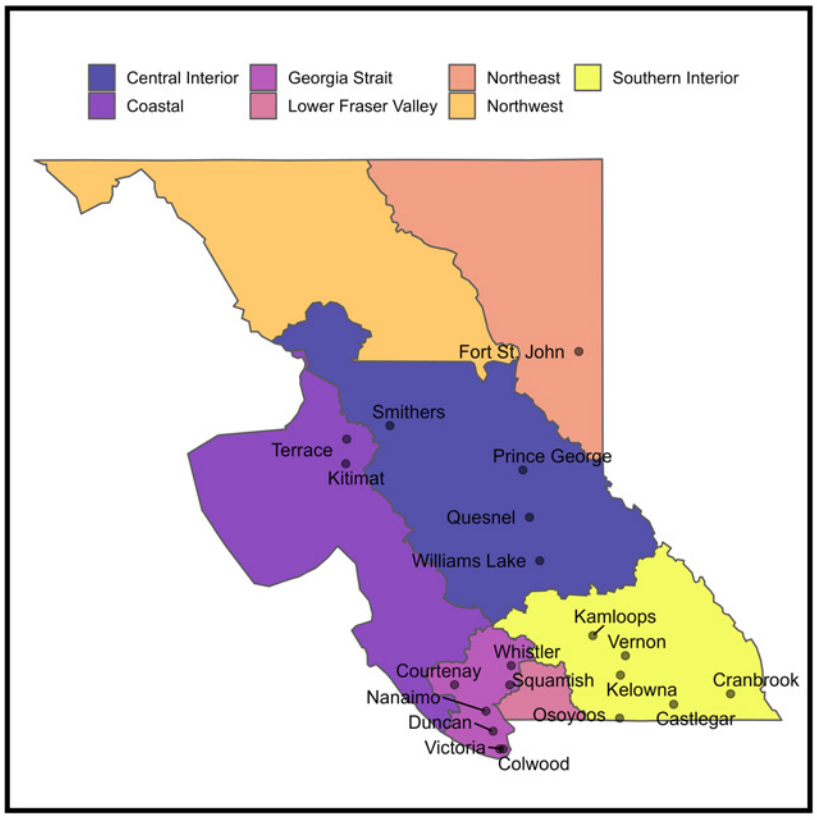
A Review of Air Quality Health Index Monitoring in British Columbia



B.C. Ministry of Environment and Climate Change Strategy
Environmental Protection Division

BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

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Author's Affiliation:
Donna Haga, Senior Air Quality Meteorologist
Monitoring, Assessment & Stewardship
Regional Operations Branch
Environmental Protection Division
Ministry of Environment & Climate Change Strategy
205 Industrial Road, Cranbrook, BC, V1C 7G5

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Data from Robles (2021) and Teucher et al. (2021).

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1. Executive Summary

1.1 Motivation

The Air Quality Health Index (AQHI) is a health protection tool designed to inform the public of short-term health risks from air pollution. The AQHI uses a scale to indicate the health risk associated with levels of air contaminants for the at risk and general populations as shown in Table 1.1:

Table 1.1: Description of the AQHI health risk categories (ENV, n.d.[a]).

Health Risk	AQHI Value	At Risk Population[a]	General Population
Low	1-3	Enjoy your usual outdoor activities.	Ideal air quality for outdoor activities.
Moderate	4-6	Consider reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	No need to modify your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	7-10	Reduce or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	Consider reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very High	Above 10	Avoid strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	Reduce or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

[a]People with heart or breathing problems are at greater risk. Follow your doctor's usual advice about exercising and managing your condition.

In BC, two versions of the AQHI operate "under the hood" - the *classic AQHI* and the *fine particulate matter AQHI* - they are calculated every hour and the greater of the two is reported to the public as the *AQHI*. This method of calculating an AQHI for British Columbia (BC) communities is also referred to as the *AQHI Plus*. The classic AQHI requires hourly monitoring for three

air contaminants (nitrogen dioxide (NO_2), ground-level ozone (O_3)[1], and fine particulate matter - particulate matter with aerodynamic diameter less than 2.5 micrometers ($PM_{2.5}$)); whereas the fine particulate matter AQHI requires only $PM_{2.5}$ to be monitored hourly. $PM_{2.5}$ is the most important air contaminant in BC from a public health perspective (BC Centre for Disease Control, n.d.; Healthlink BC, n.d.) - it is highly variable in space and time and is usually the driver for periods of degraded air quality (for example: wildfires and residential wood burning). NO_2 and O_3, on the other hand, are not as variable in space and time and are characteristic air contaminants of large urban centers. The current AQHI model in BC was developed under consultation with the British Columbia Centre for Disease Control (BCCDC) to account for periods of poor air quality in BC that are caused by elevated levels of $PM_{2.5}$ which were, under the previous model, not being categorized appropriately by the classic AQHI; it was first implemented as a pilot project prior to the wildfire season of 2018, and has since been adopted permanently on a year-round basis.

In recent years, there has been an increased demand from the public for information on the AQHI across BC and the number of AQHI monitoring stations has been increasing. However, it is difficult to justify monitoring for NO_2 and O_3 in smaller communities that are not expected to have high levels of these contaminants to satisfy the objective of AQHI reporting. This is especially true when addressing requests from communities with no air quality monitoring. This review includes a detailed investigation of the current AQHI model in BC to better understand the health messaging that is reported and how the constituent contaminants influence that reporting.

1.2 Scope

A detailed exploratory data analysis was completed of the AQHI network in BC between 2009 and 2020. This included 8.3 million combined hourly observations of the constituent air contaminants and the three versions of the AQHI (the classic AQHI, the fine particulate matter AQHI, and the AQHI). This rich monitoring history was leveraged to answer three questions:

- How often is the AQHI health risk Low, Moderate, High, and Very High? (see Section 1.3)
- Which version of the AQHI - classic or fine particulate matter - is reported the most and why? (see Section 1.4)
- Are there any alternative models? (see Section 1.5)

[1] Ozone's role in the atmosphere is two-fold. In the upper atmosphere (the stratosphere), it blocks harmful ultraviolet radiation from reaching the surface of the Earth. However, ozone in the lower atmosphere (near the surface) is called ground-level ozone and it is a harmful contaminant to people and the environment (United States Environmental Protection Agency, n.d.)

1.3 How Often is the AQHI Heath Risk Low, Moderate, High, and Very High?

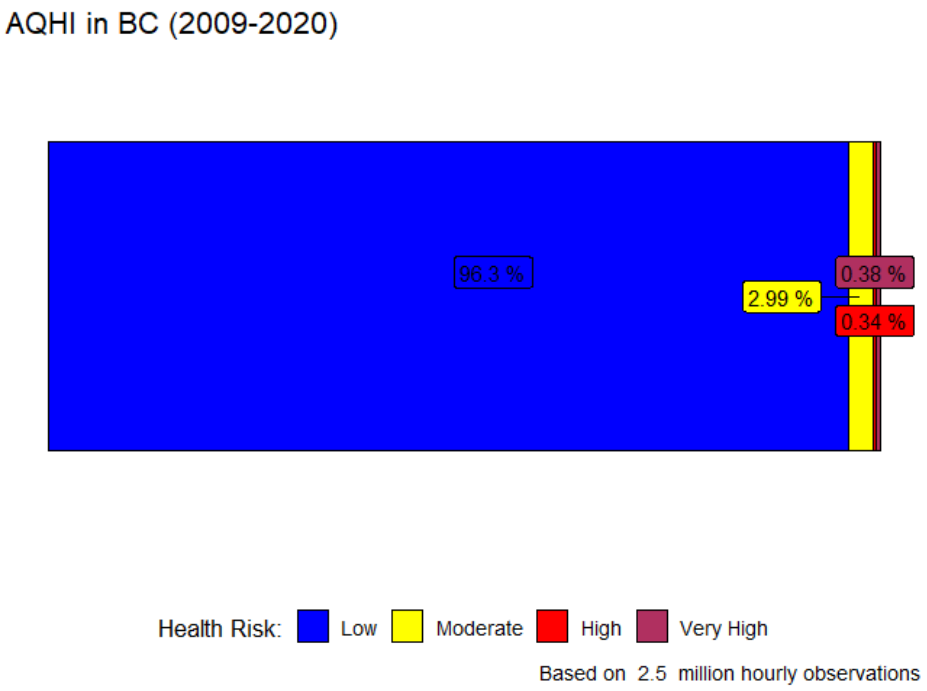


Figure 1.1: Distribution of the AQHI Plus health risk messaging under the current model in BC. Includes hourly data from 2009 to 2020.

Most of the time (96% of the hours), the health risk is “Low” under the current AQHI model in BC - British Columbians usually experience good air quality - and less than 1% of the hours were reported as either “High” or “Very High” health risk (Figure 1.1). However, the infrequent periods of poor air quality should not be overlooked since it is during these times that the public expects timely and representative information on how the air quality where they live, work and play may affect their health.

1.4 Which Version of the AQHI - Classic or Fine Particulate Matter - is Reported the Most and Why?

By looking at the relative contributions of the fine particulate matter AQHI and the classic AQHI to the AQHI reporting, we gain an understanding about the importance of the constituent contaminants. More specifically, the importance of $PM_{2.5}$ is indicated through the contribution of the fine particulate matter AQHI; and when the classic AQHI is reported, a more balanced contaminant mix that includes NO_2, O_3 and $PM_{2.5}$ must exist. Figure 1.2 shows the distribution of AQHI

reported across BC between 2009 and 2020.

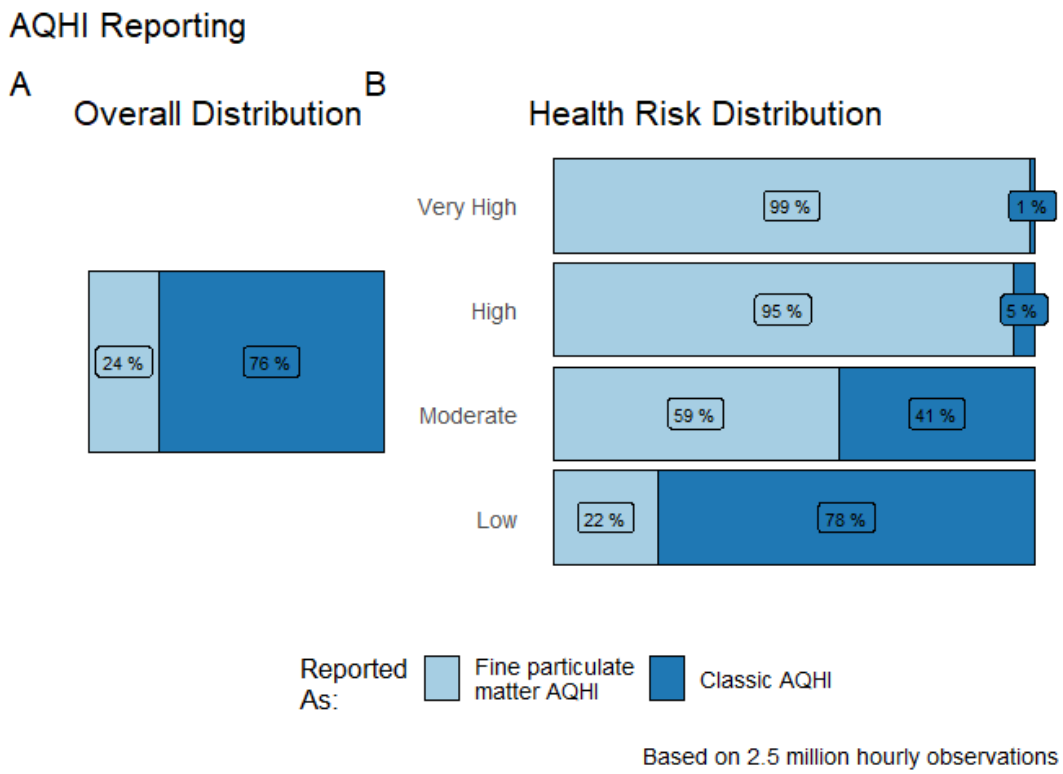


Figure 1.2: Distribution of the AQHI Plus reporting across BC between 2009 and 2020.

Had the current AQHI model been in operation through the period of this review, the classic AQHI would have been reported to the public for 76% of the time and the fine particulate matter AQHI would have been reported the remaining 24% of the time (Figure 1.2 (A)). However, when the health risk category is considered, the fine particulate matter AQHI becomes increasingly influential as the risk goes from “Low” to “Very High” (Figure 1.2 (B)). Whereas only 22% of the “Low” risk hours are reported as the fine particulate matter AQHI, 97% of the “High” and “Very High” risk hours combined are reported as the fine particulate matter AQHI.

On a monthly basis the AQHI would be reported as the classic AQHI 65-90% of the time, with higher contributions during the spring months. However, during pollution events the fine particulate matter AQHI dominated the AQHI reporting throughout the year with between 82-100% of these “High” and “Very High” health risk hours being determined solely by $PM_{2.5}$ levels.

These findings are intuitive given the intent of the fine particulate matter AQHI to provide more appropriate health messaging during periods of poor air quality that are heavily influenced by $PM_{2.5}$ levels when the classic AQHI does not.

1.5 Are There Any Alternative Models?

Two alternative models to the current AQHI approach in BC are summarized below from an exploratory data analysis perspective; that is, considerations from a public health perspective have not been taken into account. These alternatives would not require NO_2 and O_3 to be monitored at every AQHI station as the current model requires.

1.5.1 AQHI Based Only on $PM_{2.5}$

In this model the AQHI would be reported exclusively as the fine particulate matter AQHI, eliminating the requirement for NO_2 and O_3 to be monitored. This model has been evaluated by looking at the difference in health risk messaging between the fine particulate matter AQHI and the classic AQHI (Figure 1.3).

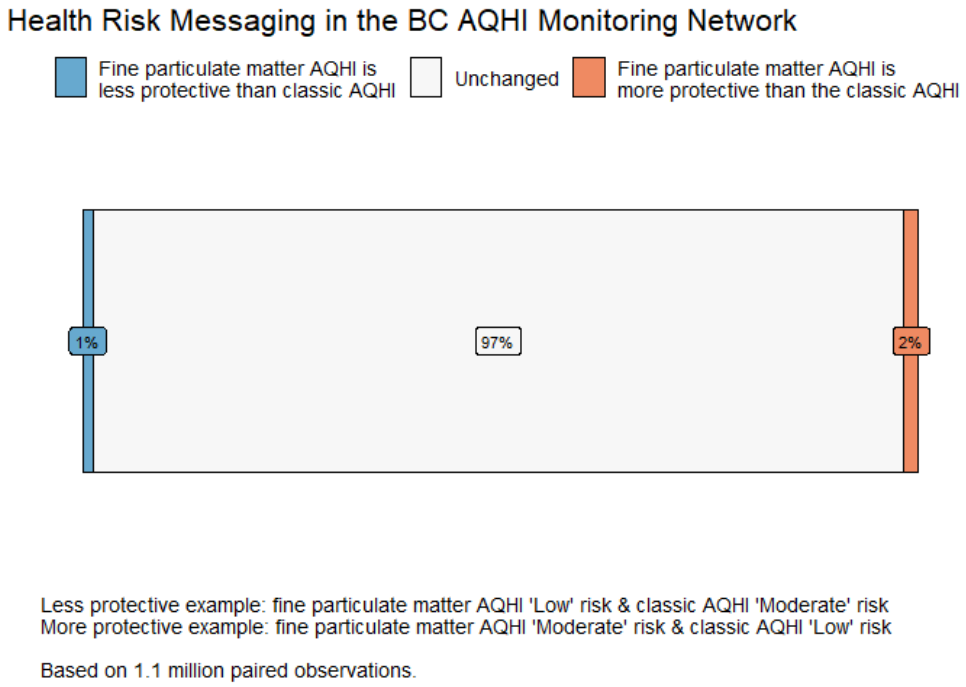


Figure 1.3: Difference in health risk messaging between the fine particulate matter AQHI and the classic AQHI.

Most of the time (97% of the 1.1 million hours) there is no difference in the health risk messaging between the fine particulate matter AQHI and the classic AQHI; 2% of the time the fine particulate matter AQHI produced more protective messaging; and the messaging from the classic AQHI was more protective 1% of the time.

Figure 1.4 examines the 3% of the time (from Figure 1.3) when the health risk messaging was

different between the fine particulate matter AQHI and the classic AQHI. From Figure 1.4 (A), the air quality was normal 81% of the time ("Low" or "Moderate" health risk). The remaining 19% of the time, the difference in health messaging occurred during pollution events - where a pollution event is an hour when the health risk messaging was different, and either the fine particulate matter or classic AQHI messaging was in the "High" or "Very High" risk categories. We are particularly interested in how the fine particulate matter AQHI and the classic AQHI behave during air pollution events as this is when a change to a more protective or responsive index could make a difference from a public health perspective. During the pollution events (Figure 1.4 (B)), the fine particulate matter AQHI provided more protective health risk messaging 98% of the time. This finding aligns with the intent of the fine particulate matter AQHI to provide appropriate health messaging during periods of degraded air quality caused by elevated $PM_{2.5}$ levels when the classic AQHI does not.

1.5.2 Regional Model for NO_2 and O_3: Vancouver Island Case Study

In this model, NO_2 and O_3 levels from a representative (surrogate) station are used for the purposes of AQHI reporting across a region. A case study was completed using the Vancouver Island AQHI network in which each of the 5 stations was used as a surrogate for the remaining stations, and the difference in health messaging was evaluated (Figure 1.5).

Across the Vancouver Island AQHI network, using surrogate NO_2 and O_3 made very little difference on the health risk messaging - 99.4% of the 1.7 million hours resulted in no change in the health message that would be reported to the public.

Figure 1.6 examines the 0.6% of the time (from Figure 1.5) when the use of surrogate NO_2 and O_3 on Vancouver Island led to a different health risk message. From 1.6 (A), 99.5% of these hours involved a change between "Low" and "Moderate" health risk, and so occurred during periods of normal air quality. There were 50 hours during pollution events when the health messaging differed with the use of surrogate NO_2 and O_3 (Figure 1.6 (B)). All but one of these 50 hours occurred during the wildfire season (July and August) when pollutant levels are highly variable in space and time.

Elevated levels of NO_2 and O_3 in Victoria, the largest urban centre on Vancouver Island, resulted in more protective messaging in the other communities when Victoria was used as a surrogate. This highlights the importance of aligning community emissions profiles when considering a regional AQHI model.



Figure 1.4: Instances when the fine particulate matter AQHI health messaging differed from the classic AQHI.

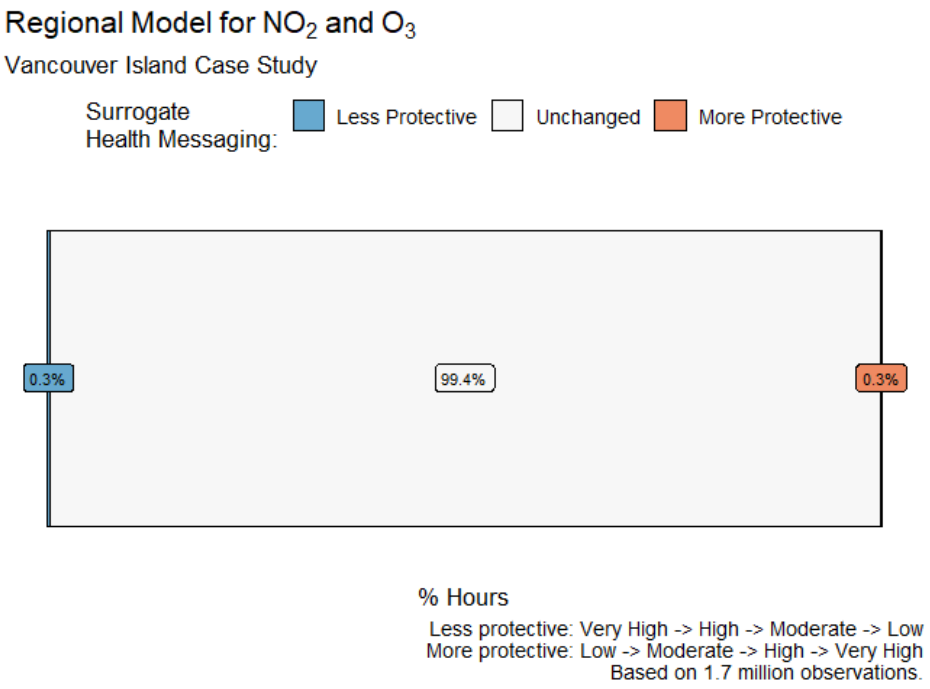


Figure 1.5: The effect on AQHI health messaging when a regional model for NO_2 and O_3 is used on Vancouver Island.

1.6 Recommendations

Pending a review by public heath experts, the findings of this review support changes to the BC AQHI network that would save resources without compromising the health risk messaging to the public. An updated AQHI model in BC should be contemplated - one that does not require NO_2 and O_3 to be monitored in every AQHI community. The additional resources could be leveraged to expand $PM_{2.5}$ monitoring across the province - under the new model, this would expand the AQHI network, as well.

1.7 Future Work

The work presented here focused entirely on an exploratory data analysis of historic AQHI data and a preliminary look “under the hood” of the current model in operation in BC. To arrive at fully informed science and evidence based recommendations for the AQHI monitoring network moving forward, input from public health experts (for example, from the health authorities in BC and the BCCDC) would be needed. The regional AQHI model evaluation should also be expanded to other areas of the province and supported by a statistical analysis.

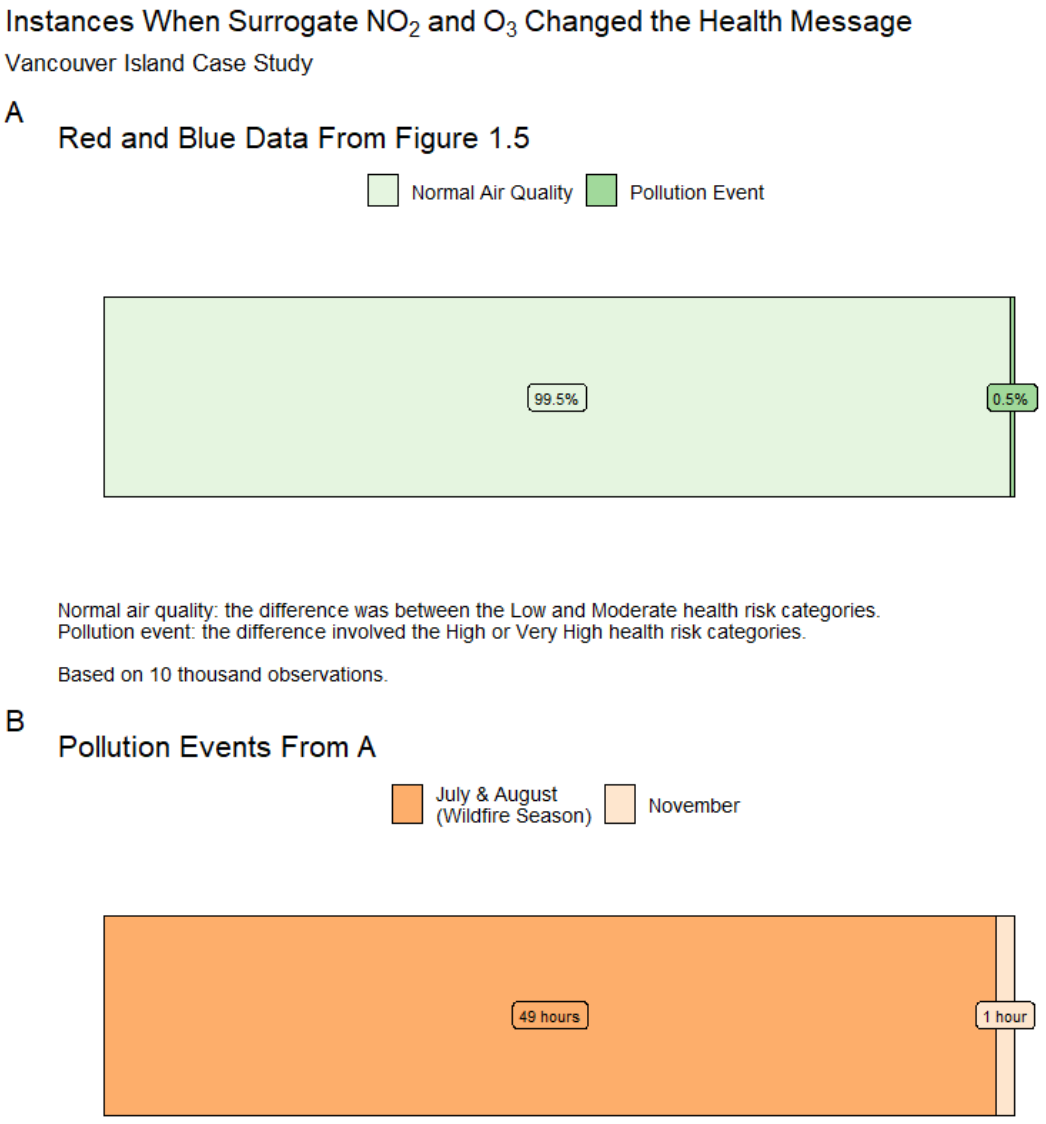


Figure 1.6: Instances when the use of surrogate NO_2 and O_3 on Vancouver Island led to a different AQHI health message.

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List of Acronyms

AQHI Air Quality Health Index

AQMS Air Quality Management System

BAM Beta Attenuation Monitor

BC British Columbia

BCCDC British Columbia Centre for Disease Control

EIA Environmental Impact Assessment

ENV the Ministry of Environment & Climate Change Strategy

FEM Federal Equivalency Method

NO_2 nitrogen dioxide

O_3 ground-level ozone

$PM_{2.5}$ fine particulate matter - particulate matter with aerodynamic diameter less than 2.5 micrometers

SHARP Synchronized Hybrid Ambient Real-time Particulate Monitor

SO_2 Sulphur dioxide

2. Introduction

2.1 Motivation

The Air Quality Health Index (AQHI) is a health protection tool designed to inform the public of short-term health risks from air pollution. It was originally developed by Health Canada (Stieb et al., 2008) using air quality and public health data from 12 large Canadian urban centers.

In recent years, there has been an increased demand from the public for information on the AQHI across British Columbia (BC). From an operational standpoint this is reflected in Figure 2.1 which shows that, between 2009 and 2019, the amount of monitoring at AQHI stations increased while the amount of monitoring at Environmental Impact Assessment (EIA) stations decreased. Internal discussions around the practicality and feasibility of increasing the number of AQHI monitoring stations in the the Ministry of Environment & Climate Change Strategy (ENV) network have been ongoing. An AQHI monitoring station requires that nitrogen dioxide (NO_2), ground-level ozone (O_3)[1] and fine particulate matter - particulate matter with aerodynamic diameter less than 2.5 micrometers ($PM_{2.5}$) be measured in near real-time. However, it is difficult to justify monitoring NO_2 and O_3 in smaller communities that are not expected to have high levels of these contaminants to satisfy the objective of AQHI reporting. This is especially true when addressing requests from communities with no air quality monitoring.

Periods of poor air quality in BC are often driven solely by $PM_{2.5}$ levels, especially in the Interior. Historically, this has led to confusion in the public when very high levels of $PM_{2.5}$ - for example, during the extreme wildfire seasons of 2017 and 2018 - have degraded air quality to unprecedented levels, but the AQHI remained in the “Low” or “Moderate” health risk category based on the relative weights of NO_2, O_3, and $PM_{2.5}$ in the original version of the AQHI (from Stieb et al. (2008), and hereafter referred to as the $AQHI_{classic}$). Based on the $AQHI_{classic}$, changes to NO_2 and O_3 levels have a greater impact on the health risk messaging when compared to changes in $PM_{2.5}$ levels.

Yao et al. (2020) studied the ability of the $AQHI_{classic}$, along with four alternative versions of the AQHI based only on $PM_{2.5}$ concentrations, to predict known health outcomes from wildfire smoke on the population of BC between 2010 and 2017. This study found that one of the $PM_{2.5}$-only versions of the AQHI ($1 - h\ PM_{2.5}\ Only\ AQHI - Plus$ and hereafter referred to as $AQHI_{PM_{2.5}}$) was

[1] Ozone’s role in the atmosphere is two-fold. In the upper atmosphere (the stratosphere), it blocks harmful ultraviolet radiation from reaching the surface of the Earth. However, ozone in the lower atmosphere (near the surface) is called ground-level ozone and it is a harmful pollutant to people and the environment (United States Environmental Protection Agency, n.d.).

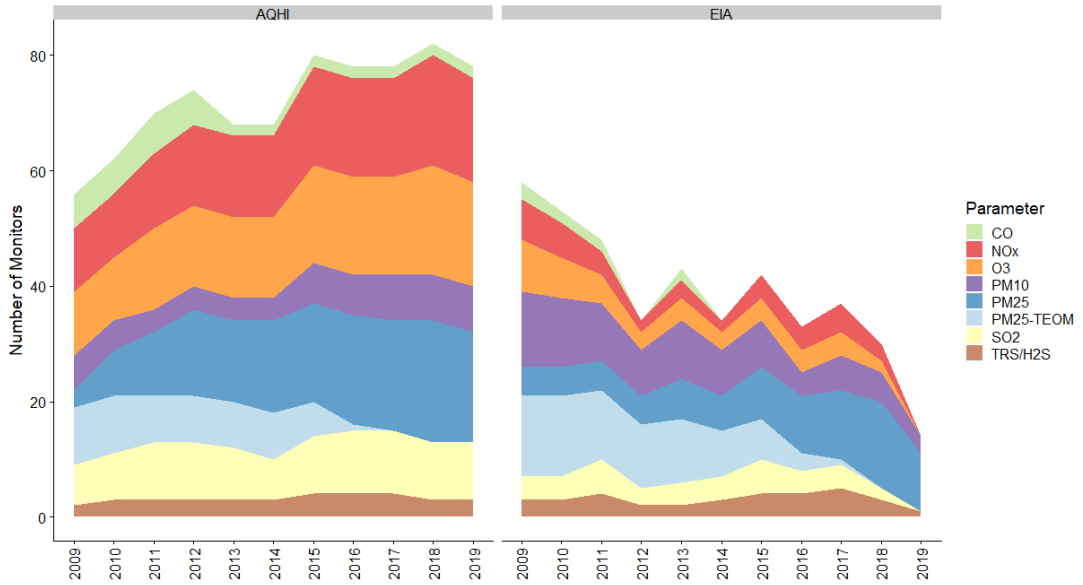


Figure 2.1: AQHI and EIA monitoring in the ENV network (credit: Gail Roth, Air Quality Section).

the strongest indicator of:

- asthma-related health outcomes; and
- of all 5 health-related outcomes that were studied during extreme periods of wildfire smoke.

Prior to the wildfire season of 2018, ENV amended the version of the ENV that is reported to the public to align with the recommendations made by Yao et al. (2020). Specifically, a pilot project was initiated in which the *AQHI* was reported as the higher of the $AQHI_{classic}$ (Equation 2.1 below) and the $AQHI_{PM_{2.5}}$ (Equation 2.2 below).

Trieu et al. (2020) assessed how the $AQHI_{classic}$ and the *AQHI* (reported as the higher of the $AQHI_{classic}$ and the $AQHI_{PM_{2.5}}$) are associated with health outcomes during the cooler seasons between 2010 and 2017, with a particular focus on BC communities which are impacted by $PM_{2.5}$ emissions from residential wood heating. They found that reporting the *AQHI* as the higher of the $AQHI_{classic}$ and the $AQHI_{PM_{2.5}}$ performed better than the $AQHI_{classic}$ alone at predicting two asthma-specific outcomes, and this has resulted in ENV adopting this *AQHI* model on a year-round basis.

This review expands on the previous work described above with an exploratory data analysis of the AQHI monitoring network in BC between 2009 and 2020.

2.2 Current AQHI Model in BC

The *AQHI* is calculated from local measurements of three key contaminants - NO_2, O_3, and $PM_{2.5}$ - and uses a scale to indicate the health risk associated with levels of air contaminants for the at risk and general populations, as shown in Table 2.1.

Table 2.1: Description of the AQHI health risk categories (ENV, n.d.[a]).

Health Risk	AQHI Value	At Risk Population[a]	General Population
Low	1-3	Enjoy your usual outdoor activities.	Ideal air quality for outdoor activities.
Moderate	4-6	Consider reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	No need to modify your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	7-10	Reduce or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	Consider reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very High	Above 10	Avoid strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	Reduce or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

[a]People with heart or breathing problems are at greater risk. Follow your doctor's usual advice about exercising and managing your condition.

In BC, three versions of the AQHI are currently in use and are described below:

1. $AQHI_{classic}$: The original version of the AQHI (Stieb et al., 2008) is calculated from 3-hour rolling average NO_2, $PM_{2.5}$, and O_3 concentrations:

$$AQHI_{classic} = \frac{1000}{10.4} \times \{\exp^{0.000871 \times NO_2(3-hour)} - 1 + \exp^{0.000537 \times O_3(3-hour)} - 1 + \exp^{0.000487 \times PM_{2.5}(3-hour)} - 1\} \quad (2.1)$$

2. $AQHI_{PM_{2.5}}$: An AQHI based solely only on hourly $PM_{2.5}$ values from Yao et al. (2020):

$$AQHI_{PM_{2.5}} = ceiling\Big\{\frac{1}{10} \times PM_{2.5}(hourly)\Big\}, \tag{2.2}$$

where ceiling takes an argument and returns the smallest integer not less than the argument (for example, $ceiling(2.1) = 3$).

3. $AQHI_{plus}$: the value reported to the public and is equal to the higher of the $AQHI_{classic}$ and the $AQHI_{PM_{2.5}}$:

$$AQHI = max(AQHI_{classic}, AQHI_{PM_{2.5}}) \tag{2.3}$$

In Kitimat, there is a pilot program underway that includes Sulphur dioxide (SO_2) concentrations via the $AQHI_{plus\ for\ SO_2}$. In this model, the AQHI is reported as the higher of the $AQHI_{classic}$, the $AQHI_{PM_{2.5}}$, and the $AQHI_{plus\ for\ SO_2}$. For more information, see ENV (n.d.[c]).

2.3 Scope

The BC AQHI monitoring network included 27 stations between 2009 and 2020, as shown in Figure 2.2. Included in Figure 2.2 are the air zones that have been defined in BC as part of the province's commitments under the Air Quality Management System (AQMS) (ENV, n.d.[b]).

The work here focuses on the 27 AQHI monitoring stations shown in Figure 2.2 for the years 2009 to 2020. This includes 4.4 million combined hourly observations of $PM_{2.5}$, NO_2 and O_3. Additional information on the AQHI network in BC and on the scope of what monitoring data is included in this review can be found in Appendix A.

2.4 Objective

The objective for this review was to answer the questions identified below. After each question is described, a reference if given to where the supporting results can be found.

1. **How often is the health risk Low, Moderate, High and Very High?** Investigate the distribution of hours in each health risk category for the $AQHI_{classic}$, the $AQHI_{PM_{2.5}}$, and the $AQHI$. Results can be found in Section 4.1.
2. **Which version of the AQHI - classic or fine particulate matter - is reported the most and why?** Investigate how often the $AQHI$ is reported to the public as the $AQHI_{PM_{2.5}}$ (based only on $PM_{2.5}$) and as the $AQHI_{classic}$ (based on NO_2, O_3, and $PM_{2.5}$; and with less weight/influence by $PM_{2.5}$ - see Equation 2.1). Results can be found in Section 4.2.

3. **Are there any alternatives to the current model?** Investigate two alternative models for AQHI reporting that would not require NO_2 and O_3 to be monitored at every station. These alternative models are described below, but it should be emphasized that the results are based on an exploratory data analysis alone and considerations from a public health perspective have not been taken into account.

   (a.) **AQHI based only on $PM_{2.5}$ levels.** This model involves reporting only the $AQHI_{PM_{2.5}}$. It is being considered here because $PM_{2.5}$ is the most important air contaminant from a human health perspective in BC (BC Centre for Disease Control, n.d.; Healthlink BC, n.d.). An analysis was completed that examines the difference in health messaging between the $AQHI_{classic}$ and the $AQHI_{PM_{2.5}}$, with a particular focus on whether the health messaging from the $AQHI_{PM_{2.5}}$ was more or less protective than the $AQHI_{classic}$ looking back through the monitoring history. Results can be found in Section 4.3 and Appendix B.

   (b.) **Regional model for NO_2 and O_3.** A model where NO_2 and O_3 levels from a representative (surrogate) station are used for the purposes of AQHI reporting across a region. A case study was completed using the AQHI monitoring network on Vancouver Island, in which a series of surrogate calculations were performed using NO_2 and O_3 from the surrogate station to calculate the $AQHI_{classic}$, the $AQHI_{PM_{2.5}}$, and the $AQHI$ at the remaining stations. Results can be found in Section 4.4 and Appendix C.

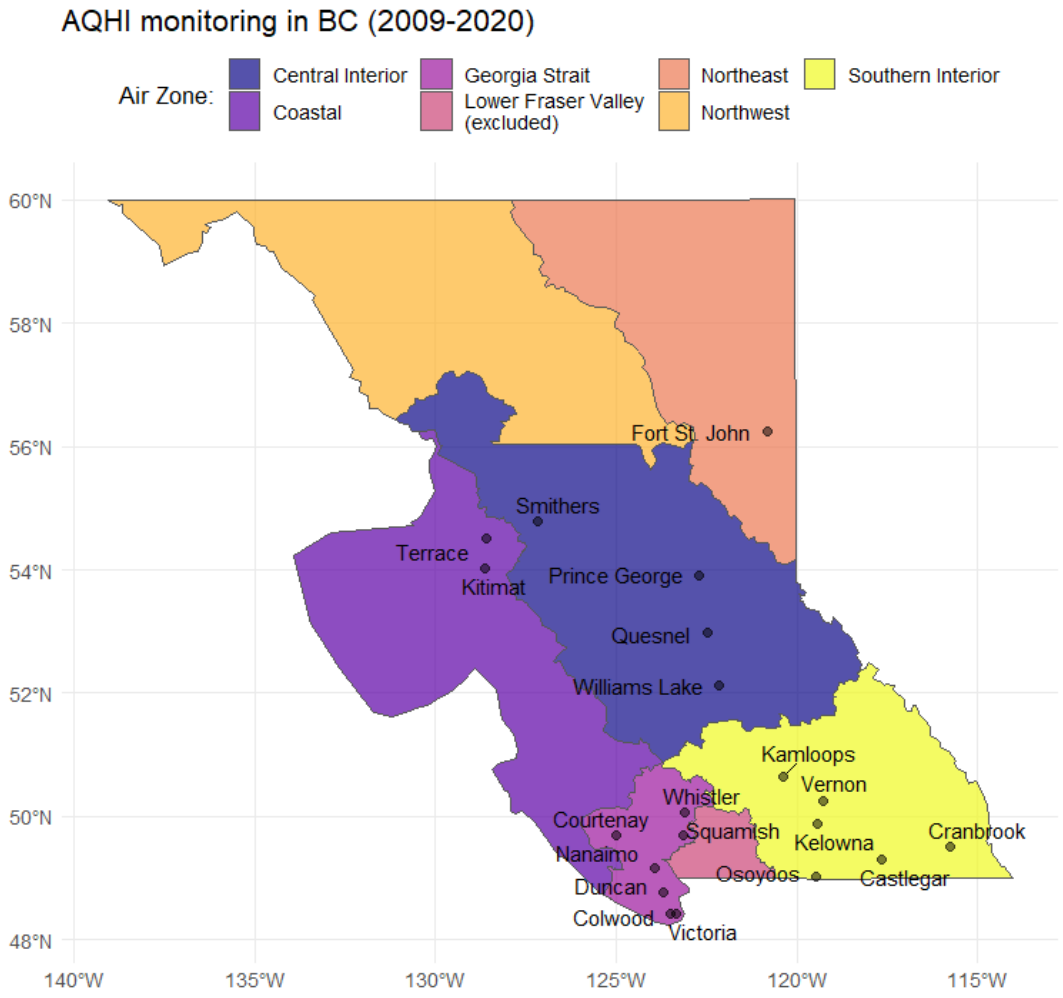


Figure 2.2: AQHI monitoring in BC at 27 locations between 2009 and 2020. Air zones have been defined as part of the province's commitments under the AQMS (ENV, n.d.[b]). Data from Robles (2021) and Teucher et al. (2021).

3. Methods

Data import, analysis, and plotting was completed using R Core Team (2020); typesetting of the pdf version of this review was done using LaTeX; and version control was tracked using Git (https://git-scm.com/). Source files are available upon request.

3.1 Data Access

Validated hourly $PM_{2.5}$, NO_2 and O_3 data from ENV AQHI sites (shown in Figure 2.2) were accessed using ENV (n.d.[d]) for the years 2009-2020. This data set has undergone Level 2 validation (*The British Columbia Field Sampling Manual* 2020). The hourly data set was converted from hour-ending (01:00-24:00) to hour-beginning (00:00-23:00), and only the following Federal Equivalency Method (FEM) $PM_{2.5}$ instrumentation was included: Beta Attenuation Monitor (BAM) 1020 and Synchronized Hybrid Ambient Real-time Particulate Monitor (SHARP) 5030(i).

3.2 Calculating the AQHIs

For each hour, the three versions of the AQHI were calculated using Equations 2.1 ($AQHI_{classic}$), 2.2 ($AQHI_{PM_{2.5}}$), and 2.3 ($AQHI$). The calculation methods were validated by Natalie Suzuki, former Senior Air Quality Science Specialist with ENV (personal communication: January 6, 2020). To calculate the 3-hour running averages of $PM_{2.5}$, NO_2, and O_3 that are required to determine the $AQHI_{classic}$, a 60% data completeness criteria was applied - that is, at least 2 hourly values were required to report the 3-hour running average.

$AQHI_{classic}$, $AQHI_{PM_{2.5}}$, and $AQHI$ hourly values were assigned a health risk category according to Table 3.1.

Table 3.1: Assignment of health risk categories to AQHI values.

Health Risk	Value
Low	$0 \leq AQHI < 3.5$
Moderate	$3.5 \leq AQHI < 6.5$
High	$6.5 \leq AQHI < 9.5$
Very High	$9.5 \leq AQHI$

3.3 Data Quality Assurance and Control

The AQHI calculations were verified by comparing a subset of the results with an independent analysis completed by Ralph Adams (former Air Quality Meteorologist with ENV) from the Kamloops Federal Building station for the period 2017-2018. The independent analysis was completed using a different data source (Envista ARM database) compared to the data source for the current analysis (ENV, n.d.[d]). The comparison indicated three hours where the data did not agree, but the differences in the constituent concentrations were negligible. All of the remaining data, which included hourly and 3-hour $PM_{2.5}$, O_3, and NO_2, and hourly $AQHI_{classic}$, $AQHI_{PM_{2.5}}$, and $AQHI$ were in complete agreement between the two data sets.

For the results presented in Section 4.3, a monthly data completeness criteria of 75% hourly data capture was appplied to the data set.

Additional data quality checks were performed throughout the course of this review and have been captured in this document's history using Git (https://git-scm.com/), a version control system. Source files are available upon request.

3.4 Regional Case Study

For the regional case study (Section 4.4), data from Duncan Cairnsmore and Duncan College Street were combined into a single dataset to represent the community of Duncan. This is justified given that the locations of the two stations are 160 metres apart (personal communication with Earle Plain, Head of the Air Quality Section (Assessments & Stewardship), October 19, 2021).

4. Results

4.1 How Often is the Health Risk Low, Moderate, High and Very High?

The public's appetite for access to AQHI monitoring and health messaging increases dramatically during periods of poor air quality. For example, the number of visitors to the BC Air Quality website, and the amount of media requests and public inquiries that ENV air quality staff respond to during periods of extreme wildfire smoke increases multiple-fold compared to periods of normal air quality. But how often do we experience poor air quality in BC - that is, what is the distribution of hours reported in each of the AQHI health risk categories (Low, Moderate, High, Very High)? This question is answered in Figure 4.1, which shows the health risk messaging distribution for each of the three versions of the AQHI that are operational in BC. For all three versions of the AQHI: most of the time (96-97% of the hours), the health risk is categorized as "Low"; a small percent of hours (2-3%) are reported with a "Moderate" health risk; and less than one percent of the hours are reported in the "High" and "Very High" health risk categories combined.

Figure 4.1 shows that the $AQHI_{classic}$ and the $AQHI_{PM_{2.5}}$ have a similar proportion of hours in the "Moderate", "High", and "Very High" health risk categories combined - 2.52% for the $AQHI_{classic}$ and 2.67% for the $AQHI_{PM_{2.5}}$. However, they deviate in the proportion of hours in the "High" and "Very High" health risk categories, with the $AQHI_{PM_{2.5}}$ reporting more hours in these categories compared to the $AQHI_{classic}$. This is reflected in the *AQHI* which also has a higher proportion of "High" and "Very High" hours compared to the $AQHI_{classic}$. This finding is intuitive given the intent of the $AQHI_{PM_{2.5}}$ to capture periods of poor air quality that are heavily influenced by high levels of $PM_{2.5}$ (for example, from wildfires or residential wood burning).

The influence of the $AQHI_{PM_{2.5}}$ on the reporting during the infrequent times when the health risk is reported to the public (via the *AQHI*) as "High" or "Very High" should not be overlooked, since it is during these periods of poor air quality that the public expects timely and representative information on how the air quality where they live, work and play may affect their health.

4.2 Which Version of the AQHI - Classic or Fine Particulate Matter - is Reported the Most and Why?

By looking at the relative contributions of the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$ to the *AQHI* reporting, we gain an understanding about the importance of the constituent contaminants. More specifically, the importance of $PM_{2.5}$ is indicated through the contribution of the $AQHI_{PM_{2.5}}$; and

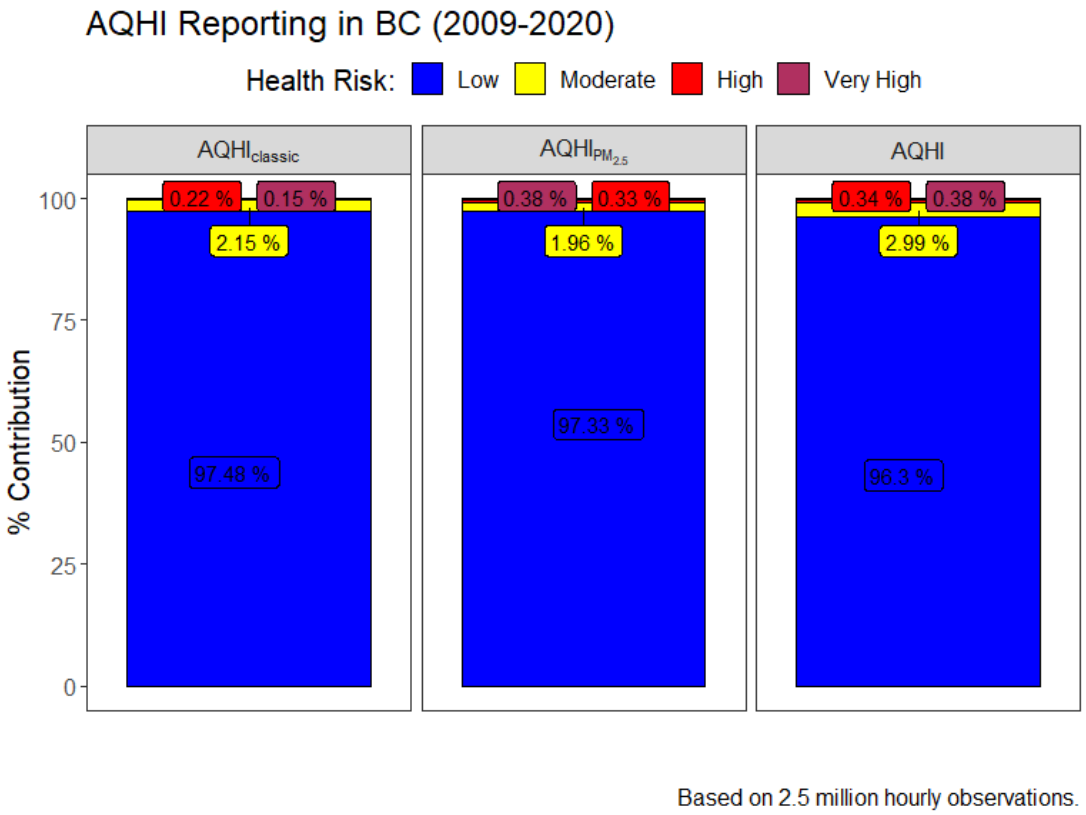


Figure 4.1: Proportion of hours in each health risk category.

when the $AQHI_{classic}$ is reported, a more balanced contaminant mix that includes NO_2, O_3 and $PM_{2.5}$ must exist. Figure 4.2 shows how often the *AQHI* was reported as the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$, by health risk category in panel A and by community in panel B.

Overall, had the current AQHI model been in operation through the period of this review, the $AQHI_{classic}$ would have been reported to the public for 76% of the time and the $AQHI_{PM_{2.5}}$ would have been reported the remaining 24% of the time.

Looking at Figure 4.2(A), a transition is apparent where the *AQHI* is increasingly reported as the $AQHI_{PM_{2.5}}$ as the health risk increases: 22% of the "Low" risk hours are reported as the $AQHI_{PM_{2.5}}$, whereas 99% of the "Very High" risk hours are reported as the $AQHI_{PM_{2.5}}$.

When the data is analyzed by reporting community (Figure 4.2(B)) the $AQHI_{classic}$ dominates the *AQHI* reporting across all communities, although to varying extents. For example, 54% of hours were reported as the $AQHI_{classic}$ at the Smithers St Joseph's station, compared to 95% of the hours reported as the $AQHI_{classic}$ at the Kamloops Brocklehurst station.

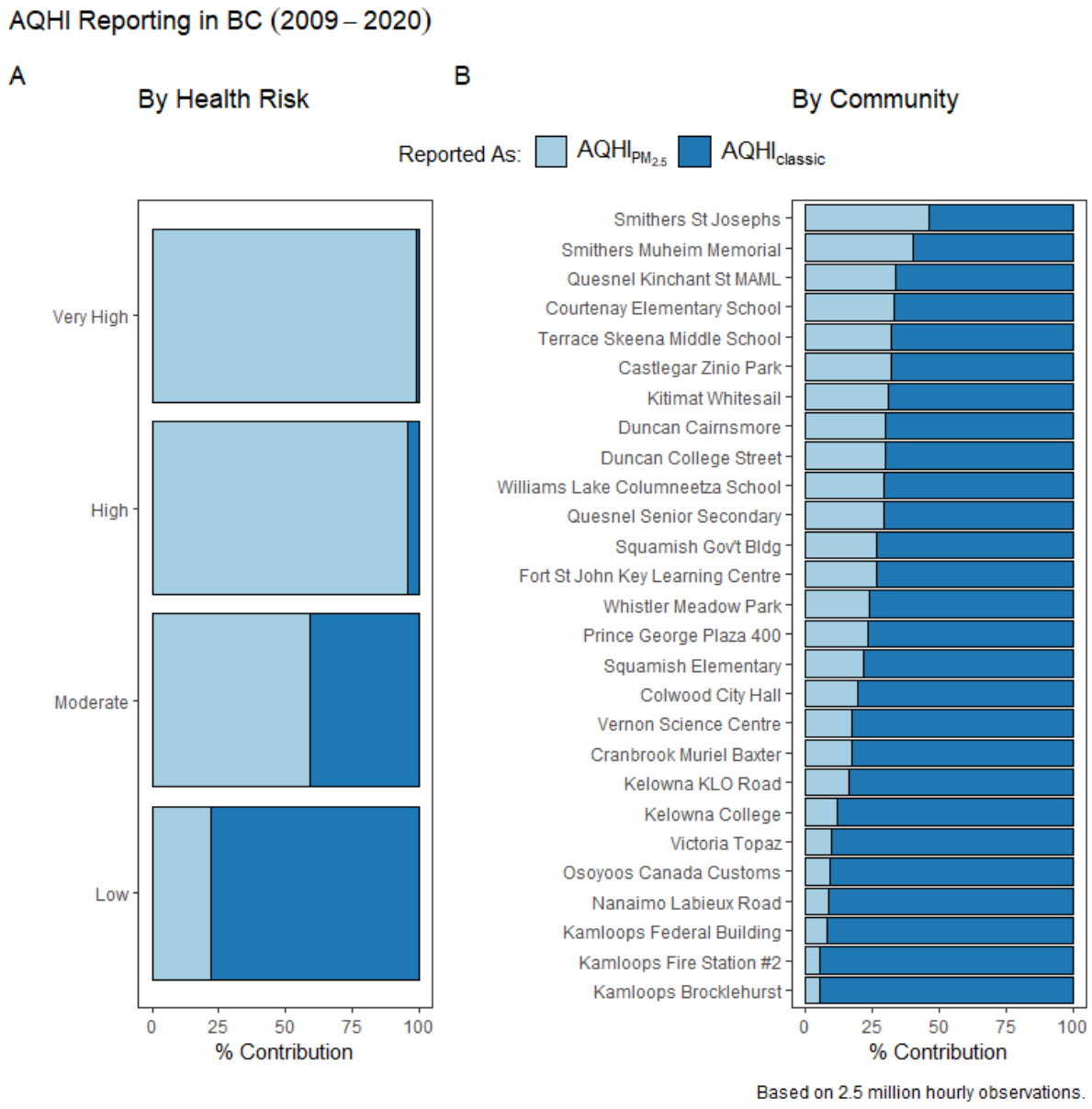


Figure 4.2: The big picture - which AQHI was reported to the public?

From Figure 4.1, the *AQHI* is in the "High" or "Very High" health risk categories a very small fraction of the time; during these pollution events, the *AQHI* is overwhelmingly reported as the $AQHI_{PM_{2.5}}$ and is therefore determined soley by $PM_{2.5}$ concentrations. This conclusion is highlighted in Figure 4.3 which combines panels (A) and (B) from Figure 4.2 to show which version of the *AQHI* is reported by health risk category across the BC AQHI monitoring network. Overall, 97% of the "High" and "Very High" health risk hours were determined solely by $PM_{2.5}$ concentrations.

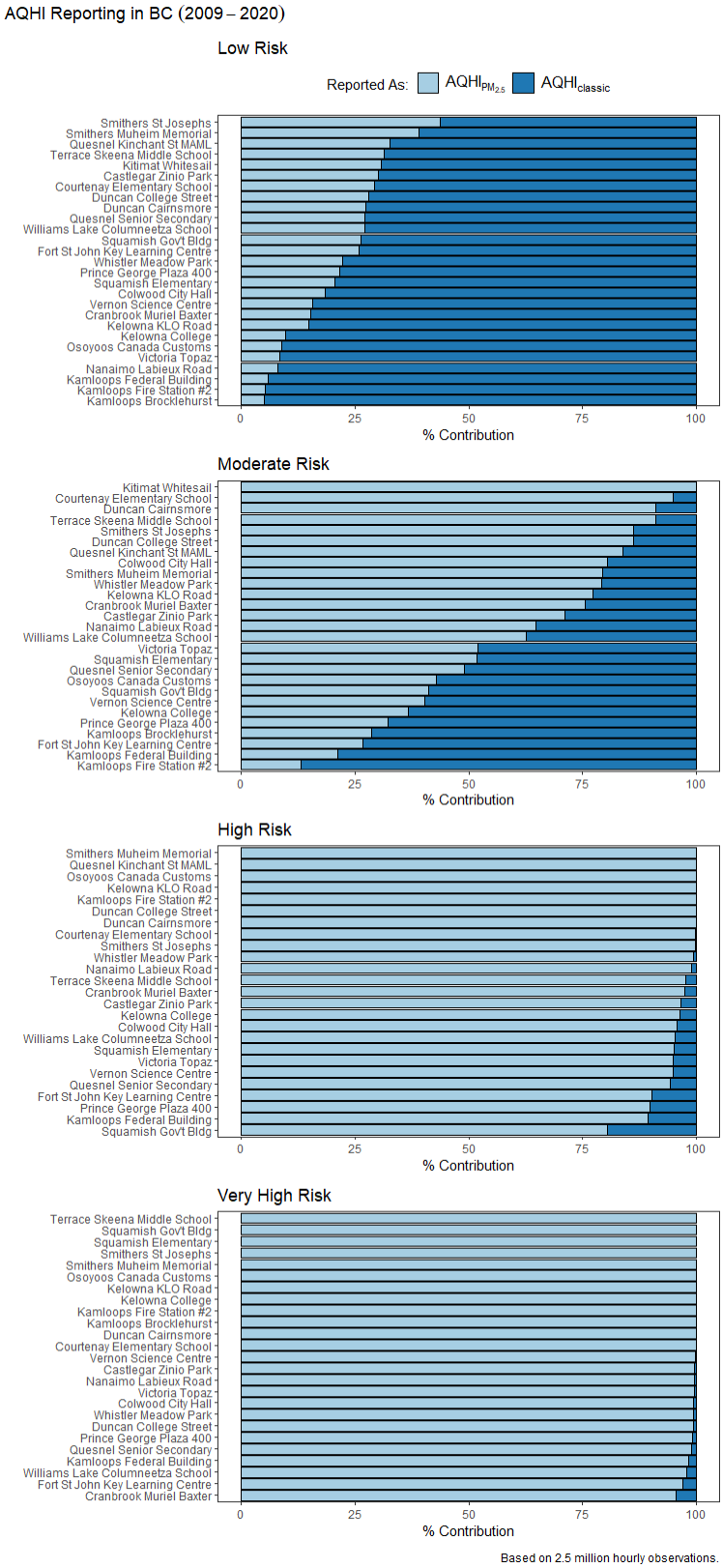


Figure 4.3: A closer look - which AQHI was reported to the public?

The monthly distribution of *AQHI* reporting is shown in Figure 4.4; panel (A) shows the monthly distribution and panel (B) shows the distribution by month and health risk combined.

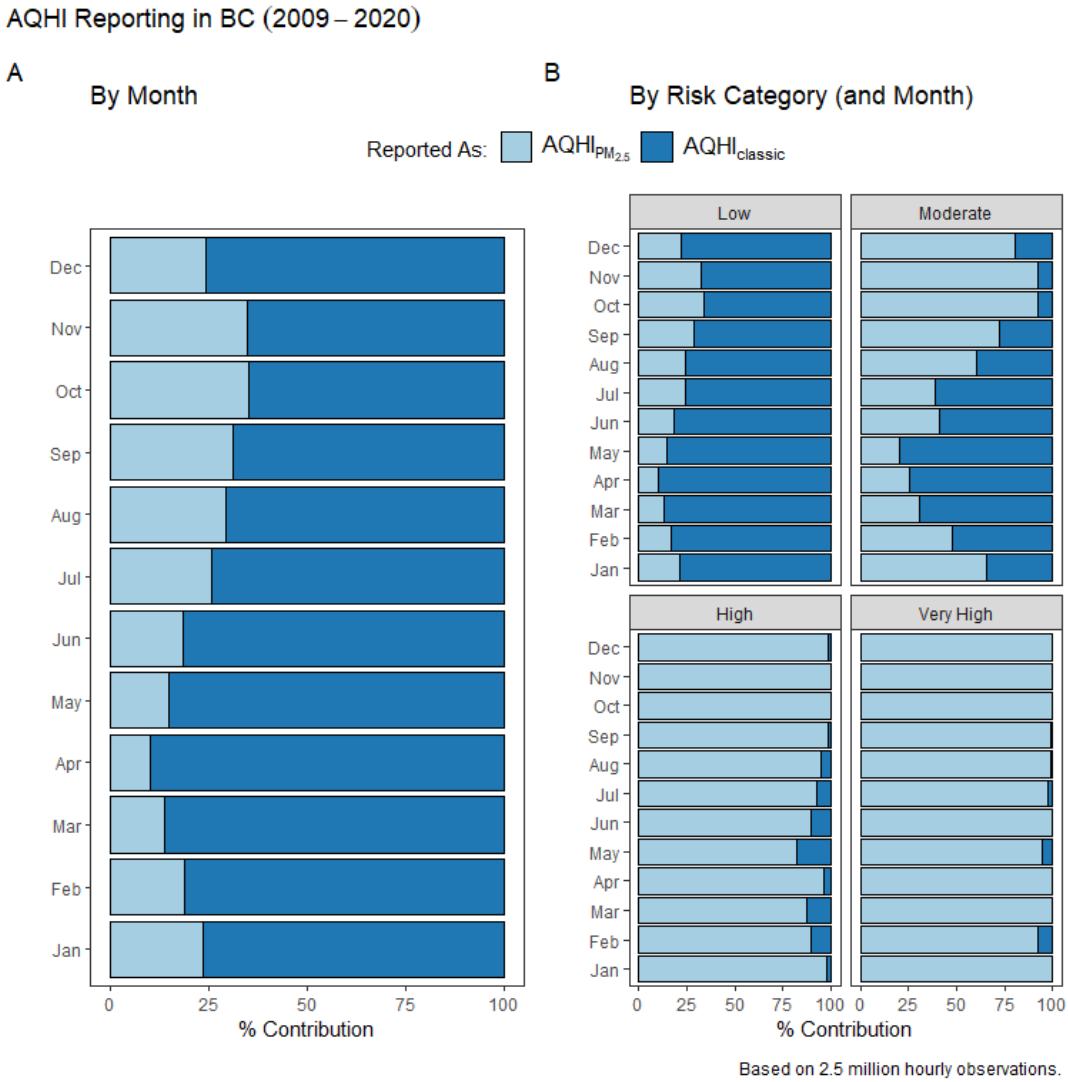


Figure 4.4: The seasonal picture - which AQHI was reported to the public?

A monthly pattern is apparent in Figure 4.4(A), where the *AQHI* is reported to a greater extent as the $AQHI_{classic}$ during the late winter, spring, and early summer months. April has the largest contribution of reporting from the $AQHI_{classic}$ at 90%; whereas during the fall months of October and November, the *AQHI* was reported as the $AQHI_{classic}$ 65% of the time. When Figure 4.4(A) is resolved further by health risk category in Figure 4.4(B), the distribution for the “Low” health risk category is almost identical to the overall monthly distribution as described above; this makes sense given the high proportion of “Low” health risk hours in the overall dataset (Figure 4.1). As the health risk increases to the “Moderate” category, the influence of seasonal sources of

$PM_{2.5}$ becomes apparent from the higher proportion of hours where the *AQHI* is reported as the $AQHI_{PM_{2.5}}$. More specifically, sources of $PM_{2.5}$ are indicated during the fall months from open burning and during the winter months from residential wood smoke. The importance of $PM_{2.5}$ to *AQHI* reporting during pollution events becomes evident looking at the "High" and "Very High" health risk categories - the $AQHI_{PM_{2.5}}$ was reported at least 82% of the time (i.e. during "High" health risk hours in May) and up to 100% of the time (i.e. during "Very High" health risk hours in January, March, April, October-December).

Overall, on a monthly basis the *AQHI* is reported as the $AQHI_{classic}$ 65-90% of the time, with higher contributions during the spring months. However, during pollution events the $AQHI_{PM_{2.5}}$ dominates the *AQHI* reporting throughout the year with between 82-100% of these "High" and "Very High" health risk hours being determined solely by $PM_{2.5}$ levels.

4.3 Alternative Model: AQHI Based Only on $PM_{2.5}$

$PM_{2.5}$ is the most important air contaminant from a human health perspective in BC (BC Centre for Disease Control, n.d.; Healthlink BC, n.d.). Based on the current AQHI model, communities with $PM_{2.5}$ monitoring but without NO_2 and O_3 monitoring are unable to report the AQHI. An alternative model is investigated below in which AQHI reporting is done based only on $PM_{2.5}$ levels (i.e. reporting only the $AQHI_{PM_{2.5}}$). This model is evaluated by looking at the difference in health messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$; the results are based on an exploratory data analysis alone and considerations from a public health perspective have not been taken into account.

Figure 4.5 shows how the health risk messaging differs between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$. Percentages in blue indicate the proportion of reported hours when the $AQHI_{PM_{2.5}}$ health risk messaging was less protective compared to the $AQHI_{classic}$, whereas percentages in red indicate the proportion of reported hours when the $AQHI_{PM_{2.5}}$ resulted in more protective health risk messaging than the $AQHI_{classic}$. Percentages in white shows the proportion of reported hours when there was no difference in the health risk messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$. From Figure 4.5, most of the time the health risk messaging remained unchanged between the $AQHI_{PM_{2.5}}$ to the $AQHI_{classic}$. This varied from 92.77% of the reported hours unchanged at the Prince George Plaza 400 station to 99.98% at the Kitimat Whitesail station (noting the shorter AQHI monitoring history of in Kitimat - as shown in Figure A.1). The influence of the contaminants used to calculate the $AQHI_{PM_{2.5}}$ ($PM_{2.5}$) and the $AQHI_{classic}$ (NO_2, O_3, and $PM_{2.5}$) become apparent upon closer examination of the percentages shown in red (more protective messaging from $AQHI_{PM_{2.5}}$) and blue (less protective messaging from $AQHI_{PM_{2.5}}$). For example, the impacts of $PM_{2.5}$ levels in Courtenay are demonstrated by roughly 5% of the reported hours resulting in more protective health risk messaging by the $AQHI_{PM_{2.5}}$; Courtenay is known to be

impacted by residential wood smoke (Hong et al., 2017). On the other hand, Prince George has higher levels of NO_2 and therefore $PM_{2.5}$ does not influence the AQHI health messaging as much; this is reflected in 5.43% of the hours having less protective health risk messaging by the $AQHI_{PM_{2.5}}$ compared to the $AQHI_{classic}$.

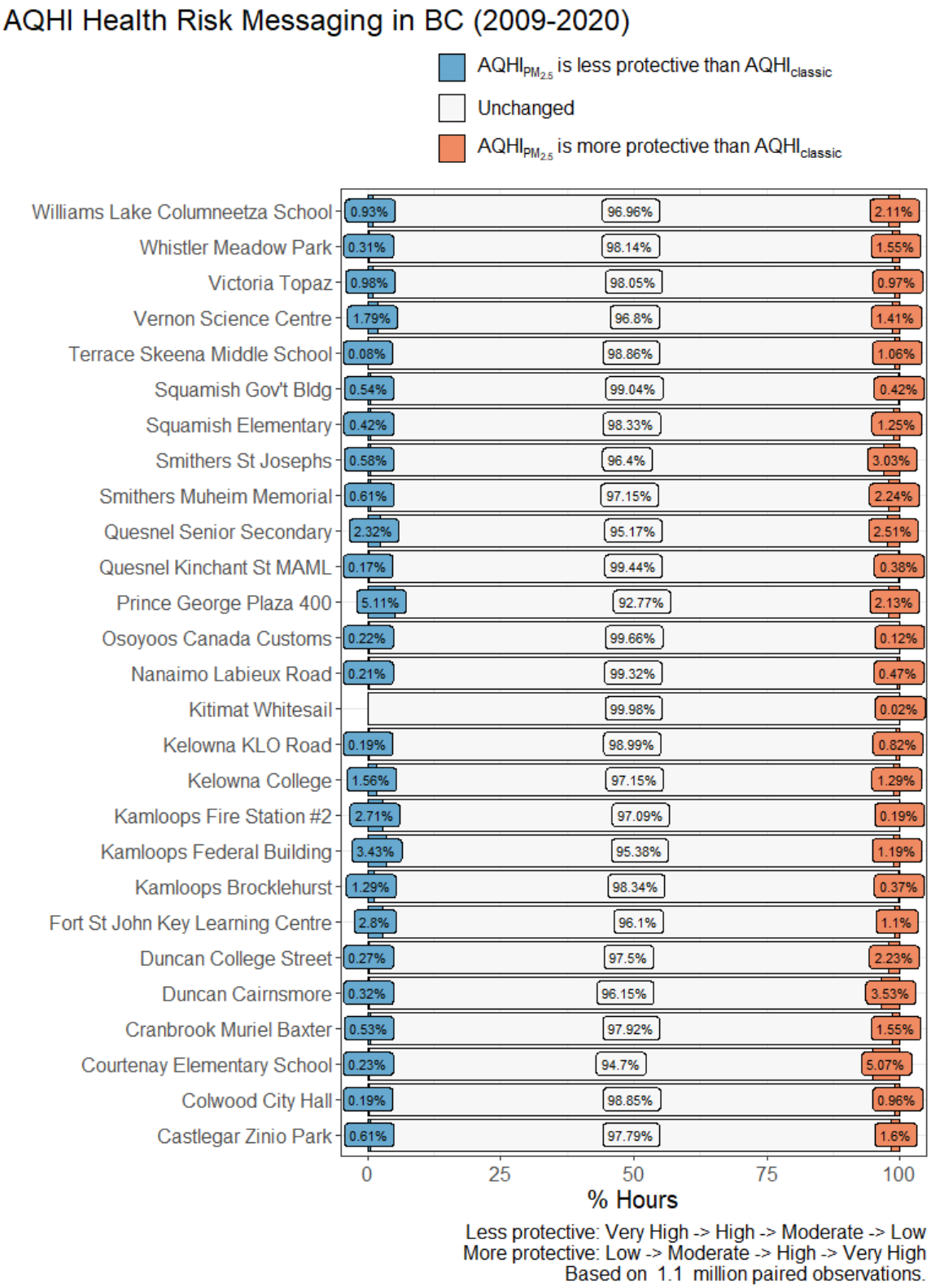


Figure 4.5: Difference in health risk messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$.

Considering the network as a whole, most of the time (97% of the hours) the health risk messaging remains unchanged regardless of which version of the AQHI is reported - the $AQHI_{PM_{2.5}}$ or the $AQHI_{classic}$. The $AQHI_{PM_{2.5}}$ resulted in more protective messaging than the $AQHI_{classic}$ for 2% of the reported hours, and the $AQHI_{PM_{2.5}}$ resulted in less protective health risk messaging than the $AQHI_{classic}$ for 1% of the reported hours.

A closer look at the variability over space and time in the difference in health risk messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$ is provided in Appendix B - Figure B.1 shows monthly resolution and Figure B.2 show year-to-year variability.

Whereas the month of June in Figure B.1 shows little difference in the health risk messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$, seasonal influences of $PM_{2.5}$, NO_2 and O_3 are apparent at other times of the year. For example, the impacts of $PM_{2.5}$ emissions from wildfire smoke are obvious during the month of August, but the influence of O_3 and NO_2 on the health risk messaging in August is also apparent for many communities, albeit to a lesser extent. This is not surprising since NO_2 and O_3 are key components of wildfire smoke, in addition to $PM_{2.5}$ which is the primary emisssion source. The influence of $PM_{2.5}$ emissions from open burning and residential wood heating is evident during the cold season months of October through February, and spring-time O_3 production is especially noticeable during February and March.

Figure B.2 shows the year-to-year variability in the difference in health risk messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$. Not surprisingly, the most noticeable differences are noted for the extreme wildfire years of 2017 and 2018, where the $AQHI_{PM_{2.5}}$ provided more protective health messaging than the $AQHI_{classic}$.

Figure 4.6 takes a closer look at the hours from Figure 4.5 when the health risk messaging differed between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$. That is, Figure 4.6 shows the 3% of the data from Figure 4.5 that are colored red and blue. 80.8% of the 33 thousand hours shown in Figure 4.6 resulted in the health messaging changing between “Low” and “Moderate” health risk categories: roughly half (51.5%) of these hours resulted in more protective messaging (“Moderate”) by the $AQHI_{PM_{2.5}}$, and roughly half (48.5%) resulted in less protective messaging (“Low”) by the $AQHI_{PM_{2.5}}$. The remaining 19.2% of the hourly observations in Figure 4.6 resulted in a change in health risk messaging towards or away from the “High” or “Very High” health risk categories - these are considered to be hours with the most impact to public reporting as they would have been during periods of degraded air quality. For 97.6% of these hours, the health messaging from the $AQHI_{PM_{2.5}}$ was more protective. This finding aligns with the intent of the $AQHI_{PM_{2.5}}$ to provide appropriate health messaging during periods of elevated $PM_{2.5}$ when the $AQHI_{classic}$ does not.

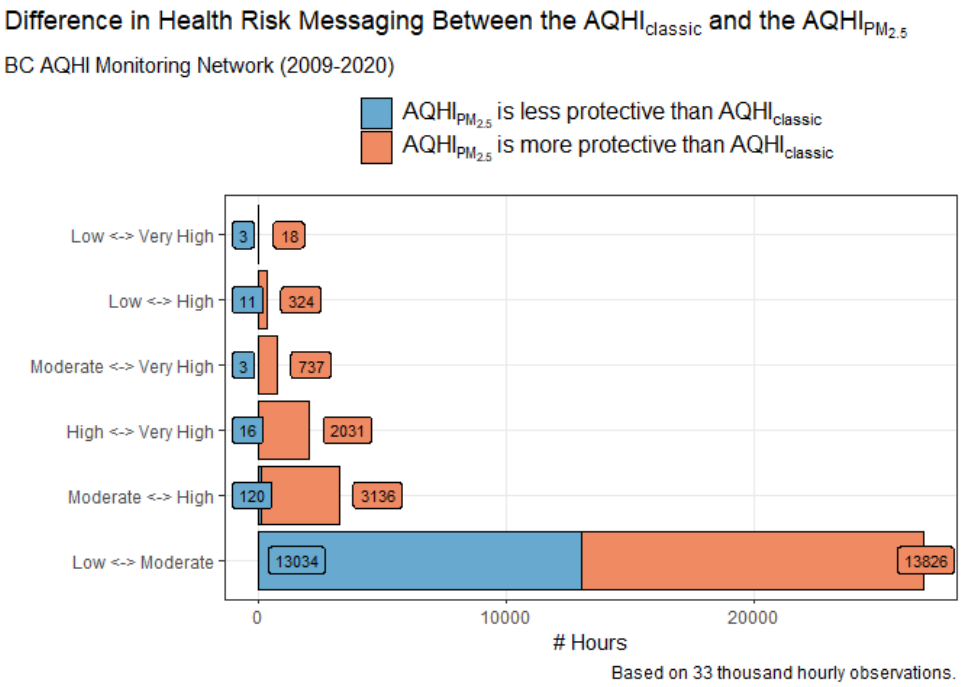


Figure 4.6: A closer look at hours when the health risk messaging differed between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$.

When the health messaging differed between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$ and when the change was considered to be of high impact to the public (resulting in “High” or “Very High” health risk being reported) - overwhelmingly, hourly $PM_{2.5}$ levels were the reason for the more protective health messaging.

4.4 Alternative Model: Regional NO_2 and O_3 (Vancouver Island Case Study)

NO_2 and O_3 are required for AQHI reporting under the current model in BC. Here, a regional model for NO_2 and O_3 is considered using the AQHI network on Vancouver Island; a case study follows in which O_3 and NO_2 were used from a surrogate station to calculate the *AQHI* at the remaining 4 stations, with the results focused on understanding the potential impacts on the health risk messaging (“Low”, “Moderate”, “High”, or “Very High”). These findings are important for examining ways to expand AQHI coverage without having to expand O_3 and NO_2 monitoring.

The AQHI monitoring network on Vancouver Island is shown in Figure 4.7 and includes 5 communities and 6 stations: Victoria (Topaz station), Colwood (City Hall station), Duncan (Cairnsmore and College Street stations), Courtenay (Elementary School station), and Nanaimo (Labieux

Road station). See Table A.1 and Figure A.1 for the monitoring history at these stations.

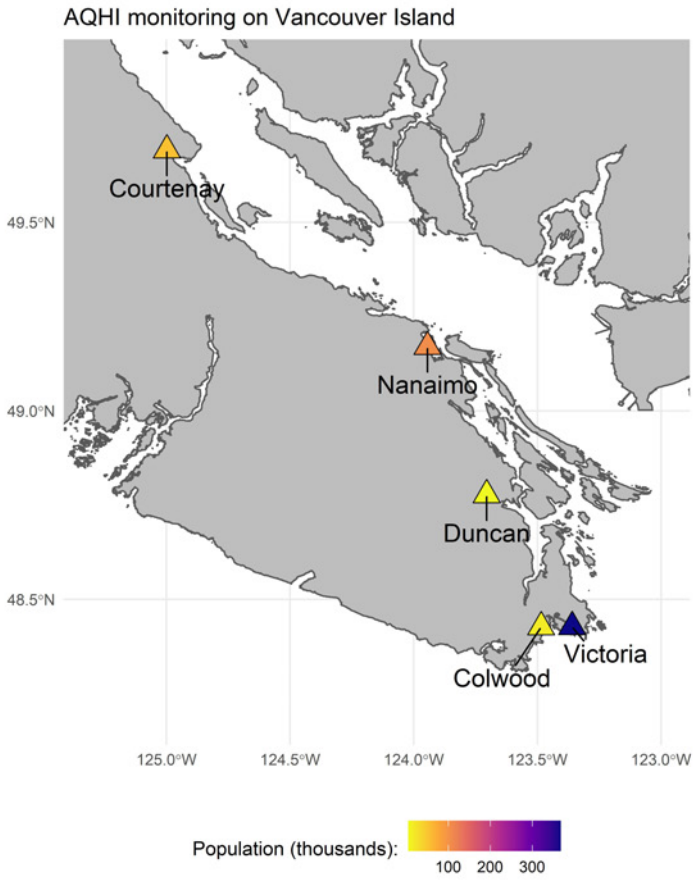


Figure 4.7: AQHI monitoring on Vancouver Island.

Figure 4.8 shows the effect of using O_3 and NO_2 from a surrogate station on the AQHI health messaging on Vancouver Island. Each panel in the figure represents a different surrogate station - for example, in the top panel, the O_3 and NO_2 from Colwood City Hall station has been used with the $PM_{2.5}$ from each of the remaining stations to calculate the *AQHI*. Data shown in blue represent less protective health messaging when surrogate O_3 and NO_2 were used; data shown in red represent more protective health messaging when surrogate O_3 and NO_2 were used; and data in white indicate no difference in the health messaging when surrogate O_3 and NO_2 were used.

Across the Vancouver Island AQHI network, using surrogate O_3 and NO_2 made very little difference on the health risk messaging - 99.4% of the hours resulted in no change in the health message that would be reported to the public.

When the health messaging did change with the use of surrogate O_3 and NO_2, 99.5% of those hours involved a change between “Low” and “Moderate” - 53.1% of these hours resulted in less protective messaging when the surrogate was used (“Low” from surrogate; “Moderate” otherwise), and 46.4% of these hours resulted in more protective messaging when the surrogate was used (“Moderate” from surrogate; “Low” otherwise). There were no hours when the health messaging changed by more than one level in either direction; for example, there were no hours when the use of a surrogate station changed the health risk messaging from “Low” to “High” or “Low” to “Very High” (and vice versa).

A closer look at what are considered to be the high impact hours where the health messaging changed between “Moderate” and “High” or “High” and “Very High” is provided in Figure 4.9. The figure includes 50 hours in total (of the 1.7 million observations included in the regional AQHI case study), and they occurred during July (4 hours), August (45 hours) and November (1 hour). July and August are known to be heavily influenced by wildfire emissions of $PM_{2.5}$, and to a lesser extent O_3 and NO_2.

Elevated levels of O_3 and NO_2 in Victoria are expected to have resulted in more protective messaging in the other communities when Topaz station was used as a surrogate. As an example, on August 2nd at 7pm higher 3-hour NO_2 concentrations at Victoria Topaz (25.8 ppb) compared to Nanaimo Labieux Road (2.8 ppb) resulted in the *AQHI* being reported as the $AQHI_{classic}$ (“High” health risk); when the *AQHI* is calculated using Nanaimo Labieux Road data, the *AQHI* is reported as the $AQHI_{PM_{2.5}}$ (“Moderate” health risk). This highlights the importance of aligning community emissions profiles when considering a regional AQHI model. Victoria is a large urban centre that is heavily influenced by mobile sources of O_3 and NO_2 that do not exist to the same extent in many small BC communities. Although the results here show that it is almost always true that the use of a surrogate station (on Vancouver Island) does not change the AQHI health messaging, bias may be introduced resulting in more or less protective messaging during those infrequent but important instances where the change is towards or away from “High/Very High” health risk.

The effects of using a surrogate station on the AQHI health risk messaging on Vancouver Island is resolved further by month and by health risk category in Appendix C. Figures C.1-C.5 support the finding already stated above - when the health risk messaging is changed with the use of a surrogate station, it is almost always between the “Low” and “Moderate” health risk categories. There is, however, a lot of variability in the surrogate station’s effects on health risk messaging that depends on which station is used as the surrogate and what month of the year it is. For example, using Victoria Topaz as the surrogate station results in more protective health risk messaging for the remaining 4 stations; and it follows that when surrogate stations are used for Victoria, the health risk messaging becomes less protective most of the time. Now looking at the

monthly variability, the months of May and July-September seem to be the most impacted with respect to changes to the health risk messaging for all of the stations except for Courtenay Elementary School, which shows a similar impact for many months of the year. These observations reflect the unique contaminant mixes on Vancouver Island (see Appendices C.2 - C.4).

Changes to the AQHI health risk messaging occurred for less than 1% of the hours when O_3 and NO_2 were used from a surrogate station on Vancouver Island. When a change in the AQHI health risk messaging did occur, it was rarely (50 in 1.7 million hours) during pollution events ("High" or "Very High" health risk), but the results were variable in space and time.

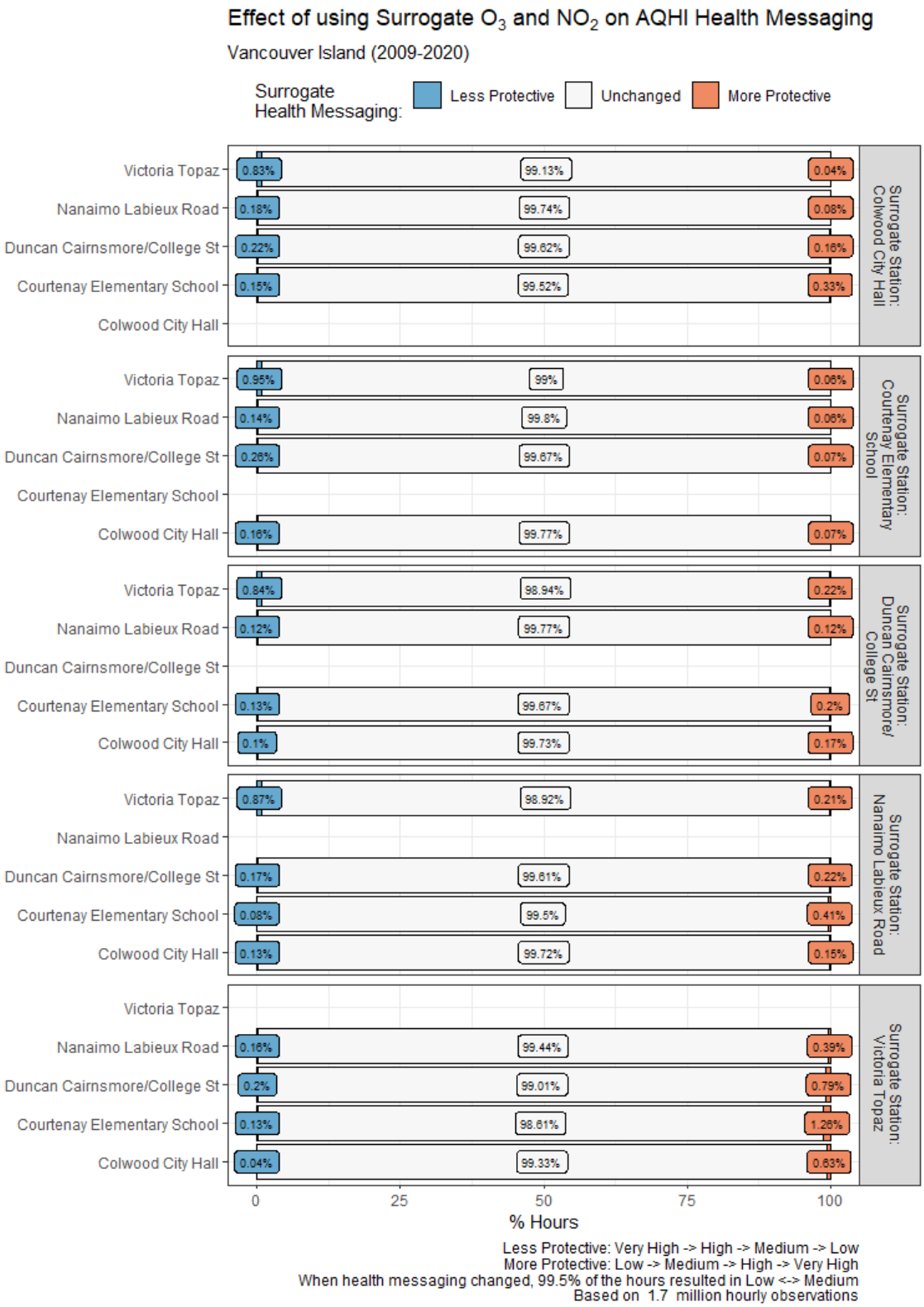


Figure 4.8: Surrogate use of O_3 and NO_2 to calculate the AQHI on Vancouver Island (2009-2020).



Figure 4.9: Surrogate use of O_3 and NO_2 to calculate the AQHI on Vancouver Island (2009-2020). A closer look at hours where the health messaging was “Moderate”, “High” or “Very High”.

5. Summary, Recommendations & Future Work

5.1 Summary

This review included an exploratory data analysis of the AQHI monitoring network in BC from 2009 to 2020, and involved a detailed examination of the three versions of the AQHI that are calculated on an hourly basis (Section 2.2): the $AQHI_{classic}$ (based on NO_2, O_3, and $PM_{2.5}$), the $AQHI_{PM_{2.5}}$ (based on $PM_{2.5}$), and the *AQHI*. The *AQHI* is equal to the higher of the $AQHI_{classic}$ and the $AQHI_{PM_{2.5}}$, and is what is reported to the public.

The objective for this review was to answer the questions below:

1. **How often is the health risk Low, Moderate, High and Very High?** (Section 4.1 - Figure 4.1)

   The distribution of reporting across the health risk categories is very similar for the $AQHI_{classic}$, the $AQHI_{PM_{2.5}}$, and the *AQHI* - most of the time (96-97% of the hours), the health risk is categorized as "Low", a small percent of hours (2-3%) are reported with a "Moderate" health risk, and less than one percent of the hours are reported in the "High" and "Very High" health risk categories combined.

   The $AQHI_{PM_{2.5}}$ has a higher proportion of "High" and "Very High" health risk hours compared to the $AQHI_{classic}$. This finding is intuitive given the intent of the $AQHI_{PM_{2.5}}$ to provide appropriate health messaging during periods of poor air quality that are heavily influenced by high levels of $PM_{2.5}$ (for example, from wildfires or residential wood burning). The influence of the $AQHI_{PM_{2.5}}$ on the reporting during the infrequent times when the health risk is reported to the public (via the *AQHI*) as "High" or "Very High" should not be overlooked, since it is during these periods of poor air quality that the public expects timely and representative information on how the air quality where they live, work and play may affect their health.

2. **Which version of the AQHI - classic or fine particulate matter - is reported the most and why?** (Section 4.2 - Figures 4.2 and 4.3)

   The $AQHI_{classic}$ is calculated from NO_2, O_3, and $PM_{2.5}$, whereas the $AQHI_{PM_{2.5}}$ is calculated from only $PM_{2.5}$. By looking at how often the *AQHI* is reported as the $AQHI_{classic}$ and the $AQHI_{PM_{2.5}}$, insight is gained on how the constituent contaminants influence the *AQHI* reporting in the province.

   Overall, the $AQHI_{classic}$ would be reported to the public as the *AQHI* for 76% of the hours included in this review. However, there is a strong relationship between which version of the AQHI is reported ($AQHI_{classic}$ or $AQHI_{PM_{2.5}}$) and the health risk category: as the health

risk transitions from “Low” towards “Very High”, the *AQHI* is increasingly reported as the $AQHI_{PM_{2.5}}$. When the health risk was “High” or “Very High”, 97% of reported hours were determined solely by $PM_{2.5}$ levels.

On a monthly basis the *AQHI* is reported as the $AQHI_{classic}$ 65-90% of the time, with higher contributions during the spring months. However, during pollution events the $AQHI_{PM_{2.5}}$ dominates the *AQHI* reporting throughout the year with between 82-100% of these “High” and “Very High” health risk hours being determined solely by $PM_{2.5}$ levels.

3. **Are there any alternatives to the current model?**

    a. **AQHI based only on $PM_{2.5}$ levels** (Section 4.3 - Figures 4.5, 4.6, B.1, and B.2)

    Considering the network as a whole, most of the time (97% of the hours) the AQHI health risk messaging remains unchanged regardless of which version of the AQHI is reported - the $AQHI_{PM_{2.5}}$ or the $AQHI_{classic}$. For the remaining 3% of the hours, the health risk messaging was different for the $AQHI_{PM_{2.5}}$ compared to the $AQHI_{classic}$. Whether the change in health risk messaging was more or less protective depended on the time of year and the unique signature of NO_2, O_3, and $PM_{2.5}$ in each community. When the change in health risk messaging was considered to be of high impact to the public (“High” or “Very High” health risk) - the hourly $PM_{2.5}$ levels were the reason for the more protective health risk messaging 98% of the time. This aligns with the intent of the $AQHI_{PM_{2.5}}$ to provide more appropriate health messaging during periods of degraded air quality caused by elevated $PM_{2.5}$ at times when the $AQHI_{classic}$ does not.

    b. **Regional model for NO_2 and O_3: Vancouver Island case study** (Section 4.4 - Figures 4.7 -4.9 and C.1-C.20)

    Across the Vancouver Island AQHI network, using surrogate O_3 and NO_2 made very little difference on the health risk messaging - 99.4% of the hours resulted in no change in the health message that would be reported to the public. When the use of surrogate NO_2 and O_3 did result in a change in the AQHI health risk messaging, it was rarely (50 in 1.7 million hours) during pollution events (“High” or “Very High” health risk), but the results were variable in space and time.

    The use of Victoria Topaz station as the surrogate station highlighted the importance of aligning community emissions profiles when considering a regional AQHI model. Victoria is a large urban centre that is heavily influenced by mobile sources of NO_2 and O_3 that do not exist to the same extent in many small BC communities. The results here show that it is almost always true (99.4% of 1.7 million hours) that the use of a surrogate station on Vancouver Island does not change the AQHI health messaging. However, bias may be introduced resulting in more or less protective messaging

during those infrequent but important instances where the change is towards or away from “High” or “Very High” health risk when a surrogate is used.

5.2 Recommendations

Pending a review by public heath experts, the findings of this review support changes to the BC AQHI network that would save resources without compromising the health risk messaging to the public. An updated AQHI model in BC should be contemplated - one that does not require NO_2 and O_3 to be monitored in every AQHI community. The additional resources could be leveraged to expand $PM_{2.5}$ monitoring across the province - under the new model, this would expand the AQHI network, as well.

5.3 Future Work

The work presented here focused entirely on an exploratory data analysis of historic AQHI data and a preliminary look “under the hood” of the current model in operation in BC. To arrive at fully informed science and evidence based recommendations for the AQHI monitoring network moving forward, input from public health experts (for example, from the health authorities in BC and the British Columbia Centre for Disease Control (BCCDC)) would be needed. The regional AQHI model evaluation should also be expanded to other areas of the province and supported by a statistical analysis.

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Appendix

A. AQHI Network Metadata

Table A.1: Summary of AQHI monitoring in BC from 2009 to 2020.

Community	Station Name	Monitoring Period
Castlegar	Castlegar Zinio Park	Apr 03, 2012 - Dec 31, 2020
Colwood	Colwood City Hall	Jan 25, 2011 - Dec 31, 2020
Courtenay	Courtenay Elementary School	Jul 14, 2011 - Dec 31, 2020
Cranbrook	Cranbrook Muriel Baxter	Aug 22, 2018 - Dec 31, 2020
Duncan	Duncan Cairnsmore	Aug 26, 2009 - Jan 15, 2018
Duncan	Duncan College Street	Jan 20, 2018 - Dec 31, 2020
Fort St. John	Fort St John Key Learning Centre	Feb 12, 2015 - Dec 31, 2020
Kamloops	Kamloops Brocklehurst	Sep 21, 2010 - May 31, 2011
Kamloops	Kamloops Federal Building	Nov 08, 2013 - Dec 31, 2020
Kamloops	Kamloops Fire Station #2	Jun 03, 2011 - Oct 28, 2013
Kelowna	Kelowna College	May 22, 2014 - Jun 12, 2019
Kelowna	Kelowna KLO Road	Sep 11, 2019 - Dec 31, 2020
Kitimat	Kitimat Whitesail	Jul 01, 2019 - Dec 31, 2020
Nanaimo	Nanaimo Labieux Road	Oct 19, 2012 - Dec 31, 2020
Osoyoos	Osoyoos Canada Customs	Aug 06, 2010 - May 01, 2012
Prince George	Prince George Plaza 400	Jul 30, 2010 - Dec 31, 2020
Quesnel	Quesnel Kinchant St MAML	May 08, 2020 - Dec 31, 2020
Quesnel	Quesnel Senior Secondary	Dec 22, 2010 - Apr 30, 2020
Smithers	Smithers Muheim Memorial	Jan 31, 2019 - Dec 31, 2020
Smithers	Smithers St Josephs	Jul 23, 2010 - Dec 07, 2018
Squamish	Squamish Elementary	Dec 17, 2015 - Dec 31, 2020
Squamish	Squamish Gov't Bldg	Oct 17, 2009 - Feb 06, 2016
Terrace	Terrace Skeena Middle School	Mar 25, 2015 - Dec 31, 2020
Vernon	Vernon Science Centre	Apr 29, 2014 - Dec 31, 2020
Victoria	Victoria Topaz	Jul 01, 2009 - Dec 31, 2020
Whistler	Whistler Meadow Park	Oct 08, 2009 - Dec 31, 2020
Williams Lake	Williams Lake Columneetza School	Jul 29, 2013 - Dec 31, 2020

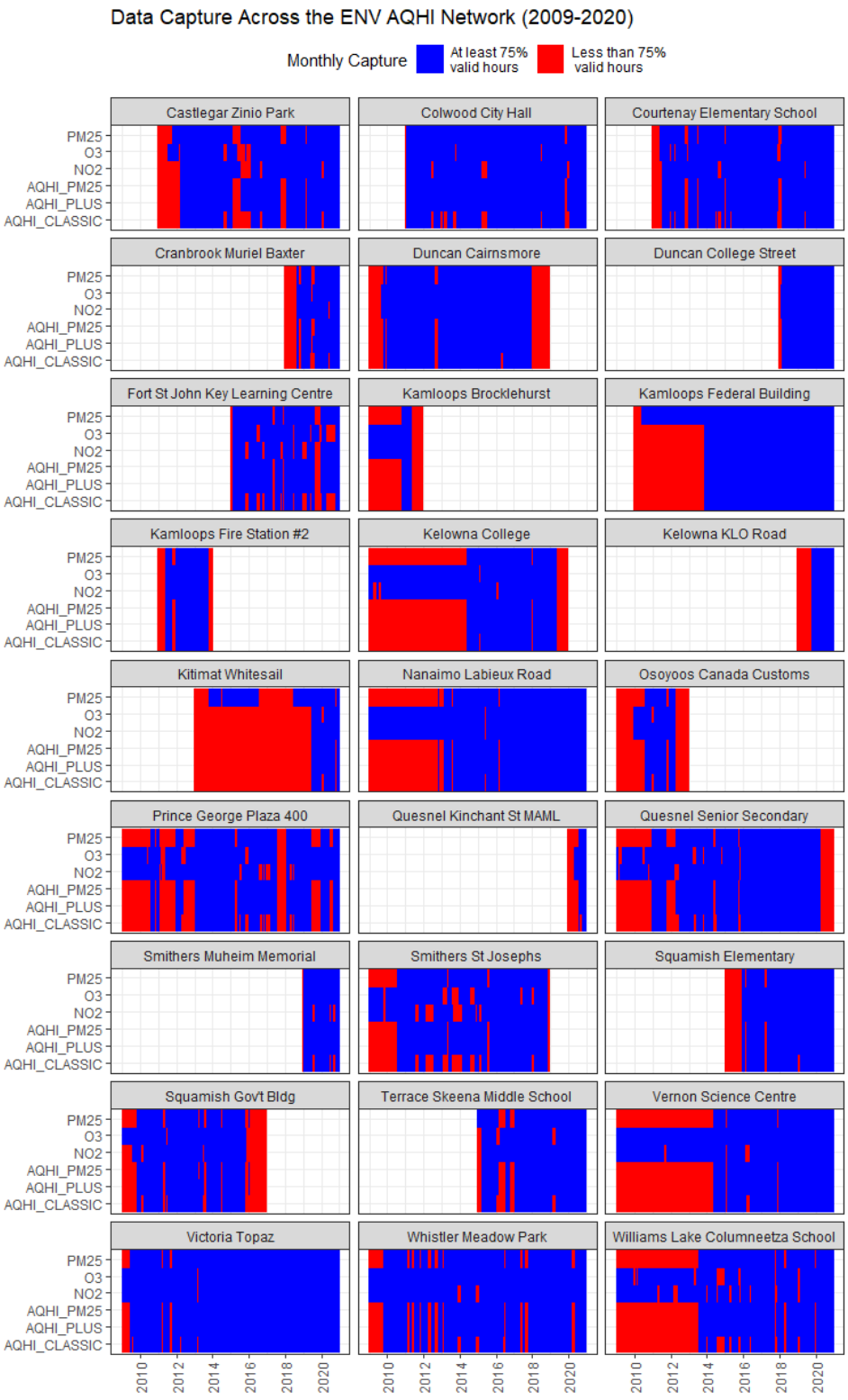


Figure A.1: Hourly data capture by month across the ENV AQHI monitoring network (2009-2020).

B. Alternative Model: AQHI Based Only on $PM_{2.5}$

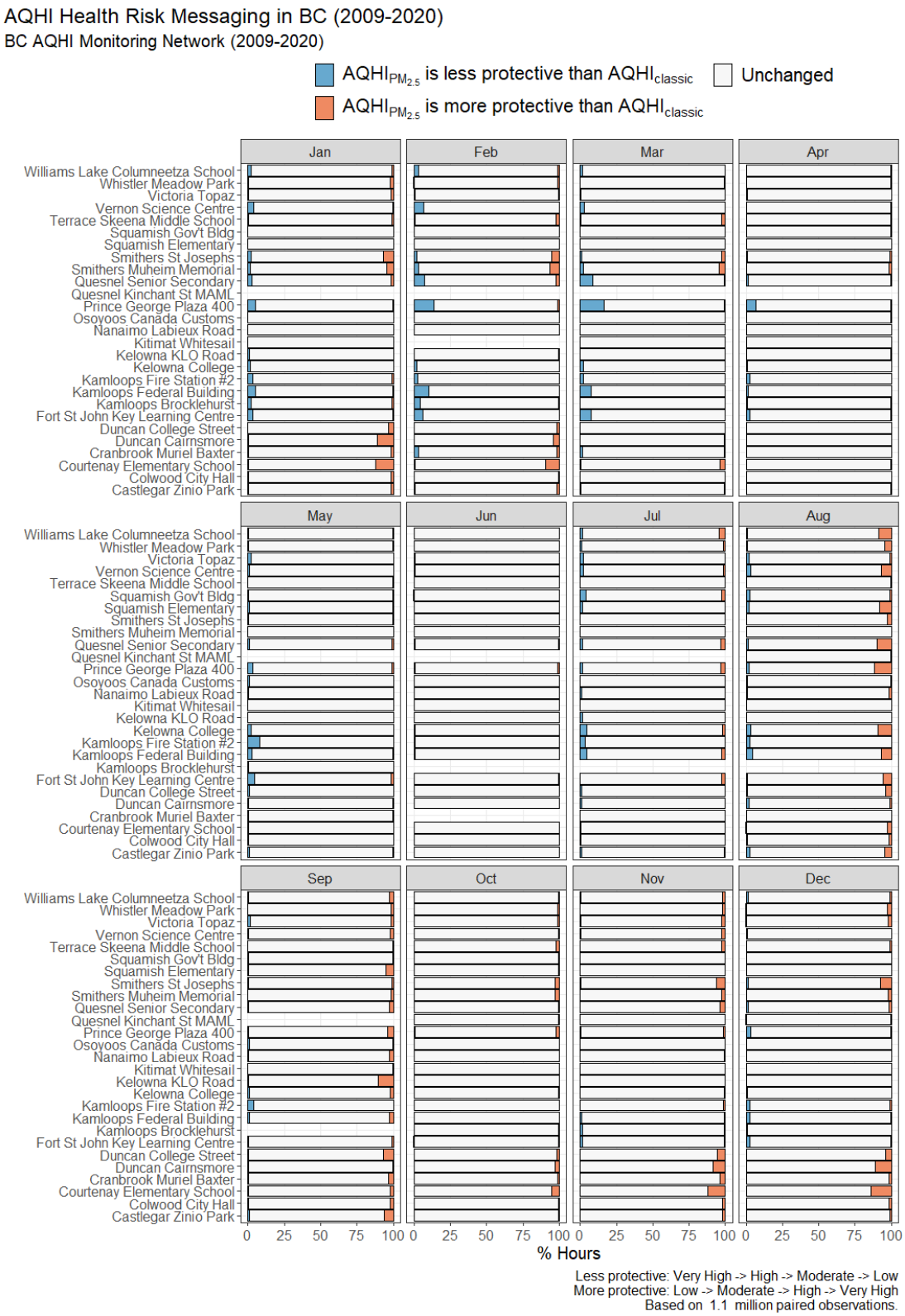


Figure B.1: Difference in health risk messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$ - by month.

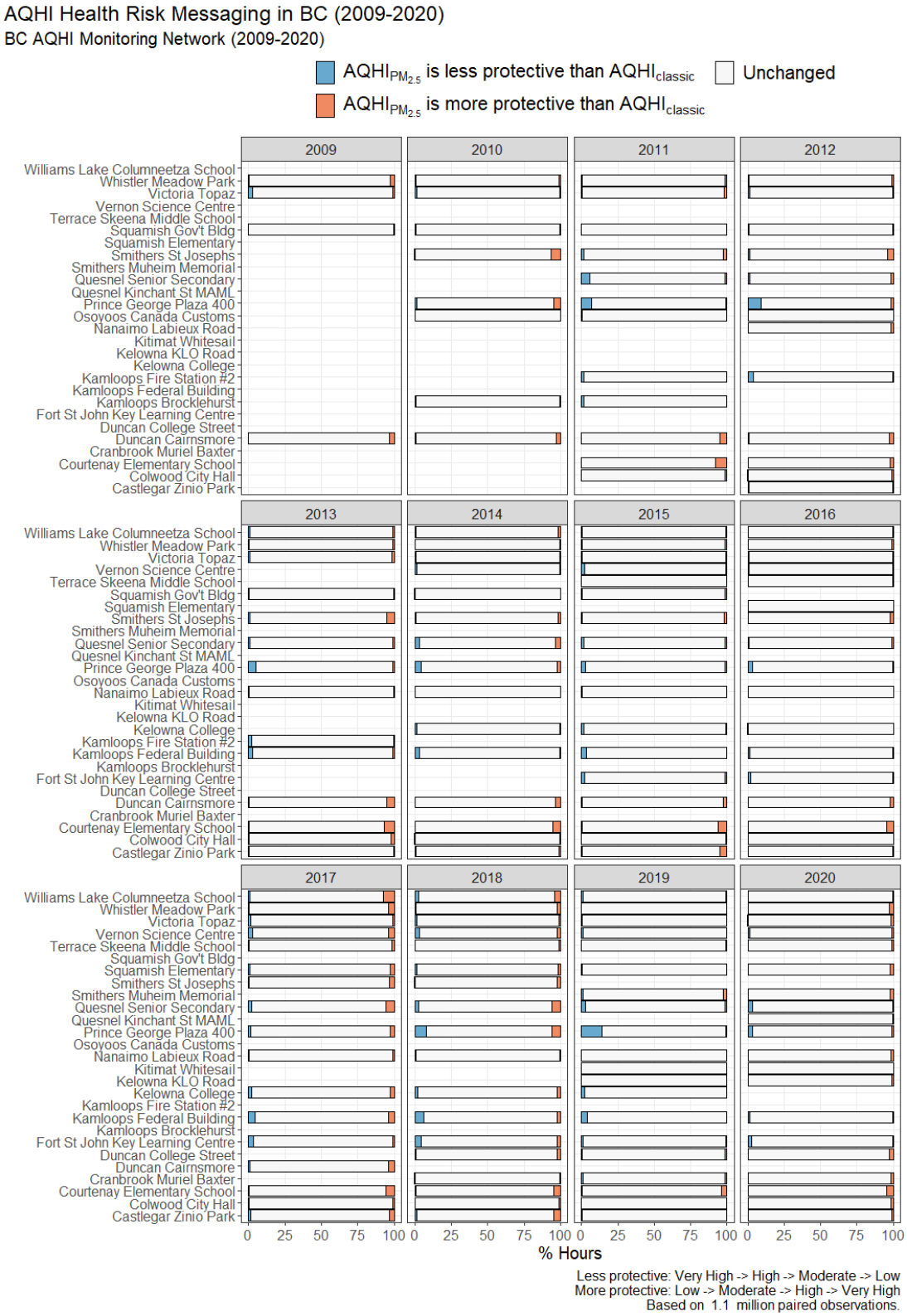


Figure B.2: Difference in health risk messaging between the $AQHI_{PM_{2.5}}$ and the $AQHI_{classic}$ - by year.

C. Alternative Model: Regional NO_2 and O_3 (Vancouver Island Case Study)

C.1 Monthly Effects on Health Messaging - By Community

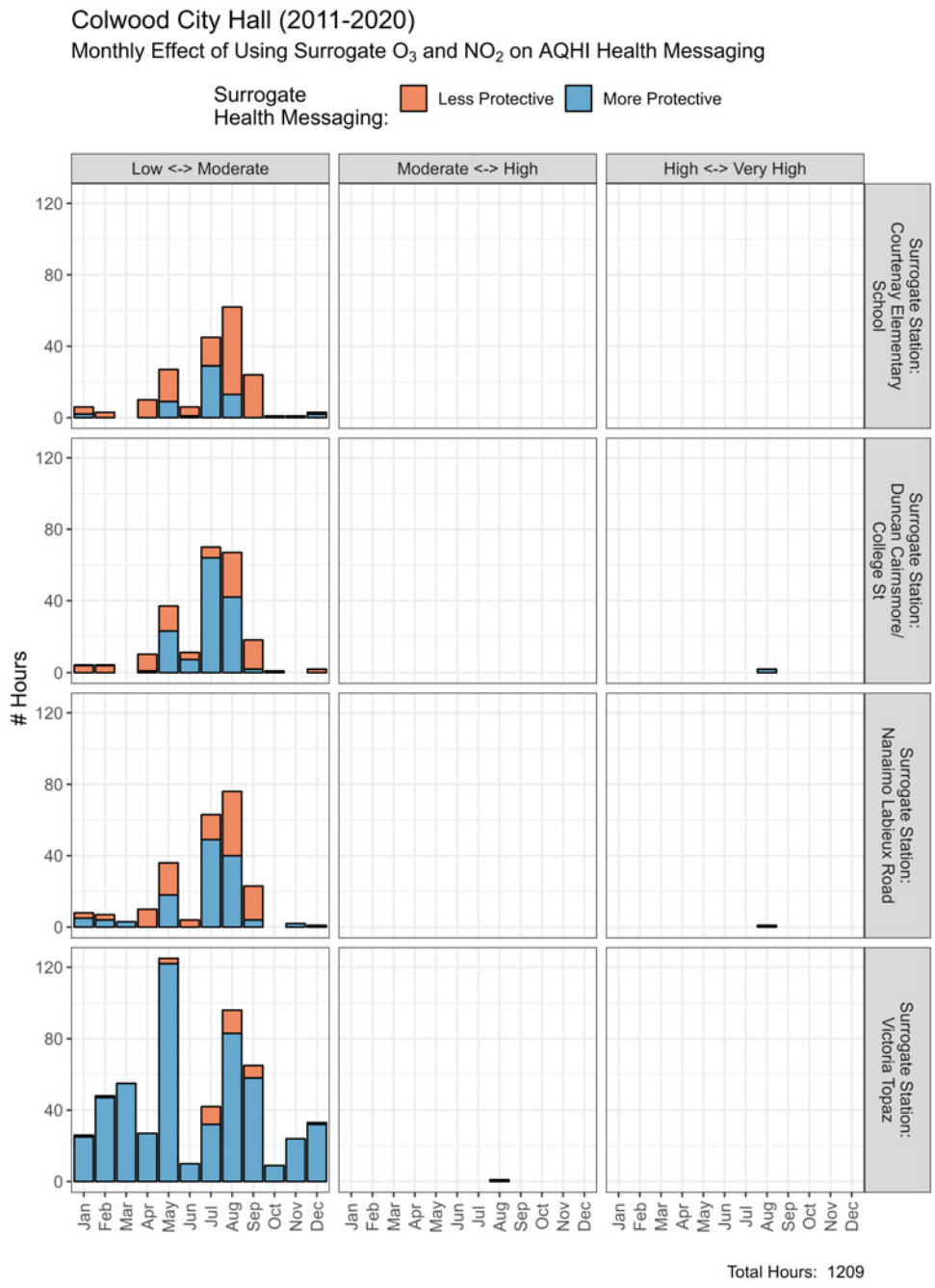


Figure C.1: Surrogate use of O_3 and NO_2 to calculate the AQHI at Colwood City Hall station.

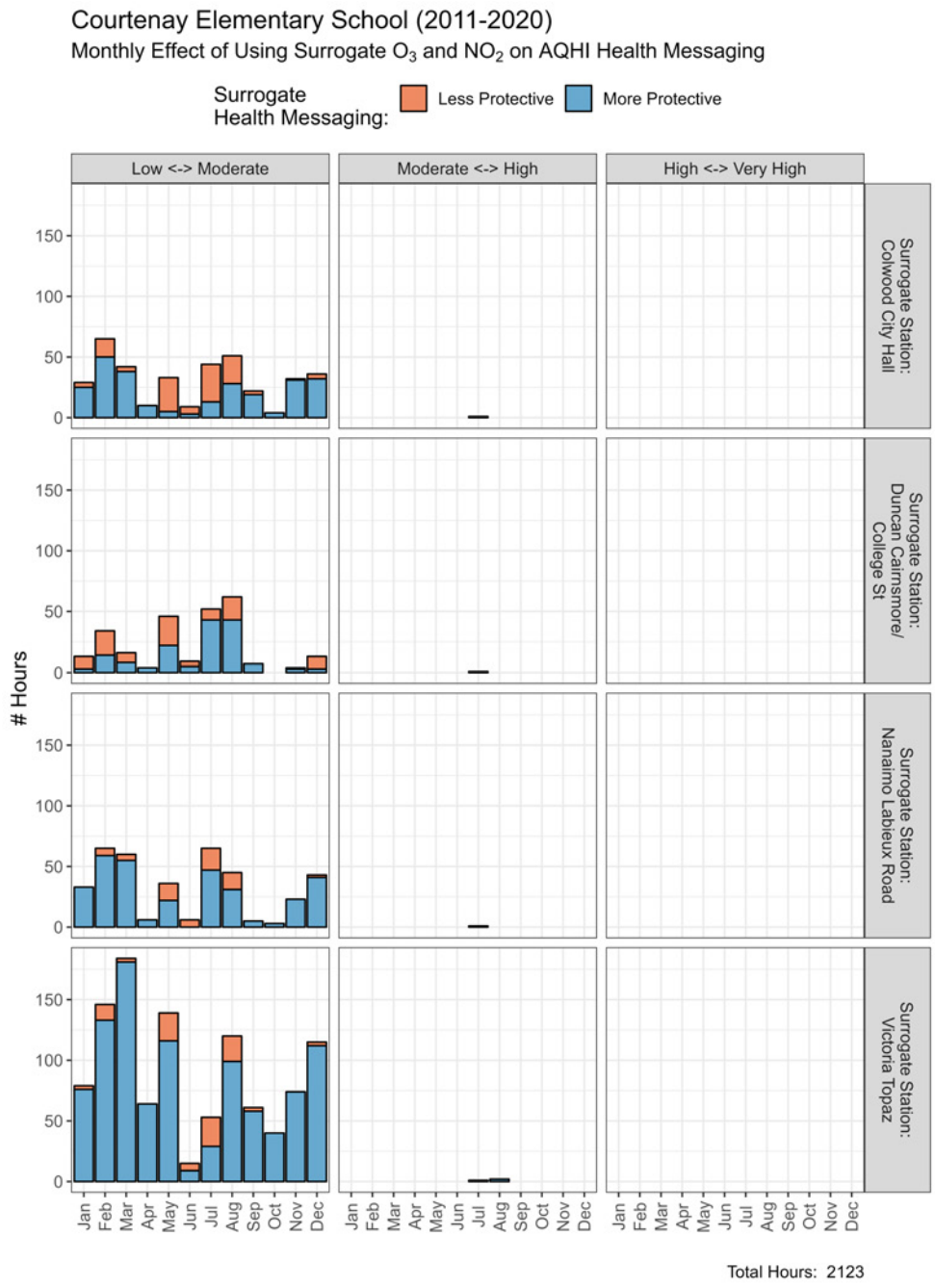


Figure C.2: Surrogate use of O_3 and NO_2 to calculate the AQHI at Courtenay Elementary School station.

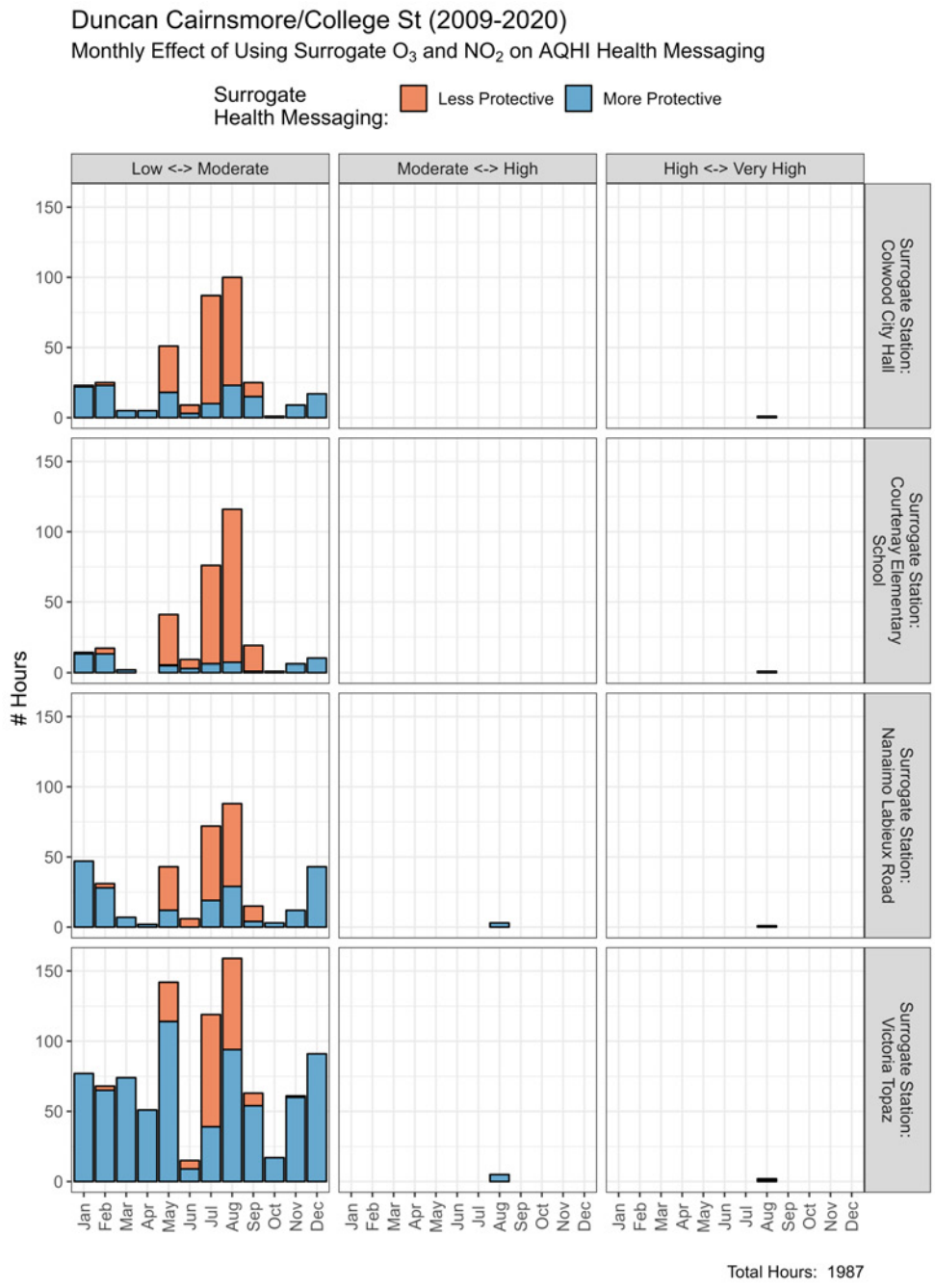


Figure C.3: Surrogate use of O_3 and NO_2 to calculate the AQHI at Duncan Cairnsmore/College Street station.

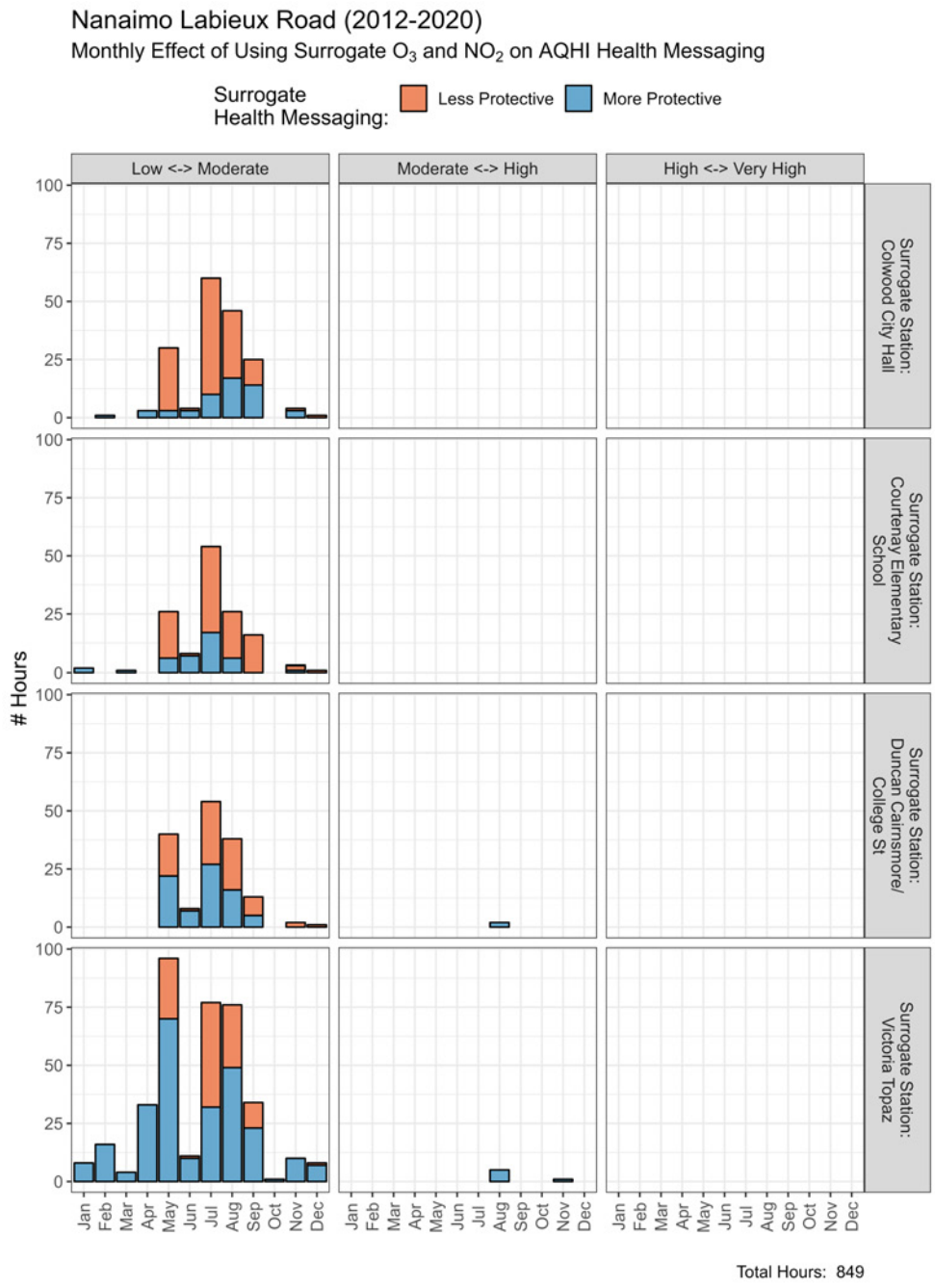


Figure C.4: Surrogate use of O_3 and NO_2 to calculate the AQHI at Nanaimo Labieux Road station.

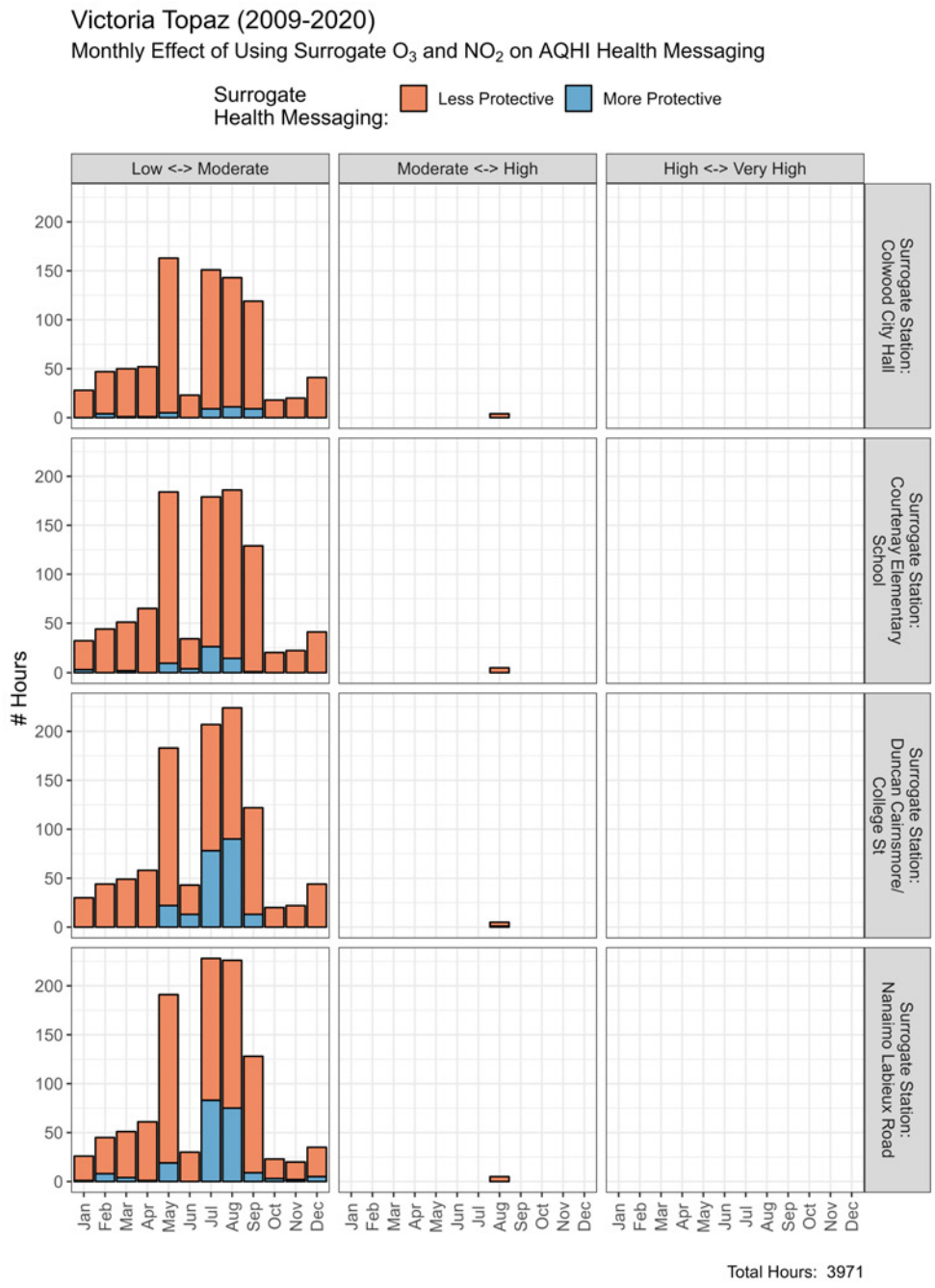


Figure C.5: Surrogate use of O_3 and NO_2 to calculate the AQHI at Victoria Topaz station.

C.2 Contaminant Profiles - Correlation Plots

C.2.1 NO_2

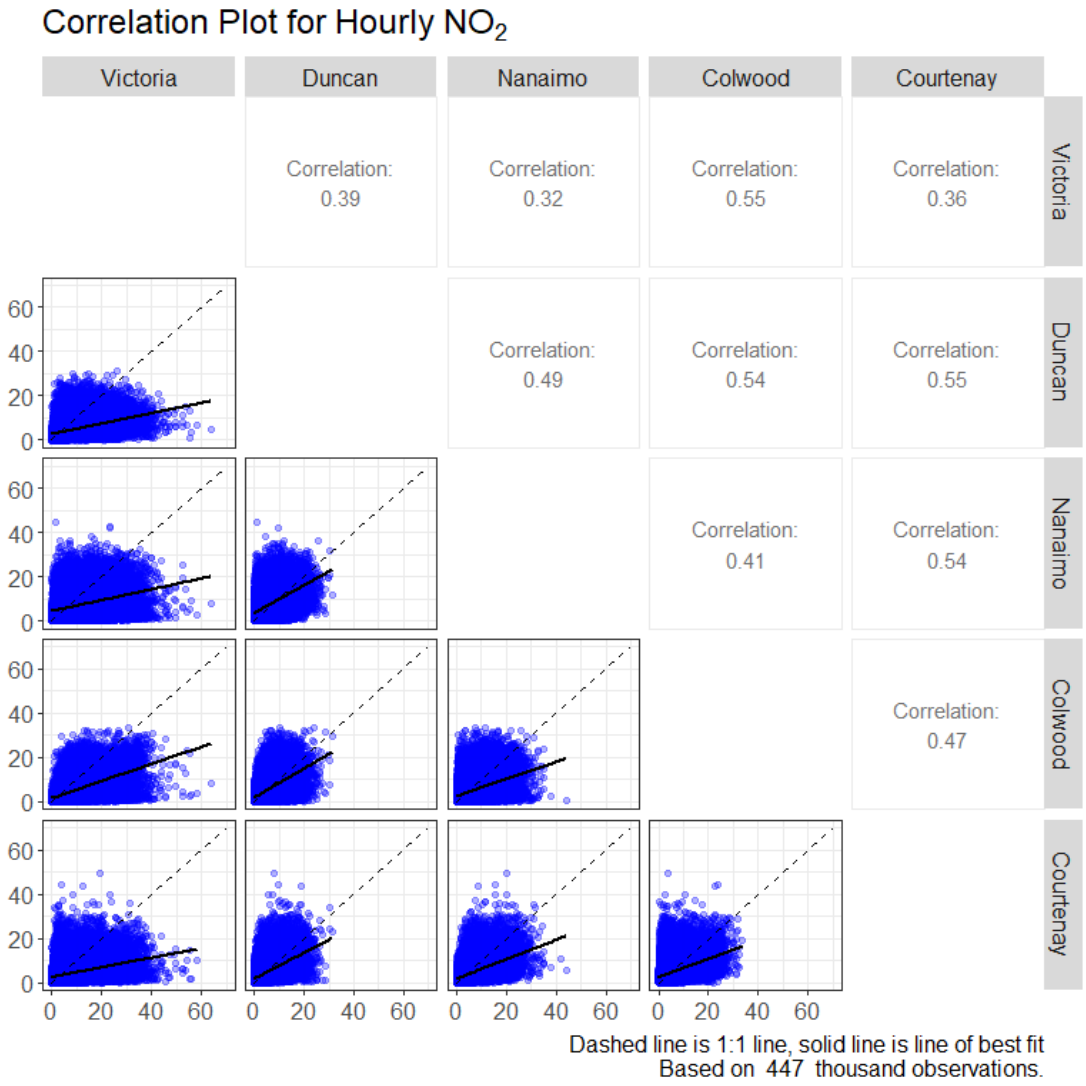


Figure C.6: Correlation plot for hourly NO_2 on Vancouver Island.

C.2.2 O_3

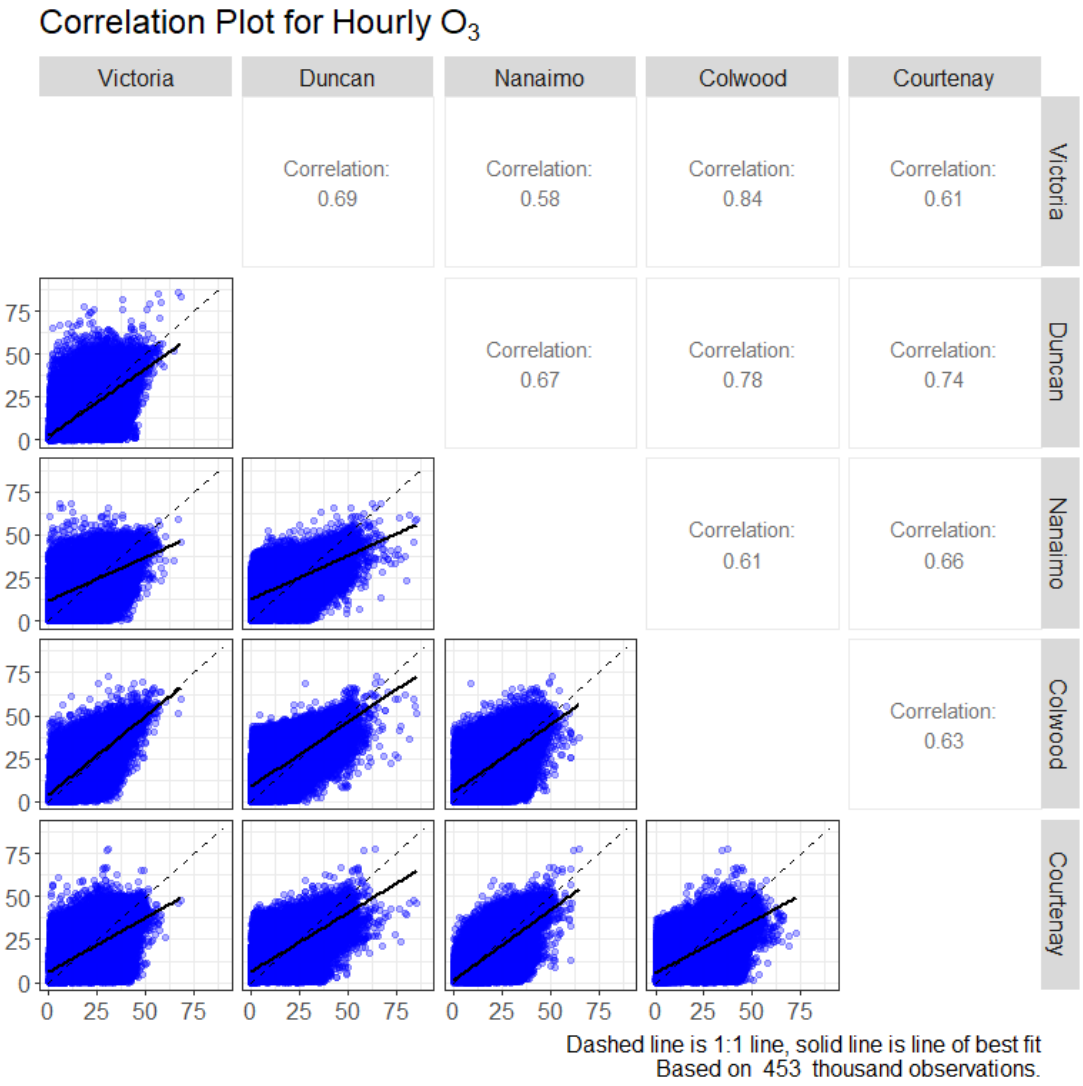


Figure C.7: Correlation plot for hourly O_3 on Vancouver Island.

C.2.3 $PM_{2.5}$

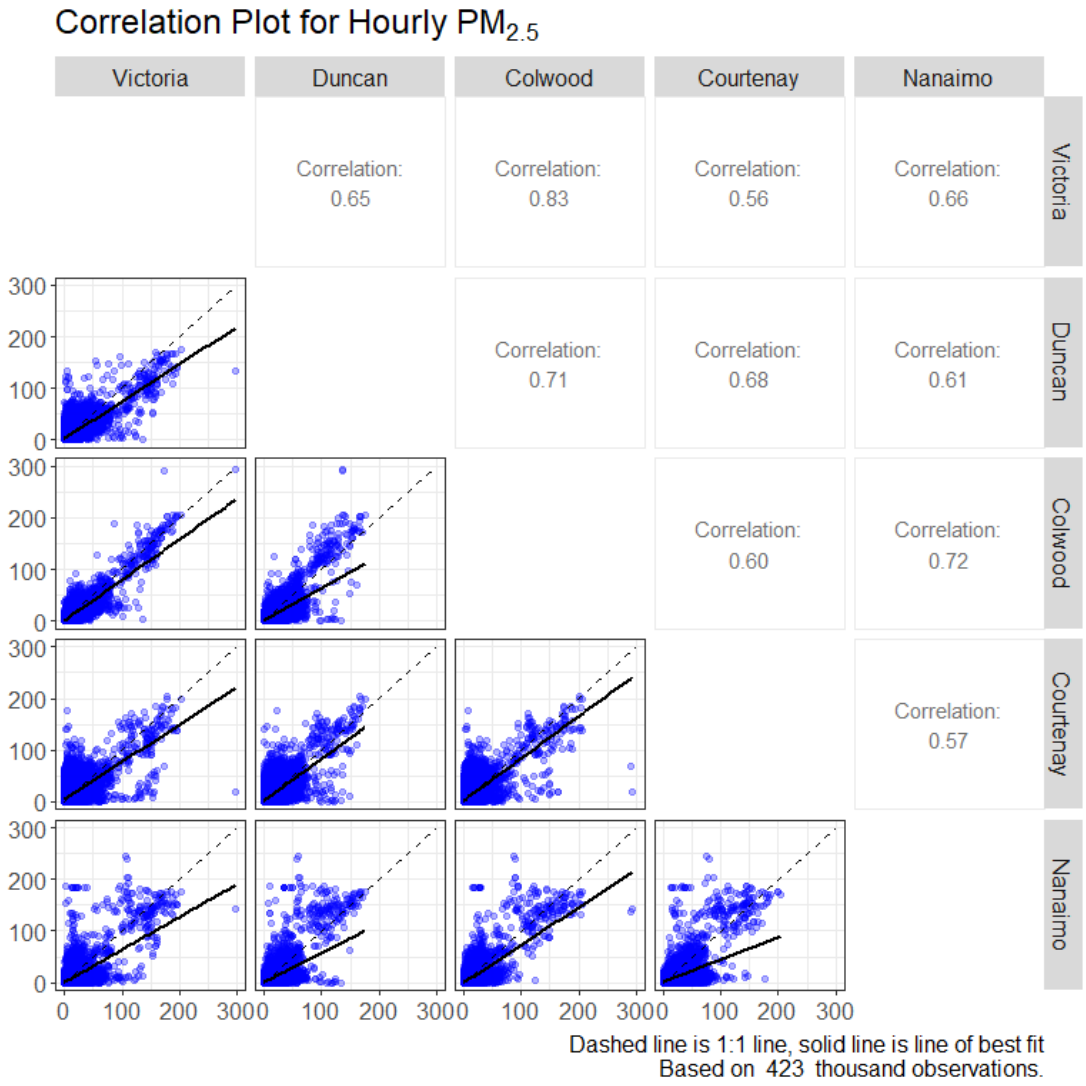


Figure C.8: Correlation plot for hourly $PM_{2.5}$ on Vancouver Island.

C.3 Contaminant Profiles - Boxplots

C.3.1 NO_2

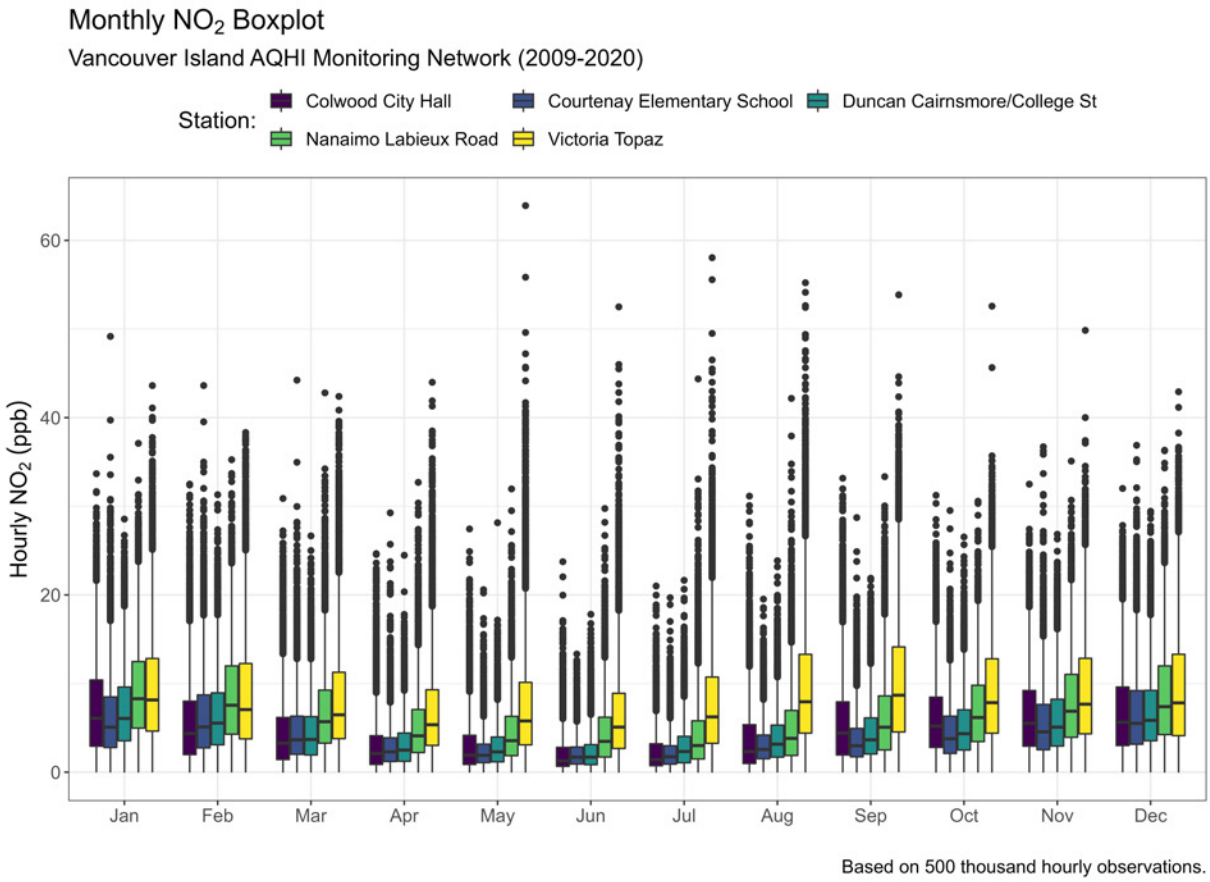


Figure C.9: Monthly boxplot for NO_2.

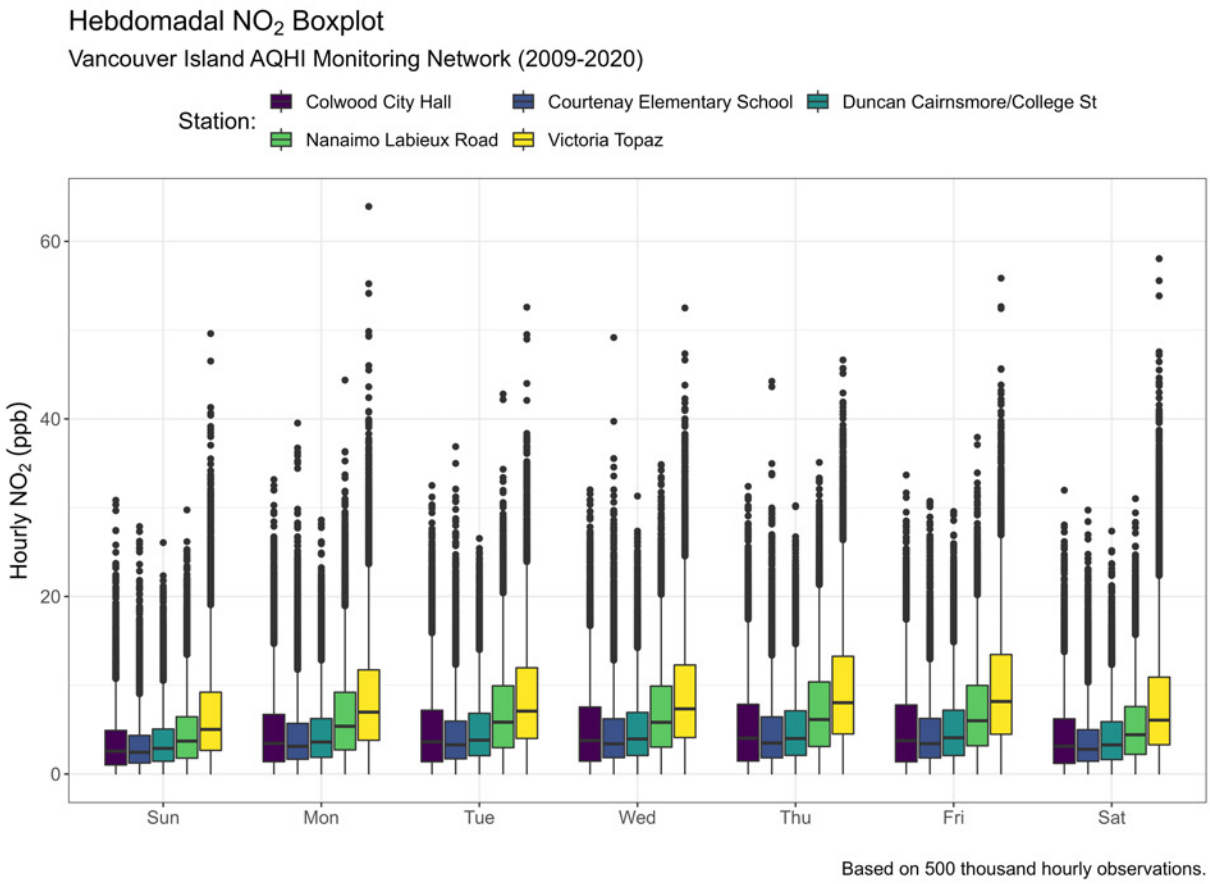


Figure C.10: Hebdomadal boxplot for NO_2.

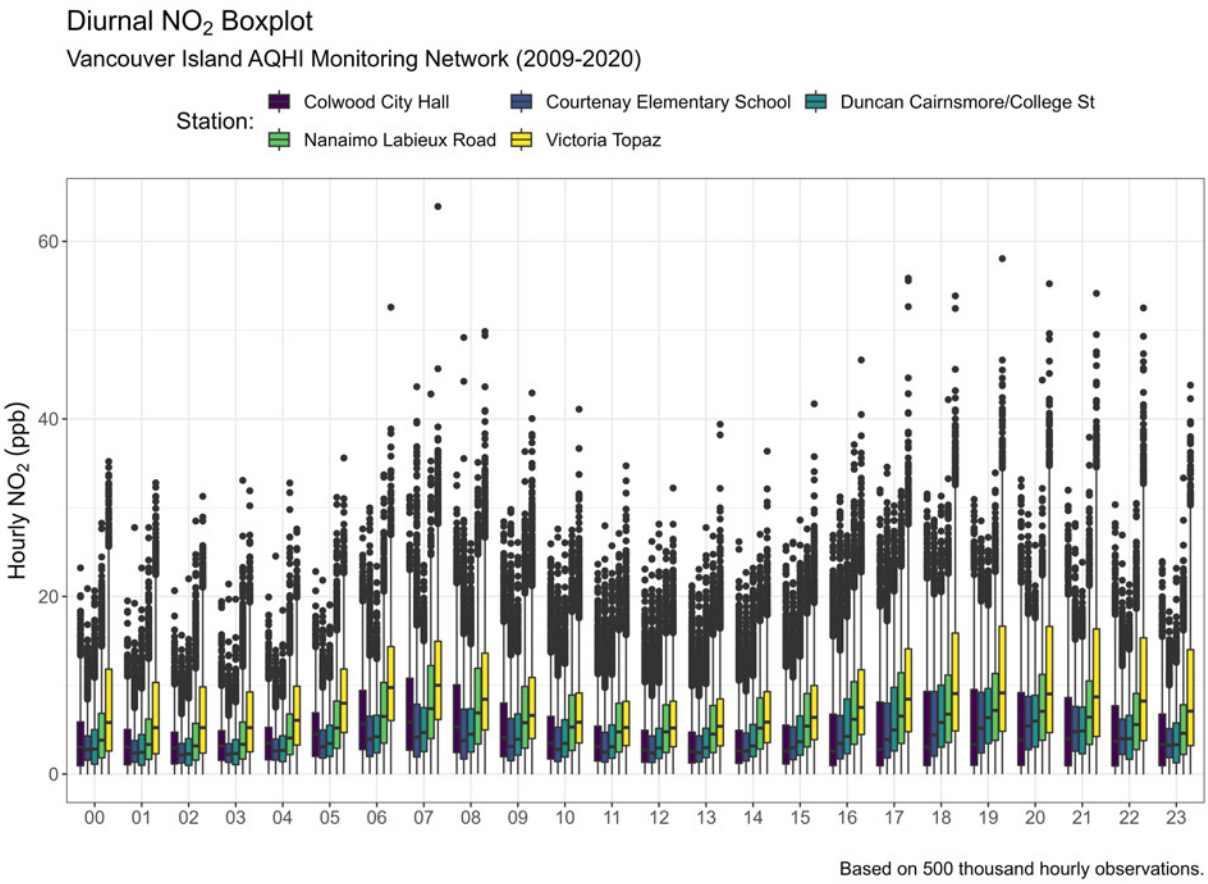


Figure C.11: Diurnal boxplot for NO_2.

C.3.2 O_3

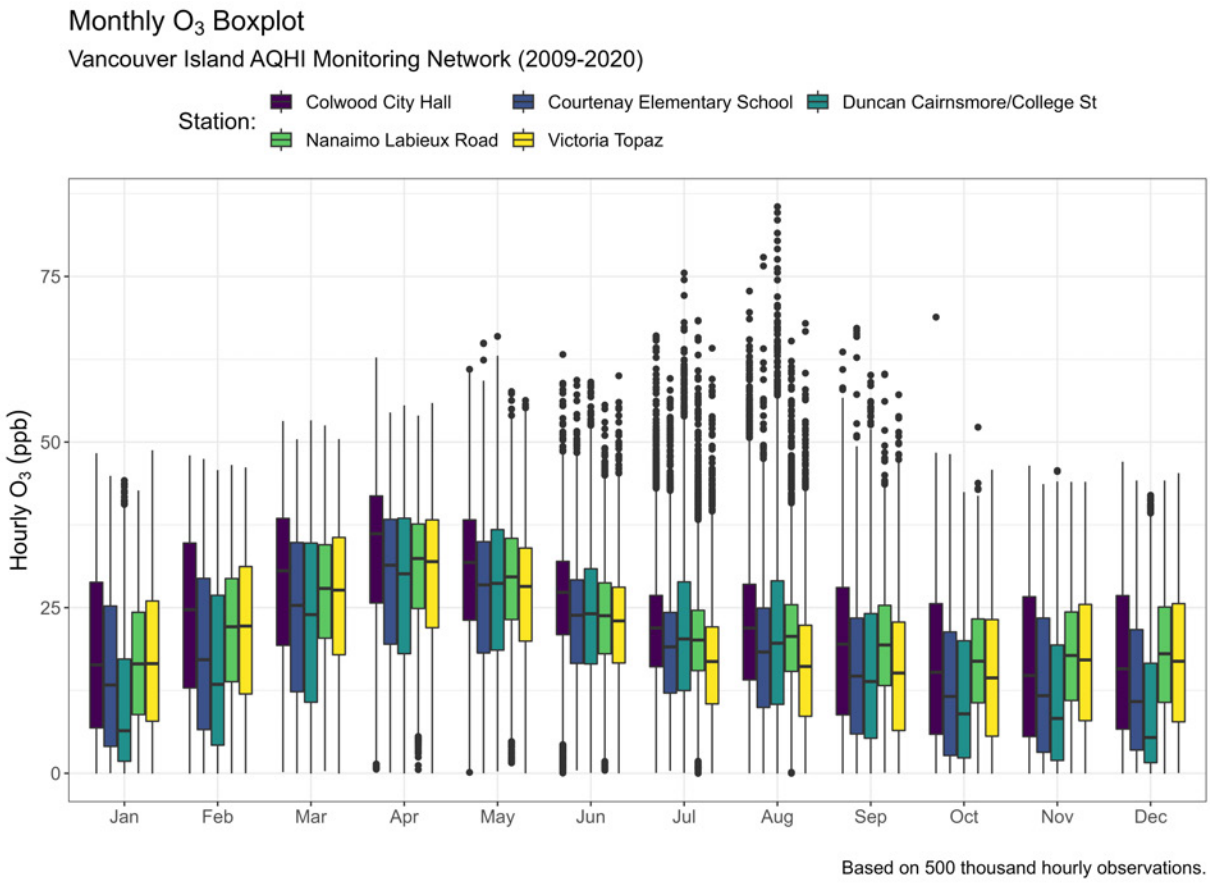


Figure C.12: Monthly boxplot for O_3.

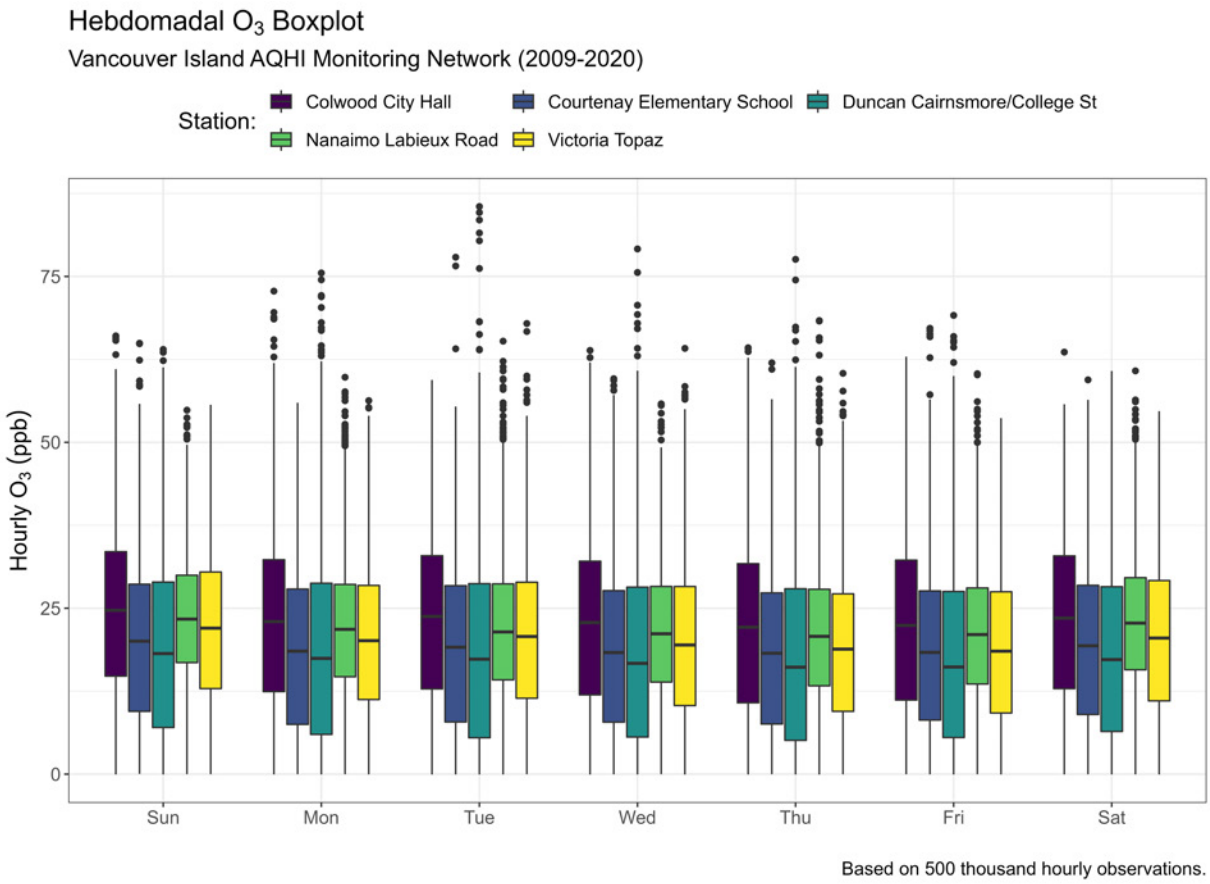


Figure C.13: Hebdomadal boxplot for O_3.

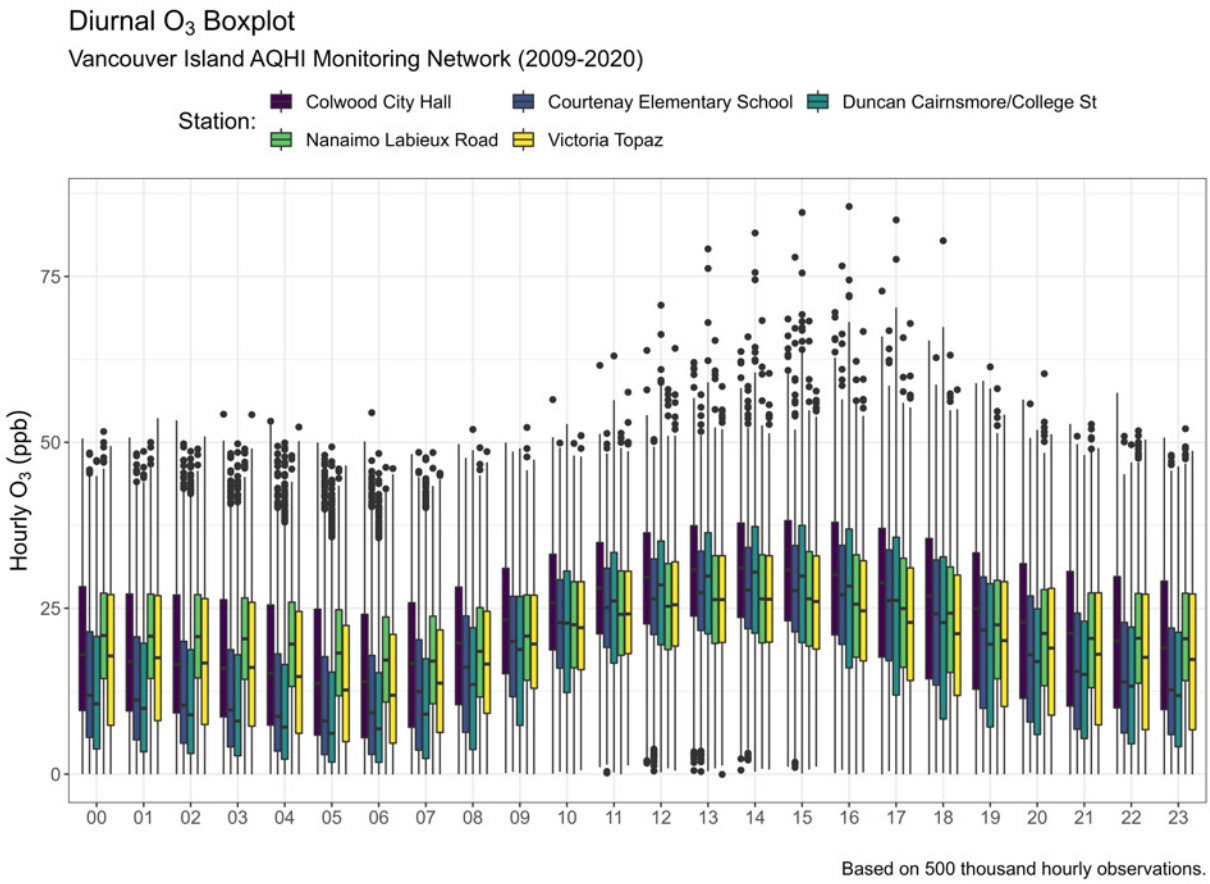


Figure C.14: Diurnal boxplot for O_3.

C.3.3 $PM_{2.5}$

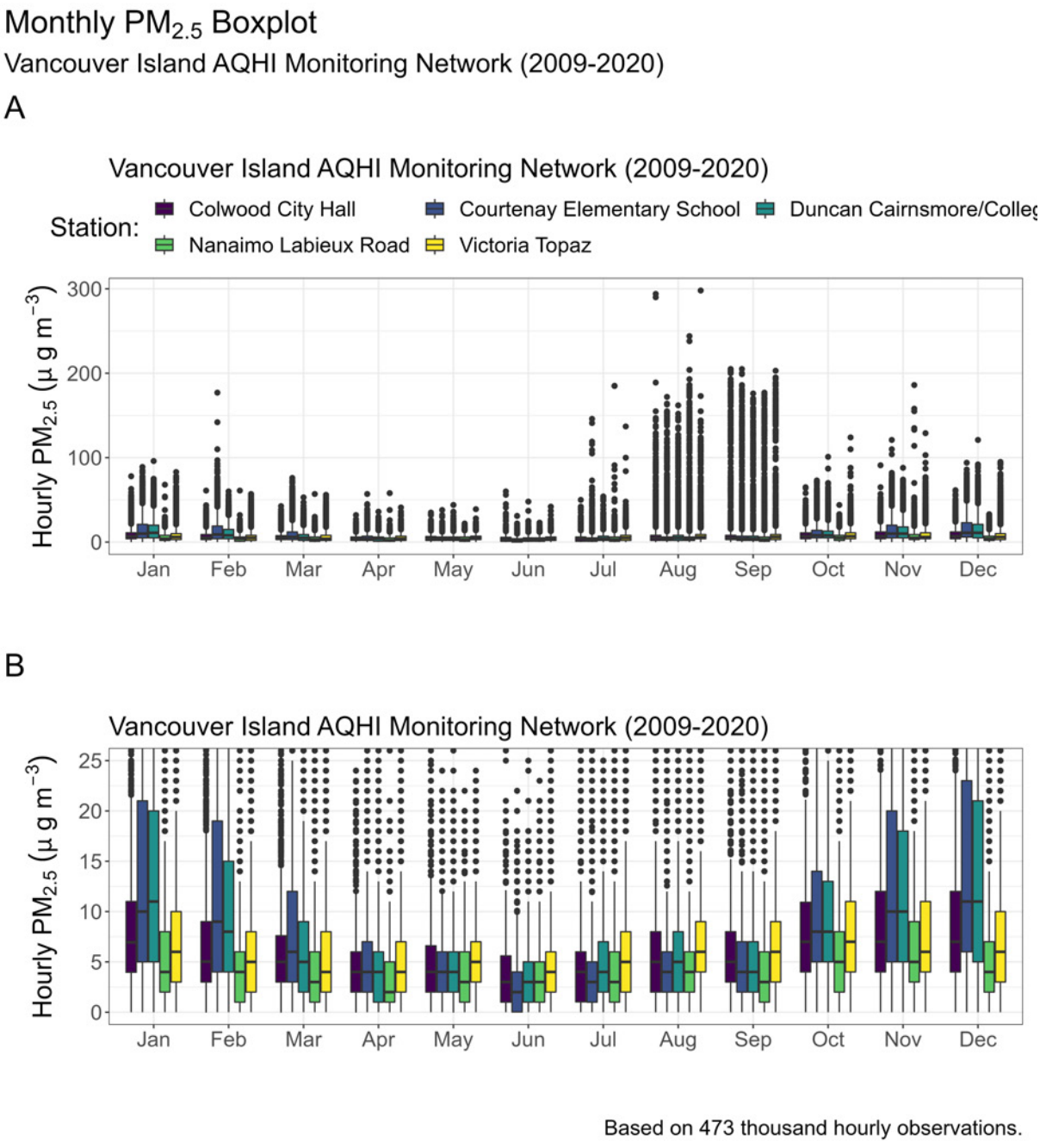


Figure C.15: Monthly boxplot for $PM_{2.5}$.

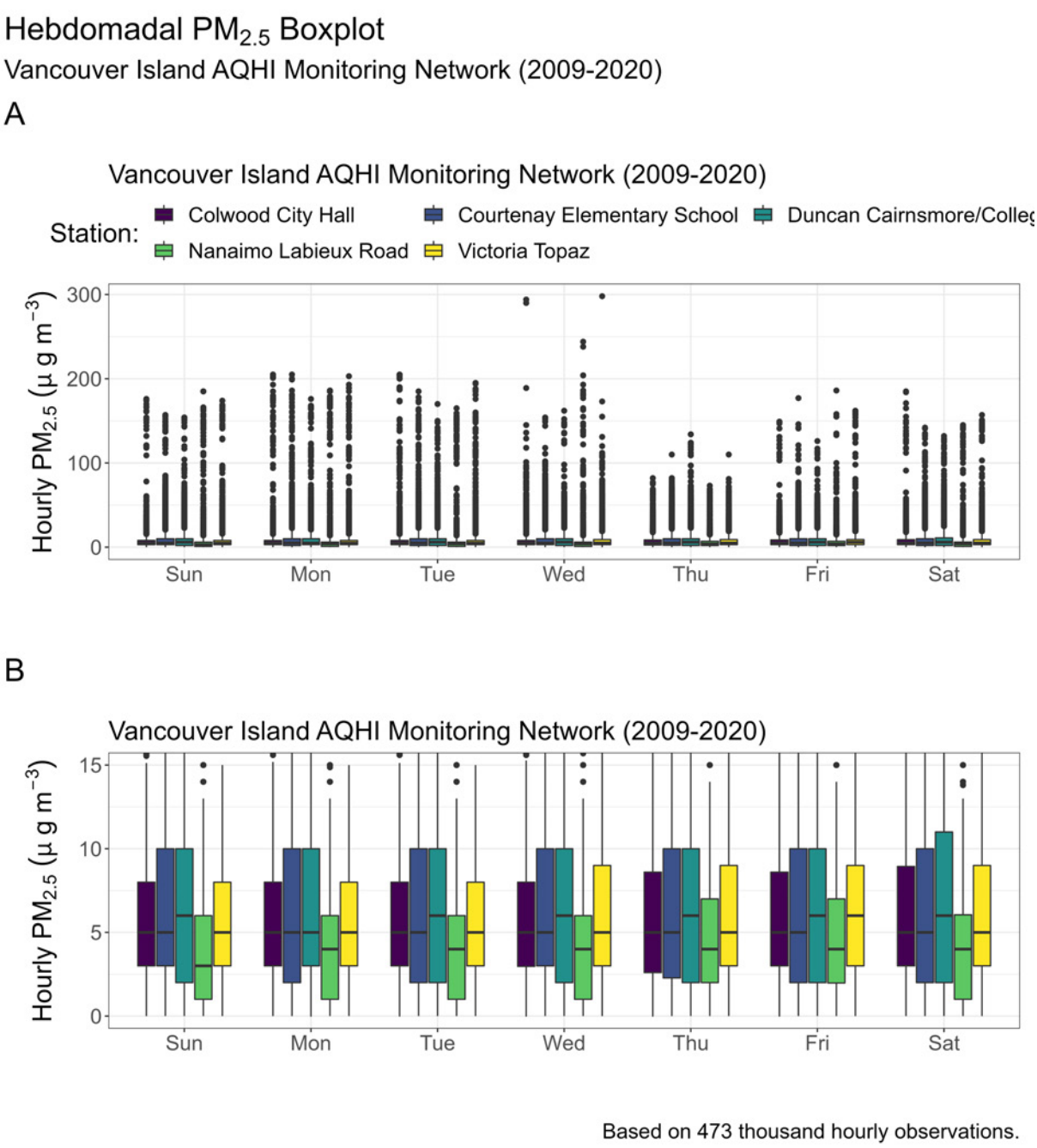


Figure C.16: Hebdomadal boxplot for $PM_{2.5}$.

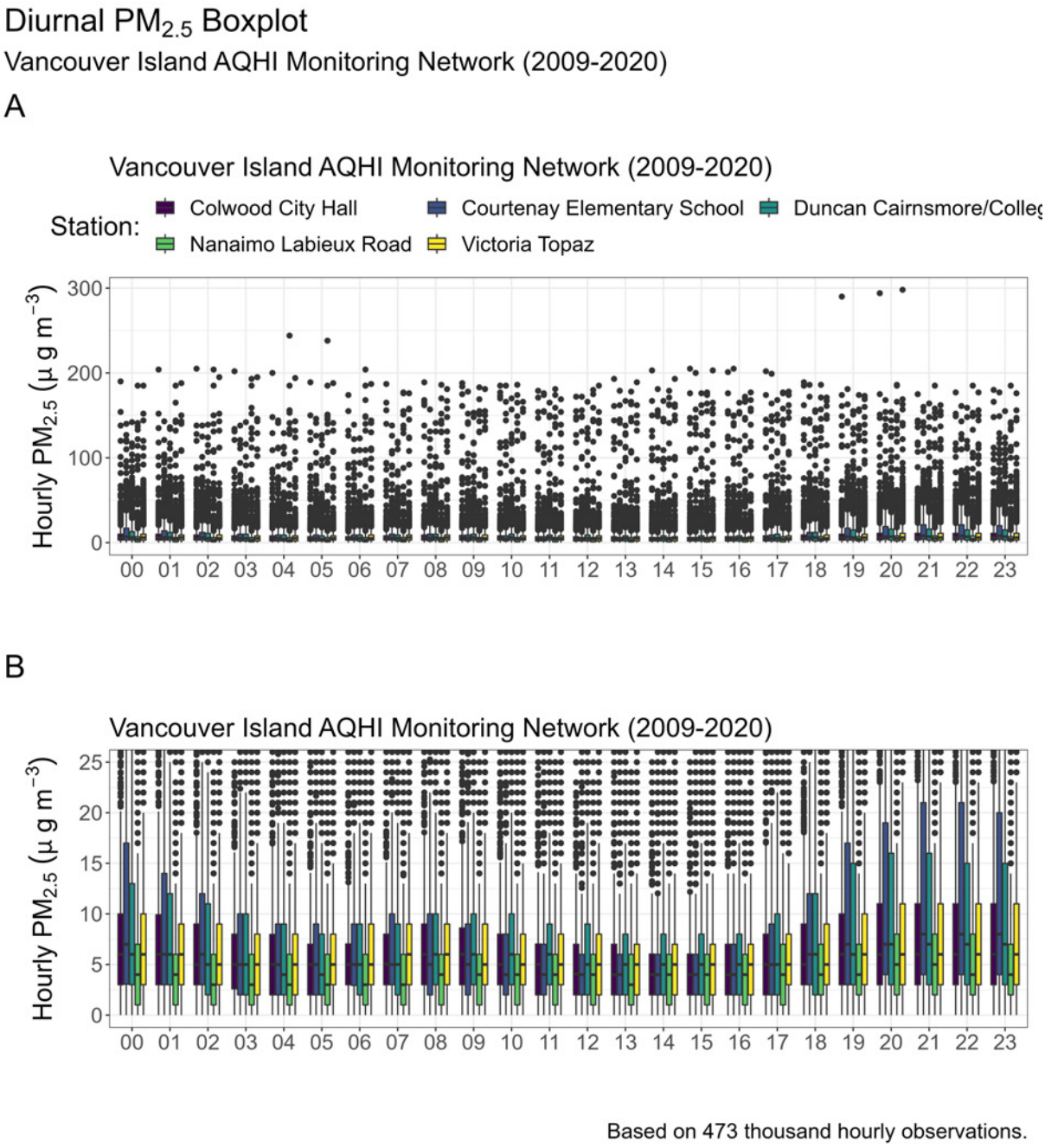


Figure C.17: Diurnal boxplot for $PM_{2.5}$.

C.4 Contaminant Profiles - Density Distributions

C.4.1 NO_2

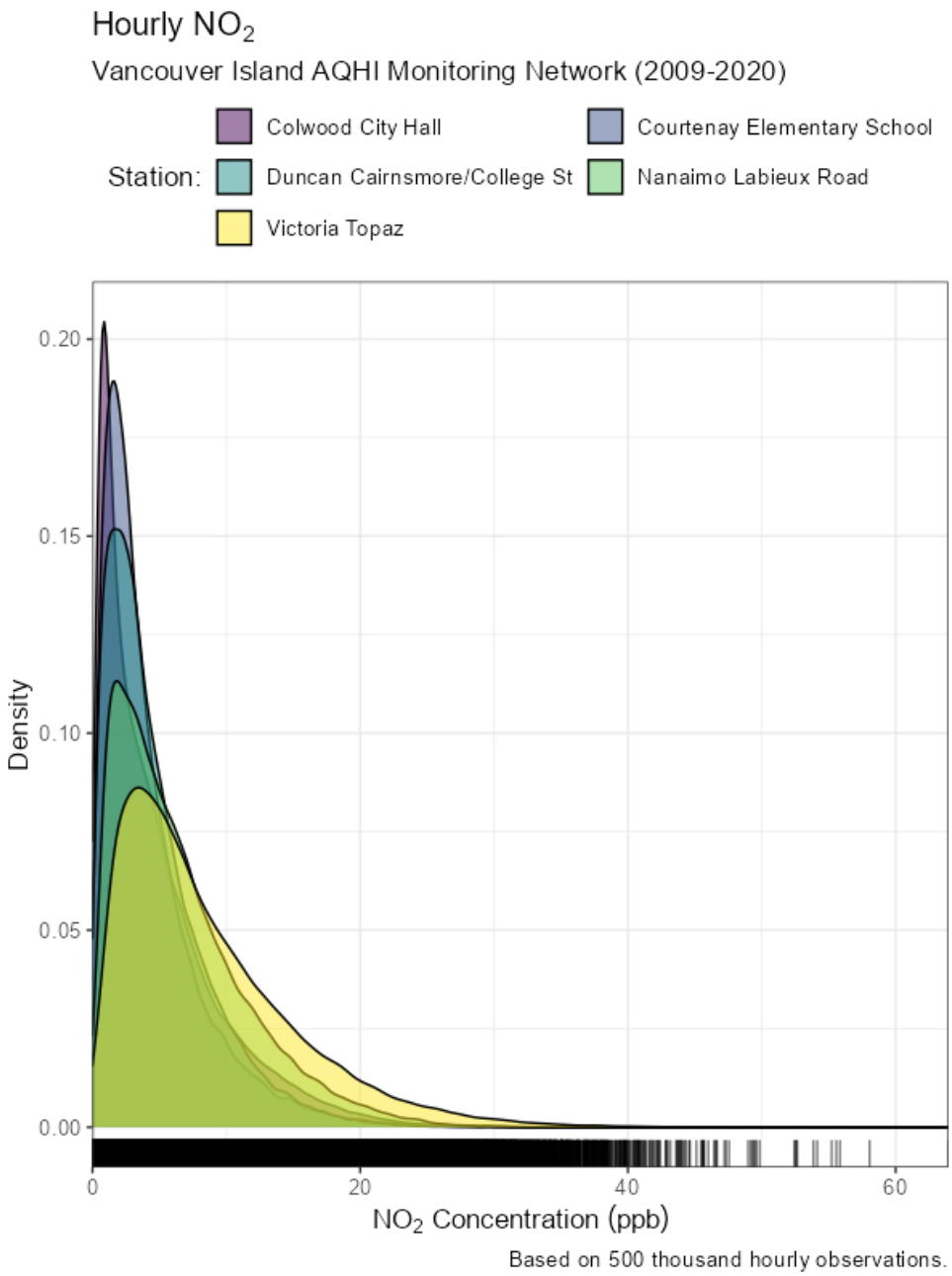


Figure C.18: Density plot of hourly NO_2 at AQHI stations on Vancouver Island (2009-2020).

C.4.2 O_3

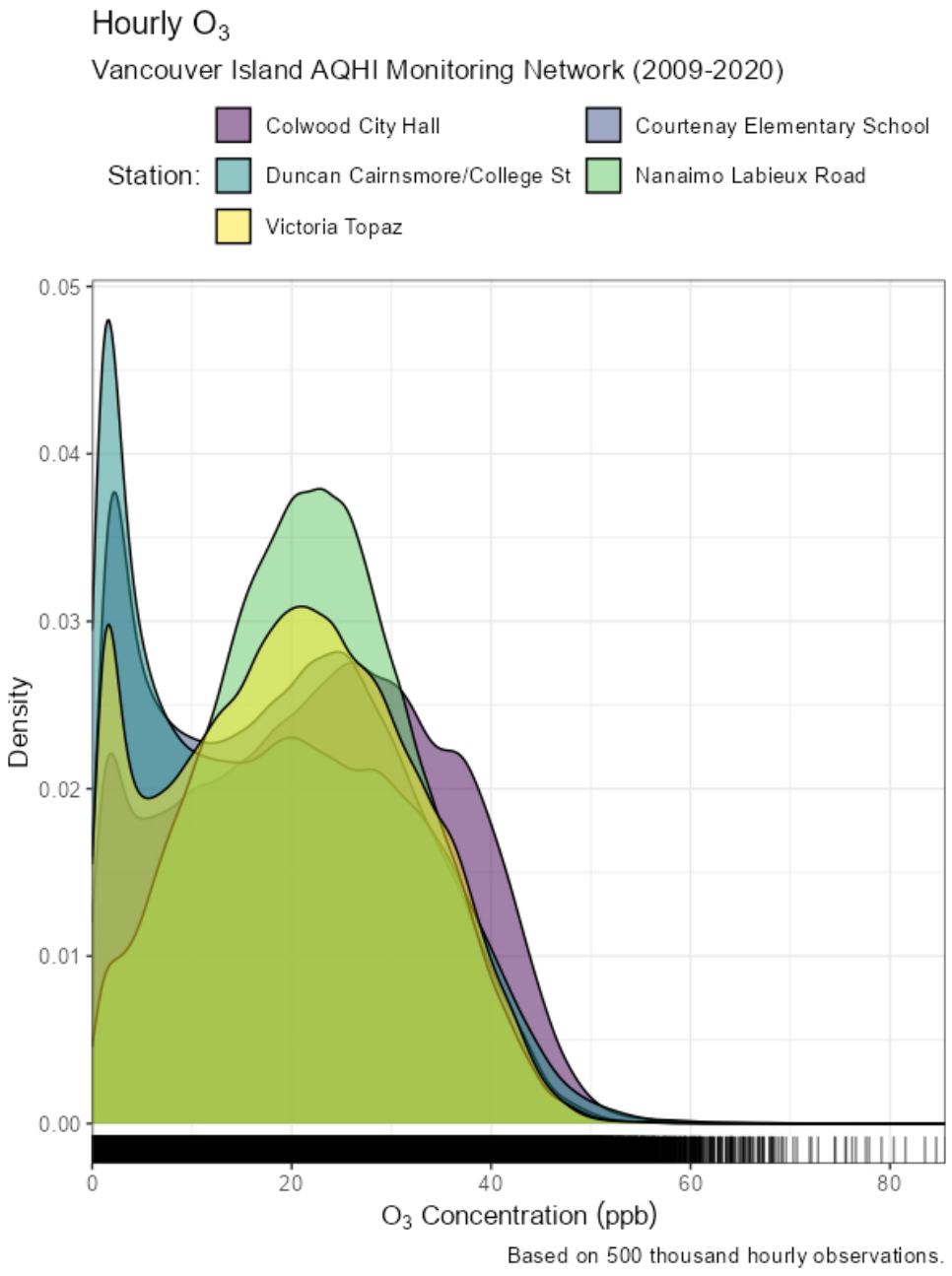


Figure C.19: Density plot of hourly O_3 at AQHI stations on Vancouver Island (2009-2020).

C.4.3 $PM_{2.5}$

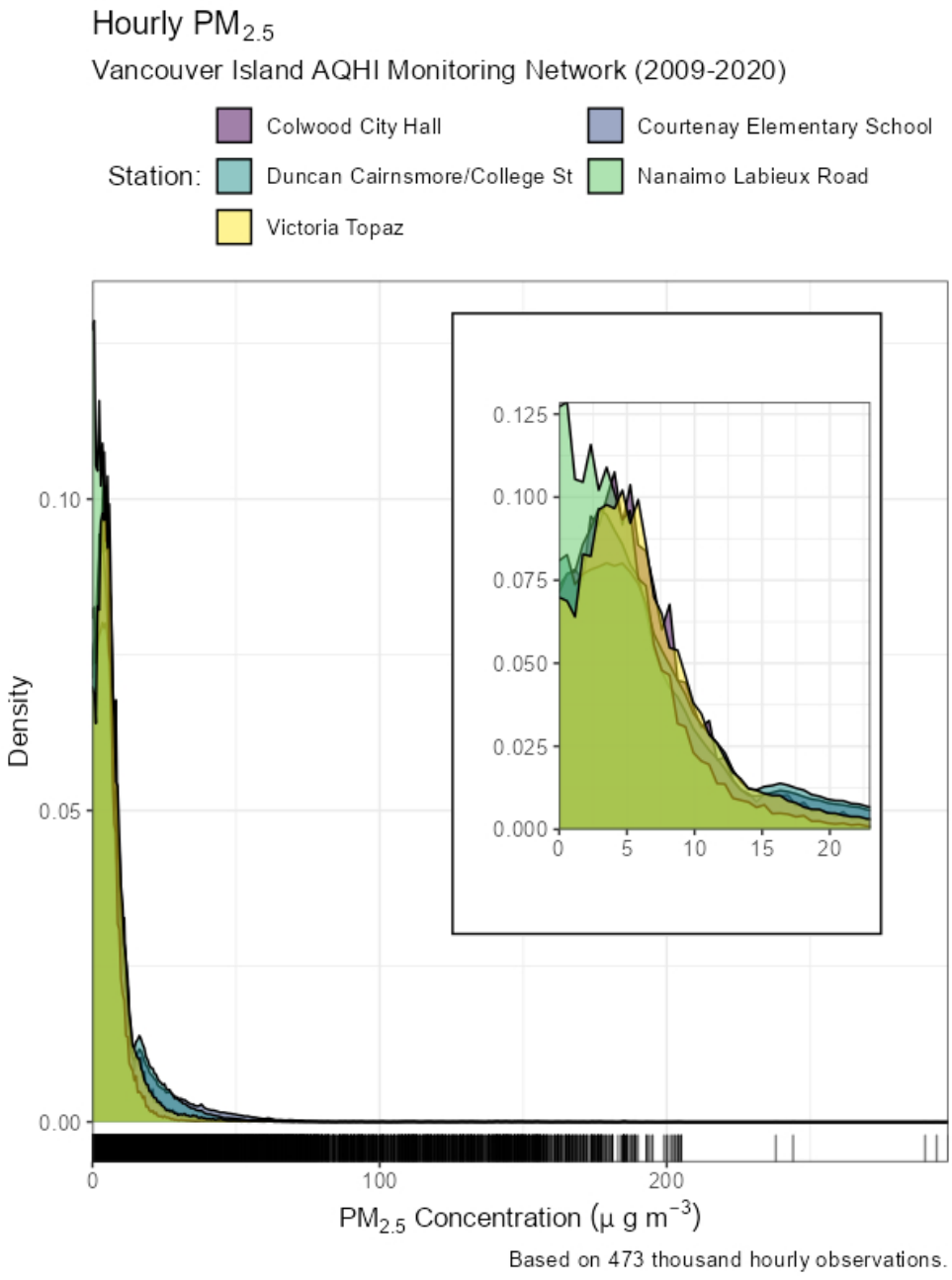


Figure C.20: Density plot of hourly $PM_{2.5}$ at AQHI stations on Vancouver Island (2009-2020).