

Community-Led Efforts to Raise Awareness, Engagement, and Capacity Building on Air Pollution Issues in East Oakland, California



Final Report prepared for Lifers Leaving a Legacy
By Sonoma Technology
and UC Riverside CE-CERT

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Community-Led Efforts to Raise Awareness, Engagement, and Capacity Building on Air Pollution Issues in East Oakland, California

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Table of Definitions

Table 1 below lists definitions and abbreviations used in this report. Definitions, explanations of sources, and the health effects of specific pollutants are included in **Appendix A**.

Table 1. Table of definitions for terms included in this report.

Term	Definition
Air Sensors	Devices used to detect and measure concentrations of pollutants in the air.
Air Pollution	A substance in the air that causes human, animal, or environmental harm.
Air Quality	The cleanliness of the air we breathe.
Anthropogenic	Pollution caused by human activities.
AQI	The Air Quality Index, a scale based on the concentration of air pollutants in the air at a given location. Visit www.airnow.gov/aqi/aqi-basics
Background Levels	The levels of pollutants in the air that are not associated with local sources.
BTEX	Acronym for benzene, toluene, ethyl benzene, and xylene. BTEX are a group of aromatic hydrocarbons found in petroleum products that are often found together. BTEX can be indicative of mobile source emissions because they are found in gasoline and vehicle exhaust.
Carcinogen/Carcinogenic	A species that has the potential to cause cancer. Carcinogenicity is a specific type of toxicity.
Clarity Sensor	The air sensors used in this project to collect PM _{2.5} , NO ₂ , and wind measurements. This sensor is produced by Clarity Movement Company.
Emissions	The release of pollutants into the air from natural or human-made sources.

Term	Definition
EPA, U.S. EPA	The U.S. Environmental Protection Agency is a federal agency that protects human health and the environment.
Exposure	Having contact with air pollution.
Local sources	Sources of air pollution that are geographically nearby.
Particles/PM	Particles, or particulate matter, defined as small liquids or solids suspended in the air. PM can be made of many different materials.
PM _{2.5} /Fine Particles	Particulate matter with a diameter of 2.5 micrometer or less, also referred to as "fine particles."
PM ₁₀	Particulate matter with a diameter of 10 micrometers or less.
Point Sources	A single, non-moving source of pollution.
Radiello	A sampler used to collect VOCs from the air over a period of time. No pump is involved, so these are referred to as "passive" samplers.
Sources	Sources of air pollution.
Toxic/Toxicity	Any species that has been found to be harmful or dangerous to human health.
VOC/VOCs	Volatile organic compounds. Many of these carbon-containing gases are human-made, though some come from natural sources (such as trees). For more information, see https://www.epa.gov/indoor-air-quality-iaq/what-are-volatile-organic-compounds-vocs

Executive Summary

Overall Takeaway

The monitoring results point to traffic as the most consistent and influential local source of both PM_{2.5} and VOCs, with winter conditions amplifying pollution levels. While most pollutant concentrations remained within health guidelines, the presence of carcinogenic VOCs and occasional PM_{2.5} spikes underscores the importance of continued monitoring and targeted emission-reduction strategies, particularly those focused on transportation and wood burning.

Summary

The goal of this work was to conduct a survey-level air study in the community, with a specific focus on identifying pollution hot spots; documenting contributions from sources such as traffic burning, and illegal waste and disposal site activity; addressing the issues affecting the community; and implementing clean up and abatement in the neighborhoods. We established a network of sensors at five community locations (Arsola's House, Church Street, East Oakland Boxing Association, Legacy House, Reems Court), which are located within busy areas and are close to traffic and residences. Sensors were located to capture representative outdoor air. The network measured PM_{2.5} and VOC measurements at each location. Arsola's House was also equipped with a sensor measuring wind direction and speed.

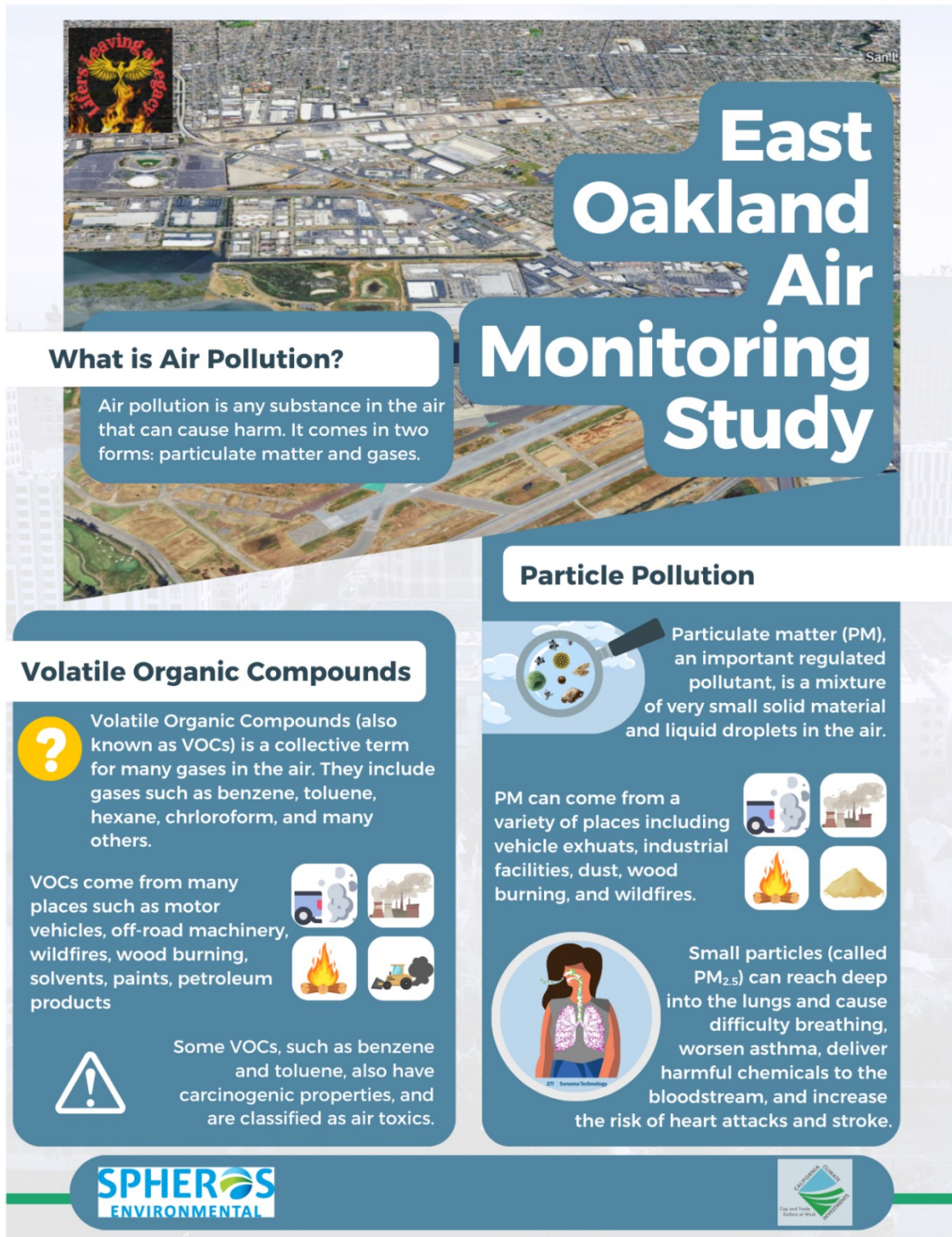
Air quality monitoring in East Oakland from September 2025 through February 2026 revealed mostly "Good" to "Moderate" levels of PM_{2.5}. One site, Church Street, experienced one day whose levels fell in the category "unhealthy for sensitive groups," indicating that vulnerable residents (such as children, older adults, and people with asthma or heart and lung disease) may have experienced health effects on that day. VOC sampling across five locations revealed a mix of traffic-related pollutants and other sources, with several toxic compounds detected.

Daily PM_{2.5} concentrations were consistent across the five monitoring sites, averaging between 9.0 and 14.0 µg/m³. The strongest daily pattern was a morning peak between 7:00–9:00 a.m. and an evening rise around 8:00 p.m., aligning with rush-hour traffic and pointing to vehicles as the dominant local source. Levels were lowest in late afternoon (around 4:00 p.m.). Seasonal trends showed an increase from fall into winter, driven by residential wood burning, higher vehicle emissions from cold starts, and winter meteorology that traps pollution near the ground. Local emissions, including traffic and wood burning, accounted for roughly one-quarter of measured PM_{2.5}, with their influence strongest in winter.

VOC samples collected every 13–20 days revealed 18 compounds detected frequently or classified as toxic, with 13 considered toxic. Approximately 38% of measured VOCs, including benzene, toluene, and xylene, originated from vehicles. The remaining VOCs derived from non-traffic sources; those VOCs were dominated by ethanol. Traffic-related VOCs rose and fell together, reinforcing their shared origin. Site-level differences were modest overall, though Reems Court consistently exhibited lower concentrations due to its distance from major roadways and industrial activity. Legacy House exhibited notably elevated levels of 1,4-dichlorobenzene. On average, traffic-related VOC concentrations in East Oakland exceeded long-term Bay Area regional averages.

All measured toxic VOC concentrations were below state *non-cancer* health guidelines for long-term exposure. Cancer risk estimates were calculated for six VOCs, with four showing measurable long-term (70-year) risk. Benzene, primarily from vehicle exhaust, and carbon tetrachloride, a persistent global pollutant, posed the highest estimated risks at roughly 19-in-a-million and 10-in-a-million, respectively. These findings indicate that while current levels do not exceed health guidelines, reducing vehicle-related emissions would meaningfully lower long-term cancer risk and improve community health.

Community Project Summary



East Oakland Air Monitoring Study

What is Air Pollution?

Air pollution is any substance in the air that can cause harm. It comes in two forms: particulate matter and gases.

Volatile Organic Compounds

? Volatile Organic Compounds (also known as VOCs) is a collective term for many gases in the air. They include gases such as benzene, toluene, hexane, chloroform, and many others.

VOCs come from many places such as motor vehicles, off-road machinery, wildfires, wood burning, solvents, paints, petroleum products

Some VOCs, such as benzene and toluene, also have carcinogenic properties, and are classified as air toxics.

Particle Pollution

Particulate matter (PM), an important regulated pollutant, is a mixture of very small solid material and liquid droplets in the air.

PM can come from a variety of places including vehicle exhausts, industrial facilities, dust, wood burning, and wildfires.

Small particles (called PM_{2.5}) can reach deep into the lungs and cause difficulty breathing, worsen asthma, deliver harmful chemicals to the bloodstream, and increase the risk of heart attacks and stroke.

SPHEROS ENVIRONMENTAL

California Clean Air Act

MEASUREMENT RESULTS

Lifers Leaving a Legacy worked with Spheros Environmental to measure air pollution levels

01. WHAT WAS MEASURED?

Fine particles (PM_{2.5})
5 locations



Individual VOCs
5 locations



02. AIR POLLUTION MEASUREMENT DETAILS

- The study ran from September 2025 to March 2026.
- Air sensors and VOC collection samplers were set up at five community locations.



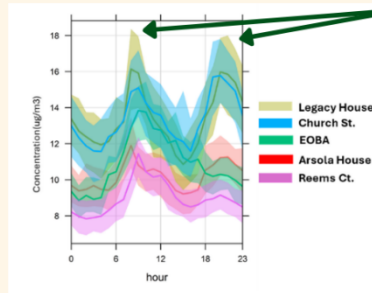
03. WHY MEASURE AIR?

- Understand current levels of different pollutants in the air.
- Identify hotspots and key pollution sources.
- Determine if the pollutants pose a health risk.

04. PM_{2.5} RESULTS

Traffic is the main source of PM_{2.5} at all locations.

- Daily levels at each site mostly fell within the "good" or "moderate" AQI category.



- PM_{2.5} levels are highest in the morning (7-9 am) and 8 pm and lowest in the afternoon (4-5 pm,) and early morning (4-5 am).
- Levels are higher in winter due to wood burning, vehicle cold starts, and weather (inversion layer) that traps pollution.

06. VOC GAS RESULTS

About 38% of VOCs were from local vehicle exhaust, including **benzene**, **toluene**, & **xylene**.

1,4 dichlorobenzene was notably elevated at Legacy House, but likely comes from indoors (space deodorant and to control moths, mold, and mildew

- Four VOCs (including benzene and carbon tetrachloride) produced long-term (70-year) cancer risk.

07. HEALTH IMPACT

Based on the pollutants measured in this study, a lifetime (70 years) of exposure to the measured levels would result in an increase in cancer risk of 32 in a million.

08. WHAT CAN YOU DO?

During poor air quality, consider using an N-95 or KN-95 mask.

Consider using air cleaners - filters will help remove particles while units with activated charcoal will help remove VOCs.

For a list of certified cleaners, visit:
<https://ww2.arb.ca.gov/list-carb-certified-air-cleaning-devices>

1. Introduction

This work is a community-led air quality monitoring effort within East Oakland, California. The primary objectives of this project were to conduct a community-led survey-level air study, with specific focus on identifying pollution hot spots; documenting contributions from sources such as traffic burning, and illegal waste and disposal site activity; addressing the issues affecting the community; and implementing clean up and abatement in these neighborhoods.

Oakland is a city of over 100 neighborhoods broken into six major districts, which include West Oakland, North Oakland, Lake Merritt, Central Business District, Oakland Hills, and East Oakland. East Oakland generally includes everything east of Lake Merritt, with Deep East Oakland starting at about Seminary Avenue. In Oakland Hills and Piedmont, the flatland of Deep East Oakland is polluted with hundreds of tons of trash accumulated from illegal and commercial dumping. East Oakland ranks in the highest decile of cumulative burden in the state and is classified as a priority environmental justice community. One of the major environmental concerns in East Oakland is poor air quality. The area is heavily industrialized, with numerous factories, refineries, and transportation facilities, including the Port of Oakland. This industrialization has led to high levels of air pollution, including particulate matter, nitrogen oxides, and VOCs. Exposure to these pollutants has been linked to a variety of health problems, including respiratory illnesses, cardiovascular disease, and cancer. CalEnviroScreen 4.0 (CES4) indicates that many neighborhoods in the region are in the top 90th percentile for diesel particulate matter, which strongly correlates with poverty levels. As such, there is a need for a better understanding of the sources and levels of pollutants experienced by the neighborhoods in this region, particularly East Oakland.

PM and VOCs are a prevalent concern in the community, especially in locations where burning activities are frequent. To address these concerns, Lifers Leaving a Legacy (Lifers) was awarded a California Air Resources Board 2022 AB 617 Community Air Grant. Lifers contracted with Sonoma Technology to 1) conduct a survey-level air for 1 year, including obtaining measurements of PM_{2.5} and VOCs. 2) Use these data to establish baseline pollutant concentrations. 3) Combine data from all sites to develop an "East Oakland" average to compare against regional concentrations. 4) Link community member-reported issues (e.g., odor, smoke, dust, etc.) with measured data. 5) Estimate the cumulative health risks from toxic air pollutants. 6) Engage in outreach efforts to discuss project findings with community and stakeholder partners.

At the time this report was prepared, community-submitted observations were still too limited to provide meaningful on-the-ground context for the monitoring results. Even so, this report offers a thorough interpretation of the available measurements.

In this report, we provide:

- Background information about general air pollutant classes.

- A table of common sources of air pollutants and any related health impacts they may pose.
- A discussion of the methods used for air monitoring.
- A discussion of methods used for data analysis.
- Results and Discussion for
 - Meteorology
 - PM_{2.5}
 - VOC measurements
 - Cumulative risk
- Conclusions

The appendices contain additional information and details about the methods, analysis, and results; they are referenced throughout the main text.

1.1 Sources and Health Impacts of Air Pollutants

1.1.1 Particulate Matter

PM is defined as microscopic solids or liquid droplets suspended in the air. Most commonly, PM measurements focus on two size ranges: particles less than 10 microns in diameter [coarse particles, PM₁₀) and particles less than 2.5 microns in diameter (PM_{2.5}). Particle size refers to particle diameter (i.e., spherical particles) or “equivalent” diameter for odd-shaped particles. The fine and coarse particles have different sources, properties, and effects.

Health research has primarily focused on PM mass because those measurements were the most common data available; they have a long measurement history at many sites across the country. PM has been shown to cause premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing. Particle size is directly linked to the potential for causing respiratory problems. Larger particles impact the upper respiratory tract, while smaller particles can enter the lower respiratory tract and even enter the bloodstream (Figure 1). Of the two size fractions, PM_{2.5} poses the greater risk to health.¹

¹ <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#effects>

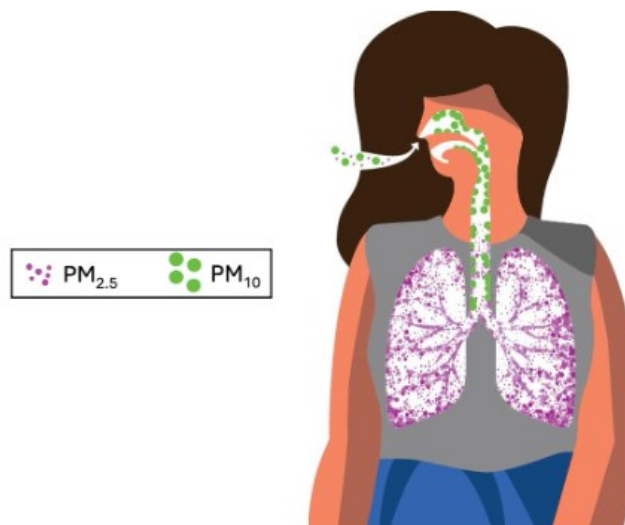


Figure 1. Areas of the respiratory tract that particles can reach.

The EPA sets National Ambient Air Quality Standards (NAAQS) to protect human health.² These standards stipulate that the average PM mass concentration in the outdoor air over a 24-hr time-period should not exceed a specific threshold, based on the findings of health and risk assessments. The PM_{2.5} NAAQS for the annual mean is 9 µg/m³ and for a 24-hr average is 35 µg/m³. The PM₁₀ NAAQS for a 24-hr average is 150 µg/m³.

The World Health Organization (WHO)³ sets air quality guidelines as a global target for national, regional, and city governments to work towards in order to improve their citizens' health by reducing air pollution. For PM_{2.5}, the guidelines include an annual average of 5 µg/m³ and a 24-hr average of 15 µg/m³. For PM₁₀, the guidelines are for an annual average of 15 µg/m³ and a 24-hr average of 45 µg/m³.

1.1.2 Volatile Organic Compounds

"Volatile organic compounds" is a collective term for many organic compounds with low boiling points. VOCs exist both indoors and outdoors. Outdoors, VOCs influence the creation of ground-level ozone (O₃) via chemical reactions with nitrogen oxide compounds (NO_x) and sunlight (referred to as photochemical reactions). As indoor air pollutants, VOCs are associated with a variety of health issues, including eye, nose, and throat irritation; headaches; organ damage; and cancer. VOCs originate from evaporation of man-made household and industrial sources, including fuel, solvents, preservatives, and pesticides. VOCs can also originate from natural sources such as vegetation and forest fires. The Office of Environmental Health Hazard Assessment (OEHHA) has set chronic

² <https://www.epa.gov/criteria-air-pollutants/naaqs-table>

³ <https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines>

reference exposure levels (RELs) (OEHHA, 2023) for several toxic VOCs, as listed in [Table 2](#). Additionally, OEHHA provides unit risk estimate (URE) values, which are used to assess cancer risk (OEHHA, 2025).

Table 2. Main VOCs of interest in this study with applicable OEEHA chronic REL and unit cancer risk data. Bolded species are carcinogenic.

Species	Chronic REL ($\mu\text{g}/\text{m}^3$)	Unit Risk Value ($1/(\mu\text{g}/\text{m}^3)$)
Benzene	3	0.000029
2-Butanone	1	NA
Carbon tetrachloride	40	0.000042
Chloroform	300	0.0000053
Cyclohexane	NA	NA
1,4-Dichlorobenzene	5	0.000011
Ethanol	NA	NA
Ethylbenzene	2000	0.0000025
Ethyl acetate	NA	NA
Heptane	NA	NA
Hexane	7000	NA
Tetrachloroethene	35	0.0000061
Trimethylbenzene	4	NA
Toluene	420	NA
Xylenes	700	NA

[Table 3](#) lists some of the key VOCs detected in this work. Those known to the State of California to cause cancer are bolded. The sources and health impacts of each species are described in more detail in [Appendix A](#).

Table 3. A summary of the common sources and health impacts of key VOCs detected in this study. Bold font indicates the species is a known carcinogen.

VOC	Common Sources	Health Impacts of Long-Term Exposure
Benzene (C ₆ H ₆)	Found in anthropogenic sources such as gasoline, vehicle exhaust, and cigarette smoke. Increased exposure associated with breathing contaminated air from areas with heavy vehicle traffic or nearby gas stations. Occurs naturally from wood burning and volcanic activity.	Long-term exposure affects blood cells and bone marrow, potentially leading to anemia. Benzene is carcinogenic and associated with bone marrow cancers.
2-Butanone (C ₄ H ₈ O)	Used as a solvent and in certain paints and glues. Also naturally occurring and produced by photochemical reactions with other air pollutants.	Long-term exposure may cause neurological, liver, kidney, and respiratory damage.
Carbon Tetrachloride (CCl ₄)	Use is mostly banned due to harmful effects. Historically used to produce refrigerants and aerosol propellants, as a cleaner, and in fire extinguishers.	Damage to the liver and kidneys. Carbon tetrachloride is a probable human carcinogen.
Chloroform (CHCl ₃)	Chloroform is produced as a byproduct from chlorine water treatment; it also used in manufacturing environments. Chloroform also occurs naturally in small amounts.	Long-term exposure damages the liver and nervous system. Chloroform is a probable human carcinogen.
Cyclohexane (C ₆ H ₁₂)	Cyclohexane is found in gasoline. Exposure most commonly occurs from breathing air contaminated with gasoline vapors.	Long-term exposure may damage the liver and kidneys.
1,4-Dichlorobenzene (C ₆ H ₄ Cl ₂)	Primarily used as a space deodorizer and in mothballs.	Long-term exposure can damage the liver, skin, and nervous system. 1,4-Dichlorobenzene is a carcinogen.
Ethanol (C ₂ H ₆ O)	Ethanol is the intoxicating substance in alcoholic beverages. It is also a gasoline additive, solvent, and disinfectant.	Ethanol is generally not associated with health impacts at ambient concentrations.

VOC	Common Sources	Health Impacts of Long-Term Exposure
Ethylbenzene (C ₈ H ₈)	Commonly found in gasoline. Proximity to highways and factories increases the risk of exposure.	Long-term exposure can cause kidney damage. Ethyl benzene is a possible human carcinogen.
Ethyl Acetate (C ₄ H ₈ O ₂)	Ethyl acetate is used as a solvent, including in nail polish remover, and as a flavor and odor agent. It is found in certain fruits including apples and bananas.	Long-term exposure to ethyl acetate can damage the liver and kidneys and decrease male fertility.
Heptane (C ₇ H ₁₆)	Heptane is found in petroleum and gasoline. It is also used as a solvent.	Long-term exposure may damage the nervous system.
Hexane (C ₆ H ₁₄)	Commonly found in gasoline and certain glues. Produced naturally by plants, forest fires, and volcanoes.	Long-term exposure is associated with neurological damage: numbness in the extremities, muscular weakness, blurred vision, headache, and fatigue.
Propylbenzene (C ₉ H ₁₂)	Found in petroleum and vehicle exhaust.	Long-term health effects are not well studied, may be toxic to the liver.
Tetrachloroethene (C ₂ Cl ₄)	Commonly used in dry cleaning. It is also used as a metal degreaser.	Long-term exposure is associated with neurological damage. Tetrachloroethylene is a carcinogen.
Trimethylbenzene (C ₉ H ₁₂)	Commonly found in gasoline and vehicle exhaust.	Long-term exposure can cause changes to blood cells and reduce clotting.
Toluene (C ₇ H ₈)	Commonly found in gasoline and vehicle exhaust.	Long-term exposure damages the nervous system, including hearing and vision.
Xylene (C ₈ H ₁₀)	Commonly found in gasoline, vehicle exhaust, and cigarette smoke.	Long-term exposure causes neurological damage.

2. Materials and Methods

2.1 Sampling Sites

This effort focuses on community locations where air quality problems have been most prevalent, but it also places where people spend extended periods of time. At each site, we collected PM_{2.5} and VOC measurements. Wind speed and wind direction measurements were collected at one site but were considered representative of all sites. The sites are shown in [Figure 2](#) and listed below; we provide a brief description of each site's location and why it was chosen.

- Legacy House (Busy roadway; at the intersection of International Blvd. and 50th Street)
- Church Street (Residential area, at the corner of Church Street and Fresno Street)
- Reems Court (Residential area; adjacent to Castlemont High School where youth spend time)
- East Oakland Boxing Association (EOBA; location where youth spend time)
- Arsola's House (Residential area; adjacent to Madison Park Academy, where youth spend time) – meteorological measurements were located at this site

The primary objective of the sensor and VOC sampler network was to conduct survey-level air measurements, estimate associated health risks, raise awareness amongst residents, establish baseline local pollutant concentrations, and survey the pollutants present. [Figure 3](#) shows the mounting location for equipment at each site.



Figure 2. Locations of sampling sites (yellow markers) within East Oakland (purple shaded area)



Figure 3. Sampling Sites.

2.2 PM_{2.5} and Meteorological Measurements

Five Clarity Node-S Air Sensors were used to measure PM_{2.5} at each location. The Arsola's House site was also equipped with equipment measuring wind speed, wind direction, and ambient temperature. The sensors at EOBA, Arsola's House, and Reems Court began measurements on September 19,

2025, and the sensors at Legacy House and Church Street began measurements on November 13, 2025. Sensor measurements are ongoing. However, for the purposes of analysis, we have included data collected through March 1, 2026. There were no significant downtime periods for any of the instruments during the study.

Clarity sensors collected data at 15-minute intervals; those data were averaged to 1-hour periods. Data underwent automatic quality control (QC) checks in the Clarity data system. Data were downloaded daily using the API, and they were reviewed monthly by an analyst.

Prior to the sampling period, a collocation check was performed on the Clarity sensors by running them side by side from September 12, 2025, to September 17, 2025 ([Figure B-4](#)). The PM_{2.5} sensor to be used at Church Street recorded higher concentrations than the other sensors during the collocation period. To adjust for this issue, the average concentration was calculated across all sensors for the collocation period to yield an “average sensor signal.” Church Street collocation data were then plotted versus the average sensor signal to obtain a linear regression fit (slope = 1.16717, intercept = -0.46154). This equation was applied to Church Street data to correct them to match the group average. This correction was subsequently applied to the sample data.

2.3 VOC Measurements

VOC samples were collected using a Radiello 130 passive sampler. Radiello 130 passive samplers collect gases from ambient air using passive diffusion into a cylindrical housing that contains a charcoal-based sorbent that can be used to detect a variety of VOCs. Since these samplers operate using passive diffusion, they do not require any energy to operate. Moreover, the measurements from these samplers represent time-averaged concentrations over the entire duration that they are deployed.

Passive sampler deployment and data collection occurred roughly every 14 days but sometimes occurred at intervals of 13–20 days. Initial sampling occurred at Arsola’s House, EOBA, and Reems Court on October 2, 2025. For Church Street and Legacy House, initial sampling occurred on November 26, 2025. Ten samples were collected at Arsola’s House, EOBA, and Reems Court, and six samples were collected at Church Street and Legacy House.

Analysis was performed by Eurofins Air Toxics, LLC following EPA Method TO-17. This analysis method uses a solvent to extract compounds that are adsorbed onto the sorbent tube. Analysis was performed using gas chromatogram mass spectrometry (GC/MS). The VOCs measured and the frequency with which they were measured above the minimum detection limit (MDL) are listed in columns 1 and 2 of [Table 4](#). The analyses and data presented in this report reflect VOC data collected from October 2, 2025, to February 18, 2026.

Table 4. VOC species measured, the percentage of time they were detected above MDL, and the mean and median concentrations. Species identified as toxic and/or carcinogenic are bolded.

Species	% Time Above MDL	Mean (ppbv)	Median (ppbv)	SD (ppbv)	IQR (ppbv)
1,1,1-Trichloroethane	0.0%	--	--	--	--
1,1,2,2-Tetrachloroethane	0.0%	--	--	--	--
1,1,2-Trichloroethane	0.0%	--	--	--	--
1,1-Dichloroethane	0.0%	--	--	--	--
1,1-Dichloroethene	0.0%	--	--	--	--
1,2,4-Trimethylbenzene	100.0%	0.071	0.065	0.030	0.044
1,2-Dichlorobenzene	0.0%	--	--	--	--
1,2-Dichloroethane	23.8%	0.009	0.008	0.004	0.002
1,3,5-Trimethylbenzene	66.7%	0.020	0.019	0.010	0.017
1,3-Dichlorobenzene	0.0%	--	--	--	--
1,4-Dichlorobenzene	26.2%	0.020	0.008	0.034	0.002
2-Butanone (MEK)	97.6%	0.082	0.081	0.030	0.043
4-Methyl-2-pentanone	2.4%	0.017	0.018	0.003	0.002
Benzene	100.0%	0.204	0.190	0.063	0.090
Carbon tetrachloride	100.0%	0.038	0.038	0.005	0.007
Chlorobenzene	0.0%	--	--	--	--
Chloroform	71.4%	0.016	0.014	0.009	0.015
Cyclohexane	100.0%	0.096	0.089	0.037	0.053
Ethanol	54.8%	2.221	0.268	4.024	0.835
Ethyl acetate	71.4%	0.117	0.086	0.090	0.117
Ethylbenzene	100.0%	0.065	0.059	0.025	0.037
Heptane	100.0%	0.127	0.106	0.087	0.068
Hexane	100.0%	0.158	0.149	0.053	0.089
Methyl tert-butyl ether	0.0%	--	--	--	--
Naphthalene	0.0%	--	--	--	--
Propylbenzene	35.7%	0.012	0.009	0.005	0.008
Styrene	11.9%	0.009	0.009	0.002	0.002
Tetrachloroethene	11.9%	0.006	0.006	0.001	0.001

Species	% Time Above MDL	Mean (ppbv)	Median (ppbv)	SD (ppbv)	IQR (ppbv)
Toluene	100.0%	0.374	0.345	0.145	0.226
Trichloroethene	0.0%	--	--	--	--
cis-1,2-Dichloroethene	0.0%	--	--	--	--
m,p-Xylene	100.0%	0.197	0.180	0.079	0.120
o-Xylene	100.0%	0.068	0.062	0.027	0.038
trans-1,2-Dichloroethene	0.0%	--	--	--	--

2.4 Meteorological Analysis Methods

The Clarity Wind Module collects wind speed and direction data at 15-minute intervals and averages those intervals to hourly measurements. Only data flagged as “calibrated-ready” by the instrument were used in subsequent analysis. The meteorological measurements collected at Arsola’s House were applied to all sites.

The OpenAir R package (Carslaw, 2015) was used to create wind rose plots. On the wind roses, the barbs show the direction the wind is coming from, and the length of the barbs indicate how often wind blew from that direction. The color of the wind barb represents the wind speed.

2.5 PM_{2.5} Analysis Methods

Clarity data checks were performed in R and Igor Pro. PM_{2.5} data were filtered to include only data flagged as “calibrated-ready.” Due to the July 4 holiday, data collected from 12:00 p.m. on July 4 through 5:00 p.m. on July 5 were removed from the main dataset and analyzed separately to assess the impact of fireworks on community air quality.

To filter for outliers in the data, a median absolute deviation filtering algorithm (Eq. 1) was applied with a factor of 10 and window (j) of 10 points:

$$outlier = |X_i - median(X_{i-j:i+j})| > factor * median(|X_{i-j:i+j} - median(X_{i-j:i+j})|) \text{ (Eq. 1)}$$

Outliers were filtered to isolate points greater than 50 µg/m³. Flagged points were further examined in Igor Pro and the Clarity dashboard to confirm the validity of outliers. Examples of the data filtering results are included in [Appendix B \(Figure B-2\)](#).

Daily and seasonal averages were calculated for all data using the timeAverage function in the OpenAir R package. A 75% completeness threshold was applied to the calculation, which required that at least 75% of the data be present to produce a daily or seasonal average value.

Population differences between each site and season were assessed using the Wilcoxon rank-sum (Mann–Whitney U) test. This non-parametric test compares the distributions of two independent samples by evaluating differences in their rank sums rather than their raw values.

Trends in PM_{2.5} concentrations were analyzed using a variety of methods. The OpenAir R package (Carslaw, 2015) was used to analyze trends in time, season, and diurnal variability (with time-variation plots) and correlations among concentration, wind speed, and wind direction (with pollution rose plots and polar plots) (Grange et al., 2016; Uria-Tellaetxe and Carslaw, 2014; Carslaw and Ropkins, 2012). Pollution rose plots are similar to wind rose plots, except the color of each wind barb represents the concentration of a given species rather than the wind speed. Polar plots combine concentration data with wind data and smooth the average levels across the plot surface to produce “hot spot” maps that can be used to understand direction and concentration of sources. These plots show how concentration varies jointly with wind speed and wind direction in polar coordinates. They represent higher concentrations with warmer colors and lower concentrations with cooler colors. The location on the plot indicates the wind direction and wind speed under which the concentration occurs. The minimum number of points per bin (min.bin) was set to two, so bins with less than two data points are shown in grey. The following months were assigned for seasonal analysis: fall = September, October, November; and winter = December, January, February.

2.5.1 Local versus Regional Analysis

Time-series data were analyzed to estimate the local and regional/background contributions to PM_{2.5} concentrations using the methodology and code developed by Wang et al. (2018). This method separates the “background” of a time series from the hourly fluctuations to yield an hourly estimate of “local” and “background” contributions. This step is achieved by separating the slower-varying, lower-frequency signal of regional-scale pollution from local sources, which vary over shorter timescales and at higher frequencies. See [Appendix B](#) for additional details about this method.

2.6 VOC Analysis Methods

VOC concentration data from Eurofins were analyzed in R. In total, 21 different VOCs were detected. Our analysis focused on VOCs that were detected in more than 50% of samples at at least one site and VOCs that are carcinogenic, even if they were detected in fewer than 50% of samples. A total of 18 VOCs were included in the analysis, 13 of which were toxic (see bolded species in [Table 4](#)). Toxic VOCs were identified using the list from the California OEHHA (OEHHA, 2023). Some toxic VOCs are carcinogenic; in this study carcinogenic VOCs were identified based on the compounds listed under California’s *Air Toxic’s “Hot Spots” Information and Assessment Act (AB 2588)* (OEHHA, 2025). AB 2588 also served as the source of the dose-response values used to estimate excess cancer risk based on the mean measured VOC concentrations.

Summary statistics were calculated for each VOC, including mean, minimum, and maximum concentrations, along with frequency of detection. Time-series plots of measured concentration were developed for each pollutant. Timeseries depicting multiple VOCs were developed using normalized concentration, rather than measured concentration, to standardize and scale VOCs with different concentration magnitudes to facilitate comparisons on the same plot. Normalization was performed using a z-score approach, where the mean concentration of each VOC was subtracted from each observation and divided by the standard deviation.

A high-level source assessment was used to evaluate whether detected VOCs were likely from mobile sources (fully or partially) or not. This assessment was based on a combination of information from government reports and scientific literature describing the chemical composition of motor vehicle exhaust and sources of these pollutants (Marques et al., 2022).

Site-level statistical analysis was performed for the VOC data to assess variation throughout East Oakland. To align the samples temporally so that some sites did not have more samples than the others, samples collected prior to November 26, 2025, were excluded. All sites had data from November 26, 2025, through February 18, 2026. The statistical site-level difference in mean concentration was evaluated using one-way analysis of variance (ANOVA), followed by Tukey's Honestly Significant Difference (HSD) test for pairwise comparisons between seasons. Preliminary modeling revealed that VOC concentration data were right-skewed and exhibited increased variance at higher concentrations. To better meet the assumptions of these statistical tests, concentrations were log-transformed prior to conducting the statistical analysis.

An East Oakland average comparison with regional measurements was performed to compare average VOC concentrations from this study with regional concentrations from EPA's Air Quality System (AQS) data. Annual average concentration data were obtained from EPA's AQS to estimate regional average VOC concentrations for the San Francisco Bay Area. AQS data from 2025 were not available at the time of analysis, so annual average concentrations from 2022–2024 were used. Data were retrieved via the AQS API for all monitors located within the San Francisco Bay Area across the counties of Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco (i.e., a total of 18 monitoring locations). The API was queried for all key VOCs from this study; however, data were only available for the VOCs listed in [Table 13](#). Regional averages were calculated by averaging all available data from the 18 monitoring locations. In addition, site-specific averages for 2022–2024 were reported for selected monitors at Laney College (AQS ID 060010012) and Oakland East (AQS ID) 060010009). The Laney College site is adjacent to I-880 and is expected to measure higher concentrations

2.7 Health Benchmark Comparison

OEHHA establishes regulatory benchmarks for toxic chemicals to protect the health of Californians. OEHHA reports chronic inhalation thresholds for toxic metals, designed to address effects due to

continuous exposure for up to a 70-year lifetime (OEHHA, 2019, 2020). The RELs for non-carcinogenic effects are the concentrations above which people may start experiencing adverse health problems other than cancer, such as breathing difficulties. Cancer data are reported as URE values in units of $1/(\mu\text{g}/\text{m}^3)$. URE values can be used to calculate the Cancer 1-in-a-million benchmark, and the excess cancer risk for a population of one million people using the equations below:

$$\text{Cancer 1-in-a-million benchmark} = (\text{URE})_x^{-1} \times 10^{-6}$$

$$\text{Excess cancer risk} = \frac{[x]_{\text{study average}}}{(\text{URE})_x^{-1} \times 10^{-6}}$$

In the above equations, URE_x is the URE value for species x , and $[x]_{\text{study average}}$ is the mean concentration of species x . Excess cancer risk is reported as "N"-in-1 million (where "N" is a number). The U.S. EPA explains that, "this means that for every 1 million people who are continuously exposed to a certain level of a pollutant over 70 years, "N" people may develop cancer. For example, a 1-in-1 million risk means that one person may develop cancer for every 1 million people exposed. A 10-in-1 million risk means 10 people may develop cancer per 1 million exposed, etc. These risks are on top of any other cancer risks from other sources." (U.S. Environmental Protection Agency, 2025)

3. Results and Discussion

3.1 Meteorological Data

Wind speed and direction measurements were obtained at Arsola's House between September 9, 2025, and March 1, 2026. [Figure 4](#) shows the wind rose plot. Winds were well distributed from all directions except for the southwest (180–270°). Wind speeds were on average 1.2 mph.

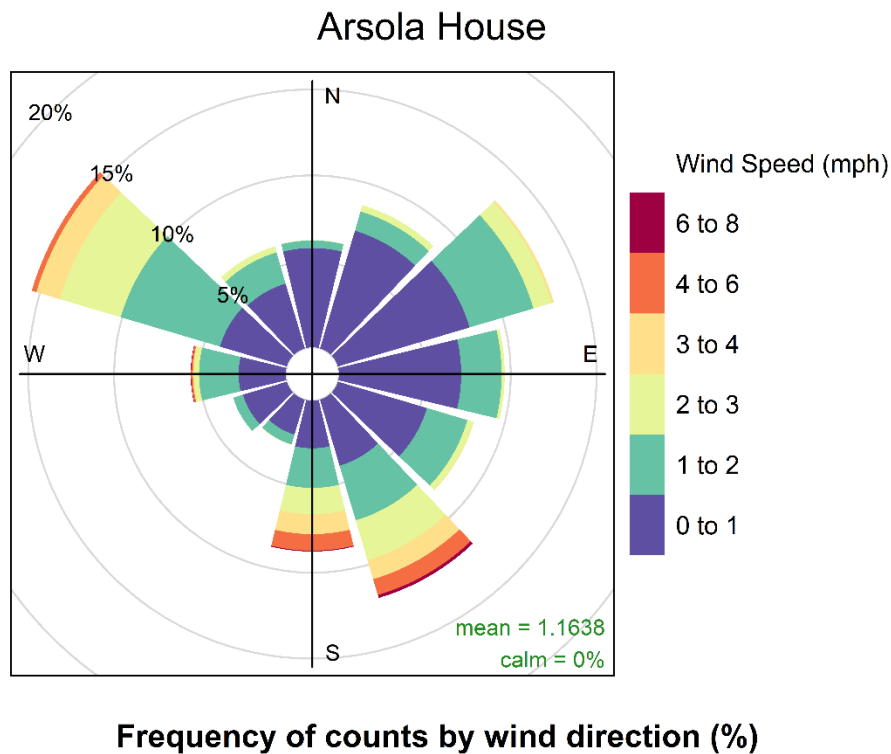


Figure 4. Wind roses for Arsola's House during the sampling period showing wind speed and wind direction trends. The concentric circles indicate the percent of time winds came from a given direction.

3.2 PM_{2.5} Results

3.2.1 Summary Overview

Overview of PM_{2.5} Results

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PM_{2.5} was collected from five locations in East Oakland between September 2025 and February 2026. Average PM_{2.5} levels at each site fell into either the **“Good”** or **“Moderate”** AQI categories. PM_{2.5} levels at Church Street reached levels in the **“Unhealthy for Sensitive Groups”** AQI category once, meaning people with asthma, heart or lung disease, older adults, and children may have experienced effects on that day.

The data showed that:

- **Daily PM_{2.5} levels were similar across all five monitoring sites**, averaging between 9.0 and 14.0 micrograms per cubic meter. **Pollution peaked in the morning (7:00–9:00 a.m.)** and again in the **evening (around 8:00 p.m.)**. The **lowest levels appeared in late afternoon (around 4:00 p.m.) and the early morning (around 4:00 a.m.)**. These patterns are consistent with **rush-hour traffic**, suggesting that cars and trucks on nearby major roads are the primary source of PM_{2.5}.
- Seasonally, PM_{2.5} levels **increased from fall to winter**. Winter exhibited the highest levels of PM_{2.5} levels at residential sites, likely because:
 - More people use **wood-burning stoves or fireplaces**, which release fine particles.
 - **Vehicles undergo cold starts**, which produce higher emissions.
 - **Meteorological conditions (inversion layers) trap pollution close to the ground**, preventing it from dispersing.
- Local emissions, such as traffic and residential wood burning, made up **about 24–27%** of the PM_{2.5} measured at each site. These local sources **contributed more in winter**, when both wood burning and weather conditions together result in pollution buildup.

3.2.2 PM_{2.5} Data Statistics

The PM_{2.5} statistical results for all five sites are listed in [Table 5](#). The mean daily concentration at the sites ranged from 9.0–14.0 µg/m³, which falls into the “Moderate” AQI category.⁴ Statistical analysis revealed that each site was statistically significantly different from the others.

A list of the specific days that resulted in poorer air quality for each site is provided in [Appendix B](#). Table 5 also lists the percentage of days that each site’s average PM_{2.5} concentration fell into the “Good,” “Moderate,” and “Unhealthy for Sensitive Groups” AQI categories. Overall, each site experienced approximately 50% of the days falling in the “Good” category and approximately 50% falling in the “Moderate” category. The exception was Reems Court, which experienced a larger number of “Good” days. Church Street also experienced 1% of days falling in the “Unhealthy for Sensitive Groups” category, which was driven by a local event causing concentrations to reach 67.5 µg/m³. The exact nature of this local event is unclear, however; conversations with community members indicate that cooking occurs frequently at this location, so the possibility that this event was a cooking- (i.e., grilling) related event cannot be ruled out.

Table 5. PM_{2.5} statistics for each sampling site. The last three columns indicate the number of days each site’s average PM_{2.5} concentration fell into various AQI categories.

Site	Daily Mean ± Standard Deviation), µg/m ³	Daily Maximum, µg/m ³	% of days in AQI categories		
			“Good” (0–9 µg/m ³)	“Moderate” (9–35.4 µg/m ³)	“Unhealthy for Sensitive Groups” (35.4–55.4 µg/m ³)
Arsola’s House	10.2±6.3	29.9	56%	44%	0%
Church St.	14.0±9.5	67.5	43%	56%	1%
EOBA	10.9±6.4	31.5	50%	50%	0%
Legacy House	13.4±5.4	31.5	43%	57%	0%
Reems Ct.	9.0±5.5	23.0	61%	39%	0%

⁴ For more information about the AQI categories, see: <https://www.airnow.gov/aqi/aqi-basics/>

3.2.3 Spatial PM_{2.5} Trends

Figure 5 **Error! Reference source not found.** (left panel) shows a map of the average PM_{2.5} concentration to highlight how sites vary in space. The right panel of **Figure 5** shows polar plots, which pair PM_{2.5} data with wind data to reveal the wind speed and direction most likely to be associated with the highest concentrations of PM_{2.5}. At all sites, the highest concentrations occurred under low wind speeds (red close to the center of each plot), indicating that the sources are very local. These sources are likely nearby roads but could also be industry or other point sources, such as wood burning.

EOBA has dominant sources in the northeast and slightly lesser sources from the west. To the northeast of EOBA is auto shops, a pallet-producing company, a Bay Area Rapid Transit (BART) station, railway tracks, and San Leandro St. To the west is 98th Avenue, railway tracks, and a portion of an industrial park with a trucking school. This section of 98th Avenue is heavily trafficked as a designated truck-through route (City of Oakland) and has street food vendors, all of which can contribute PM_{2.5}.

Legacy House has dominant sources in the northeast and northwest, which is the direction of International Blvd. This section of International Blvd. has high levels of traffic, a bus stop, and street vendors, all of which could contribute PM_{2.5}.

Reems Ct. has a dominant source in the northeast and a lesser source to the west. Reems Ct. is in a residential area with local roads. However, beyond King Estate Open Space Park, 0.6 miles to the east, is Highway 580, which is likely contributing to the levels in the east. To the west is MacArthur Blvd. and a high school. As such, it is possible that school traffic vehicle idling may contribute to the smaller source in the west.

Church St. has dominant sources ubiquitously in the north. Church St. is in the middle of a residential neighborhood with no obvious major sources or major roadways. Since this site frequently experienced aberrant elevated PM_{2.5} events, cooking events at the residence may have contributed to the observed levels.

Arsola's House shows main sources to the northwest and a lesser source to the west and northwest. There are residences and San Leandro St. 0.2 miles to the west; I-880 is to the northwest. Just past the freeway to the west is an industrial park with truck rental facilities and truck yards. The primary source to the east is not immediately apparent since Arsola's House is in a residential community.

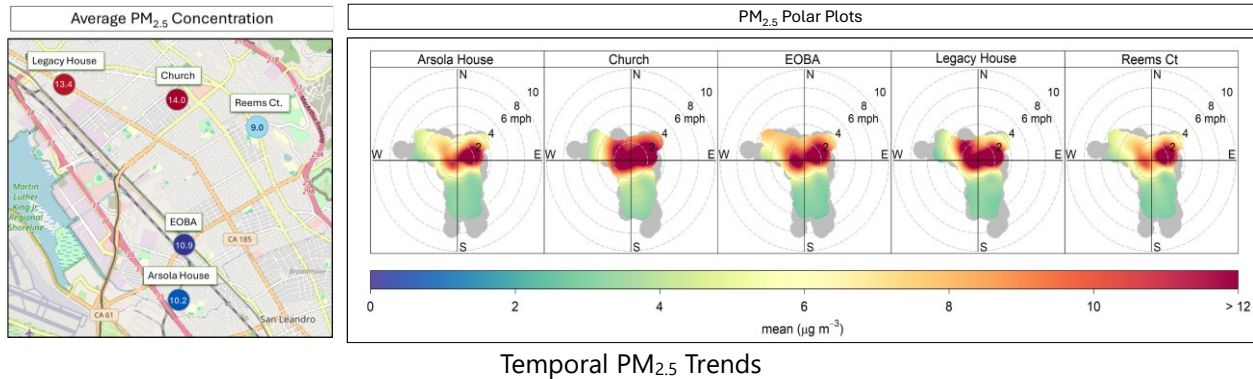


Figure 5. (Left) Map of East Oakland with mean PM_{2.5} concentrations (µg/m³). Each circle is color coded blue (lowest concentration) to red (highest concentration). (Right) Polar plots for each measurement site, which can be interpreted as hot-spot maps.

Diurnal trends can be useful for exploring emissions and the atmospheric processes that influence pollutant concentrations. Daily concentrations are driven by dispersion (e.g., mixing height), sources (e.g., traffic patterns), and transport.

All five sites had similar diurnal trends (**Figure 6**); concentrations typically peaked between 7:00 and 9:00 a.m. and reached a minimum in the late afternoon around 4:00 p.m. and overnight around 4:00 a.m. A secondary peak was present in the evening around 8:00 p.m. for all sites except for EOBA. These patterns are consistent with local traffic patterns combined with changes in the boundary layer height in the evening, indicating that vehicular emissions are the key driver of PM_{2.5} at all sites. The reason for the lack of an evening peak at EOBA is not immediately clear. The evening peaks at Legacy House and Church Street are equally as high as the morning concentrations. At Arsola's House and Reems Court, the afternoon peaks are slightly lower than the morning peaks.

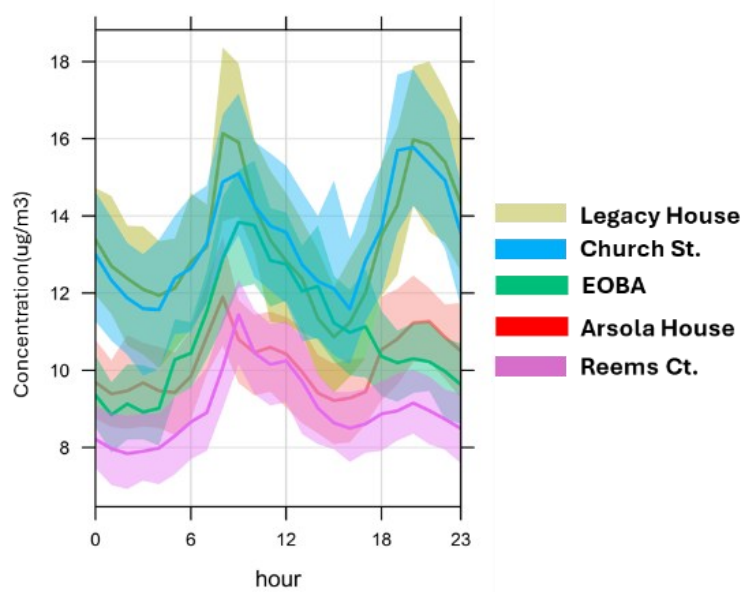


Figure 6. Diurnal profile for all sites during the sampling period. Each line is the mean concentration during the respective hour of the day. The shaded area corresponds to the confidence interval. The day of high concentration at Church Street was removed from the diurnal plotting to better represent a typical day.

At each site, $PM_{2.5}$ concentrations varied by day of the week. Unexpectedly, many of the sites reported higher weekend concentrations (**Figure 7**). This trend is the opposite to what is typically observed in urban locations where $PM_{2.5}$ concentration levels are driven by traffic—weekdays are typically higher in $PM_{2.5}$ due to work and school commutes. Saturdays were highest at all sites, while Sunday was slightly lower. The sites with the largest increase on Saturdays compared with weekdays concentrations were EOBA, Legacy House, and Church Street; these locations reported 13.2%, 10.6%, and 8.6% higher concentrations, respectively. As previously described, EOBA is adjacent to a section of 98th Avenue where street food vendors often set up. It is possible that weekend levels of $PM_{2.5}$ might be driven by food cooking near EOBA. Church Street was also reported to have cooking-related emissions, and therefore weekend cooking events might influence the Saturday levels at this site as well. A closer look at the daily trends at EOBA on the weekends versus weekdays reveals that the morning peak shifts to later in the day on the weekend, from approximately 8:00 a.m. to 10:00 a.m.

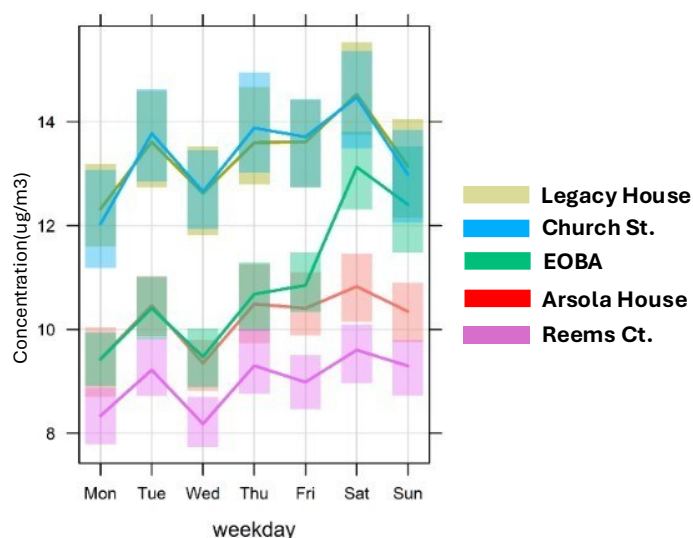


Figure 7. Average PM_{2.5} concentrations by day of week for each site.

At three of the five sites (i.e., Arsola’s House, EOBA, and Reems Court), enough data were collected to perform a comparison between fall and winter. At each of these three sites, PM_{2.5} concentrations increased between fall and winter. The average seasonal concentration results are listed in [Table 6](#). Levels are highest in winter due to a combination of inversion layer effects, vehicle cold starts, and the possible use of woodburning to heat homes. This situation is visible in the wintertime diurnal profile for this study ([Error! Reference source not found.Figure B-12Error! Reference source not found.Error! Reference source not found.](#)), which shows a higher evening peak, likely associated with residential woodburning when temperatures drop after sunset. Wintertime concentrations were also higher due to an elevated baseline throughout December ([Figure B-13](#)).

Table 6. Mean PM_{2.5} concentration by site and season.

Site	Seasonal Mean (Standard Deviation), µg/m ³	
	Fall	Winter
Arsola’s House	8.5 (4.7)	11.5 (7.2)
Church St.	NA ^a	13.8 (9.8)
EOBA	9.4 (4.6)	12.1 (7.4)
Legacy House	NA*	13.3 (7.9)
Reems Ct.	8.0 (4.6)	9.8 (6.1)

^aSite did not meet seasonal completeness criteria of >75%.

3.2.4 Local Versus Regional Contributions

Time-series data were analyzed to estimate the hourly regional (background) and local contributions to PM_{2.5}. At each site, local sources contribute 24–27% of the total PM_{2.5} (Table 7). Therefore, regional sources were responsible for the majority of PM_{2.5} measured at each site.

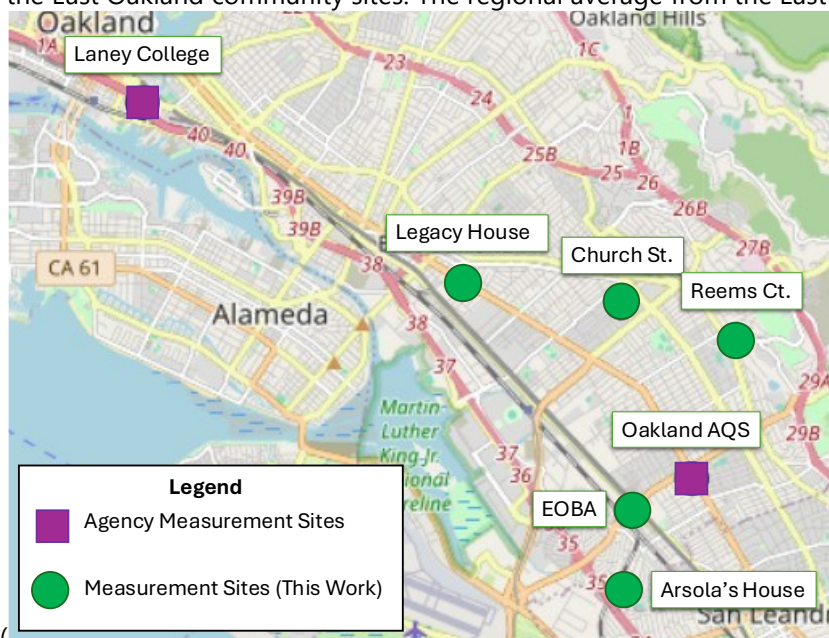
Table 7. Estimated local and regional PM_{2.5} concentrations (µg/m³) and percent local and regional contribution by site.

Site	Average Source Contribution	
	Local Sources	Regional Sources
Arsola's House	24%	76 %
Church St.	27%	73 %
EOBA	27%	73 %
Legacy House	27%	73 %
Reems Ct.	24%	76 %

3.2.5 East Oakland Levels Versus Regional Nearby Measurements

Data from all sites were combined to yield an “East Oakland average” level (i.e., 10.6 µg/m³). This value falls into the “Moderate” AQI category. Agencies such as the Bay Area Air District (BAAD) and EPA set up monitoring sites around the country to measure either regional concentrations or concentrations near a specific source. The regulatory monitors closest to East Oakland are located at Laney College (a near road site) and in East Oakland (Figure 8). The Laney College site is adjacent to I-880 and is expected to measure higher concentrations. We compared the average concentration from the agency sites with the East Oakland average to determine whether the regional monitors accurately reflect

the concentrations measured at the East Oakland community sites. The regional average from the East



Oakland AQS site was $7.9 \mu\text{g}/\text{m}^3$ (

Figure 8. Map of East Oakland sampling sites (green circles) and agency measurement sites (purple squares).

Table 8), which falls into the “Good” AQI category; the corresponding value at the Laney College site was $9.9 \mu\text{g}/\text{m}^3$, which falls into the “Moderate” AQI category. The East Oakland average concentration was approximately 34.2% higher than that of the East Oakland AQS site and 7.1% higher than that of the Laney College site. The smaller difference between the East Oakland average and Laney College values is expected since the Laney College site is situated by the freeway, a key source of vehicle-related emissions. Comparing the average concentration with the nearby regulatory measurements further illustrates the importance of understanding local sources of $\text{PM}_{2.5}$ on community air quality.

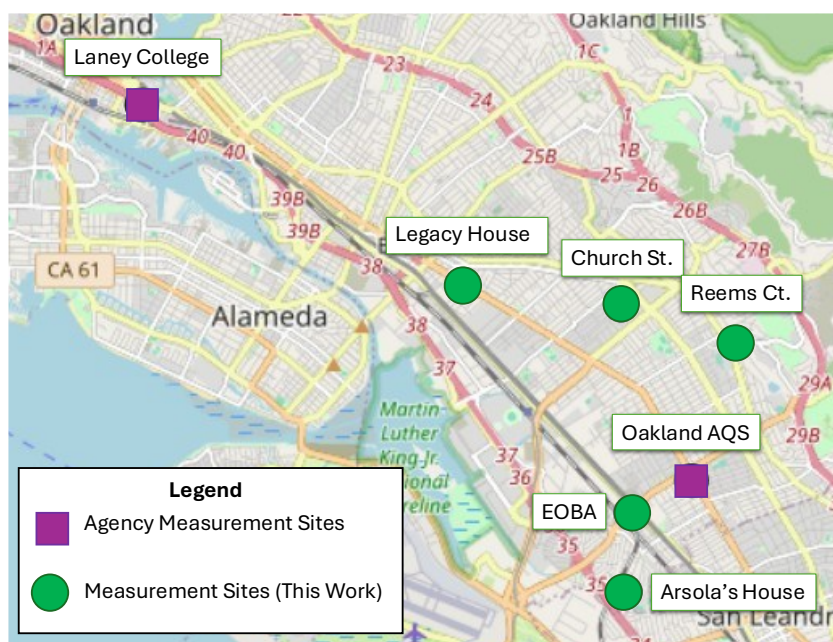


Figure 8. Map of East Oakland sampling sites (green circles) and agency measurement sites (purple squares).

Table 8. Comparison of the East Oakland average with nearby regulatory measurements. A sampling site average was calculated by averaging the daily values of all sites.

Site	Daily Mean (Standard deviation), $\mu\text{g}/\text{m}^3$	Daily Maximum , $\mu\text{g}/\text{m}^3$	Percent of Days in AQI Categories		
			"Good" (0 – 9 $\mu\text{g}/\text{m}^3$)	"Moderate" (9 – 35.4 $\mu\text{g}/\text{m}^3$)	"Unhealthy for Sensitive Groups" (35.4 – 55.4 $\mu\text{g}/\text{m}^3$)
East Oakland Community Average (this work)	10.6±6.4	29.2	53%	47%	0%
Oakland AQS	7.9±4.1	19.5	65%	35%	0%
Laney College	9.9±5.4	25.2	53%	47%	0%

3.3 VOC Results

3.3.1 Summary Overview

Overview of VOC Results

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VOC samples were collected at Reems Ct., Arsola's House, EOBA, Church Street, and Legacy House and analyzed by Eurofins Air Toxics, LLC. Here, we present an analysis and interpretation of the commonly detected VOCs. **Detailed VOC samples were collected every 13–20 days.**

The results revealed:

- 18 VOCs were detected at least 50% of the time at one or more sites, or were carcinogenic.
- 13 VOCs were toxic and/or carcinogenic.

Where did the VOCs come from?

- About **38% of the measured VOCs**, including compounds like **toluene, xylene, and benzene, came from vehicles.**
- The remaining VOCs came from **non-traffic sources**. One compound, **ethanol**, made up most of this group.
- Traffic-related VOCs tended to rise and fall together, reinforcing that they share common sources.

Site-level patterns:

- **Reems Ct.** typically had **lower concentrations** than the other sites. This site is **located farther away from major traffic corridors and industrial areas than other sites.**
- **1,4-Dichlorobenzene** concentrations were **significantly higher at Legacy House** than other sites.
- VOCs from vehicles were most different site to site.

East Oakland average versus regional values:

- The concentration of **traffic-related VOCs** measured in this study **was higher than** multiyear **average concentrations in the Bay Area** collected by EPA.

Health context:

- All measured levels of toxic VOCs were **below non-cancer state health guidelines** for long-term exposure.
- Cancer risk was estimated for six VOCs.
 - **Four VOCs** had concentrations above long-term (70-year) cancer risk levels.
 - **Benzene** (from vehicle exhaust) and **carbon tetrachloride** (a long-lasting global pollutant) and had the **highest estimated risks** of around **19 and 10 in-a-million**, respectively. Reducing vehicle-related pollutants further would protect long-term health.

3.3.2 Data Statistics and Health Risk Assessment

Of the 21 VOCs detected, 18 are used in the analysis below. Of these VOCs, 16 were detected greater than 50% of the time at at least one site, and 2 were detected less than 50% of the time; the latter were included in this analysis because they are carcinogenic. Overall, 12 of the VOCs were toxic, and 6 are also carcinogenic. The remaining six VOCs were not associated with any OEHHA health risk thresholds. [Table 9](#) lists the mean, standard deviation, minimum, and maximum concentration (ppbv) for all sites combined; the OEHHA chronic reference exposure limit (ppbv); whether each VOC is carcinogenic; and the percentage of time the species was detected in the samples. OEHHA provides chronic RELs, which assume a 70-year exposure. The time series of each of the VOCs are shown in [Figure C-3](#) through [Figure C-20](#).

Table 9. Summary of toxic and carcinogenic speciated VOCs. All measurements of the toxic compounds listed are below OEHHA exposure limits.

Compound Name	Mean and Std Dev (ppbv)	Min (ppbv)	Max (ppbv)	Exposure Limit (ppb)	OEHHA Exposure Limit Type	Carcinogenic	% Time Above Detect
1,2,4-Trimethylbenzene	0.071 (0.03)	0.031	0.140	0.81	OEHHA Chronic REL		100.0%
Benzene	0.204 (0.063)	0.110	0.344	0.94	OEHHA Chronic REL	Yes	100.0%
Carbon tetrachloride	0.038 (0.005)	0.027	0.046	6.36	OEHHA Chronic REL	Yes	100.0%
Cyclohexane	0.096 (0.037)	0.041	0.200				100.0%
Ethylbenzene	0.065 (0.025)	0.025	0.120	460.63	OEHHA Chronic REL	Yes	100.0%
Heptane	0.127 (0.087)	0.046	0.415				100.0%
Hexane	0.158 (0.053)	0.068	0.255	1986.19	OEHHA Chronic REL		100.0%
Toluene	0.374 (0.145)	0.149	0.690	111.46	OEHHA Chronic REL		100.0%
m,p-Xylene	0.197 (0.079)	0.076	0.360	161.20	OEHHA Chronic REL		100.0%
o-Xylene	0.068 (0.027)	0.028	0.130	161.20	OEHHA Chronic REL		100.0%
2-Butanone (MEK)	0.082 (0.03)	0.022	0.160				97.6%
Chloroform	0.016 (0.009)	0.005	0.037	61.44	OEHHA Chronic REL	Yes	71.4%
Ethyl acetate	0.117 (0.09)	0.025	0.370				71.4%
1,3,5-Trimethylbenzene	0.02 (0.01)	0.007	0.042	0.81	OEHHA Chronic REL		66.7%
Ethanol	2.221 (4.024)	0.096	14.329				54.8%
Propylbenzene	0.012 (0.005)	0.006	0.023				35.7%
1,4-Dichlorobenzene	0.02 (0.034)	0.006	0.166	0.83	OEHHA Chronic REL	Yes	26.2%
Tetrachloroethene	0.006 (0.001)	0.004	0.011	5.16	OEHHA Chronic REL	Yes	11.9%

Across all sites combined, the average concentration of each toxic species was below the respective non-cancer REL, meaning that at the concentrations measured, there is no anticipated non-cancer long-term health impacts. Six carcinogenic VOCs were detected: benzene, carbon tetrachloride, 1,4-dichlorobenzene, ethylbenzene, chloroform, and tetrachloroethene. **Table 10** lists the carcinogenic VOCs, their mean concentration, Cancer 1-in-a-million benchmark, and calculated excess cancer risk. Chloroform and tetrachloroethene each result in excess lifetime cancer risk below 1-in-a-million. Benzene yielded the highest estimated excess cancer risk, approximately 19-in-a-million.

Excess cancer risk is reported as "N"-in-1 million (where "N" is a number). The U.S. EPA explains that "this means that for every 1 million people who are continuously exposed to a certain level of a pollutant over 70 years, "N" people may develop cancer. For example, a 1-in-1 million risk means that one person may develop cancer for every 1 million people exposed. A 10-in-1 million risk means 10 people may develop cancer per 1 million exposed, etc."

Table 11 lists the excess cancer risk of each carcinogenic VOC based on the mean concentration measured at each individual site. Benzene has the largest range in cancer risk across all sites; Church Street levels are associated with the highest risk: 25-in-a-million. Reems Court has the lowest risk at 14-in-a-million. The mean cancer risk of 1,4-dichlorobenzene is much higher at Legacy House (i.e., 6-in-a-million) compared with the other sites.

Table 10. Summary of carcinogenic VOCs measured in VOC analysis, based on the average concentration cross all sites. Excess cancer risk is calculated per million people based on mean concentration. The Cancer 1-in-a-million benchmark is the concentration of each VOC that would result in one additional case per million people. 1,4-dichlorobenzene is presented all sites excluding Legacy House, due to the high concentrations associated with this site.

Compound Name	Mean (ppbv)	Mean (ug/m ³)	Cancer 1-in-a-million Benchmark (ug/m ³)	Excess Cancer Risk
Benzene	0.204	0.652	0.034	19 in-a-million
Carbon tetrachloride	0.038	0.237	0.024	10 in-a-million
1,4-Dichlorobenzene	0.020	0.122	0.091	1 in-a-million
Ethylbenzene	0.065	0.283	0.400	1 in-a-million
Chloroform	0.016	0.080	0.189	< 1 in-a-million
Tetrachloroethene	0.006	0.040	0.164	< 1 in-a-million

Table 11. Summary of the excess cancer risk of carcinogenic VOCs measured at each site. Excess cancer risk is calculated per million people based on mean concentration.

Excess Cancer Risk (N in-1-million)					
Species	Arsola's House	Church St	EOBA	Legacy House	Reems Ct
Benzene	17	25	19	24	14
Carbon tetrachloride	10	10	10	9	10
Ethylbenzene	1	1	1	1	< 1
1,4-Dichlorobenzene	1	1	< 1	6	< 1
Chloroform	< 1	1	< 1	1	< 1
Tetrachloroethene	< 1	< 1	< 1	< 1	< 1

3.3.3 VOC Sources

As described in [Section 2](#), a high-level review of government reports and scientific literature was performed to categorize which VOCs likely originated from mobile versus non-mobile sources. Of the 18 VOCs identified, 12 were identified as likely originating from mobile sources; 6 likely originated from non-mobile sources ([Figure 9](#)). Based on the data from all sites averaged together, 38% of the total concentration was attributable to mobile-source VOCs. The top three mobile-source VOCs with the highest concentrations were all BTEX (benzene, toluene, ethylbenzene, xylenes) compounds: toluene (0.37 ppbv), benzene (0.20 ppbv), and m,p-xylene (0.20 ppbv). Excluding ethanol (described below), 88% of the total measured concentration was attributed to mobile-source VOCs ([Figure 10](#)).

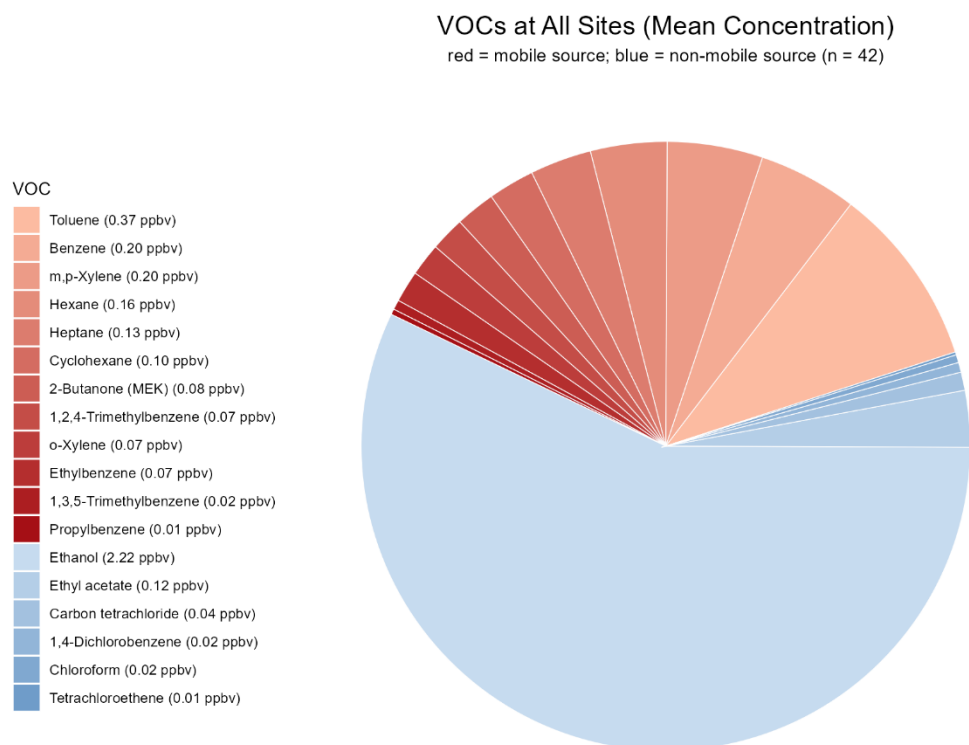


Figure 9. Pie chart of VOCs measured in this study. Shades of red indicate VOCs that likely originate from mobile sources. Shades of blue represent VOCs that do not likely originate from mobile sources.

Among the non-mobile source VOCs, ethanol was the dominant compound with a concentration of 2.22 ppbv, accounting for approximately 92% of the concentration within this category. The mean ethanol concentration was influenced by a spike that occurred at all sites, which is discussed further below. Although vehicle exhaust is a source of ethanol, the time series is decoupled from other mobile-source VOCs, indicating that mobile sources are unlikely the primary source in this study (described further below). The second most prevalent non-mobile source VOC was ethyl acetate (0.12 ppbv), followed by carbon tetrachloride (0.076 ppbv).

A time series of each VOC is presented in [Appendix D](#). For ease of comparison, in the next sections we present VOCs grouped together based on their possible sources.

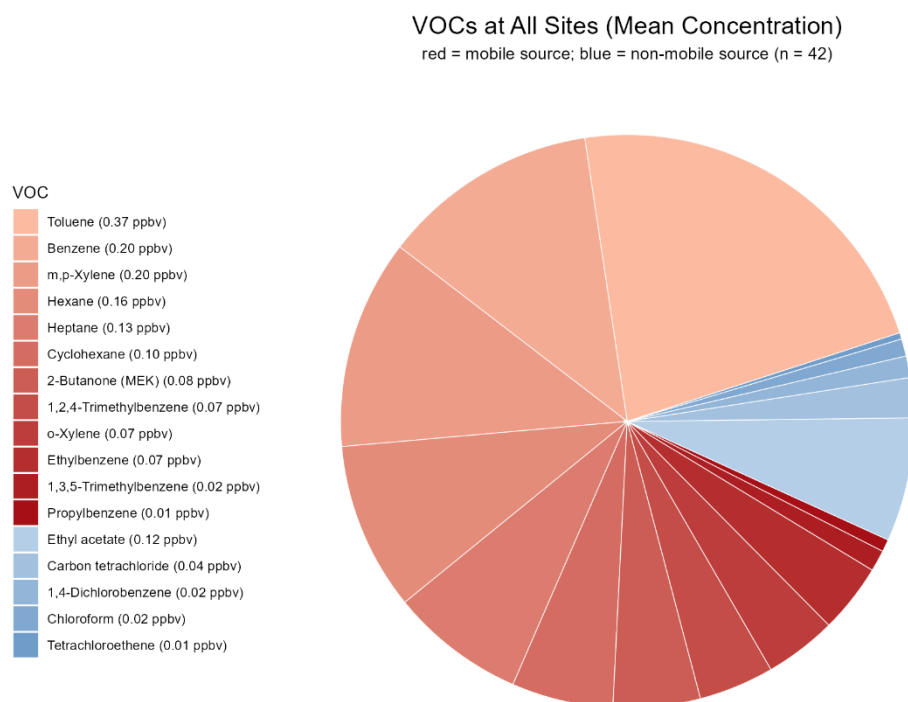


Figure 10. Pie chart of VOCs measured in this study, excluding ethanol. Shades of red indicate VOCs that likely originate from mobile sources. Shades of blue represent VOCs that do not originate from mobile sources.

3.3.4 Mobile-Source VOCs

Categorizing VOCs as coming from mobile sources (e.g., vehicles) versus non-mobile sources is useful for high-level interpretation and analysis of trends of mobile-source VOCs. **Figure 11** (top panel) shows a time series of mobile-source VOCs. Mobile-source VOCs followed a similar trend and generally increased between October and February. BTEX compounds, which represent a subset of the mobile-source VOC group, follow an even tighter trend than the mobile-source VOCs overall (middle panel). In contrast to the strong correlation in mobile-source VOCs, **Figure 11** (bottom panel) shows the time series of VOCs unassociated with mobile sources. In this plot, species exhibit differing behavior, indicating that they are likely to be emitted by different sources.

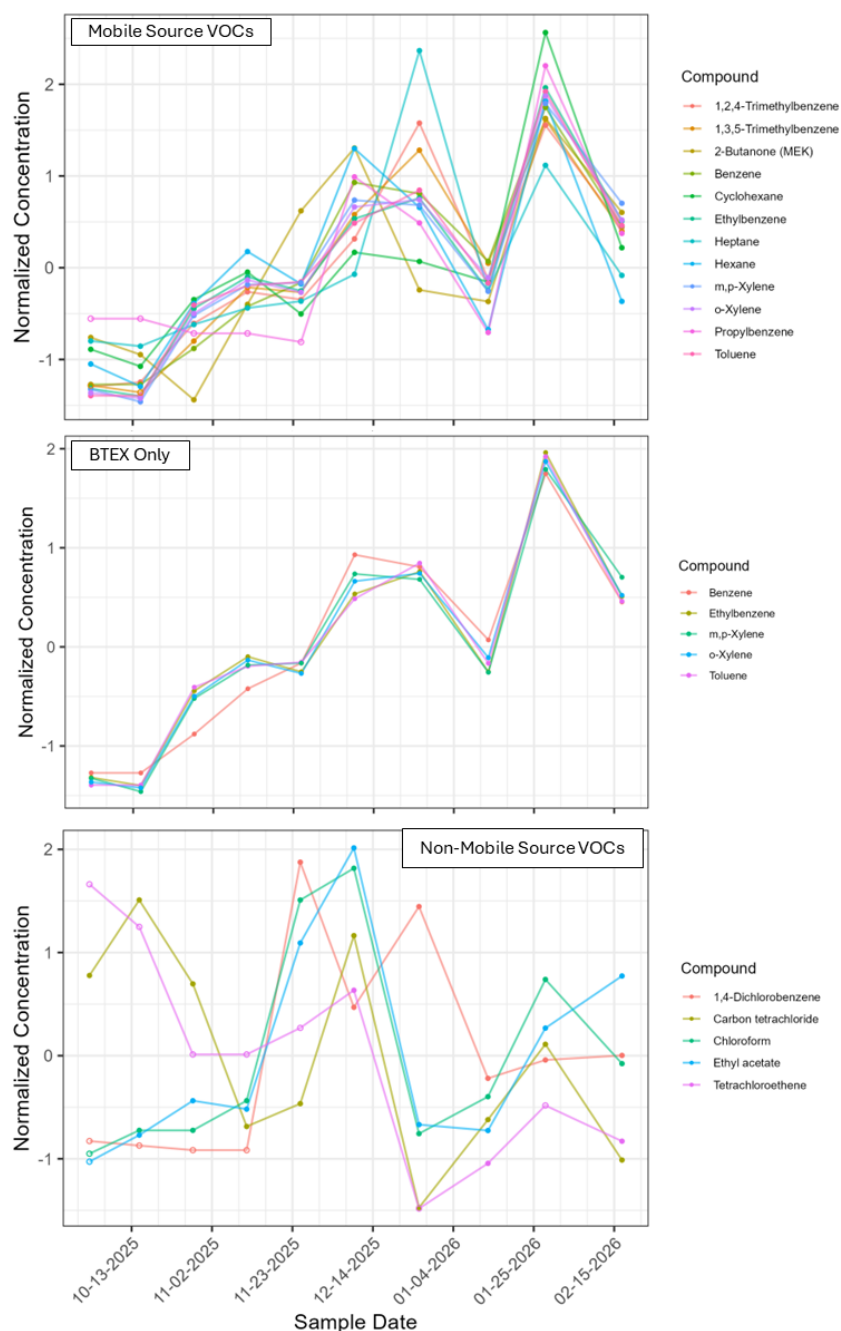


Figure 11. Timeseries of normalized mobile-source VOC concentrations to show trends in mobile source species (top panel). Timeseries of normalized BTEX VOC concentrations (middle panel). Timeseries of normalized non-mobile source VOC concentrations (bottom panel). For each species, each data point is normalized by subtracting the mean value and dividing by the standard deviation. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

3.3.5 Non-Mobile Source VOCs

To help with source identification, we calculated correlations between each of the 17 VOCs; the full set of results is shown in [Figure C-2](#). Mobile-source VOCs exhibit strong correlations with one another, indicating a shared source or sources. Two non-mobile species also correlate well with mobile sources: chloroform and ethyl acetate. These VOCs are associated with solvent use and industrial activities (Han et al., 2019; Yu et al., 2021; U.S. Department of Health and Human Services, 2024) and may be brought to the site from nearby industrial areas by the same wind gusts bringing vehicle emissions. On the other hand, carbon tetrachloride, 1,4-dichlorobenzene, and ethanol appeared relatively decoupled and exhibited fewer significant correlations overall. Ethanol had strong correlations with ethyl acetate, chloroform, and 2-butanone. It should be noted that 1,4-dichlorobenzene was only detected in 26% of samples. These compounds are described in more detail below.

Ethyl Acetate

Ethyl acetate is both a naturally occurring and anthropogenic gas. It is primarily used as a solvent (including in consumer products such as nail polish remover), but it is also used in or released during various manufacturing processes (Australia Department of Climate Change, Energy, the Environment and Water, 2022). In source apportionment studies, ethyl acetate is commonly associated with solvent use and secondary pollutant formation due to photochemical reactions in the atmosphere (Han et al., 2019; Yu et al., 2021). One source apportionment study found that ethyl acetate cooccurred with the solvent VOCs heptane, hexane, and BTEX, as well as the secondary photochemical VOCs 2-butanone (Han et al., 2019). This finding is consistent with the data collected in this East Oakland study where ethyl acetate exhibited strong significant positive relationship with BTEX, hexane, heptane, and 2-butanone ([Figure C-2](#)). The time series of ethyl acetate and the cooccurring VOCs shows that ethyl acetate is relatively well coupled with mobile emissions ([Figure 12](#)).

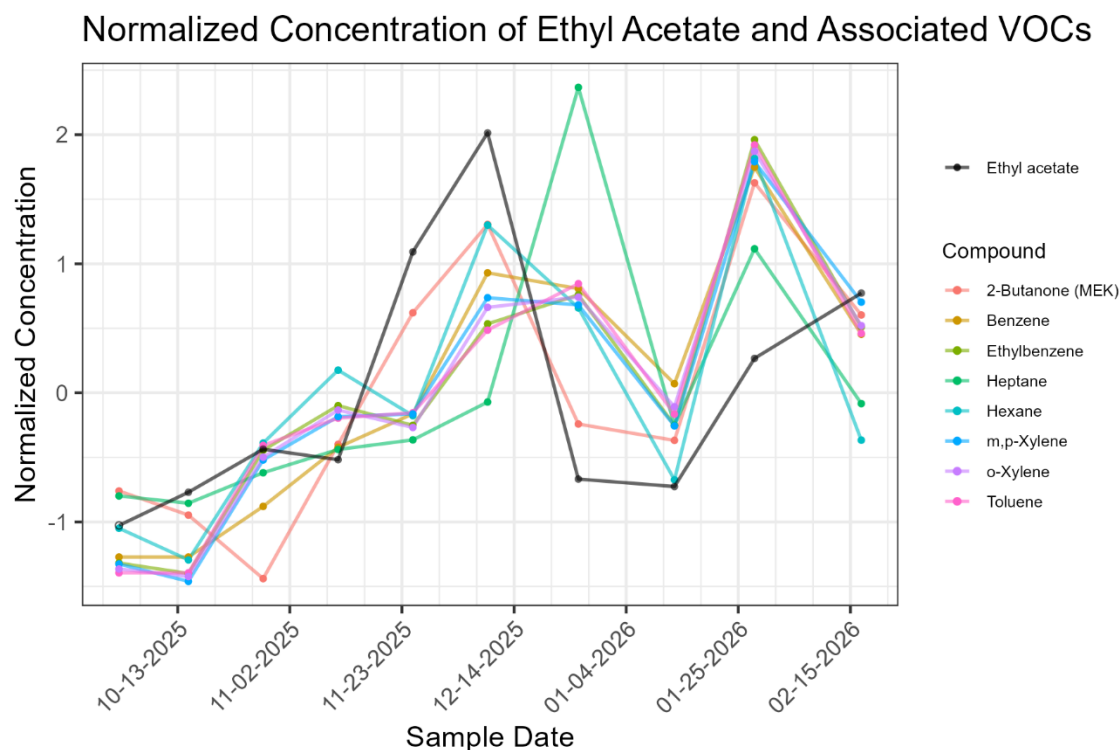


Figure 12. Time series of select mobile-source VOCs (colored lines) and ethyl acetate (black line). This plot demonstrates that ethyl acetate emissions exhibit similar behavior to mobile-source VOCs. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

Carbon Tetrachloride

Carbon tetrachloride is a long-lived (30–100 years) VOC with limited present-day use that was historically used to produce refrigerants, as an aerosol propellant, and in fire extinguishers (U.S. Department of Health and Human Services, 2005). Carbon tetrachloride is a long-lived species with a lifetime in the atmosphere of 30–100 years (Agency for Toxic Substances and Disease Registry, 2011). In 1996, the mean concentration of carbon tetrachloride across CARB’s air toxic network was 0.079 ppb (California Air Resources Board, 1997). Between 1998 and 2019, the South Coast basin-wide average concentration was between 0.104 and 0.075 ppb (Nastri et al., 2021). Analysis of the 2023 CARB Facility Toxics Inventory indicates there are no emitters of carbon tetrachloride within or nearby East Oakland (California Air Resources Board, 2023).

As expected, carbon tetrachloride followed similar trends and was measured at similar concentrations across all five measurement sites (Figure 13). The mean carbon tetrachloride concentration ranged from 0.036–0.039 ppbv across all sites. A correlation assessment indicated that carbon tetrachloride only had one significant relationship: a medium-weak negative correlation with heptane. However, due to its long lifetime in the atmosphere and heavily restricted use, carbon

tetrachloride is not expected to correlate with other newly emitted VOCs. Instead, it persists in the background at steady concentrations.

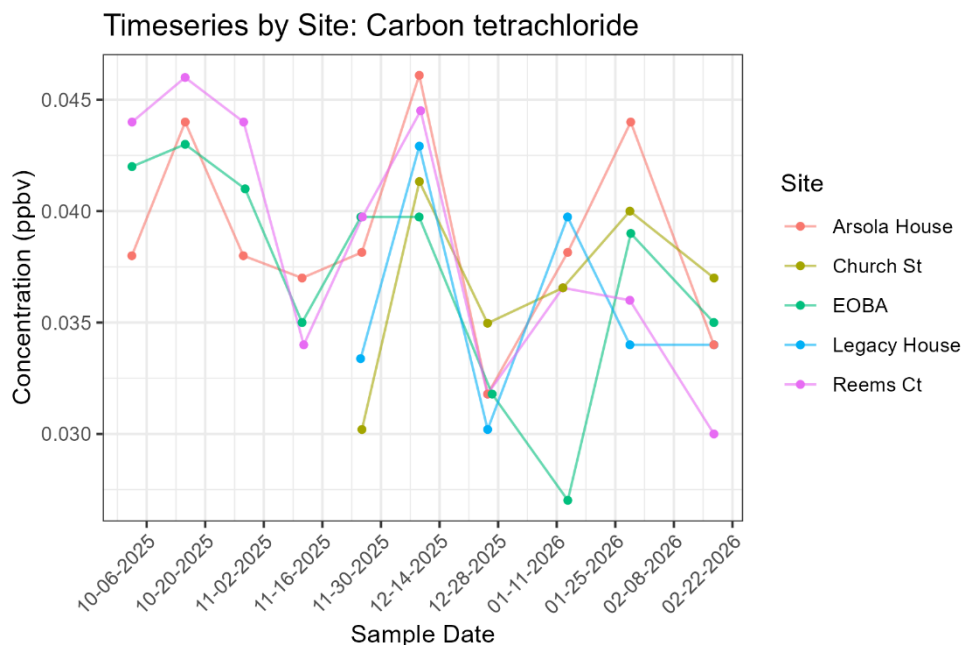


Figure 13. Time series of carbon tetrachloride concentration at each site.

1,4-Dichlorobenzene

The concentration of 1,4-dichlorobenzene was consistently higher at Legacy House than any other site; on average, it is nearly 10 times higher there. This finding suggests a localized source of 1,4-dichlorobenzene. 1,4-dichlorobenzene is used as a space deodorant and to control moths, mold, and mildew. Since Legacy House is a residential location and the sensor is in a common balcony space, it is possible that indoor sources are contributing.

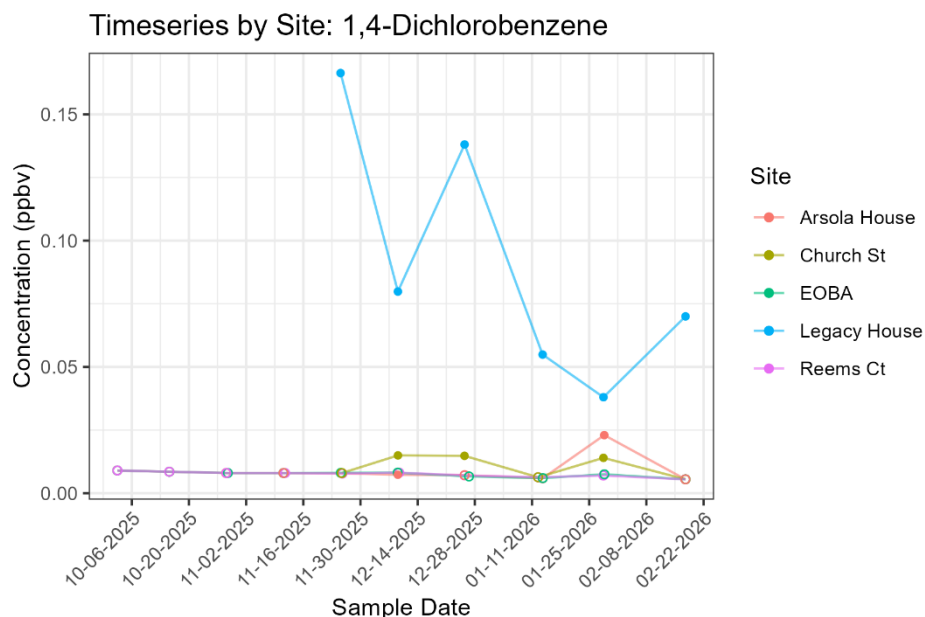


Figure 14. Time series of 1,4-dichlorobenzene concentration at each site. Solid points indicate 1,4-dichlorobenzene was detected, and hollow points indicate it was below detection for a particular sample.

Ethanol

Elevated levels of ethanol occurred on November 26, 2025, (all sites) and December 10, 2025, (all sites except Reems Court) as shown in [Figure 15](#). Prior to this time, ethanol was below detection limit at the sites that were measuring (initial sampling did not occur at Reems Court or Legacy House until November 26, 2025). After December 10, ethanol was sporadically detected at all sites at much lower concentrations.

Ethanol in ambient air can originate from a wide range of sources, including natural emissions from vegetation, fermentation processes, and biomass combustion, as well as anthropogenic sources where it is used as a solvent, fuel additive, or chemical intermediate (Millet et al., 2012). As a fuel additive, ethanol can comprise up to 10% of some gasoline blends and is emitted in vehicle exhaust (Marques et al., 2022). In this study, ethanol did not exhibit strong correlations with typical mobile-source VOCs, including BTEX compounds ([Figure C-2](#)). This finding suggests that vehicular emissions were not the dominant driver of ethanol emissions.

Meteorological conditions between November 25 and December 10, 2025, likely contributed to the observed spike in concentration. To determine how meteorology impacted the atmosphere during this time, Skew-T profiles were reviewed. Skew-T diagrams are plots of atmospheric data from radiosondes which show the temperature profile in the atmosphere. These can be used to identify inversion layers. Analysis of Skew-T profiles from Oakland (National Oceanic and Atmospheric Administration, 2023) indicated the presence of temperature inversion conditions between

November 22 and December 19, 2025, which would have reduced atmospheric mixing and promoted accumulation of VOCs near the surface. This interpretation is supported by a “Spare the Air” alert issued by the Bay Area Air Quality Management District during this timeframe, which cited a high-pressure system trapping emissions, including wood smoke, at ground level (Bay Area Air Quality Management District, 2025). Increased concentrations of other VOCs measured in this study can also be observed during this timeframe. As a result, increased ethanol concentrations during this time were likely the result of meteorological pollution trapping rather than a particular emission source.

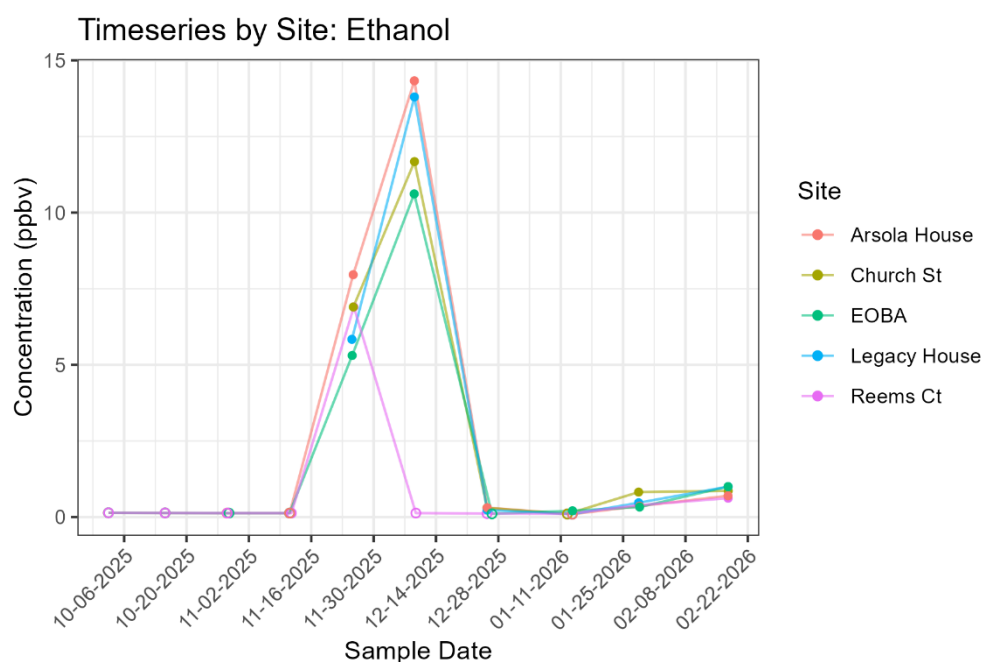


Figure 15. Time series of ethanol concentration at each site. Solid points indicate ethanol was detected, and hollow points indicate it was below detection for a particular sample.

3.3.6 Spatial Analysis

Table 12 summarizes the mean concentration of each VOC at each monitoring site for each period November 26, 2025, through February 18, 2026. Statistical differences between site means are indicated using a compact letter display (CLD), where shared letters denote no significant difference. **Figure 16** presents the same average concentration data in bar chart form for visual comparison.

This statistical comparison revealed that VOC concentrations at Reems Court were statistically lower than at the other sites 44% of the time. The site with the next-lowest concentrations was Arsola's House, which was statistically lower than the other sites 4% of the time. This finding is consistent with site characteristics: Reems Court is located farther from major traffic corridors and industrial areas than the other sites. On the other hand, Legacy House statistically had the highest levels of VOC concentrations, with concentrations higher than the other sites 22% of the time.

Mobile-source VOCs were generally statistically different from site to site; heptane was the only mobile-source VOC that was not. Concentrations measured at Reems Court were statistically lower for cyclohexane, hexane, ethylbenzene, hexane, toluene, and m,p-xylene compared with the four other sites. These site-to-site differences suggest that the local roadways and traffic volume, rather than regional traffic, impact each site, which is generally expected in urban environments.

Non-mobile source VOCs exhibited minimal variability across sites. No statistically significant site-level differences were observed for these compounds, except for 1,4-dichlorobenzene. Concentrations of 1,4-dichlorobenzene are substantially higher at Legacy House relative to all other sites, likely reflecting the influence of a localized source (see [Section 3.3.5](#)). Carbon tetrachloride, chloroform, ethanol, and ethyl acetate show no statistically significant differences across the five sites. This result indicates that non-mobile source VOCs are likely from regional, rather than local, sources.

Table 12. Summary of the mean concentration of each VOC at each site. Accompanying letters are used to indicate which site-level means are statistically different. If two means do not share a common letter, they are statistically different. Interpretation of these results is provided in the second column from the right.

Parameter	Arsola's House		Church St		EOBA		Legacy House		Reems Ct		Interpretation of Significant Relationships	Mobile-Source VOC
	Mean (ppbv)		Mean (ppbv)		Mean (ppbv)		Mean (ppbv)		Mean (ppbv)			
1,2,4-Trimethylbenzene	0.073	ab	0.094	a	0.078	ab	0.109	a	0.043	b	Church St, Legacy House > Reems Ct	Yes
1,3,5-Trimethylbenzene	0.020	ab	0.029	ac	0.023	ac	0.032	c	0.010	b	Legacy House > Reems Ct, Arsola's House Church St, EOBA > Reems Ct	Yes
1,4-Dichlorobenzene	0.009	a	0.011	a	0.007	a	0.091	b	0.007	a	Legacy House > other sites	
2-Butanone (MEK)	0.113	a	0.095	ab	0.096	ab	0.094	ab	0.070	b	Arsola's House > Reems Ct	Yes
Benzene	0.225	ab	0.269	a	0.230	ab	0.255	a	0.159	b	Church St, Legacy House > Reems Ct	Yes
Carbon tetrachloride	0.039	a	0.037	a	0.035	a	0.036	a	0.036	a	No statistical site-level difference	
Chloroform	0.019	a	0.023	a	0.017	a	0.023	a	0.013	a	No statistical site-level difference	
Cyclohexane	0.104	a	0.114	a	0.115	a	0.127	a	0.052	b	other sites > Reems Ct	Yes
Ethanol	3.959	a	3.443	a	2.927	a	3.573	a	1.376	a	No statistical site-level difference	
Ethyl acetate	0.135	a	0.115	a	0.194	a	0.184	a	0.065	a	No statistical site-level difference	
Ethylbenzene	0.069	a	0.080	a	0.078	a	0.094	a	0.037	b	other sites > Reems Ct	Yes
Heptane	0.168	a	0.146	a	0.129	a	0.219	a	0.078	a	No statistical site-level difference	Yes
Hexane	0.165	ab	0.199	a	0.169	a	0.213	a	0.099	b	other sites > Reems Ct	Yes
Propylbenzene	0.011	ab	0.015	ab	0.012	ab	0.018	a	0.007	b	Legacy House > Reems Ct	Yes
Tetrachloroethene	0.005	a	0.006	a	0.005	a	0.006	a	0.006	a	No statistical site-level difference	
Toluene	0.392	a	0.462	a	0.445	a	0.544	a	0.216	b	other sites > Reems Ct	Yes
m,p-Xylene	0.204	a	0.249	a	0.235	a	0.294	a	0.108	b	other sites > Reems Ct	Yes
o-Xylene	0.070	a	0.085	ab	0.079	ab	0.102	b	0.038	c	Legacy House > Arsola's House, Reems Ct Arsola's House > Reems Ct	Yes

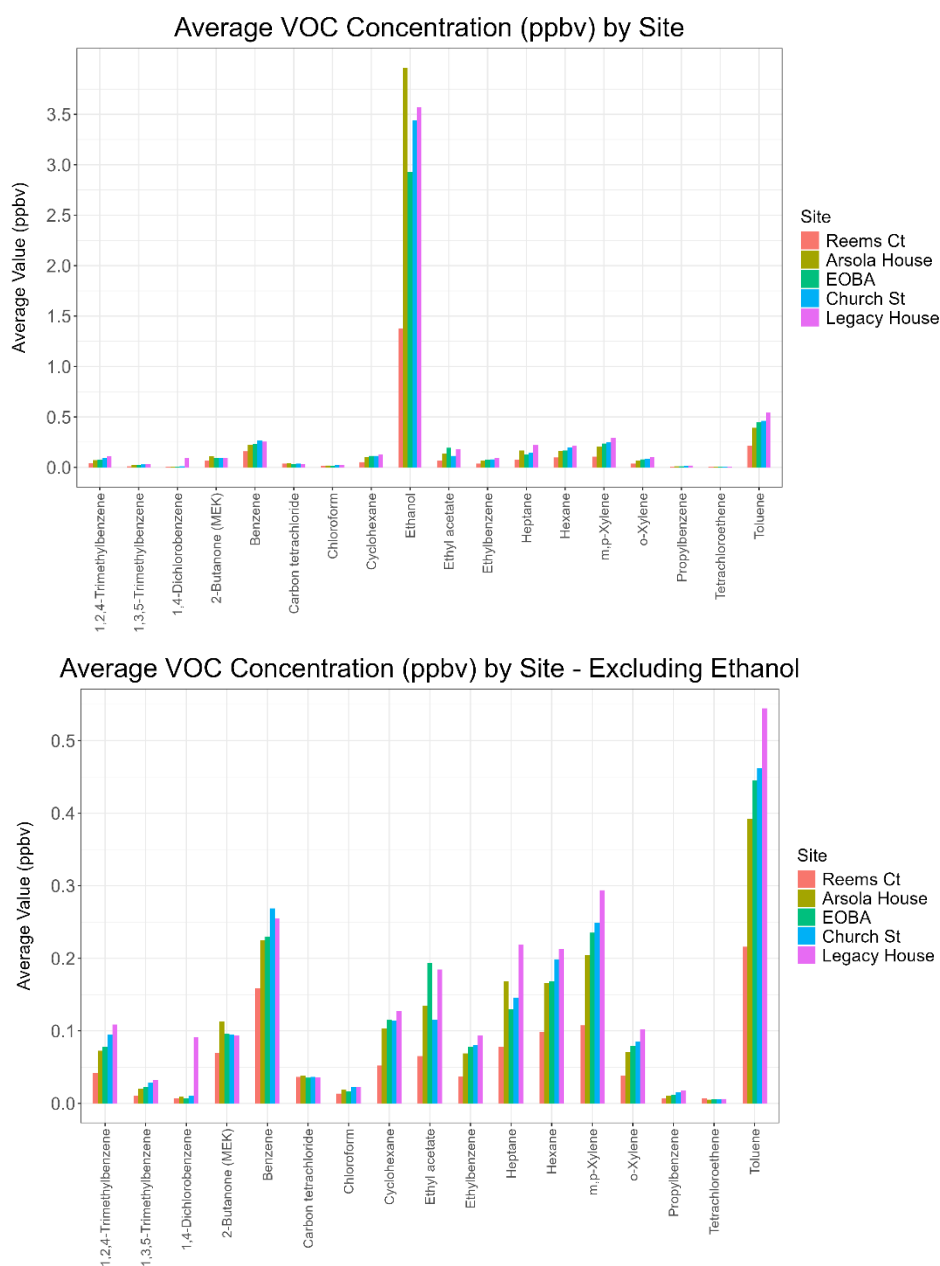


Figure 16. Bar plots of average concentration of each VOC by site. The top figure includes all 17 VOCs of interest, and the bottom figure does not include ethanol.

3.3.7 East Oakland Average Versus Regional Values

Average VOC concentrations measured in East Oakland during this study were compared with regional concentrations derived from 2022–2024 AQS data (U.S. Environmental Protection Agency, 2026). These results are presented in [Table 13](#). As discussed in [Section 2.6](#), the agency monitors closest to East Oakland are located at Laney College and in East Oakland ([Figure 8](#)). We present this comparison with acknowledgement that there are methodological differences between how data was collected which could impact accurate direct comparison. AQS uses a 24-hour canister sampling approach on a 1-in-12-day schedule with analysis via mainly TO-15. In this study we used passive samplers which measure over a 2-week sampling period and were analyzed via TO-17.

The concentrations of BTEX gases measured in this study were generally elevated compared with regional concentrations. Benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene concentrations exceeded regional concentrations by 68%, 26%, 46%, 43%, and 33%, respectively. Similarly, the measurements from this study exceeded the average BTEX concentrations measured at the Laney College site by 31–60%. When compared specifically with the East Oakland AQS site, benzene was comparatively elevated (+43%); toluene, ethylbenzene, and xylenes were within approximately -2% to +8% of the AQS values. Notably, toluene and o-xylene concentrations measured in this study were lower than the AQS averages reported for East Oakland. In contrast, 2-butanone concentrations were approximately 70% lower than regional levels.

Overall, mobile-source VOCs (BTEX and 2-butanone) were generally elevated relative to regional concentrations, indicating that East Oakland experiences a disproportionately elevated influence from vehicular emissions compared with other parts of the Bay Area. However, despite evidence from this study that 2-butanone co-occurs with BTEX, its lower concentration relative to the AQS data may suggest the methodological differences may be an influential factor.

In terms of non-mobile compounds, carbon tetrachloride, chloroform, and ethanol were all substantially lower than regional AQS concentrations (-68%, -42%, and -53%, respectively). The result for carbon tetrachloride is particularly notable, since this compound is a legacy pollutant with relatively uniform concentrations across the Bay Area (which is reflected in the AQS data). The lower carbon tetrachloride concentration noted in this study may reflect differences in differences in sampling methods, rather than true spatial variability. Finally, tetrachloroethene concentrations were elevated relative to regional concentrations by 2–3 times; however, this compound was only detected in 11.9% of samples.

Table 13. Summary of VOC concentrations from this study and EPA AQS data from 2022–2024. Data for 2022–2024 were available for the Oakland site. Only data from 2023–2024 were available for the Laney College site; the exception was tetrachloroethene, for which only 2024 data were available.

Compound Name	Study Average (ppbv)	2022–2024 AQS Average (ppbv)		
		Regional ^a	East Oakland	Laney College
2-Butanone (MEK)	0.082	0.288	0.211	0.233
Benzene	0.204	0.121	0.144	0.127
Carbon tetrachloride	0.038	0.120	0.123	0.124
Chloroform	0.016	0.028	0.024	0.023
Ethanol	2.221	4.685	3.896	2.538
Ethylbenzene	0.065	0.044	0.060	0.047
Tetrachloroethene	0.006	0.003	0.003	0.001
Toluene	0.374	0.296	0.378	0.266
m,p-Xylene	0.197	0.137	0.181	0.130
o-Xylene	0.068	0.051	0.070	0.052

^a Regional average reflects all available data from 2022–2024 from 18 Bay Area AQS sites.

3.4 Cumulative Health Risk

A cumulative health assessment allows us to quantify the combined risk from a variety of sources. Here, we follow the EPA framework for air toxics assessment, where cancer risks for individual contaminants are treated additively (U.S. Environmental Protection Agency, 2018). In this approach, cumulative risk is estimated by summing the single contaminant risks. This conservative approach assumes that individual contaminants exert their toxic effects independently of each other, and that the mixture of contaminants is well represented by the addition of the effects (Evans, 2018; U.S. Environmental Protection Agency, 2000).

Using this approach, the cumulative cancer risk posed by carbon tetrachloride, benzene, 1,4-dichlorobenzene, ethylbenzene, chloroform, tetrachloroethene is 32 in-a-million.

OEHHA states that, “according to state and federal guidance on contaminated sites, a cancer risk that is at or below 1 chance in a million (or 1×10^{-6}) is not a public health concern. This means that no more than one person in a population of one million people exposed to the same level of chemical contaminant(s) at the site would develop cancer over a lifetime” (OEHHA, 2020). The guidance also states that cancer risk above 100 in a million (or 1 in 10,000) is generally unacceptable. However, when the risk lies between 1 per million and 100 per million, state regulators consider a variety of

factors to determine whether risk should be reduced. **Figure 17** shows this same concept in a graphical format.

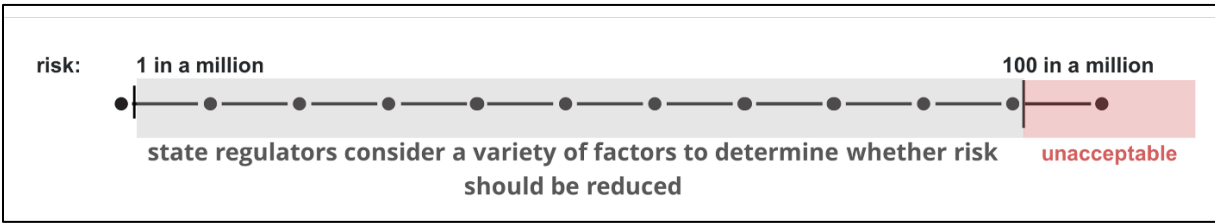


Figure 17. Graphical representation of how different risk levels are considered by State agencies.

4. Conclusions

This community air monitoring effort established a baseline of local air quality conditions in East Oakland. Across the six-month study period, fine particulate matter (PM_{2.5}) levels were generally within the “Good” to “Moderate” range, with only one day reaching “Unhealthy for Sensitive Groups” levels. This finding indicates that while acute pollution episodes were limited, daily exposures remain a concern for vulnerable individuals, particularly given the consistent morning and evening peaks tied to traffic activity.

The results revealed PM_{2.5} levels across the five sites averaging between 9.0 and 14.0 µg/m³. The pronounced rush-hour patterns, combined with wintertime increases driven by wood burning, cold-start vehicle emissions, and stagnant atmospheric conditions, point to local combustion sources as meaningful contributors to community exposure. These findings underscore the importance of targeted mitigation strategies that address both traffic emissions and residential burning practices, especially during colder months when pollution is most likely to accumulate.

VOC measurements further demonstrated the presence of multiple toxic air contaminants associated with traffic, solvent use, and other local activities. Using the EPA’s cumulative risk framework, the combined cancer risk from key detected compounds was estimated at 32 in-a-million. This value falls within the regulatory range where action is considered on a case-by-case basis. This result reinforces the need for continued monitoring, source investigation, and community-centered risk reduction.

Taken together, the results show that East Oakland residents experience a mixture of routine traffic-related pollution, seasonal combustion impacts, and measurable levels of hazardous air pollutants. These exposures, while not extreme, are persistent and occur in neighborhoods already burdened by environmental inequities. This study provides a strong foundation for advancing cleanup and abatement efforts, informing local policy, and supporting community-driven strategies to reduce emissions at their source. Continued collaboration among residents, local organizations, and regulatory agencies will be essential to ensure that the data collected here lead to meaningful improvements in neighborhood air quality and public health.

5. Community Recommendations Based on Monitoring Results

Residents have meaningful opportunities to reduce pollution and protect their own health, even while larger structural sources such as traffic and illegal burning require policy and enforcement. Monitoring results point to specific behaviors and community-level actions that can make a measurable difference.

Reducing Local Emissions

Traffic and combustion were the clearest contributors to fine particulate matter (PM_{2.5}) and volatile organic compound (VOC) levels. Residents can help reduce neighborhood pollution through a mix of personal choices and community advocacy.

Transportation and Vehicle Practices

- Limit idling during school drop-off, pick-up, and outside homes or businesses.
- Maintain vehicles regularly to reduce PM_{2.5} and VOC emissions.
- Choose active transportation (e.g., walking, biking, transit) when possible.
- Buy or rent electric, hydrogen, or hybrid vehicles when feasible.
- Support natural fleet transition to zero-emission vehicles driven by state regulations.
- Work with school districts and city agencies to modernize fleets using public grants.

Combustion and Home Activities

- When possible, minimize or avoid residential wood burning, especially on cold, stagnant winter nights when pollution accumulates.
- Limit outdoor charbroiling and refrain from any outdoor burning.
- Improve home energy efficiency to reduce regional energy demand and associated emissions.
- Reduce emissions from lawn and garden equipment by maintaining tools or transitioning to electric models.
- Make use of available incentives for clean appliances, heat pumps, electric vehicles (EVs), and energy upgrades.

Reducing Personal Exposure

Even when outdoor pollution levels are moderate, residents can take steps to reduce the pollution they breathe in when indoors and during peak pollution hours.

Indoor Air Quality

- Use portable High-Efficiency Particulate Air (HEPA) air purifiers, especially in bedrooms and living areas. For a list of certified cleaning devices, visit: <https://ww2.arb.ca.gov/list-carb-certified-air-cleaning-devices>.
- Use kitchen exhaust fans during cooking to reduce indoor PM_{2.5}.
- Reduce indoor sources of pollution such as smoking or burning candles.
- Minimize window opening during peak pollution hours (7:00–9:00 a.m. and around 8:00 p.m.) or when odors or smoke are present.

Protecting Sensitive Individuals

- Wear N-95 or KN-95 masks during high-pollution days or near known pollution hot spots.
- Plan outdoor activities during times when pollution levels are typically lower (e.g., late afternoon).

Community Action and Engagement

Collective action amplifies individual efforts and helps address structural sources such as illegal dumping, traffic, and industrial emissions.

Community Involvement

- Participate in local environmental meetings and initiatives with the U.S. Environmental Protection Agency (EPA), the California Air Resources Board (CARB), and the Bay Area Air Quality Management District (BAAQMD).
- Engage with local businesses, ports, and service providers to encourage sustainable practices.
- Support school and youth programs, because students often influence family behavior and community norms.
- Join neighborhood clean-ups to discourage illegal dumping and reduce the likelihood of waste burning.

Reporting and Enforcement

- Report illegal dumping, burning, odors, or visible emissions (“see something, say something”).

- Use the Lifers' website to report environmental concerns (<https://liferlegacy.org/lifers>)
- Report air quality violations and odors to BAAQMD for investigation.
- Make use of local enforcement resources to address recurring problem areas.

Staying Informed

- Visit and use the Lifers' data dashboard to track local air quality trends (<https://liferlegacy.org/maps>)
- Check EPA AirNow, weather forecasts, and pollen reports to plan activities and reduce exposure to pollution.
- Increase awareness within households and neighborhoods about pollution sources and health impacts.

Building Toward Long-Term Change

The cumulative cancer risk estimate of 32-in-a-million underscores the need for sustained attention. Residents can help shape long-term improvements by:

- Advocating for traffic calming, safer pedestrian routes, and tree planting.
- Supporting policies that reduce emissions from freight, industry, and waste operations.
- Collaborating with community organizations to expand monitoring and identify new hot spots.

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7. Appendix A: Volatile Organic Compound Descriptions

Benzene (C₆H₆) – Benzene is a naturally occurring and man-made chemical. Benzene is used as a solvent; to make plastics, resins, detergents, paint removers, and rubber; and as a gasoline fuel additive. Benzene is produced by combustion including forest fires, tobacco smoke, and vehicle exhaust. Increased exposure to benzene is associated with cigarette smoke and proximity to heavy motor traffic, gas stations, manufacturing facilities that use the chemical, landfills, and hazardous waste sites. Benzene breaks down in air in a few days. Benzene is a carcinogen and long-term exposure is associated with anemia.⁵ Benzene is designated by EPA as a hazardous air pollutant (HAP).

2-Butanone (C₄H₈O) – 2-Butanone, also known as methyl ethyl ketone, is a naturally occurring and man-made chemical. It is used in industrial applications as a solvent, to make paints and coatings, in glues, and as a cleaning agent. It is naturally produced by trees, found in small amounts in some fruits and vegetables, and created by the photooxidation of certain air pollutants. Exposure to 2-butanone can occur in occupational settings, from using consumer products that contain the chemical, or breathing contaminated air. Some studies have indicated that long-term exposure to 2-butanone can cause neurological, liver, kidney, and respiratory damage. 2-Butanone is not a carcinogen.^{6,7} 2-Butanone is designated by EPA as an HAP.

Carbon Tetrachloride (CCl₄) – Carbon tetrachloride is an industrial chemical used in limited applications. Historically, the chemical was used in the production of refrigerants and aerosol propellants, as a cleaner, and in fire extinguishers; however, its use has largely been banned due to health and environmental concerns. Exposure to carbon tetrachloride can occur from breathing air near manufacturing or waste sites that use the chemical. Carbon tetrachloride has a lifespan in the air of 30–100 years. Exposure to high levels of carbon tetrachloride can cause headaches; dizziness; damage to the liver, kidney, and central nervous system; and, in some cases, death. Carbon tetrachloride is a probable human carcinogen.⁸ Carbon tetrachloride is designated by EPA as an HAP.

Chloroform (CHCl₃) – Chloroform is a naturally occurring and man-made chemical. It forms in small amounts when water is chlorinated, is used as a solvent and to make other chemicals, and was historically used as an anesthetic during surgeries. Living near hazardous waste sites or facilities that chlorinate water can increase the risk of exposure. Chloroform breaks down slowly in the air and can travel long distances. Breathing low-to-moderate amounts of chloroform can cause dizziness and

⁵ <https://www.atsdr.cdc.gov/toxfaqs/tfacts3.pdf>

⁶ <https://www.atsdr.cdc.gov/toxfaqs/tfacts29.pdf>

⁷ <https://www.epa.gov/sites/default/files/2016-09/documents/methyl-ethyl-ketone.pdf>

⁸ <https://www.atsdr.cdc.gov/toxfaqs/tfacts30.pdf>

headaches, while large amounts can cause liver damage, kidney damage, and unconsciousness.⁹ Long-term exposure damages the liver and nervous system. Chloroform is a probable human carcinogen.¹⁰ Chloroform is designated by EPA as an HAP.

Cyclohexane (C₆H₁₂) – Cyclohexane is found in petroleum and gasoline. It is also used as a solvent, remover, and in the production of nylon. Exposure most commonly occurs from breathing air contaminated with gasoline vapors. Long-term exposure cyclohexane may damage the liver and kidneys, but it is not carcinogenic.^{11,12}

1,4-Dichlorobenzene (C₆H₄Cl₂) – 1,4-dichlorobenzene is used as a space deodorant and to control moths, molds, and mildews. It is commonly associated with mothballs. Exposure to 1,4-dichlorobenzene primarily occurs from breathing in air containing vapors from products that use the chemical. Long-term exposure to dichlorobenzene can damage the liver, skin, and central nervous system. 1,4-dichlorobenzene is reasonably anticipated to be a human carcinogen.^{13,14} 1,4-dichlorobenzene is designated by EPA as a HAP.

Ethanol (C₂H₆O) – Ethanol, also ethyl alcohol, is the intoxicating substance in alcoholic beverages which is also used as a solvent, gasoline additive, and disinfectant.

Ethyl Acetate (C₄H₈O₂) – Ethyl acetate is a naturally occurring and man-made chemical. It has a fruity odor and is commonly found in many fruits, including apples, bananas, and nectarines. It is used as a component of nail polish remover, in various industrial processes including as a solvent, and sometimes to add scent to certain products.¹⁵ Exposure can occur via inhalation and is most common for workers in industries that use ethyl acetate or consumers using products containing the chemical.¹⁶ Source apportionment studies have associated ethyl acetate with solvent use and secondary photochemical formation (Han et al., 2019; Yu et al., 2021). Long-term exposure can negatively affect the liver and kidneys and decrease male fertility. Ethyl acetate is not carcinogenic.¹⁷

Ethyl Benzene (C₈H₈) – Ethyl benzene is a chemical primarily used to make styrene, but also as a solvent, in fuels, and to make other chemicals. Increased exposure is associated with proximity to urban areas, factories and industries that use the chemical, highways, and fossil fuel combustion. Ethyl benzene breaks down in three days in the air. Ethyl benzene is a possible human carcinogen, and short-term exposure can cause eye and throat irritation and dizziness.¹⁸ Ethyl benzene is designated by EPA as an HAP.

⁹ <https://www.atsdr.cdc.gov/toxfaqs/tfacts6.pdf>

¹⁰ <https://www.epa.gov/sites/default/files/2016-09/documents/chloroform.pdf>

¹¹ https://www.in.gov/idem/toxic/files/studies_toxwatch_cyclohexane.pdf

¹² <https://nj.gov/health/eoh/rtkweb/documents/fs/0565.pdf>

¹³ <https://www.atsdr.cdc.gov/toxfaqs/tfacts10.pdf>

¹⁴ <https://www.epa.gov/sites/default/files/2016-09/documents/1-4-dichlorobenzene.pdf>

¹⁵ <https://cfpub.epa.gov/ncea/pprtv/documents/EthylAcetate.pdf>

¹⁶ <https://www.dccew.gov.au/environment/protection/npi/substances/fact-sheets/ethyl-acetate>

¹⁷ https://www.in.gov/idem/toxic/files/studies_toxwatch_ethyl_acetate.pdf

¹⁸ <https://www.atsdr.cdc.gov/toxfaqs/tfacts110.pdf>

Heptane (C₇H₁₆) – Heptane is a component of petroleum. It is found gasoline and other fuels and used as a solvent. Exposure can occur from breathing gasoline fumes or vapors. Heptane may negatively affect the nervous system.¹⁹

Hexane (C₆H₁₄) – Hexane is a naturally occurring and anthropogenic chemical that is primarily used as a solvent. Hexane is produced by plants, forest fires, and volcanos. It can be made from crude oil and is present in gasoline and certain glues. Exposure to low concentrations of hexane commonly occur due to its presence in gasoline.²⁰ Long-term exposure is associated with neurological damage: numbness in the extremities, muscular weakness, blurred vision, headache, and fatigue.²¹ Hexane is designated by EPA as an HAP.

Propylbenzene (C₉H₁₂) – Propylbenzene occurs in petroleum and is used in chemical manufacturing and textile dying and printing. It is released into the atmosphere via combustion, solvent evaporation, landfill leaching, and asphalt. Very little human toxicology data exist for propylbenzene, and animal studies indicate it may be toxic to the liver.²²

Tetrachloroethene (C₂Cl₄) – Tetrachloroethene, also perchloroethylene, is an anthropogenic chemical used as a dry-cleaning agent, metal degreasing solvent, and in chemical manufacturing. Exposure to tetrachloroethene is most likely for individuals who live or work near dry cleaning facilities, work using metal degreasers, or live near a site contaminated with the chemical. Tetrachloroethene has a half life in the air of 100 days. Tetrachloroethene is toxic and can cause dizziness, headache, and unconsciousness. Tetrachloroethene is likely a human carcinogen.²³ Tetrachloroethene is designated by EPA as an HAP.

Toluene (C₇H₈) – Toluene is a naturally occurring and man-made chemical. It is used as a solvent and in household products such as paint, nail polish, adhesives, and rubber; to manufacture chemicals, nylon, and plastic; and as a gasoline additive. Vehicle exhaust also contains toluene. Exposure to toluene via inhalation is more likely for people who spend time near vehicles and who work with toluene-containing products such as gasoline, paints, and dyes. Toluene is broken down rapidly in the air. Low-to-moderate exposure to toluene causes headaches, nausea, dizziness, weakness, and memory loss; and long-term daily exposure can result in brain damage and some loss of hearing and color vision.²⁴ Toluene is designated by EPA as an HAP.

Trimethylbenzene (C₉H₁₂) – Trimethylbenzene is an anthropogenic chemical produced during petroleum refining; it is present in gasoline and vehicle exhaust. It is also used as a solvent and in chemical manufacturing. Exposure to high concentrations of trimethylbenzene causes irritation of

¹⁹ <https://nj.gov/health/eoh/rtkweb/documents/fs/1339.pdf>

²⁰ <https://www.atsdr.cdc.gov/toxfaqs/tfacts113.pdf>

²¹ <https://www.epa.gov/sites/default/files/2016-09/documents/hexane.pdf>

²² [https://oehha.ca.gov/water/proposed-notification-level-n-propylbenzene#:~:text=n-Propylbenzene%20has%20been%20qualitatively, Daubert%20and%20Danner,%201989\).](https://oehha.ca.gov/water/proposed-notification-level-n-propylbenzene#:~:text=n-Propylbenzene%20has%20been%20qualitatively, Daubert%20and%20Danner,%201989).)

²³ <https://www.atsdr.cdc.gov/toxfaqs/tfacts18.pdf>

²⁴ <https://www.atsdr.cdc.gov/toxfaqs/tfacts56.pdf>

mucous membranes, headache, drowsiness, and nausea. Long-term exposure can cause changes to blood cells and reduce clotting.^{25,26}

Xylene (C₈H₁₀) – Xylene is used in the printing, rubber, and leather industries; as a solvent, cleaner, and paint thinner; and as a fuel additive. Exposure to xylene is more likely for people who use xylene-containing products, are exposed to cigarette smoke, or work in painting, automotive garages, metals, and furniture refinishing. High levels of short-term exposure are associated with irritation of the skin, eyes, nose, and throat; difficulty breathing and lung problems; delayed reaction time; memory difficulty; and, in some cases, unconsciousness or death.²⁷ Long-term exposure causes neurological damage.²⁸ Xylene is designated by EPA as an HAP.

²⁵ <https://assessments.epa.gov/risk/document/&deid%3D361166>

²⁶ <https://nj.gov/health/eoh/rtkweb/documents/fs/1929.pdf>

²⁷ <https://www.atsdr.cdc.gov/toxfaqs/tfacts71.pdf>

²⁸ <https://www.epa.gov/sites/default/files/2016-09/documents/xylenes.pdf>

8. Appendix B: PM_{2.5} Supporting Information

8.1 PM_{2.5} Site Statistics

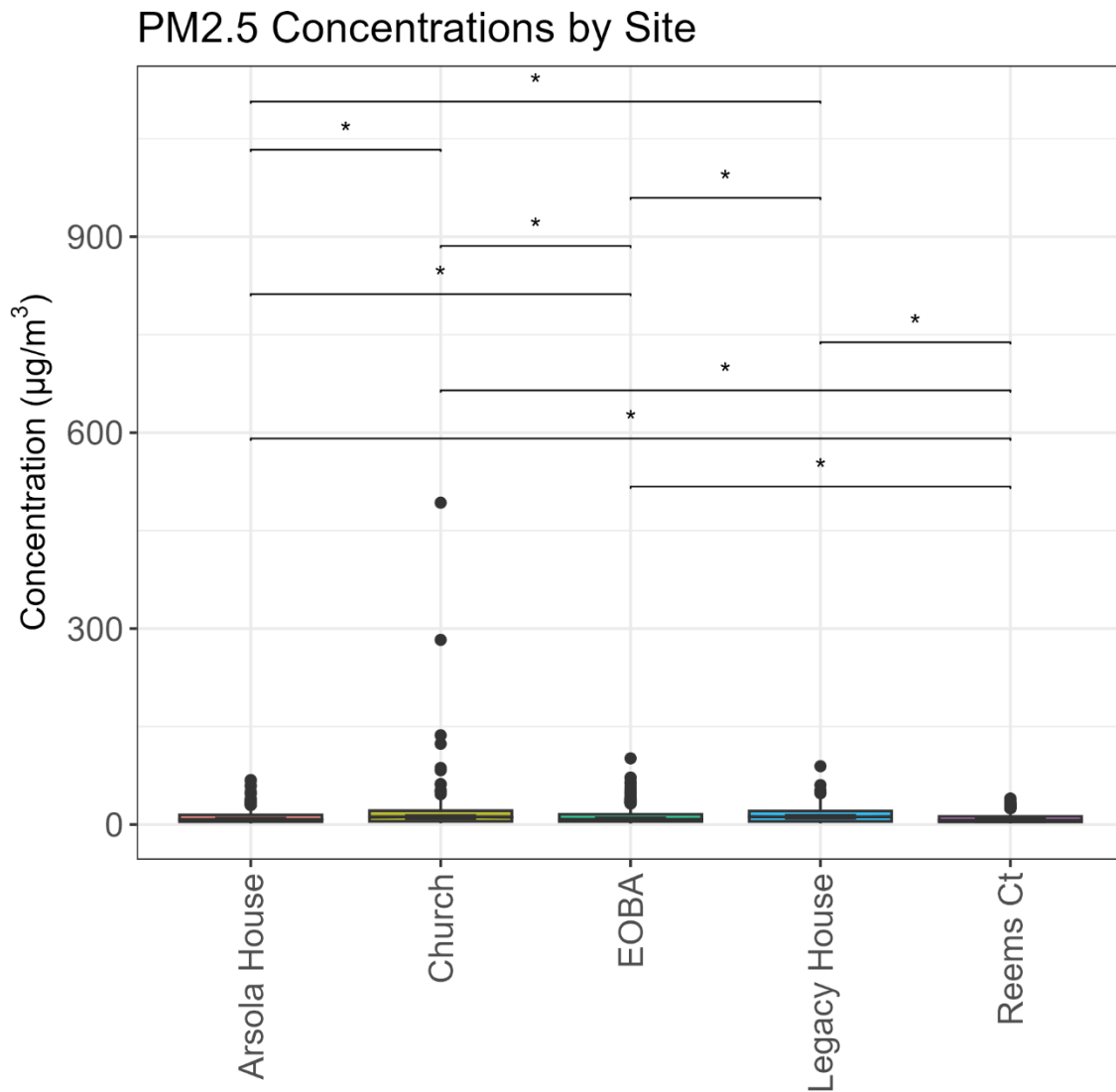


Figure B-1. Wilcoxon-rank sum test for all sites. Horizontal lines above boxplots compare sites. An asterisk above the line indicates that the sites are statistically different. All sites are significantly different.

8.2 PM_{2.5} Data Filtration Methods

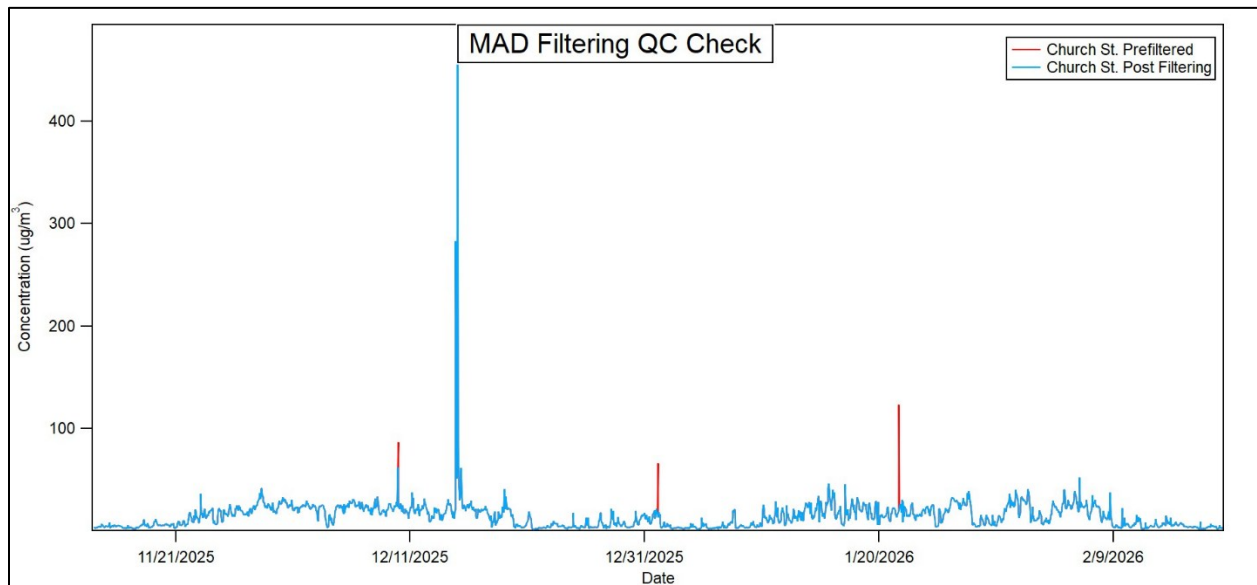


Figure B-2. Example of filtering from MAD filtering algorithm. Blue corresponds to filtered data, and red corresponds to raw data. Data were further confirmed as erroneous by examining the raw 15-minute data.

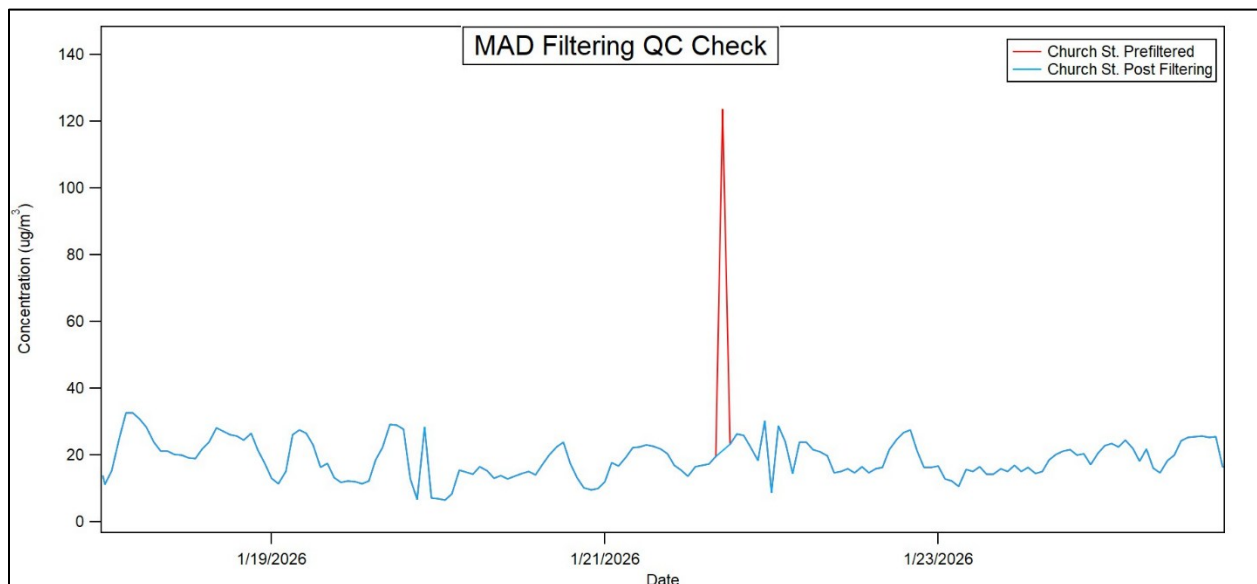


Figure B-3. Zoomed in view of Figure B2.

Prior to the sampling period, a collocation check was performed on all of the Clarity sensors by running them side by side from September 12, 2025, to September 19, 2025 (-4. Time series showing

the PM_{2.5} data during the collocation period. The sensor to be used at Church Street (yellow) exhibited higher concentrations than the other sensors during the collocation period. To adjust for this issue, the average concentration was calculated across all sensors for the collocation period. A linear regression fit (slope = 1.16717, intercept = -.46154) was then applied to the Church Street data to correct them to match the group average. This correction was subsequently applied to the sample data. The adjusted data are shown in yellow in [Figure B-5](#)**Error! Reference source not found..**

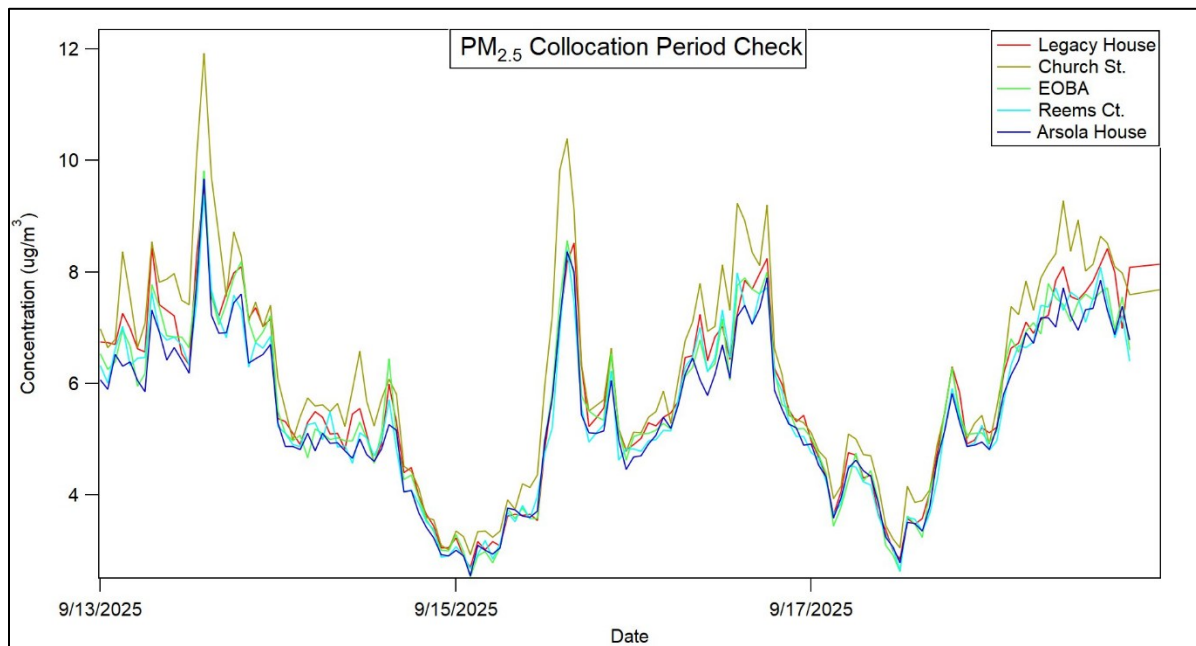


Figure B-4. Time series showing the PM_{2.5} data during the collocation period.

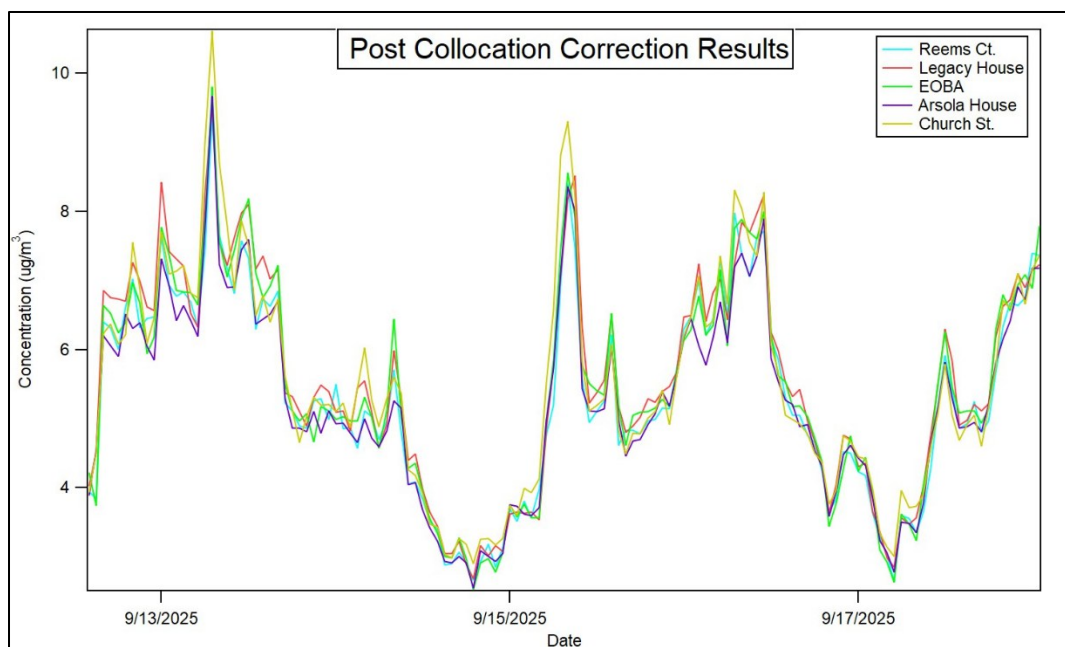


Figure B-5. Time series showing the PM_{2.5} data during the collocation period post correction.

8.3 PM_{2.5} Time-Series Plots

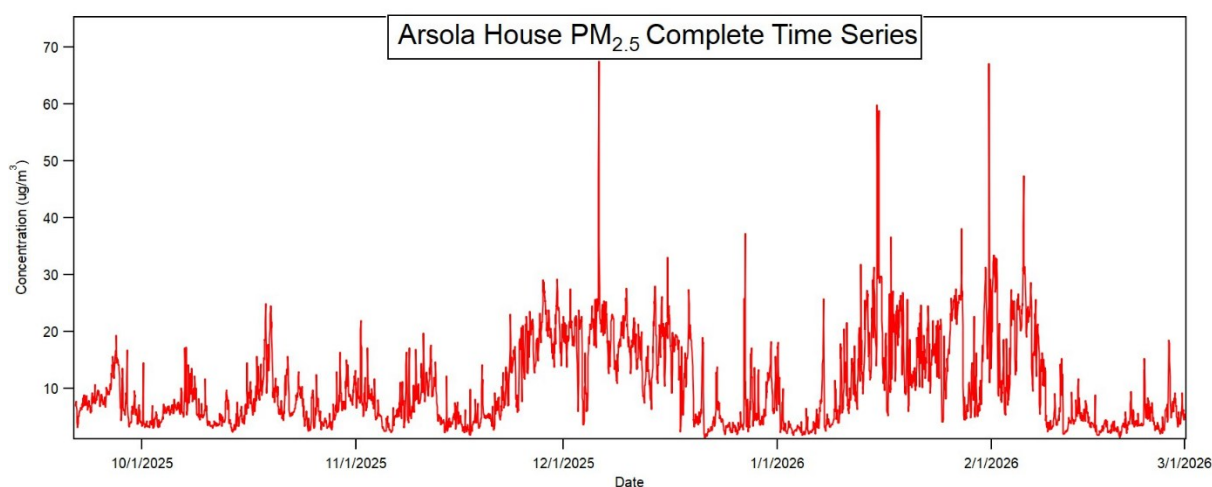


Figure B-6. Time series for Arsola's House during sampling from September 19, 2025, to February 28, 2026.

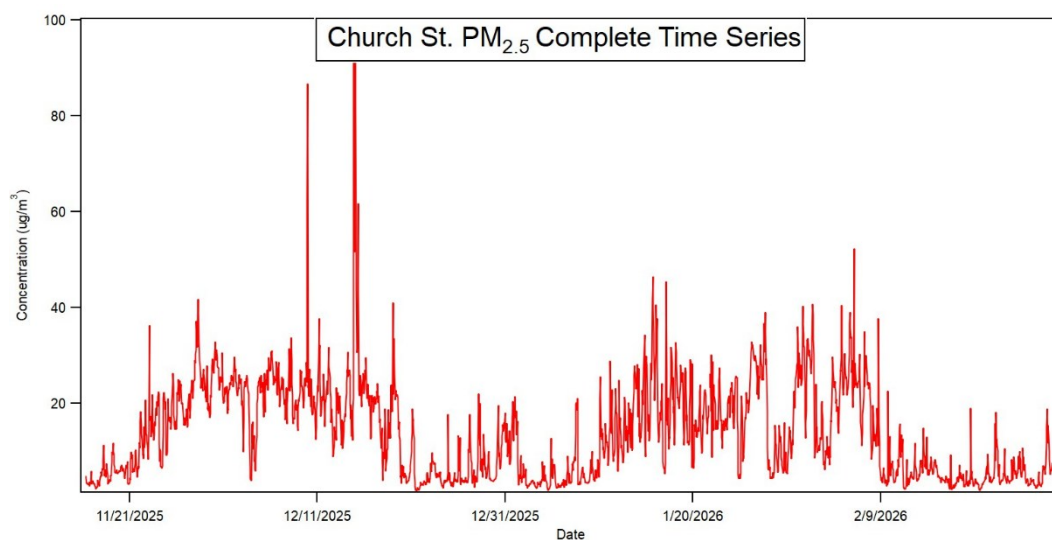


Figure B-7. Time series for Church Street during sampling from November 12, 2025, to February 28, 2026.

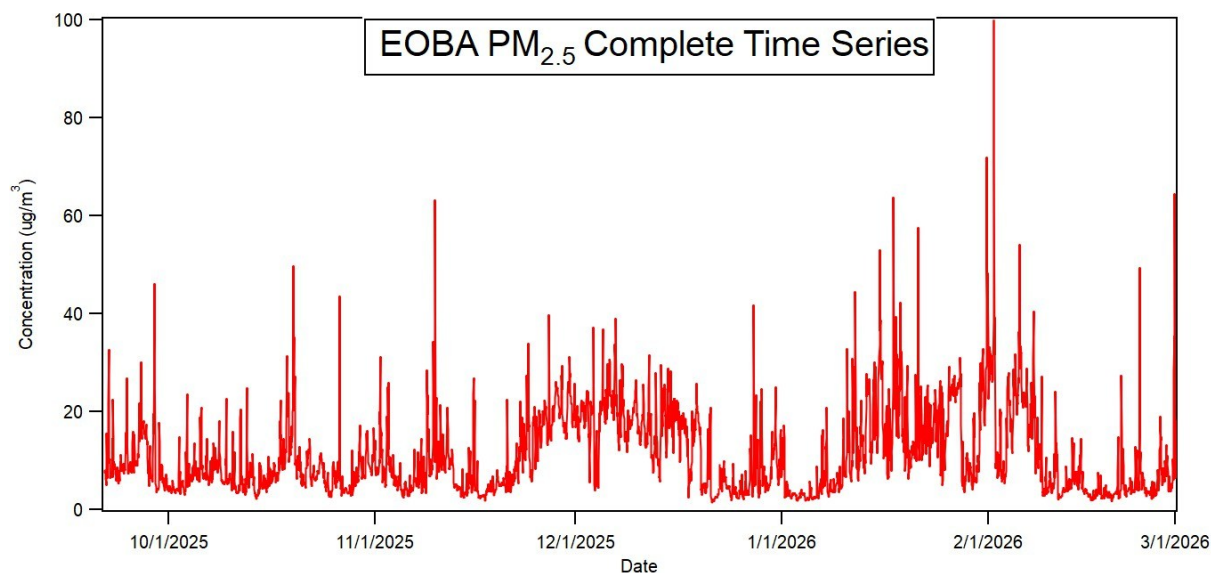


Figure B-8. Time series for EOBA during sampling from September 19, 2025, to February 28, 2026.

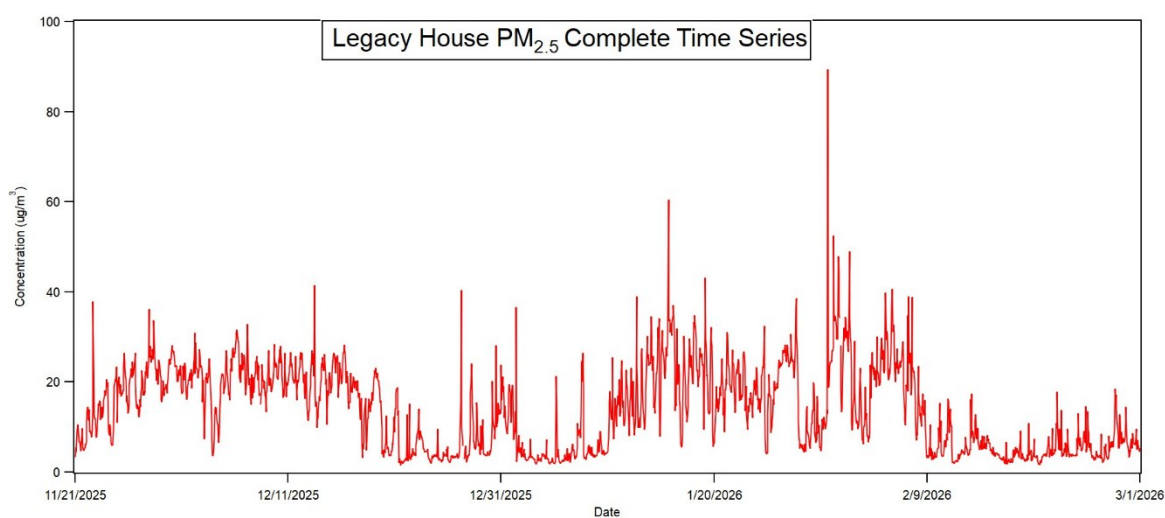


Figure B-9. Time series for Legacy House during sampling from November 12, 2025, to February 28, 2026.

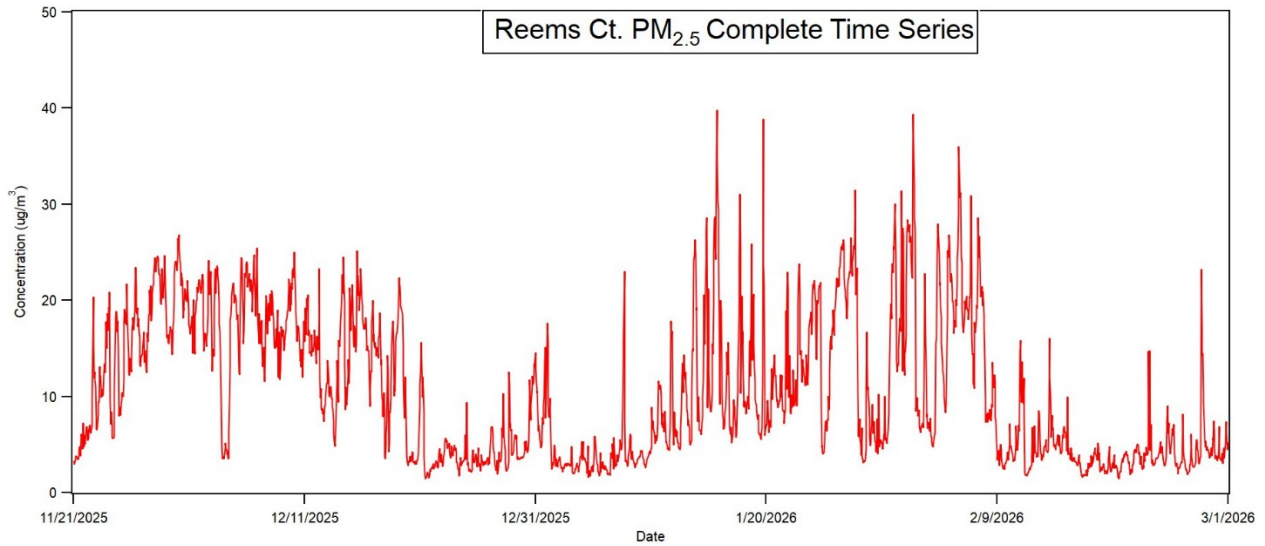


Figure B-10. Time series for Reems Ct. during sampling from September 19, 2025, to February 28, 2026.

8.4 Poorer Air Quality Days

On December 14, 2025, the average daily PM_{2.5} concentration at Church Street was above 35.4 $\mu\text{g}/\text{m}^3$, resulting in “Unhealthy for Sensitive Groups” air quality on the AQI scale. This event was likely caused by a localized event, such as cooking or a barbeque; such food-related events have been reported at this residential location. [Figure B-11](#) shows the time series at Church Street, including the concentration spike.

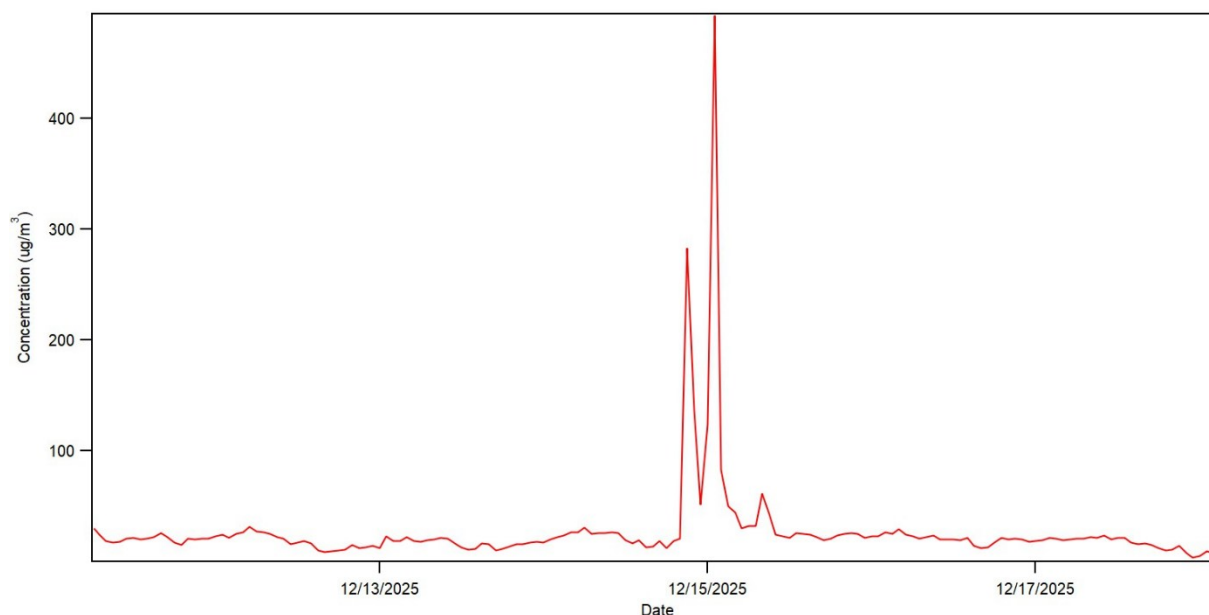


Figure B-11. Time series of Church Street hourly averaged data of PM_{2.5} from December 12, 2025, to December 18, 2025.

8.5 PM_{2.5} Seasonal Trends

8.5.1 Seasonal Diurnal Trends

Each site also had seasonal variations due to shifting meteorological conditions influencing the impact of various local sources. Seasonal polar plots also show that PM_{2.5} sources change during the winter and become more localized as winds slow down and shift ([Figure B-12](#)).

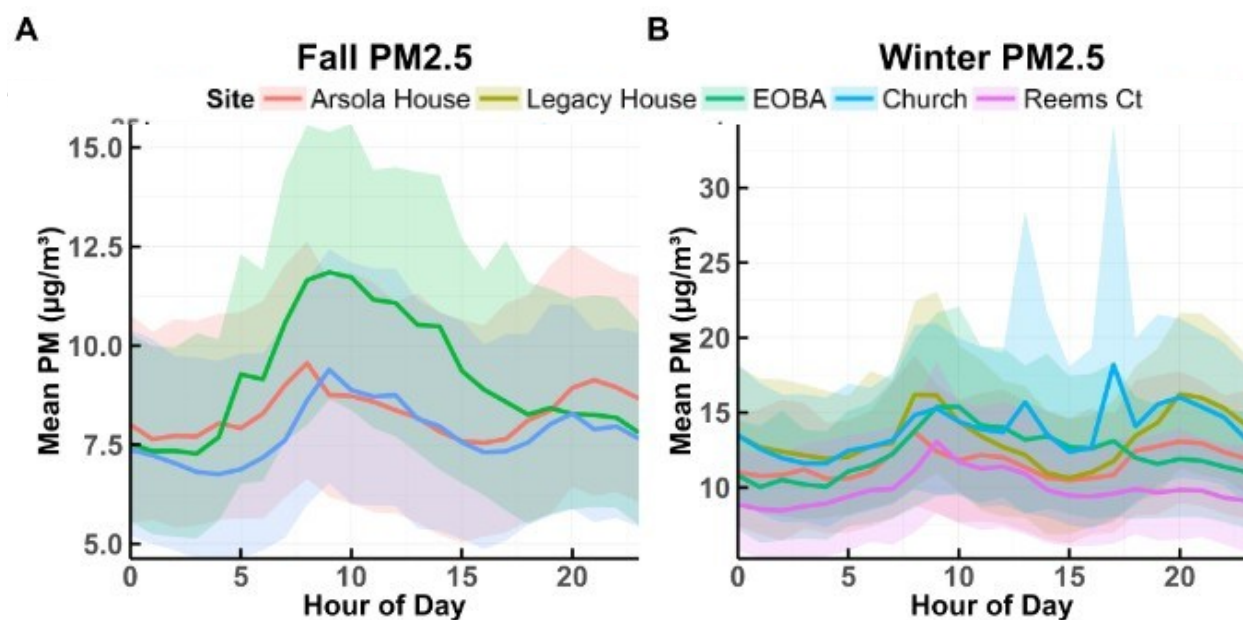


Figure B-12. Diurnal profiles of PM_{2.5} for each site during each season. A) Fall (September – November), B) winter (December – February). Legacy House and Church Street did not meet the completeness threshold for fall.

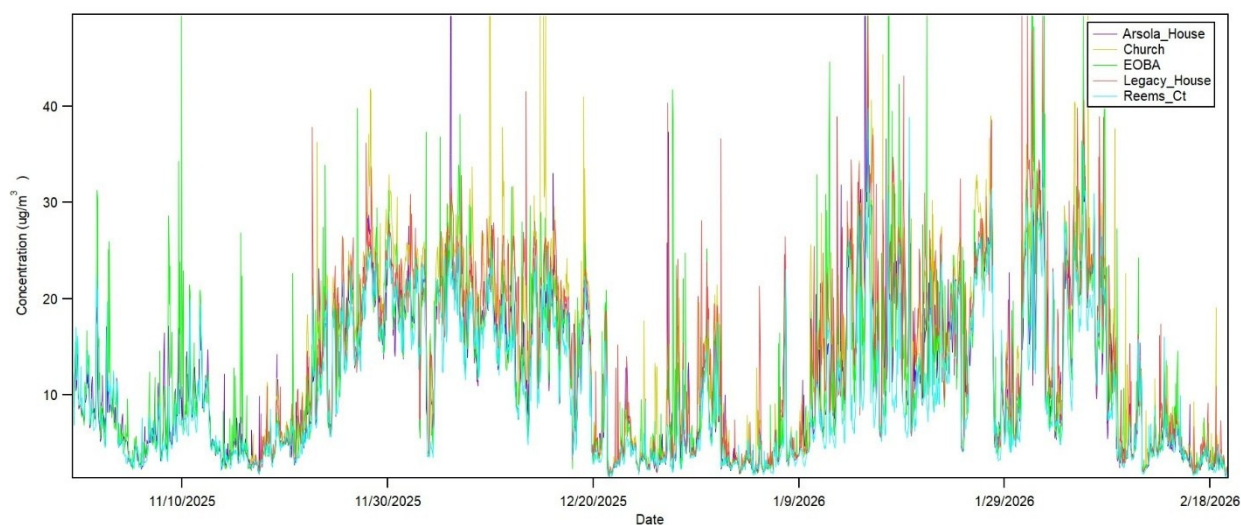


Figure B-13. Time series of PM_{2.5} for each site from November 9, 2025, to February 18, 2026. Baseline concentrations elevated at all sites from late November until mid-December. Baseline concentrations returned to normal levels before elevating again in mid-January and February.

Each site's seasonal diurnal plots are shown below; these plots provide a more detailed look at how PM_{2.5} varied across seasons.

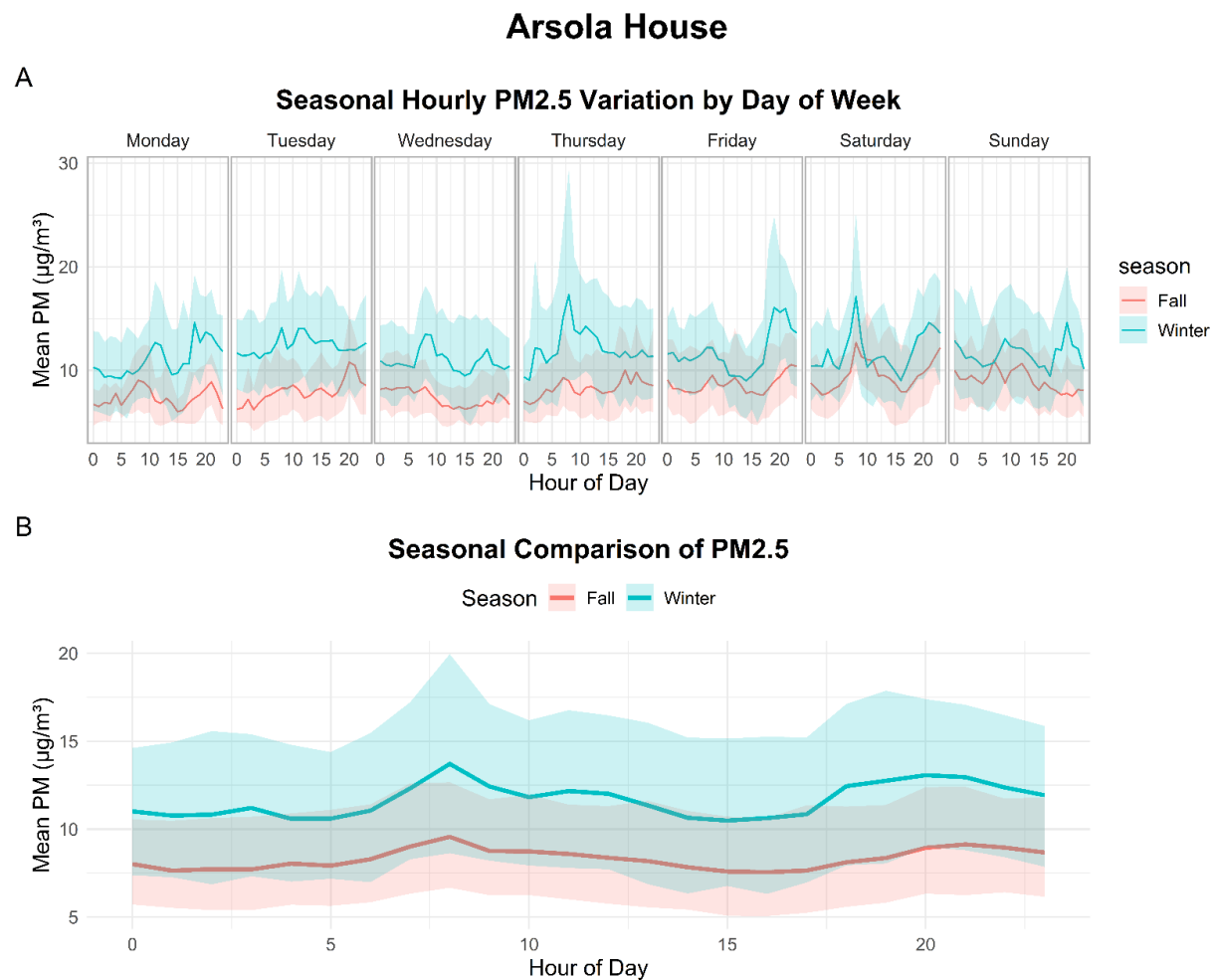


Figure B-14. Hourly and day-of-the-week diurnal profiles for Arsola's House during the sampling period, separated by season: fall (September – November) and winter (December – February).

Church

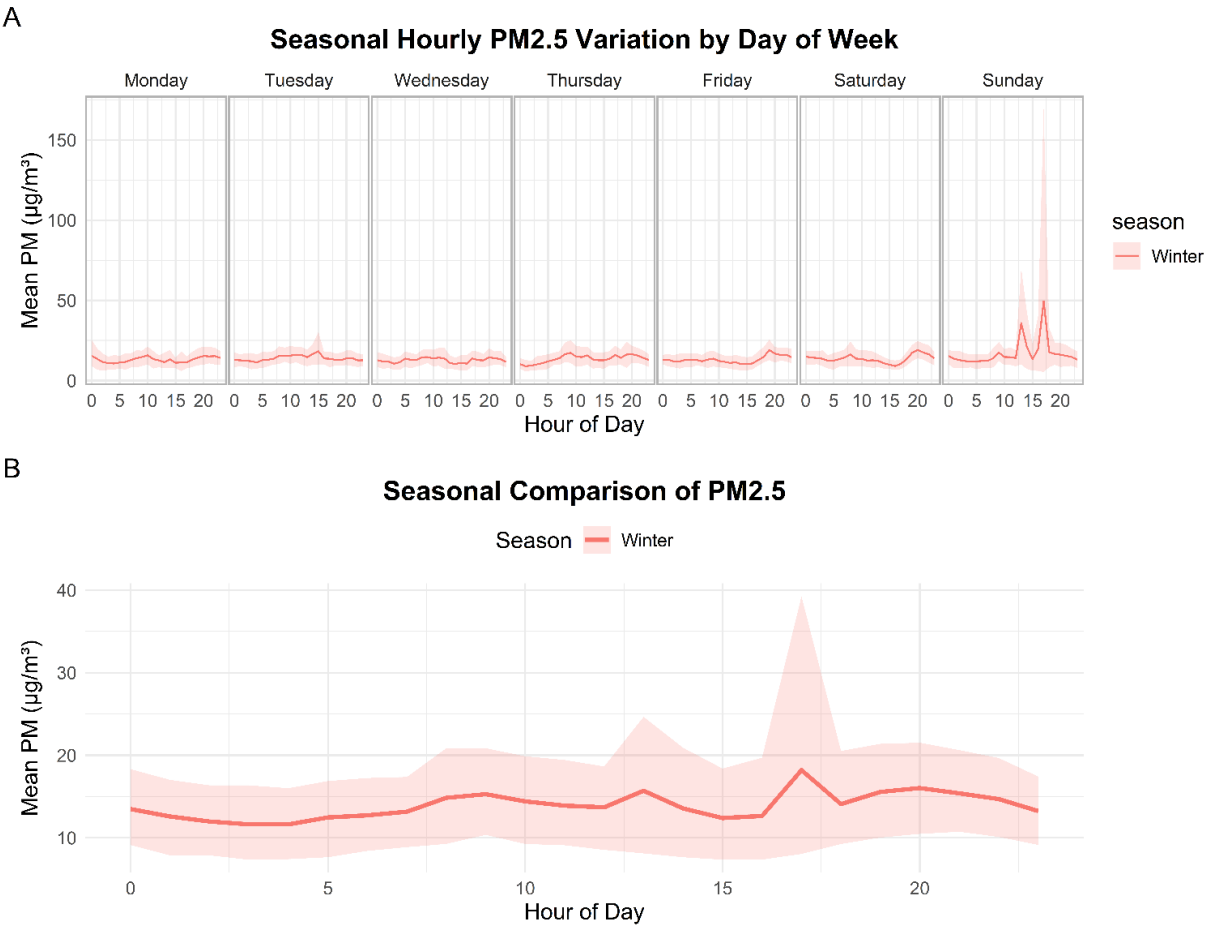
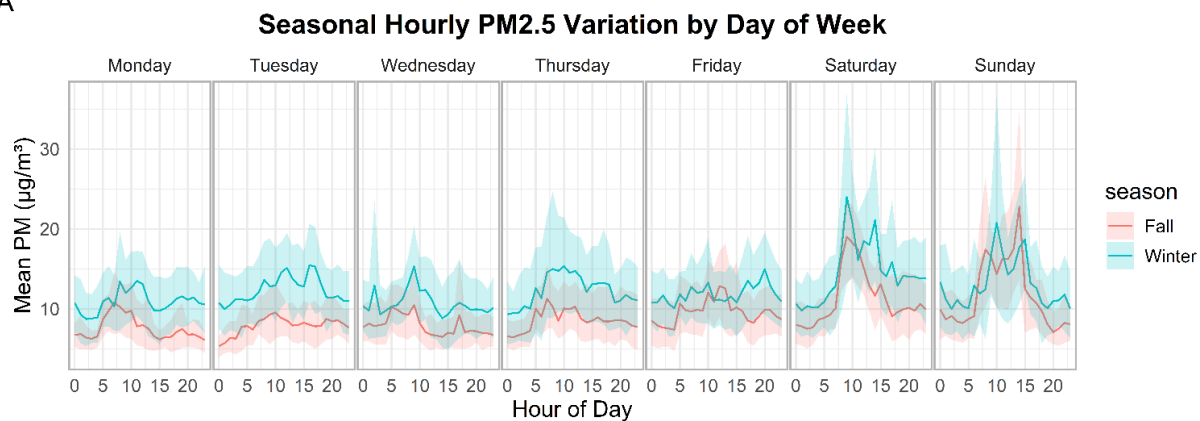


Figure B-15. Hourly and day-of-the-week diurnal profiles for Church Street during the sampling period, separated by season. This site only had sufficient data for winter (December – February).

EOBA

A



B

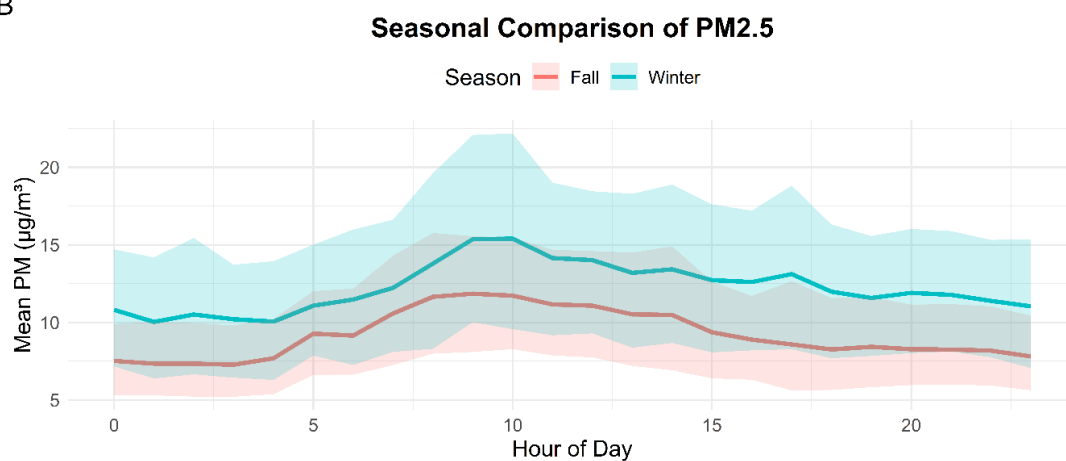
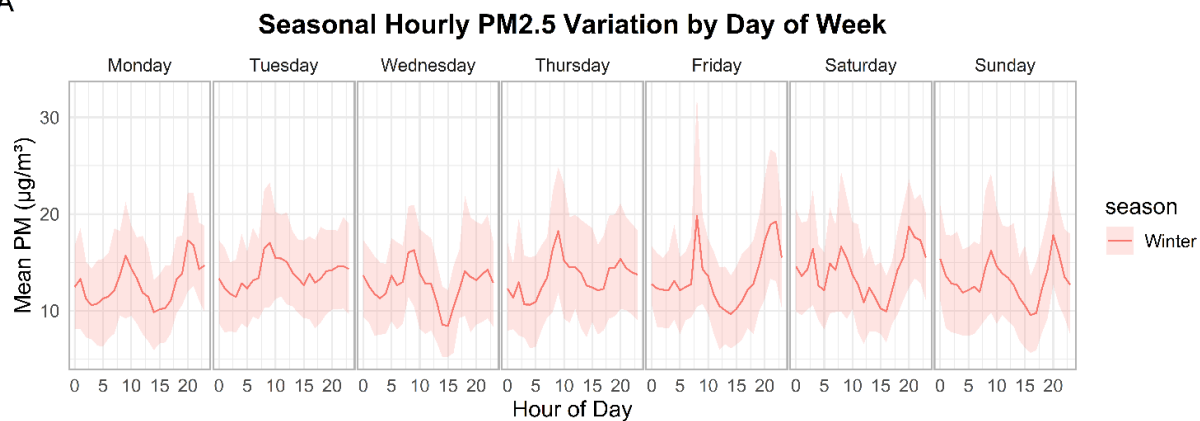


Figure B-16. Hourly and day-of-the-week diurnal profiles for EOBA during the sampling period, separated by season: fall (September – November) and winter (December – February).

Legacy House

A



B

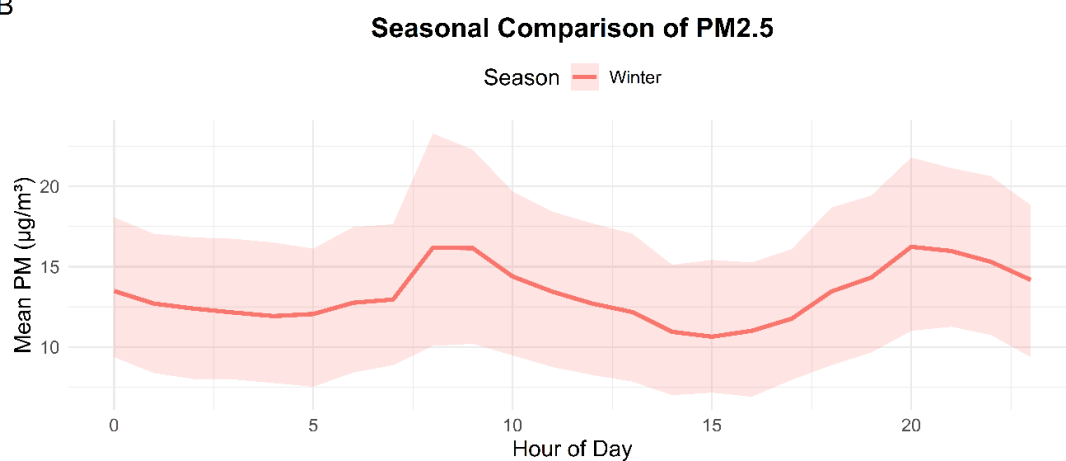
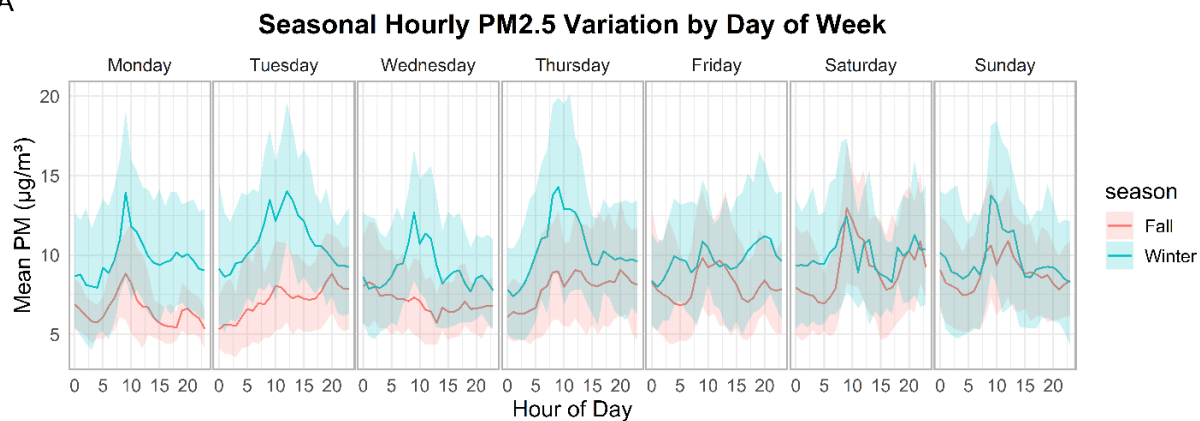


Figure B-17. Hourly and day-of-the-week diurnal profiles for Legacy House during the sampling period, separated by season. The site only had sufficient data for winter (December – February).

Reems Ct

A



B

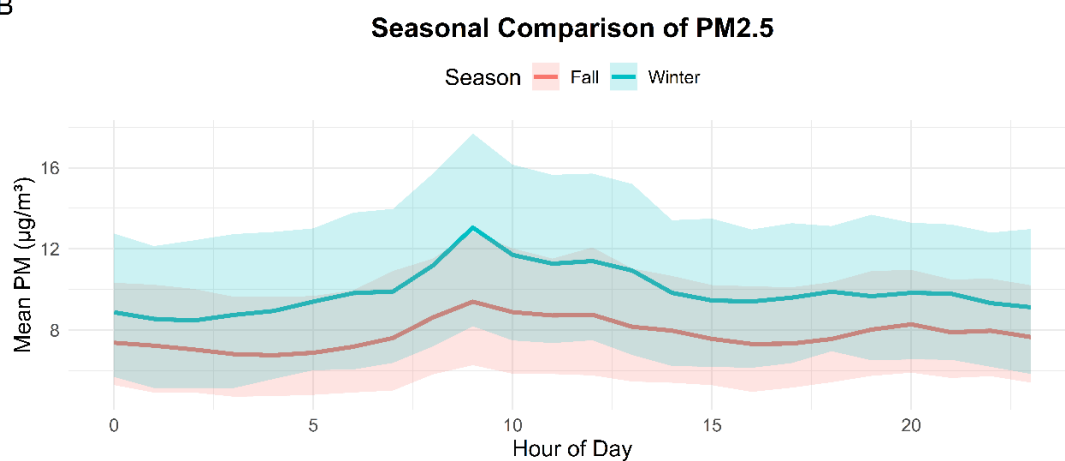


Figure B-18. Hourly and day-of-the-week diurnal profiles for Reems Court during the sampling period, separated by season: fall (September – November), winter (December – February).

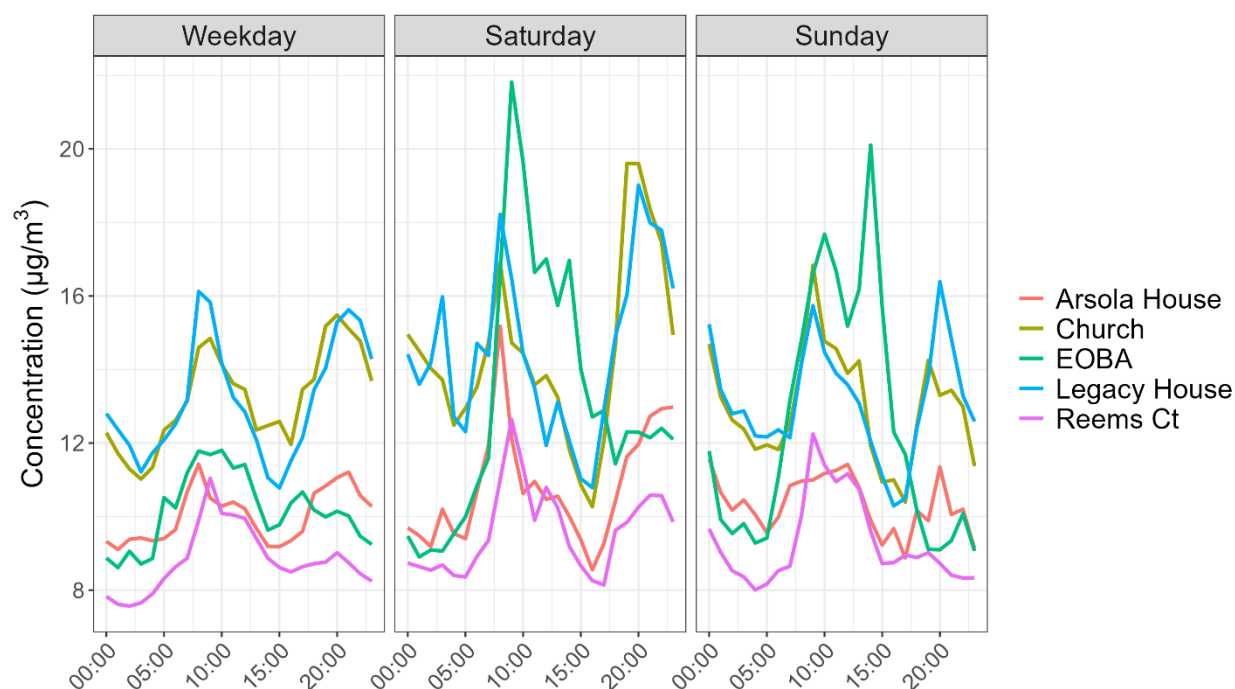


Figure B-19. PM_{2.5} diurnal concentrations separated by weekdays, Saturdays, and Sundays.

8.6 Local/Regional Analysis Details

Analysis of contributions from regional and local sources was completed using an Igor script from "Near-Road Air Pollutant Measurements: Accounting for Inter-Site Variability using Emission Factors" by Wang et al. (2018). The script does "a linear spline interpolation of minima" in 8-hour windows, iterated four times to calculate the regional contributions of sources. The calculated regional concentration was confirmed by plotting the diurnal of the calculated background concentrations to confirm a low or negligible rush hour peak (Figure B-20). The calculated background concentrations were compared with the closest regional background site, Oakland's AQS, using the methods of Wang et. al to confirm the validity of our calculated values. Figure B-20 shows winds originating from 285–30° at the Oakland AQS site that were considered "background." The Oakland AQS background signal traced reasonably for PM_{2.5} when compared with our calculated background concentrations: average concentrations were similar throughout the day, and both signals no longer exhibited diurnal peaks during expected rush hours.

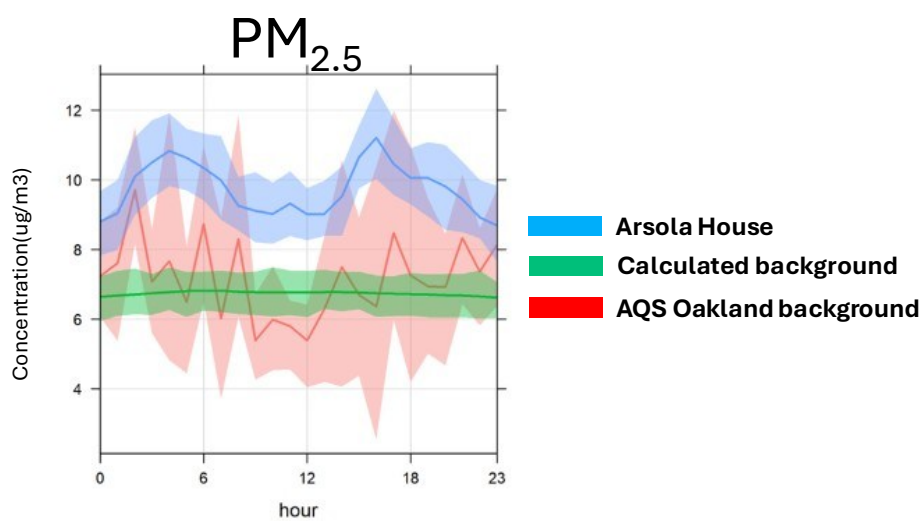


Figure B-20. Diurnal profile plot showing average $PM_{2.5}$ concentrations from the complete Clarity dataset (blue), calculated background (green), and the Oakland AQS site in Oakland (red) from wind directions of 285–300°. The lack of a morning commute peak in the calculated background helped confirm the calculations.

9. Appendix C: VOC Supporting Information

9.1 VOC Box Plots

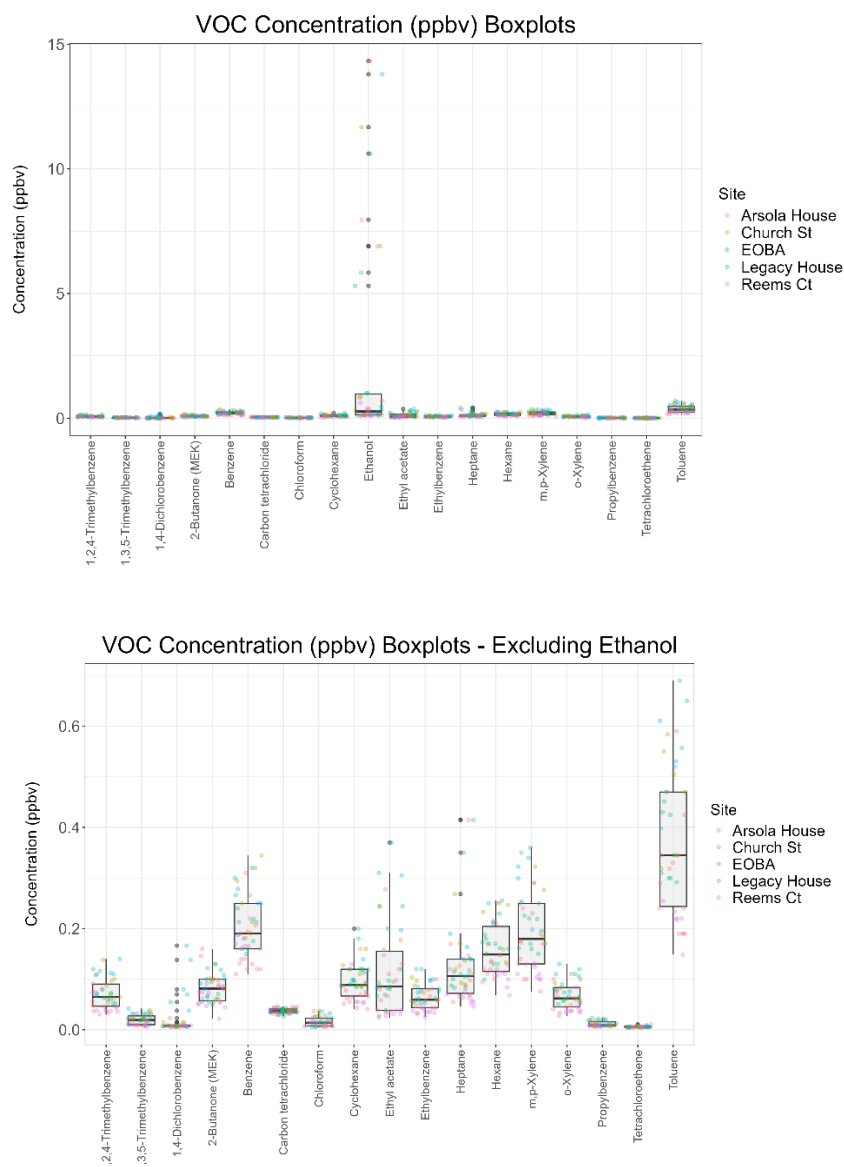


Figure C-1. Box plots of VOC concentrations. The top figure includes all VOC species, particularly ethanol, and clearly depicts the outlier values associated with the ethanol concentration spike on November 26, 2025, and December 10, 2025. The bottom figure includes all species shown in the top figure except for ethanol.

9.2 VOC Correlation Plot

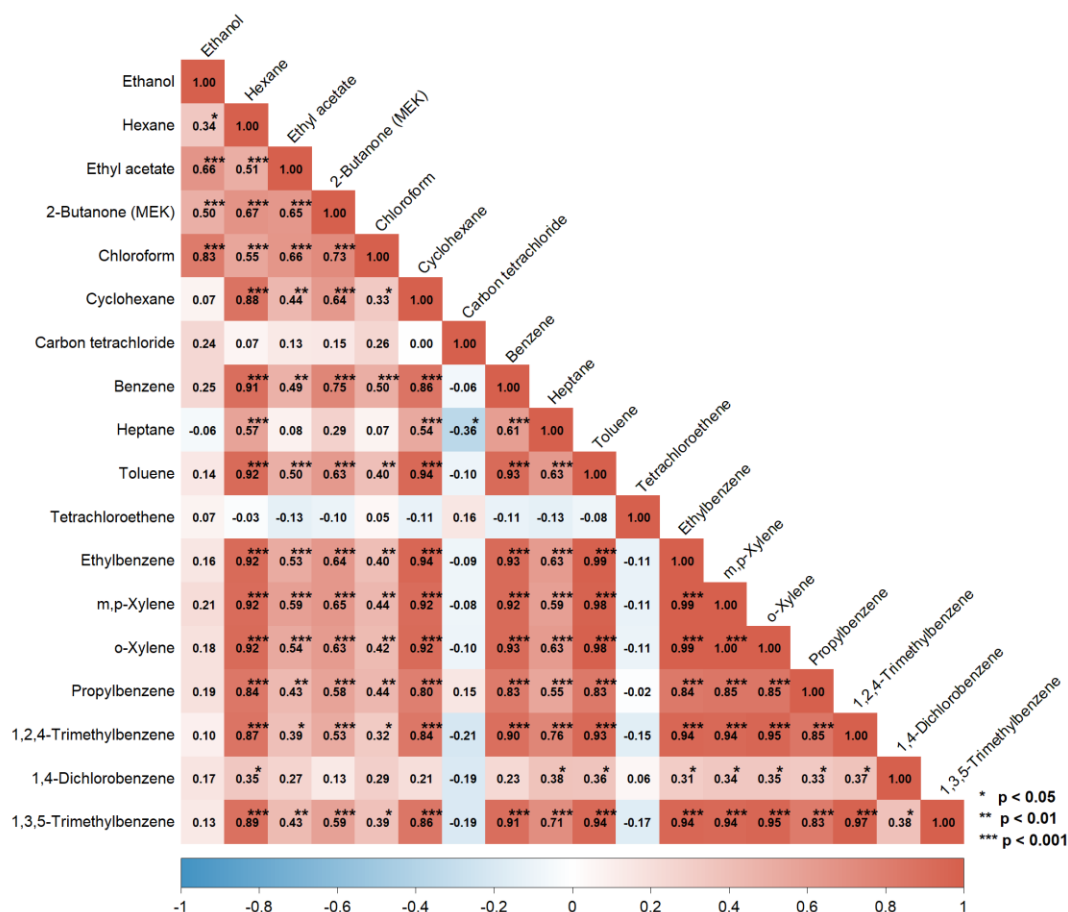


Figure C-2. Correlation matrix of measured VOCs. Cells that are darker red or blue correspond to stronger positive and negative relationships between VOCs, respectively. Statistically significant relationships are denoted by stars in a particular cell, where more stars indicates great significance. Note that tetrachloroethene and 1,4-dichlorobenzene were detected in 26.2% and 11.9% of samples respectively, which may explain their weak relationships with other species.

9.3 Site-Level VOC Time Series

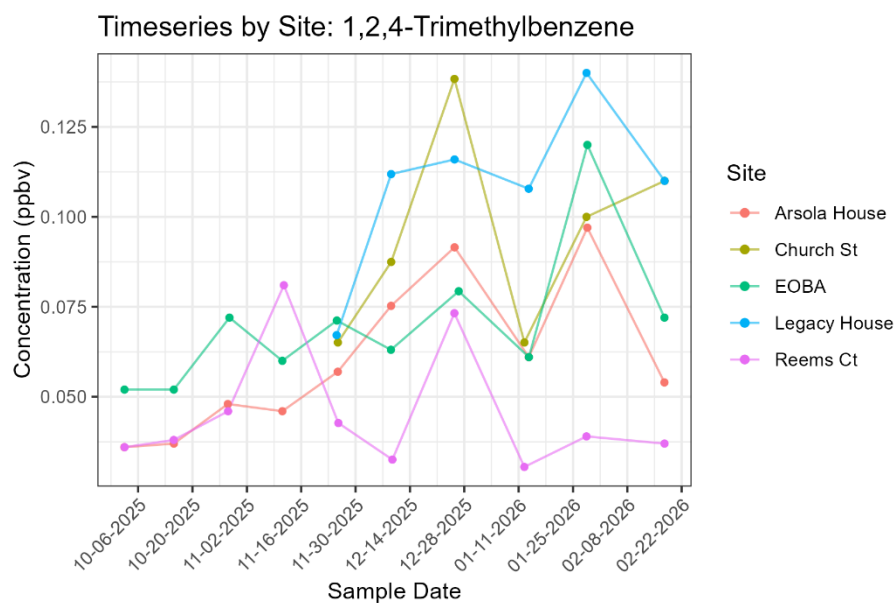


Figure C-3. Time series of 1,2,4-trimethylbenzene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

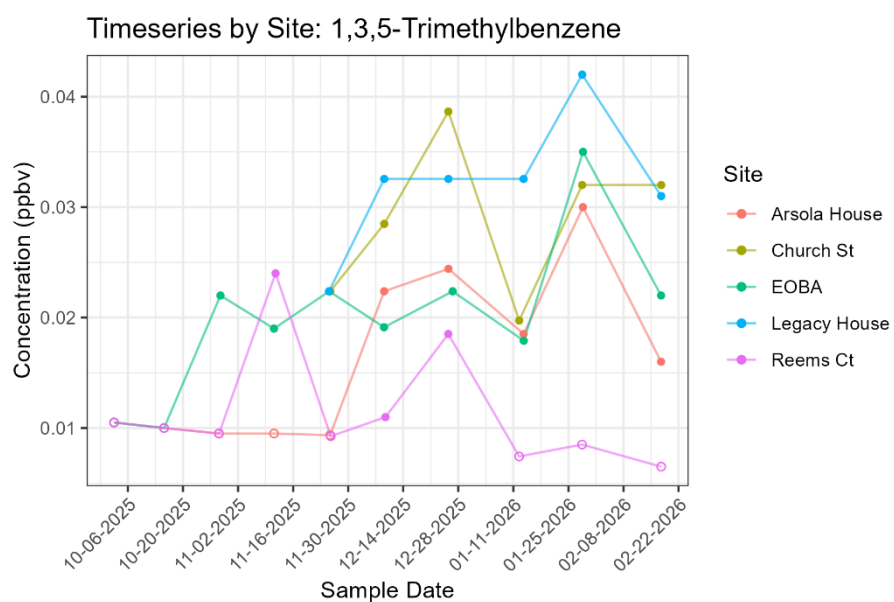


Figure C-4. Time series of 1,3,5-trimethylbenzene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

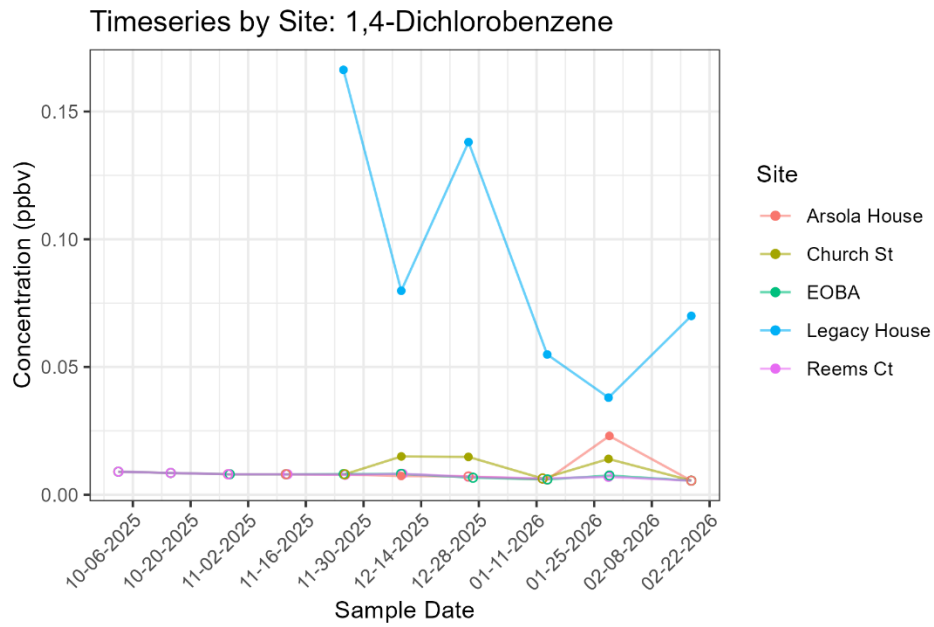


Figure C-5. Time series of 1,4-dichlorobenzene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

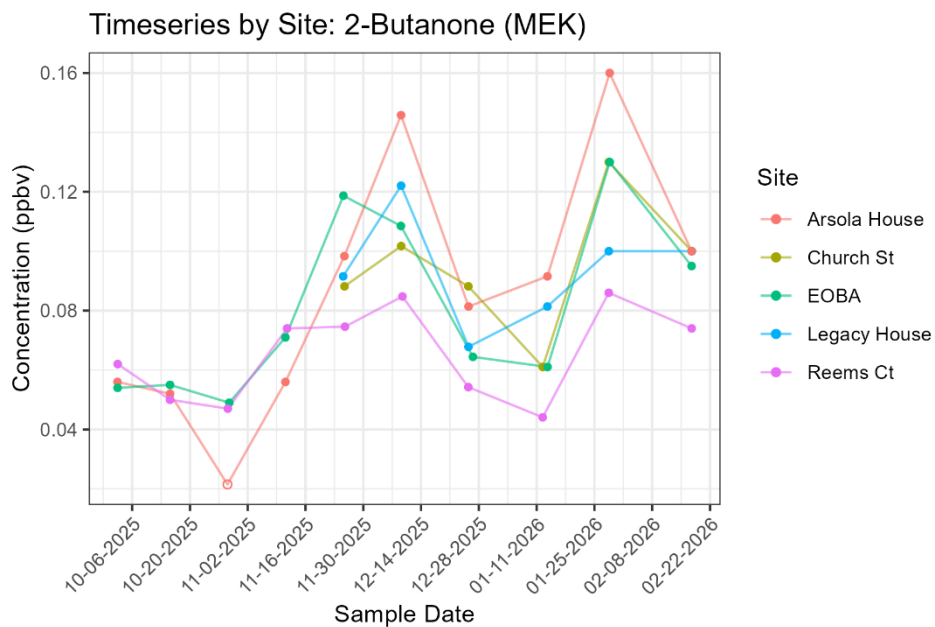


Figure C-6. Time series of 2-butanone (methyl ethyl ketone) concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

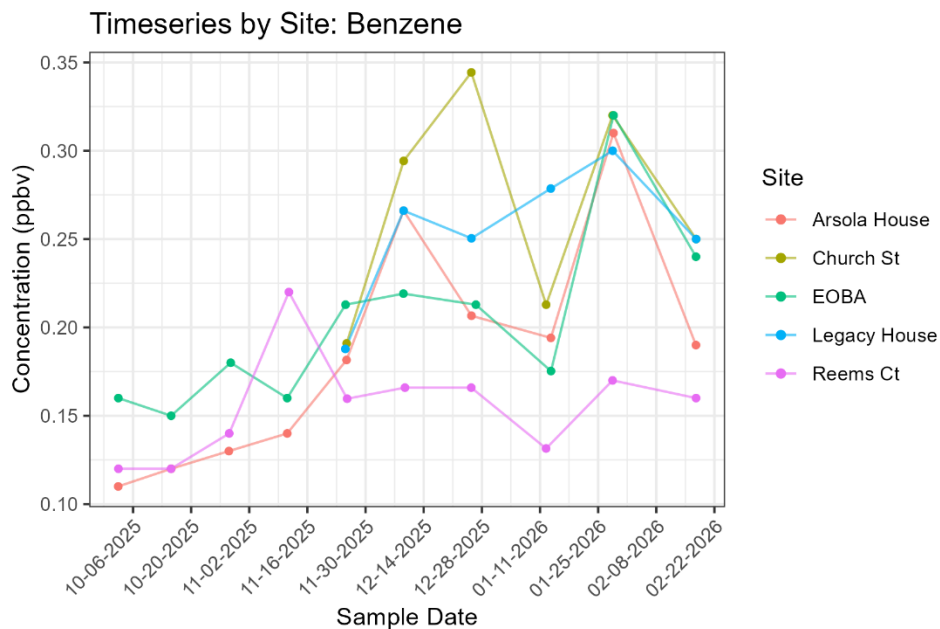


Figure C-7. Time series of benzene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

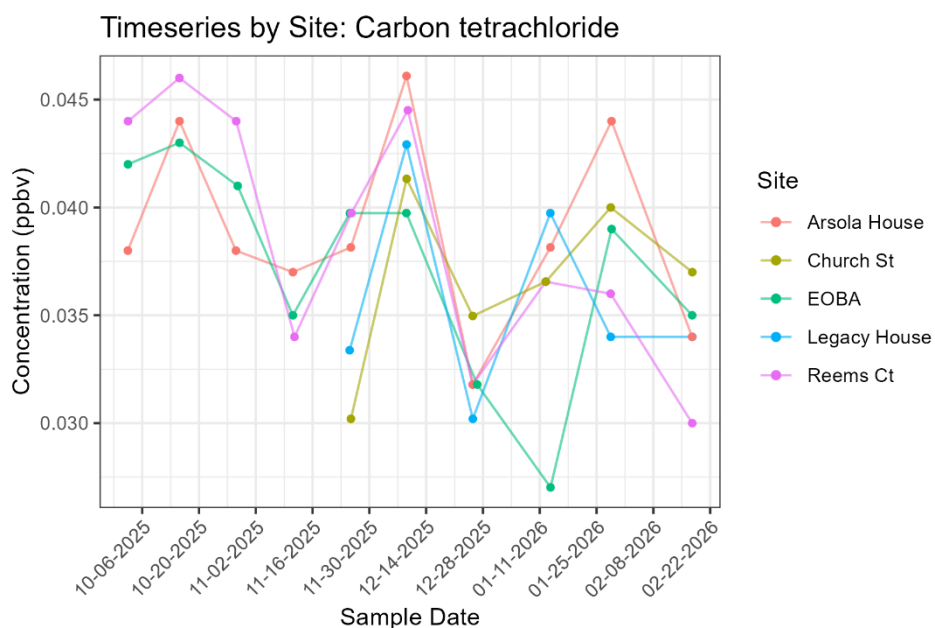


Figure C-8. Time series of carbon tetrachloride concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

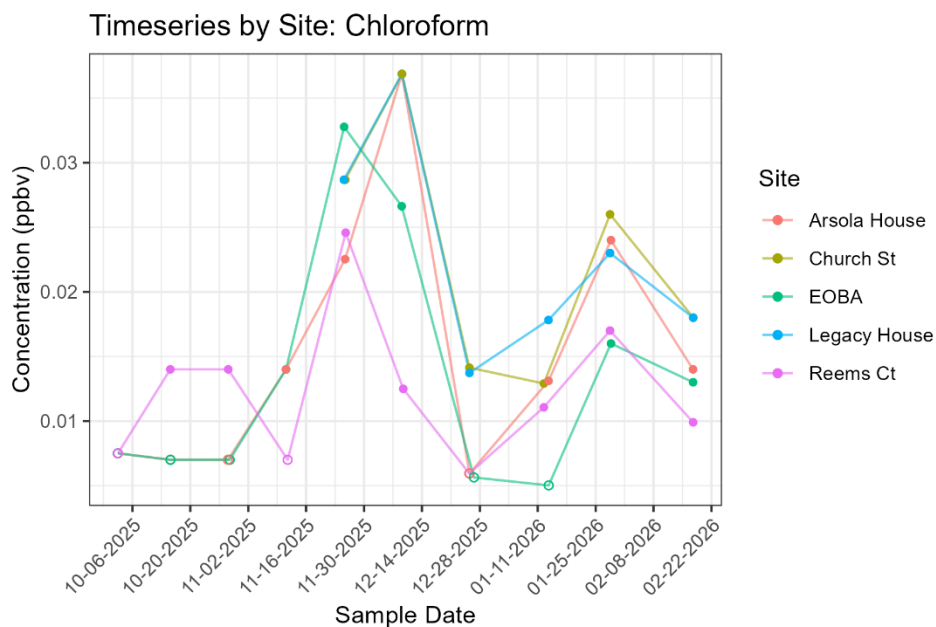


Figure C-9. Time series of chloroform concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

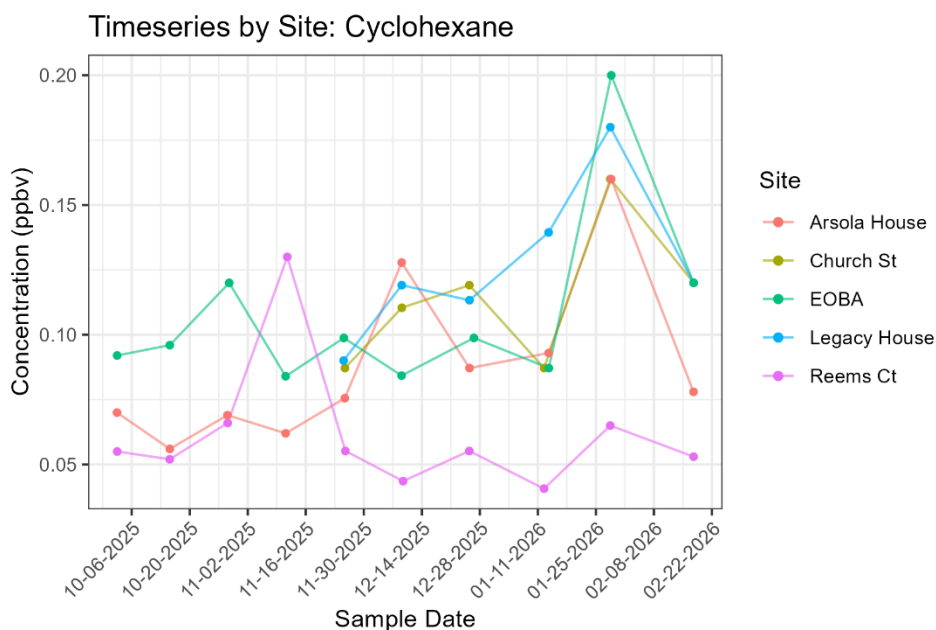


Figure C-10. Time series of cyclohexane concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

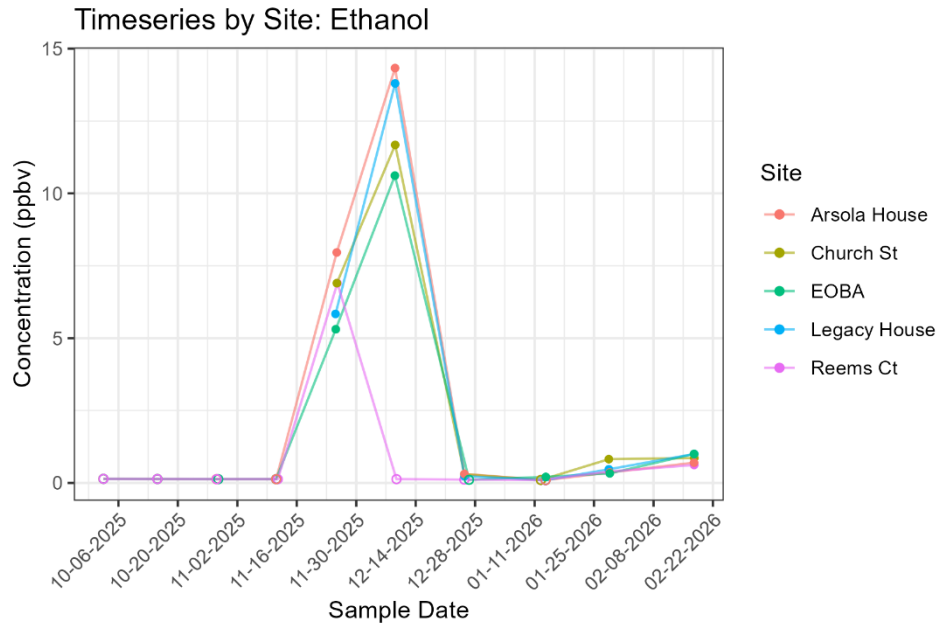


Figure C-11. Time series of ethanol concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

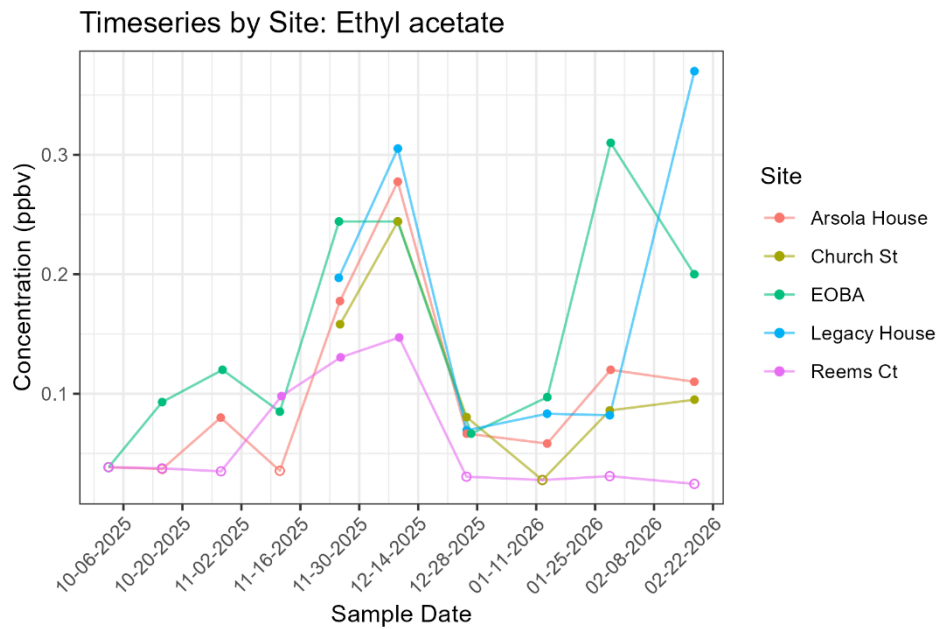


Figure C-12. Time series of ethyl acetate concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

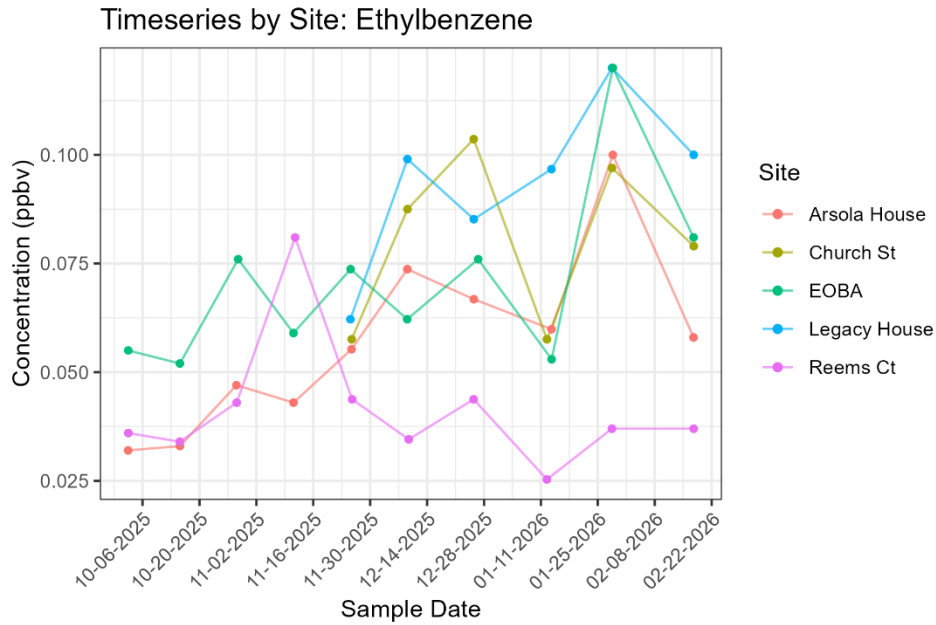


Figure C-13. Time series of ethylbenzene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

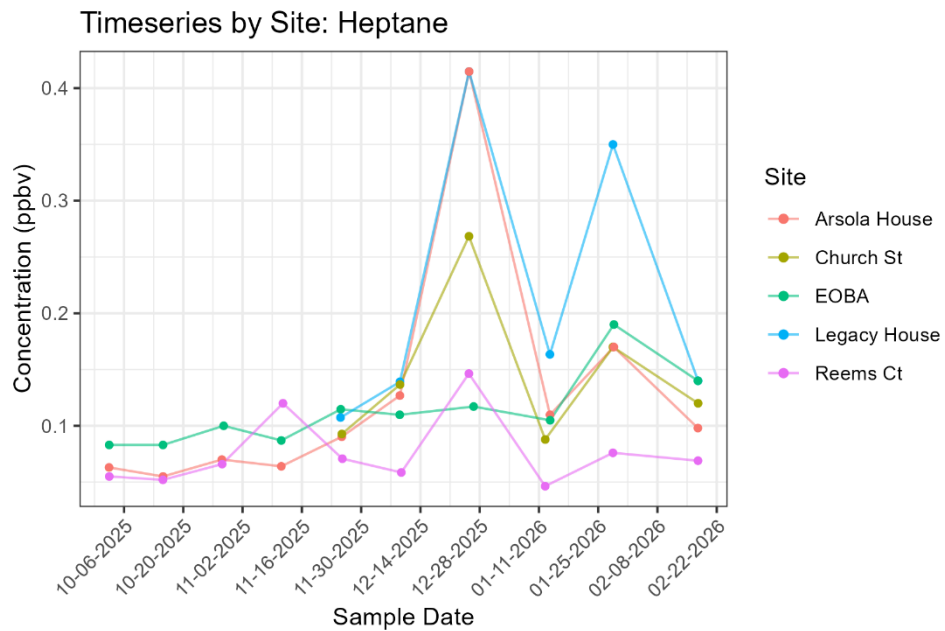


Figure C-14. Time series of heptane concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

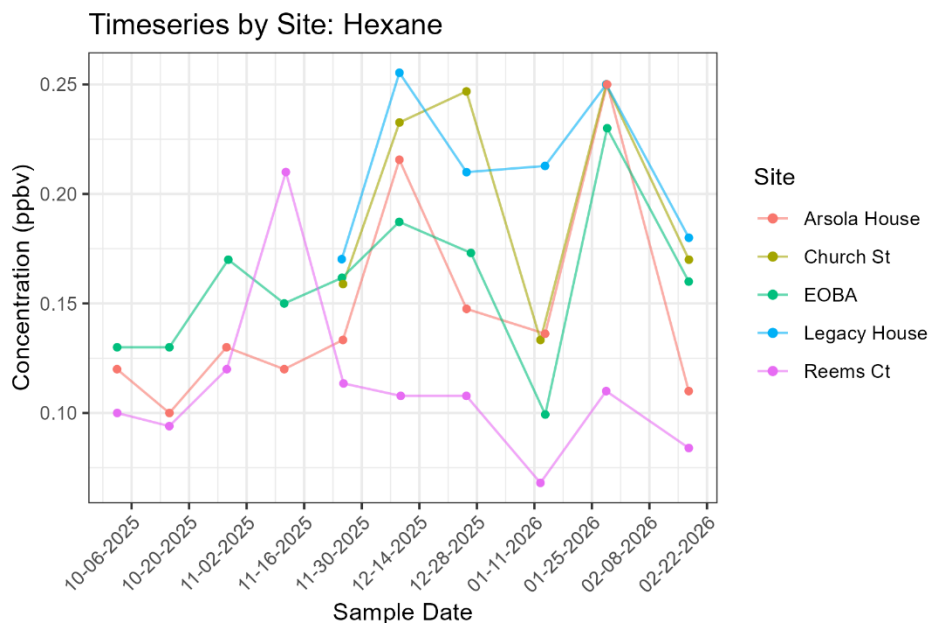


Figure C-15. Time series of hexane concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

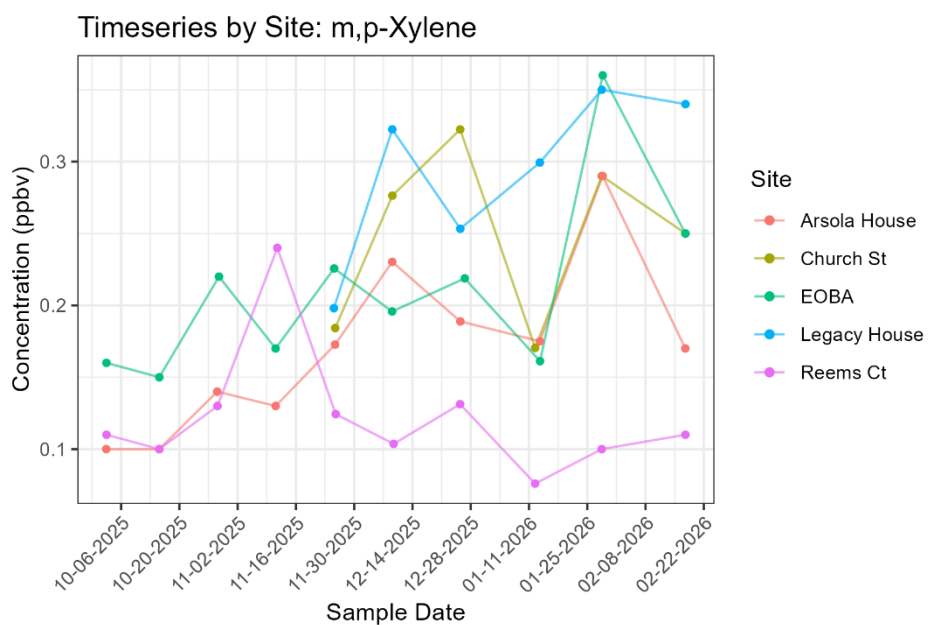


Figure C-16. Time series of m,p-xylene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

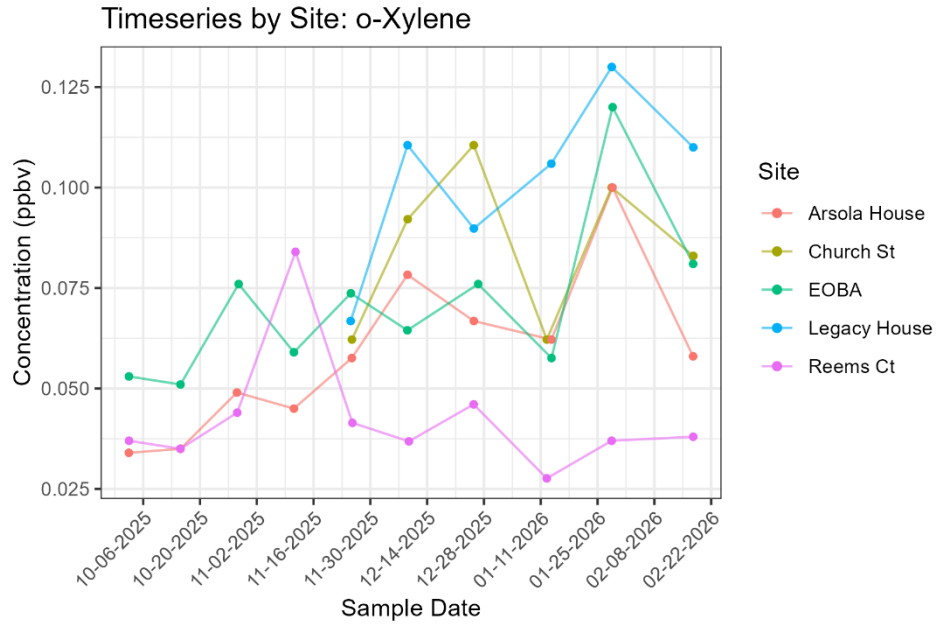


Figure C-17. Time series of o-xylene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

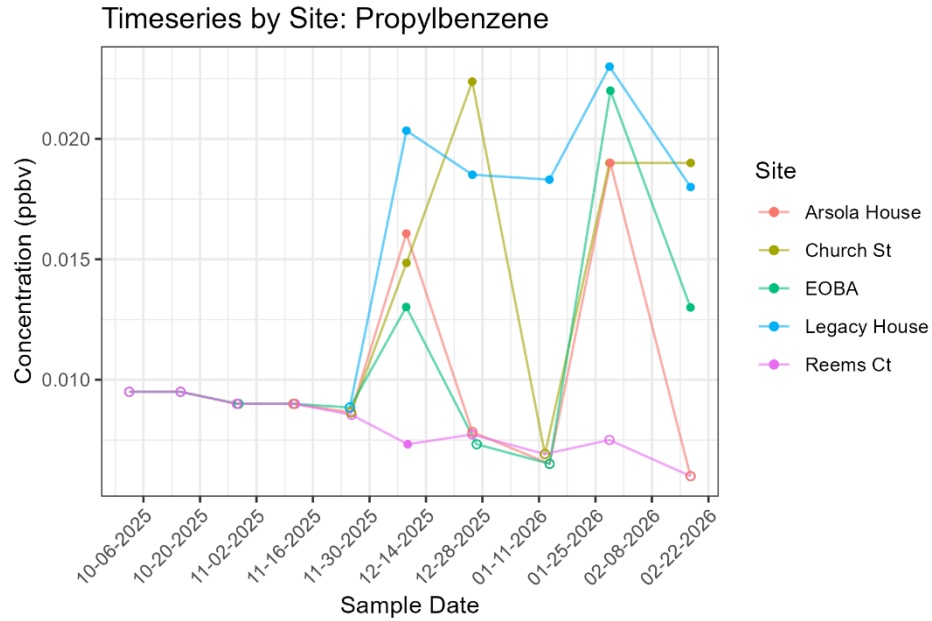


Figure C-18. Time series of propylbenzene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

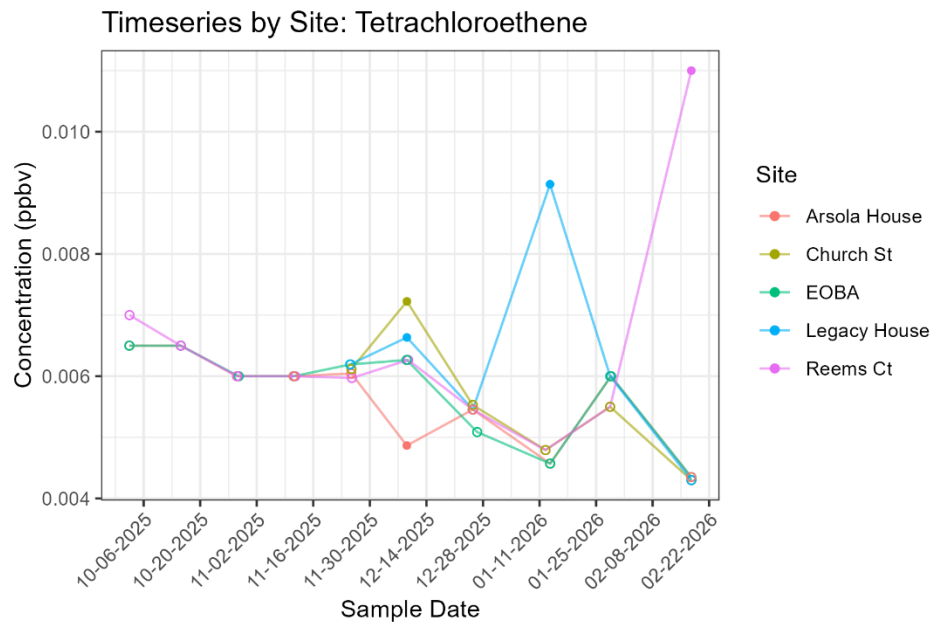


Figure C-19. Time series of tetrachloroethene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

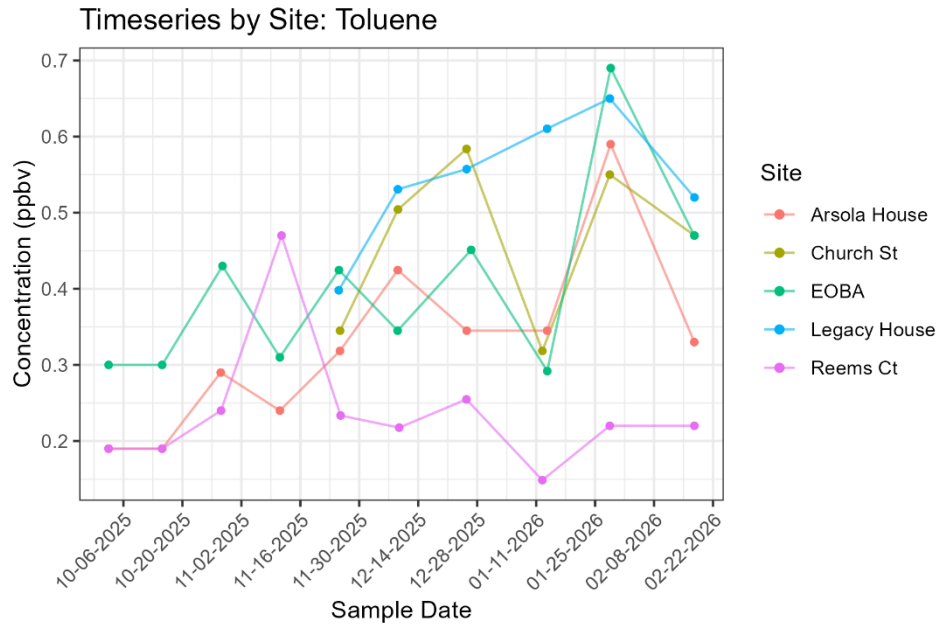


Figure C-20. Time series of toluene concentration at each site from the VOC analysis. Solid points indicate the VOC was detected, and hollow points indicate the VOC was below detection for a particular sample.

9.4 Average VOC Time Series

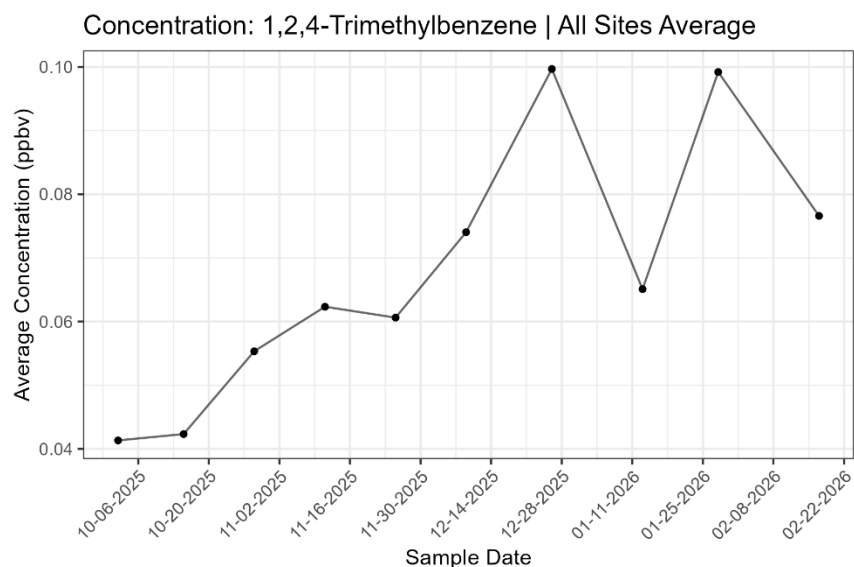


Figure C-21. Time series of average 1,2,4-trimethylbenzene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

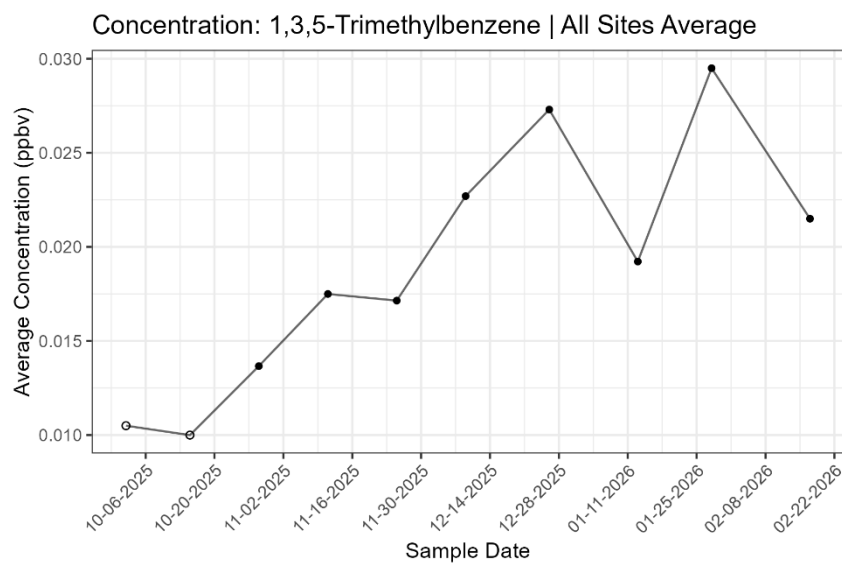


Figure C-22. Time series of average 1,3,5-trimethylbenzene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

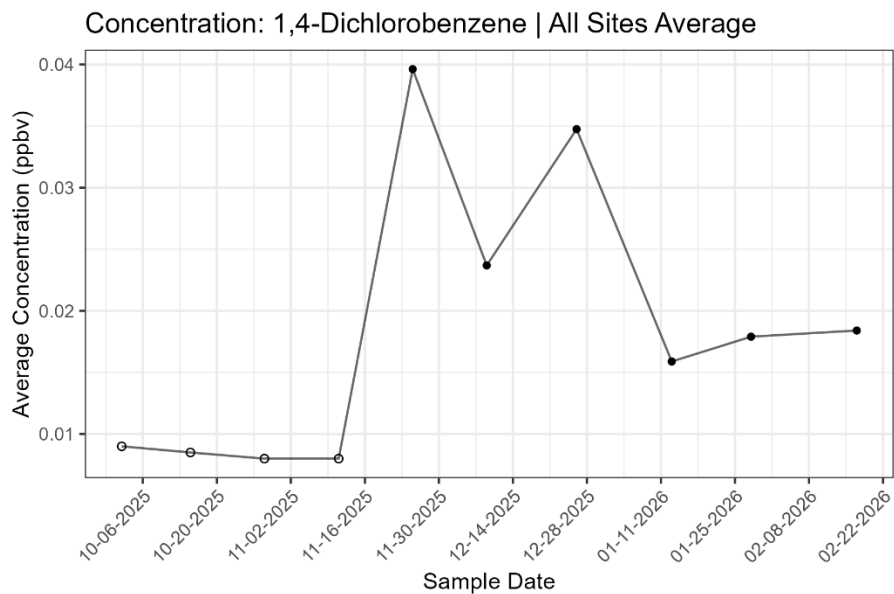


Figure C-23. Time series of average 1,4-dichlorobenzene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

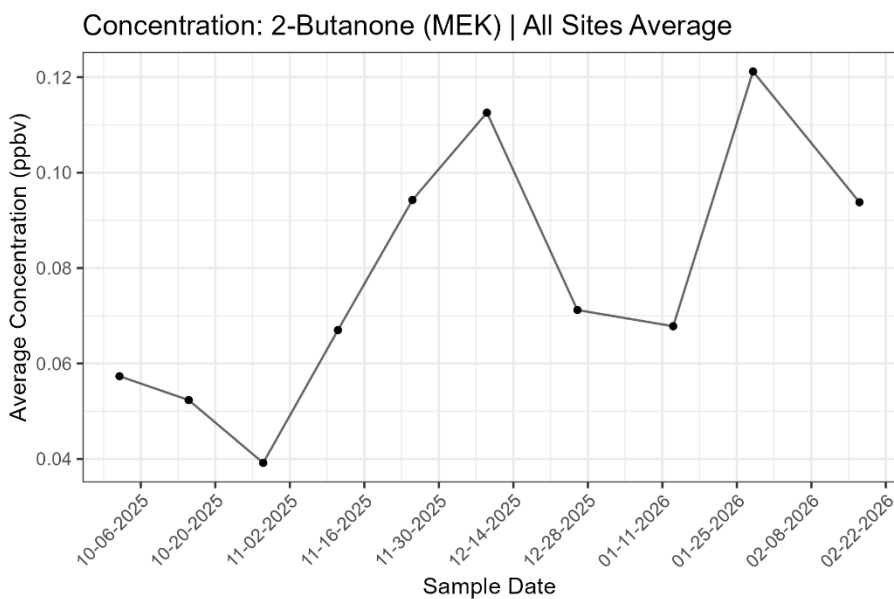


Figure C-24. Time series of average 2-butanone (methyl ethyl ketone) concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

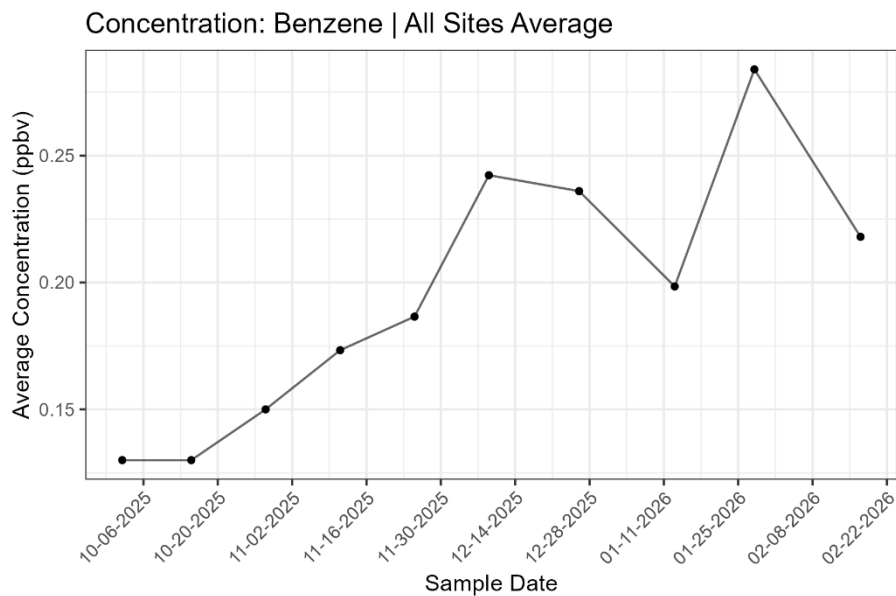


Figure C-25. Time series of average benzene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

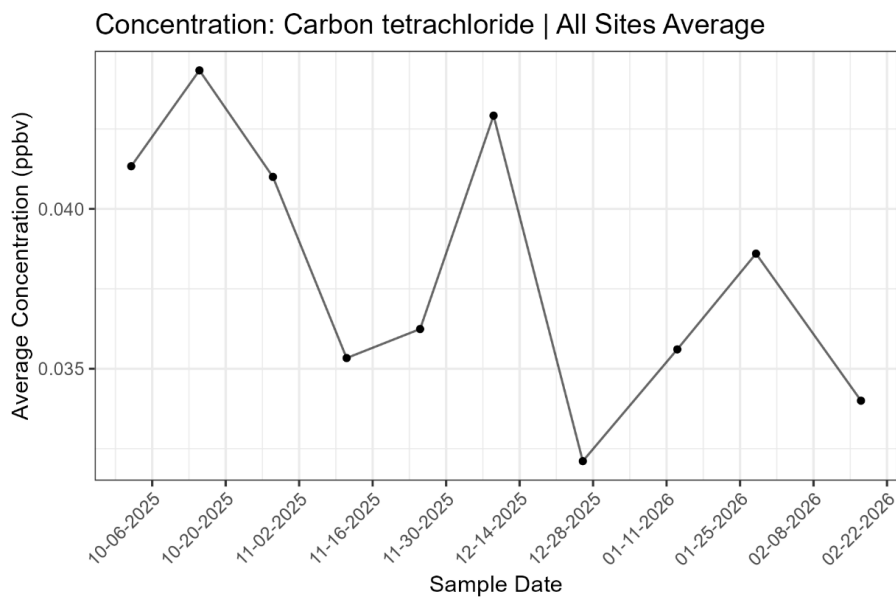


Figure C-26. Time series of average carbon tetrachloride concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

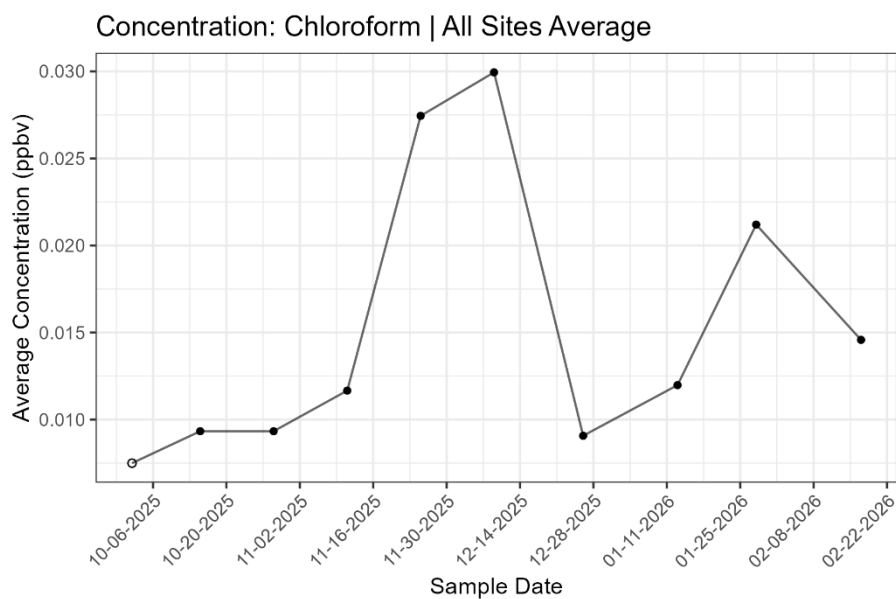


Figure C-27. Time series of average chloroform concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

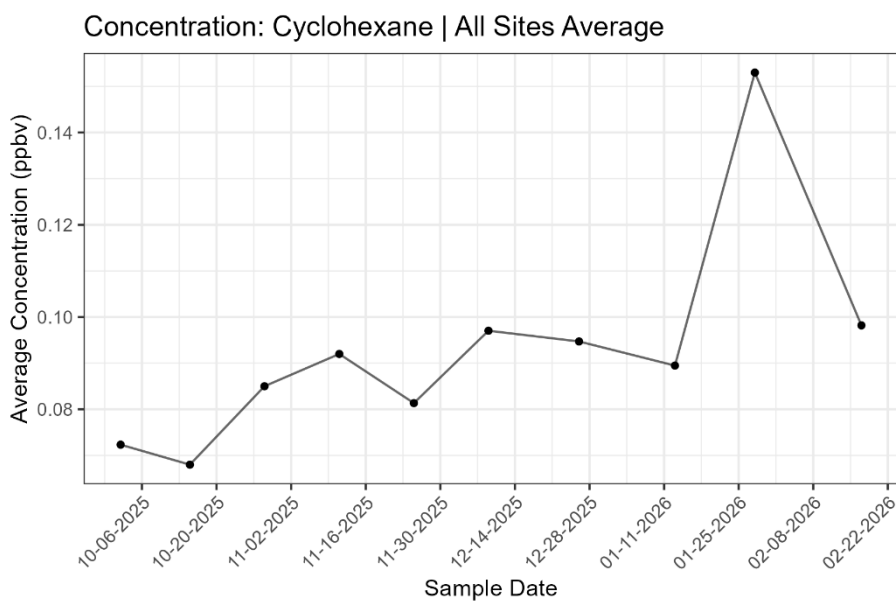


Figure C-28. Time series of average cyclohexane concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

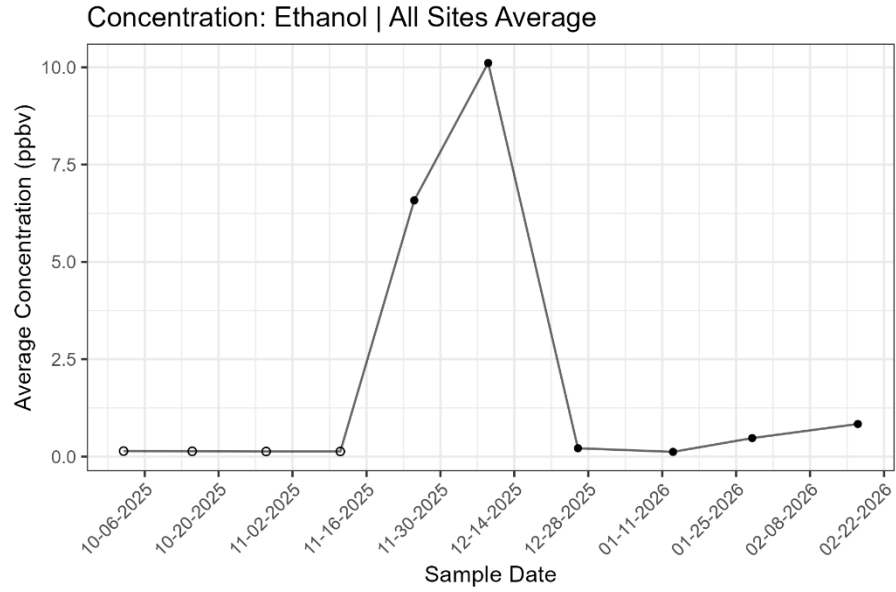


Figure C-29. Time series of average ethanol concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

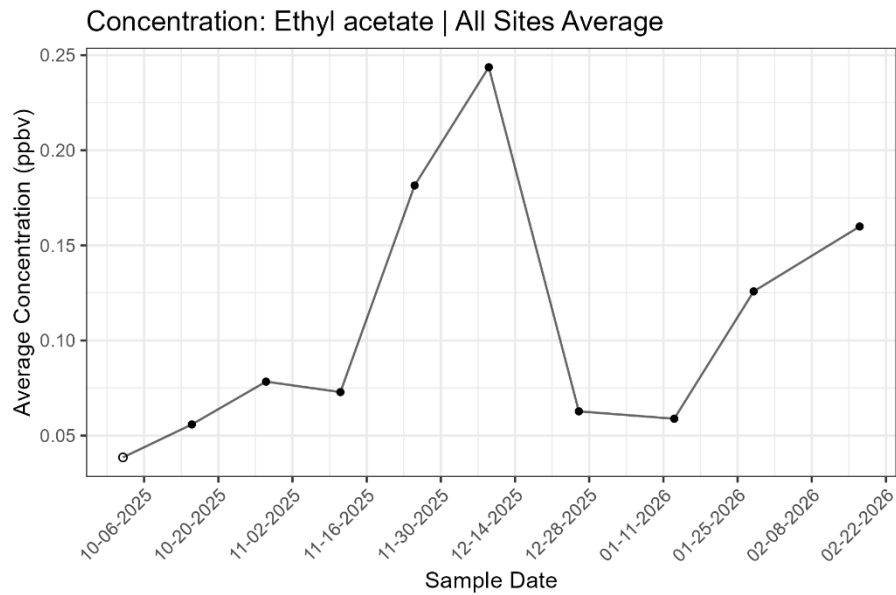


Figure C-30. Time series of average ethyl acetate concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

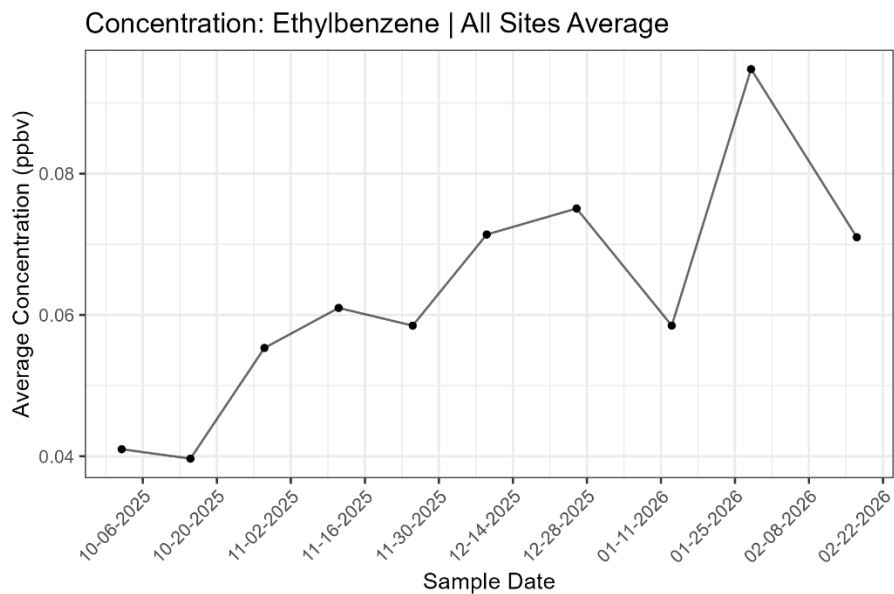


Figure C-31. Time series of average ethylbenzene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

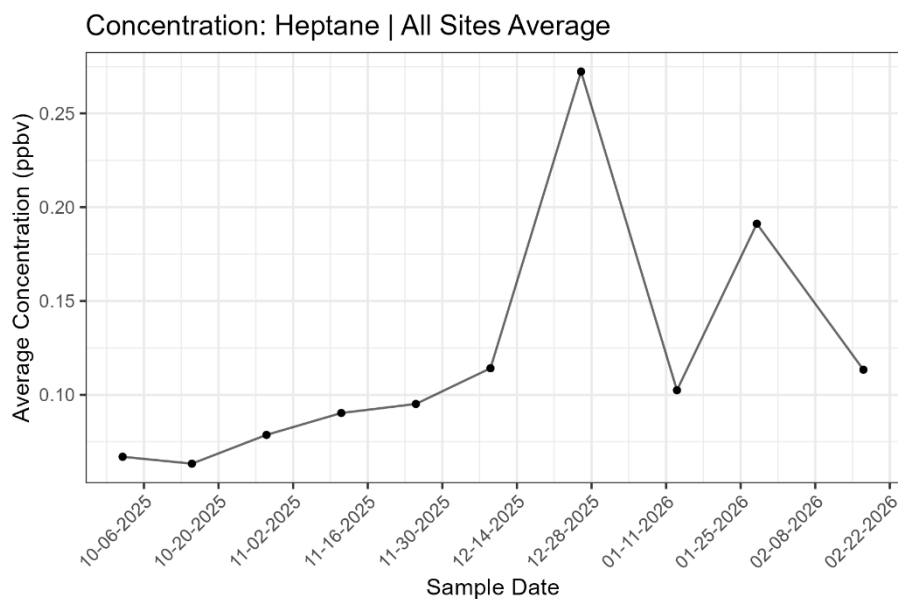


Figure C-32. Time series of average heptane concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

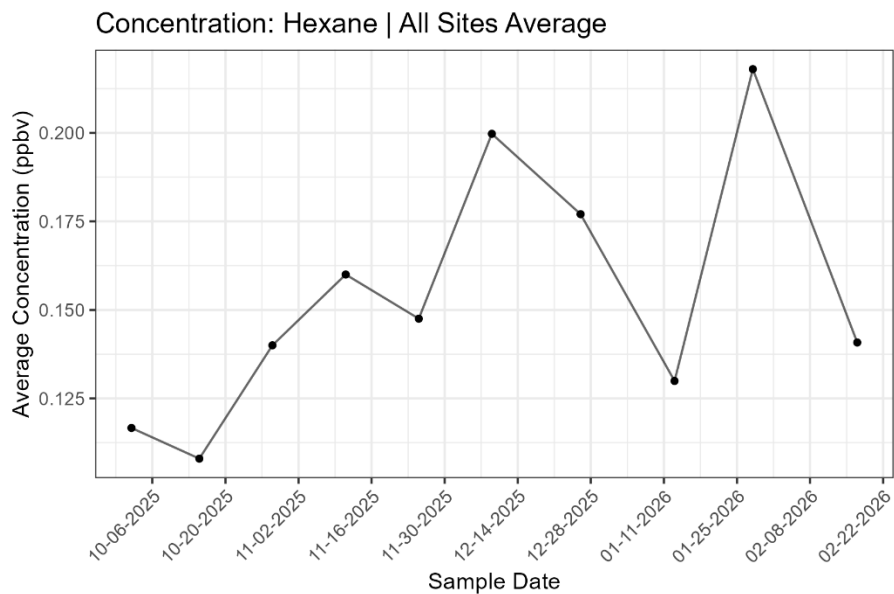


Figure C-33. Time series of average hexane concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

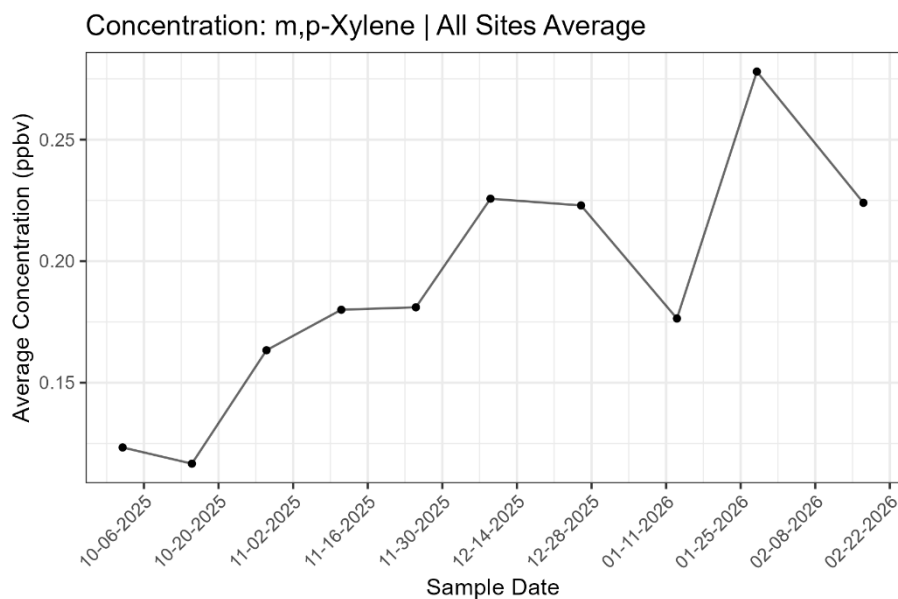


Figure C-34. Time series of average m,p-xylene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

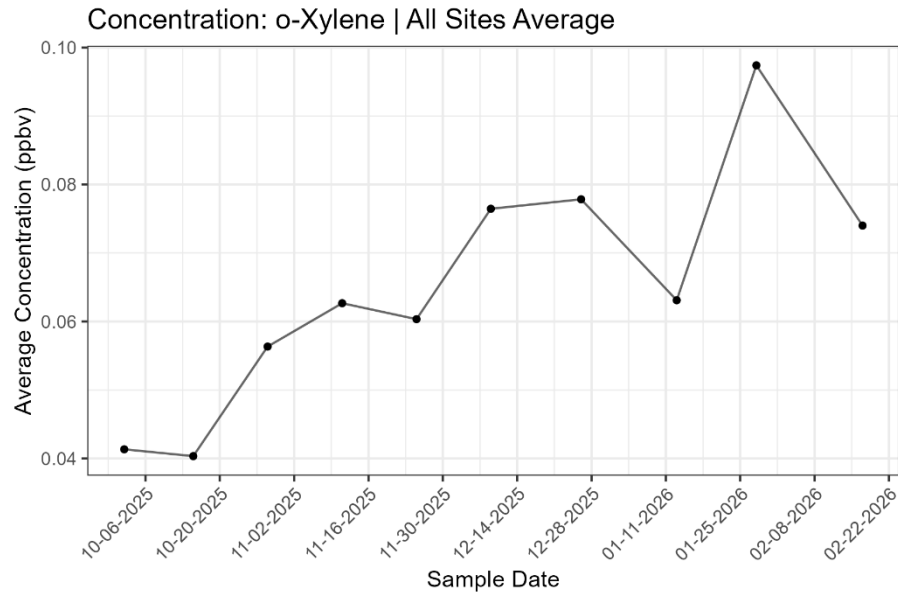


Figure C-35. Time series of average o-xylene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

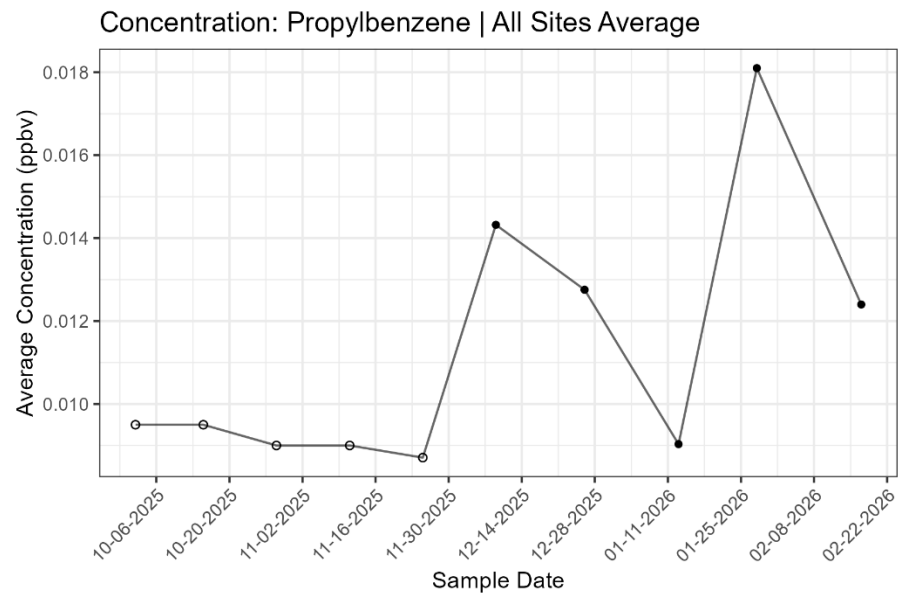


Figure C-36. Time series of average propylbenzene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

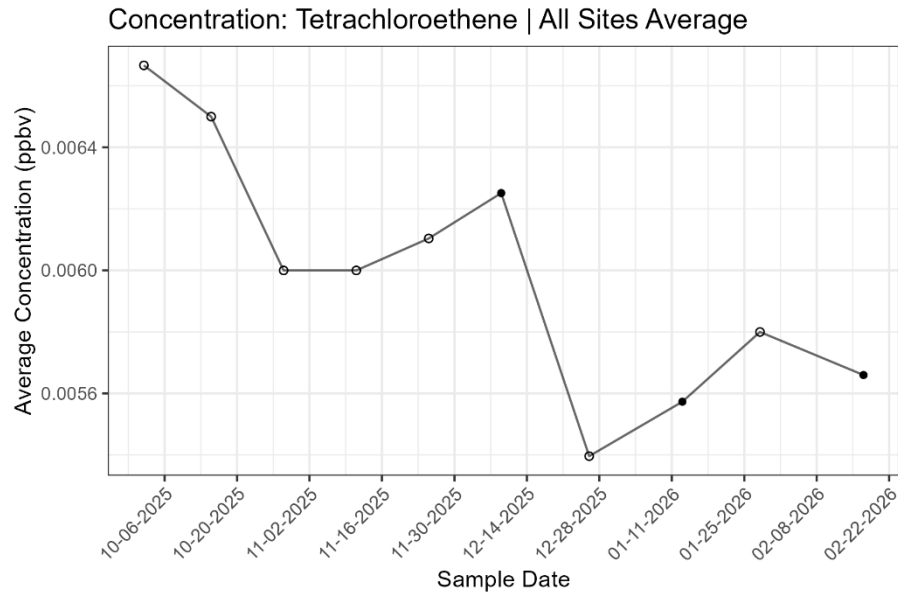


Figure C-37. Time series of average tetrachloroethene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.

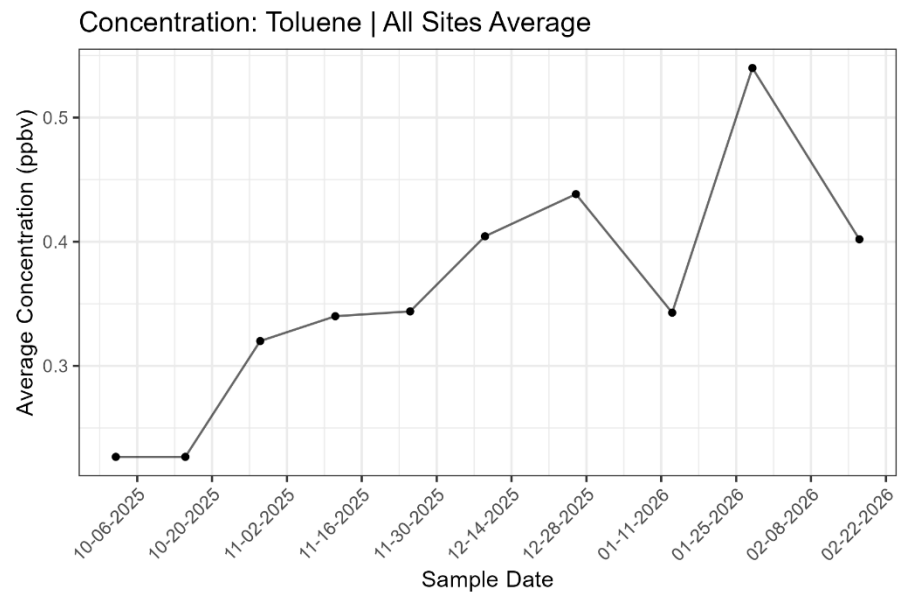


Figure C-38. Time series of average toluene concentration across all sites from the VOC analysis. Solid points indicate the VOC was detected at a minimum of one site, and hollow points indicate the VOC was below detection at all sites.