Air Quality Report

Linc. Pkwy, Red Hill Pkwy. & Downtown Core
City of Hamilton, 2022-23

SUBMITTED TO:
CITY OF HAMILTON, TRANSPORTATION PLANNING

BY:
ECOSYSTEM INFORMATICS INC.

CONTENTS

ABOUT THIS REPORT

The 2022-23 report for City of Hamilton – Extended study area measurement program conducted by Ecosystem Informatics (ESI) analyzes gas concentration data collected by ground-level monitoring devices, as aggregated through ESI's air quality platform. By comparing gas concentration levels across all the measurement days of the study, ESI strives to understand and highlight a wide variety of insights to help improve our understanding of air quality and its impacts.

INTRODUCTION

About Ecosystem Informatics Inc. (ESI)

Ecosystem Informatics Inc. (ESI) has developed a next-generation air quality monitoring and measurement technology. ESI's core competencies include wide-ranging environmental studies with active involvement in air quality and pollution monitoring, modeling, and assessments. ESI's comprehensive system includes low-footprint units that can measure, in real-time, a large set of pollutants, ambient air quality and meteorological factors. In addition to this, ESI's integrated AI based calibration and visualization software augments the data collection capabilities, for detailed analysis, predictive modeling, and customized reporting. ESI's team has extensive technical and project management experience in design, commissioning, and operation of fixed and mobile air monitoring stations; and modeling based on EPA tools like MOVES, AERMOD and CAL3HQC.

ESI's technology

ESI's hardware forms the base of the company's next-generation air quality measurement platform and the underlying technology stack. The measuring device, with its modular design, can house multiple different combinations of sensors that measure gas concentration levels in ambient air. The technology aims to achieve a leap-forward from existing air quality measurement stations (both Government owned and private sector competitors) with its dramatically reduced size and an ability to measure data accurately in both stationary and mobile modes.

The accuracy and reliability of the measured data is ensured with the help of Artificial Intelligence (AI) based calibration that sets the technology apart. ESI's devices and other devices (Government stations and competitor devices) work in a fundamentally similar way -they all have sensors that measure pollutant concentrations, air quality etc. However, sensors lose accuracy over time due to several factors but not limited to micro vibrations in mechanical moving parts, changes in operating environment etc. This must be negated regularly during a sensors' operation and is usually done by calibrating and re-calibrating the sensors. To Calibrate is to standardize (something, such as a measuring instrument) by determining the deviation from a standard to ascertain the proper correction factors to ensure measured data is accurate and reliable.

The major differentiating factor between the ESI device and other devices is the AI based calibration which allows the ESI device to be of a smaller footprint, stationary and mobile next-generation hardware. With non-ESI devices, sensors are routinely calibrated under laboratory conditions against a reference atmosphere. This process involves specialized hardware that is resource heavy. During the day-to-day operation of the conventional, non-ESI, equipment, the sensors are stabilized through hardware to keep the environment around the sensor synthetically stable, that is to keep the temperature and relative humidity at the levels in which the sensors were calibrated to in the lab. This "stabilizing" hardware adds to the size and the cost of the equipment, which in turn adds to the power needed to operate as well as makes these devices bulky needing large platforms to deploy them on.

The ESI device sensors on the other hand, are initially calibrated to an accurate source. This could be:

- An existing calibrated and accurate device like a government measurement station.
- A reference atmosphere using a controlled chamber like the method used by non-ESI devices.

The difference with ESI devices however is that the sensors are then continuously calibrated with software, i.e., the hardware used in non-ESI equipment that is used to stabilize the sensors is replaced by ESI's preparatory Artificial Intelligence (AI) algorithms. The underlying AI algorithms built by ESI can detect variations in the sensors over time, and operating environment factors like temperature, humidity, Atmospheric pressure etc. and negate the impact these variations have on the sensor readings, thereby ensuring accuracy. Sensors are recalibrated with an accurate source periodically to further ensure accuracy. This allows ESI's operation to be less demanding of resource-heavy and expensive calibration process that is required with other devices.

STUDY AREA & DATA COLLECTION

As outlined in our proposal, Ecosystem Informatics Inc. (ESI) has conducted 6 total scans; Phase 1 in Fall-Winter 2022 and Phase 2 in Spring 2023 within the agreed upon driving routes (as per image above).

Mobile monitoring units placed on ESI vehicles conducted scans along the determined route on 6 different days. The data was processed for calibration and accuracy to create charts, geographic maps, and other visualizations of emissions climate factors over the AOI. This report outlines the details of the environmental conditions, gas concentration data and other insights.

Note for Mobile scan data: The gas concentration metrics measured by ESI do not reflect the daily average numbers. The numbers are with respect to our scans which last a few hours during a single day. The numbers reflect the ambient air concentration of the respective gases for the hours during which the scan was conducted, and don’t reflect the whole day. It is also to be noted that on each scan, there were differences in the weather conditions and the traffic conditions. With respect to placement of the measurement device, it was mounted onto the car and done so at a point on the roof rails with the best chances to pick up only ambient air and not that car emissions for measurement.

AMBIENT AIR QUALITY STANDARDS

Canada Ambient Air Quality Standards (CAAQS)

Source: https://ccme.ca/en/air-quality-report

Canadian Council of Ministers for Environment (CCME)-the primary minister-led intergovernmental forum for collective action on environmental issues of national and international concern-developed Canadian Ambient Air Quality Standards (CAAQS) for PM2.5, O3, SO2 and NO2.

All CAAQS consist of three interrelated elements:
- an averaging time period
- a numerical value
- the statistical form of the numerical standard.

CAAQS are supported by four color-coded management levels. Each management level is determined by the amount of a pollutant within an air zone and provides recommended air quality management actions. If the amount of a pollutant within an air zone increases, the management actions become more stringent. This helps ensure that CAAQS are not treated as polluted-up-to levels and actions will be taken to keep clean areas clean.
When determining the CAAQS management levels, provinces and territories can consider the influence of human activities originating outside of the province or territory and of exceptional events such as forest fires

Pollutant	Averaging Time	Numerical Value		Statistical Form
		2020	2025	
Sulphur Dioxide (SO2)	1-hour	70 ppb	65 ppb	The 3-year average of the annual 99th percentile of the SO2 daily maximum 1-hour average concentrations.
	Annual	5.0 ppb	4.0 ppb	The average over a single calendar year of all 1-hour average SO2 concentrations.
Nitrogen Dioxide (NO2)	1-hour	60 ppb	42 ppb	The 3-year average of the annual 98th percentile of the daily maximum 1-hour average concentrations.
	Annual	17.0 ppb	12.0 ppb	The average over a single calendar year of all 1-hour average concentrations.

Air quality management levels	Management Levels for the Ozone CAAQS (parts per billion)		Management Levels for the 1-hour Sulphur Dioxide CAAQS (parts per billion)		Management Levels for the Annual Sulphur Dioxide CAAQS (parts per billion)		Management Levels for the 1-hour Nitrogen Dioxide CAAQS (parts per billion)		Management Levels for the Annual Nitrogen Dioxide CAAQS (parts per billion)	
	2020	2025	2020	2025	2020	2025	2020	2025	2020	2025
Red	>62	>60	>70	>65	>5.0	>4.0	>60	>42	>17.0	>12.0
Orange	57 to 62	57 to 60	51 to 70	51 to 65	3.1 to 5.0	3.1 to 4.0	32 to 60	32 to 42	7.1 to 17.0	7.1 to 12.0
Yellow	51 to 56		31 to 50		2.1 to 3.0		21 to 31		2.1 to 7.0	
Green	≤50		≤30		≤2.0		≤20		≤2.0	

Ontario Ambient Air Quality criteria

The below table shows the Ontario 1-hour Ambient Air Quality Criterion (AAQC) for the gases that were scanned.
From: https://www.ontario.ca/page/ontarios-ambient-air-quality-criteria
An AAQC is not a regulatory value. It is the concentration of a contaminant in air that is protective against adverse effects on health and/or the environment. AAQCs are used to assess general (ambient) air quality resulting from all sources of a contaminant to air. AAQCs are most used in environmental assessments, special studies using ambient air monitoring data, assessment of general air quality in a community and annual reporting on air quality across the province.
Since AAQCs are based on a review of scientific information about the effects of contaminants on health and the environment, they may be modified from time to time based on new or relevant scientific information

Gas	Averaging Time	AAQC criteria (PPB)
Carbon Monoxide (CO)	1-hour	30000
Nitrogen Dioxide (NO2)	1-hour	200
Ozone (O3)	1-hour	80
Sulphur Dioxide (SO2)	1-hour	40

FOR EASE OF HAVING A BENCHMARK TO COMPARE AGAINST AND TO HAVE A DIRECTIONAL SENSE OF THE TRENDS IN AMBIENT AIR MEASURED POLLUTANTS, IN THIS REPORT, WE HAVE USED THE COLOR SCALING ACCORDING TO THE SO2 (ANNUAL) AND NO2 (ANNUAL) SCALE AND THE O3(8 HOUR) SCALE. FOR CO, WE USED THE ONTARIO AMBIENT AIR QUALITY CRITERIA.

SCAN DATA AND INSIGHTS

INFLUENCING FACTORS

Given the nature of this project, below are some factors that can potentially influence changes in ambient air quality:

- **Seasonal Weather Changes:** Variations in temperature, wind patterns, and precipitation can influence pollutant dispersion and concentration.
- **Vegetation:** Spring growth can absorb pollutants but also release allergenic pollens.
- **Human Activities:** Increased construction, outdoor events, or agricultural activities in spring can affect air quality. Lower energy consumption for heating can also reduce overall emissions.
- **Change in Traffic Flow:** The planned diversion of trucks can decrease emissions in the city center but potentially increase them on the outskirts.
- **Change in Industrial Activities:** Variations in industrial activity can alter pollutant levels.

FINDINGS

- There was a significant increase in the ambient SO2 levels recorded in phase 2 when compared to phase 1 across the entire route. (This led to a different investigation on SO2 spikes in the city of Hamilton that was done by ESI and shared in a separate forum with relevant teams. The details of that report are out of scope in this report.)
- NO2, CO and O3 and PM had relatively similar hourly average levels in both phase 1 and phase 2.
- There is a noticeable spatial shift in locations with higher concentration levels of CO and O3 towards Red Hill Pkwy and Linc Pkwy in phase 2 when compared to phase 1.
- In both phase 1 and phase 2, NO2 concentration consistently measured above the CAAQS Green zone.
- There is spatial increase in the concentration of NO2 towards the west of the city from phase 1 to phase 2.
- Spatial locations closer to the Port and Bay Front Industrial Areas showed an increase in measured levels of PM 2.5 and PM10 in phase 2.

SCAN DATA AND INSIGHTS

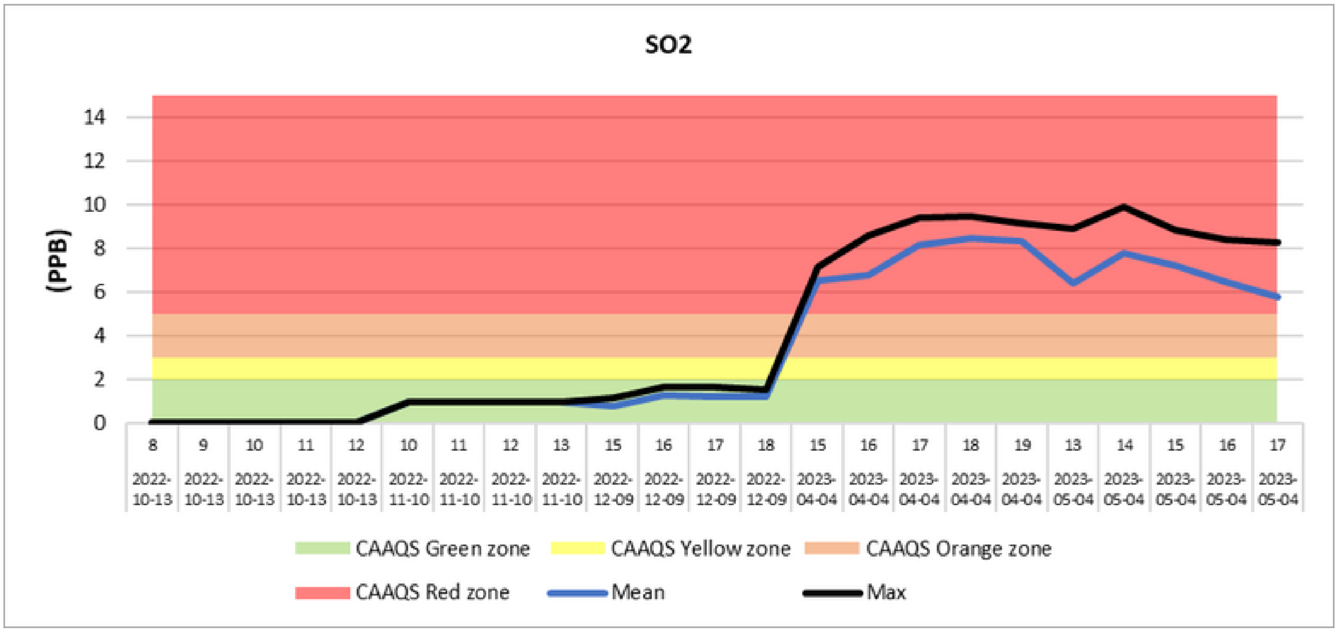
RECOMMENDATIONS

- There is a noted spatial variation in the concentration of CO over phase 2 versus phase 1 (given that transportation is one of the major contributors of CO) suggesting that the change in truck routes is showing positive results.
- The current results weigh towards being more directional, and more data is required to support the analytics further.
- Data needs to be collected at a higher frequency covering several scenarios to factor in the noise from influencing factors at a higher detail to gather more detailed results and insights.

THE FOLLOWING PAGES CONTAIN DETAILS AROUND BASIC STATISTICS AND VISUALIZATIONS ON THE GAS CONCENTRATIONS DURING THE MEASUREMENT SCANS ALONG THE FIXED ROUTES. THE SECTION DEALS WITH THE 6 MEASURED POLLUTANTS (SO_2, CO, NO_2 AND O_3, $PM_{2.5}$ AND PM_{10}).

POLLUTANT: SULPHUR DIOXIDE (SO2)

TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS



TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS (TABULATED)

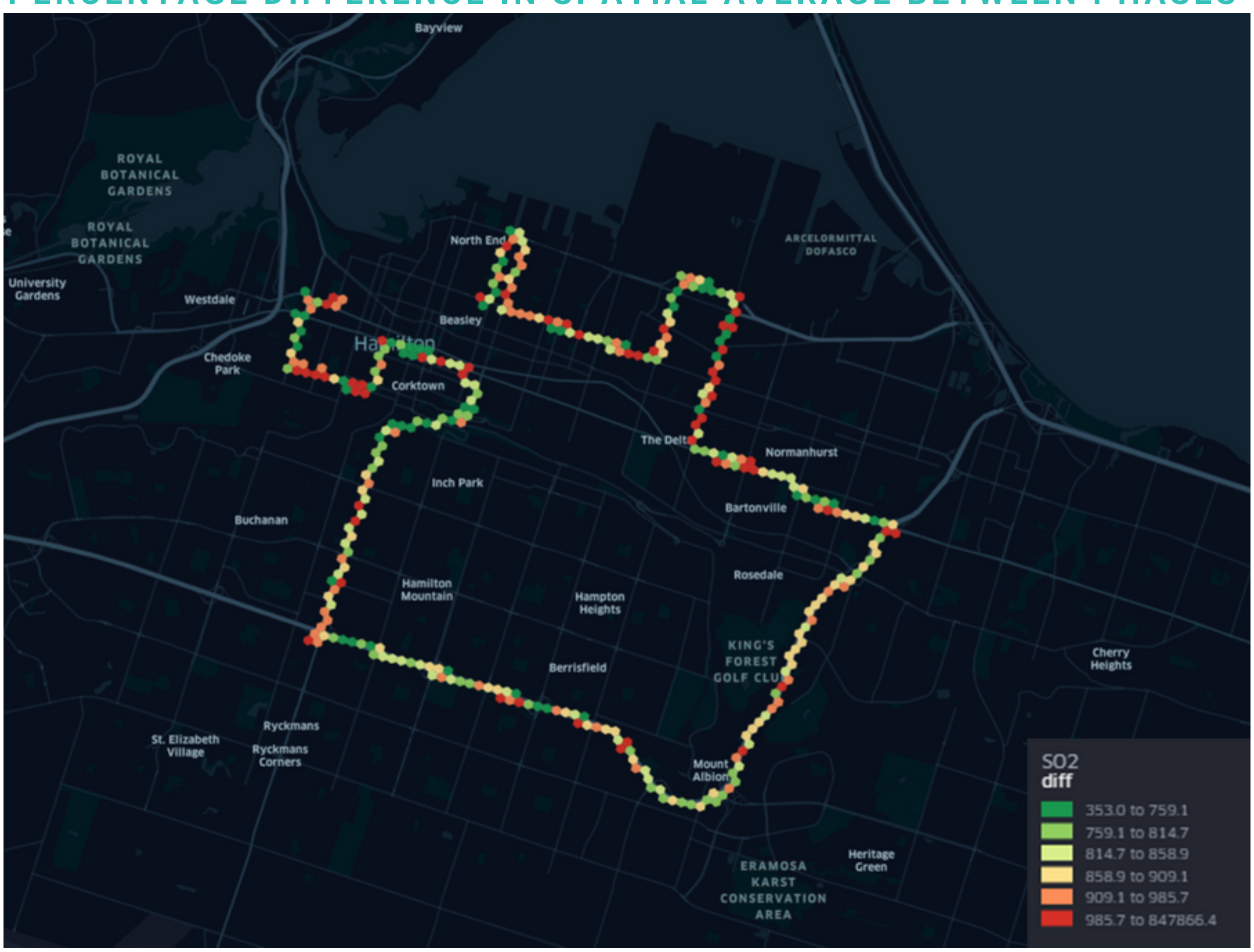
DATE	HOUR OF DAY	MEAN	MEDIAN	STD.DEV	MAX	MIN	CAAQS GREEN ZONE	CAAQS YELLOW ZONE	CAAQS ORANGE ZONE	CAAQS RED ZONE
2022-10-13	8	0.00	0.00	0.00	0.02	0.00	<=2	2.1-3	3.1-5	>5
2022-10-13	9	0.00	0.00	0.00	0.01	0.00	<=2	2.1-3	3.1-5	>5
2022-10-13	10	0.00	0.00	0.00	0.01	0.00	<=2	2.1-3	3.1-5	>5
2022-10-13	11	0.01	0.01	0.00	0.01	0.00	<=2	2.1-3	3.1-5	>5
2022-10-13	12	0.01	0.01	0.00	0.01	0.00	<=2	2.1-3	3.1-5	>5
2022-11-10	10	1.00	1.00	0.00	1.00	0.99	<=2	2.1-3	3.1-5	>5
2022-11-10	11	1.00	1.00	0.00	1.00	1.00	<=2	2.1-3	3.1-5	>5
2022-11-10	12	1.00	1.00	0.00	1.00	1.00	<=2	2.1-3	3.1-5	>5
2022-11-10	13	1.00	1.00	0.00	1.00	1.00	<=2	2.1-3	3.1-5	>5
2022-12-09	16	0.81	0.77	0.15	1.19	0.47	<=2	2.1-3	3.1-5	>5
2022-12-09	17	1.29	1.32	0.16	1.69	0.66	<=2	2.1-3	3.1-5	>5
2022-12-09	18	1.25	1.28	0.18	1.64	0.78	<=2	2.1-3	3.1-5	>5
2022-12-09	15	1.21	1.21	0.09	1.56	0.97	<=2	2.1-3	3.1-5	>5
2023-04-04	15	6.56	6.75	0.64	7.14	4.70	<=2	2.1-3	3.1-5	>5
2023-04-04	16	6.79	6.67	0.83	8.63	5.09	<=2	2.1-3	3.1-5	>5
2023-04-04	17	8.17	8.19	0.66	9.42	6.70	<=2	2.1-3	3.1-5	>5
2023-04-04	18	8.49	8.53	0.54	9.50	6.94	<=2	2.1-3	3.1-5	>5
2023-04-04	19	8.36	8.57	0.61	9.14	6.58	<=2	2.1-3	3.1-5	>5
2023-05-04	13	6.40	6.60	1.30	8.88	0.87	<=2	2.1-3	3.1-5	>5
2023-05-04	14	7.80	7.77	0.80	9.90	5.53	<=2	2.1-3	3.1-5	>5
2023-05-04	15	7.26	7.38	0.76	8.84	5.06	<=2	2.1-3	3.1-5	>5
2023-05-04	16	6.45	6.73	1.15	8.41	3.31	<=2	2.1-3	3.1-5	>5
2023-05-04	17	5.76	5.75	1.70	8.27	1.39	<=2	2.1-3	3.1-5	>5

POLLUTANT: SULPHUR DIOXIDE (SO2)

SPATIAL AVERAGE OF POLLUTANT OVER PHASES

PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

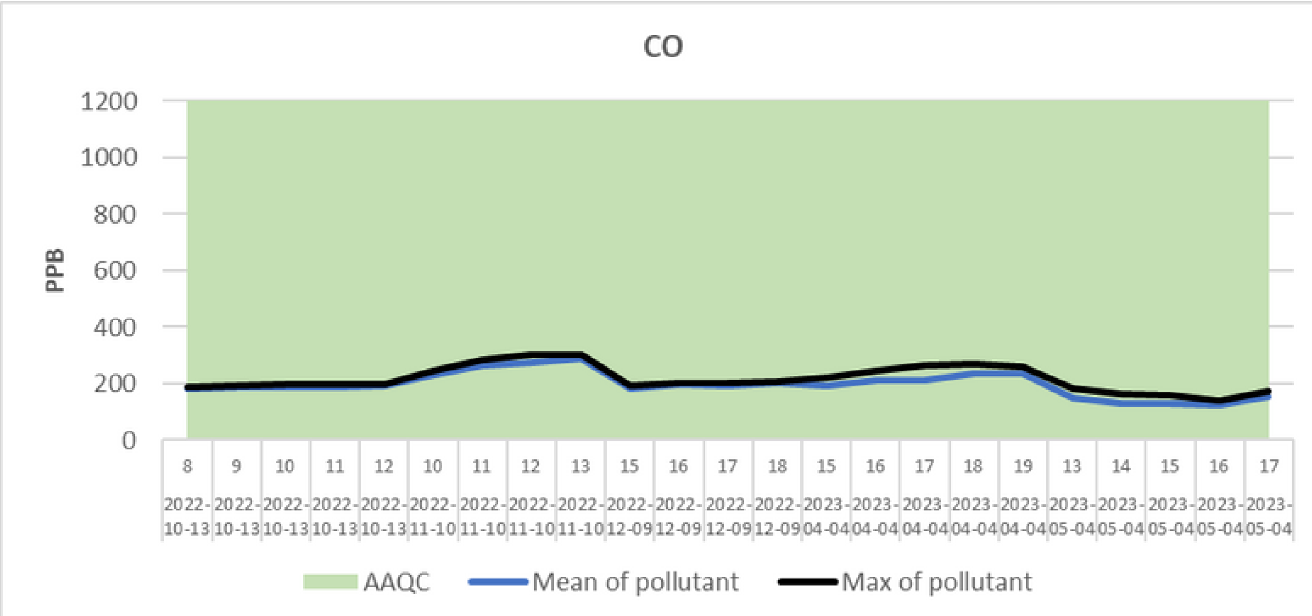
PERCENTAGE DIFFERENCE IN SPATIAL AVERAGE BETWEEN PHASES



PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

POLLUTANT: CARBON MONOXIDE (CO)

TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS



TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS (TABULATED)

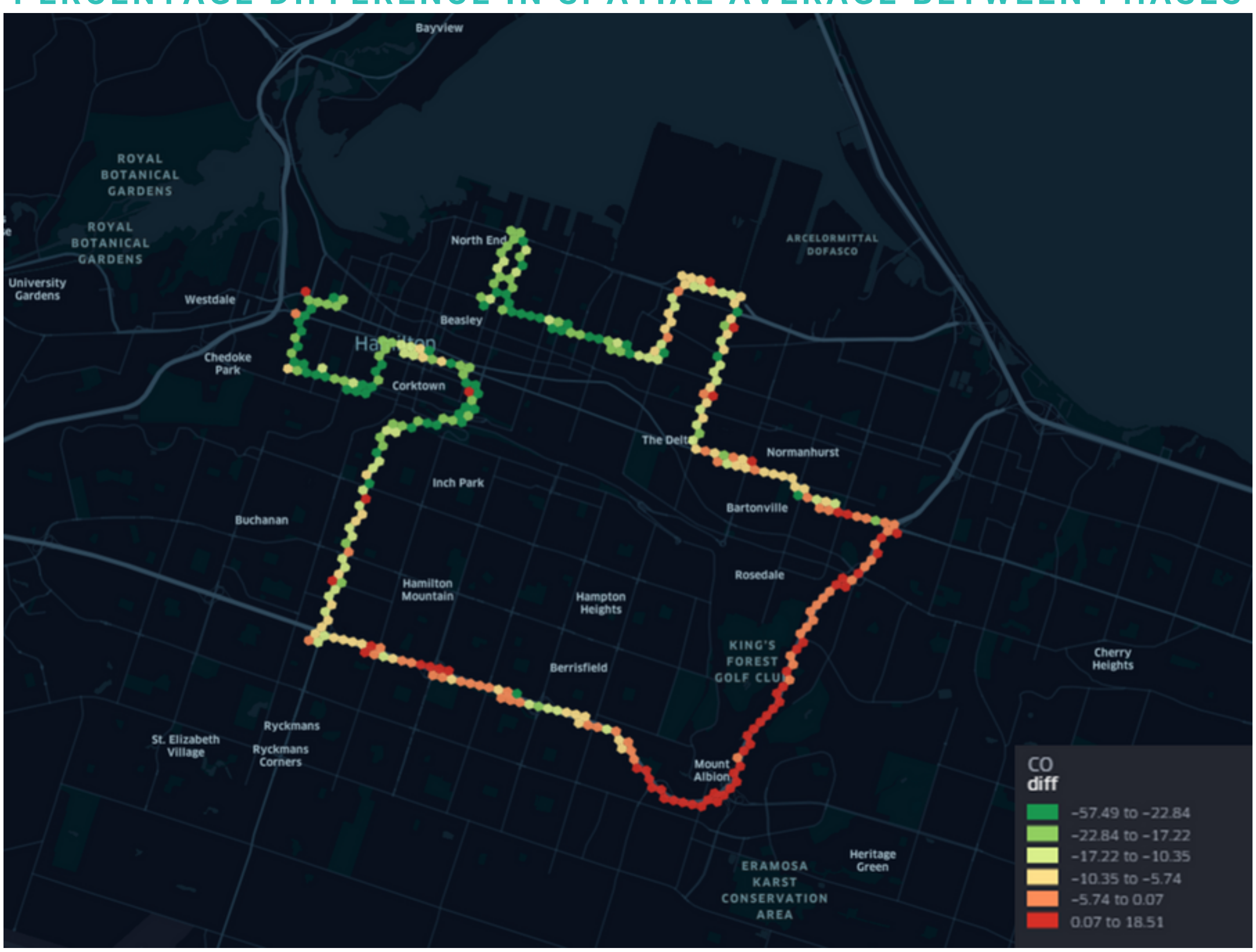
DATE	HOUR OF DAY	MEAN	MEDIAN	STD.DEV	MAX	MIN	AAQC GREEN ZONE
2022-10-13	8	182	183	3	186	176	30000
2022-10-13	9	186	186	4	193	177	30000
2022-10-13	10	187	187	4	195	179	30000
2022-10-13	11	187	188	4	195	178	30000
2022-10-13	12	194	195	2	199	190	30000
2022-11-10	10	231	232	7	245	216	30000
2022-11-10	11	264	265	14	286	235	30000
2022-11-10	12	275	275	15	301	240	30000
2022-11-10	13	290	293	11	305	264	30000
2022-12-09	15	182	181	5	194	170	30000
2022-12-09	16	197	199	4	204	180	30000
2022-12-09	17	194	195	7	203	180	30000
2022-12-09	18	200	200	3	205	192	30000
2023-04-04	15	193	196	11	222	176	30000
2023-04-04	16	212	215	20	246	163	30000
2023-04-04	17	214	212	15	265	188	30000
2023-04-04	18	236	236	13	272	215	30000
2023-04-04	19	237	236	11	258	218	30000
2023-05-04	13	148	147	18	182	100	30000
2023-05-04	14	129	127	16	164	100	30000
2023-05-04	15	128	128	15	158	102	30000
2023-05-04	16	125	128	10	140	101	30000
2023-05-04	17	152	160	17	174	120	30000

POLLUTANT: CARBON MONOXIDE (CO)

SPATIAL AVERAGE OF POLLUTANT OVER PHASES

PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

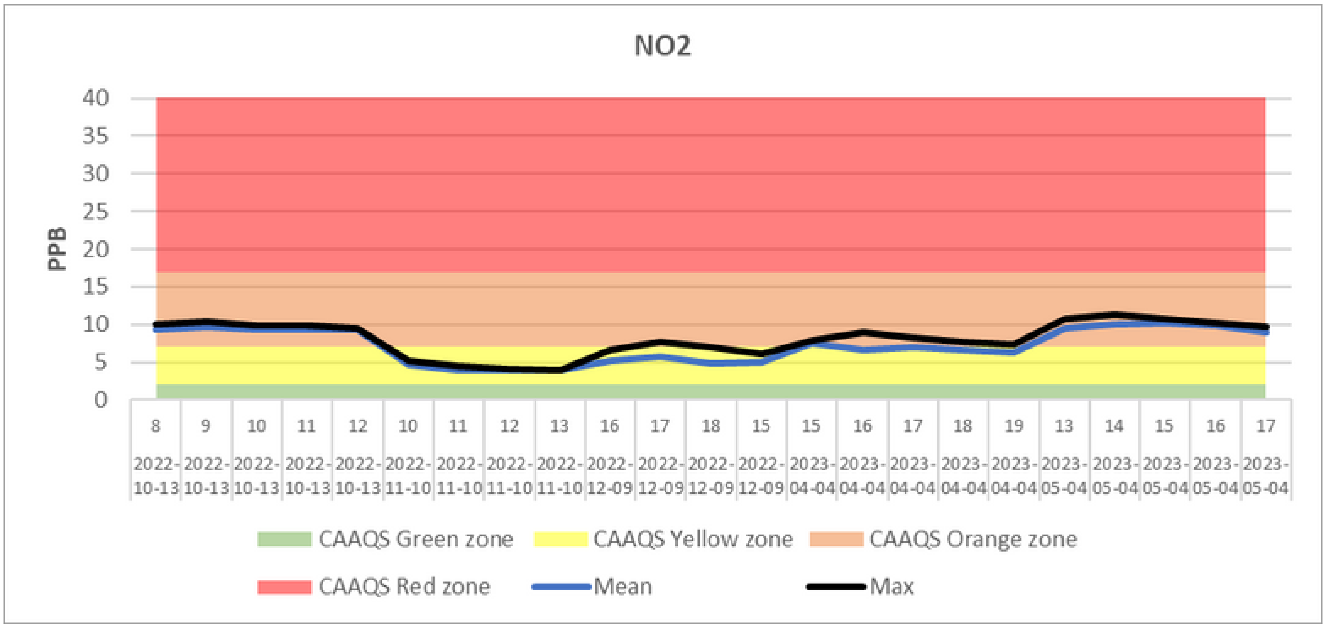
PERCENTAGE DIFFERENCE IN SPATIAL AVERAGE BETWEEN PHASES



PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

POLLUTANT: NITROGEN DIOXIDE (NO2)

TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS

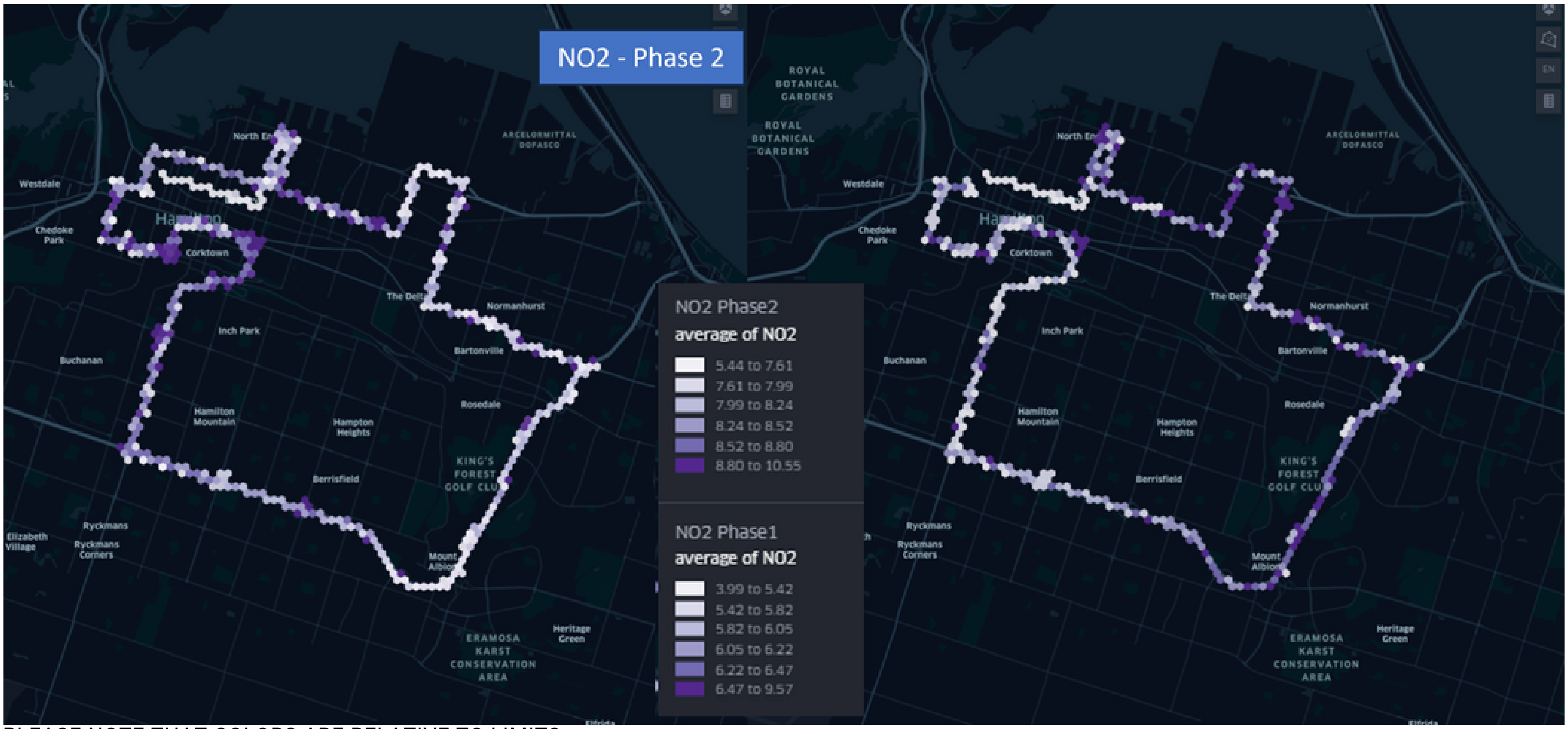


TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS (TABULATED)

DATE	HOUR OF DAY	MEAN	MEDIAN	STD.DEV	MAX	MIN	CAAQS GREEN ZONE	CAAQS YELLOW ZONE	CAAQS ORANGE ZONE	CAAQS RED ZONE
2022-10-13	8	9.3	9.2	0.3	10.1	8.9	<=2	2.1-7	7.1-17	>17
2022-10-13	9	9.6	9.6	0.3	10.3	8.9	<=2	2.1-7	7.1-17	>17
2022-10-13	10	9.3	9.4	0.2	9.8	8.5	<=2	2.1-7	7.1-17	>17
2022-10-13	11	9.4	9.5	0.3	9.8	8.6	<=2	2.1-7	7.1-17	>17
2022-10-13	12	9.3	9.3	0.2	9.6	8.9	<=2	2.1-7	7.1-17	>17
2022-11-10	10	4.7	4.6	0.2	5.1	4.1	<=2	2.1-7	7.1-17	>17
2022-11-10	11	4.0	4.0	0.1	4.4	4.0	<=2	2.1-7	7.1-17	>17
2022-11-10	12	4.0	4.0	0.0	4.2	4.0	<=2	2.1-7	7.1-17	>17
2022-11-10	13	4.0	4.0	0.0	4.0	4.0	<=2	2.1-7	7.1-17	>17
2022-12-09	16	5.1	5.1	0.4	6.6	4.2	<=2	2.1-7	7.1-17	>17
2022-12-09	17	5.8	5.8	0.8	7.6	4.2	<=2	2.1-7	7.1-17	>17
2022-12-09	18	4.8	5.0	0.6	7.0	4.2	<=2	2.1-7	7.1-17	>17
2022-12-09	15	4.9	5.0	0.6	6.1	4.2	<=2	2.1-7	7.1-17	>17
2023-04-04	15	7.5	7.5	0.3	7.8	6.5	<=2	2.1-7	7.1-17	>17
2023-04-04	16	6.7	6.7	1.0	8.9	4.7	<=2	2.1-7	7.1-17	>17
2023-04-04	17	7.1	7.0	0.4	8.2	6.3	<=2	2.1-7	7.1-17	>17
2023-04-04	18	6.7	6.6	0.5	7.8	5.4	<=2	2.1-7	7.1-17	>17
2023-04-04	19	6.4	6.3	0.5	7.4	5.1	<=2	2.1-7	7.1-17	>17
2023-05-04	13	9.5	9.5	0.4	10.8	8.0	<=2	2.1-7	7.1-17	>17
2023-05-04	14	10.1	10.0	0.4	11.3	9.5	<=2	2.1-7	7.1-17	>17
2023-05-04	15	10.2	10.1	0.3	10.8	9.4	<=2	2.1-7	7.1-17	>17
2023-05-04	16	9.9	9.9	0.2	10.3	9.4	<=2	2.1-7	7.1-17	>17
2023-05-04	17	9.0	9.0	0.3	9.6	8.5	<=2	2.1-7	7.1-17	>17

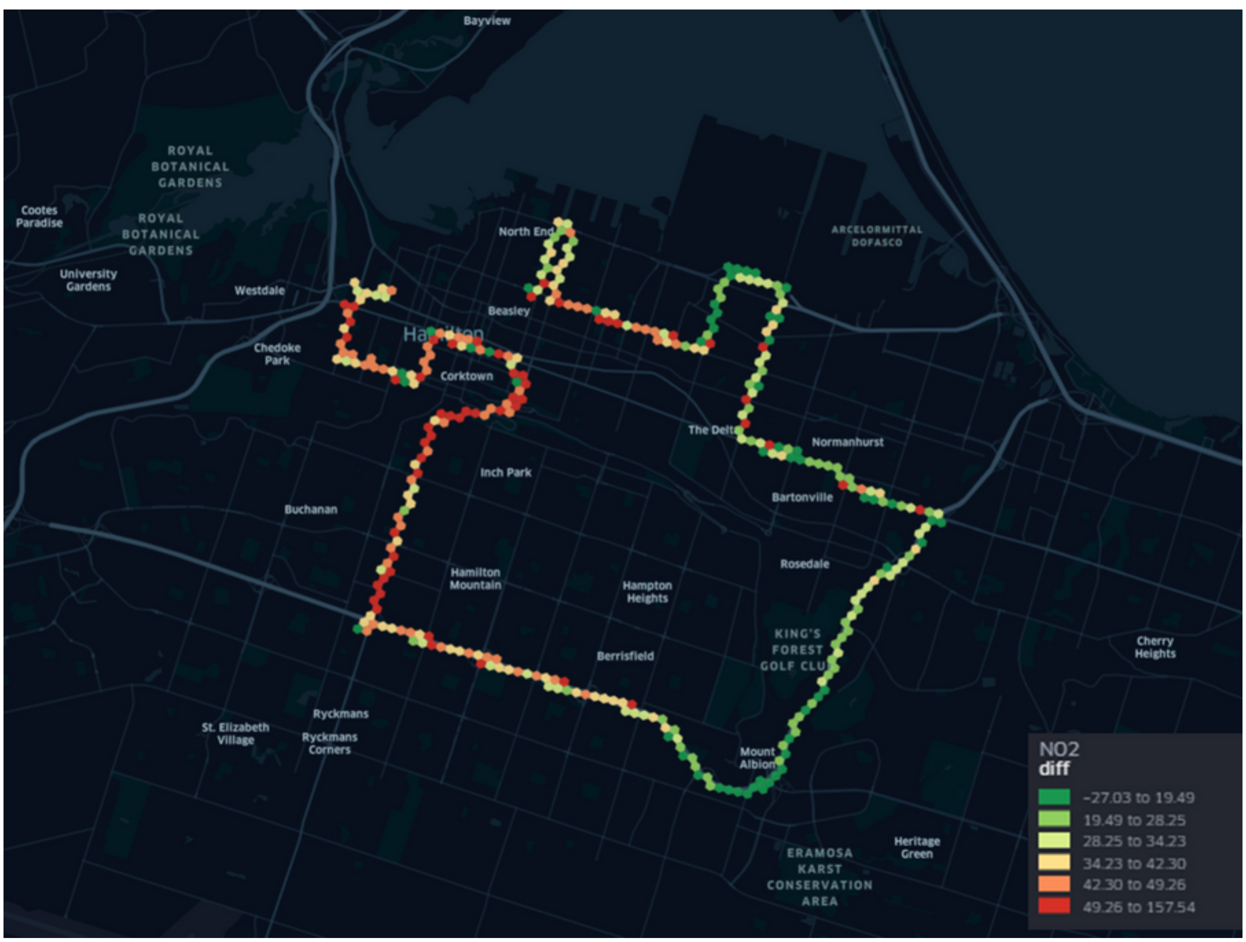
POLLUTANT: NITROGEN DIOXIDE (NO2)

SPATIAL AVERAGE OF POLLUTANT OVER PHASES



PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

PERCENTAGE DIFFERENCE IN SPATIAL AVERAGE BETWEEN PHASES



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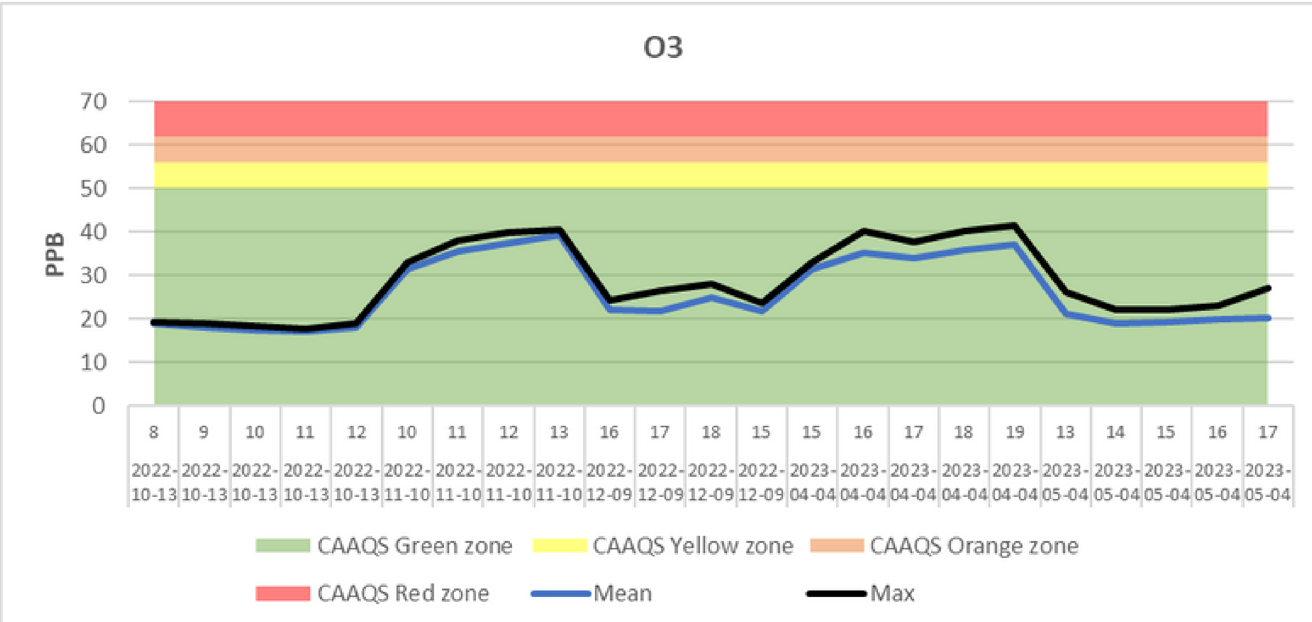
POLLUTANT: OZONE (O3)

TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS



TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS (TABULATED)

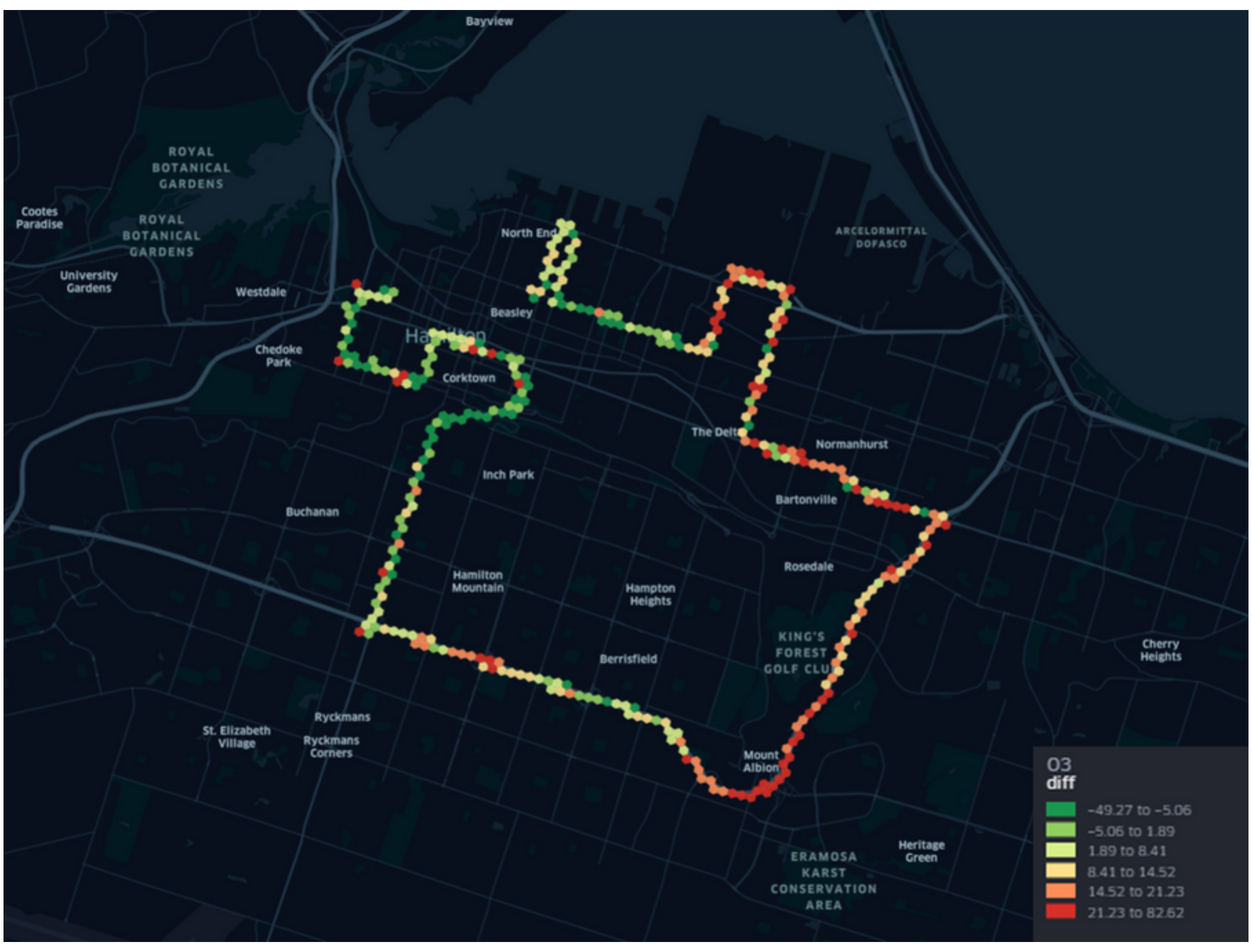
DATE	HOUR OF DAY	MEAN	MEDIAN	STD.DEV	MAX	MIN	CAAQS GREEN ZONE	CAAQS YELLOW ZONE	CAAQS ORANGE ZONE	CAAQS RED ZONE
2022-10-13	8	19.1	19.1	0.1	19.3	18.7	<=50	50-56	57-62	>62
2022-10-13	9	18.1	18.1	0.4	19.1	17.4	<=50	50-56	57-62	>62
2022-10-13	10	17.3	17.1	0.4	18.4	17.1	<=50	50-56	57-62	>62
2022-10-13	11	17.2	17.1	0.2	17.8	17.1	<=50	50-56	57-62	>62
2022-10-13	12	17.9	17.9	0.2	18.9	17.6	<=50	50-56	57-62	>62
2022-11-10	10	31.5	31.4	0.6	32.9	30.2	<=50	50-56	57-62	>62
2022-11-10	11	35.5	35.8	1.3	37.9	32.1	<=50	50-56	57-62	>62
2022-11-10	12	37.5	37.5	1.1	39.8	34.0	<=50	50-56	57-62	>62
2022-11-10	13	39.4	39.6	0.7	40.6	37.8	<=50	50-56	57-62	>62
2022-12-09	16	22.0	22.1	0.8	24.2	20.2	<=50	50-56	57-62	>62
2022-12-09	17	21.8	21.5	1.1	26.4	20.1	<=50	50-56	57-62	>62
2022-12-09	18	25.0	25.0	0.8	27.9	23.1	<=50	50-56	57-62	>62
2022-12-09	15	21.7	21.6	0.8	23.6	20.7	<=50	50-56	57-62	>62
2023-04-04	15	31.4	31.6	1.1	33.0	26.5	<=50	50-56	57-62	>62
2023-04-04	16	35.1	35.9	3.6	40.4	28.0	<=50	50-56	57-62	>62
2023-04-04	17	34.1	34.2	1.7	37.8	29.9	<=50	50-56	57-62	>62
2023-04-04	18	35.8	36.3	2.0	40.3	32.4	<=50	50-56	57-62	>62
2023-04-04	19	37.1	37.5	1.7	41.5	33.6	<=50	50-56	57-62	>62
2023-05-04	13	21.1	21.0	2.3	26.1	17.1	<=50	50-56	57-62	>62
2023-05-04	14	19.1	19.2	1.2	22.0	16.2	<=50	50-56	57-62	>62
2023-05-04	15	19.3	19.6	1.0	22.1	16.9	<=50	50-56	57-62	>62
2023-05-04	16	20.0	19.1	1.5	23.2	17.5	<=50	50-56	57-62	>62
2023-05-04	17	20.3	19.9	3.6	27.2	13.9	<=50	50-56	57-62	>62

POLLUTANT: OZONE (O3)

SPATIAL AVERAGE OF POLLUTANT OVER PHASES

PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

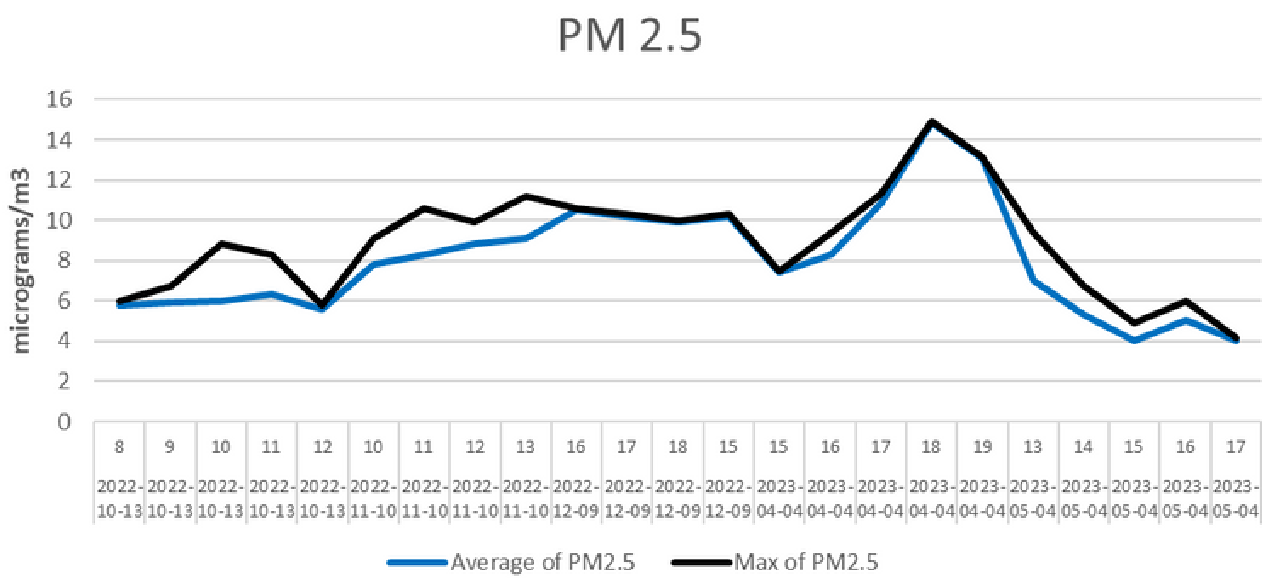
PERCENTAGE DIFFERENCE IN SPATIAL AVERAGE BETWEEN PHASES



PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

POLLUTANT: PARTICULATE MATTER (PM 2.5)

TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS



TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS (TABULATED)

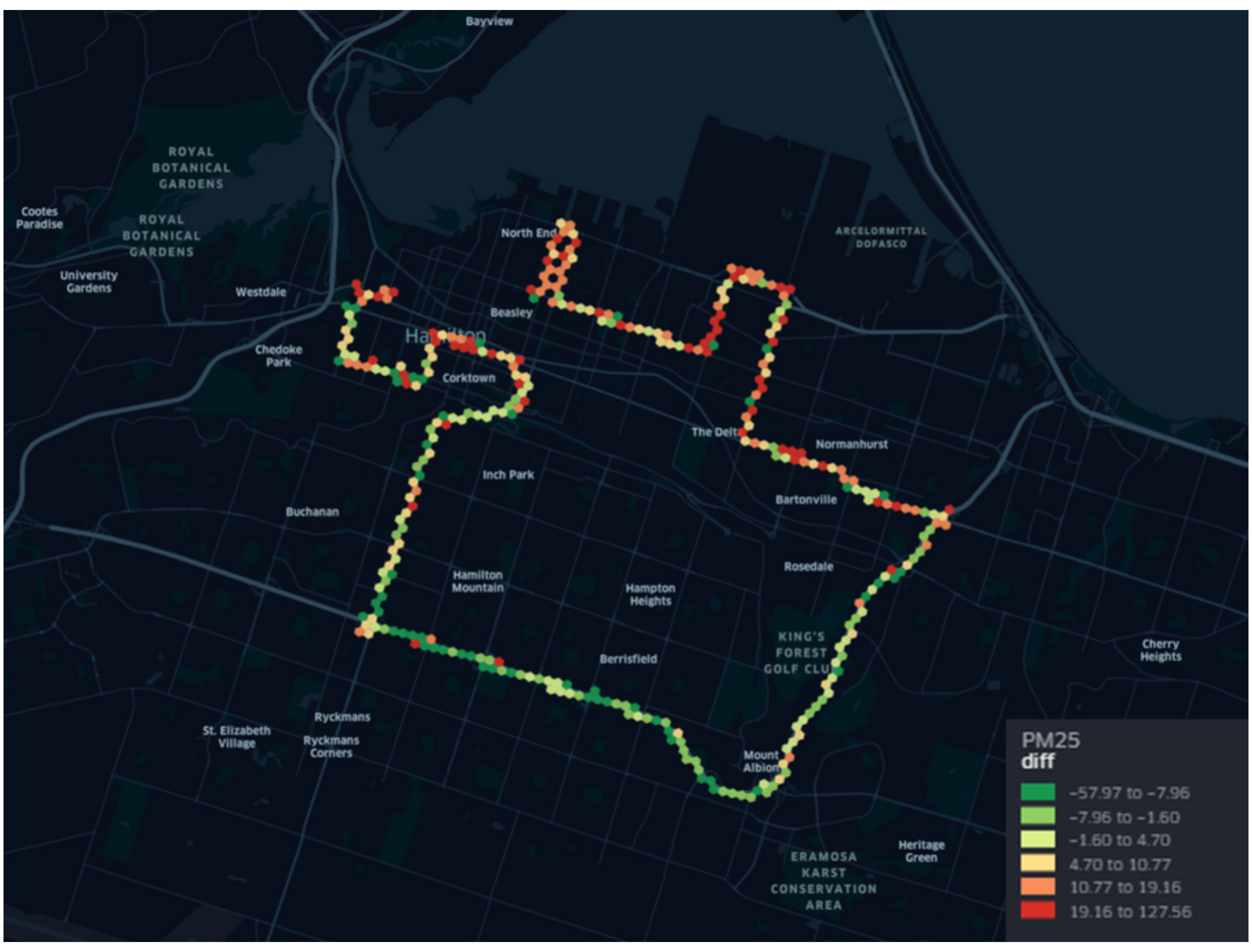
DATE	HOUR OF DAY	MEAN	MEDIAN	STD.DEV	MAX	MIN
2022-10-13	8	5.8	5.8	0.1	6.0	5.8
2022-10-13	9	5.9	5.9	0.3	6.7	5.4
2022-10-13	10	6.0	6.0	0.6	8.8	5.2
2022-10-13	11	6.3	6.3	0.5	8.3	5.4
2022-10-13	12	5.6	5.6	0.1	5.8	5.4
2022-11-10	10	7.8	7.8	0.2	9.1	7.6
2022-11-10	11	8.3	8.3	0.3	10.6	8.0
2022-11-10	12	8.8	8.8	0.2	9.9	8.4
2022-11-10	13	9.1	9.1	0.3	11.2	8.7
2022-12-09	16	10.5	10.5	0.1	10.6	10.3
2022-12-09	17	10.2	10.2	0.2	10.3	6.7
2022-12-09	18	9.9	9.9	0.1	10.0	9.7
2022-12-09	15	10.2	10.2	0.1	10.3	9.0
2023-04-04	15	7.4	7.4	0.0	7.5	7.4
2023-04-04	16	8.3	8.3	0.1	9.4	8.1
2023-04-04	17	10.8	10.8	0.1	11.3	10.7
2023-04-04	18	14.9	14.9	0.0	14.9	14.8
2023-04-04	19	13.1	13.1	0.0	13.1	13.1
2023-05-04	13	7.0	6.9	0.2	9.4	6.8
2023-05-04	14	5.3	5.2	0.2	6.7	5.0
2023-05-04	15	4.0	4.0	0.2	4.9	3.8
2023-05-04	16	5.0	5.0	0.2	6.0	4.9
2023-05-04	17	4.0	4.0	0.1	4.1	3.9

POLLUTANT: PARTICULATE MATTER (PM 2.5)

SPATIAL AVERAGE OF POLLUTANT OVER PHASES

PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

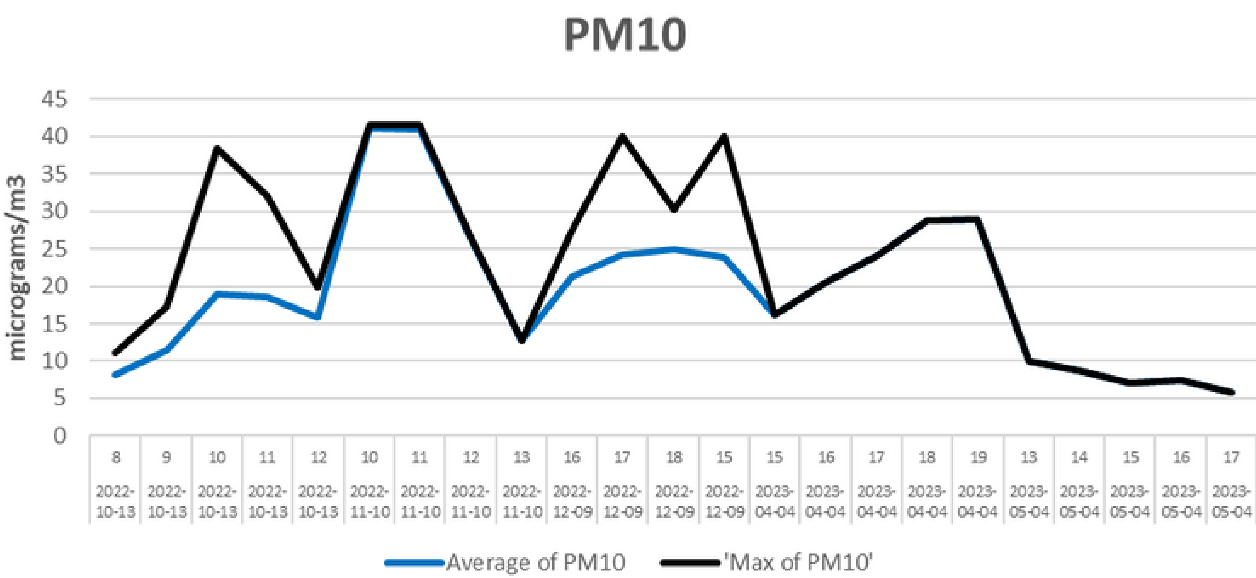
PERCENTAGE DIFFERENCE IN SPATIAL AVERAGE BETWEEN PHASES



PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

POLLUTANT: PARTICULATE MATTER (PM 10)

TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS

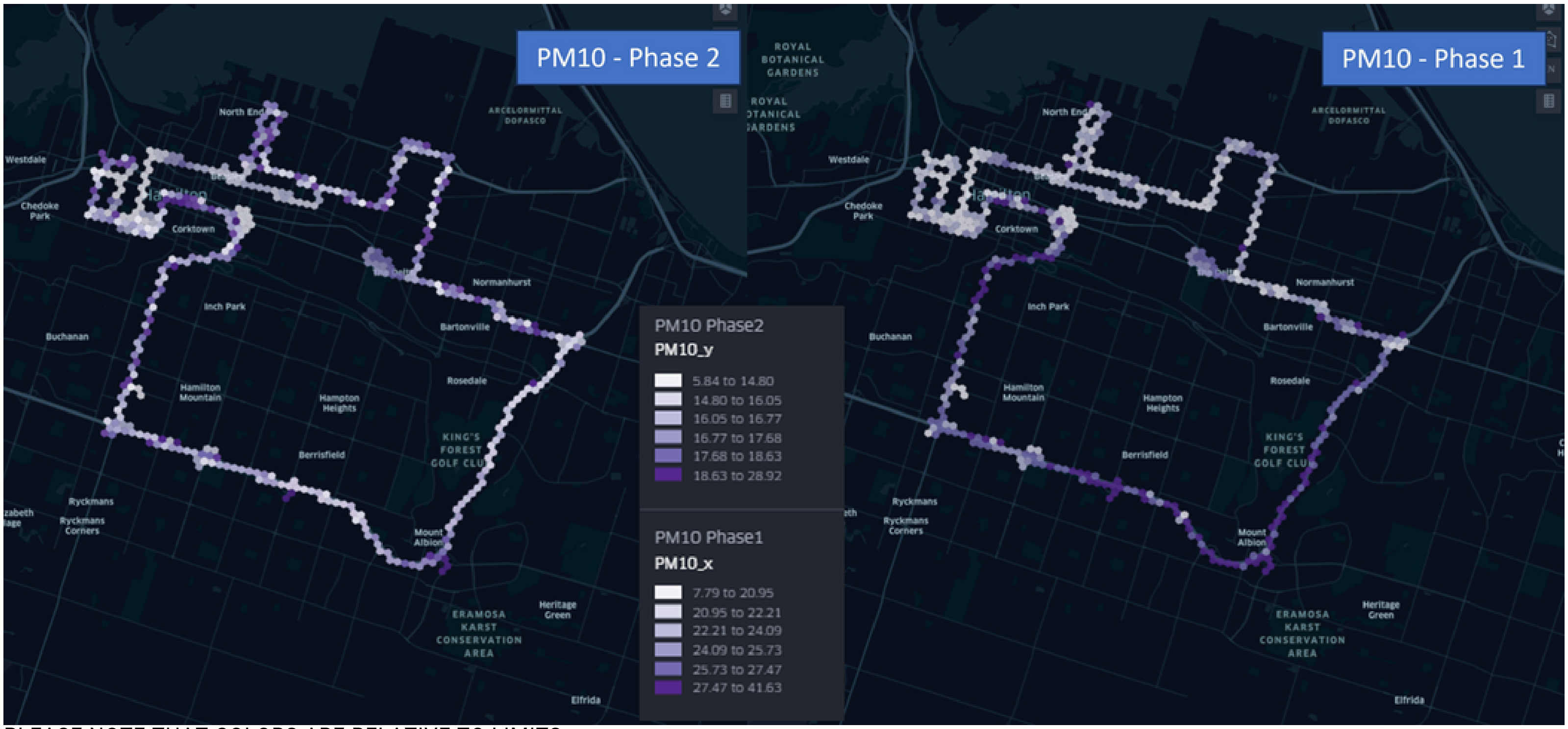


TIME SERIES: HOURLY AVERAGE OF POLLUTANT OVER SCAN DAYS (TABULATED)

DATE	HOUR OF DAY	MEAN	MEDIAN	STD.DEV	MAX	MIN
2022-10-13	8	8.1	8.1	0.9	11.1	6.8
2022-10-13	9	11.5	11.5	1.8	17.2	7.8
2022-10-13	10	19.0	19.0	4.4	38.4	13.3
2022-10-13	11	18.5	18.5	3.4	32.1	11.6
2022-10-13	12	15.8	15.8	1.7	19.9	12.7
2022-11-10	10	41.1	41.1	0.9	41.6	38.0
2022-11-10	11	41.0	41.0	1.1	41.6	37.3
2022-11-10	12	26.6	26.6	0.5	26.7	22.6
2022-11-10	13	12.7	12.7	0.2	12.8	11.3
2022-12-09	16	21.2	21.2	1.9	27.4	18.5
2022-12-09	17	24.2	24.2	3.7	40.1	21.0
2022-12-09	18	25.0	25.0	1.2	30.2	22.9
2022-12-09	15	23.8	23.8	3.5	40.0	20.3
2023-04-04	15	16.2	16.2	0.0	16.2	16.2
2023-04-04	16	20.6	20.6	0.0	20.6	20.6
2023-04-04	17	24.0	24.0	0.0	24.0	24.0
2023-04-04	18	28.7	28.7	0.0	28.7	28.7
2023-04-04	19	28.9	28.9	0.0	29.0	28.9
2023-05-04	13	9.9	9.9	0.0	9.9	9.9
2023-05-04	14	8.7	8.7	0.0	8.7	8.7
2023-05-04	15	7.1	7.1	0.0	7.1	7.1
2023-05-04	16	7.4	7.4	0.0	7.4	7.4
2023-05-04	17	5.8	5.8	0.0	5.8	5.8

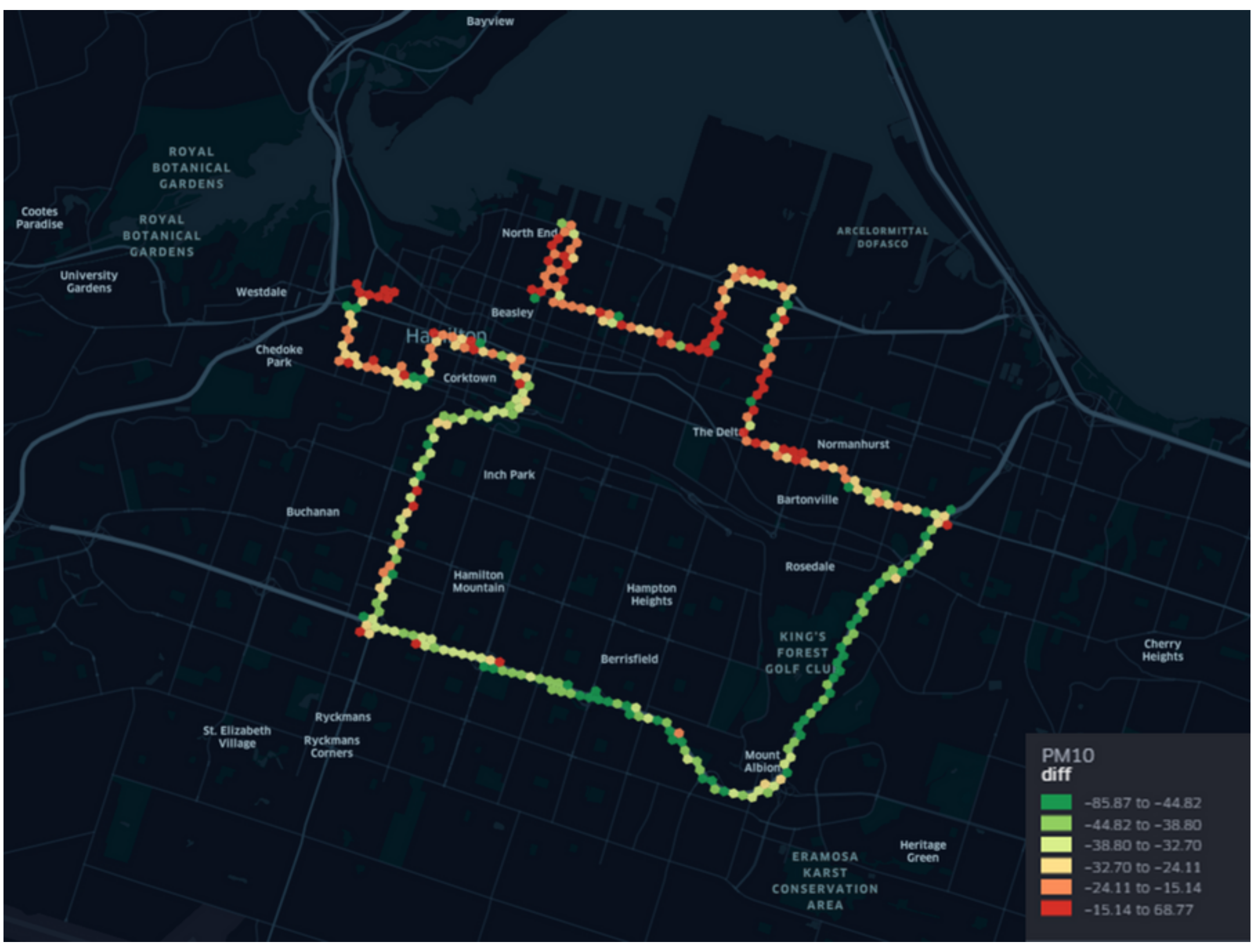
POLLUTANT: PARTICULATE MATTER (PM 10)

SPATIAL AVERAGE OF POLLUTANT OVER PHASES



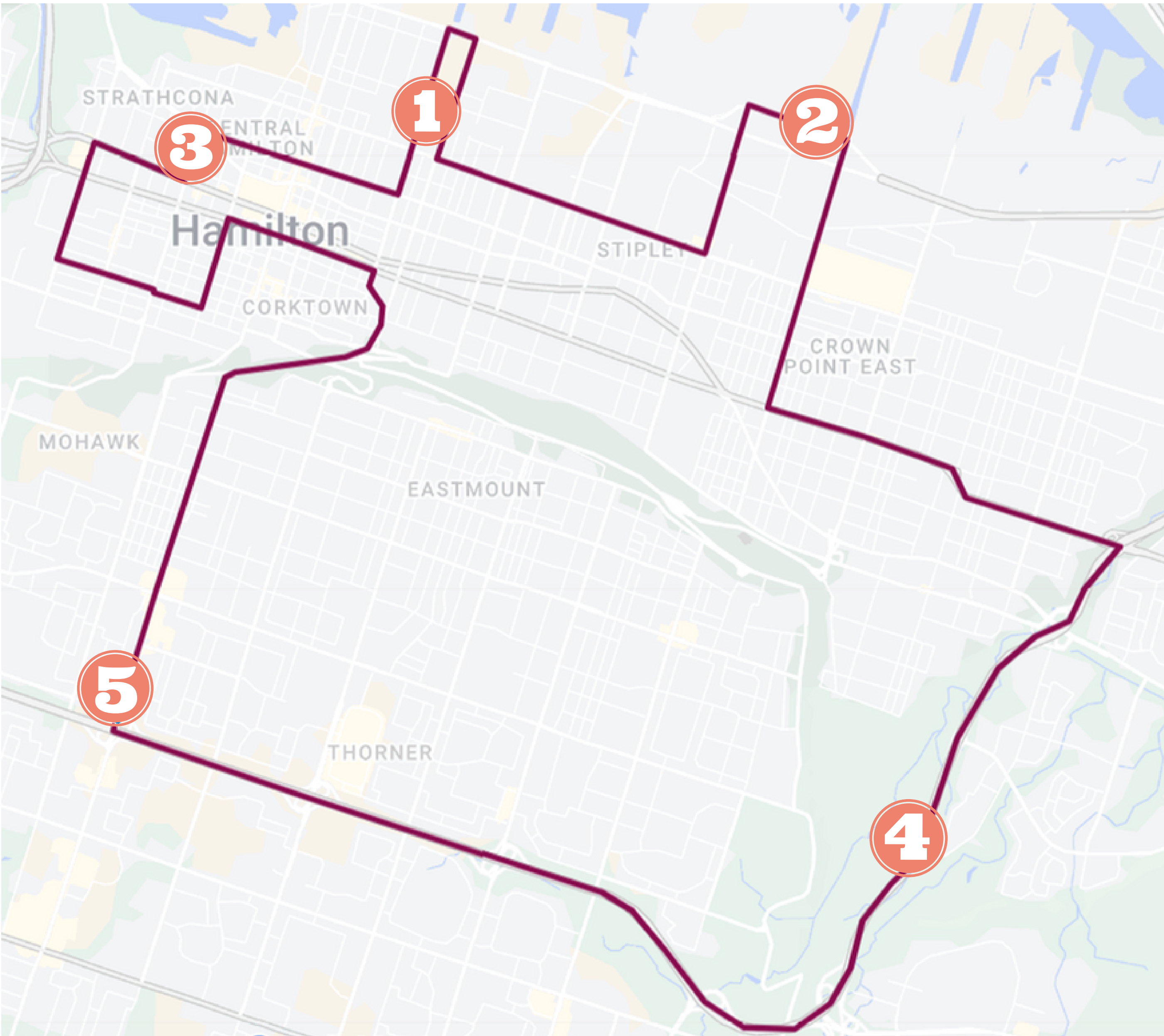
PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

PERCENTAGE DIFFERENCE IN SPATIAL AVERAGE BETWEEN PHASES



PLEASE NOTE THAT COLORS ARE RELATIVE TO LIMITS.

INSIGHTS – POINTS OF INTEREST



INSIGHTS – POINTS OF INTEREST

This section details the mean gas concentration levels at 5 identified points of interest on each scan day compared with the mean gas concentration for the overall scan.

1.HAMILTON GENERAL HOSPITAL

Chosen as a point of interest due to nature of sensitivity to air quality. Hospitals having a higher concentration of individuals with health vulnerabilities, such as patients with respiratory conditions, weakened immune systems, and other illnesses.

2.INDUSTRIAL SECTOR (CLOSE TO ARCELORMITTAL DOFASCO)

Chosen due to the fact that the industrial sector is a major source of pollutants in the City of Hamilton.

3.KING ST. W & QUEEN ST. N

This location is the physcial intersection at which max restrictions of truck by size is implemented.

4.RED HILL VALLEY PKWY (NEAR GLEN CASTLE PARK)

This locations was chosen as it is expected to have increased volume of trucks in phase 2 and due to the physcial location on the point on an inclined road where there is higher emissions from heavy vehicles including trucks due to acceleration uphill and braking downhill.

5.UPPER JAMES ST. & LINC. PKWY

This locations was chosen as it is expected to have the most impact in terms of increased volume of trucks in phase 2. It is an existing major intersection that is expected to hangle signficantly higher number of vehicles on a daily basis in phase 2 comapred to phase 1.

INSIGHTS – POINTS OF INTEREST

POLLUTANT: SULPHUR DIOXIDE (SO2)

	Phase 1	Phase 2	% Change from Phase 1 to Phase 2
Hamilton General hospital	0.8	7.3	+857%
Industrial sector	0.7	6.7	+811%
King & Queen	0.8	8.0	+939%
Red Hill valley pkwy	0.8	7.7	+911%
Upper James & Linc. pkwy	0.7	8.3	+1074%
Overall Scan	**0.7**	**7.2**	**+899%**

POLLUTANT: CARBON MONOXIDE (CO)

Location	Phase 1	Phase 2	% Change from Phase 1 to Phase 2
Hamilton General hospital	222.8	172.6	-23%
Industrial sector	217.4	186.1	-14%
King & Queen	221.5	170.6	-23%
Red Hill valley pkwy	218.3	175.3	-20%
Upper James & Linc. pkwy	209.3	182.6	-13%
Overall Scan	**215.3**	**177.5**	**-18%**

POLLUTANT: NITROGEN DIOXIDE (NO2)

	Phase 1	Phase 2	% Change from Phase 1 to Phase 2
Hamilton General hospital	6.2	8.4	+36%
Industrial sector	6.1	7.8	+28%
King & Queen	6.1	8.5	+39%
Red Hill valley pkwy	6.2	8.4	+35%
Upper James & Linc. pkwy	6.3	8.7	+37%
Overall Scan	**6.2**	**8.3**	**+33%**

INSIGHTS – POINTS OF INTEREST

POLLUTANT: OZONE (O3)

	Phase 1	Phase 2	% Change from Phase 1 to Phase 2
Hamilton General hospital	26.0	27.7	+6%
Industrial sector	25.8	29.4	+14%
King & Queen	26.1	27.0	+4%
Red Hill valley pkwy	25.5	27.4	+7%
Upper James & Linc. pkwy	24.8	26.1	+5%
Overall Scan	**25.5**	**27.3**	**+7%**

POLLUTANT: PARTICULATE MATTER (PM 2.5)

Location	Phase 1	Phase 2	% Change from Phase 1 to Phase 2
Hamilton General hospital	8.3	8.7	+5%
Industrial sector	8.3	8.7	+5%
King & Queen	8.1	8.6	+7%
Red Hill valley pkwy	8.2	8.9	+8%
Upper James & Linc. pkwy	8.3	7.8	-6%
Overall Scan	**8.2**	**8.0**	**-3%**

POLLUTANT: PARTICULATE MATTER (PM 10)

Location	Phase 1	Phase 2	% Decrease from Phase 1 to Phase 2
Hamilton General hospital	21.6	17.4	-20%
Industrial sector	24.9	16.7	-33%
King & Queen	22.3	17.4	-22%
Red Hill valley pkwy	22.1	17.3	-22%
Upper James & Linc. pkwy	25.9	15.9	-38%
Overall Scan	**23.7**	**15.7**	**-34%**

High level analysis for SO_2 spikes in the City of Hamilton (2012-Present)

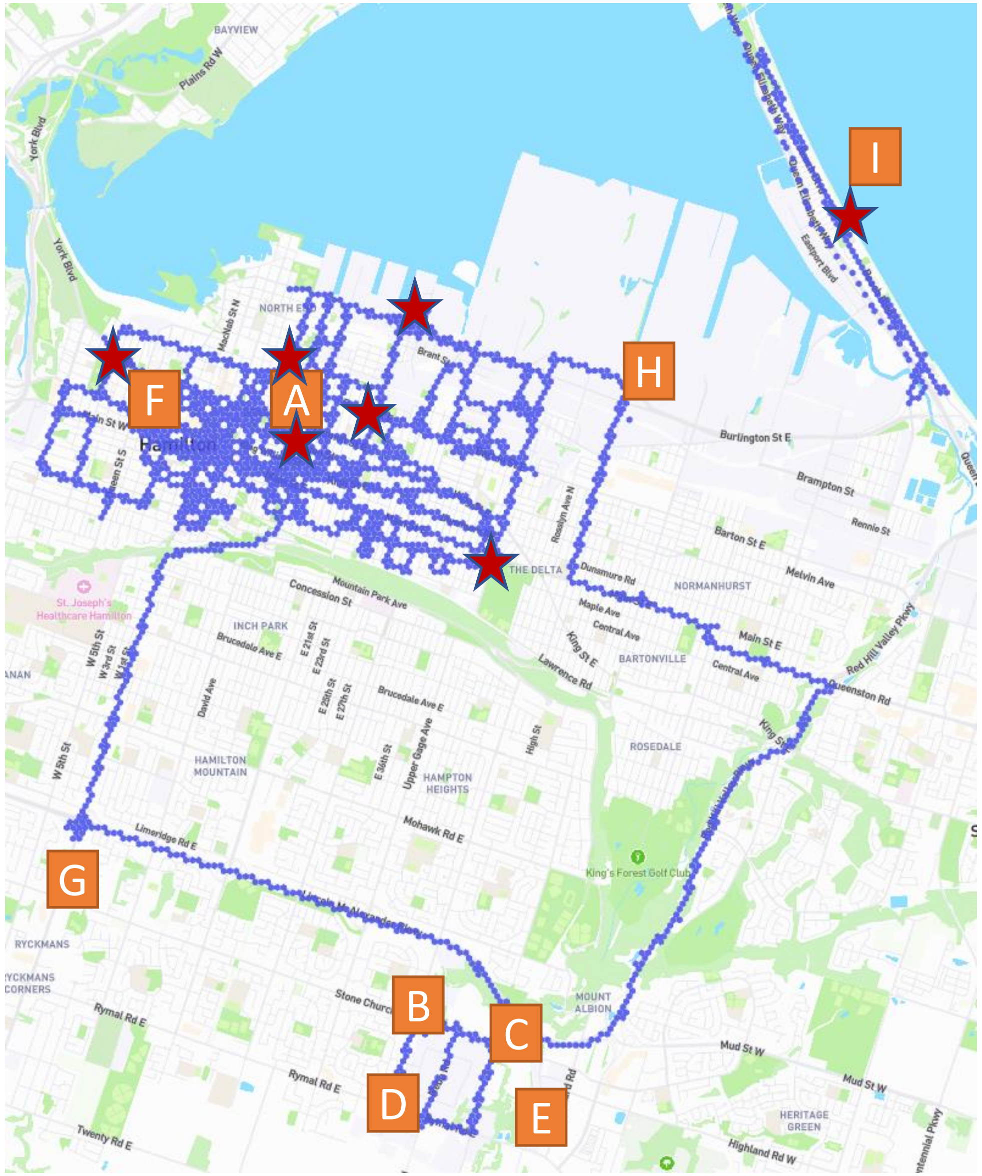
eco system informatics Inc.

Background

- ESI is an AI-powered Air Quality monitoring company that has worked with several partners in the City of Hamilton from December 2021-Present.
- During this period, ESI has measured pollutant levels in ambient air in several different locations within the City of Hamilton and has also worked to analyze MECP data (as part of internal benchmarking and demonstration of ESI data accuracy).
- ESI’s analysis showed noticeable spikes in Sulphur Dioxide(SO2) and Nitrogen Dioxide (NO2) over several different days during 2022.
- The readings were significantly outside the Ontario Ambient Air Quality guideline levels and such readings often continued for several hours at a time (and on consecutive days as well in a few instances).
- Post discussing these findings with clients from and closely connected to the City of Hamilton, the common understanding is that there is a need to understand this further, to look deeper into the findings and to understand the sources and the sinks of the pollutants.

The Next few slides present a bird's eye view of findings from ESIs data over the last year and analysis of historical MECP data going back to 2012.

Overview of ESI's presence in Hamilton



#	Type of Data	Location/Route	Timeline of availability
A	Continuous	Beasley Park	Dec2021-Dec2022
B,C,D	Continuous	Rymal Rd E & Upper Ottawa St. Upper Ottawa St. & Stone Church Rd E Rymal Rd E & Dartnall Rd	July2022-Nov2022
E	Mobile Scans	Rymal Rd East – CUBIC McMaster	July2022-Nov2022
F	Mobile Scans	Downtown core –Public Health	Dec2021-May2022
G	Mobile Scans	Extended Study Area – Transportation Planning	Oct2022-Dec2022
H	Mobile Scans	Truck Route-CITM	Feb2022-May2022
I	Mobile Scans	Beach Blvd-CITM	Oct2022-Nov2022

★ SO2 Hotspot

(Locations where ESI measured data found significantly high readings for SO2 levels. ESI measured data over timelines specified above)

Analysis includes

- Sulphur Dioxide MECP – Hamilton Downtown station data from 2012-2022.
  - Yearly number of hours with SO2 concentration >= 40 PPB (Parts Per Billion).
  - For 2021 and 2022, a monthly look at the number of hours with SO2 concentration >= 40 PPB.
- ESI data from May 2022
  - ESI mobile scan data from 2 scan-days in May 2022.
  - ESI fixed unit data (located in Beasley park) from May 2022.
- Benchmarked against Ontario Ambient Air Quality Criteria for SO2
  - 10 minutes AAQC Assesses protection against acute effects = 67 PPB
  - 1-hour AAQC Assesses protection against acute effects = 40 PPB
  - Annual AAQC Assesses protection against chronic effects = 4 PPB

Observations from MECP Station – Hamilton Downtown

11%

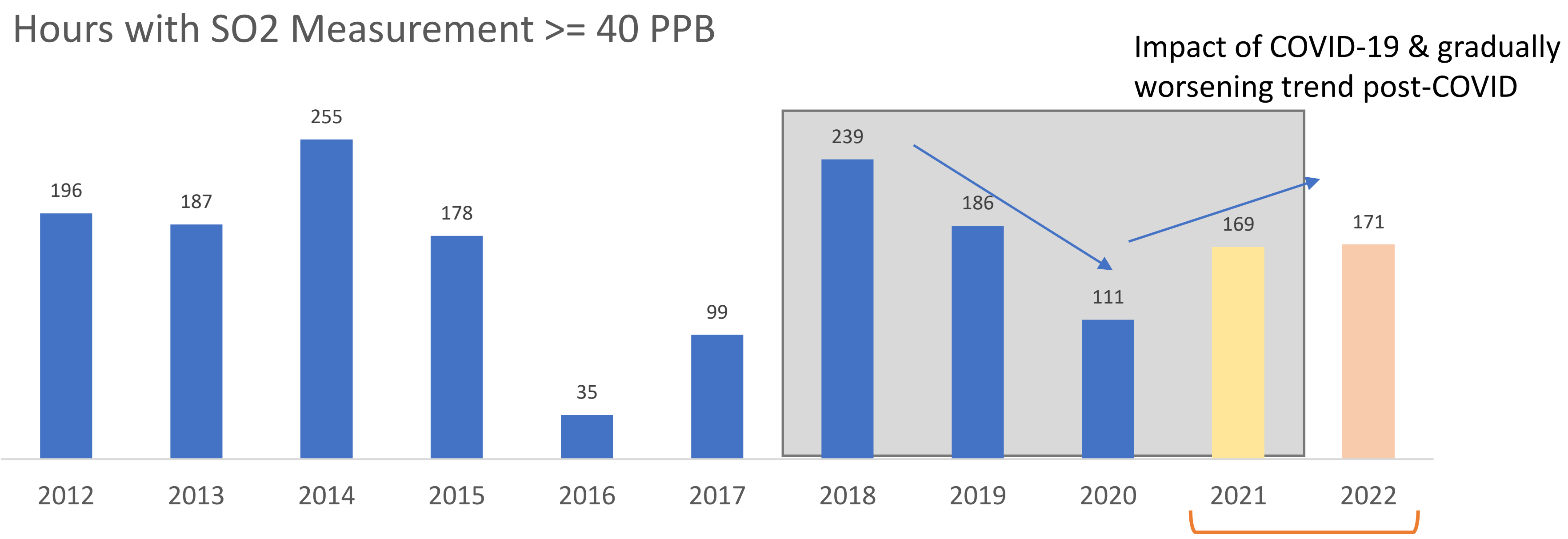
Percentage of time in May 2022 during which SO2 concentration in ambient air was >= 40 PPB.

<u>This level of SO2 is so bad that even short-term exposure can cause severe human health effects.</u>

Ontario's Ambient Air Quality Criteria for SO2

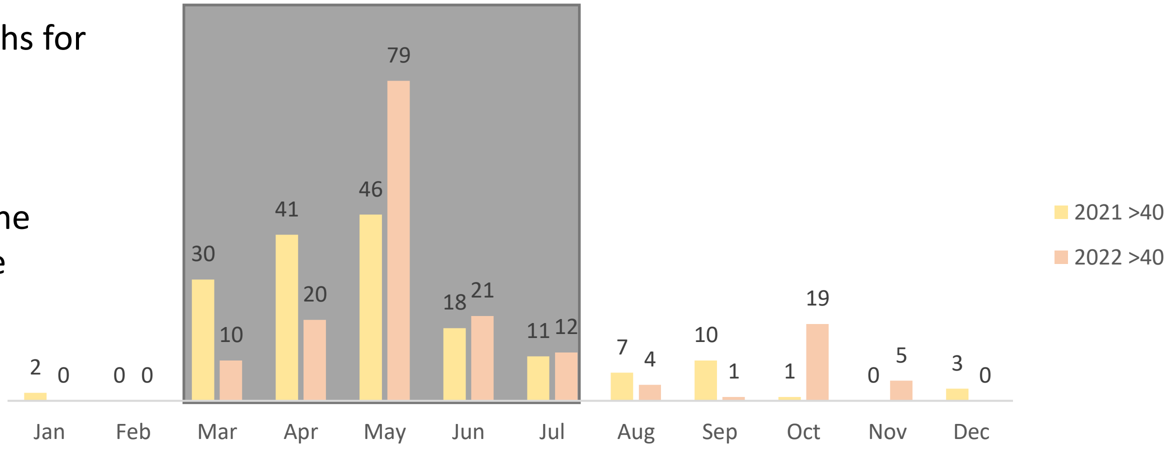
SO2
40 PPB

1-hour AAQC
Assesses protection against acute effect to human health



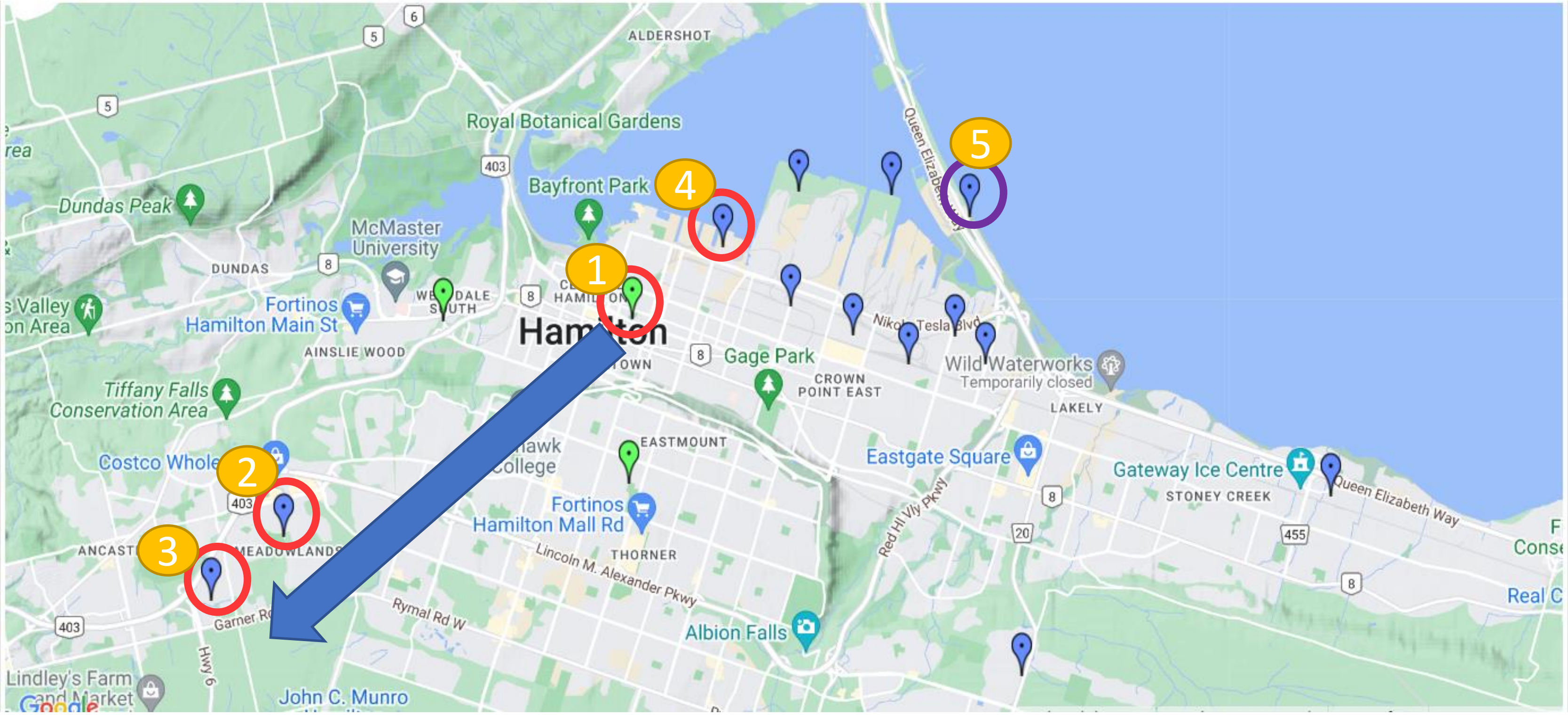
March to July are the worst months for SO2 concentration in ambient air.

In 2022, 83% of hours with concentration >=40PPB were in the months of May-June. In 2021, the number was 86%



Hamilton – Air Quality Stations – 2022 Daily Average SO2 Concentration

- Stations 1,2 and 3 showed similar daily average SO2 concentration trends and there is also a noticeable reduction in concentration level from station 1 to 3 showing a dispersion over distance. This is supported by the wind direction trend.
- Station 5 shows a substantially different trend than all the other stations and warrants further investigation.
- Station 4 shows a trend weakly similar to station 1,2 and 3.



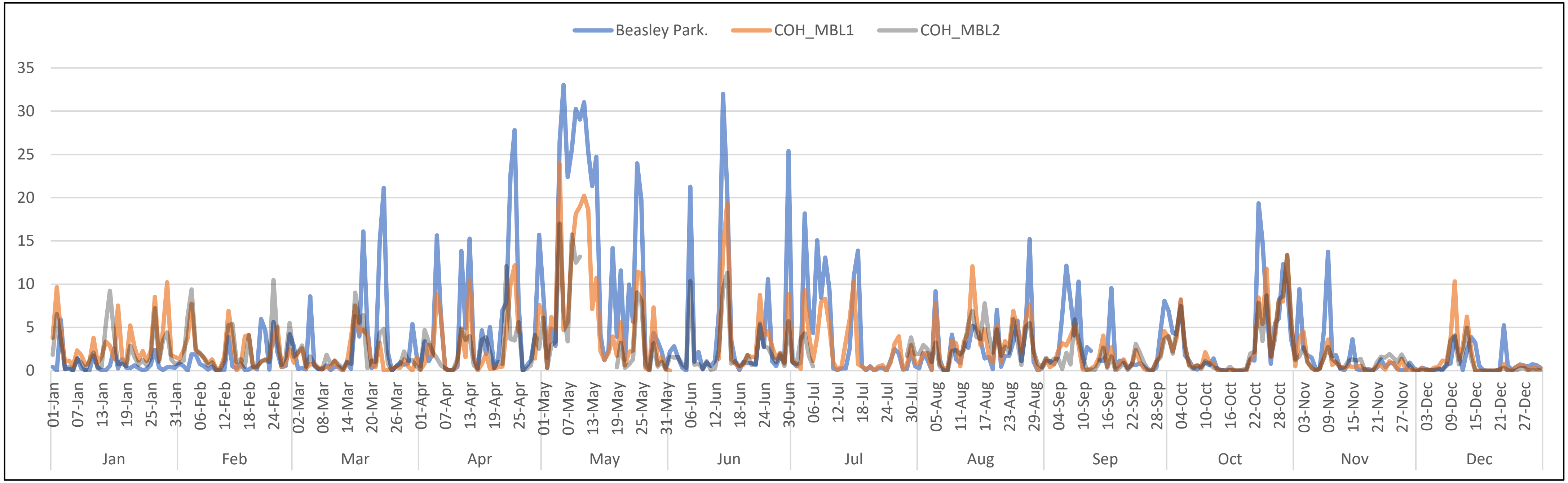
1	MECP Station – Beasley Park
2	COH_MBL1 (Meadowlands Park, Ancaster)
3	COH_MBL2 (Bookjans Park, Ancaster)
4	HAMN STN29567 – Niagara/Land St
5	HAMN STN2102 – Beach Blvd

2022 observations from Hamilton Air Quality Stations

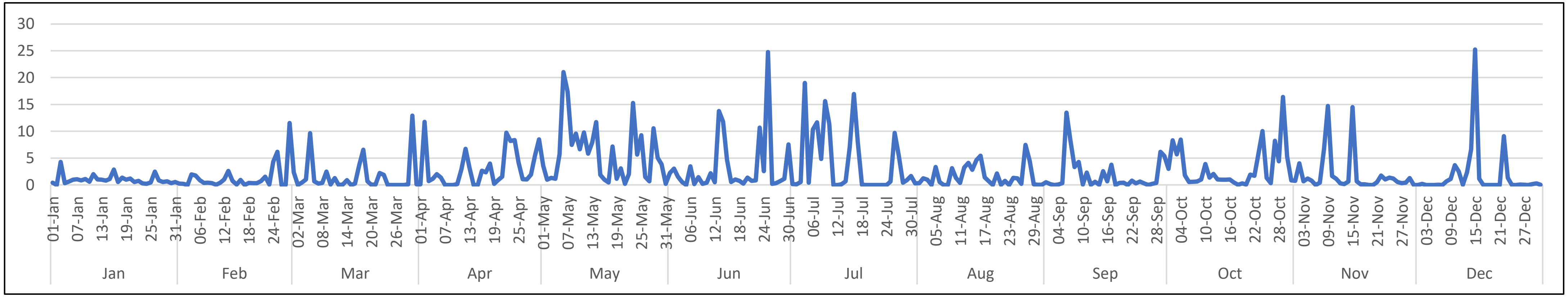
MECP Station – Beasley Park

COH- MBL1

COH-MBL2



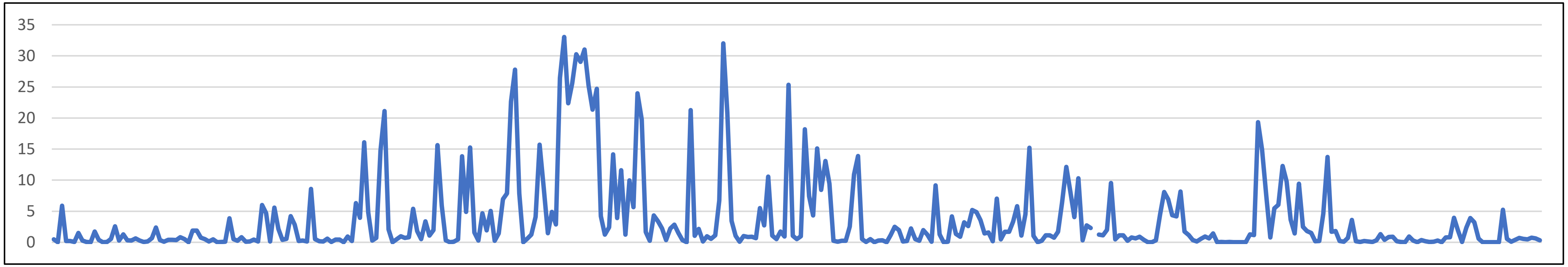
HAMN- Station Niagara/ Land St



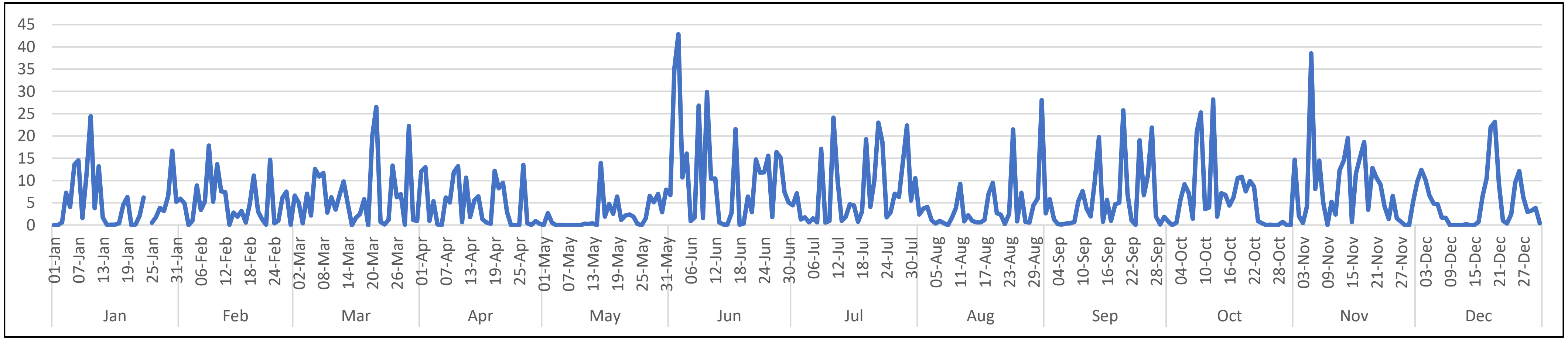
2022 observations from Hamilton Air Quality Stations

- 3 of the 5 stations that measure SO2 had very similar daily average SO2 concentration trend.
- The HAMN Station at Niagara St./Land St. had slightly different trend while…
- The **HAMN Station at Beach Blvd.** had significantly different daily average trend in SO2 concentration when compared to the other 4 stations.

MECP Station – Beasley Park

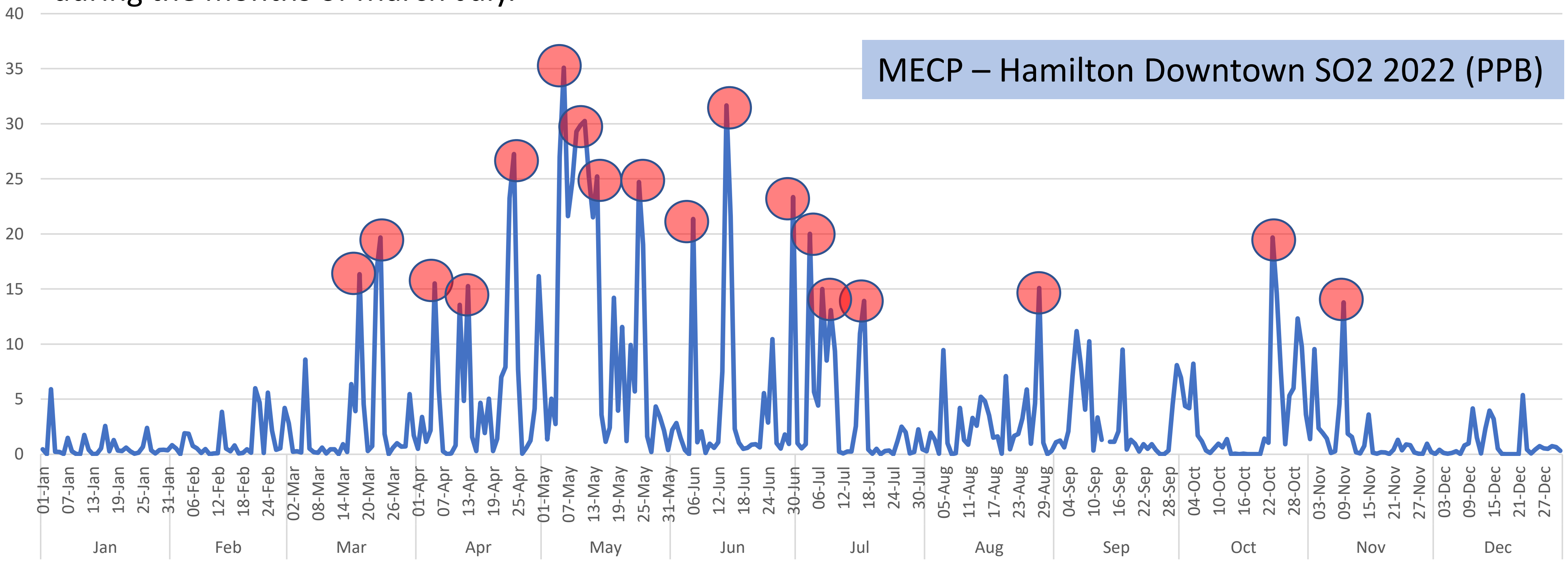


HAMN Station – Beach Blvd.



Observations of Year 2022 from MECP Station – Hamilton Downtown

- We can understand that there are days when SO2 concentration in ambient air shows a significantly high reading.
- There are several occurrences where the spikes are on consecutive days and not just restricted to a single one-off hour in the day.
- On analysis of other pollutants such as NO2, we notice similar trends of prolonged spikes being observed.
- For SO2, such days are not restricted to certain months. They occur throughout the year but occur more during the months of March-July.



Note: The above is monthly averaged data which smoothens out the extreme readings.

2022 observations from Hamilton Air Quality Stations

- From the concentration distribution below, we can observe that the HAMN STN2102- Beach Blvd is measuring higher levels of SO2 versus all other stations. This is a definite red flag on air quality around the Beach Blvd. area and needs to be investigated further.

SO2 Daily Average Concentration (PPB) distrubition over 2022					
SO2 (PPB)	**MECP Station – Beasley Park**	**COH_MBL1 (Meadowlands Park, Ancaster)**	**COH_MBL2 (Bookjans Park, Ancaster)**	**HAMN STN29567 – Niagara/Land St**	**HAMN STN2102 – Beach Blvd**
0-5	289	293	292	302	210
5-10	35	38	33	39	76
10-15	13	14	7	15	42
15-20	9	4	2	6	15
20-25	8	2		2	11
25-30	6			1	7
30-35	4				2
40-45					1
No Data	1	14	31	0	1
	365	365	365	365	365

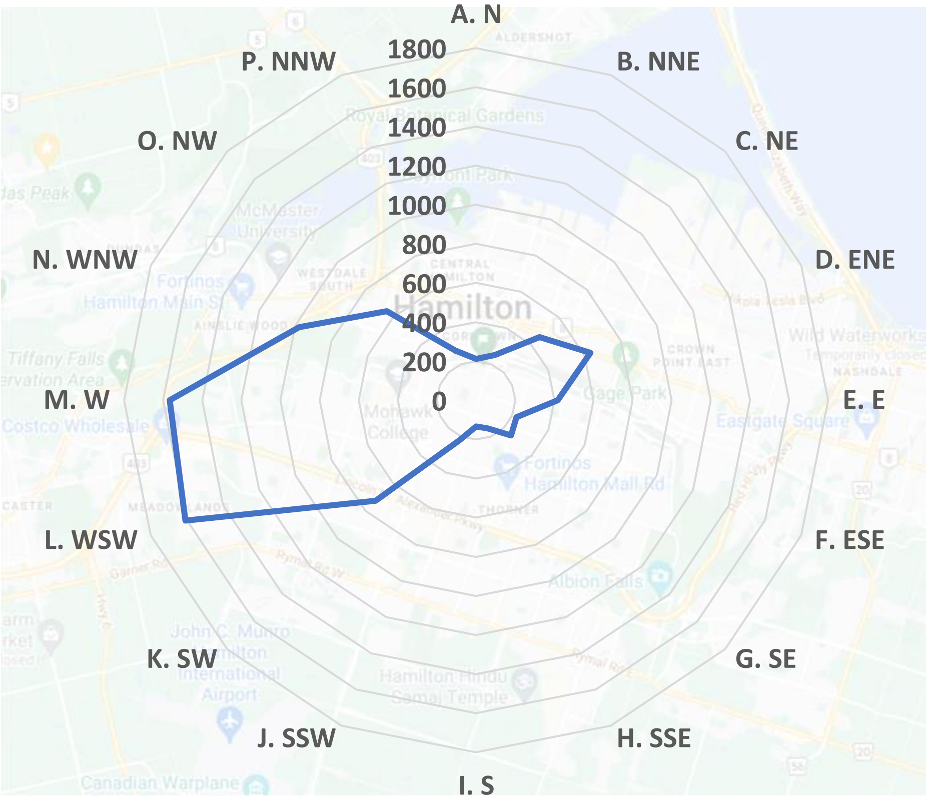
This table shows the numbers of days versus the average daily SO2 concentration measured in each of the 5 stations in 2022. For example, MECP Station – Beasley Park had a daily average SO2 concentration between 0-5 PPB on 289 days (out of 365) in 2022. Correspondingly, HAMN STN2102 – Beach Blvd. had only 210 days with daily average SO2 concentration between 0-5 PPB.

2022 observations on Wind direction in Hamilton

- Wind direction is largely westerly directional blowing in from the Lake Ontario towards the Niagara escarpment.
- This is leading to dispersion **(and only a slight reduction in concentration)** of SO_2 pollution up the escarpment and towards Ancaster.

Wind Direction	Hours in 2022	Percentage of total hours
N	212	2%
NNE	250	3%
NE	458	5%
ENE	633	7%
E	417	5%
ESE	224	3%
SE	253	3%
SSE	155	2%
S	133	2%
SSW	220	3%
SW	726	8%
WSW	1608	18%
W	1566	18%
WNW	979	11%
NW	645	7%
NNW	276	3%

Wind direction is west-oriented 47% of the time



43%

Percentage of data points collected by ESI in May 2022 where measured SO2 in ambient air was >= 40 PPB. **This level of SO2 is so bad that even short-term exposure can cause severe human health effects.**

Ontario's Ambient Air Quality Criteria for SO2

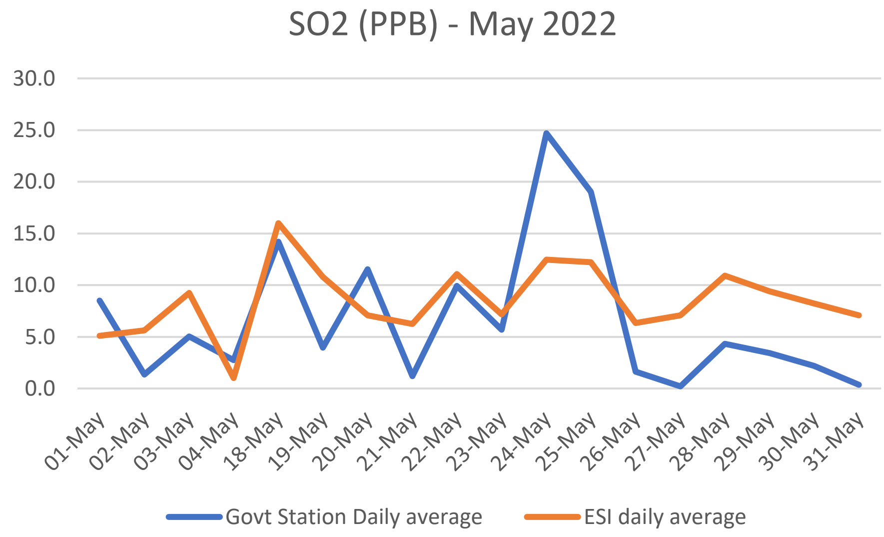
SO2
40 PPB

1-hour AAQC
Assesses protection against acute effect to human health

Observations from ESI data – May 2022

ESI collected ~6000 data points over 2 mobile scans conducted in and around the downtown core.

ESI had a fixed device that continuously collected data. In the month of May 2022, the device was active was 18 days and shows a similar trend in average daily measurement to that of the MECP station.



Possible Contributing Factors

- Industry activities within the City of Hamilton and surroundings
- Leaks from natural (geological) sources
- Human activity within the City of Hamilton
- Meteorological factors contributing to buildup and dispersion/dissipation

What can be done?

- Identify source and sink for pollutants
- Understand impact of meteorological factors on pollutant levels throughout the year
- ESI can continue city-wide scans to see a hyperlocal picture of how the concentration of pollutant is dispersed over the city geography and identify trends, hotspots and correlations
- Continuously monitor at hotspot and highly sensitive locations (ex: Beach Blvd.)
- Dive deeper to understand the reason for days with significantly high measurements of gases
- Dive deeper into analyzing other pollutants to a granular level to understand the trends, patterns and outliers in pollutant concentration, what is causing them and how to mitigate the adverse effects
- Integrate all gathered data to draw conclusions and create comprehensive analyses, draw insights to help create mitigation and action plans

This report was prepared by Ecosystem Informatics Inc. for the City of Hamilton.

To go over the details, and for any further questions and clarifications, please feel free to reach out to:

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