LV Breathes September 2025 Newsletter
Data Snapshot

Introduction

For our first snapshot of the data from the Lehigh Valley Breathes Project we are comparing levels of $PM_{2.5}$ pollution over a **single month** in 2024 from 8 monitors that capture the breadth of the Valley's diverse geography and land uses. These geographical locations range from an industrial park at the west of the Valley's urban corridor (IronRunIP-SG), to a rural residential neighborhood at the northeastern corner of the valley (Portland), to a heavily trafficked road in the Valley's largest city of Allentown (PNLV), to a highway on the eastern edge of the city of Bethlehem (HWY378&Brighton). The land-uses range from highly residential (Kirkland & Portland), to suburban (Freemansburg & IronRunIP-SG), to industrial parks in semi-rural (BathIP) and urban (HellertownBIP) areas.

The location of each monitor discussed in this data snapshot is described in the following table.

Monitor Name	Monitor Location Description
BathIP	Semi-rural area on the edge of the Valley's urban corridor, situated between two small industrial parks and just east of a cement plant
Freemansburg	Off-road urban area on edge of a park but north to northwest of Bethlehem Industrial Park.
HellertownBIP	Urban area between Bethlehem and Hellertown proximate to the Bethlehem Industrial Park and near Highway 78
Highway378&Brighton	Residential edge of a Central Business District in Bethlehem and proximate to a traffic light on Highway 378
IronRunIP-SG	Suburban area flanked by the Valley's largest industrial park on one side, and just north of where Highway 22 merges into Highway 78
Kirkland	Isolated residential community in urban corridor removed from highways and road traffic
PNLV	Dense urban area in Allentown on heavily trafficked roadway and south of heavily trafficked American Parkway
Portland	Isolated residential neighborhood in rural northeastern corner of the Lehigh Valley

Our snapshots of the data from these monitoring locations present three distinct comparisons. In **Comparison 1**, we compare data on $PM_{2.5}$ pollution in three widely separated locations during the month of July 2024: an isolated rural residential neighborhood (Portland), a suburban area within the urban corridor (Freemansburg), and a heavily trafficked road in a dense urban area (PNLV). In **Comparison 2**, we compare data on $PM_{2.5}$ pollution at homes near three industrial parks during the month of July 2024. One monitor (HellertownBIP) is in a heavily trafficked urban area that is between an industrial park and a highway, one (IronRunIP-SG) is in a suburban area on the edge of the Valley's largest industrial park, and one (BathIP) is in a semi-rural area between two industrial parks and is also flanked by a cement plant. In **Comparison 3**, we compare data on $PM_{2.5}$ pollution in two residential locations within one city in the urban corridor during the month of August 2024. One of these locations (Kirkland) is relatively isolated from highways and traffic, and the other one borders a heavily trafficked highway (HWY378&Brighton).

The Purple Air monitors continuously measure $PM_{2.5}$ pollution every two minutes, which creates a lot of data points. We help convey what all this data means by first averaging those two-minute measurements by the hour, to create an "hourly average." We then average those hourly measurements over a 24-hour period to create a "daily average."

The **hourly average distribution** of $PM_{2.5}$ pollution highlights short-term peaks and reveals the pollution's high-and-low spread, as well as the frequency of different levels of $PM_{2.5}$ pollution, and how the measurements are spread out over the entire time-period we are analyzing. By looking at hourly averages, we can see how the pollution levels vary with transient events, such as rush-hour traffic, industrial emissions, or localized combustion activities.

We also analyze the data over a 24-hour period. These **daily average** concentrations of $PM_{2.5}$ pollution help to identify variations in air quality, such as sustained levels of elevated pollution, as well as trends related to weather, traffic patterns, and industrial activity that occurs over each 24-hour period. Because the government regulates $PM_{2.5}$ pollution based on daily average concentrations, the daily average will be helpful for assessing short-term health risks and for comparing air quality to public health standards.

This first snapshot also includes a discussion of **diurnal patterns** in the data. This is a way of characterizing the daily pattern of $PM_{2.5}$ pollution that averages it by hour over the month of data presented. Diurnal patterns of $PM_{2.5}$ help us understand how pollution levels fluctuate, revealing the timing and magnitude of peak exposure periods. These patterns reflect the influence of human activity, such as traffic rush hours, or industrial operations, as well as the influence of meteorological factors like temperature inversions and boundary layer dynamics. Understanding diurnal variation is critical for identifying periods of the highest acute exposure risk to $PM_{2.5}$ pollution and for designing targeted mitigation strategies.

After discussing the three comparisons described above, this newsletter will summarize the key conclusions and the topic of our next newsletter.

COMPARISON 1: PORTLAND, FREEMANSBURG, AND PNLV LOCATIONS

Figure 1 below provides an hourly average comparison of $PM_{2.5}$ pollution at a rural residential location (Portland), an off-highway urban location (Freemansburg), and a high-traffic urban (PNLV) location during the month of July 2024.

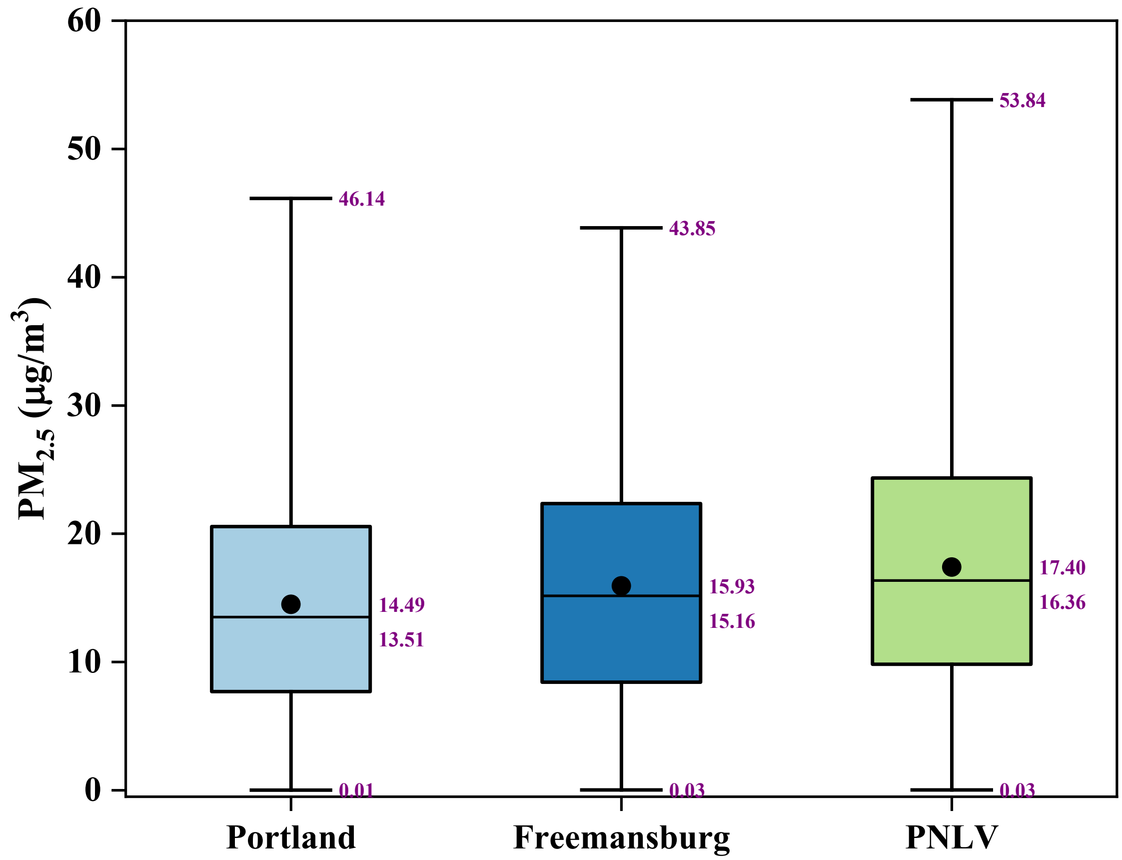

Figure 1: Comparison of hourly average $PM_{2.5}$ concentration distributions at a rural residential site (Portland), an off-road urban site (Freemansburg), and an urban near-road site (PNLV). Box plots illustrate the median (horizontal line), mean (dot), interquartile range (box), and full data range (with minimum value at bottom and maximum value at top).

The mean $PM_{2.5}$ concentration distributions across the three monitoring sites, Portland, Freemansburg, and PNLV, reveal a distinct gradient corresponding to land use and proximity to emission sources (Figure 1). A clear, progressive increase in ambient pollution is observed when moving from the rural residential site (Portland, mean of 14.49 µg/m^3) to the urban off-road site (Freemansburg, mean of 15.93 µg/m^3) and culminating at the urban near-road site (PNLV, mean of 17.40 µg/m^3). The rural Portland site consistently exhibited the lowest concentrations, representing regional background levels, while the urban near-road PNLV site recorded the highest concentrations and most severe peaks (up to 53.84 µg/m^3), highlighting the strong influence of traffic emissions.

As visualized in **Figure 2** below, the diurnal pattern of $PM_{2.5}$ pollution at these three sites during different hours of the day fluctuates significantly, revealing the timing and magnitude of peak exposure periods.

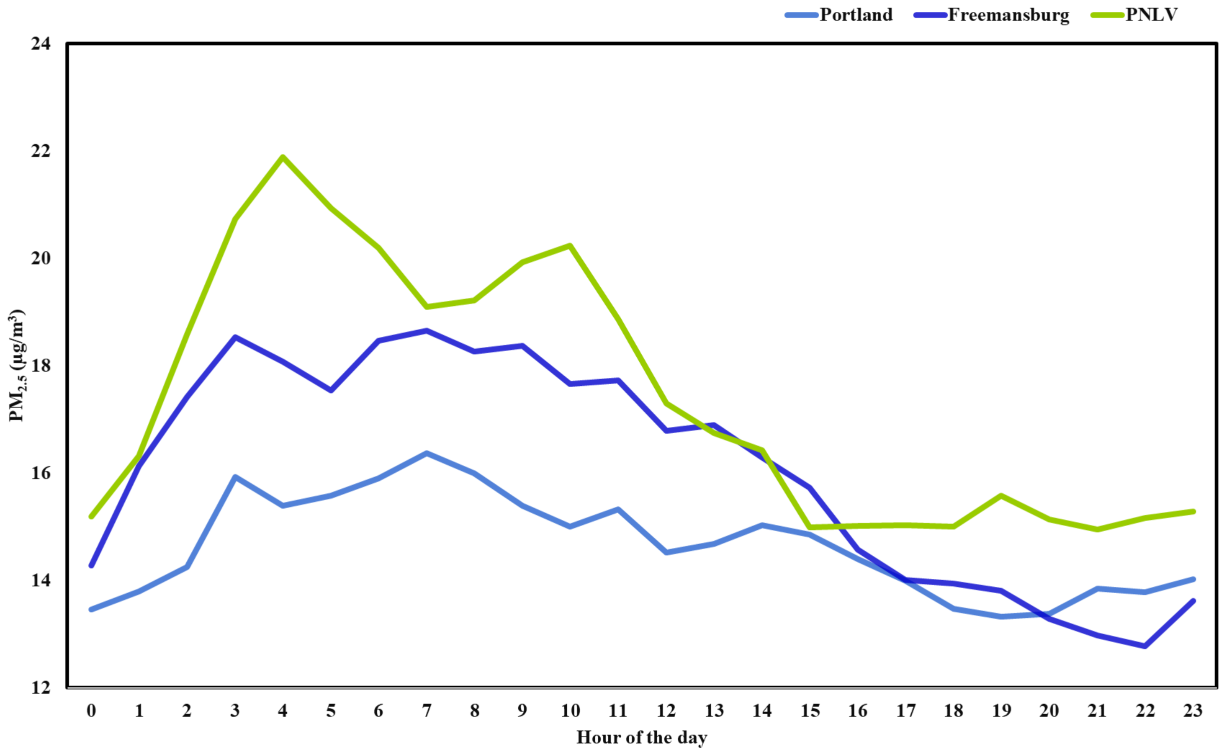

Figure 2: Diurnal $PM_{2.5}$ Patterns for Portland, Freemansburg, and PNLV sites.

The diurnal data reveal a consistent concentration hierarchy throughout the day, with the near-road PNLV site consistently recording the highest values, followed by the urban off-road Freemansburg site, and finally the rural Portland site, which represents the regional baseline. The most profound difference is the magnitude and sharpness of the mid-morning peak; the PNLV site exhibits a classic, pronounced peak between 07:00 and 09:00 in the morning, which might be the signature of rush-hour traffic emissions.[1] This traffic-related peak is present but significantly dampened at the urban off-road Freemansburg site and is only a minor feature at the rural Portland site. These diurnal patterns strongly suggest that proximity to dense traffic is the dominant factor driving peak morning concentrations in the region, with the second highest acute exposure risk occurring during commute times. The patterns demonstrate the spatial and temporal impact of urbanization and traffic emissions, highlighting how near-road environments experience not only a higher chronic pollution load but also more severe, predictable peak concentration events tied to daily human activity.

Moving on to the daily averages for these three monitors (Portland, Freemansburg, PNLV), a clear pollution gradient is again evident in the data. As visualized below in **Figure 3**, the mean concentrations of $PM_{2.5}$ pollution progressively increase from 15.05µg/m^3 at the rural Portland site, to 15.87µg/m^3 at the urban Freemansburg site, and reaching 17.38µg/m^3 at the near-road PNLV site. The most profound difference, however, lies in the corresponding increase in daily variability and peak concentrations, which highlights the escalating impact of urban and traffic-related emission sources. This finding strongly suggests that the transition from a rural to an urban near-road environment leads to more frequent and

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[1] The similarity of the peak in pre-rush hour early morning pollution across all three sites (between 3:00a.m. and 4:00a.m.) suggests that valley-wide meteorological or geographical factors are playing a significant role in the first peak in pollution. For example, atmospheric factors such as a temperature inversion can concentrate emissions in all three locations from normally occurring activities such as late-night traffic, industrial operations, or domestic activities.

higher-magnitude pollution events, emphasizing that while chronic exposure levels are moderate, short-term peaks, particularly near roads, can significantly elevate exposure. This analysis underscores how land-use characteristics and road proximity are key determinants of both baseline $PM_{2.5}$ levels and episodic high-concentration events, highlighting the necessity of site-specific monitoring for accurate assessment of air quality and exposure risk.

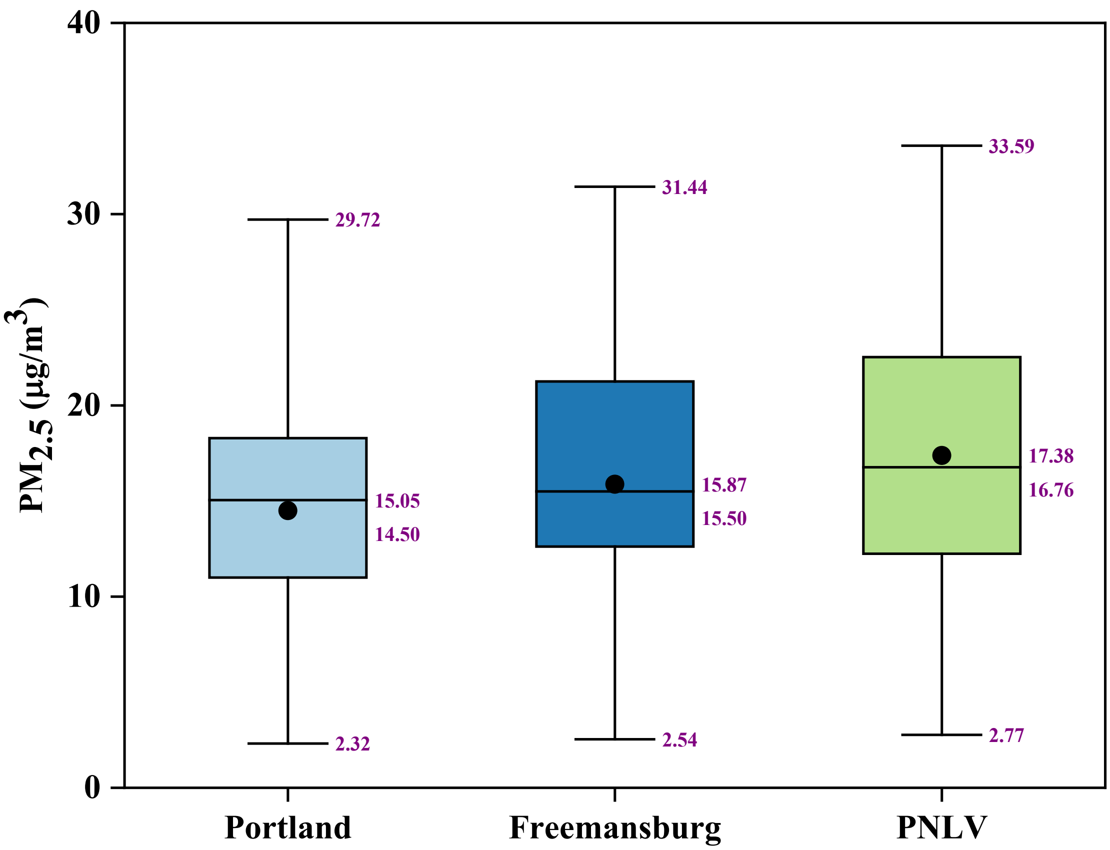

Figure 3: Comparison of daily average $PM_{2.5}$ concentration distributions at a rural site (Portland), an urban off-road site (Freemansburg), and an urban near-road site (PNLV).

COMPARISON 2: THREE INDUSTRIAL PARK LOCATIONS

Our second comparison analyzes data on $PM_{2.5}$ pollution at homes near three industrial parks during the month of July 2024. The HellertownBIP location is in a heavily trafficked urban area, situated between an industrial park and a major highway (78). The IronRunIP-SG location is in a suburban area on the northern edge of the Valley's largest industrial park. The BathIP location is in a semi-rural area between two industrial parks and just east of a cement plant. Data comparing the hourly averages of these three warehouse-adjacent sites is explained in **Figure 4** below.

A noteworthy finding is the remarkable similarity between the first two warehouse sites; despite one being near a major highway, they exhibit nearly identical mean concentrations (16.17µg/m^3 and 16.22µg/m^3, respectively) and comparable maximums (around 41µg/m^3).

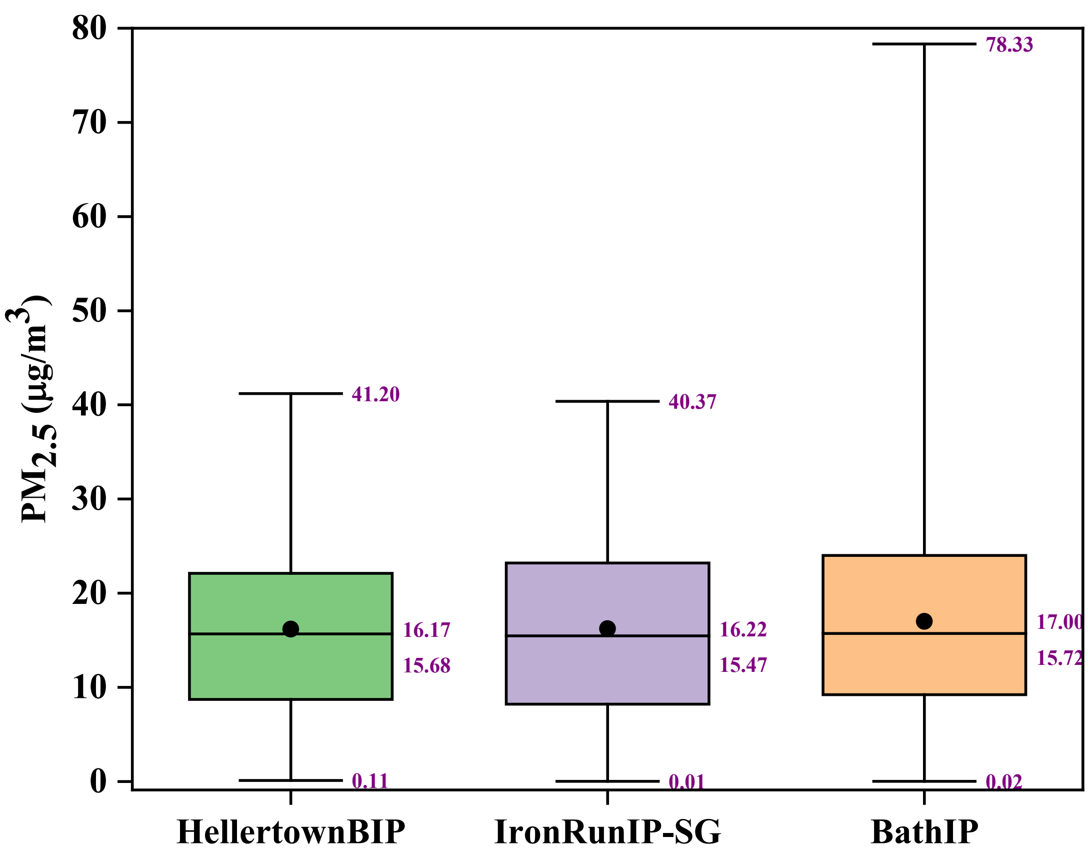

Figure 4: Comparison of hourly average $PM_{2.5}$ concentration distributions at HellertownBIP, IronRunIP-SG, and BathIP.

The most profound difference, however, emerges when comparing these first two logistical sites to the BathIP site. While the mean concentration at the BathIP is only slightly higher at 17.00µg/m^3, the BathIP monitor recorded an extreme maximum of 78.33µg/m^3, which is a peak event approximately double that of the other warehouse locations. This finding strongly suggests that while different warehouse operations may produce a consistent and comparable air quality footprint, heavy industrial sources like the cement plant are in a distinct category, characterized by severe, intermittent high-emission events.

Assessment of the diurnal patterns of $PM_{2.5}$ emissions at these three warehouse sites affirms that there are significant differences in the timing of peak concentrations. As visualized in **Figure 5**, HellertownBIP site exhibits a classic bimodal traffic pattern, with prominent peaks corresponding to the morning (approx. 7:00 a.m.) and evening (approx. 7:00 p.m.) commutes, consistent with its proximity to a major highway. In contrast, IronRunIP-SG's concentrations peak later in the morning (approx. 10:00 a.m.), which might be aligning with typical logistical and warehouse operational hours. Similarly, the early afternoon (approx. 2:00 p.m.) peak at HellertownBIP may align with heightened warehouse related truck traffic between rush hours, as truckers try to get to the Industrial Park before the afternoon rush hour begins. The industrial BathIP site displays a unique inverse pattern, with its highest concentrations occurring during overnight and early morning hours, which strongly suggests its pollution profile is dominated by industrial process schedules (at the cement plant) and nocturnal meteorological conditions that trap emissions.

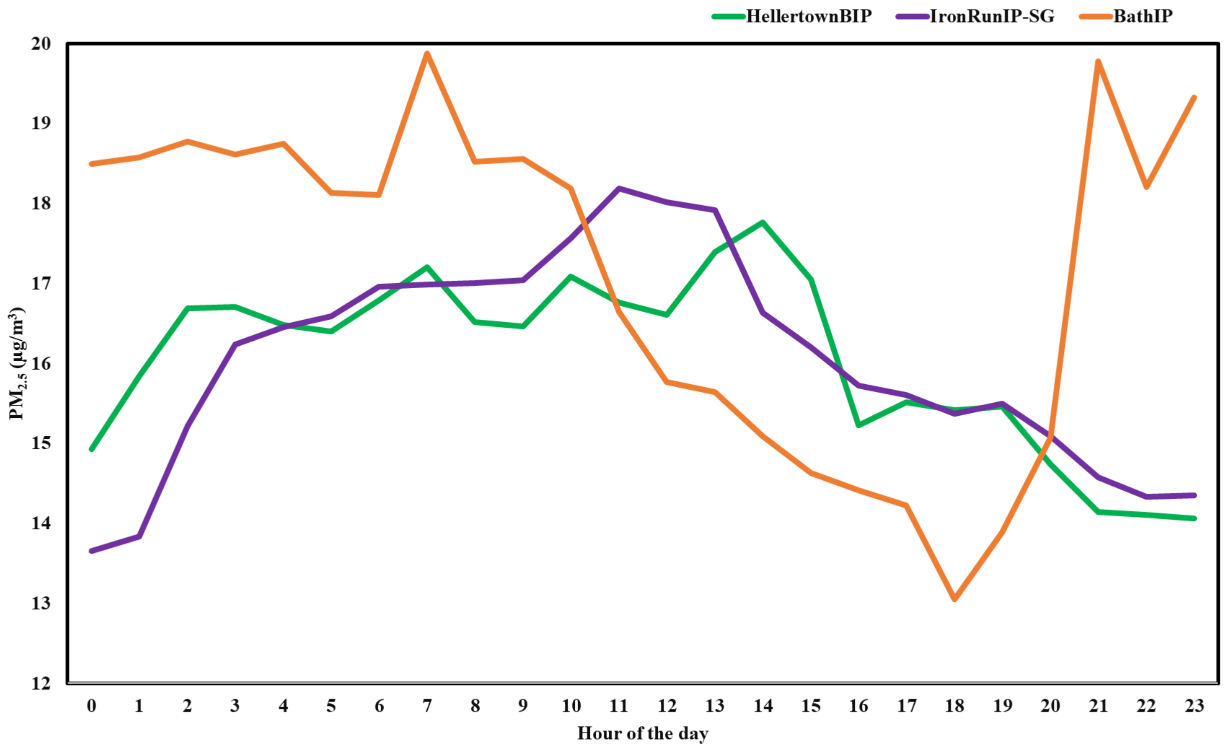

Figure 5: Diurnal $PM_{2.5}$ Patterns for HellertownBIP, IronRunIP-SG, and BathIP.

As depicted in **Figure 6** below, the daily average distribution of PM2.5 pollution at these three warehouse-adjacent locations is similar to the hourly average comparison in exhibiting remarkably similar mean concentrations across the three sites, with HellertownBIP at 16.54µg/m^3, IronRunIP-SG at 16.42µg/m^3, and BathIP at 17.02µg/m^3.

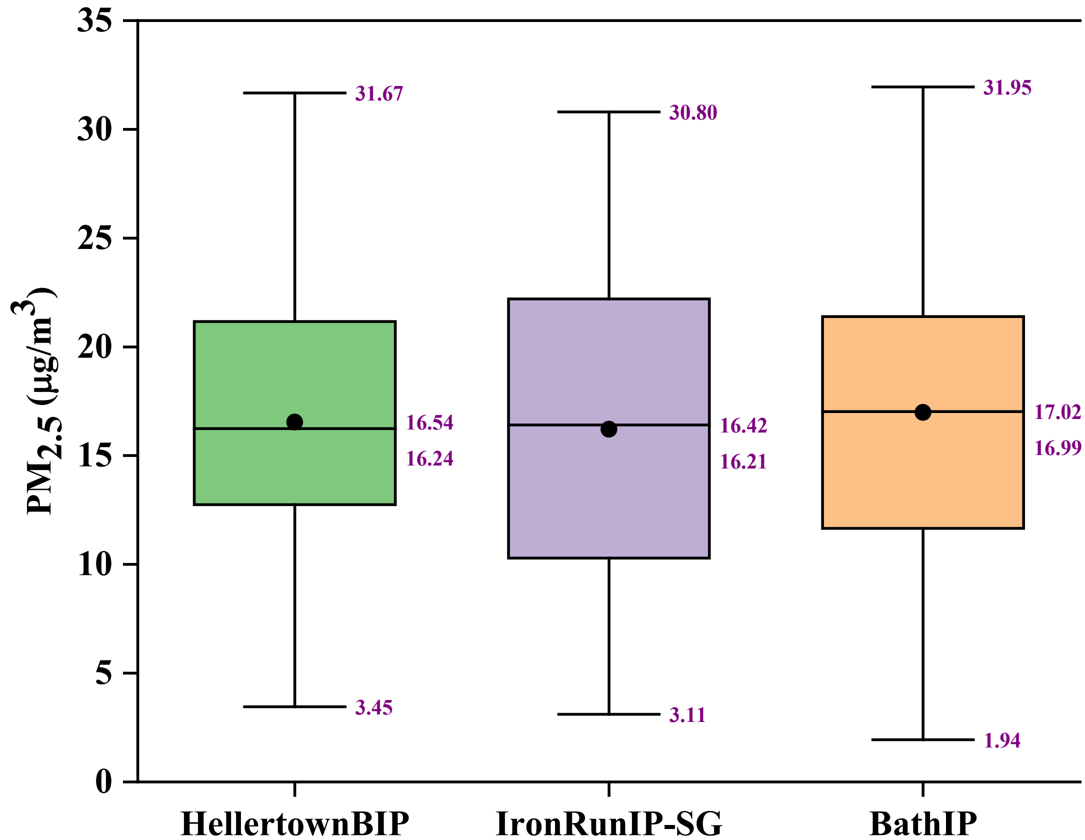

Figure 6: Comparison of daily average $PM_{2.5}$ concentration distributions at HellertownBIP, IronRunIP-SG, and BathIP.

The most profound difference lies not in the average, but in the nature of the distributions; the industrial BathIP site displays the highest median[2] (16.99µg/m^3) and a comparatively tight interquartile range[3]. This finding strongly suggests that while the overall pollution load is comparable across these sites, the emissions profile from the cement plant results in a less variable, chronically high concentration environment, whereas the warehouse sites show slightly wider operational variability. Maximum daily concentrations at all three sites were also comparable (~30-32 µg/m^3), suggesting that while short-term events occur, they are not as extreme as those in heavily trafficked locations, such as PNLV.

COMPARISON 3: TWO RESIDENTIAL LOCATIONS IN THE SAME CITY

Our last comparison for this first data snapshot assesses differences in two residential locations within the city of Bethlehem during the month of August 2024. The selected urban residential sites included Kirkland, representing a low-traffic environment, and HWY378&Brighton, representing a high-traffic environment.

[2] The median value is the middle value of the dataset, meaning half of the data points fall below this value and half fall above it.

[3] The interquartile range is the entire length of the box and represents the spread of the middle 50% of the data. The box's edges are defined by the first quartile (Q1), which marks the 25th percentile, and the third quartile (Q3), which marks the 75th percentile.

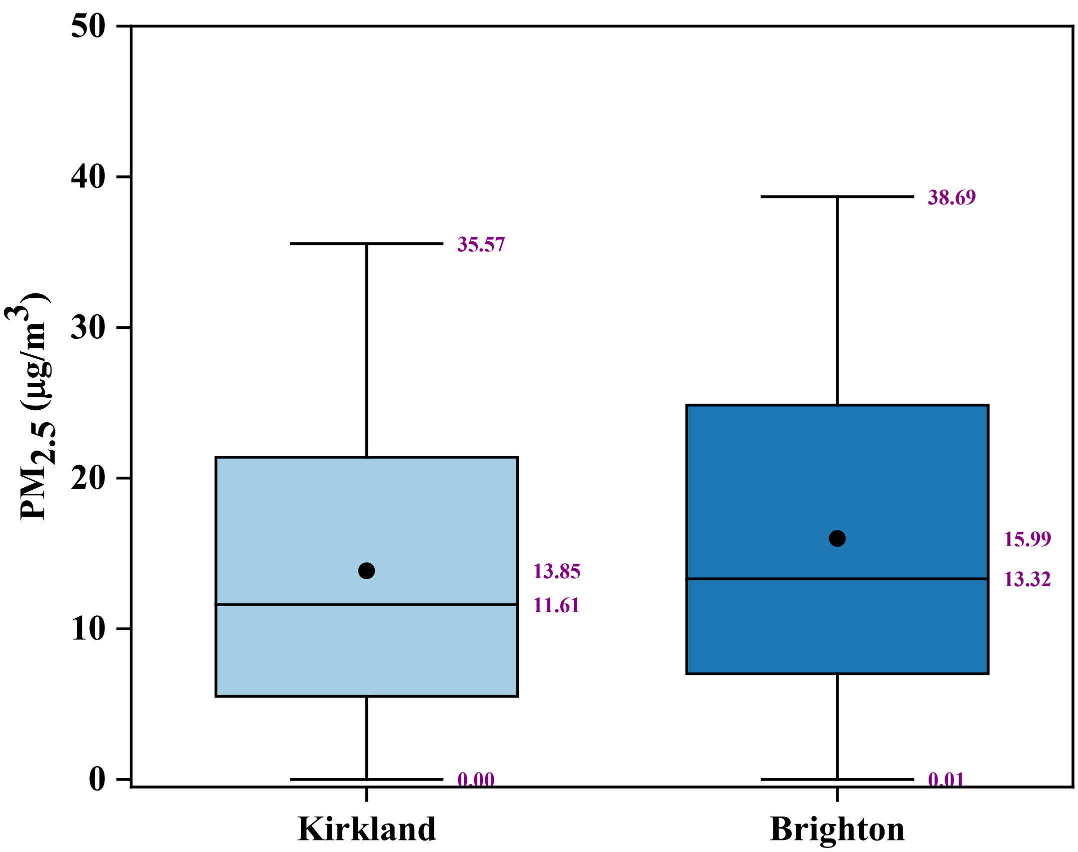

Figure 7: Comparison of hourly average $PM_{2.5}$ concentrations at Kirkland and Brighton.

The hourly average data for these two locations visualized in **Figure 7**, clearly demonstrate the impact of vehicular emissions, with the high-traffic Brighton site exhibiting a higher mean concentration of 15.99µg/m^3 compared to the 13.85µg/m^3 mean at the low-traffic Kirkland site. The most profound difference, however, extends beyond the average to include greater daily variability and a higher peak concentration (38.62µg/m^3) at the Brighton location. This finding strongly suggests that the high traffic volume at the Brighton site contributes to both an elevated pollution baseline over the general urban background and more frequent, high-magnitude emission events.

The diurnal pattern of the data for these two residential locations within the city of Bethlehem that is visualized in **Figure 8** adds to our understanding of the comparison.

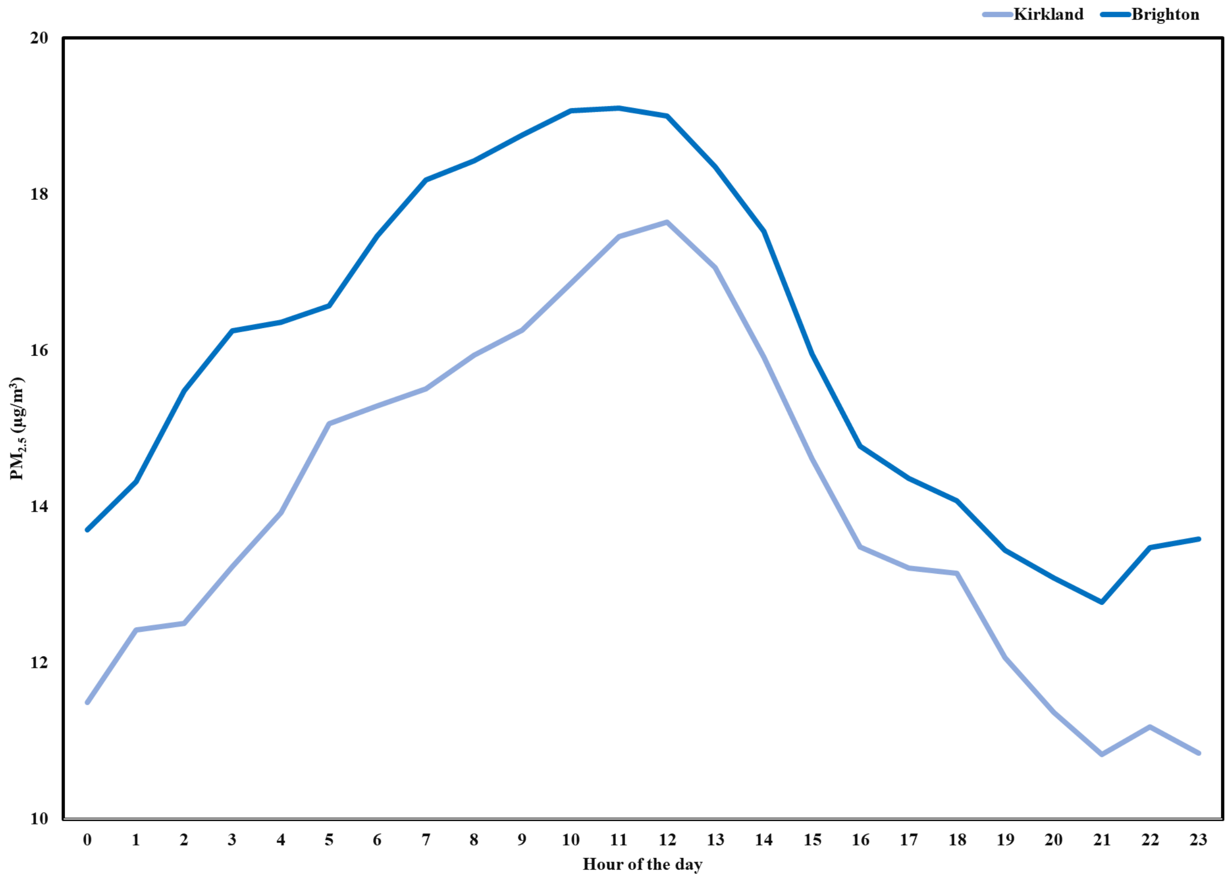

Figure 8: Diurnal $PM_{2.5}$ Patterns for Kirkland and Brighton.

The pattern of PM2.5 pollution, averaged by hour over the month of August 2024 reveals that the high-traffic Brighton site exhibits persistently and significantly higher concentrations than the low-traffic Kirkland site at all hours of the day. The most profound finding is that both sites share an identical temporal pattern, characterized by a late morning peak around 10:00-11:00, yet are offset by a near-constant margin. This strongly suggests that the Kirkland site represents the general urban background pollution for a residential area, while the elevated concentrations at Brighton represent this same background plus a significant, additional pollution load directly attributable to the adjacent high-traffic roadway. This continuous elevation in concentration at the Brighton site implies a chronically higher daily exposure for residents, increasing the long-term health risks associated with traffic-related air pollution. Therefore, the analysis of these diurnal patterns effectively isolates and quantifies the local impact of a major roadway, demonstrating that proximity to traffic results in a consistent and significant increase in pollutant concentrations throughout the entire 24-hour cycle.

To finish up with the daily average comparison for these two sites in **Figure 9**, the data again show the impact of vehicular emissions, with the high-traffic Brighton site exhibiting a substantially higher mean concentration of 16.02µg/m^3 compared to the 13.92µg/m^3 mean at the low-traffic Kirkland site. The most profound difference, however, extends beyond the average to include greater daily variability and more extreme short-term concentrations at the Brighton location, evidenced by its wider interquartile range and higher peak value. This finding strongly suggests that under typical meteorological conditions, the high volume of traffic at the Brighton site is a dominant local source contributing to both an elevated baseline and more frequent high-emission events.

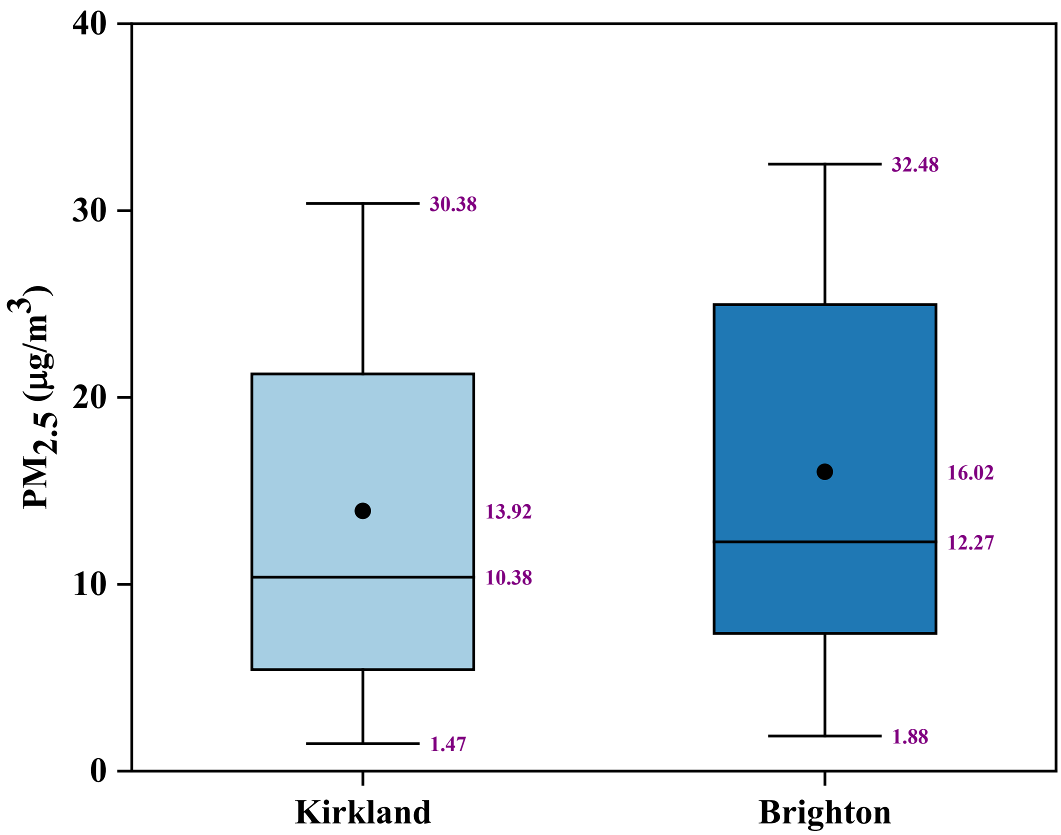

Figure 9: Comparison of daily average $PM_{2.5}$ concentration distributions at Kirkland and Brighton.

Conclusions & Future Discussion

$PM_{2.5}$ monitoring across eight diverse locations demonstrates that air pollution is highly variable in both space and time. Urban near-road and industrial sites experienced the greatest impacts, with elevated baseline concentrations and extreme short-term peaks. Analysis across multiple timescales was crucial for identifying the timing and sources of this pollution, revealing that rush hour traffic likely drives morning peaks, while truck traffic near warehousing sites likely drives mid-day peaks, with industrial activity and meteorological factors playing a key role in overnight elevations.

Understanding both the ***when*** and the ***where*** of pollution is an essential first step in understanding how it relates to public health, and it is necessary for designing targeted, evidence-based air quality management policies. In our next newsletter, we will discuss how the data from the three comparisons discussed above relates to public health standards.

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* NOTE TO NEWS MEDIA: Because this snapshot includes significant, detailed data regarding air quality, *Lehigh Valley Breathes* strongly encourages reporters to contact us with any questions about the descriptions of the data in this data snapshot, or about our interpretations of the data. Inquiries can be sent to lvbreathes@gmail.com.