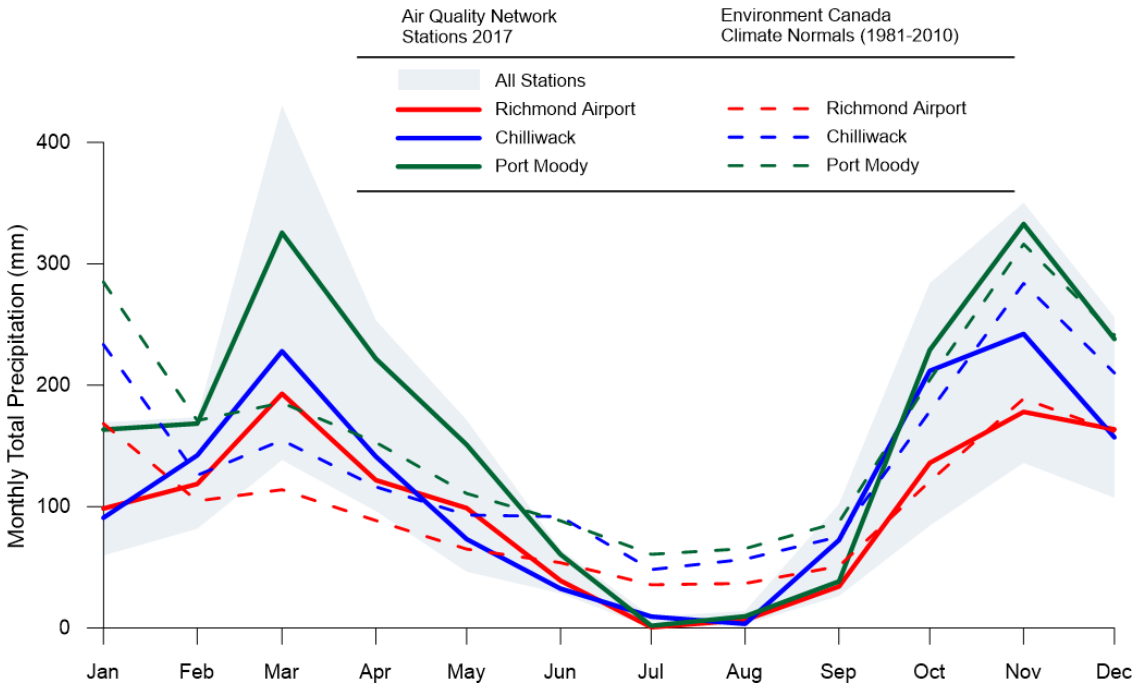
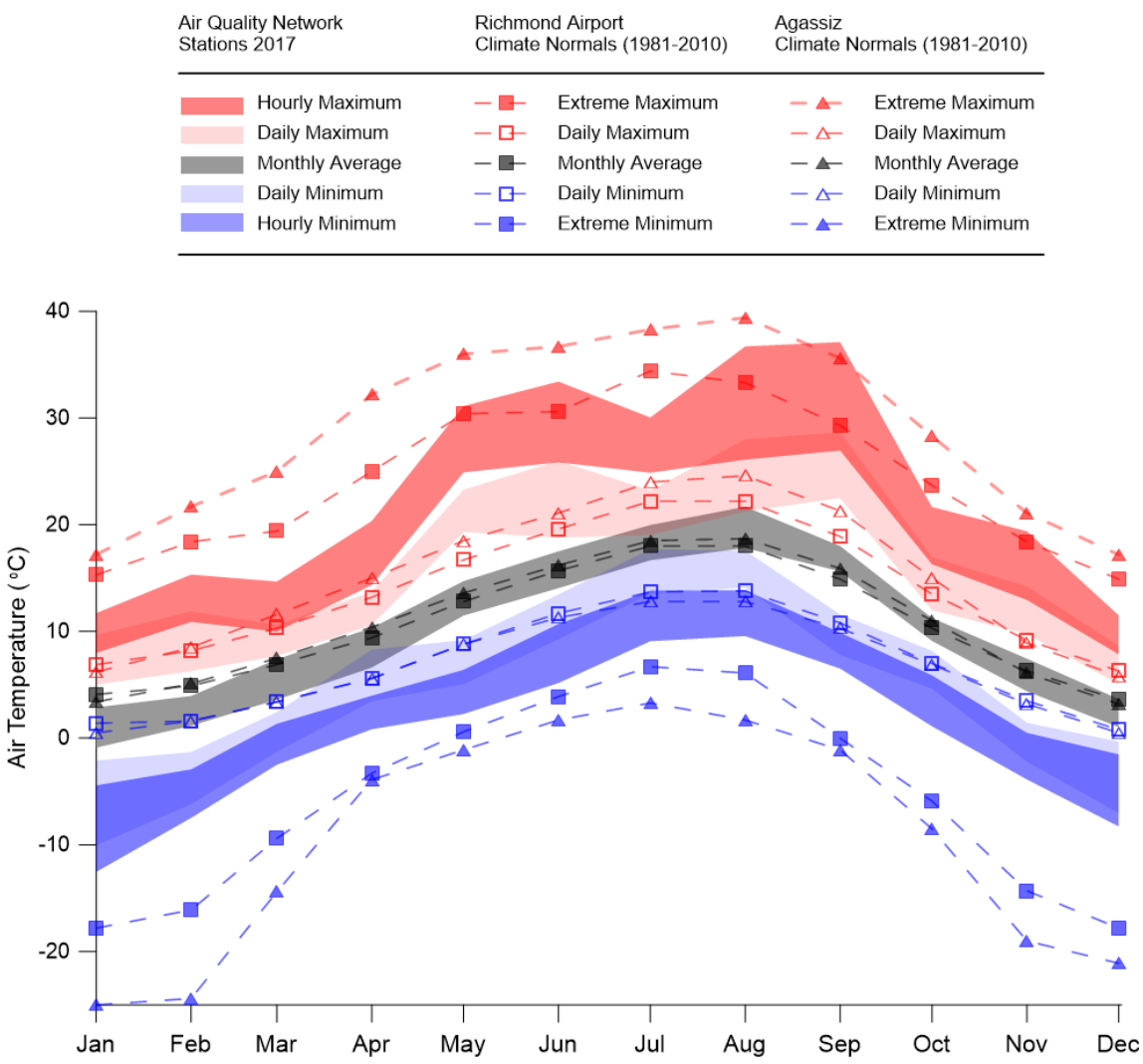


Figure 56: Annual precipitation totals in the LFV, 2017.



Note: The range of values observed at LFV air quality network stations are shown as a blue band and Environment Canada climate normals are shown as dotted lines.

Figure 57: Total monthly precipitation in the LFV, 2017.



Note: LFV air quality network stations are shown as colour bands and Environment Canada 30-year climate normals are shown as dotted lines.

Figure 58: Monthly air temperatures in the LFV, 2017.

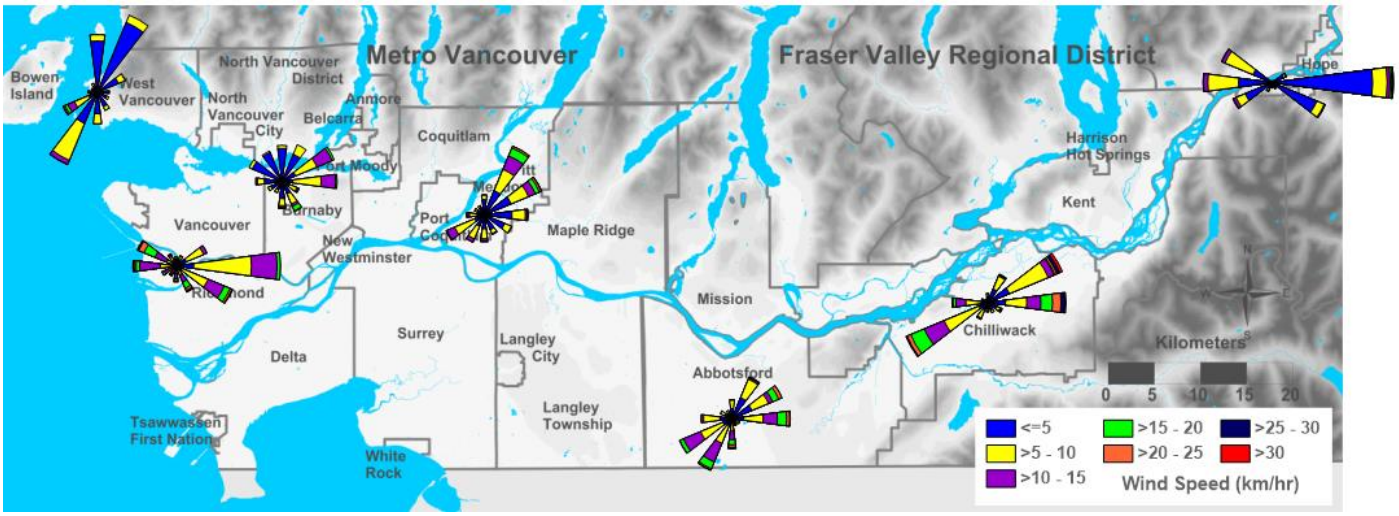


Figure 59: Selected annual wind roses throughout the LFV, 2017.

Table 10: Air temperature in LFV, 2017.

Station	Hourly Maximum (ºC)	Hourly Minimum (ºC)	Annual Average (ºC)
Hope	37.1	-12.5	10.1
Agassiz	36.6	-9.4	11.0
Abbotsford Airport	35.6	-8.0	10.5
Chilliwack	35.3	-7.8	11.0
Abbotsford-Mill Lake	35.0	-9.1	10.4
Mission	34.5	-7.4	10.6
Maple Ridge	34.1	-10.0	10.0
Pitt Meadows	33.1	-10.0	10.2
Surrey East	32.7	-6.7	9.6
Burnaby-Burmount	32.7	-5.5	11.0
Langley	32.7	-7.7	10.0
Burnaby South	32.4	-5.8	10.2
Coquitlam	32.3	-6.4	8.7
Burnaby-Kensington Park	31.7	-5.7	10.3
Port Moody	31.6	-7.2	10.7
Annacis Island	31.2	-7.8	9.9
Vancouver-Clark Drive	30.9	-9.1	10.7
N. Vancouver-Mahon Park	30.8	-6.2	10.5
North Delta	30.8	-7.3	9.7
Burnaby-Capitol Hill	30.8	-5.5	9.7
Burnaby North	29.9	-6.1	10.0
Vancouver-Portside	29.8	-5.5	10.8
Burnaby Mountain	29.7	-6.6	8.9
Vancouver-Templeton	29.1	-6.6	10.4
Richmond South	28.0	-7.7	10.1
Horseshoe Bay	27.8	-4.4	9.9
Richmond-Airport	27.7	-5.3	10.7
Tsawwassen	27.3	-5.8	10.2

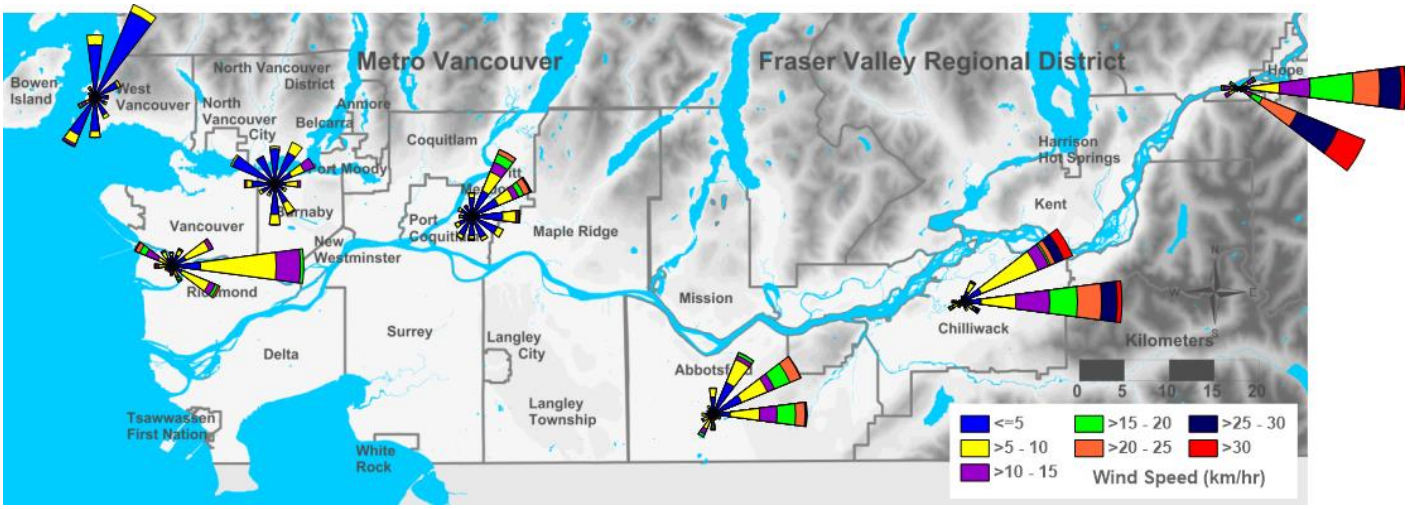


Figure 60: Winter (Jan, Feb, Dec) representative wind roses throughout the LFV, 2017.

Table 11: Frequency distribution of hourly air temperature, 2017.

Air Temperature (deg C)	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	Burnaby-Burmount	Burnaby-Capitol Hill	Burnaby North	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Horseshoe Bay	Annacis Island	Tsawwassen	Mission	Agassiz	Abbotsford Airport	Vancouver-Templeton	Vancouver-Portside	Near-Road Clark Drive
-12 to -9										13						26	7			1					2				1
-9 to -6			24	18	21	9	5	31		53			5	3	19	174	60		2	32		44		14	27	20	8		37
-6 to -3	78	8	122	241	185	233	133	132	135	123	75	135	112	89	146	413	188	69	112	193	21	122	121	292	312	218	123	76	123
-3 to 0	458	75	482	462	656	731	535	470	434	595	379	589	411	346	646	328	711	316	397	514	312	467	520	495	448	492	479	297	449
0 to 3	856	373	856	529	712	896	728	758	780	769	755	811	892	860	776	766	748	786	813	750	927	698	748	674	662	719	794	803	796
3 to 6	1431	523	819	1123	1390	1678	1107	1073	1350	1204	1046	1661	1400	1167	1073	1281	1233	1017	1011	1127	1339	780	793	948	930	1029	978	1002	960
6 to 9	1461	593	1507	1478	1406	1390	1560	1564	1574	1483	1602	1377	1483	1572	1564	1308	1448	1595	1566	1448	1685	1399	1609	1498	1516	1246	904	1619	1240
9 to 12	1029	600	1227	1208	1067	934	1208	1272	1181	1150	1309	994	1144	1234	1279	954	1103	1347	1213	1183	1148	1040	1399	1113	1040	898	660	1317	889
12 to 15	950	811	1060	1067	1054	961	982	1088	969	1035	998	946	1011	1015	1093	955	919	1117	859	1058	1182	780	1234	1068	974	881	784	1035	859
15 to 18	921	881	955	870	880	808	719	894	963	828	915	839	922	953	801	766	832	1067	473	892	1231	803	1013	900	896	824	859	1046	886
18 to 21	697	734	760	676	592	584	492	684	704	569	703	688	703	799	578	688	595	854	275	650	620	604	752	689	751	646	786	939	774
21 to 24	471	494	506	452	410	332	320	385	378	447	508	458	433	500	387	470	433	473	160	418	216	330	337	448	486	438	451	491	520
24 to 27	228	181	269	344	197	159	148	157	207	269	258	205	168	185	228	344	267	100	79	234	51	140	86	251	341	248	159	99	265
27 to 30	85	17	79	188	73	44	59	20	69	153	123	47	25	28	102	181	153	11	50	130	2	41	3	144	188	144	18	10	72
30 to 33	6	3	6	54	8		23		9	45	31	6		4	37	66	49		10	41		5		44	57	44			2
33 to 36				17						1						9	5			6				3	10	10			
>=36																5									1				
Missing Data	89	3467	88	33	109	1	741	232	7	23	58	4	51	5	31	23	9	8	1740	83	26	1507	145	179	119	903	1757	26	887
Completeness	99%	60%	99%	100%	99%	100%	92%	97%	100%	100%	99%	100%	99%	100%	100%	100%	100%	100%	80%	99%	100%	83%	98%	98%	99%	90%	80%	100%	90%

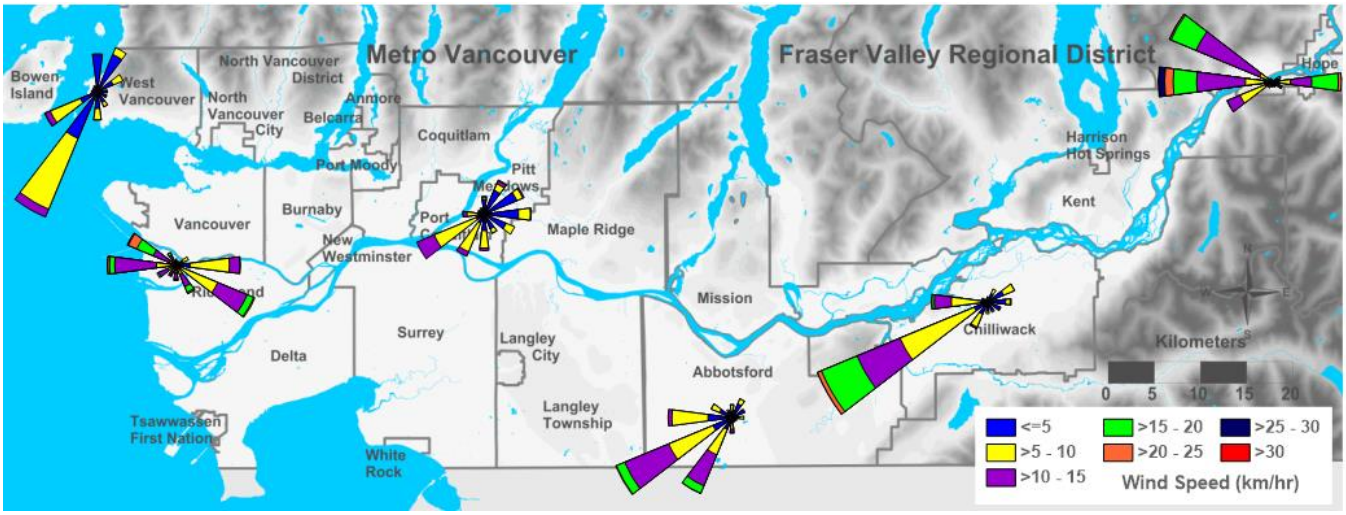


Figure 61: Summer (Jun, Jul, Aug) representative wind roses throughout the LFV, 2017.

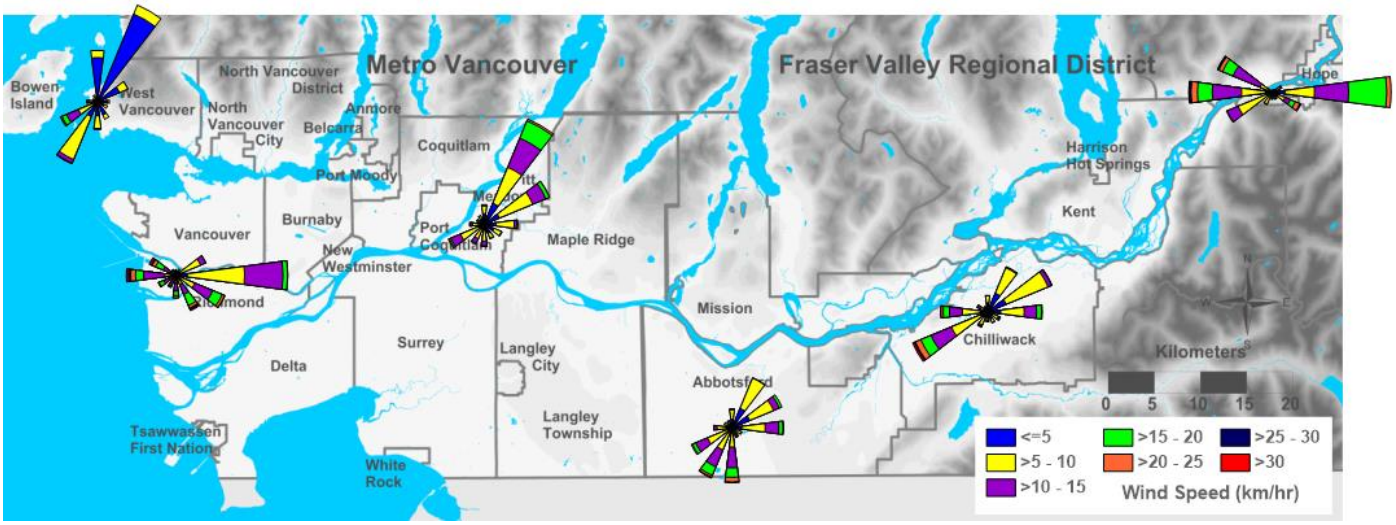


Figure 62: Spring (Mar, Apr, May) representative wind roses throughout the LFV, 2017.

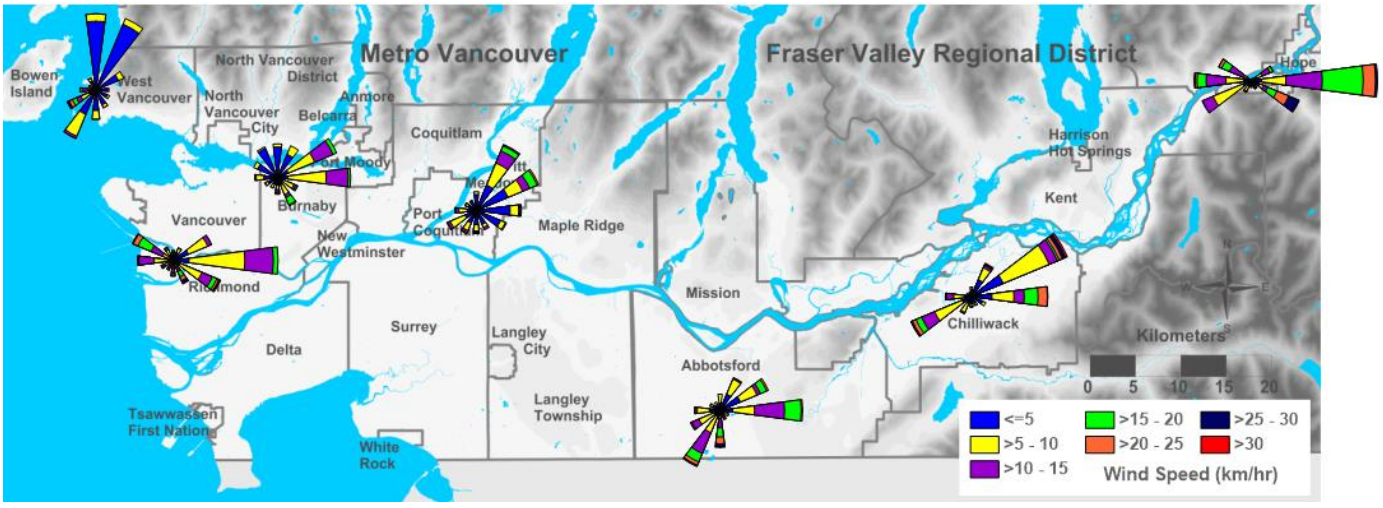


Figure 63: Fall (Sep, Oct, Nov) representative wind roses throughout the LFV, 2017.

Section H –Specialized Monitoring Initiatives

Specialized air quality monitoring studies complement the monitoring network. The studies typically allow for characterization of air quality at finer spatial scales, such as at the neighbourhood scale, and allow investigation of air quality problems on the local scale. The regional monitoring network may not be ideally suited to address local scale issues and therefore performing specialized local air quality studies is an important component to characterizing air quality in the LFV.

A Mobile Air Monitoring Unit (MAMU) that is capable of monitoring particulate and gaseous pollutants along with meteorology is utilized throughout the region to conduct specialized air quality studies. In addition to MAMU, Metro Vancouver utilizes small mobile units along with several portable air quality monitors.

Specialized studies in 2017 included Metro Vancouver's Near-Road Air Quality Monitoring Study in Vancouver to measure air pollutants near a major roadway to aid in the determination of public exposure to air pollutants. The study, conducted in partnership with Environment and Climate Change Canada and the University of Toronto, consists of two monitoring stations equipped with air quality monitoring instruments capable of measuring traffic-related pollutants.

The near-road monitoring station (shown below) was established in 2015 on Clark Drive, a busy truck route, while a background station located away from traffic emissions was established at Sunny Hill Health Center for Children in Vancouver. A number of commonly measured pollutants, volatile organic compounds, and meteorology are being monitored with standard instrumentation, along with some leading-edge instrumentation to measure ultrafine particles, and elemental and organic carbon.

Section I – Monitoring Network Operations

Network History

Air monitoring in the region began in 1949, when the City of Vancouver established a dustfall monitoring network. Monitoring for total suspended particulate was added in later years. Following the Pollution Control Act (1967), provincial air quality programs initiated monitoring of dustfall and total suspended particulate in other areas of the region.

In 1972, provincial and municipal air quality responsibilities were transferred to Metro Vancouver, including operation of air quality monitoring programs. In 1998, a Memorandum of Understanding established cooperative management of the monitoring network by both Metro Vancouver and the Fraser Valley Regional District.

Continuous monitoring of gaseous pollutants began in 1972 under the auspices of the federal National Air Pollution Surveillance (NAPS) program. Several new stations were established to measure SO_2, O_3, CO, NO_X and VOC. Over the years, stations and equipment have been added or removed in response to changing air quality management priorities. Mobile Air Monitoring Units and portable instruments provide added flexibility to carry out measurements at many locations. Some monitoring is part of co-operative programs with industry and other governments.

Monitoring Network Partners

Several partners contribute to the on-going management and operation of the Lower Fraser Valley Air Quality Monitoring Network. The government partners include:

- Fraser Valley Regional District
- Environment and Climate Change Canada
- BC Ministry of Environment and Climate Change Strategy

Other monitoring network partnerships:

- The Vancouver International Airport Authority provides partial funding for the Vancouver International Airport station (T31).
- Parkland Refining (BC) Ltd. provides funding for the Burnaby North (T24) and Capitol Hill (T23) stations.
- Trans Mountain Pipeline LP provides funding for the Burnaby-Burmount (T22) station.
- Port of Vancouver provides funding for the Tsawwassen (T39) station in Delta.

Metro Vancouver continues to operate and maintain the monitoring stations and equipment, and to collect real-time data from the regional monitoring network on behalf of all partners.

Smog seen from the Pattullo Bridge towards the Port Mann Bridge (1979), Courtesy of New Westminster Museums and Heritage Services.

Federal Government

Metro Vancouver co-operates with the federal government by providing field services for three major nation-wide sampling programs under the National Air Pollution Surveillance (NAPS) program of Environment Canada.

- Canister sampling of VOC has been conducted in the LFV since 1988. The federal government supplies equipment and Metro Vancouver staff provide field exchange of canisters, calibration and routine maintenance. Sample canisters are sent to the federal laboratory in Ottawa, for analysis of up to 175 VOC.
- A second program involves dichotomous particulate sampling at three sites. This long-term program samples PM at two size fractions: 10 to 2.5 μm (coarse), and under 2.5 μm (fine). Samples are collected every sixth day, and returned to Ottawa for detailed chemical analysis.
- In 2003 a $PM_{2.5}$ speciation sampling program was initiated. Particulate speciation samplers are operated at the Burnaby South, Abbotsford Airport and Vancouver-Clark Drive stations. $PM_{2.5}$ samples are taken every sixth day in specially designed cartridges. The samples are sent to the federal laboratory in Ottawa where they are analyzed for various particulate species.

Quality Assurance and Control

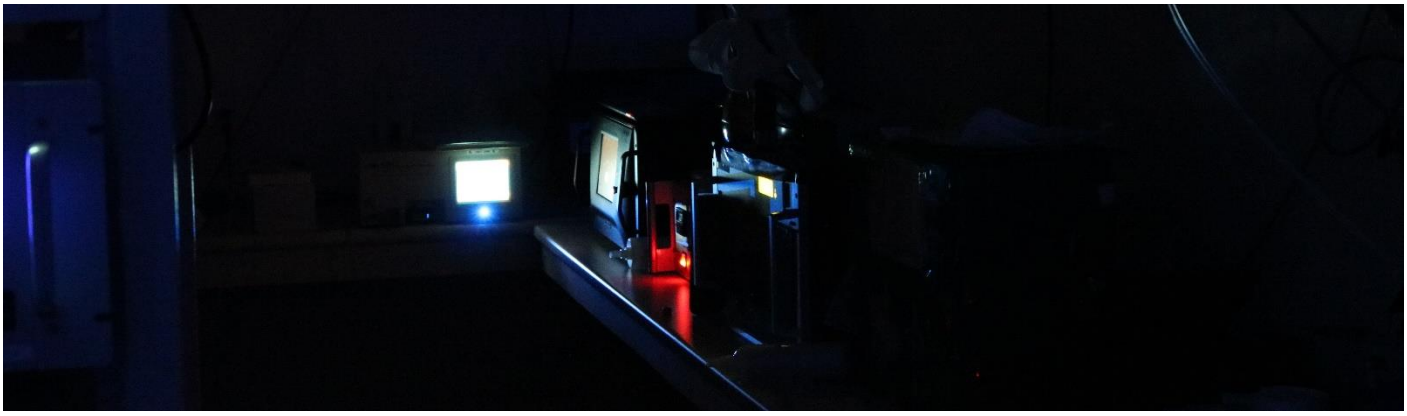
Air quality monitoring data is regularly reviewed and validated. Technicians perform regular inspections and routine maintenance of the monitoring equipment and stations.

In addition, technicians perform major repairs to any instrument in the network, as required. Through the data acquisition system, technicians can check on instruments remotely prior site visits. This system also allows for calibration of the instruments either automatically or upon demand. Portable calibration equipment is used to evaluate instrument performance.

Continuous air quality monitors are subject to performance audits and multi-point calibration every four to six months. In addition, all other instruments and samplers in the network are subjected to annual and/or biannual calibrations. All reference materials and quality control procedures meet or exceed Environment Canada and/or U.S. Environmental Protection Agency requirements. Metro Vancouver coordinates quality assurance procedures and activities with both the provincial and federal government.

Database

Data from continuous air quality analyzers are transmitted to Metro Vancouver's central database using internet, phone lines and cellular links. Hourly averages for each monitor are calculated from the one-minute data and stored in the database. For a measurement to be considered valid (and stored for further use), at least 75% of the relevant data must be available. Calibration data and instrument diagnostics are also retained by the data acquisition system



Section J –Wildfires, Air Quality and Climate Change

In recent years, wildfire activity has increased in severity and become more widespread. Wildfires produce considerable amounts of smoke that can be transported great distances. Wildfire smoke is a complex mixture of many gases and small particles. The mixture can change quickly depending on the weather, what is burning, the temperature of the fire, and how far the smoke has travelled. Of all the pollutants in wildfire smoke, fine particulate matter ($PM_{2.5}$) poses the greatest risk to human health.

Locally, the presence of wildfire smoke can result in two differing outcomes for ground-level ozone production. Wildfire smoke can either enhance or inhibit ozone production depending on the amount of smoke present. The mixture of chemical contaminants in wildfire smoke includes ozone precursors which can enhance the production of ozone. A study by Teakles et al. (2017)[1] indicated that a wildfire smoke event in 2012 was responsible for an enhancement of 8-hour ozone concentrations at coastal B.C. sites by as much as 10 ppb. However, if the wildfire smoke becomes thick enough, the smoke can block solar radiation, decrease air temperatures and inhibit the production of ozone. Effects of both inhibition and enhancement of ozone due to wildfire smoke have been experienced in the LFV.

Wildfires and Air Quality

Historically, episodes of degraded air quality due to smoke from wildfires outside the region have been infrequent. Since 2015, however, wildfire smoke impacts have increased significantly. In 2015 eight air quality advisory days occurred due to wildfire smoke, primarily associated with large fires north of Pemberton. There were no air quality advisories in 2016, but 2017 saw significant and lengthy smoke-related air quality impacts due to wildfires burning in the BC Interior, and the US west coast, leading to 19 advisory days.

In 2017, the total number of fires in British Columbia were less than in 2015 and less than the 10-year average but the total area burned was an order of magnitude greater. In 2017, 12,161 km^2 were burned while the 10-year average was 2,697 km^2 (Table 11).

Table 11. Total fires and area burned in British Columbia.

Year	British Columbia Total Fires	British Columbia Area Burned (km^2)
2015	1,858	2,806
2016	1,050	1,004
2017	1,353	12,161
10-year average	1,673	2,697

The 2017 wildfire season was one of the worst in British Columbia's history, with the largest area burned. This led to the greatest number of days when air quality advisories were in effect during summer. Figure 64 shows days the $PM_{2.5}$ objective was exceeded due to elevated $PM_{2.5}$ in two wildfire years: 2015 and 2017. The colour corresponds to the maximum 24-hour rolling average $PM_{2.5}$ concentration, with the darker red signifying a higher concentration.

In 2015, Vancouver was the most severely impacted in the region by smoke coming from wildfires burning in Pemberton and Sechelt. The maximum 24-hour rolling average within the region was measured at Vancouver-Clark Drive with a value of 121.5 $\mu g/m^3$.

Wildfire smoke impacts in 2017 were longer and more widespread. A one-day advisory was issued on July 18 for elevated $PM_{2.5}$ due to wildfires burning in the BC Interior. During the event hourly $PM_{2.5}$ was elevated throughout the region but only one monitoring station (Hope) experienced an exceedance of the 24-hour $PM_{2.5}$ air quality objective. The highest 24-hour rolling average during this event was 29 $\mu g/m^3$ at Hope. In a satellite image taken on the day of the advisory (Figure 65) smoke can be seen in valley bottoms with southerly flow out of the Fraser Canyon into the Lower Fraser Valley.

Following the advisory, a change in the weather pattern brought cooler air and a shift in winds that allowed the air quality to improve.

[1] Teakles, A.D., So, R., Ainslie, B. et al. (2017) Impacts of the July 2012 Siberian fire plume on air quality in the Pacific Northwest. Atmos. Chem. Phys. 17, pp. 2593-2611.

As wildfires continued to burn in the BC Interior, a change in weather occurred in early August that allowed the fires to intensify and grow. A southwest flow brought the smoke to the region on August 1, which initiated an unprecedented 11-day advisory, the longest advisory ever issued by Metro Vancouver. During the 11-day period, $PM_{2.5}$ was elevated throughout the region on all days and O_3 was elevated for five of the days.

The degraded air quality was the result of outflow winds that brought smoke from wildfires burning in the BC Interior. This can be seen in the satellite image taken on August 3, 2017 shown in Figure 65. As the advisory progressed smoke became more widespread and covered the Pacific Northwest as seen in the image taken August 5, 2017 (Figure 65). The highest 24-hour rolling average during this event was 101.8 $\mu g/m^3$ at Hope. Hope endured some of the highest concentrations in the region for multiple days. On August 12, 2017 a change in weather brought cooler clean marine air into the region.

On August 29, a one-day advisory was issued for both elevated O_3 and $PM_{2.5}$ due to wildfires burning in the United States. Smoke was transported northward from intense fires burning in Washington, Oregon and Northern California. The northward flow of smoke can be seen in Figure 65. During this event the highest 24-hour rolling $PM_{2.5}$ average was 28.7 $\mu g/m^3$ measured at Hope, and the highest 1-hour ozone average was 90.9 ppb at Agassiz. Exceedances of the 1-hour ozone objective were widespread on this day, occurring at Burnaby-Kensington Park, Chilliwack, Burnaby Mountain, Hope, Maple Ridge, Abbotsford-Mill Lake, Mission and Agassiz. Exceedances in the western portion of Metro Vancouver (i.e., Burnaby) are not common. For example, Burnaby-Kensington Park has not exceeded the 1-hour objective since 1990 and it is thought that ozone was enhanced on August 29, 2017 due to wildfire smoke that was prevalent throughout the region.

On September 5, a five-day advisory was initiated due to wildfire smoke from the BC Interior and Washington State. The first day of the advisory included a ground-level ozone advisory due to elevated levels of ozone. Widespread smoke can be seen throughout southwest BC and Washington state in Figure 65. The highest 24-hour rolling $PM_{2.5}$ average was 88.3 $\mu g/m^3$ measured at Hope during this event.

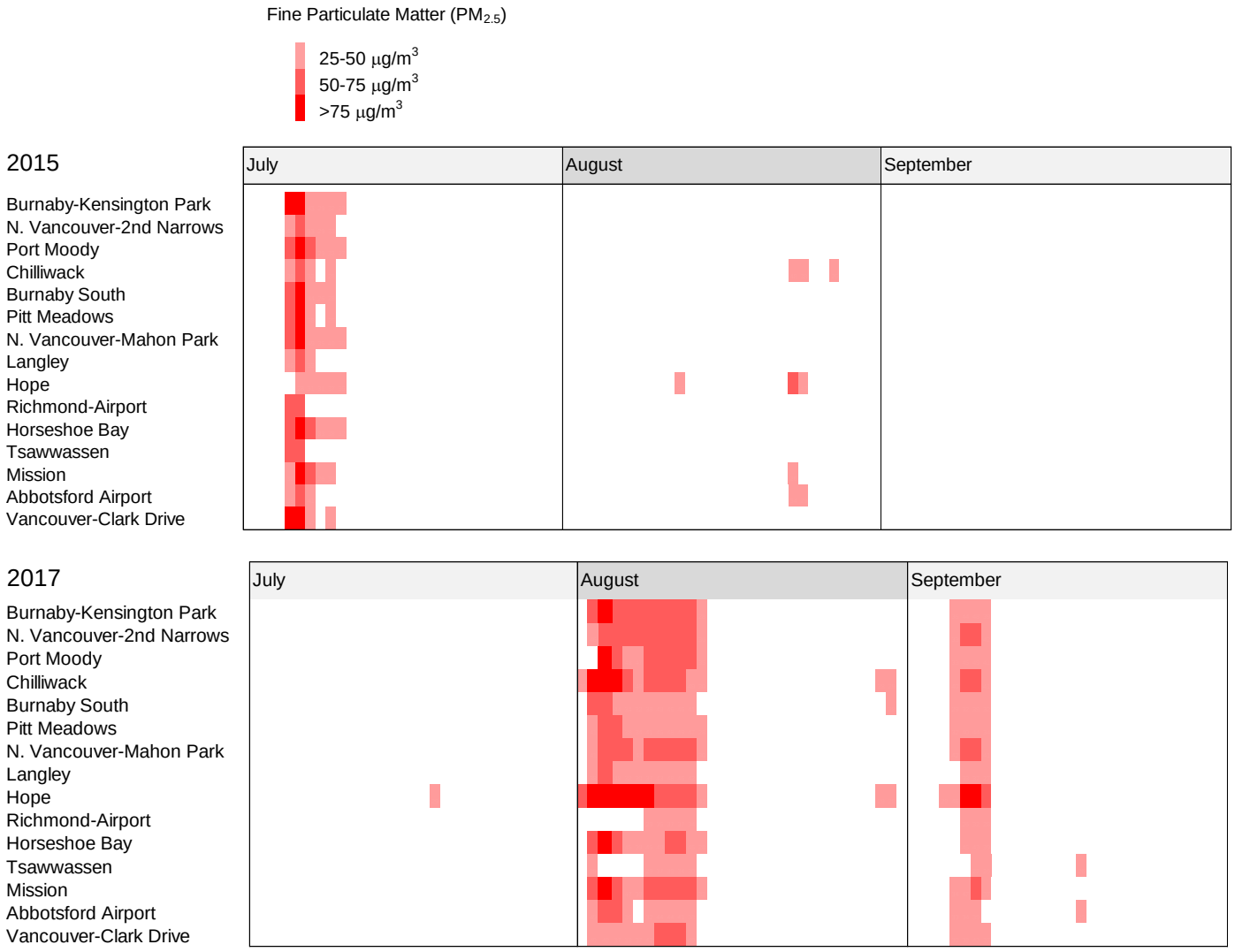


Figure 64: Comparison of exceedances days on two wildfire influenced years: 2015 and 2017, respectively.

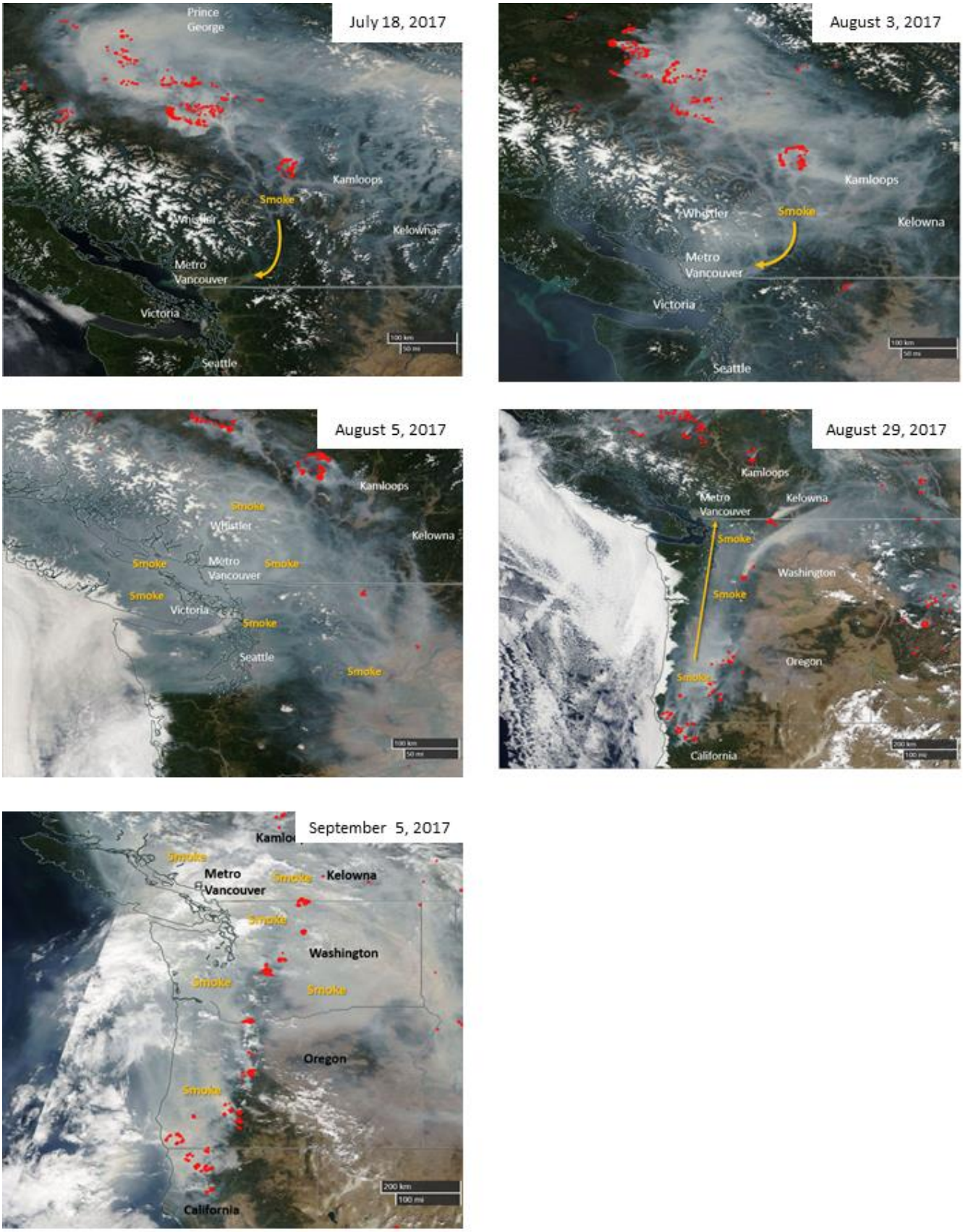


Figure 65: Satellite imagery taken from NASA Worldview during days impacted by wildfire smoke in 2017.

Climate Change

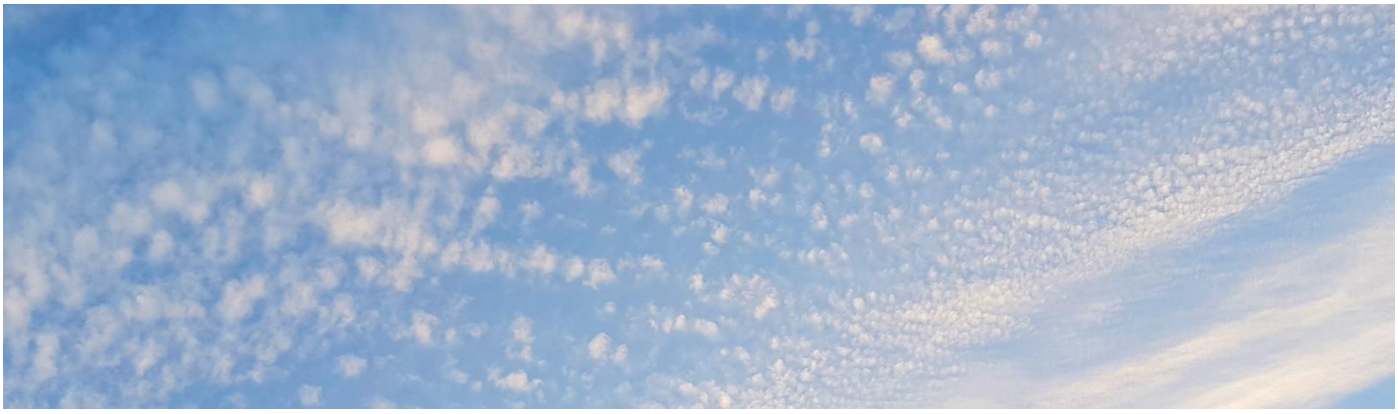
Climate projections indicate the region will experience hotter, drier summers and wetter, warmer winters. A warming climate is likely to increase frequency and duration of wildfires and associated smoke impacts, while also increasing in-region ground level O_3 formation through the intensity and duration of summer heatwaves.

A study focused on the extreme 2017 wildfire season in British Columbia, found that human-induced climate change contributed greatly to the extreme warm temperatures, high wildfire risk, and large burned areas (Kirchmeier-Young, Gillett, Zwiers, Cannon, & Anslow, 2019[2]). The authors concluded that as the climate continues to warm, it can be expected that extreme wildfire seasons like 2017 in BC will become more likely in the future.

Public awareness of air quality and health has also grown with the recent summer wildfire smoke impacts. The public has inquired about air quality, health effects, and steps that can be taken to reduce their own health risk during these events. Since late 2017, Metro Vancouver has been working with local health authorities, BC Centre for Disease Control, Health Canada, the BC MOECSS, the FVRD and experts from outside BC to develop more effective communication materials for residents on wildfire smoke health impacts and interventions for reducing these impacts.

Metro Vancouver is also looking at further developing collaborations, such as working with member jurisdiction on provision of clean air spaces, to ensure that people will be better protected from the health impacts of wildfire smoke.

Metro Vancouver is currently developing two key planning documents that are focused on consideration of a changing climate and increased wildfire activity. Metro Vancouver's updated air quality management plan, now referred to as the Clean Air Plan, will consider the increasing impacts of wildfire activity when developing strategies and actions to reduce health risk for Metro Vancouver residents. In parallel, Metro Vancouver's Climate 2050 Roadmaps will identify actions that will help the region adapt to climate-related impacts on regional air quality. For example, a warming climate is likely to increase frequency and duration of wildfires and associated smoke impacts, while also increasing in-region while also increasing in-region ground-level ozone formation through the intensity and duration of summer heatwaves.



[2] Kirchmeier-Young, M. C., Gillett, N. P., Zwiers, F. W., Cannon, A. J., & Anslow, F. S. (2019). Attribution of the Influence of Human-Induced Climate Change on an Extreme Fire Season. *Earth's Future, 7*(1), 2-10. doi:10.1029/2018EF001050

Appendix A – 2017 Non-Continuous Pollutant Measurements

This appendix summarizes non-continuous pollutant measurements collected from air quality stations in the Lower Fraser Valley (LFV) Air Quality Monitoring Network in 2017 and describes related monitoring activities and programs conducted during the year.

Air Quality Measurements

The LFV Air Quality Monitoring Network primarily employs continuous monitors which provide data in real-time every minute of the day. The network also contains specialized air quality monitors that sample the air on a non-continuous basis. Non-continuous 24-hour (daily) samples are collected on filters and/or in canisters every sixth or twelfth day depending on the site.

Non-continuous samples of volatile organic compounds (VOC) and particulate are collected throughout the LFV. VOC refers to a group of organic chemicals. A large number of chemicals are included in this group but each individual chemical is generally present at relatively low concentrations compared to other common air contaminants. These data can then be used to help determine the emission sources contributing to the contaminants in the air.

Non-continuous samples are collected in accordance with the National Air Pollution Surveillance (NAPS) program. After collection, samples are transported to and analyzed in a federal laboratory in Ottawa to determine pollutant concentrations. Obtaining results of non-continuous sampling from the federal laboratory may introduce a time lag compared to continuous monitoring, and thus this report has been produced as an appendix.

Particulate Sampling

Non-continuous 24-hour (daily) fine particulate ($PM_{2.5}$) and inhalable particulate (PM_{10}) samples are collected at five monitoring stations in the LFV. A detailed analysis is conducted for four of these stations (Port Moody, Burnaby South, Abbotsford Airport and Vancouver-Clark Drive) which includes some trace metals, sulfate, nitrate, ions, and elements.

Using specialized instrumentation that is able to provide 'speciation' of particulate matter, detailed information about individual chemical constituents and composition of fine particulate is obtained from three stations (Burnaby South, Abbotsford Airport, Vancouver-Clark Drive). From these the various compounds that form $PM_{2.5}$ are identified, including additional trace metals such as iron, vanadium, and lead and other additional elements.

Volatile Organic Compounds (VOC)

While there are many thousands of organic compounds in the atmosphere that meet the definition of a VOC, the NAPS measurement program focuses on VOC that are important precursors in ozone formation and/or are known to have toxic effects. In order to report and track the most important VOC in relation to these two main focus areas, a number of priority VOC, as defined below, have been selected and reported in this appendix.

VOC species have a range of photochemical reactivity, and thus potential to lead to ozone formation. In the report *Metro Vancouver VOC Policy Options Review* (2015), a ranking of VOC is presented based on work by Environment and Climate Change Canada that classified the reactivity of the VOC species and their relative abundance in the LFV. The top five ranked VOC for ozone formation in LFV were ethylene, 1-butene/isobutene, isoprene, 2-methyl-2-butene, and m- and p-xylene.

Toxic VOC have been identified as a concern from a human health perspective due to known acute or chronic health effects. The *Toxic Air Pollutants Risk Assessment* (2015) for the LFV commissioned by Metro Vancouver identified high priority toxic VOC in the LFV based on cancer and/or non-cancer health risks associated with measured 2010 VOC levels. The study identified five high priority VOC based on estimated health risks: formaldehyde, acrolein, benzene, acetaldehyde and 1,3-butadiene.

Non-Continuous $PM_{2.5}$ and PM_{10} Sampling

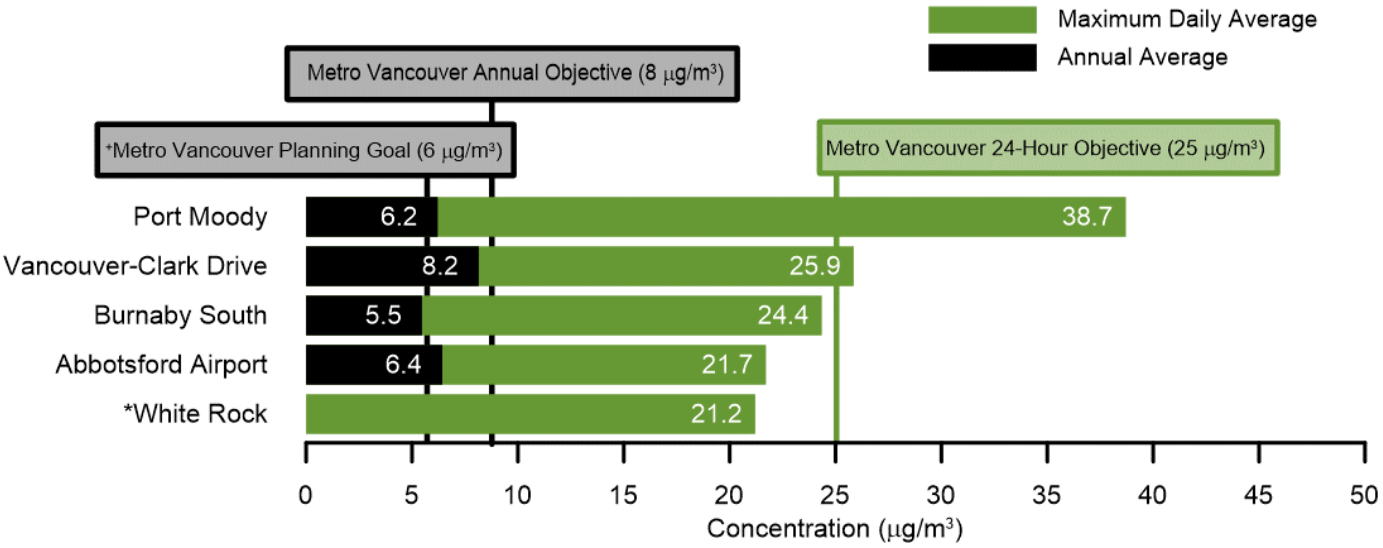
Non-continuous 24-hour (daily) $PM_{2.5}$ samples are collected on filters every sixth day in accordance with the NAPS program schedule. After sample collection, the filters are weighed in the laboratory to determine $PM_{2.5}$ concentrations.

Figure A1 presents maximum daily and average $PM_{2.5}$ values from the non-continuous monitors that operated in 2017. Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective were widespread in 2017. The objective was exceeded on August 5th at Port Moody and Vancouver-Clark Drive and on August 11th at Port Moody when an unprecedented eleven-day air quality advisory was issued due to smoke that blanketed the region transported from wildfires burning outside our region. The non-continuous maximum 24-hour average is lower than the continuous maximum 24-hour rolling average described in Section D because of the sampling schedule (i.e., the non-continuous sampler measures from midnight to midnight while the continuous monitor measures every hour, thereby allowing for a 24-hour rolling average to be calculated). Stations were below the Metro Vancouver annual objective of 8 $\mu g/m^3$ with the exception of Vancouver-Clark Drive, which is located very near a major roadway and part of a near-road study. An annual average was not calculated for White Rock since it did not meet data completeness requirements in 2017.

Using specialized particulate matter speciation instrumentation, detailed information about the chemical composition of $PM_{2.5}$ is obtained from three stations in the network (Burnaby South, Abbotsford Airport, Vancouver-Clark Drive) as a result of analysis carried out by the federal NAPS program. From the 24-hour samples collected at these three sites, the various compounds that collectively contribute to overall $PM_{2.5}$ are identified in a federal laboratory. A detailed laboratory analysis by NAPS is also carried out on the filter samples collected in Port Moody. These detailed data are not shown in this report.

Non-continuous sampling provides the longest record of $PM_{2.5}$ measurements in the LFV. Figure A2 shows $PM_{2.5}$ measurements made in Port Moody over the last two decades. The short-term peak concentrations reflect the highest levels that occur, represented by the 99th percentile of the 24-hour average for each year.

Historically, the average long-term trend shows little variation while peak trends demonstrate much greater variability. The differences in peak trends from year to year are likely driven by meteorological variability and wildfire activities. Most evident in the long-term peak trend is that in both 2015 and 2017 historically high concentrations were measured, a result of the unprecedented wildfire smoke that inundated the region.



⁺ Metro Vancouver's Planning Goal of 6 $\mu g/m^3$ is a longer term aspirational target to support continuous improvement.
**Data completeness criteria was not met at this station.*

Figure A1: Non-continuous particulate ($PM_{2.5}$) monitoring, 2017.

Non-continuous 24-hour (daily) PM coarse fraction (PM_{10} - $PM_{2.5}$) samples are collected on filters every sixth day in accordance with the NAPS program schedule. After collection, samples are weighed in a laboratory to determine the PM_{10} concentrations during the sampling period.

Figure A3 presents maximum daily average and annual average PM_{10} values from the non-continuous monitors that operated in 2017. There were no exceedances of Metro Vancouver's PM_{10} objectives.

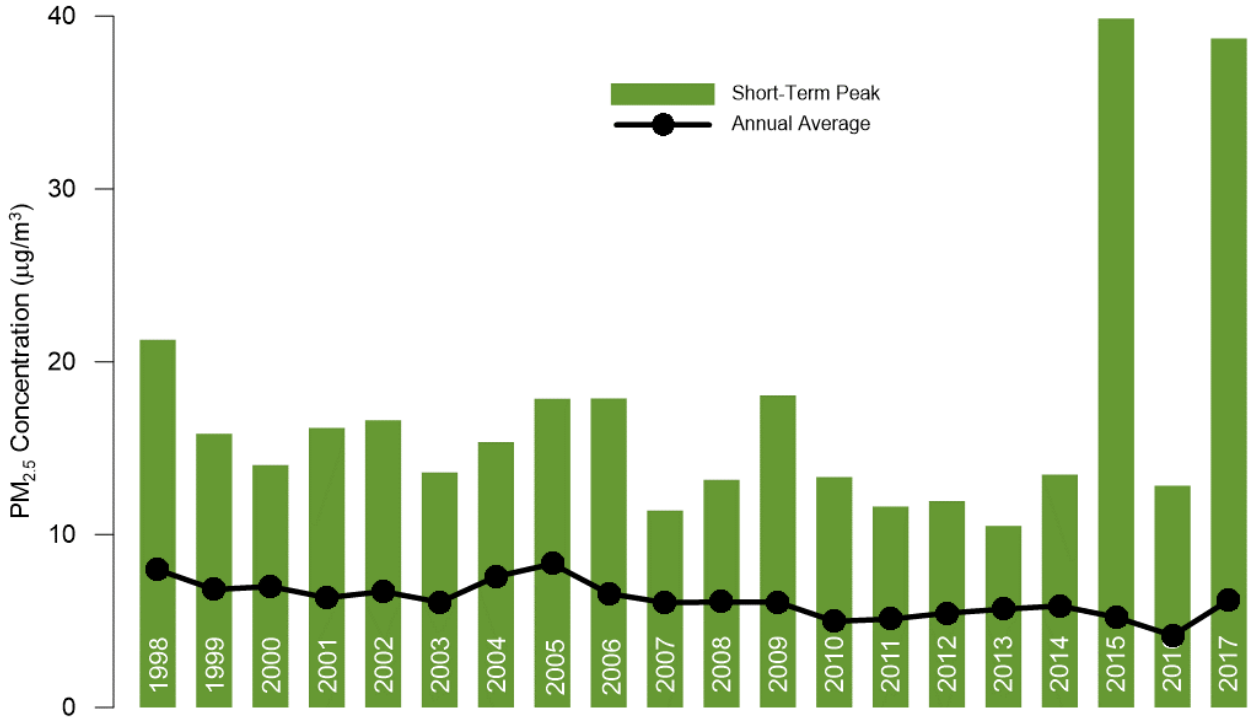
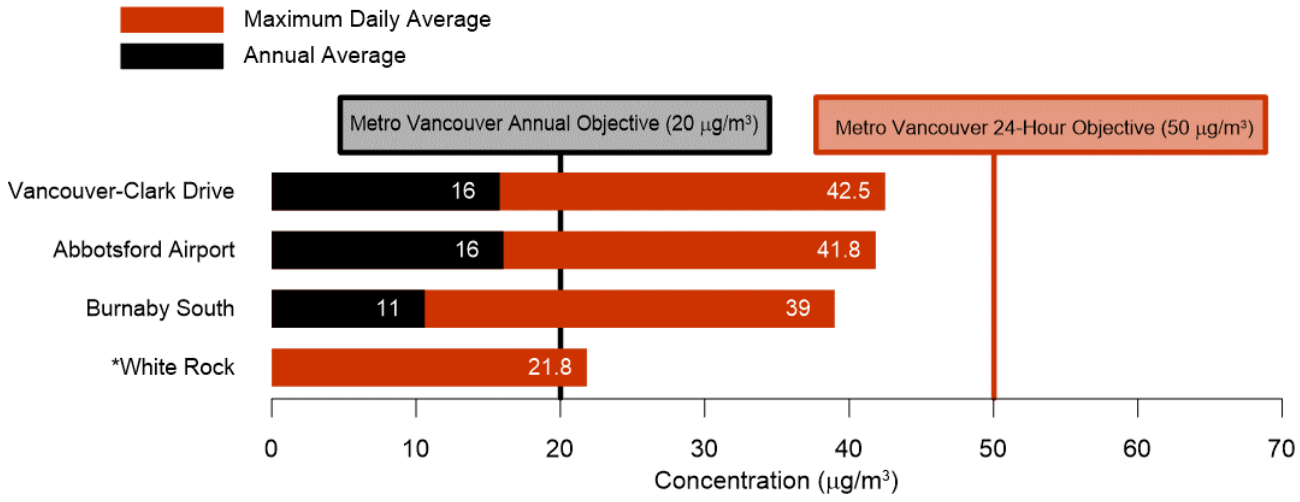


Figure A2: Fine particulate ($PM_{2.5}$) trends at Port Moody, 1998 to 2017.



**Data completeness criteria was not met at this station.*
Note: Port Moody is not shown due to incomplete data.

Figure A3: Non-continuous inhalable particulate (PM_{10}) sampling, 2017.

Volatile Organic Compounds (VOC)

Volatile organic compounds are organic compounds containing one or more carbon atoms that have high vapour pressures and therefore evaporate readily to the atmosphere. In 2017, VOC samples were collected at eight sites in the LFV. In cooperation with the federal NAPS program, canister sampling of VOC has been conducted in the LFV since 1988. Canisters sent to the federal laboratory are analyzed for up to 175 species of VOC.

For analytical purposes, VOC can be considered either nonpolar (i.e., hydrocarbons and halogenated hydrocarbons) or polar (i.e., compounds containing oxygen, nitrogen, sulphur, etc.). Nonpolar VOC can be characterized by sampling with evacuated metal canisters and well-established analytical methods. In contrast, polar VOC require specialized sampling and analytical methods to measure trace levels because of their chemical reactivity, affinity for metal and solubility in water. Because of this, polar VOC were only measured at two locations (Port Moody and Abbotsford-Airport) in 2017.

Characteristics

VOC refers to a class of organic chemicals that can vaporize into the atmosphere at normal ambient temperatures and pressures. This group comprises many chemicals but individual compounds are generally present at low concentrations in air compared to other common air contaminants.

Locally, VOC can be found in urban smog and are precursors to the formation of other contaminants present in smog such as ozone and fine particulates. Some VOC (*e.g.* carbon tetrachloride) can contribute to depletion of the stratospheric ozone layer and may contribute to climate change. Other VOC (*e.g.* benzene) can pose a human health risk.

Under the Canadian Environmental Protection Act some VOC are included in the Toxic Substances List.

Emissions of some VOC are managed under permits and industry-specific regulations within Metro Vancouver.

Sources

VOC can originate from direct emissions, volatilization (*i.e.* changing into the gas phase) of substances in the liquid or solid phase, and formation from precursor pollutants via chemical reactions in the atmosphere. Sources of VOC in Metro Vancouver include, but are not limited to, emissions from the combustion of fossil fuels, evaporation from industrial and residential solvents and paints, vegetation, agricultural activities, petroleum refineries, fuel-refilling facilities, the burning of wood and other vegetative materials, and large industrial facilities.

Monitoring Results

Figure A4 shows the maximum daily total VOC and average total VOC from each VOC monitoring station in 2017. The data indicates that the highest average total VOC levels were measured at stations close to specific industrial sources near Burrard Inlet along with the near-road monitoring station at Vancouver-Clark Drive. The highest daily total VOC concentration was observed at Burnaby-North on September 4, 2017.

Figure A5 provides data from 1998 to 2017 from sampling undertaken at the Port Moody station as an example of the long-term trends in total VOC concentrations. Both annual average and short-term peak (95^{th} percentile) VOC concentrations have decreased since the 2000s. In recent years, average and short-term peak VOC concentrations have remained relatively constant.

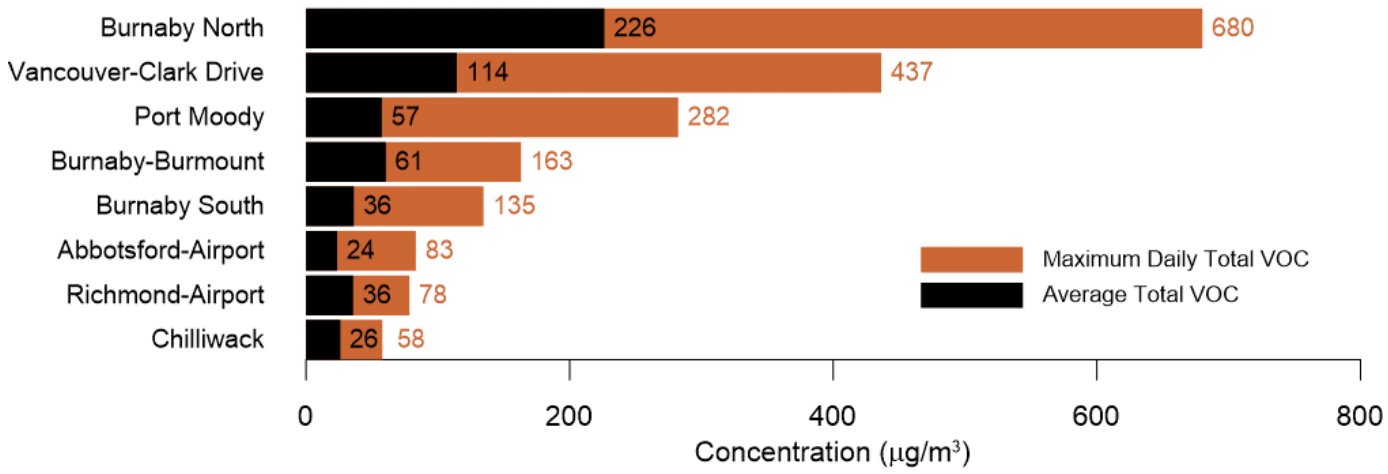


Figure A4: Total VOC monitoring, 2017.

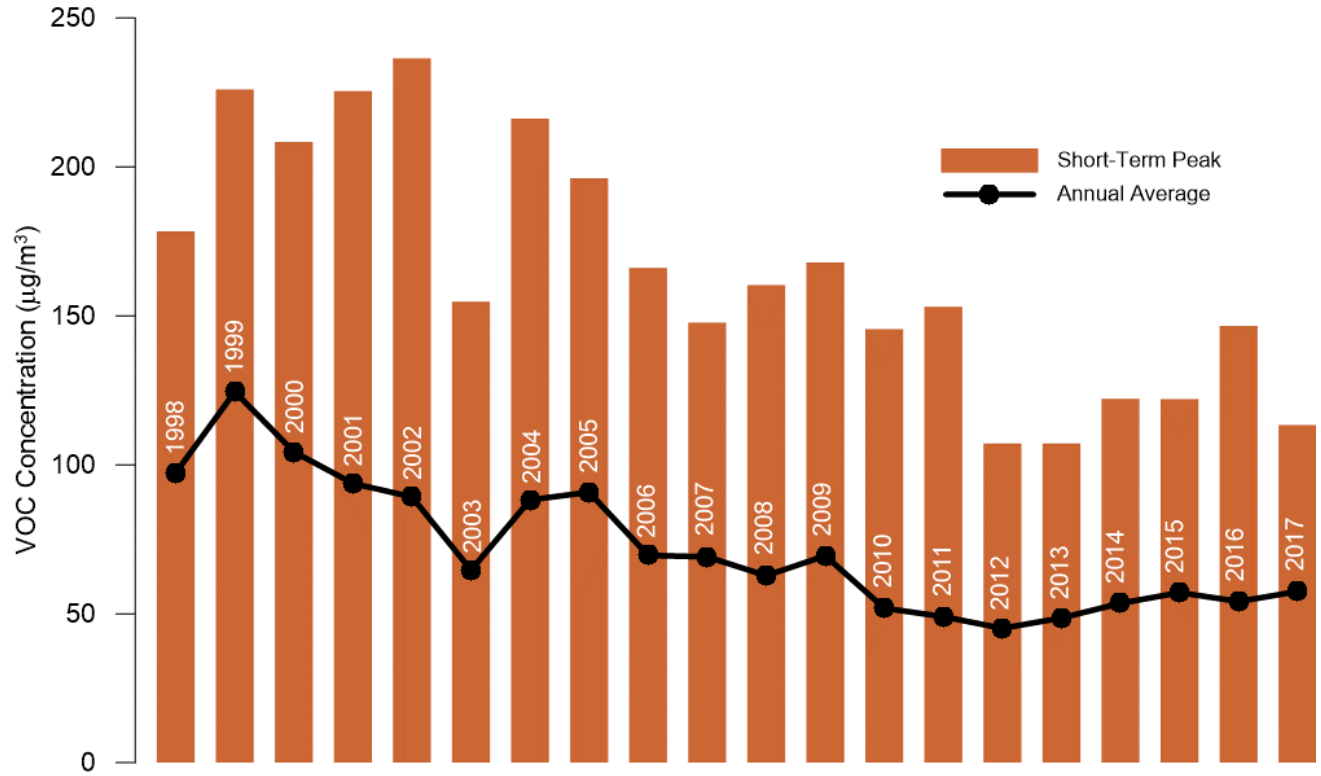


Figure A5: Total VOC trends at Port Moody, 1998 to 2017.

Ethylene

Characteristics

Ethylene has been prioritized for monitoring in the region because of its ozone producing potential. Ethylene, also known as ethene, has the chemical formula C_2H_4. It is a colorless gas with a sweet odour and taste. Ethylene is degraded in the atmosphere by reactions with hydroxyl radicals, ozone and nitrate radicals and is the number one ranked VOC in the LFV for its ozone producing potential.

Sources

Ethylene occurs naturally and is also manufactured for a number of uses. Ethylene is a natural product emitted by fruits, flowers, leaves, roots, and tubers. Ethylene is also emitted from the burning of vegetation, agricultural wastes, and refuse, and from the incomplete combustion of fossil fuels. Globally, biomass burning to clear land for agriculture or other uses is the largest source of anthropogenic ethylene emissions, followed by combustion of fossil fuels, which is estimated to be the largest anthropogenic ethylene emissions source in the LFV. Cigarette smoke contains ethylene, and it is also used as a chemical intermediate and precursor in industrial organic synthesis, in the welding and cutting of metals, as a plant growth regulator, and as a refrigerant.

Monitoring Results

Figure A6 illustrates the results of ethylene monitoring in 2017. Figure A6 displays the maximum daily concentration as well as the annual average for each ethylene monitoring location. The highest average and peak concentrations occurred at Vancouver-Clark Drive.

Ethylene is the number one ranked VOC for its ozone producing potential in the LFV. Concentrations have steadily declined over the last two decades.

Figures A7 and A8 illustrate the long-term average and peak ethylene trends in the LFV, respectively. Average levels have continually decreased at all sites in the last 20 years. Peak levels decreased considerably in the late 1990s and early 2000s at most sites but over the last five years peak concentrations have remained relatively constant. Vancouver-Clark Drive is not included in the long-term trends since the station has only recently been established.

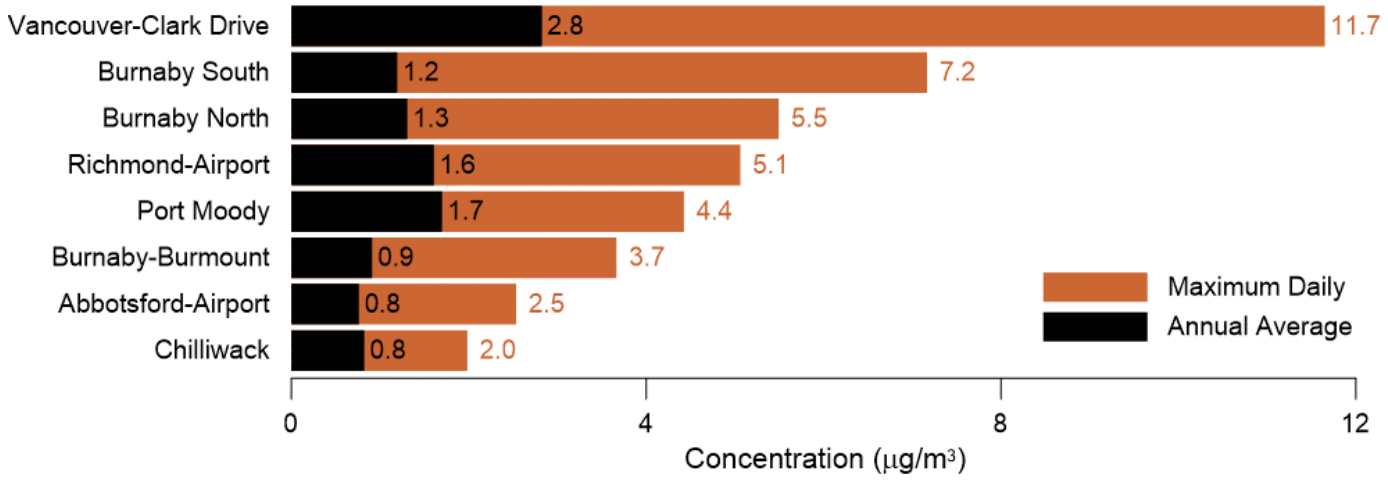


Figure A6: Ethylene monitoring, 2017.

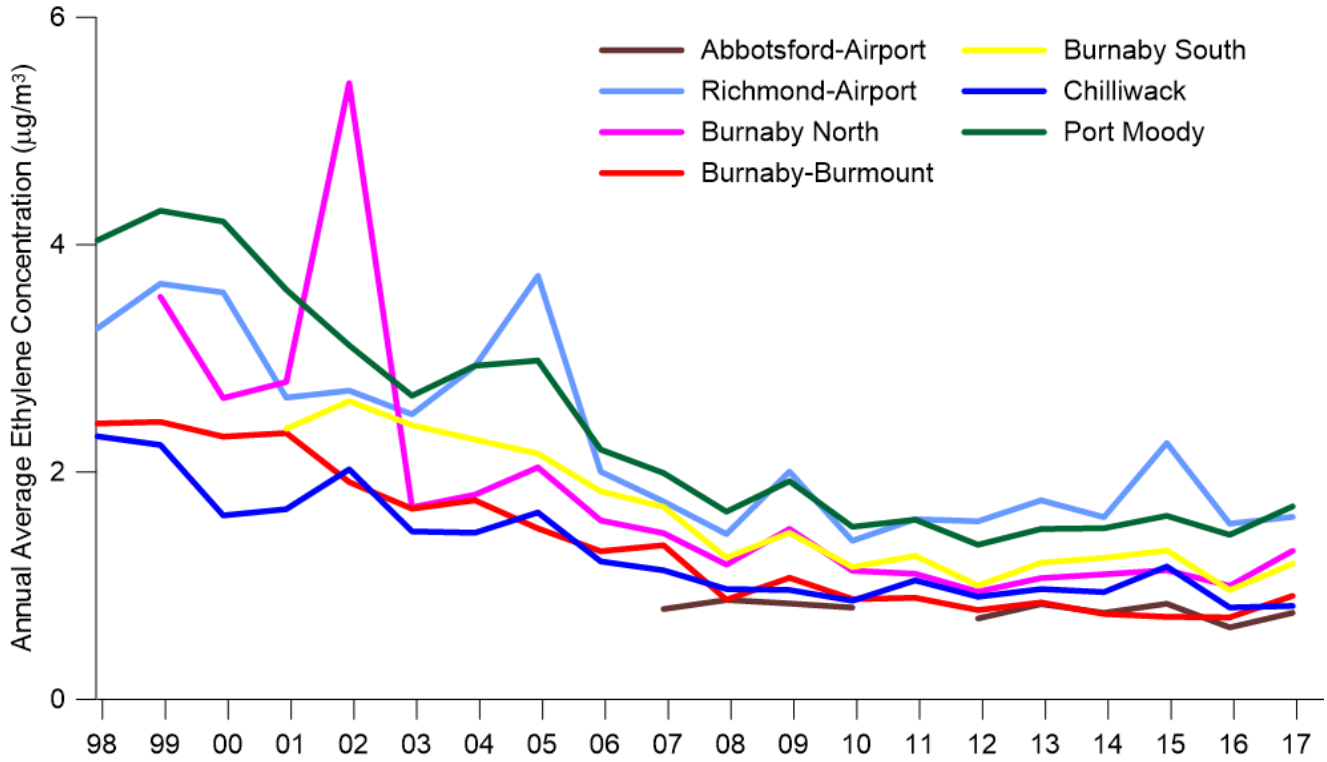


Figure A7: Annual ethylene trend, 1998 to 2017.

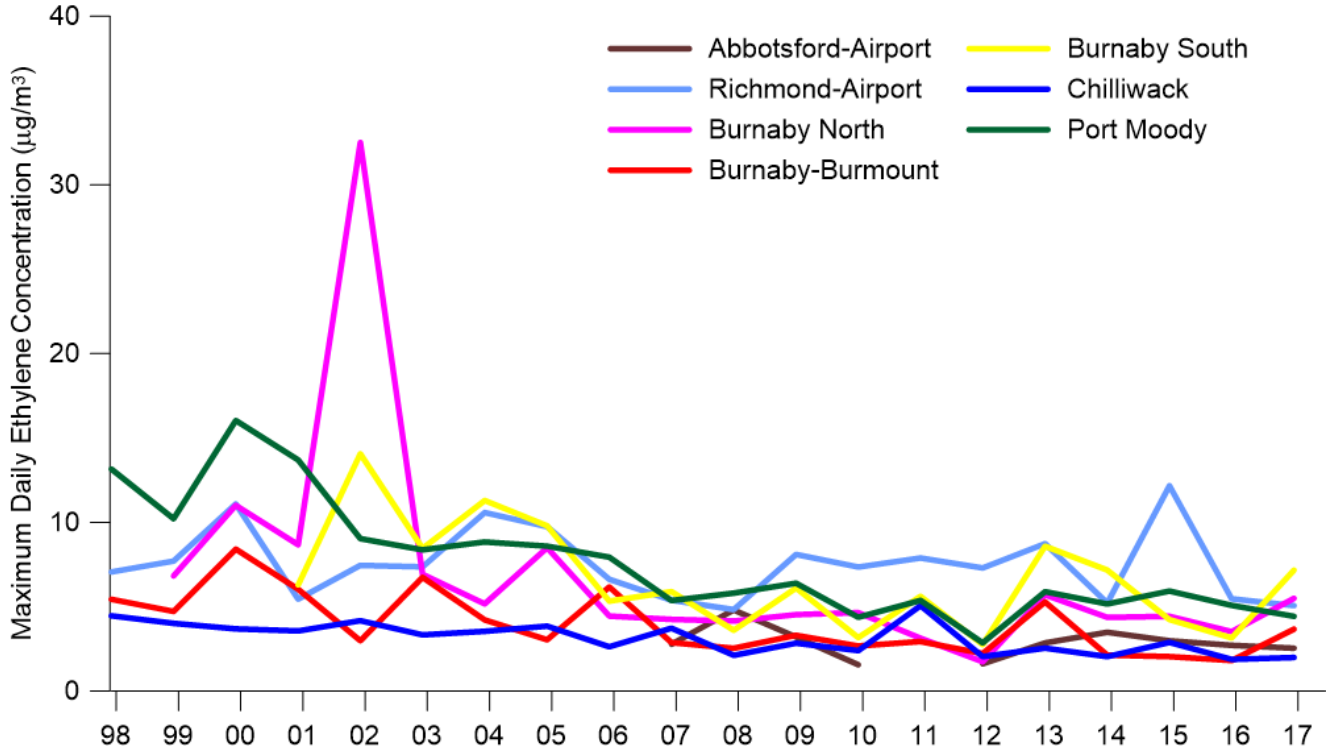


Figure A8: Short-term peak ethylene trend, 1998 to 2017.

1-Butene/isobutene

Characteristics

1-Butene/isobutene are isomers of butene with the chemical formula C_4H_8. Monitoring has been prioritized from an ozone production perspective as the second highest ranked VOC for ozone producing potential in the LFV. They are colourless gases with a slightly aromatic odour.

Sources

1-Butene/isobutene are emitted by both natural and anthropogenic sources. They are present in crude oil as minor constituents, and used by industry and consumers as components of adhesives and sealants, fuels and fuel additives, intermediates, and plasticizers. They may be released into the environment by petroleum refineries, through the burning of waste plastics, as a volatile emission from gasoline and from the burning of wood. 1-Butene/isobutene have been widely detected in the exhaust gas of vehicles using gasoline and diesel and from jet engines. They are also naturally occurring plant emissions from mixed deciduous forests, and have also been found in the volatile organic fraction emitted during the heating of soybean, rapeseed, peanut, and Canola oils. In the LFV, the primary sources of 1-butene/isobutene are gasoline solvent evaporation, chemical manufacturing, and refinery tank farm fugitive emissions.

Monitoring Results

Figure A9 illustrates the results of 1-butene/isobutene monitoring in 2017. Figure A9 displays the maximum daily concentration as well as the annual average for each 1-butene/isobutene monitoring location. The highest concentrations occurred at the Burnaby North station that is adjacent to the refinery tank farm where petroleum products are stored.

1-Butene/isobutene are emitted both by natural and anthropogenic sources and are the second most important VOC in terms of its ozone producing potential in the LFV.

Figures A10 and A11 illustrate the long-term average and peak 1-butene/isobutene trends in the LFV, respectively. Average levels have decreased considerably since the late 1990s. Historically, Burnaby North has experienced the highest average and peak levels of 1-butene/isobutene. The variability of the maximum daily concentrations is likely a result of variability in emissions and meteorology. Vancouver-Clark Drive is not included in the long-term trends since the station has only recently been established.

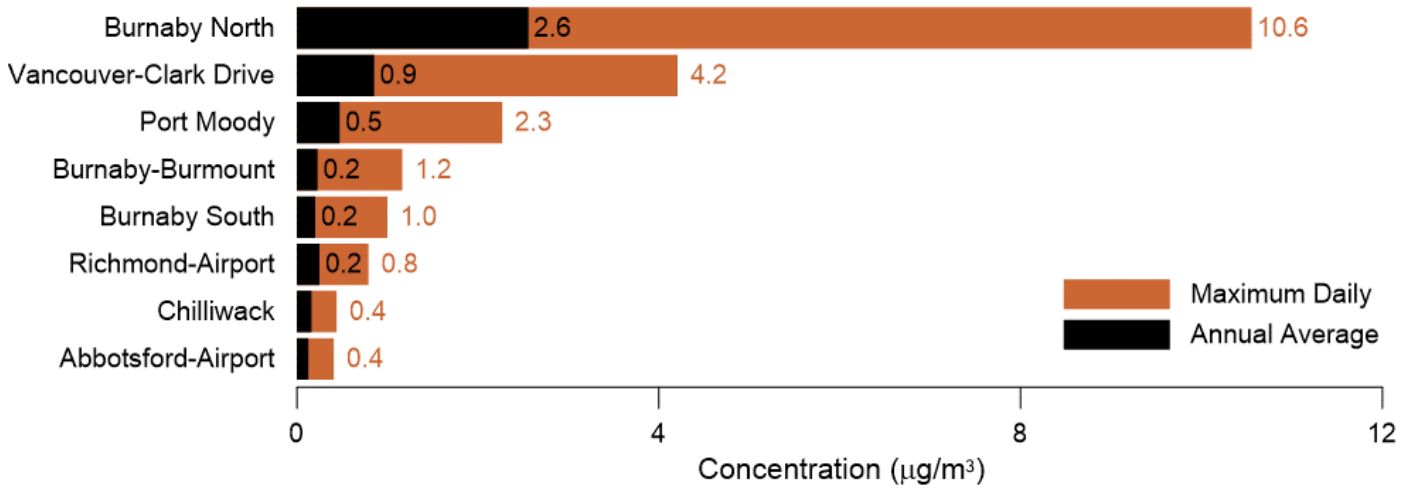


Figure A9: 1-Butene/isobutene monitoring, 2017.

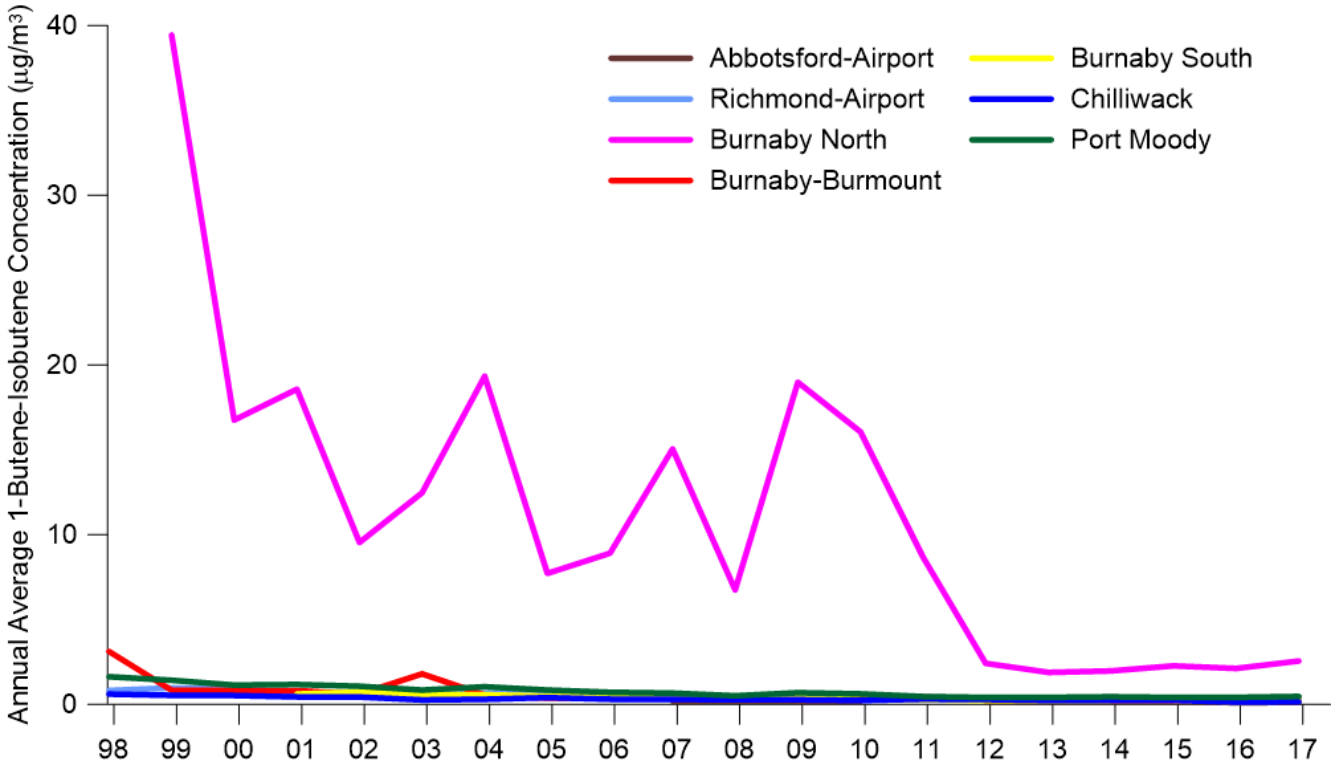


Figure A10: Annual 1-butene/isobutene trend, 1998 to 2017.

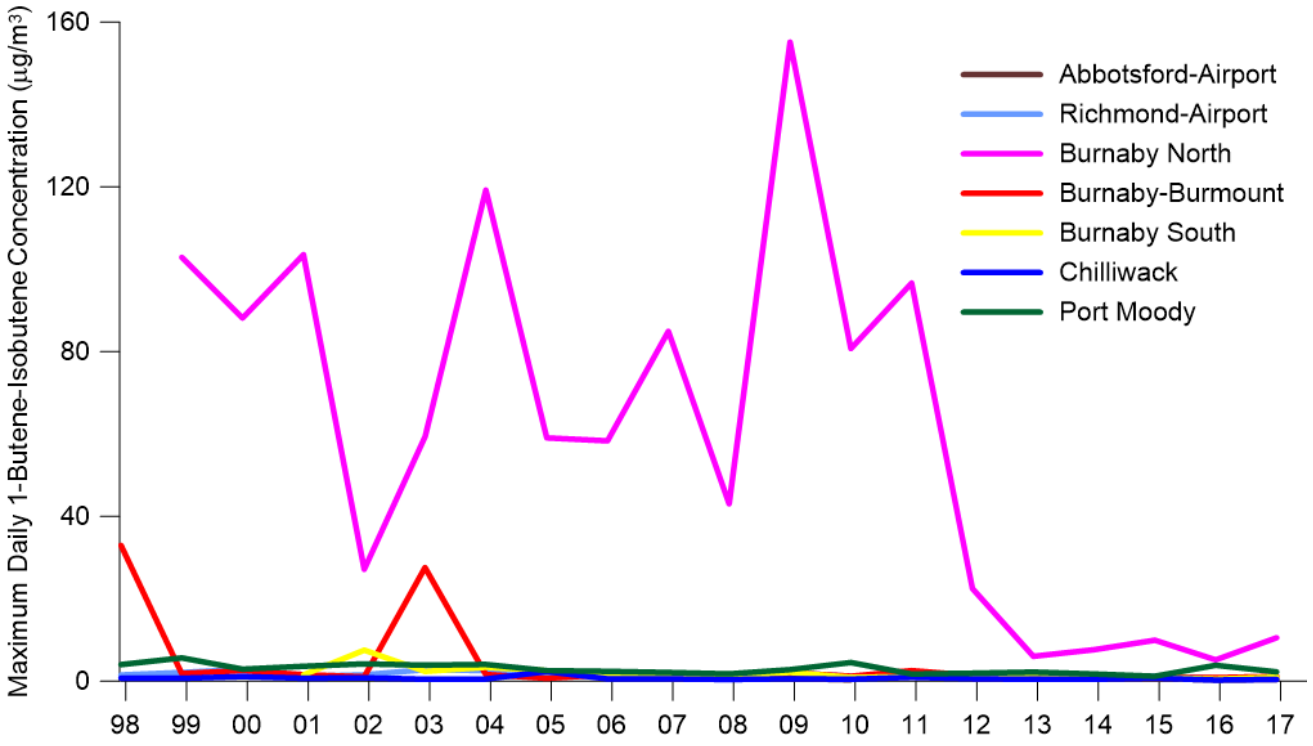


Figure A11: Short-term peak 1-butene/isobutene trend, 1998 to 2017.

Isoprene

Characteristics

Isoprene is the third highest ranked VOC for its ozone producing potential in the LFV. Isoprene is a colourless, volatile liquid hydrocarbon with the chemical formula C_5H_8 and has a mild aromatic petroleum-like odour. Vapor-phase isoprene is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals and thus is of interest due to its ozone producing potential.

Isoprene is a priority from an ozone production perspective and is released to the atmosphere by natural sources and during the production of heavy petroleum oils.

Sources

Isoprene is emitted by both natural and anthropogenic sources. Biogenic isoprene is emitted to the atmosphere by many tree and plant species. Isoprene can be emitted by petroleum refineries, the manufacture of vehicle tires and a wide variety of other products including medical equipment, toys, shoe soles, elastic films and threads for textiles and golf balls, adhesives, paints and coatings. In the LFV, biogenic emissions from plants, vehicle exhaust emissions, and refinery and tank farm fugitive emissions are the primary sources of isoprene.

Monitoring Results

Figure A12 illustrates the results of isoprene monitoring in 2017. Figure A12 displays the maximum daily concentration as well as the annual average for each isoprene monitoring location. The highest concentrations occurred at the Burnaby-Burmount station that is adjacent to the Burnaby Mountain tank farm where petroleum products are stored.

Figures A13 and A14 illustrate the long-term average and peak isoprene trends in the LFV, respectively. Historically, the North Burnaby station adjacent to the refinery tank farm measured the highest annual average isoprene levels, but over the past 10 years, the Burnaby-Burmount station adjacent to the Burnaby Mountain tank farm has recorded the highest average levels. Maximum daily values show little discernible trend from the mid-90's to present, but in recent years the maximum daily concentration has mostly been measured at the Burnaby-Burmount station. Vancouver-Clark Drive is not included in the long-term trends since the station has only recently been established.

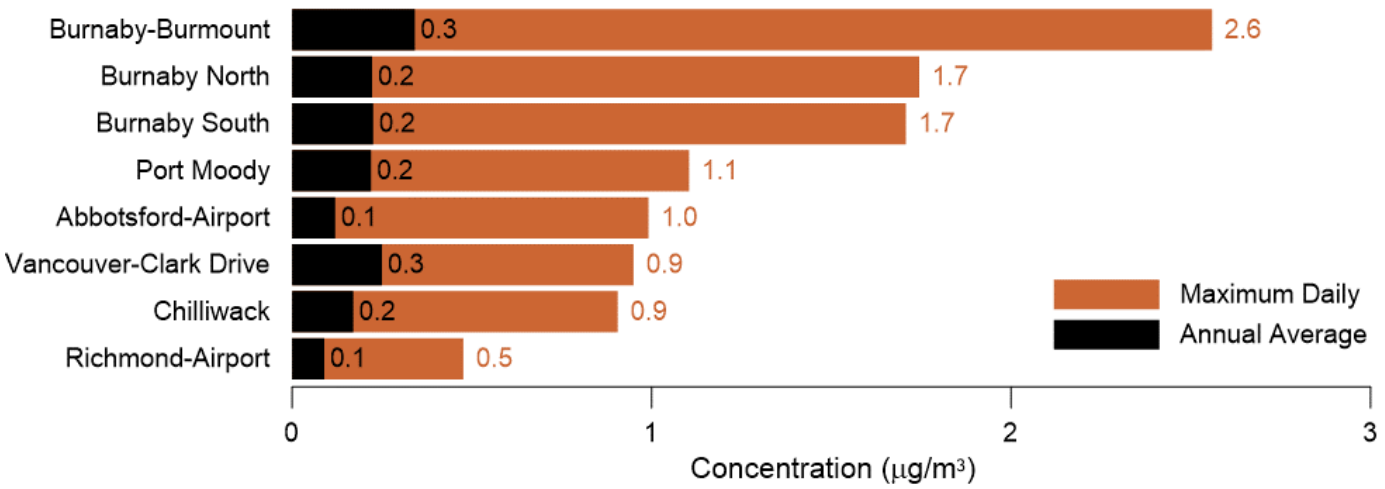


Figure A12: Isoprene monitoring, 2017.

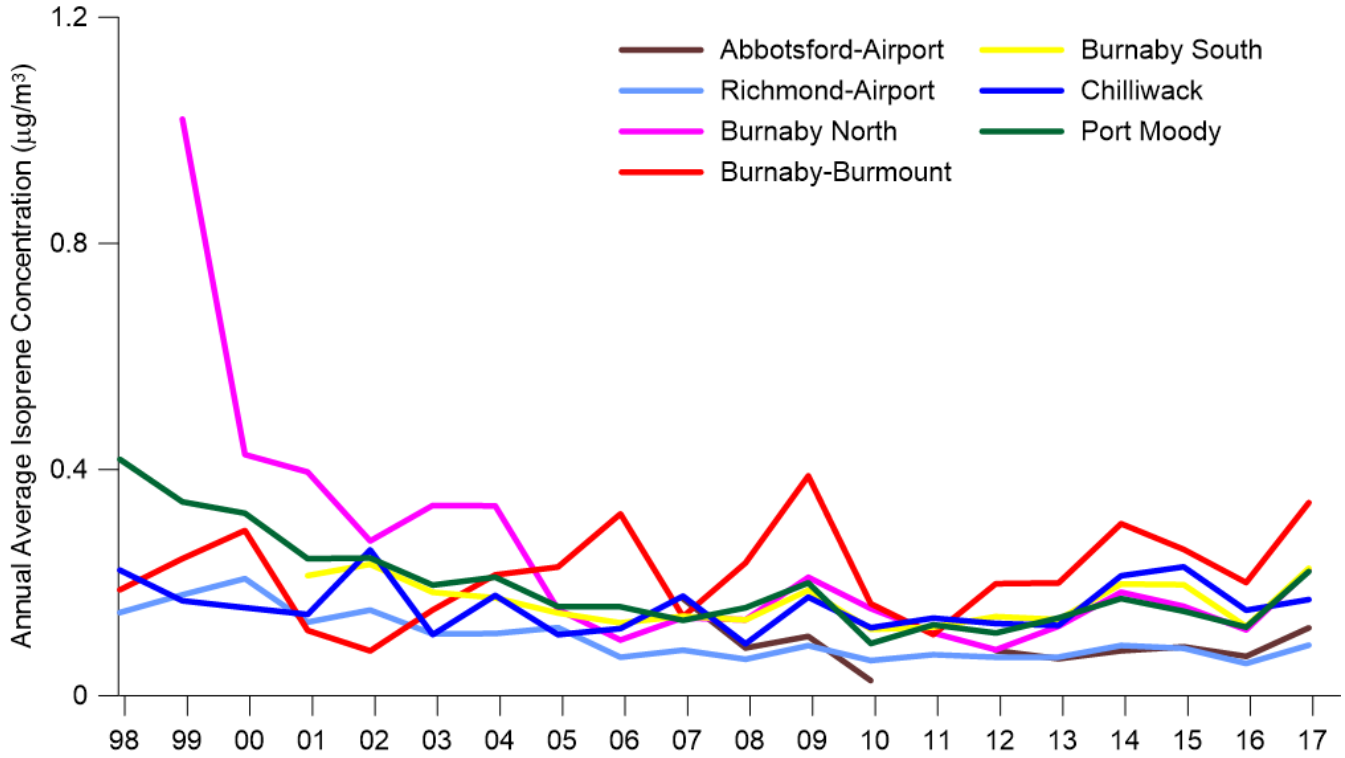


Figure A13: Annual isoprene trend, 1998 to 2017.

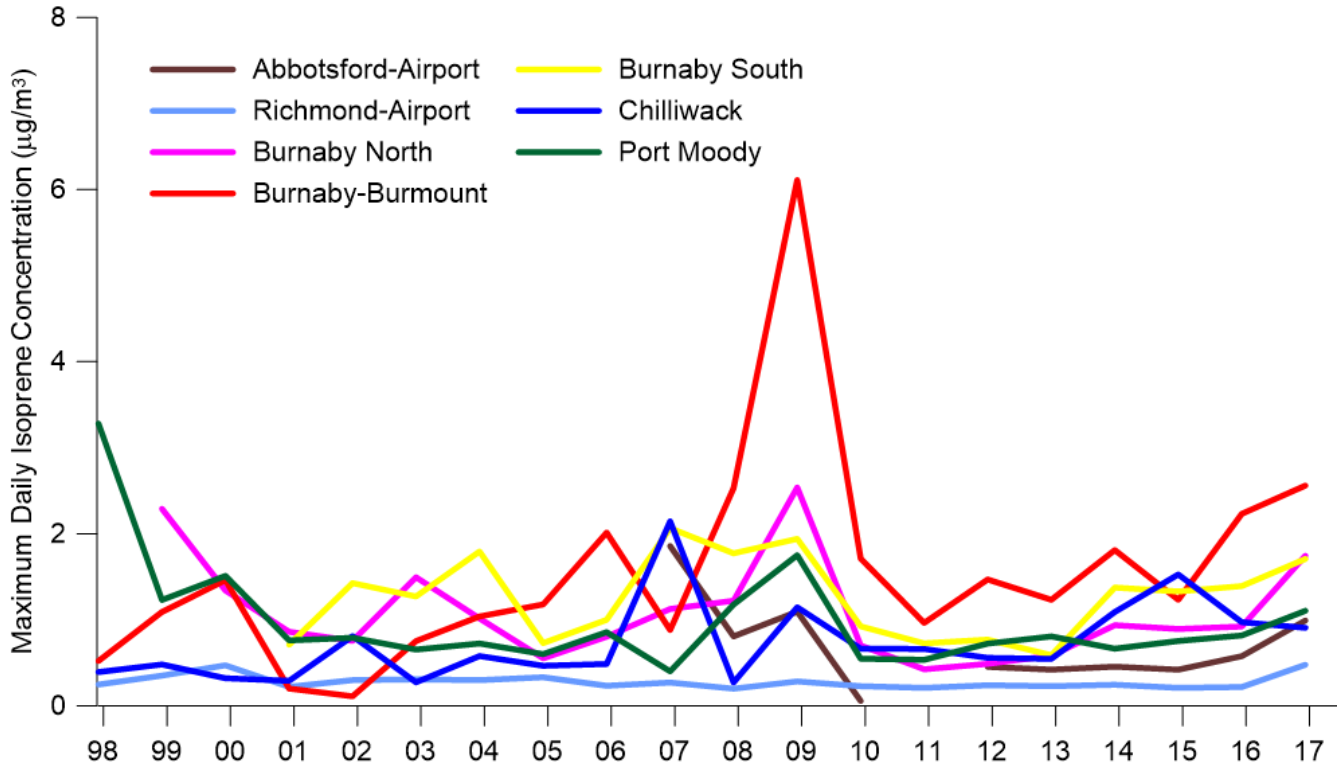


Figure A14: Short-term peak isoprene trend, 1998 to 2017.

2-Methyl-2-butene

Characteristics

2-Methyl-2-butene is a clear colourless liquid with the chemical formula C_5H_{10} and a petroleum-like odour. The compound is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals, ozone, and nitrate radical. The compound is of interest because of its involvement in the reactions that form ozone and is the fourth highest ranked VOC for its ozone producing potential in the LFV.

2-Methyl-2-butene is a component of refinery gas and used as an agricultural chemical, fuel and fuel additives, and intermediate in chemical manufacturing. It reacts to form ground-level ozone.

Sources

2-Methyl-2-butene is used by industry and consumers as an agricultural chemical, fuel constituent and fuel additive, and intermediate in chemical manufacturing. It is also a component of gas emitted during petroleum refining. The primary sources of 2-methyl-2-butene in the LFV are refinery and tank farm fugitive emissions, and vehicle exhaust emissions.

Monitoring Results

Figure A15 illustrates the results of 2-methyl-2-butene monitoring in 2017. Figure A15 displays the maximum daily concentration as well as the annual average. The highest concentrations occurred at the Burnaby North station that is adjacent to the refinery tank farm. The second highest concentrations occurred at Vancouver-Clark Drive likely due to the proximity of the station to the adjacent gas station.

Figures A16 and A17 illustrate the long-term average and peak 2-methyl-2-butene trends in the LFV, respectively. The contaminant 2-methyl-2-butene follows a similar long-term trend as 1-butene/isobutene with average levels decreasing considerably since the late 1990s. Historically Burnaby North has experienced the highest average and peak levels of 2-methyl-2-butene. The variability of the peak levels is likely due to meteorological and emissions variability. Vancouver-Clark Drive is not included in the long-term trends since the station has only recently been established.

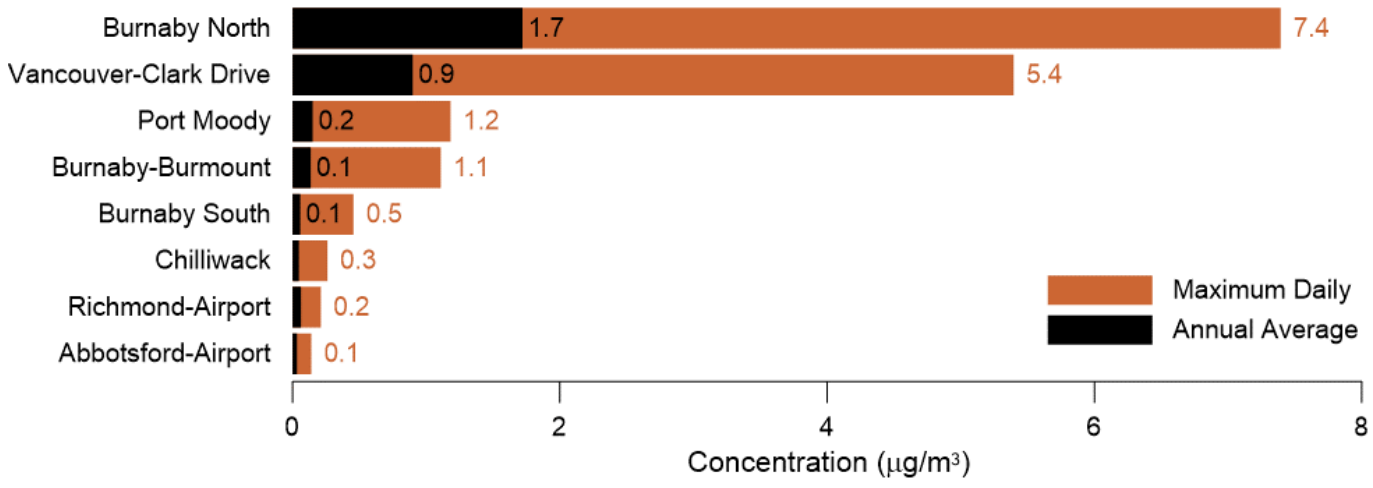


Figure A15: 2-Methyl-2-butene monitoring, 2017.

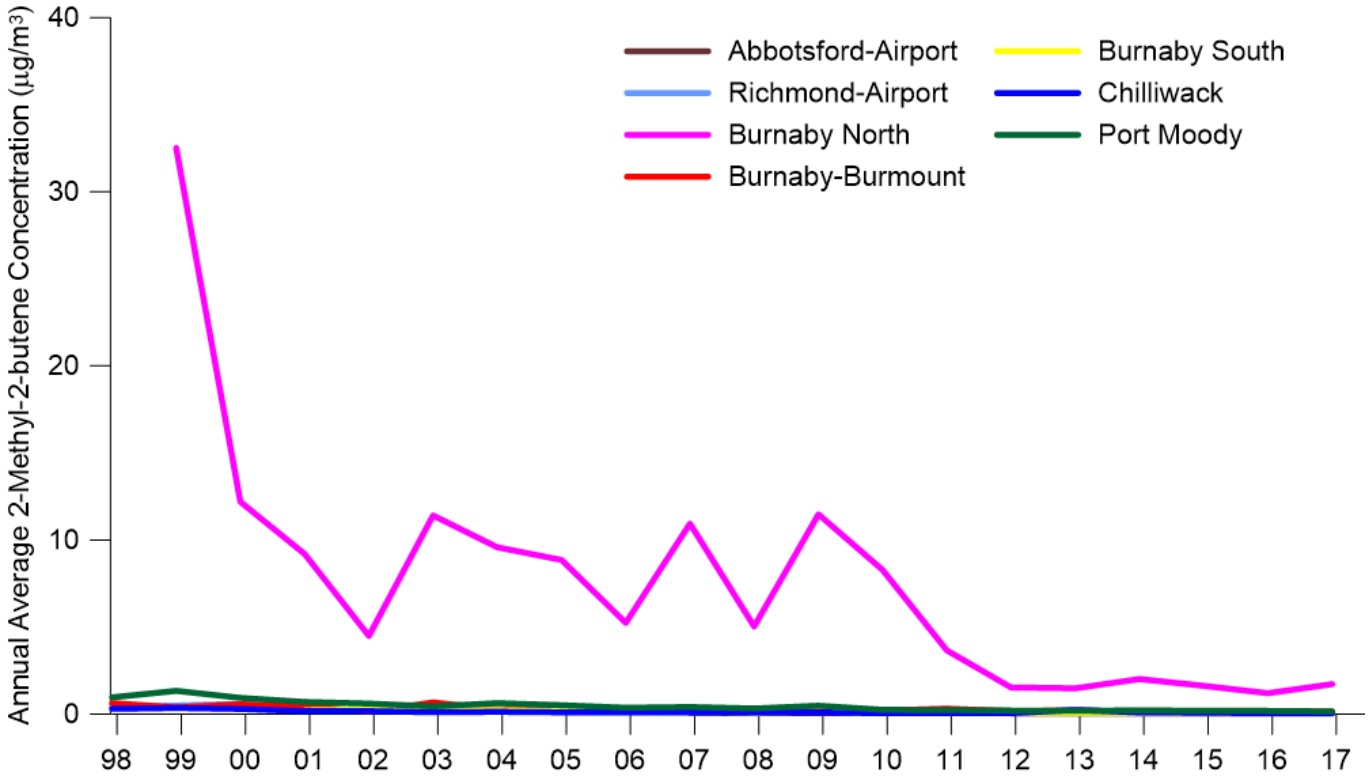


Figure A16: Annual 2-methyl-2-butene trend, 1998 to 2017.

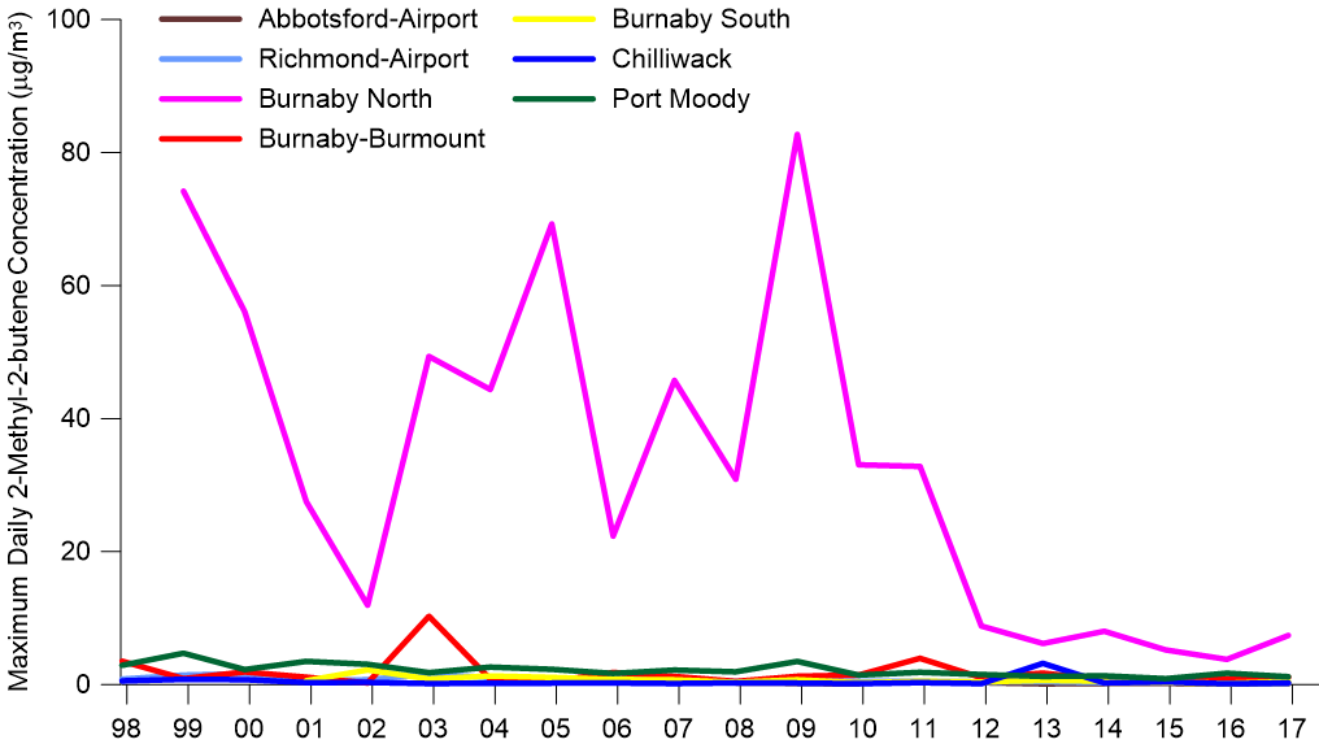


Figure A17: Short-term peak 2-methyl-2-butene trend, 1998 to 2017.

M- and p-xylene

Characteristics

Xylenes are a family of three aromatic hydrocarbon isomers (ortho-, meta- and para-xylene) with the chemical formula C_8H_{10}. They are colourless liquids that are nearly insoluble in water and have a sweet odour. From an ozone production perspective m- and p-xylene are the fifth highest ranked VOC for ozone producing potential in the LFV.

Sources

Xylenes are used in the production of industrial chemicals, as solvents in products such as paints and coatings, and are blended into gasoline. Xylenes are released into the atmosphere as fugitive emissions from industrial sources, from vehicle exhaust, and through volatilization due to their use as solvents. In the LFV, the primary sources of m- and p-xylene are vehicle emissions and solvent evaporation.

Monitoring Results

Figure A18 illustrates the results of m- and p-xylene monitoring in 2017. Figure A18 displays the maximum daily concentration as well as the annual average for each xylene monitoring location. The highest daily maximum and average concentrations occurred at Burnaby North followed by Vancouver-Clark Drive.

Xylenes, released into the atmosphere as fugitive emissions from industrial sources, vehicle exhaust, and solvents, react to help form ground-level ozone.

Figures A19 and A20 illustrate the long-term average and peak m- and p-xylene trends in the LFV, respectively. Burnaby North and Port Moody have historically experienced the highest annual average m- and p-xylene concentrations. Overall the annual average exhibits a downward trend at most locations. The most recent years exhibit lower maximum daily concentrations relative to previous years. Vancouver-Clark Drive is not included in the long-term trends since the station has only recently been established.

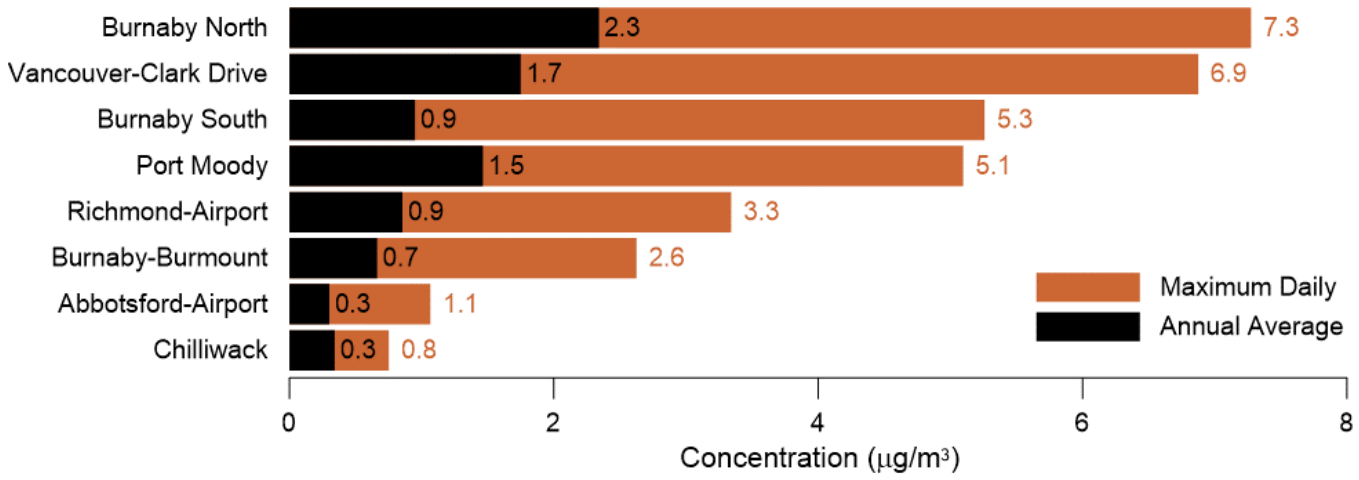


Figure A18: M- and p-xylene monitoring, 2017.

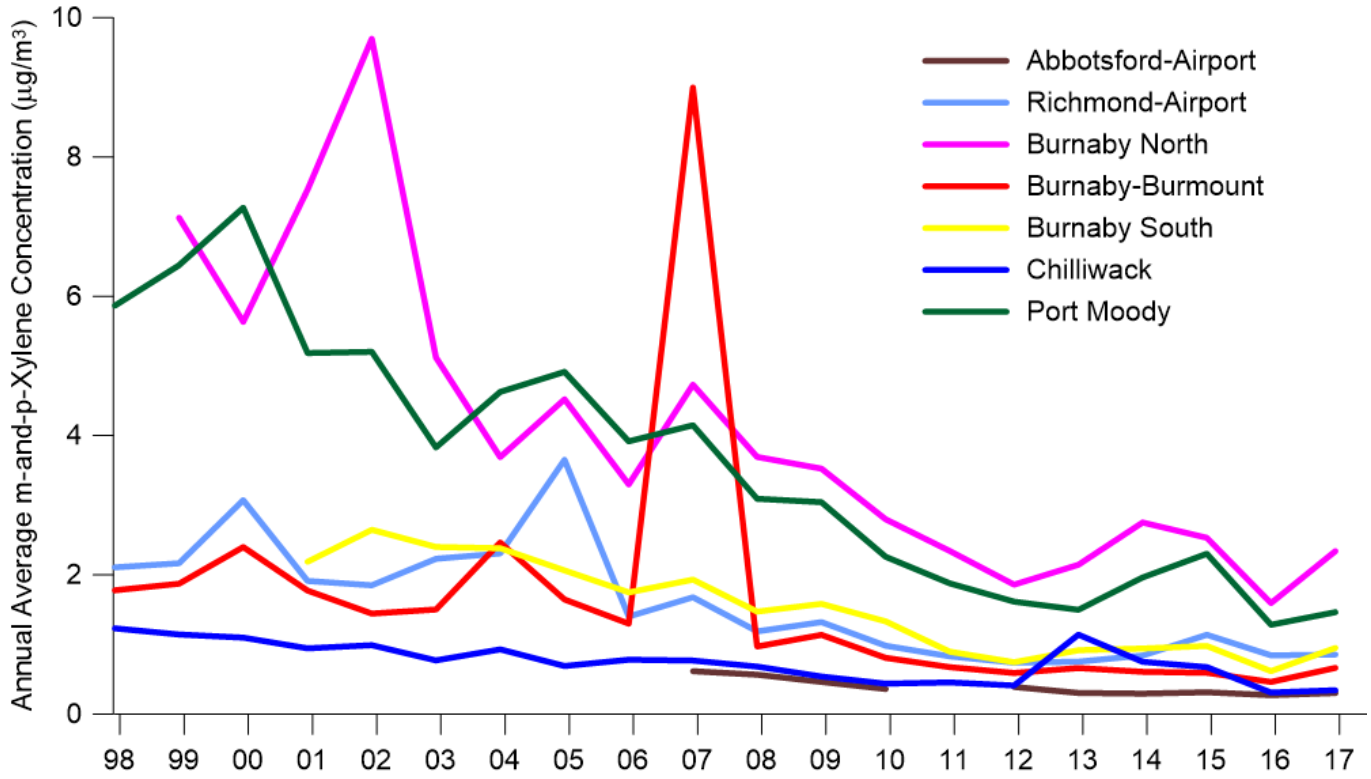


Figure A19: Annual m- and p-xylene trend, 1998 to 2017.

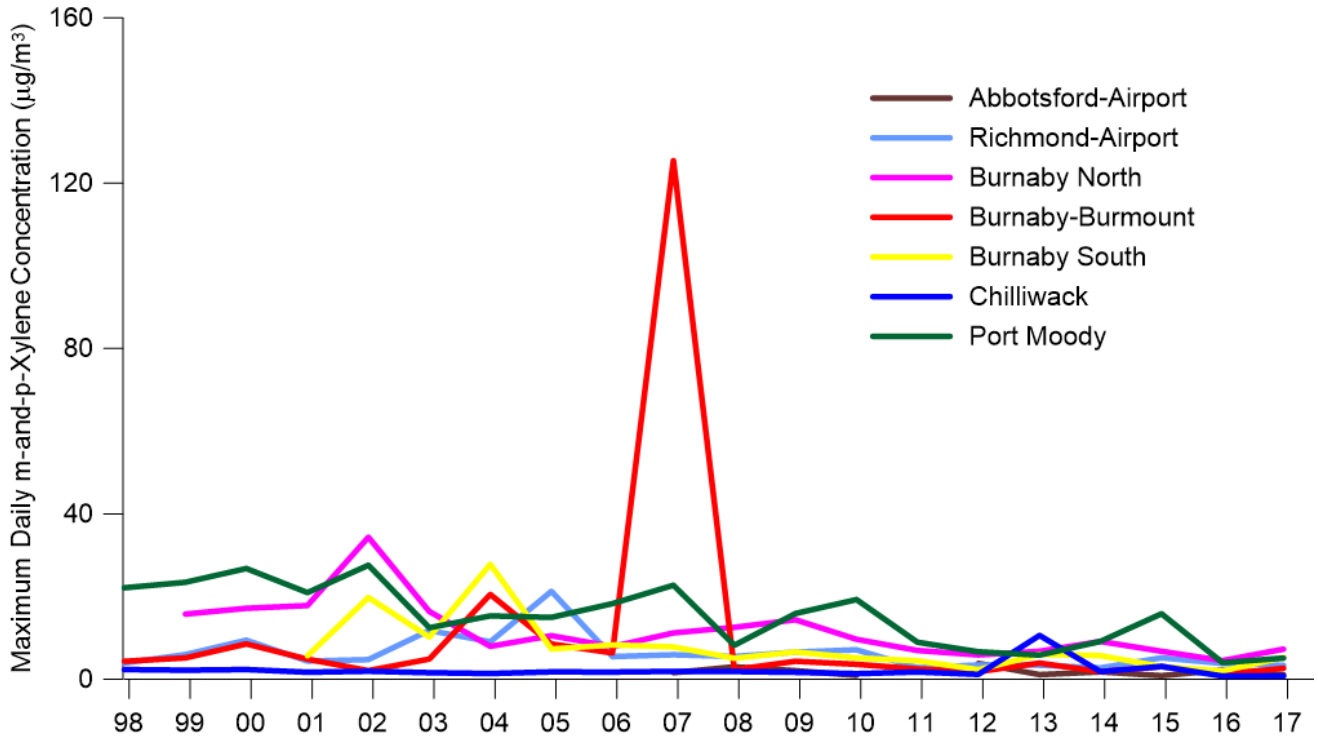


Figure A20: Short-term peak m- and p-xylene trend, 1998 to 2017.

Formaldehyde

Characteristics

The chemical formula for formaldehyde is CH_2O, and it is a colourless gas with a pungent, suffocating odour at room temperature. The US EPA considers formaldehyde a probable human carcinogen and acute (short-term) and chronic (long-term) inhalation exposure can result in adverse human health effects. At ambient concentrations measured in the LFV in 2010 it poses a lifetime cancer risk greater than Health Canada's 1 in 100,000 screening threshold[1].

Sources

Formaldehyde is used mainly to produce resins used in particleboard products and as an intermediate in the synthesis of other chemicals. One of the most common uses of formaldehyde is manufacturing urea-formaldehyde resins, used in particleboard products. It also has minor uses in agriculture, as an analytical reagent, in concrete and plaster additives, cosmetics, disinfectants, fumigants, photography, and wood preservation.

The primary sources of formaldehyde emissions in the LFV are exhaust from fossil fuel combustion, residential wood burning, and fugitive emissions from industrial facilities. It is important to note that formaldehyde may also be formed in the atmosphere through chemical reactions of other precursor species, so measured levels of ambient formaldehyde are likely due to both primary emissions and secondary formation.

Monitoring Results

Figure A21 illustrates the results of formaldehyde monitoring in 2017. Figure A21 displays the maximum daily concentration as well as the annual average for the two formaldehyde monitoring locations. The highest daily concentration occurred at the Port Moody station. Formaldehyde is a polar VOC and is sampled at two stations in the network.

Formaldehyde is a probable human carcinogen and acute and chronic inhalation exposure can result in human health effects.

Historically polar VOC have only been routinely measured at Port Moody. Figures A22 and A23 illustrate the long-term average and peak formaldehyde trends at Port Moody and Abbotsford-Airport, respectively. There does not appear to be a discernible trend in average and peak levels for formaldehyde at Port Moody. Due to resource limitations in the federal NAPS program, analysis of polar VOC was limited in Canada between 2011 and 2013 and therefore a gap is present during these years.

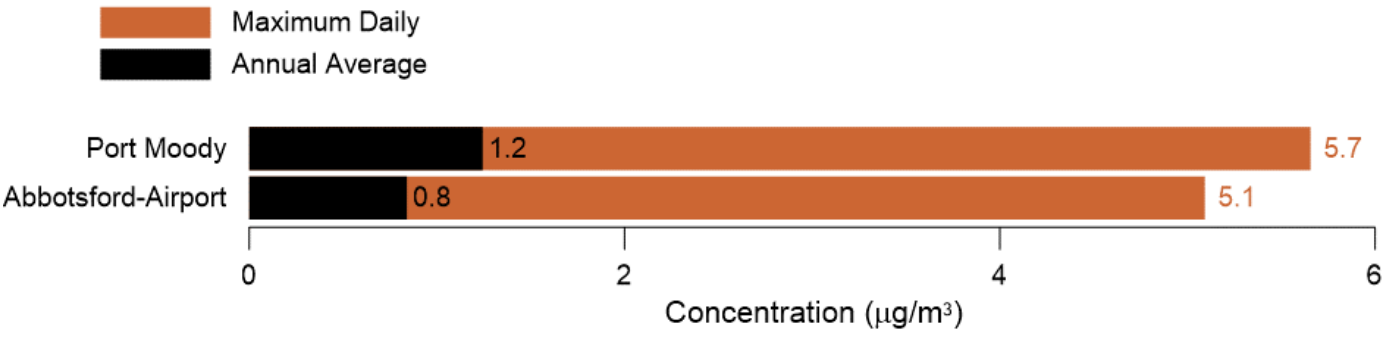


Figure A21: Formaldehyde monitoring, 2017.

[1] Toxic Air Pollutants Risk Assessment and Emissions Inventory for the Lower Fraser Valley, Metro Vancouver, 2015.

Figure A22: Annual formaldehyde trend, 1998 to 2017.

Figure A23: Short-term peak formaldehyde trend, 1998 to 2017.

Acrolein

Characteristics

Acrolein (C_3H_4O) is a clear or yellow liquid with a burned, sweet, pungent odour. Acrolein is a strong irritant for the skin, eyes and nasal passages. At ambient concentrations measured in the LFV in 2010 it poses a non-cancer health risk greater than Health Canada's 0.2 hazard quotient screening threshold[2].

Sources

Acrolein is produced during incomplete organic combustion and is used as an intermediate for various industrial and consumer uses. A main source of acrolein is incomplete organic combustion from residential fireplaces, burning of fuels, automobile exhaust, overheated vegetable and animal fats, tobacco smoke, and smoke from structural and vegetative fires. Acrolein may be released to the atmosphere during its production for use as an aquatic herbicide, warning agent in gases, fumigant, leather tanning agent, pharmaceutical, and in making plastics and perfumes.

In the LFV, the primary sources of acrolein emissions are exhaust from fossil fuel combustion and residential wood burning.

Monitoring Results

Figure A24 illustrates the results of acrolein monitoring in 2017. Figure A24 displays the value of the maximum daily concentration as well as the annual average for the two acrolein monitoring locations. The highest peak daily concentration occurred at the Port Moody station. Acrolein is a polar VOC and is sampled at two stations in the network.

Acrolein is a strong irritant for the skin, eyes and nasal passages and has known acute human health effects.

Historically polar VOC have only been routinely measured at Port Moody. Figures A25 and A26 illustrate the long-term average and peak acrolein trends at Port Moody and Abbotsford-Airport, respectively. Decreases in average and peak concentrations have been experienced between the mid-1990s to the early-2000s. In the late-2000s the trend is less apparent. Due to resource limitations in the federal NAPS program, analysis of polar VOC was limited in Canada between 2011 and 2013 and therefore a gap is present during these years.

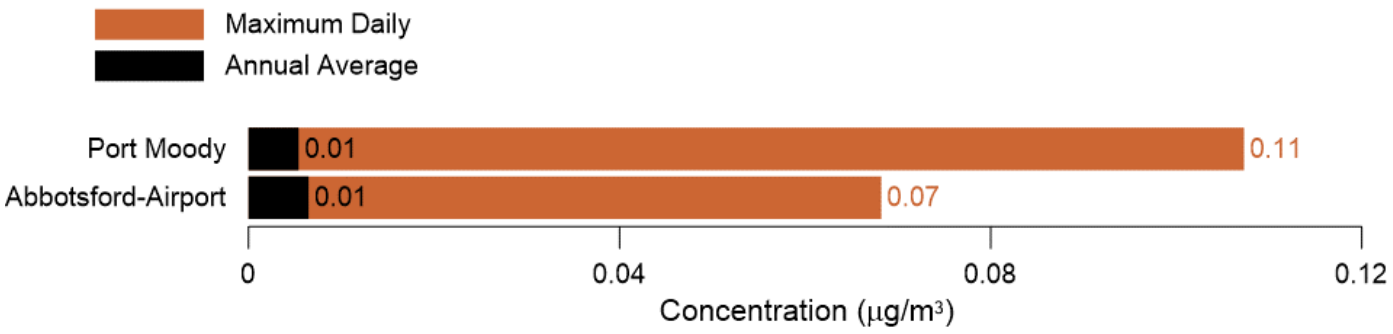


Figure A24: Acrolein monitoring, 2017.

[2] Toxic Air Pollutants Risk Assessment and Emissions Inventory for the Lower Fraser Valley, Metro Vancouver, 2015.

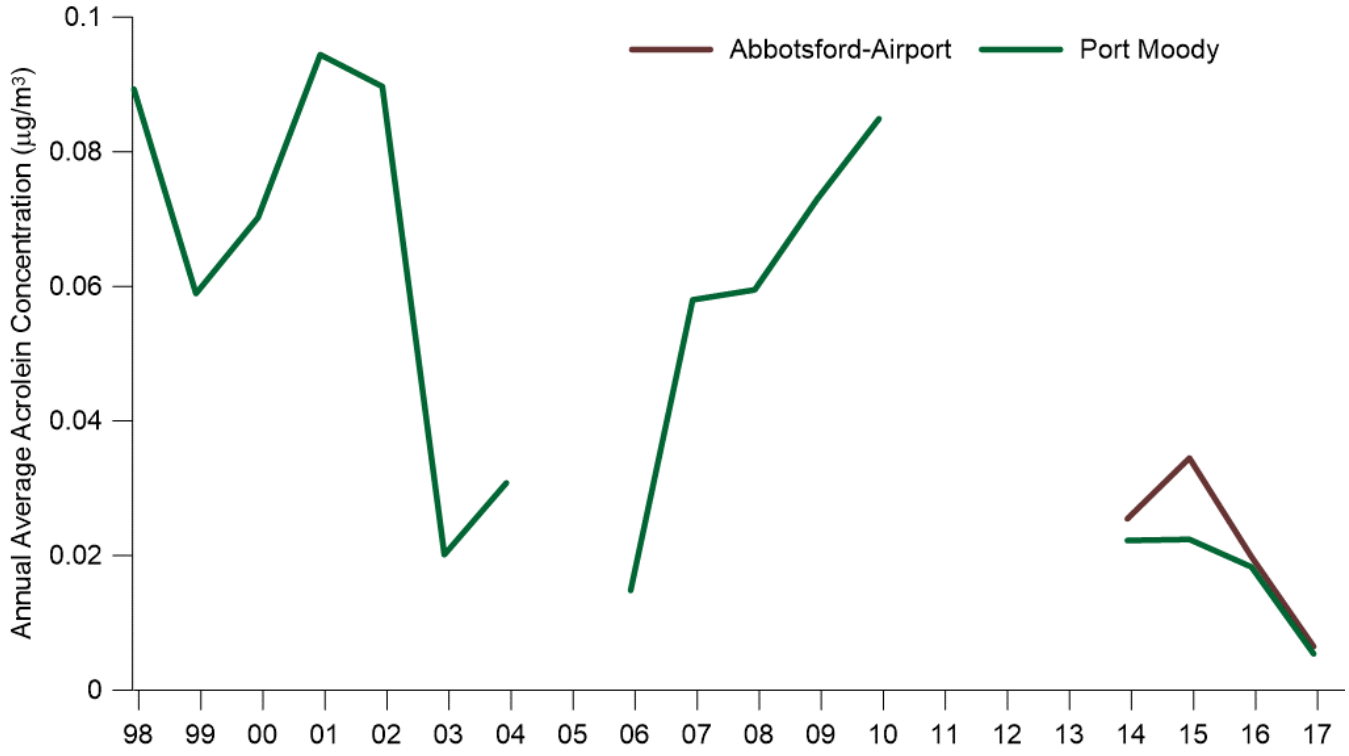


Figure A25: Annual acrolein trend, 1998 to 2017.

Figure A26: Short-term peak acrolein trend, 1998 to 2017.

Benzene

Characteristics

Benzene is an aromatic hydrocarbon with a sweet odour at high concentrations and the chemical formula C_6H_6. At ambient temperature it occurs as a volatile, colourless, highly flammable liquid that is somewhat soluble in water. Benzene has been classified by the US EPA as a known human carcinogen and has both acute and chronic inhalation exposure effects. At ambient concentrations measured in the LFV in 2010, it poses a lifetime cancer risk greater than Health Canada's 1 in 100,000 screening threshold[3].

Benzene levels have decreased regionally over the last two decades mainly due to federal gasoline regulations.

Sources

Benzene is found in emissions from burning coal and oil, motor vehicle exhaust, and evaporation from gasoline service stations and in industrial solvents. In the LFV, the primary sources of benzene include gasoline engine exhaust, service station fugitive emissions, and residential wood burning, as well as refinery and tank farm fugitive emissions.

Monitoring Results

Figure A27 illustrates the results of benzene monitoring in 2017. Figure A27 displays the maximum daily concentration as well as the annual average for each benzene monitoring location. The highest concentrations occurred at the Burnaby North station that is adjacent to the refinery tank farm. The second highest concentrations occurred at Vancouver-Clark Drive likely due to the combination of fugitive emissions from the adjacent gas station and vehicle exhaust.

Figures A28 and A29 illustrate the long-term average and peak benzene trends in the LFV, respectively. Average levels of benzene decreased considerably in the mid-2000s at Burnaby North while other monitoring sites exhibited a more constant decrease since the mid-1990s. Reductions in benzene levels regionally can be attributed mainly to benzene emission reductions from transportation and refinery sources brought on by federal gasoline regulations. Due to its proximity to the refinery tank farm, the Burnaby North has consistently exhibited the highest average annual and peak levels of benzene in the region. Vancouver-Clark Drive is not included in the long-term trends since the station has only recently been established.

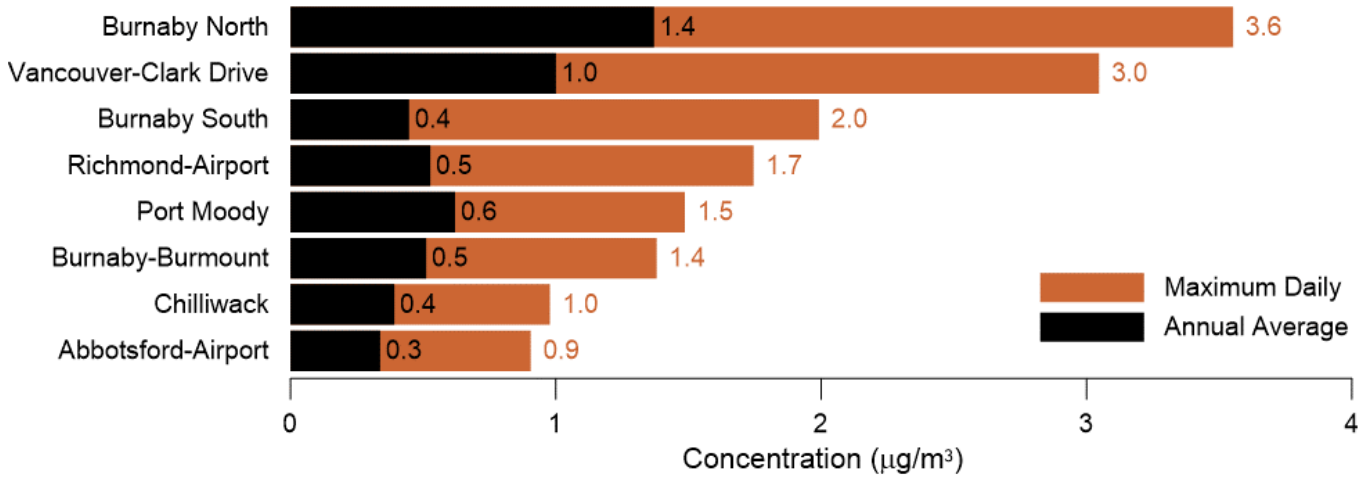


Figure A27: Benzene monitoring, 2017.

[3] Toxic Air Pollutants Risk Assessment and Emissions Inventory for the Lower Fraser Valley, Metro Vancouver, 2015.

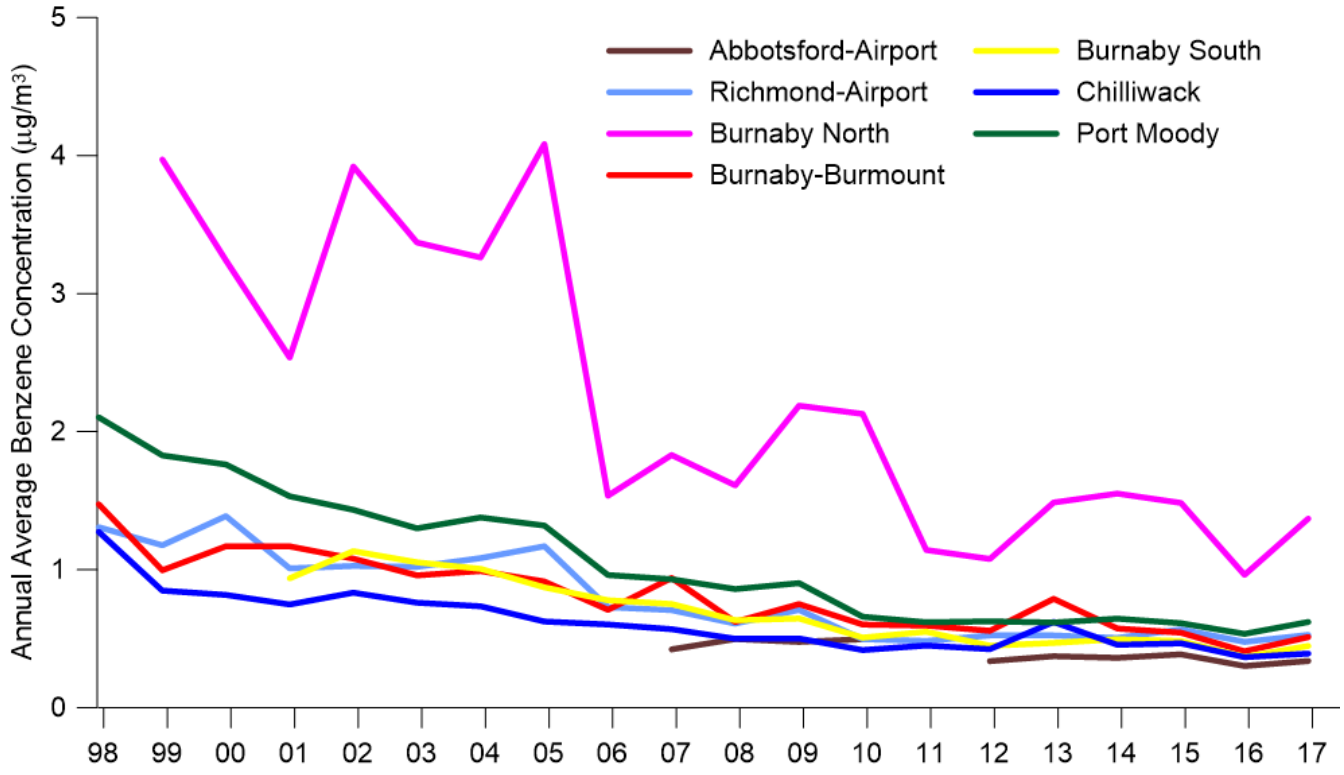


Figure A28: Annual benzene trend, 1998 to 2017.

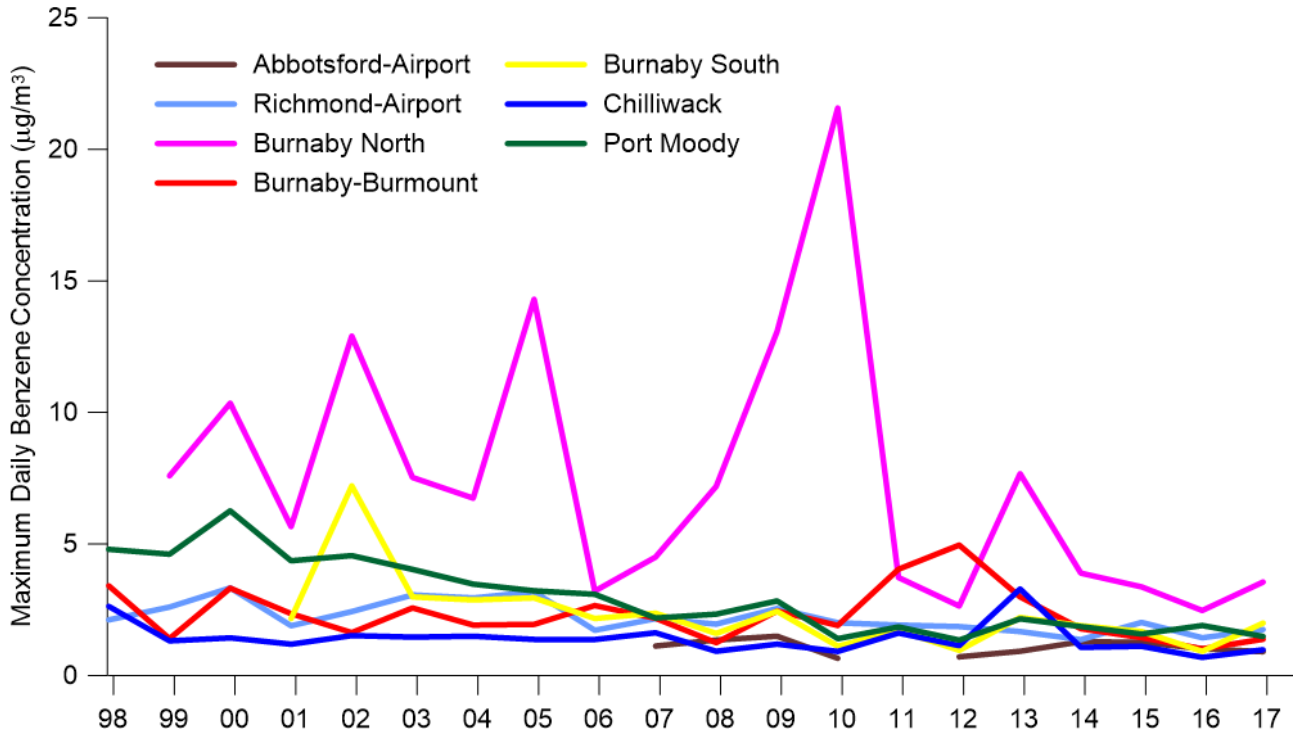


Figure A29: Short-term peak benzene trend, 1998 to 2017.

Acetaldehyde

Characteristics

Acetaldehyde is a colourless volatile liquid that is flammable and soluble in water. Its chemical formula is CH_3CHO, and at dilute concentrations it has a fruity and pleasant odour. Acetaldehyde is considered a probable human carcinogen and has both acute and chronic human health effects. In the LFV, at ambient concentrations measured in 2010, it poses a non-cancer health risk greater than Health Canada's 0.2 hazard quotient screening threshold[4].

Sources

Acetaldehyde is an intermediate product of plant respiration and formed as a product of incomplete wood combustion in fireplaces and woodstoves, coffee roasting, burning of tobacco, vehicle exhaust, and waste processing. Acetaldehyde is also used in the production of perfumes, polyester resins, and basic dyes. Acetaldehyde is also used as a fruit and fish preservative, as a flavoring agent, and as a denaturant for alcohol, in fuel compositions, for hardening gelatin, and as a solvent in the rubber, tanning, and paper industries.

In the LFV, the primary sources of acetaldehyde include natural sources, gasoline engine exhaust, and residential wood burning.

Monitoring Results

Figure A30 illustrates the results of acetaldehyde monitoring in 2017. Figure A30 displays the maximum daily concentration as well as the annual average for each acetaldehyde monitoring location. The highest concentrations occurred at the Port Moody station. Acetaldehyde is a polar VOC and is sampled at two stations in the network.

Acetaldehyde is considered a probable human carcinogen with potential for both acute and chronic human health effects.

Historically polar VOC have only been routinely measured at Port Moody. Figures A31 and A32 illustrate the long-term average and peak acetaldehyde trends at Port Moody and Abbotsford-Airport, respectively. There does not appear to be a discernible trend in average and peak levels for acetaldehyde at Port Moody. Due to resource limitations in the federal NAPS program, analysis of polar VOC was limited in Canada between 2011 and 2013 and therefore a gap is present during these years.

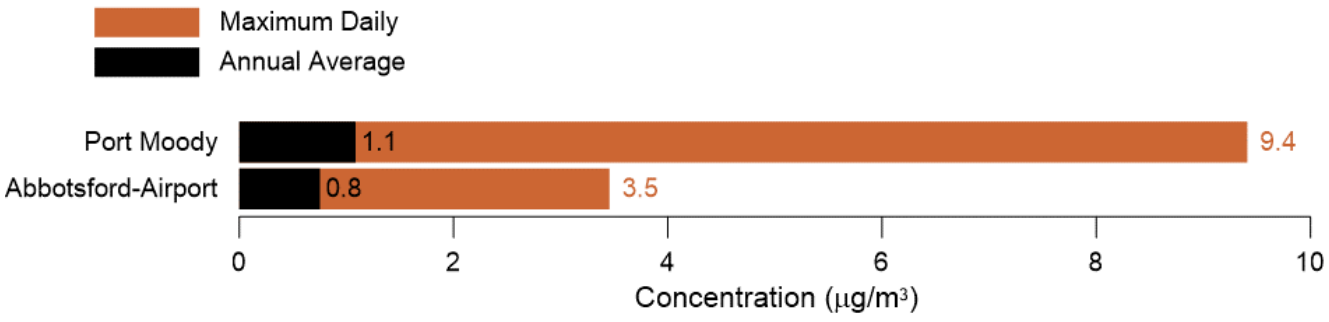


Figure A30: Acetaldehyde monitoring, 2017.

[4] Toxic Air Pollutants Risk Assessment and Emissions Inventory for the Lower Fraser Valley, Metro Vancouver, 2015.

Figure A31: Annual acetaldehyde trend, 1998 to 2017.

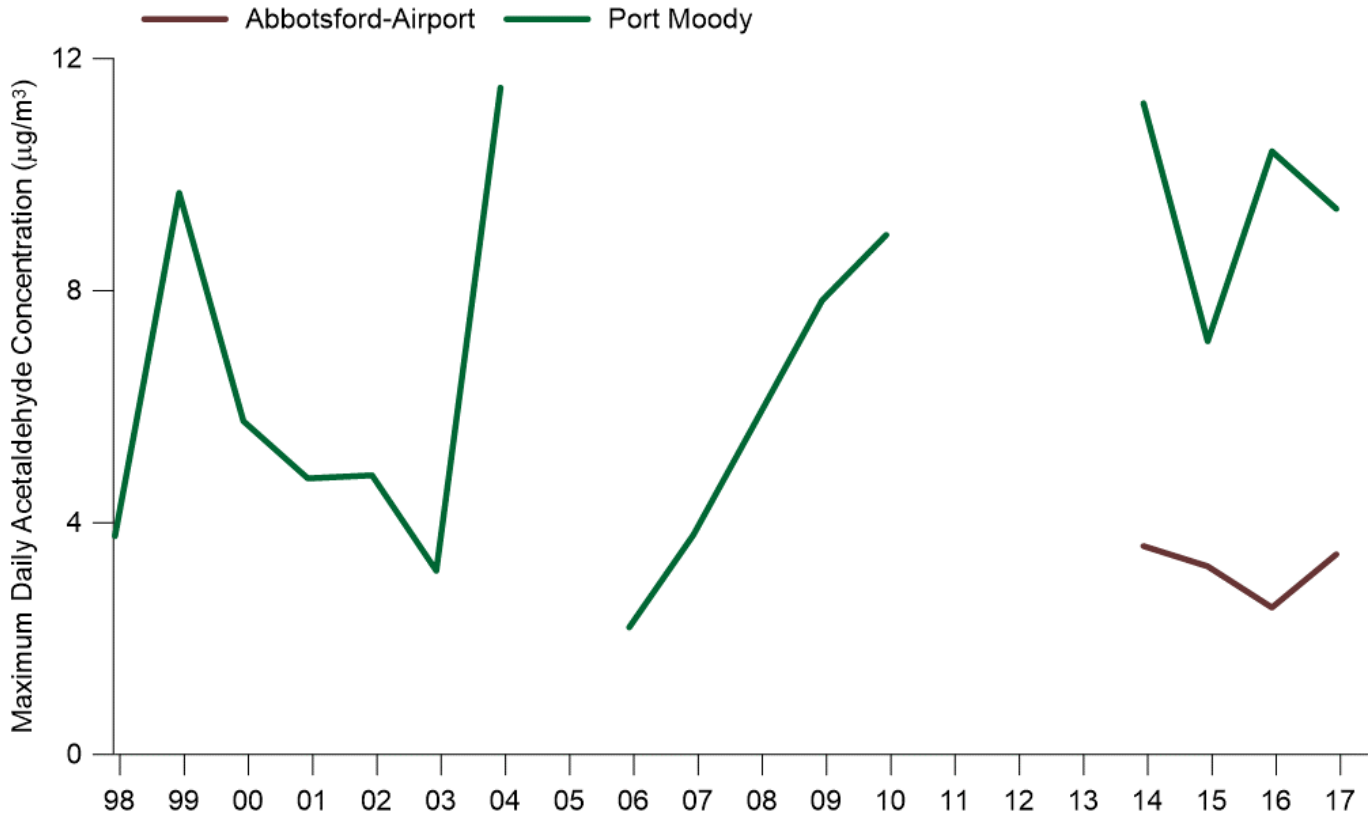


Figure A32: Short-term peak acetaldehyde trend, 1998 to 2017.

1,3-Butadiene

Characteristics

1,3-Butadiene is a colourless gas with mild gasoline-like odour with the chemical formula C_4H_6. 1,3-Butadiene has been classified by the US EPA as a known human carcinogen and has both acute and chronic inhalation exposure effects. At current ambient concentrations measured in the LFV it poses a lifetime cancer risk greater than Health Canada's 1 in 100,000 screening threshold[5].

1,3-Butadiene levels have decreased regionally over the last two decades mainly due to improvements in internal combustion engine efficiency.

Sources

1,3-Butadiene is found in emissions from gasoline internal combustion engines in on-road vehicles, off-road vehicles, and aircraft. In Metro Vancouver, residential wood burning is also a significant source, and oil refinery emissions have historically contributed to 1,3-butadiene emissions.

Monitoring Results

Figure A33 illustrates the results of 1,3-butadiene monitoring in 2017. Figure A33 displays the maximum daily concentration as well as the annual average for each 1,3-butadiene monitoring location. The highest concentrations occurred at the Vancouver-Clark Drive station.

Figures A34 and A35 illustrate the long-term average and peak 1,3-butadiene trends in the LFV, respectively. Average levels of 1,3-butadiene decreased considerably in the mid-2000s at Burnaby North while other monitoring sites exhibited a more constant decrease since the 1990s. Reductions in 1,3-butadiene levels regionally can be attributed to continuing improvement in the emissions performance of gasoline internal combustion engines driven by federal emissions regulations. Vancouver-Clark Drive is not included in the long-term trends since the station has only recently been established.

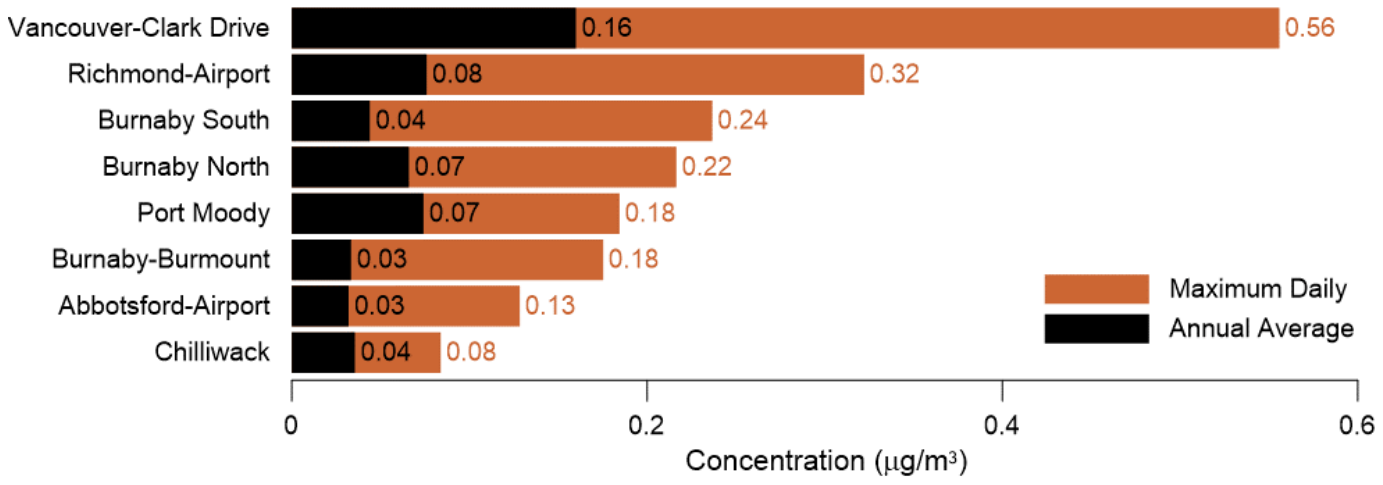


Figure A33: 1,3-Butadiene monitoring, 2017.

[5] Toxic Air Pollutants Risk Assessment and Emissions Inventory for the Lower Fraser Valley, Metro Vancouver, 2015.

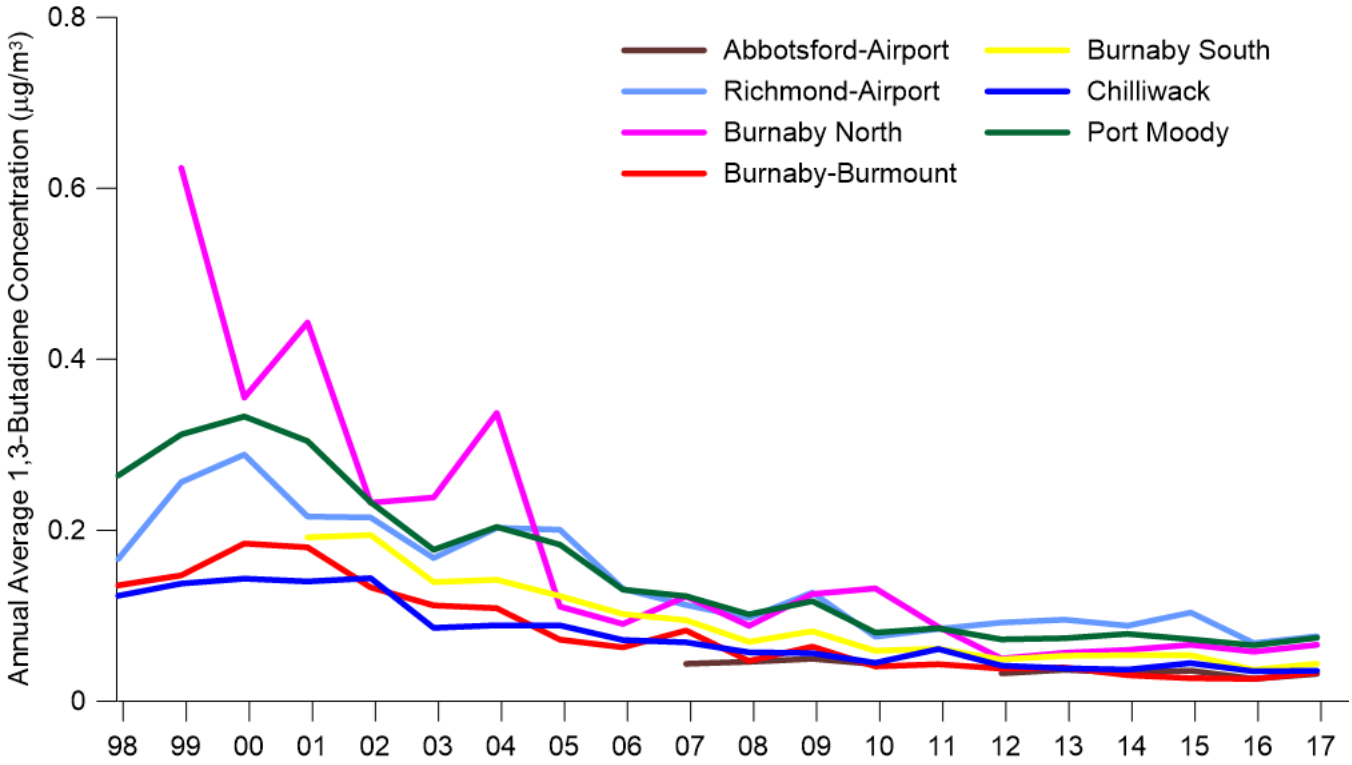


Figure A34: Annual 1,3-butadiene trend, 1998 to 2017.

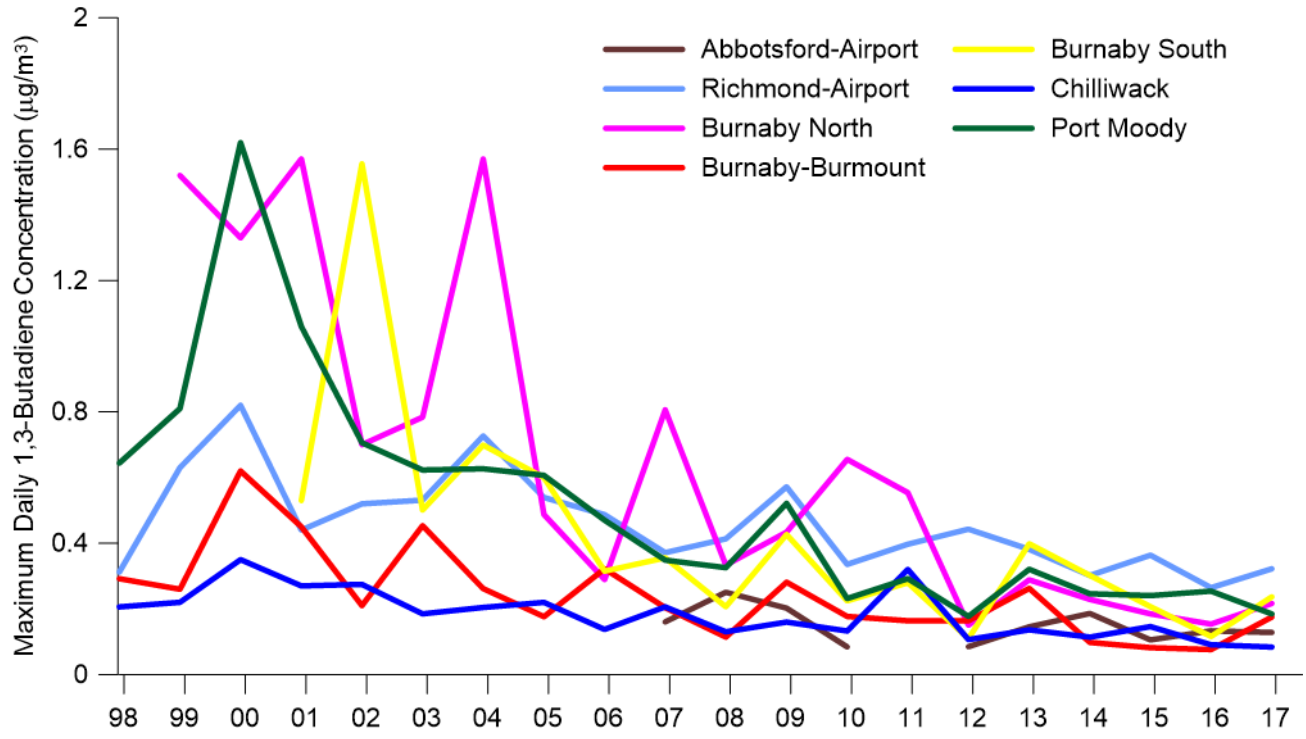


Figure A35: Short-term peak 1,3-butadiene trend, 1998 to 2017.