Environmental Monitoring Study
Church Street Waste Transfer Station

Prepared for:
The City of Evanston
Lorraine H. Morton Civic Center
2100 Ridge Ave.
Evanston, IL 60201

Prepared by:
RHP Risk Management Inc.
8745 W. Higgins Rd., Suite 320
Chicago, Illinois

Contributed by:
Serap Erdal, Ph.D.
Associate Professor
UIC School of Public Health
1603 W. Taylor St., M/C 923
Chicago, Illinois

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1 EXECUTIVE SUMMARY

In March 2019, the City of Evanston hired RHP Risk Management Inc. (RHP) to design and implement a 6-month duration air quality study. The objective of the study was to measure for ambient air pollutants that were expected to possibly be present based upon previous recommendations made by the TEX project. The purpose of the study was to determine whether the measured values for any of the target parameters demonstrate probable source-attribution to site operations at the waste transfer station, so that future evaluations, such as a long-term air monitoring and/or a human health risk assessment, may then focus on key parameters demonstrated to be of potential concern.

RHP conducted a scoping study from May 17, 2019 to November 20, 2019. Real-time air monitoring instruments were placed at four sites surrounding the property boundaries of the Church St. Waste Transfer Station, and additionally at a control site near Twiggs Park, approximately a half-mile to the northwest. Measurement values for most of the study testing parameters were recorded at 1-minute intervals which resulted in a robust data set comprised of over 112 million data points. Each of the five monitoring stations were configured to measure twelve parameters of interest: nitric oxide (NO), nitrogen dioxide (NO_2), ozone (O_3), fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), methyl mercaptan (CH_4S), formaldehyde (HCHO), Volatile Organic Compounds (VOCs), and noise. Two of the monitoring stations were additionally configured to measure wind speed and direction. Lastly, a 30-day traffic study was conducted to consider traffic patterns as a potential influence.

Air monitoring data collected was evaluated using an industry-leading statistical analysis program by SAS. The data analysis involved assessment of trends over time, spatial differences for the study area vs. control site, temporal differences for operational vs. non-operational facility hours, and the effect of other influencing factors such as wind direction and traffic patterns.

After analyzing all twelve of the parameters through six different perspectives (or lenses), we present the findings as a hierarchical ranking which prioritizes parameters according to an overall weight of evidence (WOE) scoring approach. A summary of the WOE score totals is presented in the following table. A more detailed version of the WOE score table and scoring criteria are provided in Section 5 (Findings) and Appendix A.11.

Parameter	Weight of Evidence (WOE) Score Total	Prioritization
Formaldehyde (CH_2O)	+6	1st Tier Parameters
Nitric Oxide (NO)	+6	
Sulfur Dioxide (SO_2)	+5	2nd Tier Parameters
Nitrogen Dioxide (NO_2)	+4	
Volatile Organic Compounds (VOCs)	+3	
Noise (dB)	+2	
Carbon Monoxide (CO)	+1	
Methyl Mercaptan (CH_3SH)	+1	
Hydrogen Sulfide (H_2S)	0	Deprioritized Parameters
Ozone (O_3)	-1	
Particulate Matter (PM_{TOTAL})	-2	
Particulate Matter ($PM_{2.5}$)	-4	
Particulate Matter (PM_{10})	-4	

The top two parameters with the highest WOE scores (formaldehyde and nitric oxide) were designated as 1st Tier parameters that we recommend prioritizing as parameters of greatest interest for any future work. All other parameters with positive WOE score totals (i.e., sulfur dioxide, nitrogen dioxide, Volatile Organic Compounds, noise, carbon monoxide, and methyl mercaptan) were designated as 2nd Tier parameters that we recommend considering as secondary interest parameters for any future work. Parameters with null or negative WOE score totals (hydrogen sulfide, ozone, fine, coarse, and total particulate matter) were designated as deprioritized parameters and are not recommended for additional future study. Detailed recommendations for application of these findings to future study considerations are provided in Section 7 (Recommendations).

2 BACKGROUND

The Church Street Waste Transfer Station engages in the collection, transfer, and disposal of municipal solid waste and construction and demolition waste. The site is located at 1711 Church Street in Evanston, Illinois 60201 and has been in operation since February 27, 1984. Site operations are currently managed by Advanced Disposal, Inc. Community concerns regarding potential adverse air quality impacts to surrounding residential areas led the City of Evanston to allocate funding for a study of local air quality. Additional details about community concerns related to site operations and investigative actions performed to date are documented extensively elsewhere.[1]

In December 2016, the City of Evanston was invited to participate in the Thriving Earth Exchange (TEX), an American Geophysical Union (AGU) project, that provides technical assistance to local communities on science-related topics. The City of Evanston developed a task force that was comprised of City Council members, residents, local scientists, and City staff to identify parameters of interest for possible inclusion in a future environmental monitoring study in geographic areas in close proximity to the Church St. Waste Transfer Station. The TEX project concluded in September 2018 and one of the recommendations provided was to evaluate air quality in the area surrounding the waste transfer station for target parameters which the task force determined were indicators for potentially significant air emissions from site operations, based upon a literature review for other similar sites.

In March 2019, the City of Evanston hired RHP Risk Management Inc. (RHP)/University of Illinois-Chicago (UIC) team to design and implement a 6-month long air quality study. RHP's bid response was presented as a collaborative partnership between RHP (a privately held Chicago-based health sciences consulting firm), and an academic institution through the University of Illinois-Chicago School of Public Health (UIC SPH). The project leadership team included Mr. Jacob Persky, MPH, CIH, who is a Principal at RHP and fulfilled a project lead role for the study, Dr. Frank Pagone, Ph.D., who is a Senior Associate Health Scientist at RHP and fulfilled a project manager role for the study, and Dr. Serap Erdal, Ph.D., who is an Associate Professor within the Division of Environmental and Occupational Health Sciences of the UIC SPH and fulfilled a Senior Advisor role for the study. Project support staff included Ms. Jacqueline Coreno, who is an Associate Health Scientist at RHP and assisted with weekly station visits, data analysis, and report preparation; Mr. Luke Nienhaus, CIH, who is a Manager at RHP and assisted with weekly station

[1] https://www.cityofevanston.org/about-evanston/sustainability/church-street-waste-transfer-station-information

visits for equipment maintenance and data downloads; Mr. Matt Oleszczak, who is an Associate Health Scientist at RHP and assisted with data analysis.

The study also included active community engagement, such as community meetings and equipment demonstrations, to add transparency and provide a forum for answering questions of community residents about the study objectives, methods, expectations, and timeline. A website was developed and maintained at www.evanstonair.info to share with the community about study-related developments, milestones, and events and provide timely information.

3 PROJECT PURPOSE AND OBJECTIVE

The general objective of the screening-level study was to assess ambient air quality in the vicinity of the Church Street Waste Transfer Station, based upon the TEX project recommendations.

The specific aims of the study included:

i. measurement of ambient air concentrations of twelve pollutants/parameters of interest identified by the TEX project team [i.e., nitric oxide, nitrogen dioxide, ozone, carbon monoxide, sulfur dioxide, hydrogen sulfide, methyl mercaptan, formaldehyde, Volatile Organic Compounds, particulate matter with aerodynamic size less than 10 µm and 2.5 µm (PM_{10} and $PM_{2.5}$, respectively), and noise] at four air monitoring stations in the neighborhood in close proximity to the waste transfer station and at a control site;
ii. determination of whether the measured concentrations for any of the target parameters or pollutants of interest demonstrate probable source-attribution to site operations at the waste transfer station, so that further targeted air quality assessment efforts and/or a human health risk assessment, may then be performed in the future.

4 METHODS

Air Monitoring Study Timeline

Air monitoring equipment was deployed by RHP and WindSoleil, an Evanston Based Enterprise contractor, during the week of May 8 to May 17, 2019. Data logging at all stations started on May 17, 2019 and ended on November 20, 2019. A nested study to evaluate traffic patterns around each of the five stations was subcontracted to Traffic Impact Group, LLC. The traffic study started on August 5, 2019 and ended on September 11, 2019.

Air Monitoring Stations

A 6-month long air monitoring and air quality assessment study involved placement of direct-read data-logging monitors at four stations surrounding the waste transfer station, and additionally at a control site near Twiggs Park, approximately a half-mile to the northwest in the predominantly upwind direction from the waste transfer station (see Figure 1 and Figure 2). The control site location was selected to represent background concentrations of air pollutants not influenced by a specific source or sources in the area. Air monitoring for all pollutants/parameters of interest was performed at these four locations surrounding the waste transfer station and at the control station. Figure 1 below shows the locations of the four air monitoring stations surrounding the waste transfer station.

Figure 1 shows the four site locations near the waste transfer station.

Figure 2 shows the control site in relation to the study area.

Figures 3-7 show the air monitoring equipment placed in each sampling location (i.e., Station 1, 2, 3, 4, and 5 with Station 5 being the control location). The addresses of each of the air monitoring stations are:

- <u>Station 1 (Lyons/Darrow)</u> – Located at 1721 Lyons St., 72 ft. from the northwest property boundary of the waste transfer station.
- <u>Station 2 (Lyons/Ashland)</u> – Located at 1670 Lyons St., 330 ft. from the northeast property boundary of the waste transfer station.
- <u>Station 3 (Church Street Village)</u> – Located in the back yard of Unit 1641 at Church Street Village (private property), within 1 ft. of the eastern property boundary for an abandoned railroad right-of-way abutting the waste transfer station.
- <u>Station 4 (Church Street)</u> – Located on the south side of Church St. at 1715 Church St., 94 ft. from the driveway entrance and 262 ft. from the entrance of the waste transfer station.
- <u>Station 5 (Twiggs Park)</u> – The control site was located at 1998 Simpson St. / Twiggs Park, approximately a half-mile to the northwest of the waste transfer station. The location of the control site in relation to the Study Area is shown in Figure 2.

Figure 3: Station 1 at 1721 Lyons St. – West side of waste transfer station.

Figure 4: Station 2 at 1670 Lyons St. – Northeast side of waste transfer station.

Figure 5: Station 3 at Church St. Village – East side of waste transfer station.

Figure 6: Station 4 at 1715 Church St. along south side of waste transfer station.

Figure 7: Station 5, control site at Twiggs Park.

Air Monitoring Equipment

The air sampling equipment or sensor placed at each monitoring station included two instruments, one of which was specified in Attachment B of the project RFP issued by the City of Evanston: 1) an AQMesh monitor, and 2) a MultiRAE Pro monitor. Two of the monitoring stations, one nearby the waste transfer station and one at the control station, were additionally configured with equipment to measure weather conditions (wind speed and wind direction).

AQMesh Air Quality Monitor [2]

The AQMesh Air Quality Monitor (pod) is a small sensor air quality monitor which was recommended by the TEX project as a monitoring solution to cover a significant portion of the parameters of interest. Independent research has previously been performed by the USEPA which indicated a weak or no correlation between AQMesh sensors (e.g. nitrogen oxide/nitrogen dioxide) and regulatory level monitoring equipment.[3] Comparison trials and performance testing in various conditions have been conducted by the instrument manufacturer as updated versions of the sensor software are released and these trials reportedly demonstrated a close relationship between reference stations and the AQMesh Air Quality Monitor.[4,5,6]

MultiRAE Pro (Model PGM-6248) [7]

The MultiRAE Pro is a wireless electrochemical sensor device that is compliant with MIL-STD-810G and 461F performance standards.[8]

Appendix A.2 contains a table which summarizes equipment specifications for the air quality monitors, including detection ranges and analytical Limits of Detection (LOD) for each measured parameter. The Limit of Detection is the lowest concentration that can be reliably measured by the instrument for a given parameter. If “nothing” is measured, then the recorded value is not “zero” but rather “less than the LOD”.

[2] https://www.aqmesh.com/
[3] https://www.epa.gov/air-sensor-toolbox/evaluation-emerging-air-pollution-sensor-performance
[4] https://aqmesh.com/performance/overview/
[5] https://www.aqmesh.com/performance/co-location-comparison-trials/
[6] https://www.atmos-meas-tech.net/9/5281/2016/amt-9-5281-2016-discussion.html
[7] https://www.raesystems.com/products/multirae-pro
[8] https://www.raesystems.com/customer-care/resource-center/multirae-pro-datasheet

Test Parameters

Each of the five monitoring stations were configured to measure the following aforementioned twelve parameters of interest:

Table 1: List of Test Parameters and Health Effects	
Parameter	**Health Effects**
Hydrogen Sulfide (H_2S)	Exposure to low concentration of hydrogen sulfide may cause irritation to eyes, nose, or throat as well as difficulty breathing. Respiratory distress or loss of consciousness may occur in people exposed to high concentrations.[9]
Methyl Mercaptan (CH_4S)	Methyl mercaptan gas is irritating to the eyes, skin, and respiratory tract and edema to the airway and lungs. Other possible effects include headache, dizziness, tremors, seizures, nausea and vomiting. Methyl mercaptan is a central nervous system depressant that acts on the respiratory center to cause respiratory paralysis.[10]
Formaldehyde (CH_2O)	Formaldehyde may cause irritation of the eyes, nose, and throat. The Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) have characterized formaldehyde as a human carcinogen.[11]
Organic Solvents (VOC)	VOCs include a variety of chemicals, some of which have short- and long-term health effects. Health effects include eye, nose, and throat irritation, headaches, loss of coordination, damage to liver, kidney, and central nervous system, and some are suspected or known to cause cancer in humans.[12]
Nitric Oxide (NO)	Health effects from breathing nitrogen oxides can include irritation of the respiratory system, eyes, and skin, aggravation of respiratory disease, particularly asthma, coughing, nausea, headache and difficulty breathing.[13]
Nitrogen Dioxide (NO_2)	Breathing air with high concentrations of nitrogen dioxide can irritate airways and can aggravate respiratory disease. Longer exposures to elevated concentrations may contribute to the development of asthma and increase susceptibility to respiratory infections.[14]

[9] https://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=388&tid=67
[10] https://www.atsdr.cdc.gov/MMG/MMG.asp?id=221&tid=40
[11] https://www.atsdr.cdc.gov/phs/phs.asp?id=218&tid=39
[12] https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality#Health_Effects
[13] https://toxtown.nlm.nih.gov/chemicals-and-contaminants/nitrogen-oxides
[14] https://www.epa.gov/no2-pollution/basic-information-about-no2

Table 1: List of Test Parameters and Health Effects	
Parameter	**Health Effects**
Ozone (O_3)	Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and airway inflammation. It can also reduce lung function and harm lung tissue.[15]
PM2.5	Small particles, less than or equal to 10 micrometers in diameter have been linked to a variety of health effects including premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms such as coughing or difficulty breathing.[16]
PM10	
Carbon Monoxide (CO)	Carbon monoxide can cause headache, dizziness, vomiting, and nausea. Exposure to moderate and high levels of carbon monoxide over long periods of time has also been linked with increased risk of heart disease.[17]
Sulfur Dioxide (SO_2)	Short term exposure to sulfur dioxide can harm the respiratory system and make breathing difficult. People with asthma, particularly children, are sensitive to these effects of sulfur dioxide.[18]
Noise (dB)	Environmental noise exposure is responsible for a range of health effects including increased risk of heart disease, sleep disturbance, cognitive impairment among children, stress-related mental issues, and tinnitus.[19]

Appendix A.9 contains a summary table which provides additional information about each parameter/pollutant, including a general description and potential emission sources into air.

Additionally, a traffic study of 30-day duration was conducted by a subcontracted entity (Traffic Impact Group, LLC) to measure traffic volume and vehicle type as additional variables to consider when performing statistical analysis of the air quality data since emissions from the traffic sources are contributors to ambient air quality.

Air Monitoring Data Collection

Air monitoring data collected by each of the sensors was recorded at nominal 1-minute intervals for the study duration. RHP downloaded data on a weekly basis while performing routine equipment maintenance rounds and Quality Assurance / Quality Control (QA/QC) checks.

[15] https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics
[16] https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm
[17] https://ephtracking.cdc.gov/showCoRisk.action
[18] https://www.epa.gov/so2-pollution/sulfur-dioxide-basics
[19] https://www.who.int/sustainable-development/transport/health-risks/noise/en/

Additional information about the study data management and quality control measures/protocols are presented in Appendix A.2.

Air Quality Data Analysis

Data analysis was performed using JMP 15.0 Data Analysis Software, which is an industry-leading statistical software package developed by SAS.[20] Additional information about the statistical analysis approach can be found in Appendix A.1.

The data was organized six different ways and assessed from several perspectives to view the data through various "lenses" with the goal of answering critical questions pertaining to study goals and facilitating the scientific weight of evidence assessment to be performed. These various perspectives included:

Lens 1 – Time Series Analysis (see Appendix A.3)

A time series analysis was the "first lens" through which each of the target parameters was evaluated. This allows for an overall evaluation of the temporal (over time) and spatial (over space) assessment of data collected. Graphs for each parameter were generated by plotting measured concentrations over time, which comprised of data series for each of the five stations for comparative analysis. Additional analysis included: descriptive statistics for each parameter (organized by station), statistical distribution plots, box and whisker plots, tests for distribution normality, quantile statistics, summary statistics, fitted distribution and Goodness-of-Fit Test results.

Lens 2 – Study Area vs. Control Comparison (see Appendix A.4)

The comparison of concentrations measured at the study area monitoring stations vs. those at the control station served as the "second lens" through which each of the target parameters was evaluated. This analysis seeks to answer the question of whether study area locations have higher concentrations of air pollutants as compared to the those measured at the control site. Statistical tests were performed to compare concentrations measured at the four stations within the Study Area to the those measured at the control station. For each parameter/pollutant measured, an analysis was performed to determine whether the data was statistically similar or different in comparison to the control station. This included the development of an "exposure ranking index" (which is defined as the ratio between concentration measured at the site and concentration measured at the control station) and calculation of the percent change between the four stations within the study area and the

[20] https://www.jmp.com/en_us/software/data-analysis-software.html

control station. Additionally, maps were developed to visually compare the 95th percentile upper confidence limits (95% UCLs) between the stations within the study area and the control station.

<u>Lens 3 – Operational vs. Non-Operational Facility Hours Comparison</u> (see Appendix A.5)

The comparison of concentrations measured during the operational hours of the waste transfer station vs. those measured during the non-operational facility hours served as the "third lens" through which each of the target parameters was evaluated. This analysis seeks to answer the question of whether air pollutant concentrations were higher during the operational hours of the facility as compared to those measured during the non-operational time frame. For purposes of this analysis, operating hours were defined according to the "posted hours" of Monday – Friday (6:30 AM – 3:30 PM) and Saturday (7:00 AM – 10:00 AM). Memorial Day, Independence Day, and Labor Day were identified as non-operation days. Statistical tests were conducted to compare the results from only the four stations within the Study Area while considering a second categorical variable of Operating vs. Non-Operating facility hours. For each parameter/pollutant measured, an analysis was performed to determine whether the data was statistically similar or different based upon facility operational status. Also, the "exposure ranking index" previously calculated was further examined based on facility operational status.

<u>Lens 4 – Wind Direction Analysis</u> (see Appendix A.6)

The wind direction analysis served as the "fourth lens" through which each of the target parameters was evaluated and aims to answer the question of whether air pollutant concentrations measured downwind of the facility (carrying the potential emissions from the facility) were higher as compared to those measured from other directions. Statistical tests were conducted to evaluate the results from Station 4, which was the only station that housed a weather station within the Study Area, while considering a second categorical variable of wind direction. Data values for each of the parameters logged at Station 4 were categorized into 1 of 16 bins representing a 16-sector wind-rose (e.g. N, NNE, NE, etc.). For each parameter/pollutant measured, an analysis was performed to determine whether the data in the bin representing placement of the monitoring station "downwind" of the waste transfer station was statistically similar or different than values recorded when the station was "not downwind" during facility operating hours only.

<u>Lens 5 – Data Outlier Analysis</u> (see Appendix A.7)

The data outlier analysis served as the "fifth lens" through which each of the target parameters was evaluated and served as a means to examine the data set with a focus on high concentration events (i.e., spikes/peaks), with the goal of understanding the frequency, duration, and intensity of time periods associated with higher air pollutant concentrations in the study area. In order to assess extent to which high concentration events were observed downwind of the facility, we additionally performed a statistical test to identify outlier data points in the Station 4 distributions (values at least 3 times the interquartile range past the lower and upper quantiles). We then calculated the percentage of data outliers for Station 4 that relate to the downwind direction versus all other wind directions.

<u>Lens 6 – Traffic Influence Analysis</u> (see Appendix A.8)

The traffic influence analysis allows the assessment of impact of traffic-related emissions on local air quality and served as the "sixth lens" through which each of the target parameters was evaluated. This also provides a means to assess vehicular traffic as a confounding variable in the statistical analysis. We developed multi-variate correlations to uncover the relationship between parameter/pollutant concentration and truck or all-vehicle traffic counts by minute. We sought to determine whether a positive or inverse effect on concentration was apparent as truck or all-vehicle traffic volume increased or decreased.

Weight of Evidence (WOE) Scoring

To hierarchically rank the importance of findings for each parameter/pollutant, a Weight of Evidence (WOE) scoring approach was developed. Scoring rubrics are defined in Appendix A.11 for each lens and sub-lens to provide a quantitative means of representing the degree of evidence suggestive of *possible* site influence. This allowed application of scientific weight of evidence approach in our decision-making for delineating those parameters with the highest concern for site (i.e., waste transfer facility) influence by collective accounting of the results obtained from lens 1 to lens 6 described above.

Summarily, for each parameter, when a particular lens presented evidence suggestive of *possible* site influence, then a positive score of +1 point was assigned. If no supporting information was provided for a particular parameter, then no score was assigned (e.g., 0 points). If the evidence for a particular parameter demonstrated that measured values at stations within the Study Area were of less concern than those at the Control Station, then a negative score of -1 point was assigned.

For each parameter, WOE score totals were calculated by adding the sum of scores across all lenses. The WOE score totals were then rank-ordered, and categorically assigned into three tiers or categories with decreasing level of concern for site influence from 1st Tier to Deprioritized Parameters:

- 1st Tier Parameters → 2nd Tier Parameters → Deprioritized Parameters

Traffic Study

RHP partnered with Traffic Impact Group, LLC (Downers Grove, IL) to conduct a traffic evaluation in order to understand the impact of truck and overall vehicle traffic volume on the local air quality. The traffic study was conducted from August 5, 2019 to September 11, 2019. Recorded information included speed, class of vehicle, and volume data, by direction, for each minute. Five traffic monitoring devices were placed in close proximity to each of the five air monitoring stations. Additional information about the traffic study can be found in Appendix A.10.

5 FINDINGS

Air monitoring data was collected for approximately 6 months from May 17, 2019 to November 20, 2019. Measurement values for most of the parameters/pollutants were recorded at 1-minute intervals which resulted in a robust data set with over 112 million data points. We present a weight of evidence summary table and WOE score for each parameter and lens followed by the findings organized and summarized through each of the "6 lenses" discussed above.

Weight of Evidence Summary Table and Score Totals

A summary of the WOE scores assigned for each lens and overall weight of evidence score totals are presented in the table below. A detailed WOE scoring table, which includes the scoring criteria for each lens, is included in Appendix A.11.

Table 2: WOE Scoring Table

	Lens									
Parameter	2	2A ERI	2A %C	2B	3	3A	4	5	6	WOE Score Total
Hydrogen Sulfide (H_2S)	0	0	0	+1	-1	0	-1	0	+1	0
Methyl Mercaptan (CH_3SH)	-1	0	0	+1	+1	0	-1	+1	0	+1
Formaldehyde (CH_2O)	+1	+1	+1	+1	+1	+1	-1	+1	0	+6
Volatile Organic Compounds (VOC)	+1	0	0	+1	+1	0	-1	+1	0	+3
Nitric Oxide (NO)	+1	+1	+1	+1	+1	+1	-1	+1	0	+6
Nitrogen Dioxide (NO_2)	+1	0	+1	+1	+1	0	-1	+1	0	+4
Ozone (O_3)	+1	-1	0	-1	+1	0	+1	-1	-1	-1
Particulate Matter ($PM_{2.5}$)	-1	-1	-1	-1	+1	-1	-1	+1	0	-4
Particulate Matter (PM_{10})	-1	-1	-1	-1	+1	-1	-1	+1	0	-4
Particulate Matter (PM_{TOTAL})	-1	-1	-1	-1	+1	-1	+1	+1	0	-2
Carbon Monoxide (CO)	+1	-1	0	+1	+1	-1	-1	+1	0	+1
Sulfur Dioxide (SO_2)	+1	0	0	+1	+1	0	+1	+1	0	+5
Noise (dB)	+1	0	0	+1	+1	0	0	0	-1	+2

Lens 2: Study Area vs Control
Lens 2A: Exposure Ranking Index (ERI)
Lens 2A: Percent Change (%C)
Lens 2B: Upper 95% Mean Confidence Limit
Lens 3: Operational vs, Non-Operational Hours
Lens 3A: ER Operational vs. Non-Operational Hours
Lens 4/5: Wind Direction and DW Outliers (Station 4)
Lens 6: Traffic Influence Analysis

Color key:

1st Tier Parameters
2nd Tier Parameters
Deprioritized Parameters

Parameters were assigned to one of three prioritization tiers (highlighted in red, yellow and green) based on an overall WOE score total as described above. The top two parameters with the highest WOE score were assigned to the 1st Tier; all other parameters with positive WOE score totals were assigned to the 2nd Tier. Parameters with null or negative WOE score totals were deprioritized.

Lens 1: Time Series Analysis

Graphical representation of the data provides initial insight on data trends throughout the study period and provides a high-level summary of the monitoring results. Appendix A.3.1 presents graphs for each station that show the concentrations for each parameter over time during the study period.

Descriptive statistics and box plots are provided below to summarize and visualize the distribution of 1-minute average values collected throughout the study. In order to better visualize the data distributions, the following box plots were created so that the maximum concentration shown is equal to the "maximum outlier threshold" for that parameter as provided in Appendix A.7. If the entire data range were to be shown in the following box plots, then the median and interquartile range values would be indiscernible. The elements of the box plots are described below.[21] While Appendix A.3.1 presents tables with summary statistics along with other basic statistical information Appendix A.3.2 includes additional box plot figures.

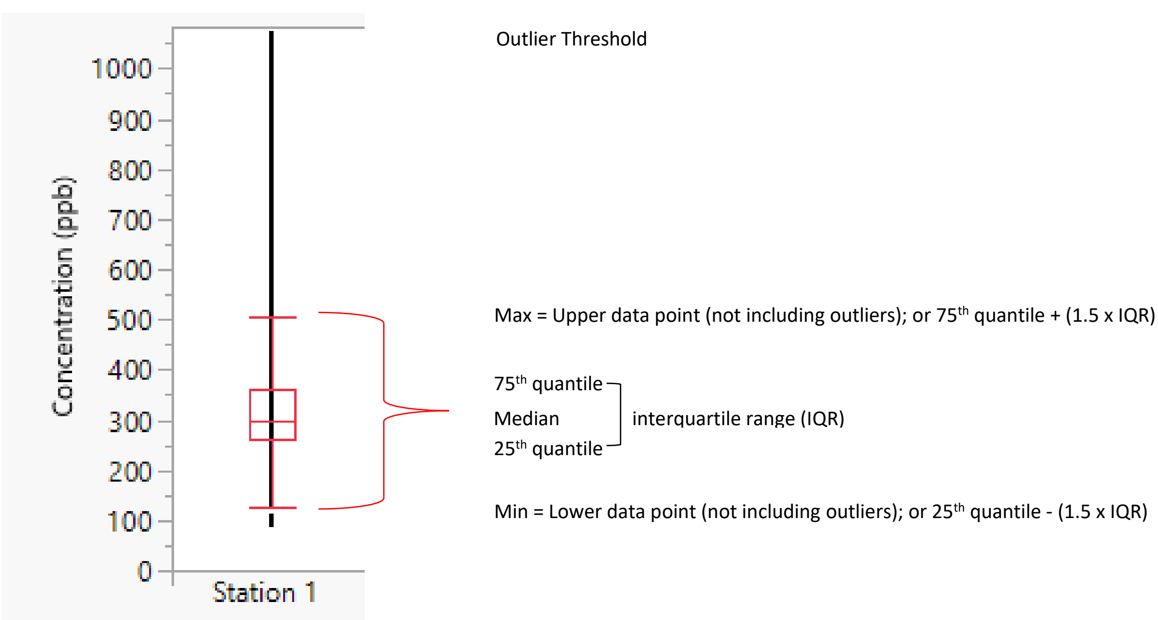

Figure 8: Example box plot and statistical elements.

[21] https://www.jmp.com/support/help/14-2/outlier-box-plots.shtml

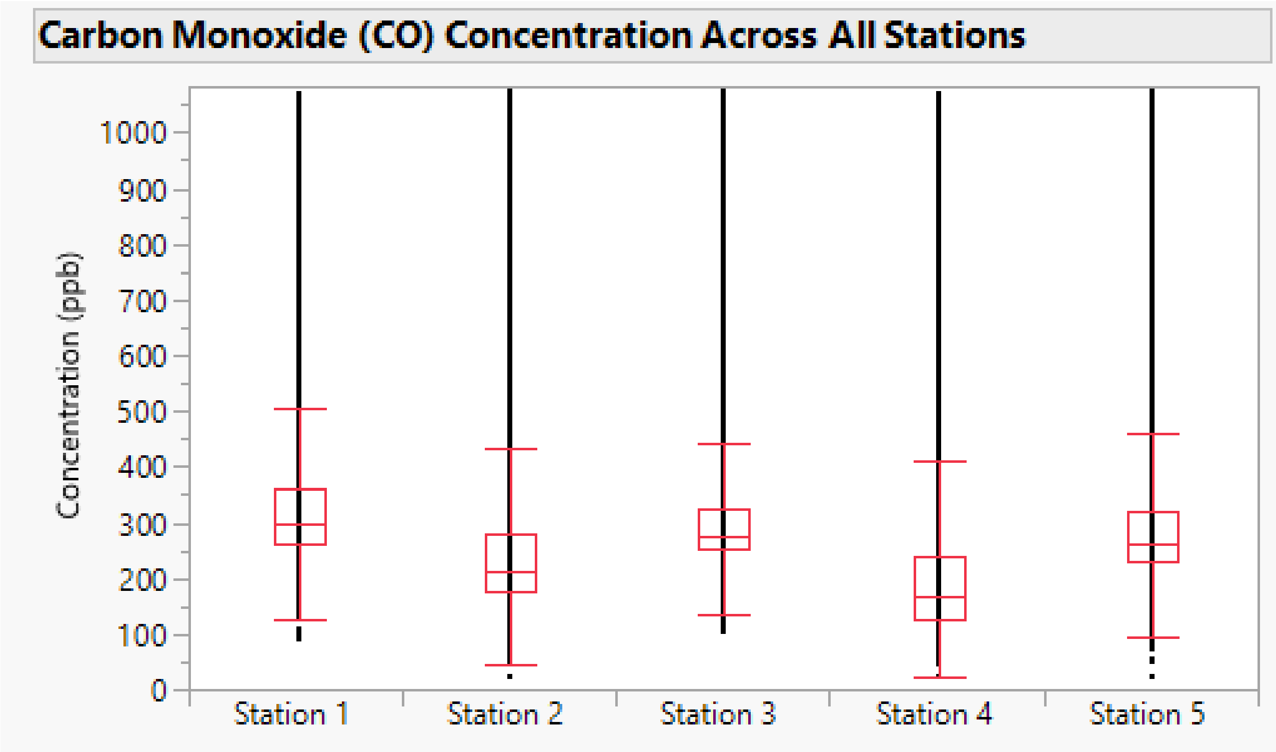

Figure 9: Box plots representing the carbon monoxide (CO) concentration at each station across the entire study duration. Threshold Max set at 1,082 ppb for data visualization.

Table 3: Carbon Monoxide (CO) (ppb)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	233,828	96	12,752	146	301	334
Station 2	230,083	25	10,691	151	217	250
Station 3	234,015	107	7,397	99	280	307
Station 4	233,912	25	10,448	147	172	207
Station 5	233,899	25	9,684	156	267	299

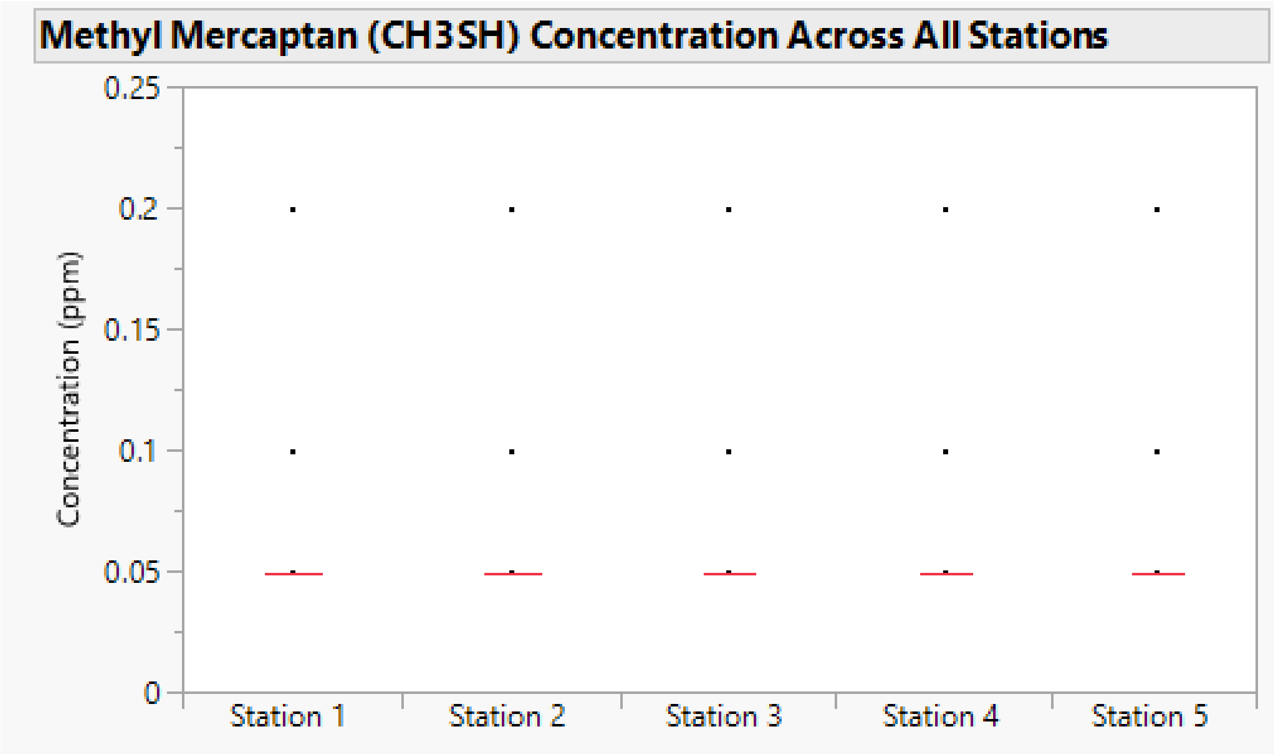

Figure 10: Box plots representing the methyl mercaptan (CH_3SH) concentration at each station across the entire study duration. Threshold Max set at 0.25 ppm for data visualization.

Table 4: Methyl Mercaptan (CH_3SH) (ppm)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	268,087	0.05	0.4	0.01	0.05	0.05
Station 2	268,579	0.05	0.2	0.01	0.05	0.05
Station 3	262,154	0.05	0.2	0.01	0.05	0.05
Station 4	265,972	0.05	3.9	0.02	0.05	0.05
Station 5	249,085	0.05	0.3	0.01	0.05	0.05

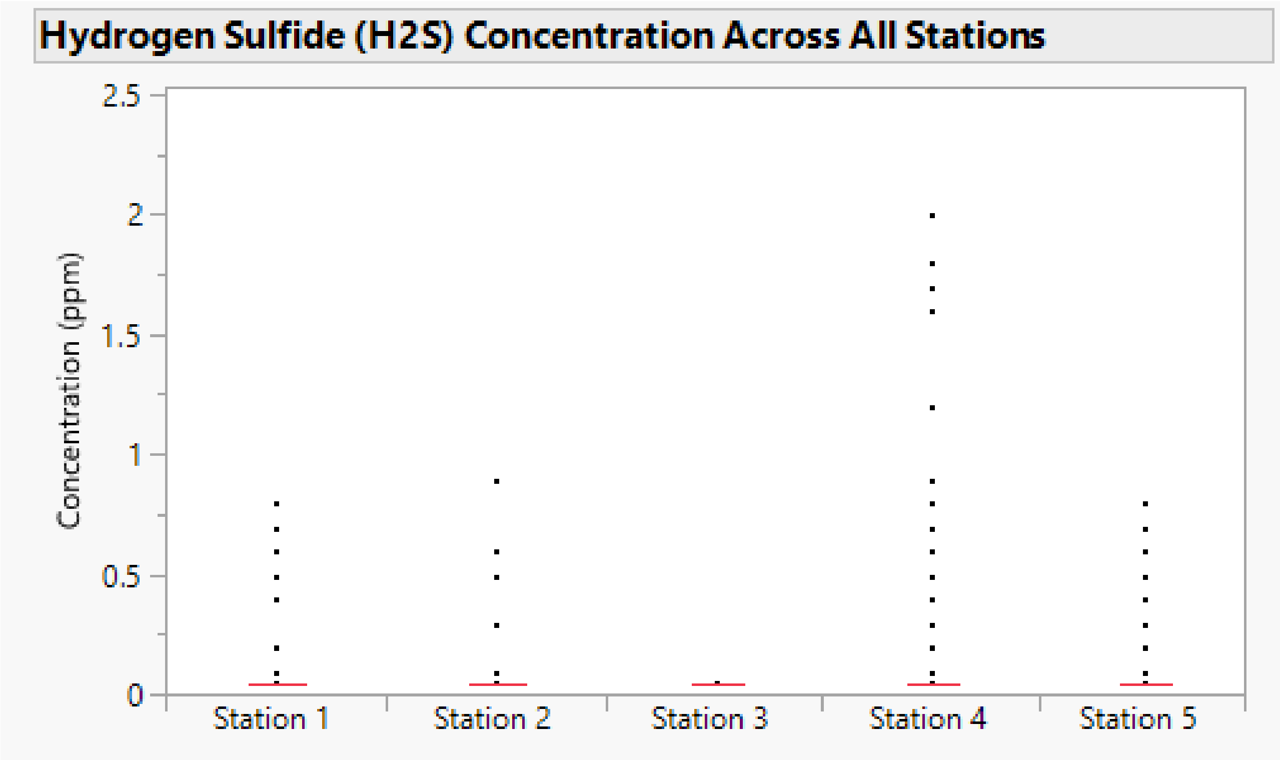

Figure 11: Box plots representing the hydrogen sulfide (H_2S) concentration at each station across the entire study duration. Threshold Max set at 2.53 ppm for data visualization.

Table 5: Hydrogen Sulfide (H_2S) (ppm)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	268,087	0.05	0.8	0.004	0.05	0.05
Station 2	268,579	0.05	0.9	0.002	0.05	0.05
Station 3	262,154	0.05	0.05	0.000	0.05	0.05
Station 4	265,972	0.05	7.7	0.030	0.05	0.05
Station 5	249,085	0.05	0.8	0.013	0.05	0.05

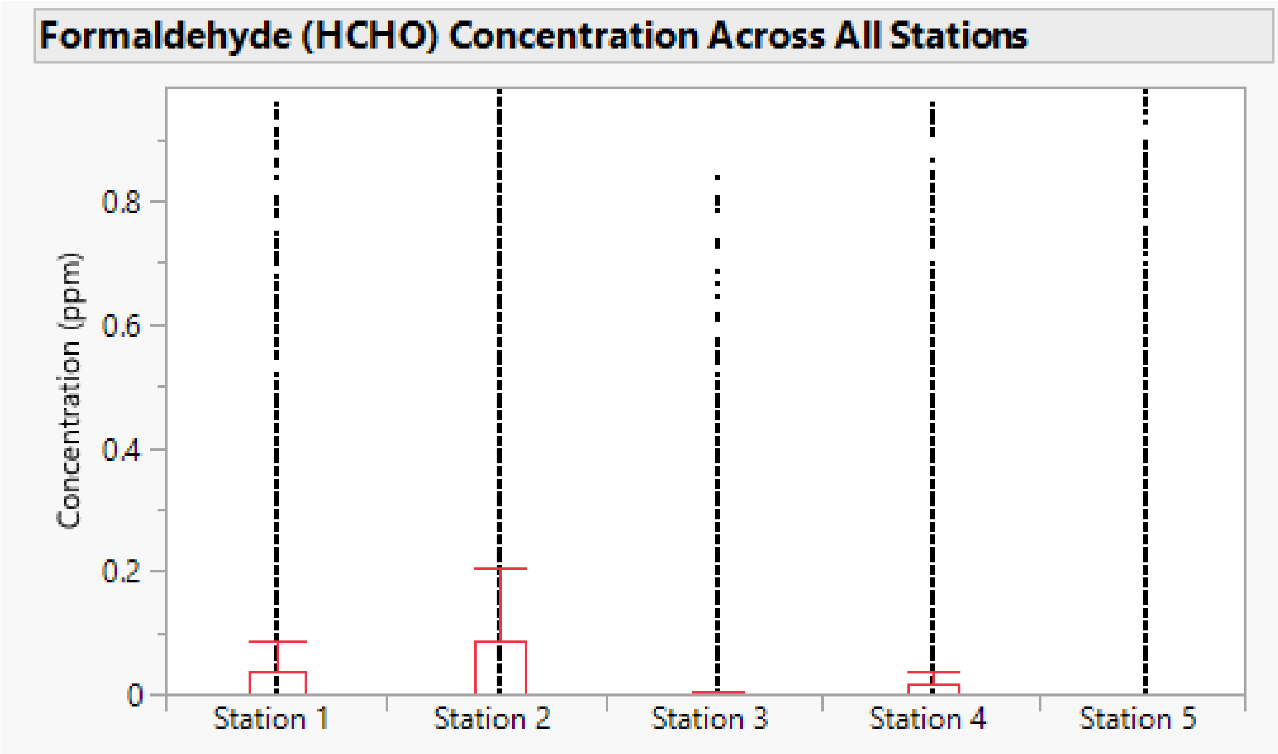

Figure 12: Box plots representing the formaldehyde (HCHO) concentration at each station across the entire study duration. Threshold Max set at 0.985 ppm for data visualization.

Table 6: Formaldehyde (HCHO) (ppm)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	268,087	0.005	6.34	0.052	0.005	0.029
Station 2	268,579	0.005	9.10	0.143	0.005	0.078
Station 3	261,434	0.005	3.90	0.038	0.005	0.019
Station 4	265,972	0.005	4.16	0.038	0.005	0.019
Station 5	249,085	0.005	8.80	0.073	0.005	0.017

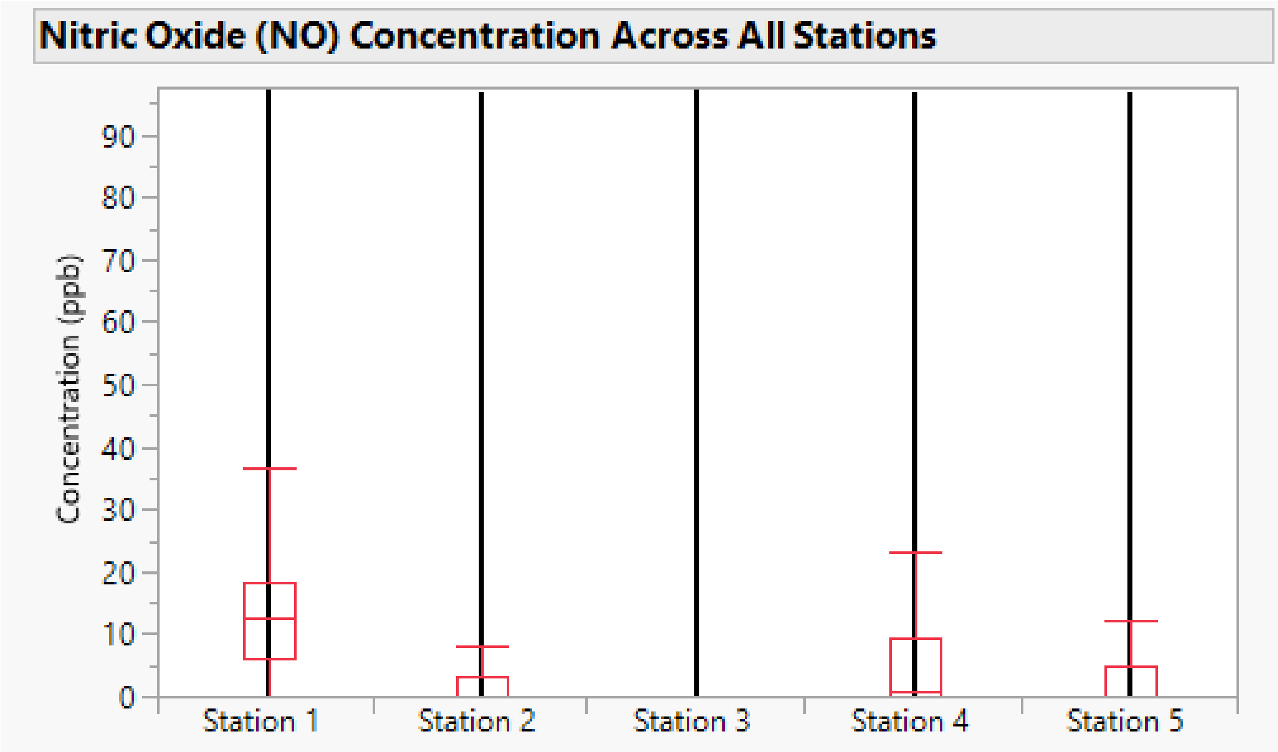

Figure 13: Box plots representing the nitric oxide (NO) concentration at each station across the entire study duration. Threshold Max set at 97 ppb for data visualization.

Table 7: Nitric Oxide (NO) (ppb)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	233,636	0.5	2,172	14.2	12.8	14.6
Station 2	230,083	0.5	1,164	11.2	0.5	3.9
Station 3	234,015	0.5	210	7.8	0.5	2.2
Station 4	233,917	0.5	6,673	35.9	1.4	8.1
Station 5	233,899	0.5	572	9.8	0.5	4.8

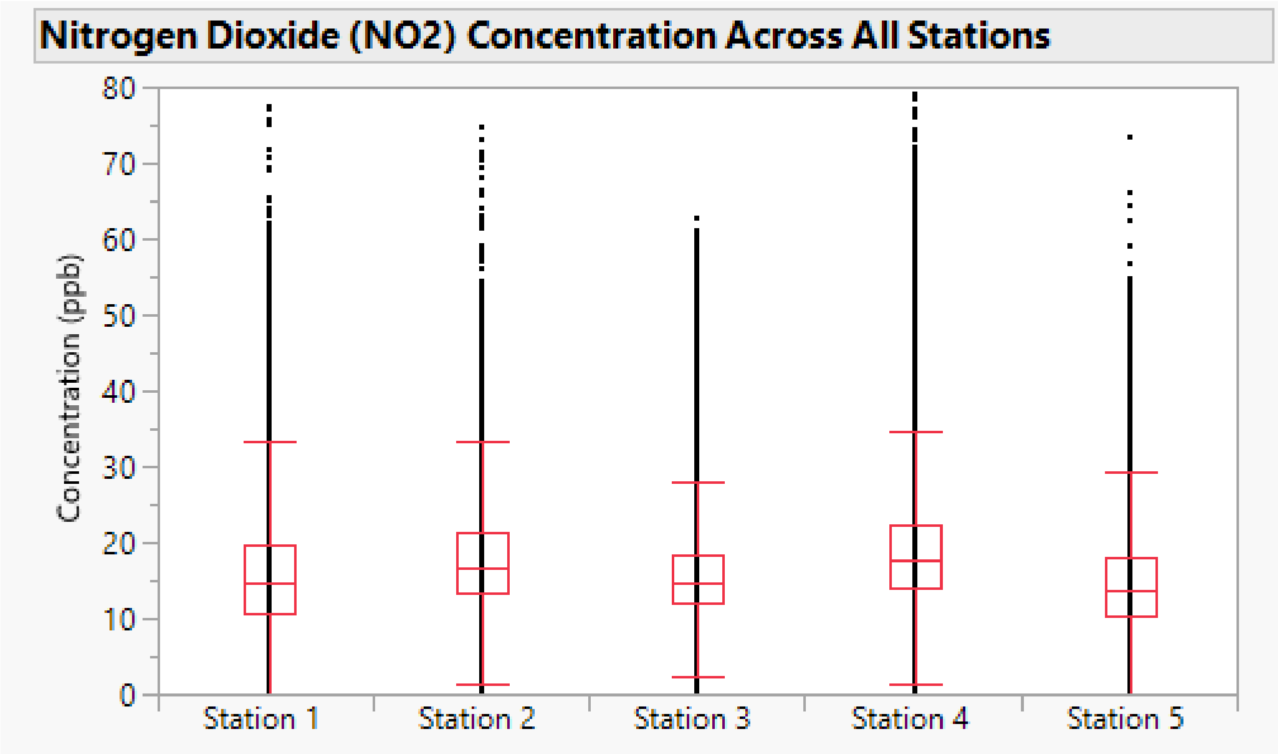

Figure 14: Box plots representing the nitrogen dioxide (NO_2) concentration at each station across the entire study duration. Threshold Max set at 80 ppb for data visualization.

Table 8: Nitrogen Dioxide (NO_2) (ppb)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	233,828	0.5	198	7.7	14.9	16.4
Station 2	230,083	0.5	320	6.4	17.1	17.9
Station 3	234,015	0.5	63	5.4	15.1	15.9
Station 4	233,917	0.5	3,189	13.4	17.9	19.2
Station 5	233,899	0.5	120	6.4	14.1	15.2

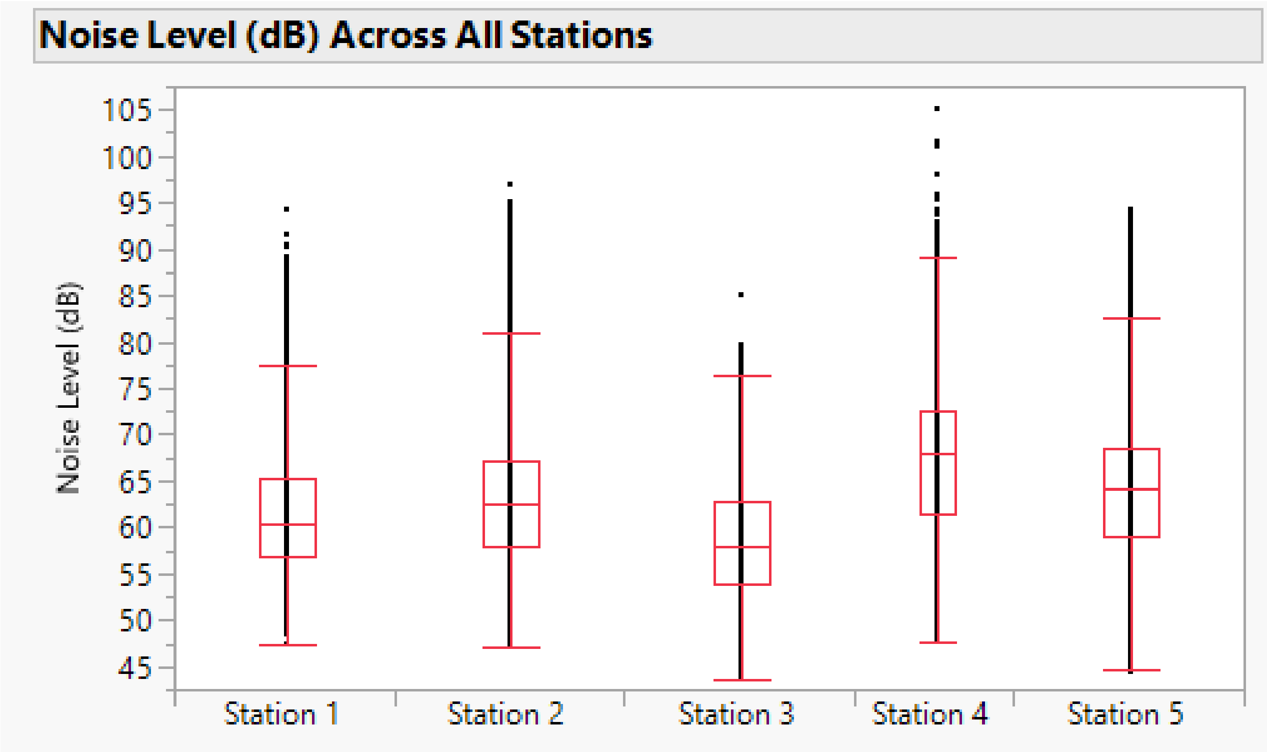

Figure 15: Box plots representing the sound level (dB) at each station across the entire study duration.

Table 9: Noise Sound Level (dB)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	217,830	47.7	94.4	5.50	60.6	47.7
Station 2	226,407	47.5	97.1	6.65	62.8	63.3
Station 3	229,539	43.9	85.3	5.88	58.2	58.7
Station 4	157,629	47.9	105.3	7.19	68.3	67.4
Station 5	227,492	44.8	94.4	6.73	64.5	64.2

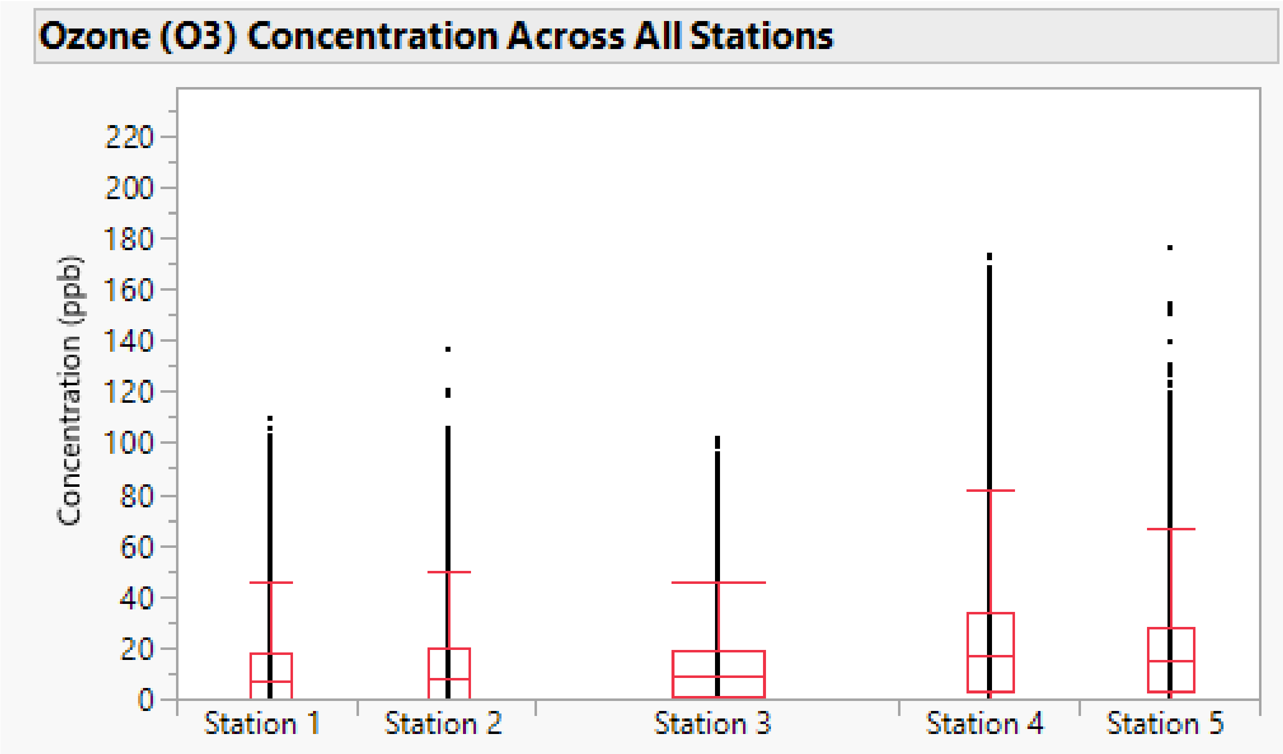

Figure 16: Box plots representing the ozone (O_3) concentration at each station across the entire study duration. Threshold Max set at 238 ppb for data visualization

Table 10: Ozone (O_3) (ppb)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	233,828	0.5	110	15.2	7.6	12.8
Station 2	230,083	0.5	137	15.8	9.3	14.1
Station 3	234,015	0.5	102	14.1	10.0	13.7
Station 4	233,911	0.5	174	25.0	17.6	24.2
Station 5	233,899	0.5	177	18.6	15.5	19.6

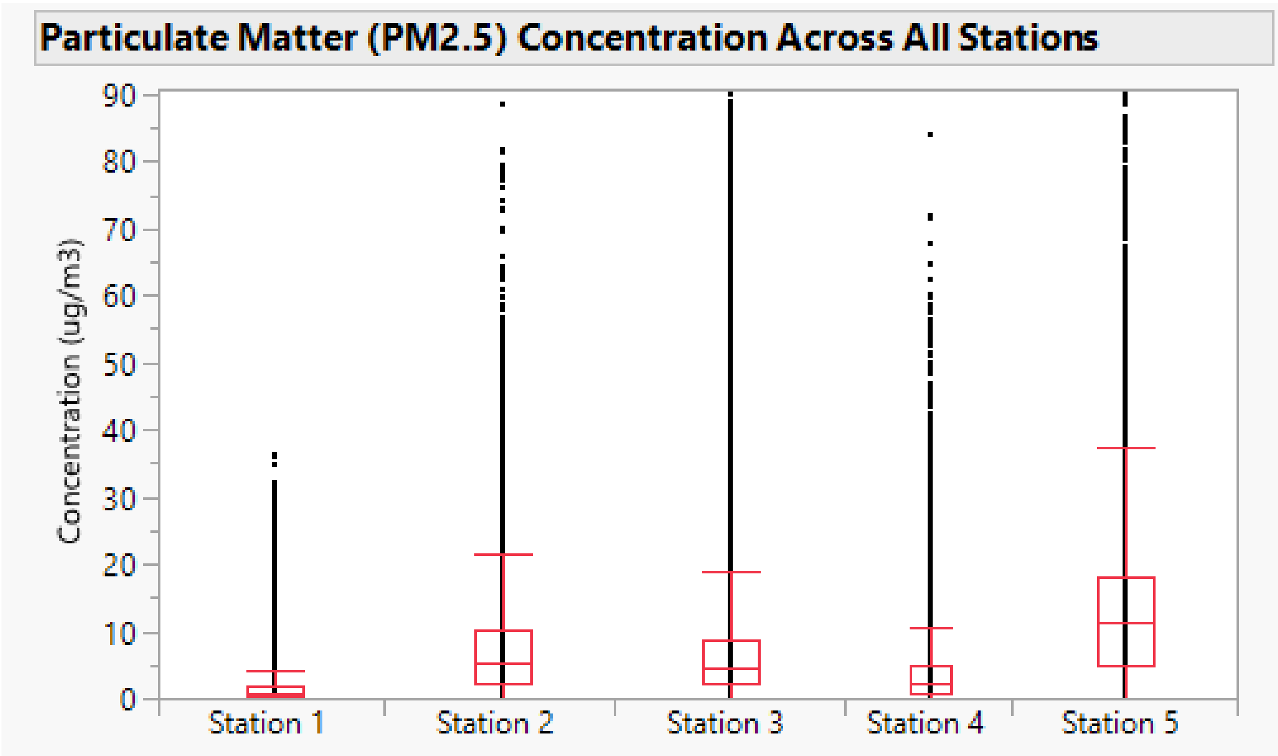

Figure 17: Box plots representing the fine particulate matter ($PM_{2.5}$) concentration at each station across the entire study duration. Threshold Max set at 90 µg/m^3 for data visualization.

Table 11: Fine Particulate Matter 2.5 (ug/m^3)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	256,069	0.01	36.65	2.01	1.30	1.87
Station 2	259,636	0.07	112.28	6.56	5.72	7.60
Station 3	259,683	0.06	488.04	7.98	5.06	7.14
Station 4	189,271	0.03	113.65	3.55	2.63	3.78
Station 5	255,341	0.13	424.84	9.25	11.62	12.90

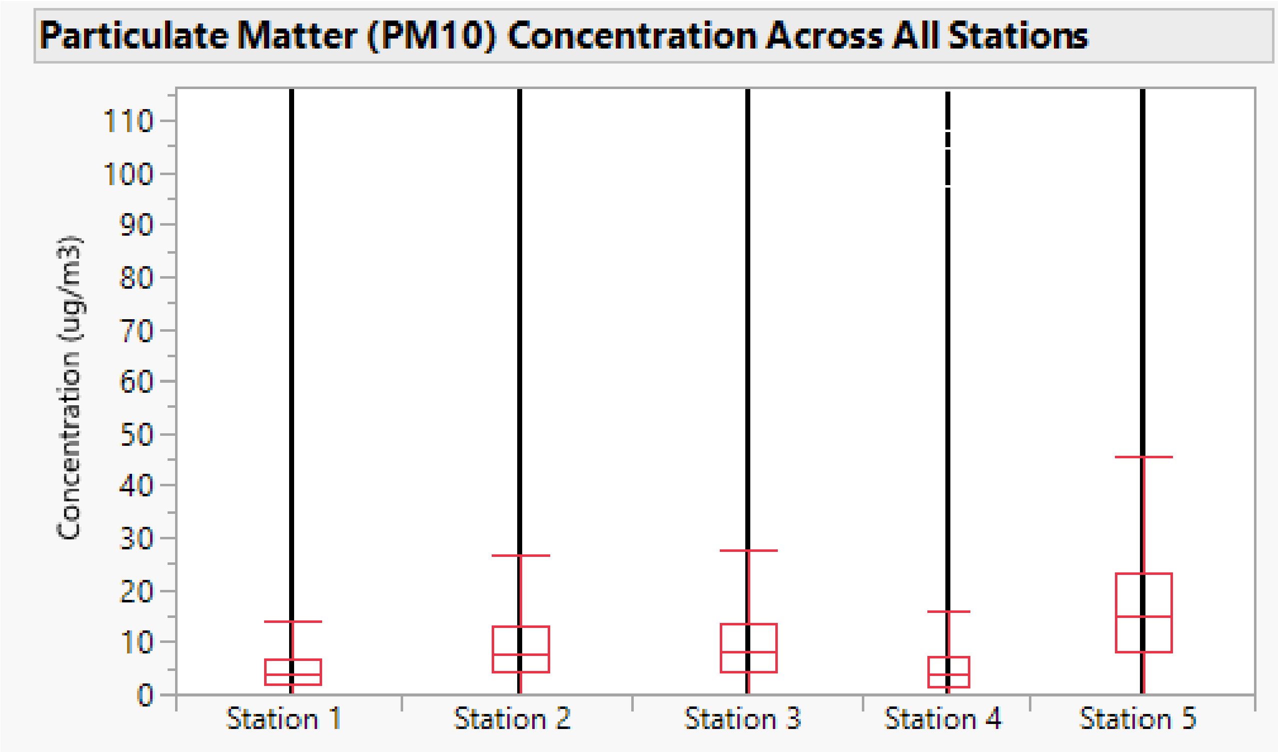

Figure 18: Box plots representing the coarse particulate matter (PM_{10}) concentration at each station across the entire study duration. Threshold Max set at 116 ug/m^3 for data visualization.

Table 12: Coarse Particulate Matter 10 (ug/m^3)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	256,069	0.01	890.88	13.8	4.43	6.59
Station 2	259,636	0.07	272.48	9.87	8.40	10.65
Station 3	259,683	0.06	1440.85	14.88	8.50	11.80
Station 4	189,271	0.03	926.75	8.22	4.19	6.16
Station 5	255,341	0.16	778.01	13.61	15.63	17.74

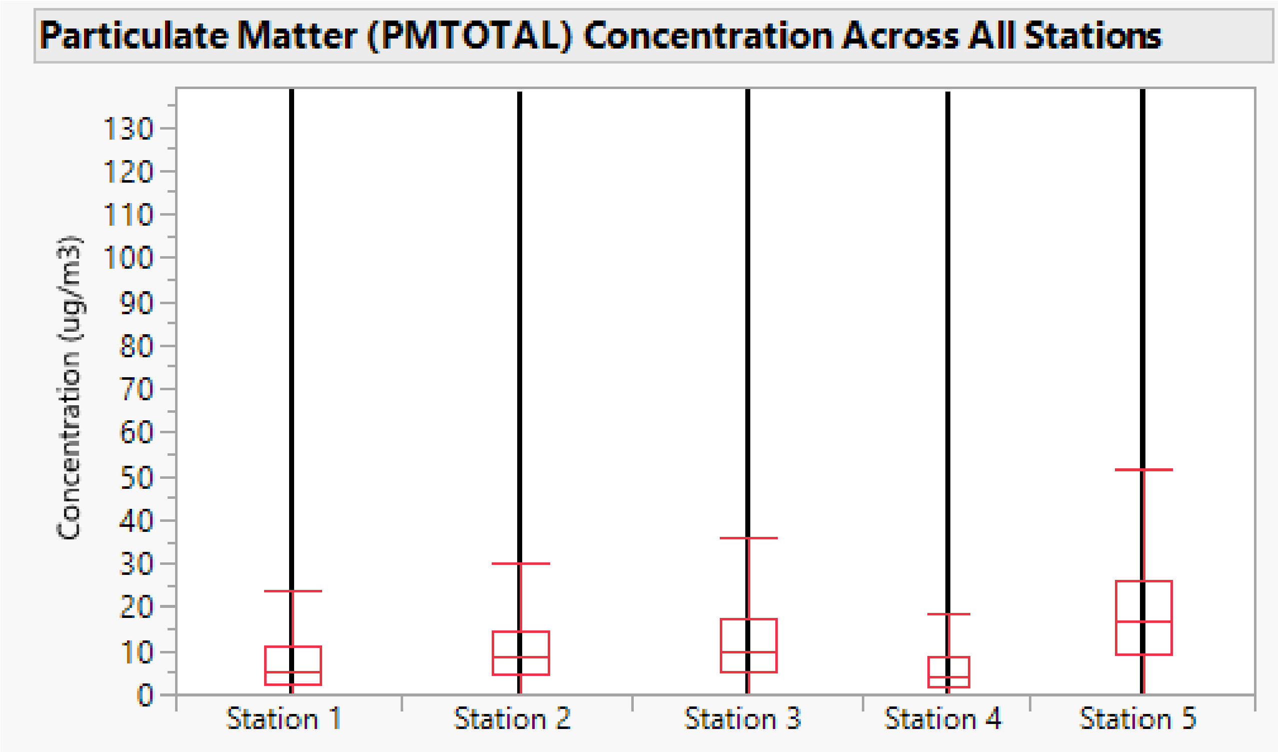

Figure 19: Box plots representing the total particulate matter (PM_{TOTAL}) concentration at each station across the entire study duration. Threshold Max set at 138 ug/m^3 for data visualization.

Table 13: Total Particulate Matter Total (ug/m^3)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	256,069	0.01	3,503.98	47.91	5.95	13.00
Station 2	259,636	0.07	727.44	12.68	9.33	12.07
Station 3	259,683	0.06	1,464.06	22.37	10.33	15.48
Station 4	189,271	0.03	1,626.72	22.24	4.60	8.30
Station 5	255,341	0.13	2,053.58	29.61	17.62	22.06

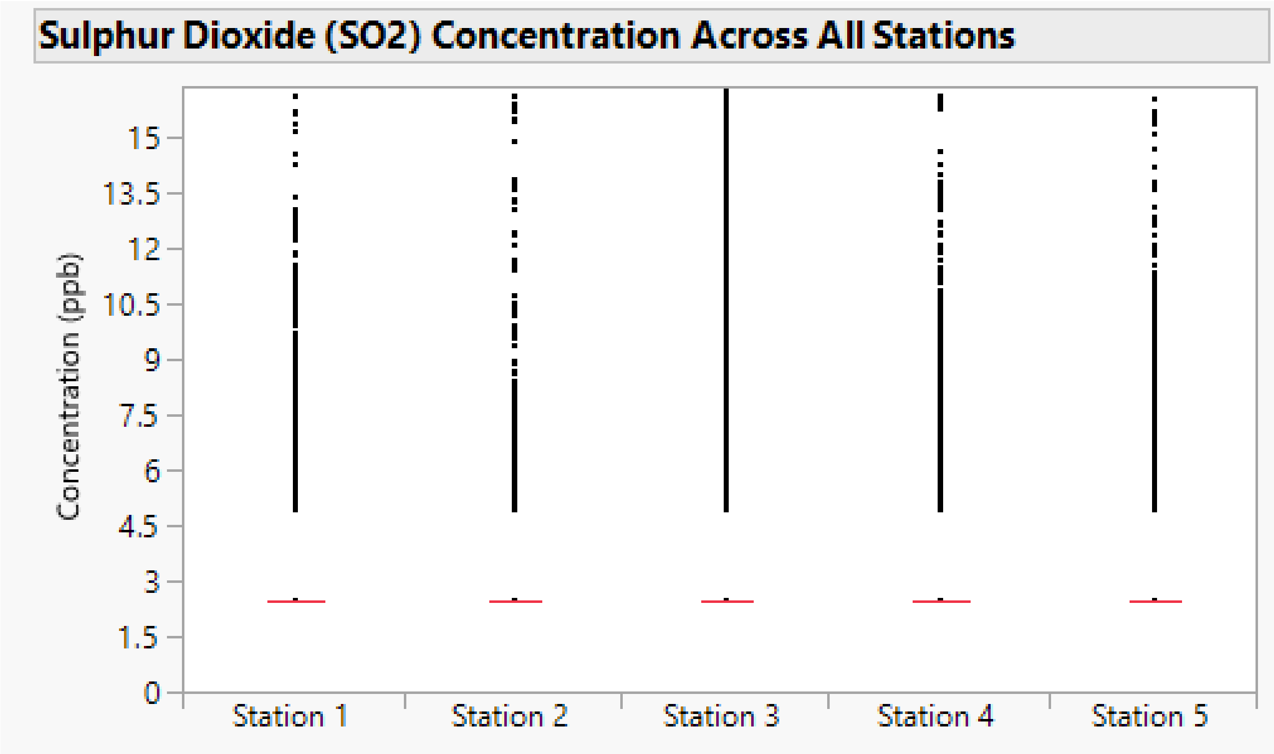

Figure 20: Box plots representing the sulfur dioxide (SO2) concentration at each station across the entire study duration. Threshold Max set at 16 ppb for data visualization.

Table 14: Sulfur Dioxide (SO_2) (ppb)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	233,828	2.5	58.3	0.38	2.5	2.51
Station 2	230,083	2.5	180.3	0.86	2.5	2.51
Station 3	217,359	2.5	76.2	1.83	2.5	2.73
Station 4	233,828	2.5	294.4	0.96	2.5	2.54
Station 5	217,712	2.5	195.0	1.46	2.5	2.64

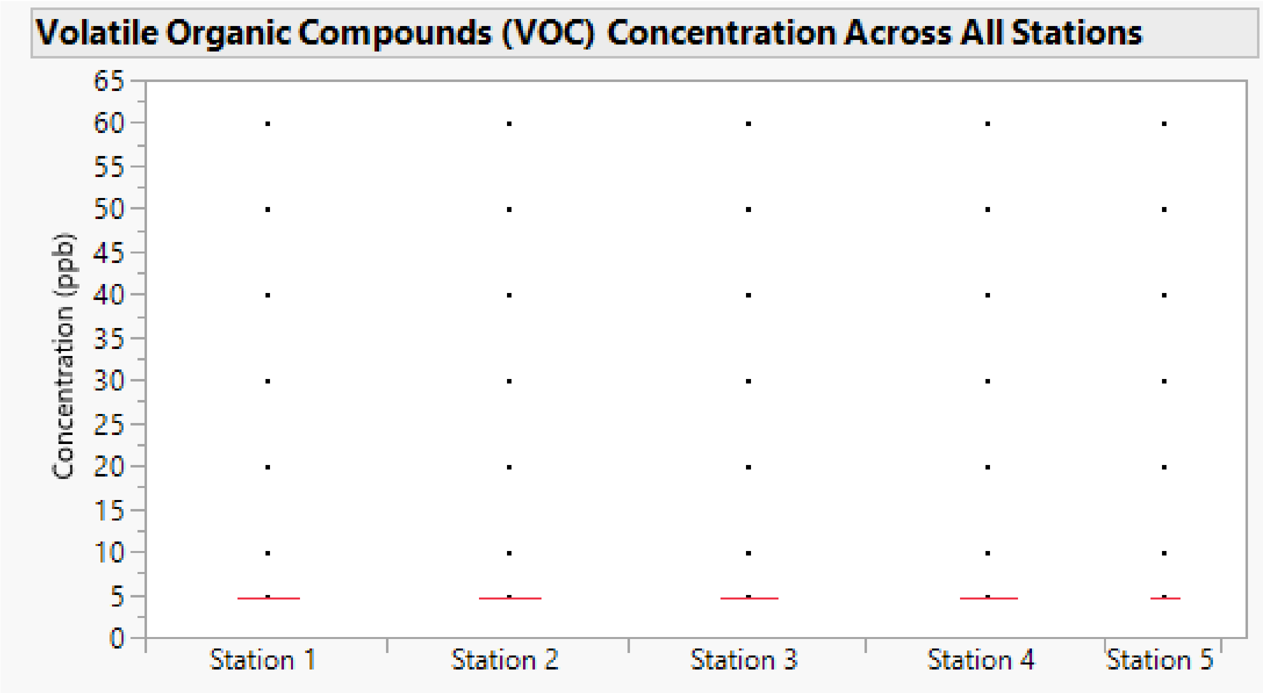

Figure 21: Box plots representing the Volatile Organic Compounds (VOC) concentration at each station across the entire study duration. Threshold Max set at 65 ppb for data visualization.

Table 15: Volatile Organic Compounds (VOC) (ppb)						
Station	N	Min	Max	Std. Deviation	Median	Mean
Station 1	268,087	5	960	23.98	5	9.83
Station 2	268,579	5	780	4.26	5	5.59
Station 3	261,434	5	400	8.53	5	6.76
Station 4	265,972	5	19,690	98.51	5	9.88
Station 5	249,085	5	880	13.94	5	6.73

Lens 2: Study Area vs. Control Comparison

The air monitoring data was analyzed to determine whether the measurements collected at each of the four monitoring stations in the study area were statistically "the same" or "different" than the data collected for the control station. This approach provides a high-level view of the data with the aim of determining whether there are any significant differences between each of the four sampling stations and the control station. Detailed information about the statistical approach used for lens 2 can be found in Appendix A.4.

<u>Critical Finding</u>: **The results of this analysis indicate that there is a statistically significant difference between the data measured at the four stations within the study area compared to the those measured at the control station. This statistically significant difference was identified for all parameters, with one exception being that there was no significant difference found for hydrogen sulfide when comparing Station 4 (Church Street) and Station 5 (Twigg's Park).**

Data measured for formaldehyde , Volatile Organic Compounds, nitric oxide, nitrogen dioxide, ozone, carbon monoxide, sulfur dioxide, and noise, indicated that one or more mean values for the Study Area were higher than those for the Control Station. Data measured for methyl mercaptan, fine particulate matter ($PM_{2.5}$), coarse particulate matter (PM_{10}), and total particulate matter (PM_{TOTAL}), indicated that one or more mean values for the Study Area were equal-to or lower than those for the Control Station.

It is important to note that the objective of the Lens 2 statistical analysis is only to identify which data sets are "the same" or "different" and does not consider whether the difference is attributed to any specific air emissions source.

<u>*Lens 2A: Exposure Ranking Index / Percent Change*</u>

To further examine the relationship between the measurements collected at each of the four monitoring stations in the study area and the control station, an "exposure ranking index" (ERI) was calculated by dividing the 1-min average value collected at each station by the contemporaneous result measured at the control station. An "exposure ranking index" greater than one indicates that the concentration measured at the study area monitoring station is greater than that measured at the control station. The results of this analysis are provided in Appendix A.4.

<u>Critical Finding</u>: **Average exposure ranking indices greater than two were calculated for nitric oxide at Station 1 (Lyons/Darrow) (ST1 ERI=11.8) and Station 4 (Church Street) (ST4 ERI=5.39);**

and for formaldehyde at all 4 stations (ST1 ERI=4.20, ST2 ERI=2.14, ST3 ERI=10.08, ST4 ERI=2.15) within the study area. Furthermore, 53% of the exposure ranking indices calculated for Noise Level at Station 4 (Church Street) were greater than one.

Average exposure ranking index values less than 0.8 were found for fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}) at all 4 stations within the study area ($PM_{2.5}$: ST1 ERI=0.16, ST2 ERI=0.62, ST3 ERI=0.61, ST4 ERI=0.34; PM_{10}: ST1 ERI=0.64, ST2 ERI=0.41, ST3 ERI=0.72, ST4 ERI=0.38); for total particulate matter (PM_{TOTAL}) at Station 1 (Lyons/Darrow), Station 2 (Lyons/Ashland), and Station 4 (Church Street) (ST1 ERI=0.72, ST2 ERI=0.68, ST4 ERI=0.44); for carbon monoxide at Station 4 (Church Street) (ST4 ERI=0.67); and for ozone at both Station 1 (Lyons/Darrow) and Station 2 (Lyons/Ashland) (ST1 ERI=0.78, ST2 ERI=0.80).

The percent change between measurements collected at each of the four monitoring stations in the study area and the control station were also calculated to assess the magnitude of differences in ambient air concentrations between the study area and the control location.

The average percent change, when compared to the control location (Station 5: Twiggs Park), was found to be both positive and above 20% for nitric oxide at Station 1 (Lyons/Ashland), Station 2 (Lyons/Ashland), and Station 4 (Church Street); for nitrogen dioxide at both Station 2 (Lyons/Darrow) and Station 4 (Church Street); and for formaldehyde at all stations within the study area.

The average percent change, when compared to the control location (Station 5: Twiggs Park), was found to be both negative and below -20% for fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}) at all stations within the study area; and total particulate matter (PM_{TOTAL}) at Station 1 (Lyons/Darrow), Station 2 (Lyons/Ashland), and Station 4 (Church Street).

The average percent change, when compared to the control location (Station 5: Twiggs Park), was found to be both negative and below -20% for ozone at Station 1 (Lyons/Darrow) and found to be both positive and above 20% for ozone at Station 4 (Church Street).

<u>2B: Upper Confidence Limit Maps</u>

In addition to the statistical analysis presented above and calculation of a “exposure ranking index”, the upper 95% confidence limit value for concentrations measured at each of the 4 monitor stations within the study area and the control station were calculated and mapped using Google Earth. The maps contain only the stations within the study area and can be found in Appendix A.4.2.

<u>Critical Finding</u>: The results indicate that one or more stations surrounding the study area had a higher 95% upper confidence limit than Station 5 (Twiggs Park) for hydrogen sulfide, methyl mercaptan, formaldehyde, Volatile Organic Compounds, nitric oxide, nitrogen dioxide, carbon monoxide, sulfur dioxide, and noise.

The results also indicate that one or more stations surrounding the study area had a lower 95% upper confidence limit than Station 5 (Twiggs Park) for ozone and all particulate matter indicators ($PM_{2.5}$, PM_{10}, PM_{TOTAL}).

Lens 3: Operational (O) vs. Non-Operational (NO) Facility Hours Comparison

A statistical analysis was performed to determine whether concentrations measured at each of the four monitoring stations in the Study Area are statistically "similar" or "different" for time periods when the facility was operating vs. not operating.

<u>Critical Finding</u>: There was a statistically significant difference between the measured ambient air concentrations across operational hours and those measured during non-operational hours. This difference existed for all parameters and all stations, except for hydrogen sulfide and fine particulate matter ($PM_{2.5}$) at Station 3 (Church Street Village) which were found to be statistically similar both during and outside posted facility hours. The mean concentrations during operational hours was higher than those for non-operational hours for one or more stations across all parameters.

<u>3A: Exposure Ranking Index (Operational vs. Non-Operational)</u>

In addition to the statistical analysis, the "Exposure Ranking Index" calculated for Lens 2 was also analyzed based on facility hours of operation.

<u>Critical Finding</u>: Formaldehyde had an average exposure ranking index greater than two (ST1 ERI=4.20, ST2 ERI=2.14, ST3 ERI=10.08, ST4 ERI=2.15) and had higher exposure ranking index during operational hours across all stations within the study area (ST1 OP ERI=4.91, ST2 OP ERI=2.57, ST3 OP ERI=11.23, ST4 OP ERI=3.03). Nitric oxide also had an elevated and higher average exposure ranking index during operational hours for Station 2 (Lyons/Ashland) (ST2 OP ERI=2.37) and Station 4 (Church Street) (ST4 OP ERI=9.1), and an elevated and higher average exposure ranking index during non-operational hours at Station 1 (Lyons/Darrow) (NON-OP ERI=12.23).

Average reduced exposure ranking indices (i.e., less than 0.8) and lower exposure ranking indices during operational hours were similarly found for fine and coarse particulate matter ($PM_{2.5}$ and

PM_{10}) at all four stations within the study area ($PM_{2.5}$: ST1 OP ERI=0.13 , ST2 OP ERI=0.57, ST3 OP ERI=0.51 , ST4 OP ERI=0.28; PM_{10}: ST1 OP ERI=0.64 , ST2 OP ERI=0.40 , ST3 OP ERI=0.66 , ST4 OP ERI=0.34); for total particulate matter (PM_{TOTAL}) at Station 1 (Lyons/Darrow) and Station 2 (Lyons/Ashland) during non-operational hours (ST1 NON-OP ERI=0.70, ST2 NON-OP ERI=0.68); and for carbon monoxide at Station 4 (Church Street) during non-operational hours (ST4 NON-OP ERI=0.65).

Average reduced exposure ranking indices (i.e., less than 0.8) were found for ozone at Station 1 (Lyons/Darrow) and Station 2 (Lyons/Ashland) (ST1 ERI=0.79, ST2 ERI=0.80). The reduced exposure ranking indices were equal (ERI=0.79) during operational and non-operational hours at Station 1 (Lyons/Darrow). The exposure ranking index was higher (OP ERI=0.81) during operational hours at Station 2 (Lyons/Ashland) as compared to non-operational hours (NON-OP ERI=0.80).

Lens 4: Wind Direction Analysis

In order to determine whether air monitoring measurements collected when a monitoring station was “downwind” of the waste transfer station was statistically similar or different than measurements recorded when the station was “not downwind”, all air monitoring measurement values were placed into one of two categories:

- Downwind – when the measurement was collected at a time when the wind direction originated from a direction between 12° NNE and 78° ENE (blue-shaded area on inset compass of Figure 8).
- Not-downwind – when the measurement was collected at time when the wind direction originated from a direction outside the blue-shaded area shown in Figure 8.

<u>Critical Finding</u>**: The results of this analysis indicate that there was a statistically significant difference between the parameter distributions “downwind” and “not downwind” during normal business hours for all parameters except for hydrogen sulfide. The average concentration was higher “downwind” for ozone, total particulate matter (PM_{TOTAL}), and sulfur dioxide. The average concentration was higher “not downwind” for hydrogen sulfide, methyl mercaptan, formaldehyde, Volatile Organic Compounds, nitric oxide, nitrogen dioxide, fine and coarse particulate matter ($PM_{2.5}$, PM_{10}), and carbon monoxide.**

As previously mentioned, the Lens 4 analysis was conducted using the data collected at Station 4 (Church Street) only because it was the only station within the Study Area that had a co-located weather station.[22] Weather data recorded at the two monitoring stations with weather equipment (Stations 4 and 5) showed that local surface topology was a significant influence and therefore the recorded wind direction data at Station 4 would be an imprecise and incorrect proxy for Stations 1, 2, and 3 in the Study Area. As shown in the figure below, data collected at Station 4 represents “downwind” data when wind-direction recorded by the weather station at Station 4 is in the blue shaded section; all other data points classified as “not-downwind”. Appendix A.6 presents the results of the analysis.

Figure 22: Wind direction analysis map and description.

Lens 5: Outlier Analysis for Station 4 (Church Street)

For each parameter, an outlier analysis was performed. Outlier data points are of interest when assessing the intensity, frequency, and duration of peak values. Outlier measurements collected at Station 4 were further evaluated based on wind direction.

<u>Critical Finding</u>: Outlier data points related to times when Station 4 was “downwind” were found for methyl mercaptan, formaldehyde, Volatile Organic Compounds, nitric oxide, nitrogen dioxide, particulate matter ($PM_{2.5}$, PM_{10}, PM_{TOTAL}), carbon monoxide, and sulfur

[22] Weather data collected at Station 4 (Church Street) and Station 5 (Twiggs Park) represents hyperlocal data and therefore was not evaluated against regional weather data recorded at NOAA monitoring stations.

dioxide. No outlier data points were recorded for ozone when Station 4 was in the "downwind" direction.

Outlier data points related to times when Station 4 was "downwind" contributed to less than 20% of the total number of outlier values for all parameters. This indicates that the detection of data outliers was not strongly associated with wind directions that place Station 4 (Church Street) "downwind" from the waste transfer station.

To help visualize the frequency of data outlier values, graphs were prepared for each parameter which show the 1-minute average concentrations for the entire study duration along with a reference line representing the "maximum outlier threshold". These graphs can be found in Appendix A.7.2.

To determine the "maximum outlier threshold", a statistical analysis was performed to calculate the "outlier threshold" for each parameter at each of the five Stations. Appendix A.7.1 presents tables with these calculated values. For each parameter, the maximum value of the five calculated "outlier thresholds" was designated as the "maximum outlier threshold".

Lens 6: Traffic Influence Analysis

In order to evaluate the impact of traffic on local air quality, we sought to determine whether a relationship exists between traffic patterns and measured values for air quality parameters. A statistical analysis was performed to assess whether the total truck count and total vehicle count data recorded at each of the five stations were correlated with measured air quality parameter/pollutant data. Total truck count included trucks with two axles or greater, excluding busses, and total vehicle count included all vehicles, including trucks.

Critical Finding: Statistically significant correlations between traffic-related variables and air quality parameters were discovered for total vehicle count and ozone at Station 3 (Church Street Village), Station 4 (Church Street), and Station 5 (Twiggs Park); total vehicle counts and particulate matter ($PM_{2.5}$, PM_{10}, and PM_{TOTAL}) at Station 5; and total truck count and noise at Station 3 (Church Street Village) and Station 5 (Twiggs Park).

A statistical analysis was also performed to assess whether the total truck count and total vehicle count data recorded at each of the five stations were correlated with measured air quality parameter/pollutant data both during and outside business hours at Station 4 (Church Street).

Statistically significant correlations were discovered between total vehicle count and both ozone and noise during non-operational hours at Station 4 (Church Street) and between total truck count and noise during non-operational hours at Station 4 (Church Street).

Appendix A.8 presents the calculated correlation coefficients and provides additional information about the strengths of the correlations.

6 CONCLUSIONS

After evaluating all twelve of the parameters through six different perspectives, we have considered the weight of the evidence to present a hierarchical ranking scheme.

1st Tier Parameters

We recommend prioritizing nitric oxide and formaldehyde as parameters of greatest interest for any future work. Formaldehyde and nitric oxide exhibited a greater frequency of outlier data points in comparison to other parameters. Further, the average exposure ranking index values calculated for nitric oxide and formaldehyde were greater than two when concentrations measured at Station 4 (Church Street) were compared against those measured at the control station (i.e., Station 5 (Twiggs Park)). These reasons form the basis for our recommendation to prioritize these parameters over the others evaluated in this study.

2nd Tier Parameters

We recommend considering sulfur dioxide, carbon monoxide, noise, Volatile Organic Compounds, nitrogen dioxide, and methyl mercaptan as parameters of secondary interest for any future work. These parameters present some conflicting perspectives, depending upon the statistical approach considered, but did not present strong evidence for deprioritization. For example, Volatile Organic Compounds, nitrogen dioxide, and methyl mercaptan were found to have distributions which were statistically significant in the Study Area vs. control station analysis, but higher mean or median values were found in the “not downwind” direction from the site, which could suggest regional influences unrelated to the site. These parameters may benefit from evaluation of long-term trends in air quality in the future.

Deprioritized Parameters

Lastly, we recommend that ozone, fine and course particulate matter ($PM_{2.5}$ and PM_{10}) and hydrogen sulfide be deprioritized as parameters of least interest for any future work. Hydrogen sulfide was found to have no significant difference between the study Area and control station, nor any significant difference in the downwind vs. not-downwind directions within the Study Area. Fine and course particulate matter ($PM_{2.5}$ and PM_{10}) parameters produced negligible correlations with traffic in the study area; the mean/median values for the distributions were higher in the not-downwind directions, suggesting non-site drivers for these parameters, and the average exposure index values calculated for all stations were below 0.80 at all locations when compared to the control location. Further, the hours of facility operation were not statistically significantly different than non-operating hours for fine particulate matter ($PM_{2.5}$) at Station 3 (Church Street Village) which was the station most removed from a roadway. Ozone appears to be statistically significant during operational hours primarily as an artifact of time with operating hours concurrent with sunlight hours, compounded with a moderately positive and greater correlation coefficient for all-vehicle traffic than truck traffic.

7 RECOMMENDATIONS

Considering that the primary goals of the project was to understand whether any of the target air quality parameters demonstrate probable source-attribution to site operations, so that such information could be taken into consideration for potential future evaluations, we present the following recommendations for consideration:

1. Formaldehyde and nitric oxide are the air quality parameters of greatest interest and should be prioritized in any future work. Sulfur dioxide, carbon monoxide, Volatile Organic Compounds, methyl mercaptan, nitrogen dioxide, and noise present lesser supporting evidence but may still warrant further investigation. Given the prominence of formaldehyde in our findings, it may be of interest to examine whether other specific Volatile Organic Compounds are present by conducting VOC speciation in any future work (e.g. toxic air pollutants listed in the Clean Air Act). We recommend deprioritizing hydrogen sulfide, fine and course particulate matter ($PM_{2.5}$, PM_{10}), and ozone parameters which appear to be related to regional air quality rather than local air quality. We should note that the International Agency for Research on Cancer classified formaldehyde as carcinogenic to humans in 2004 (i.e., Group 1) (IARC. 2012) and nitric oxide is a respiratory irritant (ATSDR, 2002) as documented in Table 1 on page 9 of this report.
2. To better understand whether the collected data represents harmful levels with the potential for adverse human health effects, a number of follow-up studies should be conducted.
    a. First, the monitors used for this study should be collocated with Federal Reference Method (FRM) or Federal Equivalent Method (FEM) equipment that is operated by the USEPA at air monitoring stations across Cook County, IL and used to monitor regional air quality. The collocated data from both monitors can then be analyzed to develop scaling (or correction) factors so that the data collected using

the low-cost real-time monitors during this study can then be adjusted and directly compared to data collected by the FRM/FEM at the EPA air monitoring stations. This will allow an assessment of whether concentrations measured in this study are within the range observed for regional air quality or whether the data represents a "hot spot" influenced by a local emission source such as the waste transfer station.

b. Secondly, the determination of compliance with the U.S. National Ambient Air Quality Standards (NAAQS) for criteria air pollutants (which are health-based standards) of interest for this study (ozone, nitrogen dioxide, $PM_{2.5}$/PM_{10}, carbon monoxide, sulfur dioxide) would require a long term air monitoring (one year or three years depending on the pollutant). The current study lasting for six months and serving as a scoping or screening-level assessment neither involved testing the performance of the monitors used against the USEPA's FRM/FEM monitors nor involved long-term monitoring. However, these studies can be undertaken in the future to assess potential health implications of the results presented in this report.

3. Furthermore, once scaling factors have been determined and applied to the data set, a Human Health Risk Assessment (HHRA) may be conducted to estimate potential human health risks. The health risk evaluation could employ estimation of Air Quality Index (AQI) for criteria air pollutants (ozone, nitrogen dioxide, $PM_{2.5}$/PM_{10}, carbon monoxide, sulfur dioxide) and would follow the four-step risk assessment paradigm developed by the National Academy of Sciences in 1983 for air toxics (e.g., formaldehyde). For air toxics, the HHRA would involve estimation of excess cancer and non-cancer health risks associated with inhalation exposures. This assessment would be performed only for toxic air pollutants (e.g., formaldehyde, benzene, and others) and represents a scientific approach to identifying those pollutants that drive the cancer and non-cancer risks for the exposed population. The findings of the AQI and the health risk evaluation would guide targeted exposure reduction and health risk reduction efforts through voluntary measures, regulatory programs, or strategically enacted community policies to improve air quality and public health.