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New Hampshire
Special Air Quality Monitoring Program
Hyper-Local Monitoring of Fine Particles in Portsmouth
Winter 2021 through Spring 2022

Prepared by: Jeffrey Underhill and David Healy, Air Resources Division
New Hampshire Department of Environmental Services
29 Hazen Drive, PO Box 95
Concord, NH 03302-0095
(603) 271-1370
www.des.nh.gov

Craig Wright, Air Resources Division Director

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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Executive Summary

During the winter of 2021 and spring of 2022, the New Hampshire Department of Environmental Services (NHDES) conducted a hyper-local air quality monitoring study in Portsmouth, NH. This study was undertaken on behalf of the City of Portsmouth and in consultation with U.S. Environmental Protection Agency (EPA) Region 1 and the Office of U.S. Representative Chris Pappas. The goal of the study was to investigate hyper-local levels of fine particulate matter (particulate matter less than 2.5 microns in aerodynamic diameter, commonly referred to as $PM_{2.5}$) in the area around the CSX railyard in the Islington Creek neighborhood of Portsmouth. In particular, EPA and the City of Portsmouth (the City) wanted to know if idling trains were affecting air quality in neighboring areas. The City also wanted to know if traffic emissions were affecting the New Franklin School. A potential concern is that odors reported at the school are coming primarily from diesel exhaust and could perhaps be causing health impacts.

For this study, NHDES utilized four PurpleAir particulate matter air quality monitors at locations around the railyard. The first three monitors were located near the railyard attempting to approximate upwind, downwind and background conditions. Theoretically, if an idling train produced emissions at a physical location that was between the upwind and downwind monitors, the difference in measured concentration would reasonably estimate increased $PM_{2.5}$ concentrations produced by the train.

The fourth monitor was located at the New Franklin School to analyze the emissions from nearby highways. This was a follow-on request from the City to investigate air quality at the school, located to the west of the Islington Creek neighborhood. The school is tightly surrounded by I-95 to the northwest, and U.S. Route 1 to the southeast. The New Franklin School portion of the study was also used to represent background location measurements.

PurpleAir monitors are part of a growing market of relatively inexpensive air quality sensors that can be used by citizen scientists, educators, environmental agencies and other interested parties to measure outdoor or indoor particulate matter air quality. For more information on PurpleAir air quality monitors, please visit the PurpleAir website. The four PurpleAir monitors deployed for the Portsmouth study were part of a larger group of PurpleAir monitors that NHDES obtained on loan from EPA.

Train Idling Study

While overall concentrations of $PM_{2.5}$ measured throughout the study were in the Good range (see EPA's Air Quality Index in **Table 2** later in this report), short variations did occur suggesting the influence of nearby emission sources. Idling trains were observed parked alongside Islington Creek neighborhoods by NHDES staff and heavy automotive traffic occurred at times during the study period. The train engines observed in the area consisted of older, more polluting models that are often used in railroad switchyards. The influence of these train emissions on measured $PM_{2.5}$ concentrations is strongly suspected, but unconfirmed due to lack of train records and observations during periods of higher $PM_{2.5}$ concentration measurements. Nearby residents have observed strong diesel odors, believed to have come from nearby idling trains at somewhat random times of the day, but these reports preceded the study.

Even though the measured $PM_{2.5}$ concentrations did not exceed the federal health standards, odors can be present at significantly lower concentrations. Diesel exhaust has a strong distinct metallic odor that can be especially irritating, particularly in areas such as residential neighborhoods and playgrounds. To reduce irritation from odors, it may be advantageous to attempt to work with the railroad on possible mitigation strategies such as the following:

- Idle locomotives in a designated area within the switchyard away from residential areas.
- Use newer, lower-emitting locomotives or auxiliary power unit (APU) technology.

New Franklin School

At New Franklin School, average $PM_{2.5}$ concentrations stayed well below federal health standards, but some $PM_{2.5}$ concentration patterns observed in the data were consistent with periodic odor complaints from school staff. Again, the presence of odors does not necessarily imply that other health concerns exist, based on current federal standards. However, odors can distract from school learning. Further, especially sensitive students could experience some breathing difficulties, such as aggravating asthma when $PM_{2.5}$ concentrations in the area are highest, even if they are still below health standards.

Although, as previously mentioned, air quality at New Franklin School meets all federal health standards, suggestions to address nuisance odors could include:

- Upgrading the school air handling system to include High Efficiency Particulate Air (HEPA) and carbon filtration to reduce odors and $PM_{2.5}$, as well as other common airborne irritants such as dust and pollen.
- If odors during outdoor time cause concern or irritation, shifting outdoor play time or holding play time indoors.

In addition to the above suggestions, EPA and NHDES recommend that school buses and other vehicles are not left idling outside the school. This includes caregivers waiting in their cars for students to be dismissed. Idling vehicles contribute to the burden of $PM_{2.5}$ and other pollutants in the ambient air.

A study performed by NHDES on behalf of the City of Portsmouth and in consultation with EPA Region 1 and the Office of U.S. Representative Chris Pappas

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Figures, Tables and Equations

1. Introduction

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2. $PM_{2.5}$ Health Effects, NAAQS and AQI

$PM_{2.5}$ is a pollutant of concern because these fine particles can penetrate deeply into the lungs when inhaled. The health effects associated with exposure to elevated $PM_{2.5}$ levels can include coughing, difficulty breathing, increased severity of asthma symptoms, reduced lung function and even premature death for those with existing heart or lung conditions. Children and older adults are those most likely to be affected by $PM_{2.5}$ exposure. In addition to health effects, elevated levels of $PM_{2.5}$ can also contribute to visibility impairment, which can diminish the view of scenic areas.

$PM_{2.5}$ is one of a set of pollutants regulated by EPA called the criteria pollutants. EPA is required by the Clean Air Act (CAA) to set health and welfare-based standards for the criteria pollutants, including $PM_{2.5}$. These standards are referred to as the National Ambient Air Quality Standards, or NAAQS. Primary NAAQS are intended to protect human health with an adequate margin of safety. Secondary NAAQS are intended to protect against welfare effects such as visibility impairment and damage to buildings, crops and animals. The NAAQS for $PM_{2.5}$ addresses two exposure averaging periods: exposure over 24 hours (midnight to midnight) and exposure over one year. The $PM_{2.5}$ NAAQS are shown in **Table 1**.

Table 1: $PM_{2.5}$ NAAQS in micrograms per cubic meter ($\mu g/m^3$)

$PM_{2.5}$ NAAQS	Averaging Period	Level	Form
Primary and Secondary	24-hour	35	98th percentile, averaged over 3 years
Primary	Annual	12	Annual mean, averaged over 3 years
Secondary	Annual	15	Annual mean, averaged over 3 years

Notes:
1) The 24-hour NAAQS is violated when the three-year average of each year's measured 98th percentile 24-hour average concentration exceeds 35 $\mu g/m^3$.
2) The annual NAAQS is violated when the three-year average of each year's mean annual concentration exceeds 12 $\mu g/m^3$ (primary) / 15 $\mu g/m^3$ (secondary).

As indicated by the notes to **Table 1**, a single isolated instance of a measured $PM_{2.5}$ (or other criteria pollutant) value exceeding the level of the NAAQS does not constitute a formal violation of the NAAQS. To violate the 24-hour $PM_{2.5}$ NAAQS, for example, the three-year average of the 98th percentile 24-hour value from each of the three most recent years of available data must exceed 35 $\mu g/m^3$. The rationale behind taking a three-year average is to avoid penalizing an area for a single air quality event that may be a remote outlier. An occasion when a single measured value exceeds the level of the NAAQS is often informally called an "exceedance". It is important to note that an exceedance is not a formal violation of the NAAQS. Although New Hampshire occasionally experiences $PM_{2.5}$ exceedances, particularly in populated valley areas where wintertime wood burning is common, New Hampshire has never had a formal violation of the $PM_{2.5}$ NAAQS.

Another important and useful indicator of air quality is EPA's Air Quality Index (AQI). For each criteria pollutant, the AQI relates the measured concentration to a scale from 0 to 500 which serves as a color-coded indicator of the associated air quality. The AQI also provides an air quality description for each level (color) of the scale. The AQI for $PM_{2.5}$ is shown in **Table 2**. Note that the AQI is a unitless index. For steps that people can take to protect their health at the various levels of the $PM_{2.5}$ AQI, please see EPA's Air Quality Guide for Particle Pollution.

Table 2: $PM_{2.5}$ Air Quality Index

Index	Air Quality Level	Air Quality Description
0 to 50	**Good**	**Air quality is satisfactory, and air pollution poses little or no risk**
51 to 100	**Moderate**	**Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.**
101 to 150	**Unhealthy for Sensitive Groups**	**Members of sensitive groups may experience health effects. The general public is less likely to be affected.**
151 to 200	**Unhealthy**	**Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.**
201 to 300	**Very Unhealthy**	**Health alert: The risk of health effects is increased for everyone.**
301 and higher	**Hazardous**	**Health warning of emergency conditions: everyone is more likely to be affected.**

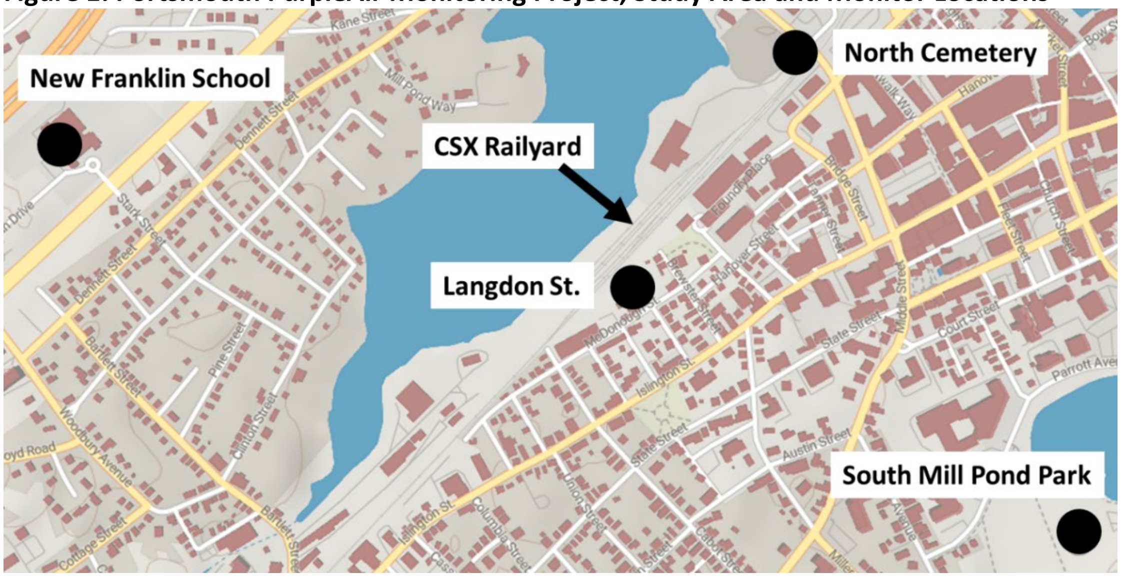
Source: EPA

Air quality in New Hampshire, as measured by the NHDES regulatory air monitoring network, is most often in the Good range, with occasional readings in the Moderate range. Measurements that indicate Unhealthy for Sensitive Groups (or USG) are relatively rare in New Hampshire and are typically due to wintertime woodsmoke in populated valley areas (for $PM_{2.5}$) or summertime regional and local pollution combined with hot and sunny weather (for ozone). Other than the rare wildfire smoke passing through New Hampshire during the summer season, measurements in the Unhealthy or higher ranges are virtually nonexistent in New Hampshire.

3. Study Area

As described earlier, NHDES deployed four PurpleAir monitors in the Islington Creek neighborhood of Portsmouth. This area was chosen because of its residential nature and its location near the CSX railyard. Train locomotives and other diesel-powered vehicles and equipment are known sources of $PM_{2.5}$ emissions. **Figure 1** shows the general study area. The locations of the four PurpleAir monitors that were deployed for this study are indicated by black circles.

Figure 1: Portsmouth PurpleAir Monitoring Project, Study Area and Monitor Locations



All the monitor locations shown in **Figure 1** were chosen because of access to electrical power and Wi-Fi signal, which are required for the monitors to operate and transmit data. However, all the monitors were strategically located to measure $PM_{2.5}$ at different distances and directions from the railyard. Numerous complaints of train exhaust odor were reported in areas near each monitor. The **Langdon St**. location is immediately adjacent to the south end of the railroad switchyard where it can easily be affected by railyard emissions when winds are blowing out of the west and northwest. The **North Cemetery** location represents an area just beyond the northeast end of the switchyard and can be affected when winds are blowing from the southwest. Under most prevailing wind conditions, this creates an upwind and downwind scenario for air monitoring.

The **South Mill Pond Park** location represents background air quality. It is somewhat further from the railyard and much less likely to be affected by trains. The **New Franklin School,** while not intended to be connected to the train study, could have some train exhaust influence with southerly and southeasterly winds. The major concern at the New Franklin School is automotive exhaust from the nearby major highways. Photos of the four study monitoring locations are shown in **Figures 2 through 9** below. Views of a train present in the railyard are shown in **Figures 5 and 7**.

It is important to understand known and potential emission sources near each monitoring location to compare one location to another. South Mill Pond (**Figures 2 and 3**) was selected as a location away from major highways, railways, airports, industry and river marine traffic, and was designed to represent background $PM_{2.5}$ concentration levels. The monitoring location was in the middle of an athletic complex in central Portsmouth, just south of the downtown area. The target monitoring area (Langdon Street, North Cemetery and New Franklin School) is located about one mile to the northwest. Other than nearby traffic, and residential heating, there are no other known significant emission sources of $PM_{2.5}$ in the nearby area.

Figure 2: South Mill Pond Monitoring Area, PurpleAir Monitor Location Marked with a Star

Figure 3: South Mill Pond Park PurpleAir Monitor Location

The rail study in the Islington Neighborhood area utilized two PurpleAir monitors to provide up and downwind locations to the rail switchyard, in proximity to where numerous odor complaints have been reported (**Figures 4 through 7**). The Langdon Street monitor was located at Regan Electric, immediately adjacent to the south side of the rail switchyard. The North Cemetery location was at the corner of North and Union Cemeteries on the north side of the switchyard. Maplewood Ave passes to the north and east of the monitoring location. Other than the switchyard, nearby traffic, residential heating and a small private blacksmith shop located about two blocks to the northeast of the Langdon Street monitor, there were no other significant known $PM_{2.5}$ emission sources in the area. A playground is located about one block away from the Langdon Street monitor. It is also directly adjected to the railyard. Train engines have been observed idling in the vicinity by NHDES staff.

Figure 4: Langdon Street and North Cemetery Monitoring Areas, Stars Show PurpleAir Monitor Locations

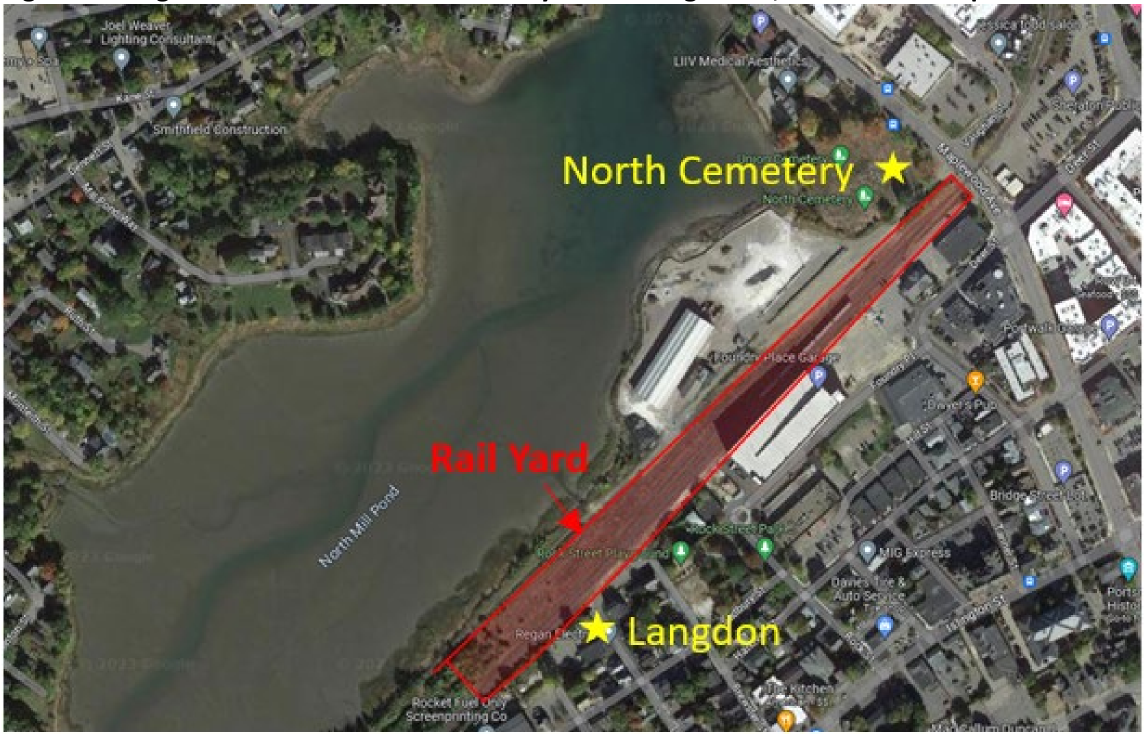


Figure 5: View of Rail Yard

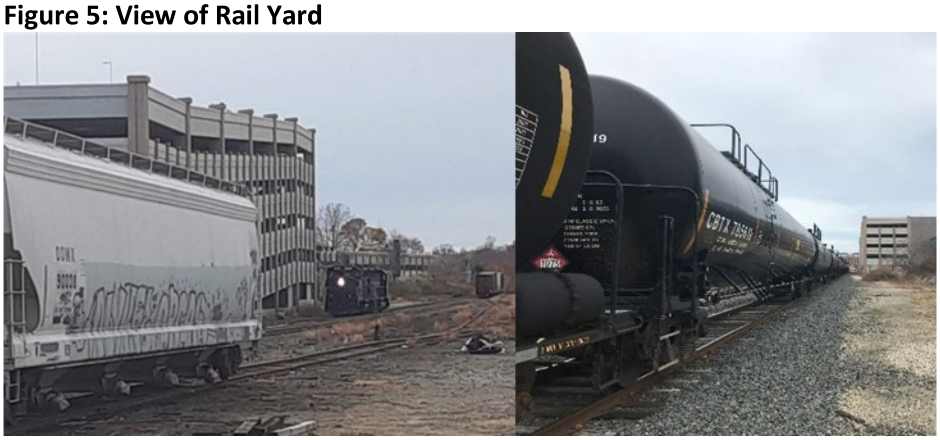


Figure 6: North Cemetery PurpleAir Monitor Location

Figure 7: Langdon Street PurpleAir Monitor Location

At the New Franklin School (**Figures 8 and 9**), staff and students have reported odors that smell like vehicle exhaust. The school is located on a small area of land surrounded by busy I-95 to the northwest and U.S. Route 1 to the southeast. The school is located about a half-mile west of the rail switchyard. I-95 passes about 120 feet away from the back edge of the school and is elevated by about 25 feet above ground level relative to the school. U.S. Route 1 is located a similar distance from the front side of the school building, with the school elevation level being about 25 feet above the highway. Of the two, I-95 is a far busier roadway, including significant truck traffic.

Just on the far side of U.S. Route 1 are two small fueling stations and some convenience stores. Immediately to the southwest are two hotels. And just beyond the hotels is the Portsmouth rotary, a New Hampshire Liquor Store, another hotel and some other small businesses. While the fuel filling stations could produce odors from volatile organic compounds, they are not likely to produce significant $PM_{2.5}$ emissions. It is believed that the major local source of $PM_{2.5}$ emissions is I-95. It should be noted that PurpleAir monitors do not measure odor. But the presence of $PM_{2.5}$ could provide insight on the presence of general air pollution, including odor, in the area.

Figure 8: New Franklin School Monitoring Area, PurpleAir Monitor Marked with a Star

Figure 9: New Franklin School Location, PurpleAir Monitor Marked with a Star

4. PurpleAir Monitors and Data Collection Methods

As mentioned in the introduction, PurpleAir is part of a growing field of vendors who provide low-cost air quality monitors that can be used by citizen scientists, educators, environmental agencies and other interested parties to measure outdoor or indoor air quality. For this study, NHDES used PurpleAir PA-II monitors. The PA-II uses two Plantower PMS-5003 laser particle sensors and a Bosch model BME280 sensor to measure atmospheric pressure, temperature and relative humidity (RH). Measured data is transmitted to the Cloud via the device's built-in Wi-Fi connectivity. A close-up view of a PurpleAir PA-II monitor is shown in **Figure 10**.

Figure 10: PurpleAir PA-II Monitor

Every ten minutes, the PA-II monitor measures $PM_{2.5}$ (as well as $PM_{1.0}$ and PM_{10}) on two channels, i.e., the two Plantower laser particle sensors. NHDES applied an EPA data cleaning and quality assurance procedure in which data points were excluded if the difference between the two readings exceeded 5 micrograms per cubic meter ($\mu g/m^3$) and 70%. Otherwise, the readings from the two channels were averaged together into a single value. Normally, data would then be corrected according to EPA recommendation. EPA derived its correction equation through extensive study[1] that compared measured data from PurpleAir monitors with co-located regulatory Federal Reference Method (FRM) and Federal Equivalent Method (FEM) $PM_{2.5}$ monitors. EPA's

[1] Barkjohn et. al., *Development and Application of a United States wide correction for $PM_{2.5}$ data collected with the PurpleAir sensor*, available at https://amt.copernicus.org/preprints/amt-2020-413/amt-2020-413.pdf.

correction equation is shown in **Equation 1**. However, NHDES used data collected during a co-location study to derive a NH Seacoast-specific correction factor for this project. This is described further in the sections below.

Equation 1: EPA Correction Equation for PurpleAir Data

When $PM2.5_{cf\_atm} < 50\ \mu g/m^3$:

$$PM_{2.5} = 0.52 \times PM25_{cf\_atm} - 0.086 \times RH + 5.75$$

When $50\ \mu g/m^3 \geq PM2.5_{cf\_atm} < 229\ \mu g/m^3$:

$$PM_{2.5} = 0.786 \times PM25_{cf\_atm} - 0.086 \times RH + 5.75$$

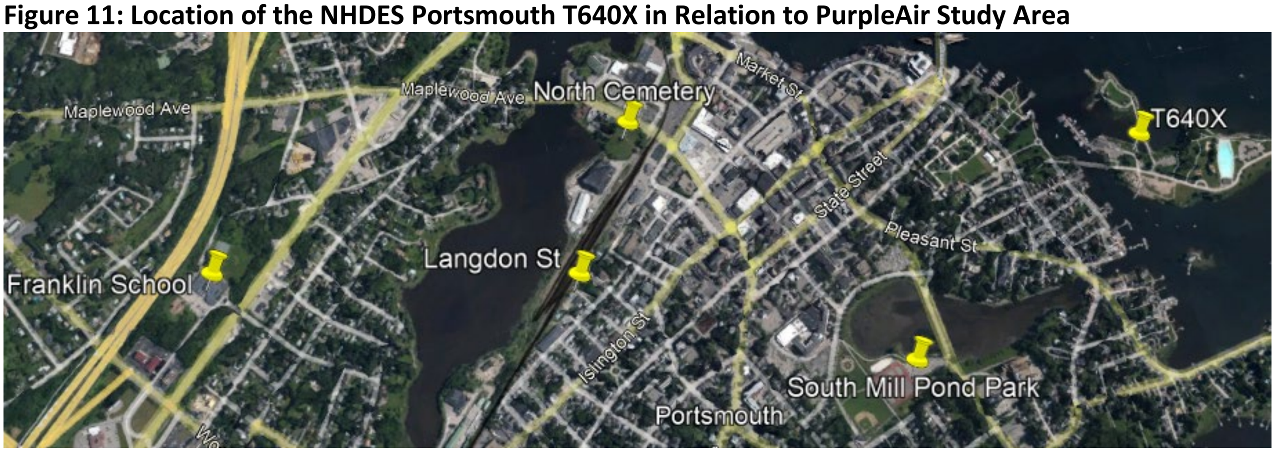
Where:

$PM_{2.5}$ = Corrected $PM_{2.5}$ value in $\mu g/m^3$
$PM2.5_{cf\_atm}$ = $PM_{2.5}$ value measured by the PA-II monitor in $\mu g/m^3$
RH = Relative humidity (%) value measured by the PA-II monitor

5. Monitor Testing and Calibration

Unit testing and calibration occurred from November 1, 2021 through December 9, 2021. The PurpleAir monitors were tested against each other and against the regulatory Teledyne API T640X FEM $PM_{2.5}$ monitor that NHDES operates at Peirce Island in Portsmouth. **Figure 11** shows the location of the T640X monitor relative to the Islington Creek PurpleAir study area.

Figure 11: Location of the NHDES Portsmouth T640X in Relation to PurpleAir Study Area



Source: Google Earth

First, the PurpleAir monitors were compared to each other to ensure reproducibility in a common airshed. **Figure 12** shows a strip chart of unadjusted measurements taken by the PurpleAir monitors (before they were moved from the NHDES Peirce Island site to the study area) and the T640X. Generally, the PurpleAir monitors (named NH8, NH9, NH10) overrespond to $PM_{2.5}$ concentrations when compared to the T640X FEM device, but as **Figures 13 (a and b)** show, hourly data correlation between PurpleAir units was excellent during testing. Direct comparison of the PurpleAir units to the T640X FEM is shown in **Figures 14 (a-d)**, which show over-measurement by the PurpleAir monitors, but a good correlation especially considering that measurements are taken by entirely different technology. NHDES PurpleAir monitor NH4 was also used in this study but was tested in Laconia as part of another study. Consider **Figure 12** which shows that each $PM_{2.5}$ concentration peak is replicated by three PurpleAir monitors, as compared to the T640x FEM, but PurpleAir concentrations over-report the FEM data throughout the test period. This confirms that the concentration patterns are captured and that by performing data correction procedures, meaningful estimates of true $PM_{2.5}$ concentrations can be made.

Figure 12: Unadjusted Hourly Measurements, PurpleAir Monitors and NHDES T640X

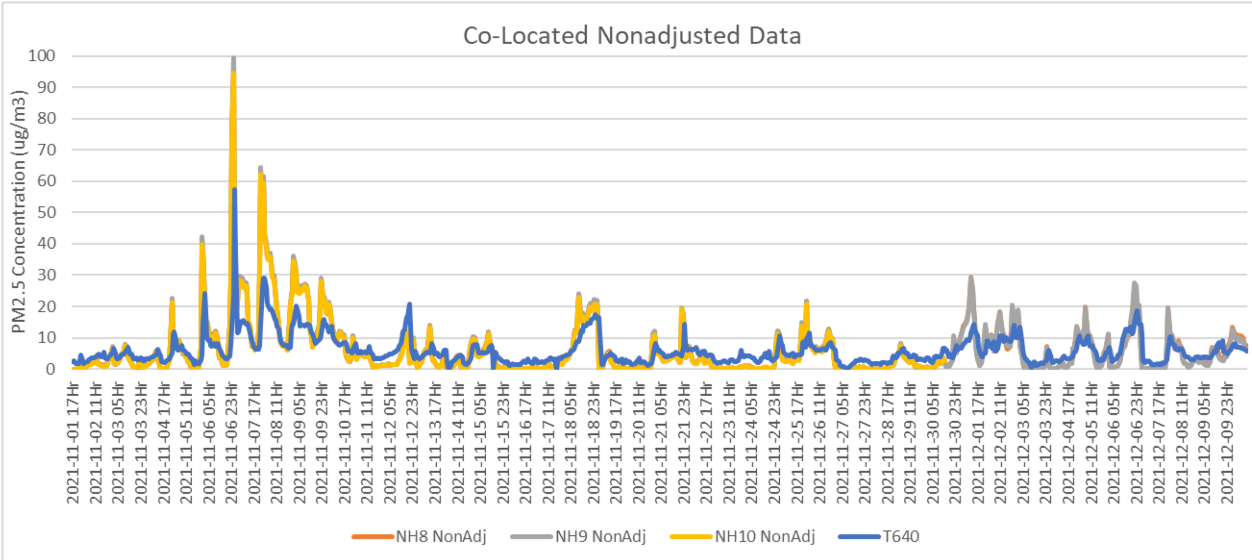


Figure 13: Scatter Plots Comparing Hourly Measurements Taken with Different PurpleAir Monitors

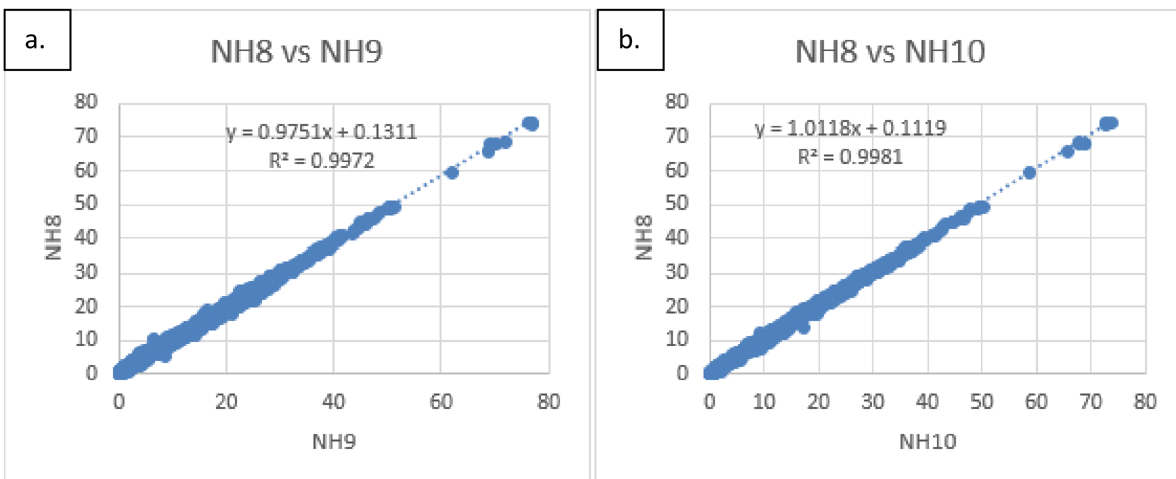
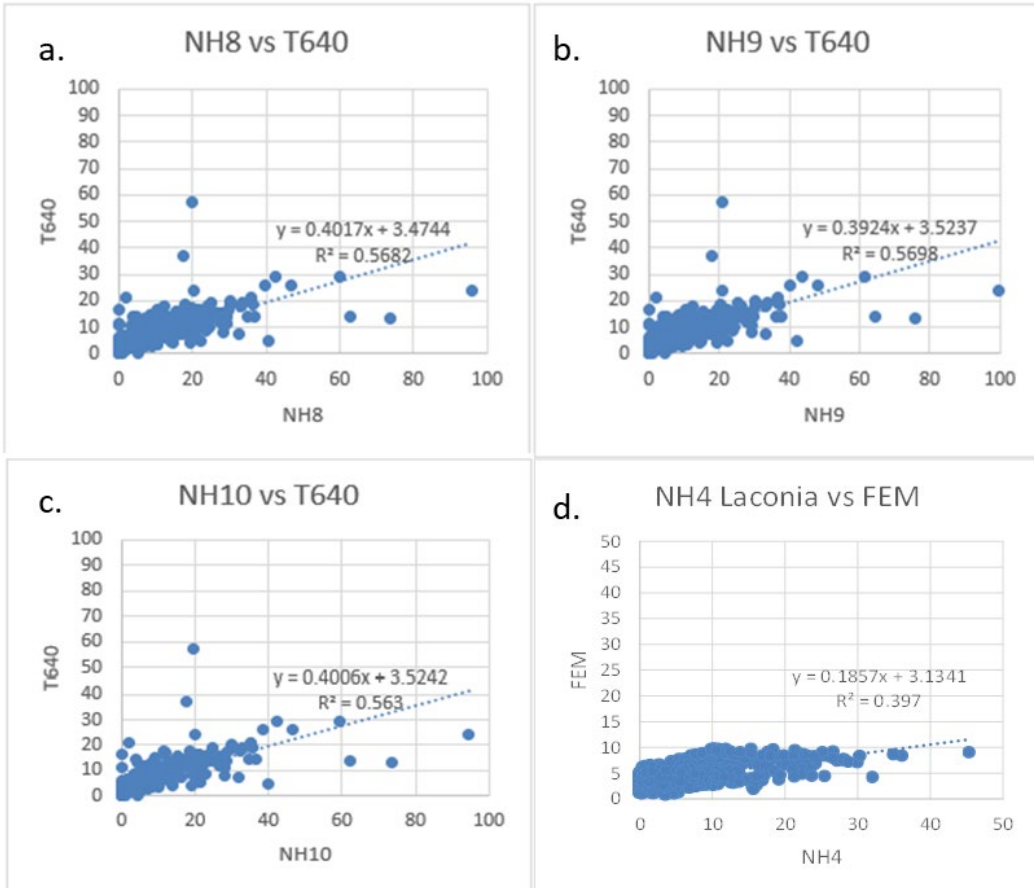


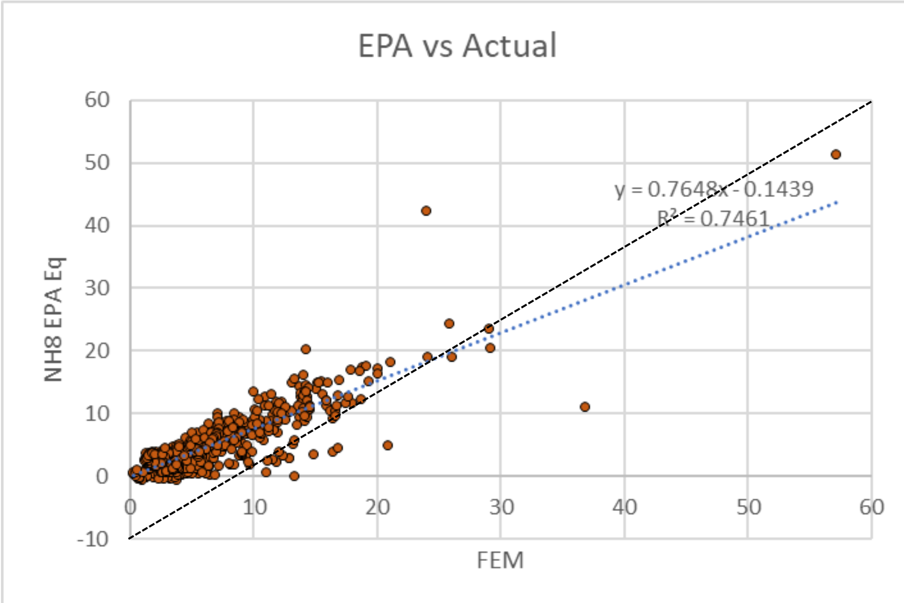
Figure 14: Scatter Plots Comparing Hourly Measurements Taken with the PurpleAir Monitors and the NHDES T640X



6. NHDES Seacoast-Specific Correction Factor

As discussed earlier, NHDES co-located three PurpleAir monitors with a FEM T640X $PM_{2.5}$ monitor in Portsmouth at the NHDES Peirce Island monitoring station. Thanks to this co-location, NHDES was able to collect enough data to derive a correction equation specific to the seacoast area. The EPA correction Equation (**Equation 1**) discussed earlier was rigorously tested with data collected in the western United States, including data collected during significant wildfire events. Much of this data is representative of dry air with a heavy wood smoke influence. Since particles vary in how they react to humidity, wood smoke particles react differently than diesel and automotive exhaust $PM_{2.5}$. When NHDES applied the EPA correction equation to the Portsmouth co-located PurpleAir data for NH8 and compared it to data from the T640X (**Figure 15**), the corrected data showed a tendency to underestimate $PM_{2.5}$ by about 23% with lower concentrations typically measured in New Hampshire, but performs better at higher concentrations.

Figure 15: Scatterplot of Actual T640x FEM and EPA Equation Corrected NH8 PurpleAir Hourly $PM_{2.5}$ Data



PurpleAir-measured $PM_{2.5}$ and humidity data were processed using the NHDES CAMP (Citizen Air Monitoring Program) data cleaning protocol, and a modified version of multifactor regression was performed similar to EPA's technique. The CAMP data cleaning process is a quality assurance routine to improve the data stream by addressing missing data, mismatches between data channels and unnatural data jumps. Since there were three PurpleAir monitors included in the Portsmouth co-location, their data was averaged into one seacoast equation (**Equation 2**). A separate high concentration equation was not developed due to the relatively low $PM_{2.5}$ concentrations measured during the study. This new correction equation was then tested against data from the T640X and it shows that the overestimation has been almost completely removed (**Figures 16** **and** **17**).

Equation 2: NHDES Seacoast Correction Equation for PurpleAir Data

$$PM_{2.5} = 0.0003 \times (PM25_{cf\_atm})^3 - 0.0179 \times (PM25_{cf\_atm})^2 + 0.85 \times PM25_{cf\_atm} - 0.014 \times RH + 2.4015$$

Where:

$PM_{2.5}$ = Corrected $PM_{2.5}$ value in $\mu g/m^3$
$PM2.5_{cf\_atm}$ = $PM_{2.5}$ value measured by the PA-II monitor in $\mu g/m^3$
RH = Relative humidity (%) value measured by the PA-II monitor

Figure 16: Scatterplot of Actual T640X FEM and NHDES-Seacoast Equation Corrected NH8 PurpleAir Hourly $PM_{2.5}$ Concentrations

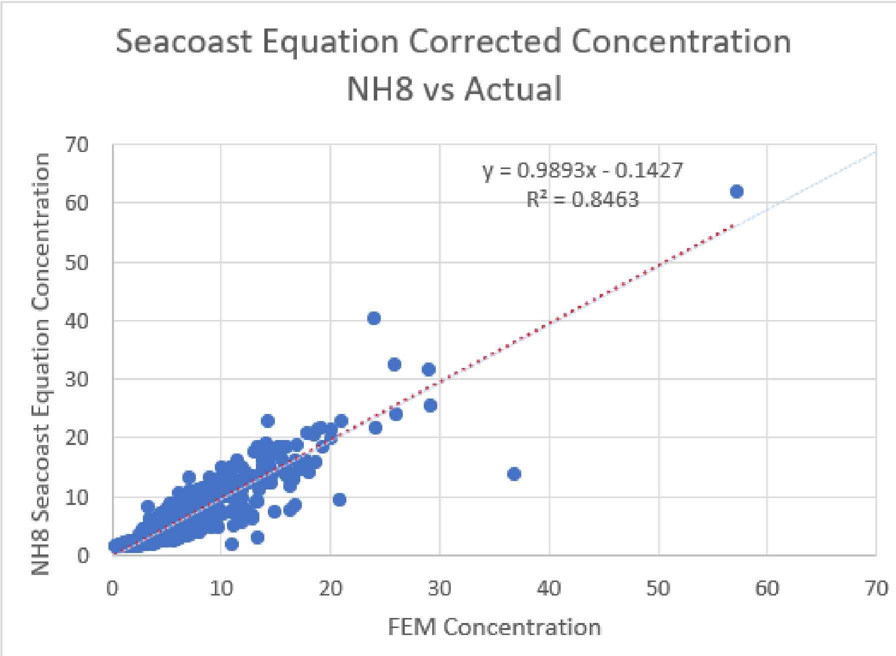


Figure 17: Strip Chart Comparing Hourly T640X data with EPA- and NHDES Seacoast-Equation Corrected NH8 PurpleAir Hourly $PM_{2.5}$ Concentrations

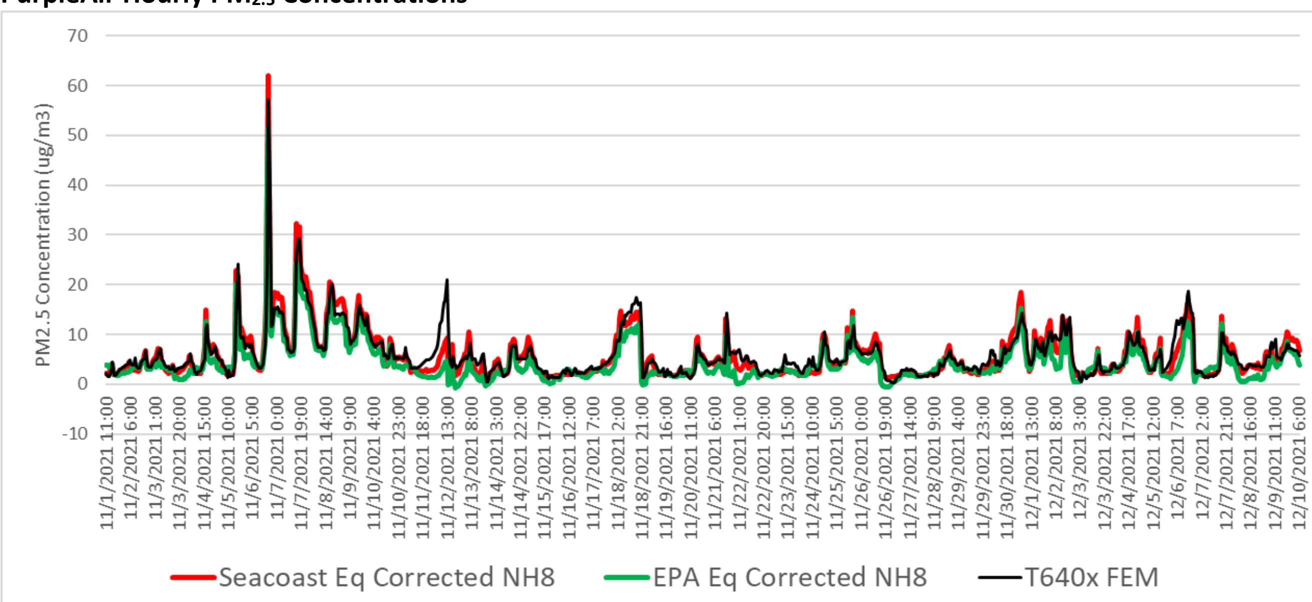
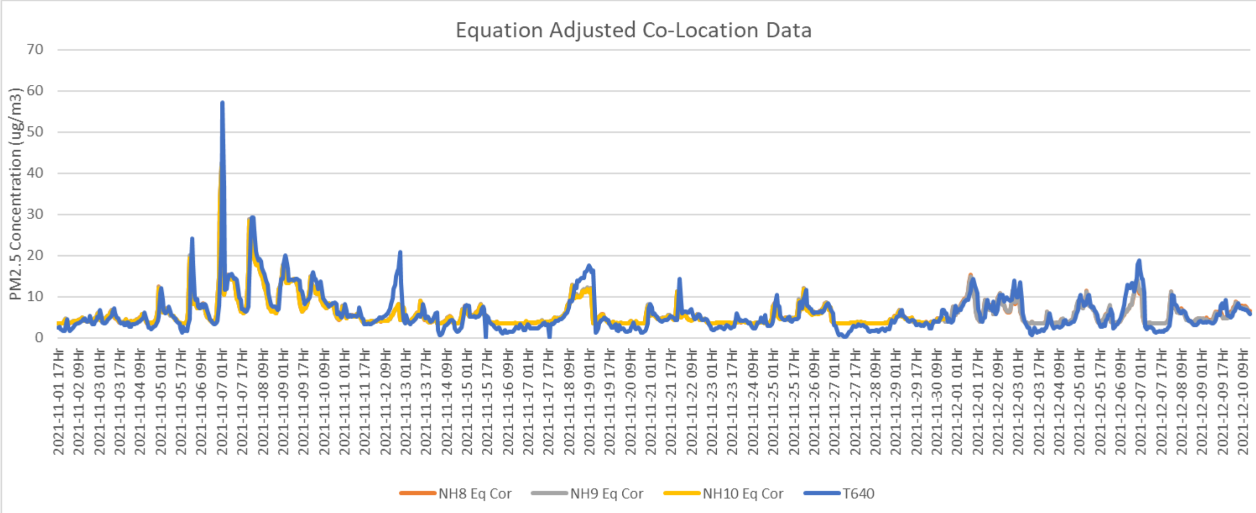


Figure 18 presents the same data as in Figure 12, but with all three NHDES PurpleAir monitors' data corrected by the NHDES Seacoast Correction Equation (Equation 2). Note that the hourly peaks and concentration patterns are well replicated in most circumstances. Overall, the PurpleAir monitors did an admirable job of replicating peak hourly average $PM_{2.5}$ patterns and concentrations when compared to the NHDES regulatory T640X monitor once the data was corrected. Therefore Equation 2 will be the correction equation of choice for data presented in this report as being “corrected” unless otherwise specified.

Figure 18: Hourly Adjusted $PM_{2.5}$ Measurements, PurpleAir Monitors and NHDES T640X



7. Field PurpleAir Monitoring at Targeted Locations

In mid-December 2021, the PurpleAir monitors were relocated from the NHDES Peirce Island monitoring station to the locations targeted for the study. Unit NH8 was moved to Langdon Street, NH9 went to South Mill Pond and NH10 went to North Cemetery. Langdon and South Mill Pond monitoring began on December 11 and North Cemetery monitoring began on December 15 (**Table 3**).

Table 3: Data Collection Start and Stop Dates for the Portsmouth PurpleAir Monitors

Location	Collection Start Date	Collection End Date
Langdon Street	12/11/21	6/23/22
South Mill Pond Park	12/11/21	6/23/22
North Cemetery	12/15/21	6/23/22
New Franklin School	4/29/22	6/11/22

8. General Air Quality Monitored in the Study Area

The 24-hour NAAQS for $PM_{2.5}$ is based on a 24-hour average for the midnight-to-midnight period. Data reported in this section is corrected with the EPA correction equation (**Equation 1**) because it is more conservative, i.e., over-measuring concentrations. This provides some degree of confidence that poor air quality isn't missed. **Table 4** presents selected statistics for the midnight-to-midnight 24-hour average $PM_{2.5}$ concentrations measured by the T640X and the four PurpleAir sensors.

The top half of **Table 4** shows the number of valid midnight-to-midnight 24-hour average concentrations collected at each location along with the maximum, minimum, average and median values. All the maximum measured concentrations are well below the 24-hour NAAQS level of 35 $\mu g/m^3$, and most were in the Good air quality range. The bottom half of **Table 4** repeats the number of valid samples and shows the number of samples in the Good and Moderate ranges of the AQI. The percentage of samples shown in each of these ranges is also shown. For each location, 95% or more of the samples were in the Good range. There were no samples in the Unhealthy for Sensitive Groups (USG) range or higher. The data in **Table 4** indicate reasonable agreement between the T640X and the PurpleAir sensors.

Table 4: Statistics for Midnight-to-Midnight 24-hour Average $PM_{2.5}$ Concentrations (EPA Data Correction)

Concentration ($\mu g/m^3$)

Statistic	T640X	Langdon Street	South Mill Pond Park	North Cemetery	New Franklin School
# Samples	191	187	181	97	34
Max	16.8	15.3	18.8	16.1	8.3
Min	1.9	-0.4	-0.5	-2.6	0.9
Avg	6.1	4.5	4.5	3.6	3.3
Median	5.3	3.6	3.6	3.1	3.1

Note: The level of the 24-hour $PM_{2.5}$ NAAQS is 35 $\mu g/m^3$.

AQI

Statistic	T640X	Langdon Street	South Mill Pond Park	North Cemetery	New Franklin School
# Samples	191	187	181	97	34
# Good	182	180	174	94	34
# Moderate	9	7	7	3	0
% Good	95	96	96	97	100
% Moderate	5	4	4	3	0

Good and Moderate air quality are defined in Table 2.

Since the human lungs do not reset themselves each midnight-to-midnight period, NHDES also examined the rolling 24-hour average, which is more conservative (i.e., more protective of health) than the midnight-to-midnight average. That is, for each hour of the sampling period a new forward-rolling 24-hour average $PM_{2.5}$ concentration is calculated and the maximum 24-hour concentration for the day is recorded. Statistics for the more conservative rolling 24-hour average $PM_{2.5}$ concentrations measured by the T640X and the four PurpleAir sensors are shown in **Table 5.** The top half of the table shows measured concentrations, and the bottom half presents the counts and percentages in each AQI range. Since the rolling 24-hour average considers the data more robustly, the number of valid data points for the rolling 24-hour average is much higher than for the midnight-to-midnight 24-hour average.

Like **Table 4**, **Table 5** shows the maximum, minimum, average and median values for each location. The rolling 24-hour average maximum $PM_{2.5}$ concentrations are higher than the midnight-to-midnight concentrations, but still well below the 24-hour NAAQS level of 35 $\mu g/m^3$. As would be expected, average and median $PM_{2.5}$ concentrations are very similar between the midnight-to-midnight and rolling average metrics. As with Table 4, the measured concentrations in Table 5 show reasonable agreement between the T640X and the PurpleAir sensors. For the rolling 24-hour average, the percentage of samples in the Good and Moderate ranges are similar to those for the midnight-to-midnight averages.

Table 6 shows the 7-month sampling period average concentration (i.e., the $PM_{2.5}$ concentration averaged over the entire data collection period) for each location. Although not directly comparable with the annual $PM_{2.5}$ NAAQS, all the period averages are well below the annual $PM_{2.5}$ NAAQS levels of 12 $\mu g/m^3$ (primary)/15 $\mu g/m^3$ (secondary).

Table 4 shows that only about 4 to 5% of the samples collected were in the Moderate range on a midnight-to-midnight basis. Only about 3 to 4% were in the Moderate range on a rolling 24-hour average basis (see Table 5).

Table 5: Statistics for Rolling 24-hour Average $PM_{2.5}$ Concentrations (EPA Data Correction)

Concentration (µg/m³)

Statistic	T640X	Langdon Street	South Mill Pond Park	North Cemetery	New Franklin School
# Samples	4,601	4,464	4,320	2,347	838
Max	23.1	19.4	23.4	20.7	8.5
Min	1.2	-0.6	-0.8	-2.6	0.6
Avg	6.1	4.6	4.5	3.6	3.4
Median	5.4	3.7	3.6	3.0	3.2

Note: The level of the 24-hour $PM_{2.5}$ NAAQS is 35 µg/m³.

AQI

Statistic	T640X	Langdon Street	South Mill Pond Park	North Cemetery	New Franklin School
# Samples	4,601	4,464	4,320	2,347	838
# Good	4,401	4,331	4,191	2,271	838
# Moderate	200	133	129	76	0
% Good	96	97	97	97	100
% Moderate	4	3	3	3	0

Good and Moderate air quality are defined in Table 2.

Table 6: 7-Month Sampling Period Average $PM_{2.5}$ Concentrations (µg/m³) (EPA Data Correction)

Location	Period Average
NAAQS – Annual	***12***
T640X	6.1
Langdon St.	4.6
South Mill Pond Park	4.5
North Cemetery	3.6
New Franklin School	3.5

9. Complaint Investigation with Short (10-minute) Duration Concentration Differences in PurpleAir Data

Comparing short-duration concentrations between two nearby monitors can provide information from short-duration or intermittent emission sources in the area, especially if the emissions source is located between the two locations. As discussed above, the PurpleAir monitoring sites located at Langdon Street and North Cemetery were selected because they were roughly on opposite sides of the rail switchyard where diesel locomotives occasionally idle. When the winds blow from southwest to northeast, the emissions from the idling train could be measured at the North Cemetery location, but not at the Langdon Street location. Those emissions would be indicated by considering the differences in $PM_{2.5}$ concentrations measured at the two locations. Positive concentration differences would be suggestive of emissions picked up from winds crossing the switchyard from southwest to northeast, and negative concentration differences would be suggestive of emissions picked up from winds crossing the switchyard from the northwest to southeast.

Not all concentration differences recorded might suggest diesel engine idling though. Crosswinds can pick up local emissions from other nearby sources, such as idling trucks, fires, some types of residential heating and construction. In fact, the North Cemetery site recorded elevated $PM_{2.5}$ concentrations on several consecutive days due to nearby road construction. NHDES could not obtain railroad logs indicating if diesel engines were idling at any given time, and local reporting was sparce, so this report can only speculate that some of the concentration spikes that could not be attributed to other nearby emission sources were due to idling trains.

10. Islington Neighborhood Train Study (7-Months)

Figure 19 presents cleaned and corrected $PM_{2.5}$ short-duration (10-minute) concentrations at the Langdon Street, North Cemetery and South Mill Pond PurpleAir monitors. In most instances, the three monitors tracked together suggesting that regional air pollution is the main driving influence for local air quality. However, when $PM_{2.5}$ concentrations at one or two locations significantly differ from the others, it suggests localized air pollution as its sources. Two such events occurred at South Mill Pond on New Years eve, which could have been firework related. The other occurring on January 9th is from an unknown cause.

Figure 19: Cleaned and Corrected 10-Minute $PM_{2.5}$ Concentrations at Langdon Street, North Cemetery and South Mill Pond

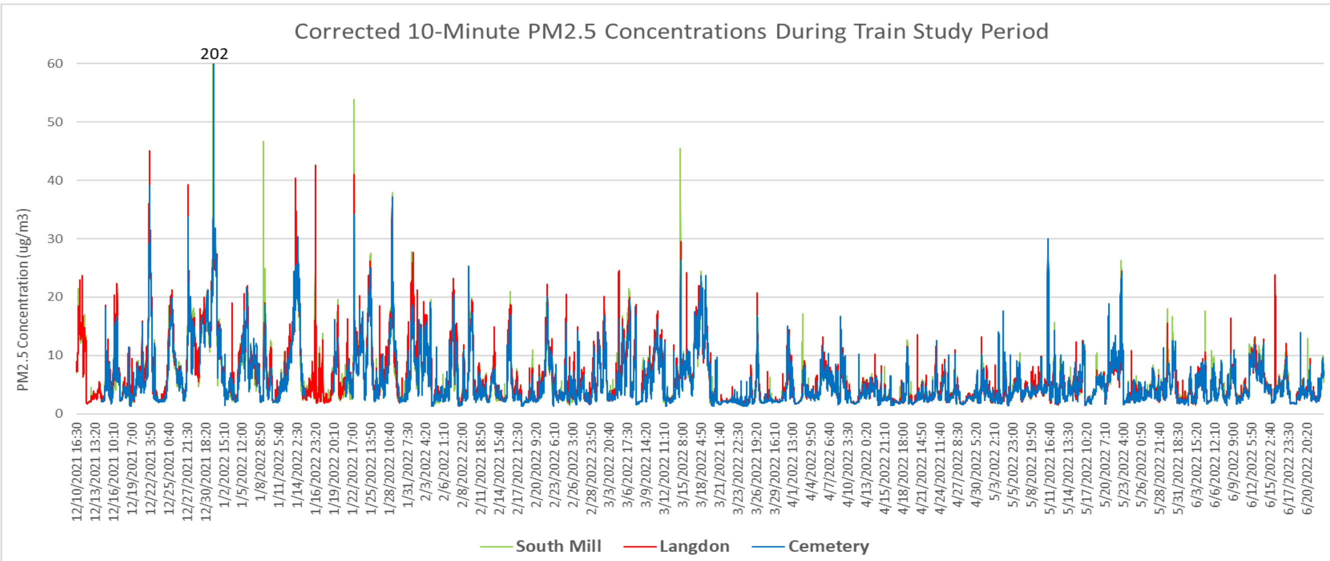


Figure 20 takes a closer look at the locations key to the train study, presenting 10-minute concentration differences at the Langdon Street and North Cemetery PurpleAir monitors. There are several instances where a local emission source, including locomotives, could affect either the North Cemetery or Langdon Street monitor location. The black dotted line is a running average of nearby datapoints included to help the eye detect longer periods of influence.

Overall, there were significant fluctuation in $PM_{2.5}$ concentration differences between Langdon Street and North Cemetery, including several periods where the $PM_{2.5}$ concentration difference between locations was ±20 $\mu g/m^3$ or more. There were 7 days where the concentration difference between locations reached 30 $\mu g/m^3$ or more for a 10-minute period and there were around ten individual events identified as being worthy of further investigation for potential train influence.

Figure 20: Cleaned and Corrected 10-Minute $PM_{2.5}$ Concentration Differences between Langdon Street and North Cemetery

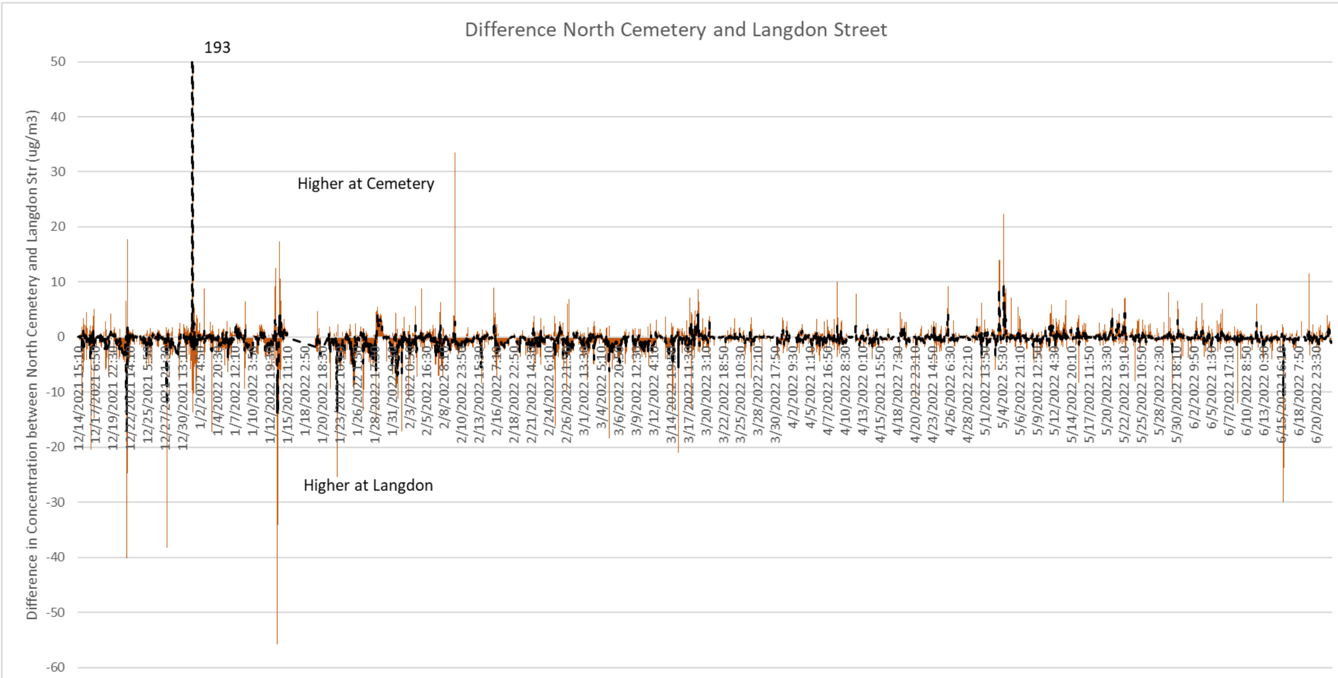


Figure 21 highlights several peak $PM_{2.5}$ concentration events of greatest interest (when multiple consecutive periods of large $PM_{2.5}$ concentration differences are recorded. Further, events occurring on December 21st, January 13th, February 1st, March 5th, March 15th and June 15th, show classic local emission source influence where concentration differences at Langdon Street reached 39.0 $\mu g/m^3$, 53.0 $\mu g/m^3$, 14.7 $\mu g/m^3$, 12.4 $\mu g/m^3$, 18.3 $\mu g/m^3$ and 26.3 $\mu g/m^3$ higher than at North Cemetery for 10-minute averages, respectively. Longer durations would be consistent with a nearby emission source being in the area for a longer than typical duration, such as a train passing slowly or idling, nearby construction, nearby wood burning or an idling diesel vehicle. The arrows in **Figure 21** indicate the direction that the prevailing wind (measured at Pease Airport) is traveling. For example, the arrow in **Figure 21a** indicates that the wind is coming from the north-northwest and traveling across the railyard towards the Langdon Street monitor.

In most, but not all, cases, the wind direction (measured at Pease Airport) is consistent, or near consistent, with placing the railroad switchyard upwind of the monitor recording the higher concentration. Wind directions between compass directions of 270 degrees clockwise to 30 degrees place the railyard upwind of the Langdon Street monitor. Railyard upwind directions to the North Cemetery monitor are between 120 to 200 degrees. Nearly consistent winds mean that winds at the railway switchyard may be slightly different from those at Pease Airport due to local wind-blocking obstructions near the railyard. The wind tends to travel the path of least resistance, effectively channeling along long open stretches. For example, winds at Pease Airport channel along the north-northwest to south-southeast runway, whereas the rail switchyard is aligned southwest to northeast. Calm wind can have a local stagnation effect where air pollutants build up in an area near the source and expand in area coverage with time. Winds during the sampling period were often nearly calm, which is often referred to as light and variable. This can cause a plume of pollution to stagnate and drift slowly in a variety of directions, thus affecting many nearby areas.

Figure 21 (a-g): 10-Minute Corrected $PM_{2.5}$ Concentrations at Langdon Str, North Cemetery and South Mill Pond for Events of Interest

Averaging data by hour of day and by location or by day of week can help provide additional information. **Figure 22a** shows corrected hourly concentrations averaged for all three study monitors, including South Mill Pond, Langdon Street and North Cemetery locations. Diurnal concentration patterns measured are typical for $PM_{2.5}$ measurements in New Hampshire, where concentrations are highest overnight during cooler months of the year. **Figure 22b** shows hourly concentration differences between North Cemetery and Langdon Street averaged by day of week. On average, $PM_{2.5}$ concentrations at the Langdon Street monitor were nearly always slightly higher than at North Cemetery with the greatest differences occurring overnight. Fluctuations from these averages routinely occurred.

Figure 23a shows a combined average of hourly corrected $PM_{2.5}$ concentrations of all three Train Study PurpleAir monitors averaged by hour of day for days of the week. **Figure 23b** shows the concentration difference between North Cemetery and Langdon Street averaged by hour of day for days of the week. These analyses indicate that there are no immediately apparent patterns to time of day or day of week when idling train exhaust has a distinct signal.

Based on the $PM_{2.5}$ concentration differences between North Cemetery and Langdon Street shown earlier in **Figure 22**, there appears to be the strong potential for emission influence from locomotive emissions on December 21, 2021, January 13, 2022, February 1, 2022, March 5, 2022, March 15, 2022 and June 15. While elevated $PM_{2.5}$ concentrations occurred late on December 31, 2021 into early January 1, 2022, especially at the North Cemetery monitor, it is likely that this was due to the First Night firework display.

Figure 22 (a) Cleaned and Corrected Hourly $PM_{2.5}$ Concentrations Averaged Over Hour of Day and (b) Concentration Differences Between North Cemetery and Langdon Street Averaged Over Hour of Day

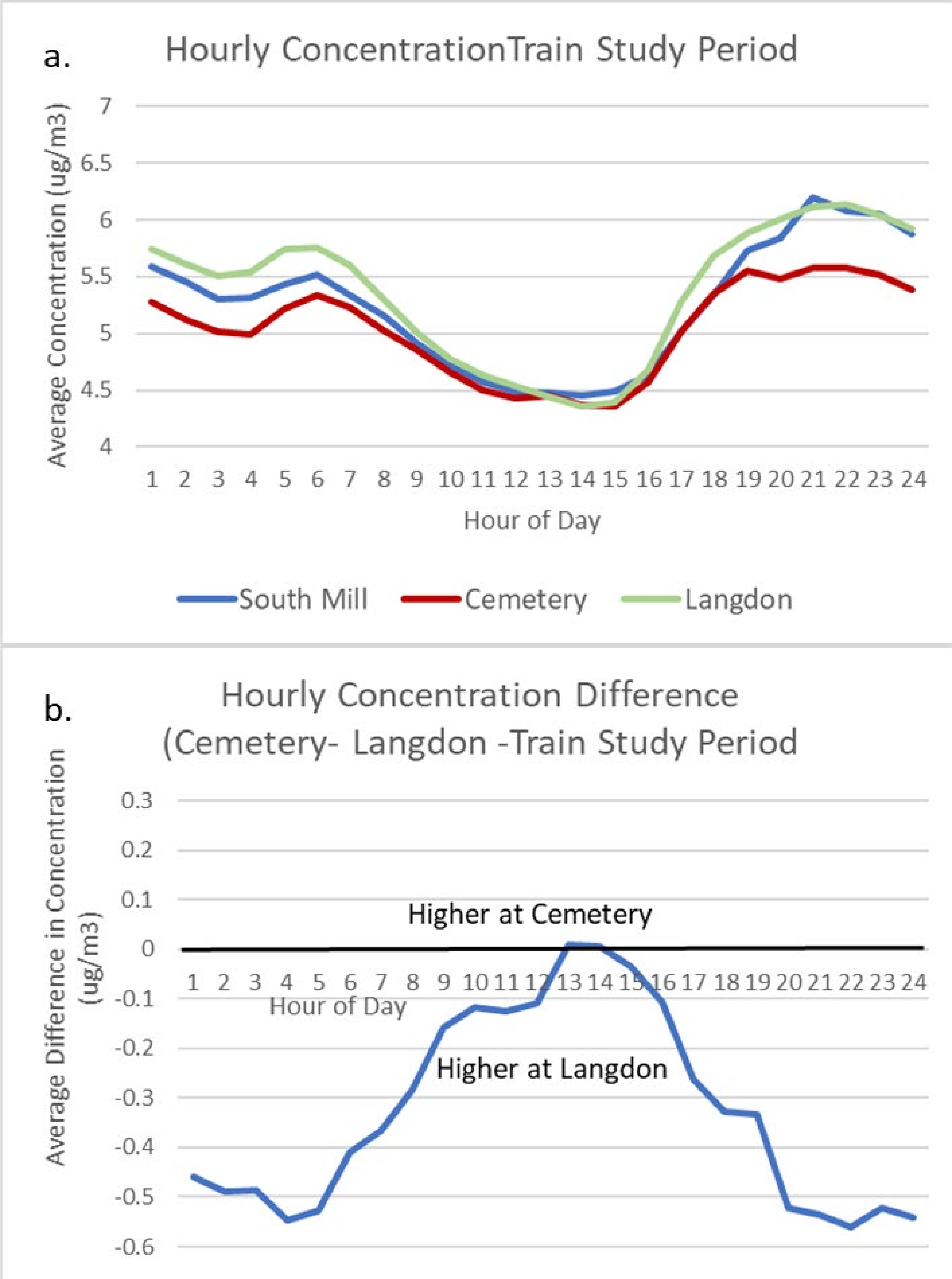
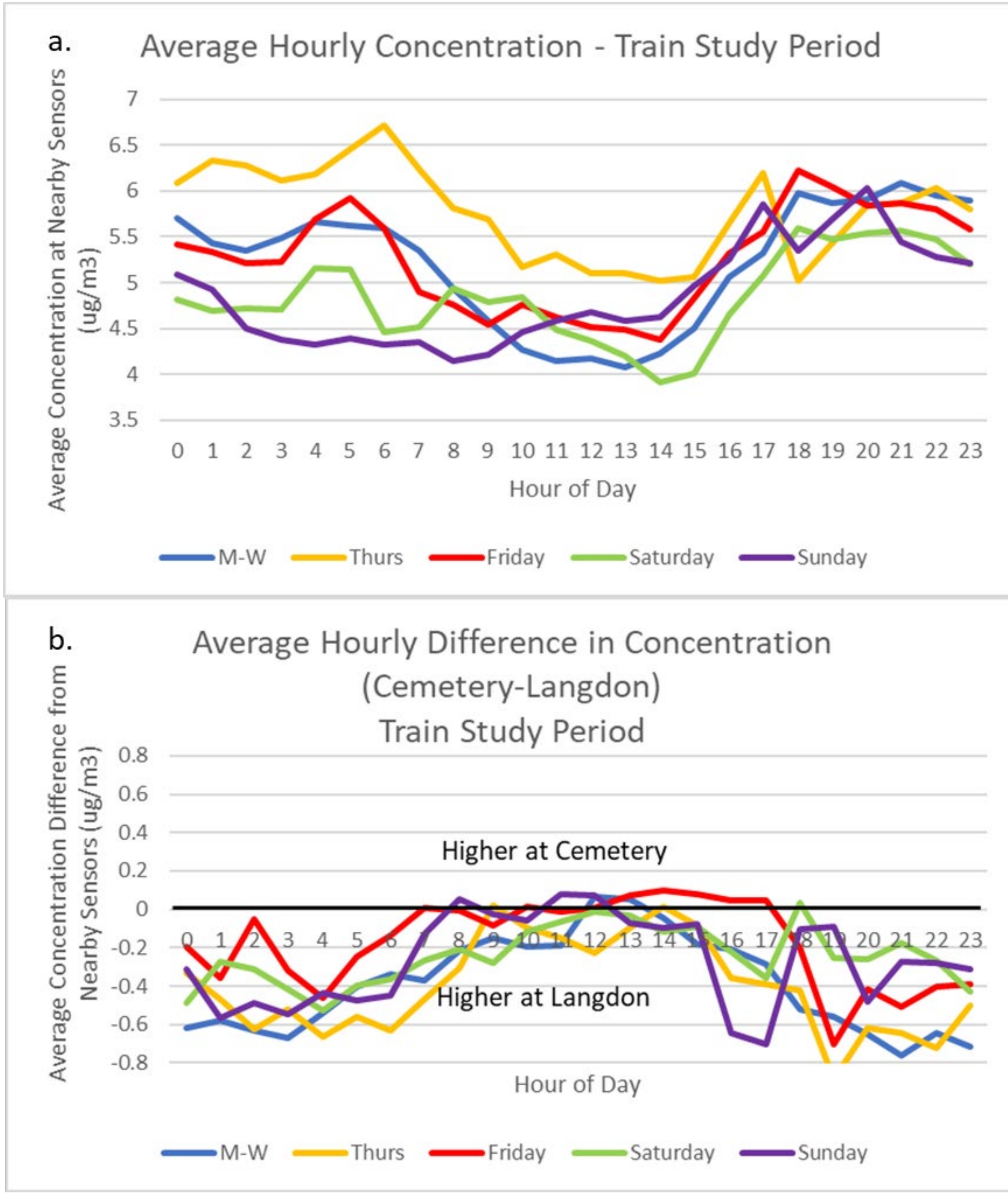


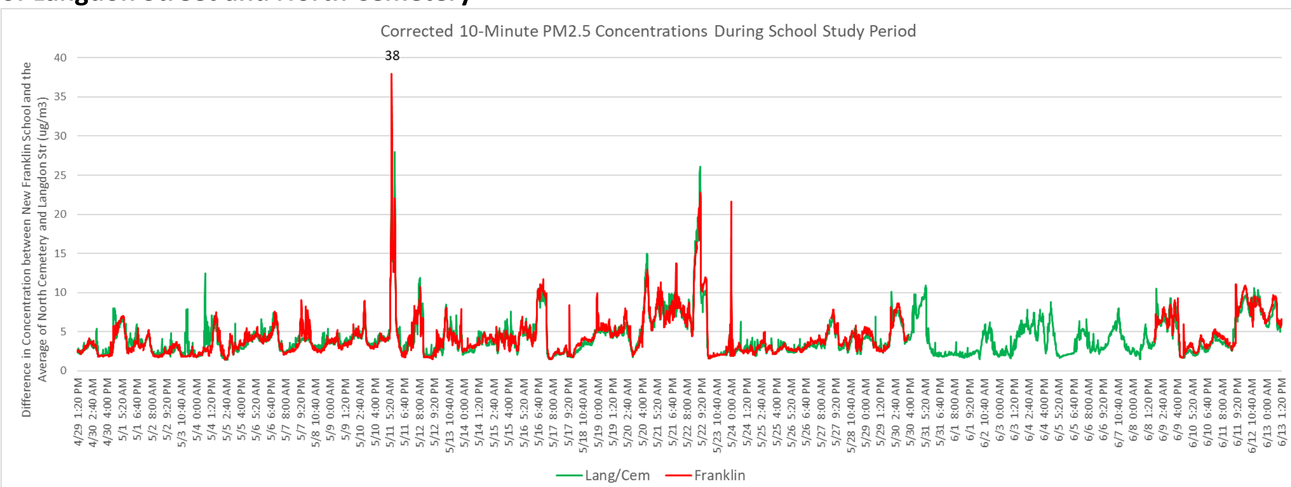
Figure 23: (a) Cleaned and Corrected Hourly $PM_{2.5}$ Concentrations Averaged Over Train Study Locations and by Day of Week and (b) Cleaned and Corrected Concentration Differences Between Langdon Street and North Cemetery Averaged by Day of Week



11. New Franklin School Study (1.5-Months)

NHDES performed PurpleAir monitoring at the New Franklin School for about 6 weeks in May and early June of 2022, to assess if pollution from nearby highways was creating an unhealthy environment for the students and school staff. In order to do this, NHDES compared $PM_{2.5}$ concentrations over 10-minute periods measured at the school with concentrations from nearby PurpleAir monitors included in the study. **Figure 24** shows the 10-minute running cleaned and corrected $PM_{2.5}$ concentrations measured at the school compared to the average $PM_{2.5}$ measurements taken at Langdon Street and North Cemetery. Overall, $PM_{2.5}$ concentrations measured at the locations mirrored each other well with only short periods of variation and were generally low in $PM_{2.5}$ concentration. The highest concentration measured at the school was 38 $\mu g/m^3$ which was one of two consecutive 10-minute periods exceeding 30 $\mu g/m^3$ on May 11, 2022. Monitors at Langdon Street and North Cemetery also exceeded 25 $\mu g/m^3$ during the same period. This compares to the NAAQS for $PM_{2.5}$, which is 35 $\mu g/m^3$ averaged for a full 24-hours.

Figure 24: Cleaned and Corrected 10-Minute $PM_{2.5}$ Concentrations at New Franklin School and the Average of Langdon Street and North Cemetery



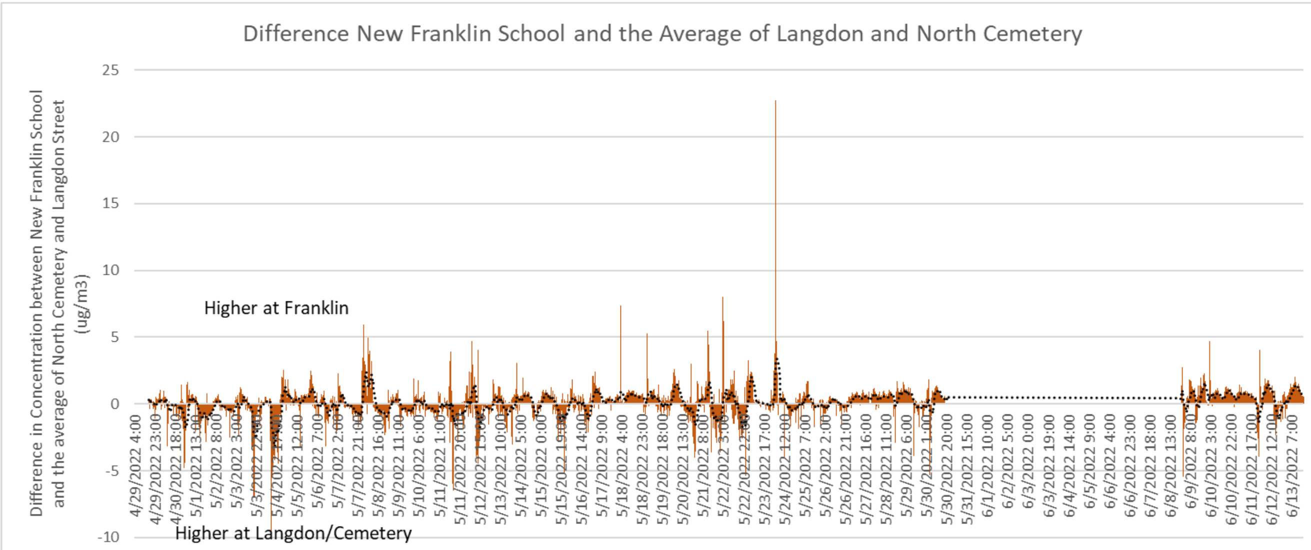
Interstate 95 is located in such a position that when winds come from compass directions (clockwise) between 200 degrees and 30 degrees, it is considered upwind of the New Franklin School monitor. When $PM_{2.5}$ concentrations at New Franklin School were most above the average $PM_{2.5}$ concentrations measured at Langdon Street and North Cemetery, I-95 was typically upwind of the school. In a few cases, winds were reported as calm, which is also consistent with the conclusion that freeway emissions are impacting the school since freeway emissions tend to spill down hills such as the one separating the school from the freeway.

Figure 25 shows the timeline of cleaned and corrected 10-minute $PM_{2.5}$ concentration differences between the New Franklin School and the average concentration of Langdon Street and North Cemetery. New Franklin School is surrounded by I-95 to the northwest and U.S. Route 1 to the southeast. When the New Franklin School concentration is higher than the average of Langdon Street and North Cemetery, it is highly likely the emissions from these road sources are impacting air quality at the school more than at the other two locations further from these busy highways.

The event of May 24th, dominating **Figure 25**, was most likely the result of a non-normal traffic emission source, such as a truck idling nearby or another temporary source of emissions in the very nearby area. $PM_{2.5}$ concentrations in the area before this concentration spike were very low when the data measured on both sensor channels suddenly jumped simultaneously in response to the nearby emission source. $PM_{2.5}$

concentrations remained relatively high for about 20 minutes before returning to their previous lower concentrations.

Figure 25: Cleaned and Corrected 10-Minute $PM_{2.5}$ Concentration Differences between New Franklin School and the Average of Langdon Street and North Cemetery



Average diurnal corrected and minimally cleaned $PM_{2.5}$ concentrations and concentration difference patterns were also assessed for the New Franklin School. **Figures 26 and 27** show patterns for days of week and for a comparison of the school to the average of Langdon Street and North Cemetery. In both cases, the tendency for overnight concentrations to be the highest still occurs but is less distinct than seen in the train study data because the sampling period during the School Study portion of the Portsmouth PurpleAir study includes fewer cold weather periods compared to the Train study portion. Warmer weather reduces the overnight stratification of the air mass which separates cleaner air above from the air at ground level where automotive and residential heating $PM_{2.5}$ emissions occur. More vertical mixing occurs throughout the day, improving dilution with cleaner air.

Figure 26: Cleaned and Corrected Average Hourly $PM_{2.5}$ Concentration Averages for New Franklin School and the Average of Langdon Street and North Cemetery

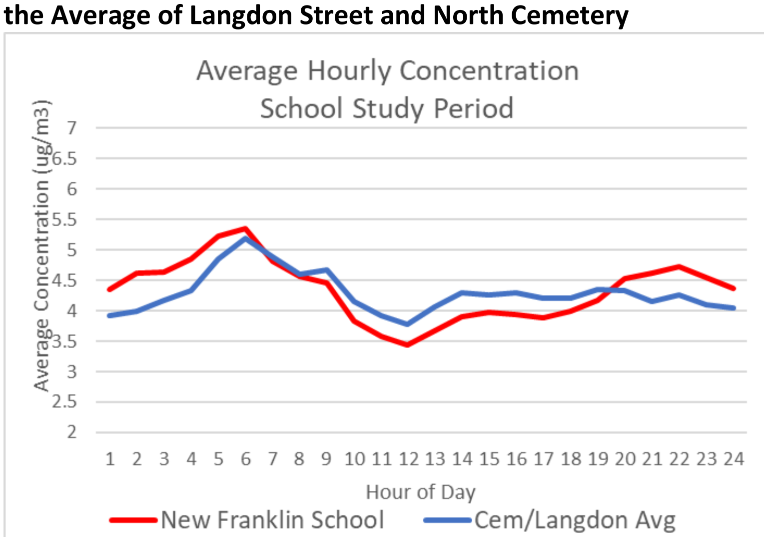
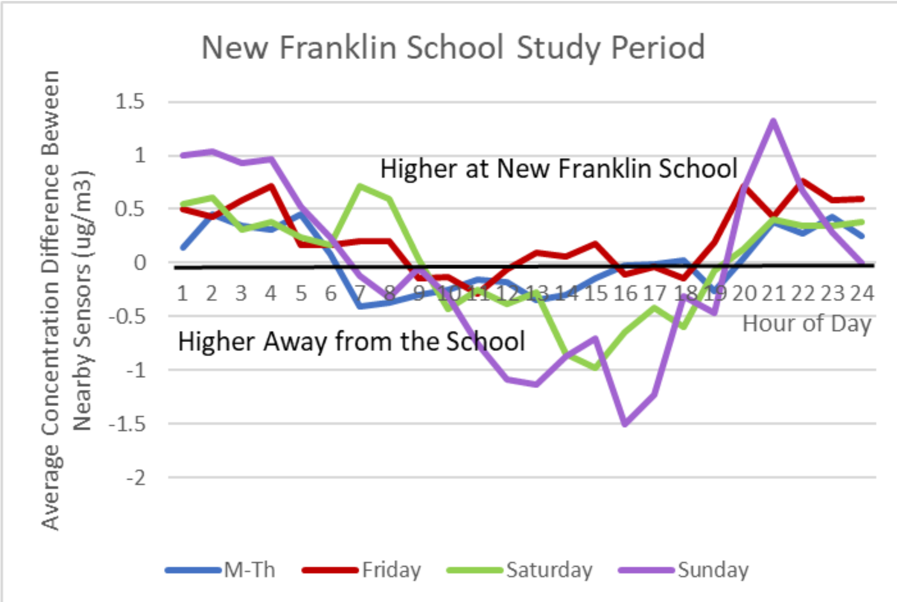


Figure 27: Cleaned and Corrected Average Hourly $PM_{2.5}$ Concentration Averages for New Franklin School by Day of Week



Three distinct patterns emerge in **Figure 27** which examines hourly $PM_{2.5}$ concentrations by hour of day and by day of week during the School Study period. First, $PM_{2.5}$ concentrations are nearly always higher overnight at the school than at Langdon Street and North Cemetery (away from the school). $PM_{2.5}$ concentrations away from the school were more likely to be higher than at the school on Saturday and Sunday afternoons. Second, there is a rapid rise in $PM_{2.5}$ that occurred late in the day on Sundays, and third, $PM_{2.5}$ concentrations on Fridays tended to stay higher than on other days of the week. Each of these observations are consistent with I-95 traffic patterns where there is a surge of traffic heading northbound for the weekend on Fridays, and a return surge of traffic late in the day on Sundays. Another observation is that $PM_{2.5}$ concentrations tended to be highest during the morning commute period. Not only is there more traffic due to rush hour on nearby roads at that time, but it is also a period when vertical mixing is at a minimum. This combination of factors allows pollution to increase.

This study concludes that $PM_{2.5}$ emissions from nearby highways do affect the air quality at New Franklin School (but not in a manner where air pollution $PM_{2.5}$ concentrations exceed or violate the federal health standards (NAAQS) as a direct result of nearby traffic emissions). This study finds that there are time periods and days of week when $PM_{2.5}$ concentrations commonly increase at the school more so than at other nearby locations. While the $PM_{2.5}$ concentrations measured in this study are generally low, odors (which are not measured in this study) can accompany $PM_{2.5}$ and thus be more noticeable. In many cases odors can be detected at concentrations that are lower than the level of the NAAQS. Noticeable odors can be a source of educational distraction and can sometimes lead to nausea in more sensitive individuals.

12. Summary and Conclusions

During the winter of 2021 and spring of 2022, NHDES conducted a study of hyper-local air quality in and around the Islington Creek neighborhood in Portsmouth, NH. NHDES deployed three PurpleAir monitors in the Islington Creek neighborhood in the vicinity of the PanAm/CSX railyard and one monitor at the New Franklin School. NHDES also operates a regulatory FEM T640X $PM_{2.5}$ monitor at Peirce Island in proximity to the Portsmouth PurpleAir study area. The T640X provided a useful data point against which to compare the performance of the PurpleAir monitors and the associated data cleaning and correction procedures. The

PurpleAir monitors with Seacoast-equation corrected data did an admirable job of replicating the peak 24-hour concentrations and the temporal variation measured by the NHDES T640X.

Train Idling Study

While overall concentrations of $PM_{2.5}$ measured throughout the study were in the Good range (see EPA's Air Quality Index in **Table 2**), short variations did occur suggesting the influence of nearby emission sources. Idling trains were observed parked alongside Islington Creek neighborhoods by NHDES staff and heavy automotive traffic occurred at times during the study period. The train engines observed in the area consisted of older, more polluting models, that are often used in railroad switchyards. The influence of these train emissions on measured $PM_{2.5}$ concentrations is strongly suspected, but unconfirmed due to lack of train records and observations during periods of higher $PM_{2.5}$ concentration measurements. Nearby residents have observed strong diesel odors, believed to have come from nearby idling trains at somewhat random times of the day, but these reports preceded the study.

As stated elsewhere in this report, even though the measured $PM_{2.5}$ concentrations did not exceed the federal health standards (NAAQS), odors can be present at significantly lower concentrations. Diesel exhaust has a strong distinct metallic odor that can be especially irritating, particularly in areas such as residential neighborhoods and playgrounds. To reduce irritation from odors, it may be advantageous to attempt to work with the railroad on possible mitigation strategies such as the following:

- Idle locomotives in a designated area within the switchyard away from residential areas
- Use newer, lower-emitting locomotives or auxiliary power unit (APU) technology

New Franklin School

At New Franklin School, average $PM_{2.5}$ concentrations stayed well below federal health standards (NAAQS), but some $PM_{2.5}$ concentration patterns observed in the data were consistent with periodic odor complaints from school staff. Again, the presence of odors does not necessarily imply that other health concerns exist, based on current federal standards. However, odors can distract from school learning. Further, some especially sensitive students could experience some breathing difficulties, such as aggravating asthma when $PM_{2.5}$ concentrations in the area are highest, even if they are still below health standards.

Although, as previously mentioned, air quality at New Franklin School meets all federal health standards, suggestions to address nuisance odors could include:

- Upgrading the school air handling system to include High Efficiency Particulate Air (HEPA) and carbon filtration to reduce odors and $PM_{2.5}$, as well as other common airborne irritants such as dust and pollen.
- If odors during outdoor time cause concern or irritation, shifting outdoor play time or holding play time indoors.

In addition to the above suggestions, EPA and NHDES recommend that school buses and other vehicles are not left idling outside the school. This includes caregivers waiting in their cars for students to be dismissed. Idling vehicles contribute to the burden of $PM_{2.5}$ and other pollutants in the ambient air.