Project & Quality Assurance Project Plan (QAPP) Examples

The following document contains examples of Quality Assurance Project Plans (QAPP) from various organizations across multiple EPA Regions. It is important to note that each QAPP is unique and tailored to the specific activities and requirements of its associated project. It is also important to note that each EPA Region may have different requirements for Quality Assurance standards.

The variability among these plans can be significant; some QAPPs may be simple and concise, consisting of only one page, while others can be more complex and extend to over one hundred pages.

These examples are provided for illustrative purposes only and should not be considered as templates or definitive models.

Region 10 - Clean Air Agency

QUALITY ASSURANCE PROJECT PLAN (QAPP)

EPA Community Scale Air Toxics Ambient Monitoring

Grant Project – Assessment of Seattle and Tacoma

QUALITY ASSURANCE PROJECT PLAN

Community Scale Air Toxics Ambient Monitoring Grant
XA01J87901-0

EPA Community Scale Air Toxics Ambient Monitoring Grant Project – Assessment of Seattle and Tacoma

Prepared by and for

Puget Sound Clean Air Agency
1904 Third Avenue, Suite 105
Seattle, WA 98101

1 Project Plan Identification and Approval

The EPA COMMUNITY SCALE AIR TOXICS AMBIENT MONITORING PROJECT – ASSESSMENT OF SEATTLE AND TACOMA quality assurance project plan is approved.

Approved by

1) Signature: Matthew Harper Date: 5/27/2021 .
Matt Harper – Project Manager, Puget Sound Clean Air Agency

2) Signature: Date: 6-1-2021 .
Erik Saganić – Technical Analysis Manager, Puget Sound Clean Air Agency

3) Signature: Beth Fried Date: 6/3/2021 .
Beth Friedman – Quality Assurance Coordinator, Department of Ecology, Washington

4) Signature: Date: 6/3/2021 .
EPA QA Manager or Designee, USEPA Region 10

DISCLAIMER

This Quality Assurance Project Plan has been prepared specifically to address the environmental data operations on behalf of EPA through grant agreement XA01J87901-0. The contents have been prepared in accordance with EPA QA/R-5, "EPA Requirements for Quality Assurance Project Plans". EPA/240/B-01/003 March 2001.

2 Acronyms and Abbreviations

AQS	Air Quality System
ANSI	American National Standards Institute
APTI	Air Pollution Training Institute
ASTM	American Society for Testing and Materials
CID	Chinatown International District, Seattle, Washington
CFR	Code of Federal Regulations
COC	Chain of custody
DAS	Data Acquisition System
DNPH	2,4 Di-Nitro-Phenyl Hydrazine (Brady's Reagent)
DQA	Data Quality Assessment
DQOs	Data Quality Objectives
EDO	Environmental Data Operation
EMAD	Emissions, Monitoring, and Analysis Division
EPA	Environmental Protection Agency
EtO	Ethylene Oxide
GIS	Geographical Information Systems
HAP	Hazardous Air Pollutants
IO	Inorganic
LAN	Local Area Network
LIMS	Laboratory Information Management System
MQOs	Measurement Quality Objectives
NAAQS	National Ambient Air Quality Standards
NATTS	National Air Toxics Trends Network
NCORE	NCore Multipollutant Monitoring Network
NIST	National Institute of Standards and Technology
NRNO2TAD	Near Road NO2 Technical Assistance Document
OAQPS	Office of Air Quality Planning and Standards
ORD	Office of Research and Development
PM2.5	Particle Matter – 2.5 microns or less
PQAO	Primary Quality Assurance Organization
PSCAA	Puget Sound Clean Air Agency
PUF	Poly-Urethane Foam
QA	Quality Assurance
QAC	Quality Assurance Coordinator
QAPP	Quality Assurance Project Plan
QMP	Quality Management Plan
SLAMS	State and Local Monitoring Stations
SOP	Standard Operating Procedure
SPMS	Special Purpose Monitoring Stations
STN	Speciation Trends Network
SVOC	Semi-Volatile Organic Compounds
TO	Toxic Organic
TSA	Technical System Audit
USEPA	United States Environmental Protection Agency
UATS	Urban Air Toxics Strategy
VOC	Volatile Organic Compound

Table of Contents

3 List of Figures and Tables

Figures

Tables

4 Distribution

This Quality Assurance Project Plan has been distributed to the individuals listed in Table 1. The document is also available upon request from the Project Manager. Any work under this project shall be initiated after the approval of the EPA Project Officer in concert with the EPA Quality Assurance Manager.

Table 1 QAPP Distribution Plan

NAME	ROLE	CONTACT
Matt Harper	Project Manager, PSCAA	matth@pscleanair.gov
Erik Saganić	Technical Analysis Manager, PSCAA	eriks@pscleanair.gov
Tania Tam Park	Environmental Justice Manager, PSCAA	taniap@pscleanair.gov
Audit File	Audit File for USEPA Grant (see Matt Harper for access)	https://pscleanair.sharepoint.com/:f:/s/TechAnalysisTeam/EsyMJU7f70JClPSItc3Qt2oBZGDR0SYUE8iXv0DP7xldOw?e=Ucv9w
Beth Friedman	Quality Assurance Coordinator, WA DOE	Befr461@ecy.wa.gov
Jill Schulte	Air monitoring Coordinator, WA DOE	Jils461@ecy.wa.gov
Christina Miller	Grant Project Officer, USEPA Region 10	Miller.christina@epa.gov
Chris Hall and Sarah Waldo	USEPA Region 10	Hall.christopher@epa.gov waldo.sarah@epa.gov
Michel Rodriguez	Grant Specialist, USEPA Region 10	Rodriguez.michel@epa.gov
Julie Swift	Senior Program Manager, ERG	Julie.swift@erg.com

5 Project Task Organization

The following paragraphs will demonstrate the plan for project roles and participant responsibilities.

PROJECT MANAGER – Responsible for all aspects of completing project tasks including accurate operational financial activities reporting, choosing fixed monitoring sites, and contracting for their use, contracting with the analysis laboratory, providing oversight for installation and operation of monitoring equipment, completing the fixed site air toxics sampling, mobile monitoring, and providing support for community directed sampling.

FOCUS COMMUNITY TEAM LEADER – Responsible for managing the PSCAA outreach/engagement team for focus communities which choose to participate in grant activities and focus communities. The engagement team responsibilities include partnering with community leaders, conducting community air quality and air toxics education sessions, soliciting, advising, and collaborating with the community leaders to provide input on monitoring site selections, make decisions about community directed sampling, following through with post sampling data evaluations, risk assessments, and collaborating with the community leaders to design mitigation strategies and action steps with the overall goal of authentic engagement with the community to help reduce community burdens to toxic air pollutants.

Community leaders – Responsible for communicating and collaborating with community members, and PSCAA community focus team members. The leaders are responsible for helping to provide information flow so that as members of the community outreach team identify opportunities for engagement, leaders can effectively share information with community members within their neighbor networks. Finally, the community leaders are responsible for collaborating with project partners to guide mitigation strategies, processes, and action steps.

USEPA REGION 10 PROJECT OFFICER – Responsible for ensuring that project budgets and expenses are reported on time, and that the project achieves the desired outcomes.

FOCUS COMMUNITY TEAM MEMBERS – The teams are cross-functional teams who are charged with being PSCAA contact touch points for the community. The team is responsible for communicating and responding to the community. The team is responsible for engaging community members about air quality concerns, providing education and air quality risk information, and providing an interface for community leaders and community members to engage in air quality improvement actions. The team does have reach-back capability so that if there are appropriate engagements that can happen with air quality experts (for example Engineering, Monitoring, Analysis, or Inspections), the team can pair community members with experts from the PSCAA staff.

PSCAA TECHNICAL ANALYSIS AND MONITORING TEAM – The analysis team is responsible for the data analysis and air toxics risk assessment that will be generated after the data has been collected. This analysis information and risk assessment will be available in the final report, and the community will have an opportunity to receive and process this information as the Community Team and PSCAA Engagement team work on outcomes from the grant associated with air quality education, risk mitigation strategies, and air quality action steps. The monitoring team is an experienced, specialized, professional team that is charged with installation, operation, quality assurance, and initial analysis of air monitoring data that is collected during this project.

QUALITY ASSURANCE OVERSIGHT – WA Department of Ecology is normally the PQAO for NAAQS air monitoring activities at the Puget Sound Clean Air Agency. Ecology has written a Quality Assurance Project Plan for its NATTS sampling at the Beacon Hill NCORE site in Seattle, Washington. PSCAA shall follow the Ecology QAPP while conducting NATTS-style sampling, adapting for the change in sampler (XONTEC to A-TEC models). Ecology will be providing a review/approval step of this project QAPP and will provide audit services of the main air toxics samplers (VOC, carbonyl samplers). However, there are monitors that are being used for this study which Ecology will not be auditing. Ecology may not have all the equipment or sufficient knowledge of every device to properly perform a performance evaluation. For this project, because it is unique and not part of the Washington State approved network, PSCAA will perform quality assurance oversight for all NON-NATTS-sampling. This document describes in detail, all the quality assurance activities and requirements that are necessary to achieve project results.

CONTRACT LABORATORY – The contract laboratory will be assigned roles of a Program manager, Program QA Officer, and various other technical advisors. The Program manager and QA Officer work together to implement the laboratory QA system according to the laboratory analysis QAPP. The QA Officer is responsible for ensuring the overall integrity and quality of the laboratory contracted results. He or she reviews the ERG and PSCAA QAPPs and determines whether procedures are executed in accordance with the QAPPs. The lines of communication between the Program manager and Program QA Officer are formally established and allow for discussion of real and potential problems, preventative actions, and corrections. At any time during the program, additional QA/QC measures may be initiated upon consultation between the Program manager and QA Officer.

Figure 1 Overall System Structure

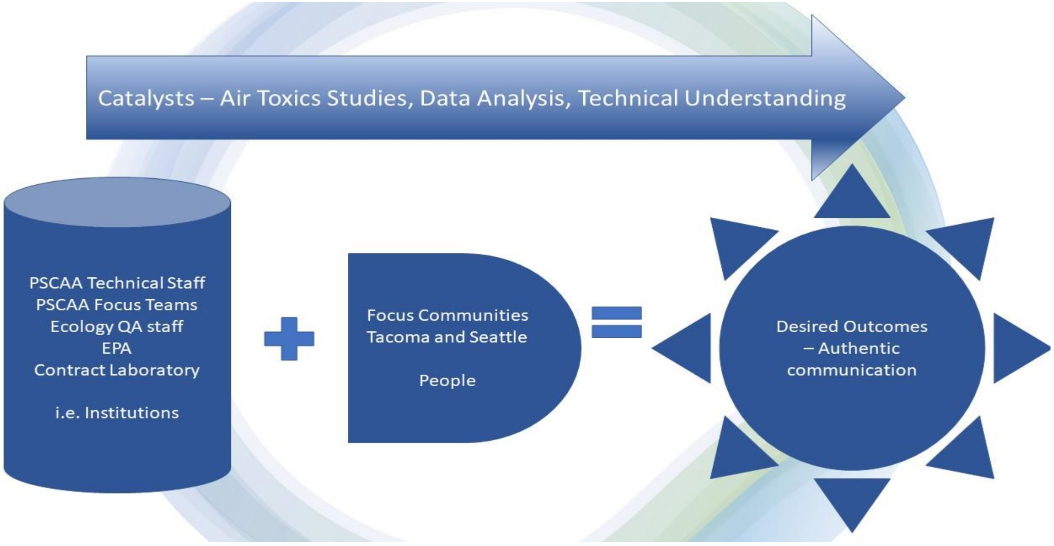


Figure 1 describes the chemical equation that will be required to make this grant work. The main ingredients will be the institutions, and the Focus Community teams working to provide the desired outcomes. The outputs (technical report) of this study will provide the catalyst for the reaction to occur. The Project teams consist of professionals working together, to bridge the gap between the science of air toxics and the communities. The PSCAA technical monitoring staff provides the sampling, air quality data, and air quality education products to allow the Focus Community Teams to connect in a meaningful way based on credible scientific work. This quality assurance project plan will put in place the elements necessary to ensure that the scientific work performed is credible, with known quality.

6 Problem Definition and Background

Problem: Understanding and Reducing Air Toxics Risk

We intend to analyze air toxics risk trends for the Puget Sound region, so that we may develop and execute strategies to reduce air toxics risk. With many different emission source changes over the years, an explosion of population growth in our region, and emerging concerns like ethylene oxide and an increase in wildfire smoke emissions, it is challenging to focus our emissions reduction efforts without more detailed air toxics data.

The agency has been working on strategies to reduce diesel exhaust sources for many years. We aim to measure current air toxics risk levels, to understand the airshed better. Sources such as diesel exhaust, wood smoke, ethylene oxide, and industrial metals have been reduced, but we have not measured air toxics risk for many years. We will produce new cancer risk estimates and compare these to past values and to the National Air Toxics Assessment. Using factor analysis on both historical data and “freshly” sampled data, we will look at changes to emissions, trends, and associated risks adjusting for weather where possible. We will use the results of this analysis to deepen our understanding of emission inventories for our region, either helping to explain the results or potentially identifying gaps where emission inventories may have mischaracterized sources.

We will engage with communities to help establish where and what air toxics we will analyze in a community-directed sampling campaign. We also propose to do an environmental justice analysis of air toxics risks over time by geography to see how gaps in equity have changed in these communities.

Background

As emission sources have changed over time, the Puget Sound region is left with many unknowns on how to characterize air toxics risk. Three factors make this a critical region to study: 1) an updated unit risk factor for ethylene oxide, 2) population growth and 3) recent changes in fleets of ships, trucks, cars, trains, industrial activities, and wood stove home heating. These factors have left open questions on how to best focus our emission reductions.

Past air toxics studies in Seattle and Tacoma showed that we are a unique area in the country. In Tacoma, we conducted a study in 2010 in which we saw higher levels of benzene in the residential area on an annual average just due to the wintertime wood smoke levels, than the large port/industrial areas of Tacoma and Seattle. Since 2006, we adopted aggressive measures to reduce wood smoke emissions, including banning and offering incentives to recycle older uncertified wood stoves and enhanced burn ban enforcement in Tacoma after its non-attainment status in 2006. With improvement in emissions reductions in shipping with the Emission Control Area and newer truck and other diesel engines, we expect air toxics risk reductions in the port/industrial areas as well. This study will help us determine how to best focus emission reductions efforts in the future.

Our prior studies have shown that the last two EPA National Air Toxics Assessment (NATA) models have performed poorly in our region, due to complex topography and meteorology. Air monitoring remains the best method to estimate local air toxics risks and extrapolate them to a wider region. Recently, the Seattle National Air Toxics Trends Stations (NATTS) site has shown lower ethylene oxide levels compared to other studied sites. Doing further ethylene oxide analysis in our region will help guide our understanding of the ambient levels of ethylene oxide.

Our 2010 study had shown that both the Seattle Duwamish Valley and Tacoma Tideflats industrial areas (Figure 2) have high levels of metals from atmospheric deposition compared to other areas in the region. A metals-in-moss sampling study led by the US Forest Service in the Seattle industrial area will be released soon, which may bring questions about what potential health risk exists if pollutant gradients are found. A similar study was completed in Portland, OR a few years ago that eventually led to the identification of an art glass maker releasing large amounts of arsenic and cadmium. PM_{10} metals sampling would be helpful to provide more definitive ambient concentrations and corresponding potential health risk.

In our last air toxics study in the Seattle Chinatown-International District, we found two types of diesel emissions from highway traffic, a "fresh" near-road diesel factor and evidence of a "background" diesel factor. To distinguish these two types of diesel emissions, we used novel approaches with positive matrix factorization (PMF) modeling using available air toxics data. Learning how the emissions are different at the near-road site in Tacoma (at the S 36th Street site) would be valuable and help us quantify the relative importance of background diesel emissions and the different vehicle fleets.

We are actively engaging with communities that face environmental and societal barriers to clean air. In our engagement with these communities, termed "focus communities", we have used monitoring tools such as our air sensor lending library, community science training, community-directed air toxics, and other emissions sampling. In this study, we will build on our experience, and continue to use community-directed sampling with our community partners.

7 Project Description and Tasks

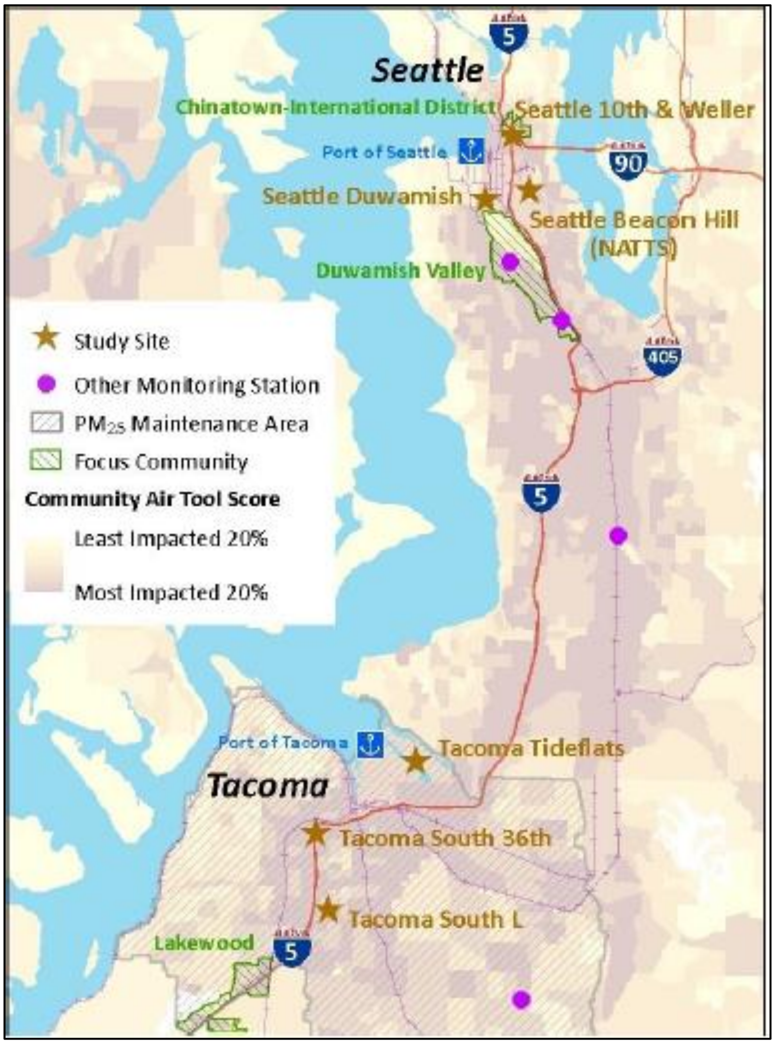
Puget Sound Clean Air Agency will perform a study to assess air toxics trends and risk in Seattle and Tacoma (Figure 2). The study will focus on changes in air toxics concentrations from diesel exhaust sources, wood smoke, ethylene oxide, and industrial source metal emissions from a previous study conducted 10 years ago. PSCAA will monitor air toxics and produce new estimates of potential cancer risk, then compare these to past values and to the National Air Toxics Assessment. Additionally, PSCAA will perform an analysis of air toxics risks using monitoring that has been directed by the environmental justice communities to assess if there are additional equity gaps.

This study will help characterize the impact of air toxics in environmentally burdened communities in Seattle and Tacoma. We will focus on key air toxics with the highest potential health risks in our region (benzene, 1,3-butadiene, carbon tetrachloride, acrolein, formaldehyde, and acetaldehyde), as well as measuring surrogates for diesel and wood smoke particulate matter (black carbon and UV channels, and PAHs). We will also monitor for ethylene oxide, which has an updated unit risk factor. We will assess whether this would or should shift our risk reduction strategies. We will look in depth at industrial atmospheric deposition by monitoring for PM_{10} metals, and better understand the sources of emissions using factor analysis by sampling PAHs.

The measurement goal of this project is to estimate the concentration, in units of micrograms per cubic meter ($\mu g/m^3$) and parts per billion/volume (ppbv) of air toxic compounds of particulates and gases, respectively. This is accomplished by using four individual sampling methods:

- Canister sampler for volatile organic compounds (VOCs)
- Carbonyl sampler with 2, 4-Dinitro-phenyl hydrazine (DNPH) coated cartridges for carbonyl compounds
- Poly-Urethane Foam (PUF) high volume air sampler for polycyclic aromatic hydrocarbons (PAHs)
- High purity filters housed in NFRM Sampler for PM10 metals.

Figure 2 Study sites, focus community locations, $PM_{2.5}$ maintenance area, and Agency EJ tool (Community Air Tool) scores



8 Sample Process (Network) Design

Sampling Locations

We will measure at five sites for one year (Table 2), and leverage select data from some sites. We will leverage data from the NCore program and NATTS program (Seattle Beacon Hill site - full suite of VOC's, aldehydes, PM_{10} metals, gaseous parameters NO, NO_2, NO_Y and CO), the $PM_{2.5}$ monitoring program (Seattle Beacon Hill, Tacoma South L St, Tacoma Tideflats, Tacoma S 36th St, Seattle 10th and Weller, and Seattle Duwamish – $PM_{2.5}$), the Near Road monitoring program (Seattle 10th and Weller and Tacoma S 36th St - NO, NO_2, NOx), the Chemical Speciation Supplemental network (Tacoma South L Street, Seattle 10th & Weller), and existing meteorology data (temperature and winds at each site) (Table 3). We will engage with our focus communities and have community-led sampling.

The sites included in the study are in near road, industrial, and residential wood smoke affected areas. The latest air toxics sampling in most of these communities took place in 2008-2009 when the Puget Sound Clean Air Agency (PSCAA) conducted an Air Toxics monitoring campaign (EPA Grant XA96069801). PSCAA also gathered air toxics data during 2016-2017 in the Chinatown-International District (EPA Grant XA01J10401).

a. Two near-road sites

To compare the near-road sites, we will have sampling for select VOCs and aldehydes. This will help us in comparing the two near-road sites that have differing wind and traffic patterns. Both sites are located within 50 meters of Interstate 5, in Seattle on the corner of 10th Ave and Weller St, and Tacoma S. 36th Street, adjacent to Jennie Reed Elementary School. We will leverage current $PM_{2.5}$ speciation data from 10th & Weller site to estimate diesel concentration.

b. Two industrial-port sites

The Puget Sound region has two port and industrial valleys, one in Tacoma and Seattle. We propose monitoring for metals, in addition to the other air toxics, as the community has raised concerns over metal deposition. We also propose adding PAHs to help better characterize the aerosols with factor analysis. We will leverage chemical speciation network (CSN) speciation data currently being collected at these sites. We have air monitoring records for the Seattle Duwamish and Tacoma Tideflats going back to the early 1970's.

c. One former nonattainment residential wood smoke impacted site

The Tacoma South L Street site historically had $PM_{2.5}$ concentrations that violated EPA's 2006 Federal Daily Standard. Since then, we have made strides to reduce wood smoke in the area, by banning uncertified stoves, implementing stove changeout programs, and enhancing enforcement. The site is representative of a "maximum concentration urban wood smoke" site in our 4-county jurisdiction.

d. Leveraged NATTS site

A sixth site, the NATTS site at Seattle-Beacon Hill, is in a residential neighborhood a few miles from the Seattle Duwamish and 10th and Weller sites, and will continue to operate without making use of funding from this grant. The Beacon Hill site is the Urban Scale monitoring site in the region, and the Washington State Department of Ecology hosts NCore and NATTS monitors here. This site has a full suite of air toxics monitors including canister (VOC) EPA Method TO-15, tube TO-11A (aldehydes), PM 10 Hi-Vol IO-3 (metals), and PUF (PAH) TO-13A samplers. Leveraged monitoring will meet NATTS quality assurance requirements for speciation samplers (including the URG3000N carbon sampler) and FEM approved NO2, CO, SO2, and PM 2.5 monitors. We will use Beacon Hill data in our analysis and conclusions as appropriate. Additionally, as shown in Table 3, we will leverage data that is already being collected through other air monitoring programs.

Table 2 Sampling sites, duration, and frequency

Sites	Measured parameters (only from this grant)	Monitoring Frequency
Tacoma S. L Street (residential)	Select VOCs (Note A) Select aldehydes (Note B) *BC*	1 in 6 1 in 6 Continuous
Tacoma Tideflats (industrial)	Select VOCs (Note A) Select aldehydes (Note B) PM-10 Metals *BC*	1 in 6 1 in 6 1 in 6 Continuous
Tacoma S. 36th street (near-road)	Select VOCs (Note A) Select aldehydes (Note B) *BC*	1 in 6 1 in 6 Continuous
Seattle 10th and Weller (near-road)	Select VOCs (Note A) Select aldehydes (Note B) *BC*	1 in 6 1 in 6 Continuous
Seattle Duwamish (industrial)	Select VOCs (Note A) Select aldehydes (Note B) PM-10 Metals PAH *BC*	1 in 6 1 in 6 1 in 6 1 in 6 Continuous
Community-directed sites	Air toxics to be determined by the community (PAH, Select VOC's, Select aldehydes, PM-10 metals) *$PM_{2.5}$ sensors*	Up to 20 samples Ad hoc

Note A: Benzene; 1,3 butadiene; carbon tetrachloride; tetrachloroethylene; ethylbenzene; acrolein; ethylene oxide

Note B: Formaldehyde and acetaldehyde

Table 3 Sampling sites and Leveraged monitoring parameters for Analysis

Sites	Leveraged parameters (not funded by this grant)	Program or QAPP
Tacoma S. L Street (residential)	*PM2.5* *PM2.5 Speciation* *Temperature, Winds*	PM2.5 grant CSN-Supplemental Met SOP
Tacoma Tideflats (industrial)	*PM2.5* *PM2.5 Speciation* *Temperature, Winds*	PM2.5 grant CSN-Supplemental Met SOP
Tacoma S. 36th street (near-road)	*NO2, NO, NOX* *PM2.5* *Temperature, Winds* *Traffic Counts*	Near Road WA State funding Met SOP WA DOT
Seattle 10th and Weller (near-road)	*NO2, NO, NOX, CO* *PM2.5* *PM2.5 Speciation* *Temperature, Winds* *Traffic Counts*	Near Road PM2.5 grant CSN-Supplemental Met SOP WA DOT
Seattle Duwamish (industrial)	*PM2.5* *PM2.5 Speciation* *Temperature, Winds*	PM2.5 grant CSN-Supplemental Met SOP
Seattle Beacon Hill	*Full suite of VOC* *PAH* *Aldehydes* *PM-10 metals* *NO2, NOx, NO, SO2, CO* *PM2.5* *PM2.5 Speciation* *Temperature, Winds*	PAMS and NATTS NATTS PAMS and NATTS NATTS NCORE PM2.5 grant STN and IMPROVE Met SOP

e. *Community-directed sampling*

In addition to the fixed sites, we will include at least six days of community-directed air toxics sampling at three locations in the Duwamish Valley and collect at least 20 samples from these locations. These locations will be decided after consultations with the community based on locations of interest. This community does not have recent air toxics data and community groups in the Duwamish Valley have expressed interest in participating in air toxics sampling. The community-directed sampling will allow the community to identify locations of interest, actively participate in collecting samples, and learn about air toxics concentrations at those locations. We will sample on the same days that fixed sites are operating to provide greater spatial gradient information. In this portion of the monitoring campaign, we will leverage continuing partnerships with the *Duwamish Community Action Program for Clean Air*, a collaborative of air quality stakeholders, that already has community networks and avenues for input to direct this portion of the sampling. Some of the initial interest has been in metal deposition (possibly PM_{10} metals and hexavalent chromium). The community-directed locations will also include the use of low-cost sensors like Dylos, AirBeam, Purple Air, etc. These low-cost sensors will only be used as a tool for creating awareness among the community members and will not be used to calculate health risks.

In addition to the Duwamish Valley targeted sampling, we will conduct outreach and educational $PM_{2.5}$ sensor sampling at sites of community interest in the Seattle and Tacoma focus communities using low-cost sampling methods to complement fixed site data collection.

Sampling Tasks

Select VOCs (Note A) - We will use an established Standard Operating Procedure as described in Appendix A - the School Air Toxics Program SOP for sampling VOC's using a passive regulator and timer for a 6L SUMMA canister. The equipment that we use will match the equipment used from the School Air Toxics Program.

Select aldehydes (Note B) - The Washington Department of Ecology previously used a carbonyl sampler called a XONTEC, and those samplers are no longer functional/available. Therefore, we will acquire the available ATEC samplers that are essentially updated XONTEC samplers. Although we will use the new ATEC samplers, we will sample using an established SOP (Appendix B) and will use the same laboratory analytical methods so that our data can be comparable to historically collected data.

PM-10 metals – We plan to sample for PM-10 metals at two fixed industrial sites by using the Rupprecht & Patashnick Model 2025 samplers that are already used in our state's Federal Reference Monitoring program. Our operators routinely operate these monitors using the Washington State Department of Ecology SOP, and we will be following the designation stated in Appendix I. These samplers are configured for collecting PM-10 filters on a 1 in 6 sampling frequency for the year of the sampling campaign. Since these samplers are limited in our inventory, and only usable at fixed sites, if we decide to use PM-10 metals sampling at community determined sites, we plan to use the N-FRM monitor provided by ARA per the procedure in Appendix L. The N-FRM monitors can be configured for short term, battery operated monitoring, and will be useful in collecting data in specific locations determined by the community.

PAH – We plan to use a standard High Volume PUF sampler to collect samples for PAH analysis at the Duwamish industrial site. The monitoring SOP that we will use is identical to what is used in the national NATTS program, and is listed in Appendix C.

BC – We plan to use the Aethalometer AE-33 model sampler to collect the 7 channel Black Carbon continuous data for use in the analysis at each of the study sites, to give us parameters that can be used (along with other data) to estimate Diesel Particulate Matter through PMF modeling.

9 Sampling Design and Objectives

Our proposed work will respond to EPA's goal "A Cleaner, Healthier Environment" by accurately measuring air toxics within disproportionally impacted communities that suffer from poor air quality in addition to substantial socio-economics challenges. With this additional dataset, we will assess risks and make sure "high air quality standards" are met.

Anticipated environmental **outputs** from the proposed work:

- Producing high quality HAP data, which will be made publicly available via EPA's AQS database
- Identification and inventory of community-specific air toxic concentrations and cancer risk
- Evaluating the NATA model and NATTS data in our region
- Evaluating progress at reducing risk and exposure, and potentially setting benchmarks for further reductions
- Disseminate results via public meetings, blog posts, social media, presentations in schools and libraries to raise awareness and present key findings to focus communities
- A final report, which will include a summary with key findings for focus communities and policy makers as well as accurate data analysis and modeling to fulfill research objectives

Anticipated environmental **outcomes** from the proposed work:

1. *Short-term:*
- Increase community awareness on air quality issues
- Identify air toxics sources
- Improve assessment of air toxics exposure and risk
2. *Mid-term:*
- Help identify source types to prioritize
- Empower respective communities with the report results
3. *Long-term:*
- Increase data inventory for the Puget Sound region available for researchers, policy makers, and public
- Future priorities for source emission reductions are more accurately identified

Performance measurements:

- All monitoring activities will comply with SOPs and the QAPP
- Project manager will hold routine meetings with the project team to review the work and the project timeline
- Project manager will check budget balances with managers monthly and adjust as needed
- Communication with EPA's program manager will be maintained through quarterly progress reports and check-ins as needed

Figure 3 Project Timeline

Timing:	*Year 1: 2020-2021*				*Year 2: 2021-2022*				*Year 3: 2022-2023*			
Milestones:	*Fall*	*Win.*	*Spr.*	*Sum.*	*Fall*	*Win.*	*Spr.*	*Sum.*	*Fall*	*Win.*	*Spr.*	*Sum.*
Community engagement	░	░	░	░	░	░	░	░	░	░	░	░
Input from communities on project and timeline	░	░										
Finalize study design	▓	▓										
Generate QAPP, SOPs	▓	▓										
Setup contract with analytical laboratory	▓	▓										
Install monitors	▓	▓										
Progress reports to EPA	█	█	█	█	█	█	█	█	█	█	█	█
Fixed-site sampling				▓	▓	▓	▓					
Community-led sampling				▓	▓	▓	▓					
Outreach events					░	░	░	░	░	░		
Data analysis							▓	▓	▓	▓		
Draft report								█	█	█		
Inform communities on findings									░	░		
Final report											█	█
Final outreach events											░	░
Community "next steps" plan											░	░

10 Quality Objectives and Criteria for Measurement Data

The purpose of the quality objectives and criteria for measurement data is to define what quality systems and requirements already exist for air monitoring data sets proposed for collection in this study, and to define what parameters need to have quality systems defined in this document.

The Plan is written using guidance from EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations (EPA QA/R5) and Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Ambient Air Quality Monitoring Program (QA Handbook).

This plan also references two key Quality Assurance Project Plans that are already implemented in the State of Washington under the Department of Ecology's Air Quality Program quality system:

- "Ecology Air Program QAP": Air Monitoring Quality Assurance Plan document 99-201 (Rev. 01/2021)
- "Ecology Toxics QAPP": Air Toxics Monitoring Quality Assurance Project Plan document 04-02-018 (Rev. 04/2020)

Further, this plan references Quality Assurance Project Plans that already are implemented by EPA in the United States under the EPA's National Monitoring Programs. Under Contract Number EP-D-14-030 from 2016, the Category 1 Quality Assurance Project Plan for UATMP, NATTS, CSATAM, PAMS, and NMOC support is used by the contract laboratory.

- "ERG Toxics QAPP": Support for the EPA National Monitoring Programs (UATMP, NATTS, CSATAM, PAMS, and NMOC Support) Contract Number EP-D-14-030 Quality Assurance Project Plan for Eastern Research Group, Inc. 601 Keystone Park Drive, Suite 700, Morrisville, NC 27560.

Furthermore, any data collected with a mobile monitor or other low-cost air sensors during the community monitoring phase will likely not have the same quality level as data collected with a Federal Equivalent monitor at a stationary monitoring site. This is because for smaller lighter sensors, there is not a built-in designed quality assurance calibration system that is utilized on a daily or weekly basis. We will approach data results with caution from sensors that don't have as comprehensive a quality system. Also, NFRM samplers being used in this study for community directed PM_{10} metals sampling will be collocated at Seattle Duwamish site with FRM and FEM samplers. The collocated sampling times will be identified, and analyzed, so that the mobile data quality can be better measured. We'll also make recommendations to community for community-directed sampling to address quality assurance in a systematic way (for example, collocation, bias testing, etc.) so that we can learn as much from the data collected from these instruments.

Data Quality Objective (DQO)

The study is based on comparison to other well established monitoring sites in the state of Washington where air toxic pollutants are also collected. Therefore, our data quality objectives are based in the same science as the already established monitoring sites and methods. As established by Department of Ecology for their Air Toxics Monitoring Quality Assurance Project Plan, the only Data Quality Objective (DQO) for the state air toxics monitoring program is:

- To be able to detect a 15% difference between two successive 3-year annual mean concentrations (rolling averages) within acceptable levels of decision error.

The formal process of establishing the DQOs is described in EPA's Guidance on Systematic Planning Using the DQO Process (EPA, 2006). It provides a general framework for ensuring that the data collected meet the needs of the intended decision makers and data users. Since this project's data set does not allow a calculation of a 3-year annual mean, we will use an alternative DQO for this project only:

- To be able to compare the air toxics concentrations observed in this study to past studies conducted in the region and to the other National Air Toxics Trends Station (NATTS) sites.

To achieve this DQO, we will follow the same Measurement Quality Objectives (MQOs) and Data Quality Indicators (DQIs) set for NATTS sites to remain consistent and comparable with the NATTS network.

Measurement Quality Objectives (MQOs) and Data Quality Indicators (DQIs)

In order to ensure comparable data among monitoring sites, consistency is a necessary component for the NATTS Program. Inherently, such consistency needs to be reflected in a standardized set of Measurement Quality Objectives (MQOs), field and laboratory operations, specific acceptance criteria for individual monitoring methods, and stability for the selected site to collect data over the required period of time. PSCAA will implement the following MQOs to attain the DQO of the NATTS Program:

- Representativeness: Representativeness is a measure of degree to which collected data represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition (ANSI/ASQC, 1994). Components such as sampling design and siting are crucial in ensuring data collected are reliable and defensible to represent the area under study. In NATTS monitoring, sampling frequency must occur every 6 days per national sampling calendar over 24 ± 1 hours, beginning and ending at midnight in local standard time (i.e., Pacific Standard Time in Washington).
- Completeness: Completeness is defined as a measure in percentage of which data is collected and validated at a given site over a calendar year. A minimum number of valid data points is necessary to perform meaningful data analysis and compare data among monitoring sites. The MQO for completeness requires at least (≥) 85% of the annual samples be valid and reported. Make-up samples should be collected when sample results are invalid, and completeness are projected to not meeting the MQO for the calendar year. A make-up sample should be collected as close to the original sampling schedule as possible and preferably before the next sampling date. If not feasible, the make-up sample should be collected within 30 days of the original invalid sampling date, or the least preferably, but acceptable, within the same calendar year.
- Precision (CV %): Precision is a measure of reproducibility of a data population to ensure concentration results are within an acceptable uncertainty. The MQO for the network precision is calculated based on at least one year of data, and a coefficient of variance (CV) of ≤ 15% must be met. The pollutants where we have an opportunity to use this precision measurement are VOC's, carbonyls, and metals in the case of community sampling. Equipment limitations will prevent us from calculating precision for metals at fixed sampling sites, and PAH's because we are not able to run two successive samples on one sampler in these cases. Duplicates can be run for VOC's and carbonyls, and metals using the community sampling equipment.
- Bias: Bias or systematic error is a measure of the difference between a measurement ("indicated") and a true or accepted ("actual") value. Bias may be attributed to data collection or the data analysis process. Laboratory bias is assessed through the NATTS proficiency testing (PT) program, in which all the analytes selected for PT must be within ± 25% of the assigned target value (defined as the NATTS laboratory average). Field bias is largely assessed based on the flow rate of the samplers. Table 4 summarizes the acceptance limits of the indicated flow rates from a flow transfer standard or design flow rate for each pollutant class. Note that as the sampling method for VOCs involves collecting whole air into a canister using negative vacuum, a constant flow rate over the entire 24-hour sampling period is of greater importance than its accuracy.

Table 4 Acceptance limits of flow rates

Pollutant Class	Flow transfer standard	Design flow rate
Carbonyl	± 10%	± 10%
PAH	± 10%	± 10%
PM10 metal (low volume)	± 4%	± 5%

In the case of lower-cost sensors, no decisions will be based on the data, so no collocation is required. However, we do regularly compare lower-cost sensors for fine particulate matter to our network, and we often find biases that we can use for education and outreach purposes.

- Sensitivity: Sensitivity of the samplers is important to be aware of to prevent misinterpretation of the data collected. As the ambient air toxics concentrations decrease, sensitivity in the sampling method is expected to increase as well. The method detection limit (MDL) MQO has been established for each of the NATTS Tier I core analytes. Refer to the annual NATTS network workplan template, available on the virtual Ambient Monitoring Technology Information Center (AMTIC), for the latest MDL MQO values. The laboratory will provide us with laboratory blank data, and we will compare lab blanks and field blanks to minimum detection limits to gain understanding of the sensitivity of the analysis.

11 Special Training Requirements/Certification

Adequate education and training are critical to any monitoring program that strives for reliable and comparable data. EPA National Monitoring programs are performed using accepted EPA, NIOSH, and OSHA sampling and analytical protocols and requiring the efforts of field sampling personnel and analytical laboratory staff. Training is aimed at increasing the effectiveness of employees involved in the project. Personnel assigned to ambient air toxics monitoring activities and for laboratory analysis activities will meet the educational, work experience, responsibility, personal attributes, and training requirements for their positions.

The Puget Sound Clean Air Agency monitoring team has experience and training with all the sampling methods that will be employed by the study. There may be occasion for community leaders or members to participate in data collection, or mobile monitoring. In these instances, the community members will be closely supervised by monitoring team members, and data will be reviewed during the analysis phase, so that the conditions under which the data were collected will not negatively impact the overall analysis or conclusions of the study. Later in this QAPP we will discuss recordkeeping requirements for this project. These requirements are in place so that data with unacceptable error are excluded from use in study conclusions.

The Quality Assurance Coordinator of the Washington State Department of Ecology will conduct courtesy audits of the NATTS style monitoring equipment to be used in this study. For Non-NATTS style monitors, the PSCAA staff will conduct the audits. The monitoring team will ensure that data that is not bracketed by passing audits is not allowed to be used in study conclusions. This step will ensure that the data used in the study will be of known quality.

The contract laboratory utilized in this project has trained technicians and supervisors who complete analyses according to the Compendium methods for Toxic Organic and Inorganic compounds, and report data to the AQS system. The monitoring data will be submitted to EPA's AQS database within 120 days after the end of the quarterly reporting periods and EPA Project Officer shall be notified of the same within 15 days of the required submittal date. The data reported to the AQS system will be of known quality because data is accompanied by appropriate flags, minimum detection levels, and metadata. The data entered in AQS system will comply meeting the 85% minimum data recovery requirements for the network monitors. Analytical laboratory personnel involved in this project have been trained in their tasks and have many years of experience in the duties they will be performing. Training of ERG laboratory personnel is recorded in the ERG Training Records in an Access database. It is the responsibility of the trainee and the laboratory's System Administrator to keep the Training Records up to date. Special certification is not needed for the analysis of the ambient samples through the contract.

The contract laboratory maintains appropriate SOPs for each of the analytical methods. These SOPs are presented in Appendix C of "SUPPORT FOR THE EPA NATIONAL MONITORING PROGRAMS" under Contract Number EP-D-14-030as presented in the Category 1 QAPP, approved by EPA in 2016.

12 Documentation and Records

All records produced during and throughout this work are of public record and will be retained by the Puget Sound Clean Air Agency under standard retention record laws. The Puget Sound Clean Air Agency will utilize several different types of records and will make all records available to the public. There will be a Final Report that will be submitted by the Puget Sound Clean Air Agency to the EPA and the community. Puget Sound Clean Air Agency will post this report on its website and will take steps to ensure that this report is readily available in multiple formats, so that persons of every ability can review the report. Puget Sound Clean Air Agency routinely (daily) backs-up all files kept on server following the back-up measures set up by their IT team in a standard way. As per IT team's standard practice, three copies are kept for each file: 1) original; 2) on-site backup; and 3) off-site to Azure cloud. All the changed blocks are backed up daily.

The resulting report from this work will be a highly technical report that will outline data collected, observations, analysis, recommended actions, and conclusions. The report will have a very technical Appendix that summarizes all the data collected during the study. The following figure 4 will be used by project participants in planning for document and record storage. Additionally, to communicate more effectively with the community, the Agency may summarize the technical findings into easier to read Information Sheets.

Figure 4 Reports Plan

RECORD TYPE	FORMAT	DESCRIPTION
Grant quarterlies	Electronic or Paper	Available on demand by contacting Project Manager
Final Report	Electronic or Paper	Available on www.pscleanair.org or by contacting PM
Agreements	Electronic or Paper	Available on demand by contacting PM
Finances	Electronic or Paper	Available on demand by contacting PM
Data - Network	Electronic	Available via WA Department of Ecology
Data – Lab	Electronic	Available via AQS or by contacting PM
Data – Mobile	Electronic	Available on demand by contacting PM
SOP QC checks	Electronic or Paper	Available on demand by contacting PM
Logs	Electronic	Available on demand by contacting PM

All Records	Electronic or Paper	Available by contacting PSCAA Public Records

13 Standard Operating Procedures for Sampling

This project requires the use of many different Standard Operating Procedures for Sampling and Analysis. This section focuses on Sampling SOP's, because the contract laboratory will be using the library of SOP's for analysis of samples. Much of the sampling techniques used in this project will already have WA Department of Ecology approved SOP's to draw from.

For sampling preservation requirements, please see the individual SOPs listed in our Figure 5 below. An example is the preservation required of TO-11 carbonyl sampling. Since sampling of carbonyls is done using a DNPH coated cartridge, when handling the sample, the operator caps the cartridge with plugs, places it in the aluminum foil pack to protect it from sunlight, seals with TFE-fluorocarbon tape, and refrigerates at 4 deg C until analysis. The sample is shipped to the lab right away, but not to exceed a two week period. There is a procedure for longer term storage of the sample, but we will not need to use that technique.

Some of the micro-sensing sampling techniques do not yet have SOP's, and these will be developed from existing guidance, and existing doctrine used in the monitoring field. Figure 5 summarizes the Methods that will be used, and the reference used by the operators as the SOP. Developed from these SOP's are already established Field procedures and protocols which will be followed to assess this quality component. Field procedures and protocols are provided in the Appendices to this QAPP.

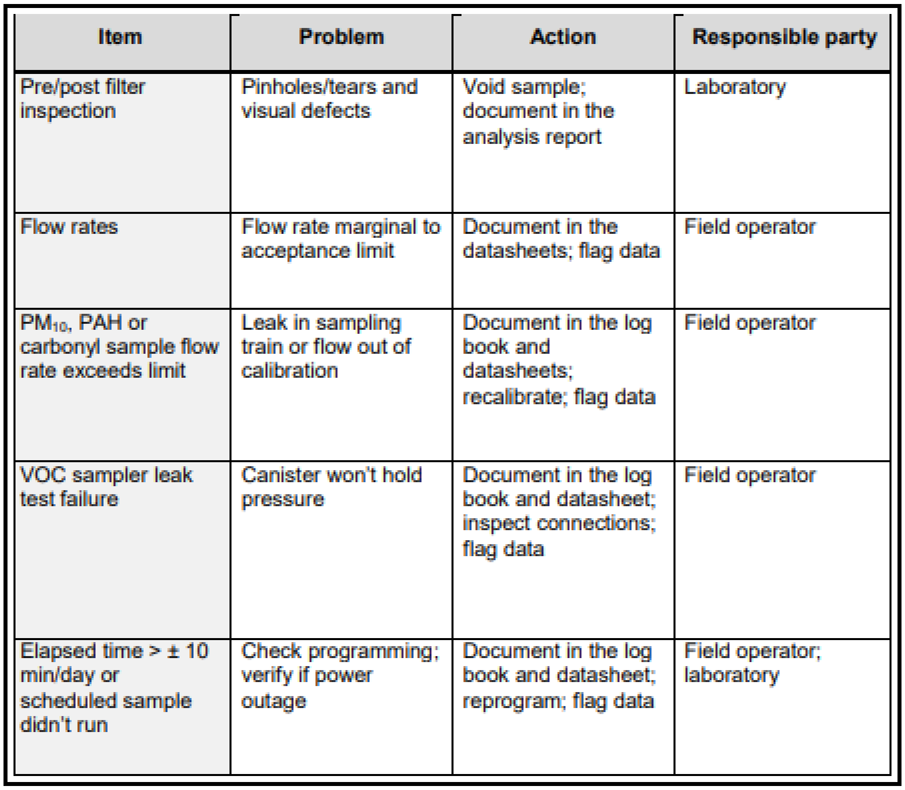
Figure 5 Reference Standard Operating Procedures

METHOD	REFERENCE SOP
TO-15a	ECOLOGY AIR TOXICS QUALITY ASSURANCE PROJECT PLAN, April 2020, AQSB SOP 805, XONTECK 901 & 910PC Canister, April 2015 and EPA Schools Air Toxics, VOC SOP August 5, 2009
TO-11a	ECOLOGY AIR TOXICS QUALITY ASSURANCE PROJECT PLAN, April 2020, SOP based on WA DOE CARBONYLS with 2,4-Dinitro-phelyl hydrazine (DNPH) coated cartridges and ATEC Operator's manual for the Model 2200 air toxics sampler.
PAH - PUF	EPA Schools Air Toxics, SVOC/PAH SOP August 24, 2009
PM-10 Metals	WA DOE PM-10 Metals with R & P Partisol Samplers using the PM2.5 Sequential Sampling Procedure modified with EPA method RFPS-0509-176 using WINS impactor bypass downtube to capture PM-10 rather than PM2.5. (Same method as the Beacon Hill PM10 Metals monitor).
PM2.5 BC	WA DOE Aethalometer SOP with modification for AE-33 upgraded model (7 channel)
NOTE: These SOPs are all listed in the Appendices to this QAPP.	

For VOCs, carbonyls, PAHs and PM_{10}, sample medium preparation involves conditioning and pre-weighing sample filters and cleaning the canisters to minimize sample contamination. ERG's Quality Assurance Project Plan (QAPP) describes these laboratory activities and the SOP's provided in the appendices of this QAPP describes the field activities. After analysis, samples will not be archived by ERG or PSCAA.

Corrective action measures will be taken to ensure data quality objective is attained. Table 5 summarizes a list of common issues found during installation, quality control check and sample retrieval. If the issue is not listed in the table, the operator will use common sense to maximize the integrity of the sample while consulting with other team-mates on a potential solution.

Table 5 Common problems in measurement system and corrective actions (Air Toxics Monitoring Quality Assurance Project Plan, WA DoE, 2020)



Item	Problem	Action	Responsible party
Pre/post filter inspection	Pinholes/tears and visual defects	Void sample; document in the analysis report	Laboratory
Flow rates	Flow rate marginal to acceptance limit	Document in the datasheets; flag data	Field operator
PM_{10}, PAH or carbonyl sample flow rate exceeds limit	Leak in sampling train or flow out of calibration	Document in the log book and datasheets; recalibrate; flag data	Field operator
VOC sampler leak test failure	Canister won't hold pressure	Document in the log book and datasheet; inspect connections; flag data	Field operator
Elapsed time > ± 10 min/day or scheduled sample didn't run	Check programming; verify if power outage	Document in the log book and datasheet; reprogram; flag data	Field operator; laboratory

13.1 Sampling Custody

Custody of samples is handled in the individual SOP's for TO-15a, TO-11a, PAH-PUF, and PM-10 Metals. VOC, carbonyl, and PAH samples must be collected within three days following sample collection and be shipped from the PSCAA to ERG as soon as feasible. PM_{10} samples will be subsequently shipped to ERG for ICP-MS analysis. PM_{10} samples must be analyzed within 180 days after sampling collection. Chain of Custody forms were established to document sample conditions during lab pre-sampling, field installation, field recovery, and upon lab recovery. Sample custody sheets are used in the Field Procedures provided in this document's appendix. For PM10 filters, Chain of Custody forms for each cooler containing samples as well as Run Data Sheets for each individual sample filter are utilized.

Samples will be mailed in between the PSCAA office and the Analytical Laboratory ERG utilizing standard FedEx methods.

13.2 Analytical Methods Requirements

Under Contract Number EP-D-14-030 from 2016, the Category 1 Quality Assurance Project Plan for UATMP, NATTS, CSATAM, PAMS, and NMOC support is used by the laboratory. The reference is:

- Support for the EPA National Monitoring Programs (UATMP, NATTS, CSATAM, PAMS, and NMOC Support) Contract Number EP-D-14-030 Quality Assurance Project Plan for Eastern Research Group, Inc. 601 Keystone Park Drive, Suite 700, Morrisville, NC 27560.

Analytical methods used for each suite of air toxics parameters are as followed:

- VOCs: EPA Compendium Method TO-15.
- Carbonyl compounds: EPA Compendium Method TO-11A.
- PAHs: EPA Compendium Method TO-13A.
- Metals on PM10 filters: EPA Compendium Method IO-3.5 via ICP-MS.

All of the QA/QC requirements of the methods specified above shall be followed throughout the sample collection and analysis process of this program. All laboratory analyses will be performed by ERG.

13.3 Quality Control Requirements

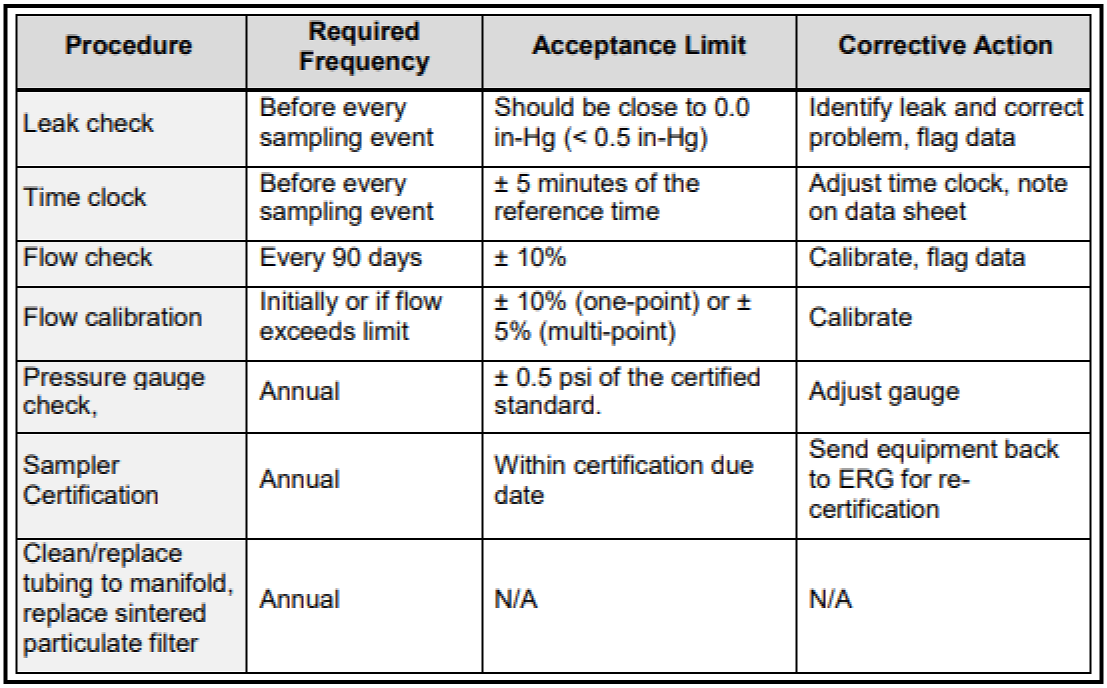
Quality Control Requirements are outlined in the individual SOP's for TO-15a, TO-11a, PAH-PUF, and PM-10 Metals. For these sampling techniques, the contract laboratory will send us blanks, and we will use blanks and collocated samples to assess quality for these sampling methods as per the QA frequency given in table 6.

Table 6 Frequency of Blanks and Collocated samples

Sampler	Blanks	Collocated Samples
VOCs samples	-	One per 10 samples
Carbonyl samples	One per 10 samples	One per 10 samples for the two-channel sampler (1 site). Cannot do collocations for the single channel samplers (4 sites).
PAH samples	One per 5 samples	-
PM10 HAP Metals	One per 5 samples	-

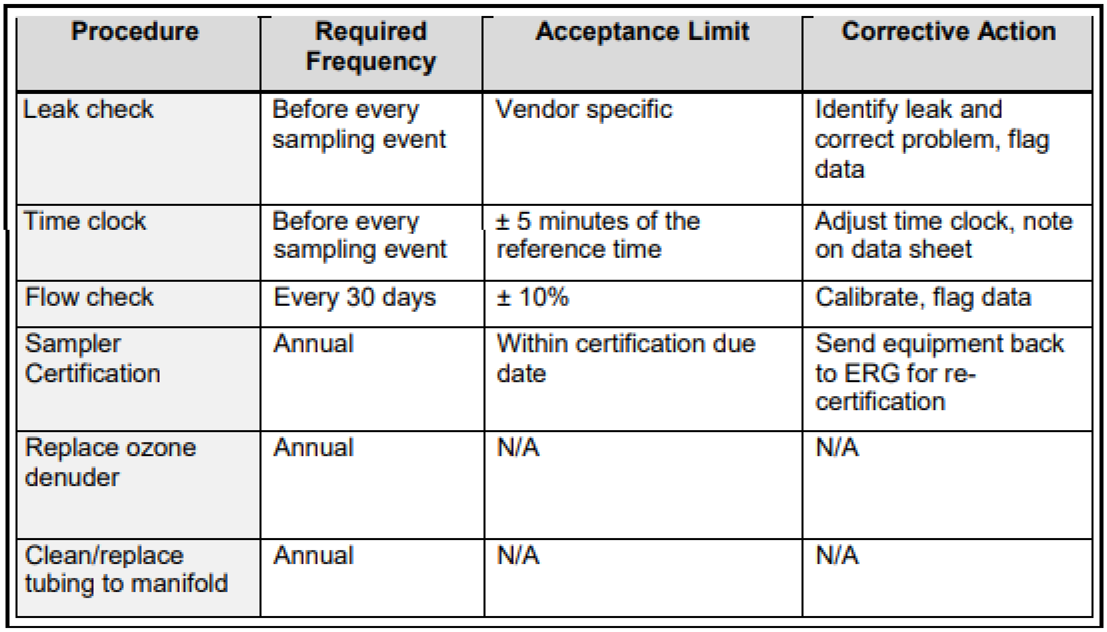
The quality control checks for the laboratory analytical instrumentation will be performed by ERG in accordance with ERG's QAPP. The minimum required frequencies, acceptance limits, and corrective actions associated with the field operations are presented in Tables 7-9.

Table 7 QC checks for VOC sampler (Air Toxics Monitoring Quality Assurance Project Plan, WA DoE, 2020)



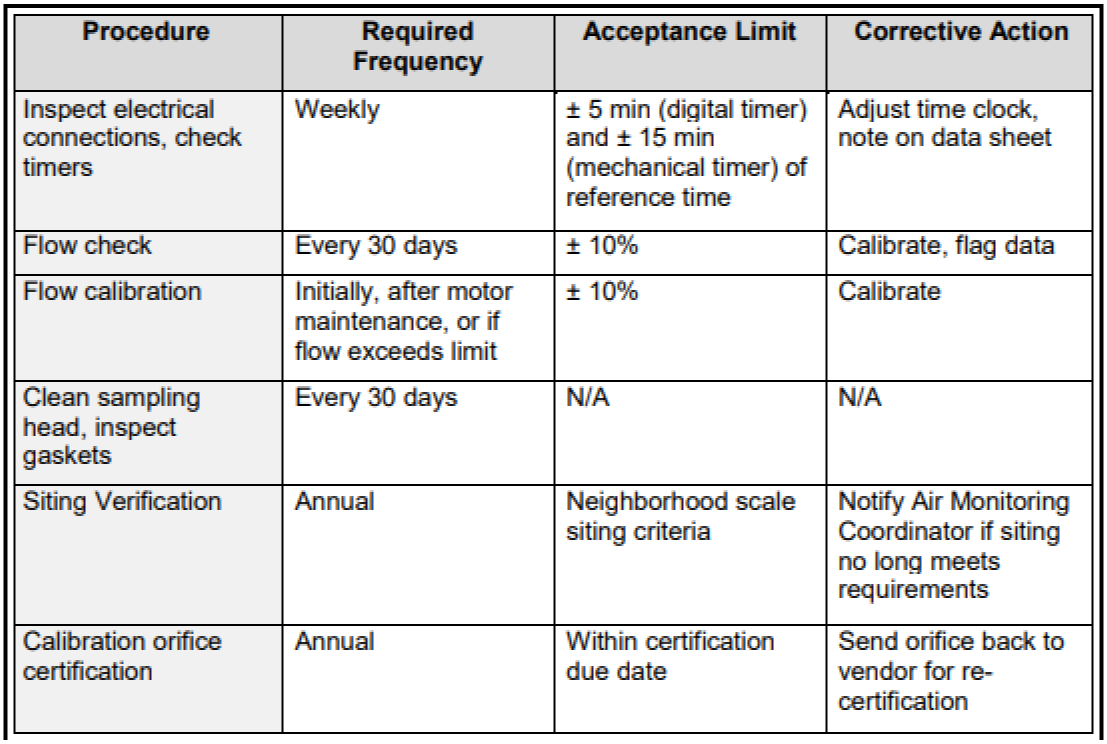
Procedure	Required Frequency	Acceptance Limit	Corrective Action
Leak check	Before every sampling event	Should be close to 0.0 in-Hg (< 0.5 in-Hg)	Identify leak and correct problem, flag data
Time clock	Before every sampling event	± 5 minutes of the reference time	Adjust time clock, note on data sheet
Flow check	Every 90 days	± 10%	Calibrate, flag data
Flow calibration	Initially or if flow exceeds limit	± 10% (one-point) or ± 5% (multi-point)	Calibrate
Pressure gauge check,	Annual	± 0.5 psi of the certified standard.	Adjust gauge
Sampler Certification	Annual	Within certification due date	Send equipment back to ERG for re-certification
Clean/replace tubing to manifold, replace sintered particulate filter	Annual	N/A	N/A

Table 8 QC checks for carbonyl sampler (Air Toxics Monitoring Quality Assurance Project Plan, WA DoE, 2020)



Procedure	Required Frequency	Acceptance Limit	Corrective Action
Leak check	Before every sampling event	Vendor specific	Identify leak and correct problem, flag data
Time clock	Before every sampling event	± 5 minutes of the reference time	Adjust time clock, note on data sheet
Flow check	Every 30 days	± 10%	Calibrate, flag data
Sampler Certification	Annual	Within certification due date	Send equipment back to ERG for re-certification
Replace ozone denuder	Annual	N/A	N/A
Clean/replace tubing to manifold	Annual	N/A	N/A

Table 9 QC checks for PAH sampler (Air Toxics Monitoring Quality Assurance Project Plan, WA DoE, 2020)



Procedure	Required Frequency	Acceptance Limit	Corrective Action
Inspect electrical connections, check timers	Weekly	± 5 min (digital timer) and ± 15 min (mechanical timer) of reference time	Adjust time clock, note on data sheet
Flow check	Every 30 days	± 10%	Calibrate, flag data
Flow calibration	Initially, after motor maintenance, or if flow exceeds limit	± 10%	Calibrate
Clean sampling head, inspect gaskets	Every 30 days	N/A	N/A
Siting Verification	Annual	Neighborhood scale siting criteria	Notify Air Monitoring Coordinator if siting no long meets requirements
Calibration orifice certification	Annual	Within certification due date	Send orifice back to vendor for re-certification

For the continuous monitoring methods, such as $PM_{2.5}$ BC, the Washington State Department of Ecology SOP does require a monthly QC leak check and flow verification. We will be following the SOP requirements for QC. For each of the systems that does not have an established SOP (Mobile monitoring sampling systems like AE-51 mobile, hand-held Micro-Aethalometer, or Low-cost sensors like AirBeam, Dylos, Purple Air), we will be using manufacturers procedures to establish methods to complete quality control assessments. For instance, the handheld micro aethalometer system recommends that a flow check be conducted periodically. We will conduct a flow verification prior to use in the study, and after use in the study. These low-cost sensors will only be used as a tool for creating awareness among the community members and will not be used to calculate health risks. Additionally, all data will be screened in accordance with established monitoring data protocols. Established monitoring data protocols include a monthly visual review of data on a chart, to screen for outliers.

13.4 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Sampler and equipment testing, inspection, and maintenance requirements are generally listed in the established SOP’s. Other testing and inspection requirements will be handled through normal troubleshooting and repair operations by the Puget Sound Clean Air Agency monitoring specialists. For all systems, when indications that maintenance needs to take place, the equipment will be taken out of service, and sampling resumed when the sampler is retested satisfactorily.

13.5 Instrument Calibration and Frequency

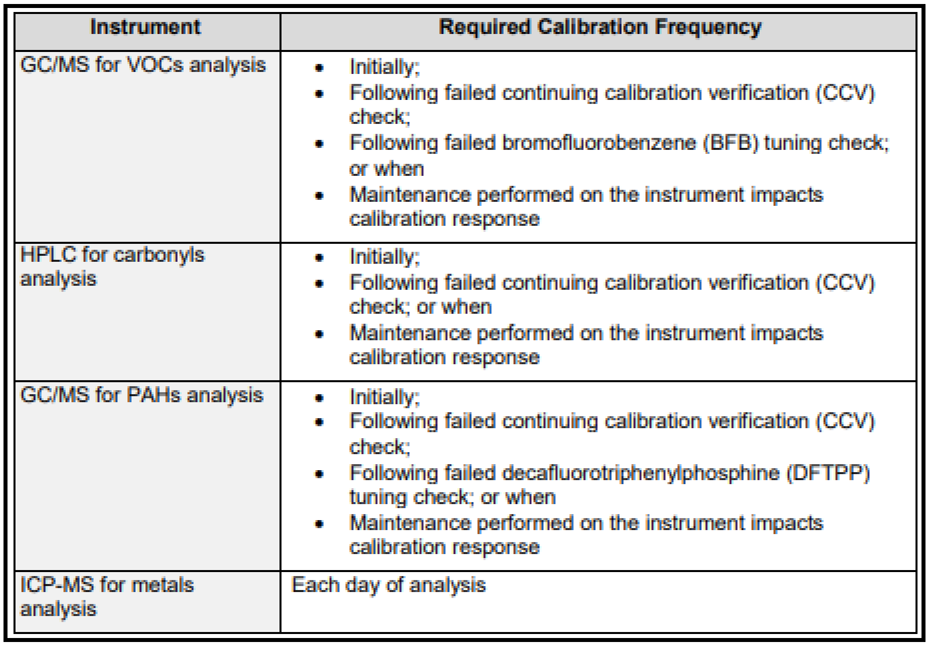
Field Instruments

Sampler and instrument calibration will be conducted in accordance with established SOP's. Instruments used in the field are calibrated at the required frequency described in Ecology's Air Toxics Operating Procedure and summarized in Section 13.3 of this QAPP. In the case of the micro sensor systems (like AirBeam, Dylos, Purple Air, etc.) which will be used for community-directed locations, PSCAA will use manufacturer's procedures. In this case, the sensors will undergo a calibration procedure initially, and then quality control checks will establish the system's measurement quality indicators, and finally, the calibration will be checked at the end of the study. This means that the microsensor systems would be checked against higher quality "core" monitoring systems already in place in the state network. For example, CO sensors would need to be collocated with the Beacon Hill CO monitor before and after the study so that a comparison to the FEM or FRM standard can be done, to put the microsensor data into perspective.

Analytical Equipment

Analytical instruments, including GC/MS for VOCs analysis, HPLC for carbonyls analysis, ICPMS for metals analysis and GC/MS for PAHs analysis, must meet the minimum calibration frequency and acceptable limit criteria set forth in EPA's NATTS TAD. Table 10 summarizes the required calibration frequency of each analytical equipment set by Department of Ecology's Air Toxics QAPP.

Table 10 Required calibration frequency for analytical equipment (Air Toxics Monitoring Quality Assurance Project Plan, WA DoE, 2020)



Instrument	Required Calibration Frequency
GC/MS for VOCs analysis	• Initially; • Following failed continuing calibration verification (CCV) check; • Following failed bromofluorobenzene (BFB) tuning check; or when • Maintenance performed on the instrument impacts calibration response
HPLC for carbonyls analysis	• Initially; • Following failed continuing calibration verification (CCV) check; or when • Maintenance performed on the instrument impacts calibration response
GC/MS for PAHs analysis	• Initially; • Following failed continuing calibration verification (CCV) check; • Following failed decafluorotriphenylphosphine (DFTPP) tuning check; or when • Maintenance performed on the instrument impacts calibration response
ICP-MS for metals analysis	Each day of analysis

In addition to the required calibrations, the analytical systems must pass calibration verification checks to verify bias are within the acceptable limits as part of the laboratory quality control procedures. ERG have established laboratory standard procedures, as listed below, for each of the analytical instruments to ensure adequate equipment performance at ERG:

- ERG-MOR-005: VOC analysis by GC/FID/MS using Method TO-15
- ERG-MOR-024: carbonyl analytic by HPLC system using Method TO-11A
- ERG-MOR-049: PAH analysis by GC/MS using Method TO-13A
- ERG-MOR-095: metal analysis by ICP-MS using Method IO-3.5

13.6 Data Acquisition Requirements

Data will be acquired primarily by the Envidas Ultimate system. Data will be recorded in the PSCAA air quality database through either the traditional FTP import method or will be acquired using the PSCAA Air Quality Drop Application.

The PSCAA Air Quality Drop application is a tool that is designed to import and export data files into a geographical as well as temporally keyed database. The system can upload a single file, or a package of files in a zip format. The Air Quality Drop can read data from the following file formats: *AeroqualVoc, AirBeam, CarClipCo, CarClipO3No2, Dylos, Enmont, GPS, GPX, HourlyTelemetry, MicroAeth, Package, RadianceResearch, SenonicsMinnow, and TsiNanoScan*.

All data files used for the project will be organized in the Projects folder under the internal PSCAA Server using the following Master Guidance:

Master Guidance for Special Project Folder and File Naming Conventions

Folder naming:

- Chinook\TechServices\Projects\
  Inside project folder there are files for each year that hold folders for individual projects that started in that year:
  - …\YYYY\ProjectName\
  - Each individual project folder will have the following:
  - Activity Log/About/ReadMe for the project (.xlsx)
    - …\raw mobile data (these are completely unaltered files)
    - …\raw fixed site data (these are completely unaltered files)
    - …\working mobile data
    - …\working fixed data
    - …\combined working reports and presentations, please also place a copy of the final report and copies of presentations in the proper folders in Chinook\New Public Documents

Naming conventions for raw data:
dataID_LocationID_YYYYMMDDThhmmss_R#[_comments].csv
e.g.

CPCO_PSBike_20140502T163000_R1_PSCAAToHome.csv
DyCt_GtS001_20150612T124000_R1_CXLmeasure.csv

Fields are described as follows:

- dataID: 4 character abbreviation of measured parameter/species, instrument, and model (e.g., CPO3, CPCO, RHum, VOCs, DyCt, MiAt,) A reference table is located in Chinook\TechServices\Projects\
- locationID: 6-character description of site, station, platform, laboratory, institute, or individual collecting (ergo the different route) e.g., ShrBrk, Shr10t, PSBike, CrbFix. We'll need to develop a reference table.
- YYYY: four-digit year
- MM: two-digit month
- DD: two-digit day
- hh: optional two-digit hour
- mm: optional two-digit minute
- ss: optional two-digit second
- R: revision number of data
- comments: optional additional information

Where the only allowed characters are: a-z A-Z 0-9_.- (that is, upper case and lower case alphanumeric, underscore, period, and hyphen). No Spaces. All fields not in square brackets are required. All times used in file names should reflect the start time in the raw file. Notes about time zone and other time/data issues should be noted in the project's Activity Log/About/Read Me file.

All Air toxics data obtained through the Contract Laboratory will undergo a coordinated data review process and will be uploaded to the AQS system by the Contract Laboratory. All geospatial data created under this project shall be consistent with the Federal Geographic Data Committee (FGDC) endorsed standards (www.fgdc.gov). All AQS data is publicly available. All study data is publicly available, upon request.

13.7 Data Validation, Verification and Analysis

EPA has defined the terms "data verification" and "data validation" and those definitions shall be used for purposes of this project. "The term "data verification" means the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements." *See* EPA QA G-8 GUIDANCE ON ENVIRONMENTAL DATA VERIFICATION AND DATA VALIDATION. The term "data validation" means the routine process designed to ensure that reported values meet the quality goals of the environmental data operations. Data validation is further defined as examination and provision of objective evidence that the requirements for a specific *intended use* are fulfilled. *Id*. For the purposes of this grant data, PSCAA will perform both "data verification", and Level 1 "data validation." Department of Ecology personnel will conduct a Level 2 data validation process for all project data associated with the Washington network. Data submitted by the contract laboratory to EPA's AQS will be subject to a level 2 review. In the event of an audit failure using NATTS style equipment, Ecology will work with PSCAA to identify invalid data and remove it from AQS.

Data Analysis will be primarily conducted by the Puget Sound Clean Air Agency analysis team, who will produce the final technical report. Other data users may analyze data collected from this study. Other users are urged to use this data with caution. As such, the table 11 can be used to guide data users as to the anticipated quality level of the data collected as part of this study.

Table 11 Methods and Anticipated Quality Levels

Parameter	Method	Quality Level *
Volatile Organic Compounds	TO-15	Regulatory
Aldehydes	TO-11A	Regulatory
PM2.5 BC and UV carbon	Aethalometer AE-33	High
PM2.5 BAM FEM	FEM Method EQPM- 0308-170	Regulatory
PM10 Metals	IO 3.5/FEM EQL-0512-202	Regulatory
PM10 Metals- NFRM	N-FRM	Medium
PAH	TO-13A ASTM method D6209	Regulatory
PM2.5 BC mobile	Micro-Aeth AE-51	Medium
Fine Particle count mobile	Air Beam	Low
Fine/Total particle count	Dylos DC-1700	Low
Ultrafine Particle Count	Enmont PUFP-C100	Medium

* Anticipated quality level – actual level may prove to be better or worse based on Data Quality Indicators.

Data verification refers to the daily work that the air monitoring specialists will perform to ensure that data is collected according to the QAPP. Data validation refers to those activities performed after the data have been collected. The difference between the data validation and quality control techniques is that the quality control techniques attempt to minimize the amount of bad data being collected, while the data validation seeks to prevent any bad data from getting through the data collection and storage systems – to prevent incorrectly collected data from informing the results. Data validation is a combination of checking that data processing operations have been carried out correctly and of monitoring the quality of the field operations. Data validation can identify problems in either of these areas. Once problems are identified, the data can be corrected or invalidated, and corrective actions can be taken for field or laboratory operations. If possible, flags denoting error conditions or QA status are saved as separate fields in any databases, so that it is possible to recover the original data. Table 12 will be used to plan the types of data checks, and the people responsible for the checks.

Table 12 Validation Check Summaries

Type of Data Check	Responsible Team member	Manual Checks	Automated Checks
Date and Time Consistency	PSCAA Air monitoring specialist	X	
Completeness of required sample fields	Lab receiving personnel	X	X

Statistical outlier checking	PSCAA Project Manager and Analysis Team	X	X
Manual inspection of charts and reports	Lab personnel	X	
Field and Lab blank checks	Lab personnel	X	

Data Analysis

The Data Analysis Team will review all the data collected in this study. PSCAA will submit summary reports of the monitoring data collected in the study to the EPA. The report will be a summarized account of the observations and recommendations that will be available in Draft form initially. After final Technical reviews are complete, the report will be finalized. We will evaluate the data in a multi-step process.

First, we will complete a full and ongoing evaluation of the data including a full quality assurance assessment. This entails checking data completeness, trends, temporal patterns, and potential interferences. Data Quality Indicators will be used to describe the actual quality of the data sets, to evaluate the data usability. Additional review will help in the analysis, including reviewing detection limits to determine the best statistical estimation techniques needed. We will calculate summary descriptive statistics such as averages, medians, percentiles, and distributions, for all the measured air toxics.

The data analysis will focus on meeting the grant's Outputs and Outcomes, and addressing the main scientific questions:

- Has average potential cancer risk from air toxics in Seattle and Tacoma changed since 2010?
- If a change in concentrations is observed, can it be explained by meteorology rather than emissions changes?
- Can patterns be detected in the data that suggest emission sources, activities, categories, or events? (e.g., transportation, industrial sectors, residential wood burning, fireworks, etc.)
- Has there been any change in the distribution of air pollutants and risk across the focus communities?
- How do our measurements and analysis compare to other available measurements and modeling (NATA and NATTS)?
- What additional tools or analysis can be developed to improve our ability to identify pollution sources, assess risk, develop plans to reduce future risk, and address community concerns?

The more complex analyses include, and will generally progress as follows:

1. Assess the potential impact of meteorology on the observed trends and patterns. We will use available meteorological data (wind speed, direction, temperature, precipitation, etc.) to assess the potential impact of meteorological factors. The analysis will include, at a minimum, looking at distributions of wind speed, direction, and temperature, to identify potential confounding influences on long-term trends.
2. Estimate potential cancer risks for fixed sites. Based on statistical summaries described above, we will calculate potential cancer risk using the Washington State Acceptable Source Impact Levels unit risk factors. Based on these estimates, we will provide a ranking of air toxics, which will help us quantify the health hazards attributed to air toxics.

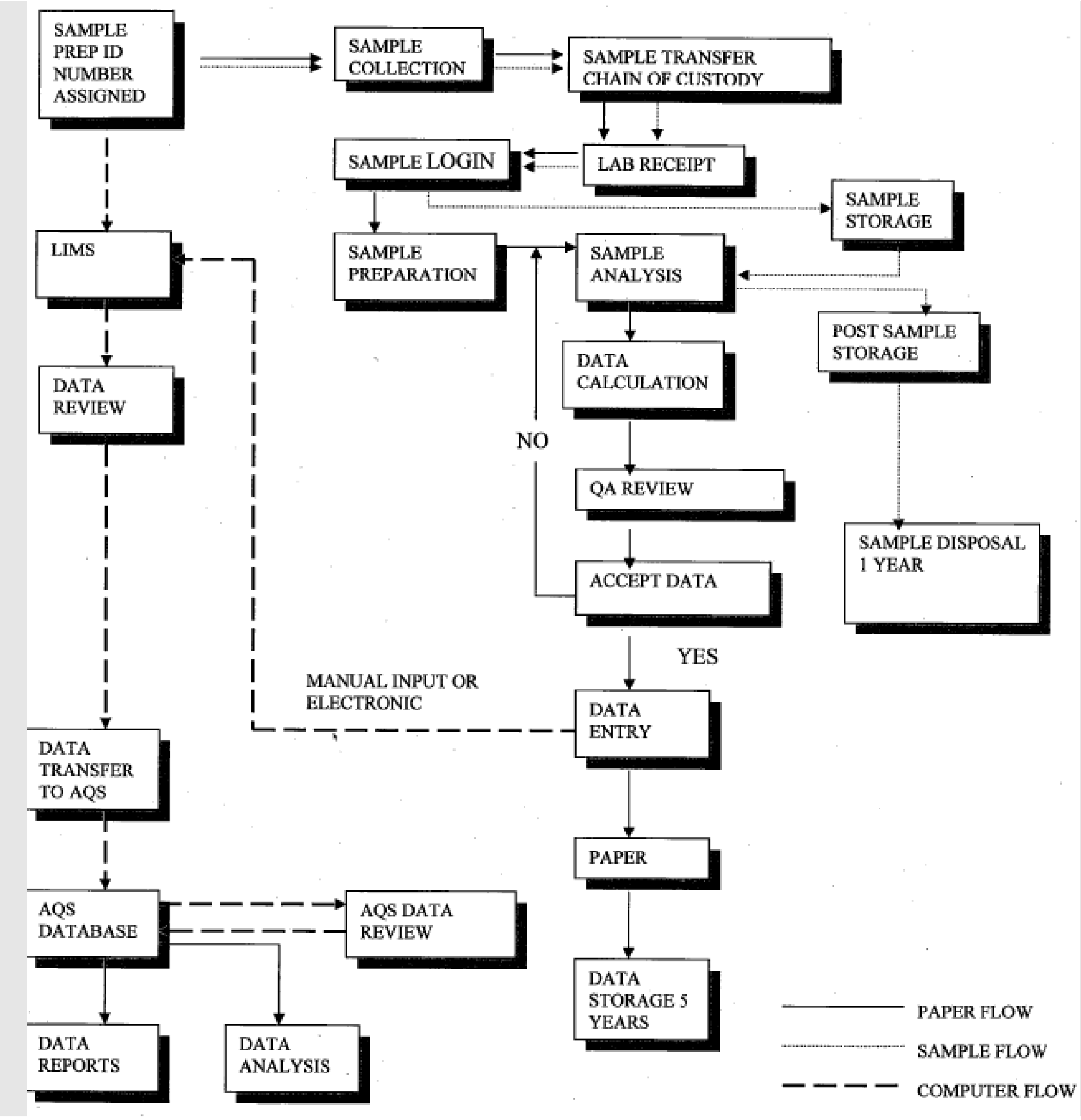
3. Compare air toxics concentrations and risks for Seattle and Tacoma from the 2010 and 2016 studies. We will use all comparable data and risk calculations to compare to the 2010 Study of Air Toxics in Tacoma and Seattle, and the 2016 study in Seattle's Chinatown-International District. We will answer how air pollution and toxic risk has changed over the last 10 years. We anticipate being able to include comparisons for diesel and wood smoke estimates at the Tacoma Alexander, Seattle Duwamish, and Beacon Hill sites. We also anticipate estimating diesel and wood smoke at 10th & Weller and Tacoma 36th sites but can't include comparisons as these sites weren't a part of the 2010 study.
4. Compare air toxics concentrations and risks to the NATTS network. We will aggregate three years of NATTS data across the country, average the results, and apply the same unit risk factors to evaluate and compare risk across the country. A key comparison will be with the nearby Seattle Beacon Hill NATTS site, which is about 1.6 miles to the east of the Seattle Duwamish site. The Beacon Hill site is at a substantially higher elevation (+ 100 m), and further away from major sources in the Duwamish Valley, providing a good regional background.
5. Compare air toxics concentrations to nearby 2017 National Air Toxics Assessment (NATA) model estimates. We will compare our results to the 2017 National Air Toxics Assessment model. The analysis will include mapping (ArcGIS or similar) and descriptive statistics for the census tracts containing or near to sampling sites, and in the focus community.
6. Identify and quantify air toxics sources through source apportionment. We will use both data collected specifically for this project and leveraged data from the existing, collocated sites. The existing instruments and data collected vary across all the fixed sites. They include aethalometers (UV to IR absorption, with2 or 7-channels), fine particulate matter (BAM and/or nephelometer), CO, NOx, and meteorological parameters (wind speed, wind direction, temperature, barometric pressure, relative humidity). We will use all of the available data in a factor analysis (e.g., PMF or Chemical Mass Balance, CMB) to identify and quantify air toxics sources such as transportation, industrial facilities, or other sectors (e.g., residential woodburning). The factor analysis will examine monitored concentrations of air toxics, metals, PAHs, black carbon, fine particles, carbon monoxide, nitric oxide, and may include supplementary data such as traffic counts, temperatures, wind speeds, and humidity. As they are available, we will also include organic carbon, elemental carbon, and many other particle fractions from any collocated speciation data provided by the Washington State Department of Ecology. We will attempt to estimate concentrations of diesel particulate matter, an important mobile source air toxic, so that we may include its estimated levels and risk (at least qualitatively) as we communicate results.
7. Extrapolate risks from the fixed sites to quantify potentially exposed populations and their potential risk. If a chemical marker or PMF pattern appears to provide relatively consistent ratios to the toxics that drive most of the risk (e.g., benzene, 1,3-butadiene, formaldehyde, ethylene oxide), we will extrapolate the air toxics levels beyond the fixed sites to the surrounding census block groups based on estimated source emissions, with associated uncertainties indicated prominently. We will investigate ratios of the marker/pattern to specific air toxics, as well as to criteria pollutants.
8. Additional multivariate geospatial analysis based on the concerns of the focus communities. Based on the concerns expressed by the focus communities, we will conduct additional analyses. The analyses could include, or be specific to, additional measurements or data requested by the communities but not specified beforehand. It could also include using existing data to produce a high-resolution gradient or map of pollutants or risk for nearby industrial

areas, the Port of Tacoma or Seattle, or gradients from the nearby roads and vehicles, or other specific concerns that the communities identify.

14 Data Management

This section describes all the aspects of data management necessary for this project. This includes an overview of the mathematical operations and analyses performed on raw, "as-collected" data. These operations include data recording, validation, transformation, transmittal, reduction, analysis, management, storage and retrieval, and reporting. Data Processing activities for air toxics data are described in the figure 6.

Figure 6 Data Management and Sample Flow Diagram



Data processing steps are integrated, to the extent possible, into the existing data processing system used for criteria pollutant monitoring. The air monitoring database resides on a dedicated database Central server at the State Department of Ecology, and a dedicated SQL database at the Puget Sound Clean Air Agency.

Sample tracking and chain of custody information is entered into a Laboratory Information Management System at two points as shown in the figure 6. Managers can obtain reports on status of samples, location of specific samples, etc. using LIMS. Different access privileges are given each authorized user depending on that person's need. The following privilege levels are defined:

- Data Entry Privilege – The individual may see and modify only data within LIMS that he or she has entered. After a data set has been "committed" to the system by the data entry operator, all further changes will generate entries into the system audit trail.
- Reporting Privilege – The individual may generate reports.
- Data Administration Privilege – Data Administrators for the LIMS can change data because of QA screening and related reasons. All operations resulting in changes to data values are logged to the audit trail.

The Data Administrators are responsible for performing the following tasks on a regular basis:

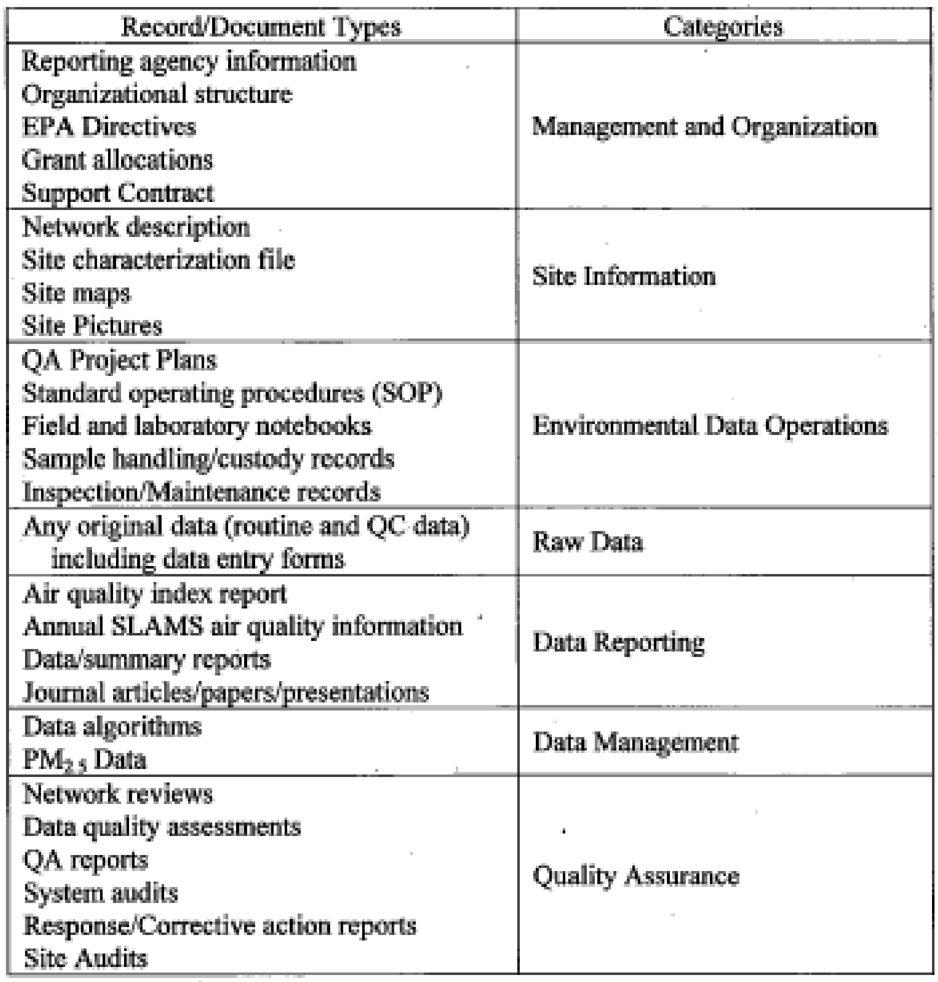
- Merging or correcting duplicate data entry files
- Running verification/validation routines, and correcting data as necessary
- Generating summary data reports for management
- Uploading validated data to EPA-AQS

All other study data will be entered into the PSCAA air quality database using tools such as automated data-loggers, and/or the Air Quality Drop tool.

Mobile Data must be uploaded using the Air Quality Drop tool, because of its dependency on spatial positioning.

Table 13 lists the routine documents and records that will be kept for this project. These documents and records will normally be kept in centralized folder structures so that the documents can be recalled later.

Table 13 List of Routine Documents and Records collected



Record/Document Types	Categories
Reporting agency information Organizational structure EPA Directives Grant allocations Support Contract	Management and Organization
Network description Site characterization file Site maps Site Pictures	Site Information
QA Project Plans Standard operating procedures (SOP) Field and laboratory notebooks Sample handling/custody records Inspection/Maintenance records	Environmental Data Operations
Any original data (routine and QC data) including data entry forms	Raw Data
Air quality index report Annual SLAMS air quality information Data/summary reports Journal articles/papers/presentations	Data Reporting
Data algorithms $PM_{2.5}$ Data	Data Management
Network reviews Data quality assessments QA reports System audits Response/Corrective action reports Site Audits	Quality Assurance

15 Assessments and Response Actions

Our analysis and results will help us better understand air toxics trends and air toxics health risks in the communities in Seattle and Tacoma. We will better understand air toxics levels at different distances to the highway, the risk context through comparisons against national monitoring sites (including the nearby Seattle NATTS site), and the NATA model. Additionally, we will engage the community to explore potential mitigation strategies beyond the time horizon of this grant.

In this study we will provide the community the unique opportunity to direct air toxics sampling based on their own concerns. Sampling will be geared toward air toxics pollution, but the community will have the latitude to identify a variety of locations and sources (for example bus stops, parking lots, intersections, loading docks, or highways).

We have already started building relationships in this community through our agency's focus community work. We also plan to continue to work in these communities to provide information and the tools to take next steps. This air toxics study provides an important part of acting against air pollution by helping to fill in identified data gaps. Ultimately this project will impact the community by informing stakeholders about the air pollution levels, the risk levels, and the potential mitigation strategies that can be employed to reduce pollution in the area over the long-term.

16 Reports to Management

PSCAA will produce a final technical report, which will be drafted, then routed to stakeholders. Feedback will be solicited, and then the final technical report will be finalized. When the report is finalized, then the report will be given to EPA, as part of the Grant Closeout Package. PSCAA will share this final technical report with all stakeholders, and will post the report to the Agency website, so that it can be publicly accessible.

Semi-annual reports on the grant progress will be forwarded to the Grant Project Officer and will be retained as part of the grant record.

17 Appendices

APPENDIX	TITLE
A	Canister Sampling Procedures
B	Carbonyl Routine Sampling Procedure
C	PUF Routine Sampling Procedure
D	The EPA 1 in 6 Sampling Calendar
E	AE-33 “7 Channel” Aethalometer Sampling Procedures
F	AE-51Micro-Aeth Quick Start Guide Procedure
G	Air-beam Operating Procedures
H	Purple Air Operating Procedure
I	PM2.5 Partisol Procedure Link and PM-10-2.5 Designation
J	Enmont Ultrafine Particle Counter Procedure
K	Air Quality Web: Air Drop Procedure
L	NFRM Metal Sampling Procedure

A. Canister Sampling Procedures

STANDARD OPERATING PROCEDURE
FOR THE COLLECTION OF
VOLATILE ORGANIC COMPOUNDS
FOR THE EPA SCHOOL AIR TOXICS PROGRAM

U.S. Environmental Protection Agency
Region 4, Science and Ecosystem Support Division
Athens, Georgia, 30605

Acknowledgement

This Standard Operating Procedure (SOP) was developed by EPA Region 4, Science and Ecosystem Support Division. This SOP is based on the Commonwealth of Kentucky's ambient monitoring SOP template. Special thanks to the State of South Carolina and ERG for operational content.

For questions or comments please contact:

Tim Slagle, EPA, Region 4, SESD at slagle.tim@epa.gov or 706-355-8741
Greg Noah, EPA, Region 4, SESD at noah.greg@epa.gov or 706-355-8635
Mike Jones, EPA-OAQPS-AQAD at jones.mike@epa.gov or 919-541-0528

Table of Contents

I. INTRODUCTION

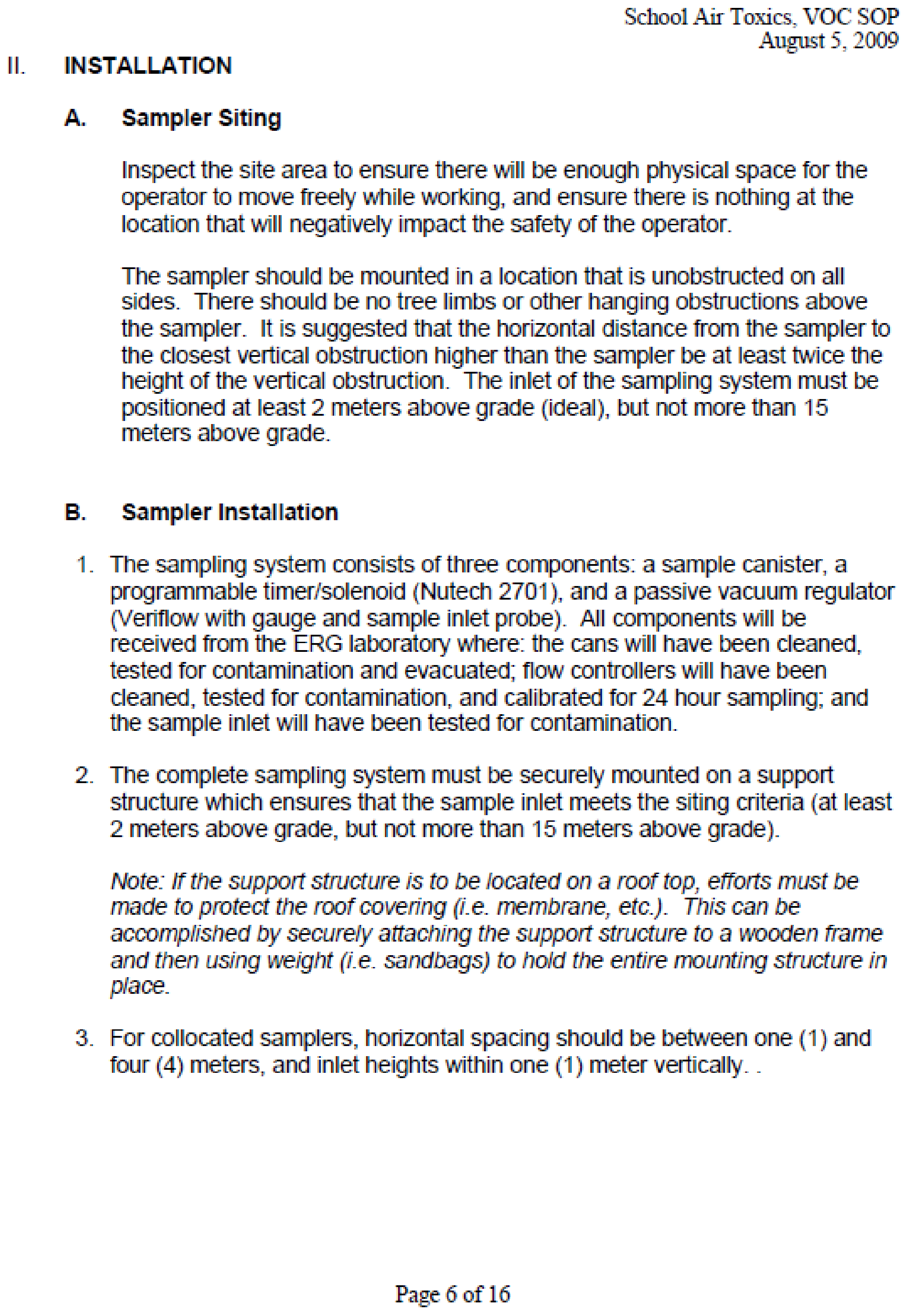
This document is designed to provide instruction on collecting volatile organic compounds in air using an evacuated canister and a passive air sampling kit.

The procedure presented is designed for sampling volatile organic compounds (VOCs) in ambient air, based on the collection of whole air samples in SUMMA® treated canisters to final pressures below atmospheric. The samples are then analyzed using EPA Compendium Methods TO14A or TO15 *Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)* using the EPA National Monitoring Program's contract laboratory (i.e. ERG).

The canisters are 6-liter stainless steel vessels whose internal walls are SUMMA® treated with an inert pure chrome-nickel oxide compound to reduce the reactivity of the air sample in the canister. The canisters are outfitted with a stainless steel bellows valve, equipped with a 1/4" Swagelock® fitting on the inlet. Prior to use, all canisters are cleaned in accordance with the specifications presented in the EPA NATTS Technical Assistance Document Rev. 2 (April 2009). Once certified as clean, the canisters are evacuated to approximately 29.5 inches of mercury ("Hg) and are ready for use. The collection approach is passive, meaning no 110 volt AC power is required. The canister is attached to a programmable timer/solenoid, a veriflow vacuum regulator, and a sample probe. Figure 1 presents the complete VOC sampling system. When the programmable timer opens the solenoid at a preset time, the canister is filled with ambient air at an integrated collection rate across the 24-hour sampling duration.

This SOP is designed to be a step by step procedure for operating the sampling system described, and is to be used in conjunction with the manufacturer's operator's manual(s). Laboratory Analysis Methodology using the TO-15 method may be referenced by contacting the Eastern Research Group (ERG) directly at 919-468-7800 or by email Julie.Swift@erg.com. Maintenance and troubleshooting should be conducted using the relevant operator's manual(s).

FIGURE 1. Photograph of Total VOC Sampling System
With Timer and Probe



II. INSTALLATION

A. Sampler Siting

Inspect the site area to ensure there will be enough physical space for the operator to move freely while working, and ensure there is nothing at the location that will negatively impact the safety of the operator.

The sampler should be mounted in a location that is unobstructed on all sides. There should be no tree limbs or other hanging obstructions above the sampler. It is suggested that the horizontal distance from the sampler to the closest vertical obstruction higher than the sampler be at least twice the height of the vertical obstruction. The inlet of the sampling system must be positioned at least 2 meters above grade (ideal), but not more than 15 meters above grade.

B. Sampler Installation

1. The sampling system consists of three components: a sample canister, a programmable timer/solenoid (Nutech 2701), and a passive vacuum regulator (Veriflow with gauge and sample inlet probe). All components will be received from the ERG laboratory where: the cans will have been cleaned, tested for contamination and evacuated; flow controllers will have been cleaned, tested for contamination, and calibrated for 24 hour sampling; and the sample inlet will have been tested for contamination.

2. The complete sampling system must be securely mounted on a support structure which ensures that the sample inlet meets the siting criteria (at least 2 meters above grade, but not more than 15 meters above grade).

   Note: If the support structure is to be located on a roof top, efforts must be made to protect the roof covering (i.e. membrane, etc.). This can be accomplished by securely attaching the support structure to a wooden frame and then using weight (i.e. sandbags) to hold the entire mounting structure in place.

3. For collocated samplers, horizontal spacing should be between one (1) and four (4) meters, and inlet heights within one (1) meter vertically. .

III. OPERATING PROCEDURE

A. Equipment and Supplies

6 liter sample collection canister
Veriflow vacuum regulator/gauge/inlet probe
Nutech 2701 programmable timer/solenoid
Support structure with holder for assembled sampling apparatus
Logbook
ERG sample paperwork

B. Sampler and Sample Media Receipt Activities

Complete Sampling System

1. Check parts and components against the packing list.

2. Ensure all fittings are present and in good condition.

3. Prior to sampling keep all components in a clean area free of contamination.

Nutech 2701 Programmable Timer/Solenoid – Battery Charge

1. Charge the internal battery by opening the front cover and plugging the supplied USB adapter cable into the labeled USB port located on the bottom right of the front panel (mini USB).

2. Plug the other end of the USB cable into a USB port on a computer (standard USB). Allow the timer to charge for at least 12 hours. A battery charge indicator is located at the top center left of the display. The battery will display 🔋 after a full charge is reached.

   Note: The display will show 🪫 *when the battery is drained. To ensure that there is always a sufficient charge on the battery, recommend recharging every six days.*

Sample Collection Canister

1. The sample collection canister and associated sample data sheet will arrive from ERG in a cardboard box.

   Note: The canisters do not need to be refrigerated after receipt or during return shipping.

2. Ensure the canister is not damaged. Confirm that the valve remained in the closed position during shipping and that the top plug is secured on the bellows valve inlet fitting.

C. Preparing for a Sampling Event

Initial Steps

1. Ensure the Nutech 2701 timer battery is fully charged. If there are not at least two (2) bars displayed, the timer must be recharged before conducting the sampling event.
2. Prepare sample paperwork. On the ERG Toxics/SNMOC Sample Data Sheet, supply all required information in the "Lab Pre-Sampling" section. Record any pertinent observations in the notes section at the bottom of the form.
3. Remove the plug attached to the bellows valve inlet. Retain the plug in a clean place so that it can be used to reseal the bellows valve inlet after the sampling event.
4. Assemble the complete sampling system.
    a. Attach the outlet fitting of the Nutech 2701 timer/solenoid to the canister bellows valve inlet.

       Note: Do not over tighten the nut. When the nut feels snug, another quarter turn should be sufficient to secure the timer inlet to the can.

    b. Attach the outlet fitting of the Veriflow vacuum controller to the inlet fitting of the Nutech 2701 timer/solenoid.

       Note: Again, do not over tighten the nut. When the nut feels snug, another quarter turn should be sufficient to secure the timer inlet to the can.

Measuring and Documenting the Pre-Collection (Set-up) Canister Pressure

The following steps are to be performed prior to programming the Nutech 2701 timer/solenoid for the initial/subsequent collection event:

1. On the timer control panel, press the bubble switch labeled "Enter" once. This will take the timer out of the power-saving/hibernation mode.

2. On the timer control panel, press the bubble switch labeled "Manu" once. This places the timer in the manual operation mode. On the display in the center of the bottom zone, the word "Open" should be present. If the word "Closed" is present, press the "Manu" bubble switch again and it should shift to the word "Open". This action manually opens the solenoid and clears a flow/pressure path between the canister valve and the Veriflow control orifice and pressure gauge.

3. Fully open the canister bellows valve. Observe the pressure (i.e., "Hg vacuum) indicated on the gauge. Fully close the canister bellows valve.

   Note: The bellows valve should be kept open for as short of a duration as possible – 10 seconds or less.

4. Record the Pre-collection Canister Pressure in the appropriate space on the supplied Chain-of-Custody.

Programming the Timer

At this point, the Nutech 2701 timer/solenoid is ready to be programmed to automatically conduct the next scheduled collection event. Follow the programming steps provided below.

1. Set the current time *(local standard time)*
   a. Push the "Set" key twice.
   b. The LCD will show flashing digits that can be changed by pushing the left or right arrow keys. When finished, press the set button to move to the day of the week.
   c. Change the day by pushing the left or right arrow keys. An arrow will be present above the selected day. When finished, press the "Enter" key to finish the time and day setting.
2. Set the sample start and end date / times
   a. Program the sampling event by pushing the "set" button once to enter event setting.
   b. Set event number (SEG on the display). Select 1 as your event number using the arrow keys. Once the event number

is set, "Open" will be flashing to set the valve function.

c. Press "Enter" to confirm the open function. The time will flash. Set the sampling start time, followed by the day of the week using the arrow keys. Confirm the settings by pressing "Enter" to complete the program.

*Note: It's critically important that **00:01** be entered for the event start time (the timer will not recognize a start time of 00:00 and will not actuate).*

d. The valve icon on the timer should appear as indicating that the valve is in the closed position. During the sampling event, the icon on the timer will appear as .

3. To set the event stop time, push "Set" once to enter event setting. Set event number (SEG) first. Select 1 as your event number. Once you set the event number the (Open) will flash. Using right arrow key to move flashing to (Close), now (Close) is flashing for you to set the valve function. Push (Enter) to confirm the close function. Then the time will be flashing. You now set your sampling stop time [use **23:50**], followed by day of the week. Select the day of the week then push (Enter) to finish.

D. Sample Recovery and Data Collection

1. Activate the timer display by pressing the "Enter" button once. This will activate the screen with the current day of the week and current time of day (in Standard Time not Daylight Savings Time). The valve icon on the timer should appear as indicating that the valve is in the closed position. The display will also indicate the total elapsed time for the previous sampling event.
2. Record the total elapsed time on the ERG Toxics/SNMOC Sample Data Sheet in the "Elapsed Time" blank in the "Field Recovery" section.
3. Open the solenoid valve by pressing the "Manu" button once.
4. Fully open the canister bellows valve.
5. Read the gauge and record the remaining pressure left in the can on the ERG Toxics/SNMOC Sample Data Sheet and record the reading in the "Field Recovery", "Field Final Can. Press. ("Hg)" blank. If the pressure is zero, note the lack of pressure in the "Comments" section of the form.

6. Close the canister bellows valve by turning the knob until it is snug.

   Note: The canister bellows valve should not be opened for any longer than is required to get an accurate pressure measurement (i.e. approximately 10 seconds).

7. Close the timer solenoid valve by pressing the "Manu" button again.

8. Disconnect the canister from the Nutech 2701 timer/solenoid by unfastening the bellows valve inlet fitting from the timer outlet fitting.

9. Replace and secure the retained plug on the canister bellows valve.

10. On the ERG Toxics/SNMOC Sample Data Sheet, supply all required information in the "Field Recovery" section. Be sure to record any observations that were made during the run period.

11. Sample Shipping

    a. Remove the pink copy of the ERG Toxics/SNMOC Sample Data Sheet and file in a site record.

    b. Pack the can and the completed white copy of the ERG Toxics/ SNMOC Sample Data Sheet in the original cardboard shipping box and tape it closed. The can does NOT need to be shipped cold.

    c. Use the pre-filled out FedEx label provided by ERG, and fill out the Sender" section with the sampling agency's address and phone number. Send priority overnight to ERG at the address below.

       ERG
       601 Keystone Park Drive
       Suite 700
       Morrisville, NC 27560
       919-468-7924

       Note: if the shipping form is lost, use the address below for shipping to ERG, and contact them directly for the FedEx accounting.

IV. QUALITY ASSURANCE

To ensure that quality data is being collected the following checks should be considered:

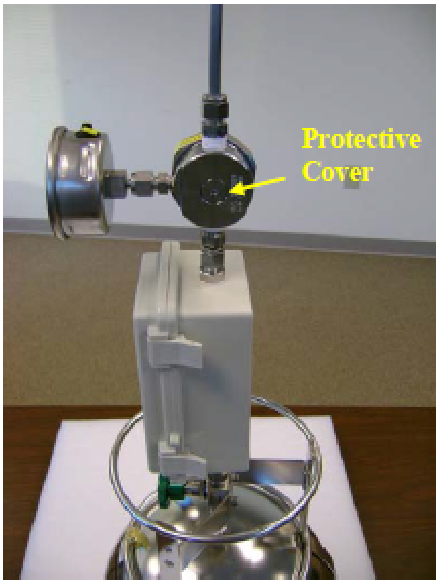
A. Flow Calibration

Prior to deployment each Veriflow must be calibrated to a collection flow rate of approximately 3.2 cc/min to insure that the final pressures obtained over a 24-hour collection duration are appropriate. This calibration will be performed by EPA Contract Laboratory prior to shipment of each Veriflow to the field. Ideally, with a collection flow rate set-point of 3.2 cc/min, a 6L canister will attain a final volume of approximately 4,700 cc over a 24-hour (i.e. 1440 min) collection duration. The final volume of 4,700 cc equates to a final sample pressure in the canister of between 6 and 7 "Hg, which is the target final pressure for the EPA SAT program.

Because the Veriflows were calibrated at the EPA Contract Laboratory in Research Triangle Park, NC, variations in elevation, temperature, and barometric pressure between the calibration site and the field deployment site can cause variations in the final flow rate set-point realized. This variation in flow rate may necessitate adjustment of the collection flow rate set-point in the field. The following procedure presents the steps to accomplish the in-the-field set-point adjustment.

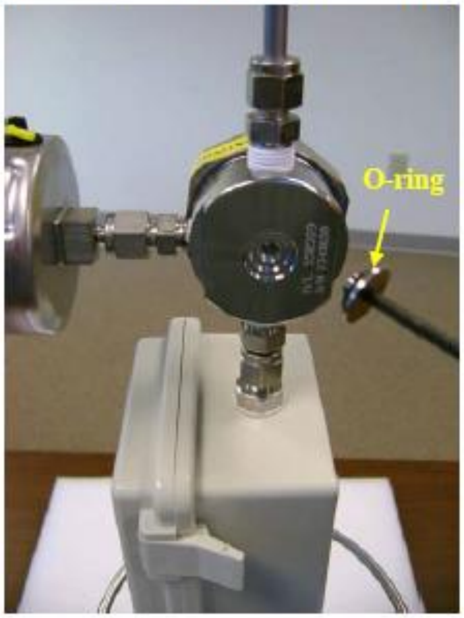
1. On the right hand side of the Veriflow unit, locate the adjustment screw protective cover (1/2 inch diameter disk with a 1/8 inch hex port located in the center) as shown in Figure 2.

Figure 2. Veriflow adjustment screw protective cover



2. Insert a 1/8 inch hex key into the hex port and rotate the protective cover counter-clockwise until it can be removed from the protective cover. Please note that the protective cover has an o-ring attached to it, as shown in Figure 3. The purpose of the o-ring is to ensure that the unit remains weather-tight while deployed. It is important that the o-ring be present when the protective cover is reattached to the Veriflow.

Figure 3. Removed protective cover with o-ring

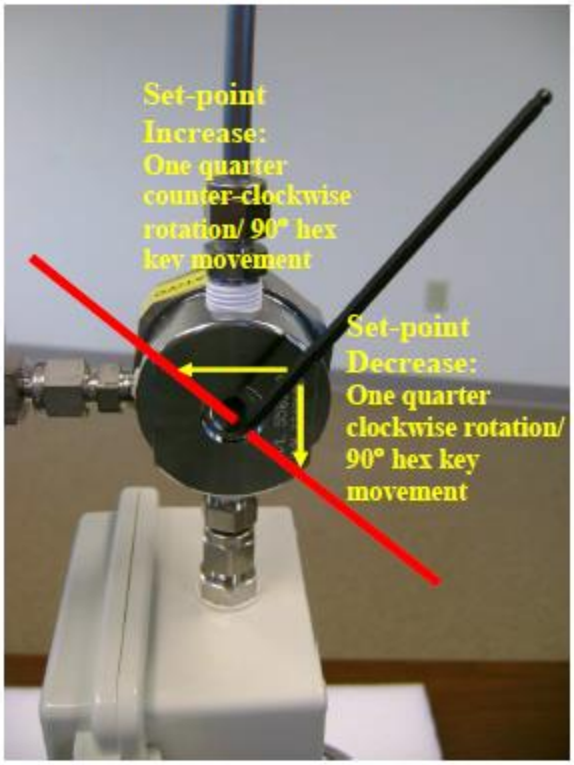


3. Under the cover is the actual flow rate adjustment screw (3/16 inch black circle with hex port located in the center), as shown in Figure 4.

Figure 4. Flow rate adjustment screw

4. To make adjustment to the flow rate set-point, insert a 1/8 inch hex key into the hex port on the adjustment screw. The Veriflow unit utilizes 5 full rotations to take the set-point from the bottom of its operational range (i.e. approximately 2 cc/min) to the top of its operation range (i.e. approximately 4 cc/min). As stated earlier, the units have been pre-calibrated for approximately 3.2 cc/min and should yield a final sample pressure is between 6 and 7 "Hg. However, it should be noted that final pressures between 1 and 10 "Hg are considered valid samples. If a final sample pressure between 1 and 10 "Hg is achieved, no adjustment is required. If the final sample pressure achieved is outside the acceptable range, or if a final pressure closer to the ideal set-point of 6 to 7 "Hg is desired a set-point adjustment will need to be made. To increase the flow rate, insert a 1/8 inch hex key into the hex port located in the center of the adjustment screw. Rotate the adjustment screw counter-clockwise. To decrease the flow rate, rotate the adjustment screw clockwise. It is recommended that adjustments be made in one quarter rotation increments between collection events, until the desired final sample pressure is achieved. The quarter turn adjustment can be easily gauged by observing the handle of the hex key so that it is positioned 90 degrees before or past its original position. See Figure 5.

Figure 5. Flow rate set-point adjustment



5. After adjustment replace the o-ring and protective cover. The Veriflow unit is now ready for use on the next sample collection episode.

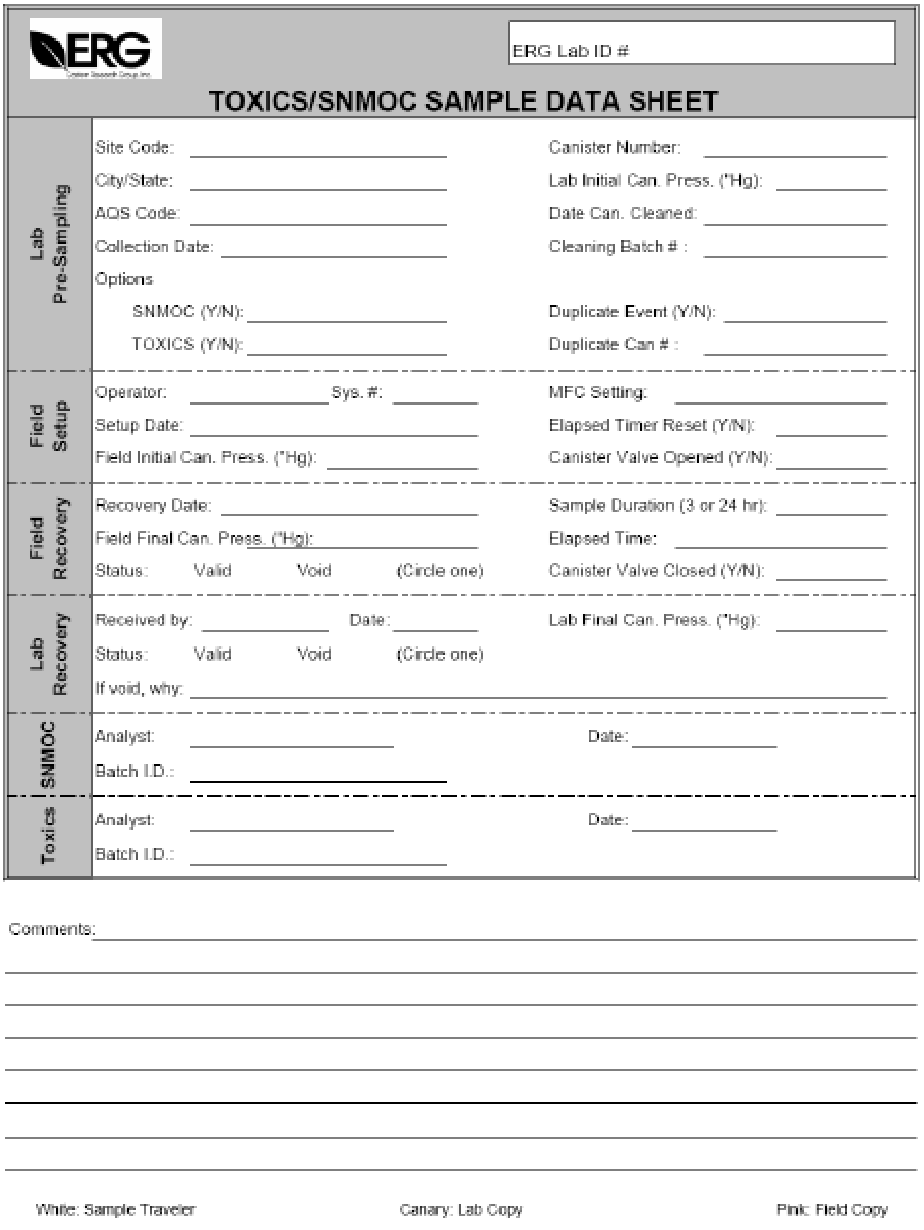
B. System Cleanliness

All equipment, with the exception of the timer, will be cleaned by ERG before shipment to the agency. If anomalies are observed, the ERG laboratory will notify the agency and a course of action will be identified. The operator should take care not to touch or contaminate the inlet, fittings, and other parts of the sampling train. These areas should be kept covered if possible when sampling is not occurring.

V. DATA FORMS

All sample related run data forms will be supplied by ERG. Check the data sheets for completion after every setup or retrieval event. The operator is expected to keep a logbook to document all site activities, quality assurance activities, and sampling activities. Figure 6 presents the ERG Toxics / SNMOC Sample Data Sheet.

FIGURE 6. ERG Toxics/SNMOC Sample Data Sheet



ERG Lab ID #

TOXICS/SNMOC SAMPLE DATA SHEET

Lab Pre-Sampling

Site Code: ______________ Canister Number: ______________
City/State: ______________ Lab Initial Can. Press. ("Hg): ______________
AQS Code: ______________ Date Can. Cleaned: ______________
Collection Date: ______________ Cleaning Batch # : ______________
Options
SNMOC (Y/N): ______________ Duplicate Event (Y/N): ______________
TOXICS (Y/N): ______________ Duplicate Can # : ______________

Field Setup

Operator: ______________ Sys. #: ________ MFC Setting: ______________
Setup Date: ______________ Elapsed Timer Reset (Y/N): ______________
Field Initial Can. Press. ("Hg): ______________ Canister Valve Opened (Y/N): ______________

Field Recovery

Recovery Date: ______________ Sample Duration (3 or 24 hr): ______________
Field Final Can. Press. ("Hg): ______________ Elapsed Time: ______________
Status: Valid Void (Circle one) Canister Valve Closed (Y/N): ______________

Lab Recovery

Received by: ______________ Date: ________ Lab Final Can. Press. ("Hg): ______________
Status: Valid Void (Circle one)
If void, why: ______________

SNMOC

Analyst: ______________ Date: ______________
Batch I.D.: ______________

Toxics

Analyst: ______________ Date: ______________
Batch I.D.: ______________

Comments: ______________

White: Sample Traveler Canary: Lab Copy Pink: Field Copy

Endnotes to School's Air Toxics Protocol

Detailed procedures are outlined in the EPA TO method TO-15. This is a description for regular field runs for passive canister samplers. ERG ships the required materials in a box to PSCAA. PSCAA then ships the collected samples back to ERG for analysis.

The stand-alone timers used with a flow control device may sometimes cause leaks and hence the following guidance should be considered prior to and during the study:

- Upon each sampling event, ensure all fittings (canister to timer, timer to flow controller, and flow controller fittings, particulate filter) are tight. Some fittings require an extra quarter turn after the fitting is finger tight. Consult tightening guidance of the fitting vendor.
- Leak test the sampling apparatus (canister, timer, and flow controller) every sampling run as per the protocol in TO-15A described below:
    - Tightly cap the inlet.
    - If the gauge is upstream of the solenoid, manually activate the solenoid (if so equipped).
    - Open and close the canister valve to generate a vacuum at the gauge.
    - Observe the gauge to assess the leak rate. There should be no perceivable pressure increase.
    - If there is a leak, gently snug the fittings and retest. If the leak persists, replace the sampling apparatus and/or canister and test.
    - Following a successful leak check, remove the inlet cap.
- Leak check timer every 10 runs.
- Replace the batteries frequently.
- Conduct a flow check on the flow controller to ensure that vacuum (4 to 11 inches of Hg) will remain in the can following the sampling duration.
- Immediately report samples that end the sampling run at ambient pressure (0 inches of Hg) to the QA staff for corrective action.

In summary, a field technician needs to go out to the field to setup the run. The technician will conduct the leak and flow tests as described above. Using the timer, the samples can be setup to run at the programmed start and stop time. The technician needs to then pick up the canister from the field after the run. The samples are collected once every 6 days.

Required Materials:

- 2 Crescent Wrenches
- Black or Blue Pen
- Canister and a backup in case of a faulty canister
- Chain of Custody Sheet
- Cell Phone

Sample Drop-off and Pickup:

- Record the city and state on the chain of custody sheet.
- Record the AQS code for the site as in the table below:

Site	AQS Code	Four Digit Site Code
Seattle 10th&Weller	05303300301	BKWA
Seattle 10th&Weller Collo	05303300302	BKWB
Seattle Duwamish	05303300571	CEWA
Seattle Duwamish Collo	05303300572	CEWB
Tacoma Alexander	05305300311	EQWA
Tacoma Alexander Collo	05305300312	EQWB
Tacoma South L St	05305300291	ESWA
Tacoma South L St Collo	05305300292	ESWB
Tacoma S 36th St	05305300241	YFWA
Tacoma S 36th St Collo	05305300242	YFWB

- Record the date that the sampler will run on in the chain of custody sheet for the respective canister.
- Write “N” for SNMOC, “Y” for Toxics.
- If this is a duplicate event, record the duplicate canister number on the custody sheet.
- Record the date of the sample set up.
- For Sample Setup, use the Schools Air Toxics SOP to set up the sample and timer in Section C. For Sample Recovery, use the Schools Air Toxics SOP to recover the sample in Section D Steps 1 through 11.

Duplicate Samples:

- ERG will ship an extra canister for the collocated samples.

Shipping

- All canisters from ERG will be shipped back to ERG in the same boxes with a postage paid FedEx return label included.
- ERG does not accept shipments on the weekends, so **shipments must be sent Monday through Thursday only**.
- In case of emergency, the lab address and phone contact are: 919-468-7923, Randy Bower, 601 Keystone Park Dr., Suite 700, Morrisville, NC 27560
- All labels should be marked "Priority Overnight" shipping if not already.

General Sampling Calendar:

If Sample run is on a:	Take out to field on:	Return from the field on:	Ship out with FedEx by 4:30PM on:
Monday	Friday	Tuesday	Tuesday
Tuesday	Monday	Wednesday	Wednesday
Wednesday	Tuesday	Thursday	Thursday
Thursday	Wednesday	Friday	Monday
Friday	Thursday	Monday	Monday
Saturday	Friday	Monday	Monday
Sunday	Friday	Monday	Monday

B. Carbonyl Routine Sampling Procedure

Detailed procedures are outlined in the EPA TO method TO-11A. This is a description for regular field runs for carbonyl samplers. ERG ships the required materials in a cooler to PSCAA. PSCAA then ships the collected samples back to ERG for analysis. In summary, the field technician needs to go out to the field to setup the unit before the run. A technician then needs to go to the field to pick up the sample as quickly as possible after the run. The sampler runs every 6 days.

We will be using ATEC model 2200 carbonyl sampler for this study. There will be one Two Channel model, which will be installed at Tacoma South L Street, and four Single Channel models used, which will be installed at the other sites. Duplicates will be run at the Tacoma South L Street site, and blanks will be used at all the sites.

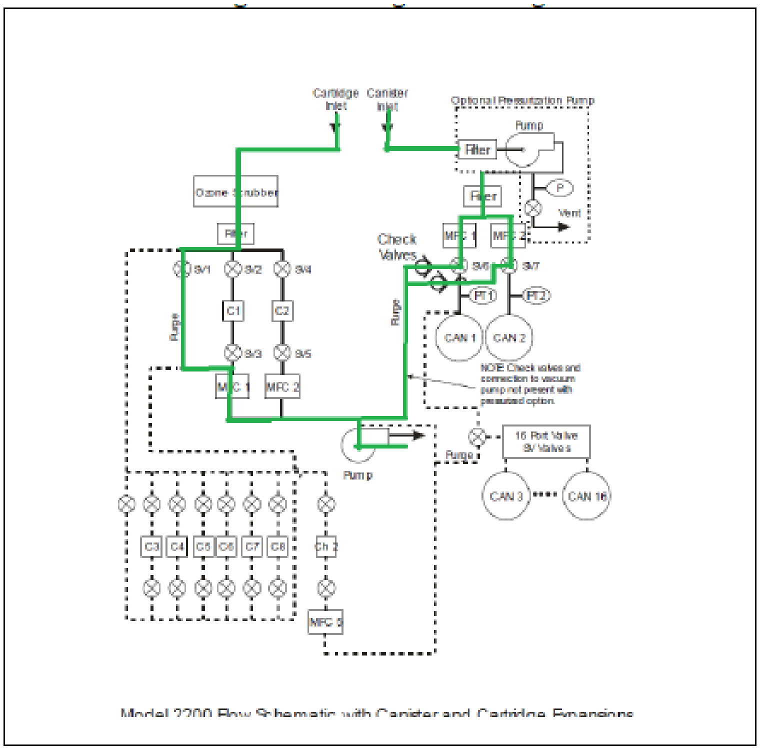
Figure: ATEC model 2200 2-channel carbonyl sampler

Summary of Method:
Using the ATEC Model 2200 Toxic Air Sampler, a 24-hour ambient air sample will be taken. Air will be drawn into cartridges for later analysis of Carbonyl compounds. The monitor has been pre-programmed to comply with EPA Methods TO-11A. Section 7.2 of EPA method TO-11A describes the DNPH adsorbent cartridges in detail. The sampler consists of a single pump that pulls ambient air into the sampler. To control and monitor the cartridge flow rates, there is an independent mass flow controller for each channel.

PSCAA operators will go into the field with a carbonyl adsorbent cartridge (cartridges to be kept cool to < 4°C), supplied by ERG's lab. **(Note: Lab will supply materials to field operators at least two days in advance of sampling).** The operator will install the collection media, program sampler, retrieve collection media, fill out appropriate paperwork, and return samples to ERG's lab for analysis. Prior to sampling, the Model 2200 will purge the sample line. The default purge time is one hour. Sampled carbonyl cartridges should be placed in cooler with ice packs after sampling for transport to maintain a temperature of <4°C.

The following materials are required:
- ATEC Model 2200 Toxic Air Sampler
- 1/8" and 1/4" Stainless Steel Sampling Tubing
- 1 - 7/16 wrench and 1 - 9/16 wrench
- 1 pair - Polyethylene gloves

- NIST Traceable BIOS Defender (100ml/min – 7 L/min)
- Carbonyl adsorbent cartridge(s) (**Note-DNPH cartridges should not be exposed to sunlight.)**
- Field data sheets
- Sampler Maintenance/Log book
- Computer with 2200 Data Retrieval Software or USB
- NIST Traceable Barometer
- NIST Traceable Thermometer
- Cooler and Ice Packs for Transport of DNPH Cartridges
- Site AIRS codes
- Calculator



Purge Flow Diagram: Purge flow paths are shown in green. Sampler is purged for 60 minutes prior to the start of each sampling event.

Equipment Installation

The ATEC Model 2200 Toxic Air Sampler should be set up in a weather protected area with 115 VAC current. Although not necessary, a controlled environment of 20-30°C is suggested for operation of the sampler.

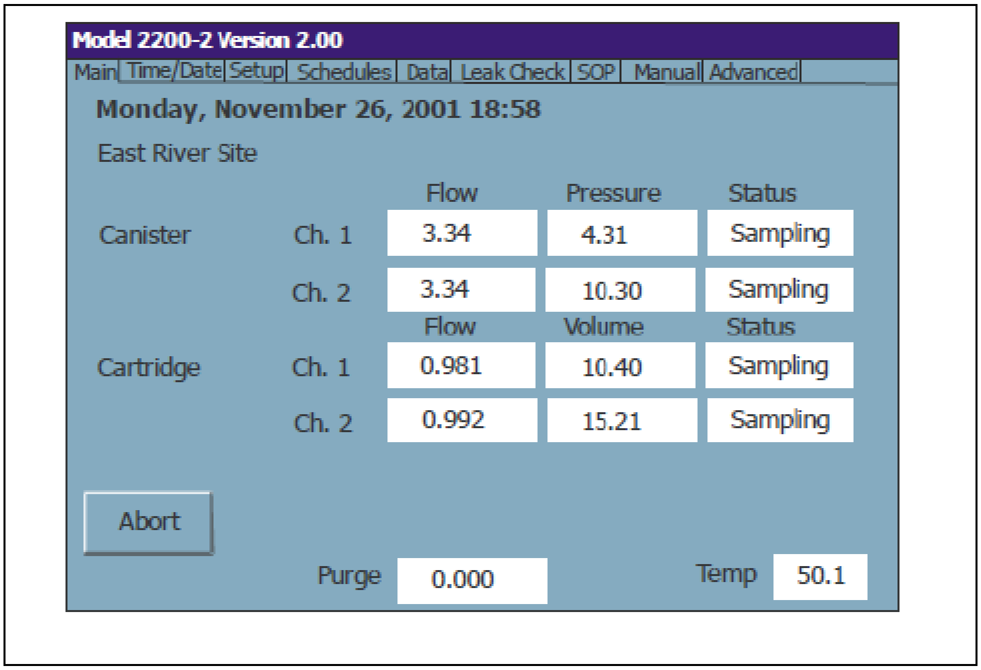
Mobilize the unit to the field-sampling site and plug into a 115 VAC outlet. Move power switch to "On". The system will "boot up" in ~ 30 seconds. The system is operated using the ¼ VGA LCD color touch screen display, which shows current status, and allows entry of information into the system's computer. A pen may be used as a "stylus" to operate the touch screen's buttons.

Run a ¼" diameter SS tube to the exterior of the sampling enclosure as a sample line. Using a ¼" Swagelok connector and ferrule, connect the sample line to the back of the sampler labeled "Input".

Cut two pieces of 1/8” SS tube to a length of ~ 2ft. (or other length as needed to reach the sampling storage area for the Summa Canisters). Place 1/8” Swagelok connectors and ferrules on both ends of this canister line. Hook one end of each line to the positions labeled “Channel 1” and “Channel 2” on the back of the sample unit. The other end of these lines has quick connectors to attach to the Summa canisters for sampling.

Sample Set-up Operation

The following steps are necessary for the daily sample set-up. Values are entered or are pre-set and may be viewed on the Model 2200’s touch screen.



Monday, November 26, 2001 18:58

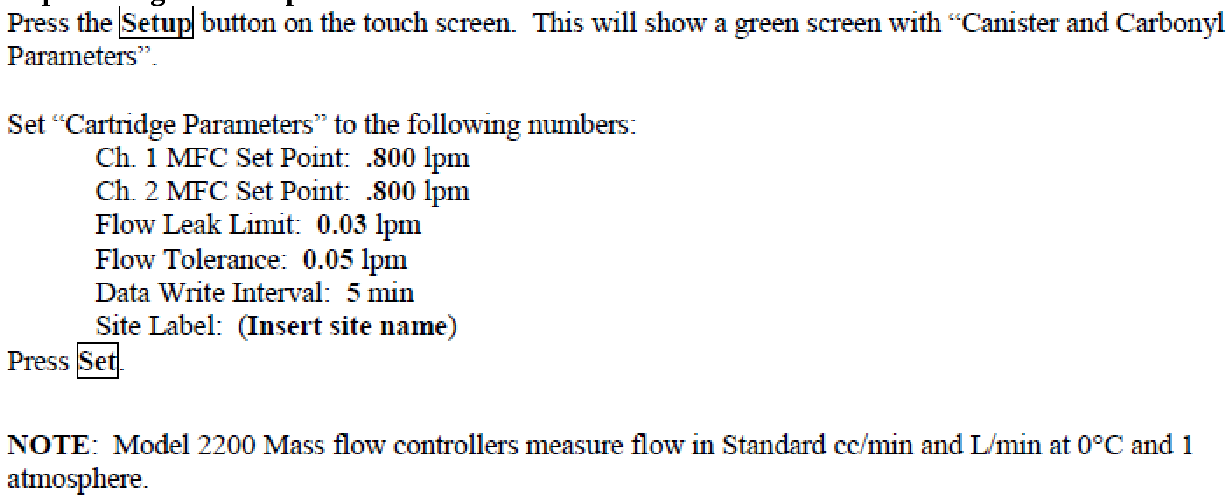
East River Site

		Flow	Pressure	Status
Canister	Ch. 1	3.34	4.31	Sampling
	Ch. 2	3.34	10.30	Sampling
		Flow	Volume	Status
Cartridge	Ch. 1	0.981	10.40	Sampling
	Ch. 2	0.992	15.21	Sampling

Purge 0.000

Temp 50.1

Sampler Program Setup



Press the Setup button on the touch screen. This will show a green screen with “Canister and Carbonyl Parameters”.

Set “Cartridge Parameters” to the following numbers:

Ch. 1 MFC Set Point: **.800** lpm
Ch. 2 MFC Set Point: **.800** lpm
Flow Leak Limit: **0.03** lpm
Flow Tolerance: **0.05** lpm
Data Write Interval: **5** min
Site Label: (**Insert site name**)

Press **Set**.

NOTE: Model 2200 Mass flow controllers measure flow in Standard cc/min and L/min at 0°C and 1 atmosphere.

Installation of Carbonyl Cartridge

NOTE: Polyethylene Gloves should be worn whenever the DNPH-Carbonyl cartridges are being handled.

On the display screen select **Schedules** button. Change the date to the current date on the carbonyl cartridge Channel 1, change the start time to 5-minutes ahead of the current time, and leave the duration to 24-hour. Press **Exit**. The ATEC 2200 machine will begin to purge itself and then perform a leak check. Once this is complete the machine goes into sampling mode, disconnect the sample line and connect the BIOS Defender to the Channel 1 cartridge position on the exit side of the DNPH cartridge in the Carbonyl cartridge sample line. Initiate the flow using the manual control and measure local flow rate. Record the ATEC current flow in L/min.Std 0°C on the Carbonyl Cartridge Field Sheet (Appendix A, Form 1). Recording the average BIOS Defender flow rate in L/min local. Stop the BIOS Defender from taking reading and abort sampling on ATEC. NOTE: The ATEC is reading in Standard Conditions while the BIOS Defender is reading in Local. Therefore, it is necessary to take the barometric pressure and temperature readings to convert the local flow reading to Standard Condition Flow (0°C, 760 mmHg) using the following equation:

$$\text{Flow Rate Std } (0^\circ C) = \text{Flow Rate}_{\text{Local}} \;\mathrm{X}\; \frac{P_{\text{site}}\ \text{mmHg}}{760\text{mmHg}} \;\mathrm{X}\; \frac{273^\circ K}{(\text{Temp}_{\text{site}}{}^\circ C + 273)}$$

This will give a comparison to the flow reading on the Model 2200. Record Standard BIOS Defender flow in L/min Std 0°C. If the percent difference is no greater than ± 2% between the ATEC and converted BIOS Defender reading then, with Polyethylene gloves on, attach the carbonyl cartridge to the appropriate Teflon sample line (Position 1 Sample/Position 2 Duplicate). Repeat this process for channel 2 if it is a duplicate sampling day. NOTE: If the percent difference is greater than ± 2%, a calibration will need to be performed. Instructions are in the ATEC Model No.2200 Operations and Maintenance Manual, pg. 40, Appendix A.

8.7.3 Perform Leak Checks/Setup.

Press SOP. A screen will appear. Select carbonyl(s) to run, and press Next to get to the Leak Screen. The instrument will run leak checks on any carbonyls that were selected in the first screen. Press Next to run the leak check. The carbonyl leak check will run for 20-seconds. Acceptance limit is set in Section 8.7.1. If leak rate is not met, connections on lock fittings should be checked and leak check re-run. If this does not solve the problem, ATEC should be contacted. Record all leak rates on the field sheets. Cartridge leak check will test the portion of the sample train from the closed upstream solenoid valves (SV1, SV2 & SV4) through the cartridge (C1 & C2), downstream solenoid valves (SV3 & SV5) and mass flow controllers (MFC1 & 2) on to the pump. See Figures 8-4 and 8-5 for details.

When the leak checks are complete, continue navigating through the SOP screens to schedule the next sample run. Enter start dates, start times, and durations of the carbonyls scheduled to run. Press Next after each carbonyl is scheduled to continue on to the next one. Upon completion, the SOP Summary Page will appear with a summary of everything scheduled to run. Confirm that the schedule is correct, and press Next. The instrument will return to the Main Screen. The status box for the carbonyls scheduled to run should say “waiting”.

NOTE: If a problem is recognized while performing any maintenance, diagnostic, or flow checks which has or could affect data, a corrective action form is to be filled out describing the problem identified and the action taken to correct the problem. See Appendix A, Form 3.

Figure 8-4: Model 2200 Flow Diagram

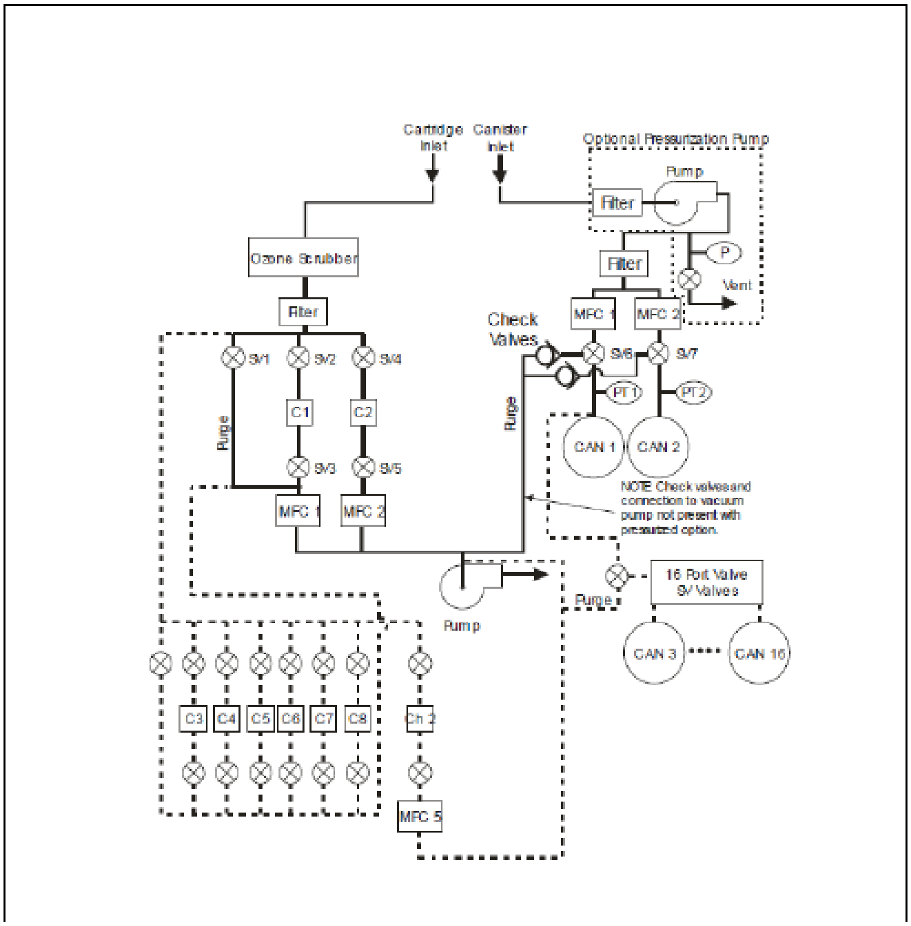
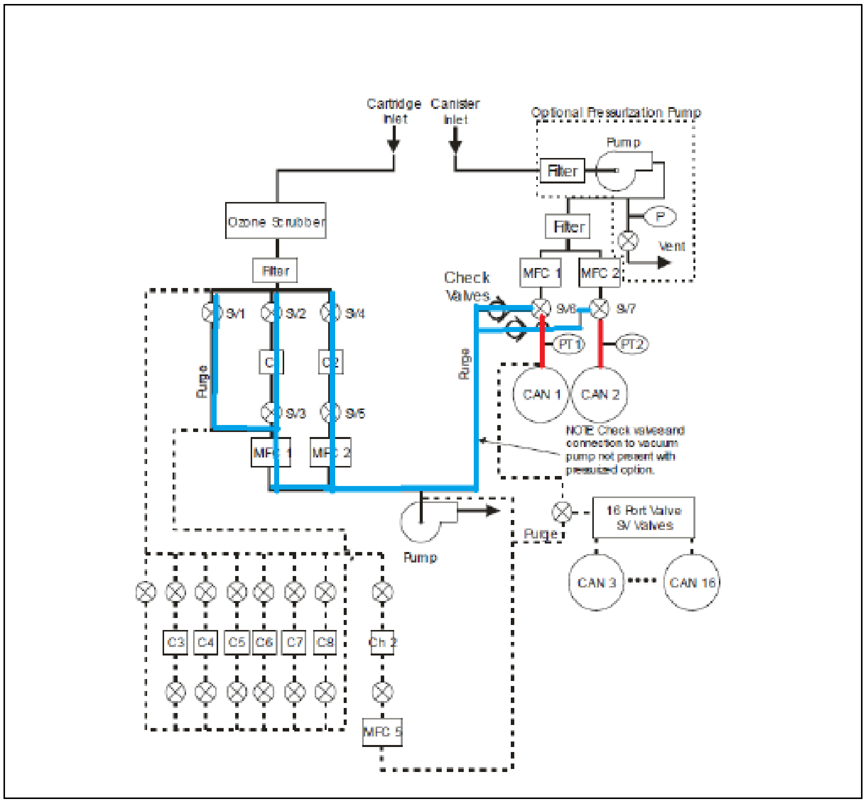


Figure 8-5: Leak Check Vacuum Train



Blue lines show sampling train under vacuum during cartridge leak check.

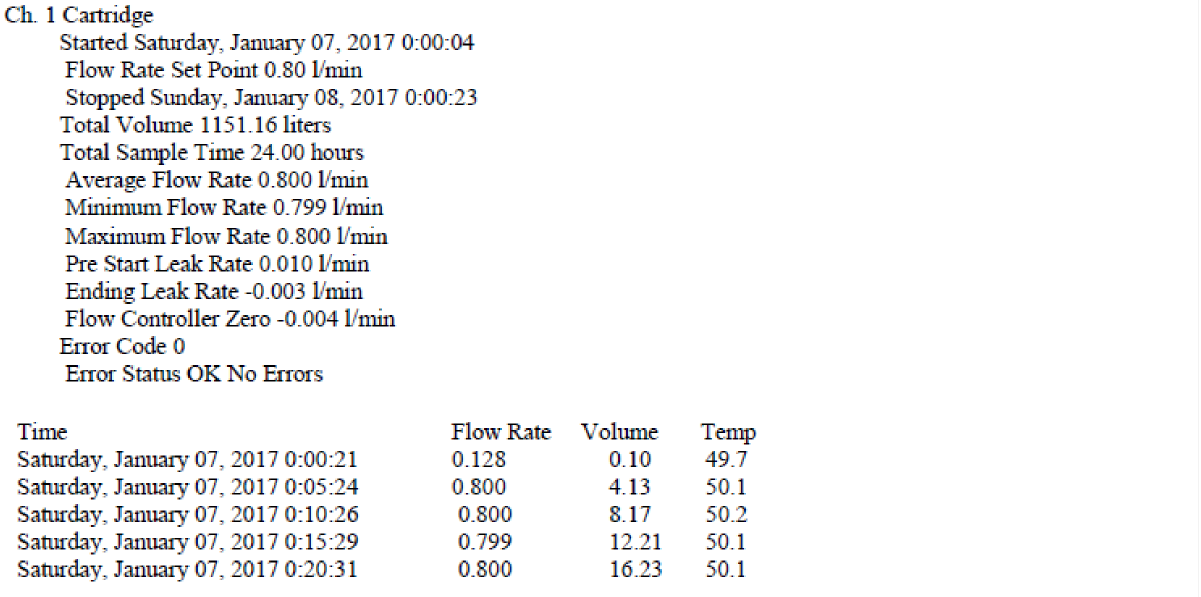
Sample Pickup Procedure

8.7.4.1 Downloading Data

Note: Data must be downloaded prior to proceeding with post-sampling checks. Otherwise, five minute data will be lost in the process.

Connect the USB Drive to the sampler's "Data" port on the front of the sampler. Press the Data button on the sampler. A screen will appear with the start date, stop date, flow, and time on it. Press the Store button on the sampler. When data transmission is complete, a screen will appear stating data was downloaded. Press OK. If during sampling a power failure occurs, the sampler will remain sampling according to schedule after power is resumed. No data should be lost, however on the downloaded data, a "power loss" error will show and there will be no data given for the powerless interval. For a 24-hour run, there will be approximately 300 lines of data. Figure 8-6 gives an example of the five minute data files.

Sample Carbonyl Download



```
Ch. 1 Cartridge
        Started Saturday, January 07, 2017 0:00:04
         Flow Rate Set Point 0.80 l/min
         Stopped Sunday, January 08, 2017 0:00:23
        Total Volume 1151.16 liters
        Total Sample Time 24.00 hours
         Average Flow Rate 0.800 l/min
         Minimum Flow Rate 0.799 l/min
         Maximum Flow Rate 0.800 l/min
         Pre Start Leak Rate 0.010 l/min
         Ending Leak Rate -0.003 l/min
         Flow Controller Zero -0.004 l/min
        Error Code 0
         Error Status OK No Errors

  Time                                      Flow Rate   Volume    Temp
  Saturday, January 07, 2017 0:00:21        0.128         0.10     49.7
  Saturday, January 07, 2017 0:05:24        0.800         4.13     50.1
  Saturday, January 07, 2017 0:10:26         0.800        8.17     50.2
  Saturday, January 07, 2017 0:15:29         0.799       12.21     50.1
  Saturday, January 07, 2017 0:20:31         0.800       16.23     50.1
```

Cartridge Pickup:

- Record the recovery date on the sample custody sheet. Put 24 hours under "Sample Duration".
- Record the post sampling Rotameter reading on the custody sheet.
- Record elapsed time.
- Check the actual data from the sampler versus what you expected the data to show to identify any mismatches.
- Remove the cartridge(s) and cap them with the provided caps.
- Place them in the RTI provided silver colored bags. Ensure that the washer is still in the black capsule.
- Record anything unusual that you may notice in the "Comments" section of the provided custody sheet. This may include instrument behavior, nearby emission sources, etc.
- Ensure that the custody sheet is fully filled in.
- When in the lab, calculate the average flow rate and total collection volume on the custody sheet as in the calculations section below.
- Store the sample at < 4ºC until shipping in the cooler, which should also be < 4ºC.
- This sample must be extracted for analysis within 14 days of sample collection, so ship the cooler out as quickly as possible.

Duplicate Samples:

- ERG will ship an extra sample for the collocated sampler.

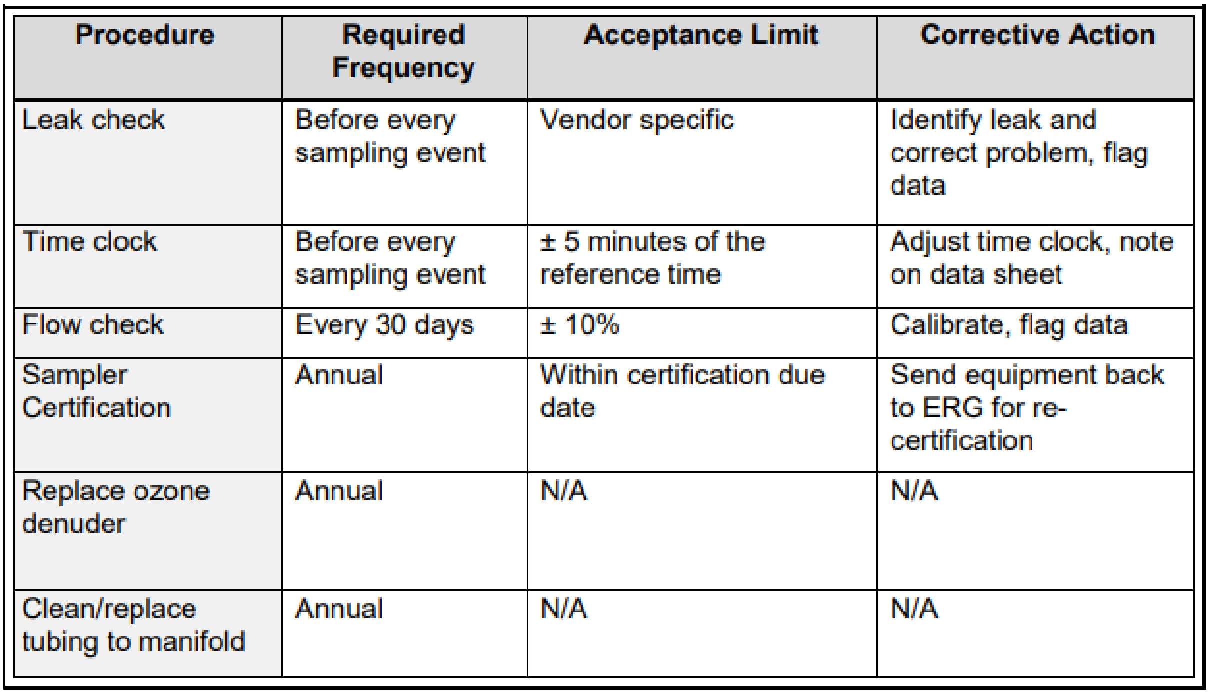
Applicable AQS Codes for the chain of custody:

Site	AQS Code	Four Digit Site Code
Seattle 10th&Weller	05303300301	BKWA
Seattle Duwamish	05303300571	CEWA
Tacoma Alexander	05305300311	EQWA
Tacoma South L St	05305300291	ESWA
Tacoma South L St Collo	05305300292	ESWB
Tacoma S 36th St	05305300241	YFWA

Shipping:

- All samples from ERG will be shipped back to ERG in the same coolers with a postage paid FedEx return label included.
- Replacement cold icepack and max T logger will be placed prior to shipping.
- ERG does not accept shipments on the weekends, so **shipments must be sent Monday through Thursday only**. If it appears that shipment will not be picked up (too late), put the sample back in the refrigerator until the shipment can be made.
- In case of emergency, the lab address and phone contact is: Randy Bower, 919-468-7923, 601 Keystone Park Dr., Suite 700, Morrisville, NC 27560

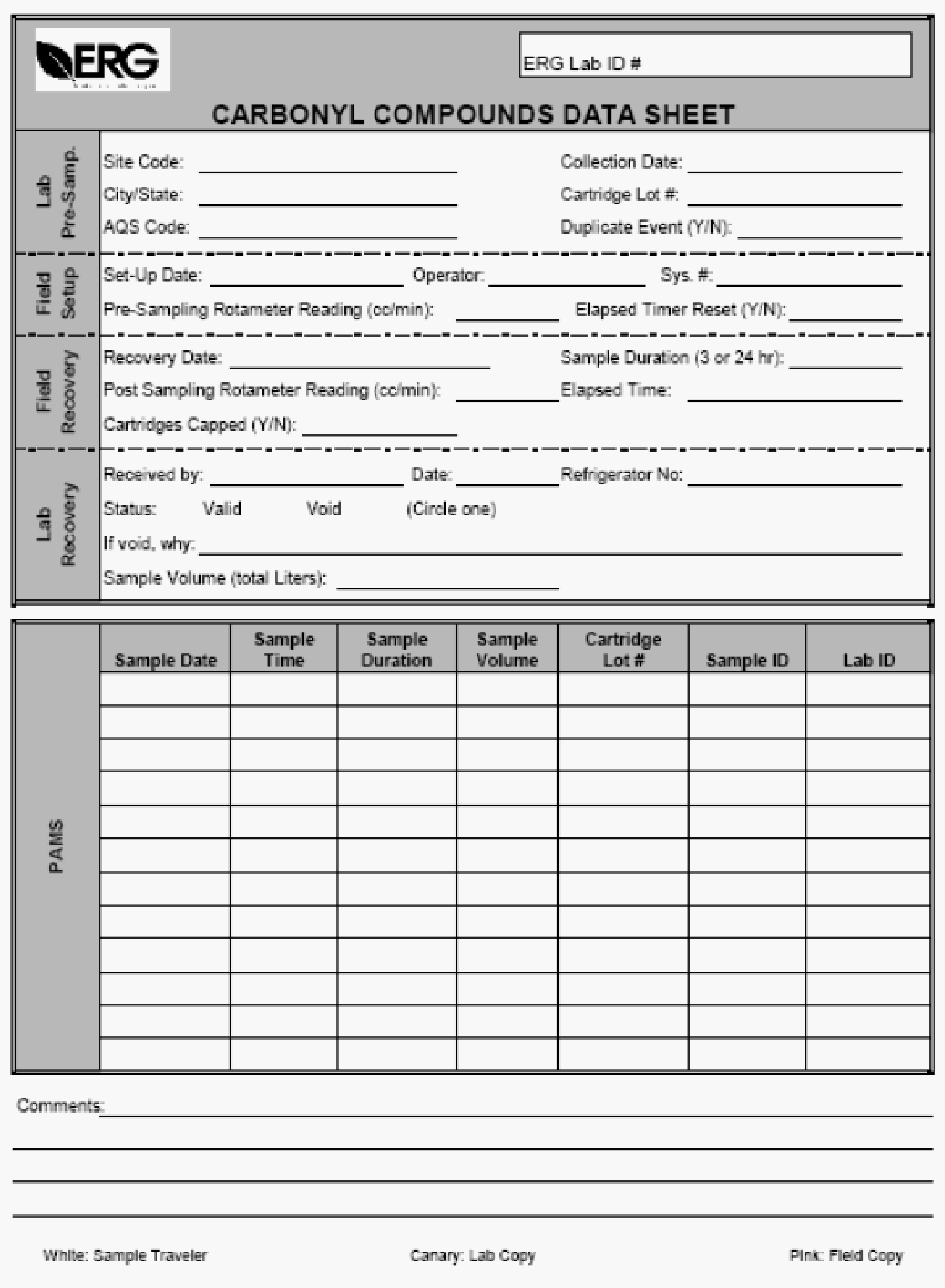
Figure: QC Checks for carbonyl Sampler (Air Toxics Monitoring Quality Assurance Project Plan, WA DoE, 2020)



Procedure	Required Frequency	Acceptance Limit	Corrective Action
Leak check	Before every sampling event	Vendor specific	Identify leak and correct problem, flag data
Time clock	Before every sampling event	± 5 minutes of the reference time	Adjust time clock, note on data sheet
Flow check	Every 30 days	± 10%	Calibrate, flag data
Sampler Certification	Annual	Within certification due date	Send equipment back to ERG for re-certification
Replace ozone denuder	Annual	N/A	N/A
Clean/replace tubing to manifold	Annual	N/A	N/A

General Sampling Calendar:

If Sample run is on a:	Take out to field on:	Return from the field on:	Ship out with FedEx by 4:30PM on:
Monday	Friday	Tuesday	Tuesday
Tuesday	Monday	Wednesday	Wednesday
Wednesday	Tuesday	Thursday	Thursday
Thursday	Wednesday	Friday	Monday
Friday	Thursday	Monday	Monday
Saturday	Friday	Monday	Monday
Sunday	Friday	Monday	Monday



ERG Lab ID #

CARBONYL COMPOUNDS DATA SHEET

Lab Pre-Samp.

Site Code: ____________________ Collection Date: ________________

City/State: ____________________ Cartridge Lot #: ________________

AQS Code: ____________________ Duplicate Event (Y/N): ____________

Field Setup

Set-Up Date: _______________ Operator: ____________ Sys. #: ______________

Pre-Sampling Rotameter Reading (cc/min): ________ Elapsed Timer Reset (Y/N): ________

Field Recovery

Recovery Date: ____________________ Sample Duration (3 or 24 hr): ________

Post Sampling Rotameter Reading (cc/min): ________ Elapsed Time: ________________

Cartridges Capped (Y/N): ____________

Lab Recovery

Received by: _______________ Date: ________ Refrigerator No: ________________

Status: Valid Void (Circle one)

If void, why: ____

Sample Volume (total Liters): ________________

	Sample Date	Sample Time	Sample Duration	Sample Volume	Cartridge Lot #	Sample ID	Lab ID
PAMS							

Comments: ____

White: Sample Traveler Canary: Lab Copy Pink: Field Copy

C. PUF Routine Sampling Procedure

Detailed procedures are outlined in the EPA TO method TO-13A. This is a description for regular field runs for PUF samplers.

ERG ships the required materials in a cooler to the PSCAA office. PSCAA then ships the collected samples back to ERG for analysis.

If there is an extra PUF sampling module available, the setup of the filter can be completed in the lab. Otherwise, the preparation needs to be done with the module in the field.

In summary, the field technician needs to go out to the field to setup the unit before the run. A technician then needs to go to the field to pick up the sample as quickly as possible after the run. The sampler runs every 6 days.

Setup of the Module:

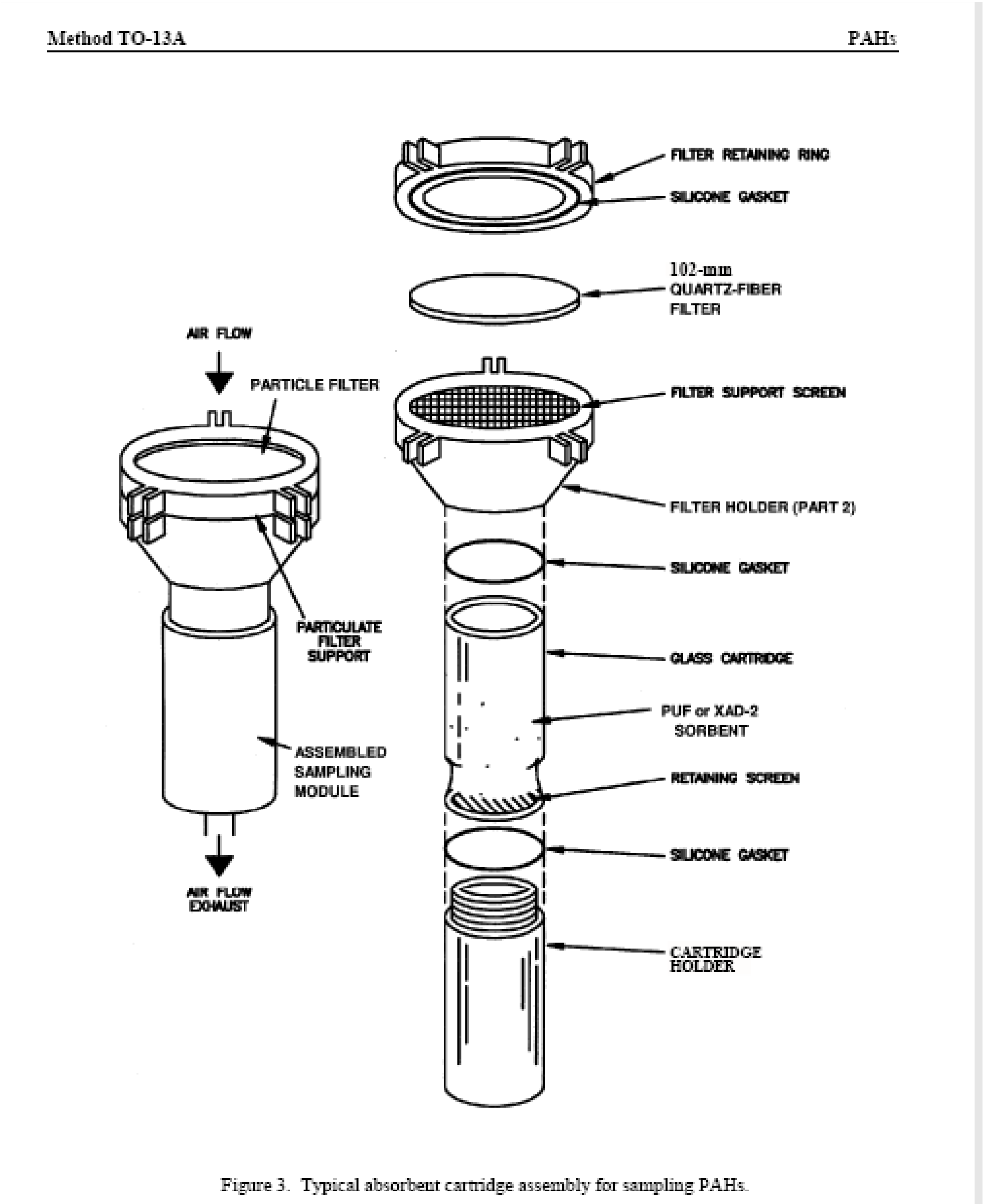
- Setup a clean workspace. A work bench disposable cover is a good option.
- Open the contents of the ERG shipment.
- Disassemble the module.
- Put on nitrile gloves.
- Open the Petri-dish containing the quartz filter so that the filter is facing “up” (the more textured surface).
- Place the filter in the module with the 2 white Teflon gaskets on either side with the filter facing “up” on the module. Use the lab supplied tweezers for this step as they are cleaned for each use for this purpose. Avoid all contact of the filter with anything else. Secure the filter retaining ring and filter in place using the 3 plastic thumb screws. If the unit requires transport to the site, put on the module shield before tightening the thumb screws.
- Open the jar shipped from ERG with the glass PUF cartridge. Remove the aluminum foil and insert the cartridge into the lower chamber (frit on the bottom) and tightly screw the top and bottom of the module together.
- If assembled in the lab, cap the bottom with aluminum foil to avoid potential diffusion of semi-volatiles.

Module Installation into Sampler:

- Remove the foil from the bottom of the module if there is any.
- Place the module into the sampler and lower the 2 clamps to secure the unit.
- Inspect the exhaust hose and check to see if it is clogged or plugged.
- If the sampler is a duplicate sampler, make sure it is plugged in.
- Open the ball valve all the way open (arm pointing downward).
- Turn the unit on with the manual switch.

- Read the magnehelic gauge and record the result on the chain of custody sheet (an example chain of custody is at the end of this document). If there is no reading on the magnehelic gauge, make sure that the aluminum cap on the top of the filter was removed.
- Adjust the timer to the necessary start day at midnight using only PST (Pacific Standard Time - not daylight savings). Also set the timer to run for 24 hours.
- Record the start time on the timer on the chain of custody sheet.
- Turn the manual switch off.
- Make sure that everything is locked at the site, that samplers are shielded from rain.

Figure: The Module Assembly and Parts



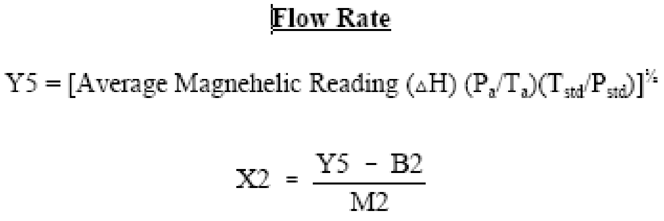
Method TO-13A PAHs

Figure 3. Typical absorbent cartridge assembly for sampling PAHs.

Module Pickup:

- Record the end sample time on the timer on the chain of custody sheet.
- Turn the unit on with the manual switch.
- Record the final magnehelic gauge reading.
- Turn off the unit with the manual switch.
- From a Partisol sampler nearby, retrieve the average pressure and average temperature for the sampling duration on the custody sheet. To retrieve the data:
  - Hit any button to “awake” the interface.
  - Press “Data”.
  - Then Press “More Data” 3 times and record the average temperatures and not the maximum 1-hour data.
  - Press “Esc” until the main screen appears.
- Record the recovery date on the custody sheet.
- Record anything unusual that you may notice in the “Comments” section of the provided custody sheet. This may include instrument behavior, nearby emission sources, etc.
- Remove the module and if being transported to the lab, cover the bottom with foil and cover the top with the aluminum plate. Try to keep the module in a cold, dark place until it is in the laboratory. Label the module for simplicity of processing in the lab.
- Call Mary before leaving the site.
- When in the lab, calculate the average flow rate and total collection volume on the custody sheet as below:

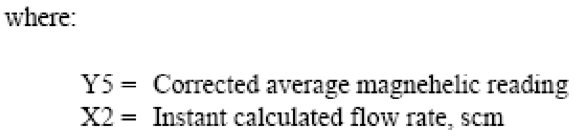
Calculations:



Flow Rate

$$Y5 = [\text{Average Magnehelic Reading } (\Delta H)\ (P_a/T_a)(T_{std}/P_{std})]^{1/2}$$

$$X2 = \frac{Y5 - B2}{M2}$$



where:

Y5 = Corrected average magnehelic reading
X2 = Instant calculated flow rate, scm

P_a = Average Pressure in mmHg
P_{std} = 760 mmHg
T_a = (Average Temperature in ºC + 273)
T_{std} = 298 K
B2 = Calibration Intercept
M2 = Calibration Slope

Total Collection Volume

$$V_{std} = \text{elapsed time} * X2$$

The B2 and M2 (calibration intercept and slope respectively) can be found at the site and PSCAA will have the original copy in their office. Calibrations are done with every motor replacement, which is done quarterly. PSCAA will provide you with these numbers for each site after any change.

Below are the current values (TBD):

Site	Sampler ID	M2 (Slope)	B2 (Intercept)
Seattle 10th&Well	tbd	tbd	tbd

Module Disassembly:

- Disassemble the top quartz filter first.
- Fold the filter with the particulate on the inside. Place the filter on top of the PUF/XAD inside of the thimble. Then, cover it with aluminum foil.
- Unscrew the bottom half of the module and remove the glass PUF cartridge, avoiding as much UV-light as possible. Put the thimble in the cooler.
    - Be careful not to ship the 2 white gaskets that retain the quartz filter to the lab.
- Cap the ends of the glass cartridge with the included Teflon caps. Then, wrap the cartridge in foil and put it in the provided bubble wrap, and put the wrapped cartridge into the plastic shipping jar.
- Store the sample at < 4ºC until shipping in the cooler, which should also be < 4ºC.
- This sample must be extracted for analysis within 14 days of sample collection, so ship the cooler out as quickly as possible.

Duplicate Samples:

- Once per month, ERG will ship an extra sample for the collocated sampler in Tacoma Alexander.
- Follow the routine procedures for this sampler but remember to plug in the unit on setup and unplug the unit for sample pickup. This will reduce unnecessary wear on the motor.

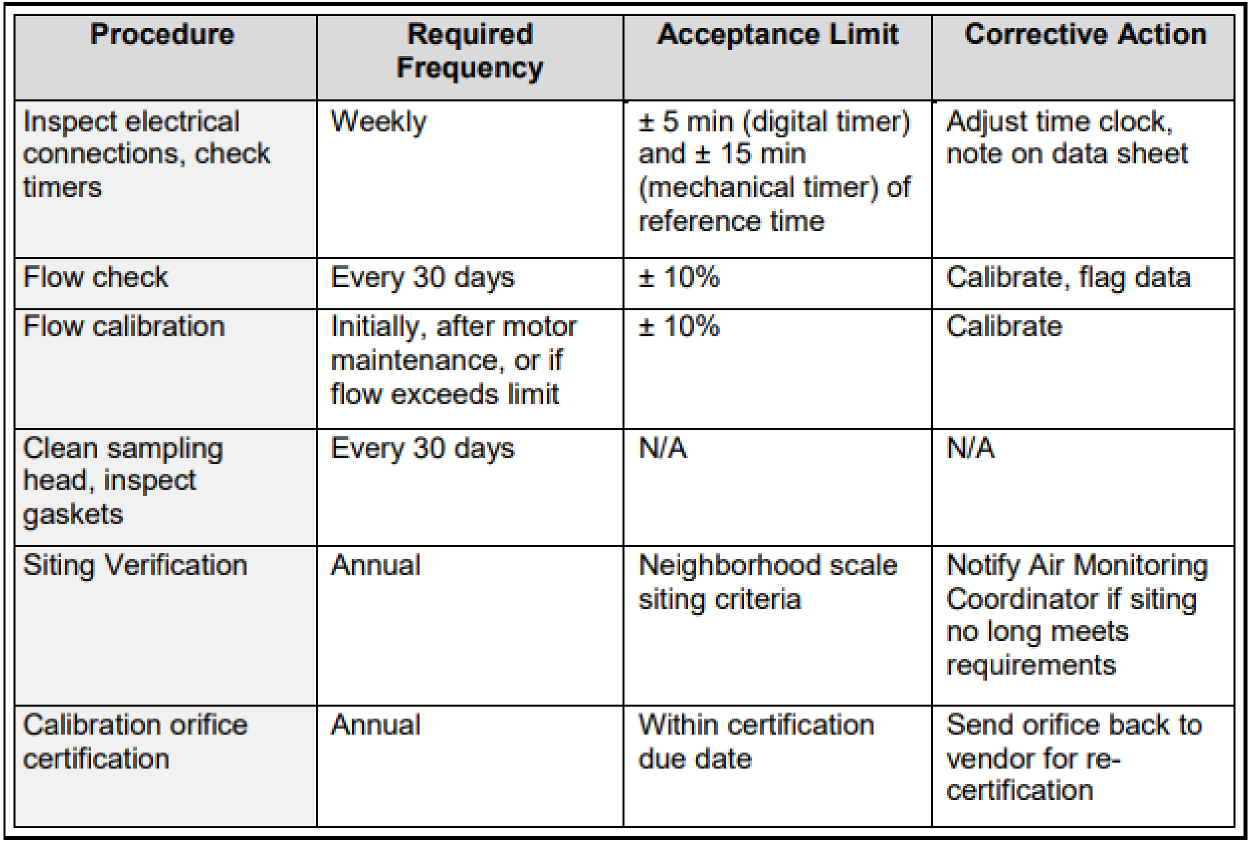
The sites will be decided after consultation with the community and appropriate AQS Codes will be used for the chain of custody.

Shipping:

- All samples from ERG will be shipped back to ERG in the same coolers with a postage paid FedEx return label included.
- All that is required is a replacement cold icepack prior to shipping.
- ERG does not accept shipments on the weekends, so **shipments must be sent Monday through Thursday only**. If it appears that shipment will not be picked up (too late), put the sample back in the refrigerator until the shipment can be made.

- If not already checked off, mark the shipping label as “Priority Overnight”.
- In case of emergency, the lab address and contact is: Randy Bower, 919-468-7923, 601 Keystone Park Dr., Suite 700, Morrisville, NC 27560

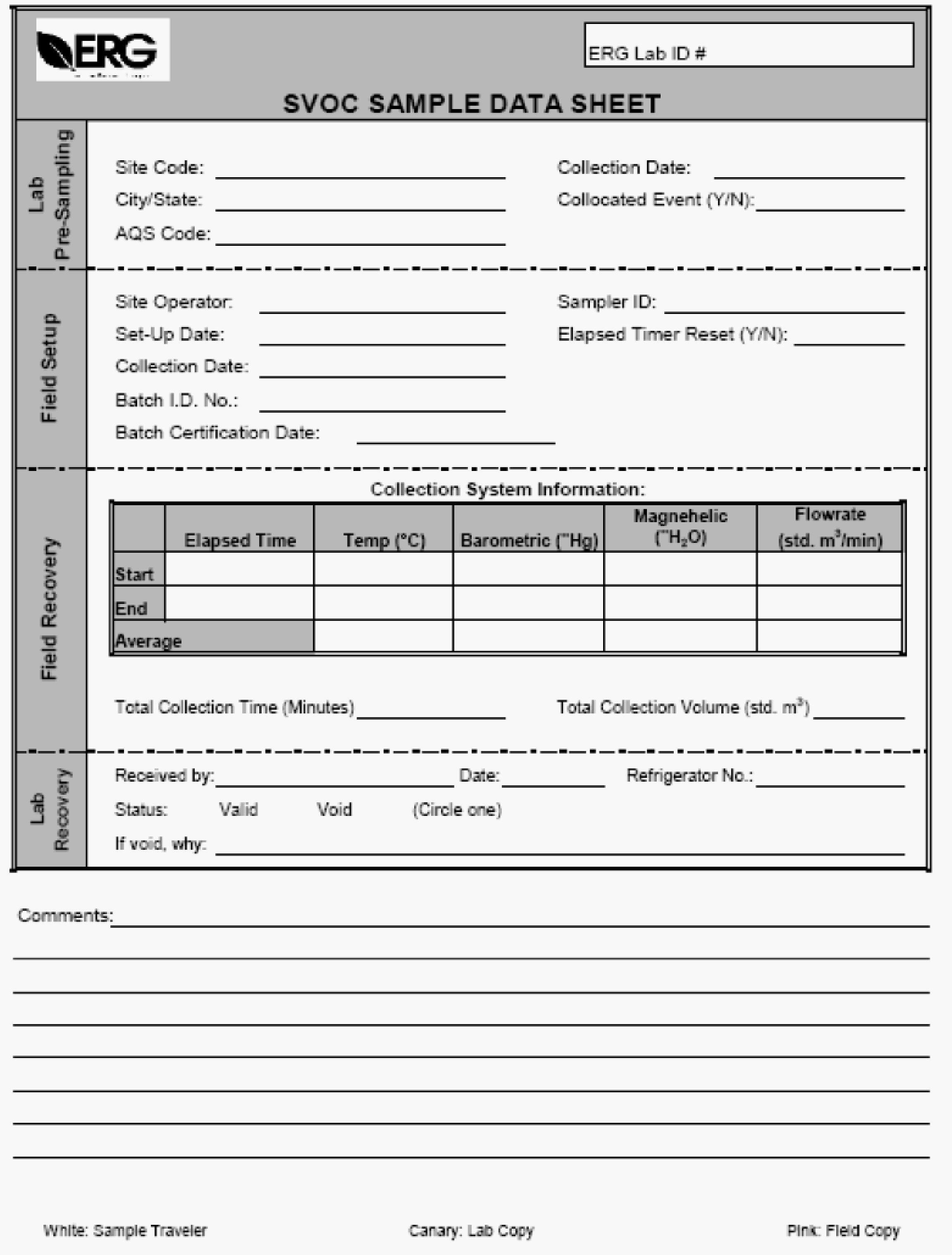
Figure: QC Checks for PAH Sampler (Air Toxics Monitoring Quality Assurance Project Plan, WA DoE, 2020)



Procedure	Required Frequency	Acceptance Limit	Corrective Action
Inspect electrical connections, check timers	Weekly	± 5 min (digital timer) and ± 15 min (mechanical timer) of reference time	Adjust time clock, note on data sheet
Flow check	Every 30 days	± 10%	Calibrate, flag data
Flow calibration	Initially, after motor maintenance, or if flow exceeds limit	± 10%	Calibrate
Clean sampling head, inspect gaskets	Every 30 days	N/A	N/A
Siting Verification	Annual	Neighborhood scale siting criteria	Notify Air Monitoring Coordinator if siting no long meets requirements
Calibration orifice certification	Annual	Within certification due date	Send orifice back to vendor for re-certification

General Sampling Calendar:

If Sample run is on a:	**Take out to field on:**	**Return from the field on:**	**Ship out with FedEx by 4:30PM on:**
Monday	Friday	Tuesday	Tuesday
Tuesday	Monday	Wednesday	Wednesday
Wednesday	Tuesday	Thursday	Thursday
Thursday	Wednesday	Friday	Monday
Friday	Thursday	Monday	Monday
Saturday	Friday	Monday	Monday
Sunday	Friday	Monday	Monday



ERG

ERG Lab ID #

SVOC SAMPLE DATA SHEET

Lab Pre-Sampling

Site Code: ______________________

City/State: ______________________

AQS Code: ______________________

Collection Date: ______________

Collocated Event (Y/N): ______________

Field Setup

Site Operator: ______________________

Set-Up Date: ______________________

Collection Date: ______________________

Batch I.D. No.: ______________________

Batch Certification Date: ______________

Sampler ID: ______________

Elapsed Timer Reset (Y/N): __________

Field Recovery

Collection System Information:

	Elapsed Time	Temp (°C)	Barometric ("Hg)	Magnehelic ("H_2O)	Flowrate (std. m^3/min)
Start					
End					
Average					

Total Collection Time (Minutes) ______________

Total Collection Volume (std. m^3) __________

Lab Recovery

Received by: ______________ Date: __________ Refrigerator No.: ______________

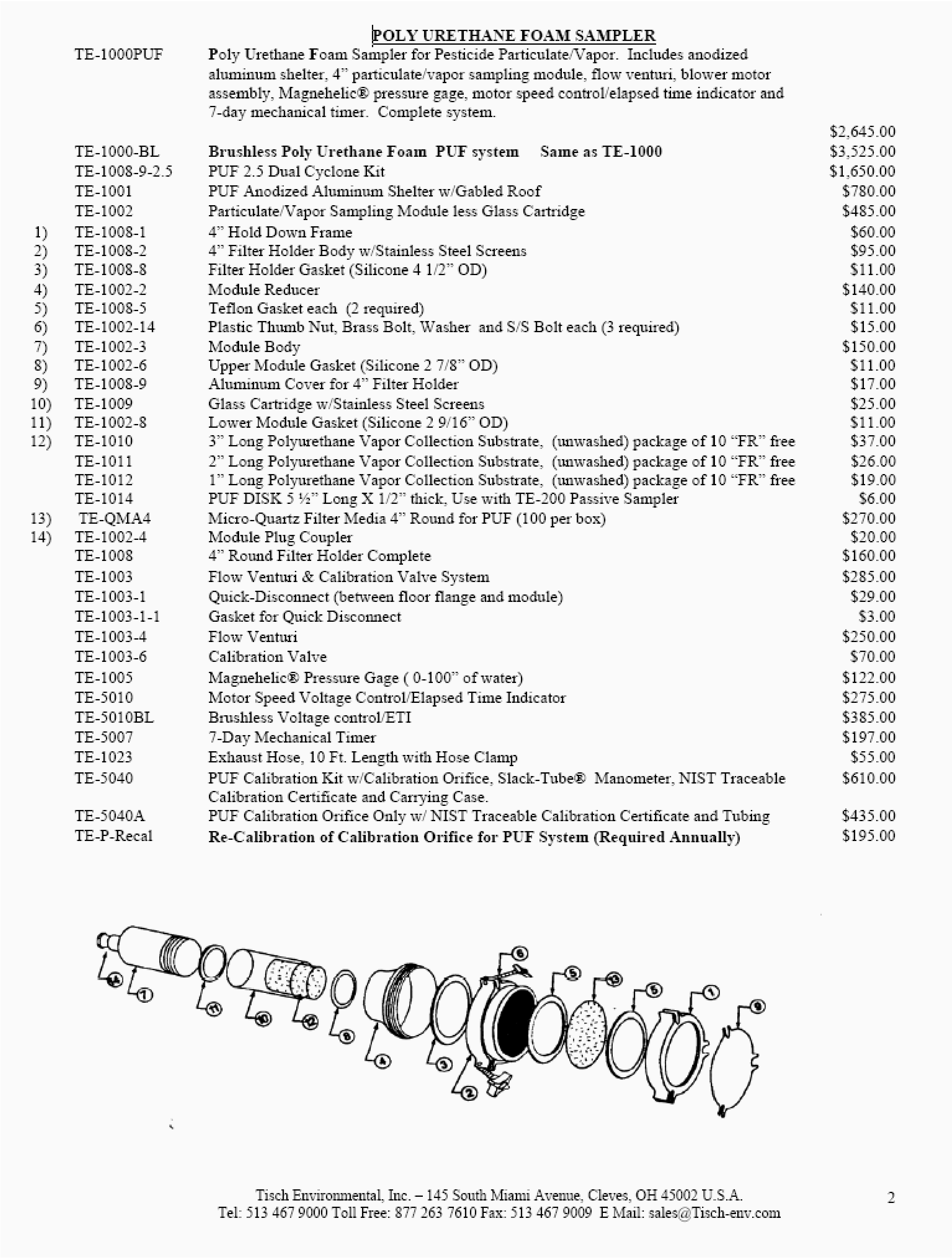
Status: Valid Void (Circle one)

If void, why: ______________________________________

Comments: ______________________________________

White: Sample Traveler Canary: Lab Copy Pink: Field Copy

Figure: Parts List for PUF Sampler

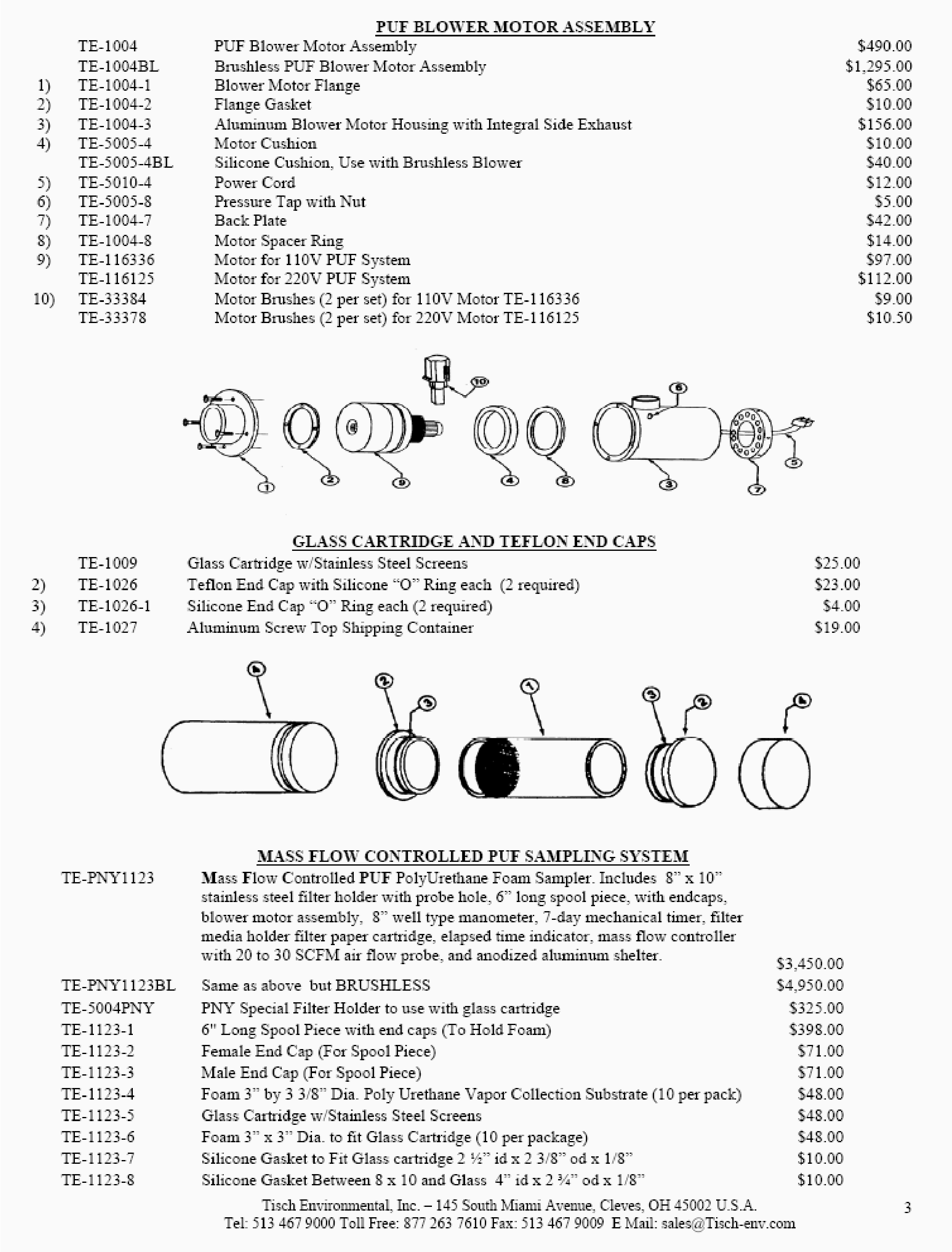


POLY URETHANE FOAM SAMPLER

	TE-1000PUF	**Poly Urethane Foam Sampler for Pesticide Particulate/Vapor.** Includes anodized aluminum shelter, 4" particulate/vapor sampling module, flow venturi, blower motor assembly, Magnehelic® pressure gage, motor speed control/elapsed time indicator and 7-day mechanical timer. Complete system.	$2,645.00
	TE-1000-BL	**Brushless Poly Urethane Foam PUF system Same as TE-1000**	$3,525.00
	TE-1008-9-2.5	PUF 2.5 Dual Cyclone Kit	$1,650.00
	TE-1001	PUF Anodized Aluminum Shelter w/Gabled Roof	$780.00
	TE-1002	Particulate/Vapor Sampling Module less Glass Cartridge	$485.00
1)	TE-1008-1	4" Hold Down Frame	$60.00
2)	TE-1008-2	4" Filter Holder Body w/Stainless Steel Screens	$95.00
3)	TE-1008-8	Filter Holder Gasket (Silicone 4 1/2" OD)	$11.00
4)	TE-1002-2	Module Reducer	$140.00
5)	TE-1008-5	Teflon Gasket each (2 required)	$11.00
6)	TE-1002-14	Plastic Thumb Nut, Brass Bolt, Washer and S/S Bolt each (3 required)	$15.00
7)	TE-1002-3	Module Body	$150.00
8)	TE-1002-6	Upper Module Gasket (Silicone 2 7/8" OD)	$11.00
9)	TE-1008-9	Aluminum Cover for 4" Filter Holder	$17.00
10)	TE-1009	Glass Cartridge w/Stainless Steel Screens	$25.00
11)	TE-1002-8	Lower Module Gasket (Silicone 2 9/16" OD)	$11.00
12)	TE-1010	3" Long Polyurethane Vapor Collection Substrate, (unwashed) package of 10 "FR" free	$37.00
	TE-1011	2" Long Polyurethane Vapor Collection Substrate, (unwashed) package of 10 "FR" free	$26.00
	TE-1012	1" Long Polyurethane Vapor Collection Substrate, (unwashed) package of 10 "FR" free	$19.00
	TE-1014	PUF DISK 5 ½" Long X 1/2" thick, Use with TE-200 Passive Sampler	$6.00
13)	TE-QMA4	Micro-Quartz Filter Media 4" Round for PUF (100 per box)	$270.00
14)	TE-1002-4	Module Plug Coupler	$20.00
	TE-1008	4" Round Filter Holder Complete	$160.00
	TE-1003	Flow Venturi & Calibration Valve System	$285.00
	TE-1003-1	Quick-Disconnect (between floor flange and module)	$29.00
	TE-1003-1-1	Gasket for Quick Disconnect	$3.00
	TE-1003-4	Flow Venturi	$250.00
	TE-1003-6	Calibration Valve	$70.00
	TE-1005	Magnehelic® Pressure Gage (0-100" of water)	$122.00
	TE-5010	Motor Speed Voltage Control/Elapsed Time Indicator	$275.00
	TE-5010BL	Brushless Voltage control/ETI	$385.00
	TE-5007	7-Day Mechanical Timer	$197.00
	TE-1023	Exhaust Hose, 10 Ft. Length with Hose Clamp	$55.00
	TE-5040	PUF Calibration Kit w/Calibration Orifice, Slack-Tube® Manometer, NIST Traceable Calibration Certificate and Carrying Case.	$610.00
	TE-5040A	PUF Calibration Orifice Only w/ NIST Traceable Calibration Certificate and Tubing	$435.00
	TE-P-Recal	**Re-Calibration of Calibration Orifice for PUF System (Required Annually)**	$195.00

Tisch Environmental, Inc. – 145 South Miami Avenue, Cleves, OH 45002 U.S.A.
Tel: 513 467 9000 Toll Free: 877 263 7610 Fax: 513 467 9009 E Mail: sales@Tisch-env.com

2



PUF BLOWER MOTOR ASSEMBLY

	TE-1004	PUF Blower Motor Assembly	$490.00
	TE-1004BL	Brushless PUF Blower Motor Assembly	$1,295.00
1)	TE-1004-1	Blower Motor Flange	$65.00
2)	TE-1004-2	Flange Gasket	$10.00
3)	TE-1004-3	Aluminum Blower Motor Housing with Integral Side Exhaust	$156.00
4)	TE-5005-4	Motor Cushion	$10.00
	TE-5005-4BL	Silicone Cushion, Use with Brushless Blower	$40.00
5)	TE-5010-4	Power Cord	$12.00
6)	TE-5005-8	Pressure Tap with Nut	$5.00
7)	TE-1004-7	Back Plate	$42.00
8)	TE-1004-8	Motor Spacer Ring	$14.00
9)	TE-116336	Motor for 110V PUF System	$97.00
	TE-116125	Motor for 220V PUF System	$112.00
10)	TE-33384	Motor Brushes (2 per set) for 110V Motor TE-116336	$9.00
	TE-33378	Motor Brushes (2 per set) for 220V Motor TE-116125	$10.50

GLASS CARTRIDGE AND TEFLON END CAPS

	TE-1009	Glass Cartridge w/Stainless Steel Screens	$25.00
2)	TE-1026	Teflon End Cap with Silicone "O" Ring each (2 required)	$23.00
3)	TE-1026-1	Silicone End Cap "O" Ring each (2 required)	$4.00
4)	TE-1027	Aluminum Screw Top Shipping Container	$19.00

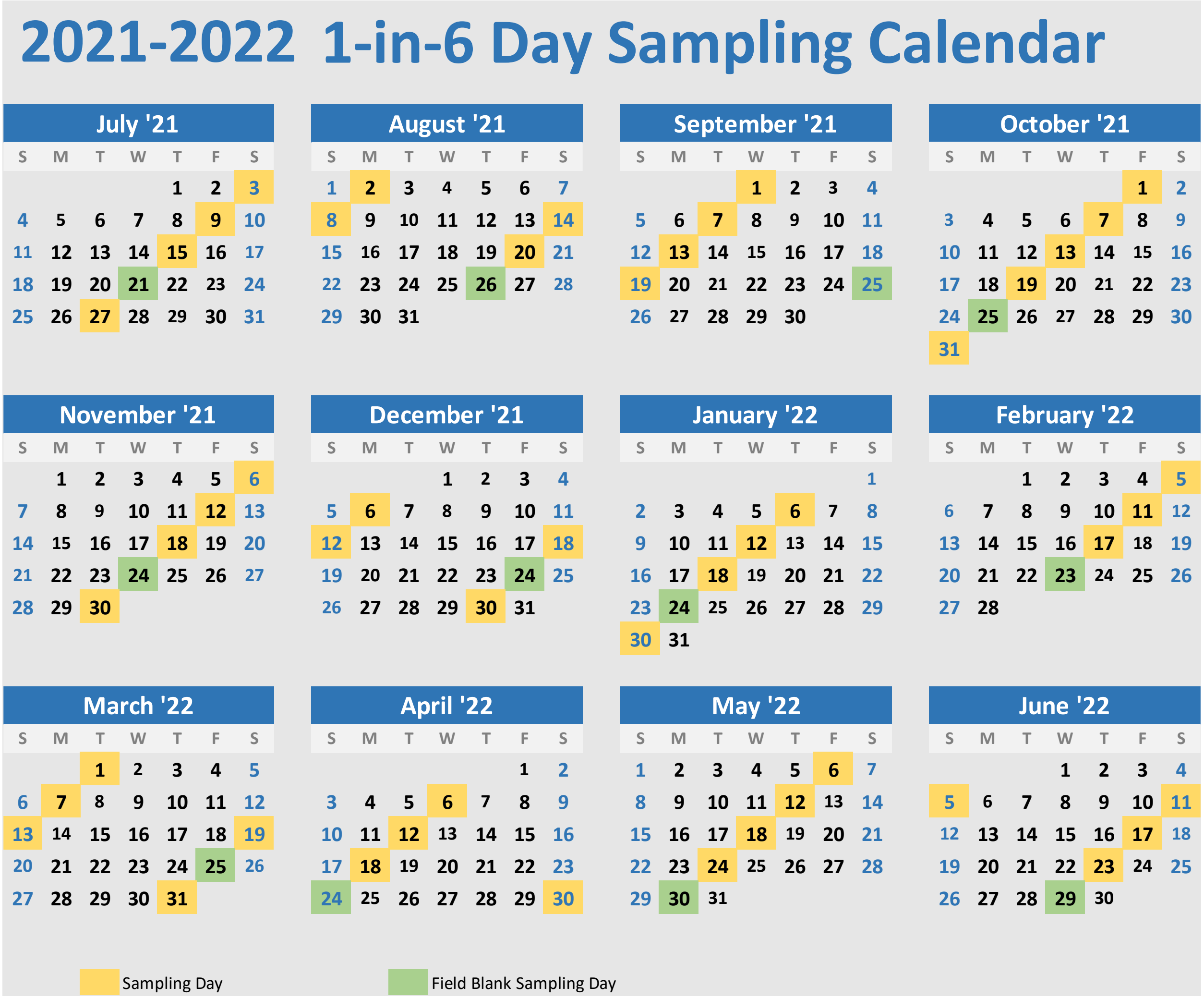
MASS FLOW CONTROLLED PUF SAMPLING SYSTEM

TE-PNY1123	**Mass Flow** Controlled **PUF** PolyUrethane Foam Sampler. Includes 8" x 10" stainless steel filter holder with probe hole, 6" long spool piece, with endcaps, blower motor assembly, 8" well type manometer, 7-day mechanical timer, filter media holder filter paper cartridge, elapsed time indicator, mass flow controller with 20 to 30 SCFM air flow probe, and anodized aluminum shelter.	$3,450.00
TE-PNY1123BL	Same as above but BRUSHLESS	$4,950.00
TE-5004PNY	PNY Special Filter Holder to use with glass cartridge	$325.00
TE-1123-1	6" Long Spool Piece with end caps (To Hold Foam)	$398.00
TE-1123-2	Female End Cap (For Spool Piece)	$71.00
TE-1123-3	Male End Cap (For Spool Piece)	$71.00
TE-1123-4	Foam 3" by 3 3/8" Dia. Poly Urethane Vapor Collection Substrate (10 per pack)	$48.00
TE-1123-5	Glass Cartridge w/Stainless Steel Screens	$48.00
TE-1123-6	Foam 3" x 3" Dia. to fit Glass Cartridge (10 per package)	$48.00
TE-1123-7	Silicone Gasket to Fit Glass cartridge 2 ½" id x 2 3/8" od x 1/8"	$10.00
TE-1123-8	Silicone Gasket Between 8 x 10 and Glass 4" id x 2 ¾" od x 1/8"	$10.00

Tisch Environmental, Inc. – 145 South Miami Avenue, Cleves, OH 45002 U.S.A.
Tel: 513 467 9000 Toll Free: 877 263 7610 Fax: 513 467 9009 E Mail: sales@Tisch-env.com

3

D. The EPA 1 in 6 Sampling Calendar



2021-2022 1-in-6 Day Sampling Calendar

July '21

S	M	T	W	T	F	S
				1	2	3 🟨
4	5	6	7	8	9 🟨	10
11	12	13	14	15 🟨	16	17
18	19	20	21 🟩	22	23	24
25	26	27 🟨	28	29	30	31

August '21

S	M	T	W	T	F	S
1	2 🟨	3	4	5	6	7
8 🟨	9	10	11	12	13	14 🟨
15	16	17	18	19	20 🟨	21
22	23	24	25	26 🟩	27	28
29	30	31				

September '21

S	M	T	W	T	F	S
			1 🟨	2	3	4
5	6	7 🟨	8	9	10	11
12	13 🟨	14	15	16	17	18
19 🟨	20	21	22	23	24	25 🟩
26	27	28	29	30		

October '21

S	M	T	W	T	F	S
					1 🟨	2
3	4	5	6	7 🟨	8	9
10	11	12	13 🟨	14	15	16
17	18	19 🟨	20	21	22	23
24	25 🟩	26	27	28	29	30
31 🟨						

November '21

S	M	T	W	T	F	S
	1	2	3	4	5	6 🟨
7	8	9	10	11	12 🟨	13
14	15	16	17	18 🟨	19	20
21	22	23	24 🟩	25	26	27
28	29	30 🟨				

December '21

S	M	T	W	T	F	S
			1	2	3	4
5	6 🟨	7	8	9	10	11
12 🟨	13	14	15	16	17	18 🟨
19	20	21	22	23	24 🟩	25
26	27	28	29	30 🟨	31	

January '22

S	M	T	W	T	F	S
						1
2	3	4	5	6 🟨	7	8
9	10	11	12 🟨	13	14	15
16	17	18 🟨	19	20	21	22
23	24 🟩	25	26	27	28	29
30 🟨	31					

February '22

S	M	T	W	T	F	S
		1	2	3	4	5 🟨
6	7	8	9	10	11 🟨	12
13	14	15	16	17 🟨	18	19
20	21	22	23 🟩	24	25	26
27	28					

March '22

S	M	T	W	T	F	S
		1 🟨	2	3	4	5
6	7 🟨	8	9	10	11	12
13 🟨	14	15	16	17	18	19 🟨
20	21	22	23	24	25 🟩	26
27	28	29	30	31 🟨		

April '22

S	M	T	W	T	F	S
					1	2
3	4	5	6 🟨	7	8	9
10	11	12 🟨	13	14	15	16
17	18 🟨	19	20	21	22	23
24 🟩	25	26	27	28	29	30 🟨

May '22

S	M	T	W	T	F	S
1	2	3	4	5	6 🟨	7
8	9	10	11	12 🟨	13	14
15	16	17	18 🟨	19	20	21
22	23	24 🟨	25	26	27	28
29	30 🟩	31				

June '22

S	M	T	W	T	F	S
			1	2	3	4
5 🟨	6	7	8	9	10	11 🟨
12	13	14	15	16	17 🟨	18
19	20	21	22	23 🟨	24	25
26	27	28	29 🟩	30		

🟨 Sampling Day

🟩 Field Blank Sampling Day

E. AE-33 “7 Channel” Aethalometer Sampling Procedures

Instrument Settings

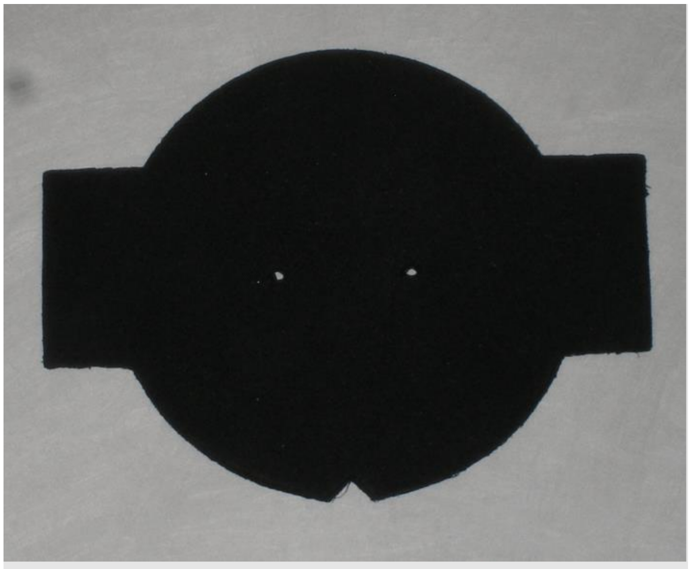
1. Time base: 1-minute (default), never 1-second
2. Max Attn: 120 (default)
3. Flow: usually 5 lpm (with BGI 1.829 cyclone for PM2.5)
4. Other settings (see setup file)

“DST off” is important, DateFormat=US
“Measure Time Stamp” = before
Recommend 1-minute “warmup” (default is 3)
Flow Standards for reporting data - Use EPA “STP” (25C) defaults are (70F or 21.1 C)
==> Settings are not saved until you start a run
Prompt to save changes

Operational Checks and the Leak Test / Flow Verification (LT/FV) Done Monthly:

1. Instrument date/time check/set: monthly and after power failure
SET clock monthly even if time is ok
Time may change on reboot
2. Tape visual inspection check: at least monthly (each LT/FV)
Look for neat, evenly grey, evenly spaced spots with sharp edges. Also: how much tape left?
. USB thumb drive data download: Use USB Key, and bring files back to the designated Folder.
Monthly - QC files can be useful (log [FVRF], FV, LT, setup, etc.)
Data/Export menu, enter date of last download
Thumb drive must not have other files on it
a “.exe” file in the root dir will cause the Aeth to stop
All data are stored internally (50 years’ worth) on CF card

3. Perform Leak Test and Flow Verification together
Stop the AE33 by pressing OPERATION > STOP
Take the time to inspect and clean the sampling head, removing carbon, debris, or bugs from the cyclone.
CAUTION: DO NOT BLOCK THE INLET FOR A LEAK TEST, this will only shut down the variable pump.
Perform the wizard in the instrument for the LEAKAGE TEST.
Use flowmeter without pressure pulses (TSI-4100)
For all flow verification, leak test or flow verifications, remember to always re-enter 25C for the Temperature of the flow measurement. Also note that the flow is entered into the instrument in milliliters per minute, not LPM (so use 5100 mlpm for 5.1 LPM).
Follow the steps that the instrument provides to measure the flow through the filter, and then the flow through the FLOW PAD, (shown below).
Some leakage is normal: 7% filter “lateral” leak assumed and used in data calculations
AE33 Flow Pad: goes in with notch facing out towards you



(Picture of the LT/FV Pad)

Example of filter leak test report (LT*.dat file)

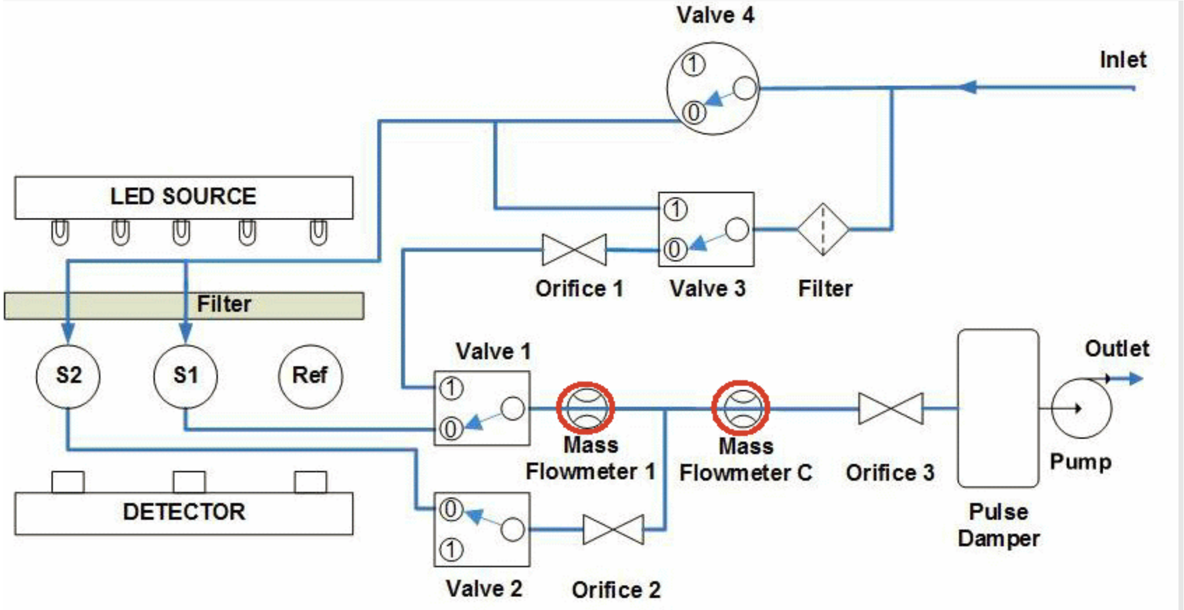
Manual leakage test report
Serial number: AE33-S02-00XXX
Date and time: 06 Mar 2015 10:12:15
Selected flow: 5000 mlpm
Flow through tape: 4920
Flow through calibration pad: 5140
Instrument leakage is: 4.3 %
Result should be ~3 to 7% and if you have leak > 10%: then take corrective action [new tape roll, mechanical problems]

AE33 Flow Check (If Flow calibration is needed, then follow procedures in the Magee Scientific Operator's Manual).

Once LT is complete, keep the Flow Verification Pad in the chamber, and then proceed onto the Wizard for the FV, which then happens at three flow levels.

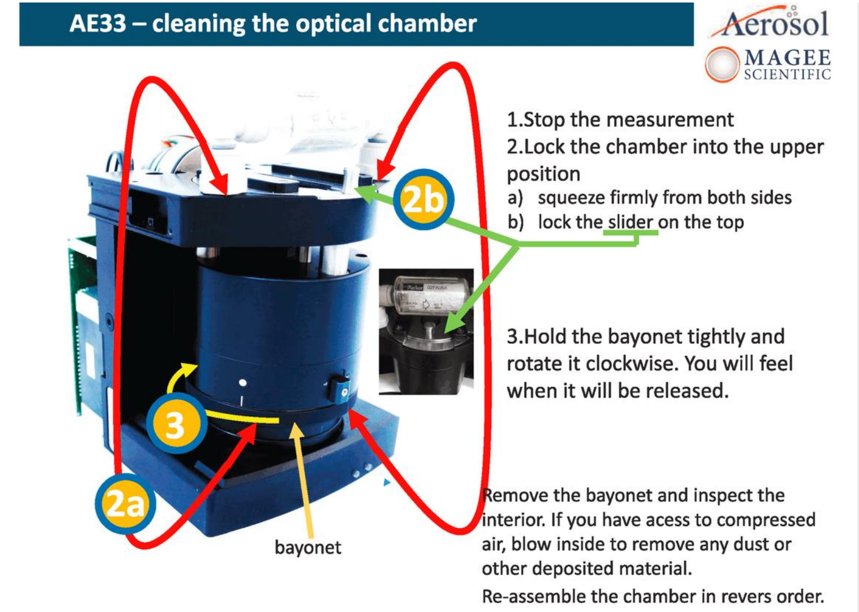
Example of AE33 / 633 Flow Verification result.
Fin" is external flow measurement (at the inlet)
F1" is flow for sensor 1 (higher loading)
Fc" is total ("control") flow, or "Flow 3" – controls the pump
Flow reporting standard: EPA 101325 Pa 25 °C
Fin F1 (%) Fc (%)
736 746 (101) 742 (101)
2470 2394 (97) 2387 (97)
4120 4190 (102) 4190 (102)

Explaining F1 and Fc: instrument flow diagram



=1 for flow cal (adjustable - sets F2/F1 ratio)
Note location of F1 and Fc flowmeters (in series for flow cal) - red circles
Fc is controlled to total flow set point
Spot 2 (Sensor 2) flow not measured directly (only used for K calc)

4. TAPE CHANGE. When you do a Tape change, then perform an Optical Chamber Clean according to the Magee Scientific Manual. (Or AS NEEDED).
About Every 3 months
AE33 / 633 Optical Chamber Cleaning - Easy, Important - AE33 is more sensitive to “stuff” in chamber
Interferes with K calculations – For Step-by-Step Instructions: see TAPI 633 Manual, section 5.6



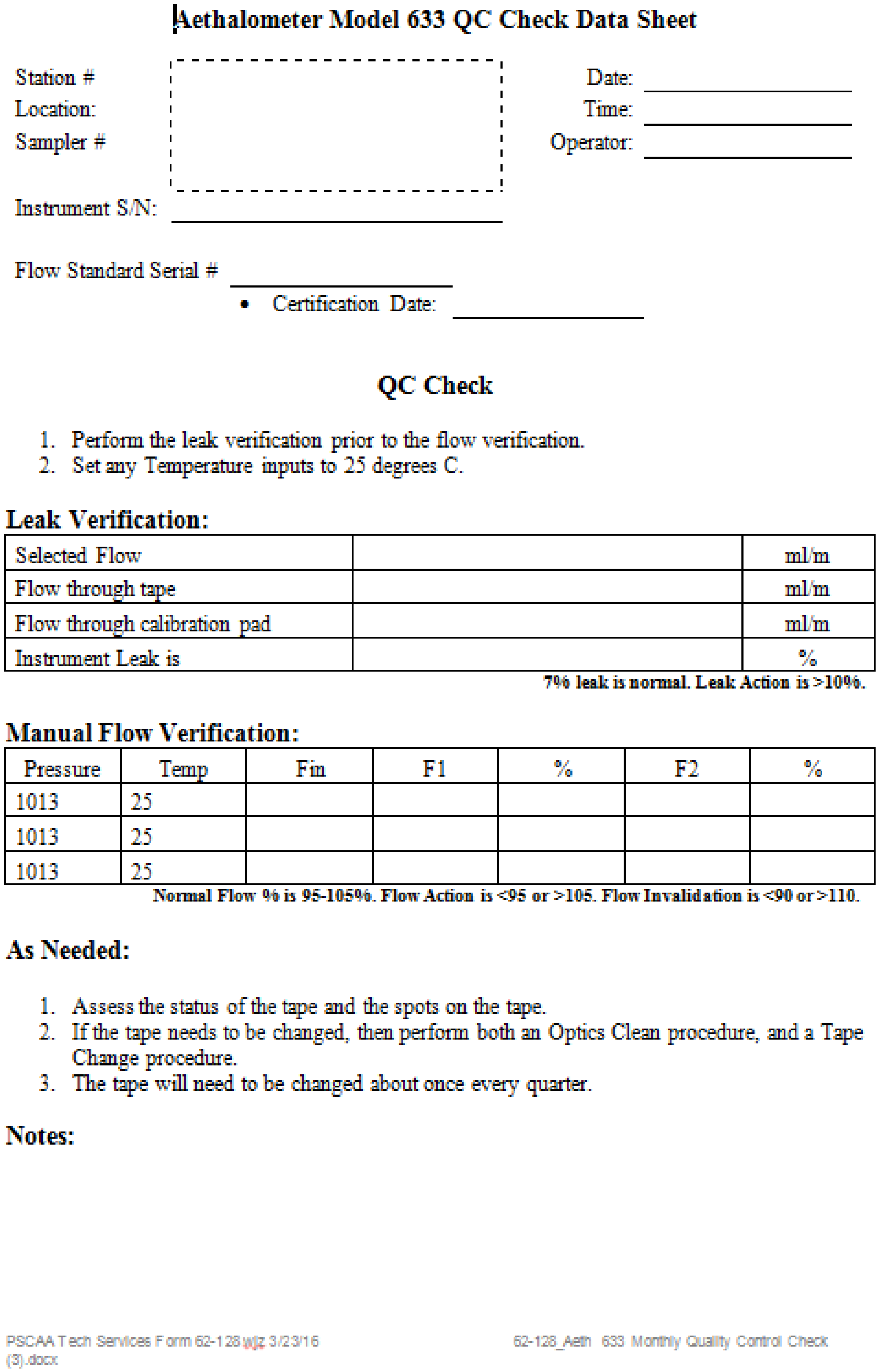
AE33 – cleaning the optical chamber

Aerosol
MAGEE SCIENTIFIC

1.Stop the measurement
2.Lock the chamber into the upper position
a) squeeze firmly from both sides
b) lock the slider on the top

3.Hold the bayonet tightly and rotate it clockwise. You will feel when it will be released.

Remove the bayonet and inspect the interior. If you have acess to compressed air, blow inside to remove any dust or other deposited material.
Re-assemble the chamber in revers order.



Aethalometer Model 633 QC Check Data Sheet

Station #
Location:
Sampler #

Date: ____________
Time: ____________
Operator: ____________

Instrument S/N: ____________

Flow Standard Serial # ____________

- Certification Date: ____________

QC Check

1. Perform the leak verification prior to the flow verification.
2. Set any Temperature inputs to 25 degrees C.

Leak Verification:

Selected Flow		ml/m
Flow through tape		ml/m
Flow through calibration pad		ml/m
Instrument Leak is		%

7% leak is normal. Leak Action is >10%.

Manual Flow Verification:

Pressure	Temp	Fin	F1	%	F2	%
1013	25					
1013	25					
1013	25					

Normal Flow % is 95-105%. Flow Action is <95 or >105. Flow Invalidation is <90 or >110.

As Needed:

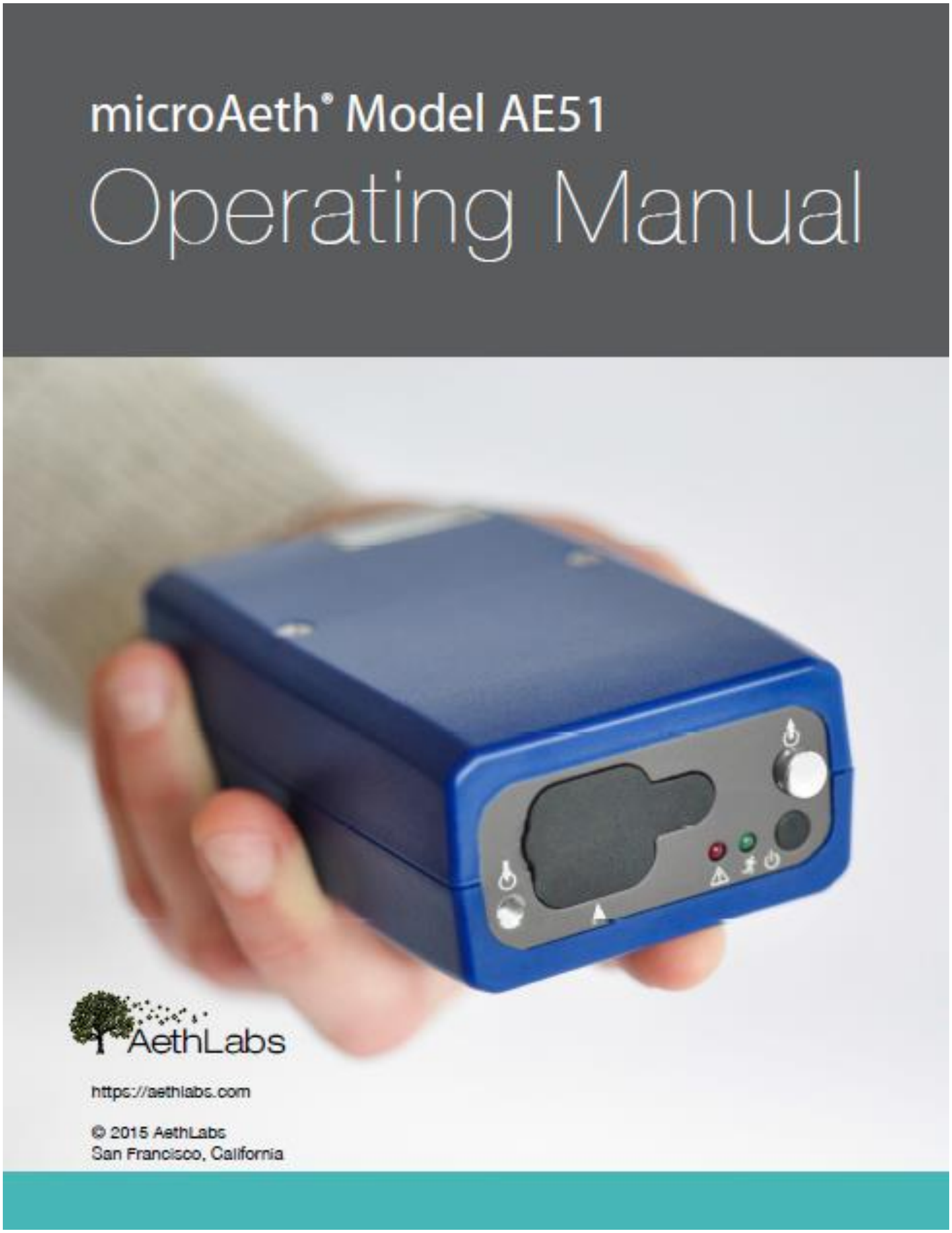
1. Assess the status of the tape and the spots on the tape.
2. If the tape needs to be changed, then perform both an Optics Clean procedure, and a Tape Change procedure.
3. The tape will need to be changed about once every quarter.

Notes:

PSCAA Tech Services Form 62-128 wjz 3/23/16 (3).docx

62-128_Aeth 633 Monthly Quality Control Check

F. AE-51 Micro Aeth Quick Start Guide



microAeth® Model AE51

Operating Manual

AethLabs

https://aethlabs.com

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San Francisco, California

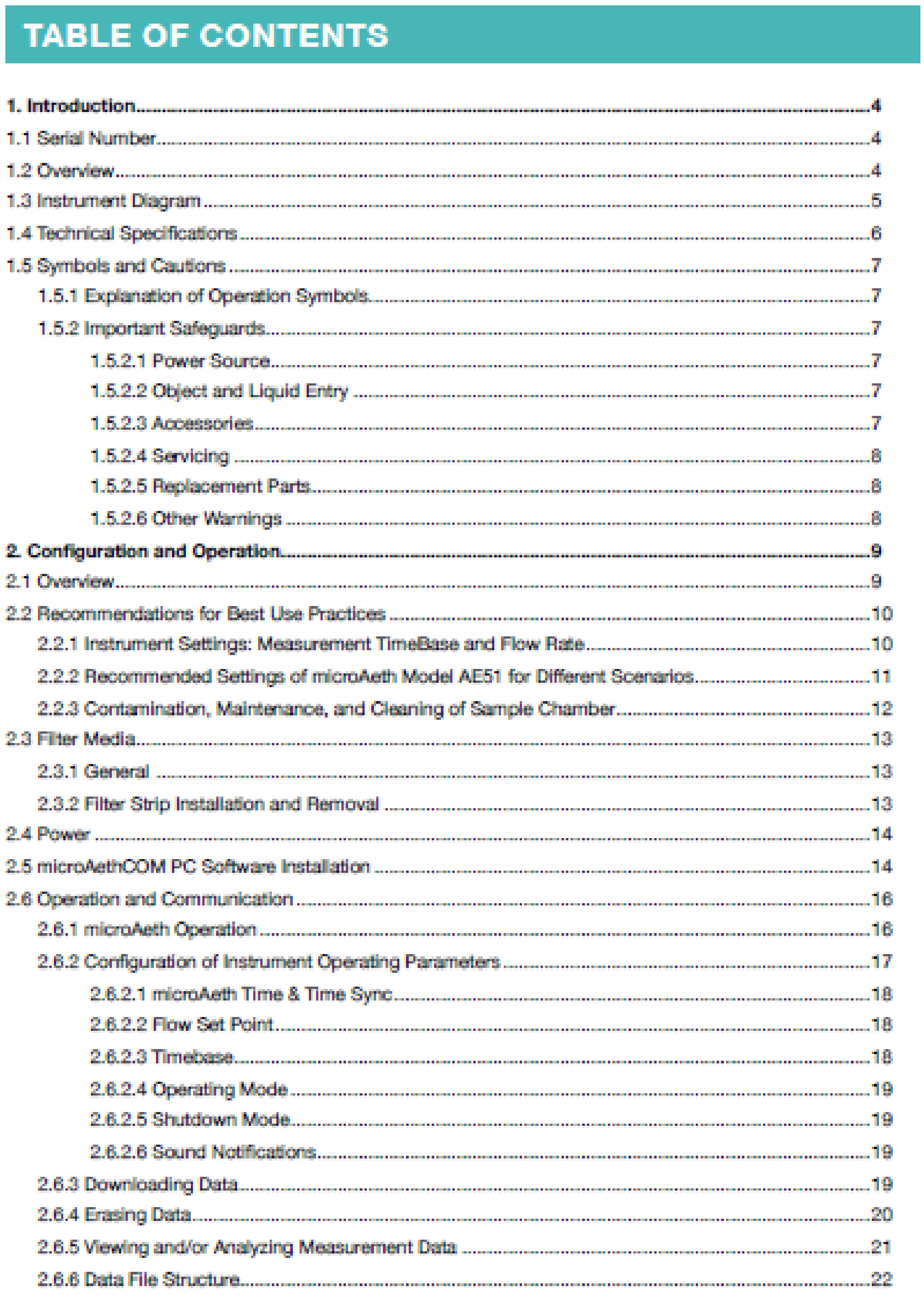


TABLE OF CONTENTS

1. INTRODUCTION

1.1 Serial Number

The model and serial number are located on the back panel. Record the serial number in the space provided below. Refer to these numbers whenever you call for service.

Model No.: microAeth® Model AE51
Serial number: AE51-S__-_____-______

1.2 Overview

Real-time Aerosol Black Carbon Personal Exposure Measurement Device

- Pocket-size, lightweight Aethalometer (250 g)
- Fast response: 1 second measurement timebase
- Low power consumption: 24 hour run time on one charge
- Onboard data processing, logging and diagnostics
- Flexible sampling options and wide dynamic range
- Filter strips for accurate sample tracking

The microAeth Model AE51 is designed specifically for investigation of personal exposure to carbonaceous particles found in ambient air. The instrument is based on Aethalometer technology that is widely used for studying indoor or outdoor air quality, and for the mobile mapping of the air quality impacts of localized sources. The instrument provides high quality, short time resolved data essential for assessing the real-time concentration of Black Carbon aerosols in a micro-environment.

The package includes:

- microAeth Model AE51 Personal Exposure Monitor
- Self-powered, LED source (880nm-IR), user-selectable measurement timebase settings of 1, 10, 30, 60, 300 seconds, flow rate settings of 50, 100, 150, 200 ml/min with internal active mass flow measurement and control
- Sample collected and analyzed on a filter strip consisting of a T60 Teflon coated borosilicate glass fiber media housed in a protective casing
- USB-based power charger with AC adapter (100-500mA) for internal 5VDC lithium ion battery.
- USB charging / interconnect cable
- Flexible conductive sample tubing (40 inches) with swivel tube connector
- Pack of 5 sample filter strips
- CD containing
  - microAethCOM communications software and USB driver
  - Operating Manual
- Quick Start Guide (hard copy)

For further information on this instrument or Black Carbon measurement, please contact:

AethLabs
San Francisco, California
https://aethlabs.com

1.3 Instrument Diagram

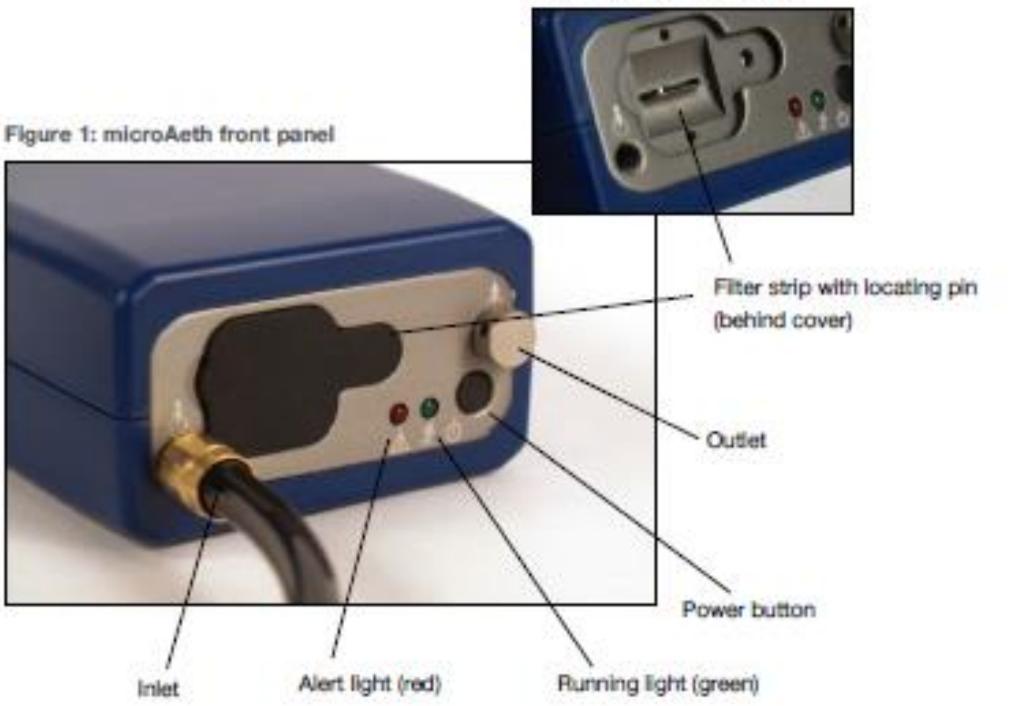
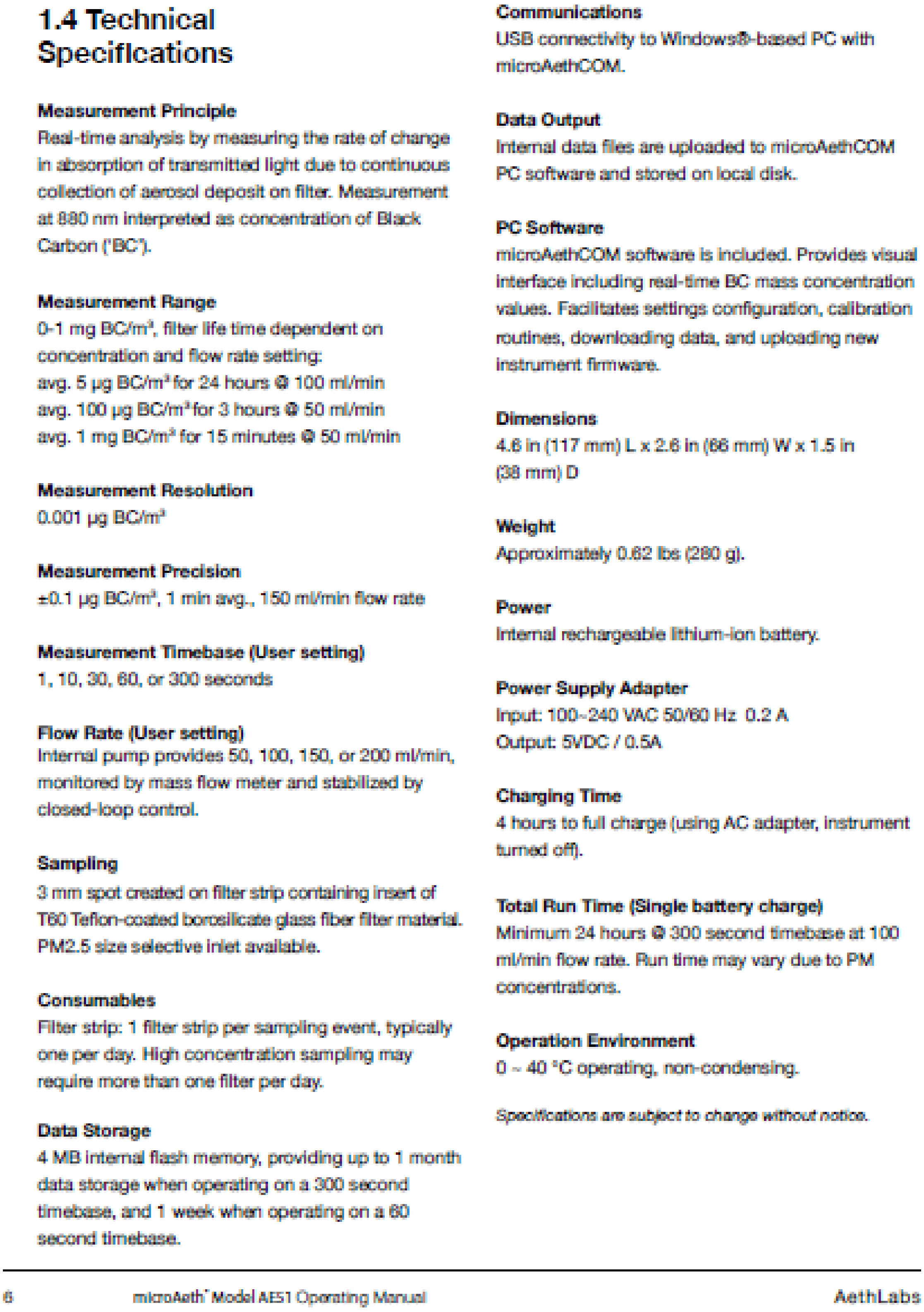


Figure 2: Filter strip slot

Figure 1: microAeth front panel

Figure 3: microAeth rear panel



1.4 Technical Specifications

Measurement Principle
Real-time analysis by measuring the rate of change in absorption of transmitted light due to continuous collection of aerosol deposit on filter. Measurement at 880 nm interpreted as concentration of Black Carbon ('BC').

Measurement Range
0-1 mg BC/m^3, filter life time dependent on concentration and flow rate setting:
avg. 5 μg BC/m^3 for 24 hours @ 100 ml/min
avg. 100 μg BC/m^3 for 3 hours @ 50 ml/min
avg. 1 mg BC/m^3 for 15 minutes @ 50 ml/min

Measurement Resolution
0.001 μg BC/m^3

Measurement Precision
±0.1 μg BC/m^3, 1 min avg., 150 ml/min flow rate

Measurement Timebase (User setting)
1, 10, 30, 60, or 300 seconds

Flow Rate (User setting)
Internal pump provides 50, 100, 150, or 200 ml/min, monitored by mass flow meter and stabilized by closed-loop control.

Sampling
3 mm spot created on filter strip containing insert of T60 Teflon-coated borosilicate glass fiber filter material. PM2.5 size selective inlet available.

Consumables
Filter strip: 1 filter strip per sampling event, typically one per day. High concentration sampling may require more than one filter per day.

Data Storage
4 MB internal flash memory, providing up to 1 month data storage when operating on a 300 second timebase, and 1 week when operating on a 60 second timebase.

Communications
USB connectivity to Windows®-based PC with microAethCOM.

Data Output
Internal data files are uploaded to microAethCOM PC software and stored on local disk.

PC Software
microAethCOM software is included. Provides visual interface including real-time BC mass concentration values. Facilitates settings configuration, calibration routines, downloading data, and uploading new instrument firmware.

Dimensions
4.6 in (117 mm) L x 2.6 in (66 mm) W x 1.5 in (38 mm) D

Weight
Approximately 0.62 lbs (280 g).

Power
Internal rechargeable lithium-ion battery.

Power Supply Adapter
Input: 100~240 VAC 50/60 Hz 0.2 A
Output: 5VDC / 0.5A

Charging Time
4 hours to full charge (using AC adapter, instrument turned off).

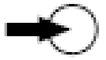
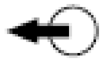
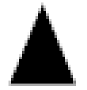
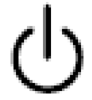
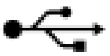
Total Run Time (Single battery charge)
Minimum 24 hours @ 300 second timebase at 100 ml/min flow rate. Run time may vary due to PM concentrations.

Operation Environment
0 ~ 40 °C operating, non-condensing.

Specifications are subject to change without notice.

1.5 Symbols and Cautions

1.5.1 Explanation Operation Symbols

	Operation indicator
	Charging indicator
	Aerosol inlet
	Aerosol outlet
	System alert indicator
	Filter strip orientation arrow (point indicates orientation of upstream face of filter strip)
	On/Off
	USB port

1.5.2 Important Safeguards

Please read these safety instructions completely before operating the instrument, and keep this manual for future reference. Carefully observe all warnings, precautions and instructions on the instrument, or as described in the operating manual and product literature.

Do not expose the microAeth or its batteries to sources of excessive heat such as sunshine or fire.

1.5.2.1 Power Source

The microAeth should be operated only from the type of power source indicated in the instrument specifications. If you are not sure of the type of electrical power supplied to your home, consult your dealer or local power company. For those devices designed to operate from battery power, or other sources, refer to the operating instructions. Also, the connections on both ends of the USB interface cable are designed to be inserted into the AC power/charger adapter or the microAeth only one way. These are safety features. If you are unable to insert the AC plug fully into the outlet, try reversing the plug. If the plug should still fail to fit, contact AethLabs.

1.5.2.2 Object and Liquid Entry

Never push objects of any kind into the AC power/charger adapter or into the microAeth (except for the filter ticket) through openings as they may touch dangerous voltage points or short out parts that could result in a fire or electric shock. Never spill liquid of any kind on the microAeth or its electrical accessories. This instrument should not be exposed to rain or moisture, and objects filled with liquids, such as vases, should not be placed on this instrument.

1.5.2.3 Accessories

Do not use accessories not recommended by the manufacturer, as they may cause hazards.

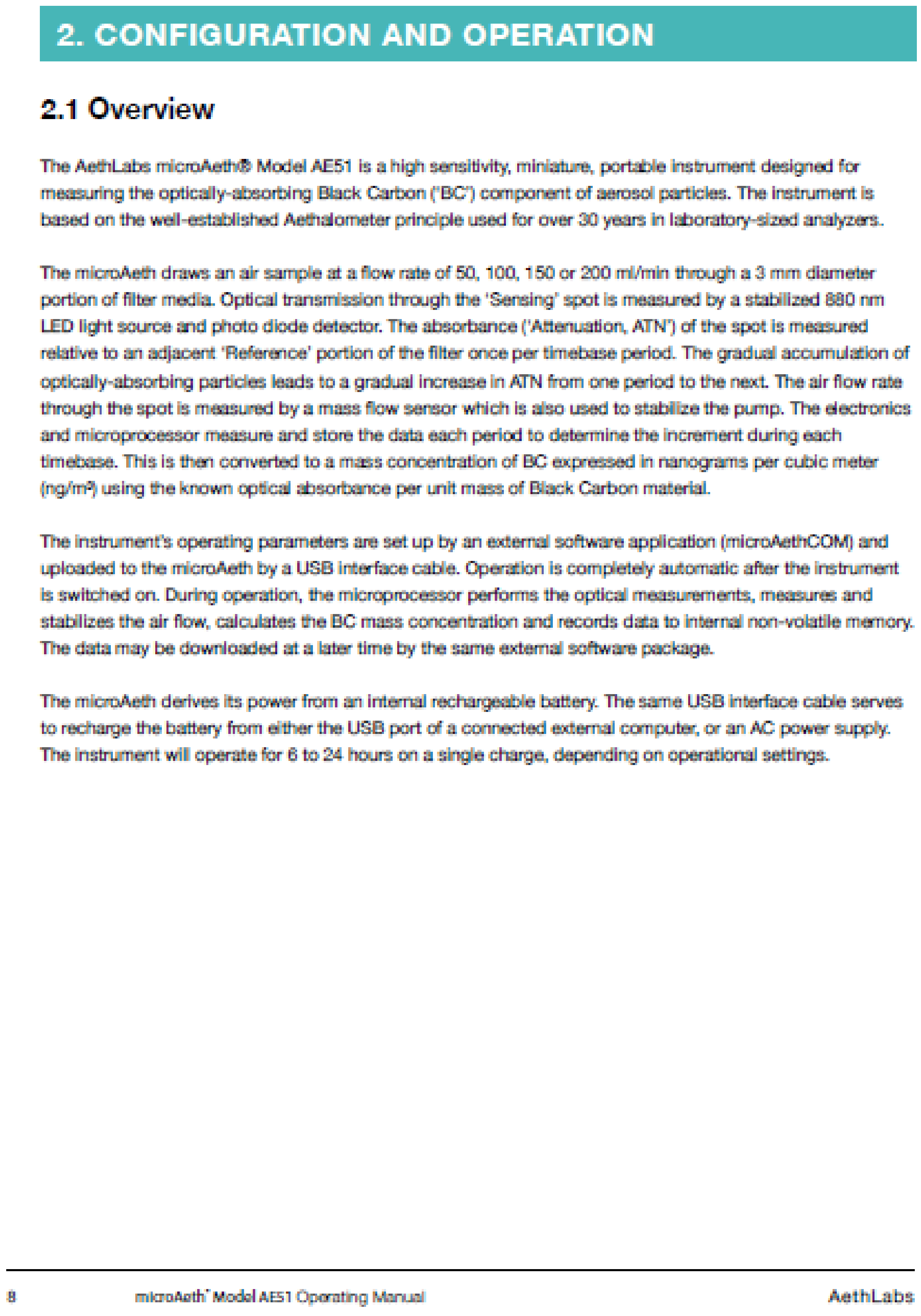
1.5.2.4 Servicing

Use extra care when servicing the instrument yourself as opening or removing covers exposes sensitive internal hardware to potential damage. Refer to all service documentation and trained, authorized service personnel for assistance.

1.5.2.5 Replacement Parts

Only genuine AethLabs parts should be used in the microAeth. Only trained, authorized service personnel should make repairs or install replacement parts.

Lithium-Ion batteries are recyclable and should be disposed of properly. **Caution:** Do not handle damaged or leaking Lithium-Ion batteries.



2. CONFIGURATION AND OPERATION

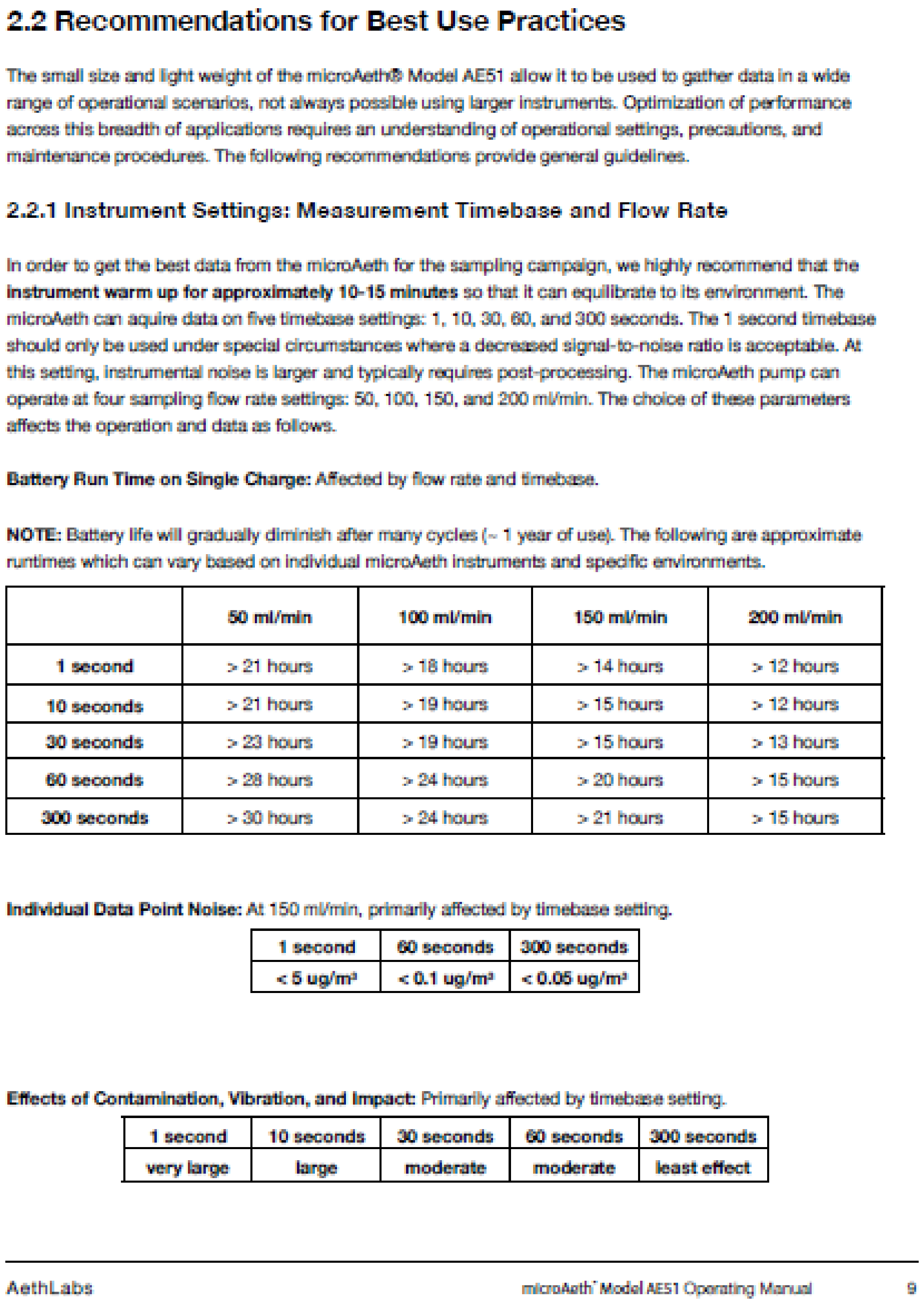
2.1 Overview

The AethLabs microAeth® Model AE51 is a high sensitivity, miniature, portable instrument designed for measuring the optically-absorbing Black Carbon ('BC') component of aerosol particles. The instrument is based on the well-established Aethalometer principle used for over 30 years in laboratory-sized analyzers.

The microAeth draws an air sample at a flow rate of 50, 100, 150 or 200 ml/min through a 3 mm diameter portion of filter media. Optical transmission through the 'Sensing' spot is measured by a stabilized 880 nm LED light source and photo diode detector. The absorbance ('Attenuation, ATN') of the spot is measured relative to an adjacent 'Reference' portion of the filter once per timebase period. The gradual accumulation of optically-absorbing particles leads to a gradual increase in ATN from one period to the next. The air flow rate through the spot is measured by a mass flow sensor which is also used to stabilize the pump. The electronics and microprocessor measure and store the data each period to determine the increment during each timebase. This is then converted to a mass concentration of BC expressed in nanograms per cubic meter (ng/m^3) using the known optical absorbance per unit mass of Black Carbon material.

The instrument's operating parameters are set up by an external software application (microAethCOM) and uploaded to the microAeth by a USB interface cable. Operation is completely automatic after the instrument is switched on. During operation, the microprocessor performs the optical measurements, measures and stabilizes the air flow, calculates the BC mass concentration and records data to internal non-volatile memory. The data may be downloaded at a later time by the same external software package.

The microAeth derives its power from an internal rechargeable battery. The same USB interface cable serves to recharge the battery from either the USB port of a connected external computer, or an AC power supply. The instrument will operate for 6 to 24 hours on a single charge, depending on operational settings.



2.2 Recommendations for Best Use Practices

The small size and light weight of the microAeth® Model AE51 allow it to be used to gather data in a wide range of operational scenarios, not always possible using larger instruments. Optimization of performance across this breadth of applications requires an understanding of operational settings, precautions, and maintenance procedures. The following recommendations provide general guidelines.

2.2.1 Instrument Settings: Measurement Timebase and Flow Rate

In order to get the best data from the microAeth for the sampling campaign, we highly recommend that the **instrument warm up for approximately 10-15 minutes** so that it can equilibrate to its environment. The microAeth can aquire data on five timebase settings: 1, 10, 30, 60, and 300 seconds. The 1 second timebase should only be used under special circumstances where a decreased signal-to-noise ratio is acceptable. At this setting, instrumental noise is larger and typically requires post-processing. The microAeth pump can operate at four sampling flow rate settings: 50, 100, 150, and 200 ml/min. The choice of these parameters affects the operation and data as follows.

Battery Run Time on Single Charge: Affected by flow rate and timebase.

NOTE: Battery life will gradually diminish after many cycles (~ 1 year of use). The following are approximate runtimes which can vary based on individual microAeth instruments and specific environments.

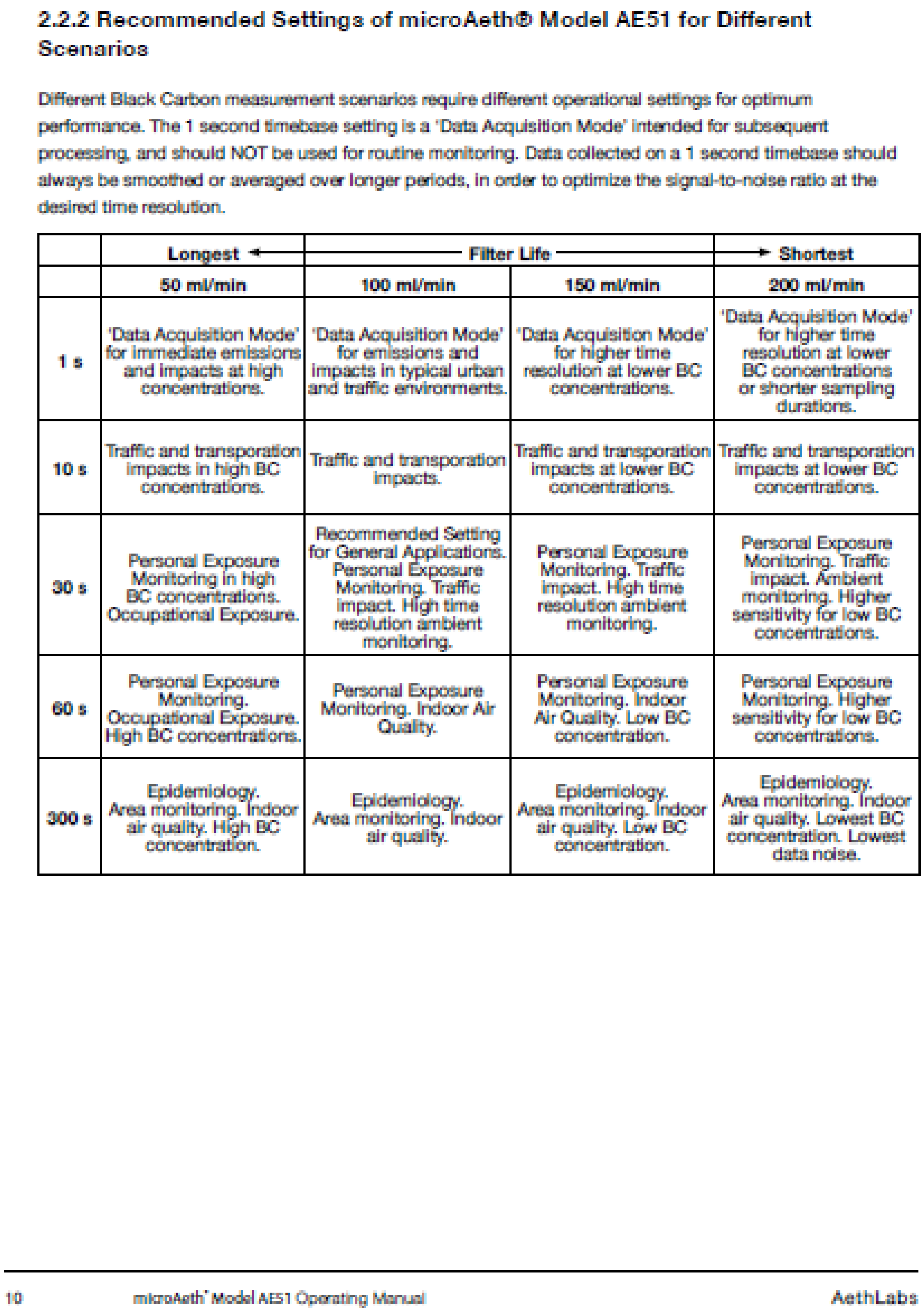
	50 ml/min	**100 ml/min**	**150 ml/min**	**200 ml/min**
1 second	> 21 hours	> 18 hours	> 14 hours	> 12 hours
10 seconds	> 21 hours	> 19 hours	> 15 hours	> 12 hours
30 seconds	> 23 hours	> 19 hours	> 15 hours	> 13 hours
60 seconds	> 28 hours	> 24 hours	> 20 hours	> 15 hours
300 seconds	> 30 hours	> 24 hours	> 21 hours	> 15 hours

Individual Data Point Noise: At 150 ml/min, primarily affected by timebase setting.

1 second	**60 seconds**	**300 seconds**
< 5 ug/m³	**< 0.1 ug/m³**	**< 0.05 ug/m³**

Effects of Contamination, Vibration, and Impact: Primarily affected by timebase setting.

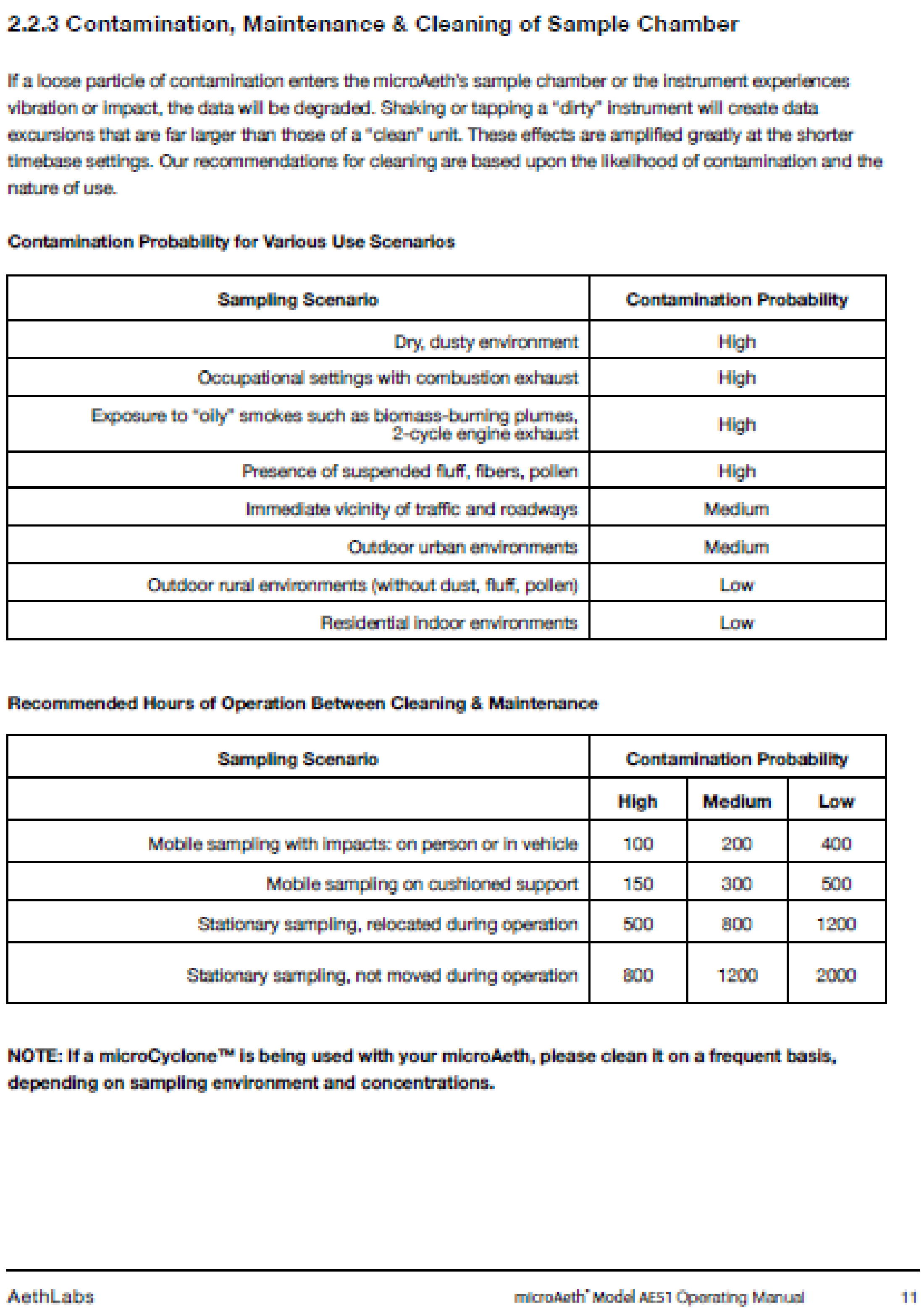
1 second	**10 seconds**	**30 seconds**	**60 seconds**	**300 seconds**
very large	**large**	**moderate**	**moderate**	**least effect**



2.2.2 Recommended Settings of microAeth® Model AE51 for Different Scenarios

Different Black Carbon measurement scenarios require different operational settings for optimum performance. The 1 second timebase setting is a 'Data Acquisition Mode' intended for subsequent processing, and should NOT be used for routine monitoring. Data collected on a 1 second timebase should always be smoothed or averaged over longer periods, in order to optimize the signal-to-noise ratio at the desired time resolution.

	Longest ←	**Filter Life**		**→ Shortest**
	50 ml/min	**100 ml/min**	**150 ml/min**	**200 ml/min**
1 s	'Data Acquisition Mode' for immediate emissions and impacts at high concentrations.	'Data Acquisition Mode' for emissions and impacts in typical urban and traffic environments.	'Data Acquisition Mode' for higher time resolution at lower BC concentrations.	'Data Acquisition Mode' for higher time resolution at lower BC concentrations or shorter sampling durations.
10 s	Traffic and transporation impacts in high BC concentrations.	Traffic and transporation impacts.	Traffic and transporation impacts at lower BC concentrations.	Traffic and transporation impacts at lower BC concentrations.
30 s	Personal Exposure Monitoring in high BC concentrations. Occupational Exposure.	Recommended Setting for General Applications. Personal Exposure Monitoring. Traffic impact. High time resolution ambient monitoring.	Personal Exposure Monitoring. Traffic impact. High time resolution ambient monitoring.	Personal Exposure Monitoring. Traffic impact. Ambient monitoring. Higher sensitivity for low BC concentrations.
60 s	Personal Exposure Monitoring. Occupational Exposure. High BC concentrations.	Personal Exposure Monitoring. Indoor Air Quality.	Personal Exposure Monitoring. Indoor Air Quality. Low BC concentration.	Personal Exposure Monitoring. Higher sensitivity for low BC concentrations.
300 s	Epidemiology. Area monitoring. Indoor air quality. High BC concentration.	Epidemiology. Area monitoring. Indoor air quality.	Epidemiology. Area monitoring. Indoor air quality. Low BC concentration.	Epidemiology. Area monitoring. Indoor air quality. Lowest BC concentration. Lowest data noise.



2.2.3 Contamination, Maintenance & Cleaning of Sample Chamber

If a loose particle of contamination enters the microAeth's sample chamber or the instrument experiences vibration or impact, the data will be degraded. Shaking or tapping a "dirty" instrument will create data excursions that are far larger than those of a "clean" unit. These effects are amplified greatly at the shorter timebase settings. Our recommendations for cleaning are based upon the likelihood of contamination and the nature of use.

Contamination Probability for Various Use Scenarios

Sampling Scenario	Contamination Probability
Dry, dusty environment	High
Occupational settings with combustion exhaust	High
Exposure to "oily" smokes such as biomass-burning plumes, 2-cycle engine exhaust	High
Presence of suspended fluff, fibers, pollen	High
Immediate vicinity of traffic and roadways	Medium
Outdoor urban environments	Medium
Outdoor rural environments (without dust, fluff, pollen)	Low
Residential indoor environments	Low

Recommended Hours of Operation Between Cleaning & Maintenance

Sampling Scenario	Contamination Probability		
	High	**Medium**	**Low**
Mobile sampling with impacts: on person or in vehicle	100	200	400
Mobile sampling on cushioned support	150	300	500
Stationary sampling, relocated during operation	500	800	1200
Stationary sampling, not moved during operation	800	1200	2000

NOTE: If a microCyclone™ is being used with your microAeth, please clean it on a frequent basis, depending on sampling environment and concentrations.

2.3 Filter Media

IMPORTANT NOTE:

- **Always make sure that a filter strip is installed in the microAeth when it is operating.**
- **Whenever the filter strip is exchanged, the microAeth should be turned off to prevent dust or debris from being drawn into the inlet and analysis chamber.**

2.3.1 General

The sample collection and analysis is performed on a filter strip, consisting of a small section of filter material held between and supported by a specially designed filter holder to create the filter strip assembly. As the aerosol sample is drawn through the filter media by the instrument's integrated, internal sample pump, the aerosol sample collects gradually on the filter medium to create a gray spot 3 mm in diameter. The microAeth determines the attenuation of the source light as the accumulated black carbon increases the optical density of the filter spot. After the optical density reaches a certain level, the filter strip must be replaced to maintain measurement integrity.

To maintain a leak-free sample path, the filter strip is clamped between two halves of the spring-loaded sampling head. A release button opens the clamp to allow the filter strip to be inserted and removed. A locating pin in the head engages in a matching hole in the filter strip holder to ensure correct placement.

2.3.2 Filter Strip Installation and Removal

1. The sample deposit side of the filter strip is the white side. When the filter strip is installed in the sample chamber, the white side of the filter strip should be facing the same direction as indicated by the white arrow on the faceplate of the microAeth.

Figure 5: Top of microAeth

Figure 6: Bottom of microAeth with filter strip release button.

Figure 7: White sample deposit side of filter strip faces the top.

Figure 8: Metal side of filter strip faces the bottom.

2. Hold the microAeth in one hand so that the filter chamber release button is on the bottom of the enclosure (Figure 9) (all of the icons will be right side up).

3. Loosen the rubber cover on the front of the microAeth by pulling the tab away from the instrument. This will expose the filter strip slot.

Figure 9: Inserting and removing filter strip while depressing filter release button on bottom of microAeth.

4. If there is a filter strip already installed, depress the release button with your thumb and pull the filter strip out of the sampling head.

5. Install a new filter strip by pressing and holding the release button and then inserting the new filter strip into the sample chamber opening with the white plastic side facing up (Figure 9).

6. Make sure to push the new filter strip all the way into the slot and that the locating pinhole on the filter strip is not visible.

7. Release the release button and verify the locating pin has registered properly in the filter strip locating hole.

8. Replace the rubber cover. A tight fit is essential to prevent the entry of contamination and stray light into the sample chamber.

2.4 Power

The power switch is located on the front panel of the instrument. There are two options for recharging:

- USB to PC-USB port (500mA): 4 hours to full charge
- USB to AC-USB wall adapter (500mA): 4 hours to full charge.

The instrument uses a USB-based power charger (100-500mA) for internal 5VDC lithium ion battery. The yellow charging light illuminates when the microAeth is connected to an external power source and is recharging the battery. When the battery is fully charged, the yellow light turns off.

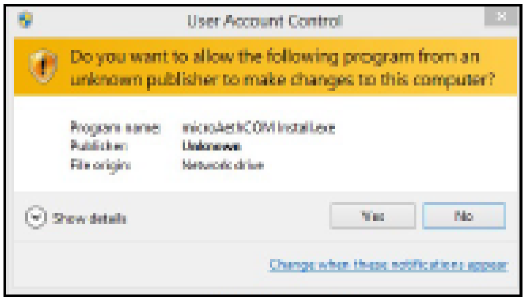
2.5 microAethCOM PC Software Installation

The microAethCOM software application is designed to install and operate on a PC using Windows® XP with Service Pack 3, Windows® 7, and Windows® 8. All software components are included in the installer named microAethCOM Install.exe which is located on the CD included with the microAeth or can be downloaded from the AethLabs website. This installer will install the microAethCOM, manual flow calibration software and the firmware file.

1. Do not connect the microAeth to the USB port on the computer until the software installation is complete.

2. Make sure that you have the necessary user privileges on your computer to install software.

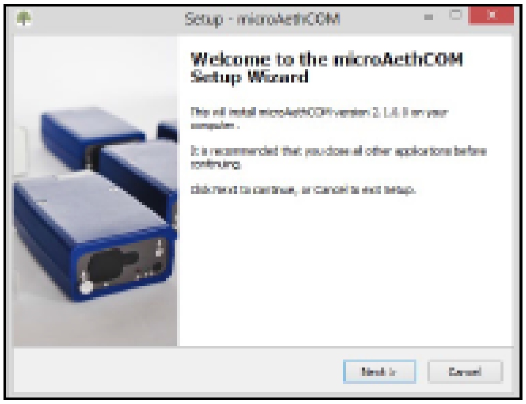
3. Locate and double click microAethCOM Install.exe to start the install. The installer will prompt you through the setup.



User Account Control

Do you want to allow the following program from an unknown publisher to make changes to this computer?

Program name: microAethCOM Install.exe
Publisher: Unknown
File origin: Network drive



Setup - microAethCOM

Welcome to the microAethCOM Setup Wizard

4. In order to install the microAethCOM software, please read and accept the license agreement.

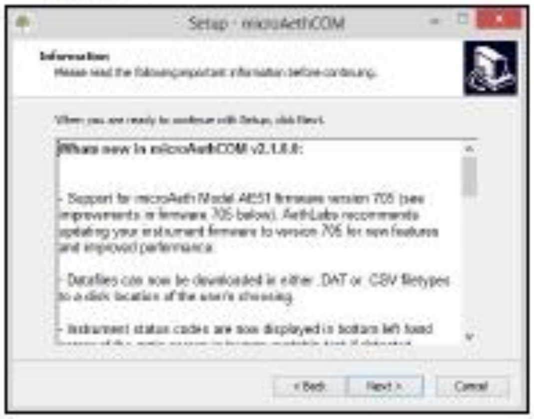
END USER LICENSE AGREEMENT

READ THIS END USER LICENSE AGREEMENT ("AGREEMENT") CAREFULLY BEFORE USING THE ACCOMPANYING SOFTWARE (THE "SOFTWARE"). BY DOWNLOADING AND USING THE SOFTWARE, YOU ACKNOWLEDGE THAT YOU HAVE READ THIS AGREEMENT, THAT YOU UNDERSTAND IT, AND

● I accept the agreement

○ I do not accept the agreement

5. Please review changes to microAethCOM and firmware.



What's new in microAethCOM v2.1.8.0:

- Support for microAeth Model AE51 firmware version 705 (see improvements in firmware 705 below). AethLabs recommends updating your instrument firmware to version 705 for new features and improved performance.

- Datafiles can now be downloaded in either .DAT or .CSV filetypes to a disk location of the user's choosing.

- Instrument status codes are now displayed in bottom left hand

6. Select the directory location where microAethCOM, manual flow calibration software and the firmware file should be installed on the computer.

Setup will install microAethCOM into the following folder.

To continue, click Next. If you would like to select a different folder, click Browse.

7. The communication drivers will need to be installed next. The installer will prompt you through this section of the setup.

Welcome to the Device Driver Installation Wizard!

This wizard helps you install the software drivers that some computers devices need in order to work.

To continue, click Next.

8. Once all the correct drivers are installed, the setup will be complete.

Completing the microAethCOM Setup Wizard

Setup has finished installing microAethCOM on your computer. The application may be launched by selecting the installed icons.

Click Finish to exit Setup.

2.6 Operation and Communication

Before starting a sampling run, it is recommended that the user verify all parameter settings. A description of each operating parameter and its configuration is described in section 2.6.2 Configuration of Instrument Operating Parameters.

The microAeth startup sequence automatically begins when the power is turned on. Sampling and data collection begin starting the next minute after the startup process is complete. A new measurement data file is created for the new sampling session. The microAeth will continue sampling and storing data until the instrument is shutdown. At shutdown, the data file is closed. Any active sampling session and data file will also be closed if data is downloaded or erased or if settings are saved to the microAeth. In order to start a new sampling session, the microAeth must be restarted.

Status indicator lights located on each end panel of the microAeth provide information regarding the instrument operating status. Please read section 2.6.8.1 LED Status Indications for more information.

2.6.1 microAeth Operation

IMPORTANT NOTE:

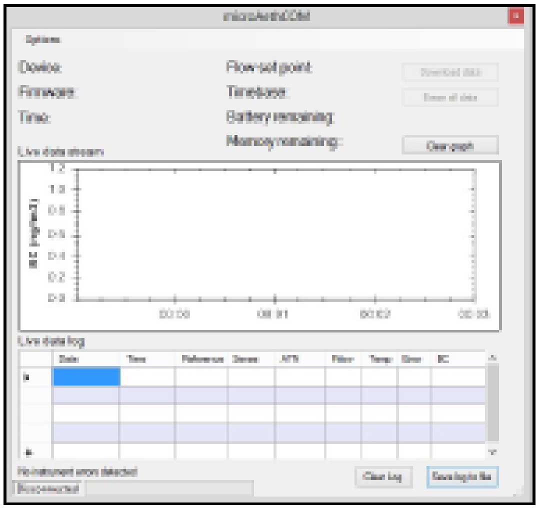
- **Always make sure that a filter strip is installed in the microAeth when it is operating.**
- **Whenever the filter strip is exchanged, the microAeth should be turned off to prevent dust or debris from being drawn into the inlet and analysis chamber.**
- **A new sampling session and data file is created each time the microAeth is turned on and completes the automatic startup sequence.**
- **Any active sampling session and data file will be closed if the microAeth is shutdown, data is downloaded or erased, or if settings are saved to the microAeth. In order to start a new sampling session, the microAeth must be restarted.**

1. Make sure that a filter strip is installed in the microAeth. Turn on the microAeth by depressing the power button for 4 seconds until the microAeth beeps for the second time and the red and green LEDs illuminate together.

2. Release the power button and wait for a few seconds. The pump will turn on and the LEDs will then begin to blink on and off in unison about every second until the beginning of the next minute. When the LEDs stop blinking, the instrument will chirp indicating the start of data collection.

3. While the unit is operating, the green LED will blink periodically. If the unit is set to store data to its internal memory, the green LED will emit single blinks every few seconds. If it has been set to store data internally and stream data, the green LED will blink twice every few seconds.

4. Start the microAethCOM software.



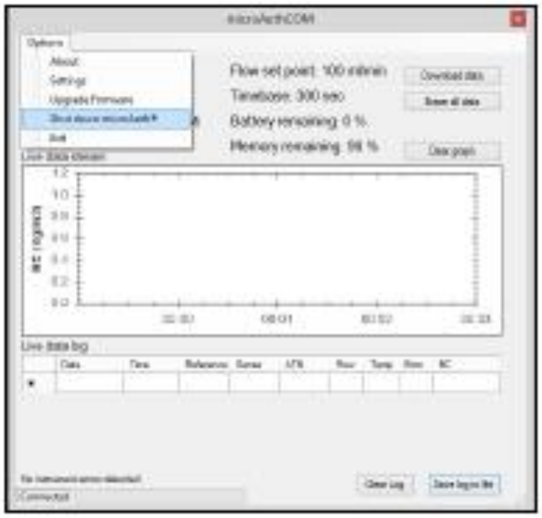
5. Connect the USB cable to the microAeth and your computer.

6. After the microAeth establishes communication with the microAethCOM software, the connection status in the bottom left corner of the main screen will change to Connected and the microAeth serial number, status, and settings will be displayed.

Device: AE51-S4-756-7303
Firmware: 706
Time: 30 Jul 2013 5:07:40 PM
Flow set point: 100 ml/min
Timebase: 60 sec
Battery remaining: 88 %
Memory remaining: 100 %

7. If the serial number, status, and settings are not displayed, disconnect the USB cable and reinsert it.

8. To shut down the microAeth through the microAethCOM software, click Options then Shut down microAeth. Depending on the current settings of the microAeth, the power button on the front of the instrument can be used to shut down the instrument.



Flow set point: 100 ml/min
Timebase: 300 sec
Battery remaining: 0 %
Memory remaining: 98 %

2.6.2 Configuration of Instrument Operating Parameters

IMPORTANT NOTE:

- **The microAeth will not collect data with new saved settings until it has been restarted.**

All instrument parameters are configured through the microAethCOM user interface. The various parameters are accessed through Settings in the Options menu on the tool bar.

1. Turn on the microAeth.

2. Start the microAethCOM software.

3. Connect the USB cable to the microAeth and the computer. Wait until the microAeth establishes communication with microAethCOM.

4. Click Options then Settings

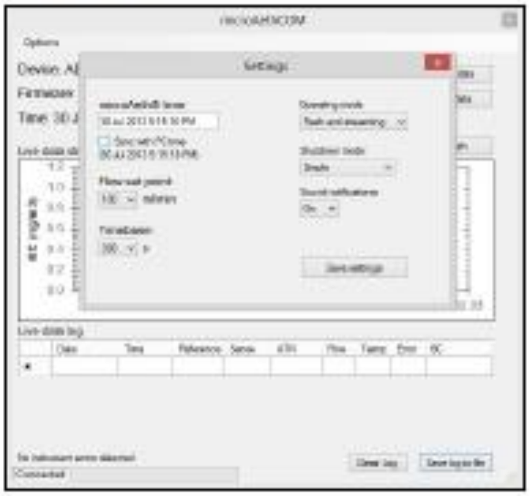
Flow set point: 100 ml/min

Timebase: 300 sec

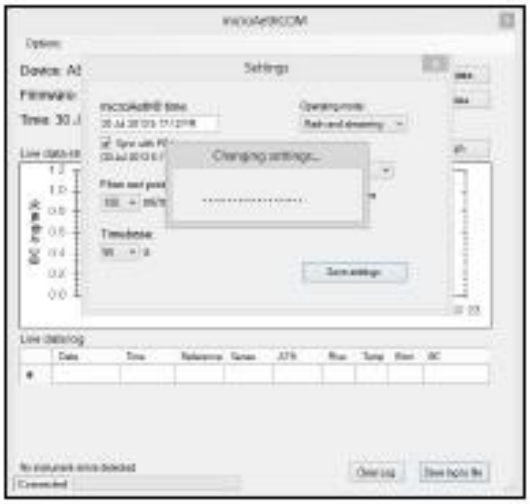
Battery remaining: 0 %

Memory remaining: 66 %

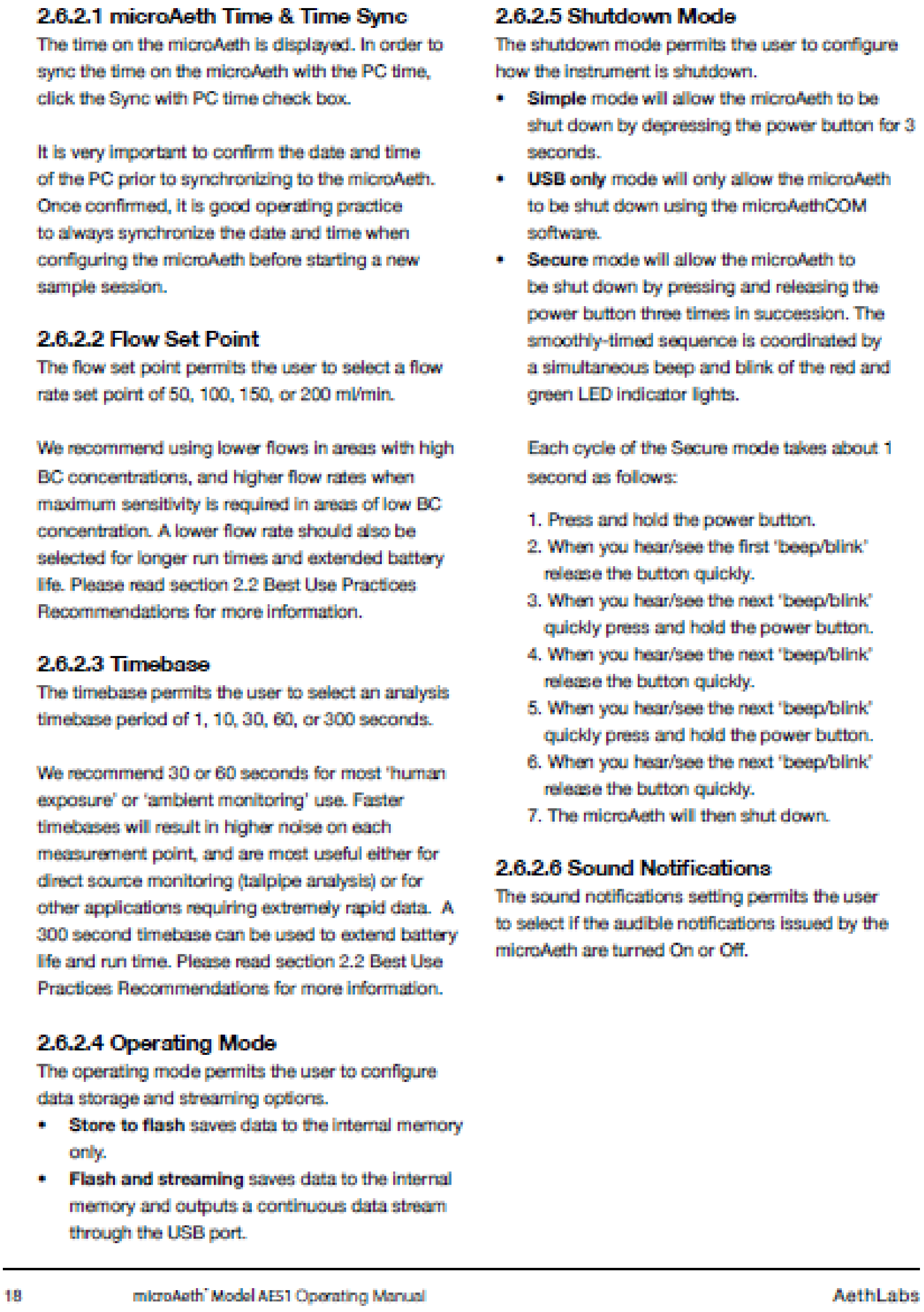
5. On the Settings screen, the microAeth can be configured.



6. When all settings are selected as desired, click the Save settings button.



7. Once the settings have been saved, you will be prompted to shut down the microAeth. **The microAeth will not collect data with the new saved settings until it has been restarted.**



2.6.2.1 microAeth Time & Time Sync

The time on the microAeth is displayed. In order to sync the time on the microAeth with the PC time, click the Sync with PC time check box.

It is very important to confirm the date and time of the PC prior to synchronizing to the microAeth. Once confirmed, it is good operating practice to always synchronize the date and time when configuring the microAeth before starting a new sample session.

2.6.2.2 Flow Set Point

The flow set point permits the user to select a flow rate set point of 50, 100, 150, or 200 ml/min.

We recommend using lower flows in areas with high BC concentrations, and higher flow rates when maximum sensitivity is required in areas of low BC concentration. A lower flow rate should also be selected for longer run times and extended battery life. Please read section 2.2 Best Use Practices Recommendations for more information.

2.6.2.3 Timebase

The timebase permits the user to select an analysis timebase period of 1, 10, 30, 60, or 300 seconds.

We recommend 30 or 60 seconds for most 'human exposure' or 'ambient monitoring' use. Faster timebases will result in higher noise on each measurement point, and are most useful either for direct source monitoring (tailpipe analysis) or for other applications requiring extremely rapid data. A 300 second timebase can be used to extend battery life and run time. Please read section 2.2 Best Use Practices Recommendations for more information.

2.6.2.4 Operating Mode

The operating mode permits the user to configure data storage and streaming options.

- **Store to flash** saves data to the internal memory only.
- **Flash and streaming** saves data to the internal memory and outputs a continuous data stream through the USB port.

2.6.2.5 Shutdown Mode

The shutdown mode permits the user to configure how the instrument is shutdown.

- **Simple** mode will allow the microAeth to be shut down by depressing the power button for 3 seconds.
- **USB only** mode will only allow the microAeth to be shut down using the microAethCOM software.
- **Secure** mode will allow the microAeth to be shut down by pressing and releasing the power button three times in succession. The smoothly-timed sequence is coordinated by a simultaneous beep and blink of the red and green LED indicator lights.

Each cycle of the Secure mode takes about 1 second as follows:

1. Press and hold the power button.
2. When you hear/see the first 'beep/blink' release the button quickly.
3. When you hear/see the next 'beep/blink' quickly press and hold the power button.
4. When you hear/see the next 'beep/blink' release the button quickly.
5. When you hear/see the next 'beep/blink' quickly press and hold the power button.
6. When you hear/see the next 'beep/blink' release the button quickly.
7. The microAeth will then shut down.

2.6.2.6 Sound Notifications

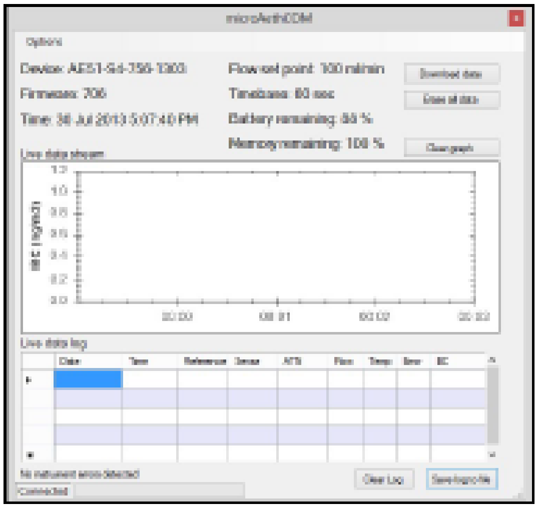
The sound notifications setting permits the user to select if the audible notifications issued by the microAeth are turned On or Off.

2.6.3 Downloading Data

1. Turn on the microAeth.

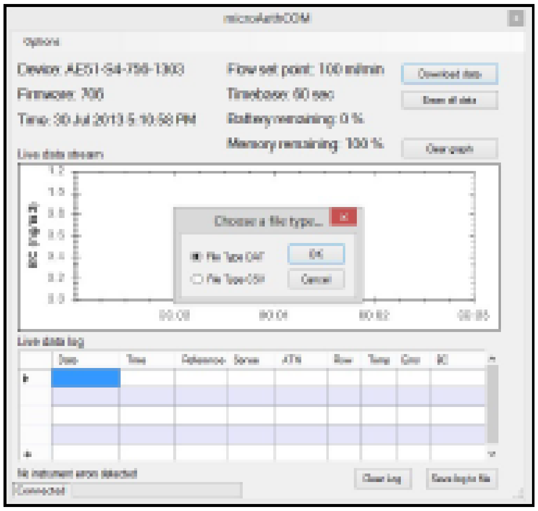
2. Start the microAethCOM software.

3. Connect the USB cable to the microAeth and the computer. Wait until the microAeth establishes communication with microAethCOM.

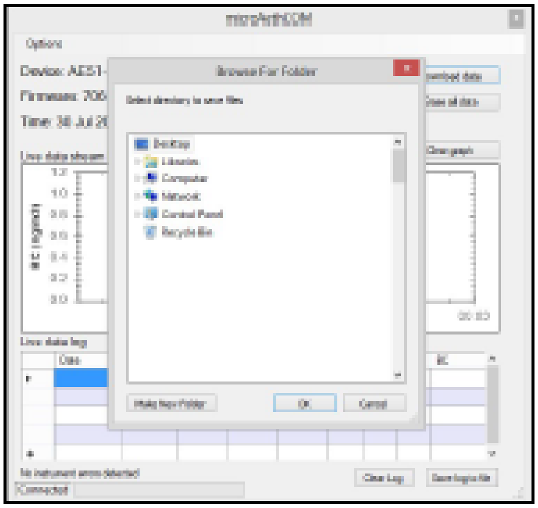


4. Click the Download data button to download the data stored on the internal memory of the microAeth.

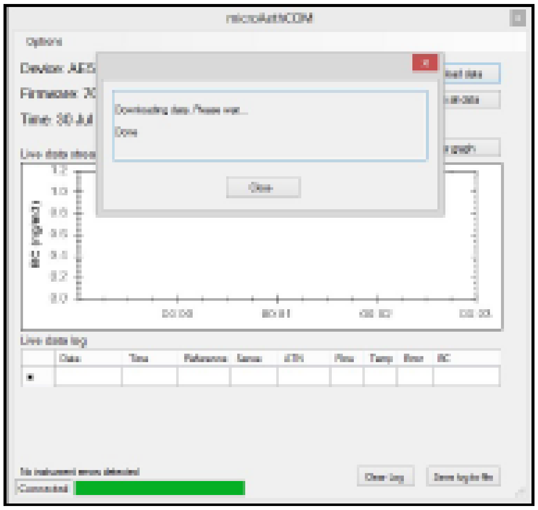
5. Select .DAT or .CSV data file type to download.



6. Select the directory to save the data. The data will be saved in a folder named **AE51-SX-XXX-YYMM** in this directory.

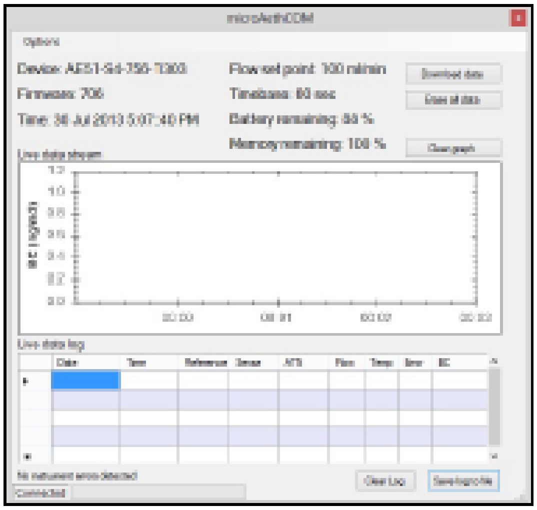


7. Wait until the download has completed. The progress bar in the bottom left corner of the main screen will show you the progress of the download. The status window will also inform you when the download is complete.

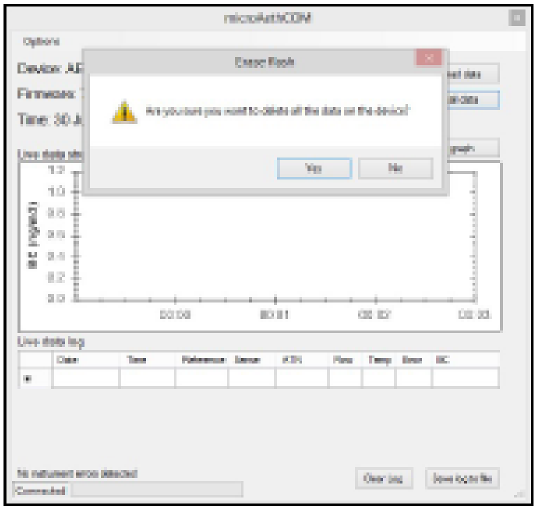


2.6.4 Erasing Data

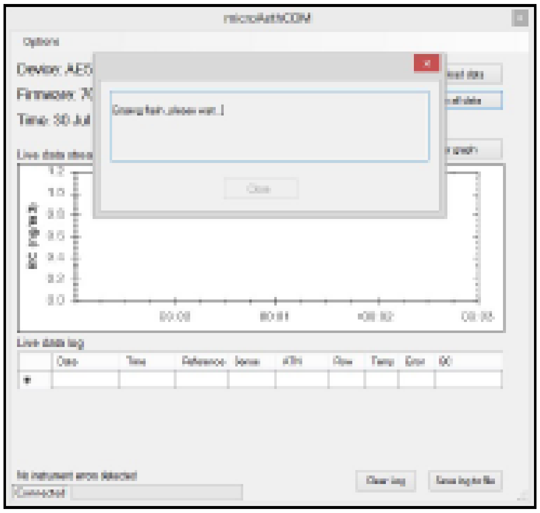
1. Turn on the microAeth.
2. Start the microAethCOM software.
3. Connect the USB cable to the microAeth and the computer. Wait until the microAeth establishes communication with microAethCOM.



4. Click the Erase all data button to erase all the data stored on the internal memory of the microAeth.
5. You will be prompted to confirm to erase all the data stored on the microAeth.



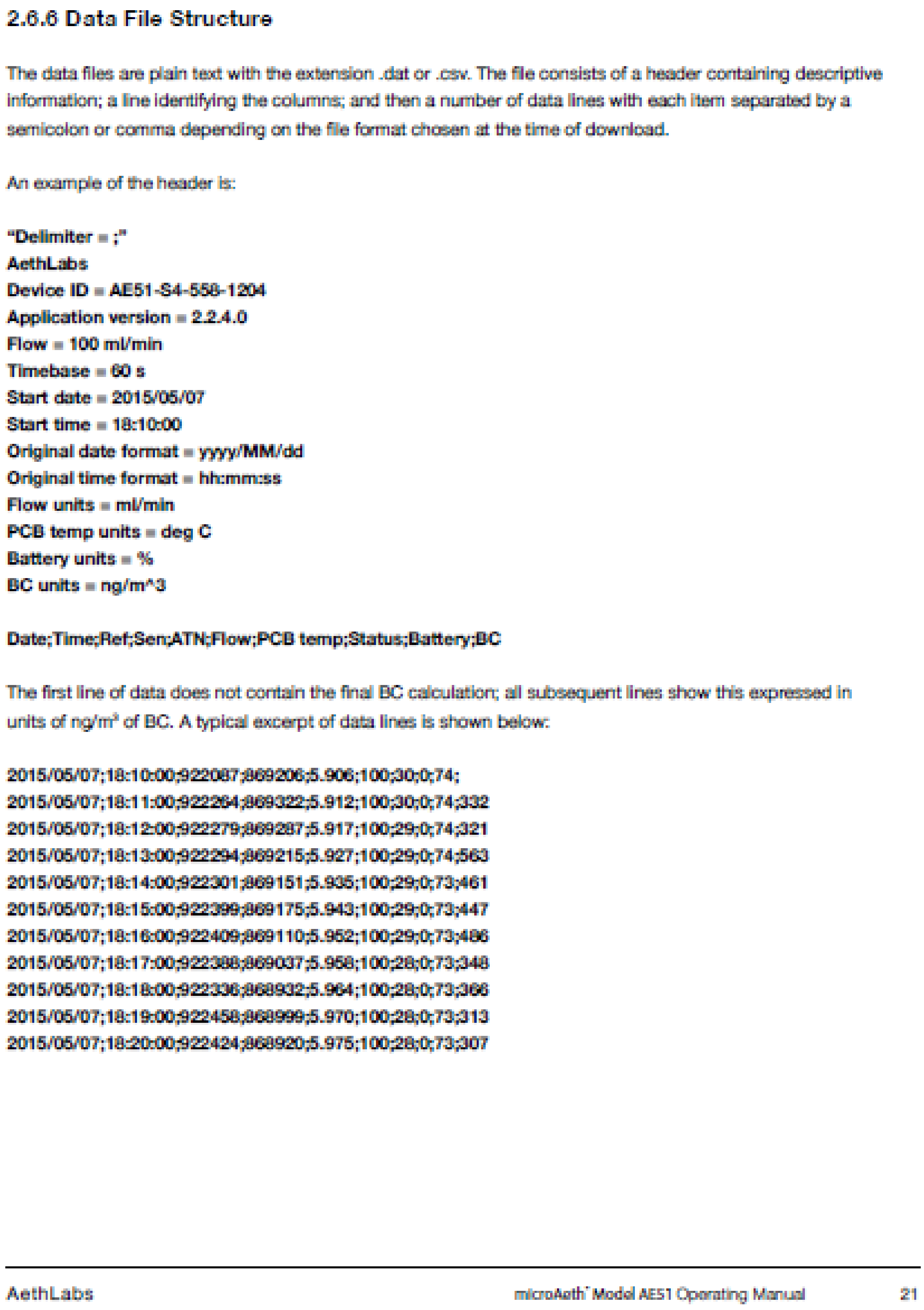
6. Wait until the data erase has completed. The status window will show that the memory is being erased.



7. The status window will disappear when the memory has been erased.

2.6.5 Viewing and/or Analyzing Measurement Data

Data files are named using the following naming convention: AE51-SX-XXX-YYYYMMDD, where XXX is the instrument unique indentifer number. Data files are formatted such that they can be imported directly into Microsoft Excel® or can be uploaded to the AethLabs website. Please note that when opening data files in Microsoft Excel®, formatting may automatically be changed, making it difficult to upload to the website.



2.6.6 Data File Structure

The data files are plain text with the extension .dat or .csv. The file consists of a header containing descriptive information; a line identifying the columns; and then a number of data lines with each item separated by a semicolon or comma depending on the file format chosen at the time of download.

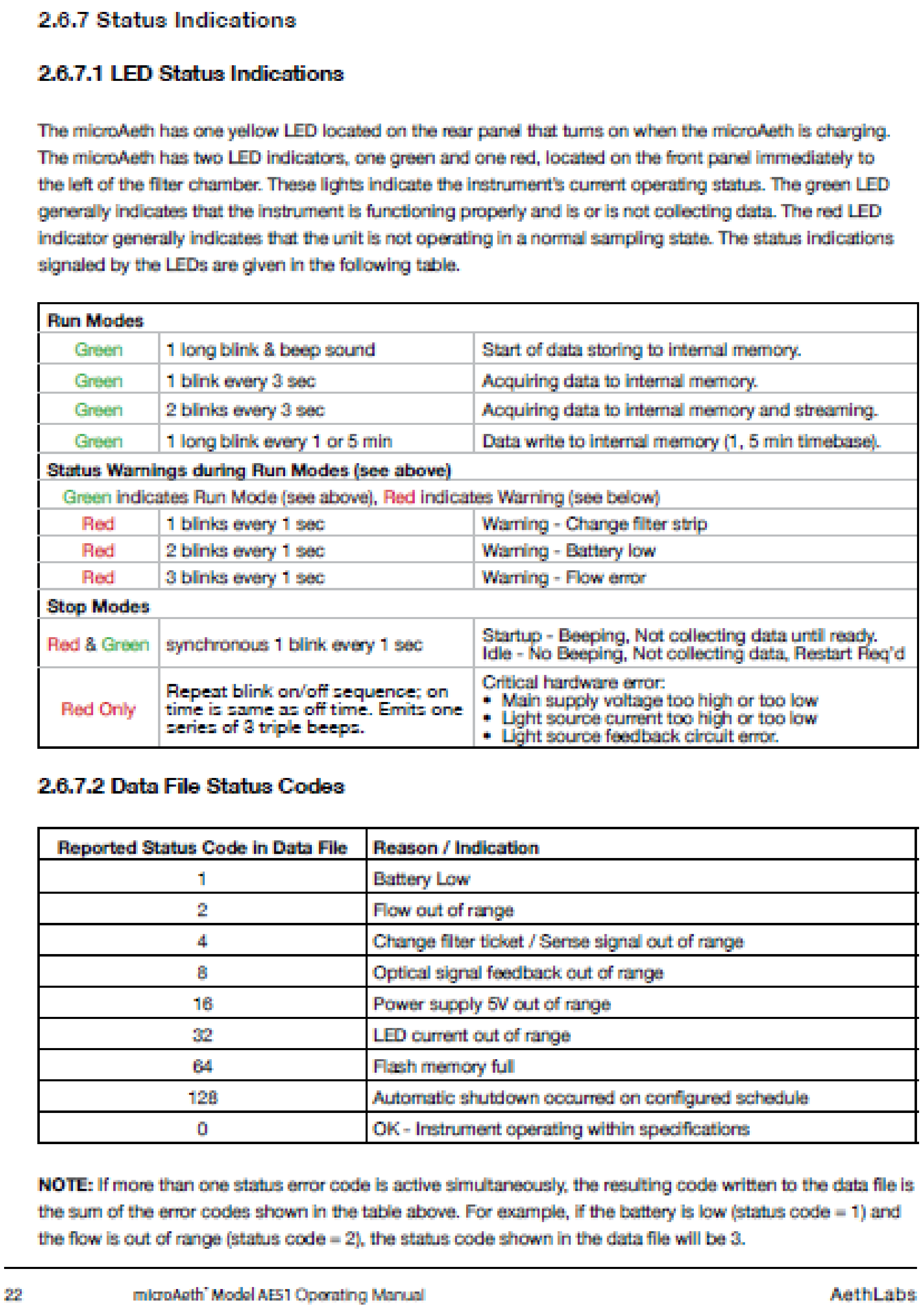
An example of the header is:

```
“Delimiter = ;”
AethLabs
Device ID = AE51-S4-558-1204
Application version = 2.2.4.0
Flow = 100 ml/min
Timebase = 60 s
Start date = 2015/05/07
Start time = 18:10:00
Original date format = yyyy/MM/dd
Original time format = hh:mm:ss
Flow units = ml/min
PCB temp units = deg C
Battery units = %
BC units = ng/m^3

Date;Time;Ref;Sen;ATN;Flow;PCB temp;Status;Battery;BC
```

The first line of data does not contain the final BC calculation; all subsequent lines show this expressed in units of ng/m³ of BC. A typical excerpt of data lines is shown below:

```
2015/05/07;18:10:00;922087;869206;5.906;100;30;0;74;
2015/05/07;18:11:00;922264;869322;5.912;100;30;0;74;332
2015/05/07;18:12:00;922279;869287;5.917;100;29;0;74;321
2015/05/07;18:13:00;922294;869215;5.927;100;29;0;74;563
2015/05/07;18:14:00;922301;869151;5.935;100;29;0;73;461
2015/05/07;18:15:00;922399;869175;5.943;100;29;0;73;447
2015/05/07;18:16:00;922409;869110;5.952;100;29;0;73;486
2015/05/07;18:17:00;922388;869037;5.958;100;28;0;73;348
2015/05/07;18:18:00;922336;868932;5.964;100;28;0;73;366
2015/05/07;18:19:00;922458;868999;5.970;100;28;0;73;313
2015/05/07;18:20:00;922424;868920;5.975;100;28;0;73;307
```



2.6.7 Status Indications

2.6.7.1 LED Status Indications

The microAeth has one yellow LED located on the rear panel that turns on when the microAeth is charging. The microAeth has two LED indicators, one green and one red, located on the front panel immediately to the left of the filter chamber. These lights indicate the instrument's current operating status. The green LED generally indicates that the instrument is functioning properly and is or is not collecting data. The red LED indicator generally indicates that the unit is not operating in a normal sampling state. The status indications signaled by the LEDs are given in the following table.

Run Modes		
Green	1 long blink & beep sound	Start of data storing to internal memory.
Green	1 blink every 3 sec	Acquiring data to internal memory.
Green	2 blinks every 3 sec	Acquiring data to internal memory and streaming.
Green	1 long blink every 1 or 5 min	Data write to internal memory (1, 5 min timebase).
Status Warnings during Run Modes (see above)		
Green indicates Run Mode (see above), Red indicates Warning (see below)		
Red	1 blinks every 1 sec	Warning - Change filter strip
Red	2 blinks every 1 sec	Warning - Battery low
Red	3 blinks every 1 sec	Warning - Flow error
Stop Modes		
Red & Green	synchronous 1 blink every 1 sec	Startup - Beeping, Not collecting data until ready. Idle - No Beeping, Not collecting data, Restart Req'd
Red Only	Repeat blink on/off sequence; on time is same as off time. Emits one series of 3 triple beeps.	Critical hardware error: • Main supply voltage too high or too low • Light source current too high or too low • Light source feedback circuit error.

2.6.7.2 Data File Status Codes

Reported Status Code in Data File	Reason / Indication
1	Battery Low
2	Flow out of range
4	Change filter ticket / Sense signal out of range
8	Optical signal feedback out of range
16	Power supply 5V out of range
32	LED current out of range
64	Flash memory full
128	Automatic shutdown occurred on configured schedule
0	OK - Instrument operating within specifications

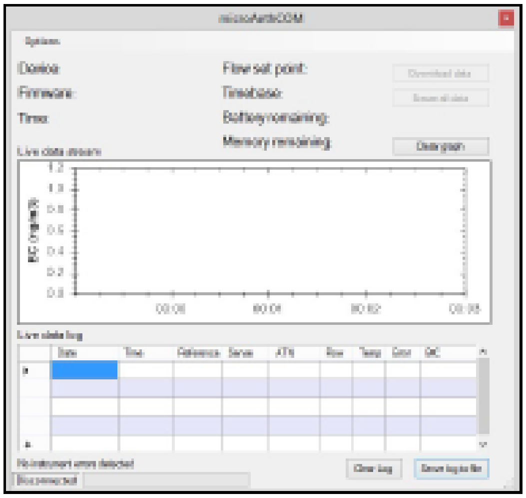
NOTE: If more than one status error code is active simultaneously, the resulting code written to the data file is the sum of the error codes shown in the table above. For example, if the battery is low (status code = 1) and the flow is out of range (status code = 2), the status code shown in the data file will be 3.

2.7 Upgrading microAeth Operating System Firmware

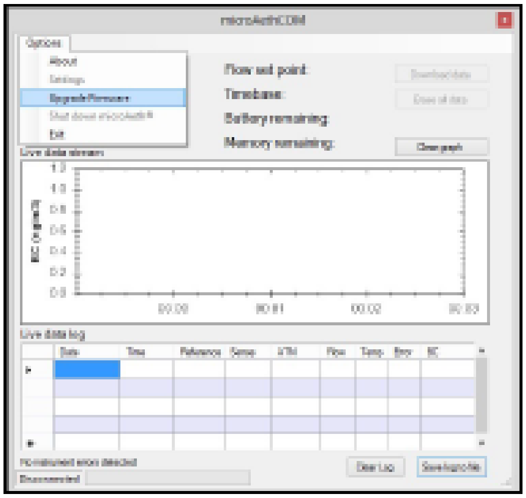
Before upgrading the microAeth operating system firmware, make sure that all data on the instrument has been downloaded. After the new firmware has been installed, the memory of the microAeth will need to be erased.

1. Start the microAethCOM software.

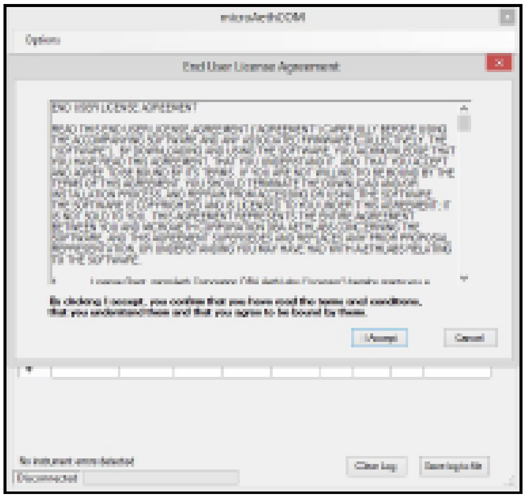
2. Connect the USB cable to the microAeth and the computer. **Do not turn on the microAeth.** The microAethCOM software will show that the microAeth is Disconnected.



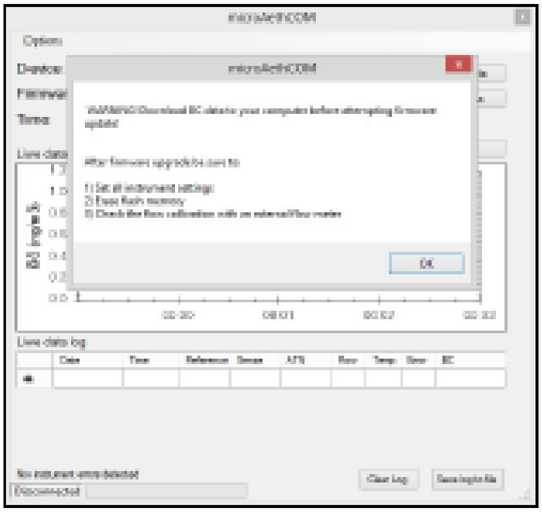
3. Click Options then Upgrade Firmware



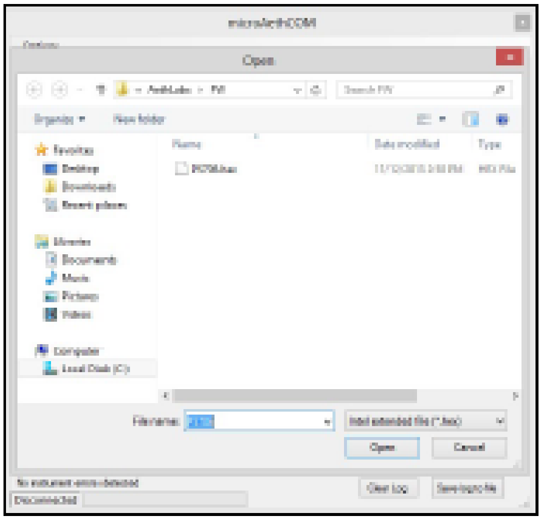
4. In order to install the firmware on the microAeth, please read and accept the license agreement.



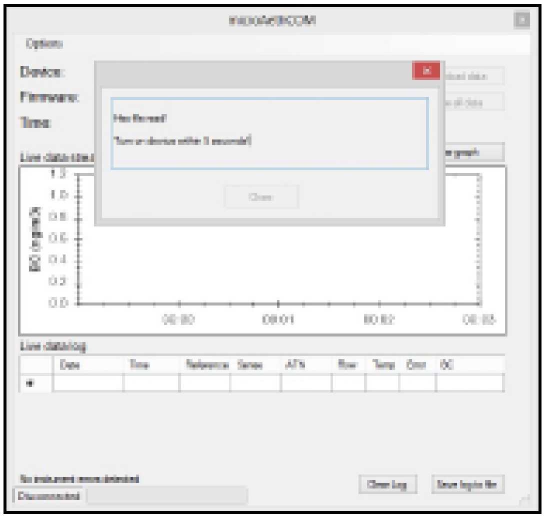
5. A warning window will appear to make sure that all data on the device has been downloaded and to inform the user of what should be completed after the upgrade.



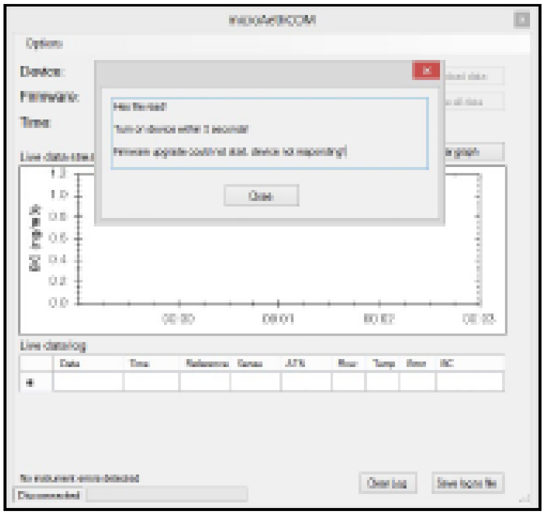
6. Select the hex file PSxxx.hex where xxx refers to the version number to install on the microAeth.



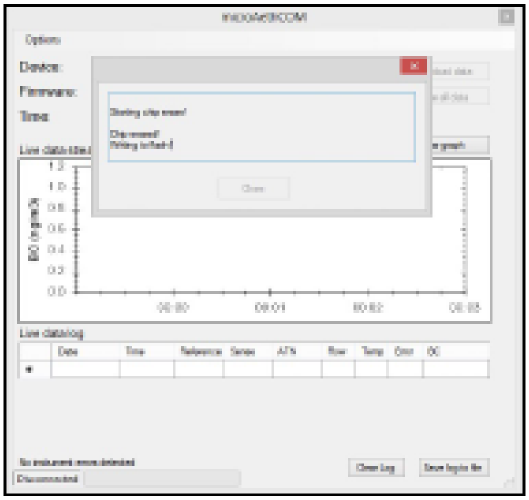
7. When prompted, turn on the microAeth within 5 seconds.



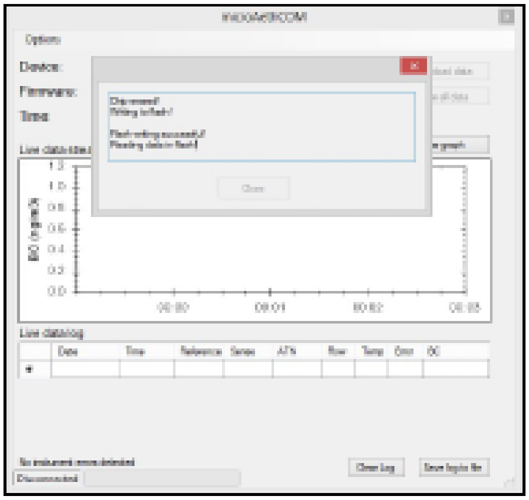
8. If the microAeth is not turned on within 5 seconds, the user will be told that the device did not respond. The user will have to close the window and start the firmware upgrade over again. If this occurs, go back to step 3.



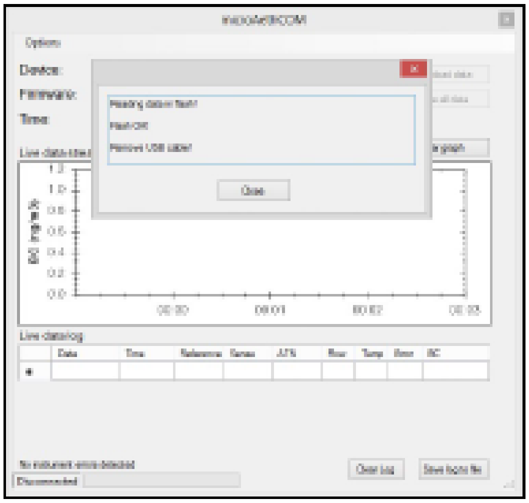
9. If the microAeth is turned on within 5 seconds, the firmware installation will begin. The memory will be erased and the new firmware will be written to memory.



10. Once the firmware has been installed, the microAethCOM software will check the memory for errors.



11. If no errors are found, the firmware installation will complete and the user will be prompted to unplug the microAeth.



12. After a successful firmware upgrade, the following should be completed before using the microAeth for a new sampling session:

- **Set all instrument settings.** Please read section 2.6.2 Configuration of Instrument Operating Parameters for more information.
- **Erase all data on flash memory.** Please read section 2.6.4 Erasing Data for more information.
- **Check the flow calibration with an external flowmeter.** Please read section 2.8 Flow Calibration Procedure for more information.

2.8 Manual Flow Calibration Procedure

In order to complete a manual flow calibration of the microAeth, you will need to use the AE51 FlowCal software. The installation of the microAethCOM PC software automatically installs the AE51 FlowCal software into the directory chosen by the user during the installation process. Please read section 2.5 microAethCOM PC Software for more information about the installation process.

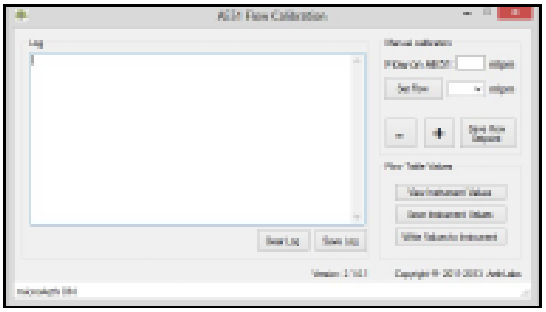
1. **Install a clean, unused filter strip into the microAeth.** Please read section 2.3.2 Filter Strip Installation and Removal for more information. **NOTE:** A pre-used filter strip with heavy loading may create an offset in the flow calibration table of the microAeth.

2. Connect the external flowmeter to the inlet of the microAeth.

3. Turn on the microAeth and the external flowmeter. Let the flowmeter stabilize for at least 10 minutes before use.

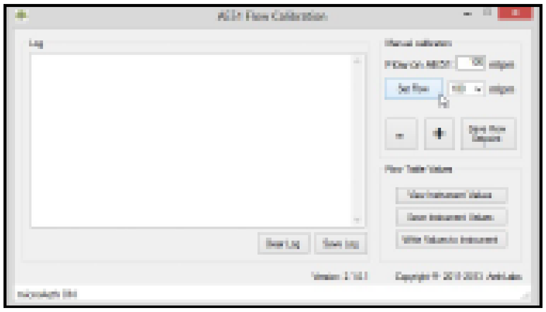
4. Start the AE51 FlowCal software.

5. Connect the USB cable to the microAeth and the computer. Wait until the microAeth establishes communication with AE51 FlowCal software. The status bar in the bottom left corner of the software will show the connection status of the microAeth and AE51 FlowCal software. If the status bar does not show microAeth ON status, check your connections and ensure that communication with the microAeth has been initiated as previously described and disconnect the USB cable from the computer and reinsert it.

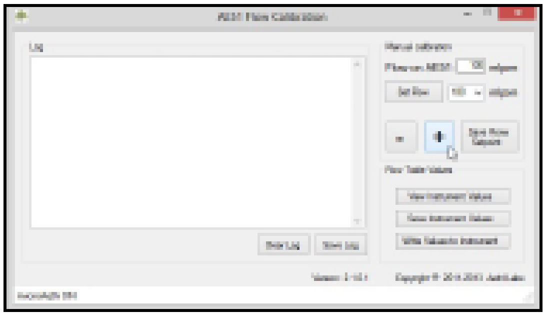


6. Select the flow setpoint to calibrate from the dropdown menu in the Manual calibration section of the software. Then click the Set Flow button.

7. The flow rate of the microAeth will change and the text box to the right of Flow on AE51: should be populated with the desired flow setpoint.



8. Use the + and - buttons to adjust the pump speed of the microAeth until the flow rate on the external flowmeter closely matches the selected flow setpoint in the software.



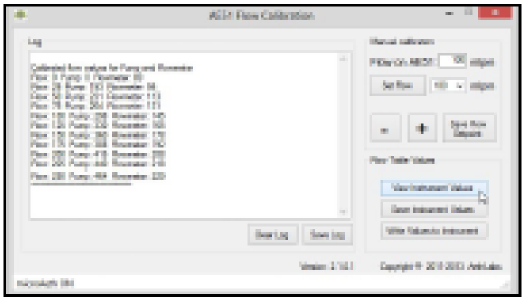
9. Then click the Save Flow Setpoint button to save the setpoint calibration in the microAeth flow calibration table stored in the instrument.

Saving setpoint calibration...

10. Repeat steps 6-9 for all flow setpoints in the dropdown menu in the Manual calibration section of the software.

    NOTE: If the internal pump of the microAeth cannot reach the highest flow rate setpoint, contact AethLabs for further assistance.

11. Click the View Instrument Values button. This will display all the values of the flow calibration table.



12. **Please check the values to make sure that as the flow setpoint increases from 0 to 250 ml/min, the pump drive and internal flowmeter values also increase.** If this is not the case, please try again to calibrate the microAeth. If this issue persists, please contact AethLabs for further assistance.

View Instrument Values

The View Instrument Values button requests the contents of the flow calibration table stored in the microAeth.

The flow calibration table shows the pump drive values and internal flowmeter values for the specified flow setpoints.

VERY IMPORTANT: As the flow setpoint increases from 0 to 250 ml/min, the pump drive and internal flowmeter values should increase. If this is not the case, please try again to calibrate the microAeth. If this issue persists, please contact AethLabs for further assistance.

Save Instrument Values

The Save Instrument Values button will prompt the user to select a location to save the flow calibration table file.

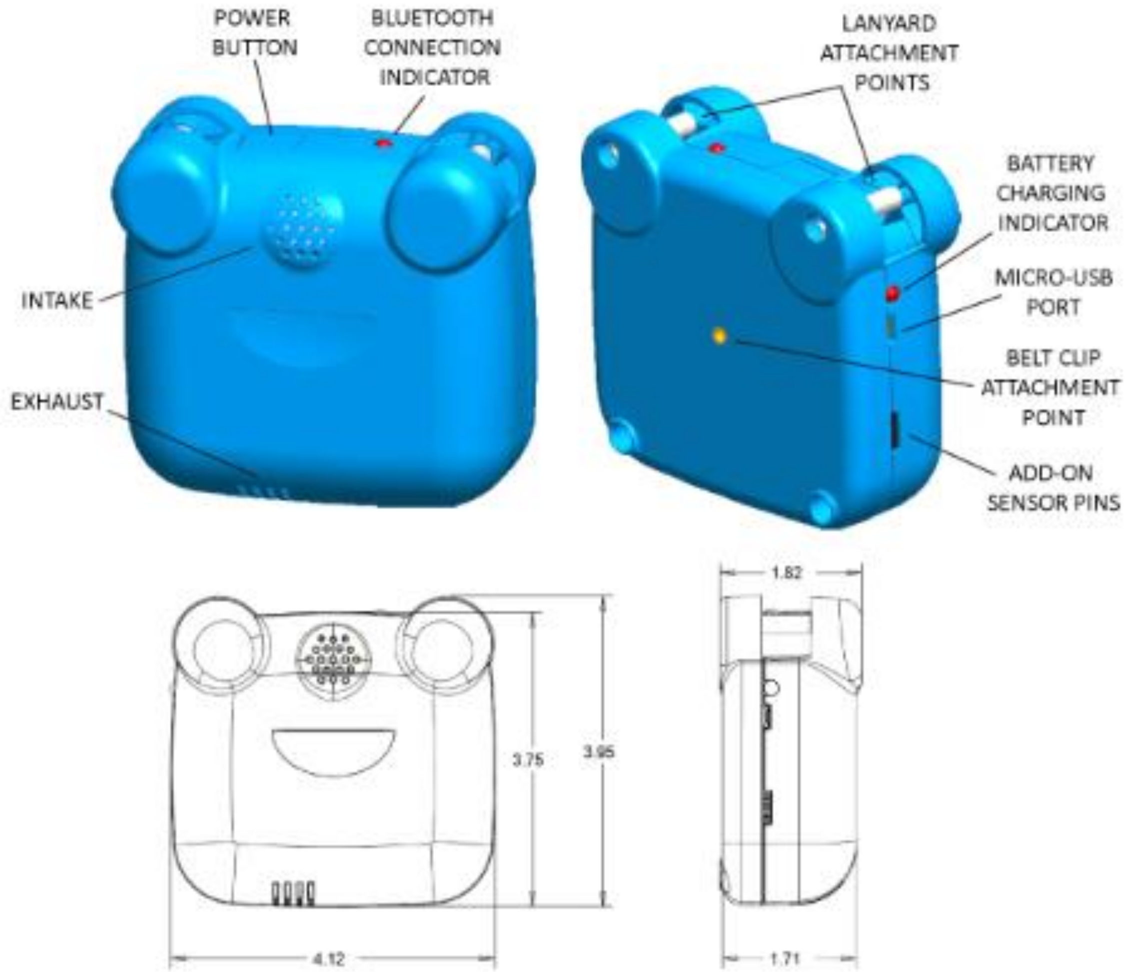
The flow calibration table values will be read from the microAeth and saved to a selected location where it can be kept for archival purposes and comparison, or can be retrieved and uploaded to the microAeth at a later time.

Write Values to Instrument

The Write Values to Instrument button will prompt the user to select a previously saved flow calibration table file for upload to the microAeth.

G. AirBeam Operating Procedures

AirBeam Technical Specifications, Operation & Performance



Hardware Specifications

Weight: 7 ounces

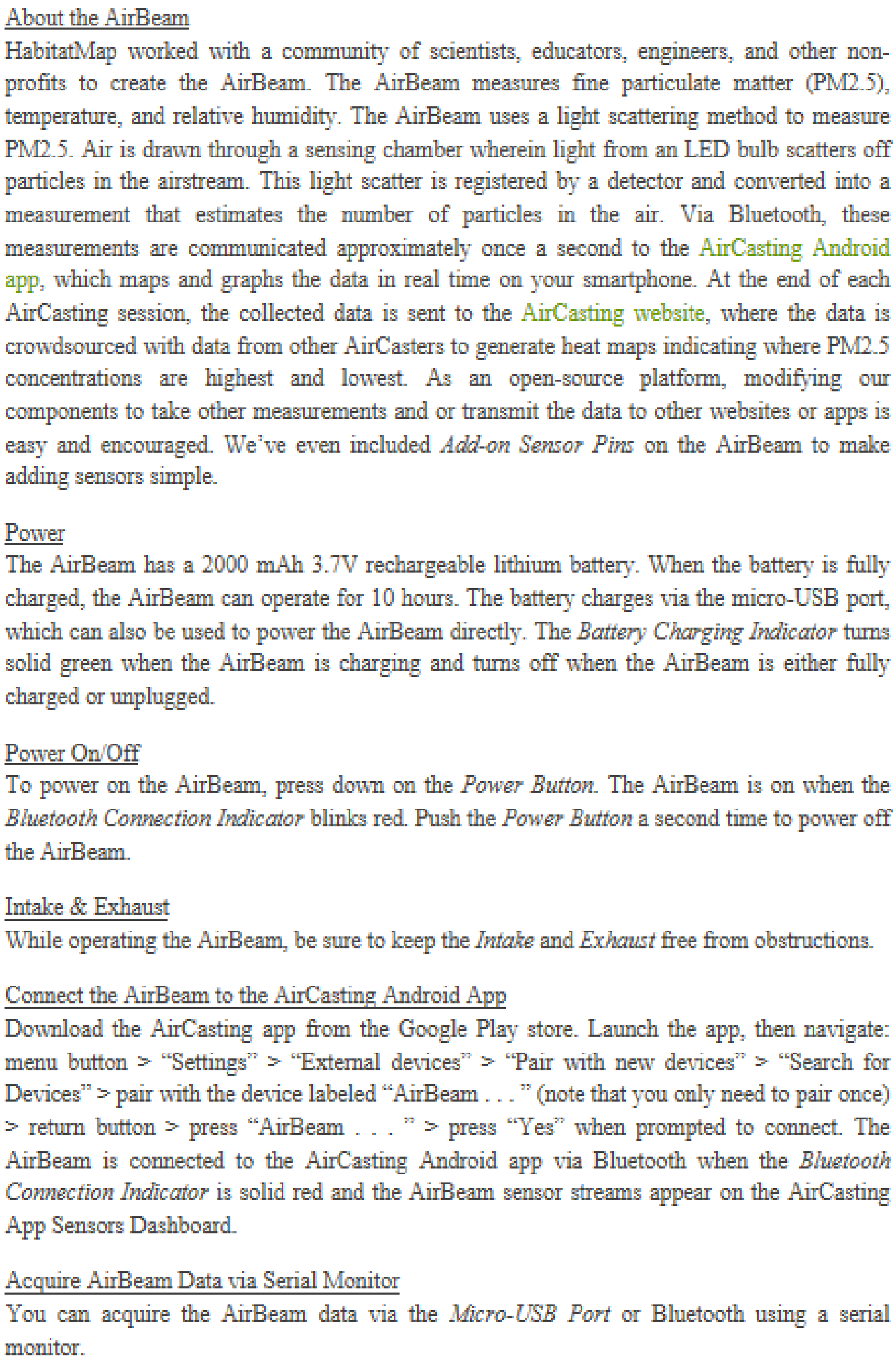
Particle Sensor: Shinyei PPD60PV

Temperature & Relative Humidity Sensor: MaxDetect RH03

Bluetooth: Nova MDCS42, Version 2.1+EDR

Microcontroller: Atmel ATmega32U4

Bootloader: Arduino Leonardo



About the AirBeam

HabitatMap worked with a community of scientists, educators, engineers, and other non-profits to create the AirBeam. The AirBeam measures fine particulate matter (PM2.5), temperature, and relative humidity. The AirBeam uses a light scattering method to measure PM2.5. Air is drawn through a sensing chamber wherein light from an LED bulb scatters off particles in the airstream. This light scatter is registered by a detector and converted into a measurement that estimates the number of particles in the air. Via Bluetooth, these measurements are communicated approximately once a second to the AirCasting Android app, which maps and graphs the data in real time on your smartphone. At the end of each AirCasting session, the collected data is sent to the AirCasting website, where the data is crowdsourced with data from other AirCasters to generate heat maps indicating where PM2.5 concentrations are highest and lowest. As an open-source platform, modifying our components to take other measurements and or transmit the data to other websites or apps is easy and encouraged. We've even included *Add-on Sensor Pins* on the AirBeam to make adding sensors simple.

Power

The AirBeam has a 2000 mAh 3.7V rechargeable lithium battery. When the battery is fully charged, the AirBeam can operate for 10 hours. The battery charges via the micro-USB port, which can also be used to power the AirBeam directly. The *Battery Charging Indicator* turns solid green when the AirBeam is charging and turns off when the AirBeam is either fully charged or unplugged.

Power On/Off

To power on the AirBeam, press down on the *Power Button*. The AirBeam is on when the *Bluetooth Connection Indicator* blinks red. Push the *Power Button* a second time to power off the AirBeam.

Intake & Exhaust

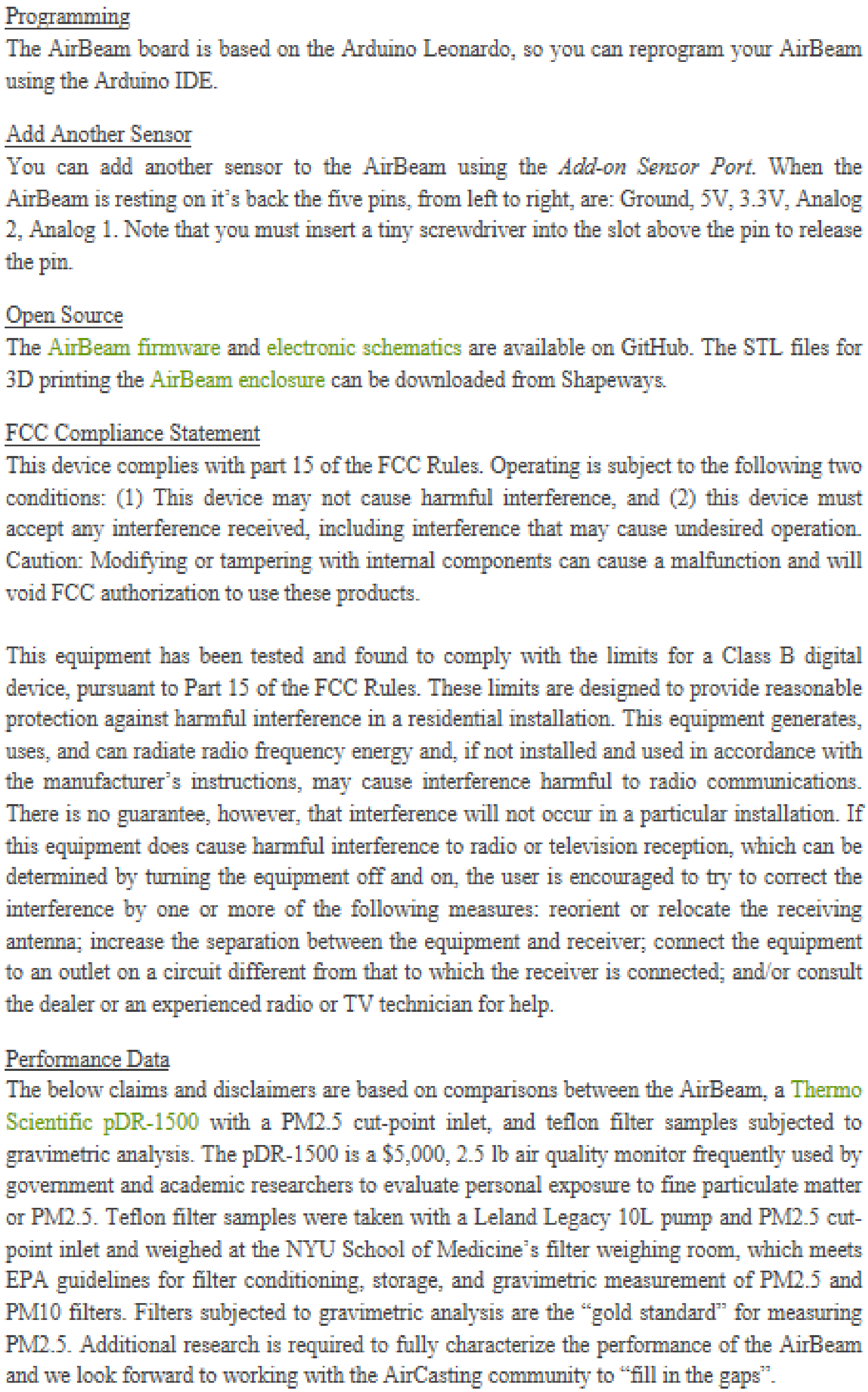
While operating the AirBeam, be sure to keep the *Intake* and *Exhaust* free from obstructions.

Connect the AirBeam to the AirCasting Android App

Download the AirCasting app from the Google Play store. Launch the app, then navigate: menu button > "Settings" > "External devices" > "Pair with new devices" > "Search for Devices" > pair with the device labeled "AirBeam . . . " (note that you only need to pair once) > return button > press "AirBeam . . . " > press "Yes" when prompted to connect. The AirBeam is connected to the AirCasting Android app via Bluetooth when the *Bluetooth Connection Indicator* is solid red and the AirBeam sensor streams appear on the AirCasting App Sensors Dashboard.

Acquire AirBeam Data via Serial Monitor

You can acquire the AirBeam data via the *Micro-USB Port* or Bluetooth using a serial monitor.



Programming

The AirBeam board is based on the Arduino Leonardo, so you can reprogram your AirBeam using the Arduino IDE.

Add Another Sensor

You can add another sensor to the AirBeam using the *Add-on Sensor Port*. When the AirBeam is resting on it's back the five pins, from left to right, are: Ground, 5V, 3.3V, Analog 2, Analog 1. Note that you must insert a tiny screwdriver into the slot above the pin to release the pin.

Open Source

The AirBeam firmware and electronic schematics are available on GitHub. The STL files for 3D printing the AirBeam enclosure can be downloaded from Shapeways.

FCC Compliance Statement

This device complies with part 15 of the FCC Rules. Operating is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Caution: Modifying or tampering with internal components can cause a malfunction and will void FCC authorization to use these products.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the manufacturer's instructions, may cause interference harmful to radio communications. There is no guarantee, however, that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures: reorient or relocate the receiving antenna; increase the separation between the equipment and receiver; connect the equipment to an outlet on a circuit different from that to which the receiver is connected; and/or consult the dealer or an experienced radio or TV technician for help.

Performance Data

The below claims and disclaimers are based on comparisons between the AirBeam, a Thermo Scientific pDR-1500 with a PM2.5 cut-point inlet, and teflon filter samples subjected to gravimetric analysis. The pDR-1500 is a $5,000, 2.5 lb air quality monitor frequently used by government and academic researchers to evaluate personal exposure to fine particulate matter or PM2.5. Teflon filter samples were taken with a Leland Legacy 10L pump and PM2.5 cut-point inlet and weighed at the NYU School of Medicine's filter weighing room, which meets EPA guidelines for filter conditioning, storage, and gravimetric measurement of PM2.5 and PM10 filters. Filters subjected to gravimetric analysis are the "gold standard" for measuring PM2.5. Additional research is required to fully characterize the performance of the AirBeam and we look forward to working with the AirCasting community to "fill in the gaps".

When presenting our performance data on the AirBeam below, we include R2 or R-squared values to indicate how the AirBeam compares with other methods for measuring PM2.5. R2 is a statistical measure that indicates how well data fit a statistical model, in this case, the prediction of the Y-axis (AirBeam) from the X-axis (pDR-1500) using a linear (straight) or nonlinear (curved) line. The R2 value is a fraction that ranges from 0.0 to 1.0 with higher values indicating that the regression came more closely to the points. An R2 value of 1.0 means that the predictive power of the model is perfect, that all the points lie along the line or curve with no scatter.

Below 100 micrograms per cubic meter (µg/m³), samples collected in ambient air in Manhattan (samples were collected on 11 different occasions and averaged over 12 hour periods) and while burning cardboard indoors (samples were collected over a 1 hour period and averaged every minute) both showed a strong linear relationship between the AirBeam and pDR-1500 measurements. As illustrated in Figure 1, the R2 values below 24 µg/m³ for two AirBeams in ambient air in Manhattan were .98 or better.

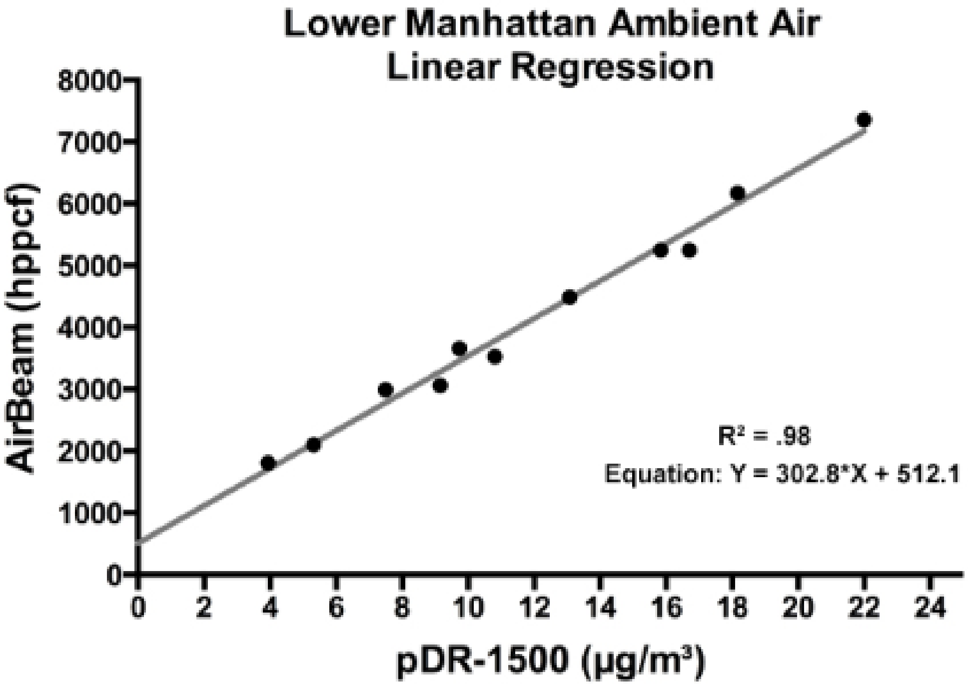


Figure 1

As illustrated in Figure 2, the R2 values below 100 µg/m³ for four AirBeams while burning cardboard indoors were .94 or better. Also shown in Figure 2, "out-of-the-box" variability between AirBeams is more pronounced as the measurements climb above 30 µg/m³. Meaning that measurements recorded by two AirBeams exposed to identical air samples may begin to drift apart as PM2.5 concentrations increase. Out-of-the-box variability can be substantially reduced by using the AirCasting app calibration feature (still in beta) and adjusting the side-facing potentiometer on the Shinyei PPD60PV.

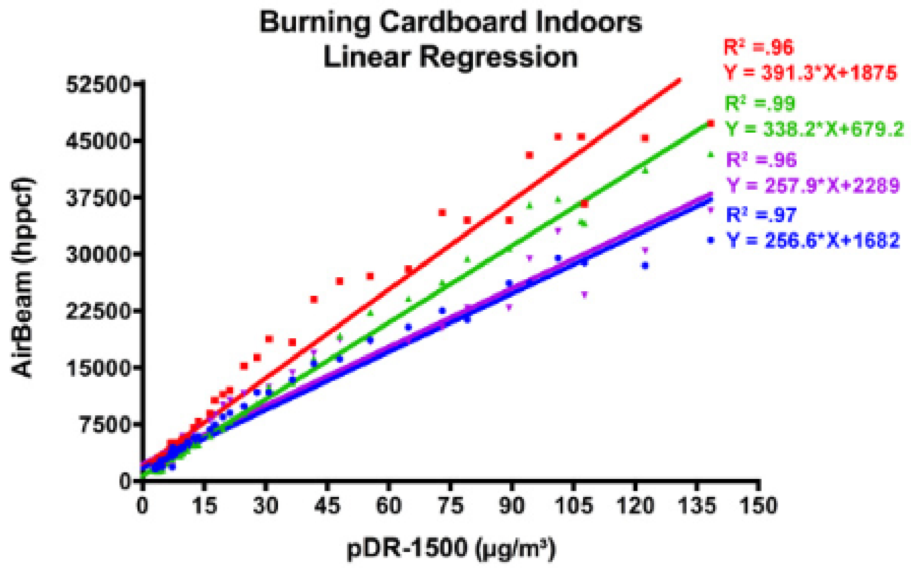


Figure 2

Because the relationship between the AirBeam and pDR-1500 measurements becomes increasingly non-linear above 100 $\mu g/m^3$, a nonlinear regression curve was used to determine the relationship between the AirBeam and pDR-1500 measurements at higher concentrations, see Figure 3 (samples were collected over a 1 hour period and averaged every minute). During separate sampling runs, we calculated R2 values for the nonlinear regression curve ranging from 0.60 to 0.80. The decrease in R2 values as compared to the linear regression is likely attributed to higher variability near and above the AirBeam's maximum limit of detection, which we estimate to be approximately 400 $\mu g/m^3$.

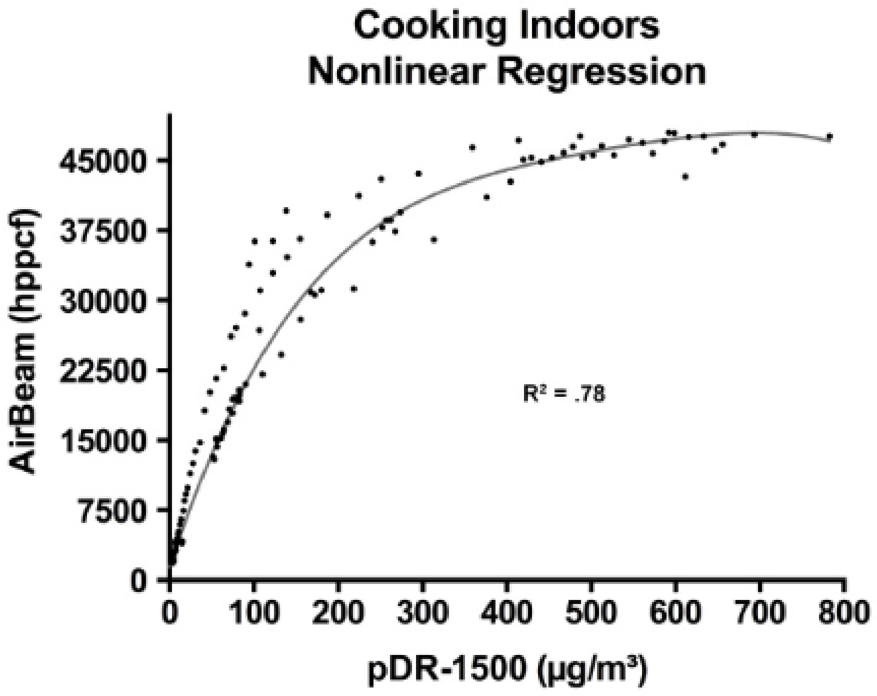


Figure 3

Additional research is required to see how the maximum limit of detection is impacted by the reflectivity of the aerosol being sampled. The relative reflectivity of aerosols impacts the AirBeam measurements. Highly reflective aerosols, like wood smoke, bias the AirBeam measurements upwards, whereas less reflective aerosols, like diesel exhaust, bias the AirBeam measurements downwards.

During ambient air sampling in Lower Manhattan during the summer months, measurements from a pDR-1500 and two Airbeams were compared against a teflon filter subjected to gravimetric analysis, see Figure 4. Sampling was done in 12-hour averages each day for 11 days and averaged to compare the real time instruments against the gravimetric filters. When compared against the gravimetric filters, the R2 value of AirBeams was found to be 0.70 compared to 0.76 for the pDR-1500. Time weighted averages of the gravimetric filter data showed consistently higher values as compared to the pDR-1500 at ambient levels. We assume this downward bias is also in effect with the AirBeam, since both are light scattering particle counters. Further, we assume part of this this bias can be attributed to the relative reflectivity of the aerosol being measured. The R2 value of the pDR-1500 measured against the AirBeams during these 12-hour day averages was found to be 0.98.

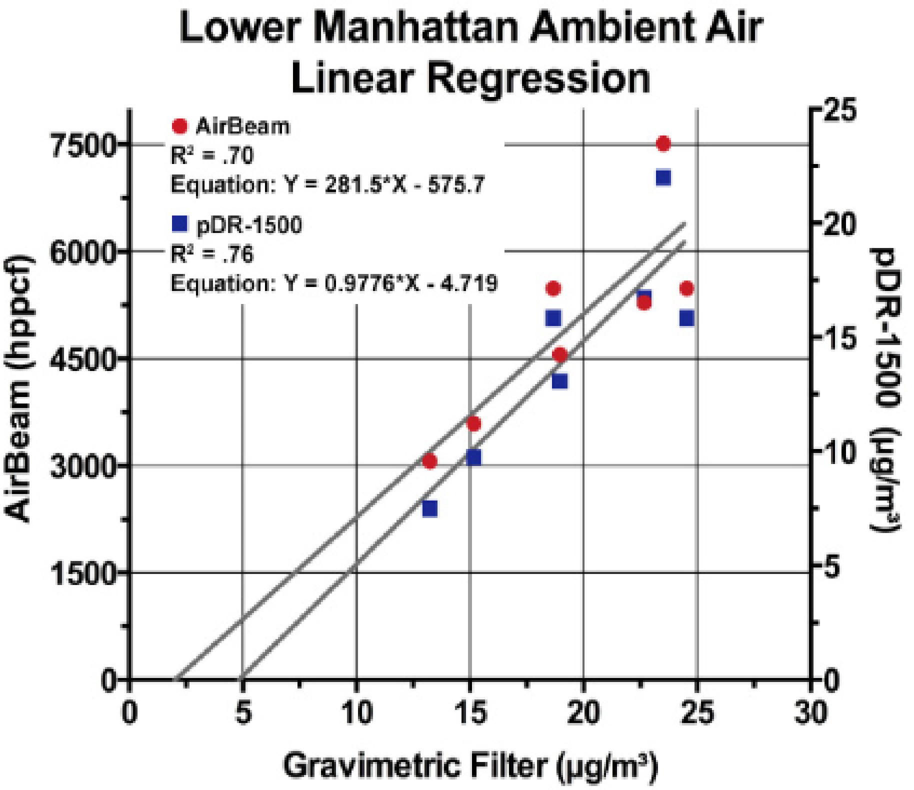
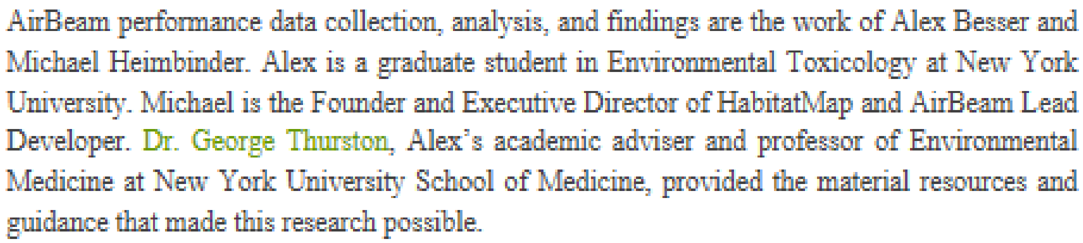


Figure 4

Research conducted by others on light scattering particle counters indicates that high relative humidity (>80%) is likely to have a negative impact on the accuracy of the AirBeam. When relative humidity is high, aerosols take on water becoming more reflective. Additional research is required to better characterize this effect as it applies to the AirBeam.



AirBeam performance data collection, analysis, and findings are the work of Alex Besser and Michael Heimbinder. Alex is a graduate student in Environmental Toxicology at New York University. Michael is the Founder and Executive Director of HabitatMap and AirBeam Lead Developer. Dr. George Thurston, Alex's academic adviser and professor of Environmental Medicine at New York University School of Medicine, provided the material resources and guidance that made this research possible.

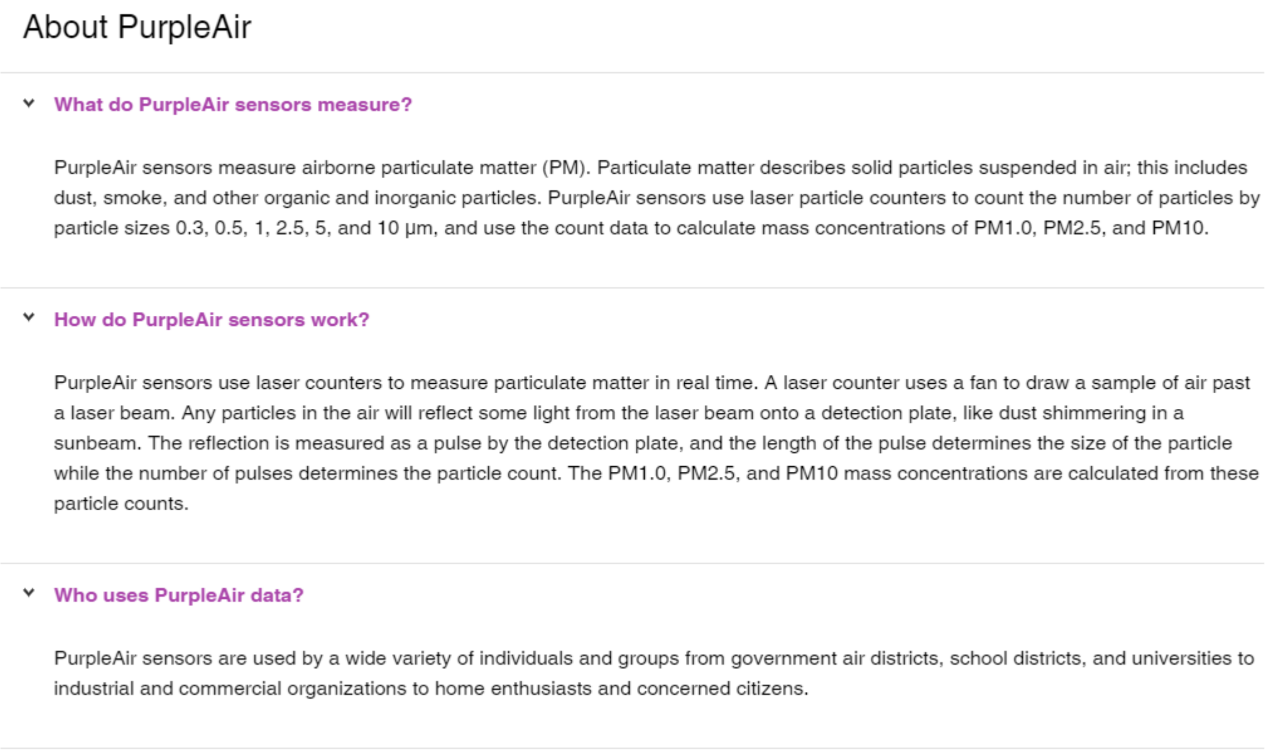
PSCAA Comments about the purpose and use of the AIRBEAM monitor

CAUTION: The Air Beam monitors are used for primarily educational purposes. The Air Beam monitor measurement is NOT regulatory in nature. This data CANNOT be used as evidence to force regulatory change. However, the Air Beam monitors can be very useful as screening tools, and as educational tools.

This light scattering measurement technique is highly susceptible to bias associated with the nature of the aerosol, as noted in the operating notes from the manufacturer. Further, the technique is also sensitive to Relative Humidity. As RH goes up, hygroscopic growth can occur, and the measurements can be biased high.

For this study, the Air Beam monitor is to be used for Educational purposes. The data may also be used to confirm other measurements, but shall not be used to draw any conclusions, or primarily drive any recommendations.

H. Purple Air Operating Procedure



About PurpleAir

What do PurpleAir sensors measure?

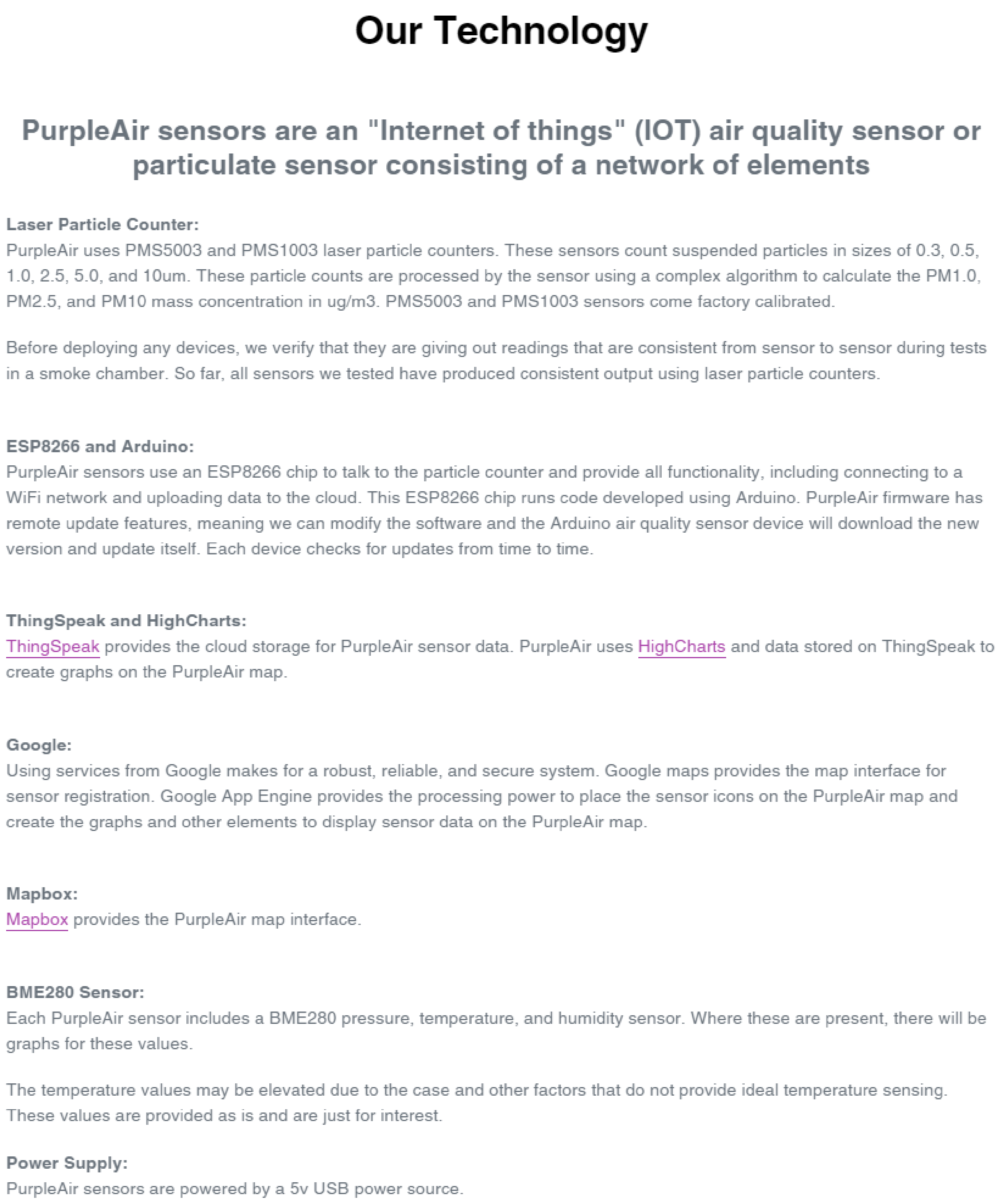
PurpleAir sensors measure airborne particulate matter (PM). Particulate matter describes solid particles suspended in air; this includes dust, smoke, and other organic and inorganic particles. PurpleAir sensors use laser particle counters to count the number of particles by particle sizes 0.3, 0.5, 1, 2.5, 5, and 10 µm, and use the count data to calculate mass concentrations of PM1.0, PM2.5, and PM10.

How do PurpleAir sensors work?

PurpleAir sensors use laser counters to measure particulate matter in real time. A laser counter uses a fan to draw a sample of air past a laser beam. Any particles in the air will reflect some light from the laser beam onto a detection plate, like dust shimmering in a sunbeam. The reflection is measured as a pulse by the detection plate, and the length of the pulse determines the size of the particle while the number of pulses determines the particle count. The PM1.0, PM2.5, and PM10 mass concentrations are calculated from these particle counts.

Who uses PurpleAir data?

PurpleAir sensors are used by a wide variety of individuals and groups from government air districts, school districts, and universities to industrial and commercial organizations to home enthusiasts and concerned citizens.



Our Technology

PurpleAir sensors are an "Internet of things" (IOT) air quality sensor or particulate sensor consisting of a network of elements

Laser Particle Counter:
PurpleAir uses PMS5003 and PMS1003 laser particle counters. These sensors count suspended particles in sizes of 0.3, 0.5, 1.0, 2.5, 5.0, and 10um. These particle counts are processed by the sensor using a complex algorithm to calculate the PM1.0, PM2.5, and PM10 mass concentration in ug/m3. PMS5003 and PMS1003 sensors come factory calibrated.

Before deploying any devices, we verify that they are giving out readings that are consistent from sensor to sensor during tests in a smoke chamber. So far, all sensors we tested have produced consistent output using laser particle counters.

ESP8266 and Arduino:
PurpleAir sensors use an ESP8266 chip to talk to the particle counter and provide all functionality, including connecting to a WiFi network and uploading data to the cloud. This ESP8266 chip runs code developed using Arduino. PurpleAir firmware has remote update features, meaning we can modify the software and the Arduino air quality sensor device will download the new version and update itself. Each device checks for updates from time to time.

ThingSpeak and HighCharts:
ThingSpeak provides the cloud storage for PurpleAir sensor data. PurpleAir uses HighCharts and data stored on ThingSpeak to create graphs on the PurpleAir map.

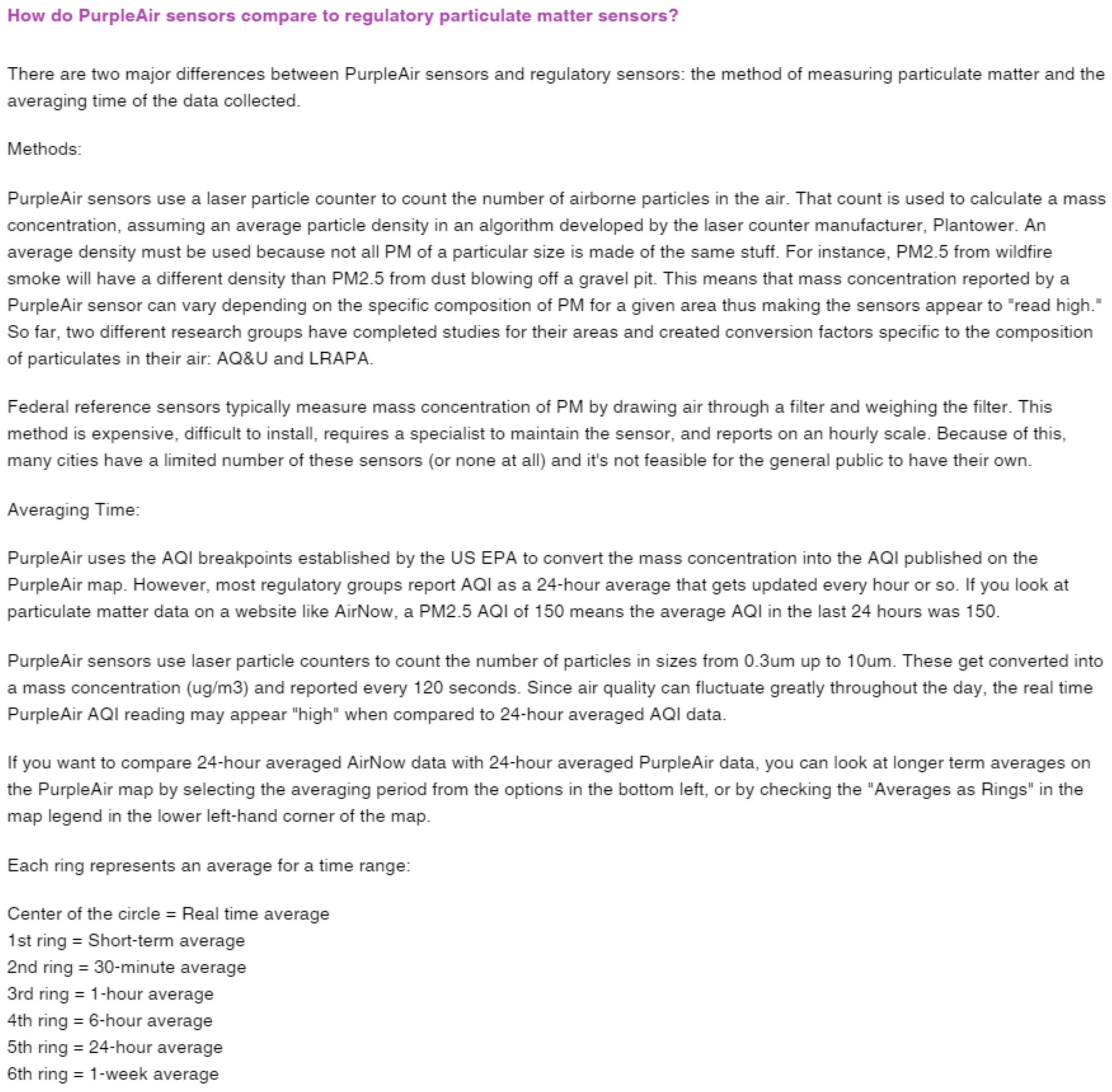
Google:
Using services from Google makes for a robust, reliable, and secure system. Google maps provides the map interface for sensor registration. Google App Engine provides the processing power to place the sensor icons on the PurpleAir map and create the graphs and other elements to display sensor data on the PurpleAir map.

Mapbox:
Mapbox provides the PurpleAir map interface.

BME280 Sensor:
Each PurpleAir sensor includes a BME280 pressure, temperature, and humidity sensor. Where these are present, there will be graphs for these values.

The temperature values may be elevated due to the case and other factors that do not provide ideal temperature sensing. These values are provided as is and are just for interest.

Power Supply:
PurpleAir sensors are powered by a 5v USB power source.



How do PurpleAir sensors compare to regulatory particulate matter sensors?

There are two major differences between PurpleAir sensors and regulatory sensors: the method of measuring particulate matter and the averaging time of the data collected.

Methods:

PurpleAir sensors use a laser particle counter to count the number of airborne particles in the air. That count is used to calculate a mass concentration, assuming an average particle density in an algorithm developed by the laser counter manufacturer, Plantower. An average density must be used because not all PM of a particular size is made of the same stuff. For instance, PM2.5 from wildfire smoke will have a different density than PM2.5 from dust blowing off a gravel pit. This means that mass concentration reported by a PurpleAir sensor can vary depending on the specific composition of PM for a given area thus making the sensors appear to "read high." So far, two different research groups have completed studies for their areas and created conversion factors specific to the composition of particulates in their air: AQ&U and LRAPA.

Federal reference sensors typically measure mass concentration of PM by drawing air through a filter and weighing the filter. This method is expensive, difficult to install, requires a specialist to maintain the sensor, and reports on an hourly scale. Because of this, many cities have a limited number of these sensors (or none at all) and it's not feasible for the general public to have their own.

Averaging Time:

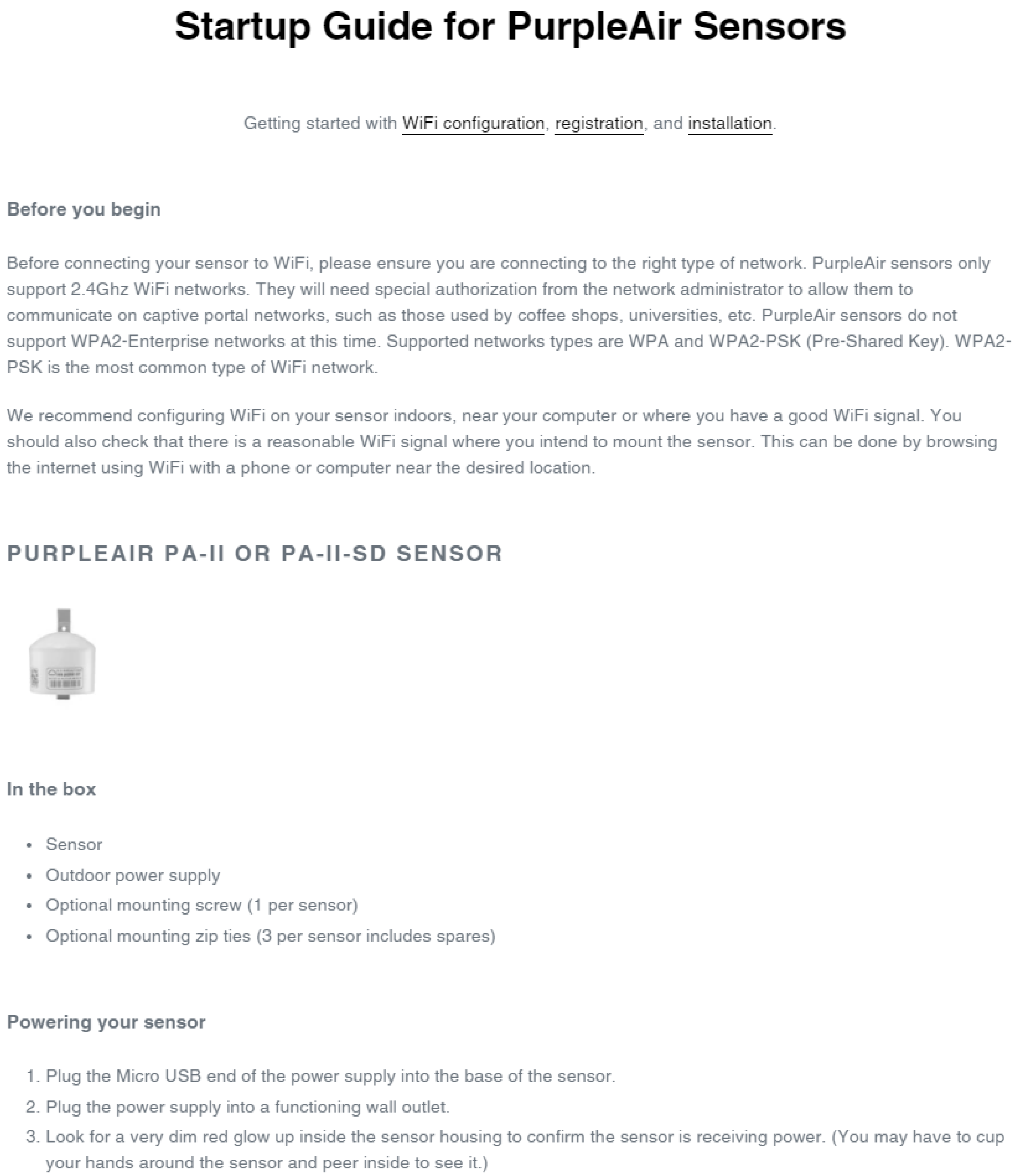
PurpleAir uses the AQI breakpoints established by the US EPA to convert the mass concentration into the AQI published on the PurpleAir map. However, most regulatory groups report AQI as a 24-hour average that gets updated every hour or so. If you look at particulate matter data on a website like AirNow, a PM2.5 AQI of 150 means the average AQI in the last 24 hours was 150.

PurpleAir sensors use laser particle counters to count the number of particles in sizes from 0.3um up to 10um. These get converted into a mass concentration (ug/m3) and reported every 120 seconds. Since air quality can fluctuate greatly throughout the day, the real time PurpleAir AQI reading may appear "high" when compared to 24-hour averaged AQI data.

If you want to compare 24-hour averaged AirNow data with 24-hour averaged PurpleAir data, you can look at longer term averages on the PurpleAir map by selecting the averaging period from the options in the bottom left, or by checking the "Averages as Rings" in the map legend in the lower left-hand corner of the map.

Each ring represents an average for a time range:

Center of the circle = Real time average
1st ring = Short-term average
2nd ring = 30-minute average
3rd ring = 1-hour average
4th ring = 6-hour average
5th ring = 24-hour average
6th ring = 1-week average



Startup Guide for PurpleAir Sensors

Getting started with WiFi configuration, registration, and installation.

Before you begin

Before connecting your sensor to WiFi, please ensure you are connecting to the right type of network. PurpleAir sensors only support 2.4Ghz WiFi networks. They will need special authorization from the network administrator to allow them to communicate on captive portal networks, such as those used by coffee shops, universities, etc. PurpleAir sensors do not support WPA2-Enterprise networks at this time. Supported networks types are WPA and WPA2-PSK (Pre-Shared Key). WPA2-PSK is the most common type of WiFi network.

We recommend configuring WiFi on your sensor indoors, near your computer or where you have a good WiFi signal. You should also check that there is a reasonable WiFi signal where you intend to mount the sensor. This can be done by browsing the internet using WiFi with a phone or computer near the desired location.

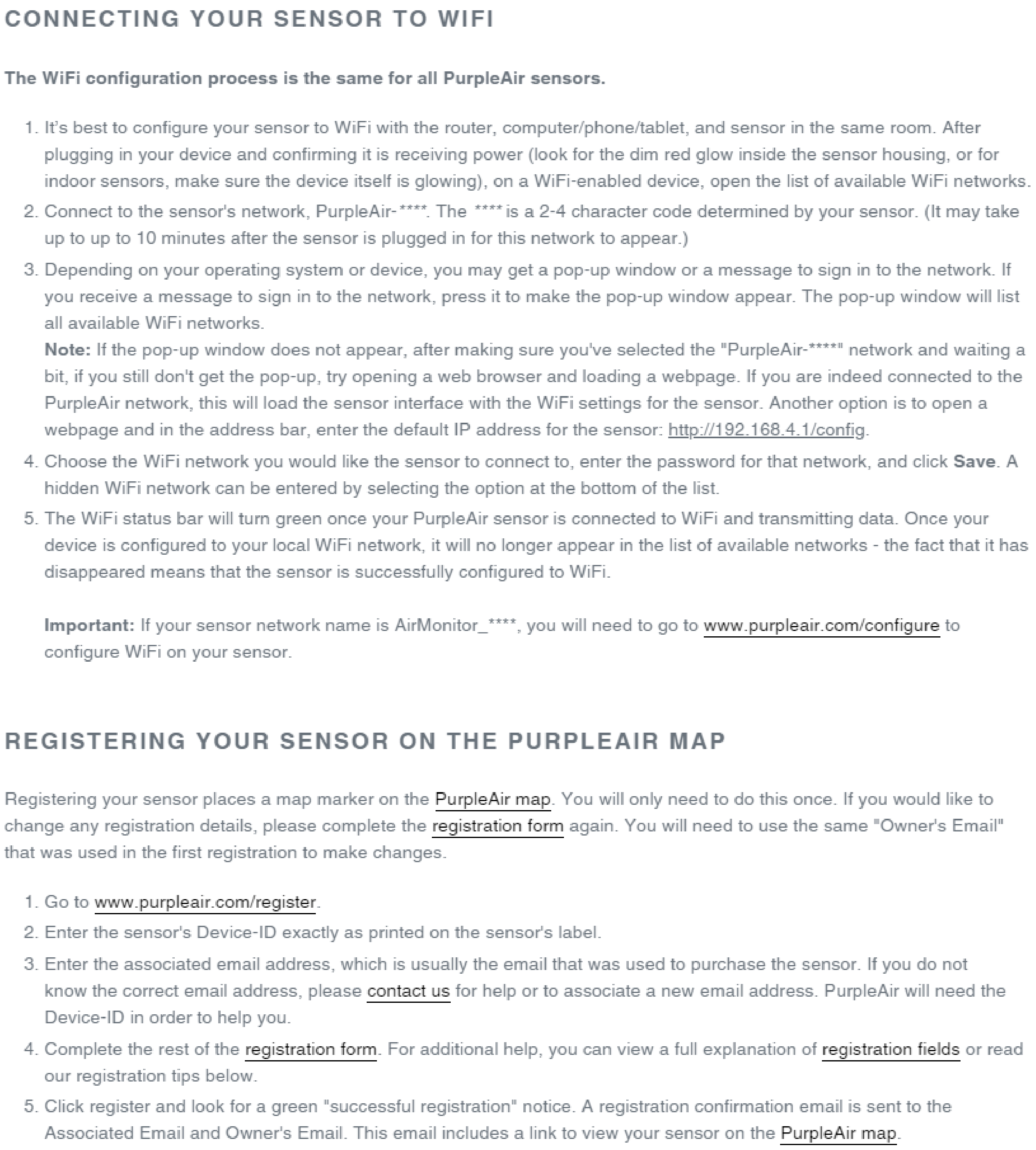
PURPLEAIR PA-II OR PA-II-SD SENSOR

In the box

- Sensor
- Outdoor power supply
- Optional mounting screw (1 per sensor)
- Optional mounting zip ties (3 per sensor includes spares)

Powering your sensor

1. Plug the Micro USB end of the power supply into the base of the sensor.
2. Plug the power supply into a functioning wall outlet.
3. Look for a very dim red glow up inside the sensor housing to confirm the sensor is receiving power. (You may have to cup your hands around the sensor and peer inside to see it.)



CONNECTING YOUR SENSOR TO WIFI

The WiFi configuration process is the same for all PurpleAir sensors.

1. It's best to configure your sensor to WiFi with the router, computer/phone/tablet, and sensor in the same room. After plugging in your device and confirming it is receiving power (look for the dim red glow inside the sensor housing, or for indoor sensors, make sure the device itself is glowing), on a WiFi-enabled device, open the list of available WiFi networks.
2. Connect to the sensor's network, PurpleAir-****. The **** is a 2-4 character code determined by your sensor. (It may take up to up to 10 minutes after the sensor is plugged in for this network to appear.)
3. Depending on your operating system or device, you may get a pop-up window or a message to sign in to the network. If you receive a message to sign in to the network, press it to make the pop-up window appear. The pop-up window will list all available WiFi networks.
   Note: If the pop-up window does not appear, after making sure you've selected the "PurpleAir-****" network and waiting a bit, if you still don't get the pop-up, try opening a web browser and loading a webpage. If you are indeed connected to the PurpleAir network, this will load the sensor interface with the WiFi settings for the sensor. Another option is to open a webpage and in the address bar, enter the default IP address for the sensor: http://192.168.4.1/config.
4. Choose the WiFi network you would like the sensor to connect to, enter the password for that network, and click **Save**. A hidden WiFi network can be entered by selecting the option at the bottom of the list.
5. The WiFi status bar will turn green once your PurpleAir sensor is connected to WiFi and transmitting data. Once your device is configured to your local WiFi network, it will no longer appear in the list of available networks - the fact that it has disappeared means that the sensor is successfully configured to WiFi.

   Important: If your sensor network name is AirMonitor_****, you will need to go to www.purpleair.com/configure to configure WiFi on your sensor.

REGISTERING YOUR SENSOR ON THE PURPLEAIR MAP

Registering your sensor places a map marker on the PurpleAir map. You will only need to do this once. If you would like to change any registration details, please complete the registration form again. You will need to use the same "Owner's Email" that was used in the first registration to make changes.

1. Go to www.purpleair.com/register.
2. Enter the sensor's Device-ID exactly as printed on the sensor's label.
3. Enter the associated email address, which is usually the email that was used to purchase the sensor. If you do not know the correct email address, please contact us for help or to associate a new email address. PurpleAir will need the Device-ID in order to help you.
4. Complete the rest of the registration form. For additional help, you can view a full explanation of registration fields or read our registration tips below.
5. Click register and look for a green "successful registration" notice. A registration confirmation email is sent to the Associated Email and Owner's Email. This email includes a link to view your sensor on the PurpleAir map.

Tips on PA-II and PA-II-SD installation

- Choose a location that is convenient to reach, has access to a power outlet, and falls within range of the WiFi network.
- If possible, mount the sensor away from vents, local sources of pollution such as BBQs, and any foliage that would increase the likelihood of insects getting inside the laser counters.
- Install the sensor in the vertical position, with the open end facing toward the ground. The housing is designed to protect the device from the elements while allowing air to flow freely past the two laser counters.
- Be sure to mount the sensor high enough off of any surface that would allow rain water to splash up into the underside of the sensor.
- The power supply should be mounted so that it will not be submerged in water or covered by snow.
- Use either cable ties or a screw to mount the sensor and power supply, and fashion a "drip loop" to prevent water from running down the wires and into the electronics.
- PurpleAir outdoor sensors can withstand direct sun without being damaged. Mounting the sensor in a shady spot will produce temperature readings that are not affected by direct sunlight.
  Please note that temperature readings are already elevated by as much as 10 degrees Fahrenheit due to heat generated by the WiFi module inside the sensor.
- Connect the power supply to a power outlet and tuck the wires away.

PurpleAir sensors employ a dual laser counter to provide some level of data integrity. This is intended to provide a way of determining sensor health and fault detection. Some examples of what can go wrong with a laser counter are a fan failure, insects, or other debris inside the device or just a layer of dust from long term exposure. If both laser counters (channels) are in agreement, the data can be seen as excellent quality. If there are different readings from the two channels, there may be a fault with one or both. In the case of a fault, the channel may be marked as flagged or downgraded (suspect or known faulty).

PurpleAir provides ways to get direct access to the data and there are a few different ways to do this. The simplest way to download the data is using the download page available at https://www.purpleair.com/sensorlist. This page provides an easy-to-use interface to download data based on a date range. You access this page by zooming into the map, then using the download button in the bottom right of the screen. Alternatively, a download link is available per sensor in the “Get this widget” section after clicking a map icon.

- Select the sensor/s in the list you want to download.

- At the top of the page, enter the desired date range, then click Download Selected.

Correction Factors for Purple Air data:

PurpleAir sensors use laser particle counters that measure the particle count, before converting that count into a mass concentration. The purpose of this is to make it comparable to data reported by regulatory sensors. To do this, the laser counters must assume an average particle density. An average density must be used because, as mentioned above, not all particulate matter of a certain size has the same density. For example, if you weighed 1000 particles of wildfire smoke and 1000 particles generated from gravel dust, the wildfire smoke would be much lighter. In the case where the predominant source of PM2.5 is from wildfire smoke that has a lighter density than the assumed density used by the sensor, the sensor data will predictably overestimate the mass concentration and read higher than the regulatory monitor. Similarly, if the predominant source of PM2.5 was a denser material like gravel dust, the sensor data would predictably underestimate the mass concentration and read lower than the regulatory monitors.

EPA and Oregon's Lane Regional Air Protection Agency (LRAPA) have created their correction factors to make Purple Air data more comparable to regulatory monitors and avoid over-estimating the PM2.5 concentrations. We will be using one of these conversion factors for the data collected during our study period.

PSCAA Comments about the purpose and use of the Purple Air monitor

CAUTION: The Purple Air monitors are used for primarily educational purposes. The Purple Air monitor measurement is NOT regulatory in nature. This data CANNOT be used as evidence to force regulatory change. However, the Purple Air monitors can be very useful as screening tools, and as educational tools. This particular light scattering measurement technique is highly susceptible to bias associated with the nature of the aerosol, as noted in the operating notes from the manufacturer and by EPA.

For this study, the Purple Air monitor is to be used for Educational purposes. The data may also be used to confirm other measurements, but shall not be used to draw any conclusions, or primarily drive any recommendations.

I. PM2.5 Partisol Procedure Link and PM-10-2.5 Designation

The link below goes to the $PM_{2.5}$ Partisol sampling procedure for sequential sampling. The PSCAA has been using this procedure since 1999 and is very familiar with this sampling equipment.

PSCAA will modify this equipment to sample for PM_{10} rather than $PM_{2.5}$ by installing the WINS bypass downtube (RFPS-1298-127). This method replicates the sampling method for PM_{10} metals at the Beacon Hill monitoring site, so this procedure is chosen to maintain the ability to compare data from the fixed study site (10th & Weller) to the Beacon Hill monitoring site, which is sampling that is already in place due to the NCORE requirements.

https://apps.ecology.wa.gov/publications/documents/1802020.pdf

Thermo Scientific Partisol®-Plus 2025 Sequential PM10-2.5 Air Sampler Pair or Thermo Fisher Scientific Partisol® 2025i Sequential PM10-2.5 Air Sampler Pair
Manual Reference Method: RFPS-0509-176
"Thermo Scientific Partisol®-Plus 2025 Sequential PM10-2.5 Air Sampler Pair" or "Thermo Fisher Scientific Partisol® 2025i Sequential PM10-2.5 Air Sampler Pair," for the determination of coarse particulate matter as PM10-2.5, consisting of a pair of Thermo Scientific Partisol®-Plus 2025 sequential samplers or a pair of Thermo Fisher Scientific Partisol® 2025i sequential samplers, with one configured as a PM2.5 sampler (RFPS-0498-118) and the other configured as a PM10c sampler with the PM2.5 separator replaced with a Thermo Scientific Partisol® 2025 downtube (RFPS-1298-127). Partisol®-Plus 2025 to be operated with any software version 1.003 through 1.5 and Partisol® 2025i with firmware version 2.0 or greater, with the modified filter shuttle mechanism. Method to be operated in accordance with the Partisol®-Plus 2025 or Partisol® 2025i instruction manual supplement, as appropriate.
Federal Register: Vol. 74, page 26395, 06/02/2009
Latest modification: 06/ 2011

J. Enmont Ultrafine Particle Monitor Procedure

PUFP

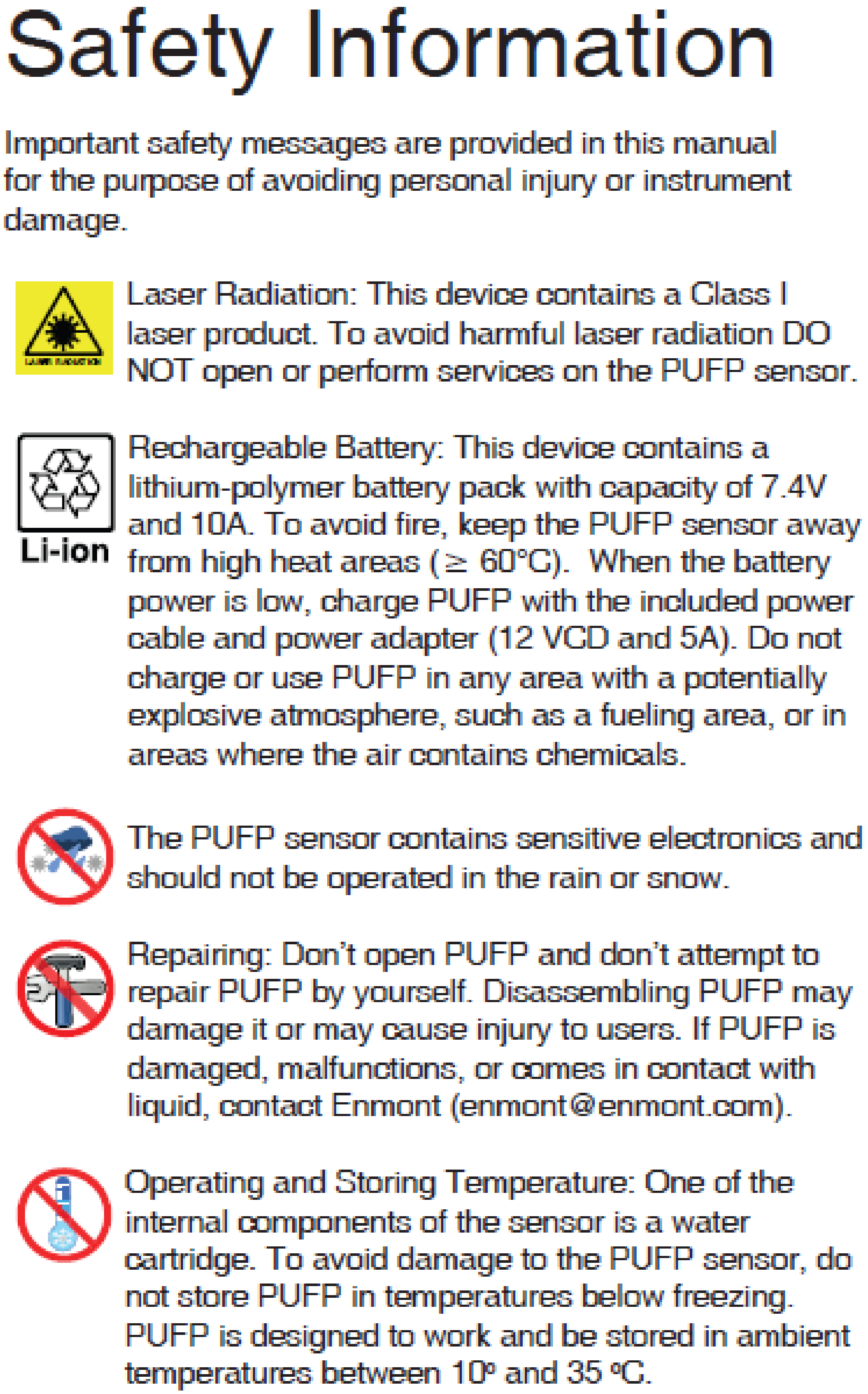
Personal Ultrafine Particle Counter

Contents

Notes and Cautions

Notes are helpful information that can help you make better use of the PUFP Sensor and its components.

Cautions are warning about potential damage to the PUFP Sensor if used improperly.



Safety Information

Important safety messages are provided in this manual for the purpose of avoiding personal injury or instrument damage.

Laser Radiation: This device contains a Class I laser product. To avoid harmful laser radiation DO NOT open or perform services on the PUFP sensor.

Rechargeable Battery: This device contains a lithium-polymer battery pack with capacity of 7.4V and 10A. To avoid fire, keep the PUFP sensor away from high heat areas (≥ 60°C). When the battery power is low, charge PUFP with the included power cable and power adapter (12 VCD and 5A). Do not charge or use PUFP in any area with a potentially explosive atmosphere, such as a fueling area, or in areas where the air contains chemicals.

The PUFP sensor contains sensitive electronics and should not be operated in the rain or snow.

Repairing: Don't open PUFP and don't attempt to repair PUFP by yourself. Disassembling PUFP may damage it or may cause injury to users. If PUFP is damaged, malfunctions, or comes in contact with liquid, contact Enmont (enmont@enmont.com).

Operating and Storing Temperature: One of the internal components of the sensor is a water cartridge. To avoid damage to the PUFP sensor, do not store PUFP in temperatures below freezing. PUFP is designed to work and be stored in ambient temperatures between 10° and 35 °C.

Unpacking & Parts Identification

1	PUFP C100
2	Optional Silicon Exhaust Tube
3	Syringe to refill water cartridge
4	USB cord
5	EView Software
6	Water bottle
7	Power adapter and cord
8	Additional Aerosol Inlet Fitting

1	Air intake
2	Water refill OUTLET
3	Water refill INLET
4	Micro SD card port
5	USB connection
6	Charging port
7	Exhaust
8	Air Outlet
9	Fan / Air Inlet

PUFP Sensor Setup

Battery and Charging

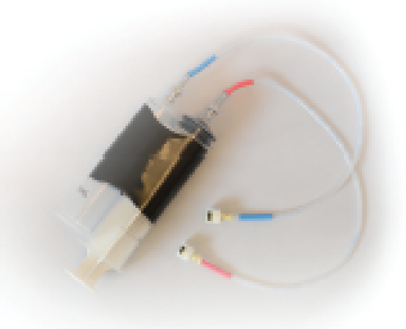
A battery pack is installed in a PUFP. The battery allows up to 6 hours of continuous operation. Operation hours can shorten over time. The length of operating hours is dependent on the age of the battery. The percentage of battery remaining is shown on the bottom of the sensor display screen. When fully discharged, the battery will take approximately 8 hours to charge fully. To charge the sensor, attach the power cord to the charging port on the sensor and plug the cord into an electrical outlet. When connected to a power source the sensor display screen will show "CHG" during operation. The screen will display "DSG" when the sensor is in operation and not connected to a power source.

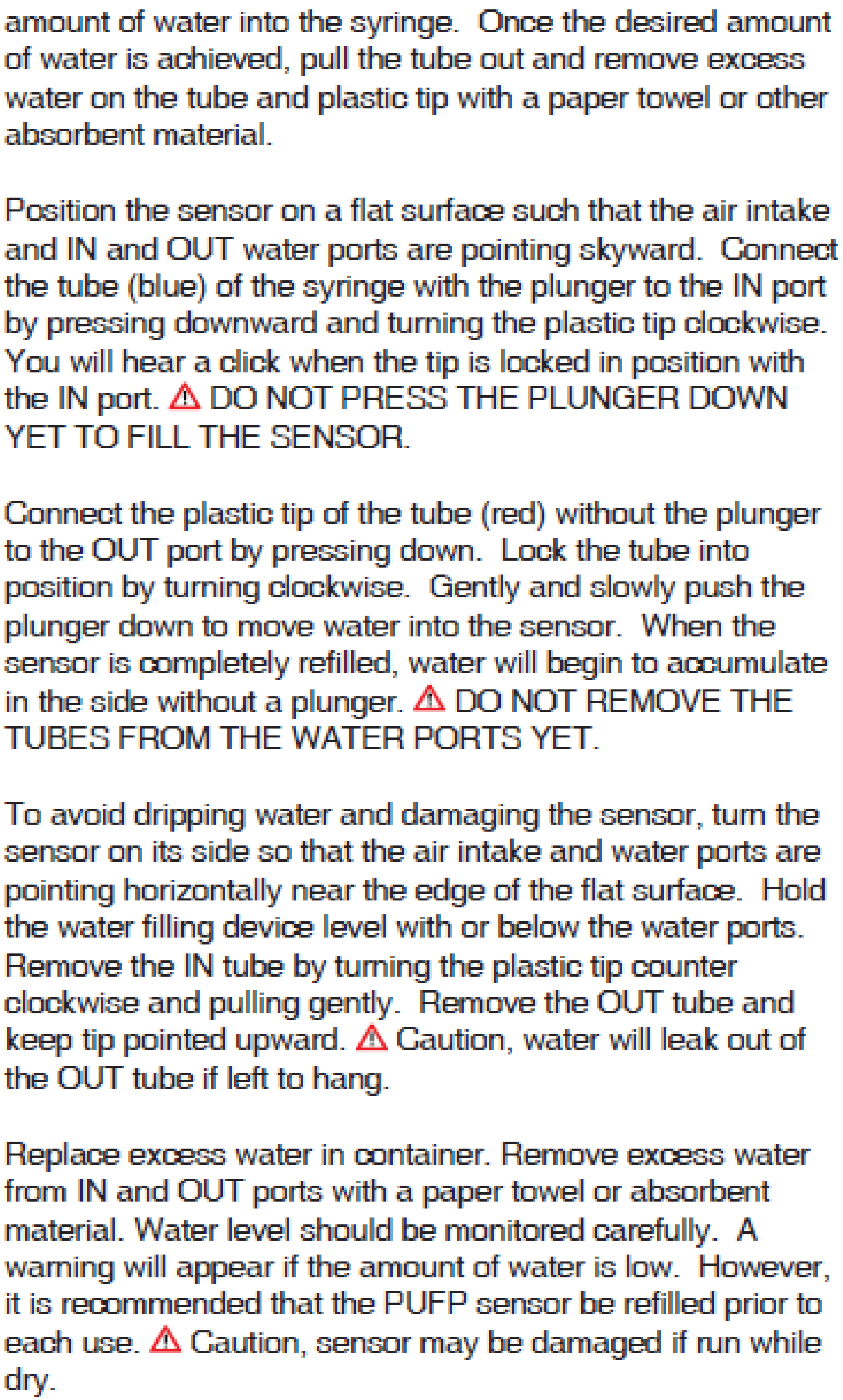
Refilling Water

⚠ Caution: Purified water like distilled or de-ionized water should be used in the PUFP sensor. Using tap or other types of water may result in damage to the sensor.

The device for filling the sensor with water consists of two syringes, one with a plunger, and one without. The syringe with the plunger is used to transport water into the sensor. Small tubes are connected to each syringe.

To refill the sensor with water, submerge the end of the small tube attached to the syringe with the plunger in water. Pull the plunger back to draw the desired





amount of water into the syringe. Once the desired amount of water is achieved, pull the tube out and remove excess water on the tube and plastic tip with a paper towel or other absorbent material.

Position the sensor on a flat surface such that the air intake and IN and OUT water ports are pointing skyward. Connect the tube (blue) of the syringe with the plunger to the IN port by pressing downward and turning the plastic tip clockwise. You will hear a click when the tip is locked in position with the IN port. ⚠ DO NOT PRESS THE PLUNGER DOWN YET TO FILL THE SENSOR.

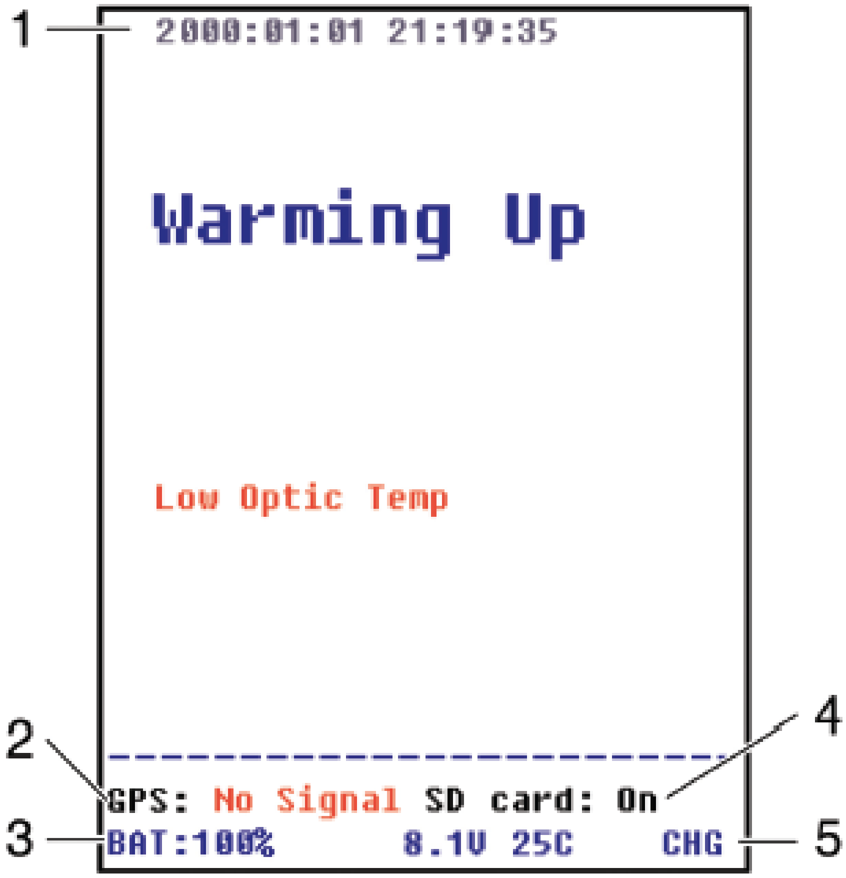
Connect the plastic tip of the tube (red) without the plunger to the OUT port by pressing down. Lock the tube into position by turning clockwise. Gently and slowly push the plunger down to move water into the sensor. When the sensor is completely refilled, water will begin to accumulate in the side without a plunger. ⚠ DO NOT REMOVE THE TUBES FROM THE WATER PORTS YET.

To avoid dripping water and damaging the sensor, turn the sensor on its side so that the air intake and water ports are pointing horizontally near the edge of the flat surface. Hold the water filling device level with or below the water ports. Remove the IN tube by turning the plastic tip counter clockwise and pulling gently. Remove the OUT tube and keep tip pointed upward. ⚠ Caution, water will leak out of the OUT tube if left to hang.

Replace excess water in container. Remove excess water from IN and OUT ports with a paper towel or absorbent material. Water level should be monitored carefully. A warning will appear if the amount of water is low. However, it is recommended that the PUFP sensor be refilled prior to each use. ⚠ Caution, sensor may be damaged if run while dry.

Sensor Display

Information regarding GPS signal, battery life, date and time, PUFP concentration, and amount of water is shown on the display screen.



2000:01:01 21:19:35

Warming Up

Low Optic Temp

GPS: No Signal SD card: On

BAT:100% 8.1V 25C CHG

Display information:

1 Date and time

2 GPS Status

3 Battery life

4 SD Card notification

5 Charging (CHG) or Discharge (DSG)

Operating the PUFP Sensor

⚠ Caution: During operation, keep objects clear of the air intake, fan, and air outlet. Obstructing these ports will result in damage to the sensor.

⚠ Caution: The PUFP sensor is assembled with a protective black plastic covering on the air intake. This must be removed before operation to avoid damage to the PUFP sensor.

Turning on the sensor

Turn on the PUFP sensor by pressing and holding the power button (⏻) at the center of the key pad (about 2 seconds). The sensor must operate for a short period of time (~10 minutes) before measurements can be made in order heat to the internal components of the sensor. During this period, the sensor display will show "Warming Up." The time remaining for the warm up process will appear on the sensor display.

When the warm up is complete "Measuring" will appear on the sensor display. The sensor will begin making measurements and recording data. During operation, it is normal for water to drip from the air outlet. Water can be directed away from the sensor by attaching the provided 1/8" silicon tubing.

User Settings

To adjust the settings of the sensor, press down and hold the right arrow (▶) approximately two seconds. A screen will appear, showing “SELECT KEY”—press down (▼). Date and time, screen brightness, and resetting options will appear. Use the up (▲) and down (▼) keys to scroll through menu options. As you scroll downward, the selected menu item will be highlighted blue. Continuing to scroll up or down will take you to a new page that shows “GPS Time Difference.” This is covered in the next section.

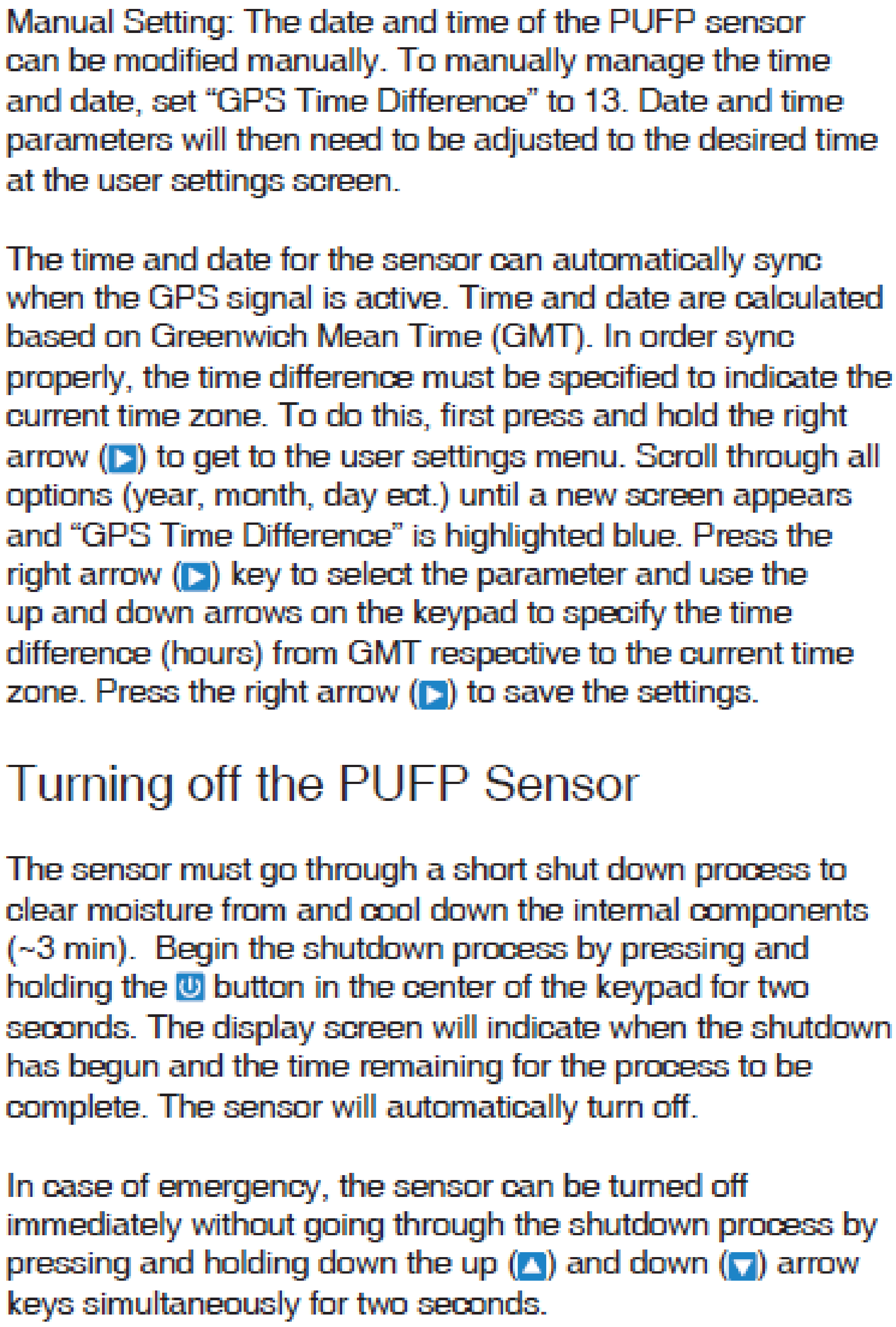
To select a parameter, press the right arrow (▶). Selected parameters will appear in red. Use the up (▲) and down (▼) keys to adjust the parameter. To save the desired settings, press the right arrow key (▶) and the parameter will again turn blue. Press the left (◀) arrow to exit to the main display.

GPS Status

The PUFP sensor will indicate whether a GPS signal has been received. The sensor display will show “GPS Active” when GPS data is being recorded. When the GPS signal is inactive, “GPS No Signal” will be shown at the bottom left side of the display screen.

Date and Time Setting

The PUFP provides two ways for the user to set the date and time: 1) Manual setting and 2) GPS-based setting. The PUFP has an internal clock to track the date and time, which is powered by a token battery on an electronic board. The format is YYYY:MM:DD HH:MM:SS.



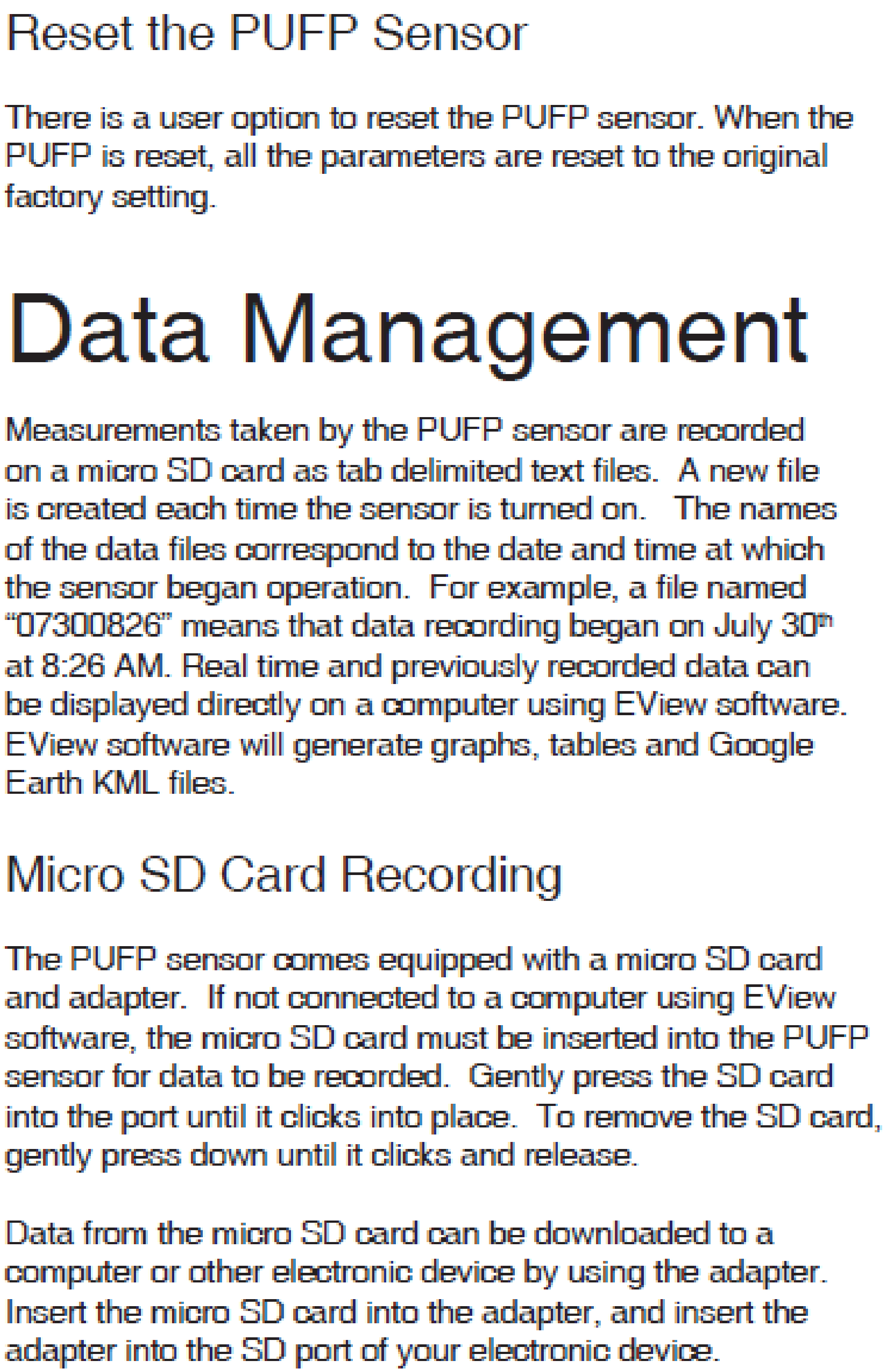
Manual Setting: The date and time of the PUFP sensor can be modified manually. To manually manage the time and date, set “GPS Time Difference” to 13. Date and time parameters will then need to be adjusted to the desired time at the user settings screen.

The time and date for the sensor can automatically sync when the GPS signal is active. Time and date are calculated based on Greenwich Mean Time (GMT). In order sync properly, the time difference must be specified to indicate the current time zone. To do this, first press and hold the right arrow (▶) to get to the user settings menu. Scroll through all options (year, month, day ect.) until a new screen appears and “GPS Time Difference” is highlighted blue. Press the right arrow (▶) key to select the parameter and use the up and down arrows on the keypad to specify the time difference (hours) from GMT respective to the current time zone. Press the right arrow (▶) to save the settings.

Turning off the PUFP Sensor

The sensor must go through a short shut down process to clear moisture from and cool down the internal components (~3 min). Begin the shutdown process by pressing and holding the ⏻ button in the center of the keypad for two seconds. The display screen will indicate when the shutdown has begun and the time remaining for the process to be complete. The sensor will automatically turn off.

In case of emergency, the sensor can be turned off immediately without going through the shutdown process by pressing and holding down the up (▲) and down (▼) arrow keys simultaneously for two seconds.



Reset the PUFP Sensor

There is a user option to reset the PUFP sensor. When the PUFP is reset, all the parameters are reset to the original factory setting.

Data Management

Measurements taken by the PUFP sensor are recorded on a micro SD card as tab delimited text files. A new file is created each time the sensor is turned on. The names of the data files correspond to the date and time at which the sensor began operation. For example, a file named "07300826" means that data recording began on July 30th at 8:26 AM. Real time and previously recorded data can be displayed directly on a computer using EView software. EView software will generate graphs, tables and Google Earth KML files.

Micro SD Card Recording

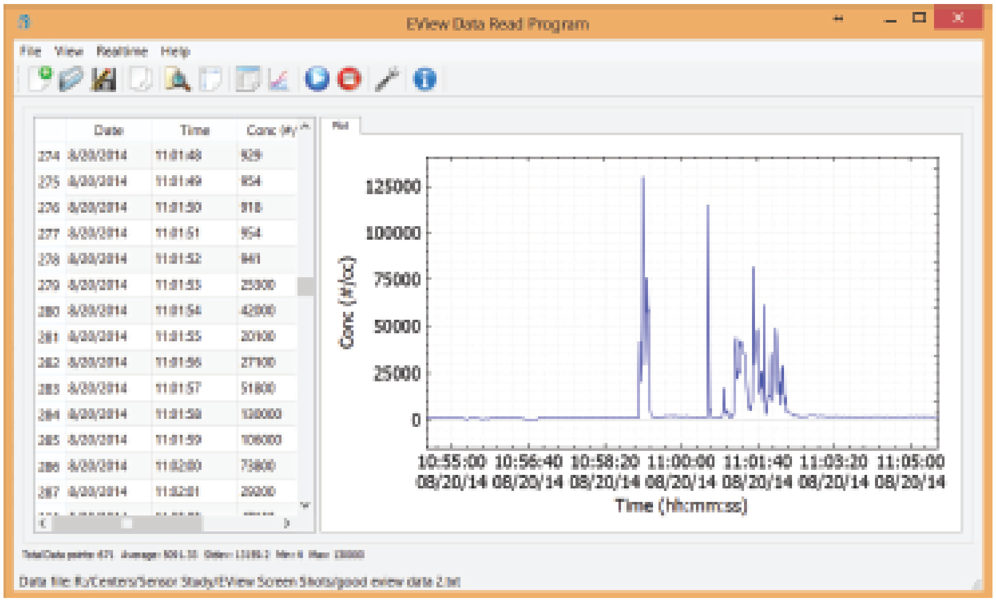
The PUFP sensor comes equipped with a micro SD card and adapter. If not connected to a computer using EView software, the micro SD card must be inserted into the PUFP sensor for data to be recorded. Gently press the SD card into the port until it clicks into place. To remove the SD card, gently press down until it clicks and release.

Data from the micro SD card can be downloaded to a computer or other electronic device by using the adapter. Insert the micro SD card into the adapter, and insert the adapter into the SD port of your electronic device.

EView Software

EView software can be installed on either Mac or Windows computers. Graphs and charts can be generated from previously recorded data or can be used to record and show real time UFP measurements.

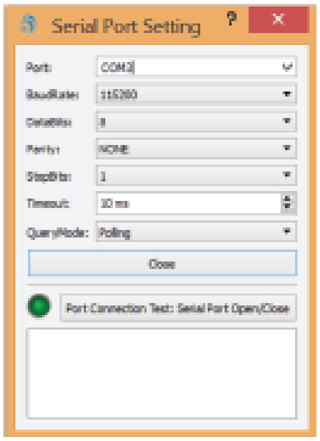
Previously measurements can be opened by going to File>Open. When the desired file is opened, a chart and graphed data will appear. The data can be navigated by clicking on the graph area and dragging up and down and side to side.



	Date	Time	Conc (#/
274	8/20/2014	11:01:48	929
275	8/20/2014	11:01:49	854
276	8/20/2014	11:01:50	918
277	8/20/2014	11:01:51	954
278	8/20/2014	11:01:52	841
279	8/20/2014	11:01:53	25300
280	8/20/2014	11:01:54	42800
281	8/20/2014	11:01:55	20100
282	8/20/2014	11:01:56	27100
283	8/20/2014	11:01:57	51800
284	8/20/2014	11:01:58	120000
285	8/20/2014	11:01:59	106000
286	8/20/2014	11:02:00	73800
287	8/20/2014	11:02:01	20000

Data file: R:/Centers/Sensor Study/EView Screen Shots/good eview data 2.txt

To record data in real time, connect the PUFP sensor with the USB cable to your Mac or Windows computer while EView software is running. Driver software from the PUFP sensor will begin to install on your computer. Once complete, click on the wrench icon on the toolbar at the top of the EView screen. A screen will appear named “Serial Port Setting.”



Port: COM3
BaudRate: 115200
DataBits: 8
Parity: NONE
StopBits: 1
Timeout: 10 ms
QueryMode: Polling

Turn on the port connection by selecting "Port Connection Test: Serial Port Open/Close." Measurements should begin to appear in the dialogue box. If text does not appear, adjust the port options. When text begins to appear, close the window.

To begin recording data, select the blue play button on the toolbar or select the "Realtime" option on the menu bar and then "Realtime Mode." To stop recording data, select the red stop button.

Save data by selecting File> Save/Save As. Data can be saved in multiple formats. For example, data can be kept as tab delimited or CSV files and imported into statistical software for analysis. Graphs can be saved as picture files (PDF, JPEG, PNG). Exposure data can also be saved as KML files and loaded into Google Earth software to show the spatial distribution of measured UFP concentrations.

Maintenance

Air intake nozzle with dust-mesh filter

The PUFP sensor comes equipped with an additional air intake nozzle. The air intake nozzle has a mesh covering to catch large particles and dust. This should be cleaned periodically by using an air canister.

Enmont
environmental monitoring technology

PSCAA Comments about the purpose and use of the Enmont monitor

CAUTION: The Enmont monitors are used for primarily educational purposes. The Enmont monitor measurement is NOT regulatory in nature. This data CANNOT be used as evidence to force regulatory change. However, the Air Beam monitors can be very useful as screening tools, and as educational tools.

For this study, the Air Beam monitor is to be used for Educational purposes. The data may also be used to confirm other measurements, but shall not be used to draw any conclusions, or primarily drive any recommendations.

K. Air Quality Web: Air Drop Procedure

Air Quality Web: Air Drop

March 2016

Version 1.0.0

Puget Sound Clean Air Agency

1904 Third Avenue – Suite 105

Seattle, WA 98101

Document Revisions

Date	Version Number	Document Changes
6/18/16	1.0.0	Initial draft

Air Drop Overview

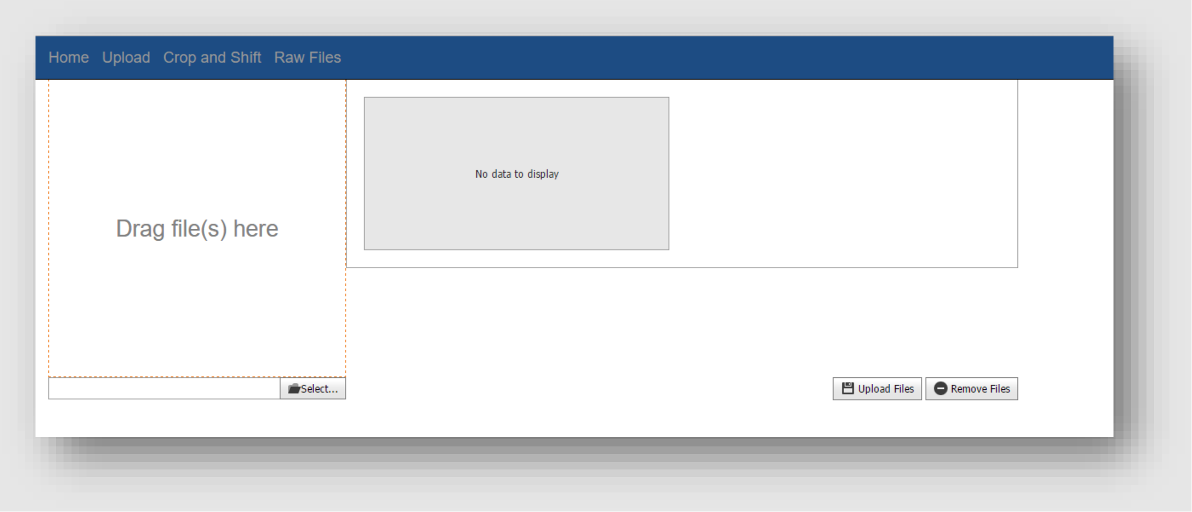
Air Drop is a tool that can be used to upload, crop, and shift data from mobile air quality studies. Once you have uploaded your data and made any necessary changes to the observation times, your data will be ready for review in our Telemetry database. You can retrieve your raw files from this application at any time.

Navigating to Air Drop

Air Drop is a web app that is available via this URL: https://secure.pscleanair.org/AirQualityWeb/. While this app is responsive to different screen sizes, it is for intended desktop and not optimized for mobile use.

Uploading Data

Overview



Accepted formats

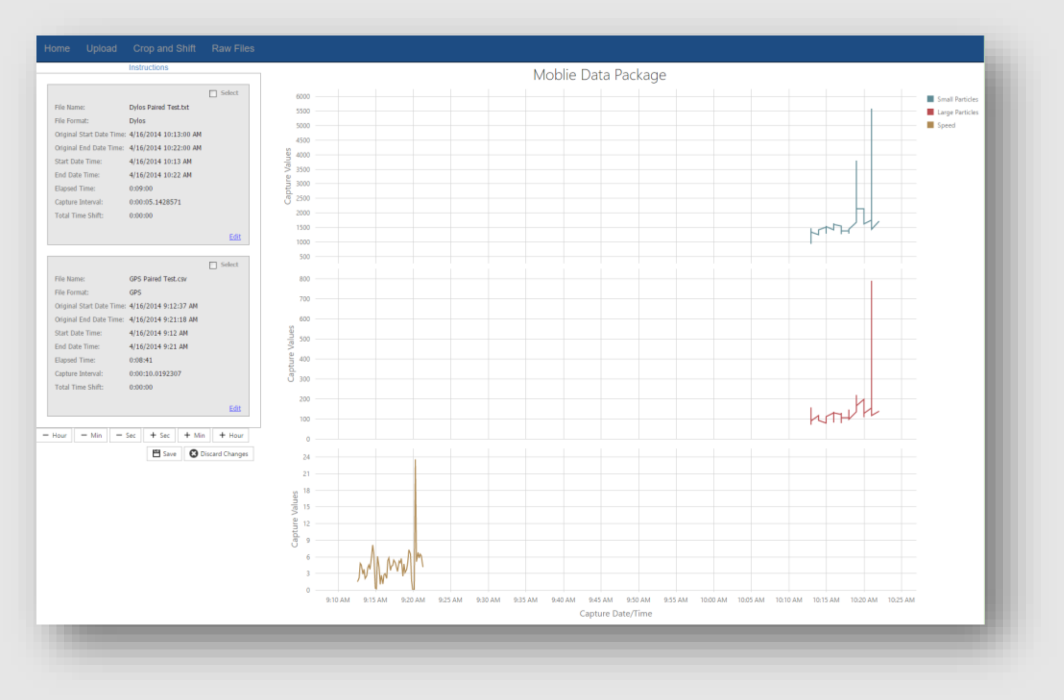
You can upload a single file or a package of files in a .zip file. The current version of Air Drop can read data from these file formats: *AeroqualVoc, AirBeam, CarClipCo, CarClipO3No2, Dylos, Enmont, GPS, GPX, HourlyTelemetry, MicroAeth, Package, RadianceResearch, SenonicsMinnow, and TsiNanoScan*. **If additional formats need to be supported, please let Ross or Nate know so the work can be planned**.

Uploading

You can upload your file(s) via the drag and drop feature or by browsing for them. To use the drag and drop feature, drag your file(s) from their file location to the drop zone on the web page. If you wish to use the browsing feature, click the select button under the drop zone and navigate to your file(s). After a successful upload you will be taken to the page where you may crop and shift your data.

Cropping and Shifting Data

Overview

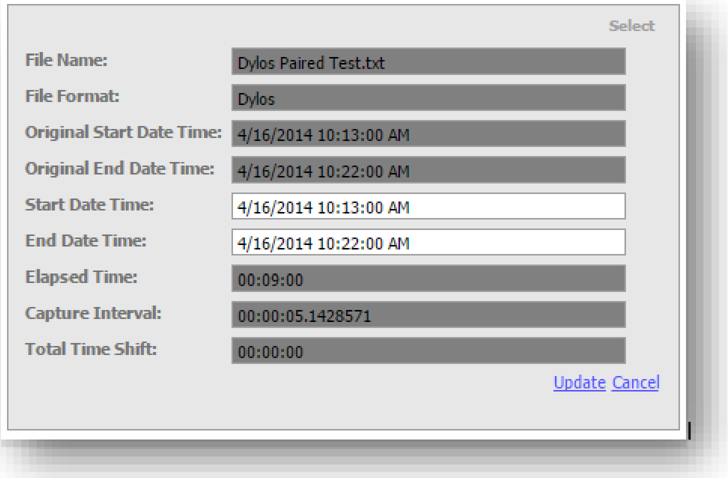


File Name: Dylos Paired Test.txt
File Format: Dylos
Original Start Date Time: 4/16/2014 10:13:00 AM
Original End Date Time: 4/16/2014 10:22:00 AM
Start Date Time: 4/16/2014 10:13 AM
End Date Time: 4/16/2014 10:22 AM
Elapsed Time: 0:09:00
Capture Interval: 0:00:05.1428571
Total Time Shift: 0:00:00

File Name: GPS Paired Test.csv
File Format: GPS
Original Start Date Time: 4/16/2014 9:12:37 AM
Original End Date Time: 4/16/2014 9:21:18 AM
Start Date Time: 4/16/2014 9:12 AM
End Date Time: 4/16/2014 9:21 AM
Elapsed Time: 0:08:41
Capture Interval: 0:00:10.0192307
Total Time Shift: 0:00:00

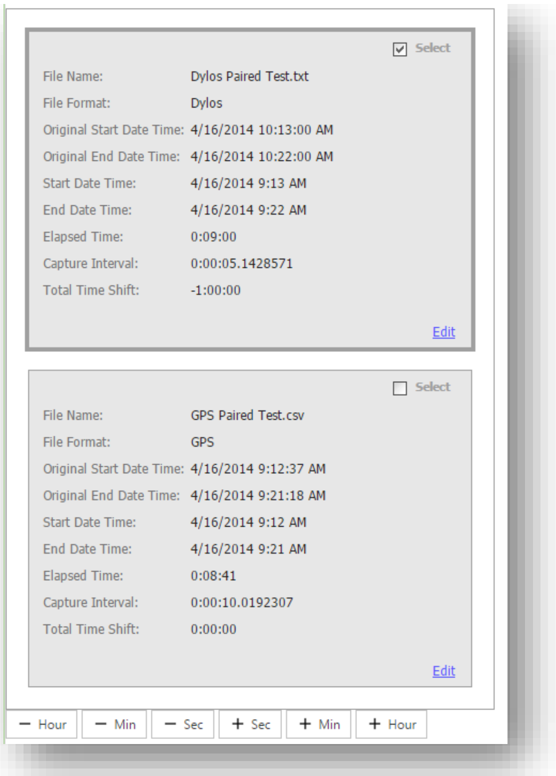
On this page, your data will be displayed on a line chart. If you have multiple QMUs in your data set, they will be displayed on separate panes. This allows you to visualize any time discrepancies in your data. You can see details about your files on the left side of the page. Each file will have a separate "card view". This view allows you to edit the start and end date/times of your files, thereby cropping your data set. By selecting the file's card view, you can use the shift buttons to adjust the observation times of your study.

Crop



File Name:	Dylos Paired Test.txt
File Format:	Dylos
Original Start Date Time:	4/16/2014 10:13:00 AM
Original End Date Time:	4/16/2014 10:22:00 AM
Start Date Time:	4/16/2014 10:13:00 AM
End Date Time:	4/16/2014 10:22:00 AM
Elapsed Time:	00:09:00
Capture Interval:	00:00:05.1428571
Total Time Shift:	00:00:00

If all sensors did not start or end at the same time and you would like to trim remaining data points from display, you can do that with this card view. Select edit in the bottom right and you will see what is displayed in the screen shot to the right. As you can see, only the start and end date fields are editable. Select update after you have made your changes and you will see your modified data displayed. Please note: your data is not being deleted when it is cropped. It will still exist in our database and ignored in display.

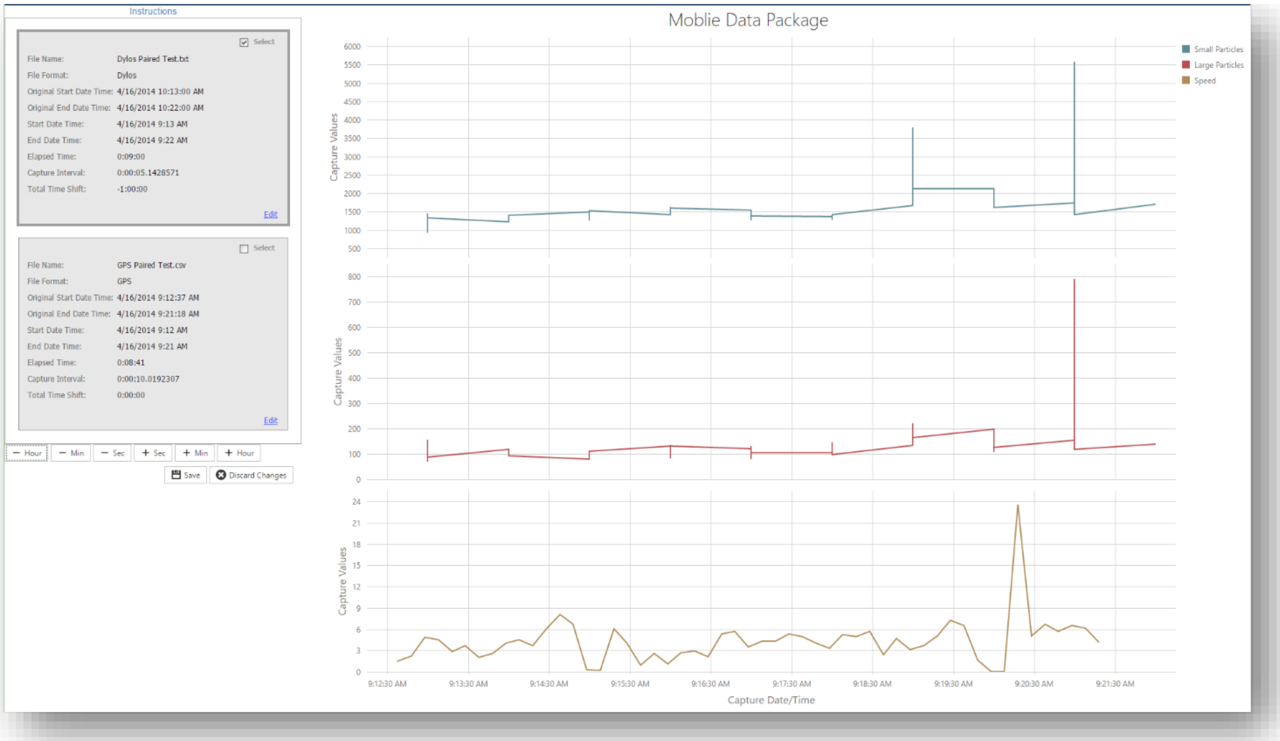


File Name:	Dylos Paired Test.txt
File Format:	Dylos
Original Start Date Time:	4/16/2014 10:13:00 AM
Original End Date Time:	4/16/2014 10:22:00 AM
Start Date Time:	4/16/2014 9:13 AM
End Date Time:	4/16/2014 9:22 AM
Elapsed Time:	0:09:00
Capture Interval:	0:00:05.1428571
Total Time Shift:	-1:00:00

File Name:	GPS Paired Test.csv
File Format:	GPS
Original Start Date Time:	4/16/2014 9:12:37 AM
Original End Date Time:	4/16/2014 9:21:18 AM
Start Date Time:	4/16/2014 9:12 AM
End Date Time:	4/16/2014 9:21 AM
Elapsed Time:	0:08:41
Capture Interval:	0:00:10.0192307
Total Time Shift:	0:00:00

Shift

If your sensors' internal clocks are not in sync, you can shift all the observation times in a file by hour, minute, or second. To do this, select one or more files by checking *Select* in the upper right of the card view and clicking the time adjustment buttons below the card view(s). In this example you can see the Dylos monitor was an hour ahead of the GPS device. I have applied a one-hour shift and the screen shot below is the result. The Dylos file recorded two QMUs and the time shift was applied to both since they are contained in the same file. Now you can visualize this data set is in sync.



☑ Select

File Name: Dylos Paired Test.txt
File Format: Dylos
Original Start Date Time: 4/16/2014 10:13:00 AM
Original End Date Time: 4/16/2014 10:22:00 AM
Start Date Time: 4/16/2014 9:13 AM
End Date Time: 4/16/2014 9:22 AM
Elapsed Time: 0:09:00
Capture Interval: 0:00:05.1428571
Total Time Shift: -1:00:00

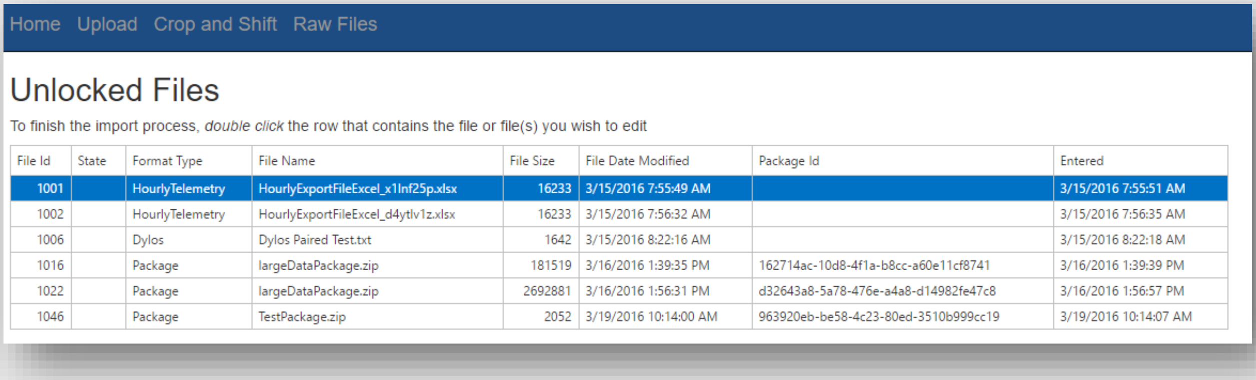
☐ Select

File Name: GPS Paired Test.csv
File Format: GPS
Original Start Date Time: 4/16/2014 9:12:37 AM
Original End Date Time: 4/16/2014 9:21:18 AM
Start Date Time: 4/16/2014 9:12 AM
End Date Time: 4/16/2014 9:21 AM
Elapsed Time: 0:08:41
Capture Interval: 0:00:10.0192307
Total Time Shift: 0:00:00

Save and Discard

Once you are satisfied with your changes simply select the save button that is also located below the card view. At this point, your raw data is being adjusted according to your changes and moved into a permanent structure. Depending on your data size this may take a few moments. After saving, your raw files will become locked, preventing any adjustments to the time shift as well as the start and end dates. If you wish to discard changes you may do so my clicking the discard changes button.

Unlocked Files



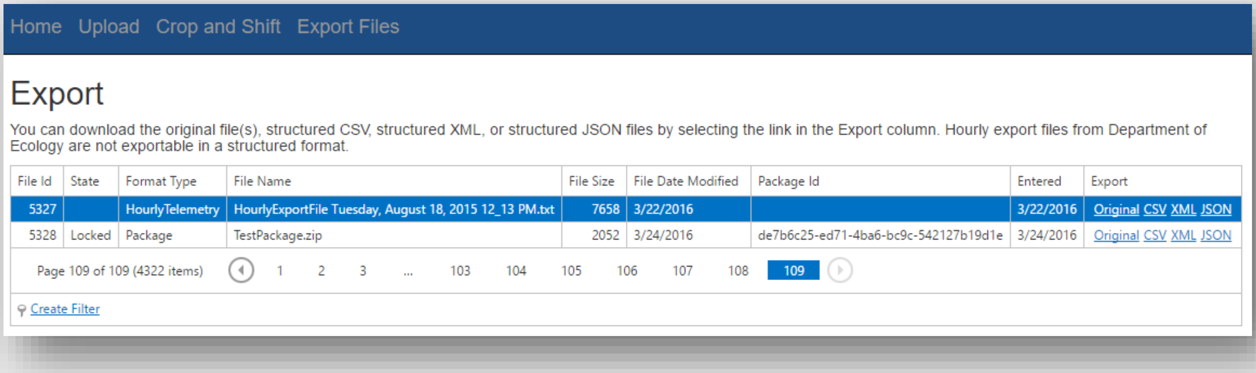
Unlocked Files

To finish the import process, *double click* the row that contains the file or file(s) you wish to edit

File Id	State	Format Type	File Name	File Size	File Date Modified	Package Id	Entered
1001		HourlyTelemetry	HourlyExportFileExcel_x1Inf25p.xlsx	16233	3/15/2016 7:55:49 AM		3/15/2016 7:55:51 AM
1002		HourlyTelemetry	HourlyExportFileExcel_d4ytlv1z.xlsx	16233	3/15/2016 7:56:32 AM		3/15/2016 7:56:35 AM
1006		Dylos	Dylos Paired Test.txt	1642	3/15/2016 8:22:16 AM		3/15/2016 8:22:18 AM
1016		Package	largeDataPackage.zip	181519	3/16/2016 1:39:35 PM	162714ac-10d8-4f1a-b8cc-a60e11cf8741	3/16/2016 1:39:39 PM
1022		Package	largeDataPackage.zip	2692881	3/16/2016 1:56:31 PM	d32643a8-5a78-476e-a4a8-d14982fe47c8	3/16/2016 1:56:57 PM
1046		Package	TestPackage.zip	2052	3/19/2016 10:14:00 AM	963920eb-be58-4c23-80ed-3510b999cc19	3/19/2016 10:14:07 AM

If you upload your file(s) and were not able to complete the crop and shift process you can pick your file(s) from this list and continue. You can navigate here by selecting the *Crop and Shift* link in the header. Simply find your file or package and double click to be directed to the crop and shift page.

Exporting Files



Export

You can download the original file(s), structured CSV, structured XML, or structured JSON files by selecting the link in the Export column. Hourly export files from Department of Ecology are not exportable in a structured format.

File Id	State	Format Type	File Name	File Size	File Date Modified	Package Id	Entered	Export
5327		HourlyTelemetry	HourlyExportFile Tuesday, August 18, 2015 12_13 PM.txt	7658	3/22/2016		3/22/2016	Original CSV XML JSON
5328	Locked	Package	TestPackage.zip	2052	3/24/2016	de7b6c25-ed71-4ba6-bc9c-542127b19d1e	3/24/2016	Original CSV XML JSON

You can retrieve your files at any time via this page. You can get the original unmodified data or structured CSV, XML, and JSON formats.

L. NFRM Metal Sampling Procedure

ARA N-FRM Sampler

Operation Manual

March 19, 2020

Overview

In response to the need for a low cost alternative to traditional site-based particulate monitors, ARA Instruments introduced a sampler that establishes a new class of air sampler we call "Near FRM" (N-FRM). The ARA N-FRM Sampler is a portable, rapidly deployable, battery powered particulate sampling and monitoring device that delivers Federal Reference Method (FRM) level of performance. It integrates with many additional components for unmatched versatility. The compact sampler collects 24-hour TSP, PM10, or PM2.5 filter samples and can simultaneously measure local meteorological parameters. It can also be equipped with a Real-Time Particulate (RTP) Profiler to log temporal particulate variations. For added versatility, the N-FRM Sampler can be operated in directional wind sampling mode or collect only sensor data in meteorological mode.

The N-FRM Sampler offers near FRM performance, while costing a fraction of traditional site-based air samplers. Its compact size and battery-powered function, gives the N-FRM Sampler many advantages over traditional air samplers. Deployment and relocation is quick and easy, and allows monitoring in locations that are inaccessible with traditional air samplers. Flexible mounting options allow for stand–alone support or the use of existing poles and structures. The ability of the N-FRM to operate on rechargeable batteries also significantly reduces the cost of establishing a monitoring site.

The N-FRM is designed for easy operation and maintenance. The intuitive user interface makes programming and calibrating the sampler simple. PM10 and PM2.5 inlets are field serviceable and require only monthly cleanings. Filter holders accept standard 47mm FRM cassettes for easy handling of various filter media. Batteries can be recharged in approximately 1-hour. Data log files with 5-min averages for all sensors can easily be downloaded to a USB Flash drive.

Cities and governments are deploying networks of N-FRM Samplers to survey unmonitored areas and validate permanent Reference Method equipment. Researchers and consultants use the N-FRM in air quality studies and environmental impact assessments. They are also utilized in industrial pollution applications, such as mines and quarries, and in large construction projects for fence line and roadside monitoring. The small and quiet N-FRM air sampler is also a great tool for indoor and industrial workplace sampling that requires high accuracy.

1.1 Principles of Operation

The N-FRM Sampler is specifically designed to meet the US-EPA operational specifications for PM10 and PM2.5 air sampling. To meet the EPA specifications, the N-FRM Sampler is designed to operate at 16.7 LPM and collect 24-hour samples to compare to EPA National Ambient Air Quality Standards. The ARA N-FRM Sampler is a microprocessor-controlled portable air sampler, which can be operated manually or programmed to collect scheduled samples. As specified by the EPA, all critical air sampling parameters are continuously monitored and logged as time indexed 5-min averages to validate the sample. These parameters include: flow rate, temperature, barometric pressure, and accumulated volume. Other sampler related performance parameters are also logged. If the N-FRM Sampler is equipped with the Real-Time Particulate (RTP) Profiler and meteorological sensors, then PM10, PM2.5, wind speed, and wind direction are also included in the data record.

The N-FRM sampler can be easily deployed. It can be mounted on a variety of structures using our universal mounting bracket that can be screwed, clamped, or attached to utility poles, trees, fence posts, etc. Another option is to use a freestanding tripod.

The N-FRM Sampler is equipped to operate from either AC or DC power sources. In the DC mode, the sampler operates from an internal battery pack. A charged battery pack is capable of operating the sampler for about 30-40 hours. This robust capacity allows the sampler to be used in cold weather and high altitude applications. A charger is supplied so the batteries can be re-charged in approximately one hour.

1.2 Particulate Matter Sampling

The N-FRM Sampler can be set up for TSP, PM10, or PM2.5 particulate sampling by configuring the sampling inlet components prior to the filter medium. To measure TSP, the omnidirectional Louvered Inlet is all that is required. For PM10 sampling, an FRM style inertial separator (PM10 Impactor) is added. To collect PM2.5, the sharp-cut ARA VIS-A Cyclone is attached, which physically selects particles 2.5 microns and below. Common N-FRM inlet configurations are shown in FIG. 1.

The N-FRM inertial separators (PM10 Impactor) are designed to operate at a nominal sampling rate of 1 cubic meter per hour (16.7 liters per minute). The N-FRM Sampler incorporates a microprocessor-based active flow control to maintain the sampling rate as ambient conditions and filter loading changes. The sampling rate is monitored and adjusted several times a second and logged at 5-min intervals along with all other important sampling parameters.

To allow for unattended operation, the N-FRM Sampler is easily programmed to initiate and stop sampling. For each sampling event, the N-FRM Sampler generates a summary of important sampling parameters such as start and stop times, total sampling volume, and average ambient temperature and pressure as well as 5-min averages of all ambient and sampler operational parameters. The logged data file can be easily downloaded to a USB flash drive by the operator. The “csv” (comma separated value) file can easily be imported into a spreadsheet.

2 Hardware Description

2.1 PM10 Inlet

The ARA omnidirectional PM10 Inlet is a compact version of the EPA prescribed Reference Method Inlet. It features a screened inlet, wind deflector, and precision PM10 inertial separator (impactor) with moisture trap. The PM10 Inlet is designed to operate at 1 cubic meter per hour (16.67 LPM). The inlet can be used alone for PM10 sampling or in combination with the ARA VIS-A sharp-cut vortex inversion separator for PM2.5.

2.2 PM2.5 Cyclone

The ARA VIS-A (Vortex Inversion Separator) is a precision engineered and compact sharp-cut cyclone fitted to the N-FRM inlet that physically selects particles 2.5 microns and below. This ensures precise measurement of only the PM2.5 size fraction. The PM2.5 separator is designed to operate at 1 cubic meter per hour (16.67 LPM) and requires the ARA PM10 omnidirectional inlet to collect accurate PM2.5 samples.

2.3 Filter Holder

The aluminum filter holder is precisely manufactured for a tight seal and no contamination of the filter media. The filter holder is designed to use common EPA specified 47mm cassettes for PM2.5 sampling.

2.4 Flow Control System

The N-FRM Sampler incorporates a microprocessor-based active flow control to maintain the sampling rate as ambient conditions and filter loading changes. The sampling rate is monitored and adjusted several times a second and logged at 5-min intervals along with all other important sampling parameters. Under normal conditions the active flow control will maintain the sampling well within +/- 2%. If the sampling rate cannot be maintained within +/- 5% a flow error is generated and logged, and if the error continues for 5-minutes the sampler will shut down.

3.3 Power Source

3.3.1 Batteries

Each N-FRM Sampler is equipped with two 18V/5Ah DeWalt lithium-ion batteries.

Check Battery Charge

Each battery has a Charge Gauge on the front, consisting of three green LED lights and a button. Press and hold the Charge Gauge button. The LED lights will illuminate designating the level of charge left. See Figure 4 to determine if your batteries need to be charged.

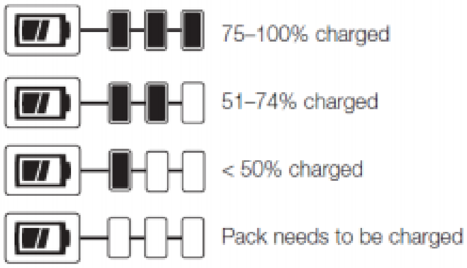


Figure 4. Battery Charge Levels

Charge Batteries

Plug the charger into an appropriate AC outlet. The charger provided by ARA Instruments is rated for 220VAC. If you prefer a 110VAC charger, we recommended DeWalt DCB105.

Insert the battery into the charger as shown in Figure 5. The red charging light will blink continuously, indicating the charging process has started. Batteries should be fully charged within 1 hour. Completion of the charging cycle is indicated by the red light remaining ON continuously. The battery is fully charged and may be used at this time or left in the charger.

The charger is designed to detect certain problems that can arise. Problems are indicated by the red charging light flashing at a fast rate. Try a different battery to determine if the charger is working properly. If the new battery charges correctly, then the original battery is defective and cannot be used.

Figure 5. Battery Charger

Please read all of the DeWalt instructions for the batteries and charger included with your sampler for more details about charging and storing batteries.

Install Batteries

Insert two charged batteries into the ARA N-FRM Battery Holder as shown in Figure 6. Make sure the batteries are fully seated and latched to the Battery Holder.

Insert the Battery Holder into the ARA N-FRM.

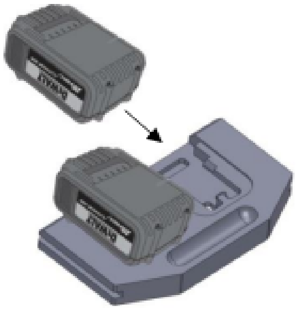


Figure 6. Battery Inserted Into Holder

3.3.2 AC Power Supply

Each N-FRM Sampler is also equipped with a 120/240V AC Power Supply to be used when an outlet is available.

3.3.3 Using Batteries and AC Power Supply

The AC Power Supply **does not** charge the batteries. The batteries can only be charged with the included Dewalt Battery Charger.

When both the AC Power Supply and Batteries are connected, the N-FRM Sampler will run off the AC Power Supply. If the AC Power Supply is interrupted, the Batteries will take over until AC Power Supply is restored.

3.3.4 Solar Panel System

The ARA N-FRM Sampler utilizes a Zamp 24V Solar Panel System.

3.4 Powering N-FRM Sampler On/Off

Place the Power ON/OFF Rocker switch at the lower right of the front panel of the air sampler in the **ON** position. The Sampler will boot up into the Home Screen. The default operational mode is **MODE:OFF**.

3.5 Navigation

Navigate through the menus by rotating the selector knob to highlight a desired selection. Press the knob to select. The menu system is intuitive, especially to those with air sampling experience. To exit any menu, rotate the selector knob to highlight the top item of all menus and select **EXIT**. **MODE: OFF** takes you back to the Home Screen.

3.6 Sleep Mode

The N-FRM Sampler enters power saving "sleep mode" after a few minutes of no input from the selector knob. In this mode, the LCD screen is blank. To wake up the N-FRM Sampler, press and hold the selector knob for 3-seconds.

3.7 Setting Time and Date

On the Home Screen, confirm that the date and time are accurate. If necessary, follow these steps to set the correct Time and Date:

- Select **SETUP** from the Home Screen
- Scroll down, highlight **SYSTEM SETUP** and select
- Scroll down, highlight **DATE/TIME** and select
- Scroll down until the Day is highlighted and select
- Rotate the selector knob until the correct date is highlighted and select
- Repeat for Month, Year, Hour, Minute, and Second
- Select **DATE/TIME:EXIT**
- Select **YES** to save Date/Time
- Select **SYSTEM:EXIT** and then **SETUP:EXIT** to return to Home Screen

3.8 Filter Media

3.8.1 Choosing Filter Media

The ARA N-FRM Sampler is designed to use the filters specified by the US-EPA Federal Reference Method for PM2.5 Sampling. These types of filters work best for sampling…

- 2 um PTFE Teflon Filter w/support ring – Recommended if chemical analysis for non-carbon based compounds will follow gravimetric analysis**. Several manufacturers produce Teflon filters that meet the US-EPA specifications, and work well in the N-FRM Sampler. The key specification to meet for operation on battery power for is: Filter Resistance of < 30 cm-H2O @ 16.7 LPM. If you will be running samplers on battery power, we recommend the PALL Teflo Filters (#R2PJ047) as they have a very low resistance and will maintain battery charge beyond 24 hours.**
- Teflon-Coated Glass Filter – Ideal for gravimetric analysis.
- Pure Quartz Filter – Recommended if chemical analysis for carbon based compounds will follow gravimetric analysis.

For the sampler to maintain flow and run efficiently, use filters with a maximum pressure drop (with a clean filter) of 30 cm H2O column @ 16.67 LPM clean air flow. If filter media is too restrictive, the sampler will not be able to complete a 24-hour run and will automatically shut-off if batteries are depleted.

3.8.2 Installing a Filter

⚠ *Note: This procedure should take place in a laboratory or clean area. Contact and handling of all filter media should be limited to the non-exposed outer edge with smooth tipped forceps (non-serrated) or plastic tipped forceps. Filter media should never be handled with fingers.*

- Unscrew the Filter Holder Top from the Filter Holder Bottom
- Remove Filter Cassette
- Use ARA Cassette Separator to open the cassette. The top and bottom of the Filter Cassette are machined for a press fit. The Filter Cassette Top has a large beveled interior edge. See Figure 7 for appropriate use of Cassette Separator.

⚠ *Warning: Manually prying the cassette apart with fingers can result in the cassette violently opening, causing damage to filter media or support screen.*

Figure 7. Open 47mm Cassette

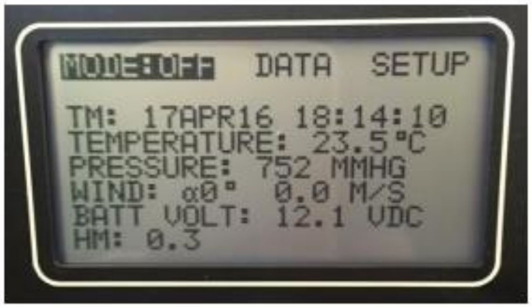
- With forceps, place a pre-weighed, clean filter media onto the Support Screen in the Filter Cassette Bottom. Install the Filter Cassette Top, firmly and evenly pressing down to complete the assembly.
- Place the Filter Cassette into the Filter Holder and reassemble by firmly screwing together the Filter Holder Top and Filter Holder Bottom. *Note: Cassettes can be handled with fingers. But make sure not to touch filter media.*

4 Operational Overview

4.1 Home Screen

Once the N-FRM Sampler is powered ON, the Home Screen appears. The Home Screen displays the Time, Temperature, Barometric Pressure, Wind Speed, Battery Voltage, and Hour Meter (Total Pump Operating Hours).

There are three menu selections across the top of the Home Screen: OFF, DATA, SETUP. These are the Administrative Modes.



```
MODE:OFF   DATA   SETUP

TM: 17APR16 18:14:10
TEMPERATURE: 23.5°C
PRESSURE: 752 MMHG
WIND: α0°  0.0 M/S
BATT VOLT: 12.1 VDC
HM: 0.3
```

4.2 Operational Modes

4.2.1 Mode: OFF

When the N-FRM Sampler is powered on, Mode: OFF is the default setting.

Select this administrative mode to move between the Operational Modes: OFF, ON, MET, PROGRAM, SECTOR and REMOTE.

4.2.2 Mode: ON

Select to manually turn the N-FRM pump ON.

4.2.3 Mode: MET

Select to view and log current meteorological parameters and particle sensor data if the Wind Sensor and RTP Profiler are installed. In this mode, data logging begins after 5 minutes. The pump will not run in **MET MODE**.

4.2.4 Mode: PROGRAM

Select to set the sampler to run at user-defined parameters: time, date, duration, interval, and flow rate. This mode logs all standard parameters, in addition to real-time particle data and meteorological data (if installed). This mode also allows the user to set parameters for conditional sampling. Options include: minimum wind speed, wind direction (defined sector), and minimum PM2.5 and PM10 concentrations (if Real Time Profiler is installed).

4.3 Data

The **DATA** administrative mode allows the user to view or erase summaries of the last few sampling events.

VIEW SUMMARIES – In this selection, the last 10 sampling events are stored and organized by Start Time. The summary data for each event is viewed by scrolling down the LCD screen. To change and view other events, scroll and select **ST** (start time and date). Each press of the selector knob changes the event data to view.

EXPORT LOG – Scrolling to the bottom of the **VIEW SUMMARIES** screen and selecting **EXPORT LOG** allows the user to export a summary, including 5-minute averages of sensor data and sampling parameters of the selected event to a USB flash drive.

ERASE ALL SUMMARIES – Selecting this option allows the user to erase all sampling event data. Note: It is not necessary to erase summaries. The newest sampling event will overwrite the oldest summary data once the maximum has been reached.

4.4 Setup

The **SETUP** administrative mode has various options relating to the sampler program and system setup.

SET PROGRAM: Allows the user to set the program for the next sampler run. Instructions that are more specific can be found in Section 5.1.1.

CLEAR ALL DATA: Will delete all sampler runtime data.

EXPORT SETUP: Using USB drive, the user can download sampler settings.

IMPORT PROGAM: A program may be imported from the USB drive.

SYSTEM INFO: Lists sampler information, including the Serial Number and latest Firmware version.

UPDATE FIRMWARE: With the correct file on a USB drive the user can update the firmware of the sampler. The latest firmware is available on the ARA Instruments website – www.arainstruments.com

SYSTEM SETUP: This menu allows the user to set the date and time and other sampler parameters.

⚠ DATE/TIME: User can set the current date and time. ***Note: When the sampler battery is removed, the sampler will hold the current date and time for approximately two weeks.***

FLOW RATE: User can turn the pump on and off and set the flow rate. This mode is useful for flow audits and calibration. There is a user adjustable SLOPE and INT (Intercept) if flow calibration is needed.

AMBIENT TEMPERATURE: This mode allows the user to turn ON or OFF the ambient temperature sensor if desired. If turned OFF the sampler defaults to a user adjustable, standard temperature of 25° C. The user can also enter an offset for calibration purposes.

BAROMETRIC PRESSURE: This mode allows the user to turn ON or OFF the ambient pressure sensor. If turned OFF the sampler defaults to a user adjustable, standard pressure of 760 mmHg. The user can also enter an offset for calibration purposes.

STANDARD TEMP PRESS: This mode allows the user to adjust the standard temperature and pressure used to calculate "standard" flow and volume, and also the default conditions if the temperature and/or ambient pressure sensors are turned off. Also, in this screen the user can select to sample at standard conditions or local conditions. The default for the sampler is sample at actual conditions of local temperature and pressure (LTP).

LCD BRIGHTNESS: Allows adjustment of the LCD backlight.

RESTORE DEFAULTS: Will set sampler back to factory defaults ***(be cautious in using this option since it will erase all user input calibration data)***.

BLUETOOTH CONTROL: For future use.

PARTICLE COUNTER: The N-FRM Sampler comes with default mass values for PM2.5 and PM10 particulates. Users can adjust these values proportionally to match their local aerosol characteristics.

BOOT HISTORY: This mode is for troubleshooting firmware issues.

REBOOT: Will reboot the sampler.

5 Operating the N-FRM Sampler

5.1 User-Defined Programming

5.1.1 Creating a Program to Operate at a Specific Time Interval

There are two methods to view the **SET PROGRAM** screen.

> Method 1: On the Home Screen, highlight **SETUP** and select by pushing the selector knob. Scroll down to **SET PROGRAM** and select.
>
> Method 2: On the Home Screen, highlight **MODE: OFF** and select. Rotate the knob until **MODE: PROGRAM** is highlighted and select. Scroll down to **ST** (start date and time) and select to open the **SET PROGRAM** page.

You can now select the fields you desire to edit as you setup the sampler to run:

> **CLEAR PROGRAM**: Select this option if you want to clear the current program. This is not necessary but can be helpful if you plan to change most of the parameters.
>
> **SAMPLE ID**: A unique 4-digit ID can be entered but is not necessary. Sometimes used to identify site or filter media.
>
> **START**: Select this option to enter the Start Date and Time. Scroll to the field that you would like to edit and push to edit. Turn the selector knob to choose the desired date or time variable, then select and continue to scroll through the fields until the START Date and Time are set as desired.
>
> **DURATION**: Select this option to enter the duration of the sample event. Enter hours and minutes by turning the selector knob and pushing to edit the desired field.
>
> **INTERVAL**: This option is used to setup a repeating sample event. Enter the hours and minutes from the end of the programmed run that you would like the event to repeat. An entry of 72:00 would repeat the sample every 72 hours. For a single non-repeating event set the INTERVAL to 00:00.
>
> **SET FLOW**: Use this field to set the desired flow for the programmed event. The nominal flow rate for ARA PM10 and PM2.5 inertial separators is 16.7 LPM.
>
> **CONDITIONS**: Select this field to open a sub-menu for conditional sampling. When conditions are set the sample pump will run after the condition has been met for 5-min, and will turn off when condition has not been met for 5-min. If multiple conditions are set all conditions must be met for the sample pump to run.
>
> > **MINIMUM WIND:** Set a minimum wind speed threshold. The default is 0.0 meters/sec.
> >
> > **SECTOR AZIMUTH:** Works with Central Angle for Directional Sampling. Set a centerline azimuth wind direction (direction wind is from) . The default is 0 degrees.

CENTRAL ANGLE: Set the size of the central angle (bisected by Sector Aziumth). The default is 0 degrees. *For example, if the Sector Azimuth was set to 90 degrees, and the Central Angle was set to 40 degrees, the sampler pump would only turn on when the wind direction was between 70 and 110 degrees.*

PM2.5: Set a minimum PM2.5 Concentration threshold. The default is 0 micrograms/cubic meter.

PM10: : Set a minimum PM10 Concentration threshold. The default is 0 micrograms/cubic meter.

REMOTE TRIGGER: Allows user to turn on the sampling pump with a external relay. (requires factory modification). The default is NO.

CLEAR CONDITIONS: Select this option to reset all conditions to default.

NOTE ON SAMPLING AT STANDARD CONDITIONS: If the method requires sampling at standard conditions, this can be changed in **SETUP** -> **SYSTEM SETUP** -> **STANDARD TEMP PRESS**. (See Section 4.4)

5.1.2 Running a Program

To activate the sampler at the programmed time and interval the sampler must be set to the Program Operational Mode.

On the Home Screen, select **MODE: OFF**. Rotate the knob until **MODE: PROGRAM** is highlighted and select.

The LCD screen displays **TM** (current date and time) and **ST** (start date and time) of the programmed event. Confirm that these parameters are correct and leave the sampler in Program Mode.

5.1.3 Ending a Program

After a programmed sampling event, the sampler remains in **MODE: PROGRAM** unless manually changed.

Highlight **MODE: PROGRAM** at the top of the LCD screen and select. Rotate the selector knob until **MODE: OFF** is highlighted and select. The Home Screen will appear.

5.4 View Summaries

A summary of the programmed event can be viewed and downloaded by selecting **DATA** from the Home Screen. Scroll down until **VIEW SUMMARIES** is highlighted and select. The LCD screen shows the **ST** (start date and time) of the last programmed event and the important sample parameters. *Note: Repeated selecting of **ST** will scroll through the last ten sample events.*

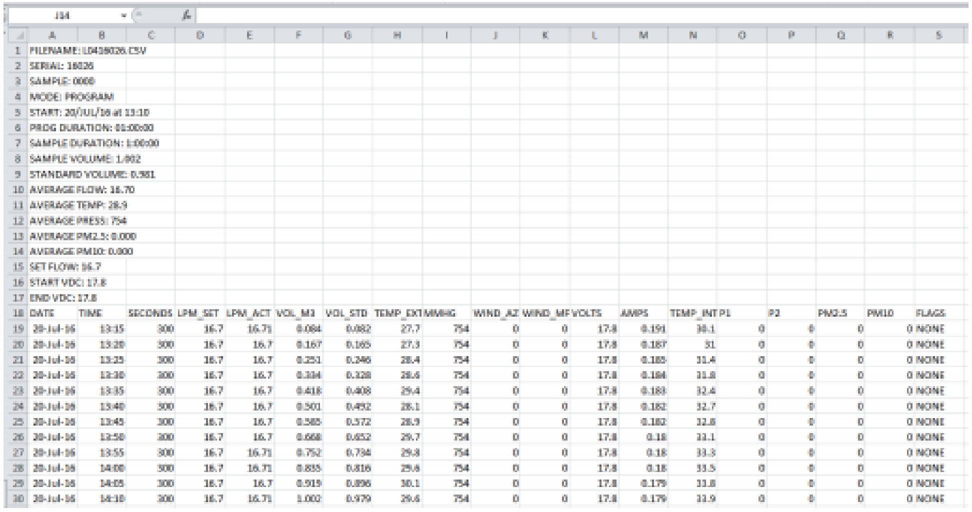
- Sample Duration, hrs:min
- Sample Volume, cubic meters (at sampling conditions)
- Average Sample Flow Rate, LPM
- Average Ambient Temperature, °C
- Average Barometric Pressure, mm-Hg
- Error Codes, if any
- Sample Volume, cubic meters (at standard conditions for PM10 sampling)
- Starting Battery Voltage
- Ending Battery Voltage

5.5 Export Data

In the **VIEW SUMMARIES** menu, scroll down and select **EXPORT LOG**. Follow the prompts and insert a USB Flash Drive.

Warning: The USB port has low power capabilities. Plugging in devices other than USB Flash Drives, such as cell phone chargers and portable hard drives, can damage the port. The best option for data removal is using a USB 2.0 Flash Drive.

The LOG file is a CSV (Comma Separated Value) file suitable for import into a Spreadsheet Program for viewing, printing, and analyzing. In addition to the summary of key sampling parameters at the top, the file contains time delimited 5-minute averages of all sensors for analysis and sample validation. See Figure 8 for an N-FRM Sampler CSV file imported into Excel.



FILENAME: L0418026.CSV
SERIAL: 18026
SAMPLE: 0000
MODE: PROGRAM
START: 20/JUL/16 at 13:10
PROG DURATION: 01:00:00
SAMPLE DURATION: 1:00:00
SAMPLE VOLUME: 1.002
STANDARD VOLUME: 0.981
AVERAGE FLOW: 16.70
AVERAGE TEMP: 28.9
AVERAGE PRESS: 754
AVERAGE PM2.5: 0.000
AVERAGE PM10: 0.000
SET FLOW: 16.7
START VDC: 17.8
END VDC: 17.8

DATE	TIME	SECONDS	LPM_SET	LPM_ACT	VOL_M3	VOL_STD	TEMP_EXT	MMHG	WIND_AZ	WIND_MF	VOLTS	AMPS	TEMP_INT	P1	P2	PM2.5	PM10	FLAGS
20-Jul-16	13:15	300	16.7	16.71	0.084	0.082	27.7	754	0	0	17.8	0.191	30.1	0	0	0	0	NONE
20-Jul-16	13:20	300	16.7	16.7	0.167	0.165	27.3	754	0	0	17.8	0.187	31	0	0	0	0	NONE
20-Jul-16	13:25	300	16.7	16.7	0.251	0.246	28.4	754	0	0	17.8	0.185	31.4	0	0	0	0	NONE
20-Jul-16	13:30	300	16.7	16.7	0.334	0.328	28.6	754	0	0	17.8	0.184	31.8	0	0	0	0	NONE
20-Jul-16	13:35	300	16.7	16.7	0.418	0.408	29.4	754	0	0	17.8	0.183	32.4	0	0	0	0	NONE
20-Jul-16	13:40	300	16.7	16.7	0.501	0.492	28.1	754	0	0	17.8	0.182	32.7	0	0	0	0	NONE
20-Jul-16	13:45	300	16.7	16.7	0.585	0.572	28.9	754	0	0	17.8	0.182	32.8	0	0	0	0	NONE
20-Jul-16	13:50	300	16.7	16.7	0.668	0.652	29.7	754	0	0	17.8	0.18	33.1	0	0	0	0	NONE
20-Jul-16	13:55	300	16.7	16.71	0.752	0.734	29.8	754	0	0	17.8	0.18	33.3	0	0	0	0	NONE
20-Jul-16	14:00	300	16.7	16.71	0.835	0.816	29.6	754	0	0	17.8	0.18	33.5	0	0	0	0	NONE
20-Jul-16	14:05	300	16.7	16.7	0.919	0.898	30.1	754	0	0	17.8	0.179	33.8	0	0	0	0	NONE
20-Jul-16	14:10	300	16.7	16.71	1.002	0.979	29.6	754	0	0	17.8	0.179	33.9	0	0	0	0	NONE

Figure 8. CSV file imported into Excel

The LOG file name is an 8-digit number designated as 'NNNNJJJH'.

NNNN = Last 4 digits of Sampler serial number
JJJ = Start day of sampling event , Julian (Ordinal) Day Number (Example: February 5th = 36)
H = Start hour of sampling event, Letter (Example: 2 a.m. = B)

The following is a description of the sampling parameters found in the exported LOG file:

PARAMETER	DESCRIPTION
DATE	Sample Date (Day-Month-Year)
TIME	Sample Time Interval (5 minute averages)
SECONDS	Interval Time (seconds)
SLPM_STD	Flow Rate (standard conditions, SLPM)
LPM_LTP	Flow Rate (Local Temp and Press, LPM)
VOL_M3	LTP Sample Volume (cubic meters, accumulated)
VOL_STD	Sample Volume at Standard Conditions (cubic meters, accumulated)
TEMP_EXT	External Temperature (degrees Celsius)
MMHG	Barometric Pressure (mmHg)
WIND_AZ	Wind Azimuth (degrees)
WIND_MPS	Wind Speed (meters per second)
VOLTS	Battery Voltage
AMPS	Battery Amps
TEMP_INT	Internal Temperature (degrees Celsius)
PM2.5	Estimated Concentration (micrograms per cubic meter)
PM10	Estimated Concentration (micrograms per cubic meter)
AQI	US-EPA PM2.5 Air Quality Index
FLAGS	NONE – No errors during sampling B – Battery failed, not enough voltage F – Flow rate could not be maintained W – Wind direction is in programmed sector A – Amps are too high. Possible pump failure. V – External Valve activated (cartridge sampler option)

PUGET SOUND
Clean Air Agency

Tacoma and Seattle Air Toxics Trends Technical Report

In Fulfillment of EPA Grant XA01J87901

December 2023

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For more information about this report, please contact Graeme Carvlin at (206) 689-4082 or Erik Saganić at (206) 689-4003.

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Accessibility

The Seattle and Tacoma Air Toxics Trends report is available for viewing or downloading on the internet at **https://www.pscleanair.gov/**

Links to additional documents for download are also available at the web site.

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This material is available in alternate formats for people with disabilities. Please call Joanna Cruse at 206-689-4067.

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Report authors and researchers

Lead author: Graeme Carvlin

In alphabetical order:

- Graeme Carvlin
- Matt Harper
- Isha Khanna
- James Laing
- Clément Miège
- Adam Petrusky
- Erik Saganić
- Phil Swartzendruber

Contents

List of figures

List of tables

List of appendices

Appendix A. Monitoring site descriptions

Appendix B. Quality assurance

Appendix C. Meteorology representativeness

Appendix D. Pollution roses for $PM_{2.5}$ and black carbon

Appendix E. Low carbon tetrachloride samples

Appendix F. The effect of temperature on aldehydes

Appendix G. Comparison of Purple Air data to NFRMs

Appendix H. Community interest: Attempt to spatially extrapolate moss study results to air samples

Appendix I. Community interest: Attempt to map pollutant-specific and zoning maps for moss comparison

Appendix J. Comparison to Portland moss study

Appendix K. PMF site pie charts and factor profiles

Appendix L. Additional PMF analysis including air toxics

Appendix M. Metal ratios compared to crustal abundance ratios

Appendix N. Single race graphs for average potential cancer risks from on-road diesel particulate matter

Appendix O. Box plots for PAHs

Appendix P. Summary statistics for fixed sites

Appendix Q. Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) model estimates

List of abbreviations

AQS	Air Quality System
ASIL	Acceptable Source Impact Level
BC	Black carbon
CFR	Code of Federal Regulations
CO	Carbon monoxide
DAS	Data Acquisition System
DQOs	Data Quality Objectives
EPA	Environmental Protection Agency
EtO	Ethylene Oxide
GIS	Geographical Information System
GPS	Global positioning system
IO	Inorganic (refers to methods for measuring inorganic compounds)
MQOs	Measurement Quality Objectives
m^3	Cubic meter
NAAQS	National Ambient Air Quality Standard
NATA	National Air Toxics Assessment
NATTS	National Air Toxics Trends Stations
N-FRM	Near - Federal Reference Method
ng	Nanogram (10^{-9} grams)
NO	Nitric oxide
NO$_2$	Nitrogen dioxide
NOx	Nitrogen oxides (NO + NO2)
NOy	Total reactive nitrogen. The sum of NOx, nitric acid, and organic nitrates.
PAHs	Polycyclic aromatic hydrocarbons
PM$_{2.5}$	Particulate matter less than 2.5 micrometers in diameter
PM$_{10}$	Particulate matter less than 10 micrometers in diameter
PMF	Positive Matrix Factorization
ppb	Parts per billion
ppm	Parts per million
PSCAA	Puget Sound Clean Air Agency
PUF	Poly-urethane foam
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan

SLAMS	State and Local Air Monitoring Stations
SOP	Standard Operating Procedures
STN	Speciation Trends Network
SVOC	Semi-Volatile Organic Compounds
TO	Toxic Organic (refers to methods to measure toxic organic compounds)
UFP	Ultrafine particles
VOCs	Volatile organic compounds
μg	Microgram (10^{-6} grams)

Executive summary

Air toxics are a broad group of chemicals found in air that are known to or suspected to cause serious health problems. Potential health effects are broad and include cancer, lung damage, and nerve damage, and more systemic effects.[1] Typical air toxics found in our region include individual chemicals like benzene and formaldehyde, but also include mixtures like diesel particulate matter and wood smoke. The Agency has made observations of air toxics for over two decades in partnership with the Washington State Department of Ecology and the US Environmental Protection Agency.

This study updates air toxics health risks and trends. This study also included community-directed air monitoring, which focused on metals (within dust size particles 10 micrometers in diameter or smaller known as PM_{10}) at the Duwamish Valley community's request.

We sampled at six sites over the course of a year spanning 2021-2022. These sites, which are in our routine regulatory network, were equipped with instruments that measure volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), PM_{10} metals, and metal and ion speciated fine particles (particles 2.5 micrometers or smaller known as $PM_{2.5}$).

Our study's main finding was that overall cancer risk from air toxics continues to be dominated by diesel particulate matter, with around 85% of the risk across all sites. The other 15% is split between estimated hexavalent chromium (~6%), wood smoke (~4%), and other compounds. A total of 12 compounds had a cancer risk over our health screening cancer threshold of one-per-million potential cancer risk. One compound was above the non-cancer health threshold, acrolein, though levels were similar to other sites across the country. All other air toxics monitored (n=26) were below both the cancer risk and non-cancer risk screening thresholds.

These air toxics contributions are consistent with our previous studies in our region dating back to 2003, showing that diesel particulate matter was and continues to be the major contributor to cancer risk from air pollution. We also found **wood smoke is still a contributor to air toxics risk in the region**, with levels of benzene and other air toxics at wood smoke sites being comparable or higher than industrial sites. Wood

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[1] US EPA "What are Air Toxics" Module, extracted Oct 2023, https://airknowledge.gov/Mod/What_Are_Air_Toxics/Web/index.html#/

smoke levels have decreased from many efforts, including outreach, incentive programs to recycle older stoves, and enforcement.

Despite our region growing 30% in population, **air toxics levels have dropped by half since we started monitoring for them in 2003**. Improved technology standards, particularly for cleaner engines, fuels, and wood stoves have resulted in significant reductions in air toxics, particularly in diesel particulate matter.

In this report, we identified on-road diesel particulate matter exposure is not equitably distributed. **We found Black, Indigenous, and other people of color and lower income households have higher potential cancer risks from living near major freight corridors.** In our region, targeting diesel particulate matter can have a great impact on addressing socioeconomic differences in pollution exposure and health outcomes.

Ethylene oxide is a newly prioritized air toxic since its unit risk factor was updated in 2016 to be 34 times more protective. And in 2019, the Washington State Department of Ecology updated the acceptable source impact level for ethylene oxide to be 57 times more protective; incorporating age dependent factors to account for the extra impact to children. Past comparisons to other monitors around the country showed the lowest levels of ethylene oxide were in Western Washington (Seattle Beacon Hill and Lacey, WA). Our comparison in this study showed median levels to be uniform (with the lowest site within 32% of the highest site). From our results, **we could not conclude any obvious sources of ethylene oxide to our region**. Ethylene oxide sampling has two known issues: the limited ability to detect the very low concentrations of ethylene oxide in ambient air and issues with sampling canisters being contaminated by previous uses. Most of our ethylene oxide samples were flagged for these reasons. Therefore, we didn’t include ethylene oxide potential cancer risk in the summary results. However, we did include concentration box plots within this report. When quality assurance methods improve, we will revisit estimating potential cancer risk from ethylene oxide.

For the **community-directed sampling,** we worked with a community partner, the Duwamish River Cleanup Coalition (DRCC), to gather community concerns, locations to sample, and types of pollution to sample. Throughout the analysis phase of the study, we shared initial results with the community. Now that the study is complete, we will continue to discuss the results with the community to understand their interpretation and discuss follow up actions.

The community was interested in sampling PM_{10} metals to build upon the metals-in-moss studies[2] performed by DRCC, the Duwamish Valley Youth Corp, Western Washington University, the US Forest Service, and others. In that study the Duwamish Valley Youth Corp took samples of moss from trees around the Duwamish Valley and sent samples to a lab to measure the amount of metals in the moss. While moss sampling may show gradients of metal levels, the values are not directly related to human exposure pathways and ambient air levels. This community-led sampling effort provided an opportunity to perform follow up air sampling for PM_{10} metals in areas that the community identified to be of concern from moss sampling.

The community chose five sites, two in industrial areas and two in residential areas in Georgetown and South Park and one next to King County International Airport (Boeing Field). Overall, **metals levels at the industrial and residential sites were similar to our longstanding Duwamish Valley air monitoring site**, which was established in 1971.

We estimated that **hexavalent chromium has the highest potential cancer risk of PM10 metals in ambient air in the Duwamish Valley**. Arsenic was next highest, with risks of 5 per million or less. The remaining metals were all below the one-in-a-million potential cancer risk screening level, and none were over non-cancer screening levels. To estimate hexavalent chromium, we applied the best available but outdated ratio based on a previous sampling[3] and a meta-analysis study[4]. **We will conduct a follow-up study starting in 2024 to measure current hexavalent chromium to total chromium ratios.** If the follow up study shows substantial differences, we will publish an addendum to this report to update potential cancer risk from hexavalent chromium.

Measured lead levels were well below the EPA health-based standard and health screening level. Additionally, lead levels were lowest at our near-airport site. Community and others have expressed recent concerns with leaded fuels from propeller planes still used at King County International Airport. The Duwamish Valley

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[2] Duwamish River Community Coalition, 2019, "Moss Study Community Fact Sheet", https://static1.squarespace.com/static/5d744c68218c867c14aa5531/t/5f10f3cae34eb20502407d57/1594946507283/Duwamish+moss+Fact+Sheet+final.pdf.

[3] PSCAA, 2013 Air Quality Data Summary, http://dl.pscleanair.org/Datasummaries/AQDS2013.pdf.

[4] Torkmahalleh M.A., Yu C.H., Lin L., Fan Z., Swift J.L., Bonanno L., Rasmussen D.H., Holsen T.M., Hopke P.K. (2013). "Improved atmospheric sampling of hexavalent chromium". J Air Waste Manag Assoc. 63(11):1313-23.

did have higher lead levels than other study sites, but still far below health benchmarks.

In our report, we hypothesize that **dust resuspended by vehicles is a main contributor to the metals found in our air samples and in moss samples**. The near-airport site had the lowest metal values overall and was set back furthest from any vehicle traffic.

Based on the findings from this report, **we will continue to focus on reducing diesel particulate matter in our region** through emissions reduction incentives. The Agency leverages grant funding to switch diesel vehicles to cleaner and electric vehicles and to remove old highly polluting wood stoves. This is work that we have been doing for many years, starting with our Diesel Solutions program—developed following the recommendations in the original 2003 air toxics study.

We will also continue to address wood smoke. We heavily invested in our wood stove programs following EPA designating Tacoma-Pierce County nonattainment in 2009 for $PM_{2.5}$. Today, we continue to support wood smoke reductions through outreach, incentives, and enforcement.

We also actively work with industry to comply with regulations through our inspection, permitting, and complaint response programs.

As we move forward with our 2030 Strategic Plan, we will use the information obtained through this study to help guide our work to address the most harmful air pollutants and reduce socioeconomic disparities in air pollution health risk.

Introduction

In 2020, the United States Environmental Protection Agency (EPA) awarded the Puget Sound Clean Air Agency (Agency) a Community Scale Air Toxics Grant to characterize the impacts of air toxics in communities in and around Seattle and Tacoma, Washington. The air toxics study includes updating baseline potential cancer risk values, looking at trends, and spatial analyses. The award also funded a community-directed portion to follow up on community concerns about metals in the Duwamish Valley. This grant was a three-year award.

Our Agency is a municipal corporation dedicated to healthy air, climate, and environmental justice for the benefit of all people in the Puget Sound region. The mission of the agency is to preserve, protect, and enhance air quality and public health, enforce the Clean Air Act, support policies that reduce climate change, and partner with communities to do this work equitably.

The purpose of this report is to analyze the long-term trends associated with air toxics risks, in the hopes of informing policymakers, educating the public, and focusing resources on where the pollution reductions can make the most impact to improve the health and well-being of all people in King, Pierce, Kitsap, and Snohomish counties.

In this study, we collected air toxics samples over one year in 2021 and 2022 in the Seattle and Tacoma areas. In our analysis, we also included various air toxics studies in the region over the last two decades to make comparisons. We also included data from the National Air Toxics Trends monitoring site at the Beacon Hill station that is run by the Washington State Department of Ecology (Ecology).

Background

The Agency has completed several air toxics studies and analyses over the years. This section gives a brief overview of the studies included in our analysis.

For this project, we built upon the results of our previous studies and community engagement work to characterize the impacts of air toxics in environmentally overburdened communities in Seattle and Tacoma.

Agency Overburdened Communities

We sampled in areas that are a priority for the Agency: all monitoring sites in this study were completed within our Agency Overburdened Communities Map. Our Community Air Tool shows that the area where we did community-directed sampling in the Duwamish Valley is one of the most disproportionately impacted areas in our region.

Community-directed sampling: community interest in metal sampling

Based on past air deposition studies, both the Seattle Duwamish Valley and Tacoma Tideflats industrial areas have higher levels of metals from atmospheric deposition compared to other areas.[5,6] A more recent metals-in-moss sampling study (in 2019, led by a group of Duwamish Valley partners including support from the US Forest Service and Duwamish Valley Community Coalition) in the Seattle Duwamish Valley found metal gradients in moss samples, and raised questions about how that translates to air quality health risks.[7]

We actively engaged with community members from the Georgetown and South Park neighborhoods of the Duwamish Valley to gather input. We engaged early in the planning process for this grant. This included gathering input online and through an in-person public workshop that resulted in the identification of pollutants of concern at five locations in the Duwamish Valley, including specific feedback telling us where to monitor in the Georgetown and South Park neighborhoods. The community also emphasized an interest in sampling for metals based on recent metals-in-moss sampling results collected by the Duwamish Valley Youth Corps.

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[5] King County Department of Natural Resources and Parks, Dec 2013, "Lower Duwamish Waterway Source Control: Bul Atmospheric Deposition Study Final-Data Report", https://your.kingcounty.gov/dnrp/library/wastewater/iw/SourceControl/Studies/Air/2013/LDW_BulkAirDepFinalDataReport_Dec2013.pdf.

[6] Washington State Department of Ecology, "Control of Toxic Chemicals in Puget Sound Phase 3: Study of Atmospheric Deposition of Air Toxics to the Surface of Puget Sound", Pub no 10-02-012, 2012, https://apps.ecology.wa.gov/publications/UIPages/documents/1002012.pdf.

[7] Duwamish River Community Coalition, 2019, "Moss Study Community Fact Sheet", https://static1.squarespace.com/static/5d744c68218c867c14aa5531/t/5f10f3cae34eb20502407d57/1594946507283/Duwamish+moss+Fact+Sheet+final.pdf.

Previous studies: diesel particulate matter is the highest priority air toxic

Previous studies have highlighted that traffic pollution is a significant source of air toxics risk nationally and in our region. In 2003, the Agency and Ecology completed a toxics study in the Seattle area.[8] This study found that the most important air toxics risk was from diesel particulate matter (with 70-85% of total potential cancer risk from air toxics) and wood smoke, with significant contributions from formaldehyde, hexavalent chromium, and benzene. This 2003 study did not include a near-road monitoring site.

In 2010, in partnership with the University of Washington, we completed another air toxics monitoring campaign that extended the evaluation to three sites in the Tacoma area and the industrial valley in Seattle.[9] This study identified vehicles, specifically diesel particulate matter, as the main source of air toxics risk in the region (with over 70% of the total potential cancer risk from air toxics). The study also confirmed that wood smoke was also an important contributing factor. The 2010 study confirmed much of the knowledge gained from the 2003 study, including the pollutants that drive air toxics risk in the region.

Our most recent air toxics study was completed in 2018 and looked at near-road emissions centered in Seattle's Chinatown-International District (CID).[10] We used novel approaches with positive matrix factorization (PMF) using air toxics data to identify two types of diesel emissions from highway traffic, a "fresh" near-road diesel factor and evidence of a "background" diesel factor. This project also included community-directed samples that showed an expected spatial gradient from the adjacent freeways and was dominated by diesel PM air toxics risk. In this study, diesel particulate matter contributed over 75% of the total potential cancer risk from air toxics.

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[8] Puget Sound Clean Air Agency, "Final Report: Puget Sound Air Toxics Evaluation", 2003, https://pscleanair.gov/DocumentCenter/View/2355/Puget-Sound-Air-Toxics-Evaluation-Final-ReportPDF?bidId=.

[9] Puget Sound Clean Air Agency, "Tacoma and Seattle Area Air Toxics Evaluation", 2010, https://pscleanair.gov/DocumentCenter/View/2361/Tacoma-and-Seattle-Area-Air-Toxics-Evaluation-Full-ReportPDF?bidId=.

[10] Puget Sound Clean Air Agency, "Near-road Air Toxics Study in the Chinatown-International District", 2018, https://pscleanair.gov/DocumentCenter/View/3398/Air-Toxics-Study-in-the-Chinatown-International-District-Full-Report.

Ethylene oxide

In 2016, the EPA Integrated Risk Information System (IRIS) updated the cancer risk factor for ethylene oxide,[11] listing it as significantly more carcinogenic than previously estimated. Also, EPA has recently included ethylene oxide in the standard suite of measured volatile organic compounds. Prior to this study, limited sampling at the Seattle Beacon Hill site showed a few values above the detection limit. However, because the cancer risk factor was increased, samples that just meet the detection limit now translate to cancer risk estimates in the hundreds per million potential cancer risk. In this study, we aimed to collect more ethylene oxide samples around the region to see how the Beacon Hill site compares and identify potential sources.

Sampling study design

Overview

The sampling was primarily designed to update air toxics risks in the Puget Sound region. By studying areas where we have measured air toxics risks in previous campaigns, we also designed the study to evaluate long term trends. Additionally, we designed the study to better estimate risks from specific sources using $PM_{2.5}$ speciation data and source apportionment techniques.

Core fixed monitoring locations used in this study included three sites in Seattle and three sites in Tacoma. The sites included: Seattle Duwamish (industrial area), Seattle 10th & Weller (near-road), Seattle Beacon Hill (NATTS - National Air Toxics Trends Station), Tacoma Tideflats (industrial site), Tacoma South L Street (residential), and Tacoma South 36th Street (near-road). Seattle Beacon Hill and the near-road sites are operated by Ecology. The core monitoring site locations can be found on Figure 1 and further details in Appendix A. The core monitoring stations are already part of the approved Ecology State and Local Air Monitoring Stations (SLAMS) network.

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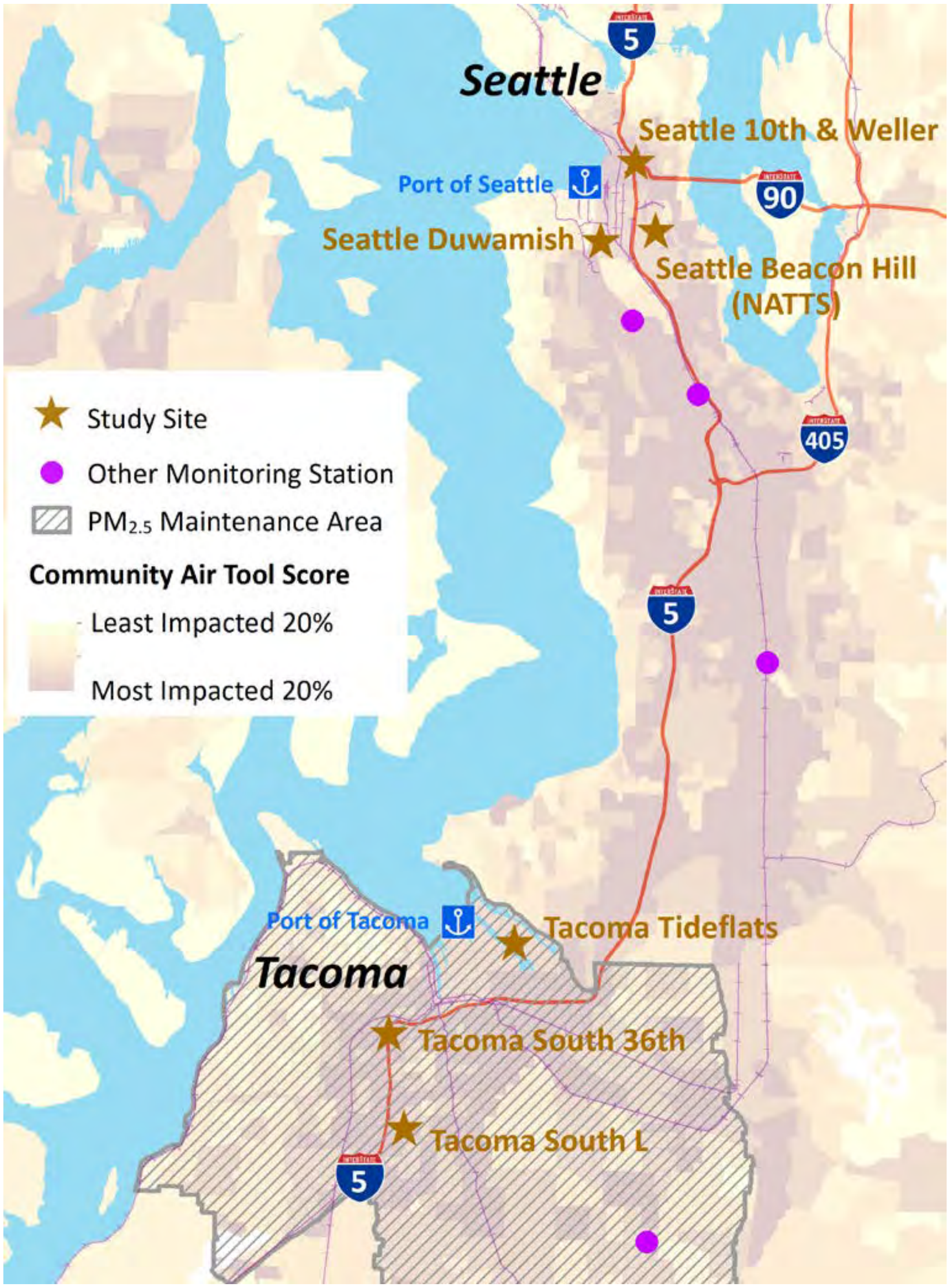
[11] EPA Integrated Risk Information System, Ethylene Oxide, 2016, https://iris.epa.gov/ChemicalLanding/&substance_nmbr=1025.

Figure 1. Study sites, $PM_{2.5}$ maintenance area, and an Agency environmental justice map (Community Air Tool) scores.



Since the Seattle Beacon Hill site is a NATTS site, there is a historical record of air toxics since 2000 at this location. The Beacon Hill site data served as a consistent historical trend at the urban spatial scale. The urban spatial scale is defined by EPA as a site which can represent overall city conditions with dimensions on the order of 4 to 50 kilometers. Seattle Duwamish, Tacoma Tideflats, and Tacoma South L Street were also used in the 2009 air toxics study. These sites are defined by EPA as neighborhood-scale sites, which represent concentrations within some extended area of the city that has relatively uniform land use with dimensions in the range of 0.5 to 4 kilometers.

The near-road monitoring sites were established by updated EPA requirement; Seattle 10th & Weller in 2014 and Tacoma South 36th Street in 2016. These sites were designed to collect data on mobile sources from nearby large freeways. We utilized the Seattle and Tacoma near-road sites to quantify air toxics from freeways. Near-road sites are generally considered microscale, defined as concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 meters. The usefulness of the microscale sites is that they are designed to achieve an understanding of the highest concentrations of air pollutants. Near-road monitoring locations are helpful for characterization of air toxics emissions and risks from freeways.

Sampling details

Table 1 shows the sampling equipment that was added specifically for this study. More details can be found in the data completeness table located in Appendix B (Table B-1). The following table, Table 2, shows the sampling equipment that was already in-use at the study sites and could be leveraged.

Table 1. Sampling sites, parameters monitored, duration, and frequency.

Sites	Measured parameters	Duration	Monitoring Frequency
Tacoma S L Street (residential)	Select VOCs (Note A) Select aldehydes (Note B)	August 2, 2021 – Sep 2, 2022	1 in 6 1 in 6
Tacoma Tideflats (industrial)	Select VOCs (Note A) Select aldehydes (Note B) PM_{10} metals	August 2, 2021 – Sep 2, 2022	1 in 6 1 in 6 1 in 6
Tacoma S 36th street (near-road)	Select VOCs (Note A) Select aldehydes (Note B)	August 2, 2021 – Sep 2, 2022	1 in 6 1 in 6
Seattle 10th and Weller (near-road)	Select VOCs (Note A) Select aldehydes (Note B)	August 2, 2021 – Sep 2, 2022	1 in 6 1 in 6
Seattle Duwamish (industrial)	Select VOCs (Note A) Select aldehydes (Note B) PM_{10} metals (Note C) Polycyclic Aromatic Hydrocarbons (PAHs) (Note D)	August 2, 2021 – Sep 2, 2022	1 in 6 1 in 6 1 in 6 1 in 6
Community-directed sites	PM_{10} metals $PM_{2.5}$ sensors	Summer 2022 start dates varies between sites	Week-long samples per request to cover as much time as possible with no breaks

Note A: Benzene, 1,3 butadiene, carbon tetrachloride, tetrachloroethylene, ethylbenzene, acrolein, and ethylene oxide.

Note B: Formaldehyde and acetaldehyde.

Note C: Antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium.

Note D: Acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, coronene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, perylene, phenanthrene, and pyrene.

Table 2. Sampling sites and leveraged monitoring parameters for analysis.

Sites	Leveraged parameters (not funded by this grant)	Procedure (see QAPP)
Tacoma S L Street (residential)	$PM_{2.5}$ $PM_{2.5}$ speciation Temperature, winds Black carbon	$PM_{2.5}$ SOPs CSN-Supplemental Met SOP Black carbon SOP
Tacoma Tideflats (industrial)	$PM_{2.5}$ $PM_{2.5}$ speciation Temperature, winds Black carbon	$PM_{2.5}$ SOPs CSN-Supplemental Met SOP Black carbon SOP
Tacoma S. 36th street (near-road)	NO_2, NO, NO_X $PM_{2.5}$ Temperature, Winds Traffic Counts Black carbon	NOx SOPs $PM_{2.5}$ SOPs Met SOP WA DOT Black carbon SOP
Seattle 10th and Weller (near-road)	NO_2, NO, NO_X, CO $PM_{2.5}$ $PM_{2.5}$ speciation Temperature, Winds Traffic Counts Black carbon	NOx, CO SOPs $PM_{2.5}$ SOPs CSN-Supplemental Met SOP WA DOT Black carbon SOP
Seattle Duwamish (industrial)	$PM_{2.5}$ $PM_{2.5}$ speciation Temperature, winds Black carbon	$PM_{2.5}$ SOPs CSN-Supplemental Met SOP Black carbon SOP
Seattle Beacon Hill	Full suite of VOCs PAH Aldehydes PM_{10} metals NO_2, NO, NO_X, SO_2, CO $PM_{2.5}$ $PM_{2.5}$ speciation Temperature, Winds	PAMS and NATTS NATTS PAMS and NATTS NATTS NCORE $PM_{2.5}$ SOPs STN and IMPROVE Met SOP

Select Volatile Organic Compounds (VOCs) - We used an established Standard Operating Procedure (SOP) as described in Appendix A of the study Quality Assurance Project Plan (the School Air Toxics Program SOP for sampling VOC's using a passive regulator and timer for a 6L SUMMA canister). The equipment that we used was from Entech, which was equivalent to the equipment used in the SOP. The select VOCs that were sampled were based on prior air toxics monitoring of compounds that had potential cancer risks of one-in-a-million or higher. These compounds were benzene, 1,3 butadiene, carbon tetrachloride, tetrachloroethylene, ethylbenzene, acrolein, and ethylene oxide.

Select aldehydes - The Washington Department of Ecology (Ecology) previously used a carbonyl sampler called a XONTECK; and those samplers are no longer functional/available. Therefore, we acquired and tested the available ATEC samplers. We used an established SOP as described in Appendix B of the QAPP, and we used the same laboratory analytical methods so that our data can be comparable to historically collected data. The compounds measured were formaldehyde and acetaldehyde.

PM_{10} metals – We sampled for PM_{10} metals at two fixed industrial sites by using the Thermo (formerly Rupprecht & Patashnick) Model 2025 samplers that are already used in our state's Federal Reference Monitoring program. Our operators routinely operate these monitors using the Ecology SOP, and we followed the designation stated in Appendix I of the QAPP. These samplers were configured for collecting PM_{10} filters on a 1-in-6 sampling frequency for the year of the sampling campaign. We have a limited number of this model of instrument and due to their size, they could only be used at our primary sampling sites. For the PM_{10} Metals sampling at community determined sites, we used the N-FRM monitor provided by ARA per the procedure in Appendix L of the QAPP. The N-FRM monitors were tested and then configured for collecting filters for 1-week durations, which was the sampling period selected by the community. These samplers proved useful for collecting data in the five specific locations determined by the community. The metals sampled were Antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium.

Polycyclic Aromatic Hydrocarbons (PAHs) – We used a standard High Volume PUF sampler to collect samples for PAH analysis at the Duwamish industrial site per the SOP in Appendix C of the QAPP. This method is identical to the one used for the NATTS sites. The compounds sampled were acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, coronene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, perylene, phenanthrene, and pyrene.

Black carbon (BC) – We used the Aethalometer AE-33 model sampler to collect the 7-channel black carbon continuous data for use in the analysis at each of the study sites, to give us a surrogate measure for diesel particulate matter.

Laboratory analysis was conducted by Eastern Research Group (ERG), the national contract laboratory for the NATTS program.

Table 3 below shows the frequency of field blanks and collocated sampling. QC checks were performed monthly on the ATECs, Partisols (PM_{10} metals), AE-33s, and BAMs. Leak checks were performed on VOC canisters before and after every sample.

Table 3. Frequency of blanks and collocated samples.

Sampler	**Blanks**	**Collocated Samples**
VOC canister (ENTECH)	None	One per 10 samples
Carbonyl samples	1 every 10 samples	One per 10 samples for the only 2-channel sampler (ESWA).
PAH samples	1 every 5 samples	None
PM_{10} HAP metals	1 every 5 samples	None

The EPA-approved Quality Assurance Project Plan (QAPP) provides a high level of detail about the sites, pollutants, locations, chemicals, periodicity of the monitoring, as well as the detailed site descriptions. The QAPP is available upon request.

The results of the collocations, blanks, flow checks, and other quality assurance parameters mostly met quality thresholds as outlined in the QAPP for all the data used for analysis included in this report. For collocated samples, seven out of the nine ethylene oxide duplicates were outside of 80-120% recovery. For all other analytes there were 19 duplicate samples outside of the 80-120% recovery window, out of 445 duplicate samples. In most of these cases the sample concentrations were low and at least one of the samples was less than 3 times the method detection limit. Appendix Table B-5 shows the duplicate samples that were outside 80-120% recovery and had both primary and duplicate sample concentrations greater than 3x the MDL.

For blank samples there were some analytes which had blank concentrations close to sample concentrations, but in most of those cases the concentrations were close to or below detection limits. Appendix Table B-6 provides the mean ambient concentration, mean field blank concentration, and mean MDL concentration for all sites and analytes at which field blank samples were collected.

Community sampling

We reached out to community members to involve them in discussions around the nature and objectives for the community sampling. Ultimately five sites were chosen to perform additional monitoring of air toxic metals using a PM_{10} sampler which collected material on a filter, which was further analyzed for air toxic metals. Table 4 shows the community feedback, describing the locations where the community desired extra sampling. Table 5 below shows the interest of community in the types of areas to do monitoring. Figure 2 shows a map of outreach results and corresponding locations of where monitors were eventually placed (green stars) with the corresponding name of the site. The level of community interest is represented by the size of the blue circles.

Table 4. Sampling locations selected by community.

Letter on Map	Location	Response
G	South Park residences	28%
C	The “triangle” (higher concentration from metals-in-moss study)	20%
D	Georgetown residences	15%
F	South Park industrial area (higher concentration from metals-in-moss study)	13%
H	Near King County Airport	11%
E	North Georgetown	8%
A	West industries	3%
B	North industries	3%

Table 5. Type of areas of interest to community.

Area type of interest	**Response**
Residential areas	34%
Higher concentration areas from the moss study (E Marginal Way S and northern South Park)	22%
Industrial sources	14%
How metal levels compare to other places with similar data, such as Tacoma or Beacon Hill in Seattle	11%
King County Airport	10%
Major roadways	8%

Figure 2. Map of outreach results and corresponding location of where monitors were placed.

Based on the community input, there were five temporary sampling locations which were chosen to sample for PM_{10} metals. Table 6 shows the sampling locations; community sites are in blue and core monitoring sites are in yellow. The community directed monitoring sites are considered middle-scale, which represents concentrations typical of areas up to several city blocks in size with dimensions ranging from about 100 meters to 0.5 kilometer.

The community indicated that for PM_{10} metals sampling, they preferred continuous monitoring to not miss any potential spikes in pollution during a week. Longer sample duration also helped collect enough sample that detection limit issues were less common. Therefore, for the temporary community-directed PM_{10} metals samples, we collected samples for week-long periods, and adjusted our Quality Assurance Practices to accommodate that change.

Sampling locations

Table 6 below shows the site locations used in the study. More detailed information, site descriptions, and satellite imagery can be found in Appendix A.

Table 6. Site names and addresses with permanent monitoring sites (first 6 rows) and community-directed sites (last 5 rows).

Site common name	**Site code**	**Site address***
Seattle 10th and Weller	BKWA	10th Ave S & S Weller St, Seattle, WA 98104
Seattle Beacon Hill	SEWA	4103 Beacon Ave S, Seattle, WA 98108
Seattle Duwamish	CEWA	4700 E Marginal Way S, Seattle, WA 98134
Tacoma Tideflats	EQWA	2301 Alexander Ave E, Tacoma, WA 98421
Tacoma 36th	YFWA	1802 S 36th St, Tacoma WA 98418
Tacoma South L St	ESWA	7802 S L St, Tacoma, WA 98408
Georgetown South Seattle College	UAWA	6737 Corson Ave S, Seattle, WA 98108
South Park Residential	UBWA	S Elmgrove St & 12th Ave S, Seattle, WA 98108
Georgetown Residential	UCWA	Carleton Ave S & S Willow St, Seattle, WA 98108
Georgetown Steam Plant	UDWA	6605 13th Ave S, Seattle, WA 98108
South Park Industrial	UEWA	S Fontanelle St. & 3rd Ave S, Seattle, WA 98108

* We only provide approximate locations for the residential community-directed sites.

Monitoring results

Most of our data come from monitoring we conducted between August 2021 and September 2022, but we were also able to leverage air toxics data from the Seattle Beacon Hill site and speciation data from Seattle 10th and Weller, Tacoma South L, and Tacoma Tideflats, with instruments maintained by the WA State Department of Ecology. The monitoring results in this section encompass the fixed sites and the community-directed sampling that occurred in the Seattle Georgetown and South Park neighborhoods in the summer of 2022. The data include air toxics (VOCs, Carbonyls, SVOC PAHs, PM_{10} metals), $PM_{2.5}$, black carbon, meteorology (barometric pressure, ambient temperature, wind speed and direction), and $PM_{2.5}$ chemical speciation. Summary statistics for fixed sites can be found in Appendix P.

Data considerations

Impact of wildfire smoke

Wildfire smoke impacts occurred in our region on August 12-14, 2021. August 12th and 13th had regional impacts, whereas the 14th was primarily isolated to eastern Snohomish County. So, even though August 14th was a sample day, the impacts were deemed to be minimal.

Weather summary and representativeness

The full extent of sampling for this project was from August 2, 2021 to September 2, 2022. The core sites Seattle 10th & Weller, Seattle Beacon Hill, Seattle Duwamish, Tacoma South L, Tacoma Tideflats, and Tacoma S 36th included VOCs, carbonyls, $PM_{2.5}$ speciation, and black carbon. These data represent slightly more than a full calendar year. The community-directed PM_{10} metals samples were collected during the following times: two sites ran from late July 2022 through September 2, 2022, two other sites ran from July 1, 2022 through Sept 2, 2022, and one site ran from March 25 through September 2, 2022 (Appendix B, Table B-1). These samples would represent only summer conditions.

For both time periods, it is important to note the degree to which these represent A) a typical year, B) a typical late summer, and C) how representative a late summer is in relation to a full year.

The primary meteorological factors for consideration of representativeness in this study are temperature, wind speed and direction, and precipitation. Based on past analyses of regional weather patterns, longer term anomalies (more than just a few days) are almost always regional, and so would not be confined to a single monitor. Therefore, precipitation from the University of Washington Atmospheric Sciences Building (about 5 miles to the north), and temperature, wind speed, and wind direction from the Duwamish site should be sufficient to address the issue of temporal representativeness for all sites.

As can be seen in Figure C-1 in the Appendix, the temperatures tracked the 10-year average fairly well. There were only a few large departures beyond +/- 1 standard deviation that were relatively short. The only notable deviance from the average was the period from mid-April through late June that was mostly below or well below average temperatures. This is likely indicative of greater than normal cloud cover and precipitation. During the metals sampling period of July though the beginning of September, the temperatures were close to average with a normal amount and range of variation.

A similar plot for daily average wind speeds is shown in Figure C-2 in the Appendix. November and December appear to be moderately windier, while January through mid-March appear to be somewhat calmer than typical. During the metals sampling period, winds appear to be fairly typical for that time of year.

Wind directions also appear to be typical for the past decade. As shown in Figure C-3 in the Appendix, the wind rose of wind speeds and direction for the sampling year are very similar to the past 10 years. The biggest difference appears to be a slightly lower frequency of winds from the NW. For the metals sampling period, there is also a close similarity between the sampling period and previous years. Figure C-4 shows the metals sampling year and the previous year during the same period. Other years (not shown) are very similar to the previous year. The largest observable difference is slightly more southerlies and fewer SSW in the metals sampling period (Jul-Aug, 2022).

Weekly precipitation is shown in Figure C-5. The full sampling period had the second highest total precipitation out of the adjacent 10 years (in the same period of the calendar year). Ten weeks had the greatest weekly precipitation of the full 10-year comparison period (5 or 6 would be typical). There were four notable periods: well above normal precipitation in late October/early November and briefly in early January; mid-January through mid-February was atypically dry; and May into early June were modestly wetter than normal. The metals sampling period (July and August) was almost completely dry, as is typical. Deviations from typical precipitation that would be worthy of noting for air quality purposes would be extended below normal precipitation in the winter and extended above normal precipitation in the summer.

Since the wind directions and speeds were close to normal, it appears unlikely that any typical major contributors would have been missed, or that any atypical sources would have been sampled. The only atypical meteorological factor that has the potential to influence or bias the results would be the greater than normal precipitation in the late fall and early winter. This may have reduced the amount of residential wood smoke that would have accumulated and been detected but could also have been offset by the relatively dry period from mid-January through mid-February. The other atypical weather pattern, modestly cooler temperatures and greater precipitation from mid-May through mid-June, could have reduced ozone production, but this would not impact any of the sample collection sites of this campaign.

Box plots

The box plots below show the 25th percentile (bottom of box), median (middle line in box), 75th percentile (top of box), and outliers (circles) for the compounds that we sampled. The whiskers are the furthest data point from the box within 1.5 times the inter-quartile range. The box plots are shaded only for aesthetic effect. Data from our sites are shown alongside data from 2019-2021 at all National Air Toxics Trend Stations (NATTS) sites. Only the sites which sampled for the given compound are shown. The dashed line is the minimum detection limit (MDL). Any values below the MDL may not be accurate. The asterisks next to site names indicate that a t-test showed the mean for that site was significantly ($p > 0.05$) different than the NATTS sites. In some graphs, very high outliers at NATTS sites are removed so that the boxes aren't shrunk so far that it makes them hard to compare visually. Boxplots for PAHs can be found in Appendix O. None of our sites had any PAH values above the MDL.

The purpose of the NATTS network is to provide long-term measurement of air toxics[12]. There are 26 NATTS sites; 21 urban and 5 rural. Some are located close to nearby air toxics sources and others measure primarily background concentrations. The NATTS network provides the most comprehensive national view of air toxics, however it is not strictly a national average.

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[12] Air Toxics Ambient Monitoring, EPA. 2023. https://www.epa.gov/amtic/air-toxics-ambient-monitoring#natts.

Acetaldehyde

The EPA lists acetaldehyde as a probable human carcinogen. Acute exposure to high concentrations of acetaldehyde is also associated with irritation of the eyes, throat, and lungs.[13] Main sources of acetaldehyde include wood burning and car and truck exhaust. Agency efforts that target vehicle exhaust and wood stove emission reductions also reduce acetaldehyde emissions. Since 2000, we found a statistically significant drop in risk from acetaldehyde at a rate of about 0.1 per million per year at Seattle Beacon Hill.[14]

The box plot in Figure 3 shows that our fixed sites are lower than most of the NATTS concentrations. Like formaldehyde, acetaldehyde is also readily formed in the atmosphere. So, we would expect the concentration patterns to be similar to formaldehyde.

Appendix F shows the relationship between acetaldehyde and temperature. Generally, acetaldehyde increases with increasing temperature.

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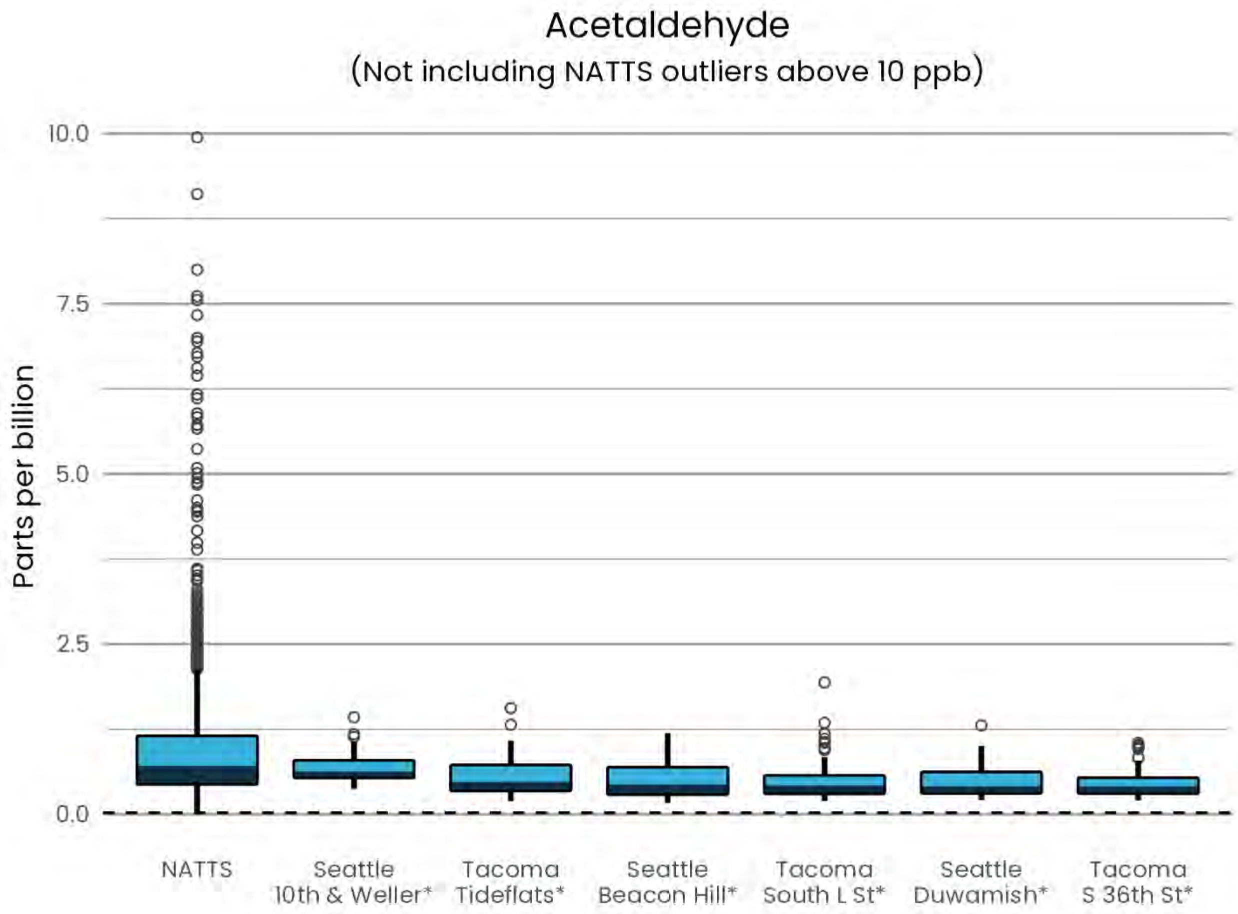
[13] EPA Hazard Summary, https://www.epa.gov/sites/production/files/2016-09/documents/acetaldehyde.pdf.

[14] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 3. Acetaldehyde box plot.



Acrolein

Only one air toxic, acrolein, failed the screen for non-cancer health effects, with measured concentrations consistently exceeding the reference concentration. Non-cancer health effects are measured using a parameter called the hazard quotient, where any value over 1 is beyond the reference concentration. A hazard quotient above 1 does not mean that health effects will definitely occur, however, a higher hazard quotient is associated with a higher likelihood of health effects. The average hazard quotient at our sites was 1.8, slightly higher than the NATTS average of 1.6. Acrolein is a byproduct of combustion of fossil fuels, high-temperature cooking of some foods, and cigarette smoking. It irritates the lungs, eyes, and nose.[15]

The box plot in Figure 4 below shows a higher median at most of our sites compared to NATTS sites, except for Beacon Hill.

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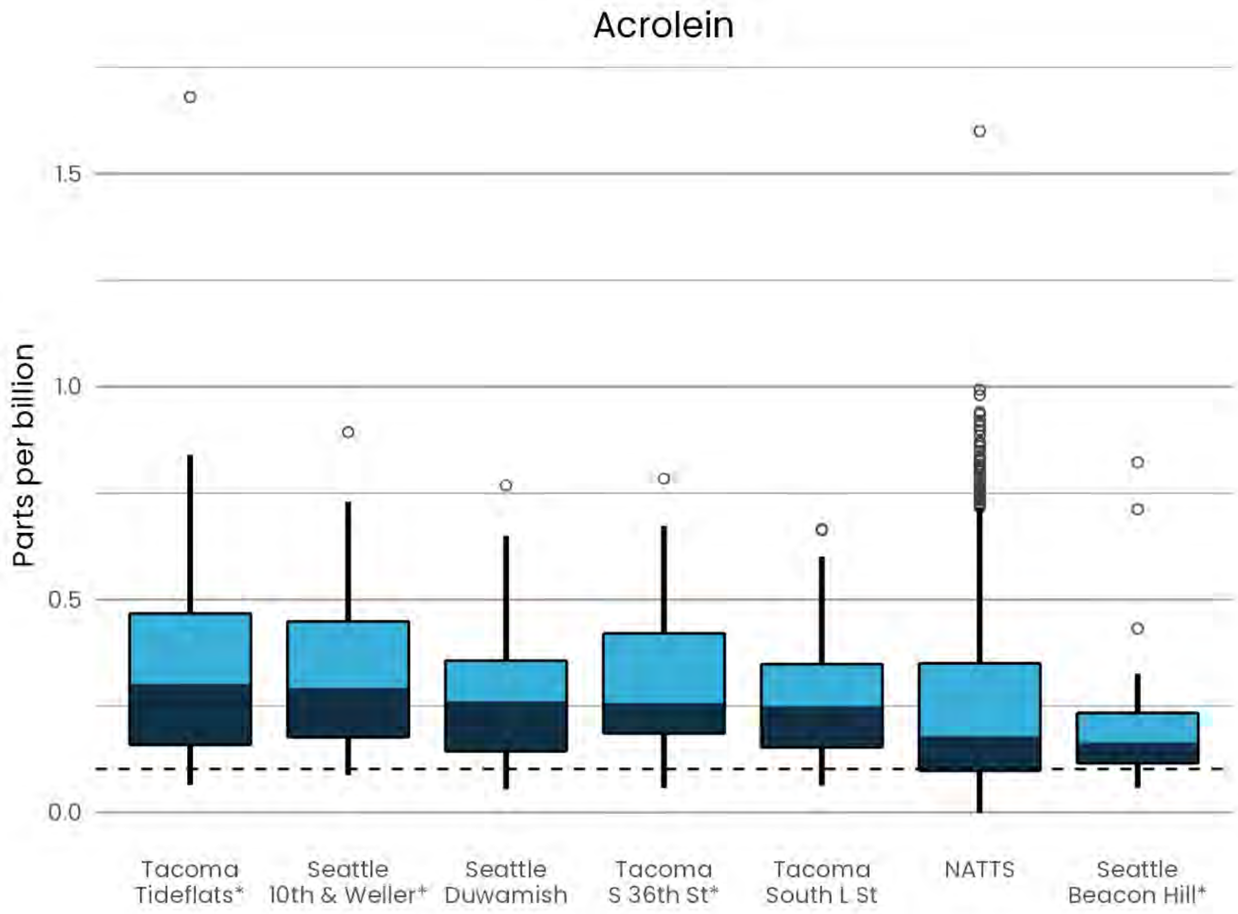
[15] EPA Hazard Summary, https://www.epa.gov/sites/production/files/2016-08/documents/acrolein.pdf.

Figure 4. Acrolein box plot.

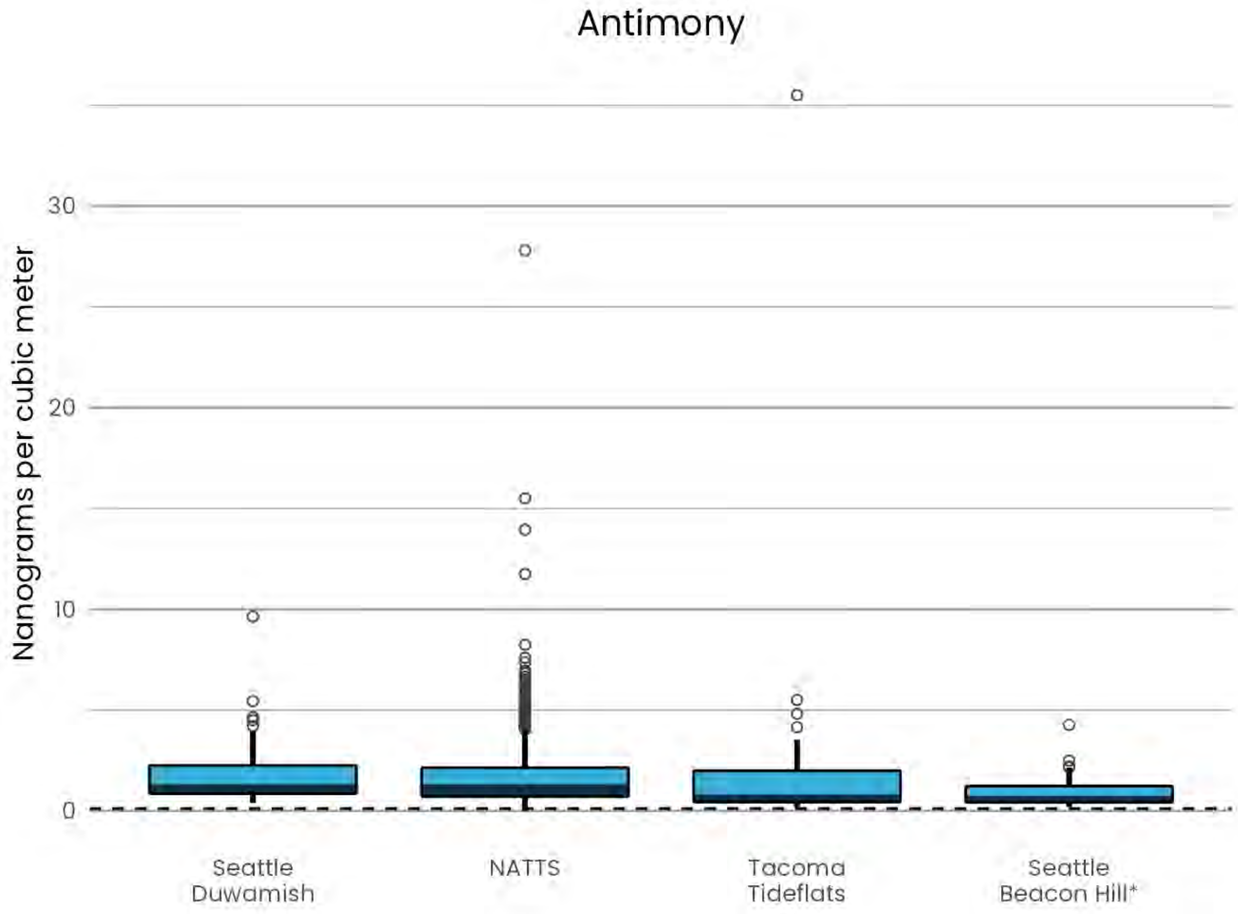


Antimony

Acute exposure to antimony can lead to irritation of the skin and eyes, while chronic exposure can cause lung inflammation and disease[16]. Antimony occurs naturally in the environment; however high levels can be produced by metal working industries. Many metal working businesses are regulated by our agency.

Figure 5 shows median antimony levels were higher at Duwamish than NATTS sites. However, Tacoma Tideflats and Beacon Hill were lower – with the exception of a single high sample at Tacoma Tideflats.

Figure 5. Antimony box plot.



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[16] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/antimony-compounds.pdf.

Arsenic

EPA lists arsenic as a known carcinogen. Exposure to arsenic is also associated with skin irritation and liver and kidney damage.[17] Arsenic is used to treat wood and was historically used in glass coloring. Combustion of distillate oil is also a source of arsenic in the Puget Sound area. Since 2000, we found a statistically significant drop in risk from arsenic at a rate of about 0.05 per million per year at the Seattle Beacon Hill site.[18]

The Agency's permitting program also works with and regulates industrial sources of arsenic to reduce emissions. Illegal burning can also contribute to arsenic emissions in our area.

The box plot in Figure 6 shows that arsenic is higher at the Duwamish and Tacoma Tideflats sites compared to the NATTS sites. Beacon Hill has a similar median as the NATTS sites.

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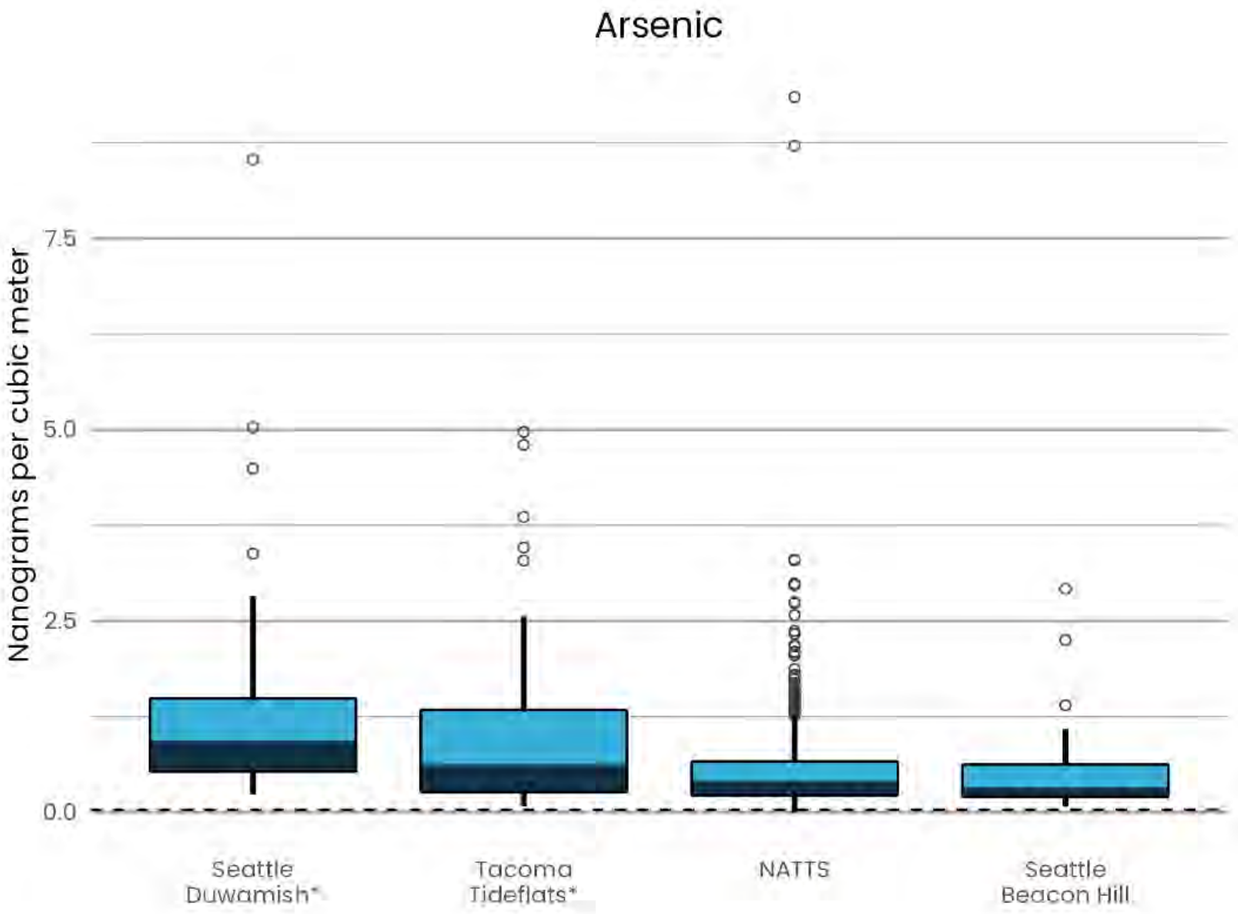
[17] EPA Hazard Summary, https://www.epa.gov/sites/production/files/2016-09/documents/arsenic-compounds.pdf.

[18] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 6. Arsenic box plot.



Benzene

The EPA lists benzene as a known human carcinogen. Benzene inhalation is also linked with blood, immune and nervous system disorders.[19] This air toxic comes from a variety of sources, including car and truck exhaust, cigarette smoking, wood burning, evaporation of industrial solvents, and other combustion.

Benzene levels are likely decreasing in our area due to factors including less automobile pollution with cleaner vehicles coming into the fleet, better fuels, and fewer gas station emissions due to reduced vapor loss and spills (better compliance and use of control measures). At the Seattle Beacon Hill site, we found a statistically significant drop in risk from benzene at a rate of about 0.35 per million per year since 2000.[20]

Figure 7 below shows the box plot for benzene. The median benzene was highest at the near-road site, 10th & Weller, which is located approximately 50 feet from I-5. The median benzene was also high at the other near road site, Tacoma S 36th St. The residential Tacoma location, S L St, with significant impacts from wood smoke in the winter months, had median levels comparable to the industrial valleys on an annual average. Meanwhile most of those higher days fell in the winter heating months with significantly lower levels in the summer months. The median values at most of the sites were comparable to the NATTS sites.

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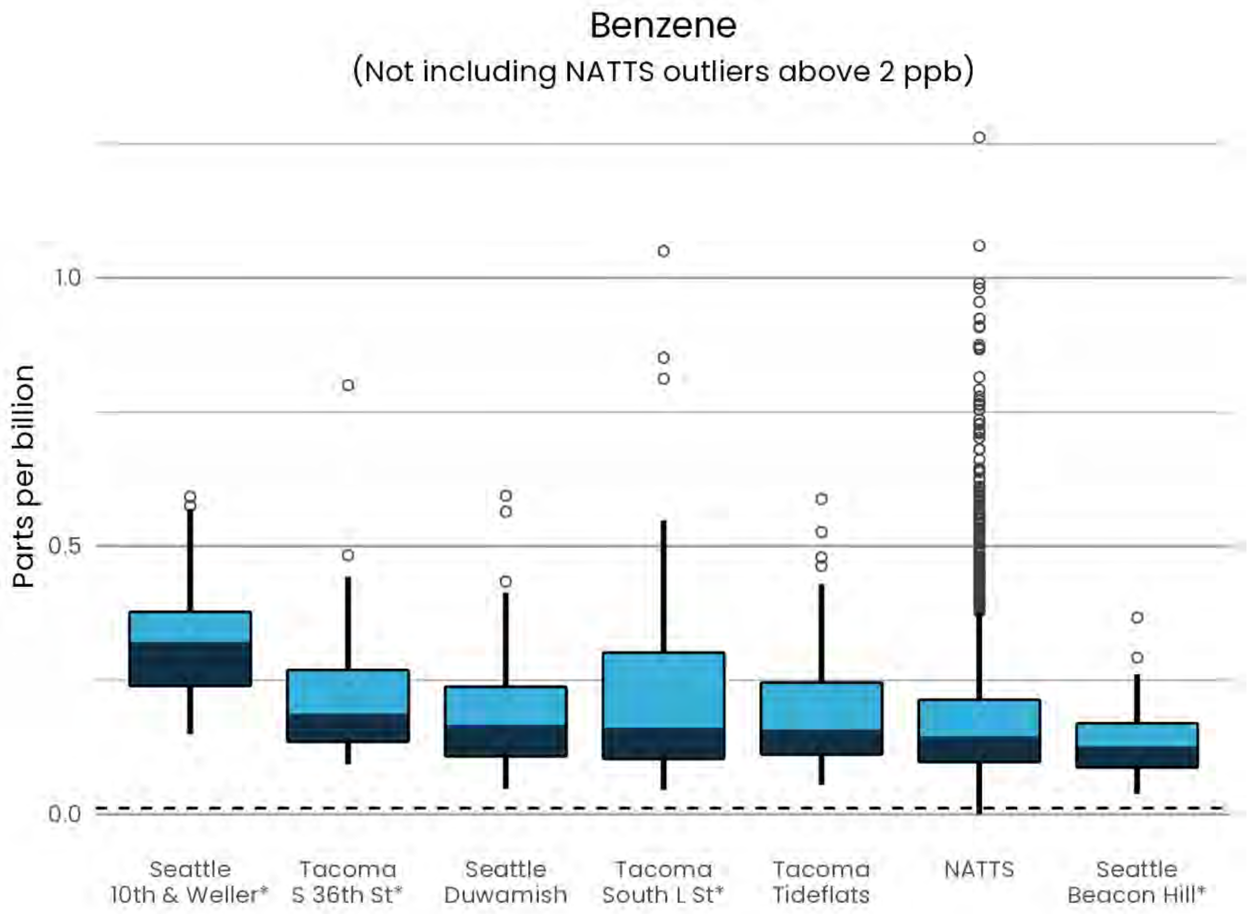
[19] EPA Hazard Summary; https://www.epa.gov/sites/production/files/2016-09/documents/benzene.pdf.

[20] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 7. Benzene box plot.

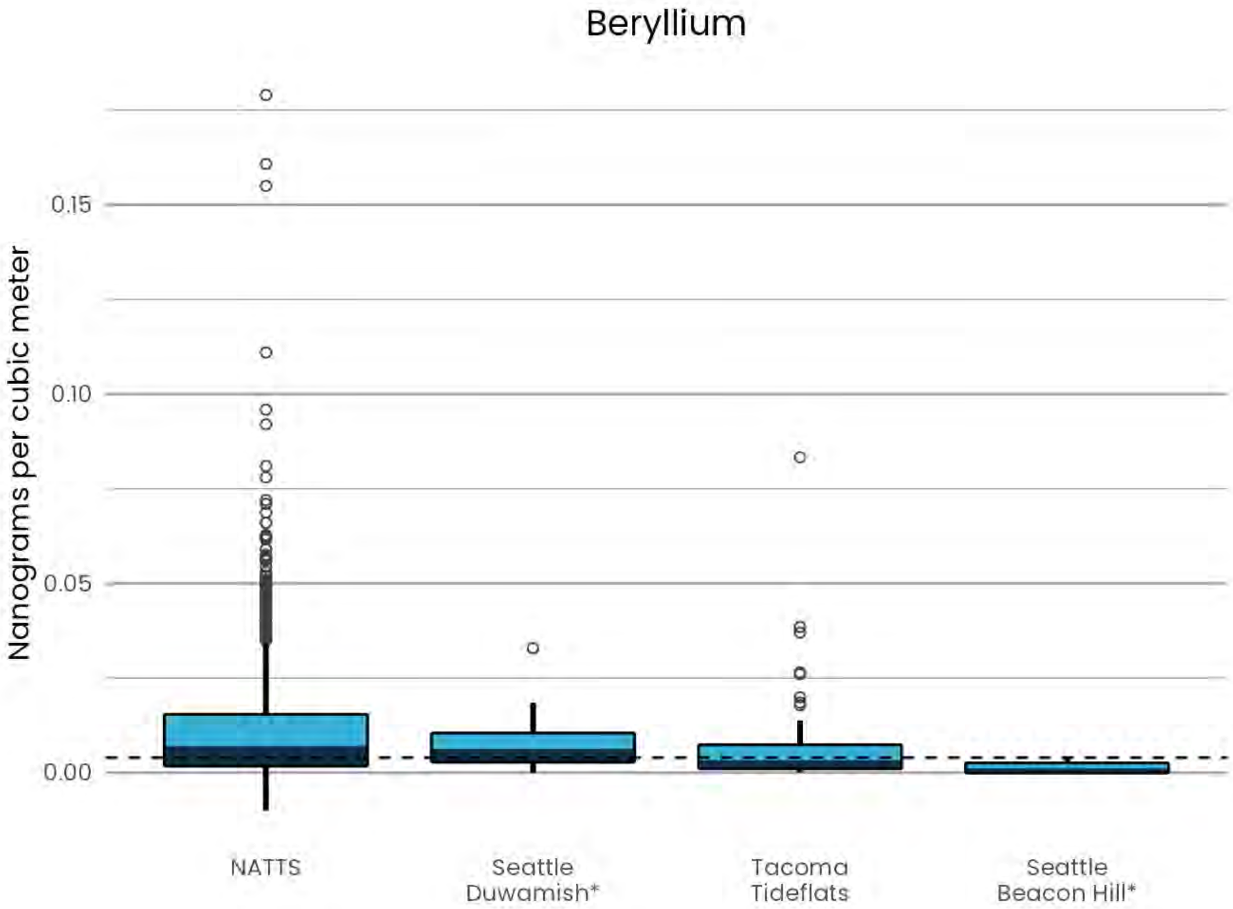


Beryllium

Acute exposure to high levels of beryllium can cause lung inflammation[21]. Chronic exposure can cause berylliosis, a disease characterized by non-cancerous lung lesions. EPA has classified beryllium as a probable human carcinogen. Beryllium occurs naturally in the environment. However, high levels can be produced by metal working industries. Many metal working businesses are regulated by our agency.

Figure 8 shows the median level of beryllium was higher at NATTS sites than our sites. However, Tacoma Tideflats did have a few days with higher concentrations.

Figure 8. Beryllium box plot.



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[21] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/beryllium-compounds.pdf.

1,3-Butadiene

The EPA lists 1,3-butadiene as a known human carcinogen, and inhalation is also associated with neurological effects. [22] Primary sources include cars, trucks, buses, and wood burning. Our Agency has efforts that reduce vehicle exhaust and wood stove emissions, which helps reduce 1,3-butadiene emissions. Since 2000, we have found a statistically significant drop in risk from 1,3-butadiene at the Seattle Beacon Hill site at a rate of about 0.1 per million per year.[23]

For this study, all our 1,3-butadiene concentrations were higher than the median of the rest of the NATTS. The highest sites were our near-road sites, 10th & Weller and Tacoma S 36th St. With most of our sites near a major highway, heavy diesel traffic, or wood burning households, we expect to have higher levels than most other NATTS sites. The exception is Beacon Hill, which is higher in elevation, further from I-5/I-90, and generally has lower air toxics levels that come from fuel combustion. As expected, the inter quartile range (IQR) of the Seattle Beacon Hill data falls within the IQR of the NATTS. Also, note there is substantial uncertainty in the values with many medians near the detection limit (dashed line).

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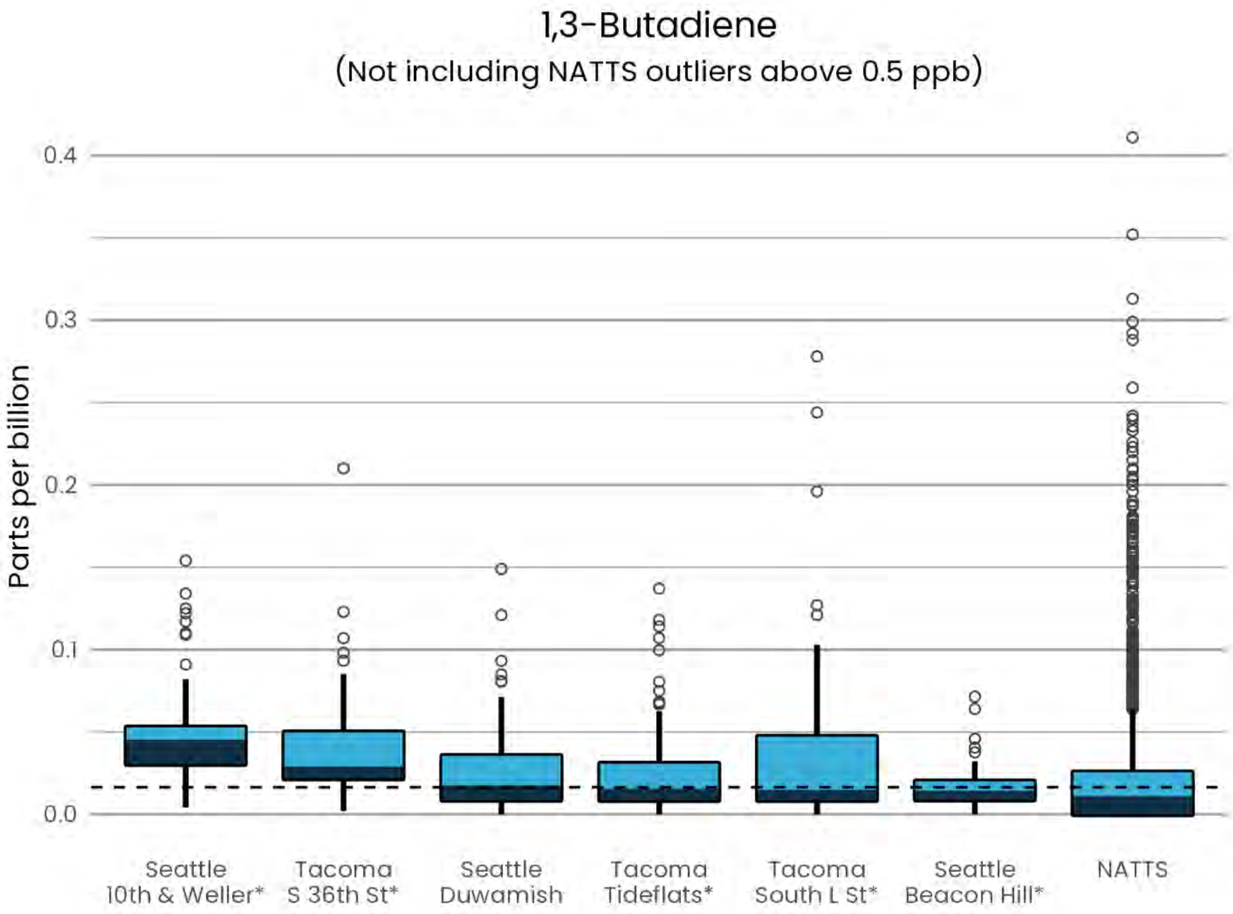
[22] EPA Hazard Summary; https://www.epa.gov/sites/production/files/2016-08/documents/13-butadiene.pdf.

[23] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 9. 1,3-butadiene box plot.



Cadmium

Acute exposure to cadmium can cause lung irritation[24]. Chronic exposure can cause kidney disease. EPA has classified cadmium as a probable human carcinogen. Cadmium is released by burning fossil fuels and incinerating municipal waste. We have programs that aim to reduce fossil fuel use and we regulate waste incinerators.

Since 2000, we have not found a statistically significant change in risk from cadmium.[25]

Figure 10 below shows the median level of cadmium was higher at Duwamish Valley than NATTS sites. Tacoma Tideflats had one day with a high concentration near two nanograms per cubic meter.

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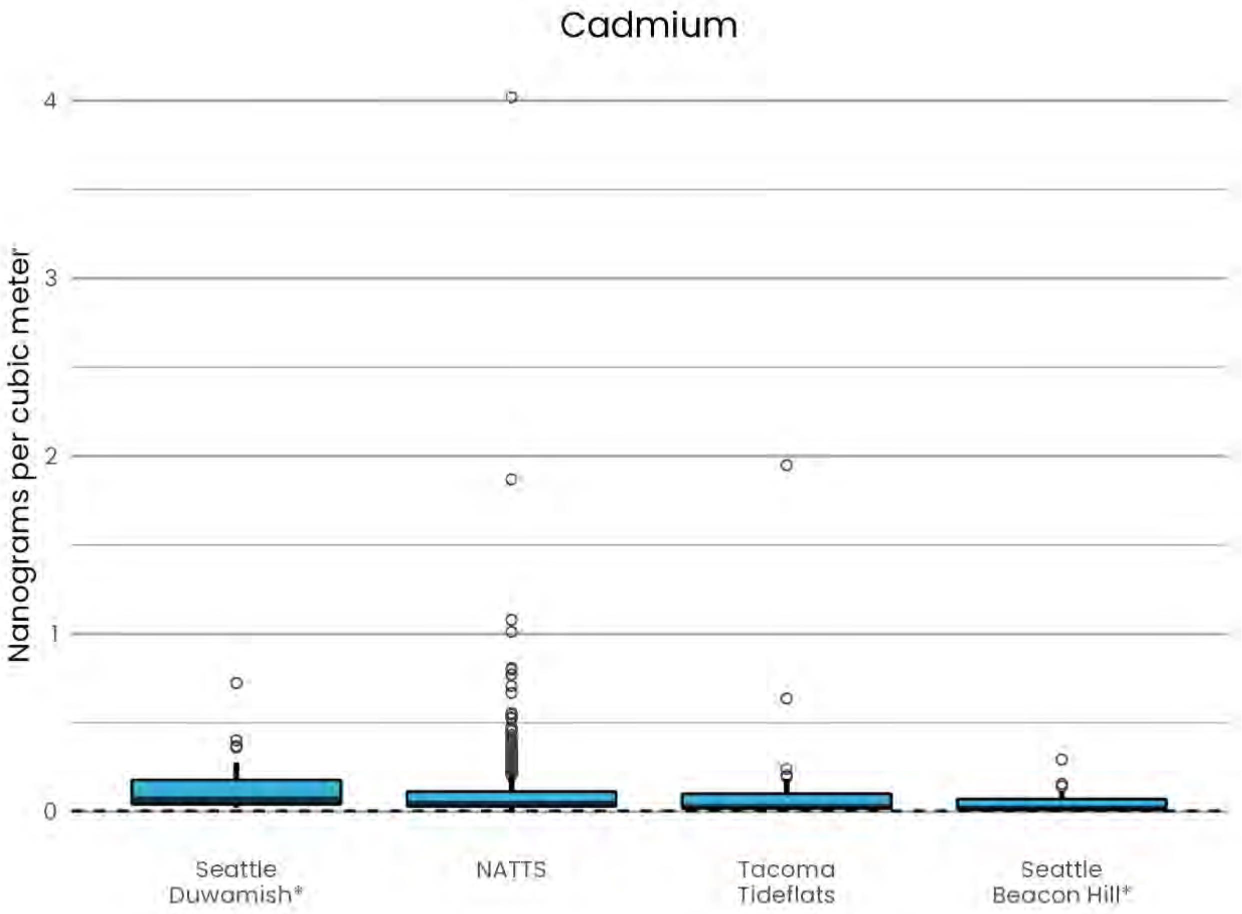
[24] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/cadmium-compounds.pdf.

[25] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 10. Cadmium box plot.



Carbon tetrachloride

The EPA lists carbon tetrachloride as a probable human carcinogen.[26] Carbon tetrachloride inhalation is also associated with liver and kidney damage. It was widely used as a solvent for both industry and consumers but was banned from consumer use in 1995. Trace amounts are still emitted by local sewage treatment plants. Carbon tetrachloride has a relatively long lifetime in the atmosphere, and since emissions have dropped significantly, it is well mixed in the atmosphere and concentrations are similar in urban and rural areas.

The Agency does not target efforts at reducing carbon tetrachloride emissions, as carbon tetrachloride has already been banned. At the Seattle Beacon Hill site, we have not found a statistically significant trend in carbon tetrachloride levels since 2000.[27]

Figure 11 below shows the box plot for carbon tetrachloride. The data show no significant differences across the sites in Seattle or nationally. Because carbon tetrachloride is a relatively constant background pollutant, we expect values to have a relatively small range.

As shown in the graph, some samples had low carbon tetrachloride values. This occurred both at our sites and at the NATTS sites. This happened to approximately 2% of our samples. Those samples, when compared with the sample mean, were 20% lower when averaging across all other pollutants. It could be that there was an analysis issue for some of these samples; either only affecting carbon tetrachloride or affecting all compounds. However, with the small number of samples, we cannot decipher any difference. Visual analysis of graphs highlighting the low carbon tetrachloride days does not reveal any obvious pattern (Appendix E). And benzene and 1,3-butadiene, which used the same canister as carbon tetrachloride, did not show any difference on low carbon tetrachloride days compared to the mean. Days with low carbon tetrachloride had higher nickel, but with the very small number of samples (4), this was likely coincidental (Table E-1, Appendix E). Performing the same

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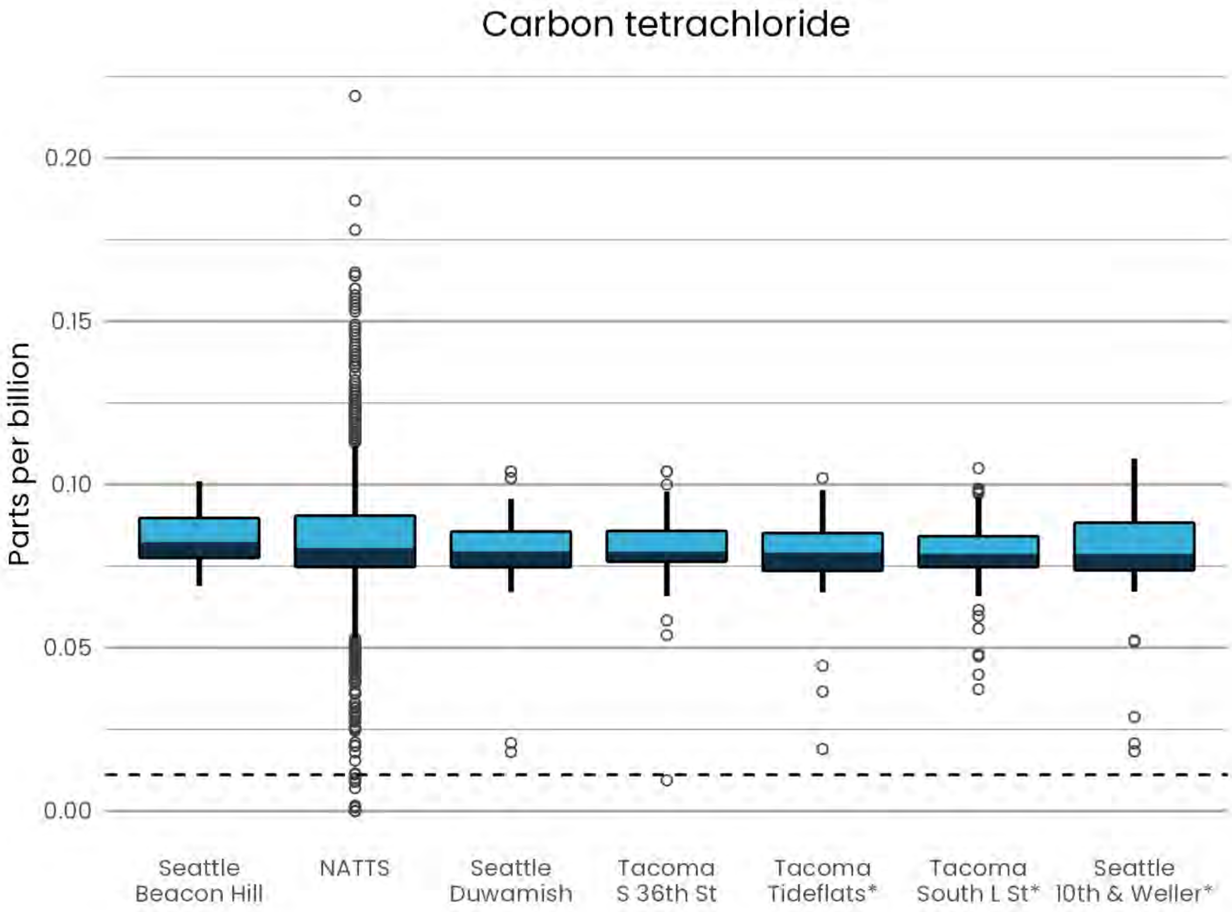
[26] EPA Hazard Summary; https://www.epa.gov/sites/production/files/2016-09/documents/carbon-tetrachloride.pdf.

[27] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

comparison for all NATTS sites led to no strong positive associations and a strong negative association with 1,3-butadiene (Table E-2, Appendix E). We performed a sensitivity analysis by removing the samples that had low carbon tetrachloride. This resulted in a less than one-per-million change in our cancer risk estimate (<1% difference).

Figure 11. Carbon tetrachloride box plot.



Chromium

There are two main forms of chromium – Cr III (trivalent) and Cr VI (hexavalent). Trivalent chromium is an essential mineral for humans, while hexavalent chromium is highly toxic. EPA has classified hexavalent chromium as a carcinogen, and it has a very low unit risk factor; meaning that it is harmful in small amounts.[28] Aside from cancer, acute and chronic exposure to hexavalent chromium causes respiratory effects. Trivalent chromium occurs naturally in the environment, while hexavalent chromium is mostly produced by industrial processes. The Agency regulates businesses that emit chromium. At the Seattle Beacon Hill site, we have found in past years a statistically significant reduction in cancer risk due to estimated hexavalent chromium of 0.7 per million per year since 2000.[29]

Figure 12 below shows total chromium. Only a small amount of the total chromium in the air is hexavalent chromium. Since we did not have a speciated chromium sampler, we don't know the actual hexavalent chromium ratio, which could differ by site. A 2013 study at our Beacon Hill site showed hexavalent chromium to be 0.8% of total chromium.[30] In our cancer risk analysis that follows, we have chosen a more conservative value of 3% and applied that to all of our sites. A meta-analysis of hexavalent chromium sampling showed that the ratio can vary from about 1% up to 30%, when sampling next to large metal factories. [31]

Median total chromium levels were highest at Seattle Beacon Hill, where the 25th percentile was higher than the 75th percentile of NATTS sites. We do not know of an obvious source of chromium at this site. The Seattle Duwamish site also saw higher levels than NATTS sites. The Tacoma Tideflats site was comparable to the NATTS sites. However, we cannot infer much from the data as the results are all technically below the detection limits across the sites.

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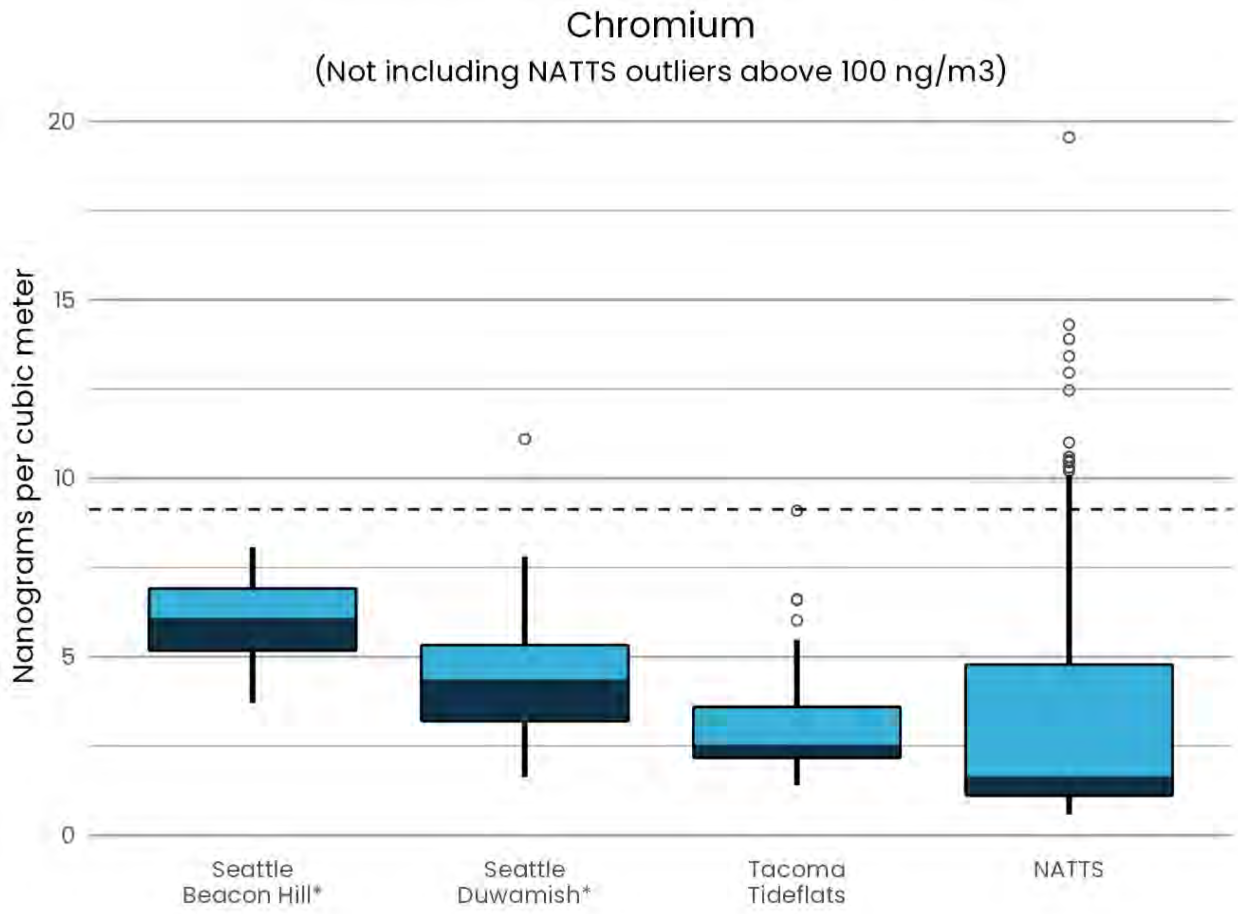
[28] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/chromium-compounds.pdf.

[29] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

[30] *ibid*, PSCAA 2013 Data Summary

[31] *ibid*, Torkmahalleh (2013)

Figure 12. Total chromium box plot.



Cobalt

Cobalt is an essential element for humans, used in producing vitamin B_{12}. It is found naturally in the environment and can be found in high concentrations in some metal working industries.[32] Another potential source of cobalt could be from resuspended dust from cobalt-rich soils. Acute exposure to high levels of cobalt can cause lung damage. Chronic exposure can lead to more pronounced respiratory symptoms, cardiac effects, and organ congestion. Many metal working businesses are regulated by our agency.

Figure 13 below shows the median level of cobalt at the Duwamish site was close to the 75th percentile at NATTS sites. The Tacoma Tideflats had a lower median, but higher 75th percentile and outliers.

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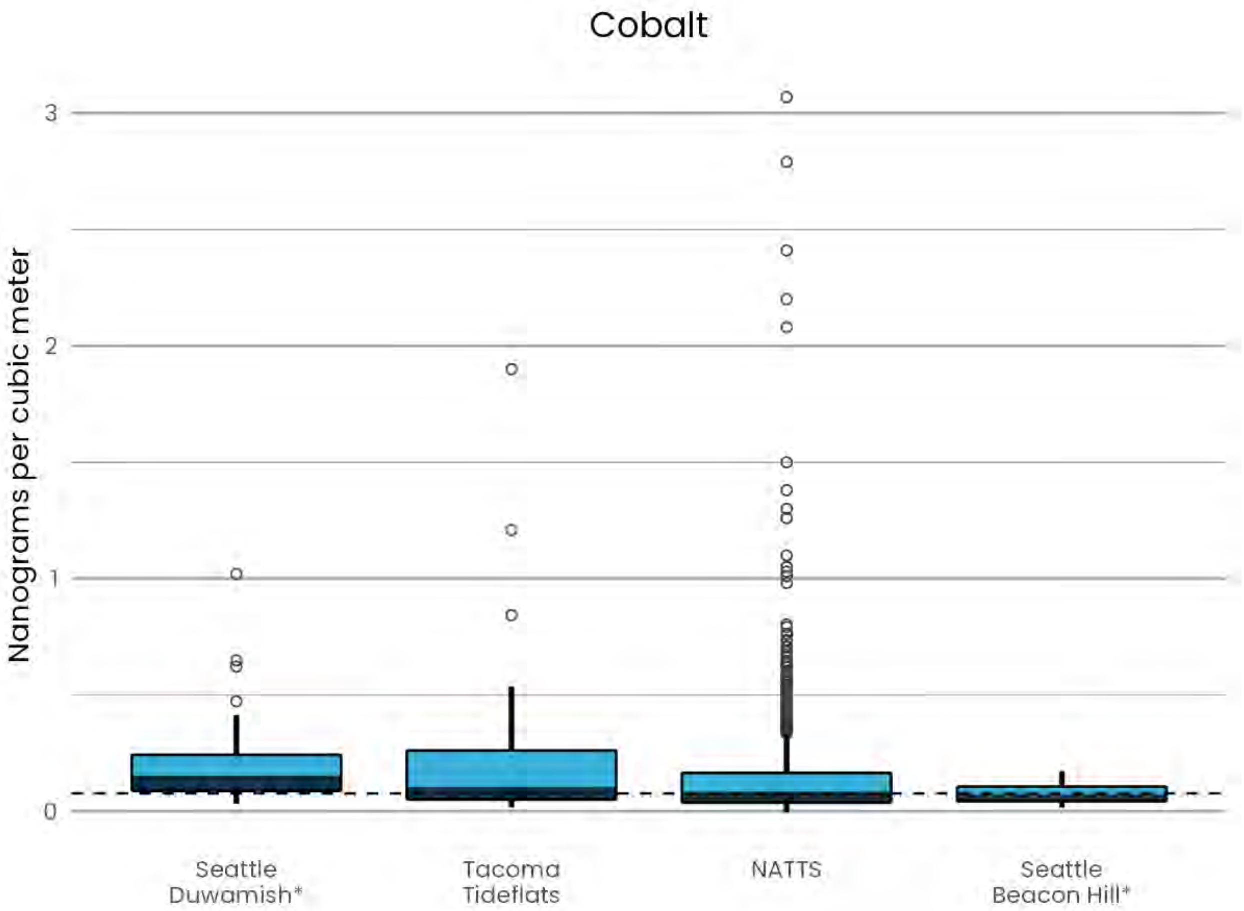
[32] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/cobalt-compounds.pdf.

Figure 13. Cobalt box plot.



Ethylbenzene

EPA lists ethylbenzene as a Group D pollutant, which is not classifiable as to human carcinogenicity due to limited data.[33] Chronic exposure to ethylbenzene may affect the blood, liver, and kidneys. Local sources of ethylbenzene are likely from combustion of fossil fuels and volatilization from fuels, asphalt, naphtha, and other solvents. It is also used in styrene production. At Seattle Beacon Hill, we did not find a statistically significant trend in ethylbenzene levels over the time frame that we had data.[34] The Agency works with and regulates solvent-using businesses to reduce ethylbenzene emissions.

Figure 14 shows slightly higher ethylbenzene at Duwamish and 10th & Weller compared to the NATTS sites. Our other sites were similar to the NATTS sites.

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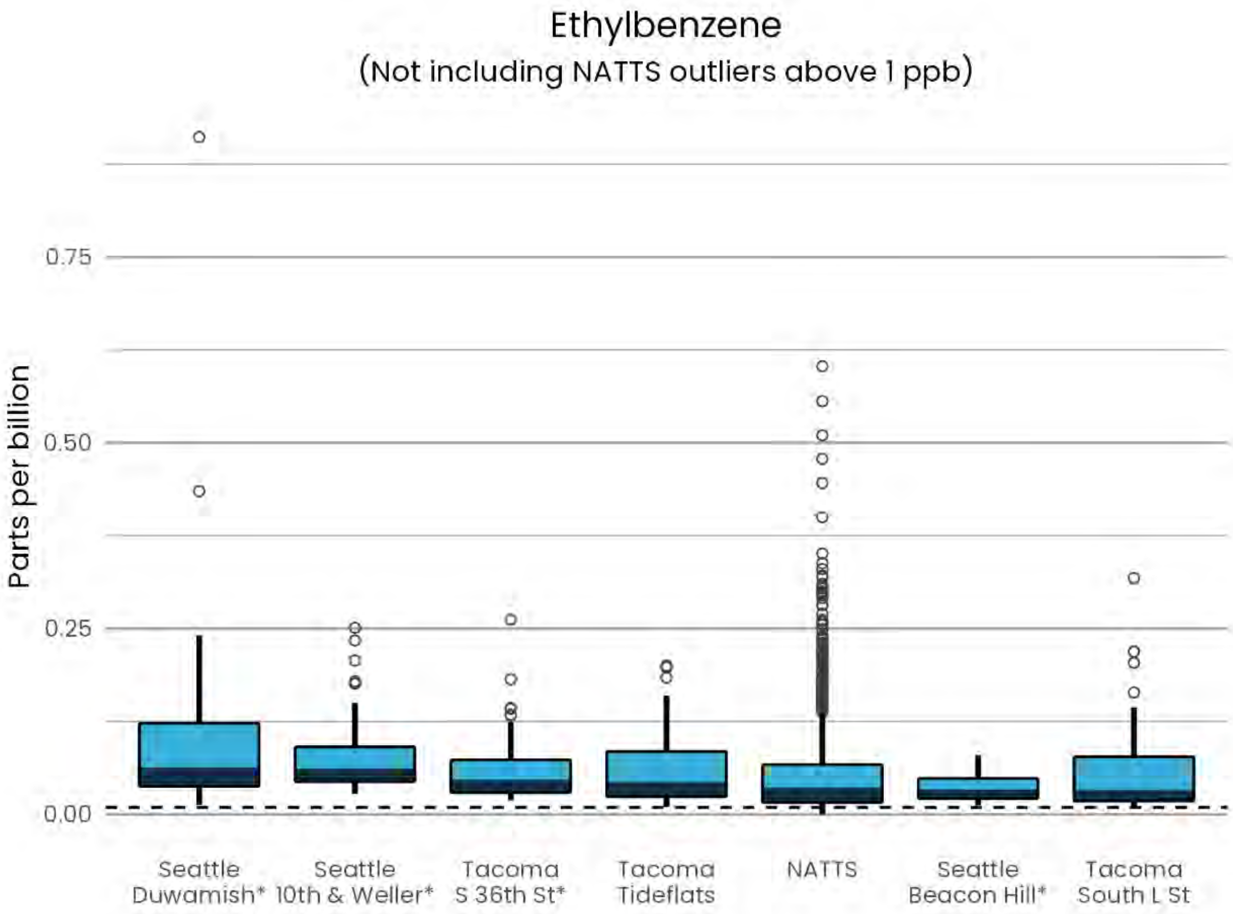
[33] EPA Hazard Summary, https://www.epa.gov/sites/production/files/2016-09/documents/ethylbenzene.pdf.

[34] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 14. Ethylbenzene box plot.



Ethylene Oxide

Ethylene oxide (EtO) is a flammable colorless gas with a sweet odor. It is primarily used to produce other chemicals including antifreeze, textiles, detergents, polyurethane foam, solvents, medicine, adhesive and other products[35]. In smaller amounts, it can be used as a pesticide and a sterilizing agent for medical purposes. EtO has the ability to damage DNA, which makes it effective as a sterilizing agent, but it also accounts for cancer-causing activity.

In industrial settings, ethylene oxide is used in closed systems. Occupational exposure risk is decreased if the chemical is used in more tightly closed systems. However, people can be exposed to EtO through uncontrolled emissions from industrial facilities, as a by-product of tobacco smoke, and the use of products that were sterilized by EtO such as medical products, cosmetics, and beekeeping equipment. In our jurisdiction there is only one registered source that currently has an EtO sterilizer. During the study, there was a second source that was rarely operating an EtO sterilizer, but they have since shut it down.

The Environmental Protection Agency has concluded that EtO is carcinogenic to humans by the inhalation route of exposure. Evidence in humans indicates that exposure to EtO increases the risk of lymphoid cancer and breast cancer.

EPA changed its toxicity value for EtO in December 2016 to be 34 times more protective.[36] Based upon that, in 2019 the Washington State Department of Ecology updated the acceptable source impact level for ethylene oxide to be 57 times more protective (from 0.0114 to 0.0002 $\mu g/m^3$). The new value, which we use in risk assessments, reflects our updated understanding that EtO is more toxic than in previous estimates. When the EPA released the 2018 National Air Toxics Assessment, this new information was included in the models. Since then, the EPA has included ethylene oxide in its list of chemicals that is monitored through the National Air Toxics Trends Laboratory Contract. This is the first air toxics study in the region estimated EtO concentrations.

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[35] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/ethylene-oxide.pdf.

[36] EPA, IRIS Evaluation of the Inhalation Carcinogenicity of Ethylene Oxide (Final Report), Aug 2023, https://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=329730.

EPA added ethylene oxide into the routine air toxics suite in 2019. A comparison study[37] across the country showed Seattle Beacon Hill had the lowest levels. The results are shown in the map below in Figure 15.

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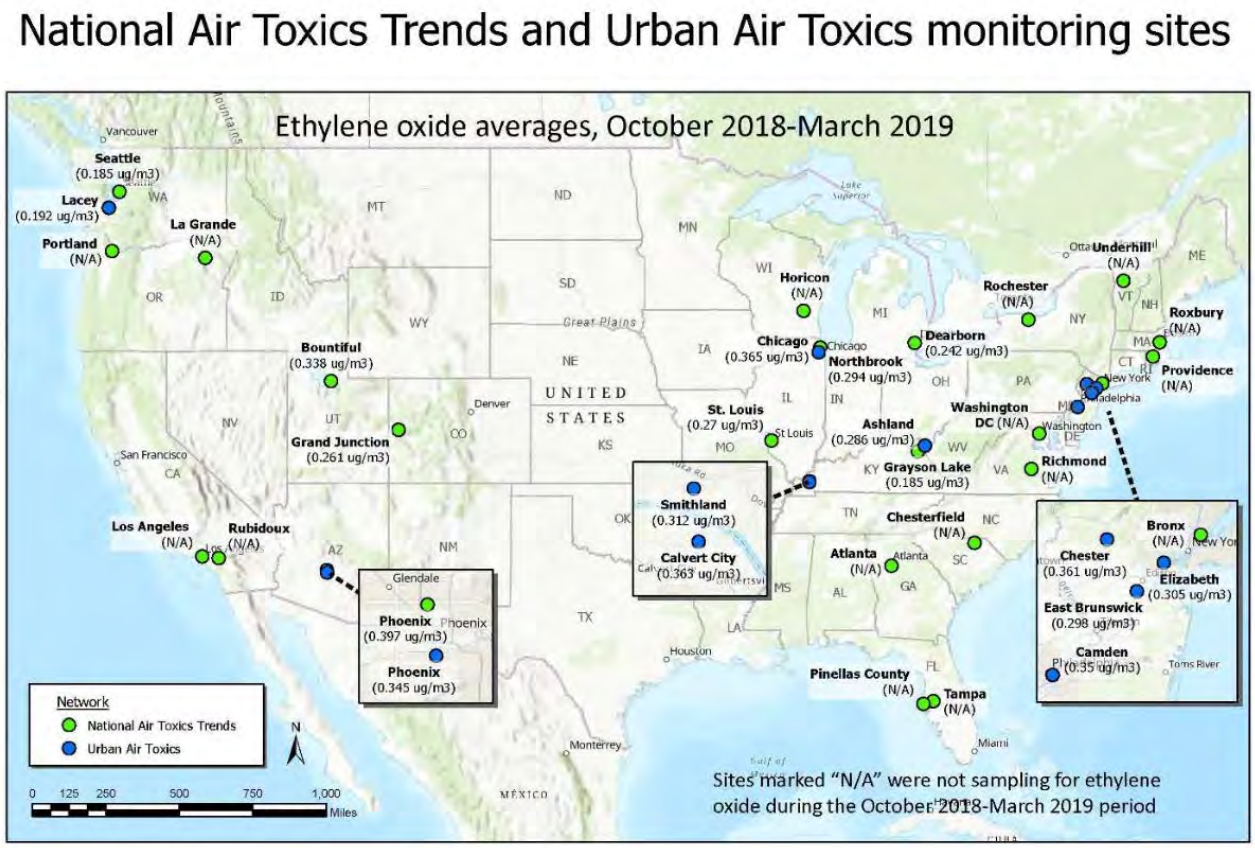
[37] EPA 2019. Map of ethylene oxide averages from NATTS/UAT Sites, https://www.epa.gov/sites/production/files/2019-11/documents/map_of_natts_uatmp.pdf

Figure 15. Results from EPA analysis of NATTS site data from late 2018 to early 2019 showing Seattle Beacon Hill's site with the lowest levels nationally.



Current monitoring methods for ethylene oxide have multiple issues. The current sampling method is not sensitive enough to get adequate measurements to quantify effectively. The method detection limits equate to potential cancer risks in the hundreds per million. For 2021, we estimated the ethylene oxide average potential cancer risk estimate at Seattle Beacon Hill at 700 in one million. Ethylene oxide also tends to "stick" to the sampling canisters, which can carry over false readings into subsequent samples.[38] During our study, the contract lab flagged most of the samples for being potentially inaccurate for ethylene oxide.

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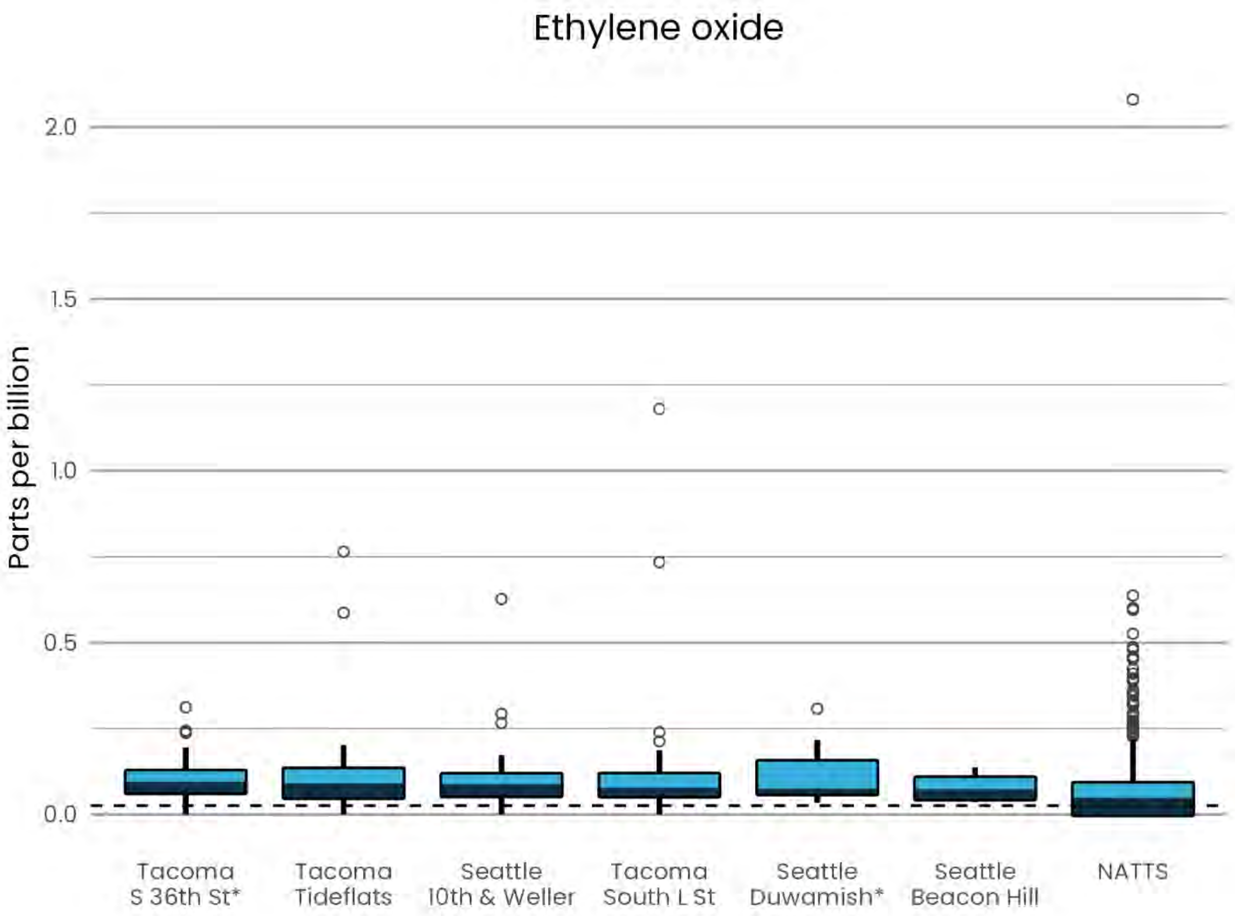
[38] EPA 2020, EPA's Work to Understand Background Levels of Ethylene Oxide, https://www.epa.gov/system/files/documents/2021-10/background-eto-explainer-doument.pdf.

Despite high uncertainty, we created box plots (Figure 16) to compare sites. Samples below the MDL are shown as-is. Samples that were flagged for canister contamination were removed; this comprised about half of the samples and left about 20-30 samples per site. We generally saw uniform medians across all the sites, including the compiled national site data (NATTS). However, 75th percentiles are generally higher at the other sites compared to Seattle Beacon Hill and the NATTS sites. The Beacon Hill location generally has less pollution (e.g., fine particle and black carbon) than other monitoring site locations across Puget Sound.

We look forward to improvements in sampling methodology to better understand levels of EtO and related health risk in our region.

Figure 16. Ethylene oxide box plot.



Formaldehyde

The EPA lists formaldehyde as a probable human carcinogen. Inhalation is also associated with eye, nose, throat, and lung irritation.[39] Ambient formaldehyde can both be emitted directly from a source or formed in the atmosphere from emissions from plants and trees, automobiles, trucks, wood burning, cigarettes, and other combustion sources. Agency efforts that target vehicle exhaust and wood stove emission reductions also reduce formaldehyde emissions. Since 2000 at the Seattle Beacon Hill site, we found a statistically significant drop in risk from formaldehyde at a rate of about 0.35 per million per year, however the risk has been increasing slightly in recent years.[40]

Figure 17 below shows the formaldehyde data as a box plot. Our sites are much lower than the median of the NATTS. This is likely due to formaldehyde being mostly generated as a byproduct of atmospheric chemical transformations of other pollutants. Our region is better ventilated by cleaner Pacific winds with less secondary chemistry and reactions than the rest of the country. Our airshed typically ventilates out daily, especially in the summer months, when temperatures are warmer and typically formaldehyde production is highest. This incoming background air has less direct emissions and less atmospheric formation than other parts of the country.

Appendix F shows the relationship between formaldehyde and temperature. Generally, formaldehyde increases with increasing temperature.

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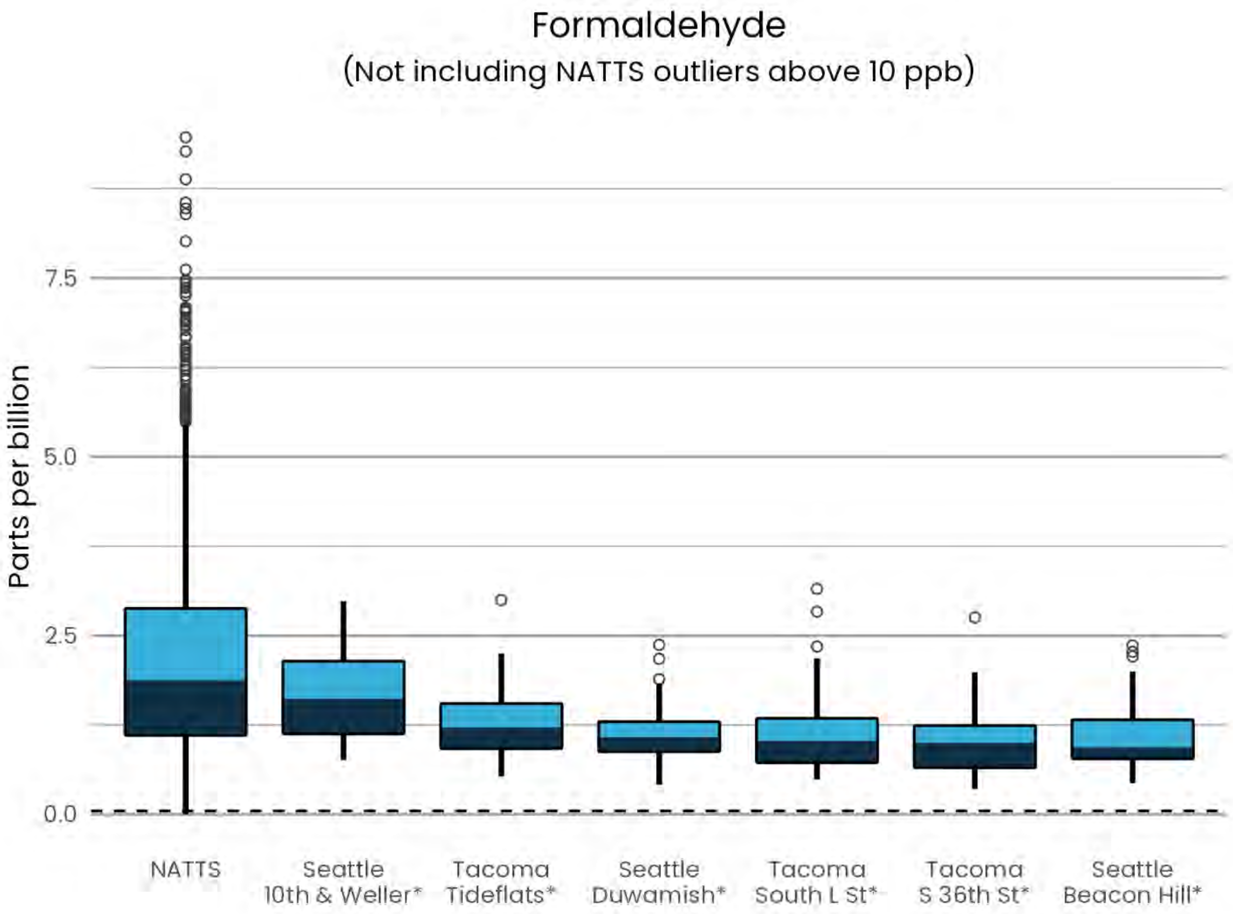
[39] EPA Hazard Summary, https://www.epa.gov/sites/production/files/2016-09/documents/formaldehyde.pdf.

[40] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 17. Formaldehyde box plot.



Lead

Chronic exposure can cause damage to the nervous, renal, cardiovascular, and immune systems and slow cognitive development in children. Acute exposure to high levels of lead can cause neurological deficiencies, injure the kidneys, and cause reproductive issues, and gastrointestinal symptoms.[41] EPA has concluded that lead is likely carcinogenic to humans. Lead can be emitted into the air from metal working industries, waste incineration, resuspended dust from contaminated soils, and small aircraft. Many metal working businesses are regulated by our agency.

Figure 18 shows the median level of lead at the Seattle Duwamish site was higher than the 75th percentile of NATTS sites. Duwamish also had some of the highest daily lead values. The Tacoma Tideflats site was also higher than NATTS sites. For health context and lead results from the community-directed sampling campaign, see section on "Community-directed monitoring" later in this report.

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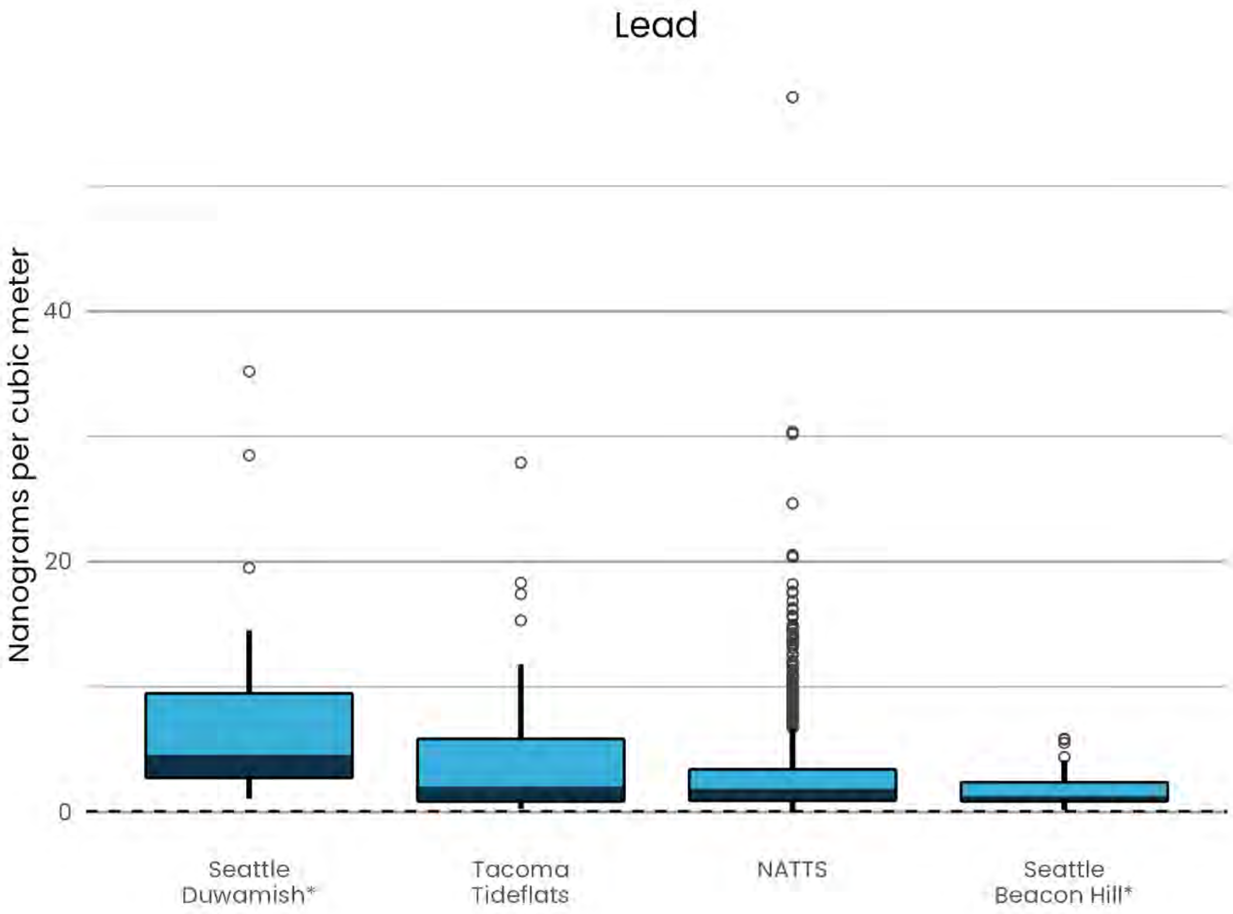
[41] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/lead-compounds.pdf.

Figure 18. Lead box plot (not including community-directed samples).



Manganese

Manganese is a necessary mineral for human nutrition and naturally occurs in the environment. However, chronic exposure to high levels can lead to central nervous system effects, respiratory effects, and a condition called manganism—characterized by weakness, tremors, and psychological issues.[42] Manganese can be emitted into the air from metal working industries and power plants. Many metal working businesses are regulated by our agency.

Figure 19 below shows the median level of manganese at the Duwamish site was close to the 75th percentile at NATTS sites. Duwamish also had two days with an order of magnitude higher concentration.

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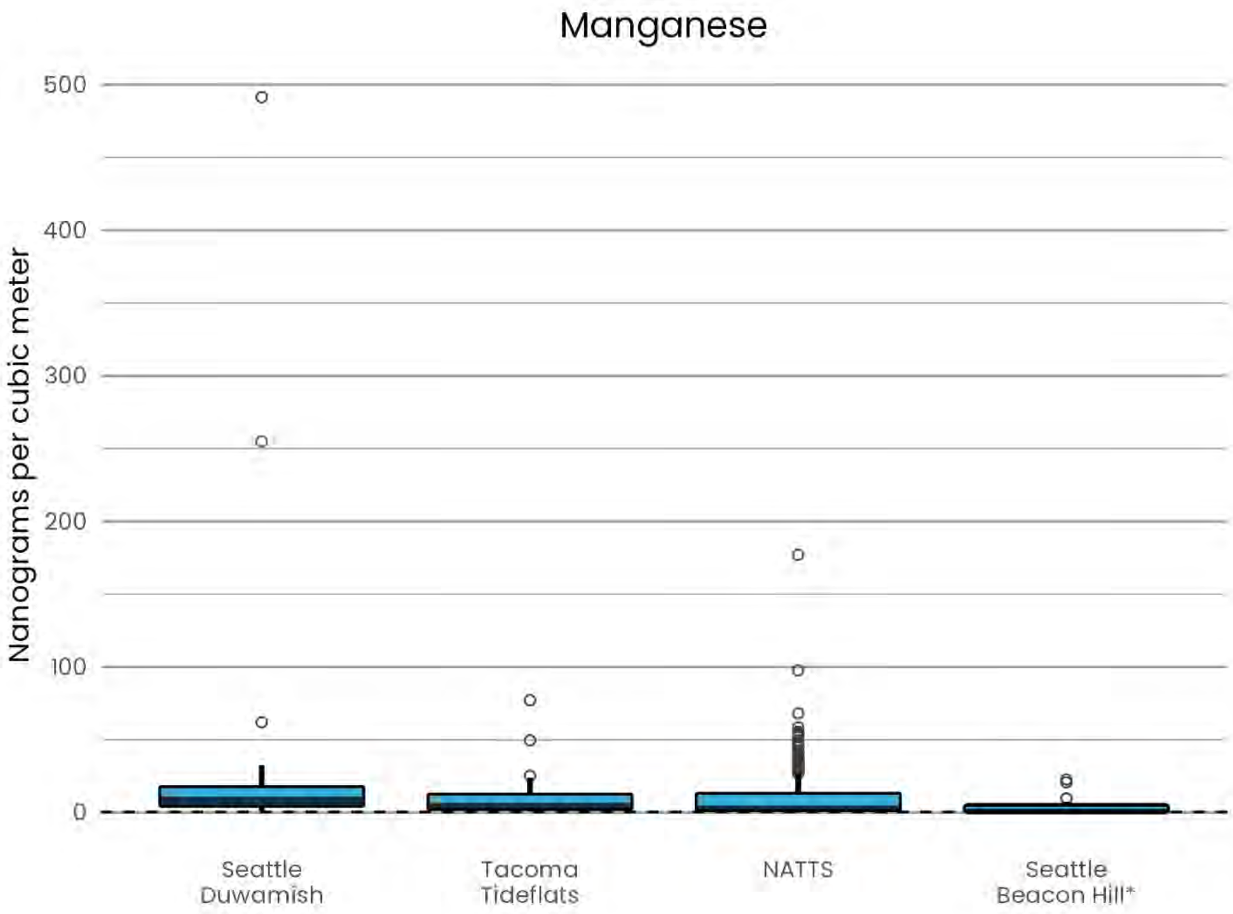
[42] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-10/documents/manganese.pdf.

Figure 19. Manganese box plot.



Mercury

Mercury is found naturally in the soil and can be emitted into the air from metal working industries, waste incineration, and fossil fuel combustion.[43] Humans can also be exposed to mercury through dental fillings and by eating fish. Depending on the form of mercury (elemental, inorganic, or organic) acute effects include gastrointestinal problems, irritation of mucous membranes, central nervous system problems, and renal problems. Chronic effects are similar, with a more pronounced effect on the kidneys for inorganic mercury.

Many metal working and waste management businesses are regulated by our agency. We also work to reduce fossil fuel combustion by helping the transition to electric vehicles.

The mercury found in our analysis is particle-bound mercury, meaning it is adhered to small particles, and is likely mostly elemental mercury with some inorganic mercury. The median level of mercury at all our sites was lower than NATTS sites. There was one outlier of 1.6 ng/m^3 at the Seattle Duwamish site, which was removed from the graph for display. We have no definitive conclusion on the source of the outlier, but it may be a lab handling issue or other source.

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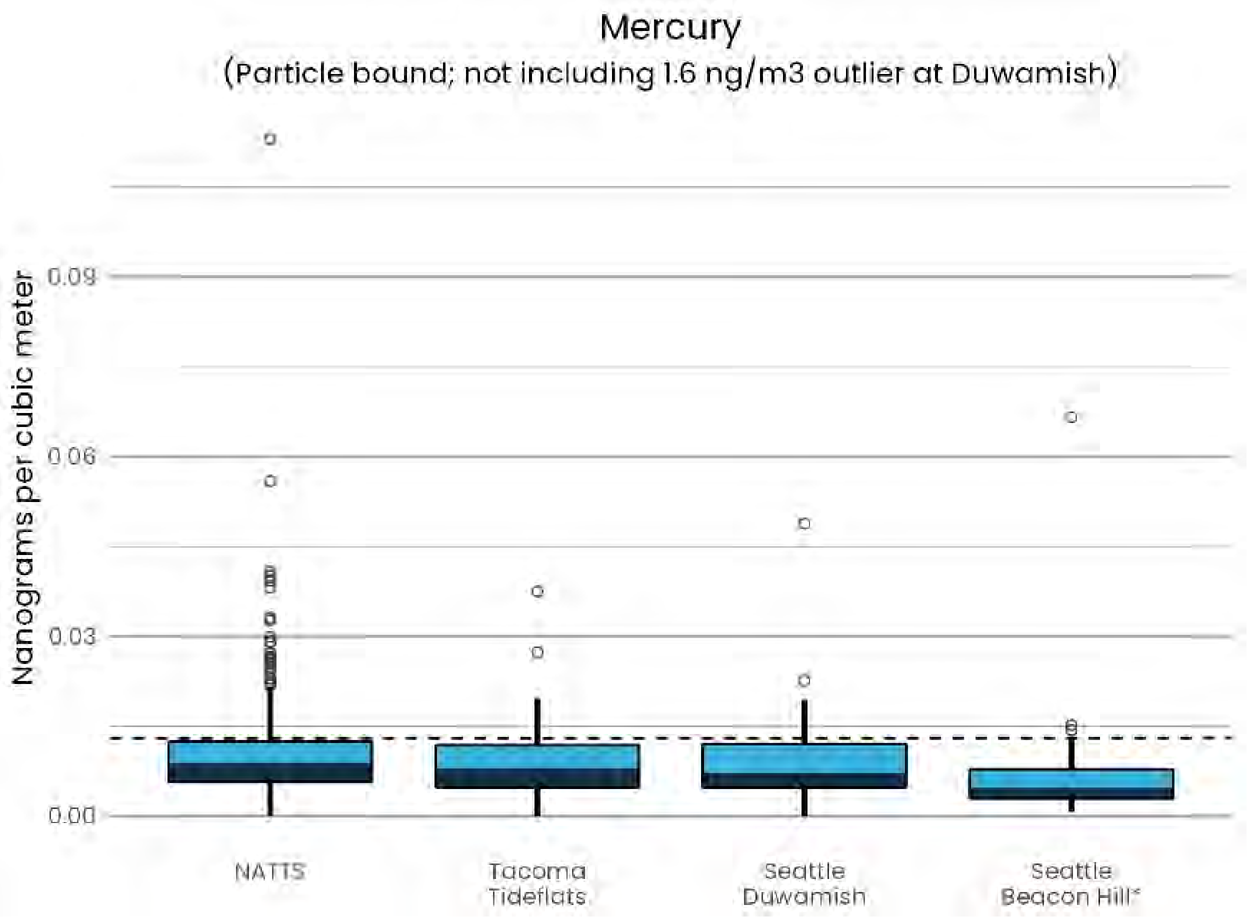
[43] EPA Hazard Summary, https://www.epa.gov/system/files/documents/2021-12/mercury-compounds_12-3-2021_final.pdf.

Figure 20. Mercury box plot.

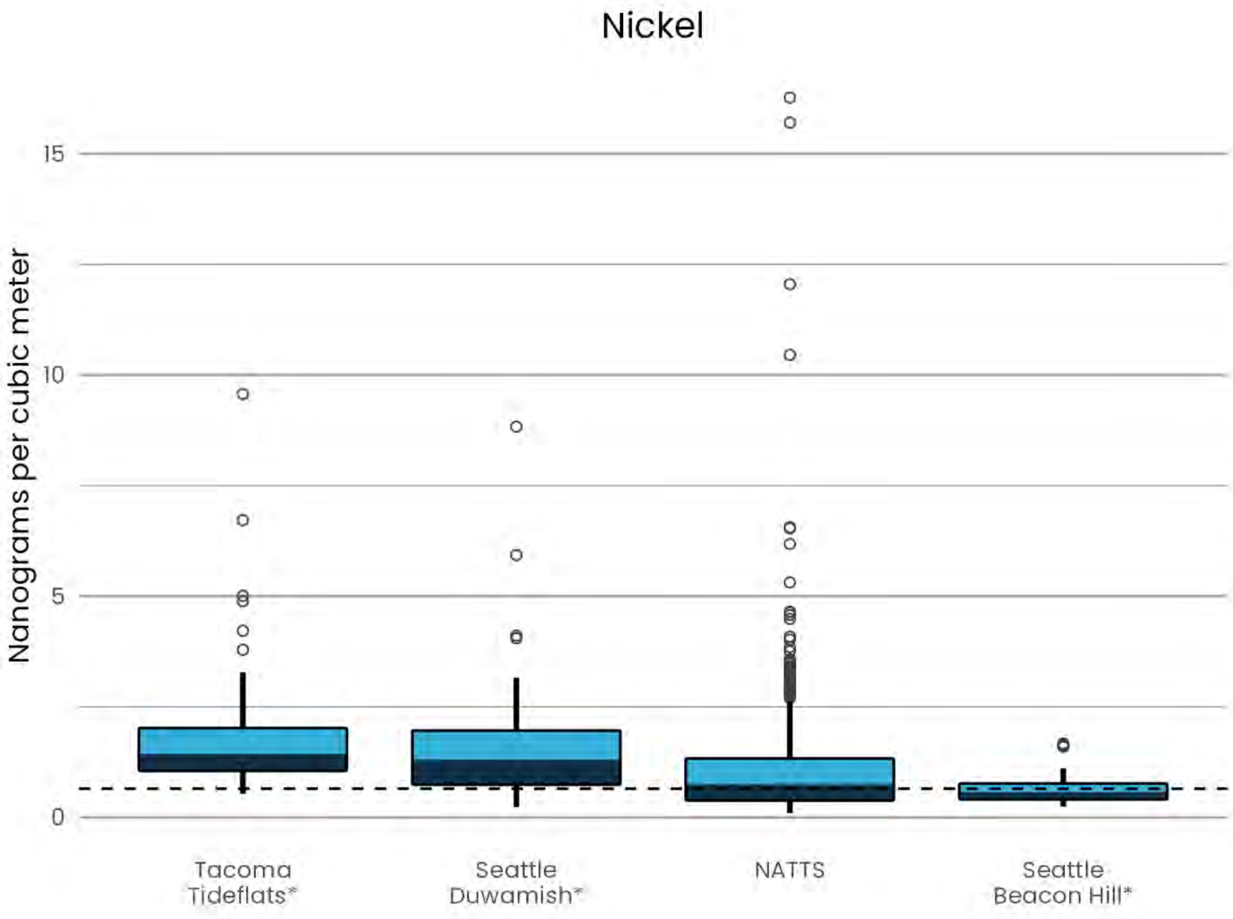


Nickel

EPA lists nickel as a known human carcinogen. Nickel is also associated with respiratory effects.[44] Combustion of gasoline and diesel fuels (car, truck, and vessel exhaust) is a main source of nickel in the Puget Sound area. Agency efforts that target reducing vehicle exhaust also reduce nickel emissions.

Figure 21 below shows the Duwamish and Tacoma Tideflats sites are higher than the NATTS sites and have some high daily values. Seattle Beacon Hill is lower than the NATTS sites.

Figure 21. Nickel box plot.



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[44] EPA Hazard Summary, https://www.epa.gov/sites/production/files/2016-09/documents/nickle-compounds.pdf.

Selenium

Selenium is a necessary mineral for human nutrition and naturally occurs in the environment. However, it is harmful at high concentrations. Acute exposure can lead to irritation of the mucous membranes, gastrointestinal problems, and headaches.[45] Selenium can be emitted into the air from glass production, electronics production, and industries that work with selenium containing pigments. We regulate glass manufacturers and many types of painting businesses.

Figure 22 below shows the 25th percentile at the Seattle Duwamish site was higher than the 75th percentile at NATTS sites. The Duwamish site also had the highest daily values of selenium. Tacoma Tideflats and Beacon Hill were lower than NATTS sites. We did not conclude why the Seattle Duwamish had higher selenium levels than elsewhere.

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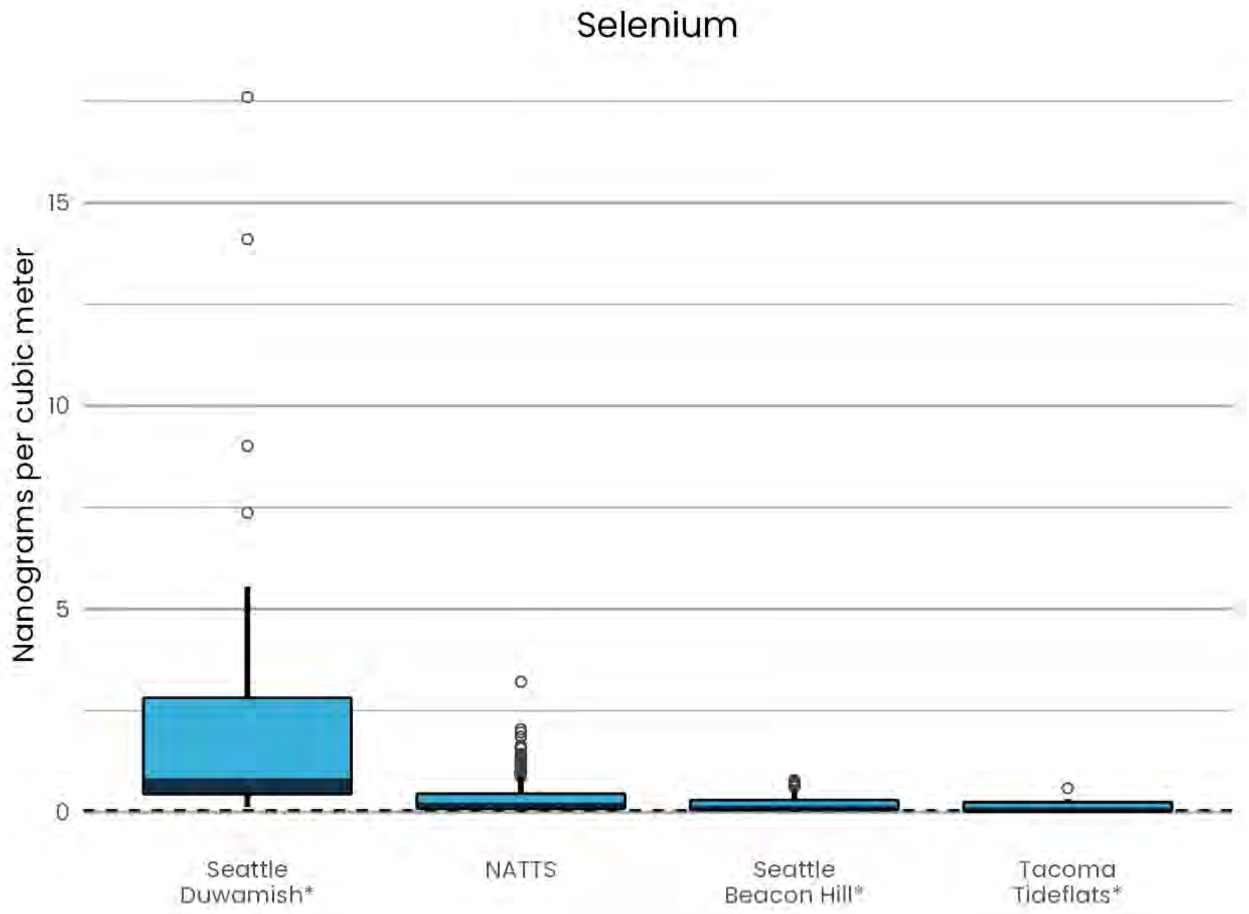
[45] EPA Hazard Summary, https://www.epa.gov/sites/default/files/2016-09/documents/selenium-compounds.pdf.

Figure 22. Selenium box plot.



Tetrachloroethylene

EPA lists tetrachloroethylene, also known as perchloroethylene or “perc”, as a probable human carcinogen. Tetrachloroethylene inhalation is also associated with central nervous system effects, liver and kidney damage, and cardiac arrhythmia.[46] Dry cleaners are the main source of tetrachloroethylene.

The Agency works with dry cleaners to monitor for and repair leaks in their equipment to reduce the release of tetrachloroethylene. Since 2000, we found a statistically significant drop in risk from tetrachloroethylene at a rate of about 0.04 per million per year.[47]

Figure 23 below shows that all of our sites are similar to or lower than the NATTS sites and most samples are below the minimum detection limit.

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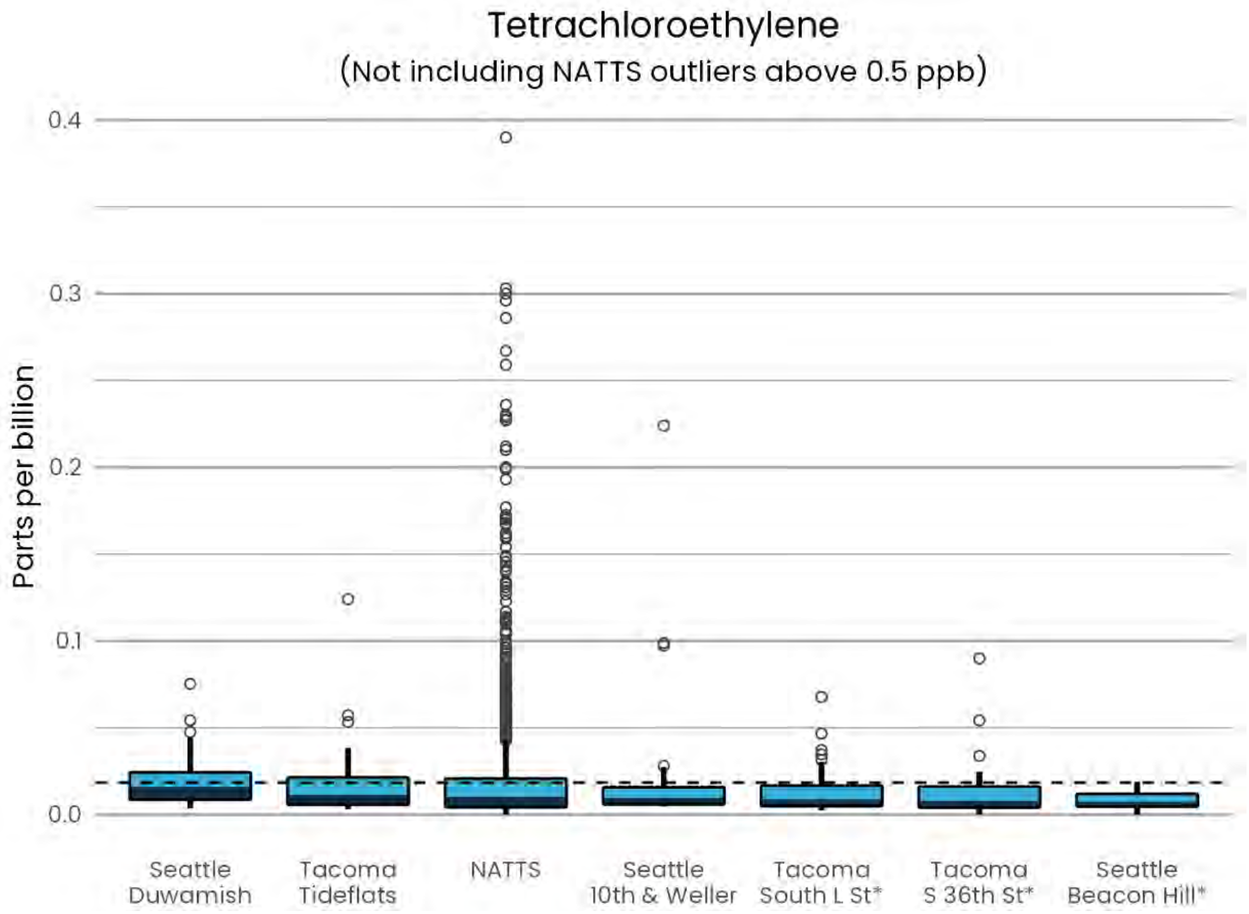
[46] EPA Hazard Summary, https://www.epa.gov/sites/production/files/2016-09/documents/tetrachloroethylene.pdf.

[47] Puget Sound Clean Air Agency, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF.

Figure 23. Tetrachloroethylene box plot.



Potential non-cancer risk

Table 7. Potential non-cancer hazard quotients by compound

	Seattle 10th & Weller	**Seattle Beacon Hill**	**Seattle Duwamish**	**Tacoma South L**	**Tacoma S 36th St**	**Tacoma Tideflats**
1,3-Butadiene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acetaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acrolein	2	1.4	1.8	1.7	1.9	2.2
Arsenic		<0.1	<0.1			<0.1
Benzene	0.3	0.1	0.2	0.2	0.2	0.2
Beryllium		<0.1	<0.1			<0.1
Carbon tetrachloride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ethylbenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Formaldehyde	0.2	0.1	0.1	0.1	0.1	0.1
Hexavalent Chromium		<0.1	<0.1			<0.1
Manganese		<0.1	0.2			0.1
Mercury		<0.1	<0.1			<0.1
Nickel		<0.1	0.1			0.1
Tetrachloroethylene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 7 shows the hazard quotient value across the primary study sites. This list includes compounds that have a chronic reference exposure level (REL) assigned by CA OEHHA [48]. A chronic reference exposure level is the "concentration of a chemical at or below which adverse noncancer health effects are not anticipated to occur" over the course of a lifetime[49]. To calculate the hazard quotient, the average concentration of each compound across the duration of the study is divided by the REL. A hazard quotient value over 1 indicates an elevated risk of non-cancer health impacts over a lifetime of exposure to that level of a compound. Lead has non-cancer health effects and has a national ambient air quality standard based on those health effects. Lead results are addressed later in this report under community-directed sampling. The only compound with a hazard quotient above 1 is acrolein, where the hazard quotient is between 1.4 and 2.2. See the Box Plot listing for acrolein above for a discussion of sources.

Compounds with a hazard quotient between 0.1 and 1 are benzene, formaldehyde, and, at some sites, manganese and nickel. All other compounds have a hazard quotient less than 0.1 or do not have an REL.

Hazard quotients can be added together for compounds that effect the same body system into a hazard index.

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[48] OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary. California Office of Environmental Health Hazard Assessment. Updated Oct 11, 2023. https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary.

[49] Technical Support Document for the Derivation of Noncancer Reference Exposure Levels. California Office of Environmental Health Hazard Assessment. 2008. https://oehha.ca.gov/media/downloads/crnr/noncancertsdfinal.pdf.

Table 8. Compounds and associated body systems for non-cancer effects

Compound	Target System
1,3-Butadiene	Reproductive
Acetaldehyde	Respiratory
Acrolein	Respiratory
Arsenic	Development; cardiovascular; nervous; respiratory; skin
Benzene	Hematologic
Beryllium	Respiratory; immune
Carbon tetrachloride	Alimentary; nervous; development
Ethylbenzene	Alimentary (liver); kidney; endocrine; development
Formaldehyde	Respiratory
Hexavalent Chromium	Respiratory
Manganese	Nervous
Mercury	Nervous; development; kidney
Nickel	Respiratory; hematologic
Tetrachloroethylene	Kidney; alimentary

Table 8 shows the relationship between air toxics and the body systems that they can impact due to non-cancer health effects[50]. "Development" stands for developmental effects.

Table 9. Potential non-cancer hazard indexes by body system

	Seattle 10th & Weller	Seattle Beacon Hill	Seattle Duwamish	Tacoma South L	Tacoma S 36th St	Tacoma Tideflats
Alimentary	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cardiovascular		<0.1	<0.1			<0.1
Development	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Endocrine	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

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[50] *ibid*, OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary. 2023.

Hematologic	0.3	0.2	0.3	0.2	0.2	0.3
Immune		<0.1	<0.1			<0.1
Kidney	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nervous	<0.1	<0.1	0.3	<0.1	<0.1	0.2
Reproductive	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Respiratory	2.2	1.6	2.1	1.8	2.0	2.5
Skin		<0.1	<0.1			<0.1

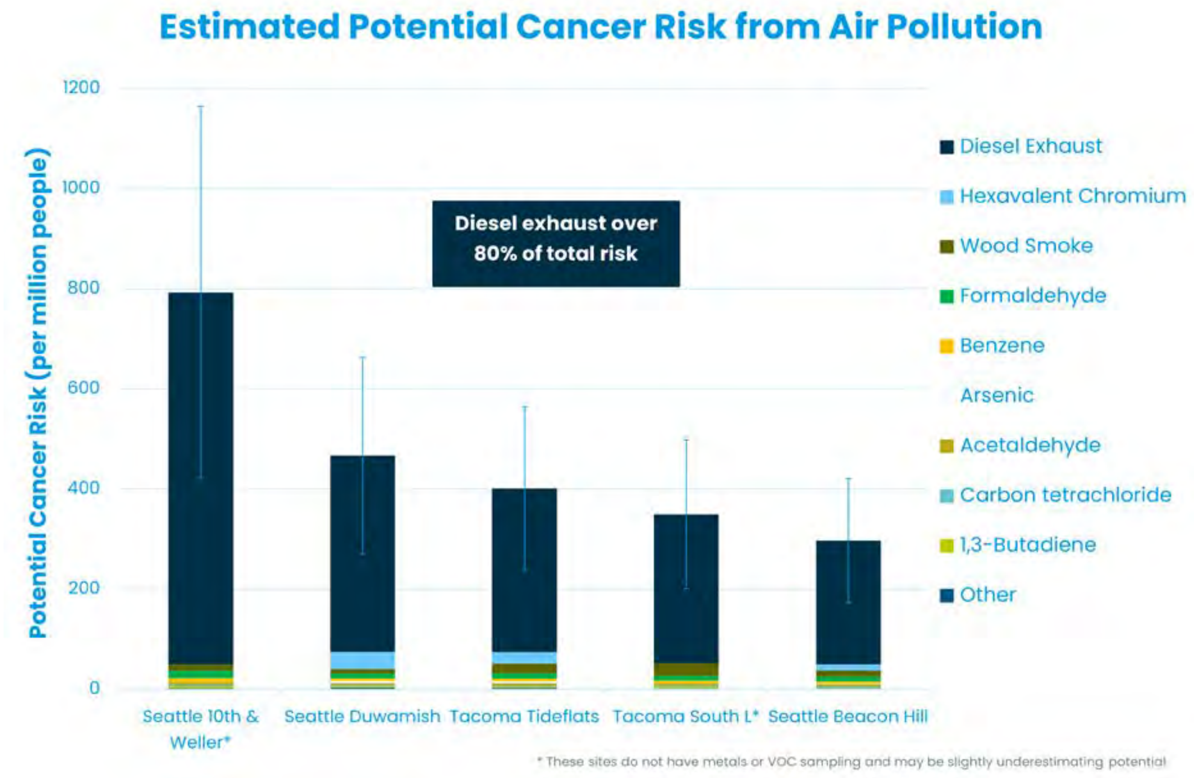
Table 9 shows the hazard index values for various body systems and developmental effects. The only body system with a hazard index above 1 is the respiratory system, which is almost completely due to the effect of acrolein. The hematologic system has hazard indexes above 0.1, primarily due to benzene. Finally, the nervous system has hazard indexes above 0.1 at some sites, due to primarily to manganese.

Potential cancer risk

Overall potential cancer risk estimates

We found the majority of cancer risk (82-94%, 86% on average) is due to diesel particulate matter across the sites. This is because of the high toxicity of diesel particulate matter and relatively high concentration (compared to metals and VOCs). Estimated hexavalent chromium is the second highest with approximately 6% of the risk. Figure 24 shows the estimated potential cancer risk at all of our sites that had $PM_{2.5}$ speciation data (which excludes the Tacoma near-road site at S 36th St).

Figure 24. Estimated total potential cancer risk from air pollution at 5 Sites.



Seattle 10th & Weller and Tacoma South L did not have metals or PAH samples and Tacoma Tideflats did not have any PAH samples, so the total cancer risk is slightly underestimated in those locations (less than 10 per million).

Potential cancer risk estimate methodology

The diesel particulate matter and wood smoke estimates are based on the Positive Matrix Factorization analysis reported later in this report. The diesel particulate matter unit risk factor, $3x10^{-4}$ risk per μg/m^3, is from California OEHHA.[51] The wood smoke unit risk factor, $1x10^{-5}$ risk per μg/m^3, is from Lewtas J. (1988).[52]

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[51] OEHHA Chemical Database - Diesel Exhaust Particulate, https://oehha.ca.gov/chemicals/diesel-exhaust-particulate.

[52] Lewtas J. (1988). "Genotoxicity of Complex Mixtures: Strategies for the Identification and Comparative Assessment of Airborne Mutagens and Carcinogens from Combustion Sources". Funda and Appl Tox 10: 571-589.

Cancer risk estimates for other pollutants used the Washington State Acceptable Source Impact Levels updated in 2019.[53]

Hexavalent chromium estimates were from a 3% assumption of total chromium values for Duwamish and Tideflats. The 3% assumption is based on a range found in a meta-analysis.[54] We included a 1% error estimate to help cover some of the uncertainty in the hexavalent to total chromium ratio from the meta-analysis. Beacon Hill uses a 0.8% ratio based on our 2013 study at that site.[55]

Ethylene oxide risk estimates are not included due to potential detection limit issues and sampling canister cleaning problems as discussed in a recent EPA letter.[56]

The diesel cancer risk in the graph above combines two PMF factors: 1) "diesel + crustal" and 2) "sulfate rich". The diesel + crustal factor combines on-road diesel particulate matter with a crustal component. We attribute the combination of road dust (crustal) and diesel particulate matter to the trucks and other heavy vehicles that couldn't be statistically delineated separately. The sulfate-rich factor is associated with maritime diesel emissions.

The diesel + crustal estimates are multiplied by a site-specific adjustment factor to remove the crustal component. Comparing the ratio of diesel particulate matter to crustal factors from previous PMFs at our study sites, led to an adjustment factor of

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[53] Washington State Acceptable Source Impact Levels, 2019, https://apps.leg.wa.gov/wac/default.aspx?cite=173-460-150.

[54] *ibid*, Torkmahalleh (2013)

[55] *ibid*, PSCAA 2013 Data Summary

[56] EPA, Technical Note: The Ethylene Oxide (EtO) Canister Effect, 2021, https://www.epa.gov/sites/default/files/2021-05/documents/technical-note-on-eto-canister-effect-052521.pdf.

0.56 at Duwamish; 0.33 at Tideflats; and 0.68 at Beacon Hill.[57,58,59,60] The uncertainty bars are set to the site-specific adjustment factor for diesel particulate matter.

This may not work well at the Tacoma Tideflats site, which had a much higher diesel + crustal factor compared to previous PMF studies. It was also much higher than expected in the analysis of other study sites and nearby truck tonnage. This could be due to the large amount of construction work happening during the study period that may have contributed significantly to the crustal component. The sulfate-rich maritime component generally agreed with previous studies at Beacon Hill and Duwamish but was lower at the Tideflats site. This could mean that the maritime part of the diesel estimate for Tideflats is an underestimate and was combined in the diesel + crustal factor.

At the Duwamish site, 27% of the total diesel was on-road (107 per million) and 73% was maritime (285 per million). At Tideflats, 35% was on-road (114 per million) and 65% was maritime (213 per million). At Beacon Hill, 51% was on-road (127 per million) and 49% was due to maritime (120 per million). At 10th & Weller, 61% was on-road (452 per million) and 39% was maritime (291 per million).

Potential cancer risk from VOCs, aldehydes, and PAHs

This section focuses on potential cancer risk from VOCs, aldehydes, and PAHs (with the diesel particulate matter, wood smoke, and metals risks removed). These findings are directly measurable air toxics, whereas diesel and wood smoke are mixtures estimated in other ways (e.g., PMF modeling). Metals are presented in the Community-directed monitoring section. We only included compounds that have greater than one-per-million potential cancer risk. The largest contributor is

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[57] Kotchenruther R. (2013). "A regional assessment of marine vessel $PM_{2.5}$ impacts in the U.S. Pacific Northwest using a receptor-based source apportionment method". Atmos Env 68: 103-111.

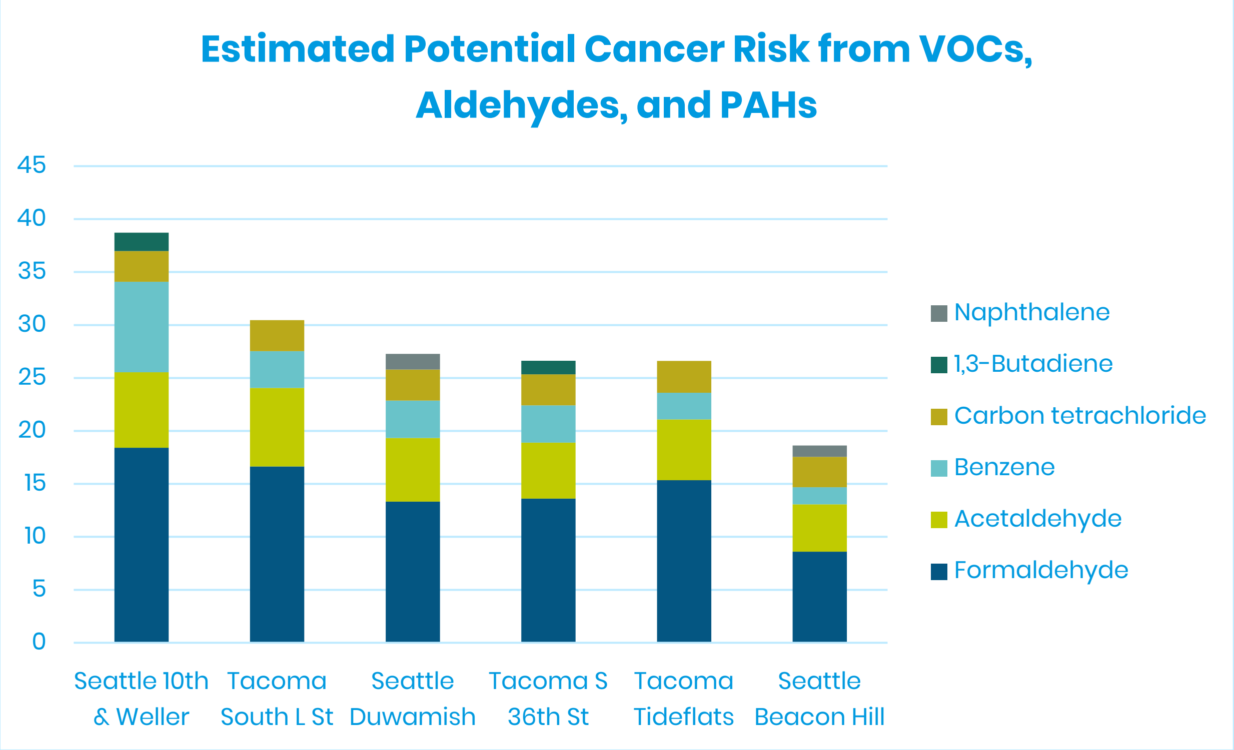
[58] Hopke P., Kim E. (2008). "Source characterization of ambient fine particles at multiple sites in the Seattle area". Atmos Env 42:6047-6056.

[59] Friedman, B. (2023). "Technical Report: Port of Tacoma Source Apportionment Study". WA Ecology, Publication 23-02-075. https://apps.ecology.wa.gov/publications/documents/2302075.pdf.

[60] Kotchenruther R. (2020). "Recent changes in winter $PM_{2.5}$ contributions from wood smoke, motor vehicles, and other sources in the Northwest U.S." Atmos Env 237:117724.

formaldehyde at around 9-18 per million. Then acetaldehyde with around 4-7 per million. The Seattle near-road site, 10th & Weller, is higher than other sites, largely due to higher benzene and formaldehyde. The only PAH that was above the 1 per million threshold was naphthalene. Figure 25 below summarizes these results.

Figure 25. Estimated potential cancer risk from VOCs, aldehydes, and PAHs only.



Air toxics trends

In this section, we compare this current study to previous studies in our region to understand long-term trends in air toxics. Overall, we saw air toxics cut in half or more over the last two decades.

Trends in VOCs and aldehydes

Over the past 20 years, the cancer risk from VOCs has decreased substantially. Most VOCs have seen a reduction in every subsequent study. One exception is carbon tetrachloride, which remains a national concern for potential cancer risk. Although this chemical has been banned from most applications for many years, low level emissions continue to impact the area and country. The chemical is stable in the atmosphere, and there are no known reduction or mitigation methods available.

Acetaldehyde also did not see significant changes. Acetaldehyde is often the product of secondary chemistry, including dependence on temperature and meteorology. We expect the lack of change is due to complex photochemistry equilibria, but we did not pursue further investigation at this time.

The following five figures (Figure 26 through Figure 30) all show the potential cancer risks from VOCs and aldehydes.

Figure 26. Historical trend of VOCs and aldehydes at Seattle Beacon Hill.

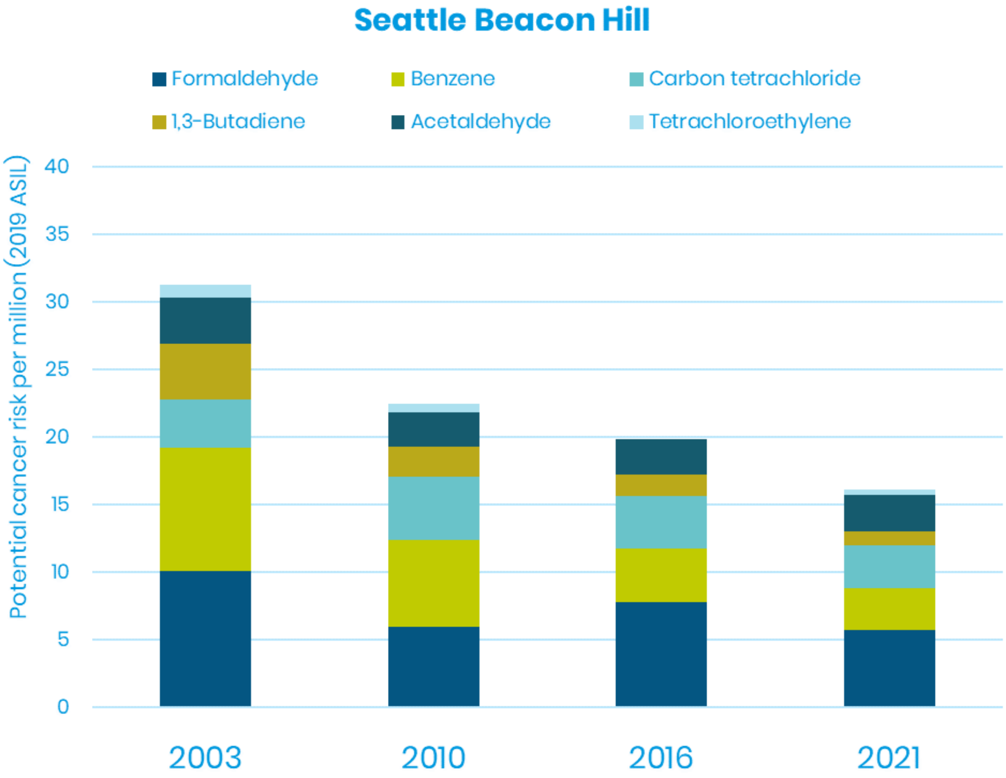


Figure 27. Historical trend of VOCs and aldehydes at Seattle Duwamish Valley.

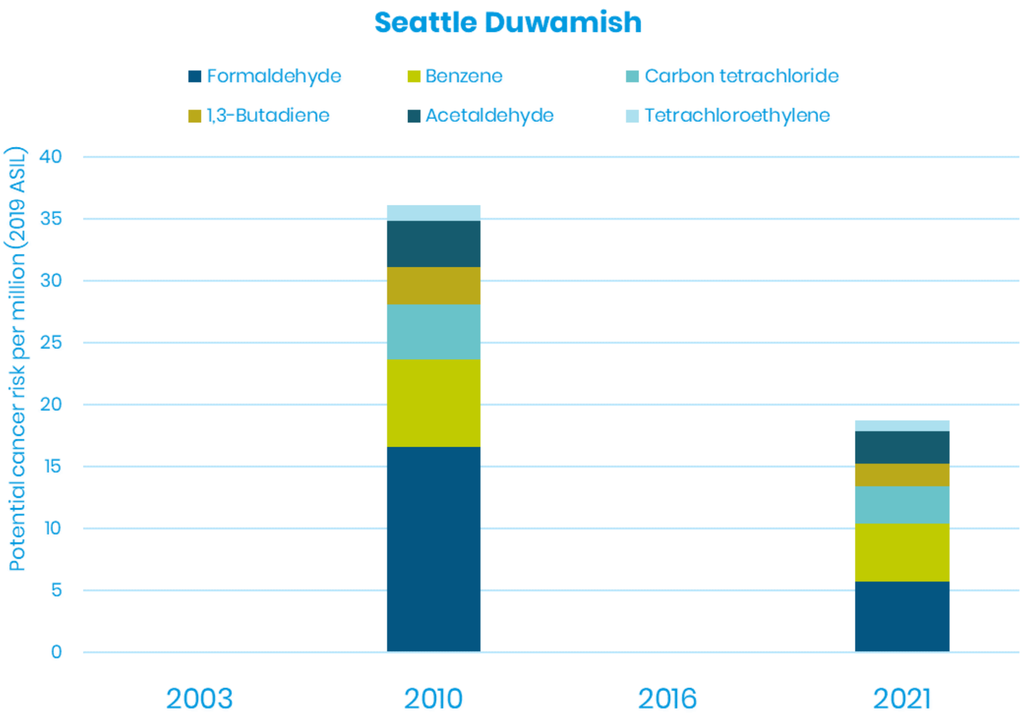


Figure 28. Historical trend of VOCs and aldehydes at Seattle 10th and Weller.

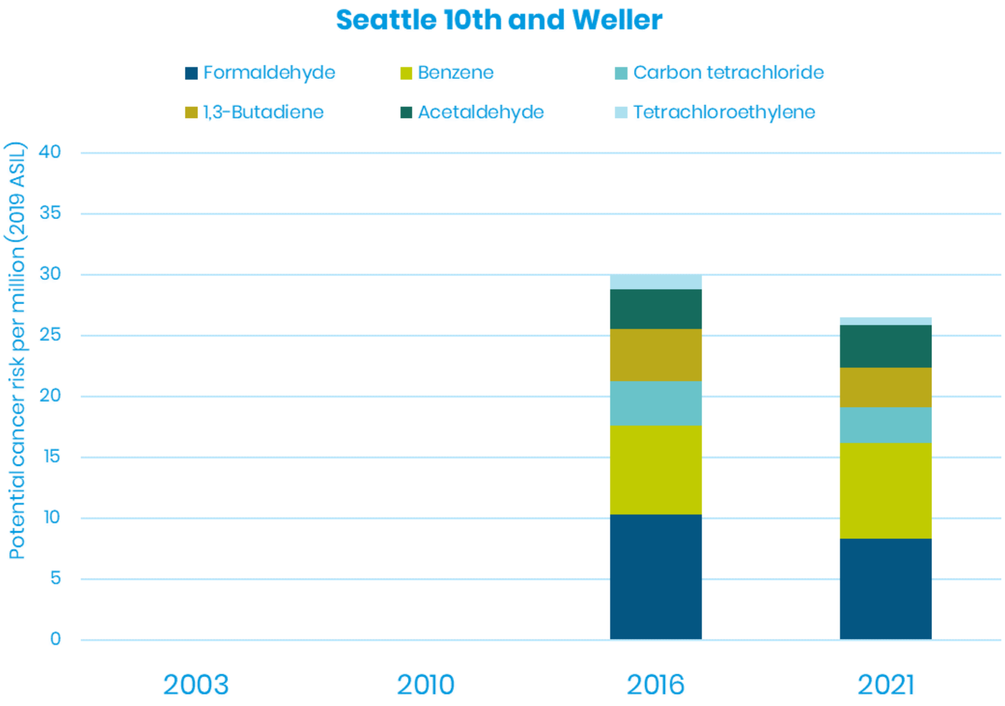


Figure 29. Historical trend of VOCs and aldehydes at Tacoma South L St.

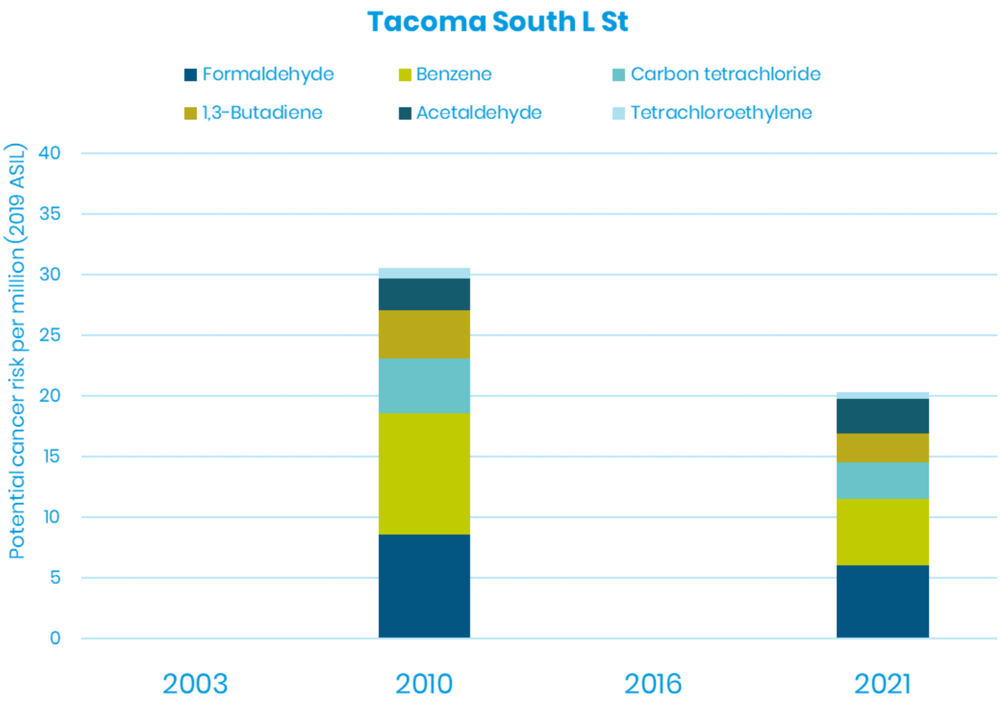
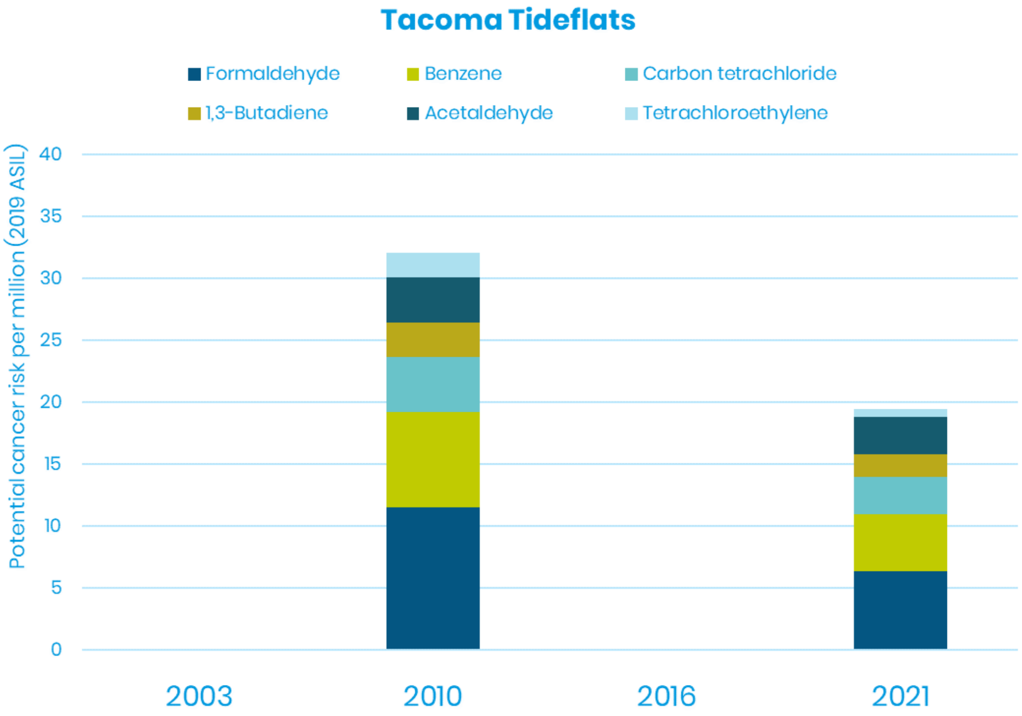


Figure 30. Historical trend of VOCs and aldehydes at Tacoma Tideflats.



Trends in wood smoke

In this section, we describe the change in estimated potential cancer risk from wood smoke at our Tacoma South L site.

Figure 31 below shows our estimated potential cancer risk from wood smoke at the Tacoma South L Street site. The results show nearly half the wood smoke impact when comparing 2006-2011 to 2018-2021. The earliest studies show a cancer risk of 51 per million in the mid to late 2000s, consistent with the high levels of wood smoke at that time. After the Agency took many actions to reduce wood smoke in the area,[61] the potential cancer risk levels were significantly lower at 39 per million. And continued to drop as measured in our study to 25 per million.

Figure 31We estimated wood smoke levels by combining "fresh" and "aged" wood smoke factors from various PMF analyses.[62,63,64] The 2006-2011 category in the figure below represents the average of 3 studies. The 2018-2021 result is from the PMF completed and described later in this report.

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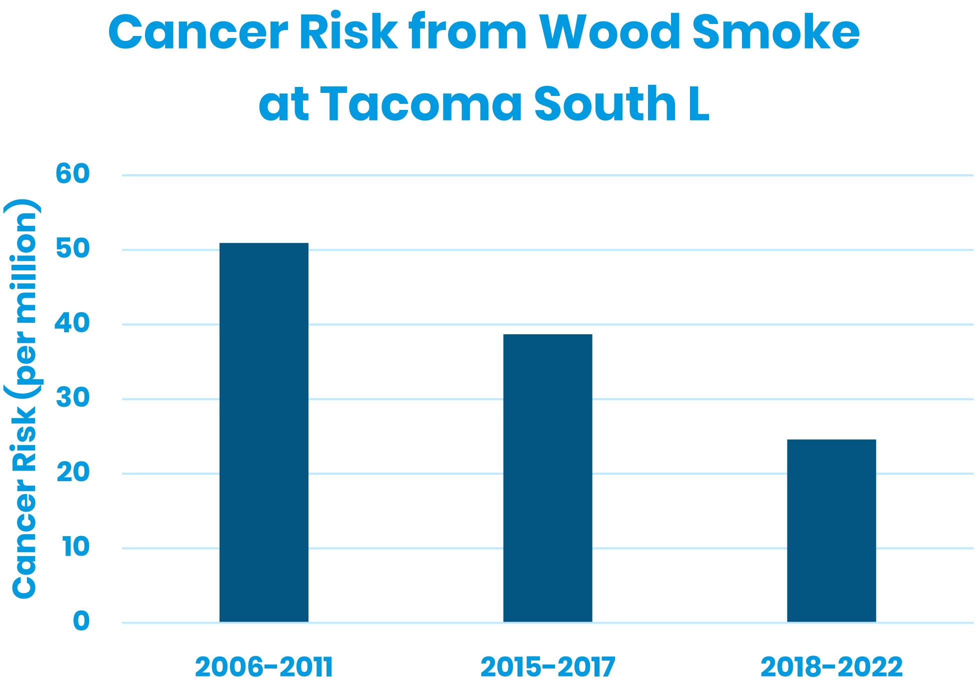
[61] WA State Dept of Ecology and Puget Sound Clean Air Agency, "Progress in Reducing Fine Air Pollution in Tacoma-Pierce County", April 2019. https://apps.ecology.wa.gov/publications/documents/1902009.pdf

[62] *ibid* Kotchenruther 2013

[63] *ibid* Kotchenruther 2020

[64] Ogulei D. (2010). "Sources of Fine Particles in the Wapato Hills-Puyallup River Valley $PM_{2.5}$ Nonattainment Area". WA Ecology, Publication 10-02-009. https://apps.ecology.wa.gov/publications/documents/1002009.pdf.

Figure 31. Estimated wood smoke potential cancer risk trend at Tacoma South L.



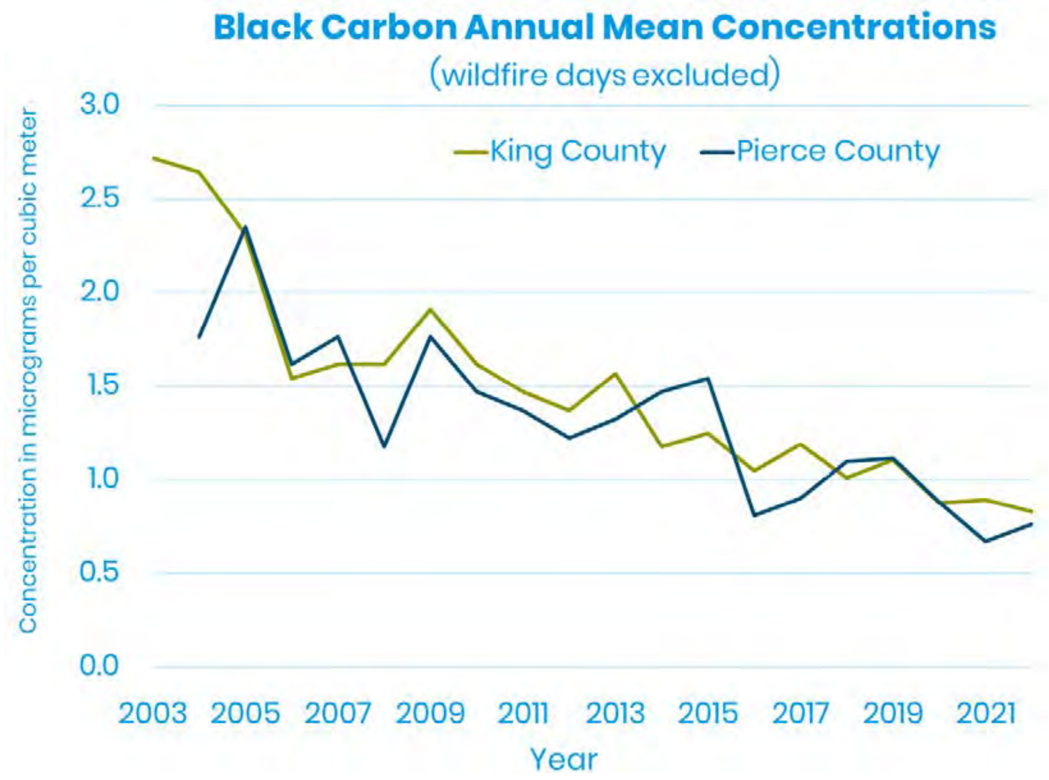
Trends in diesel particulate matter

Because of uncertainty between different PMF factors that represent diesel particulate matter, we did not do a comparison of PMF diesel particulate matter values as was done for the wood smoke section above.

However, we did include black carbon measurements over the last two decades. Black carbon can be a surrogate for diesel particulate matter and can give us more of an apples-to-apples comparison at our study sites.

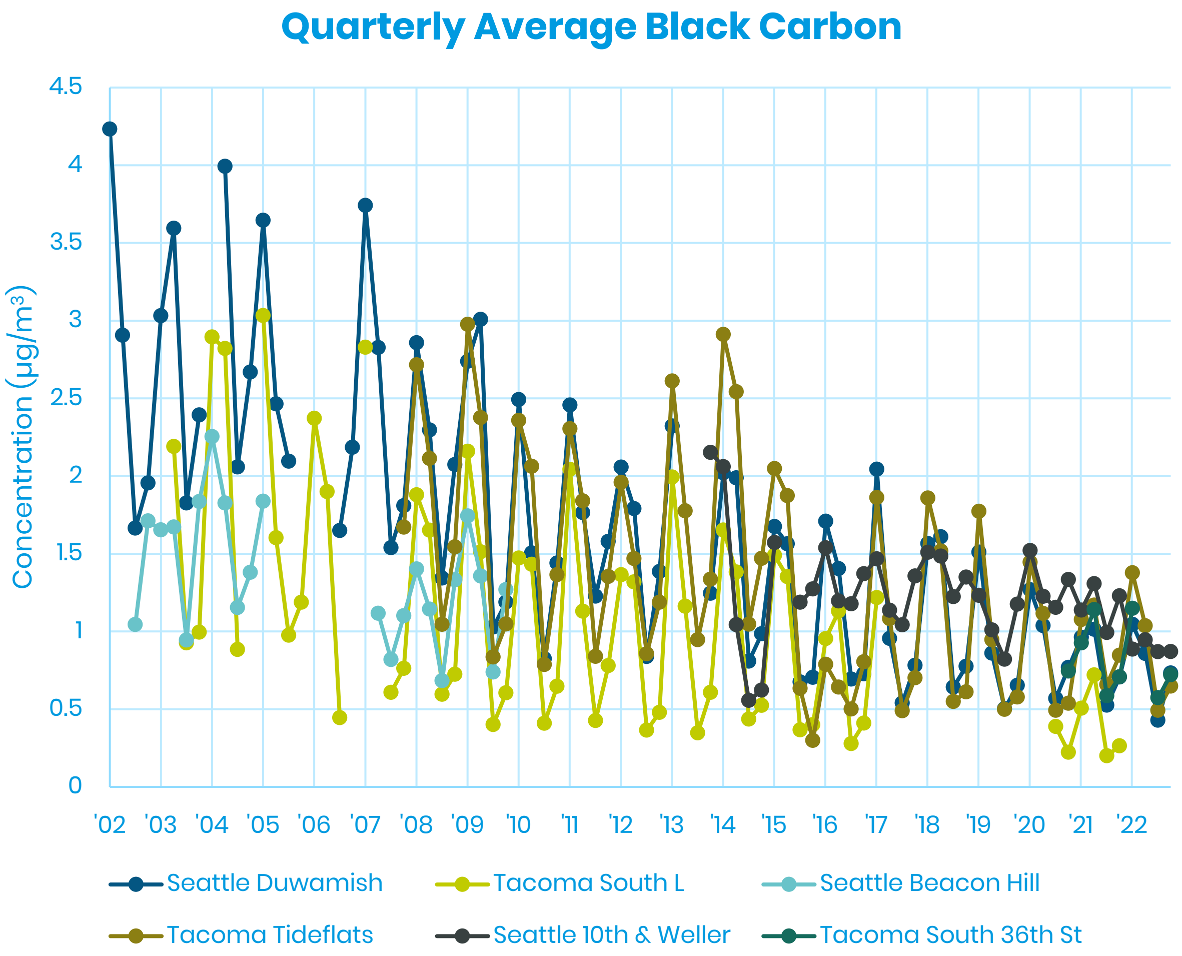
Figure 32 below shows the decreasing trend in black carbon over the past 20 years in King and Pierce Counties. This graph averages all sites within each county and excludes wildfire days. Over the last two decades, black carbon has decreased significantly, from an average of around 2.5 $\mu g/m^3$ to around 0.75 $\mu g/m^3$, a 70% reduction. Both diesel particulate matter and wood smoke contribute to black carbon, with diesel particulate matter year-round and wood smoke only in the winter months.

Figure 32. Annual black carbon trend.



We also included the quarterly trend in black carbon at our study sites since the fourth quarter of 2002 (Figure 33), also with wildfire days excluded. Black carbon has decreased in both the winter and summer, suggesting that both diesel and wood smoke have decreased over time.

Figure 33. Quarterly average black carbon trend.



How trends compare to population and vehicle miles traveled

In this section, we show changes in population growth and vehicle miles traveled.

This graph shows the total population for our four-county region, King, Kitsap, Pierce, and Snohomish Counties, from 2000 to 2022.[65,66,67] Over that period, the population has risen from 3.3 million to 4.3 million people, a 30% increase. Yet, air toxics levels fell by roughly 50% over that time.

Figure 34. Population of King, Kitsap, Pierce, and Snohomish Counties since 2000.

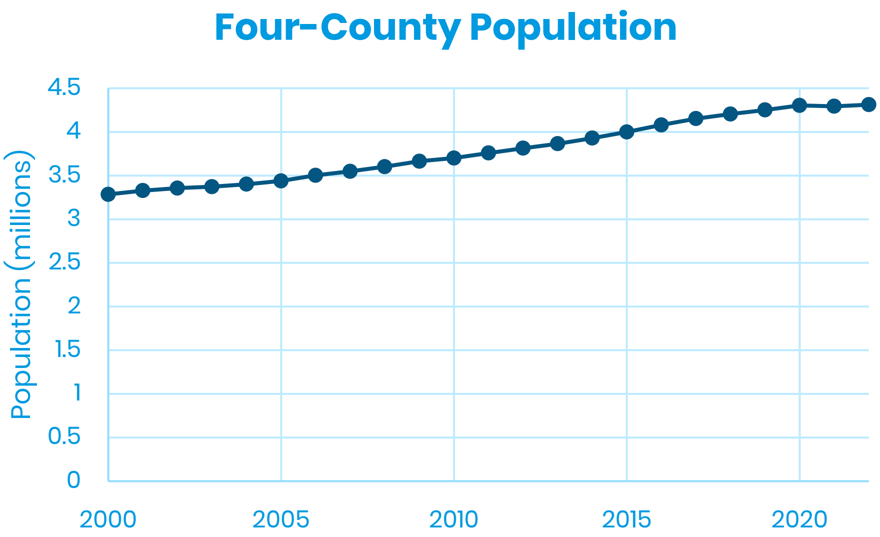


Figure 35 below shows the increase in daily vehicle miles traveled (VMT) in King, Kitsap, Pierce, and Snohomish Counties.[68] There was a 14% increase in daily VMT between 1999 and 2019. The COVID pandemic dramatically decreased daily VMT before starting to rebound in 2021. Even with a nearly flat comparison of VMT for 2022 vs the last two decades, we still saw pronounced reductions in air toxics.

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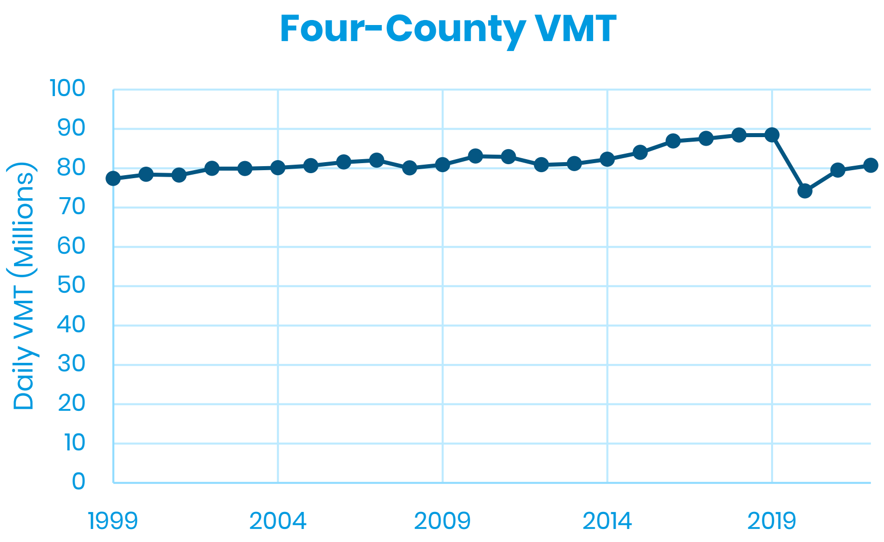
[65] U.S. Census Bureau (2012). County Intercensal Tables: 2000-2010. https://www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-counties.html.

[66] U.S. Census Bureau (2020). County Population Totals: 2010-2019. https://www.census.gov/data/tables/time-series/demo/popest/2010s-counties-total.html.

[67] U.S. Census Bureau (2022). County Population Totals and Components of Change: 2020-2022. https://www.census.gov/data/tables/time-series/demo/popest/2020s-counties-total.html.

[68] Washington State Department of Transportation, Highway Performance Monitoring System, received via email request to WSDOT in November 2023, https://wsdot.wa.gov/about/transportation-data/travel-data/annual-mileage-and-travel-information.

Figure 35. Daily vehicle miles traveled (VMT) for King, Kitsap, Pierce, and Snohomish Counties.



These results indicate that improved technology standards for vehicle engines, non-road equipment, fuels, and other emission reduction programs are the main reason for the significant reduction in air toxics in our region. In our region, we have also seen reductions for $PM_{2.5}$ generally, as can be seen in our latest annual data summary.[69]

AirToxScreen comparison

AirToxScreen (previously called the National Air Toxics Assessment or NATA) is a yearly product created by the EPA to model and display air toxics concentration and risk. It contains information at the census tract level. We can compare the AirToxScreen concentrations and cancer risks to our monitoring results using the census tracts that our monitors are located in. For this analysis, we have included AirToxScreen results from 2017, 2018, and 2019 (the latest publicly available at the time of writing).

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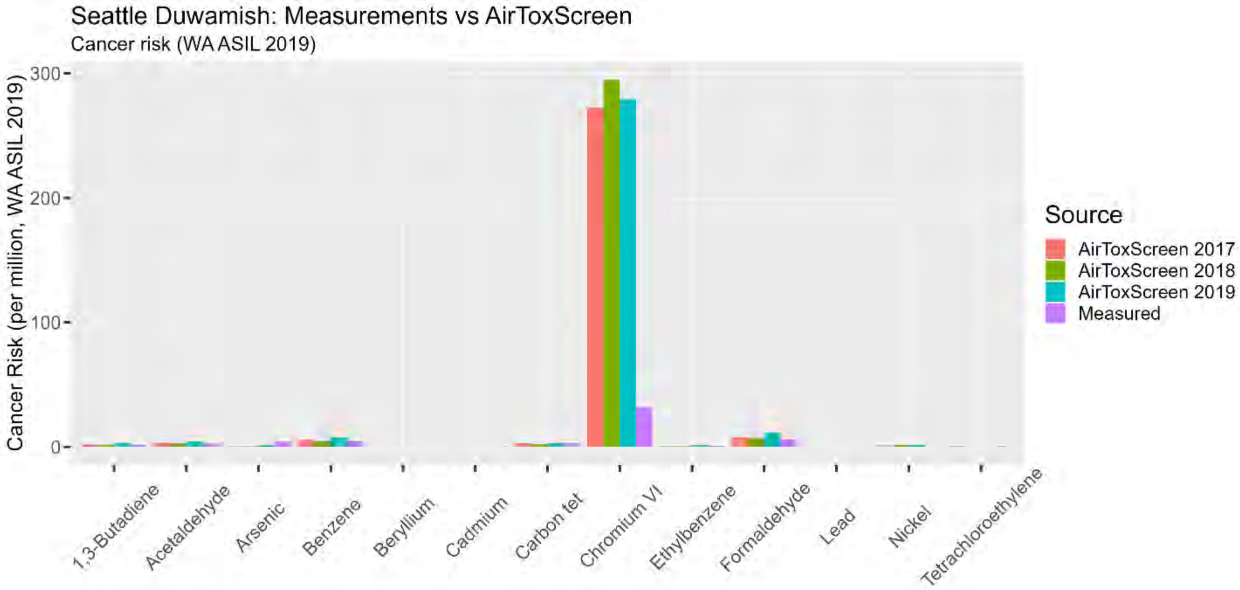
[69] PSCAA, 2021 Air Quality Data Summary, https://pscleanair.gov/DocumentCenter/View/4828/Air-Quality-Data-Summary-2021-PDF?bidId=.

In order to make the cancer risk estimates comparable, AirToxScreen cancer risks have been recalculated from AirToxScreen concentration data using the 2019 WA ASILs that were used for the cancer risk calculations for our data.

Seattle Duwamish Valley comparison

This graph in Figure 36 shows the cancer risk for AirToxScreen predictions and our measurements (in purple). AirToxScreen estimates most of the risk is born by hexavalent chromium. For this site, AirToxScreen predicts almost 10x more hexavalent chromium than what is estimated by our monitoring. This may be because AirToxScreen bases its models off self-reported emission from sources that is input into the National Emissions Inventory (NEI). For example, we know one of the three listed sources has had a significant decrease in production since the latest AirToxScreen. Another possible discrepancy is that we estimated hexavalent chromium levels from prior total chromium-to-hexavalent chromium ratios. Because of these results and to increase our certainty, we are planning on doing a follow-up hexavalent chromium study in the area to refine our estimates to ensure we have a more accurate assessment of the risk in the Duwamish Valley.

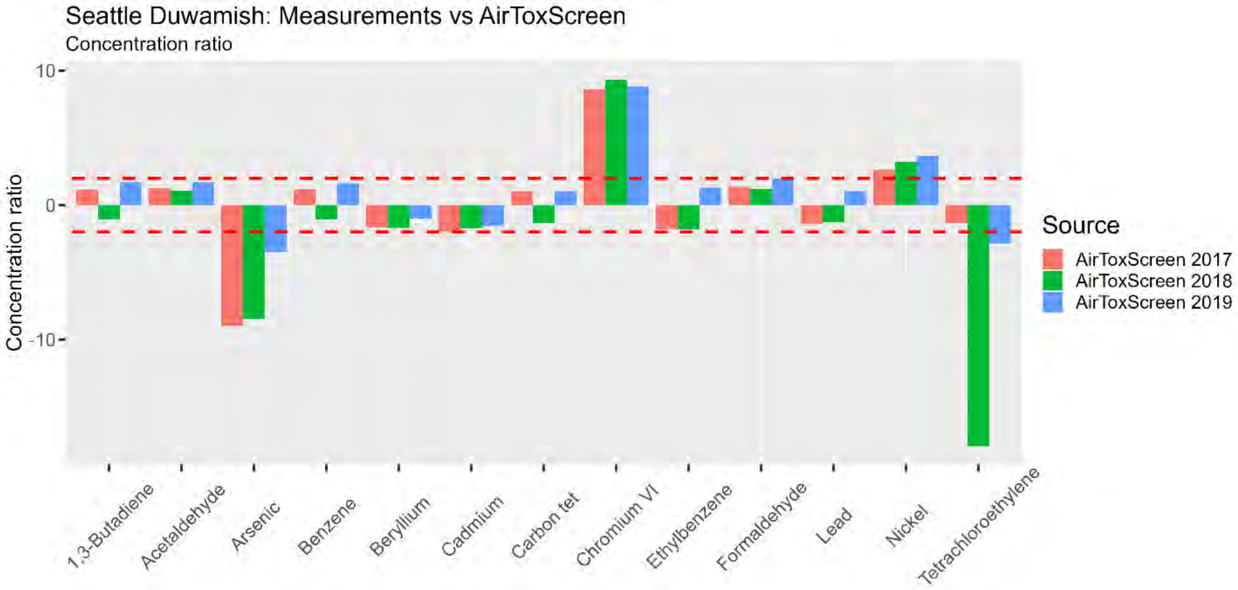
Figure 36. Seattle Duwamish AirToxScreen cancer risk comparison.



A note regarding the concentration ratio graphs below: If the bars are positive then AirToxScreen is overestimating, and if the bars are negative, then AirToxScreen is underestimating. The dotted red lines indicate when an AirToxScreen concentration is more than 2x different from the measured value. If the AirToxScreen concentration is greater than or equal to the measured concentration, then the value is AirToxScreen/Measured. If the AirToxScreen concentration is less than the measured concentration, then the value is -1/(AirToxScreen/Measured). This means that a value of 5 can be read as "the pollutant is 5x higher on AirToxScreen" and a value of -5 can be read as "the pollutant is 5x lower on AirToxScreen".

Figure 37 below shows the ratio between AirToxScreen and our measurements for the Duwamish site. The graph shows that AirToxScreen overpredicts hexavalent chromium (as discussed above) and nickel, and underpredicts arsenic and tetrachloroethylene. Because hexavalent chromium carries most of the cancer risk the net result is an overestimate of cancer risk.

Figure 37. Seattle Duwamish AirToxScreen concentration comparison.



Nickel is likely overpredicted for the same reason as hexavalent chromium. That is, the results are dependent on self-reported emissions from sources that gets input into the NEI and may not reflect actual operations.

The largest arsenic source listed in the NEI is the rail yard. Arsenic in resuspended dust and soils would also be unaccounted for in AirToxScreen. At this time, we do not have a direct conclusion why arsenic is underreporting in the NEI.

The NEI does not have any significant sources for tetrachloroethylene listed within King County. Additionally, there are no open drycleaning businesses that use tetrachloroethylene nearby. However, this underprediction is the case for all our sites. Therefore, it is likely that AirToxScreen's background estimate of tetrachloroethylene is generally too low for our region.

Seattle Beacon Hill comparison

Figure 38 below shows the cancer risk comparison for Beacon Hill. At this location, we estimated the hexavalent chromium value from total chromium results using a 0.8% ratio that we calculated from previous monitoring results there.[70] AirToxScreen also overestimated hexavalent chromium at the Beacon Hill site but improved somewhat with more recent versions of AirToxScreen.

Figure 38. Seattle Beacon Hill AirToxScreen cancer risk comparison.

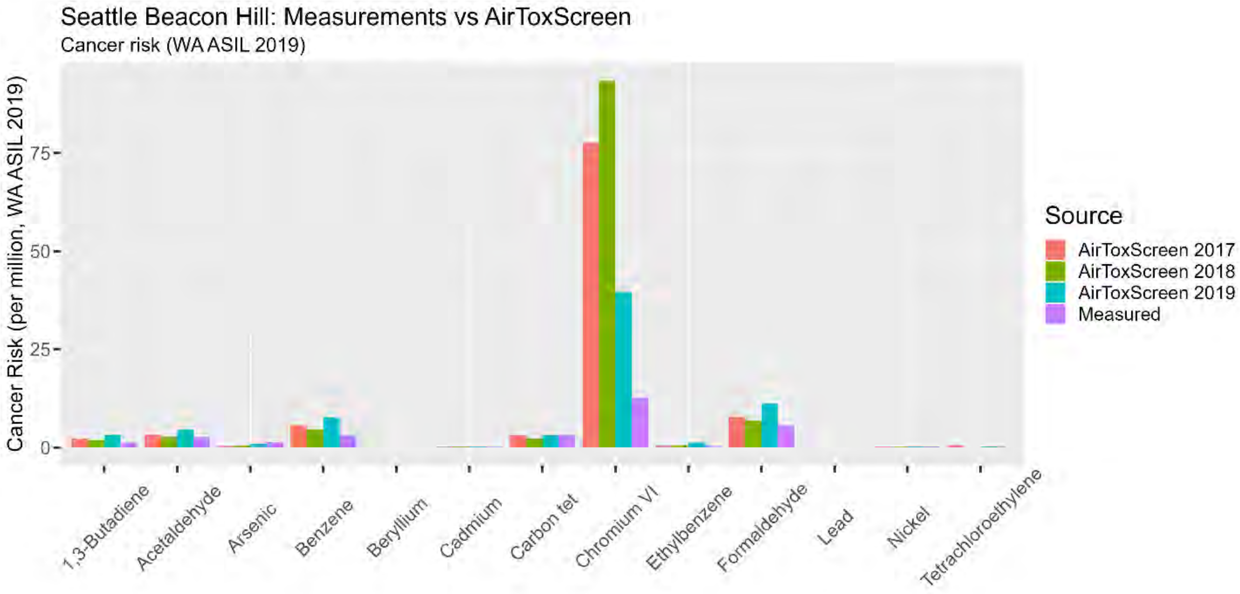


Figure 39 shows the Beacon Hill concentration ratios. The 2017 and 2018 AirToxScreen estimates of arsenic were low, but the latest version is closer. The AirToxScreen beryllium estimates are higher than our measurements. Generally, AirToxScreen is overpredicting for most of the air toxics generally at this location.

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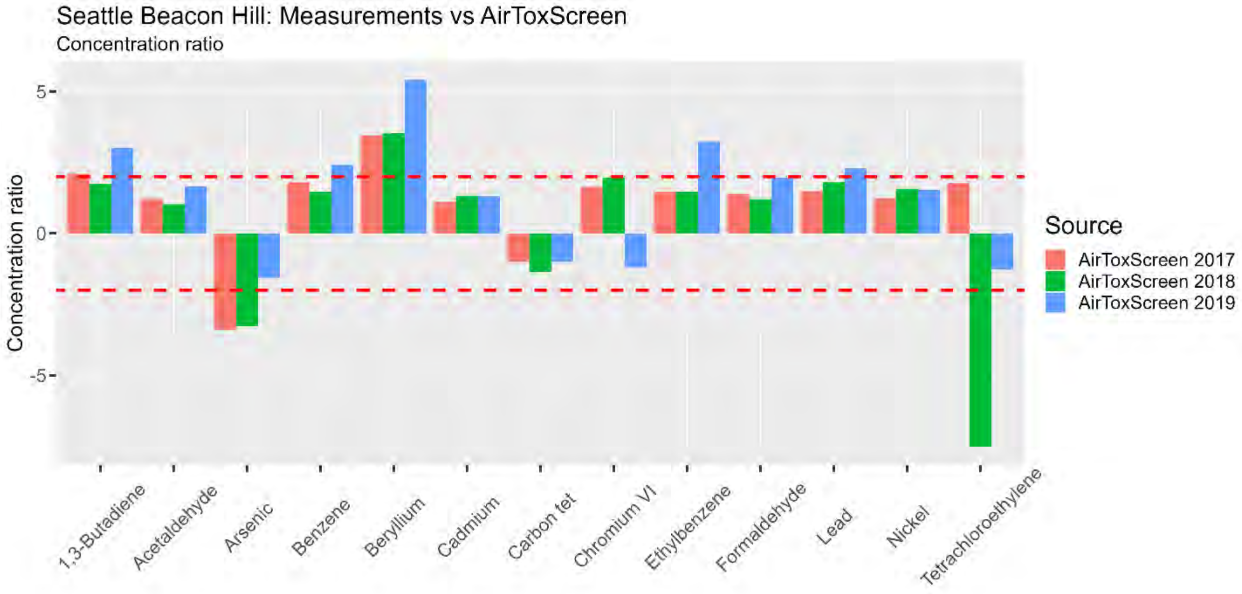
[70] Puget Sound Clean Air Agency, Air Quality Data Summary, 2013, http://dl.pscleanair.org/Datasummaries/AQDS2013.pdf.

Figure 39. Seattle Beacon Hill AirToxScreen concentration comparison.



Tacoma Tideflats comparison

Figure 40 and Figure 41 shows the results for the Tacoma Tideflats site. AirToxScreen underestimates arsenic, beryllium, and tetrachloroethylene. Beryllium values and tetrachloroethylene values are generally near the detection limit and will look variable. Arsenic is also underpredicted by AirToxScreen as we found in other sites.

Figure 40. Tacoma Tideflats AirToxScreen cancer risk comparison.

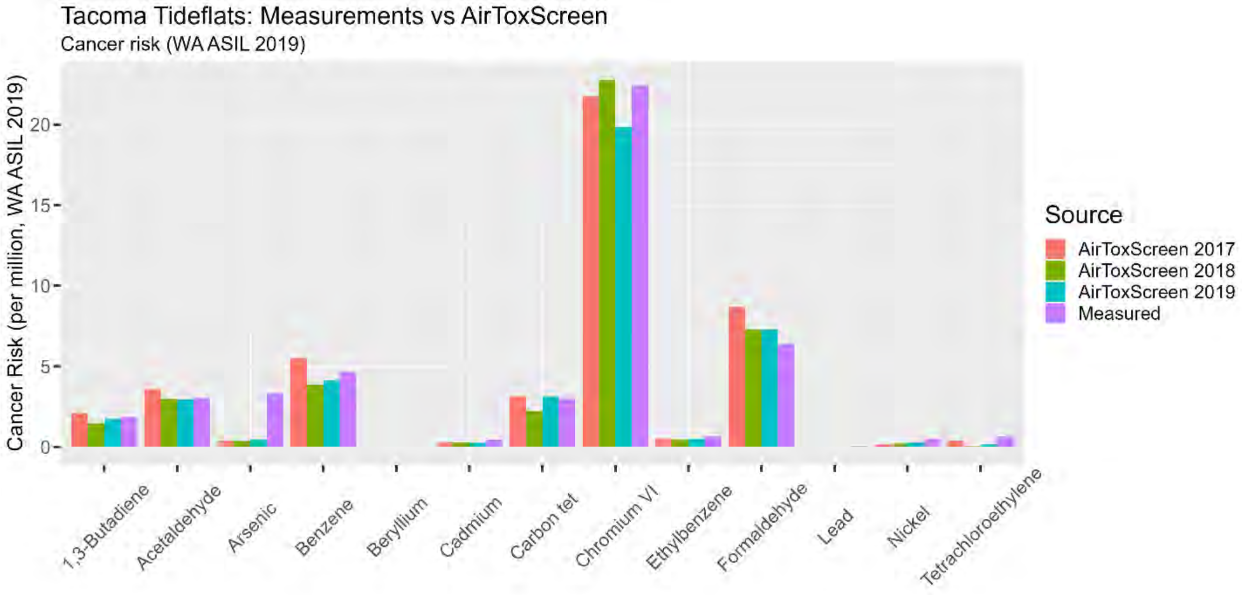
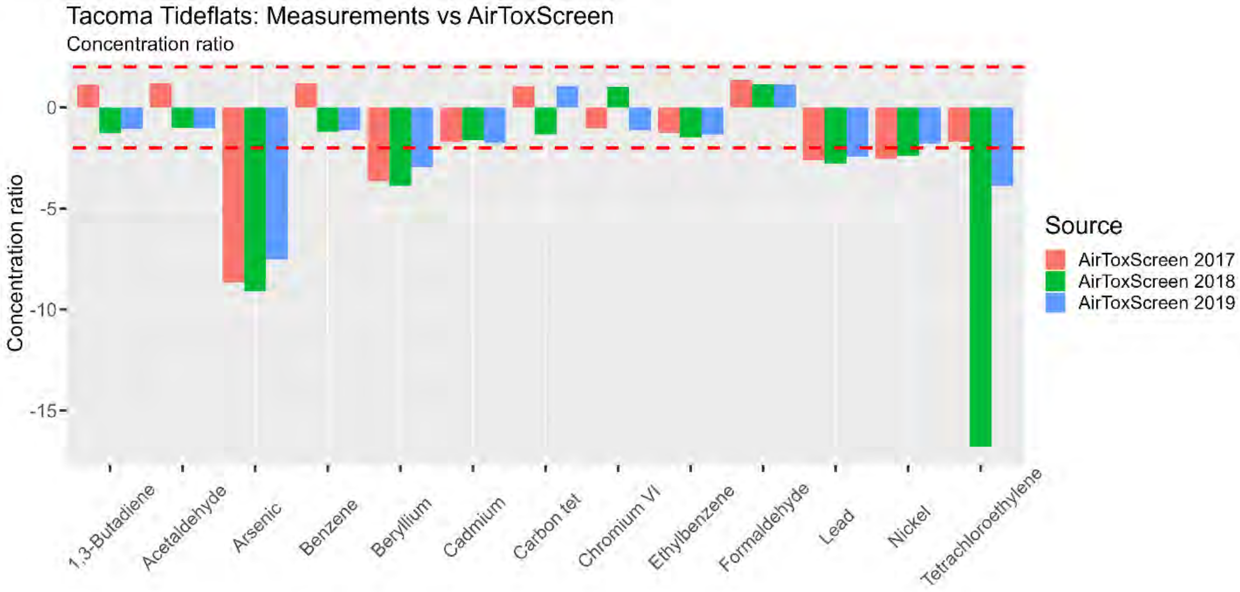


Figure 41. Tacoma Tideflats AirToxScreen concentration comparison.



Seattle 10th and Weller comparison

Figure 42 and Figure 43 show the Seattle 10th and Weller comparisons. AirToxScreen estimates were within two times the measured values and had generally close risk approximations at 10th & Weller. The only exception was tetrachloroethylene (which was discussed earlier).

Figure 42. Seattle 10th & Weller AirToxScreen cancer risk comparison.

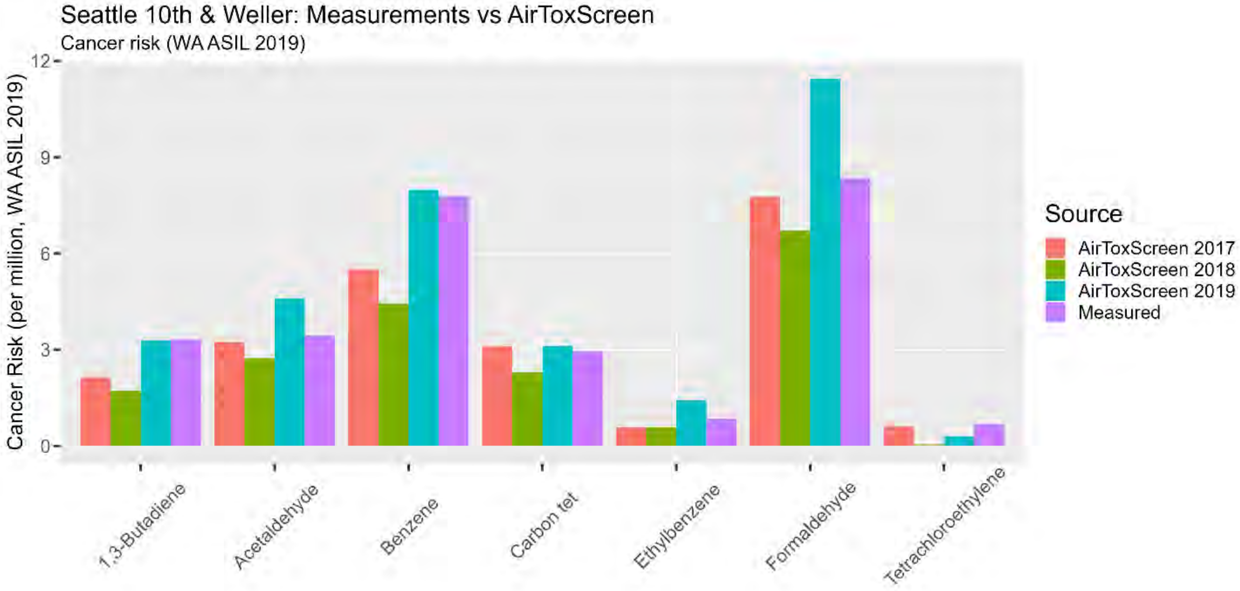


Figure 43. Seattle 10th & Weller AirToxScreen concentration comparison.

Tacoma South L Street comparison

Figure 44 and Figure 45 shows the results for Tacoma South L Street. AirToxScreen was within two times the measured values and resulted in generally close approximations for risk at Tacoma South L St. The only exception is tetrachloroethylene (which was discussed earlier).

Figure 44. Tacoma South L AirToxScreen cancer risk comparison.

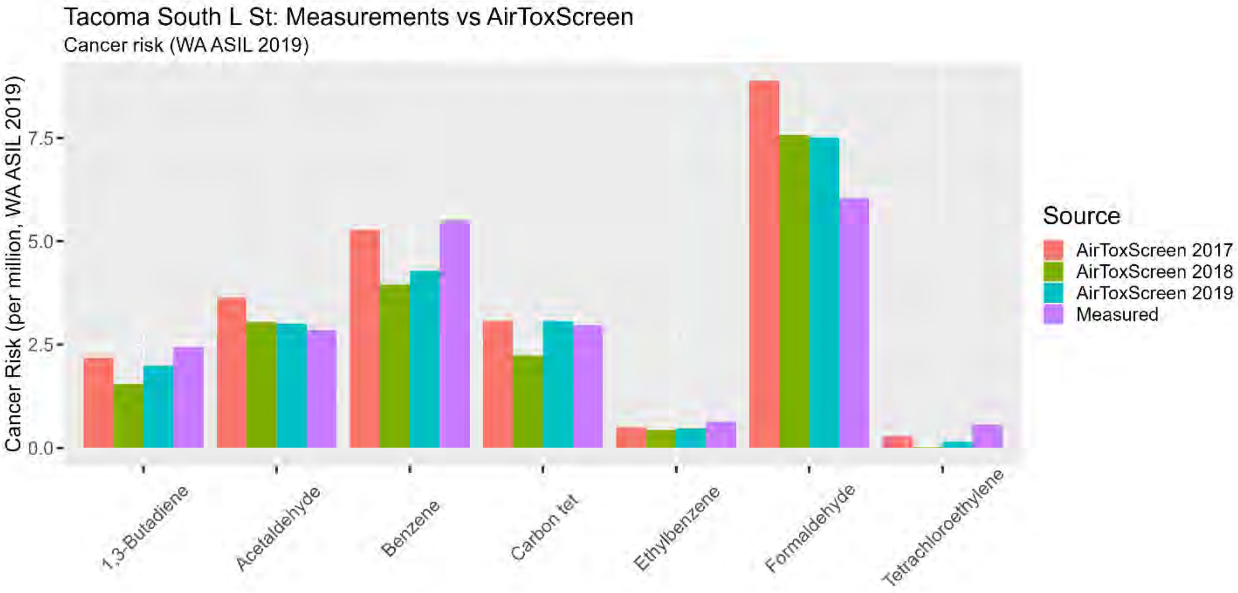
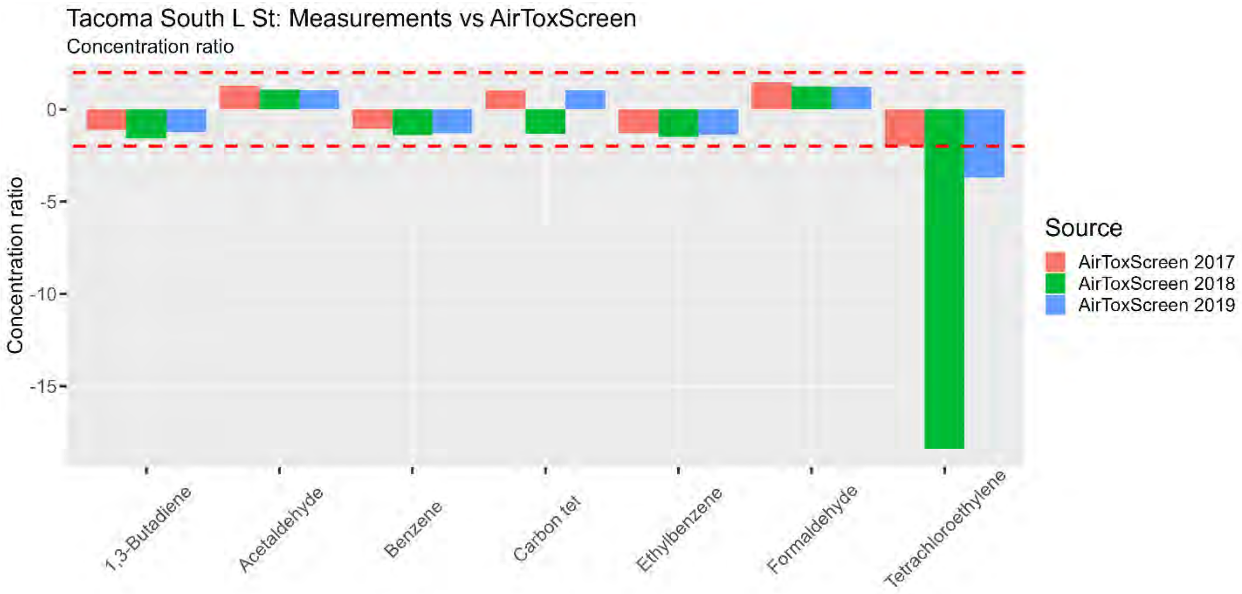


Figure 45. Tacoma South L AirToxScreen concentration comparison.



Tacoma S 36th St comparison

Figure 46 and Figure 47 show the results for the Tacoma S 36th St site. The risks and concentration ratios were generally in range, like the Tacoma South L and Seattle 10th and Weller locations.

Figure 46. Tacoma South 36th AirToxScreen cancer risk comparison.

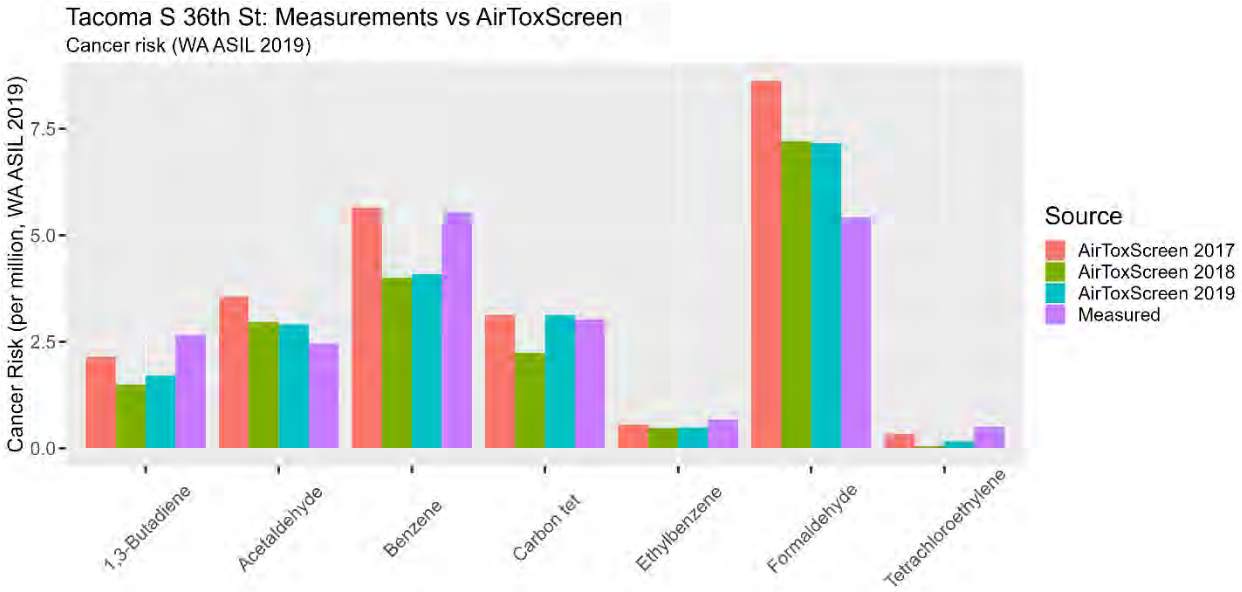
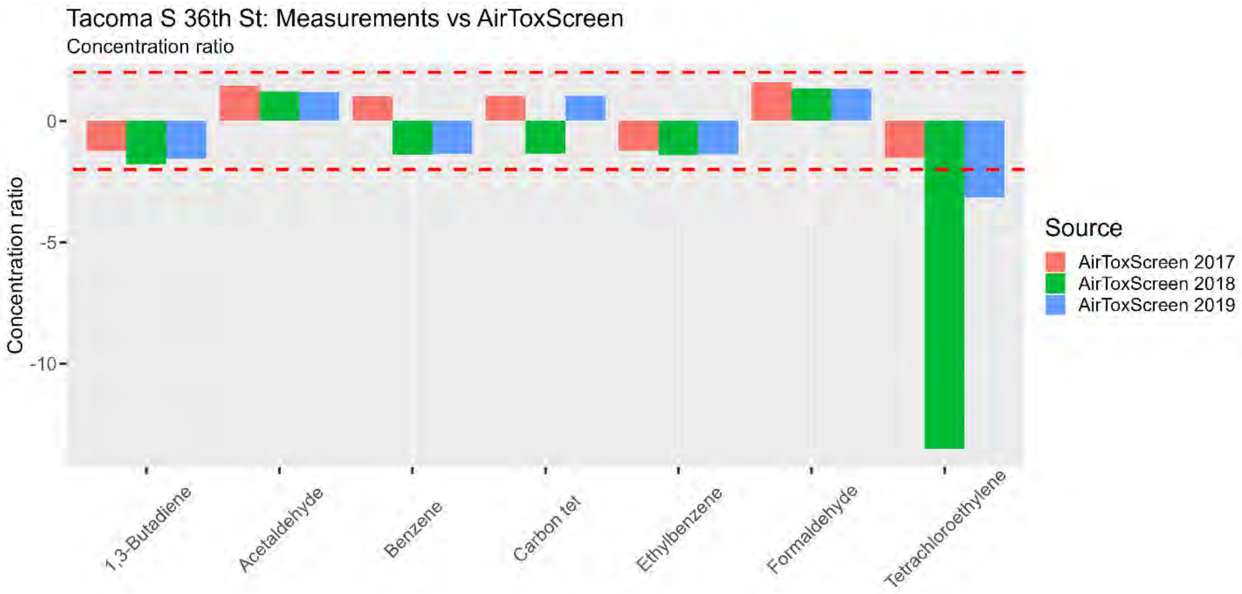


Figure 47. Tacoma South 36th AirToxScreen concentration comparison.



Source apportionment

About source apportionment

We completed source apportionment analyses on five of the study locations to better estimate risk from diesel particulate matter and wood smoke. Positive Matrix Factorization (PMF) is a widely used factor analysis tool used to identify source contributions in complex, mixed airsheds. PMF reduces a complex set of data into factors that have both a fingerprint comprised of differing amounts of each pollutant, and a time series of the factor showing the strength of that factor at any given time. Briefly, this modeling approach assumes 1) that a small number of source categories or factors (typically 5-10) are responsible for the vast majority of the chemical mass measured in a data set, 2) after being emitted, dispersion and mixing are the primary changes that occur and any loss or production is relatively consistent, 3) the contributions from each source add together to form the sum for each chemical, and 4) the source emissions profiles don't change significantly throughout the study period. The PMF algorithm identifies the individual factors (which can be associated with sources to varying degrees of completeness) that could generate the observed data set. The individual factors can be compared to known emission profiles and temporal activity profiles to test for consistency. If an underlying source changes in time, or there are changing losses or secondary production, a source could be split into two or more factors that have temporal structure. The PMF approach has been widely used and is generally regarded as reliable to the extent that the underlying data are sufficiently extensive, of good quality, and the solutions are found to be robust with respect to sampling uncertainty and rotational ambiguity.[71,72]

Methodology

Source apportionment was done using EPA's PMF 5.0 model.[73] For our analysis, we used daily average (24-hour, midnight to midnight) values from $PM_{2.5}$ Chemical Speciation Network (CSN) data. PMF analysis was done separately for Seattle sites (10th and Weller, Beacon Hill, and Duwamish) and Tacoma sites (South L and Tideflats). CSN samples are collected every 6 days at all sites except Beacon Hill, where samples are collected every 3 days. At Duwamish and 10th and Weller, 24-hour average brown carbon (BrC) was added to the analysis. BrC is calculated as the black carbon (BC) minus the UV (ultraviolet absorption) channel measured by AE-33 aethalometers. Dataset descriptions for each site are in Table 10. Site dataset descriptions for PMF analysis.. The missing samples are all from March 2022 – August 2022 during Covid pandemic shutdowns.

Table 10. Site dataset descriptions for PMF analysis.

Site	**Start date**	**End Date**	**# samples**	**Missing samples**
Seattle Duwamish	8/12/2018	6/28/2022	237	29
Seattle 10th and Weller	8/12/2018	7/28/2022	242	30
Seattle Beacon Hill	8/12/2018	9/29/2022	506	60
Tacoma South L	8/12/2018	9/26/2022	252	29
Tacoma Tideflats	8/12/2018	2/10/2022	214	28

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[71] Paatero P., Hopke P.K. Discarding or downweighting high-noise variables in factor analytic models. 2003. Anal. Chim. Acta 490: 277-289.

[72] Norris G., Duvall R., Brown S., Bai S. EPA Positive Matrix Factorization (PMF) 5.0 Fundamentals and User Guide. 2014. U.S. Environmental Protection Agency. EPA/600/R-14/108.

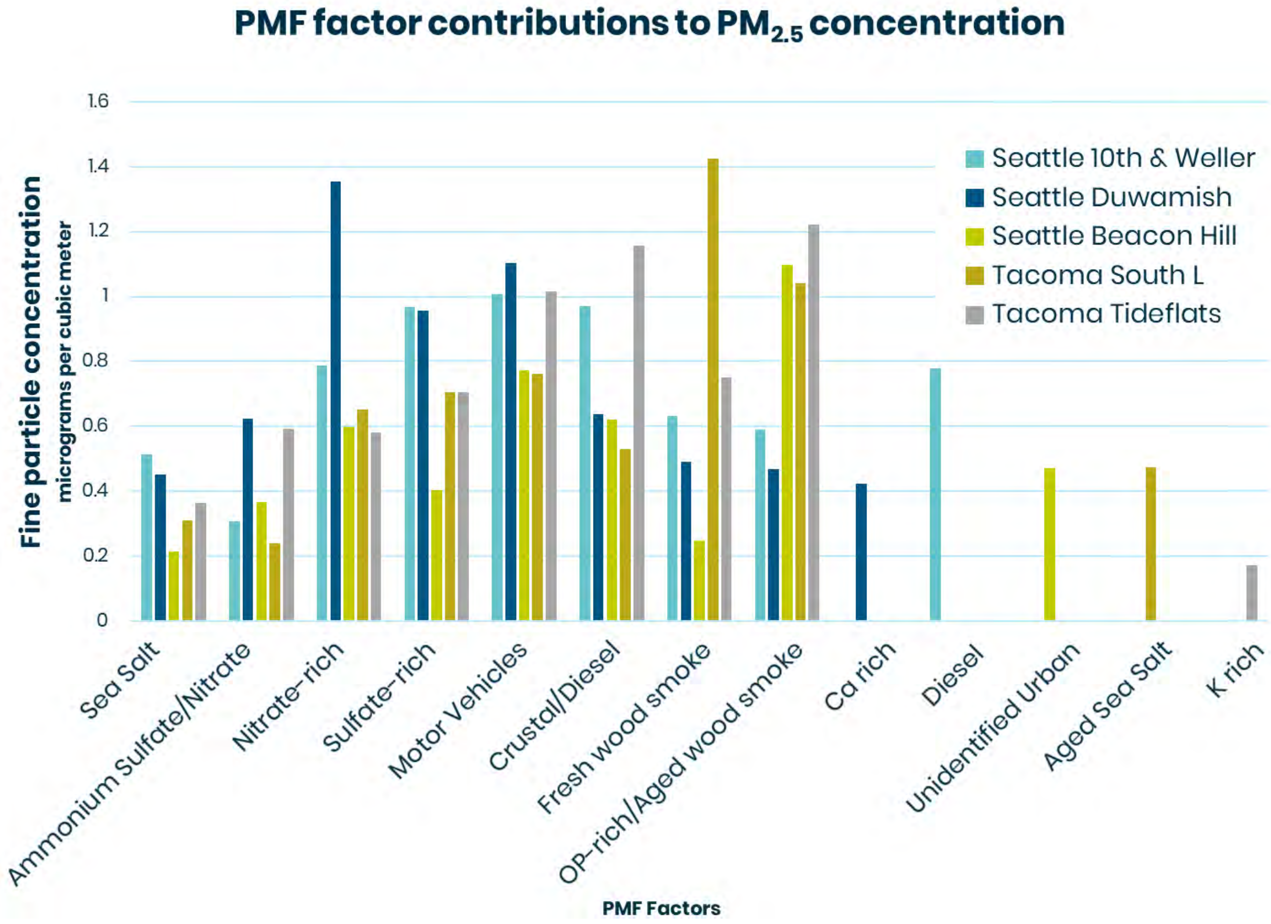
[73] EPA, Positive Matrix Factorization Model for Environmental Data Analyses, https://www.epa.gov/air-research/positive-matrix-factorization-model-environmental-data-analyses.

The CSN data was corrected for field blank concentration by subtracting the mean field blank concentration from the sample concentration. The PMF model requires an uncertainty for each sample. Sample values were not changed if they were below the method detection limit (MDL), but their uncertainty was calculated differently. For samples above the MDL, uncertainty was calculated as analytical uncertainty plus 1/3rd of the MDL. For samples below the MDL, uncertainty was calculated as 5/6th of the MDL. Missing and negative values were replaced with the species' median concentration, and the associated sample uncertainty was set to four times the species' median concentration. For species without an analytical uncertainty or MDL, the uncertainty was calculated as the measured value divided by 10. Species were not included in the dataset in the percentage of samples below the method detection limit (MDL) was greater than 75%. Unfortunately for our analysis, but fortunately for the health of the population, a majority of the metals have greater than 75% of samples below the MDL. The species not included in any analysis include nickel and vanadium, which are markers for residual fuel oil combustion and marine diesel. Certain chemical species measured are very similar (ex. sodium and sodium ion, chloride and chlorine, potassium and potassium ion), so in order not to double count the species, we selected those with the lower signal to noise ratio was discarded from the analysis. To avoid double counting sulfate/sulfur non-sulfate sulfur (NSS = SO4 - S) was calculated by subtracting the sulfur component of the measured sulfate concentration from the measured sulfur concentration and having NSS replace sulfur in the analysis. Similarly, EC1 was recalculated to remove the OP portion in EC1 (EC1=EC1-OP). Samples with high concentrations from fireworks and wildfires were excluded from the dataset. Species with a signal-to-noise ratio less than 0.5 were excluded from the dataset. Species with a signal-to-noise ratio between 0.5 and 1 were marked "weak" in the PMF analysis.

Results

Figure 48 below shows the factor specific $PM_{2.5}$ mass for each site. All sites shared eight common factors we identified and labeled as: Sea Salt, Ammonium Sulfate/Nitrate, Nitrate-rich, Sulfate-rich (potentially a maritime related factor), Crustal/Diesel (road dust and diesel particulate matter combined), Motor Vehicles – Gasoline, Fresh Wood Smoke, and OP-rich/Aged Wood Smoke. Each site also had its own unique factor. Seattle 10th & Weller had a separate diesel factor. Seattle Duwamish had a calcium (Ca)-rich factor, potentially associated with nearby cement plants. Seattle Beacon Hill had an Unidentified Urban factor with no obvious source, but most closely related to secondary organic aerosols from fuel combustion. Tacoma South L had an Aged Sea Salt factor. Tacoma Tideflats had a potassium (K)-rich factor associated with fireworks. A full discussion of each factor and factor pie charts for each site can be found in Appendix K.

Figure 48. PMF contribution to $PM_{2.5}$ mass concentration.

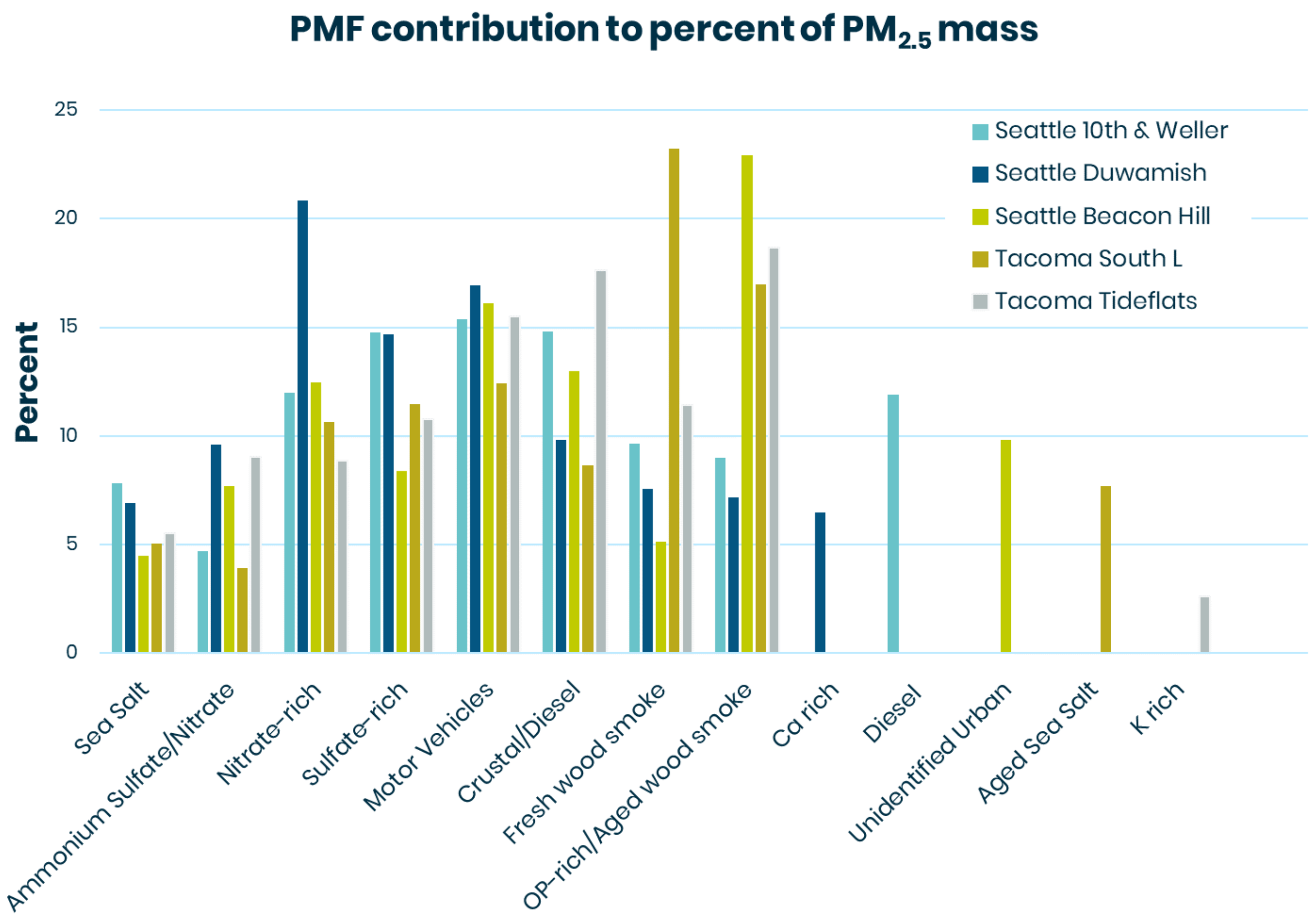


Generally, 10th & Weller, a near-road site, saw higher contributions from diesel, with both the Crustal/Diesel and Diesel factors. Tacoma South L, a residential wood smoke impacted site, saw higher contributions from fresh wood smoke and equal contributions from aged wood smoke. The crustal/diesel factor was also high at Tacoma Tideflats, possibly because there was a high amount of construction going on during the sampling period, which involved large trucks driving on dirt roads, contributing to the combined mix of diesel particulate matter and dust. Seattle Duwamish had a large contribution from the Nitrate-rich factor. This factor was higher in the winter for all sites, which potentially is secondary nitrate. Along with the presence of carbon species, this points to the presence of wood smoke. Seattle

Duwamish had the lowest contribution from aged wood smoke, so this may have balanced out by being factored into the larger contribution from the nitrate-rich factor.

Figure 49 shows the factor specific percentage contribution by site. This graph shows generally similar percent contributions by category. It also illustrates the observations outlined above more clearly as the total mass concentration of $PM_{2.5}$ differed by site.

Figure 49. PMF contribution to percent of $PM_{2.5}$.



Community-directed monitoring and community concerns

Community engagement summary

In addition to fixed sites detailed above, our EPA grant application included a component for community-directed sampling in the Duwamish Valley. We listened to community concerns and found there was significant interest in knowing more about heavy metals levels in the Duwamish Valley following an earlier metals-in-moss study.

Before deploying the air toxics samplers, we worked with the Duwamish River Community Coalition (DRCC) over several weeks to find the best ways to talk to community members about air quality and collect input on the best locations to place air monitoring equipment.

On Tuesday August 17th, 2021, we hosted a community workshop in collaboration with DRCC in the South Park neighborhood of Seattle. We introduced information on air toxics, sources of air pollution in the area, and the health impacts of air pollution. We provided all participants with food and a box fan filter kit, and had interpretation available for Khmer, Spanish, Somali, and Vietnamese speakers.

We also invited high school students for the Duwamish Valley Youth Corps (DVYC) to share the results of their metals-in-moss sampling campaign. In 2019 and 2021, twenty-six students partnered with scientists from the US Forest Service (USFS) to sample moss from 80 locations in the Duwamish Valley and surrounding areas. The samples were analyzed for 25 heavy metals in a USFS laboratory.

Finally, we asked for participants input through four activities. The first had them explore a large map of the area and identify exact locations for monitoring air toxics. Second, we asked them to rank what additional areas were also a priority for them. Third, we taught them how to assemble and use a box fan filter and then gave them their own kit to take home. The fourth activity was a visioning exercise where participants added their thoughts and ideas with sticky notes.

Online community feedback

We invited community members to share their input and identify locations that should be prioritized for study. We gathered feedback online from August 6 - September 22, 2021, in English, Spanish, Somali, Vietnamese, and Khmer.

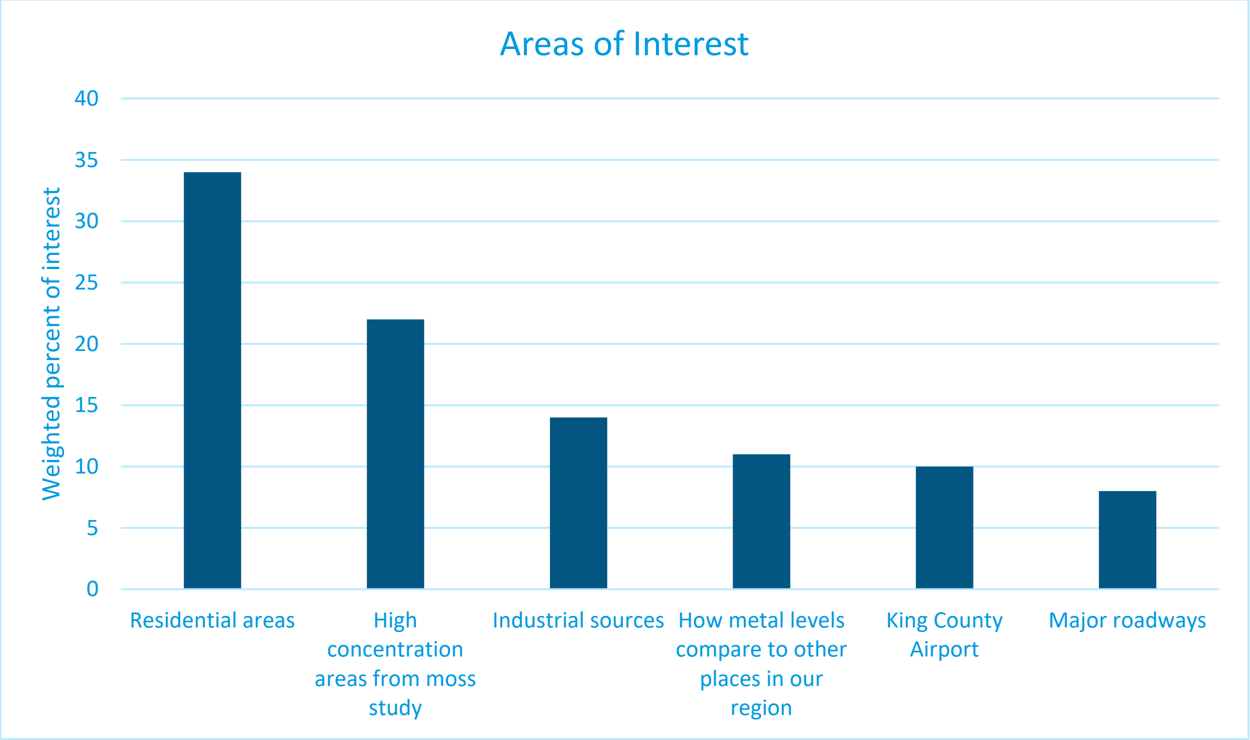
Community members could also provide feedback via internet connected tablets at Duwamish Riverfest—an in-person event. We also shared our request for feedback with multiple organizations, including Villa Comunitaria, Environmental Coalition of South Seattle (ECOSS), South Park Neighborhood Association, Georgetown Community Council, and DRCC.

Community feedback results

The community feedback results indicated community members were primarily interested in monitoring in residential areas, particularly in the South Park and Georgetown neighborhoods. Areas of interest also included locations with the highest values as identified by the moss study, industrial areas of South Park, and near the King County International Airport. Figure 50 below summarizes the results on a map. The map shows areas of increasing interest by size of circle. Green stars are where we placed monitors to correspond with the areas of interest. Figure 51 below also shows the types of areas of most interest. The areas with the highest values from the moss sampling study is "C" in the map.

Figure 50. Spatial community input results and eventual temporary monitoring locations.

Figure 51. Community feedback on sampling locations.



$PM_{2.5}$ sensor measurements at community sites

Based on community feedback, we deployed small $PM_{2.5}$ sensors at five locations where the greatest interest was indicated. Two types of sensors were deployed, N-FRM and Purple Air (PA) – see Appendix G for details on data quality control and adjustments of these air sensors. The sampling dates are shown in Figure 52. The period from July 1 – Sept 1 when the $PM_{2.5}$ sensors were operating at all the community directed sites is called the 'intensive' period in this section.

Figure 52. The dates of sampling for $PM_{2.5}$ at locations based on community interest.

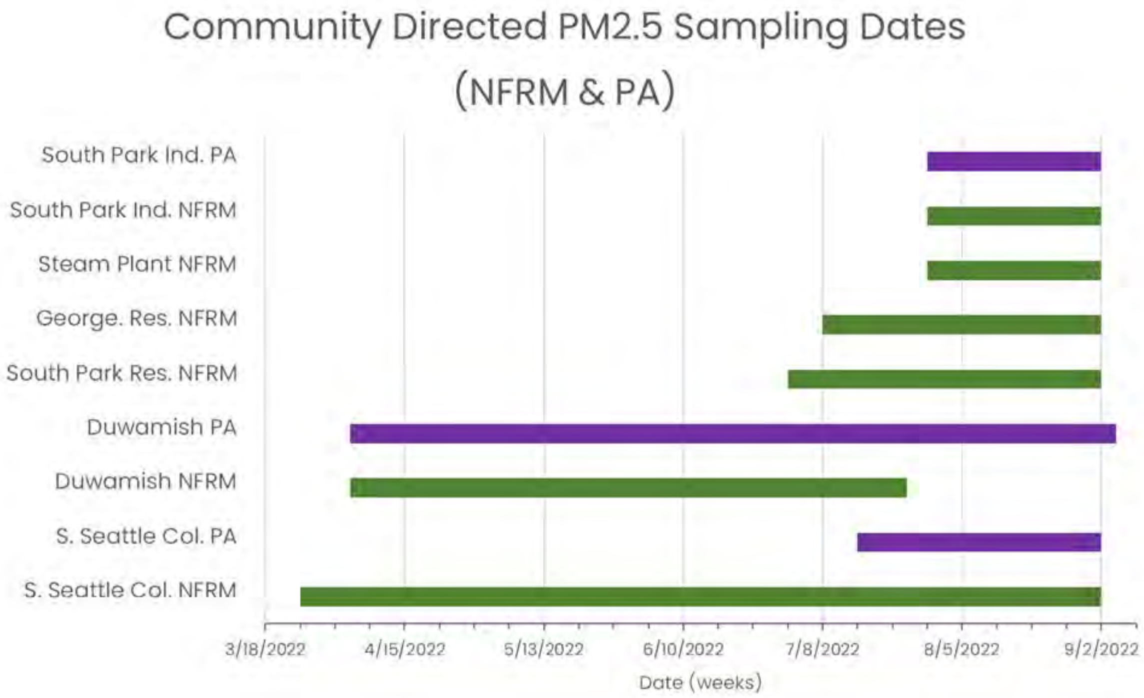
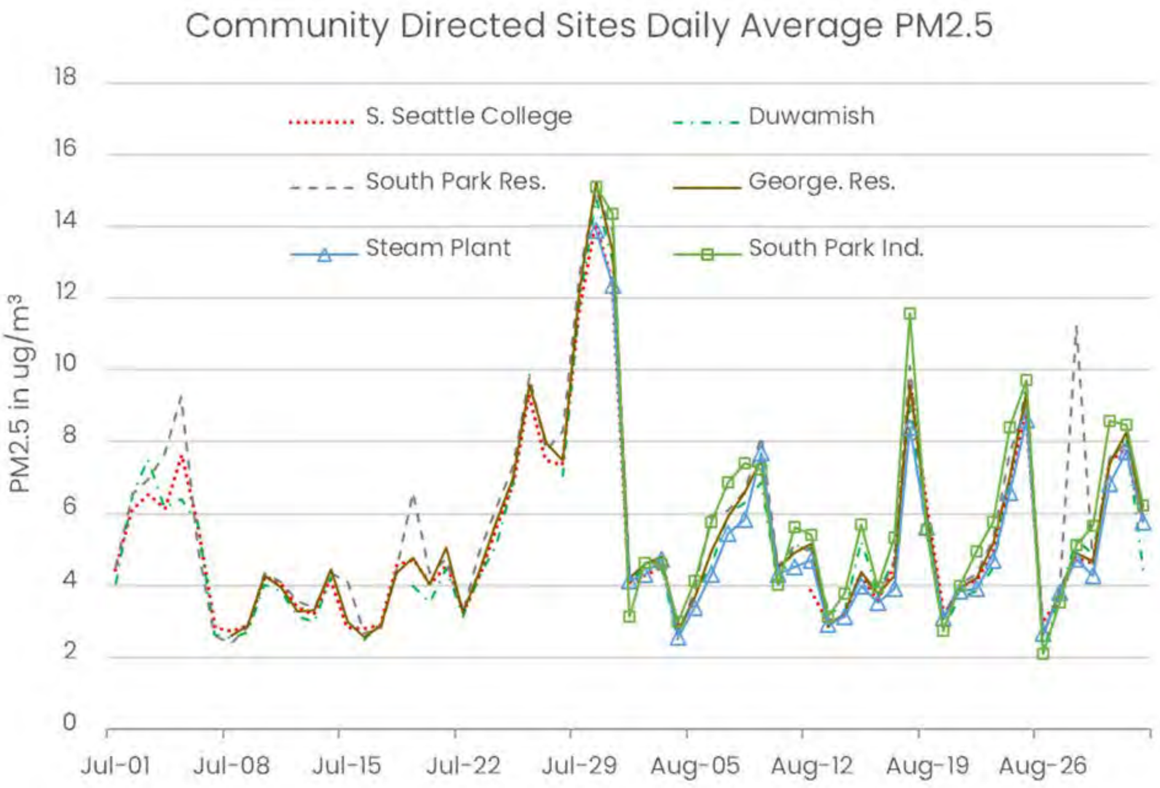
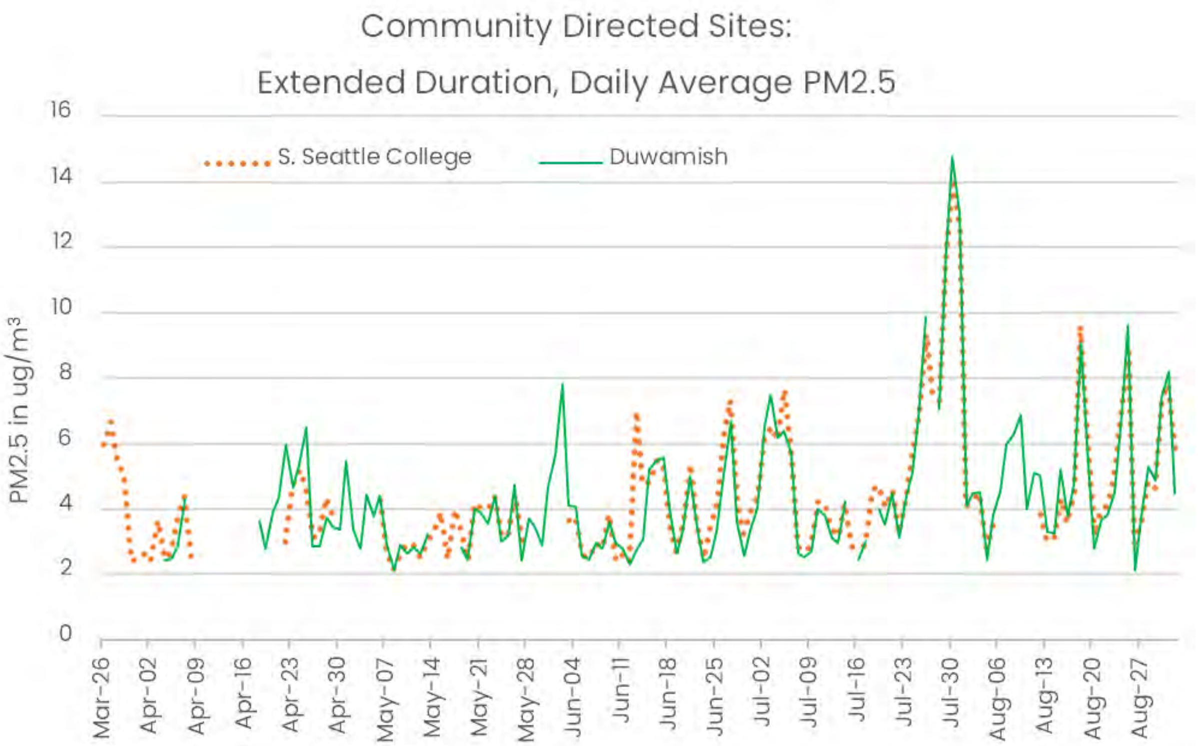


Figure 53. A timeseries of the $PM_{2.5}$ measurements at the community directed sites (all in 2022), shown as daily averages.



A time series of the $PM_{2.5}$ measurements at the community directed sites during the intensive sampling period, is shown in Figure 53. On most days, the values from all the sites are very similar and are difficult to visually distinguish in the figure, with the exception of South Park Residential, which on three days spiked above all of the other sites.

Figure 54. Community-directed $PM_{2.5}$ sites over an extended duration.



An extended timeseries of the small sensor $PM_{2.5}$ measurements is shown in Figure 54. Only the South Seattle College site was available for the extended duration, and a small sensor was also installed at the existing Duwamish site to provide some comparison data. This range also includes the intensive period shown in Figure 53 and used for Figure 55.

During the intensive sampling period (July 1 – Sept 1), the hourly average $PM_{2.5}$ concentrations were well correlated. All sites except for South Park Residential had very strong correlations (Pearson's R) > 0.96, while South Park Residential was still strong, > 0.91, with all of the other sites.

Figure 55. Distribution of daily average $PM_{2.5}$ concentrations for July 1 - Sept 1, 2022

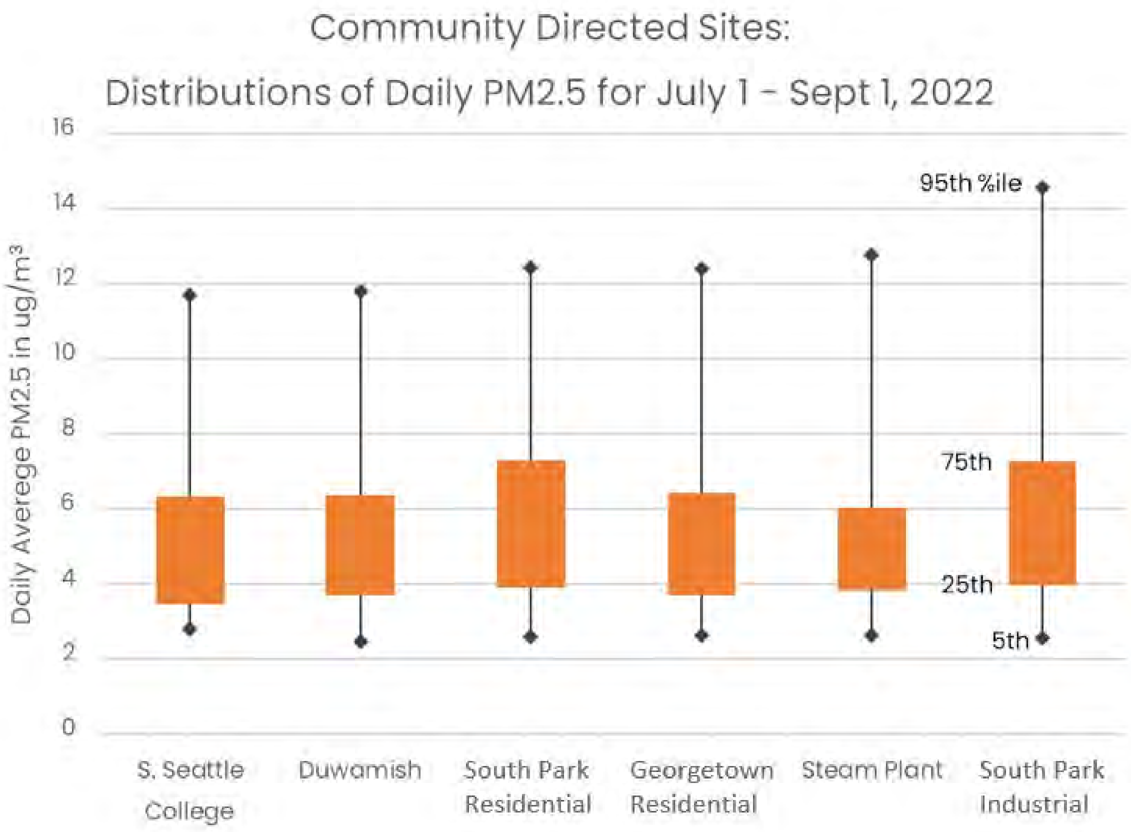
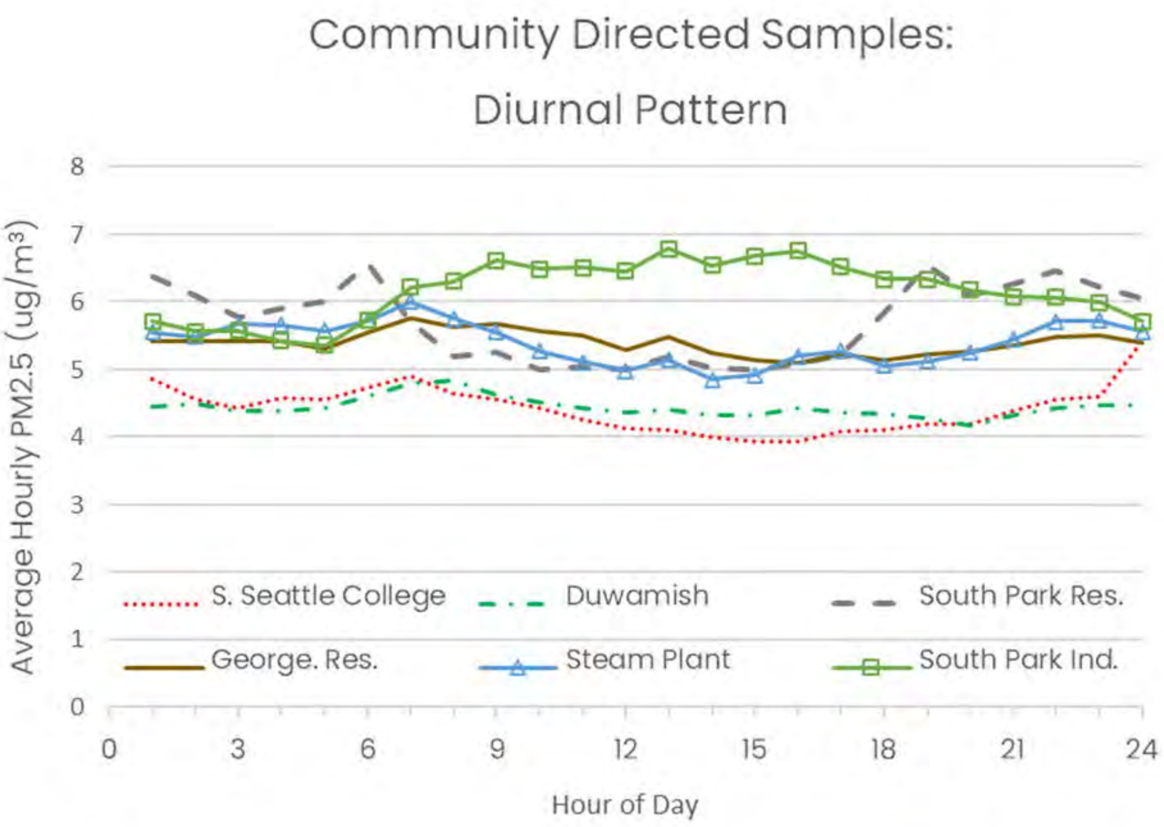


Figure 55 shows the distribution of $PM_{2.5}$ concentration data from only within the intensive period of July 1 – September 1, 2022. In this figure, the box represents the range of half of the data, going from the 25th percentile to the 75th percentile (aka the interquartile range). The extremes are represented by the lines above and below the box which extend to the 5th and 95th percentile. The South Park Residential and Industrial sites had similar, but slightly higher 75th percentile values, while the South Park Industrial site had a 95th percentile value above the other sites.

Figure 56. Diurnal (hour of the day, midnight to midnight) average for the community directed PM2.5 measurements.



The diurnal pattern (hour of the day average) for the community directed $PM_{2.5}$ samples during the intensive period is shown in Figure 56. Several noteworthy items in this figure include: South Park Residential appears to have a diurnal pattern with a spike in the early morning, and an elevation in the evening. Also, South Park Industrial rises in the early morning and then slowly declines in the late afternoon and evening. And, South Seattle College has a significant spike in the 11 pm-midnight hour, due to a single event on June 13 in which the hourly values exceed 100 $\mu g/m^3$. Lastly, South Seattle College and Duwamish are both offset (lower) from the other sites. This amount of offset is within the normal uncertainty in accuracy (bias) for these instruments.

Community-directed small sensor $PM_{2.5}$ discussion

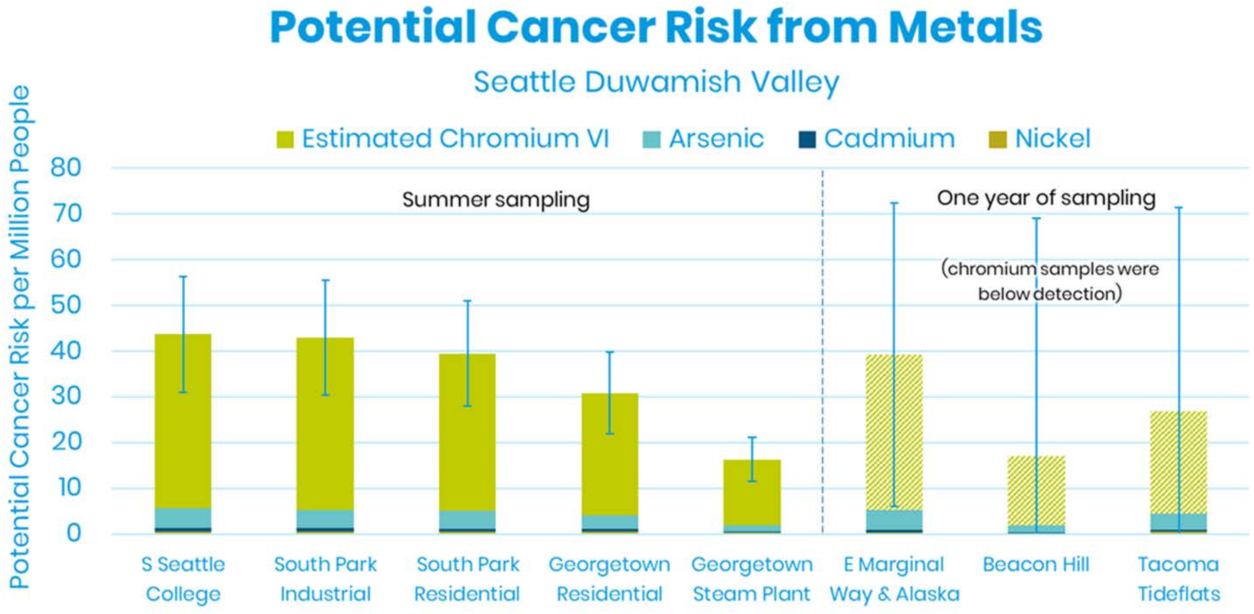
The daily average concentrations in the intensive period were very well correlated. This level of correlation would be consistent with an area that doesn't have any significant, localized $PM_{2.5}$ sources (that is, affecting only an area of less than a km), with the possible exception of near South Park Residential and South Park Industrial. Based on the diurnal patterns shown in Figure 56. Diurnal (hour of the day, midnight to midnight) average for the community directed PM2.5 measurements., the South Park Residential site may be experiencing a short early morning spike and small evening elevation, both about 1 ug/m^3 above other sites. This diurnal pattern is typical for the influence of residential wood burning but considering that the sampling period is the late summer, home heating is unlikely to be a major factor. It could also be due to vehicle traffic, including commuting/personal (early morning commute & commute home and personal travel) or delivery vehicles which leave in the early morning and return in the evening.

Also based on the diurnal patterns, the South Park Industrial site has the signature of a high-traffic highway or active industrial area, or both. The PM concentration increases in the early morning and stays high through the day and slowly decreases in the late afternoon and evening. Since this site was well correlated with the other sites, it is likely sampling the same general sources, but is closer and so experiences and is detecting a higher concentration of the same sources.

Duwamish Valley cancer risk from metals

Figure 57 shows cancer risk from metals sampled from July 29th, 2022 through Sept 2nd, 2022 at the Duwamish Valley community-directed sampling sites. The other sites to the right were sampled for the full year along with the other air toxics sampling described in this report above. Only compounds with greater than 0.1 per million cancer risk are shown. The primary contributor is estimated hexavalent chromium. Estimated hexavalent chromium contributes about 14-38 per million. The next highest contributor is arsenic at around 1-4 per million.

Figure 57. Estimated cancer risk from metals with risks over 0.1 per million.



Antimony, beryllium, cobalt, manganese, mercury, and selenium all below 0.1 potential cancer risk per million people.

Note, hexavalent chromium is estimated at 3% of total chromium for Duwamish sites and the Tideflats site. The error bars represent an additional 1% due to the uncertainty of the estimate being drawn from literature and past sampling in the area. These estimates are described in more detail in the "Overall potential cancer risk" section earlier in this report. Beacon Hill is shown here using a 0.8% estimate because we have a direct measurement for this ratio for the Beacon Hill site from a previous study.[74] Beacon Hill metals lab analysis lagged significantly and were past protocol holding times. Beacon Hill total chromium values were higher than the rest of the samples across all the regions. At the time of writing this report, we don't have a specific explanation for Beacon Hill's higher total chromium samples.

The samples with the annual averages were taken in 24-hour increments, which for chromium was below detection. The error bars in the graphic includes the total chromium method detection limit, which translates into roughly 70 per million with the 3% hexavalent assumption.

The Georgetown residential, Tideflats, and especially the Georgetown Steam Plant sites are lower than the other sites. The Steam Plant site had the lowest average cancer risk for chromium, arsenic, and nickel. This may be because it is further away

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[74] *ibid*, PSCAA 2013 Data Summary

from the industrial areas and roadways than other sites. Elsewhere in this report, we hypothesize most of the trends in the metal concentrations to be a result of resuspended dust and soils from vehicle traffic.

Appendix H contains an analysis comparing the results from the prior moss studies performed by DRCC and partners with the air sampling from this study.

Community interest: Lead

As part of the community-led monitoring, we measured lead levels at the five temporary monitoring locations in the Duwamish, along with our one year of metals sampling at the Tacoma Tideflats and Seattle Duwamish sites for comparison.

Like many metals in this study, lead levels can result in non-cancer health impacts. For lead a main impact is cognitive development in children.[75] Lead is unique in that it is an both an air toxic as well as a criteria pollutant with a National Ambient Air Quality Standard.

The EPA is in the process of reviewing the national ambient air quality standard for lead (last retained at 0.15 µg/m^3 in 2016) and recently released an endangerment finding that lead from propeller aircraft "may reasonably be anticipated to endanger public health and welfare".[76]

The results of the study showed all the lead levels were well below the EPA ambient air standard.[77] The levels were also well below the Washington State Acceptable Source Impact Level screening level.[78] However, the results were higher in the Duwamish Valley compared to other locations such as the Tacoma Tideflats industrial area and the average of national monitors. You can see a summary of these results in Figure 58 below.

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[75] https://www.epa.gov/lead/learn-about-lead

[76] https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-lead-emissions-aircraft

[77] https://www.epa.gov/lead-air-pollution/timeline-lead-pb-national-ambient-air-quality-standards-naaqs

[78] Washington Administrative Code 173-460-150, https://app.leg.wa.gov/wac/default.aspx?cite=173-460-150.

The result at the near-airport site was the lowest among the Duwamish Valley temporary monitoring locations. This result likely demonstrates that propeller aircraft isn't directly making a significant contribution of lead to the area. We hypothesize elsewhere in this report also, that the metals and lead deposition in the region is attributed to soil dust resuspension. The soils can resuspend from gusts of wind or vehicles driving over unpaved curbs and corners. The soils themselves in the Duwamish Valley are likely higher from a legacy of older leaded vehicle fuels and decades of older unregulated industry before the Clean Air Act existed. This is also evidenced by a King County Deposition Report that showed higher values in the Lower Duwamish Valley compared with other parts of King County.[79]

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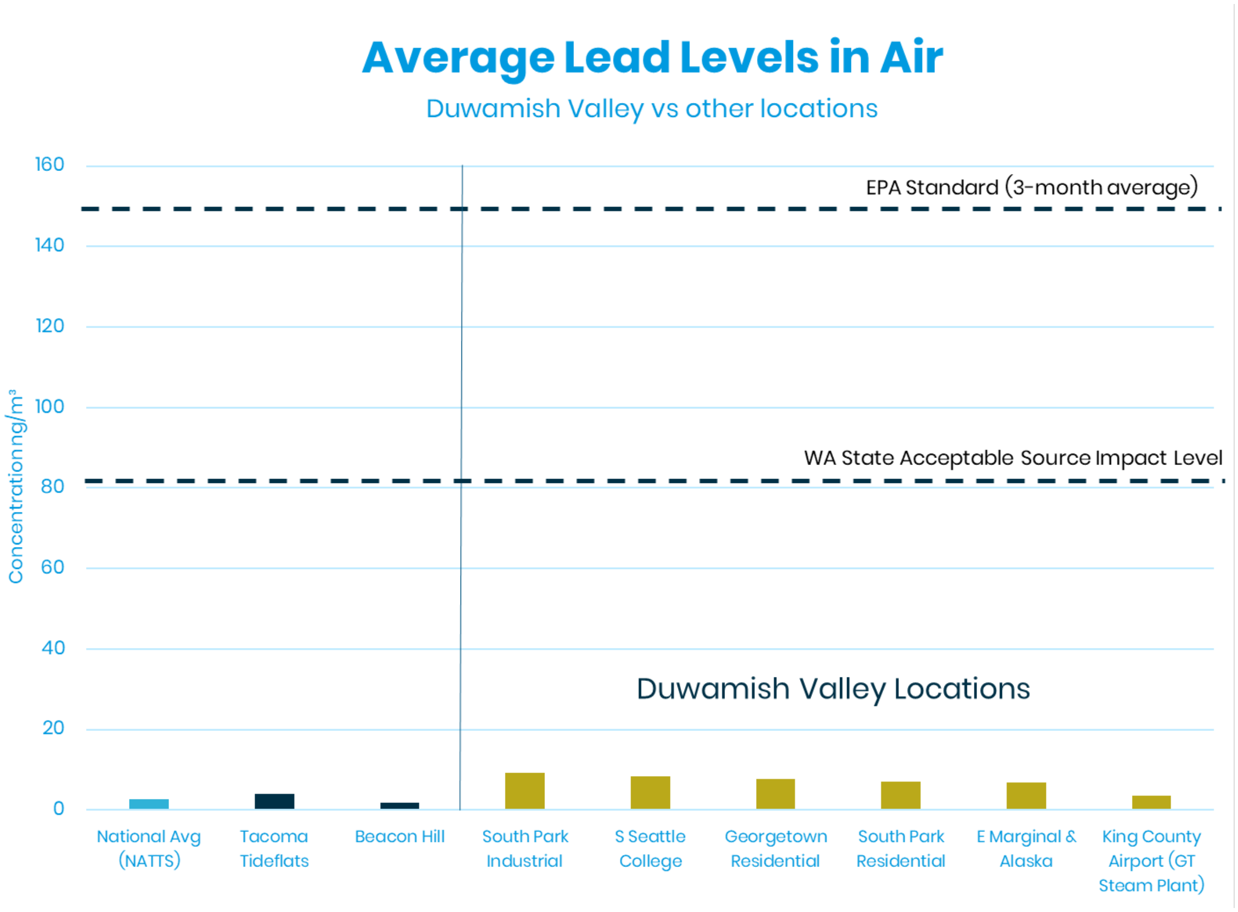
[79] King County DNRP, Lower Duwamish Waterway Source Control: Bulk Atmospheric Deposition Study Final-Data Report, Dec 2013, https://your.kingcounty.gov/dnrp/library/wastewater/iw/SourceControl/Studies/Air/2013/LDW_BulkAirDepFinalDataReport_Dec2013.pdf

Figure 58. Average lead levels sampled at temporary Duwamish Valley locations.



This figure shows the average lead levels sampled at temporary Duwamish Valley locations during the summer months of 2022, and the Seattle Duwamish Valley site, the Tacoma Tideflats site, Seattle Beacon Hill, and all National Air Toxics Trends Assessments sites sampled for a full year. The dashed bars represent the EPA National Air Quality Standard for lead[77] and the Washington State Acceptable Source Impact Level[78] for permit screening as established by the Washington State Clean Air Act.

Crosswalk of air lead levels to blood lead levels

To provide greater context to these results, we did a sensitivity comparison using the highest lead sample we collected at the highest monitoring location, using the most conservative (showing highest risk) of all the blood to air slope values.

This slope is a value that helps translate air samples to blood lead levels and was taken from the EPA Integrated Science Assessment[80] that comes with their review of

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[80] EPA, Lead Integrated Science Assessment, 2013, page 584, https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=518908

the standard each cycle. Figure 59 below shows a portion of the table that lists seven different studies. The crosswalk value ranges from 3 to 9.

To estimate the respective blood lead level, we use the following equation:

(lead concentration in micrograms per cubic meter) x (blood to air slope value) = (blood lead level in micrograms per deciliter)

The highest site during our sampling was at the South Park Industrial Site, and it was 0.009 μg/m^3 (9 ng/m^3). If we use the most conservative slope of 9.3, we estimated a 0.08 μg/dL increase in blood lead levels from the air at the highest site using the most conservative crosswalk value.

This is our best estimate, there is uncertainty in that the slopes are all from studies with much higher ambient lead levels (an order of magnitude). All our samples we collected were below all the levels in the studies from the table.

Similarly, using cautious values to estimate IQ scores, a value of less than 0.1 μg/dL blood lead level less than a 0.1 children's IQ score change.[81]

The CDC updated their reference for action level to 3.5 μg/dL blood lead level in 2021.[82] As a result, the most conservative estimate contributes to 2% of the CDC action level threshold.

In Appendix Q we present estimated daily lead intake for children using EPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) software. The software comes with a set of default parameters that were used as-is, however the air concentration was updated to the highest value from this study (0.009 μg/m^3). Lead from air only contributed 0.05% of the overall lead intake; with most being from the ingestion of outdoor soil and indoor dust (74%) and diet (23%).

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[81] Jusko et al, "Blood Lead Concentrations < 10μg/dL and Child Intelligence at 6 Years of Age", Environmental Health Perspectives, 2007, https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.10424.

[82] https://www.cdc.gov/nceh/lead/data/blood-lead-reference-value.htm

Figure 59. Portion of table showing blood lead to air lead slope factors from the most recent EPA Integrated Science Assessment.

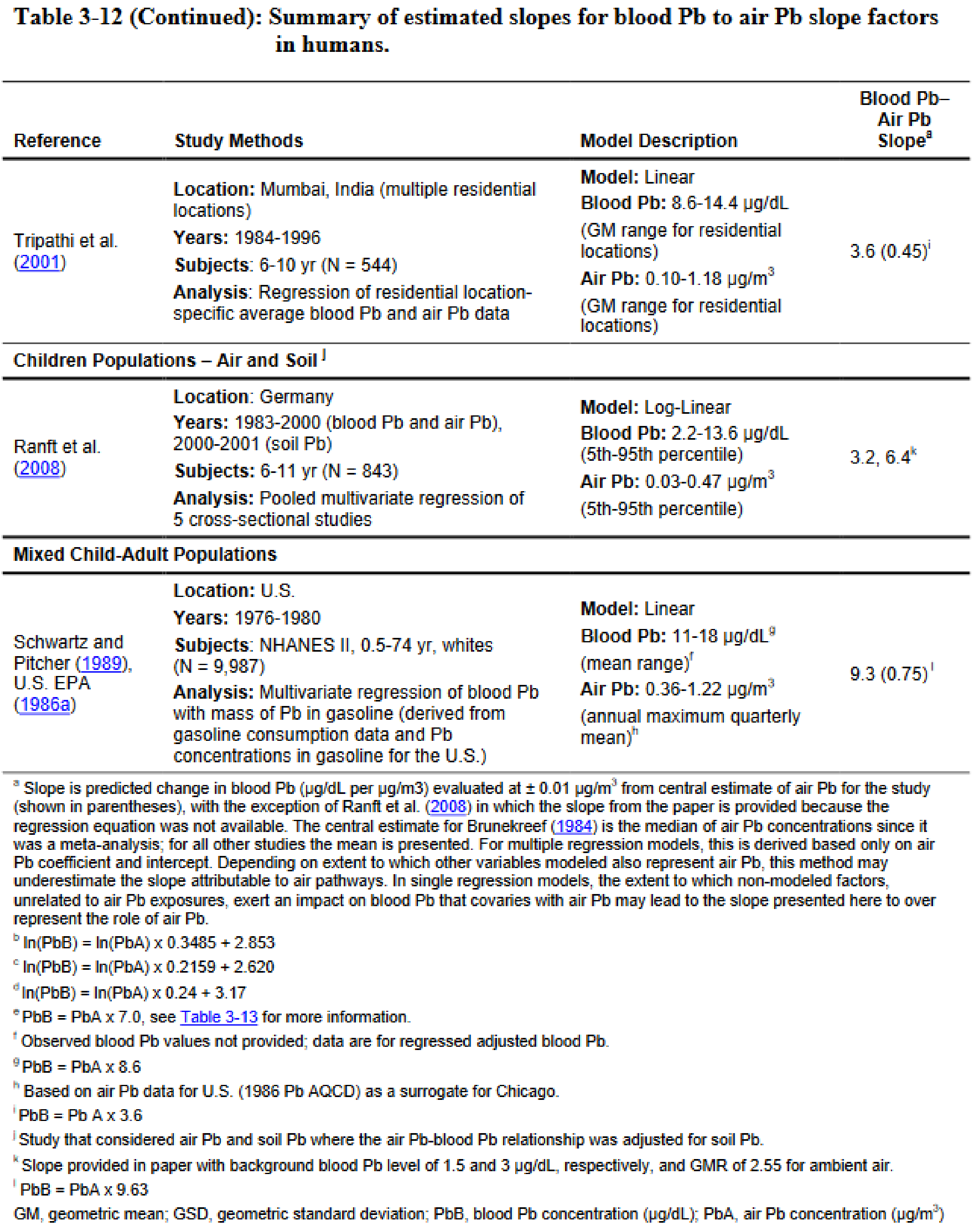


Table 3-12 (Continued): Summary of estimated slopes for blood Pb to air Pb slope factors in humans.

Reference	Study Methods	Model Description	Blood Pb–Air Pb Slope[a]
Tripathi et al. (2001)	**Location:** Mumbai, India (multiple residential locations) **Years:** 1984-1996 **Subjects:** 6-10 yr (N = 544) **Analysis:** Regression of residential location-specific average blood Pb and air Pb data	**Model:** Linear **Blood Pb:** 8.6-14.4 µg/dL (GM range for residential locations) **Air Pb:** 0.10-1.18 µg/m^3 (GM range for residential locations)	3.6 (0.45)[i]
Children Populations – Air and Soil[j]			
Ranft et al. (2008)	**Location:** Germany **Years:** 1983-2000 (blood Pb and air Pb), 2000-2001 (soil Pb) **Subjects:** 6-11 yr (N = 843) **Analysis:** Pooled multivariate regression of 5 cross-sectional studies	**Model:** Log-Linear **Blood Pb:** 2.2-13.6 µg/dL (5th-95th percentile) **Air Pb:** 0.03-0.47 µg/m^3 (5th-95th percentile)	3.2, 6.4[k]
Mixed Child-Adult Populations			
Schwartz and Pitcher (1989), U.S. EPA (1986a)	**Location:** U.S. **Years:** 1976-1980 **Subjects:** NHANES II, 0.5-74 yr, whites (N = 9,987) **Analysis:** Multivariate regression of blood Pb with mass of Pb in gasoline (derived from gasoline consumption data and Pb concentrations in gasoline for the U.S.)	**Model:** Linear **Blood Pb:** 11-18 µg/dL[g] (mean range)[f] **Air Pb:** 0.36-1.22 µg/m^3 (annual maximum quarterly mean)[h]	9.3 (0.75)[l]

[a] Slope is predicted change in blood Pb (µg/dL per µg/m3) evaluated at ± 0.01 µg/m^3 from central estimate of air Pb for the study (shown in parentheses), with the exception of Ranft et al. (2008) in which the slope from the paper is provided because the regression equation was not available. The central estimate for Brunekreef (1984) is the median of air Pb concentrations since it was a meta-analysis; for all other studies the mean is presented. For multiple regression models, this is derived based only on air Pb coefficient and intercept. Depending on extent to which other variables modeled also represent air Pb, this method may underestimate the slope attributable to air pathways. In single regression models, the extent to which non-modeled factors, unrelated to air Pb exposures, exert an impact on blood Pb that covaries with air Pb may lead to the slope presented here to over represent the role of air Pb.

[b] ln(PbB) = ln(PbA) x 0.3485 + 2.853

[c] ln(PbB) = ln(PbA) x 0.2159 + 2.620

[d] ln(PbB) = ln(PbA) x 0.24 + 3.17

[e] PbB = PbA x 7.0, see Table 3-13 for more information.

[f] Observed blood Pb values not provided; data are for regressed adjusted blood Pb.

[g] PbB = PbA x 8.6

[h] Based on air Pb data for U.S. (1986 Pb AQCD) as a surrogate for Chicago.

[i] PbB = Pb A x 3.6

[j] Study that considered air Pb and soil Pb where the air Pb-blood Pb relationship was adjusted for soil Pb.

[k] Slope provided in paper with background blood Pb level of 1.5 and 3 µg/dL, respectively, and GMR of 2.55 for ambient air.

[l] PbB = PbA x 9.63

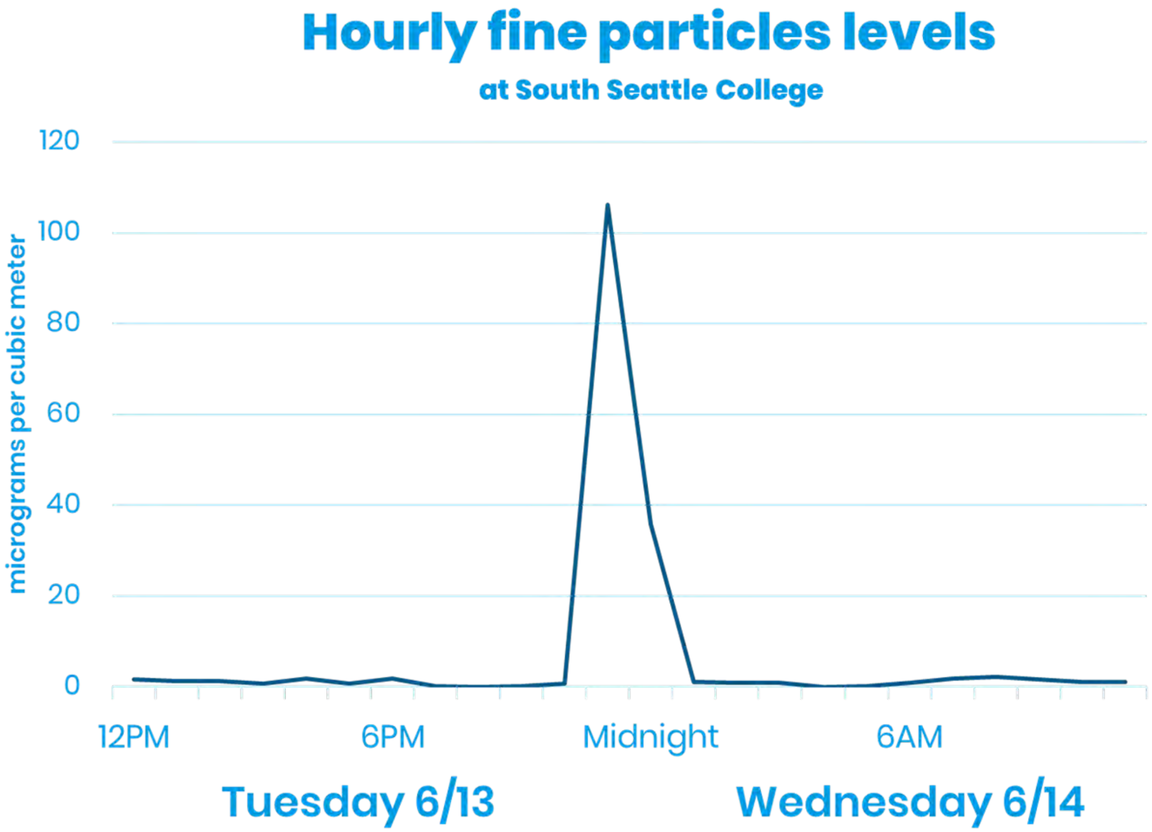
GM, geometric mean; GSD, geometric standard deviation; PbB, blood Pb concentration (µg/dL); PbA, air Pb concentration (µg/m^3)

Community interest: Local fire on June 13th, 2022

In the late evening of 6/13/2022, a fire broke out on the property of Seattle Iron and Metals from approximately 11PM to 1AM. The wind direction at time (Figure 60 below) shows our South Seattle College temporary air monitoring station was downwind at the time. Our metals samples sample for an entire week, so no significant difference was expected, and was confirmed to be true when we compared to other samples at that site or comparing to other locations sampled during the same week. Fine particle monitoring (via light scattering) is shown in Figure 61.

Figure 60. Wind direction during the hours of 6/13/22 11PM to 6/14/22 1AM and potential trajectory of smoke generated from a fire at the Seattle Iron and Metals facility.

Figure 61. Hourly fine particle (PM2.5) levels on 6/13/2022.



We responded to community concerns after the event and presented these results to the Georgetown Community Council on 6/20/2022. We shared that all EPA health categories are based on 24-hour exposures. The noon-to-noon average during the fire was still in the GOOD category of 6.9 micrograms per cubic meter.

With the short duration of this event (3 out of 168 hours sampled), the sampled metal concentrations for that week were not impacted in any measurable way.

Dust as a source of metals in Duwamish Valley air samples

We hypothesize that most of the metals in the air samples were coming from the soils across the Duwamish Valley more broadly. A likely contributor could be vehicles driving through roadways, especially unpaved shoulders and unpaved roads, which can cause dust to resuspend, particularly in dry episodes during the summer.

A recent study based on moss sampling in the Duwamish Valley found two factors from a principal component analysis. The main factor that explained most of the result showed strong correlation among all the metals broadly. This would point to no point specific sources, but a broader ubiquitous source, like soils.

A follow-up study of the moss sampling results identified traffic volume as the most consistent predictor of increasing heavy metals. Similarly, proximity to dirt roads predicter higher arsenic and chromium levels.

These studies do not identify an originating source of the metals to the soils in the valley. We can presume a legacy of over a hundred years of industrial activity and leaded fuels may have contributed.

To investigate this hypothesis with our air sampling, we performed correlations of various metals to compare to typical crustal soils. See Appendix M.

We found that arsenic, cadmium, and lead concentrations sampled at the Duwamish Valley monitoring sites had some correlation. We investigated these correlations and found that they generally matched crustal abundance ratios. Crustal abundance ratio is the ratio of the given elements in the earth's crust. These ratios can be used to represent dust in the atmosphere.

Spatial modeling to extrapolate risk from on-road diesel particulate matter and equity analysis

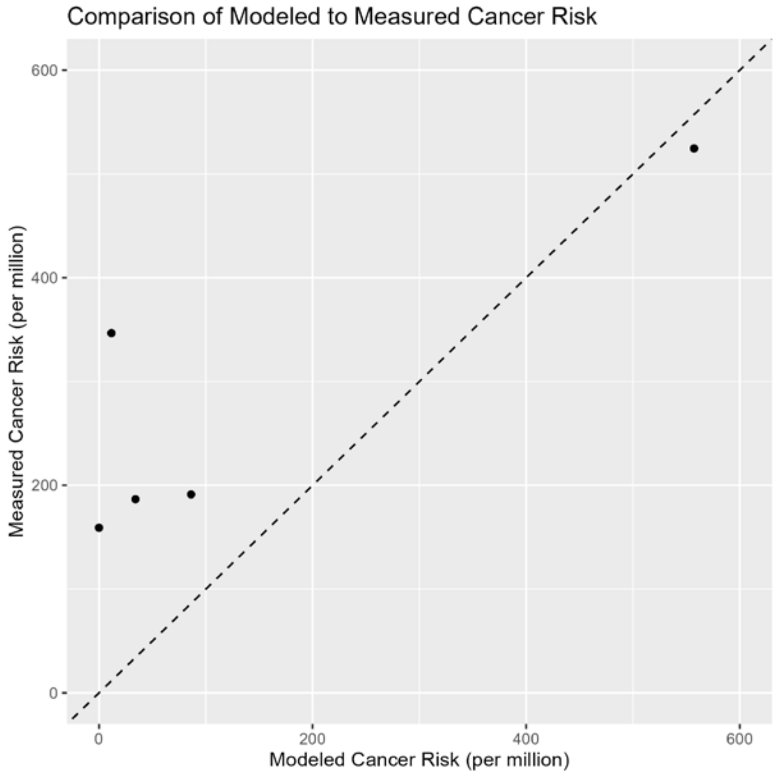
The PMF analysis resolved several factors. One that is directly linked to health, and contributes the majority of the cancer risk, is diesel particulate matter. The diesel particulate matter factor from the PMF analysis is a measure of near-road diesel particulate matter with some crustal elements from road dust. We identify specifically on-road diesel particulate matter, which means diesel particulate matter that was recently emitted and hasn't undergone secondary chemistry or from more distant sources to form “aged diesel particulate matter”. Using this metric of on-road diesel particulate matter, we can apply the unit risk factor to the site averages to get an estimate of cancer risk from just the on-road portion.

To understand the impact of diesel particulate matter on a larger scale, the potential cancer risk at our sites was correlated with measures of truck traffic and that calibration can be applied to all the blocks in our region. For this analysis, the measure of truck traffic we chose was the sum of truck tonnage within 500m of census block centroids. The sum of truck tonnage is a measure of the total weight of trucks for a given road segment. This estimate is provided by the Washington State Department of Transportation and encompasses most medium and large size roads, where there is appreciable truck traffic. The analysis was performed on the census block level, which is quite granular. Truck tonnage was summed only within 500m of the center of a block because some blocks in rural areas are quite large and summing within 500m of the entire block polygon would have included roadways that were at the edge of those rural blocks.

2020 census block shapefiles for our four-county region were downloaded from Puget Sound Regional Council. Demographic data for our four-county region was downloaded from data.census.gov. Specifically, the P5 table, “Hispanic or Latino origin by race”, from the 2020 decennial census at the block level and table B19013, “Median Household Income in the Past 12 Months (In 2021 Inflation-adjusted Dollars)”, from the 5-year American Community Survey 2021 at the block group level. For block groups where the median annual income is greater than $250,000 the ACS data file says “>$250,000”. This was adjusted so that those block groups had a value of exactly $250,000, however that is certainly an undercount. Though the effects of this are likely to only be seen on the very last data point for the income graphs.

The truck tonnage data layer was joined to block centroids, and PSCAA sites within 500m and summed. Then the PSCAA data were exported into R and a linear model was created (see Figure 62). The linear model had the intercept set to 0 so that blocks far away from roads did not end up with inflated “background” levels of on-road diesel potential cancer risk. The adjusted R^2 of the model was 0.56. (And a model without a set intercept had an adjusted R^2 of 0.64). In general, sites with lower cancer risk were slightly underpredicted (a facet of setting the intercept to 0). One site that stands out as quite different from the others is the Tacoma Tideflats site. This is the point in the model comparison graph at the center left. The model significantly underestimates on-road diesel particulate matter potential cancer risk at Tacoma Tideflats. This could be because there is another source of diesel particulate matter other than trucks, such as maritime activities, which is not accounted for in the model. Or it could be that the PMF diesel particulate matter factor for that site is slightly different compared to other sites and is pulling in another source of pollution.

Figure 62. Estimated diesel particulate matter cancer risk model performance.



After the model was created, it was applied to the census block shapefile. This was then combined with the block level race and ethnicity data and the block group level income data and re-exported for analysis in R.

From the total population count per block and race/ethnicity specific population counts, the percent of each race/ethnicity was calculated for each block. Two types of analyses were performed: (1) a logistic regression model predicting whether a block was likely to be in the top 5% of potential cancer risk from air pollution by race, ethnicity, and income; (2) comparisons of race, ethnicity, and income versus average cancer risk. These analyses will be discussed along with associated graphs below.

The map below (Figure 63) shows the estimated potential cancer risk from on-road diesel particulate matter. The highest values are seen near large highways (I-5, I-405, I-90). Lower values are seen near medium sized roads. Blocks not near large or medium size roads have a lower potential cancer risk.

Figure 63. Estimated on-road diesel particulate matter potential cancer risk map.

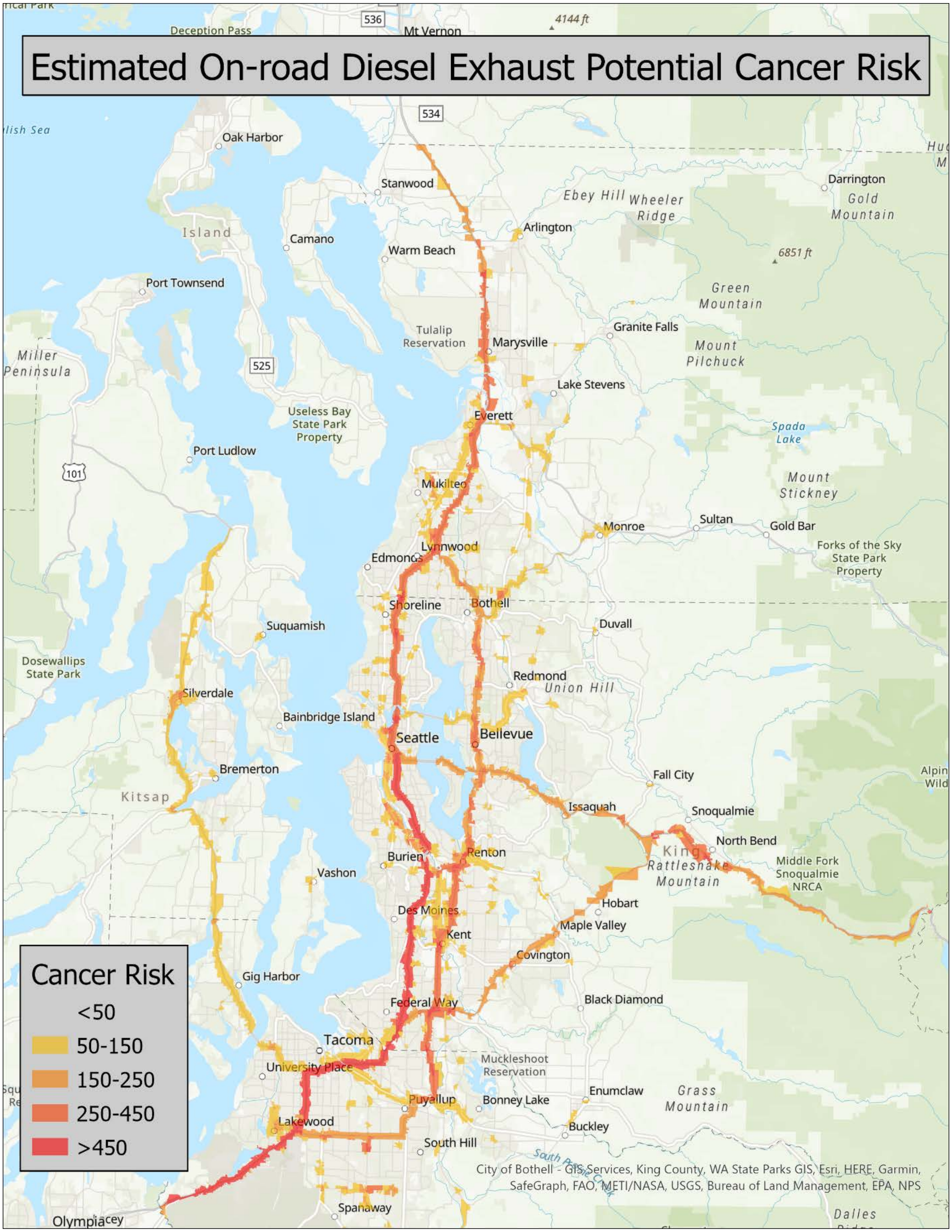


Figure 64 below shows the 5th, 25th, 50th, 75th, and 95th percentile of potential cancer risk from on-road diesel particulate matter for race, ethnicity, and income groups. Here, BIPOC includes all non-white race groups. These values are calculated on a per-person level (not a per-block level). So, for race and ethnicity, the potential cancer risk value for a block is assigned to each person in that block. Then the summary statistics are calculated. For income, each person in the block is assigned the median annual income and the block's potential cancer risk. Also, from that dataset the potential cancer risk percentiles are calculated.

Figure 64. On-road diesel particulate matter potential cancer risk statistics by race, ethnicity, and income.

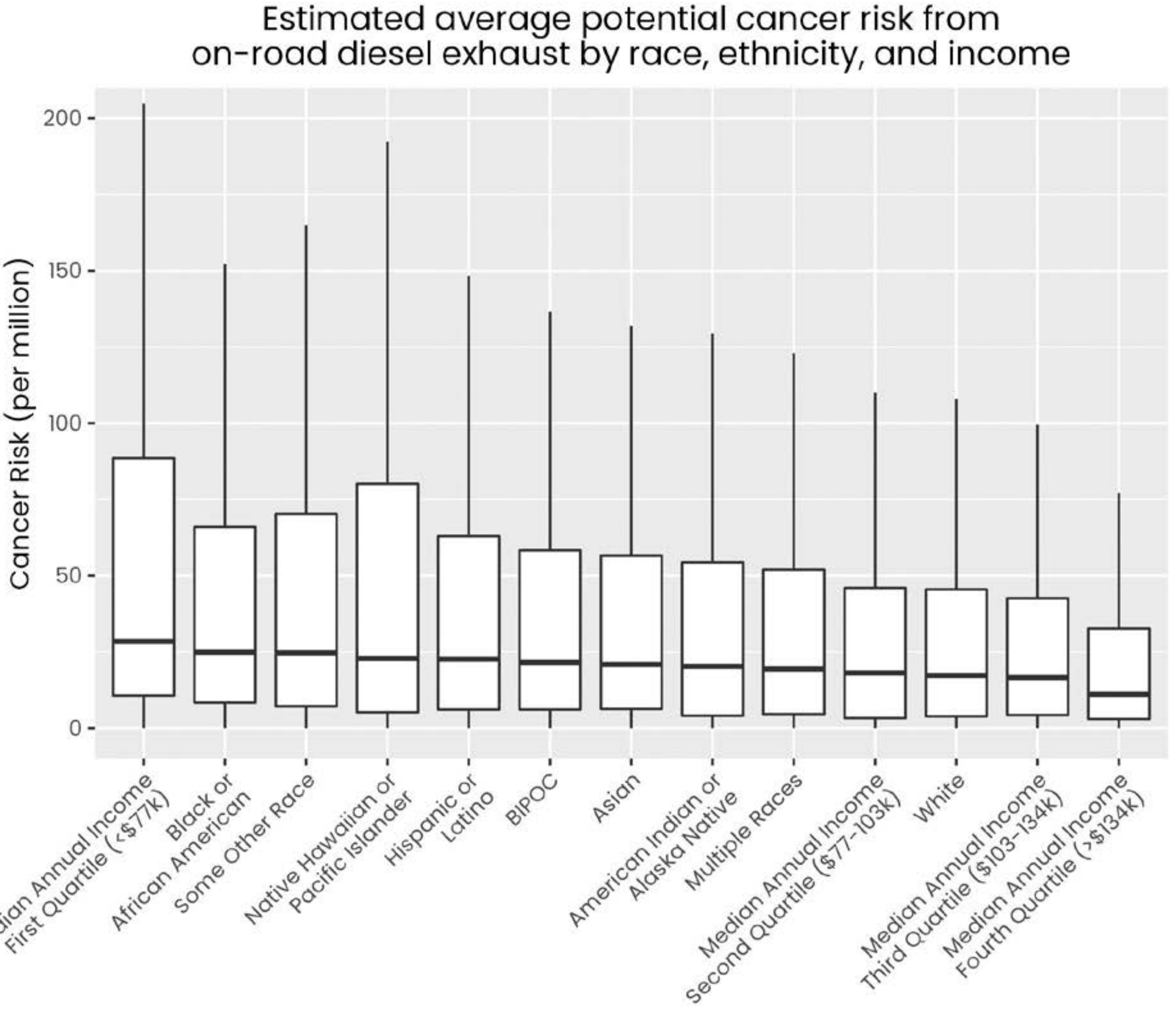


Figure 65 below shows the probability of living in the top 5% of cancer risk blocks by percent Black, Indigenous, People of Color (BIPOC) and median annual income.

BIPOC, for the purposes of the graphs in this section, is defined as any non-white census racial group. Hispanic is not a racial group in the 2020 census and is treated separately. This graph is based on a simple logistic regression model. In the graph, we can see the separate effects of race and income. With higher incomes less likely to be associated with higher potential cancer risk blocks. And, apart from income, blocks with more BIPOC residents are more likely to have high cancer risk. The 95th percentile for cancer risk is 333.5 per million. The low category for BIPOC is when the population is 0-26% BIPOC, the medium category is 26-46%, and the high category is above 46%.

Figure 65. Probability of living in top 5% potential cancer risk from on-road diesel particulate matter block by income and race.

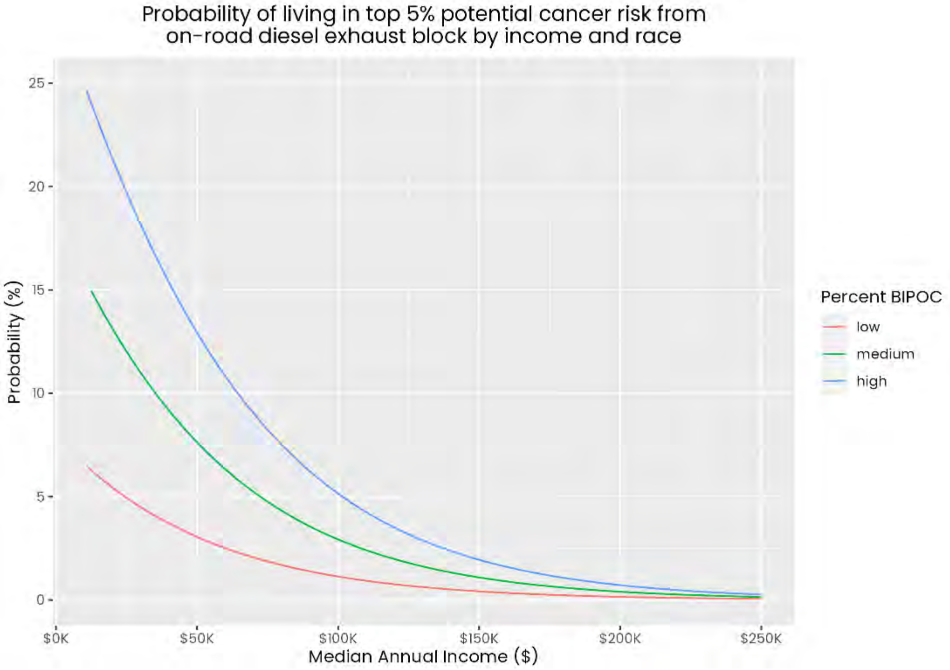
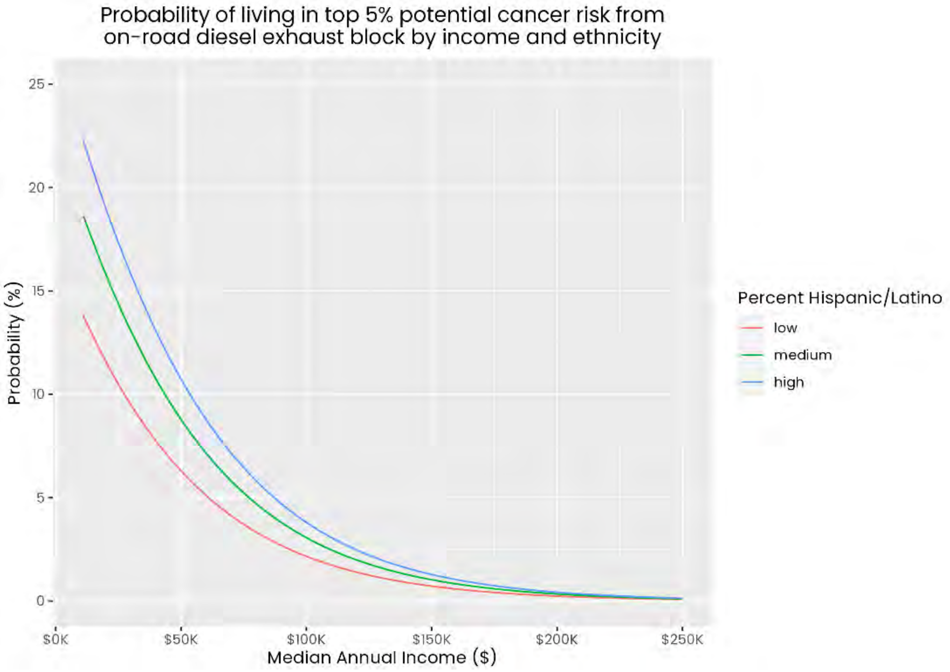


Figure 66 below shows the probability of living in the top 5% of potential cancer risk blocks by Hispanic/Latino and median annual income. The low category for Hispanic/Latino is when the population is 0-5% Hispanic/Latino, the medium category is 5-13%, and the high category is >13%. The graph also shows a separate effect for income and ethnicity, with areas with a higher percentage of Hispanic/Latino residents and lower income more likely to be in blocks with high potential cancer risk.

Figure 66. Probability of living in top 5% potential cancer risk from on-road diesel particulate matter block by income and ethnicity.



These graphs (Figure 67 to Figure 70) show average potential cancer risk from diesel particulate matter by race, ethnicity, and income. They only contain data from blocks with more than 11 people (greater than the 5th percentile). This was done to limit the effects of small numbers leading to large percentages and affecting the tails of the graphs. The dotted black line is the average overall potential cancer risk from on-road diesel. The dotted red line is a trendline; the trend equation and r^2 are shown on the graph. See Appendix N for all single-race graphs.

Figure 67. Potential cancer risk from on-road diesel particulate matter by race - BIPOC.

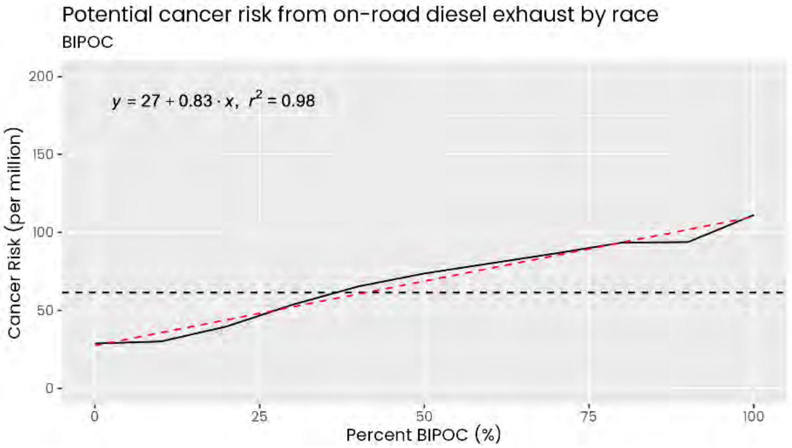


Figure 68. Potential cancer risk from on-road diesel particulate matter by ethnicity – Hispanic/Latino.

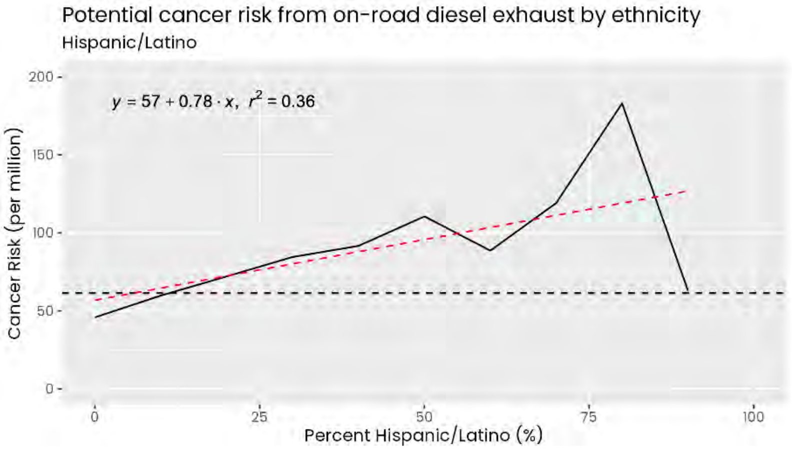


Figure 69. Potential cancer risk from on-road diesel particulate matter by race – White.

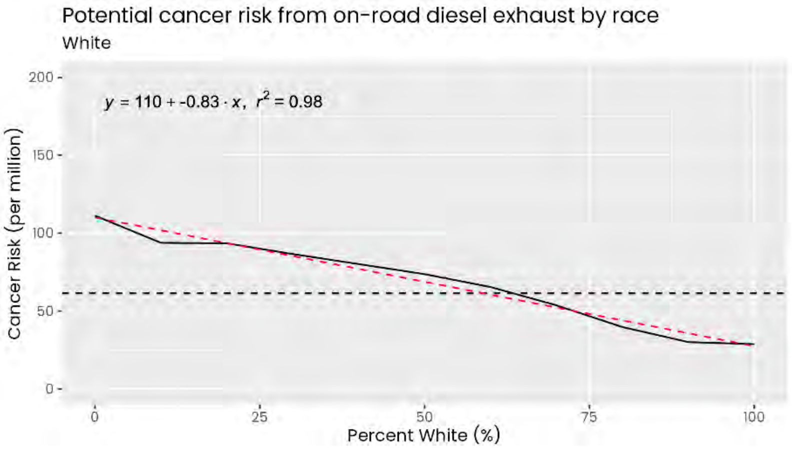
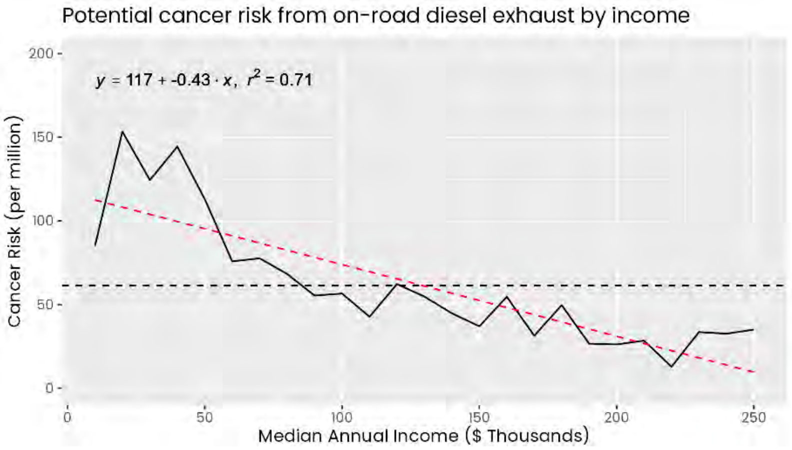


Figure 70. Potential cancer risk from on-road diesel particulate matter by income.



The average estimated cancer risk due to on-road diesel particulate matter for a block with no BIPOC population is 29 per million. For blocks with 100% BIPOC population the estimated cancer risk is 111 per million. The White graph is the inverse relationship by our definition, since BIPOC includes all non-White races. The Hispanic or Latino graph has a less straight line and the final datapoint may be swayed heavily by only having a small number of blocks. However, the general trend upwards, from a risk of 29 per million to around 119 per million at the highest. The first point on the income graph is lower than the following points, likely due to the lower number of blocks with that income level. However, the average cancer risk drops from about 140 per million to around 25 per million as income increases.

In summary, the population that lives near larger roads tends to be more non-White and have a lower income. This leads to a disproportionate health impact from on-road diesel particulate matter.

Conclusions

Consistent with our studies in 2003, 2010, and 2016, this report found that diesel particulate matter continues to be the primary contributor to the total potential cancer risk in the region. Most sites across those studies measured diesel particulate matter as being above 70% of the total potential cancer risk, much larger than the second highest pollutant.

Air toxics concentrations have been decreasing over time. Levels of VOCs have decreased by half at the Beacon Hill site over the past 20 years. All other sites presented have shown decreases in VOCs. Estimated wood smoke has been decreasing over time as well at our Tacoma South L site. This follows the large-scale effort to return to attainment of the national standards after being designated non-attainment in 2009. It also tracks with the updated wood stove standards and our efforts to recycle or replace older, more polluting wood stoves.

We estimate diesel particulate matter levels to be about half of what they were two decades ago, despite 30% population growth and corresponding increases in economic activity. In terms of tracking diesel particulate matter concentrations over time, PMF has become increasingly more challenging to use. One important factor is the increasingly smaller quantities of species we could include in the factor analysis due to lower and lower signal (ambient concentrations) with air quality improvements. That is, many of these species are now below detection limits while in prior years, they were well above. Additionally, there are other variables that can make PMF more challenging such as choice of number of factors, robustness of the model, uncertainty, and co-emission of sources. In essence, while you may have a specific factor in mind to quantify, such as diesel particulate matter, that source can be co-emitted with other types of particles, such as road dust, and the two can become inseparable with PMF. However, if we use black carbon as a surrogate for diesel particulate matter the trends become clearer. All sites, with the exception of 10th & Weller, measured a decrease in black carbon over time. Seattle 10th & Weller, which is only a few feet from I-5, showed a static (no) trend. However, population and vehicle miles traveled (VMT) (apart from the impact of COVID) have been increasing over time (Figure 34 and Figure 35). So, having a flat measure of black carbon suggests a significant downward trend in emissions per vehicle.

EPA reporting[83] and internal analysis[84] suggests that diesel particulate matter emissions will continue to decrease over time. With a steady activity level (VMT) we would expect at least a 90% drop in diesel particulate matter by 2030, compared to before 2007.

Overall, places near large highways show the greatest potential cancer risk from air pollution, driven by diesel particulate matter. Our equity analysis showed that those locations often also have higher percent BIPOC and higher percent lower-income populations.

Residential wood smoke, while having decreased substantially over the past two decades, still presents an ongoing addition to potential cancer risk. Depending on the site, it is the second or third highest potential cancer risk and, unlike metals, contributes significantly to overall $PM_{2.5}$ mass, which is associated with cardiovascular risk and mortality.[85] Our work in this area continues with our wood stove recycling program, burn ban enforcement, and education and outreach.

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[83] EPA, 2000. Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements. EPA420-R-00-026. See i.a. table II.B-5

[84] Based on MOVES data supplied by Sally Otterson (WA Dept of Ecology), in an email on May 1, 2019, in the file "IM_Sunset_documentation_Final.docx", and MOVES data supplied by Kelly McGourty (PSRC), in an email dated Feb 13, 2019, in the file "Final RTP emissions.pdf".

[85] EPA, Integrated Science Assessment for Particulate Matter, 2019. https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter.

The community directed sampling showed that estimated hexavalent chromium had the highest risk of the metals sampled. The ratio used to estimate what fraction of total chromium is hexavalent chromium is drawn from literature and older studies in our region. We have received an EPA grant to perform a follow up study to do total and speciated chromium sampling in the Duwamish Valley region to get a more accurate ratio. This study will begin in mid-to-late 2024.

Lead, a major concern of the community, was higher in the Duwamish than other areas, but was well below state and federal standards and would be associated with only a minor increase in blood lead levels (less than 0.1 μg/dL using the most cautious estimates or less than 0.1 IQ score change in children[86]).

EPA's AirToxScreen model matched well with many monitoring results from this study. However, the model underpredicted arsenic and tetrachloroethylene and overpredicting hexavalent chromium at Seattle Duwamish and Seattle Beacon Hill. We make some suggestions in our report on how to make the model more accurate.

Ethylene oxide was analyzed separately from other compounds due to the high amount of uncertainty in its measurement and the large number of samples that were flagged. In 2016, EPA increased the unit risk factor for ethylene oxide by 34x. With the new unit risk factor, even results that are at the limit of detection lead to potential cancer risk estimates in the hundreds per million. Complicating this detection limit issue is a widespread sampling issue.[87] It is hypothesized that ethylene oxide can stick to the inside of the sampling canister since many samples ended up with failed duplicates and outliers with no found patterns. Many of the samples in this study were flagged for that issue. While there is much uncertainty, Beacon Hill has the lowest average ethylene oxide concentration of all NATTS sites. And the other sites in our study were at similar concentrations.

Mitigation recommendations and resources

Diesel particulate matter is the primary risk driver in our region. It is also one of the main areas of focus in our strategic plan. One of the primary goals of the strategic

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[86] Jusko et al, "Blood Lead Concentrations < 10μg/dL and Child Intelligence at 6 Years of Age", *Environmental Health Perspectives*, 2007, https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.10424.

[87] EPA 2020, EPA's Work to Understand Background Levels of Ethylene Oxide, https://www.epa.gov/system/files/documents/2021-10/background-eto-explainer-doument.pdf.

plan is to "reduce harmful diesel pollution emissions and exposures."[88] This goal has targets related to replacing diesel equipment with electric, specifically electric drayage trucks, electric yard trucks, and electric equipment at rail yards.

This focus on diesel particulate matter is a continuation of our work in this area, which started as our "Diesel Solutions" program after the original 2003 air toxics study. There are several emissions reduction strategies that our Agency has been involved in over the years including administering grants to change out older more polluting diesel engines with newer cleaner models and helping ports install shore power so that idling ships can turn off their diesel engines. We have also worked with rail yards to convert their on-premise diesel equipment to electric. Much of the funding for these efforts have come through the state legislature and EPA Diesel Emissions Reduction Act (DERA) programs, Dept of Ecology budgets, and the NW Seaport Alliance. The benefit from these emissions reductions has the largest impact in near-road and near-port communities, which in turn are benefiting overburdened communities most. As shown in the spatial-demographic analysis of diesel emissions, these communities typically have higher percentages of BIPOC residents and lower median annual income.

The last federal heavy-duty engine standard with PM limits was for model year 2007 (and was fully implemented by 2010).[89] Since then, there have been two phases of standards to reduce greenhouse gas emissions and improve fuel efficiency, the first affecting model years 2014-2018 and the second affecting model years 2018-2027[90]. A third phase was proposed in 2023, which would take effect on model year 2027 and later vehicles[91]. In addition to federal regulation, in 2022 Washington State created the Clean Vehicles Program, which adopted standards developed by the California

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[88] PSCAA, 2030 Strategic Plan, https://pscleanair.gov/DocumentCenter/View/5038/2030-Strategic-Plan-Final-.

[89] EPA, Final Rule for Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, 2023, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-new-motor-vehicles.

[90] EPA, EPA Emission Standards for Heavy-Duty Highway Engines and Vehicles, 2023, https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-heavy-duty-highway-engines-and-vehicles.

[91] EPA, Proposed Rule: Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3, 2023, https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-greenhouse-gas-emissions-standards-heavy.

Air Resources Board.[92] This includes the Heavy-Duty Engine and Vehicle Omnibus rules that require lower PM, NOx, and GHG emissions from heavy-duty vehicles starting in model year 2026. It also includes Advanced Clean Cars II rule which requires a shift to EVs for passenger cars, light duty trucks, and medium duty vehicles starting in model year 2026 with a goal of 100% EV sales for new passenger vehicles by 2035.

In terms of maritime emissions standards, the EPA created the North American Emission Control Area for Marine Vessels (ECA), which put in place a fuel sulfur requirement in 2015 and NO_x standard in 2016.[93] Other efforts in the maritime space include installing shore power, which allows ships to run off electricity when docked, and switching the state's ferries over to hybrid electric.[94,95]

The top contributors to potential cancer risk from metals were estimated hexavalent chromium and arsenic. We will conduct a follow-up study to monitor hexavalent chromium directly and to calculate the percent of total chromium that is hexavalent. We will continue to enforce our regulations that impact businesses that work with metals, including chromium and arsenic.[96]

Lead results did not indicate that lead air pollution is a significant risk driver in our jurisdiction, but we continue to track regulatory actions, such as the EPA's efforts to eliminate lead in some aviation fuels,[97] lead based paint hazards, and clean-up sites that still suffer from lead contamination.

Ethylene oxide measurements had high uncertainty, canister issues, and no obvious trend across sites. However, its high unit risk factor leads to hundreds per million

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[92] WA Department of Ecology, Clean Vehicles Program, 2023, https://ecology.wa.gov/Regulations-Permits/Laws-rules-rulemaking/Rulemaking/WAC173-423-400Jan18.

[93] EPA, Designation of the North American Emission Control Area for Marine Vessels, 2023, https://www.epa.gov/regulations-emissions-vehicles-and-engines/designation-north-american-emission-control-area-marine.

[94] Northwest Seaport Alliance, Shore Power, https://www.nwseaportalliance.com/environment/clean-air/investing-cleaner-air.

[95] Washington State Department of Transportation, Ferry system electrification, https://wsdot.wa.gov/construction-planning/major-projects/ferry-system-electrification.

[96] PSCAA, Regulations, https://pscleanair.gov/219/PSCAA-Regulations.

[97] EPA, Regulations for Lead Emissions from Aircraft, 2023, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-lead-emissions-aircraft.

cancer risk even for samples near the detection limit. We support EPA's efforts to reduce the use of ethylene oxide in sterilization of medical and other devices and reduce the amount of ethylene oxide being emitted from chemical production plants.[98]

Other combustion-related potential cancer risk drivers such as acetaldehyde, benzene, 1,3-butadiene, and formaldehyde could be reduced by continued effort in both reducing transportation emissions and wood smoke. We continue to support national programs that improve wood stove and transportation standards.

Efforts to reduce wood smoke emissions include our Wood Stove Reduction Program, which offers a cash incentive for people to recycle their old wood stoves; air quality burn bans; and our outdoor burning regulations.[99,100,101] We also have done outreach and education efforts, such as the Clean Burning Challenge, in which participants can get a free wood moisture meter after completing a quiz about how to burn cleaner.[102] Regulations also don't allow homes to smoke out their neighbors via smoke density (opacity) standards.[103]

There are also federal and state standards for wood heating devices. EPA promulgated the first New Source Performance Standard (NSPS) for wood heating devices in 1988.[104] Washington state adopted these standards (finalized in 1990) in WAC 173-443-100.[105] In 2015, EPA amended their wood heating device standards and reduced the PM emission limits. There is ongoing work into ensuring the effectiveness

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[98] EPA, Actions to Protect Workers and Communities from Ethylene Oxide (EtO) Risk, 2023, https://www.epa.gov/hazardous-air-pollutants-ethylene-oxide/actions-protect-workers-and-communities-ethylene-oxide-eto.

[99] PSCAA, Puget Sound Wood Stove Program, https://pscleanair.gov/409/Wood-Stove-Program.

[100] PSCAA, About Air Quality Burn Bans, https://pscleanair.gov/172/About-Air-Quality-Burn-Bans.

[101] PSCAA, Outdoor Burning, https://pscleanair.gov/328/Outdoor-Burning.

[102] PSCAA, Clean Burning Challenge, https://pscleanair.gov/622/Clean-Burning-Challenge.

[103] PSCAA, Regulation I Article 9, https://pscleanair.gov/DocumentCenter/View/162/Regulation-I-Section-911-PDF?bidId=.

[104] EPA, Final Standards of Performance for New Residential Wood Heaters and New Residential Hydronic Heaters and Forced-Air Furnaces, https://www.epa.gov/sites/default/files/2020-03/documents/wood_heaters_final_nsps_fact_sheet.pdf.

[105] Washington State Legislature, WAC 173-433-100, https://apps.leg.wa.gov/WAC/default.aspx?cite=173-433-100.

of the wood heating device testing program and making sure that the wood stove standards are updated every eight years, as required.

Beyond emissions reductions, another way to reduce health risk is to focus on exposure reduction. Even though most people spend a significant amount of time indoors, outdoor pollution can enter the indoor environment. This is most obvious in extreme cases such as heavy wildfire smoke, where the thick smoke can enter a building through a leaky building envelope or a poorly configured HVAC system. Also, diesel particulate matter can enter homes from living near a freeway.

Some techniques to reduce exposure to outdoor pollution indoors include: HVAC upgrades (especially a system that can use a MERV-13 or higher rated filter), air cleaners, and DIY filter fans. Alongside those methods of removing pollution, education regarding when to close or open windows and doors, use air cleaners, and where to check the latest air quality are also helpful.

Throughout this discussion of emissions and exposure reduction, it is critical to think of the populations that would benefit most from the interventions. For example, a high value location for HVAC upgrades may be a school located near a busy highway. Also, focusing on certain pollutants, such as diesel particulate matter, will have a higher benefit to near-road communities, which often have a higher percentage of people of color and lower median annual income.

Another aspect of mitigating exposure is the educational component to community engagement and outreach. One of the goals of our 2030 strategic plan is to "measure, analyze, and communicate air quality risk", with targets related to expanding community science engagement events and providing tools to clearly communicate air pollution risk information.[106] We participate in many community events, resource fairs, health fairs, youth education workshops, and presentations each year. And one of the main topics is explaining the main sources of air pollution, associated health risk, and measures that people can take to protect themselves. We will continue these efforts over the course of our 2030 strategic plan and expand them to reach all overburdened communities within our jurisdiction.

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[106] *ibid*, PSCAA 2030 Strategic Plan.

Appendix

to the Tacoma and Seattle Air Toxics Trends Report (2023)

Contents

Appendix A. Monitoring site descriptions

Table A-1. Summary of site locations for the permanent monitoring and the community-directed temporary sites.

Site name	Site code	Site address*	Site main attribute	Latitude (°)	Longitude (°)	Elevation (m)
Seattle 10th and Weller	BKWA	10th Ave S & S Weller St, Seattle, WA 98104	Near road	47.5974	-122.3198	42
Seattle Beacon Hill	SEWA	4103 Beacon Ave S, Seattle, WA 98108	Residential, NATTS**	47.5682	-122.3086	102
Seattle Duwamish	CEWA	4700 E Marginal Way S, Seattle, WA 98134	Industrial	47.5599	-122.3382	5
Tacoma Tideflats	EQWA	2301 Alexander Ave E, Tacoma, WA 98421	Industrial	47.2655	-122.3850	1
Tacoma 36th	YFWA	1802 S 36th St, Tacoma WA 98418	Near road	47.2263	-122.4625	108
Tacoma South-L	ESWA	7802 S L St, Tacoma, WA 98408	Residential	47.1863	-122.4516	103
South Seattle College - Georgetown	UAWA	6737 Corson Ave S, Seattle, WA 98108	Community-directed	47.5418	-122.3257	4
South Park Residential	UBWA	S Elmgrove St & 12th Ave S, Seattle, WA 98108	Community-directed	47.5305	-122.3178	3
Georgetown Residential	UCWA	Carleton Ave S & S Willow St, Seattle, WA 98108	Community-directed	47.5411	-122.3222	6
Georgetown Steam Plant	UDWA	6605 13th Ave S, Seattle, WA 98108	Community-directed	47.5427	-122.3157	5
South Park Industrial	UEWA	S Fontanelle St. & 3rd Ave S, Seattle, WA 98108	Community-directed	47.5367	-122.3301	3

* We only provide the nearest cross street address for the community-directed sites.

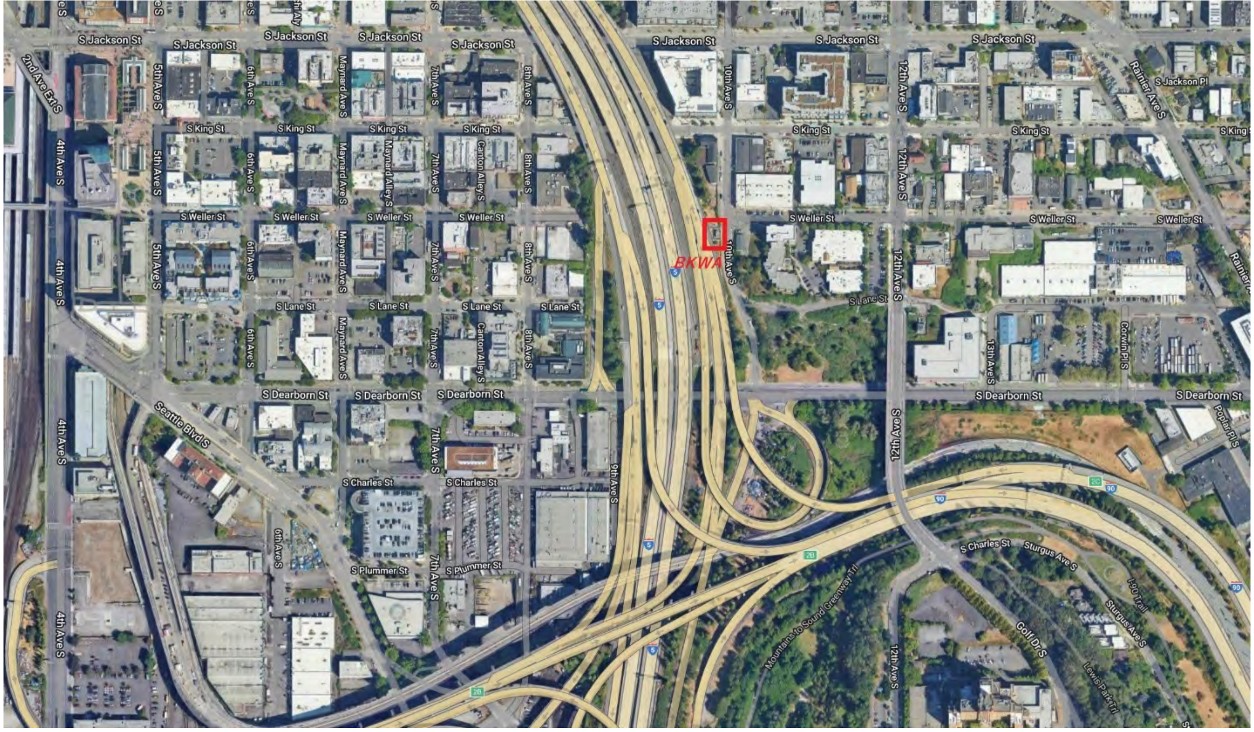
**NATTS: National Air Toxics Trends Station – network of stations providing long-term air toxics monitoring.

Seattle 10th & Weller (BKWA):

This station is Washington state's primary near-road monitoring site. Washington State Dept. of Ecology installed the site in April of 2014. The site is located within 10 meters from Interstate-5 highway and 350 meters from Interstate-90 highway. It has been routinely collecting CO, NO_2, NO_x, $PM_{2.5}$, and black carbon data, along with weather variables (wind & ambient temperature). The station has been used in several studies and is a common location for additional monitoring (e.g. $PM_{2.5}$ speciation, air toxics).

Figure A- 1. Seattle 10th and Weller monitoring site from Google Maps imagery.

Figure A-2. Seattle 10th and Weller Ecology air-quality monitoring site is located in the red square. Aerial imagery is from Google Earth Engine.



Seattle Beacon Hill (SEWA):

Figure A-3: Seattle Beacon Hill monitoring site from Google Maps imagery.

This site, also operated by WA State Department of Ecology, is located in the middle of Jefferson Park near the highest part of the ridge connecting Beacon Hill and North Beacon Hill. It is surrounded by a golf course and a public park with open grass fields and a playground. I-5 is approximately 0.8 km to the west at the bottom of a sharp, 100-meter slope that is the edge of Duwamish Valley and Beacon Hill. The road nearest the site with major traffic is Beacon Ave S, which is about 100 m to the east. The closest residences are about 350 m to the west. The site is run by WA Ecology and has been a primary monitoring station since at least 1979, although the location within Jefferson Park has changed. The station includes monitors for ozone, CO, SO_2, NO_y, $PM_{2.5}$, along with $PM_{2.5}$ speciation and weather data (wind and ambient temperature). It is also a part of the National Air Toxics Trends Stations (NATTS) network and continuously monitors air toxics (Carbonyls, VOCs, PAHs) for recording long-term trends.

Figure A-4. Seattle Beacon Hill Ecology air-quality monitoring site is located in the red square. Aerial imagery is from Google Earth Engine

Seattle Duwamish (CEWA):

Figure A-5. Seattle Duwamish monitoring site from Google Maps imagery

The Seattle Duwamish monitoring site has been in place for about 50 years (since 1971) in the Duwamish industrial valley. This site is designed to be a neighborhood-scale site, representative of South Seattle neighborhoods and ambient exposure in the industrial valley. This site is influenced by a complex mixture of mobile sources, marine sources, industrial sources, winter home heating wood smoke, and other pollution sources. The site used to be located about 400 meters NW of the current site. It is located about 80 meters East of E Marginal Way S, which is a main arterial for many large haul trucks, as well as service vehicles, and personal cars. The site collects continuous air quality data such as $PM_{2.5}$, Black carbon, along with weather variables (wind, ambient temperature and pressure, rain gauge (SPU – RG15)). Given its settings, it is also a common location for additional studies such as $PM_{2.5}$ speciation and/or air toxics (Carbonyls, VOCs, SVOCs, etc.)

Figure A-6. Seattle Duwamish air-quality monitoring site is located in the red square. Aerial imagery is from Google Earth Engine.

Tacoma Tideflats (EQWA):

This monitoring site has been in place since 1987 collecting air pollution data at the Port of Tacoma, also known as the Tacoma Tideflats. It is a large container port in North America and represents a critical hub for containers, heavy cargo, cars, and trucks. The main industrial activities at the port include manufacturing (metal, lumber, concrete, paper), oil refining, and large goods movement (warehouse, shipping/receiving). The port is also connected to railroads and the major roadways Hwy-509 and I-5 are located within 2 km and 2.7 km, respectively.

Figure A-7. Tacoma Tideflats air-quality monitoring site is located in the red square. Aerial imagery is from Google Earth Engine.

Tacoma S 36th St:

Figure A-8: Tacoma S 36th monitoring site from Google Maps imagery.

This monitoring site, operated by WA State Dept. of Ecology, corresponds to Tacoma's near-road air-quality monitoring site. It is located at 15 meters from Interstate-5 highway and is routinely collecting NO_2, NO_x and $PM_{2.5}$. We added a black-carbon monitor (Magee AE-33 aethalometer) when we started the 1-yr air-toxics monitoring campaign in the summer of 2021. Weather variables such as wind and ambient temperature are also recorded at this site.

Figure A-9. Tacoma S 36th air-quality monitoring site from the Department of Ecology is located in the red square. Aerial imagery is from Google Earth Engine.

Tacoma South L St:

This site has been in place since 1999 in the South part of Tacoma. It is a neighborhood scale site and aims to be representative of Tacoma residential area. The main source of air pollution comes from home heating using wood burning. The site is also around 1 km from any substantial traffic (I-5, Hwy-512, and neighborhood arterials). While there are other sources likely contributing to PM2.5 concentration, the majority is winter home heating from wood burning. This monitoring site has the highest design value in the Puget Sound region for PM2.5 for the 24-hr standard.

Figure A-10. Tacoma South L monitoring site photo

Figure A-11. Tacoma South L air-quality monitoring site is located in the red square. Aerial imagery is from Google Earth Engine.

<u>Community-directed sites</u>:

These sites were identified after consultation with the Duwamish Valley community (as described in the main report) to see what where their highest area of concern regarding air pollution and where they wanted to locate the air-quality instruments. These sites encompass various settings and aim to be representative of more industrial settings (UEWA), residential settings (UBWA & UCWA, for South Park and Georgetown, respectively), near regional airport (UDWA) and where a previous study reported highest levels of metals for the area (UAWA). Nearest intersections are shared in the main report.

Figure A-12. Locations of the 5 community-directed sites for the summer of 2022 where we collected weekly PM10 metal samples in the Georgetown and South Park neighborhoods. Aerial imagery is from Google Earth Engine.

Appendix B. Quality assurance

This appendix contains information on data completeness, non-detects (NDs), samples that were below the detection limit (MDL), any recorded sampling issues, collocated duplicate samples, and mean field blank values.

Table B-1. Data completeness and total sample collections for each studied site

Group of pollutants analyzed	Collection Start	Collection End	Time interval	Total samples collected	Data Completeness (%)
Tacoma South L (ESWA) 53 053 0029					
VOCs	Aug 2, 2021	Sep 2, 2022	1-in-6 days	64	95.5%
Carbonyls	Aug 2, 2021	Sep 2, 2022	1-in-6 days	66	98.5%
$PM_{2.5}$ Speciation	Aug 2, 2021	Sep 2, 2022	1-in-6 days	67	100%
$PM_{2.5}$	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9216	96.7%
Black Carbon	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9370	98.3%
Wind	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9468	99.4%
Tacoma S 36th (YFWA) 53 053 0024					
VOCs	Aug 2, 2021	Sep 2, 2022	1-in-6 days	62	92.5%
Carbonyls	Aug 2, 2021	Sep 2, 2022	1-in-6 days	63	94%
$PM_{2.5}$	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	8880	93.2%
Black Carbon	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9515	99.9%
Wind	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9518	99.9%
Tacoma Tideflats (EQWA) 53 053 0031					
VOCs	Aug 2, 2021	Sep 2, 2022	1-in-6 days	65	97%
Carbonyls	Aug 2, 2021	Sep 2, 2022	1-in-6 days	63	94%
$PM_{2.5}$ Speciation	Aug 2, 2021	Feb 10, 2022	1-in-6 days	33	100%
$PM_{2.5}$	Aug 2, 2021	Sep 2, 2022	Continuous	9132	95.8%

			(hourly)		
Black Carbon	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9245	97%
PM$_{10}$ Metals	Aug 2, 2021	Sep 2, 2022	1-in-6 days	65	97%
Wind	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9352	98%
Seattle Duwamish (CEWA) 53 033 0057					
VOCs	Aug 2, 2021	Sep 2, 2022	1-in-6 days	62	92.5%
Carbonyls	Aug 2, 2021	Sep 2, 2022	1-in-6 days	64	95.5%
PM$_{2.5}$ Speciation	Aug 2, 2021	Jun 28, 2022	1-in-6 days	56	100%
PM$_{2.5}$	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9366	98.3%
Black Carbon	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9480	99.5%
PM$_{10}$ Metals	Aug 2, 2021	Sep 2, 2022	1-in-6 days	67	100%
Wind	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9492	99.6%
SVOC PAH	Aug 2, 2021	Sep 2, 2022	1-in-6 days	62	92.5%
Seattle Beacon Hill (SEWA) 53 033 0029					
VOCs	Aug 2, 2021	Sep 2, 2022	1-in-6 days	62	92.5
Carbonyls	Aug 2, 2021	Sep 2, 2022	1-in-6 days	67	100%
PM$_{2.5}$ Speciation	Aug 2, 2021	Sep 2, 2022	1-in-3 days	133	100%
PM$_{2.5}$	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9136	95.9%
PM$_{10}$ Metals	Aug 2, 2021	Sep 2, 2022	1-in-6 days	98**	100%
Wind	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	8989	94.2%*
SVOC PAH	Aug 2, 2021	Sep 2, 2022	1-in-6 days	72**	100%
Seattle 10th & Weller (BKWA) 53 033 030					
VOCs	Aug 2, 2021	Sep 2, 2022	1-in-6 days	64	95.5%
Carbonyls	Aug 2, 2021	Sep 2, 2022	1-in-6 days	63	94%
PM$_{2.5}$ Speciation	Aug 2, 2021	Jul 28, 2022	1-in-6 days	61	100%

$PM_{2.5}$	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9342	98%
Black Carbon	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9510	99.8%
Wind	Aug 2, 2021	Sep 2, 2022	Continuous (hourly)	9522	99.9%
South Seattle College (UAWA)					
PM_{10} Metals	Mar 4, 2022	Sep 2, 2022	weekly	26	100%
South Park Residential (UBWA)					
PM_{10} Metals	Jul 1, 2022	Sep 2, 2022	weekly	9	100%
Georgetown Residential (UCWA)					
PM_{10} Metals	Jul 1, 2022	Sep 2, 2022	weekly	8.2	100%
Georgetown Steam Plant (UDWA)					
PM_{10} Metals	Jul 29, 2022	Sep 2, 2022	weekly	5	100%
South Park Industrial (UEWA)					
PM_{10} Metals	Jul 25, 2022	Sep 2, 2022	weekly	5.6	100%

*Beacon Hill wind data were invalidated due to a 6-8° misalignment for 12/3/21 – 3/11/22. While slightly above our 5° tolerance, we still used the data in the wind/pollution rose analysis (Appendix D); since it did not impact substantially the wind direction binned averages.

**Beacon Hill SVOCs and PM_{10} metals had some extra samples (+ 5 and +31, respectively) collected over the study period which are included in the data analysis, but we capped the data completeness at 100%.

Table B-2. Air toxics log of instrument & sampling issues resulting in a missed sample, or a sample being rescheduled (within +/- 3 days of planned date).

Date	Site(s) affected (code)	Types	Sample	Reason(s)
Aug-2 2021	BKWA, CEWA, EQWA, YFWA	Carbonyl (TO-11A)	No	Not started
Aug-2 2021	CEWA	SVOCs (TO-13A)	No	Not started
Aug-2 2021	CEWA, EQWA	PM_{10} metals (IO-3.5)	No	Not started
Aug-5 2021	CEWA	Carbonyl (TO-11A)	Yes	Sample ran on 8/5 instead of 8/2

Aug-8 2021	BKWA, EQWA, YFWA	Carbonyl (TO-11A)	No	Not started yet
Aug-2 2021	CEWA	SVOCs (TO-13A)		Not started
Aug-14 2021	BKWA, CEWA, EQWA, YFWA, ESWA	VOCs (TO-15)	No	Skipped
Aug-14 2021	BKWA, CEWA, EQWA, YFWA, ESWA	Carbonyl (TO-11A)	No	Not started or skipped due to coordination with lab.
Aug-14 2021	CEWA	SVOCs (TO-13A)		Not started yet
Aug-20 2021	YWFA	VOCs (TO-15)	No	Sample voided – can cross threaded
Aug- 26 2021	YWFA	VOCs (TO-15)	No	No canister received from lab for collection
Aug-26 2021	SEWA	Carbonyl (TO-11A)	Yes	Sample ran on 8/29 instead of 8/26
Sep-7 2021	BKWA, CEWA, EQWA, YFWA, ESWA	VOCs (TO-15)	No	Skipped because of no canisters ready for sampling (shipping delays)
Sep-13 2021	ESWA	VOCs (TO-15)	No	Canister voided because reading ambient pressure at the lab (no vacuum left)
Sep-13 2021	SEWA	VOCs, SVOCs, Carbonyl	Yes	Samples ran on 9/16 instead of 9/13
Sep-19 2021	BKWA, CEWA	VOCs (TO-15)	No	Canister voided because reading ambient pressure at the lab (no vacuum left)
Sep-25 2021	SEWA	VOCs (TO-15)	No	Sample missing
Oct-13 2021	BKWA	VOCs (TO-15)	Yes	Canister voided (no vacuum at reception)

				but was able to use a different canister and still collect data for that day
Oct-25 2021	CEWA	Carbonyl (TO-11A)	No	Instrument malfunction
Oct-25 2021	SEWA	Carbonyl (TO-11A)	No	Void – power outage
Oct-25 2021	EQWA	VOCs (TO-15)	Yes	Final field vacuum = 0
Oct-31 2021	BKWA, CEWA, YFWA, ESWA	VOCs (TO-15)	Yes	Final field vacuum at 0 with time shut-off issues due to cold temperatures.
Nov-30 2021	CEWA	VOCs (TO-15)	No	Sample did not collect (valve remained close)
Nov-30 2021	SEWA	VOCs, SVOCs, Carbonyl	Yes	Samples ran on 12/1 instead of 11/30
Dec-30 2021	EQWA	PM_{10} metals (IO-3.5)	No	Sample did not collect (instrument did not run)
Jan-29 2022	BKWA	VOCs (TO-15)	Yes	TO-15 started at -12 inHg (instead of -30) vacuum.
Feb-28 2022	CEWA	VOCs (TO-15)	No	TO-15 voided, canister was not open for sampling
Feb-28 2022	EQWA	Carbonyl (TO-11A)	No	Instrument did not run
Mar-6 2022	YFWA	VOCs (TO-15)	No	Valve did not open – corrosion on timer.
Mar-18 2022	BKWA, CEWA	VOCs (TO-15)	Yes	Only ran for 13:50 and 14:50 hours, respectively
Mar-30 2022	SEWA	Carbonyl (TO-11A) & SVOCs (TO-13A)	Yes	Sample ran on 4/2 instead of 3/30

Apr-5 2022	SEWA	VOCs (TO-15)	Yes	Sample ran on 4/2 instead of 4/5
Apr-5 2022	YFWA	VOCs (TO-15)	Yes	TO-15 started at -25 inHg (instead of -30) vacuum.
Apr-11 2022	YFWA	Carbonyl (TO-11A)	No	Power outage
May-5 2022	BKWA	VOCs (TO-15)	Yes	TO-15 started at -24 inHg (instead of -30) vacuum.
May-29 2022	SEWA	VOCs (TO-15)	No	Sample did not run - received vacuum of 29.0 inHg at the lab
Jun-10 2022	SEWA	VOCs (TO-15)	No	Sample did not run - received vacuum of 29.0 inHg at the lab
Jun-22 2022	EQWA	Carbonyl (TO-11A)	Yes	Instrument off due to power outage. Make up sample ran on 6/30
Jun-22 2022	SEWA	VOCs (TO-15)	Yes	Sample ran on 6/25 instead of 6/22
Jul-1 2022	UCWA	PM_{10} metals (IO-3.5)	Yes	Sample ran for 25 hours instead of 1 week
Jul-4 2022	BKWA	Carbonyl (TO-11A)	No	Instrument did not run
Jul-10 2022	SEWA	Carbonyl (TO-11A)	No	Perhaps a low-sample time but would need to confirm with Ecology
Jul-10 & 16 & 22 2022	SEWA	VOCs (TO-15)	No	Samples did not run – received at high vacuum in lab.
Aug-3 2022	SEWA	SVOCs (TO-13A)	No	Voided by lab. Sample fails all surrogates

				likely due to an extraction error.
Aug-9 2022	SEWA	Carbonyl (TO-11A)	No	Sample did not run – monitoring or operation error.
Aug-9 & 15 2022	SEWA	VOCs (TO-15)	No	Samples did not run – received at high vacuum in lab.
July-29 2022	UEWA	PM_{10} metals (IO-3.5)	Yes	Sample ran for 5 days instead of 7 days
Sept-2 2022	CEWA	VOCs (TO-15)	Yes	Sample ended at -18 inHg somehow

Table B-3. Percentage (%) of non-detect (ND) samples for each chemical compound (analyte) measured per site.

Groups	**Analytes**	**BKWA**	**CEWA**	**EQWA**	**ESWA**	**SEWA**	**YFWA**
Carbonyls	Acetaldehyde	0	0	0	0	0	0
	Formaldehyde	0	0	0	0	0	0
VOCs	1,3-Butadiene	0	5	2	2	6	0
	Acrolein	2	0	0	2	0	3
	Benzene	0	0	0	0	0	0
	Carbon Tetrachloride	0	0	0	0	0	0
	Ethylbenzene	0	0	0	0	0	0
	Ethylene oxide	6	0	2	2	0	2
	Tetrachloroethylene	0	0	0	0	2	2
PM_{10} Metals*	Manganese		0	0		0	
	Lead		0	0		0	
	Chromium		0	0		0	

	Antimony		0	0		0	
	Nickel		0	0		0	
	Selenium		0	2		0	
	Arsenic		0	0		0	
	Beryllium		19	14		24	
	Cadmium		0	0		0	
	Cobalt		0	0		1	
	Mercury		4	6		0	
SVOCs	Naphthalene		0			0	
	Acenaphthene		31			38	
	Phenanthrene		0			0	
	Fluorene		0			0	
	Fluoranthene		0			0	
	Pyrene		0			4	
	Acenaphthylene		35			50	
	Anthracene		13			0	
	Benzo(a)anthracene		13			13	
	Benzo(a)pyrene		8			24	
	Benzo(b)fluoranthene		44			49	
	Benzo(e)pyrene		8			11	
	Benzo(g,h,i)perylene		10			16	
	Benzo(k)fluoranthene		21			38	
	Chrysene		61			65	
	Coronene		11			14	

	Dibenz(a,h)anthracene		87			83	
	Indeno(1,2,3-c,d)pyrene		15			21	
	Perylene		89			93	

*No non-detect (ND) samples were reported for the community-directed weekly samples at the UAWA, UBWA, UCWA, UDWA, UEWA sites.

Table B-4. Percentage (%) of samples below the method detection limit (MDL) for each chemical compound (analyte) measured per site. This percentage includes the non-detect samples (Table B-3).

Groups	**Analytes**	**BKWA**	**CEWA**	**EQWA**	**ESWA**	**SEWA**	**YFWA**
Carbonyls	Acetaldehyde	0	0	0	0	1	0
	Formaldehyde	0	0	0	0	1	0
VOCs	1,3-Butadiene	8	48	54	53	71	23
	Acrolein	17	23	17	22	29	13
	Benzene	0	0	0	0	0	0
	Carbon Tetrachloride	0	0	0	0	0	2
	Ethylbenzene	0	0	0	3	0	0
	Ethylene oxide	8	3	9	6	5	6
	Tetrachloroethylene	80	63	75	80	98	84
PM_{10} Metals*	Manganese		0	0		0	
	Lead		0	0		0	
	Chromium		97	98		90	
	Antimony		0	0		0	
	Nickel		12	3		48	
	Selenium		0	18		6	
	Arsenic		0	0		0	
	Beryllium		40	57		98	

	Cadmium		0	5		3	
	Cobalt		34	46		62	
	Mercury		81	82		93	
SVOCs	Naphthalene		0			0	
	Acenaphthene		31			38	
	Phenanthrene		0			0	
	Fluorene		0			0	
	Fluoranthene		0			0	
	Pyrene		0			4	
	Acenaphthylene		35			50	
	Anthracene		13			3	
	Benzo(a)anthracene		13			21	
	Benzo(a)pyrene		18			38	
	Benzo(b)fluoranthene		44			50	
	Benzo(e)pyrene		10			15	
	Benzo(g,h,i)perylene		16			22	
	Benzo(k)fluoranthene		39			53	
	Chrysene		61			67	
	Coronene		11			15	
	Dibenz(a,h)anthracene		89			85	
	Indeno(1,2,3-c,d)pyrene		15			24	
	Perylene		95			96	

*Samples reported below the MDL (method detection limit) for the community-directed weekly samples are presented in the table below. UCWA MDL percentages are due to a partial sample collected on Jul 1st of 25 hours instead of 7 days (table B-2).

Table B-5. Percentage (%) of samples below the method detection limit (MDL) for each chemical compound (analyte) measured per site.

Groups	Analytes	UAWA	UBWA	UCWA	UDWA	UEWA
PM_{10} Metals	Manganese	0	0	0	0	0
	Lead	0	0	0	0	0
	Chromium	4	0	11	0	0
	Antimony	0	0	0	0	0
	Nickel	4	0	0	0	0
	Selenium	0	0	0	0	0
	Arsenic	0	0	0	0	0
	Beryllium	0	0	11	0	0
	Cadmium	0	0	0	0	0
	Cobalt	4	0	0	0	0
	Mercury	4	0	11	0	0

Table B-6. Table of collocated duplicate samples with percent recovery greater than ± 20%. Samples were only included if the primary and duplicate concentrations were greater than 3x the method detection limit (MDL).

Site	Sample Date	Analyte	Primary Conc	Duplicate Conc	MDL	Units	Percent Recovery
SEWA	8/5/2021	Acenaphthylene	0.09	0.113	0.003	ng/m³	126
CEWA	2/16/2022	Beryllium	0.015	0.019	0.004	ng/m³	131
CEWA	11/18/2021	Cobalt	0.346	0.424	0.077	ng/m³	123
SEWA	7/15/2021	Dibenz(a,h)anthracene	0.021	0.016	0.005	ng/m³	78
EQWA	11/18/2021	Ethylene oxide	0.099	0.196	0.026	ppbv	199
ESWA	9/19/2021	Ethylene oxide	0.187	0.099	0.026	ppbv	53
YFWA	2/16/2022	Ethylene oxide	0.141	0.407	0.026	ppbv	289
EQWA	9/19/2021	Lead	0.744	0.905	0.065	ng/m³	122
CEWA	11/18/2021	Manganese	444	539	0.625	ng/m³	121

Table B-7. Mean ambient, field blank, and MDL concentrations for all Sites and Analytes for which blank values were collected. Field blank values were not collected for VOCs, and field blanks were not collected for the community-directed PM10 metals samples.

Site	Analyte	Type	Units	Median Ambient Conc	Mean Field Blank Conc	Mean MDL
BKWA	Acetaldehyde	Carbonyl	ug/m³ Air	1.243	0.020	0.031
BKWA	Formaldehyde	Carbonyl	ug/m³ Air	2.098	0.024	0.044
CEWA	Acetaldehyde	Carbonyl	ug/m³ Air	0.886	0.019	0.031
CEWA	Formaldehyde	Carbonyl	ug/m³ Air	1.336	0.020	0.044
CEWA	Antimony	Metal	ng/m³ Air	1.797	0.013	0.109
CEWA	Arsenic	Metal	ng/m³ Air	1.315	0.011	0.032
CEWA	Beryllium	Metal	ng/m³ Air	0.006	0.001	0.004
CEWA	Cadmium	Metal	ng/m³ Air	0.126	0.003	0.010
CEWA	Chromium	Metal	ng/m³ Air	4.514	1.988	8.890
CEWA	Cobalt	Metal	ng/m³ Air	0.191	0.010	0.098
CEWA	Lead	Metal	ng/m³ Air	6.800	0.082	0.084
CEWA	Manganese	Metal	ng/m³ Air	22.328	0.321	0.346
CEWA	Mercury	Metal	ng/m³ Air	0.033	0.002	0.013
CEWA	Nickel	Metal	ng/m³ Air	1.594	0.487	0.640
CEWA	Selenium	Metal	ng/m³ Air	2.036	0.009	0.050
CEWA	Acenaphthene	SVOC	ng/m³ Air	4.016	0.069	0.073
CEWA	Acenaphthylene	SVOC	ng/m³ Air	0.455	0.005	0.005
CEWA	Anthracene	SVOC	ng/m³ Air	0.295	0.008	0.023
CEWA	Benzo(a)anthracene	SVOC	ng/m³ Air	0.048	0.006	0.005
CEWA	Benzo(a)pyrene	SVOC	ng/m³ Air	0.048	0.008	0.008
CEWA	Benzo(b)fluoranthene	SVOC	ng/m³ Air	0.051	0.011	0.009
CEWA	Benzo(e)pyrene	SVOC	ng/m³ Air	0.067	0.008	0.008
CEWA	Benzo(g,h,i)perylene	SVOC	ng/m³ Air	0.092	0.010	0.005
CEWA	Benzo(k)fluoranthene	SVOC	ng/m³ Air	0.040	0.006	0.010
CEWA	Chrysene	SVOC	ng/m³ Air	0.021	0.008	0.007
CEWA	Coronene	SVOC	ng/m³ Air	0.056	NA	0.007
CEWA	Dibenz(a,h)anthracene	SVOC	ng/m³ Air	0.006	NA	0.005
CEWA	Fluoranthene	SVOC	ng/m³ Air	1.808	0.015	0.040
CEWA	Fluorene	SVOC	ng/m³ Air	3.537	0.021	0.054
CEWA	Indeno(1,2,3-c,d)pyrene	SVOC	ng/m³ Air	0.074	0.009	0.006
CEWA	Naphthalene	SVOC	ng/m³ Air	43.319	0.550	1.730
CEWA	Perylene	SVOC	ng/m³ Air	0.006	NA	0.009

Site	Analyte	Type	Units	Median Ambient Conc	Mean Field Blank Conc	Mean MDL
CEWA	Phenanthrene	SVOC	ng/m³ Air	8.045	0.055	0.143
CEWA	Pyrene	SVOC	ng/m³ Air	2.532	0.014	0.033
EQWA	Acetaldehyde	Carbonyl	ug/m³ Air	1.012	0.026	0.032
EQWA	Formaldehyde	Carbonyl	ug/m³ Air	1.526	0.022	0.044
EQWA	Antimony	Metal	ng/m³ Air	1.864	0.034	0.111
EQWA	Arsenic	Metal	ng/m³ Air	1.050	0.013	0.033
EQWA	Beryllium	Metal	ng/m³ Air	0.010	0.002	0.004
EQWA	Cadmium	Metal	ng/m³ Air	0.105	0.003	0.011
EQWA	Chromium	Metal	ng/m³ Air	2.989	1.644	9.000
EQWA	Cobalt	Metal	ng/m³ Air	0.207	0.012	0.099
EQWA	Lead	Metal	ng/m³ Air	3.995	0.097	0.085
EQWA	Manganese	Metal	ng/m³ Air	9.582	0.610	0.345
EQWA	Mercury	Metal	ng/m³ Air	0.009	0.002	0.013
EQWA	Nickel	Metal	ng/m³ Air	1.856	0.649	0.648
EQWA	Selenium	Metal	ng/m³ Air	0.150	0.017	0.051
ESWA	Acetaldehyde	Carbonyl	ug/m³ Air	0.961	0.019	0.032
ESWA	Formaldehyde	Carbonyl	ug/m³ Air	1.408	0.022	0.045
SEWA	Acetaldehyde	Carbonyl	ug/m³ Air	0.927	0.026	0.029
SEWA	Formaldehyde	Carbonyl	ug/m³ Air	1.308	0.044	0.043
SEWA	Antimony	Metal	ng/m³ Air	1.045	0.008	0.105
SEWA	Arsenic	Metal	ng/m³ Air	0.471	0.006	0.032
SEWA	Beryllium	Metal	ng/m³ Air	0.002	0.000	0.004
SEWA	Cadmium	Metal	ng/m³ Air	0.045	0.003	0.012
SEWA	Chromium	Metal	ng/m³ Air	6.293	4.991	8.688
SEWA	Cobalt	Metal	ng/m³ Air	0.101	0.040	0.098
SEWA	Lead	Metal	ng/m³ Air	2.376	0.030	0.089
SEWA	Manganese	Metal	ng/m³ Air	5.130	0.175	0.371
SEWA	Mercury	Metal	ng/m³ Air	0.007	0.001	0.013
SEWA	Nickel	Metal	ng/m³ Air	0.821	0.162	0.606
SEWA	Selenium	Metal	ng/m³ Air	0.249	0.005	0.050
SEWA	Acenaphthene	SVOC	ng/m³ Air	2.383	0.155	0.067
SEWA	Acenaphthylene	SVOC	ng/m³ Air	0.129	0.026	0.004
SEWA	Anthracene	SVOC	ng/m³ Air	0.130	0.008	0.022
SEWA	Benzo(a)anthracene	SVOC	ng/m³ Air	0.041	0.002	0.005
SEWA	Benzo(a)pyrene	SVOC	ng/m³ Air	0.044	NA	0.007

Site	Analyte	Type	Units	Median Ambient Conc	Mean Field Blank Conc	Mean MDL
SEWA	Benzo(b)fluoranthene	SVOC	ng/m³ Air	0.062	0.004	0.008
SEWA	Benzo(e)pyrene	SVOC	ng/m³ Air	0.051	0.004	0.007
SEWA	Benzo(g,h,i)perylene	SVOC	ng/m³ Air	0.056	NA	0.004
SEWA	Benzo(k)fluoranthene	SVOC	ng/m³ Air	0.031	NA	0.009
SEWA	Chrysene	SVOC	ng/m³ Air	0.024	0.004	0.006
SEWA	Coronene	SVOC	ng/m³ Air	0.029	NA	0.007
SEWA	Dibenz(a,h)anthracene	SVOC	ng/m³ Air	0.009	NA	0.005
SEWA	Fluoranthene	SVOC	ng/m³ Air	0.889	0.016	0.037
SEWA	Fluorene	SVOC	ng/m³ Air	2.334	0.024	0.052
SEWA	Indeno(1,2,3-c,d)pyrene	SVOC	ng/m³ Air	0.057	NA	0.005
SEWA	Naphthalene	SVOC	ng/m³ Air	26.939	0.665	1.132
SEWA	Perylene	SVOC	ng/m³ Air	0.010	NA	0.008
SEWA	Phenanthrene	SVOC	ng/m³ Air	3.892	0.063	0.136
SEWA	Pyrene	SVOC	ng/m³ Air	0.507	0.012	0.027
YFWA	Acetaldehyde	Carbonyl	ug/m³ Air	0.851	0.024	0.032
YFWA	Formaldehyde	Carbonyl	ug/m³ Air	1.285	0.065	0.045

Appendix C. Meteorology representativeness

Figure C-1 below shows the '10-yr History' line (blue), which is the 7-day running average of the daily average temperature for the past 10 years. The +/- 'stdv' lines are + and – 1 standard deviations, calculated daily, for each day of the daily average temperature for the past 10 years. The 'Sample Period' line (rust orange) is the daily average temperature for the sampling period of this study.

Figure C-1. Daily average temperatures at the Seattle Duwamish Valley site.

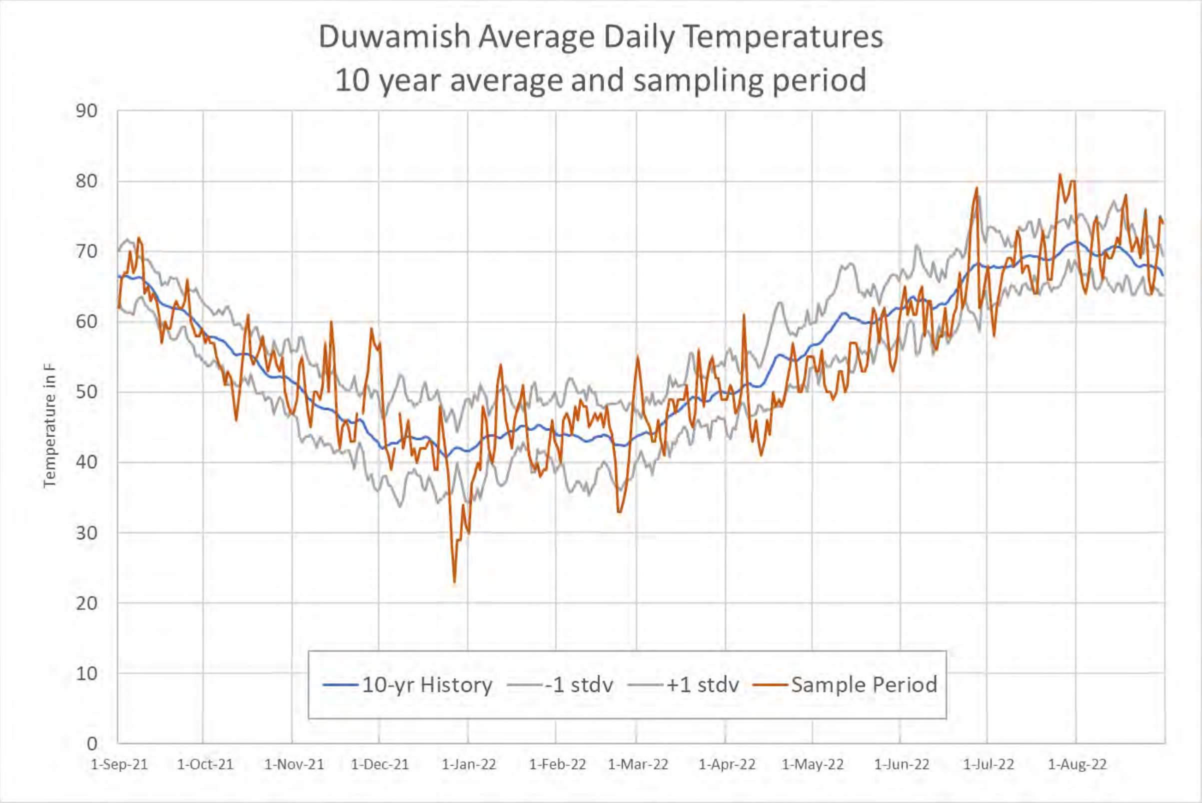


Figure C-2 below shows the '10-yr History' line (in blue) as the 7-day running average of the daily average wind speed for the past 10 years. The +/- stdv lines are + and – 1 standard deviations, calculated daily, for each day of the daily average wind speed for the past 10 years. The 'Sample Period' line (rust orange) is the daily average wind speed for the sampling period of this study.

Figure C-2. Daily average wind speed at the Seattle Duwamish Valley site.

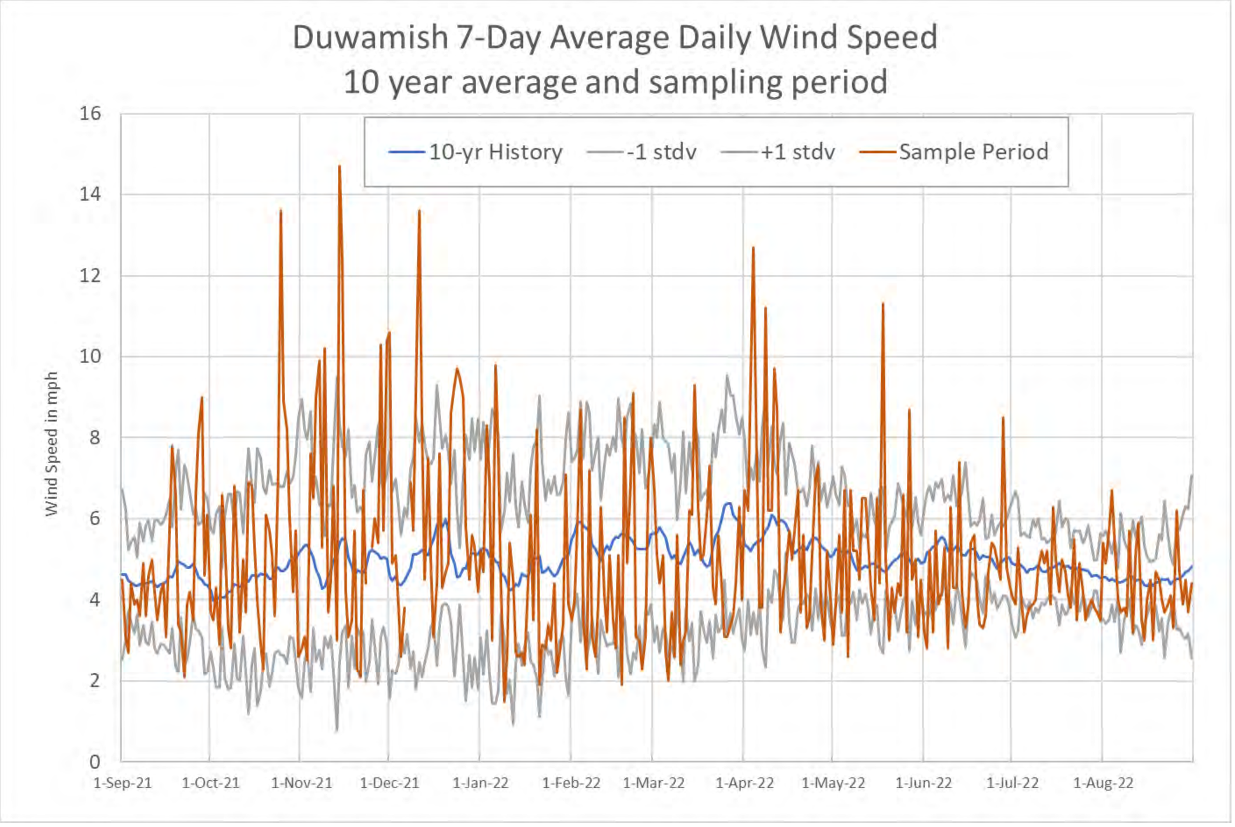
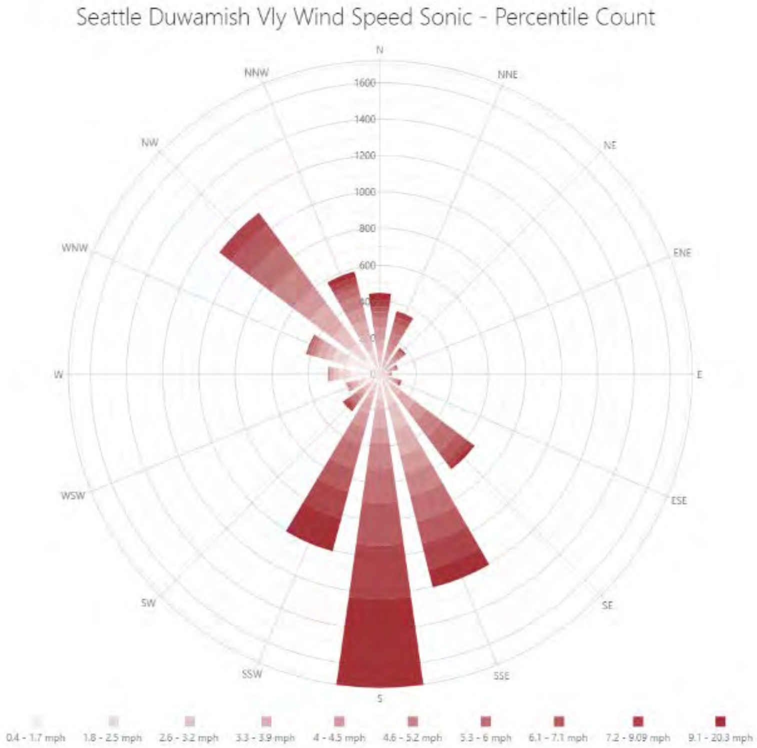


Figure C-3. Counts of hourly wind direction, colored by wind speed bin, for the past 10 years (below, top) and for the year of the toxics sampling campaign (below, bottom).



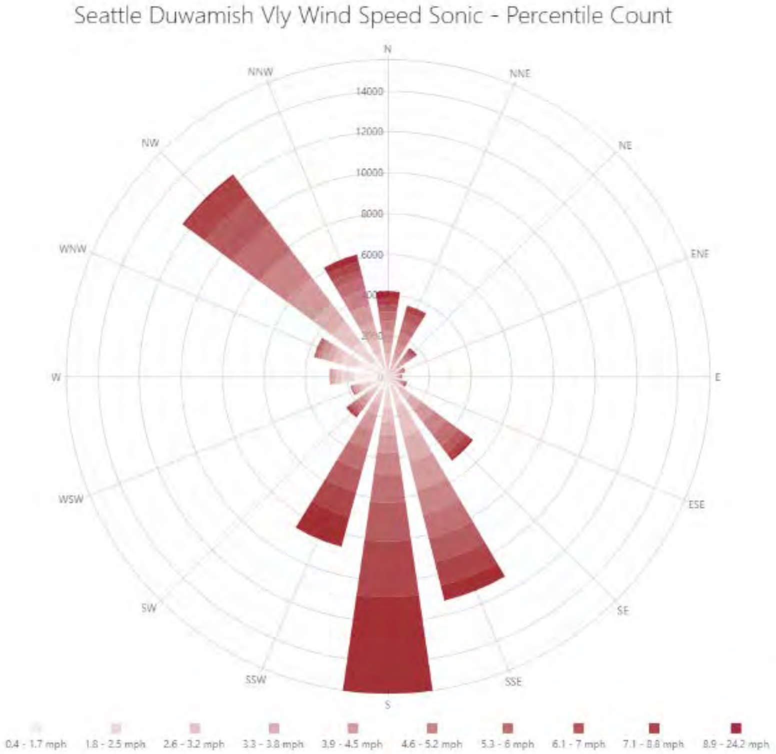


Figure C-4. Counts of hourly wind direction, colored by wind speed bin, for the July-Aug period for 2021 (below, top) and for July-Aug period of the toxics sampling campaign 2022 (below, bottom)

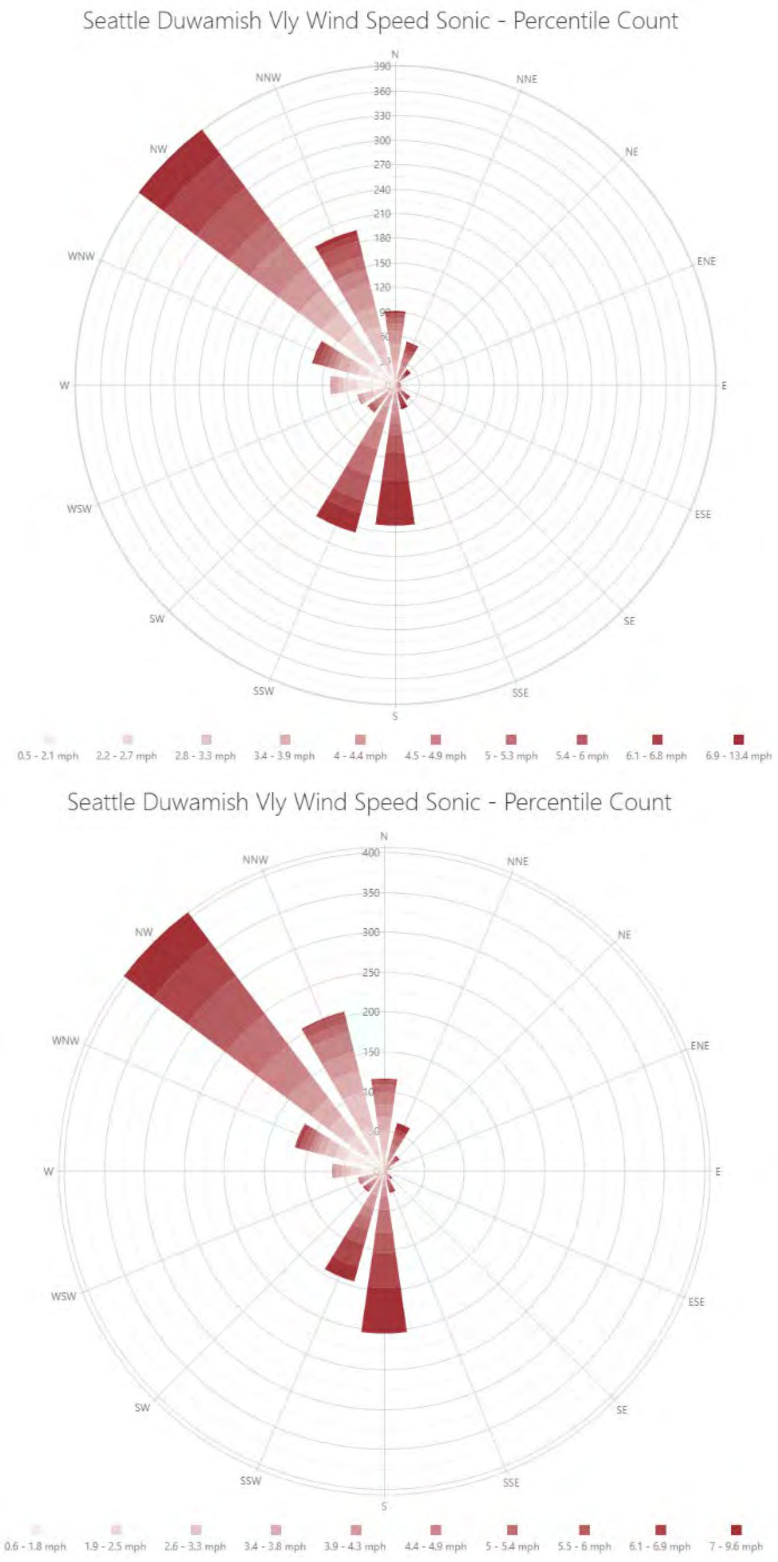
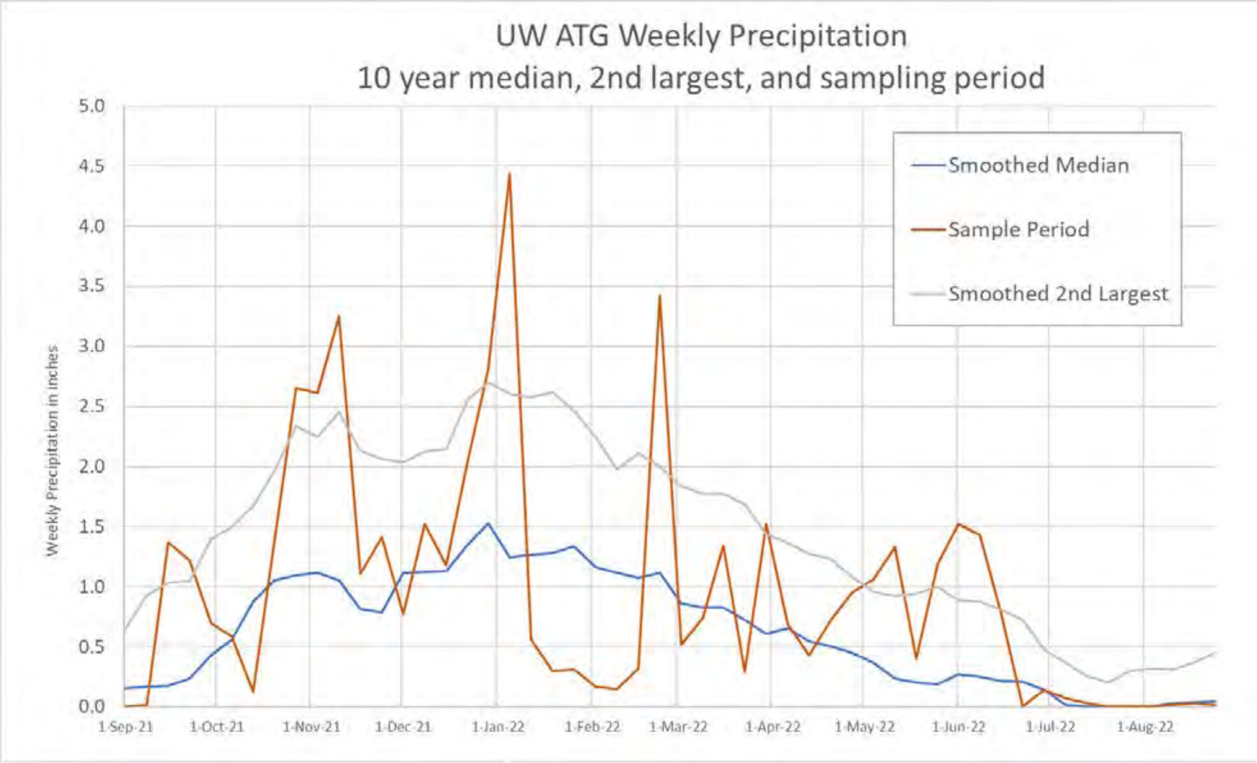


Figure C-5 below shows results from precipitation measured at the University of Washington Atmospheric Sciences building. Because precipitation is not distributed smoothly like many other parameters (it has many zeros and extreme values, so is not statistically 'normal'), the data must be treated differently to analyze for outliers and general trends. Here, this means not using extreme values, and averaging or smoothing daily values to longer periods. For identifying extreme events, the median and the second greatest weekly values were found for each week over the 10 years. The values were then smoothed with a 5-week running average, plotted at the center week. The median line shows a typical or central value, and the '2nd Largest' line shows a value that we would expect to be significantly exceeded 5 or 6 times in a typical year. Deviations from typical precipitation that would be worthy of noting would be extended below normal precipitation in the winter and extended above normal precipitation in the summer. The period from mid-January to mid-February was unusually dry, and May through mid-June was unusually wet.

Figure C-5. UW Atmospheric Sciences-Geophysics Building precipitation values.



Appendix D. Pollution roses for PM$_{2.5}$ and black carbon

Figure D-1: Maps of the wind data collection in the Seattle area (A) and in the Tacoma area (B). The location codes can be identified as follow: Seattle 10th and Weller (BKWA), Seattle Duwamish (CEWA), Seattle Beacon Hill (SEWA), Tacoma Alexander Ave (EQWA), Tacoma 36th St (YFWA) and Tacoma South L St (ESWA). Background maps are from Google Earth Engine.

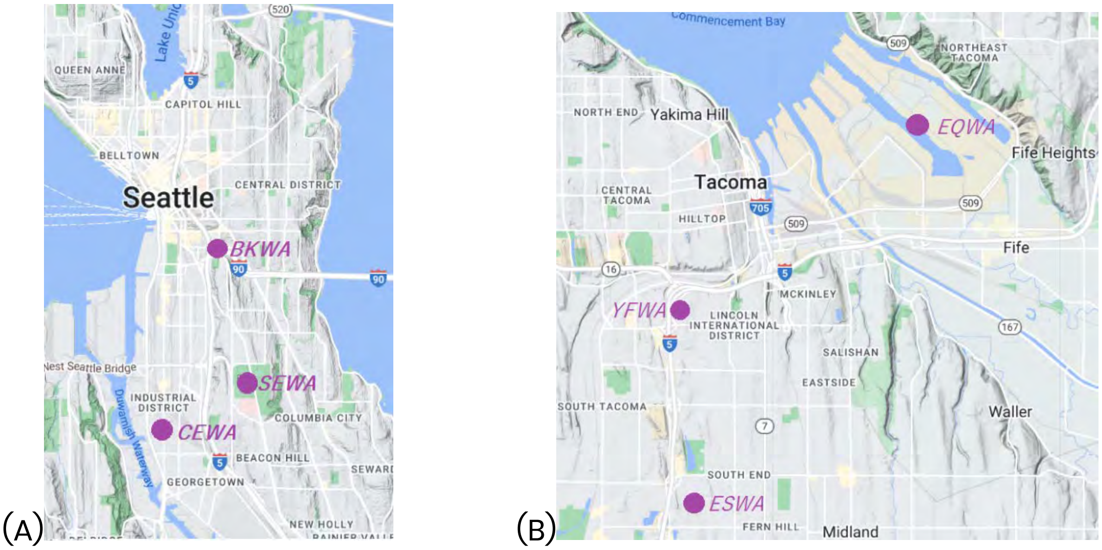


Figure D-2. Hourly wind roses (wind speed) coincident with air-toxics samples (1 every 6 days) between August 2021 and September 2022.

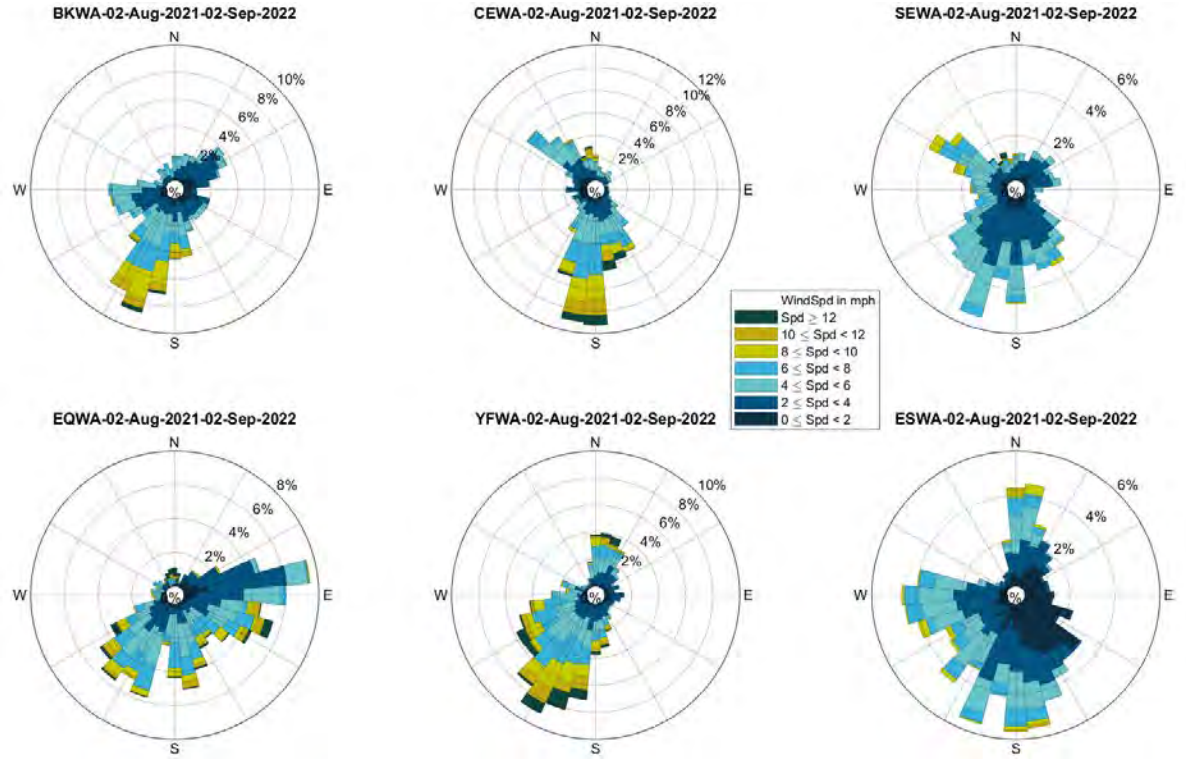


Figure D-3: Daily $PM_{2.5}$ times series (gray dots) at our 6 studied sites with teal colors representing 1-in-6 air-toxics sampling days between August 2021 and September 2022. The green line represents the 1-in-6-day average, and the black line represents the overall average for the entire sampling period.

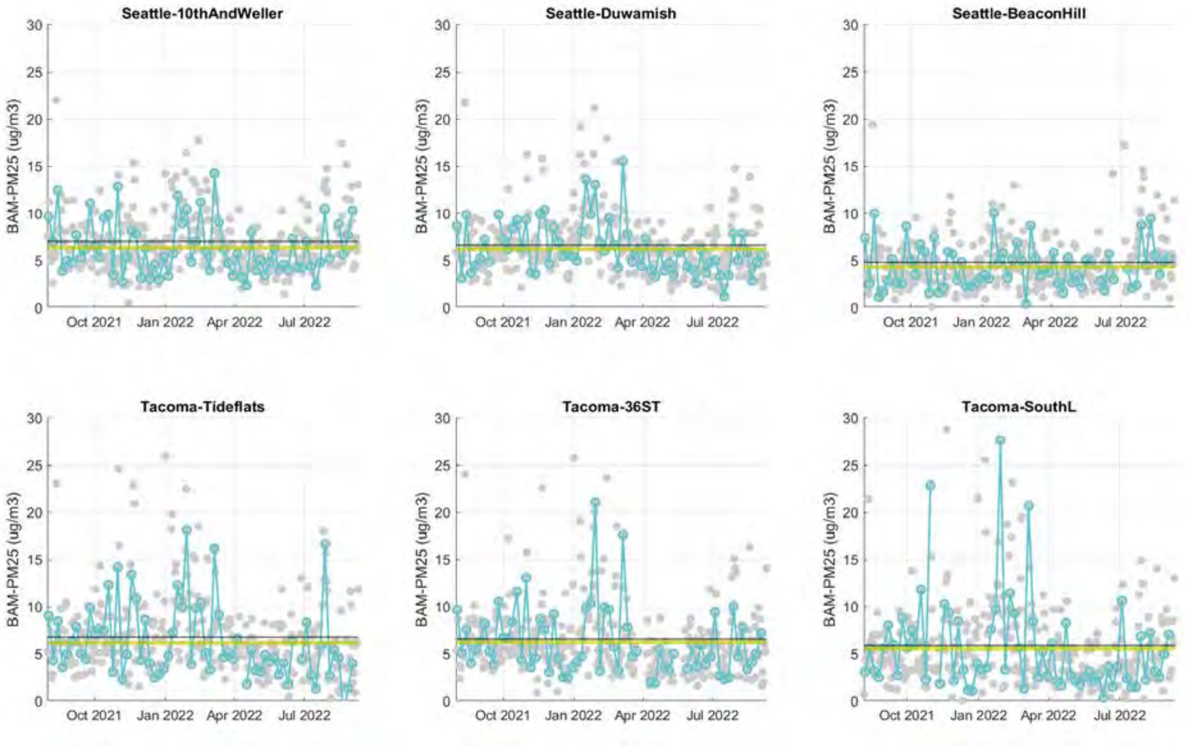


Figure D-4. Corresponding hourly pollution roses ($PM_{2.5}$) coincident with air-toxics samples (1 every 6 days) between August 2021 and September 2022.

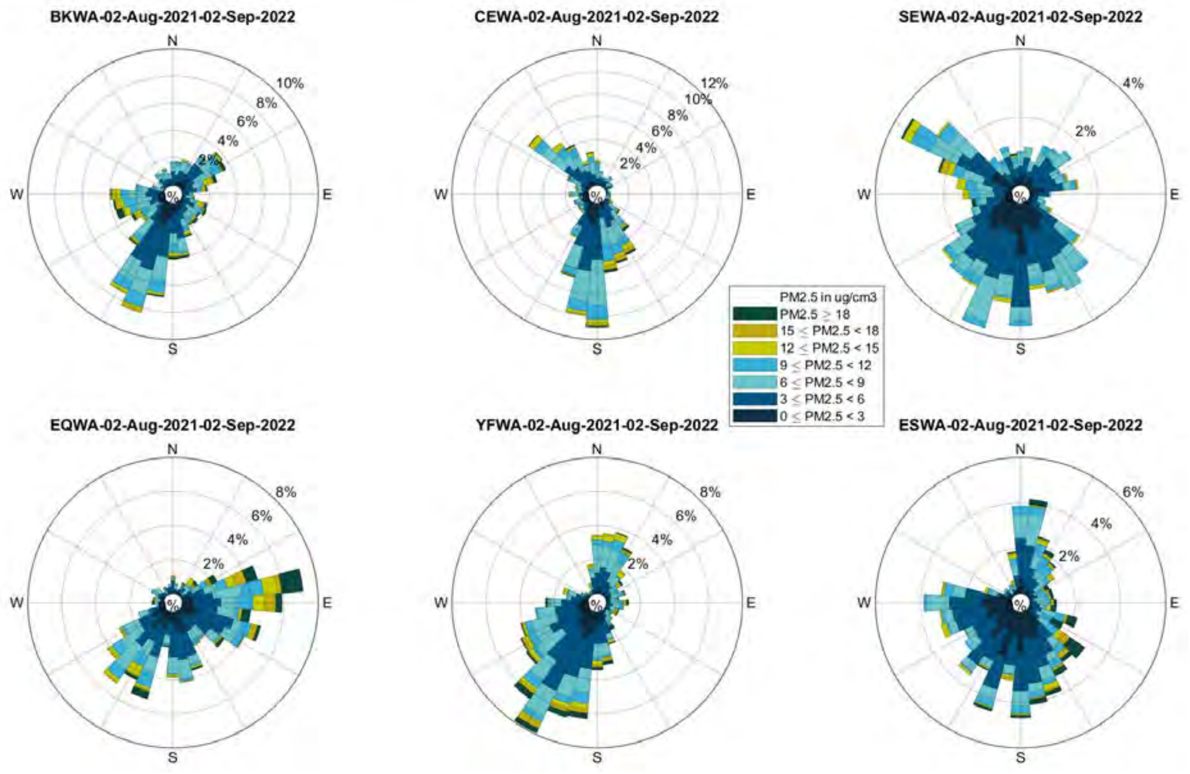


Figure D-5: Daily black carbon (BC) times series (gray dots) at our 6 studied sites with teal colors representing 1-in-6 air-toxics sampling days between August 2021 and September 2022. The green line represents the 1-in-6-day average, and the black line represents the overall average for the entire sampling period. Beacon Hill site (SEWA) does not record continuous black carbon concentrations.

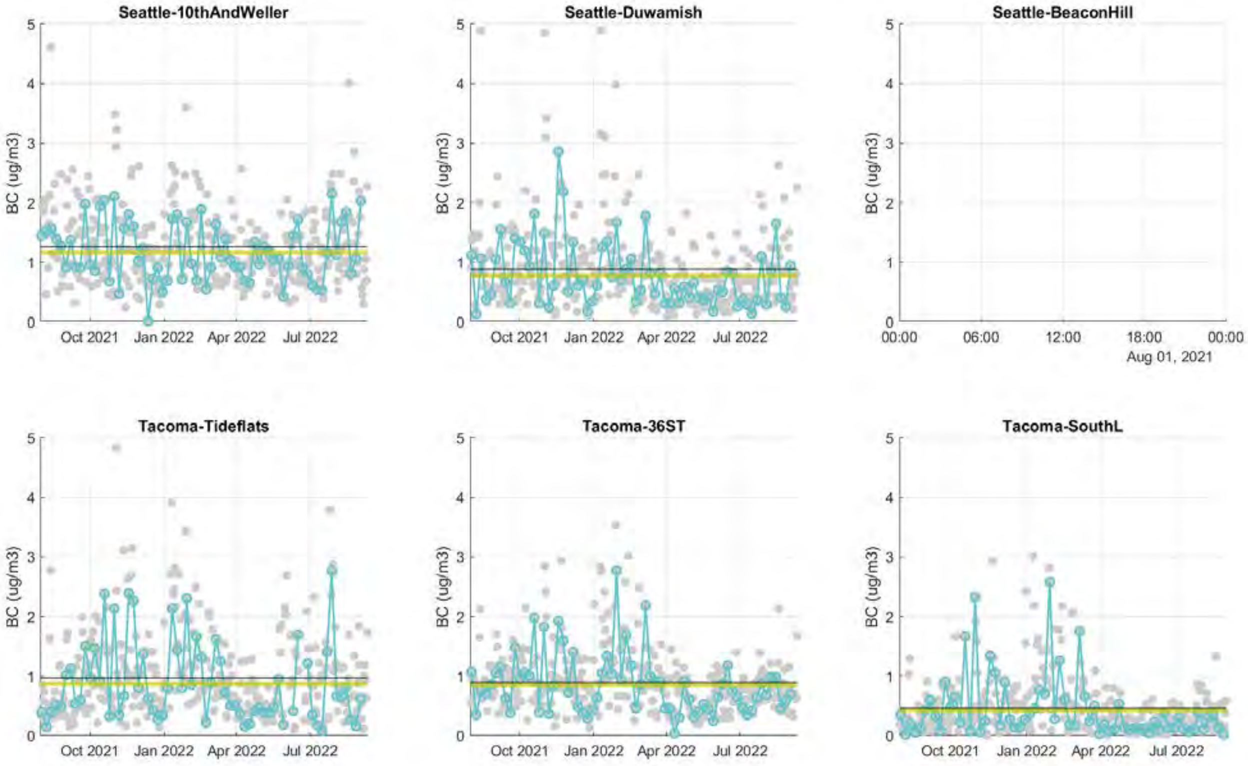


Figure D-6. Corresponding hourly pollution roses (black carbon - BC) coincident with air-toxics sample (1 every 6 days) between August 2021 and September 2022. Beacon Hill site (SEWA) does not record continuous black carbon concentrations.

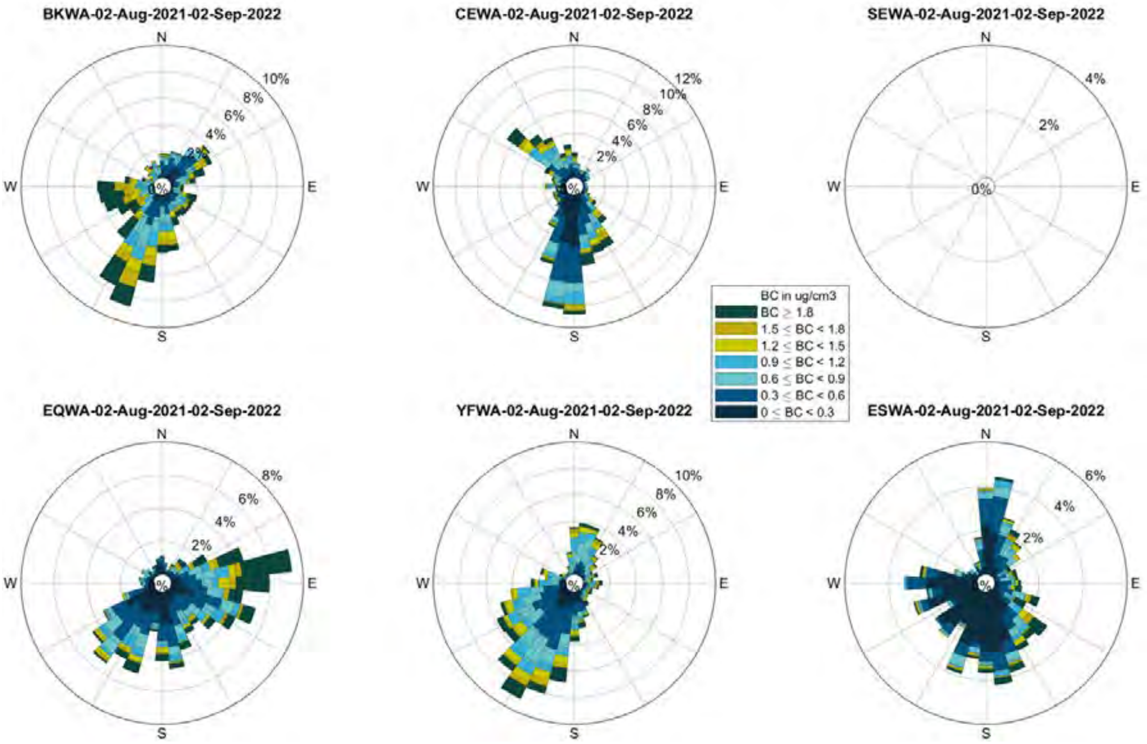


Figure D-7: (A) Map of the wind data collection in the Georgetown and South Park neighborhoods of Seattle. The location codes can be identified as follow: Seattle Duwamish (CEWA) & South Park (SEASPRK) are the two permanent air-quality monitoring sites. South Seattle College (UAWA), South Park Residential (UBWA), Georgetown Residential (UCWA), Georgetown Steam Plant (UDWA) and South Park Industrial (UEWA) are the community-directed temporary sites. Background map is from Google Earth Engine. (B) Comparison of Duwamish and Boeing Field wind roses for the summer of 2022. Note that Boeing Field wind sensor does not resolve wind speeds less than 3.5 mph assigning a value of 0 in both wind direction and speed, which are not included in the wind rose.

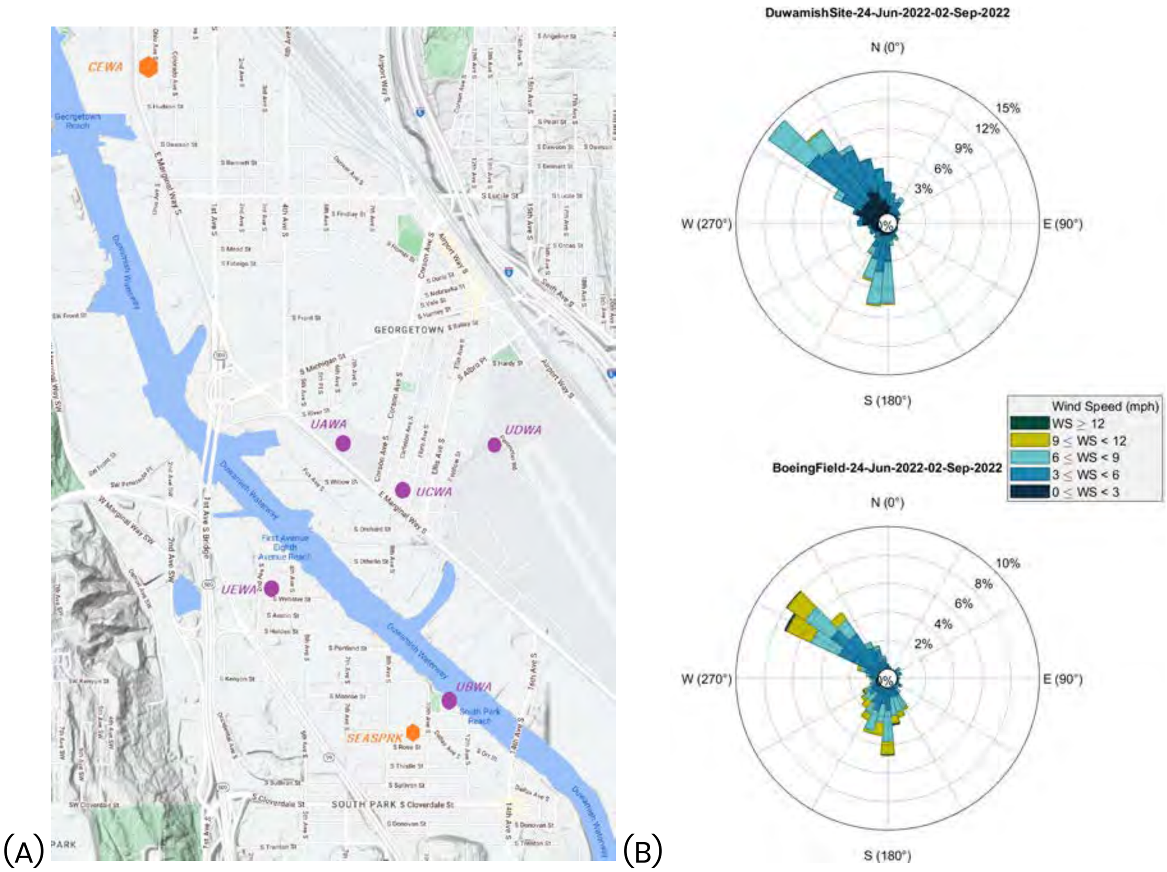


Figure D-8: Weekly evolution of the $PM_{2.5}$ and PM_{10} metals at the community directed samples over the 2022 summer. Week 1: Jun 24th – Jul 1st. $PM_{2.5}$ and wind data are from our Seattle Duwamish regulatory site (CEWA). The blue horizontal bar represents the weekly detection limit in the PM_{10} metal bar plots. The CEWA PM_{10} metals represents a 1-day sample (green shade in time series) while the other sites are 7-day samples.

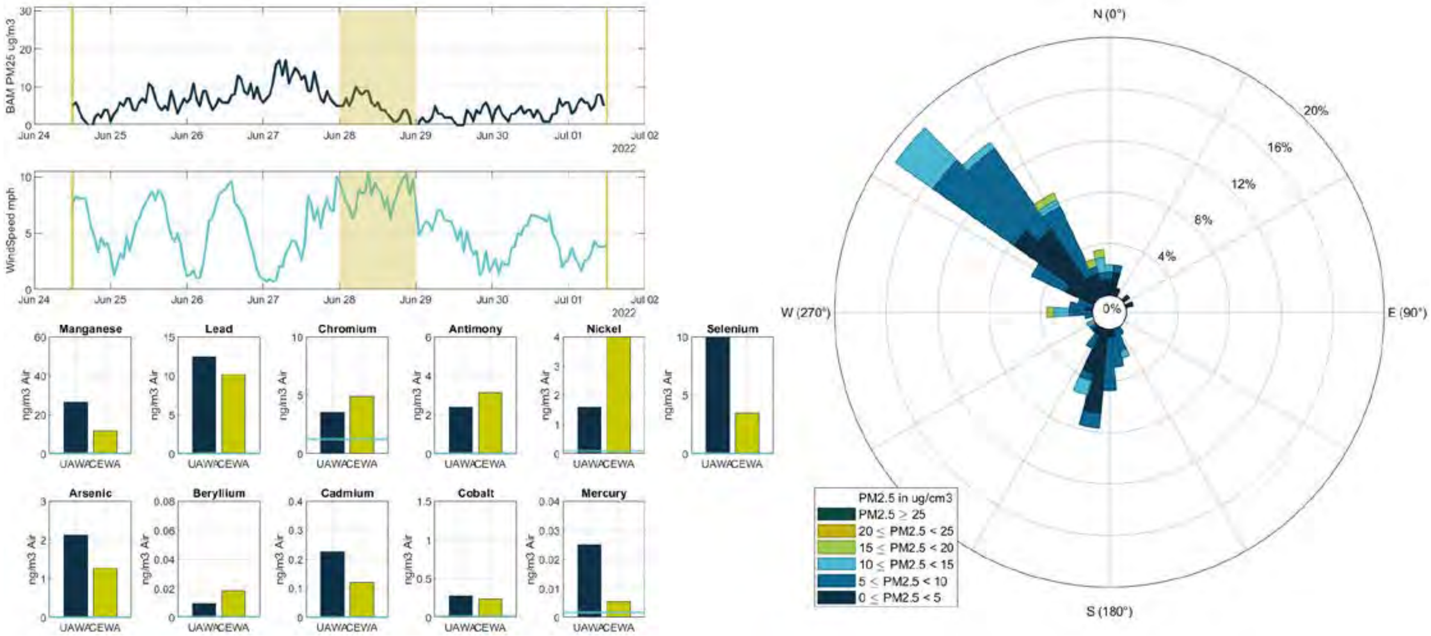


Figure D-9. Weekly evolution of the $PM_{2.5}$ and PM_{10} metals at the community directed samples over the 2022 summer. Week 2: Jul 1st – Jul 8th. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

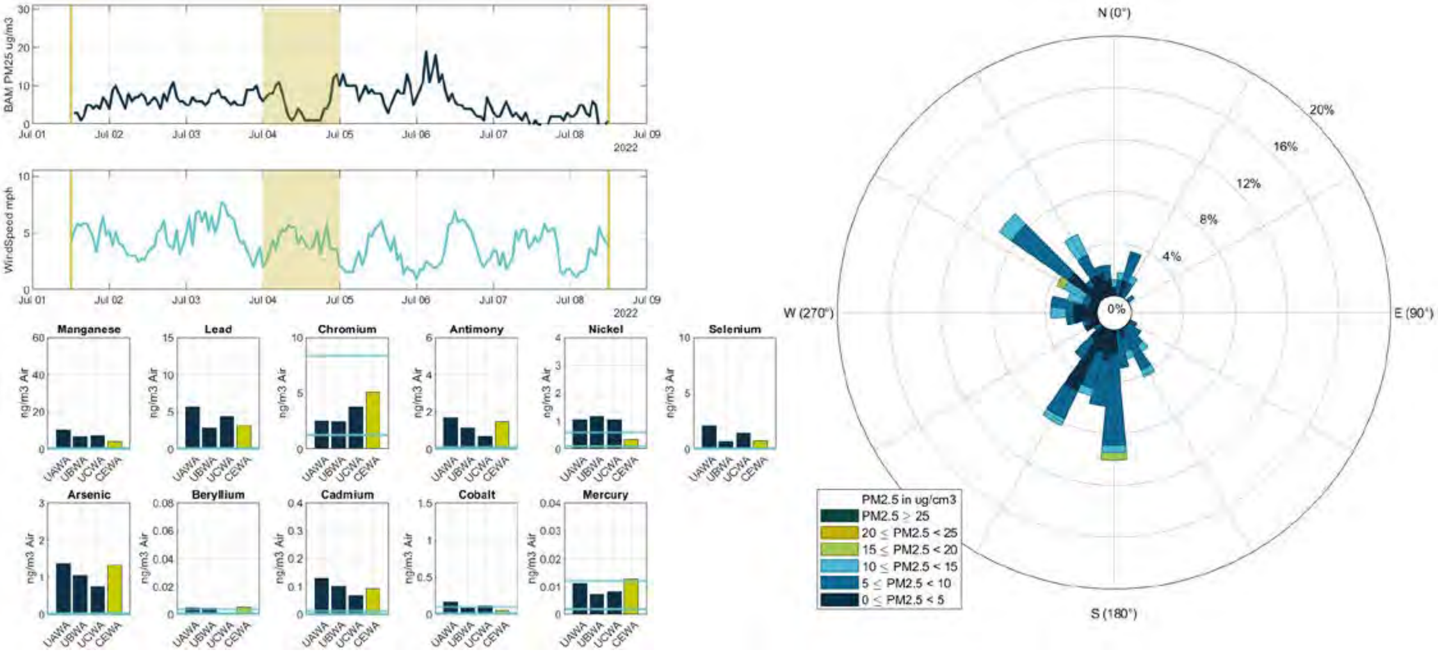


Figure D-10. Weekly evolution of the $PM_{2.5}$ and PM_{10} metals at the community directed samples over the 2022 summer. Week 3: Jul 8th – Jul 15th. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

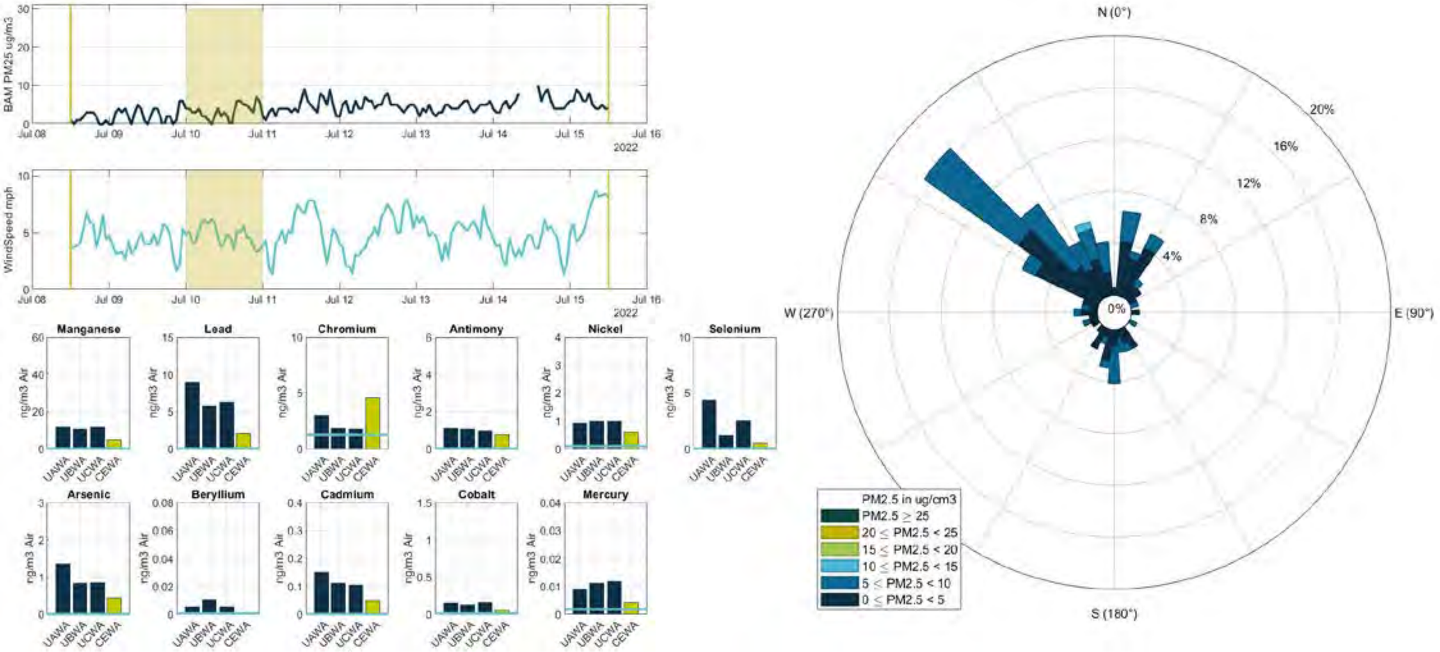


Figure D-11. Weekly evolution of the $PM_{2.5}$ and PM_{10} metals at the community directed samples over the 2022 summer. Week 4: Jul 15th – Jul 22nd. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

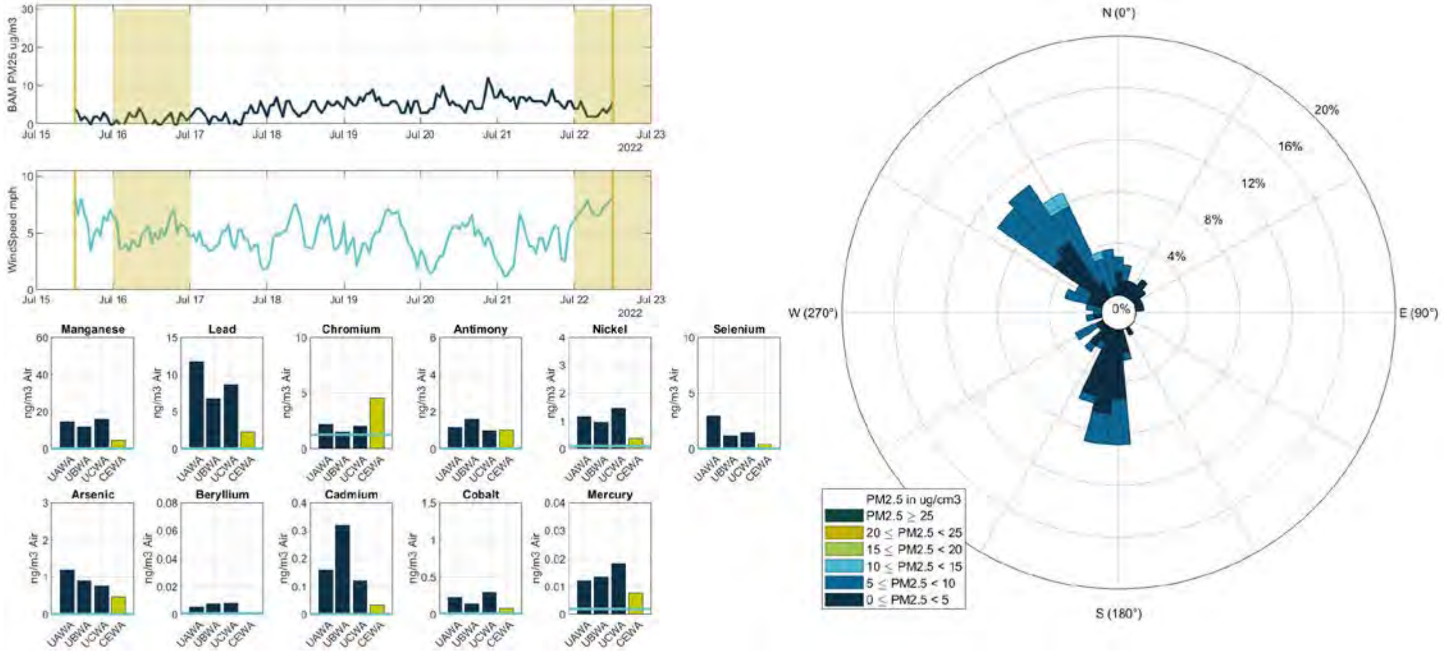


Figure D-12. Weekly evolution of the PM2.5 and PM10 metals at the community directed samples over the 2022 summer. Week 5: Jul 22nd – Jul 29th. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

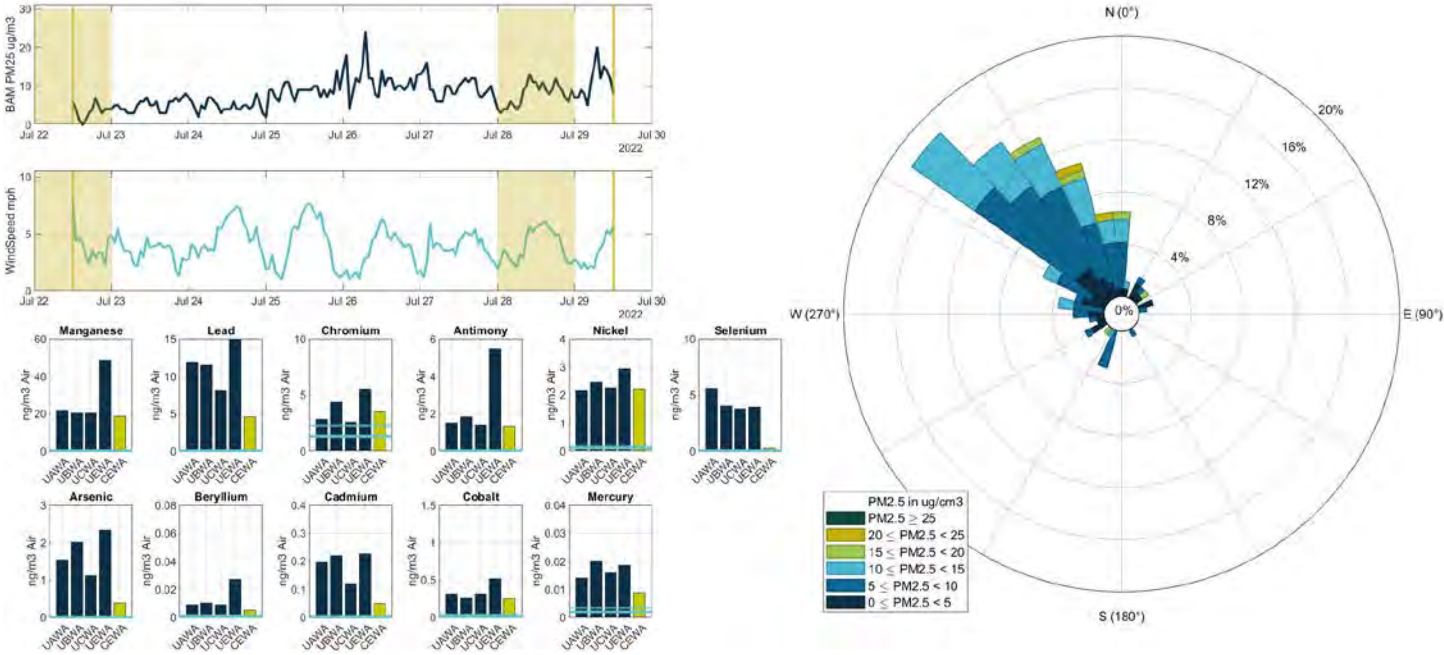


Figure D-13. Weekly evolution of the PM2.5 and PM10 metals at the community directed samples over the 2022 summer. Week 6: Jul 29th – Aug 5th. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

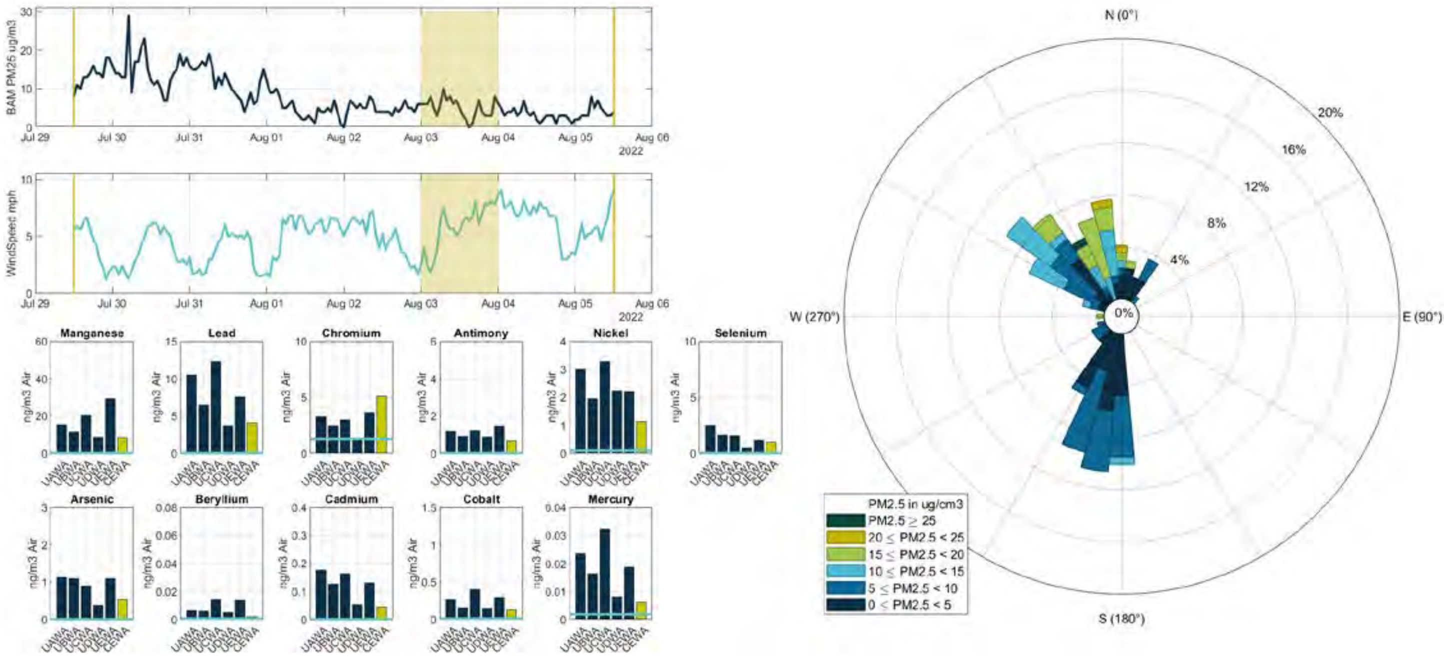


Figure D-14. Weekly evolution of the PM2.5 and PM10 metals at the community directed samples over the 2022 summer. Week 7: Aug 5th – Aug 12th. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

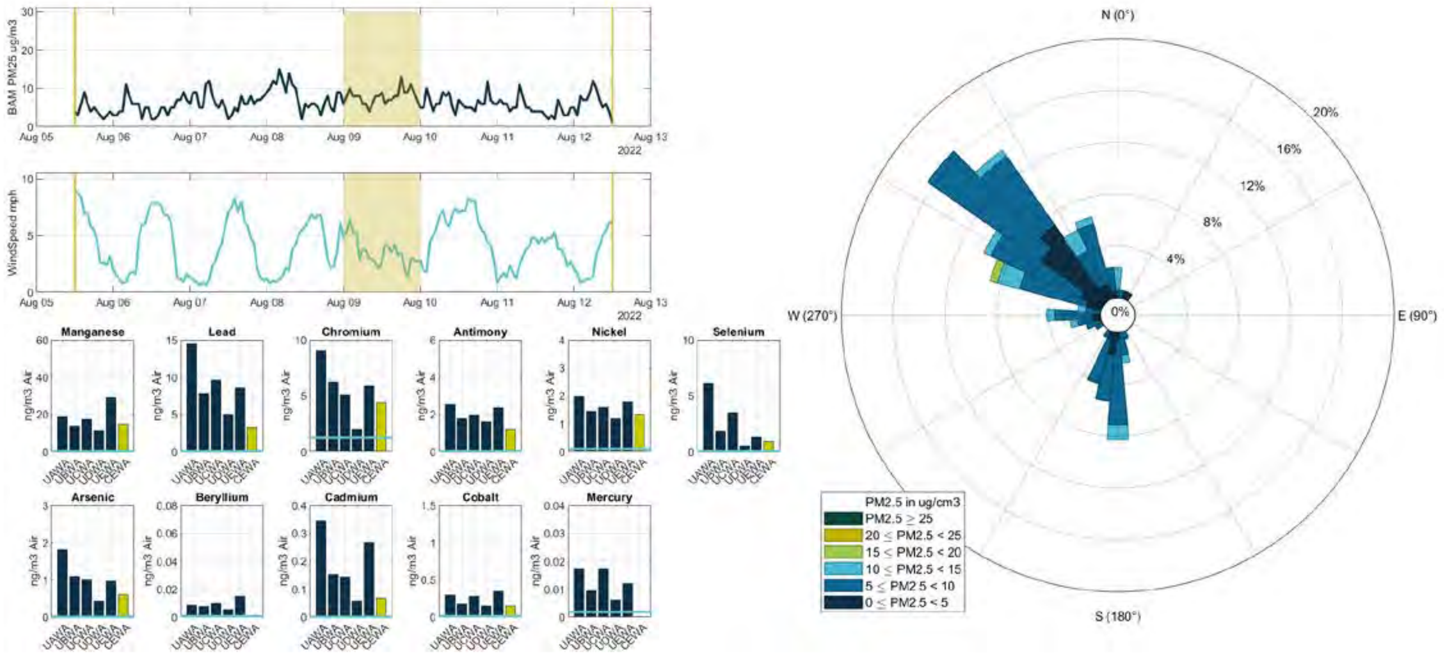


Figure D-15. Weekly evolution of the $PM_{2.5}$ and PM_{10} metals at the community directed samples over the 2022 summer. Week 8: Aug 12th – Aug 19th. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

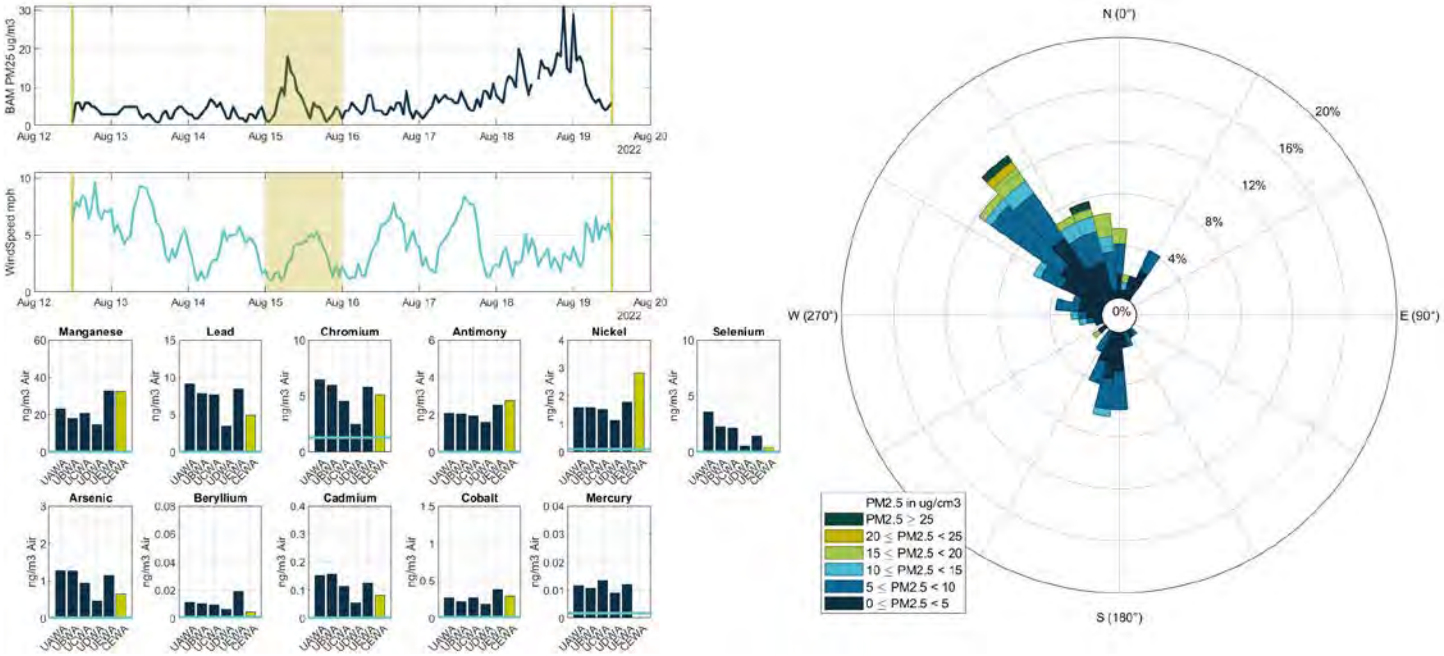


Figure D-16. Weekly evolution of the $PM_{2.5}$ and PM_{10} metals at the community directed samples over the 2022 summer. Week 9: Aug 19th – Aug 26th. See caption of Figure D-8 for more details (colors, shades, bars, etc.).

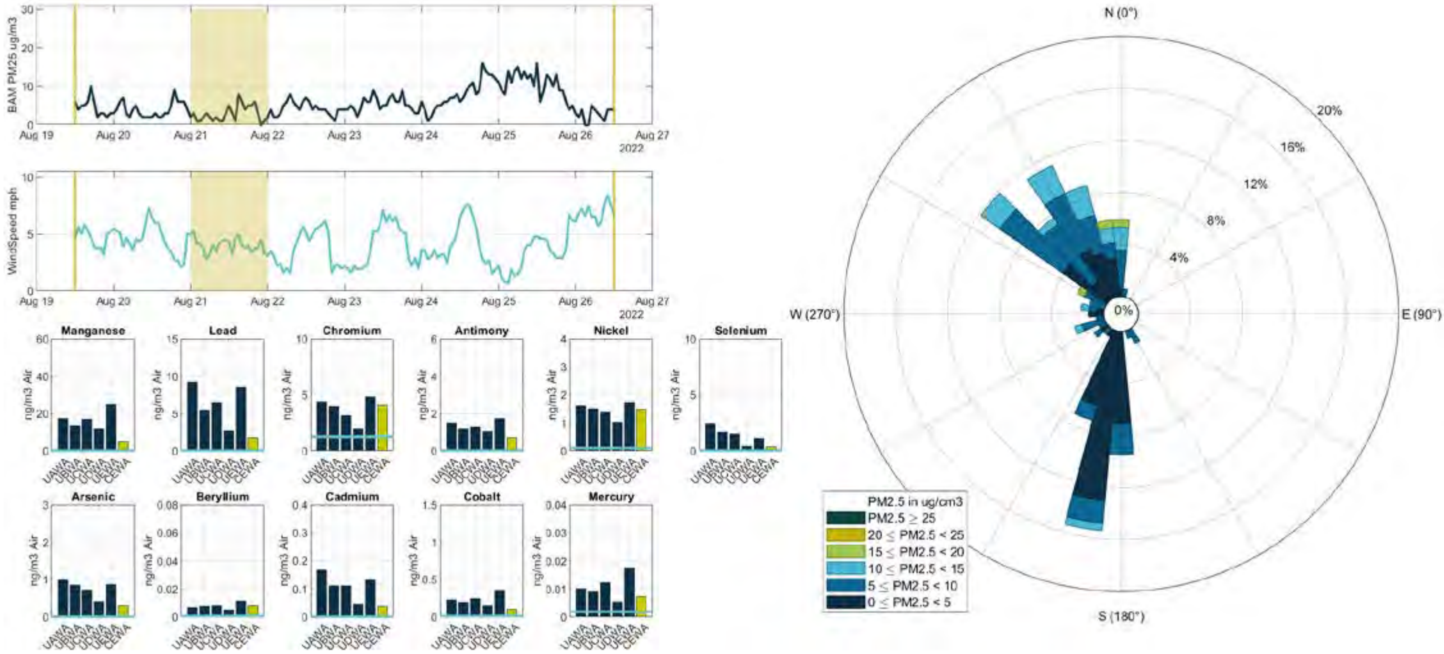
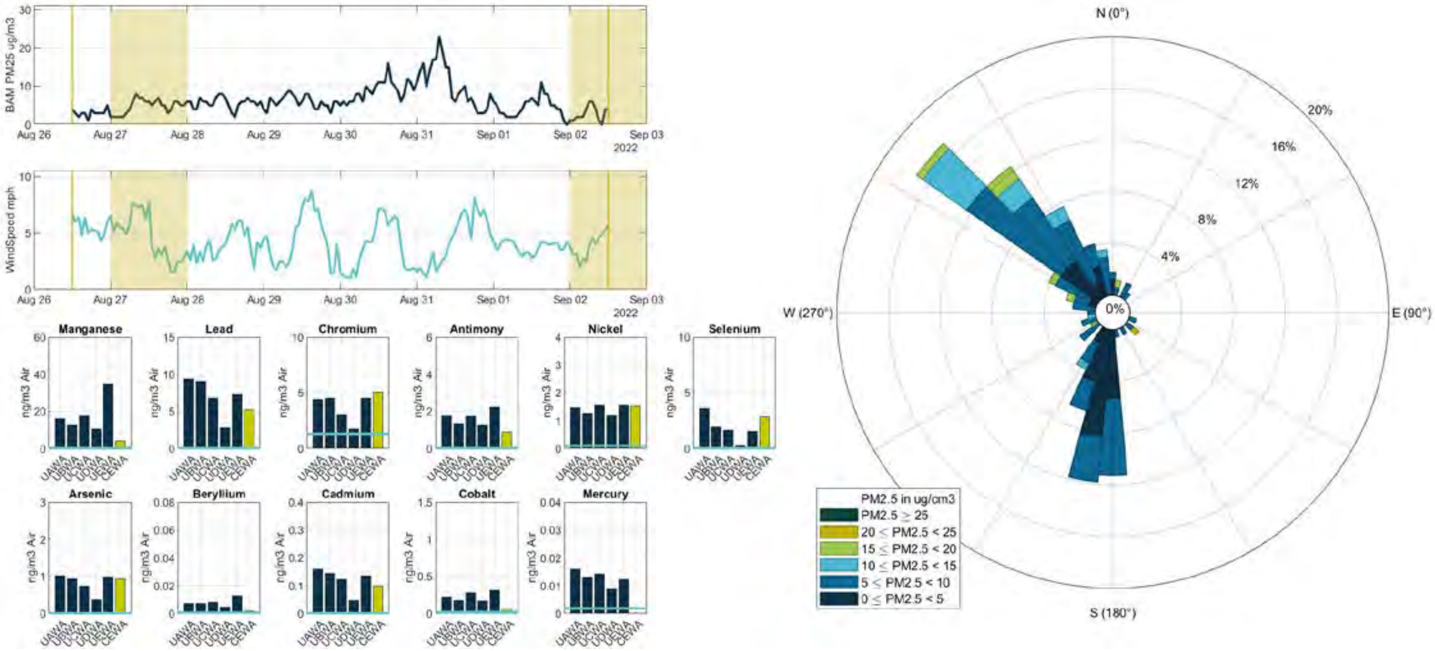


Figure D-17. Weekly evolution of the $PM_{2.5}$ and PM_{10} metals at the community directed samples over the 2022 summer. Week 10: Aug 26th – Sep 2nd. See caption of Figure D-8 for more details (colors, shades, bars, etc.).



Appendix E. Low carbon tetrachloride samples

Table E-1. Percent difference between samples on days with low carbon tetrachloride and study (annual) mean for PSCAA sites.

Pollutant	Percent Difference (%)	Number of Samples
Nickel	66	4
Chromium	16	4
Acrolein	10	19
Antimony	8	4
Benzene	2	19
1,3-Butadiene	0	19
Cobalt	-5	4
Manganese	-7	4
Ethylene oxide	-11	19
Arsenic	-16	4
Ethylbenzene	-21	19
Acetaldehyde	-28	19
Tetrachloroethylene	-31	19
Formaldehyde	-34	18
Cadmium	-38	4
Lead	-44	4
Selenium	-47	4
Beryllium	-56	4
Mercury	-68	4
Carbon tetrachloride	-75	19

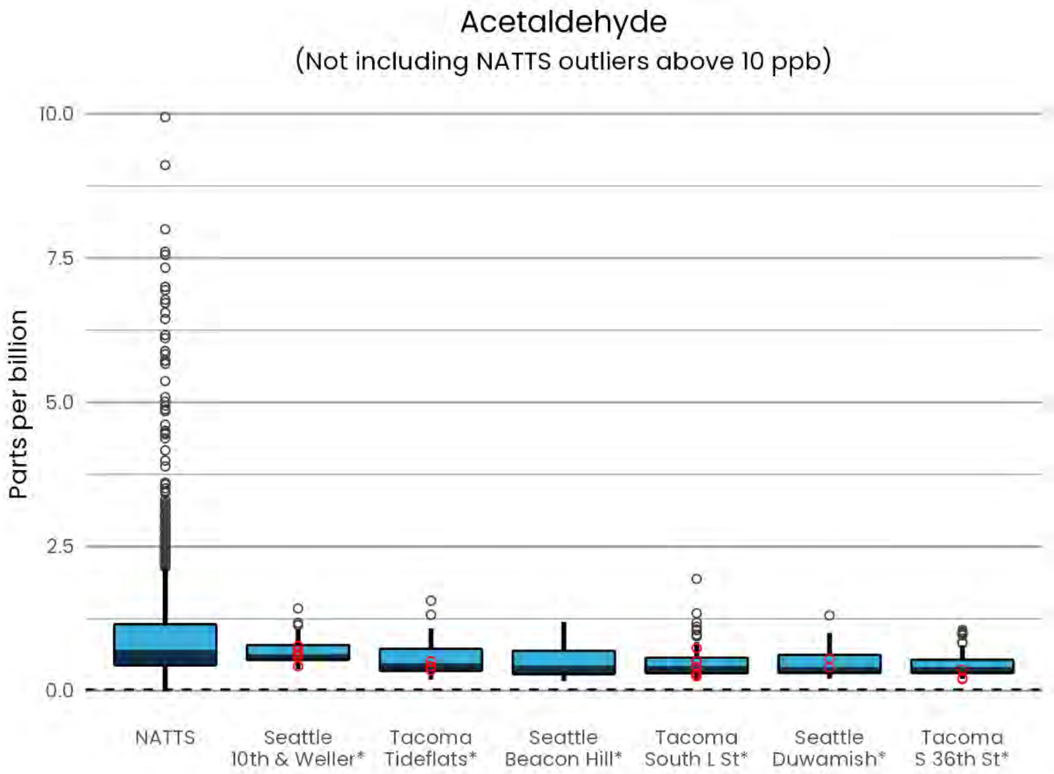
Table E-2. Percent difference between samples on days with low carbon tetrachloride and study (annual) mean for NATTS sites.

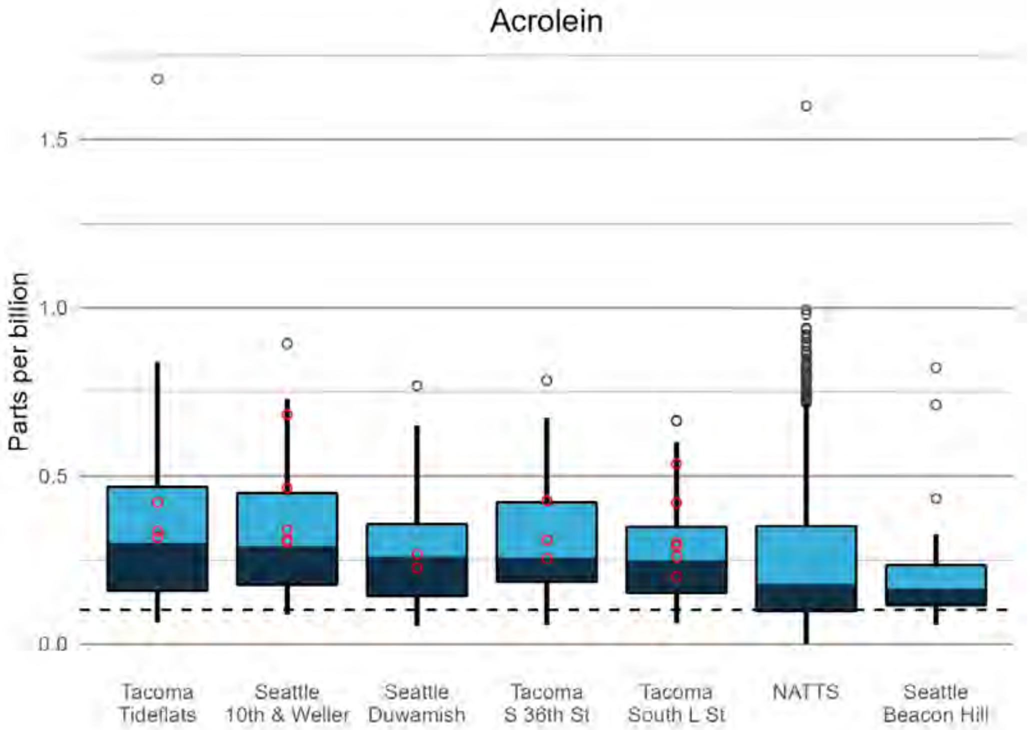
Pollutant	**Percent Difference (%)**	**Number of Samples**
Mercury	5	26
Acrolein	1	87
Acetaldehyde	-5	176
Benzene	-6	178
Chromium	-6	82
Nickel	-8	82
Cadmium	-13	82
Manganese	-13	77
Antimony	-14	28
Lead	-16	49
Arsenic	-20	84
Cobalt	-20	41
Formaldehyde	-20	180
Ethylene oxide	-27	80
Beryllium	-29	78
Ethylbenzene	-35	200
Selenium	-36	40
Tetrachloroethylene	-41	209
Carbon tetrachloride	-54	210
1,3-Butadiene	-81	158

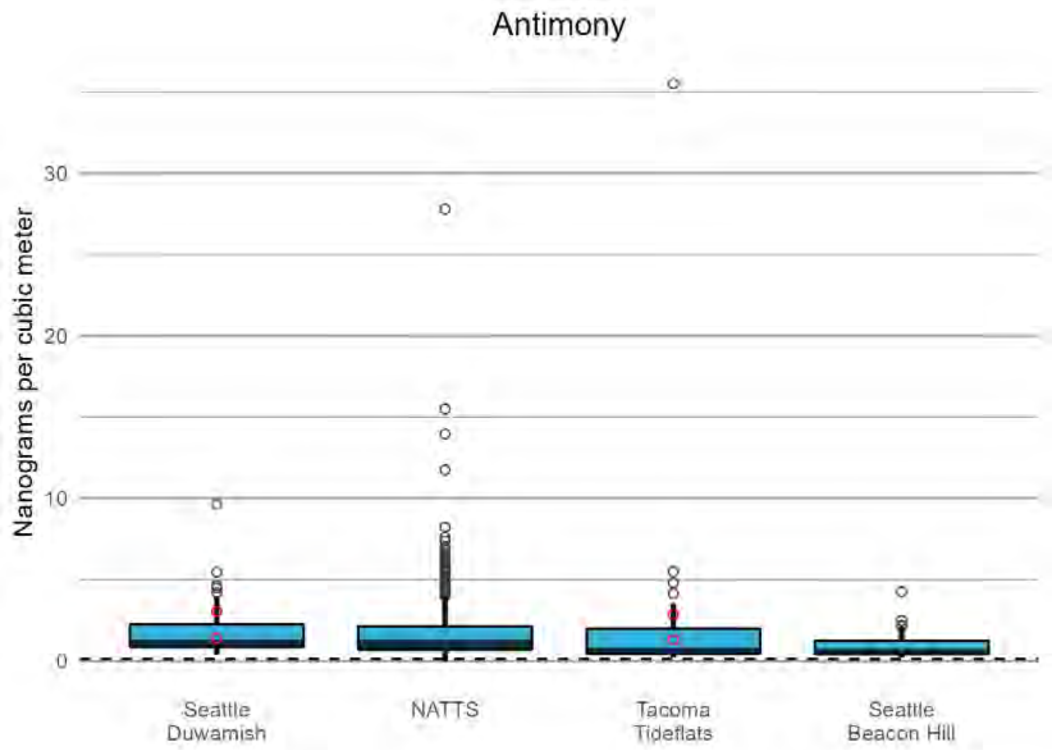
Note: This only includes NATTS data that overlapped with our sampling time.

With the NATTS sites, there are no strong positive associations and one very strong negative association (1,3-Butadiene). Overall, the low carbon tetrachloride samples were 27% lower than the mean for all pollutants.

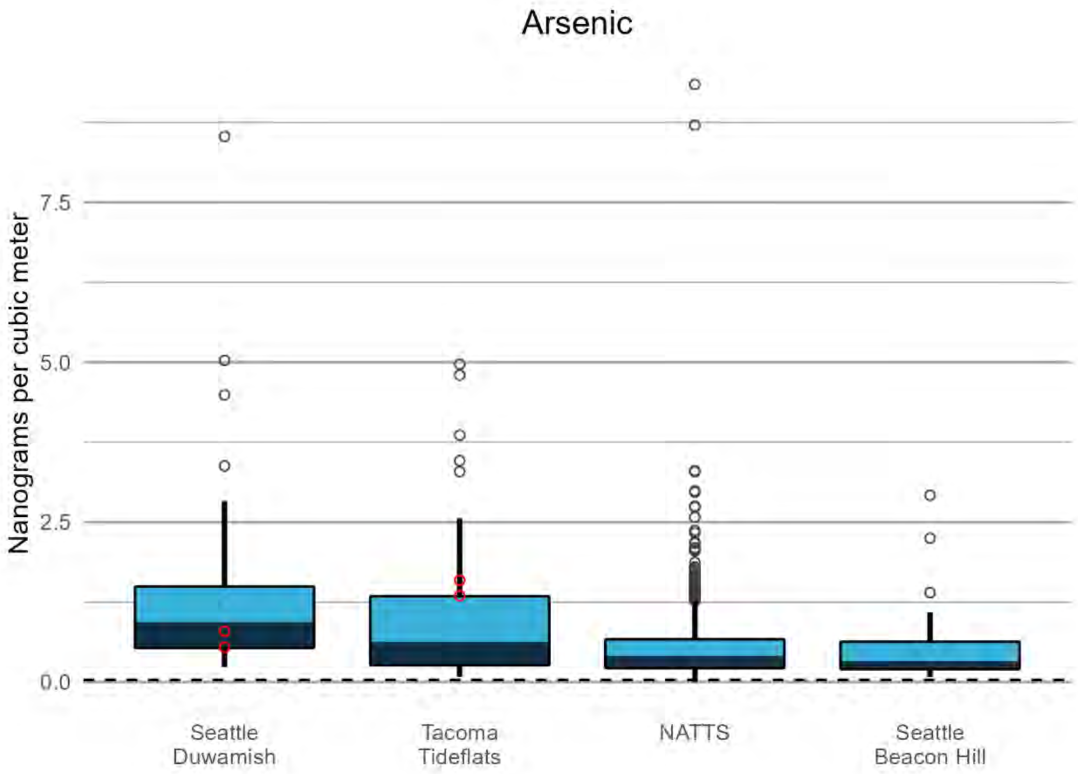
The following are boxplots showing the low carbon tetrachloride samples (in red) compared to the rest of the samples.



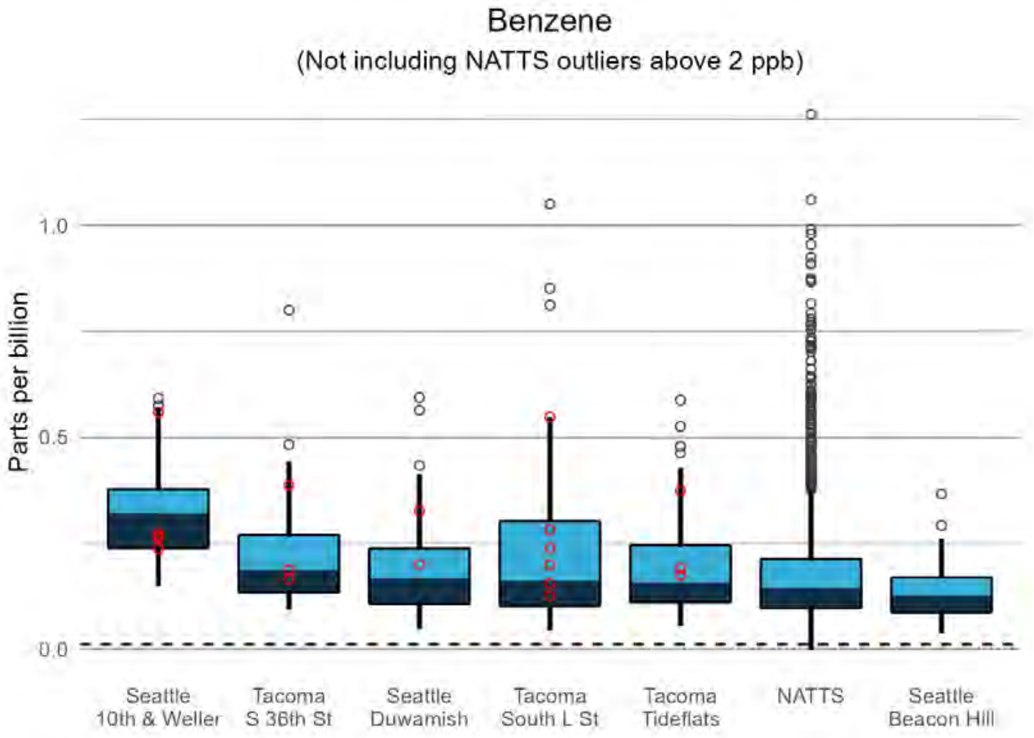


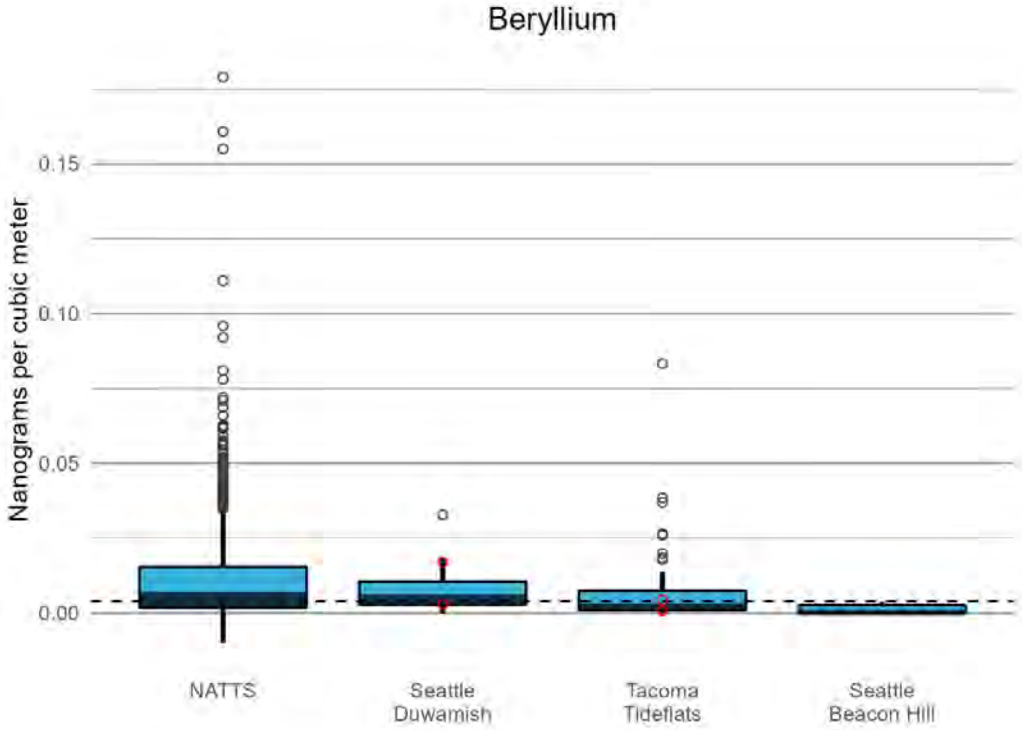


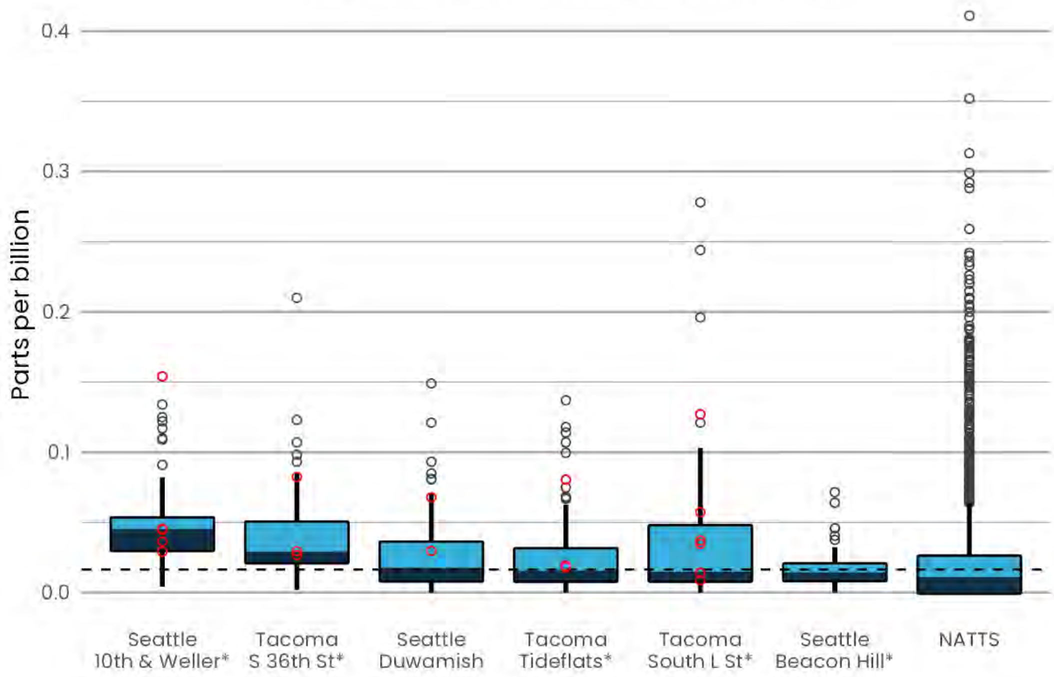
Antimony



Arsenic

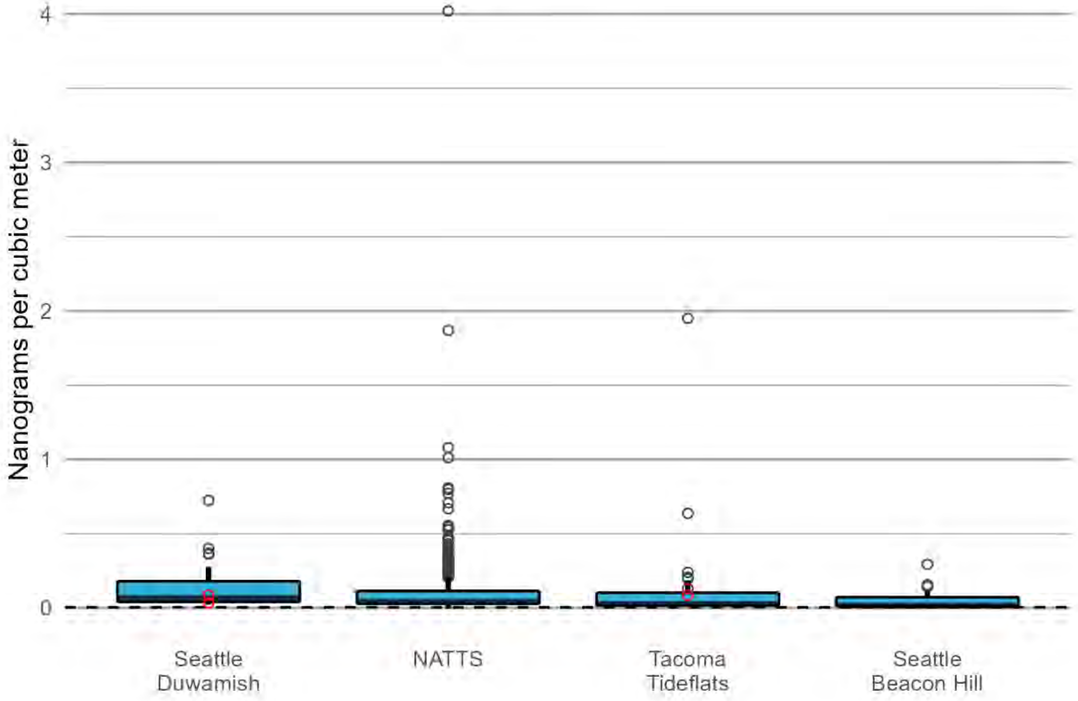

Benzene
(Not including NATTS outliers above 2 ppb)


Beryllium

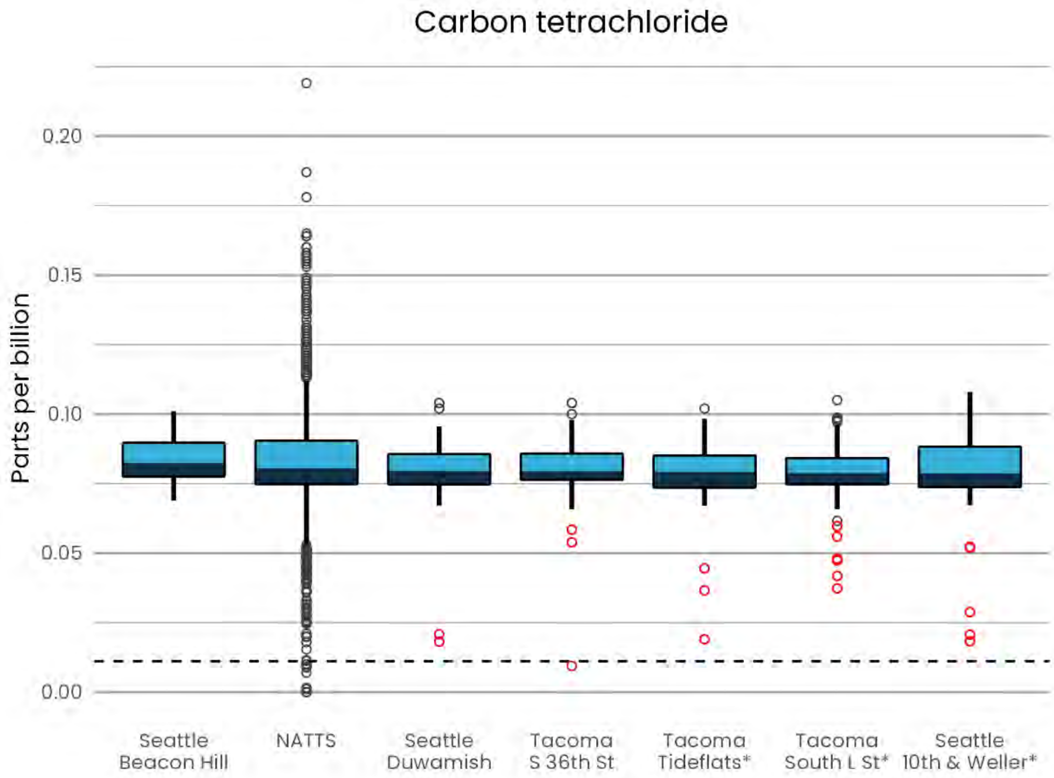


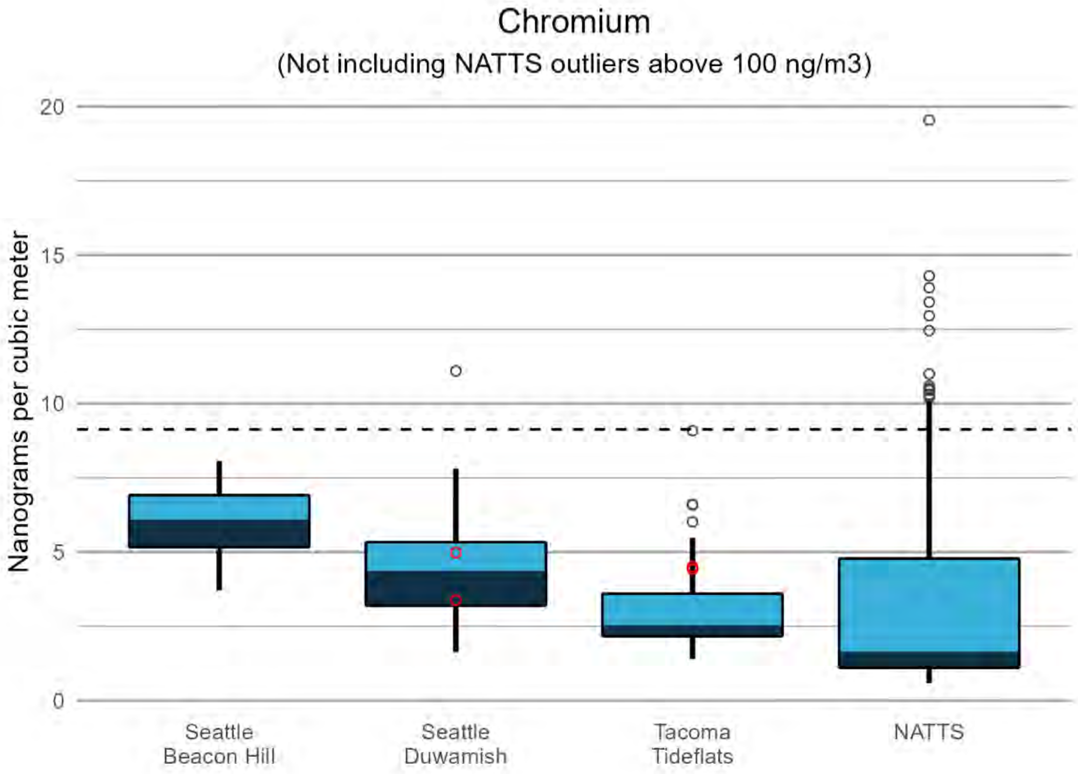
1,3-Butadiene

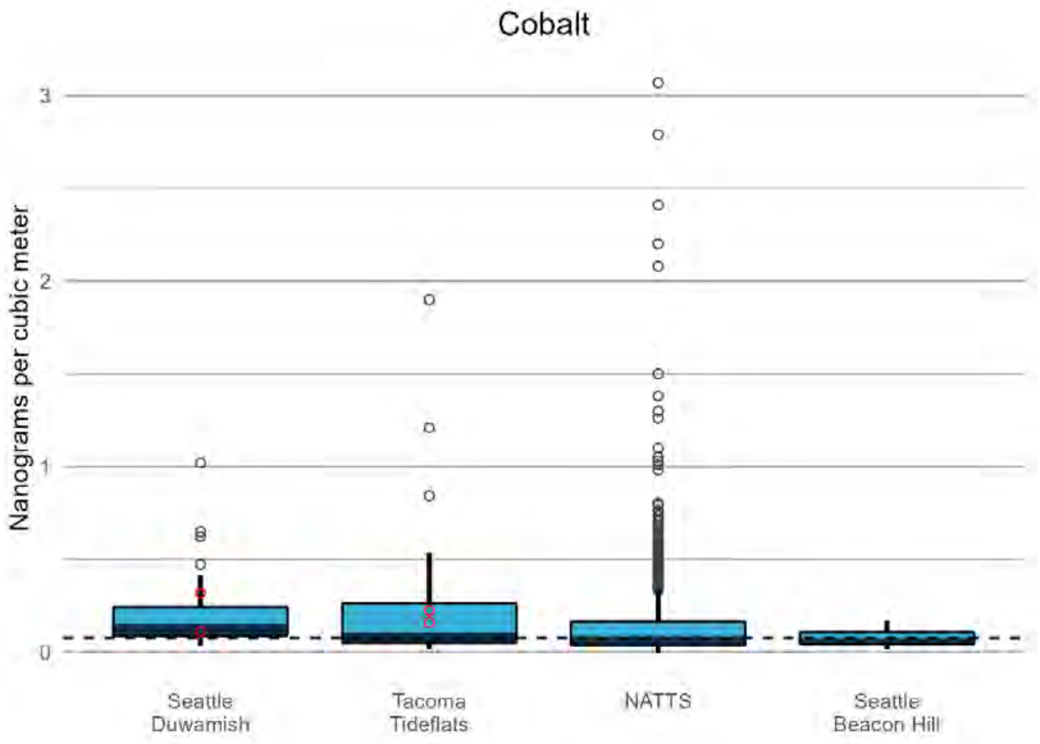
(Not including NATTS outliers above 0.5 ppb)

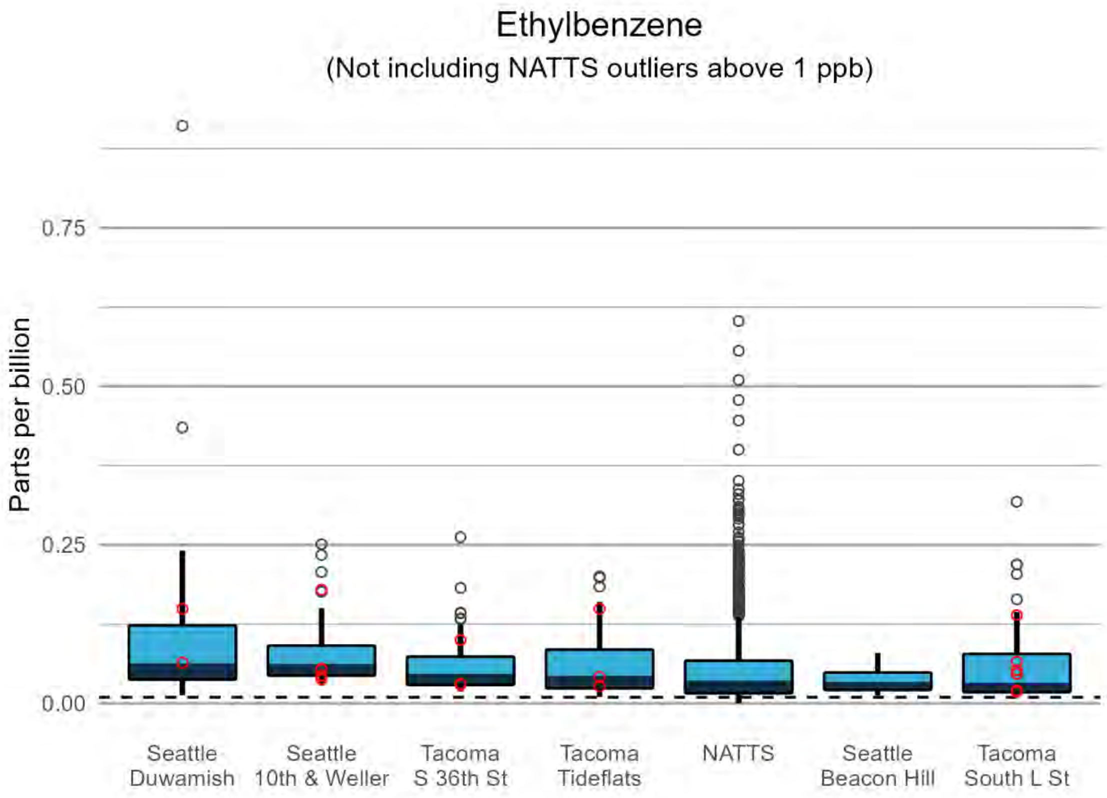


Cadmium

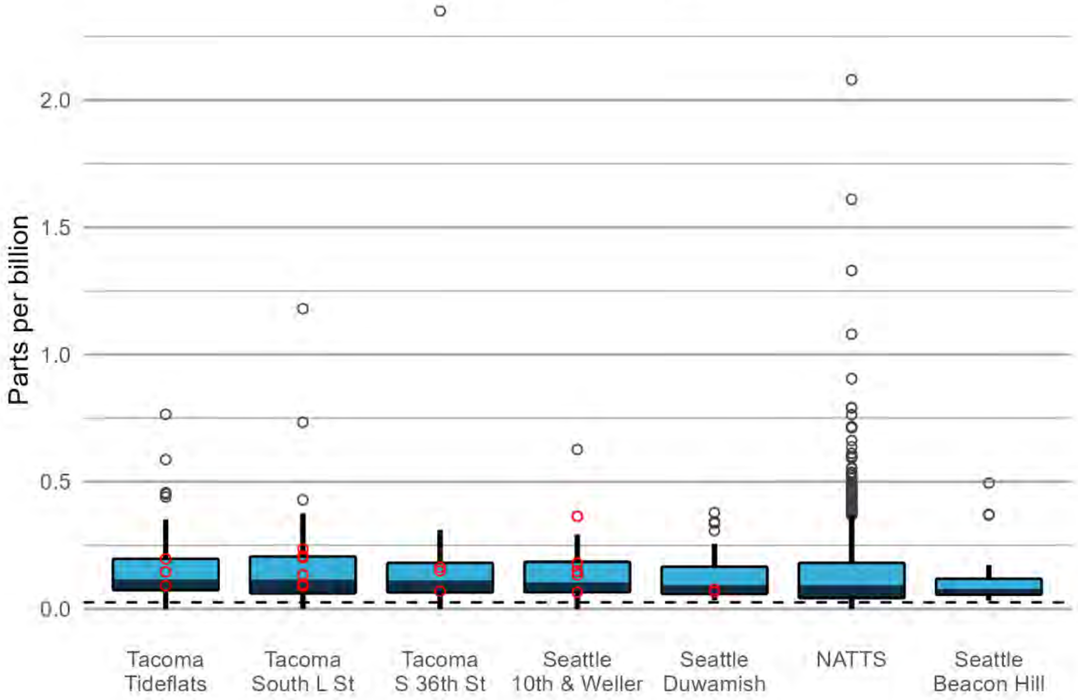

Carbon tetrachloride
Parts per billion
0.20
0.15
0.10
0.05
0.00
Seattle Beacon Hill
NATTS
Seattle Duwamish
Tacoma S 36th St
Tacoma Tideflats*
Tacoma South L St*
Seattle 10th & Weller*


Chromium
(Not including NATTS outliers above 100 ng/m3)
Nanograms per cubic meter
20
15
10
5
0
Seattle Beacon Hill
Seattle Duwamish
Tacoma Tideflats
NATTS


Cobalt
Nanograms per cubic meter
3
2
1
0
Seattle Duwamish
Tacoma Tideflats
NATTS
Seattle Beacon Hill

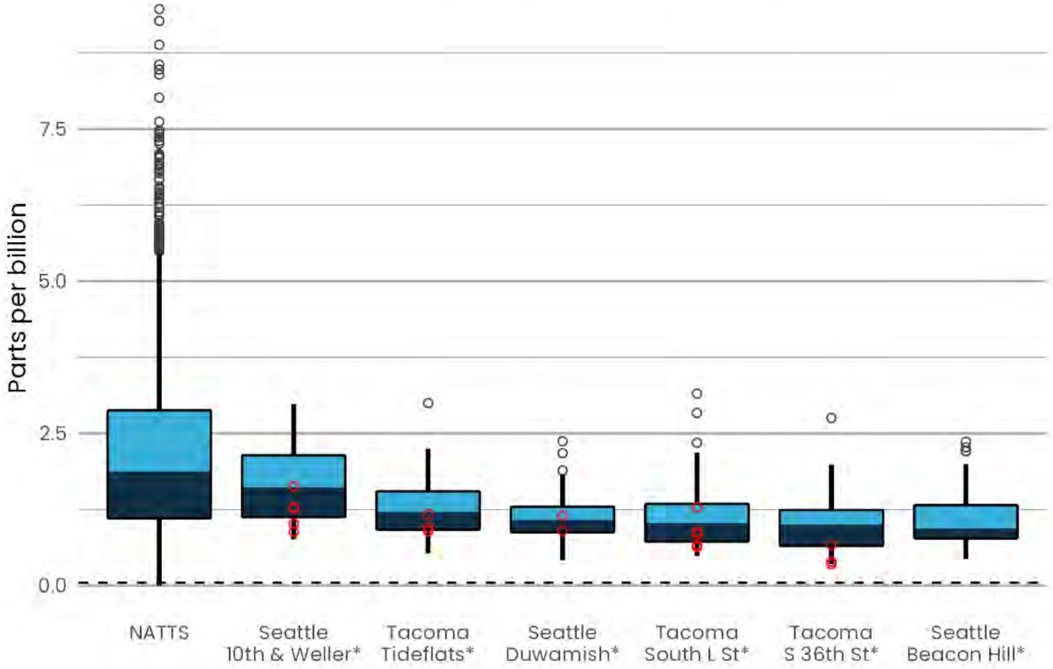

Ethylbenzene
(Not including NATTS outliers above 1 ppb)
Parts per billion
0.75
0.50
0.25
0.00
Seattle Duwamish
Seattle 10th & Weller
Tacoma S 36th St
Tacoma Tideflats
NATTS
Seattle Beacon Hill
Tacoma South L St

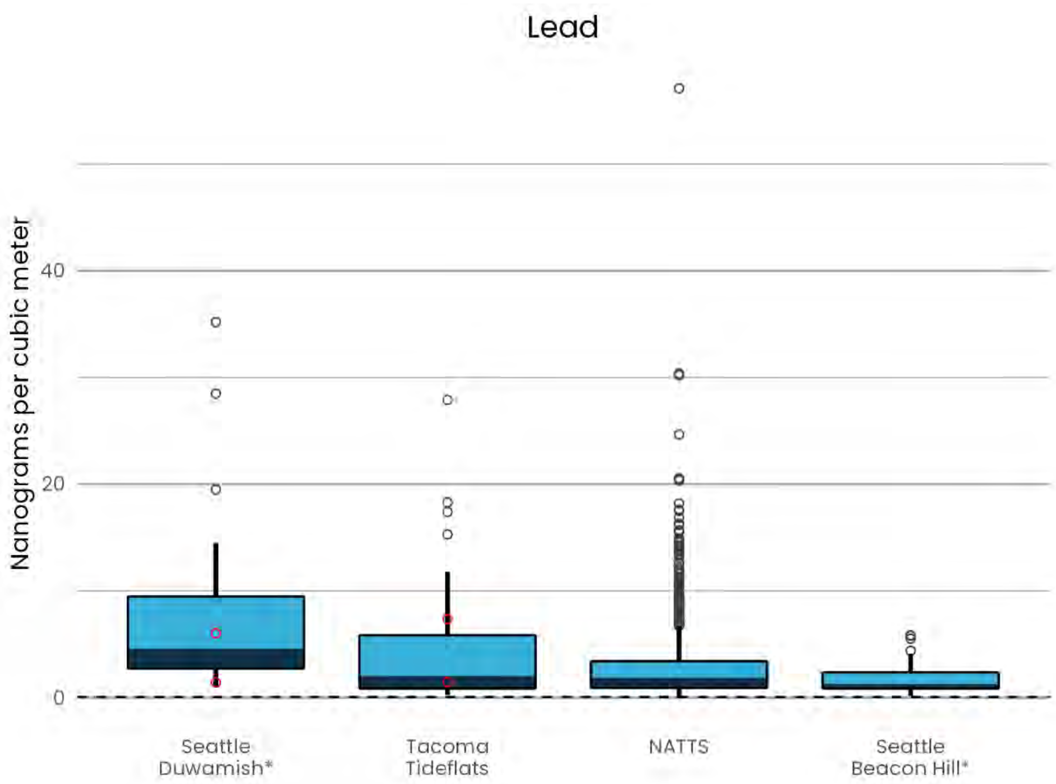
Ethylene oxide

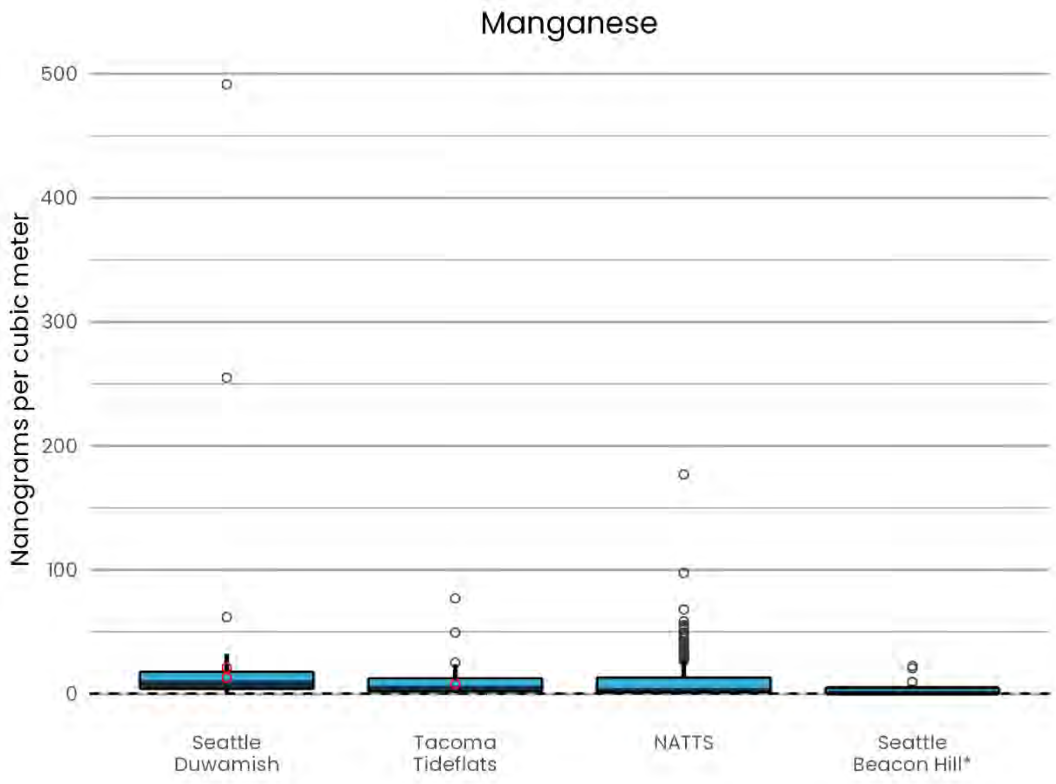


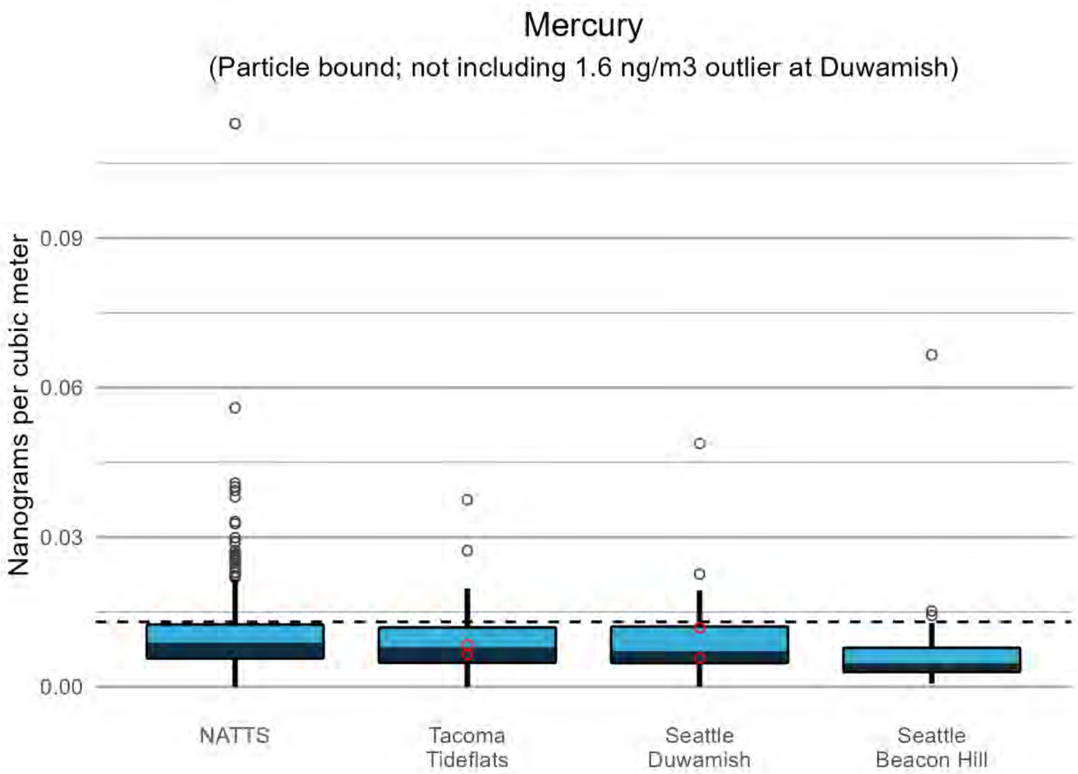
Formaldehyde

(Not including NATTS outliers above 10 ppb)

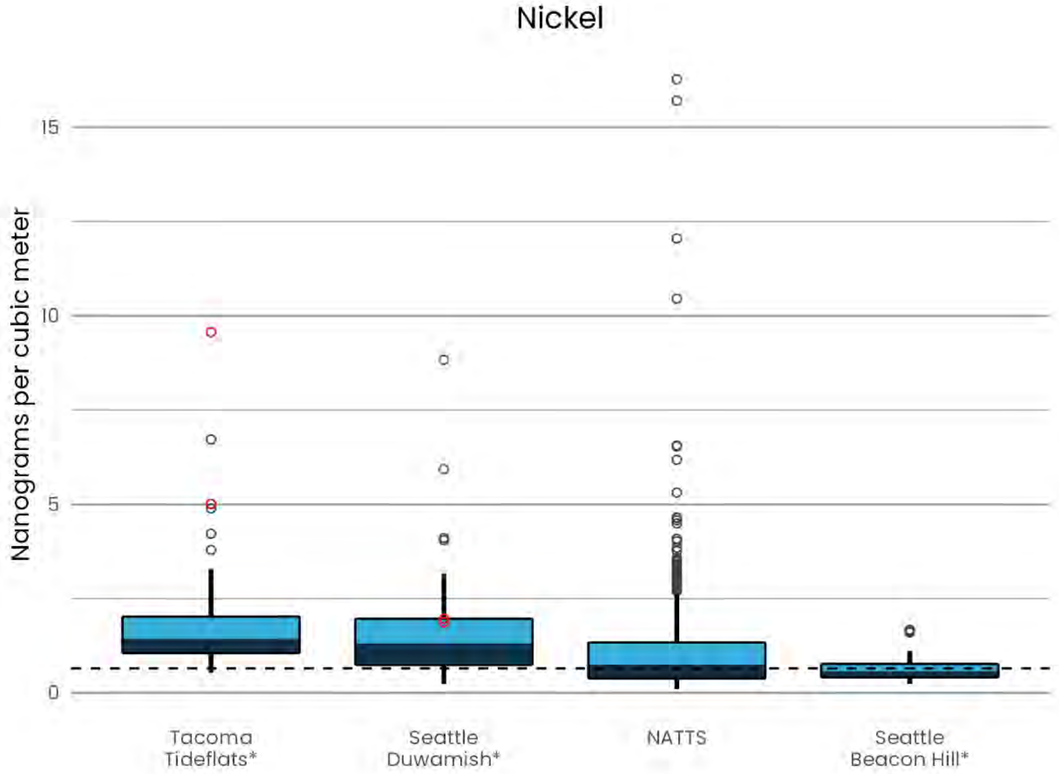


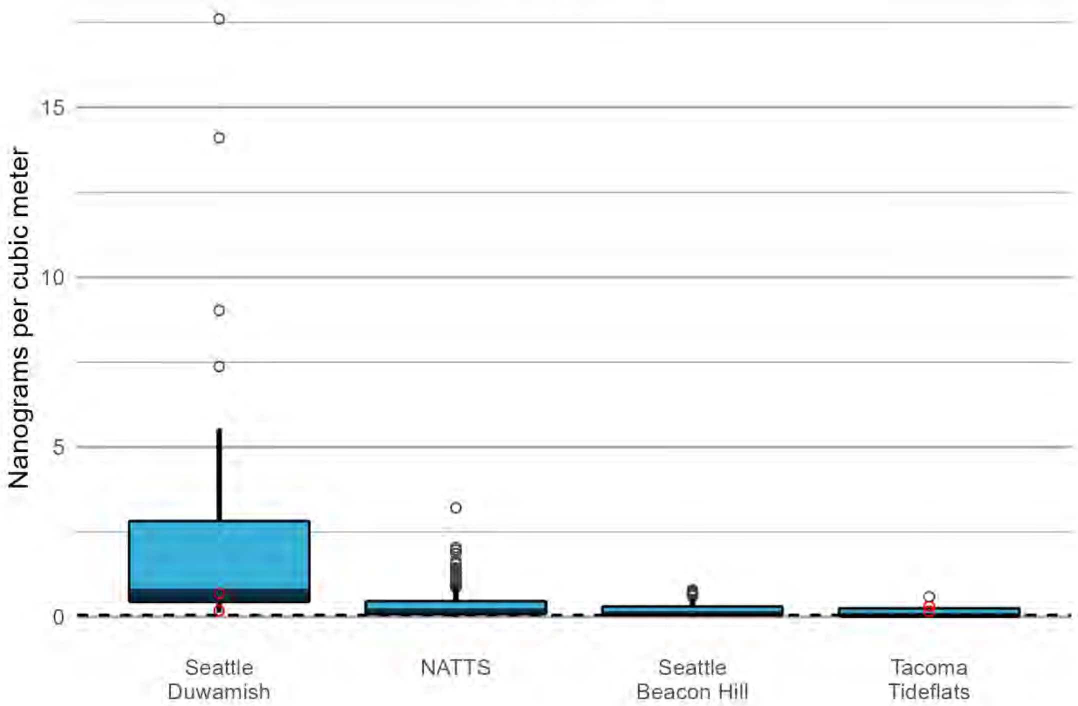

Lead
Nanograms per cubic meter
40
20
0
Seattle Duwamish*
Tacoma Tideflats
NATTS
Seattle Beacon Hill*


Manganese
Nanograms per cubic meter
500
400
300
200
100
0
Seattle Duwamish
Tacoma Tideflats
NATTS
Seattle Beacon Hill*

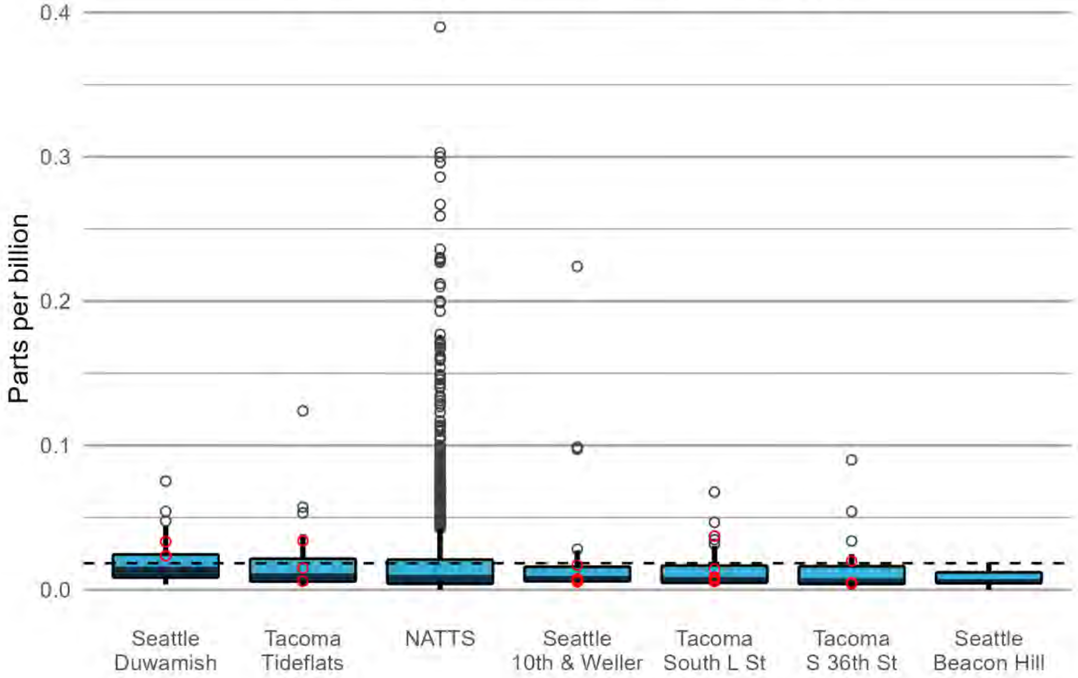

Mercury

(Particle bound; not including 1.6 ng/m3 outlier at Duwamish)


Nickel



Selenium

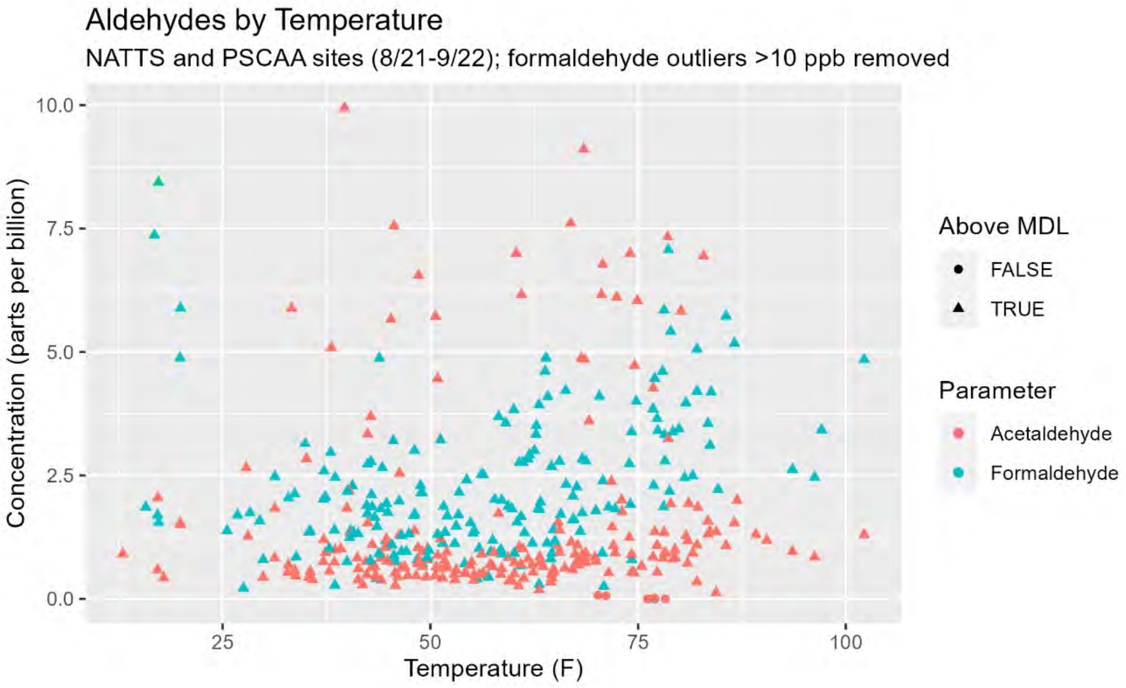


Tetrachloroethylene

(Not including NATTS outliers above 0.5 ppb)

Appendix F. The effect of temperature on aldehydes

Figure F- 1. Aldehydes by Temperature



This graph shows acetaldehyde (pink) and formaldehyde (blue) versus temperature. Data points that are above the minimum detection limit are triangles and those lower than the MDL are circles. This graph combines NATTS sites and PSCAA sites and shows data from August 2021 through September 2022. Formaldehyde concentrations above 10 ppb were removed. These all occurred at one NATTS site that is next to a water plant. Generally, aldehyde concentrations are modestly higher at higher temperatures.

Appendix G. Comparison of Purple Air data to NFRMs

In this Appendix, we present both Purple Air data and ARA N-FRM (Near-Federal-Reference-Method) RTP (Real-Time Particle profiler) sensor data (Figure G-1). Both air sensors use Plantower© light-scattering sensors (one for ARA-NFRM and two for Purple Air) to provide real-time data for two size ranges approximating PM_{10} and $PM_{2.5}$. While the PM_{10} data from the air sensors remain unfortunately inaccurate (see AQMD – AQ-SPEC field evaluation) and are not used in this study, the continuous $PM_{2.5}$ air sensor data, once its concentrations are adjusted using a reference monitor, shows relatively accurate trends. Overall, these Plantower sensors are low-cost compared to research-grade instruments, and their main intend is to show trends during the weekly sample runs, supplementing the PM_{10} metals filter data by providing higher temporal resolution.

Figure G-1: illustration of the N-FRM installation at our UEWA (Fontanelle St.) site, with Purple Air sensor added to the setup(left). The other two photos (borrowed from Purple Air© and ARA instruments© websites), provide a more detailed look at the N-FRM RTP (upper right) and Purple Air sensor (lower right).

Air sensor data adjustment process:

The N-FRM RTP sensor logs $PM_{2.5}$ concentrations at 5-min interval, while the Purple Air logs at 2-min interval. Both sensor data are averaged hourly. The Purple Air raw (PA_{cf_1}) $PM_{2.5}$ concentrations are adjusted using the following EPA's 2021 Purple Air correction equation: $PM_{2.5} = 0.52 \times PA_{cf\_1} - 0.086 \times RH + 5.75$ (Barkjohn et al., 2021).

During the study, we collocate an N-FRM RTP sensor with a Purple Air sensor at South Seattle College – Georgetown campus (Figure G-2) and at our Seattle Duwamish permanent monitor (Figure G-3), where we also have a BAM 1020 (Beta Attenuation Monitor) providing our most accurate PM2.5 concentrations.

Figure G-21. South Seattle College – Georgetown campus (UAWA) N-FRM RTP and Purple Air collocation. Both Purple Air channels have been adjusted using EPA's U.S. wide 2021 correction equation (Barkjohn et al., 2021).

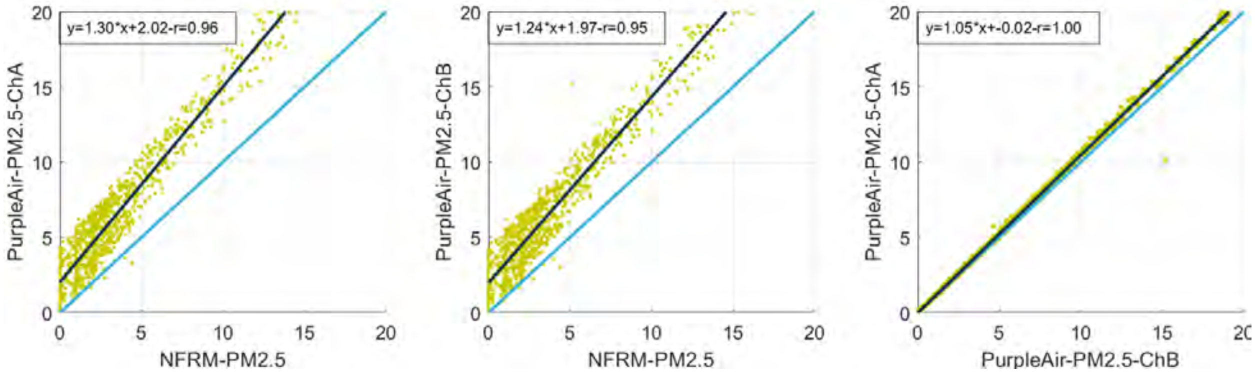
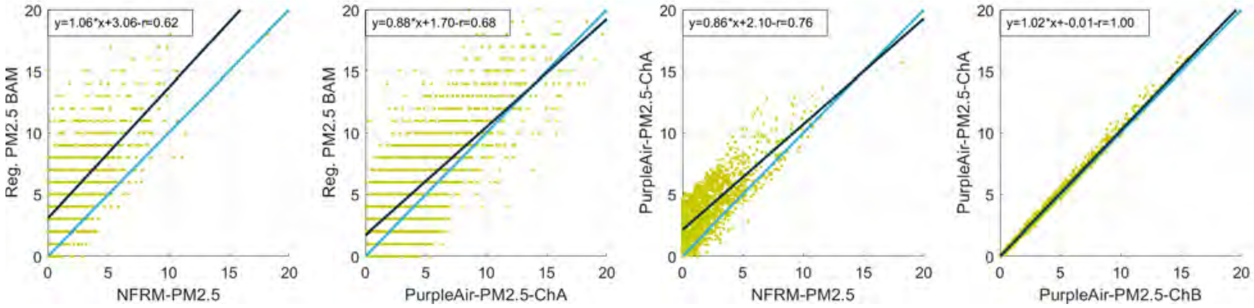


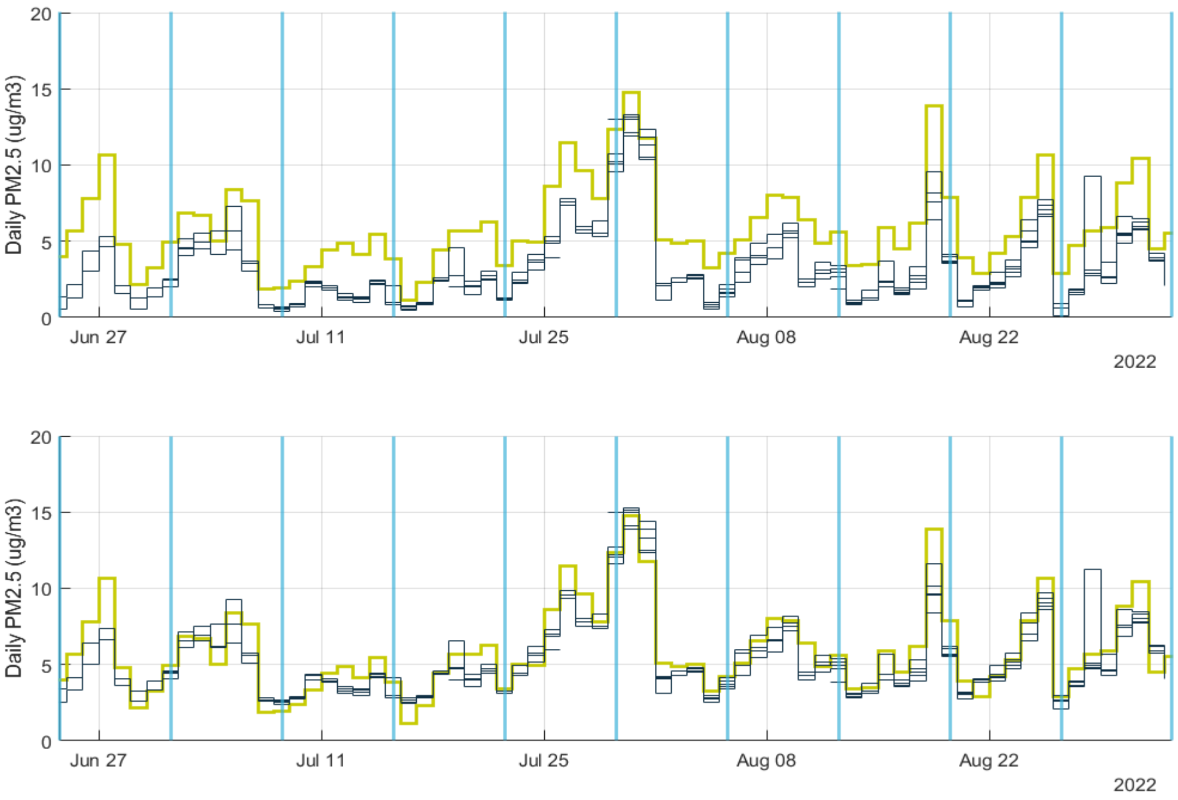
Figure G-3. Seattle Duwamish regulatory site (CEWA) BAM $PM_{2.5}$, N-FRM RTP and Purple Air collocation. Both Purple Air channels have been adjusted using EPA's U.S. wide 2021 correction equation (Barkjohn et al., 2021).



An initial data adjustment was made for the Fontanelle St. (UEWA) site where the N-FRM RTP sensor did not work; and we installed a Purple Air to estimate the N-FRM RTP PM2.5 concentrations. We obtained an ordinary least square regression equation from the collocation between the Purple Air sensor and the N-FRM RTP at South Seattle College – Georgetown campus (UAWA), which showed a strong correlation coefficient of R=0.96 (Figure G-3). The equation: $\textit{N-FRM RTP PM2.5}_{estimate} = \textit{Purple Air PM2.5}_{EPAadjusted} / 1.3 - 2$; was then used to estimate the PM2.5 concentrations.

After comparing the BAM PM$_{2.5}$ data at our Duwamish site with the different N-FRM RTP PM$_{2.5}$ time series, we notice that adding 2 μg/m^3 to the entire N-FRM RPT dataset provided a sufficient adjustment at the different sites and showed overall agreement with the BAM PM2.5 time series (Figure G-4).

Figure G-4. Illustration of the N-FRM RTP overall data adjustment before adding 2 µg/m^3 (top plot) and after (bottom plot) for the daily PM2.5 averages. The green time series represents the Duwamish BAM PM$_{2.5}$ data while the black time series represent the several N-FRM RTP time series. The blue vertical lines represent the start/end dates of the weekly samples.



Appendix H. Community interest: Attempt to spatially extrapolate moss study results to air samples

In 2019 and 2021, the Duwamish Valley Youth Corp collected samples of moss and had them analyzed for metals.[1] The group attempted to use moss sampling to provide information on the spatial distribution of metals by deposition. However, there are inherent limitations in this approach, including how long metals reside in the moss. That is, moss may leach metals with varying levels of precipitation, growth rates, and likely other variables. Therefore, inherently, linking moss samples directly to air samples the concentration is potentially flawed, and is seasonally effected.

Even with these inherent uncertainties, we attempted to match the moss samples with the air samples to estimate a potential cancer risk surface in the graph below. The first step was to krige the moss samples, combining both 2019 and 2021 data. The kriging predictions were calculated on a grid with 5m x 5m cells. The prediction closest to each of our air monitoring sites was chosen for comparison. A simple linear regression was calculated with the kriging predictions as the x variable and the average of the air monitoring data for each site as the y variable. Each linear model had 6 datapoints, one for each of our sites. The scatterplot below in Figure H-1 shows the model performance for chromium. The full set of model performance graphs can be found at the end of this section. Pearson correlations were above 0.5 for cobalt (0.91), nickel (0.88), cadmium (0.56), and arsenic (0.53) and lower for lead (0.31), chromium (0.27), manganese (0.24), and selenium (0.05). Despite low correlation for chromium, we still used it for the purpose of this demonstration as it may include the highest potential cancer risks depending on the ratio that is hexavalent chromium. The linear models were applied to all the moss sample results. Metals that had Washington State Acceptable Source Impact Levels were converted to potential cancer risk. Potential cancer risk was then summed across all metals for each community site. The combined estimated potential cancer risk was kriged and displayed in Figure I-12. Both the initial and final kriging were using ordinary kriging with the model parameters chosen by the R function autoKrige.

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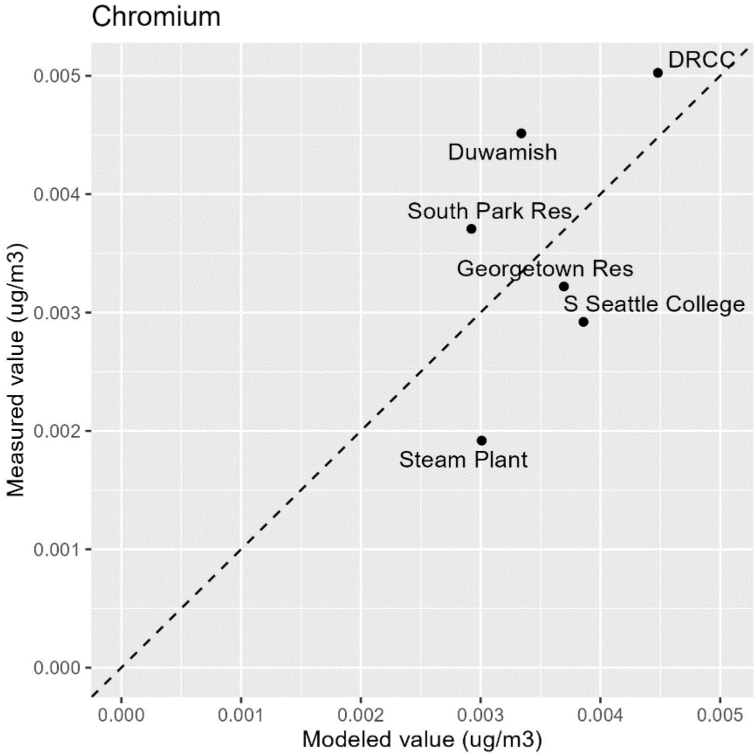
[1] Jovan S., Zuidema C., Derrien M., Bidwell A., Brinkley W., Smith R., Blahna D., Barnhill R., Gould L., Rodríguez A., Amacher M., Abel T., and López P. (2022). “Heavy metals in moss guide environmental justice investigation: A case study using community science in Seattle, WA, USA”. Ecosphere.

For selenium, almost all 2019 moss samples and one 2021 result were below the detection limit and were removed.

One of the major limitations to this approach is that the moss samples were taken at a different time than the air samples and represent the cumulative exposure of the moss throughout its life.

It is also important to note the low correlation with chromium (0.27) since estimated hexavalent chromium contributes the largest amount to cancer risk from metals.

Figure H-1. Moss comparison model for chromium.

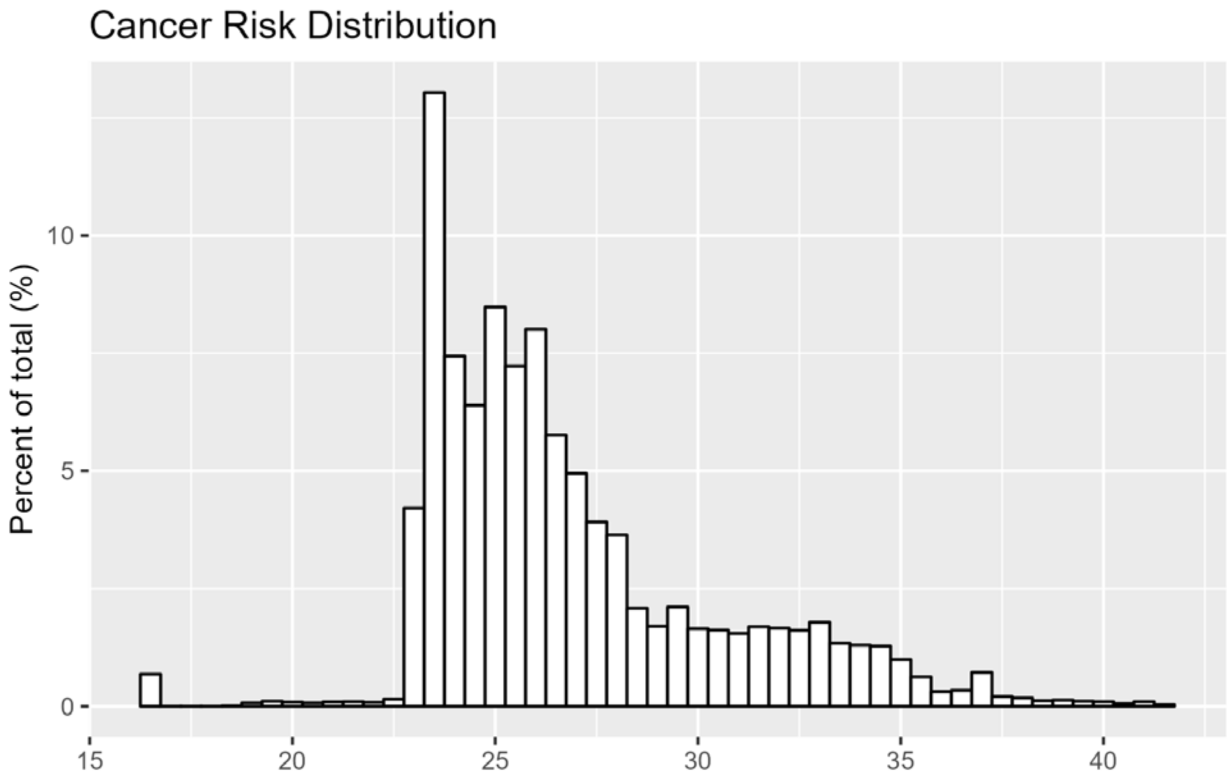


In Appendix I, Figure I-12 shows the estimated potential cancer risk from the metals that were sampled in both the moss studies and our study. These metals are arsenic, cadmium, estimated hexavalent chromium, lead, and nickel. Hexavalent chromium was estimated to be 3% of total chromium as referenced earlier in this report.

Estimated potential cancer risk from metals in the air was higher in the industrial area of north South Park, along E Marginal Way S, and along 1st Ave S. The highest estimated potential cancer risk was approximately ten times lower than the estimated diesel cancer risk as described earlier in this study.

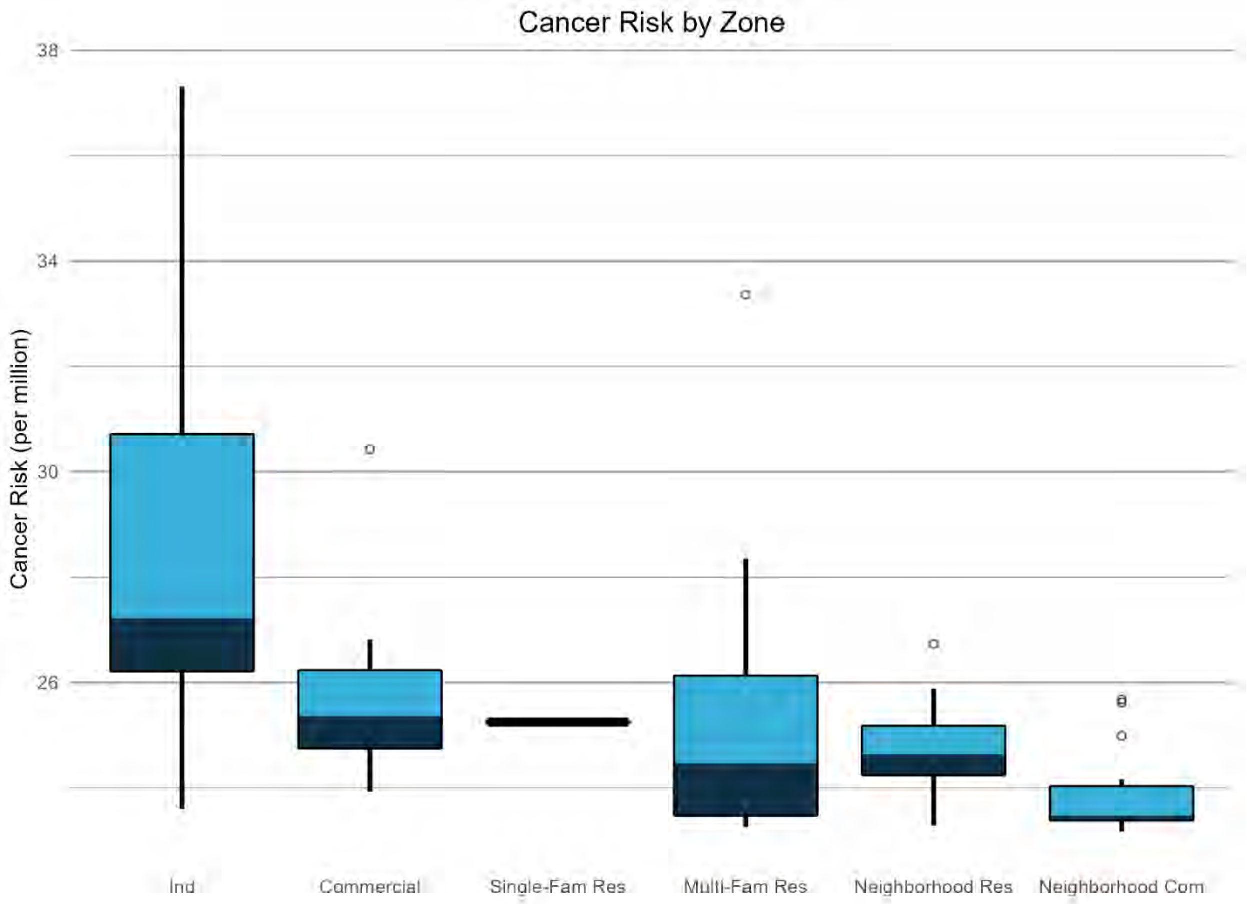
The graph shows the distribution of cancer risk values from the cancer risk raster. Most of the values are between 23 and 28 per million. The lower end of the cancer risk range (approximately 16-23 per million) is concentrated around the Georgetown Steam Plant site. That is because the Steam Plant site had significantly lower values than the other sites for chromium and arsenic. So, when interpreting the map, the residential areas of "background" risk east and west of the Duwamish River have a risk around 23 per million.

Figure H-2. Kriged metals estimated potential cancer risk distribution.



We also attempted to quantify the difference in potential cancer risk based on zoning. A zone shapefile for the City of Seattle was downloaded and the average cancer risk for each zone was calculated. The average cancer risk for commercial zones was 25 per million; residential, 25 per million; and industrial, 28 per million. When looking at the average cancer rate by detailed zone information, the industrial zones have a higher cancer risk than commercial and residential zones. The commercial and residential average cancer risk is close to the background risk of approximately 23 per million. See Figure I-1 in Appendix I for a detailed map of the zones overlayed on top of the potential cancer risk layer.

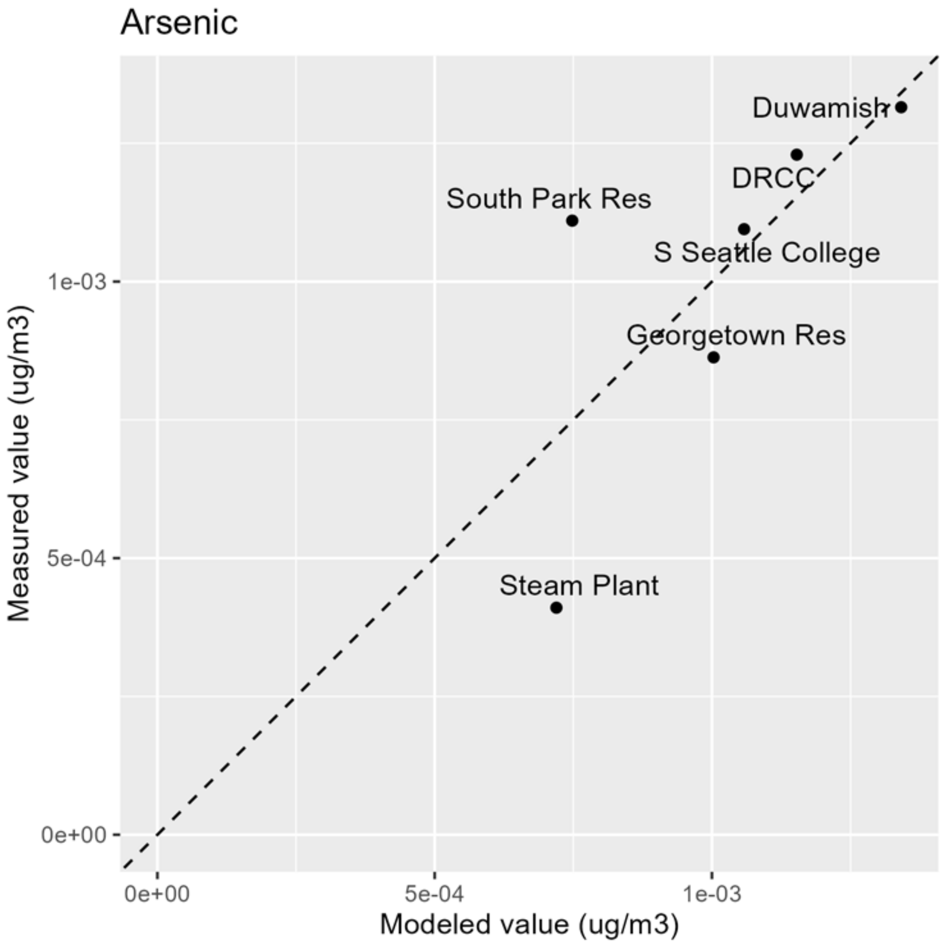
Figure H-3. Estimated metals potential cancer risk by land use zone.



This bar plot shows more detailed zoning categories and the associated potential cancer risk. The outlier for the commercial zone is a zone that encompasses the South Seattle College Georgetown campus, where we had a monitoring site. The multi-family residential outlier is a small area just south of the West Seattle Bridge (see Appendix I).

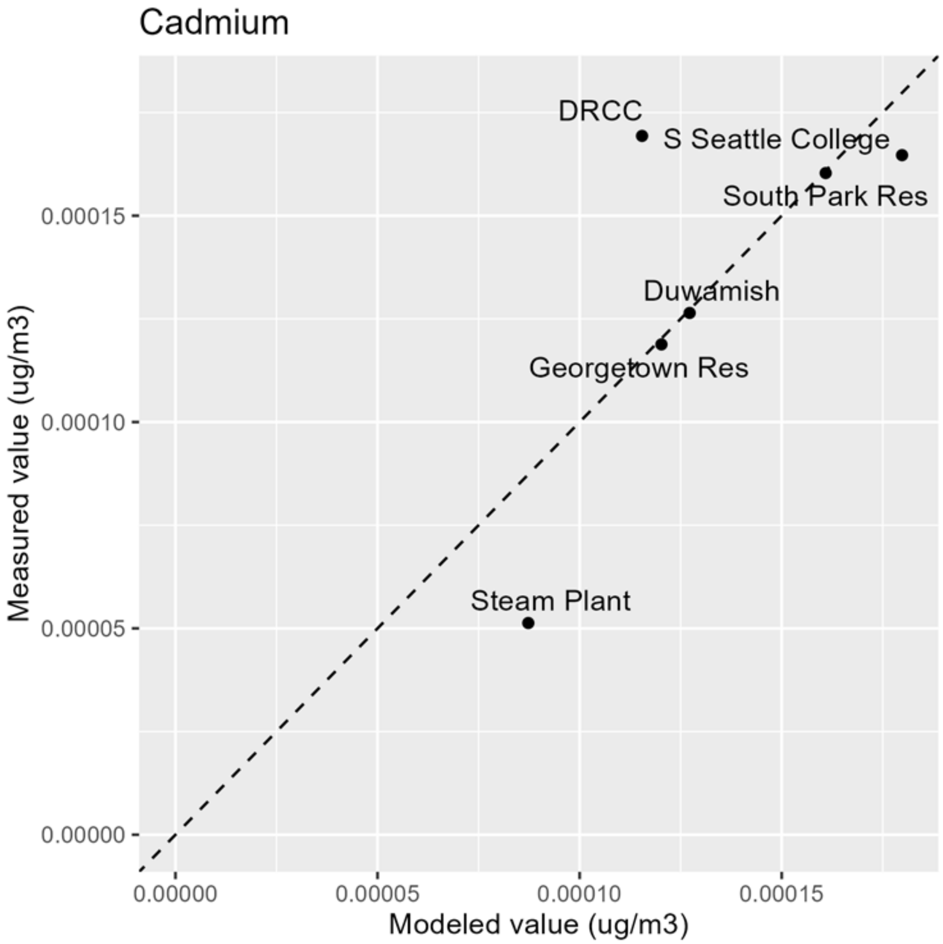
The following scatterplots show the model performance for the other metals.

Figure H-4. Moss Model Performance - Arsenic



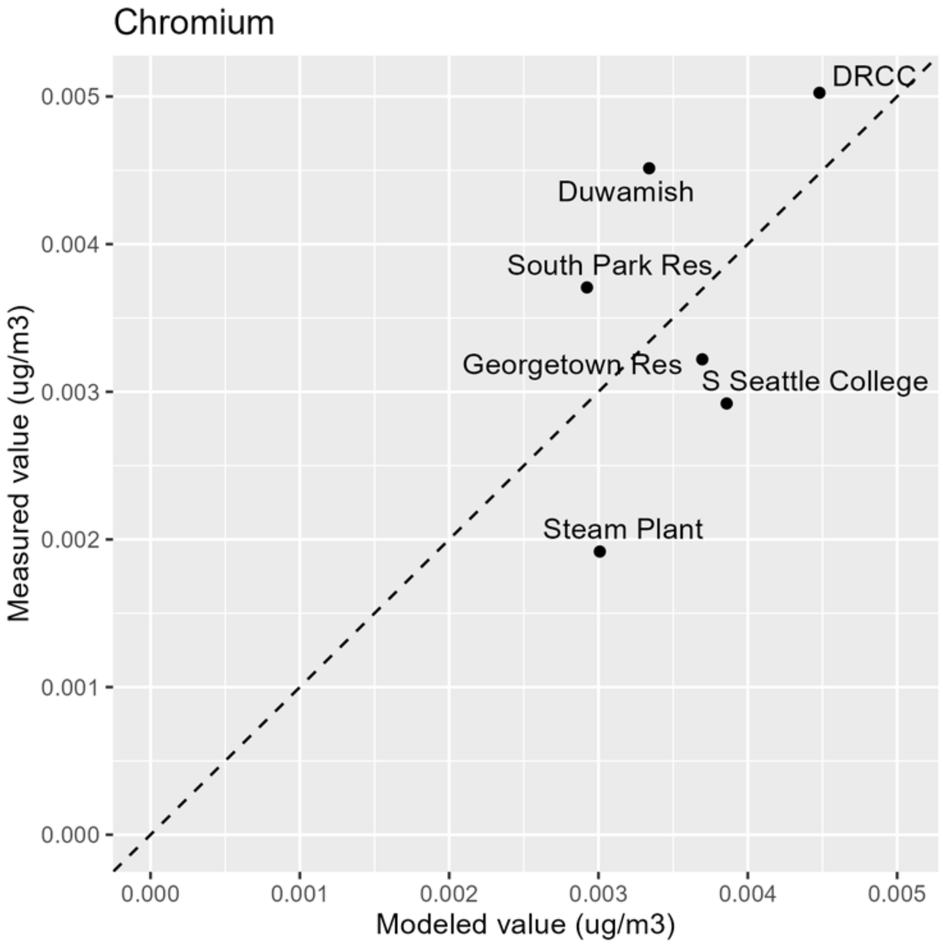
Summary statistics: R^2 = 0.53, adjusted R^2 = 0.41, RMSE = 0.21 ng/m^3, sample mean = 1 ng/m^3

Figure H-5. Moss Model Performance - Cadmium



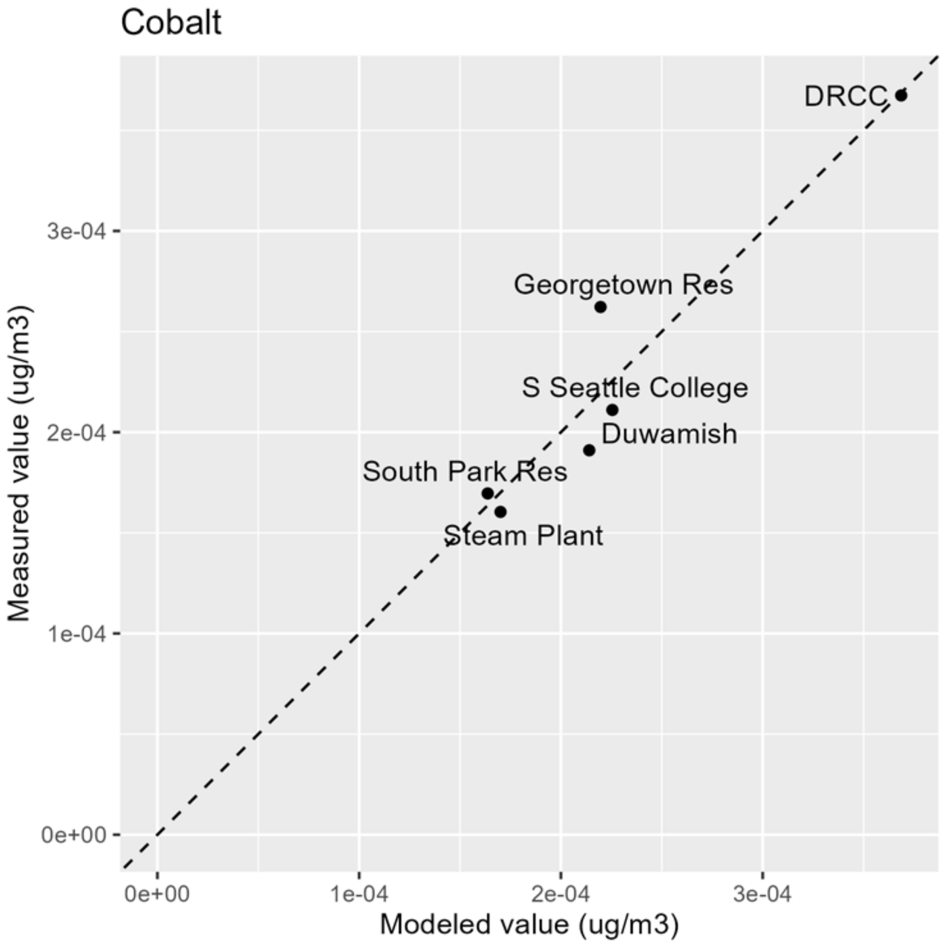
Summary statistics: R^2 = 0.56, adjusted R^2 = 0.45, RMSE = 0.03 ng/m^3, sample mean = 0.13 ng/m^3

Figure H-6. Moss Model Performance - Chromium



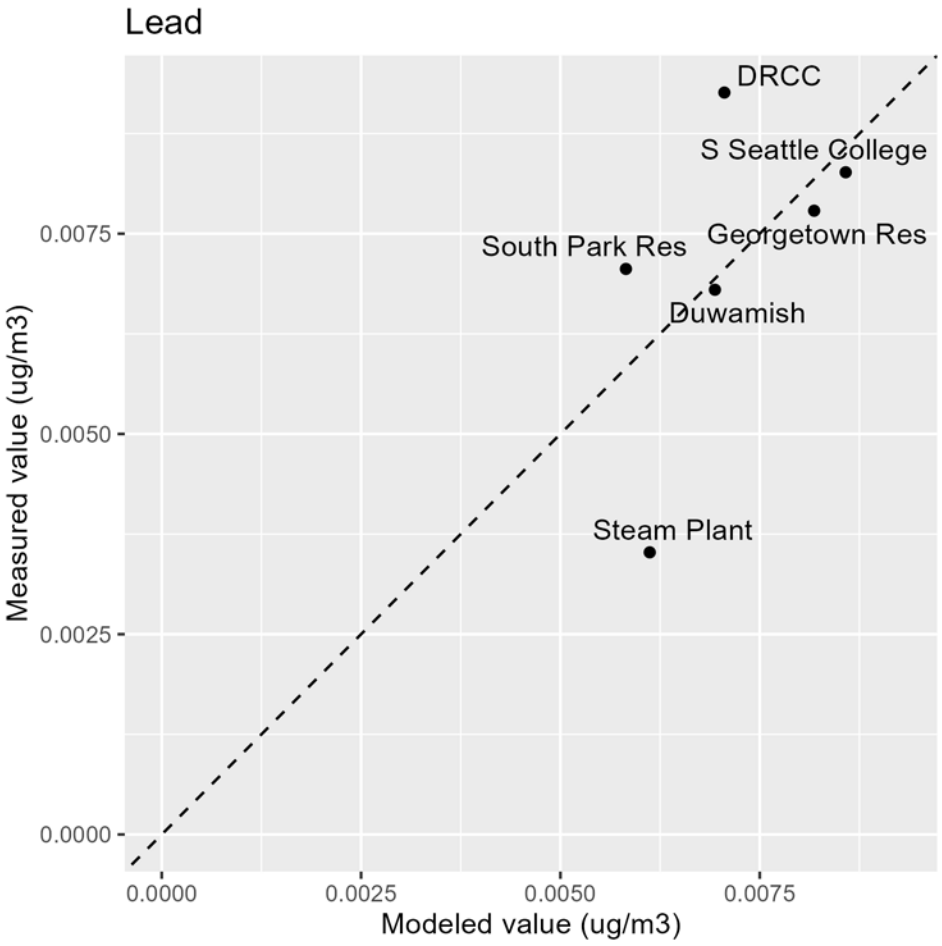
Summary statistics: R^2 = 0.27, adjusted R^2 = 0.09, RMSE = 0.87 ng/m^3, sample mean = 3.55 ng/m^3

Figure H-7. Moss Model Performance - Cobalt



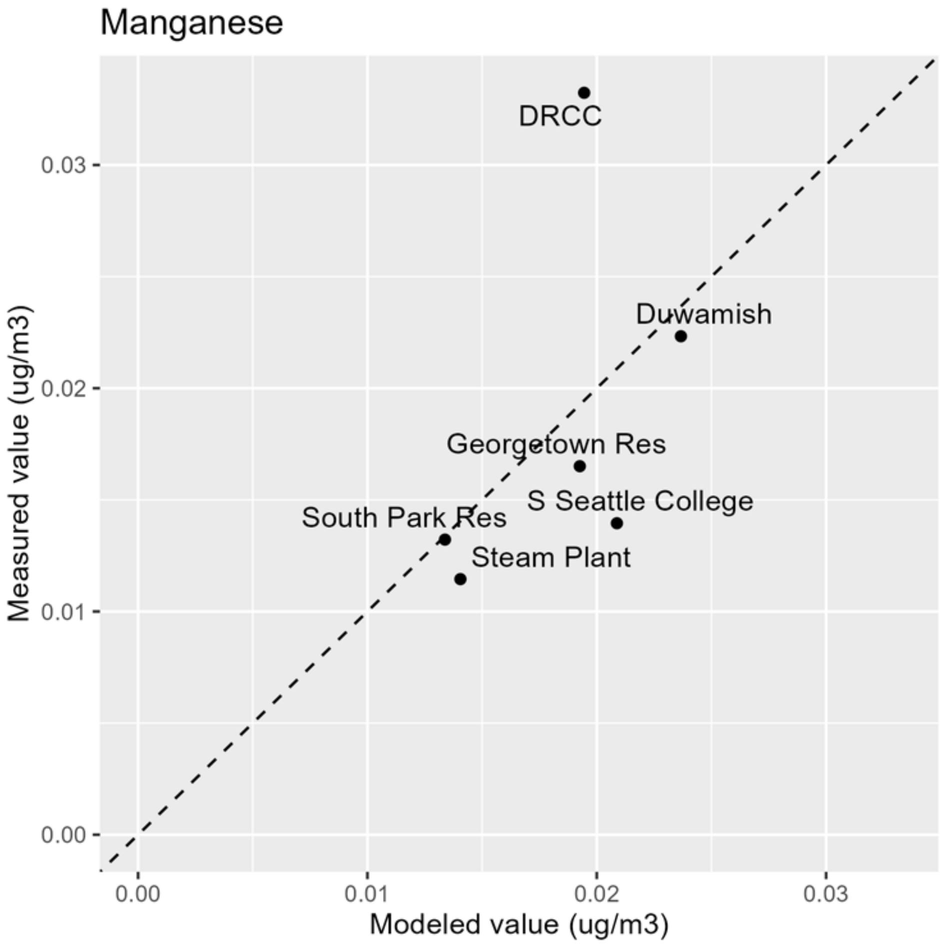
Summary statistics: $R^2 = 0.91$, adjusted $R^2 = 0.89$, RMSE = 0.02 ng/m^3, sample mean = 0.23 ng/m^3

Figure H-8. Moss Model Performance - Lead



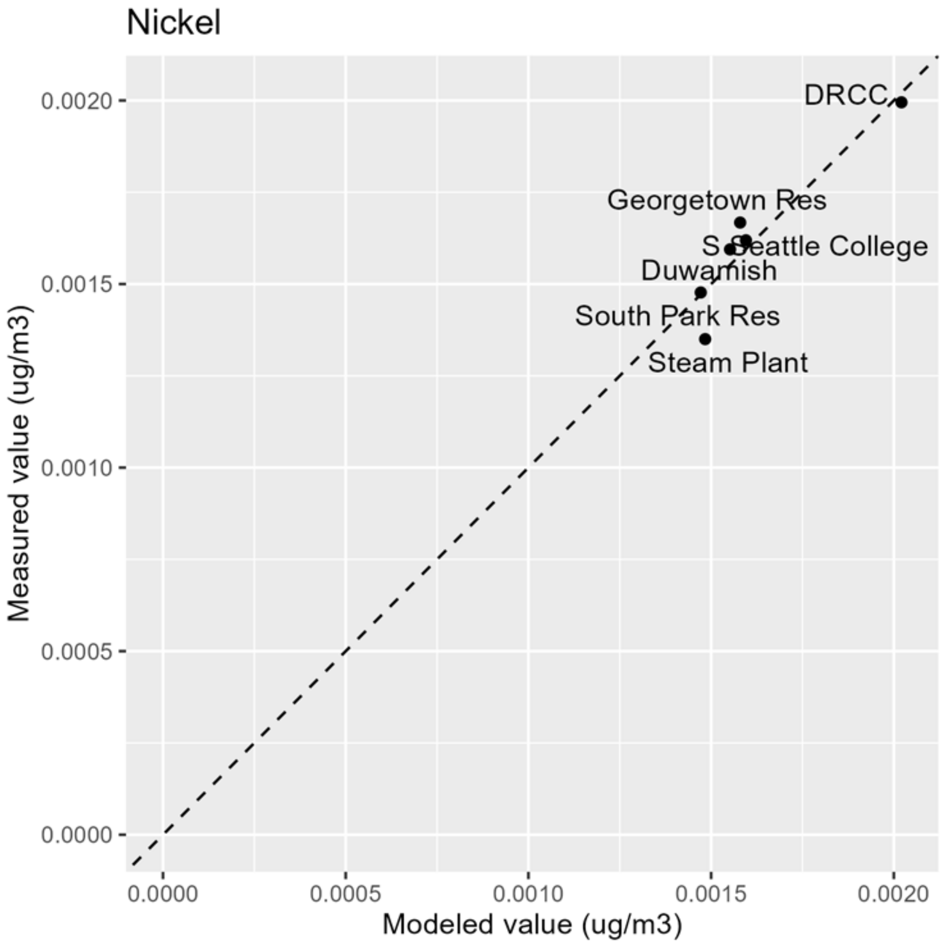
Summary statistics: $R^2 = 0.31$, adjusted $R^2 = 0.14$, RMSE = 1.5 ng/m^3, sample mean = 7.12 ng/m^3

Figure H-9. Moss Model Performance - Manganese



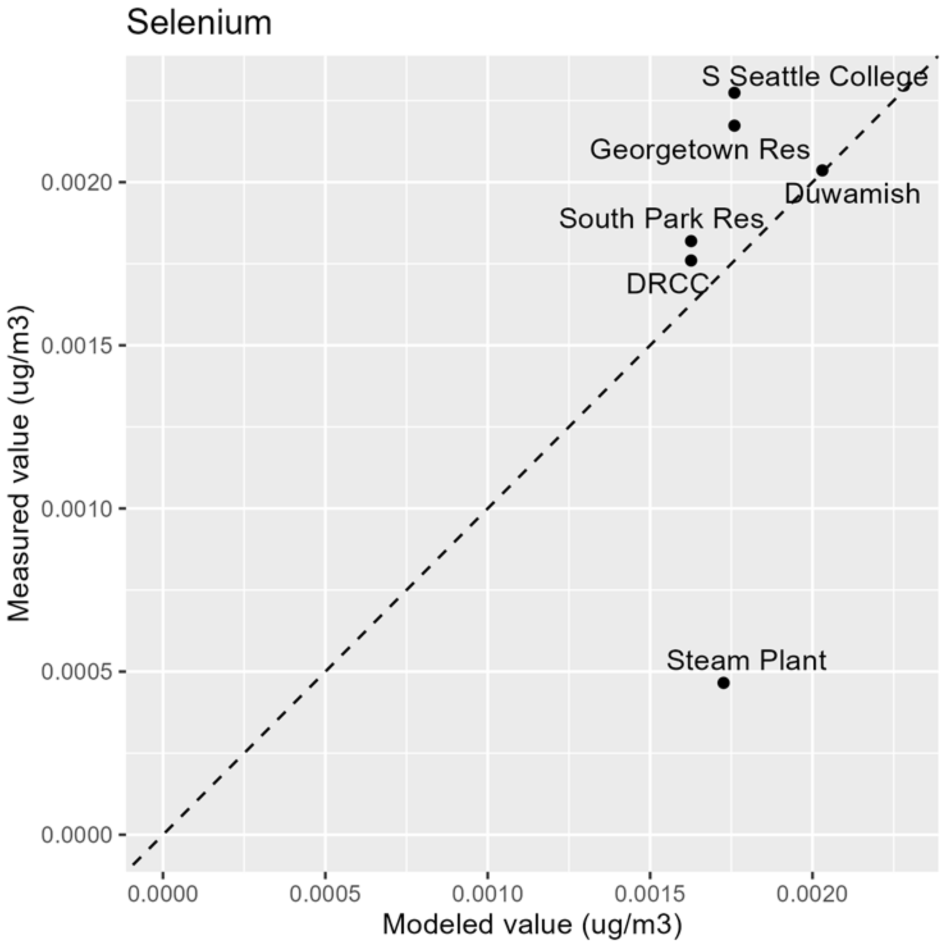
Summary statistics: $R^2 = 0.24$, adjusted $R^2 = 0.05$, RMSE = 6.51 ng/m^3, sample mean = 18.45 ng/m^3

Figure H-10. Moss Model Performance - Nickel



Summary statistics: R^2 = 0.88, adjusted R^2 = 0.85, RMSE = 0.07 ng/m^3, sample mean = 1.62 ng/m^3

Figure H-11. Moss Model Performance - Selenium



Summary statistics: $R^2 = 0.05$, adjusted $R^2 = -0.19$, RMSE = 0.59 ng/m^3, sample mean = 1.75 ng/m^3

Appendix I. Community interest: Attempt to map pollutant-specific and zoning maps for moss comparison

Despite the many limitations with this approach, including low correlations to the chromium value (0.27) which drives most of the risks herein, we proceeded to display the maps below for reference for transparency. Appendix H above describes the approach in more detail.

Figure I-1. Estimated cancer risk from metals including zone definitions.

Note: There is an area west of the playfield that has some residential lots, which were allowed to keep their designation when the area was re-zoned as industrial. When these lots are sold, they will become industrial.

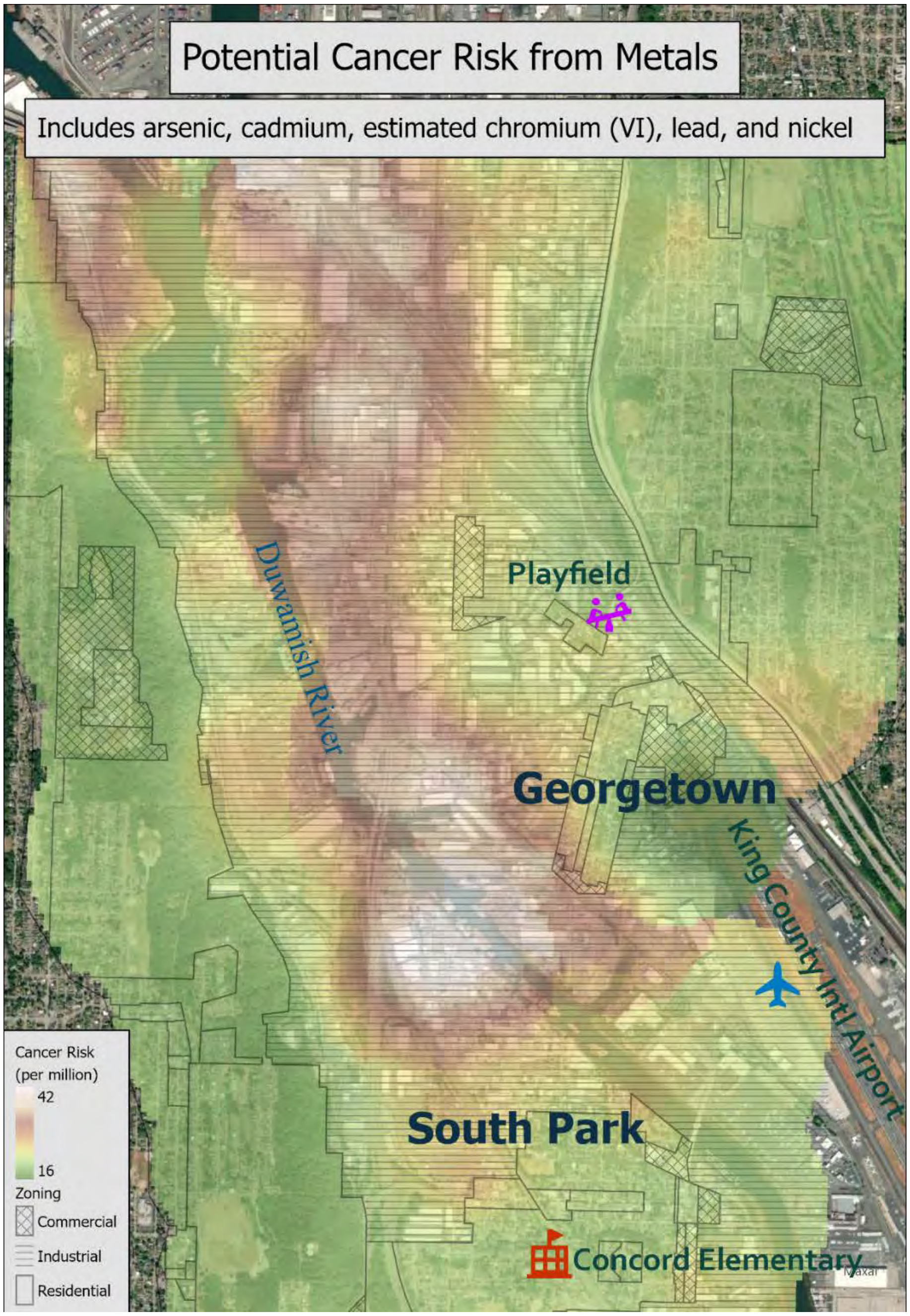
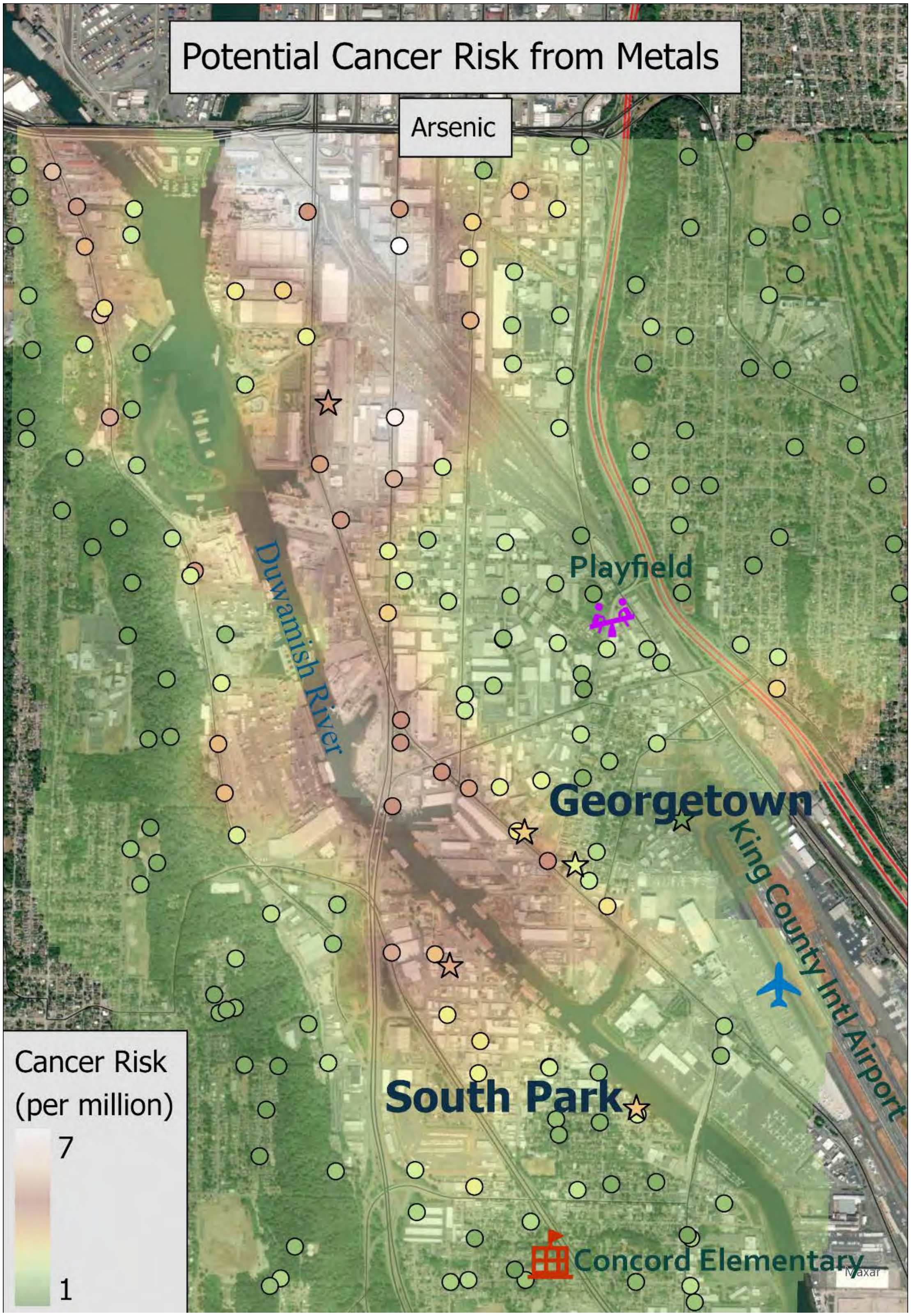
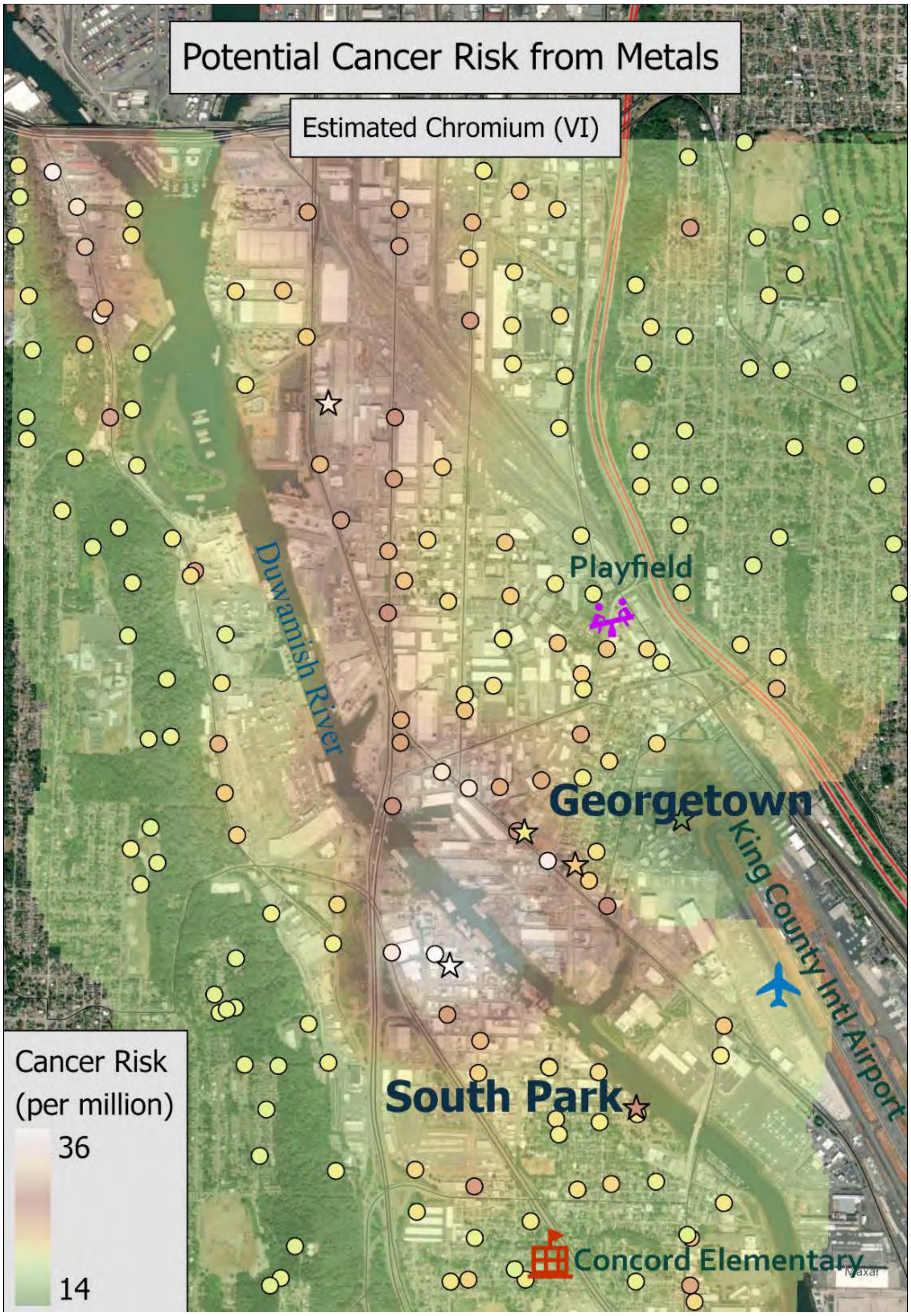


Figure I-2. Estimated cancer risk from arsenic.



Across all moss and air sampling sites, arsenic accounted for about 10% of cancer risk from metals.

Figure I-3. Estimated cancer risk from hexavalent chromium.



Across all moss and air sampling sites, estimated hexavalent chromium accounted for about 87% of cancer risk from metals.

Figure I-4. Estimated arsenic concentrations in ng/m³.

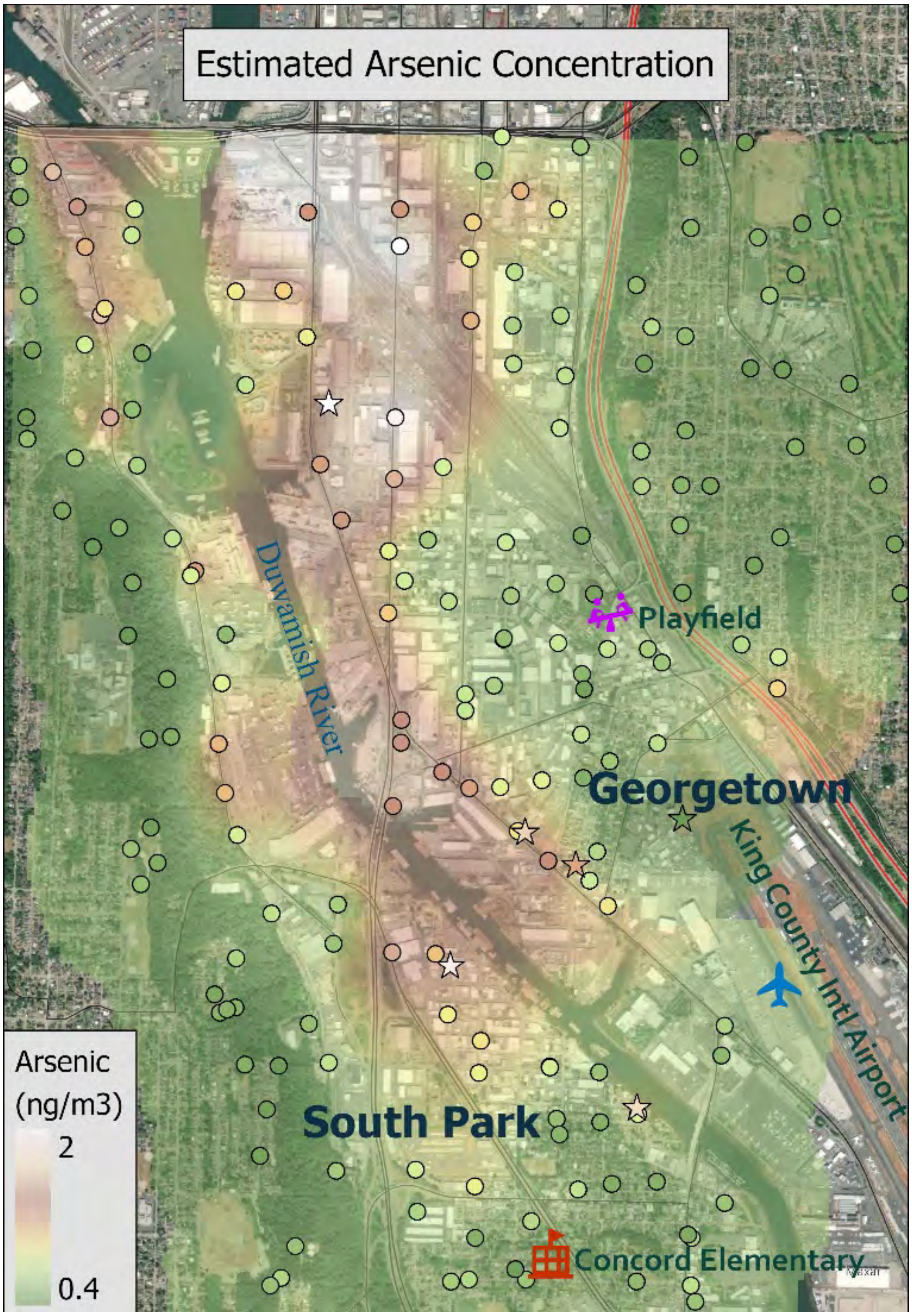


Figure I-5. Estimated cadmium concentrations in ng/m³.

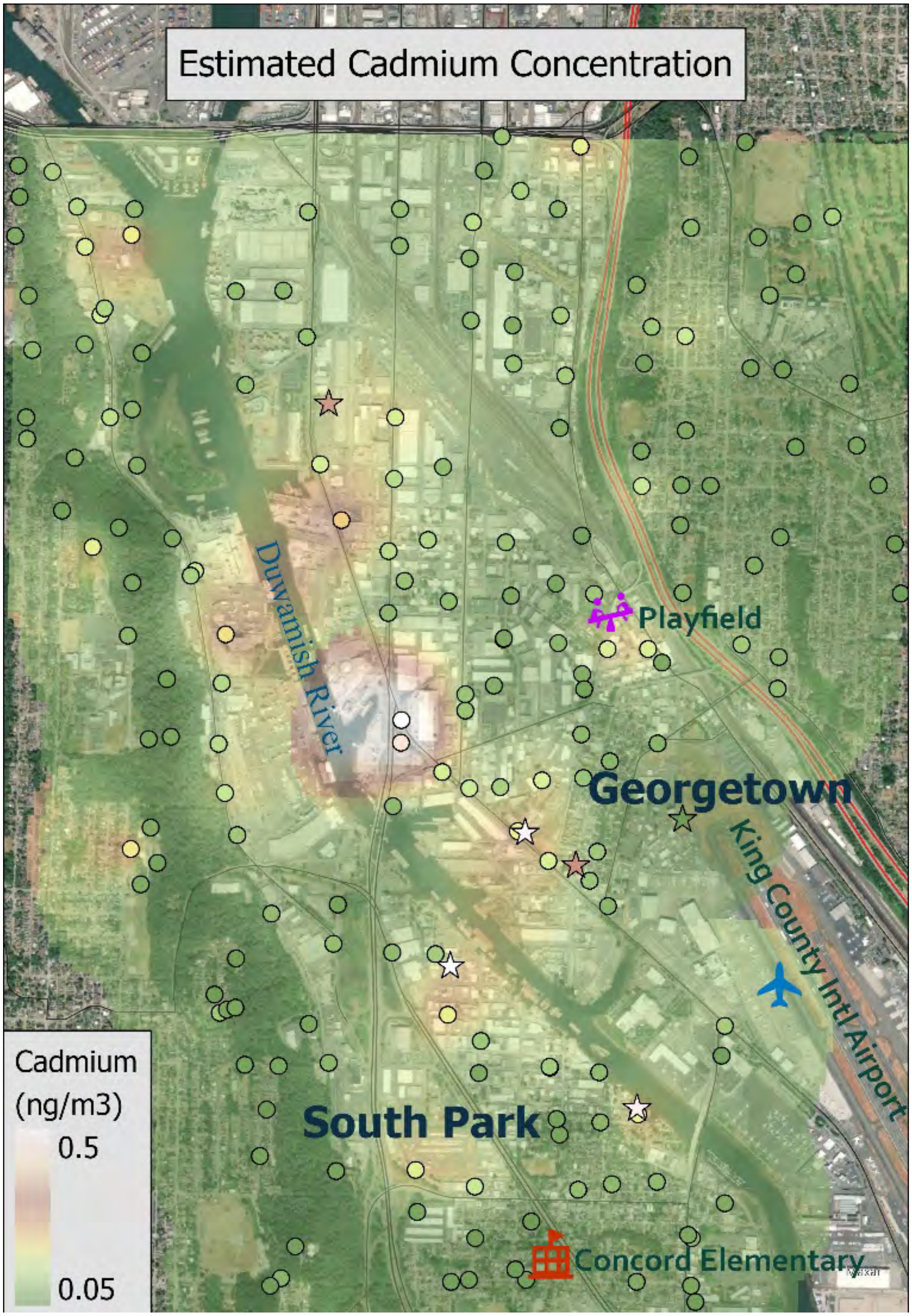


Figure I-6. Estimated total chromium concentrations in ng/m³.

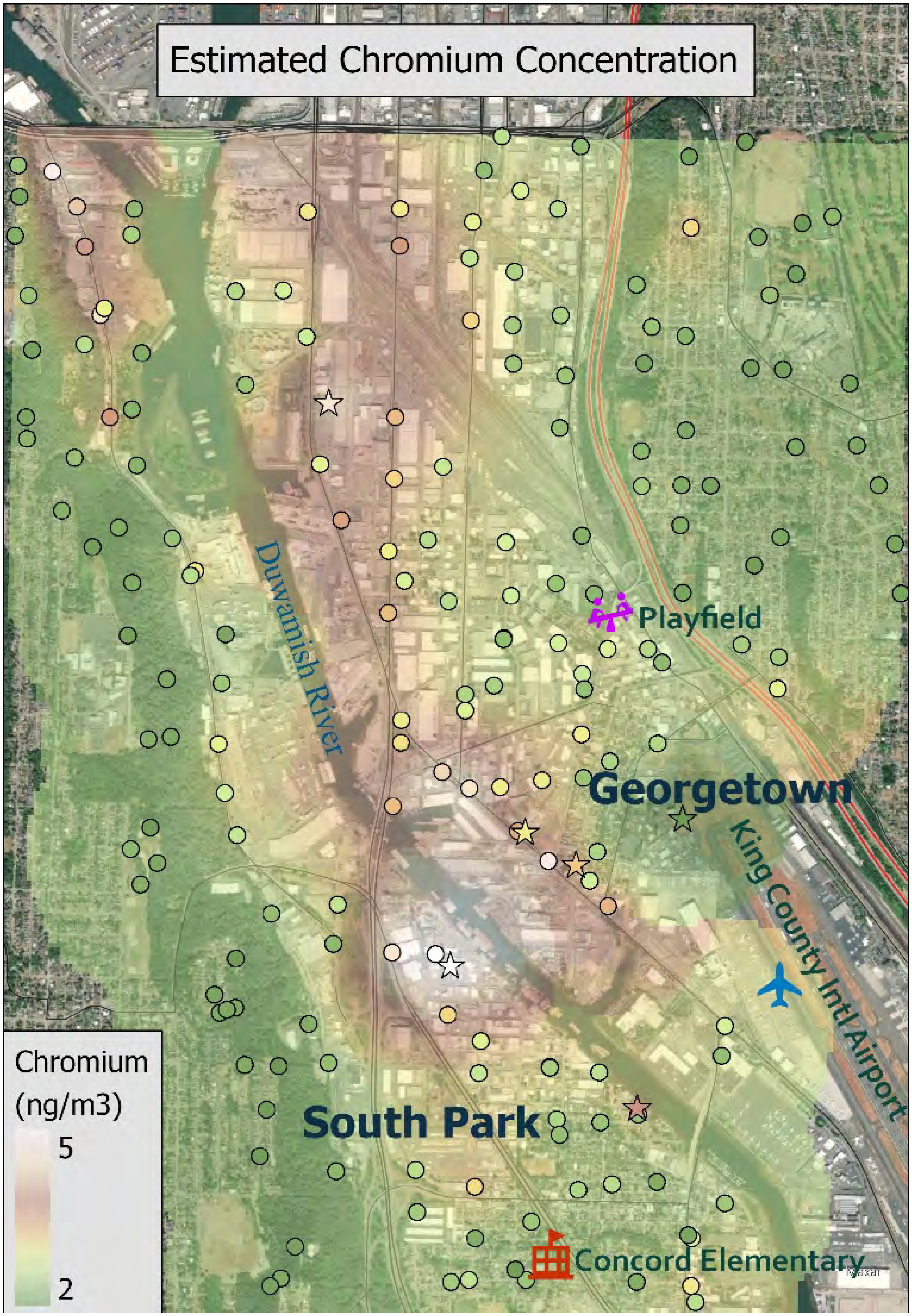


Figure I-7. Estimated cobalt concentrations in ng/m³.

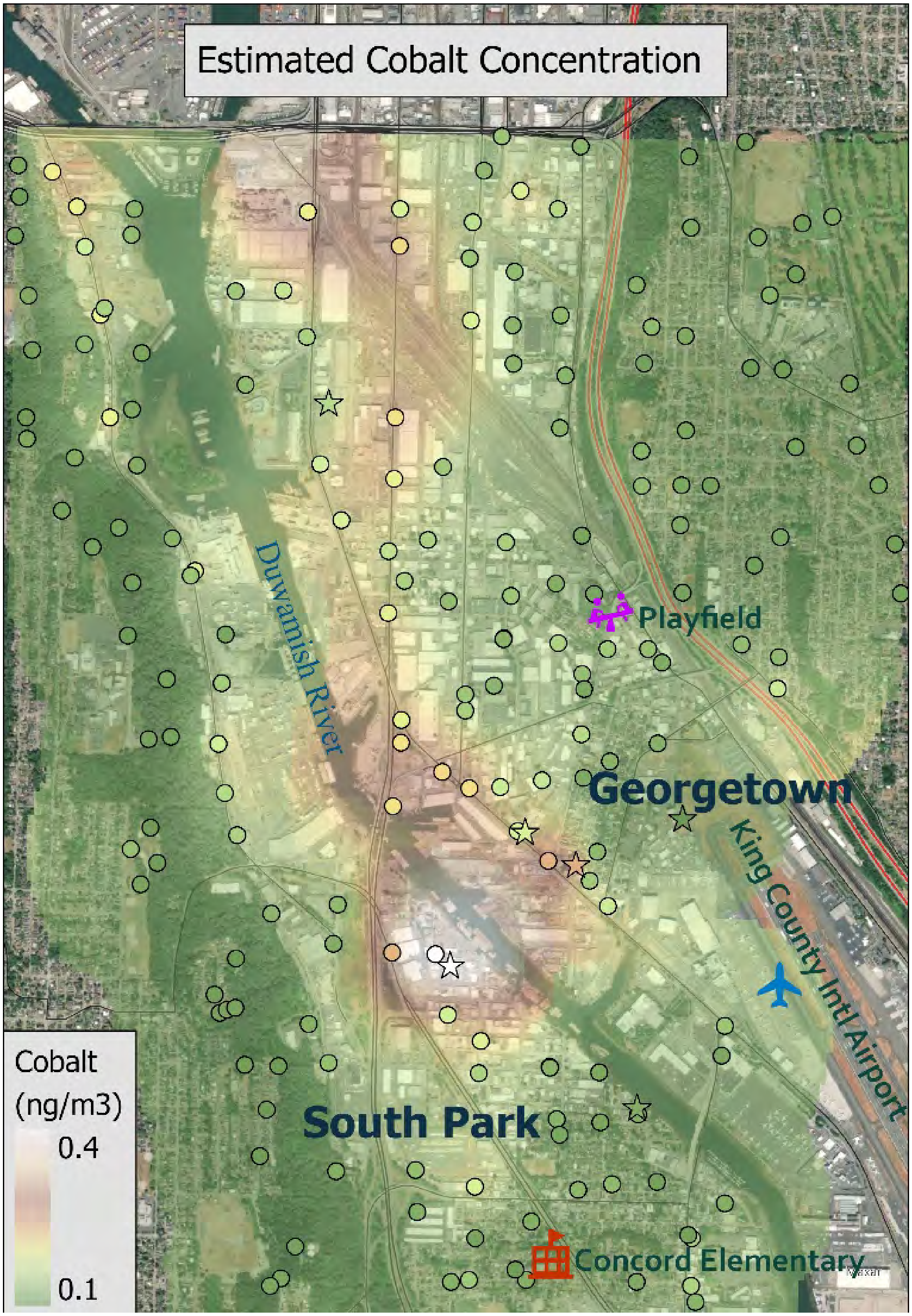


Figure I-8. Estimated lead concentrations in ng/m³.

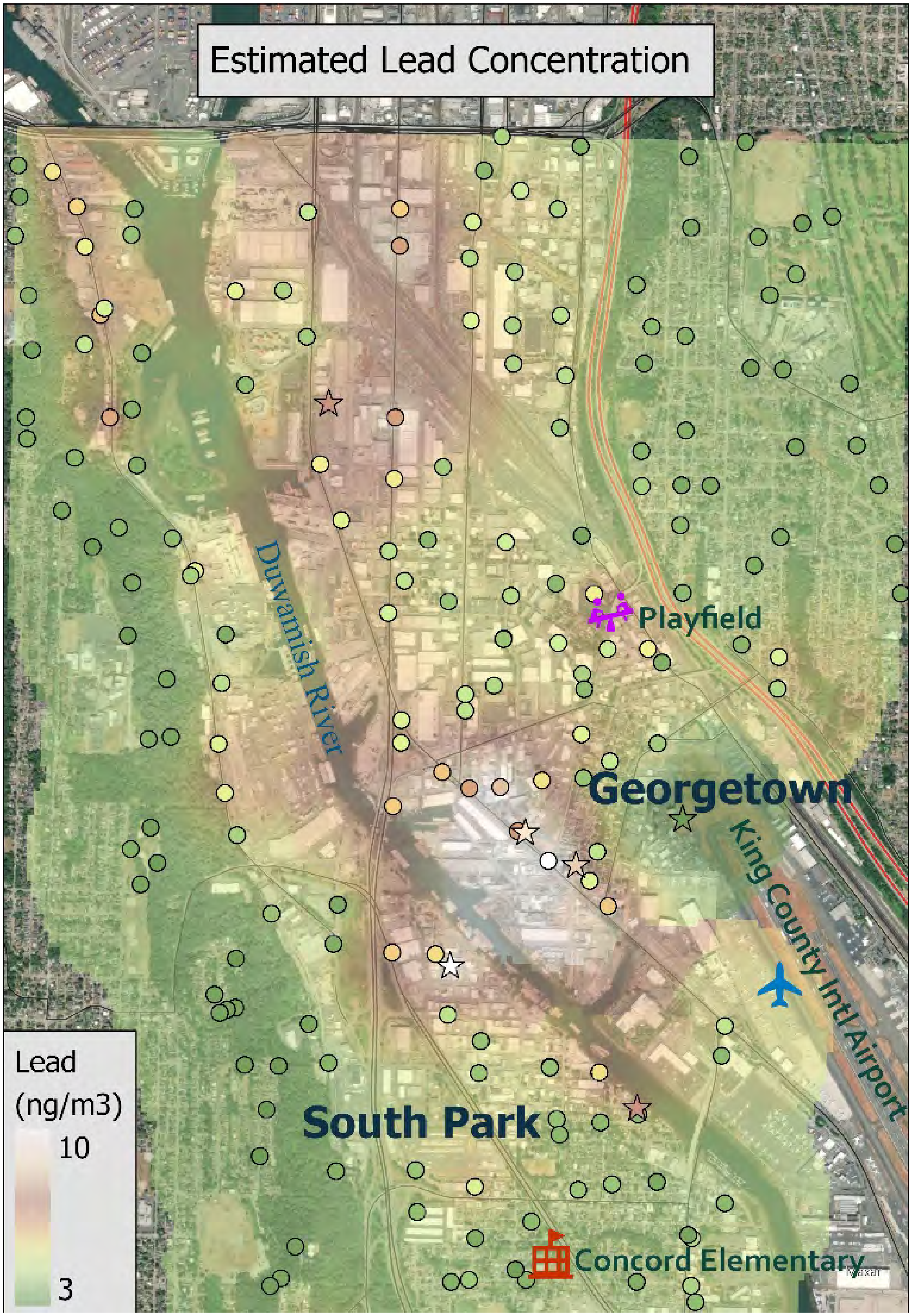


Figure I-9. Estimated manganese concentrations in ng/m³.

Figure I-10. Estimated nickel concentrations in ng/m³.

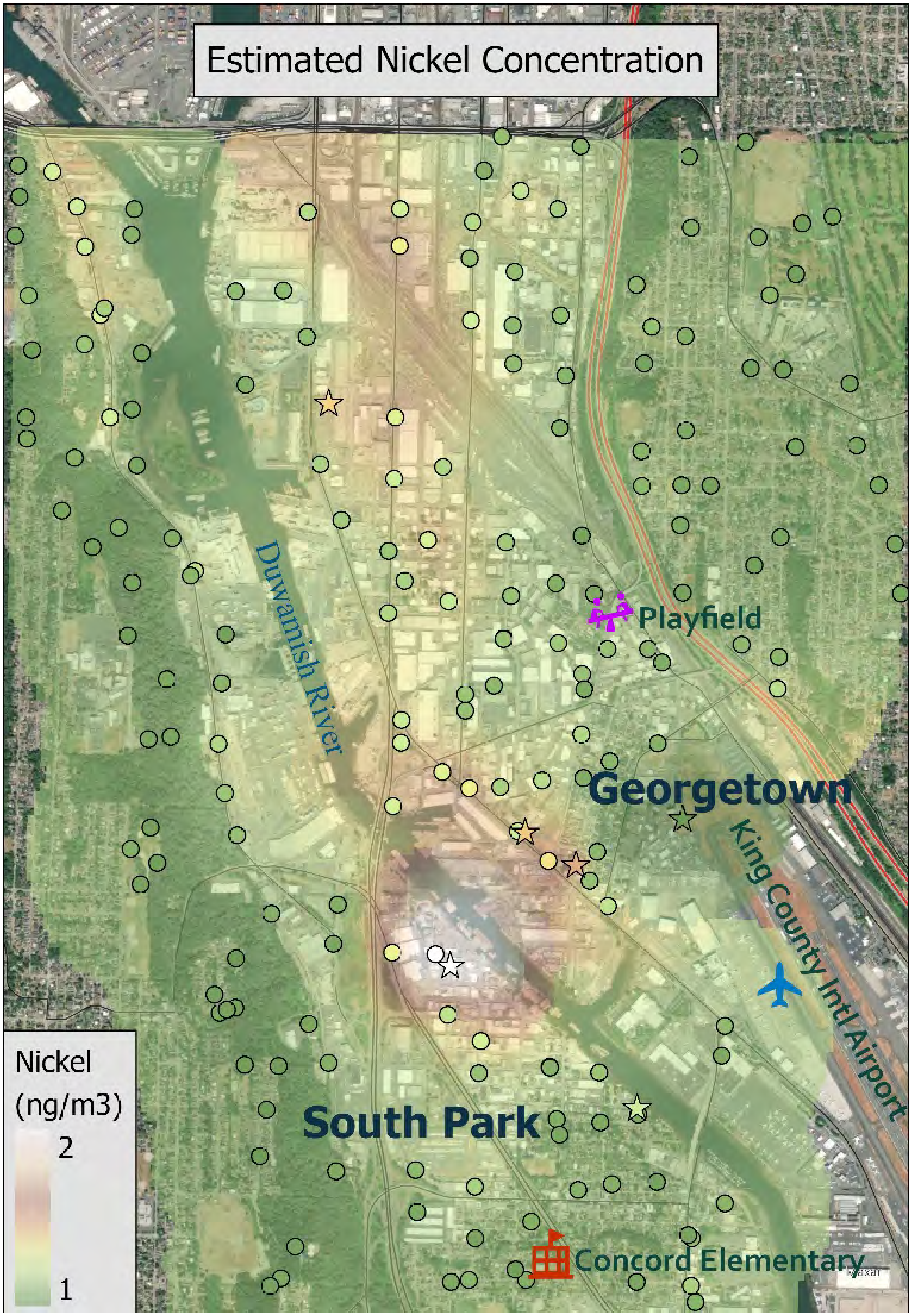
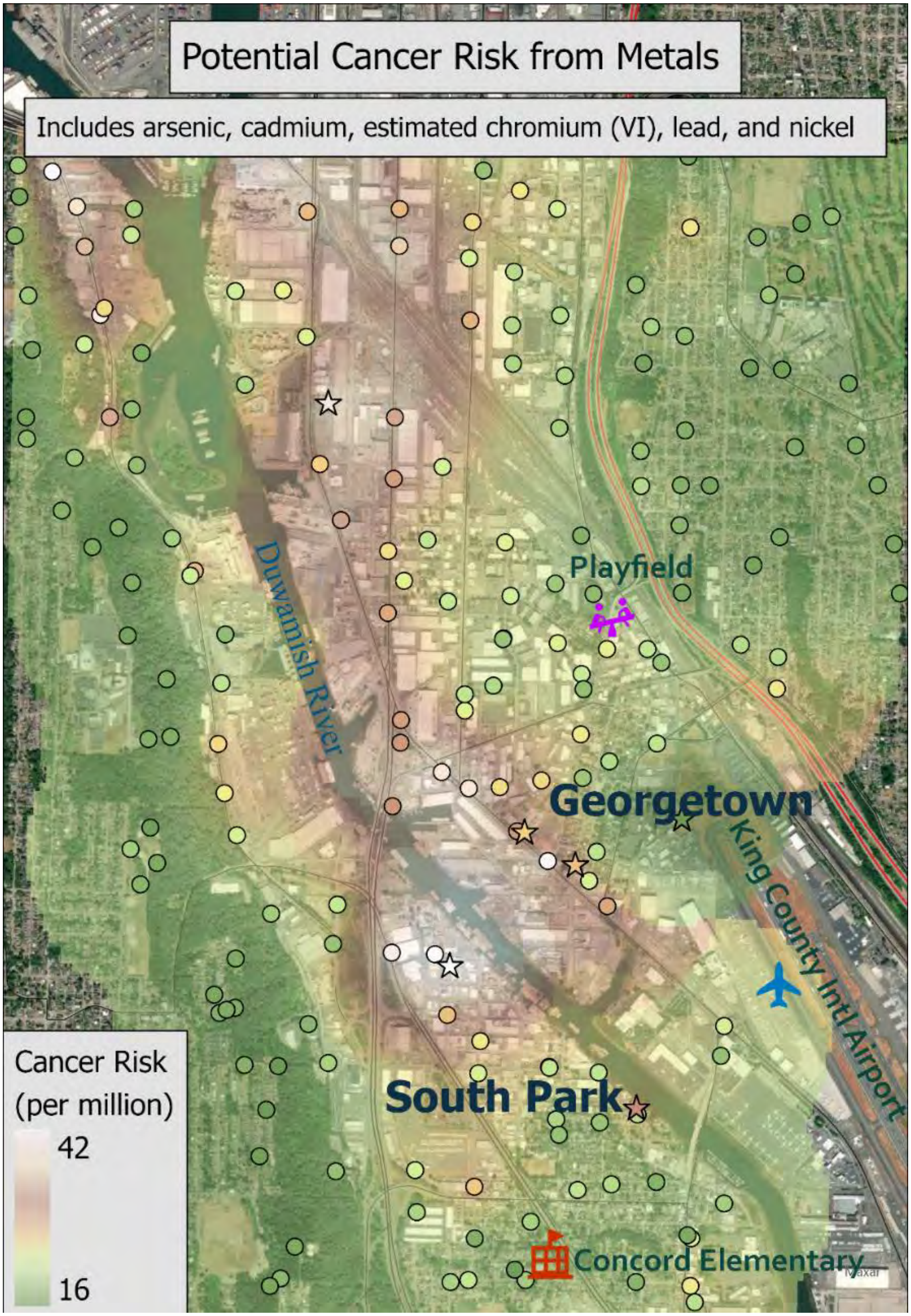


Figure I-11. Estimated selenium concentrations in ng/m³.

Figure I-12. Map with potential cancer risk from metals in the Duwamish Valley extrapolated from moss samples calibrated to adjacent air quality samples.



Appendix J. Community interest: Comparison to Portland moss study

Overall

In the Portland moss study, elevated cadmium and arsenic levels were found in moss near a stained-glass manufacturer (denoted as stained glass #1 in the report).[2] Oregon DEQ followed up with air sampling near the facility. That air sampling campaign recorded a maximum cadmium concentration of nearly 200 ng/m^3 and an average of 29 ng/m^3. The air monitoring performed in our study had a maximum cadmium concentration of 1.9 ng/m^3 and site-averages of 0.1-0.2 ng/m^3. The maximum concentration of arsenic in the air in the Portland study was approximately 100 ng/m^3 with an average of 32 ng/m^3. In this study, we found a maximum of 8.5 ng/m^3 arsenic and a site-averages of 0.4 - 1.3 ng/m^3. **The levels of arsenic and cadmium seen in our study were much lower than the Portland study** and don't indicate a specific extreme source as in Portland.

It is important to note that, at least with current sampling and quantification protocols, moss has not been established to be a reliable quantitative method for assessing ambient concentrations of pollution in the air between regions or studies (while regulatory methods explicitly have been). Moss inherently introduces additional variables and measurement uncertainty (confounders) due to the complexity of the collection media (a living, biological material) and its variability in the sampling environment, both of which are factors that have been deliberately designed out of the regulatory methods (e.g. PM_{10} and deposition methods) because of the uncertainty they bring. An incomplete list of potential confounders that could easily make the Seattle and Portland samples not directly comparable include: the type of moss, the sampling duration, weather conditions during sampling including temperature, sunlight, rain, relative humidity, wind direction, all of which could affect growth, surface uptake of particles, and ion exchange activity on the surfaces. Current research has shown that the basic mechanisms of metal uptake by moss

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[2] Donovan G., Jovan S., Gatziolis D., Burstyn I., Michael Y., Amacher M., and Monleon V. (2016). "Using an epiphytic moss to identify previously unknown sources of atmospheric cadmium pollution". 2016. Sci of the Total Env 559:84-93.

are not well understood, much less well controlled in current sampling methods and thus semi-quantitative/not-comparable results are common.[3,4]

Arsenic and cadmium ratios

One way to assess the transferability of moss results is to calculate the air to moss ratio. This is simply the concentration of the metal in the air (ng/m^3) divided by the concentration of that metal in moss (mg/dry kg). For the Portland study, the cadmium ratio was 29.4 ng/m^3 (the average air concentration) divided by 4 mg/kg (the average of the highest quintile of nearby moss samples), which equals 7.4. In our study the cadmium ratio was 0.1 ng/m^3 (the average of all our sites) divided by 0.9 mg/kg (the average of the kriging predictions closest to our sites), which equals 0.14. The arsenic ratio was 31.7 ng/m^3 divided by 0.5 mg/kg, which equals 63. In our study, the arsenic ratio was 1 ng/m^3 divided by 1.7 mg/kg, which equals 0.6.

The ratios found in our study were not similar to the ratios found in the Portland study from the air sampling performed near the stained-glass manufacturer. So, applying the Portland ratio to the moss samples from Seattle would not result in accurate estimates of the air concentration.

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[3] Int J Environ Res Public Health. 2022 Apr; 19(8): 4706, doi: 10.3390/ijerph19084706, Is Active Moss Biomonitoring Comparable to Air Filter Standard Sampling?, P. Świsłowski, A. Nowak, S. Wacławek, Z. Ziembik, and M. Rajfur.

[4] Orthotrichum Lyellii as an Active Moss Biomonitor: Examining the Interplay Between Ambient PM10, Bulk Deposition and Heavy Metals in an Urban Environment, Kiel, Scott Bradley. Portland State University, ProQuest Dissertations Publishing, 2022. 29319498.

Appendix K. PMF site pie charts and factor profiles

General descriptions:

Sources were identified from the PMF analysis based on their composition, seasonality, and correlation to other measured parameters. At all five sites, nine factors were found to be the most reasonable. Eight of these factors were found at all sites: Ammonium sulfate/nitrate, Sea Salt, Nitrate-rich, Sulfate-rich, Crustal/Diesel, Motor Vehicles – Gasoline, Fresh Wood Smoke, and OP-rich/Aged Wood Smoke. In addition, each site had a unique factor. Seattle 10th and Weller had a Motor Vehicles – Diesel factor; Seattle Beacon Hill had an Unidentified Urban factor; Tacoma Tideflats a K rich factor; Tacoma South L an Aged Sea Salt factor; and Seattle Duwamish a Ca rich factor.

Below are pie charts of several the most important chemicals or pollutants/measures. In the figures below, the stripped factors indicate those that are regarded as being primarily diesel or having a large contribution from diesel.

Site descriptions:

Below are pie charts of the PMF factor components as fraction of $PM_{2.5}$ mass, pollution rose plots for the PMF factors using daily wind speeds, and seasonal trends for the PMF factors for each site.

Figure K-1. Seattle Duwamish PMF Factor Pie Chart

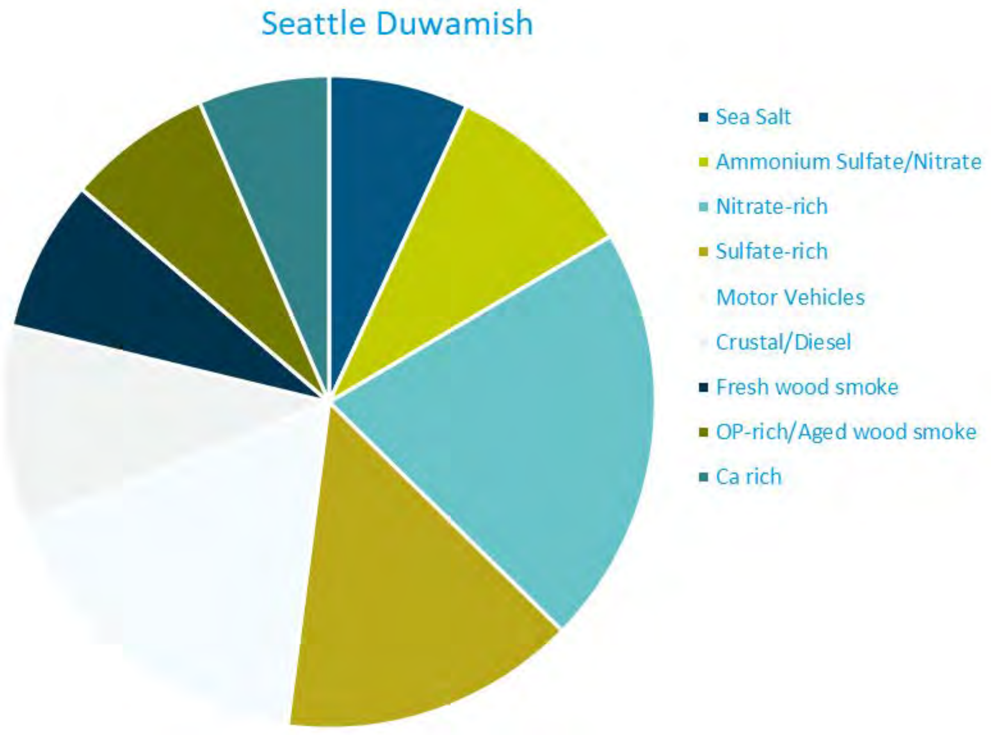


Figure K-2. Seattle Duwamish daily pollution roses for PMF factors

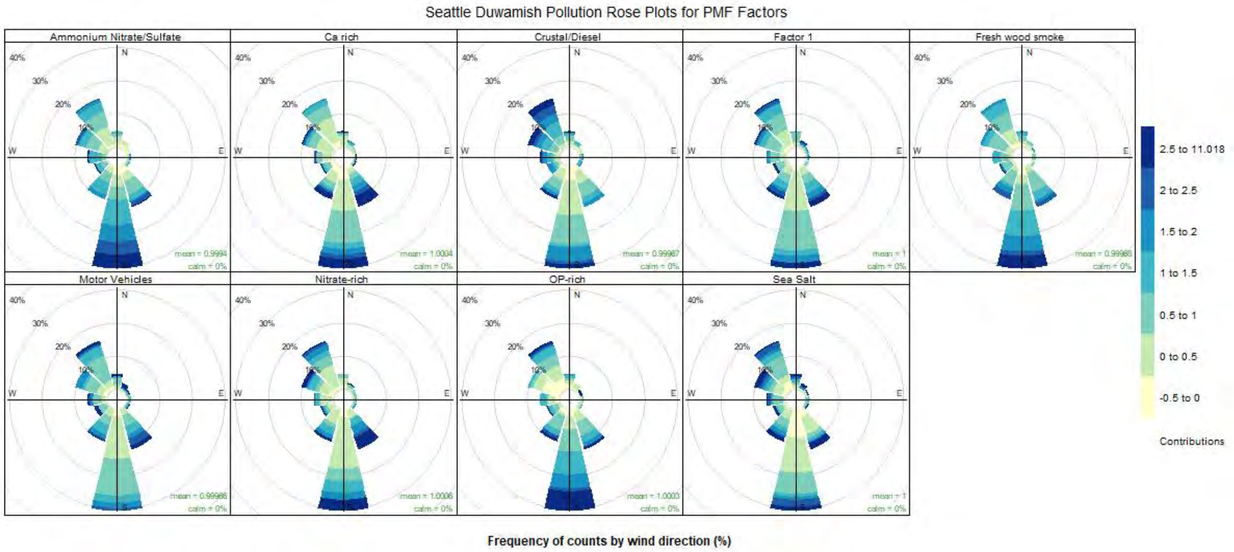


Figure K-3. Seattle Duwamish seasonal trend for PMF factors

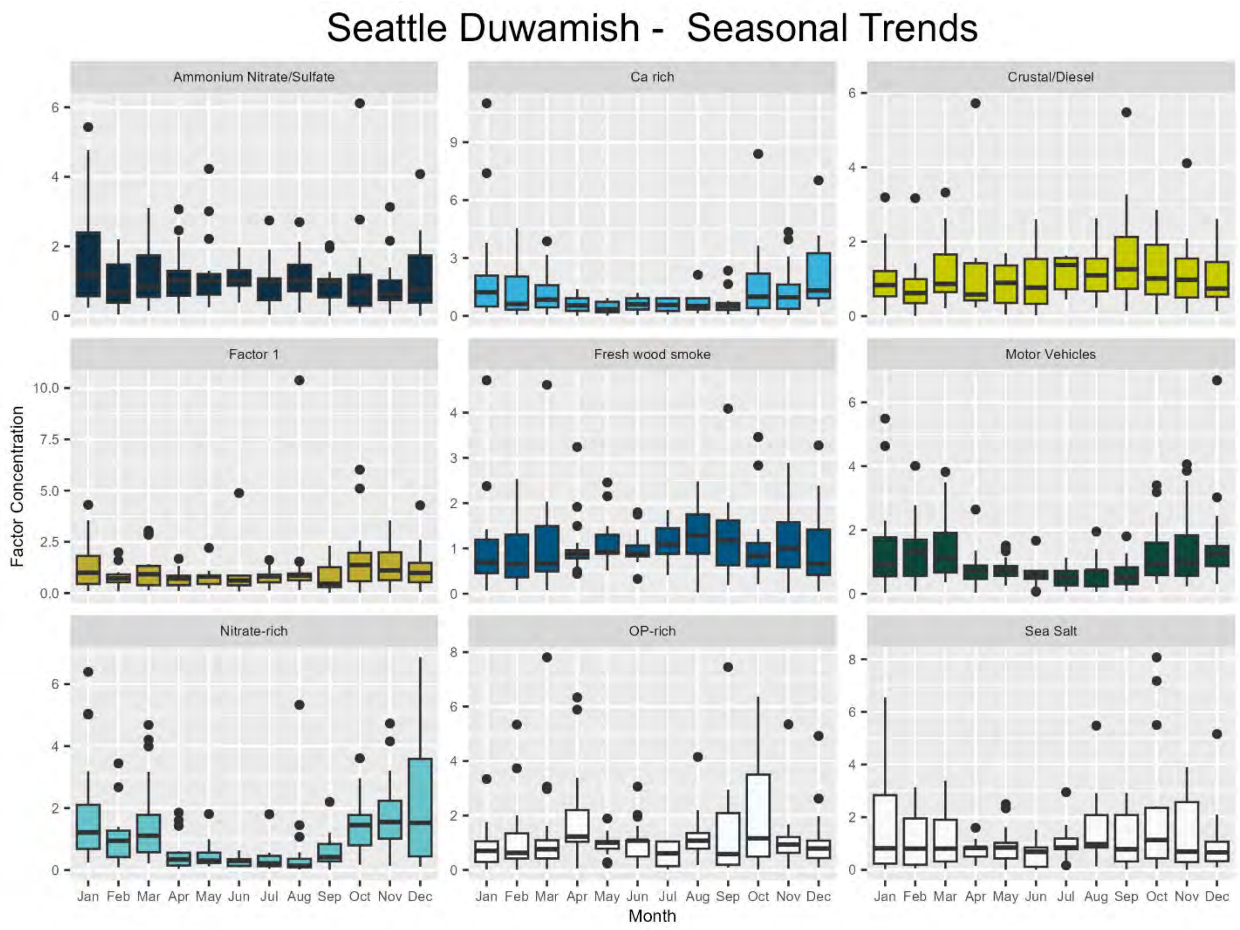


Figure K-4. Seattle 10th & Weller PMF Factor Pie Chart

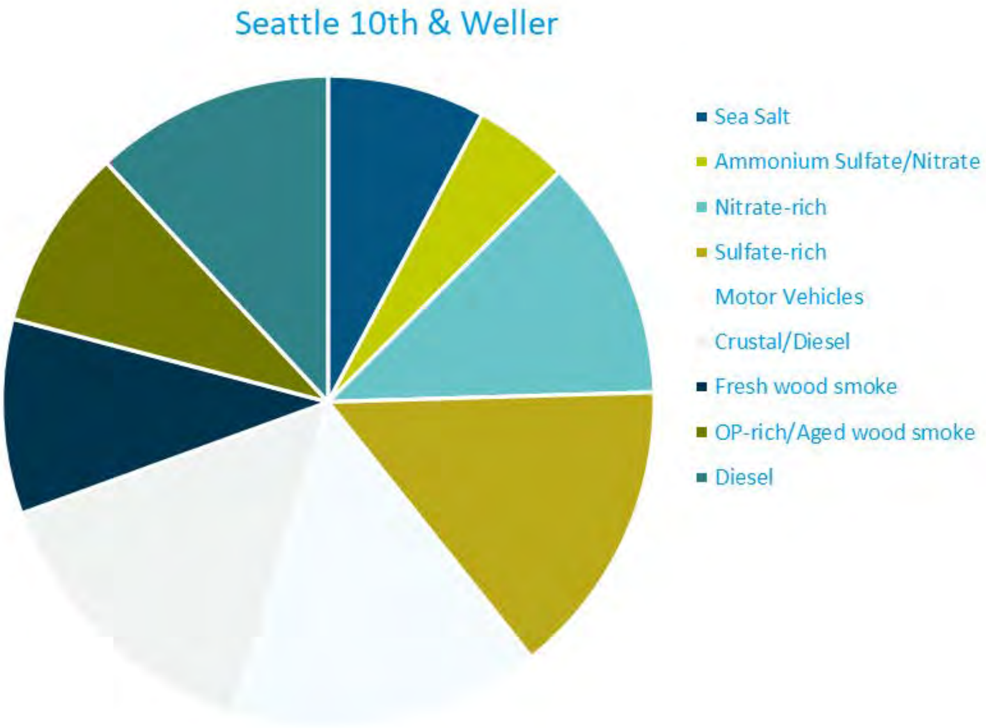


Figure K-5. Seattle 10th & Weller daily pollution roses for PMF factors

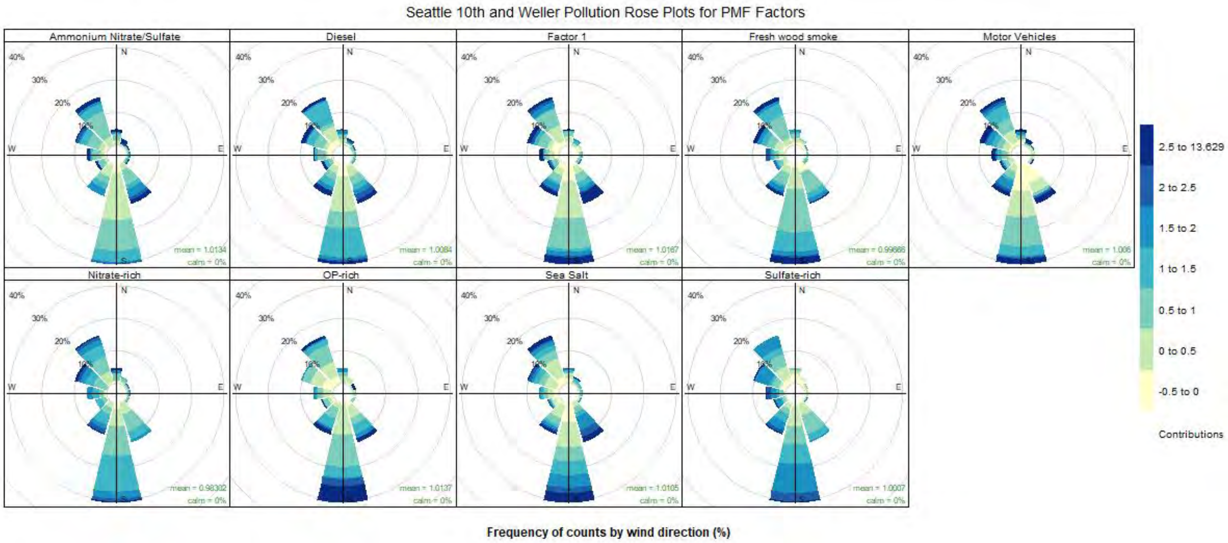


Figure K- 6. Seattle 10th & Weller seasonal trend for PMF factors

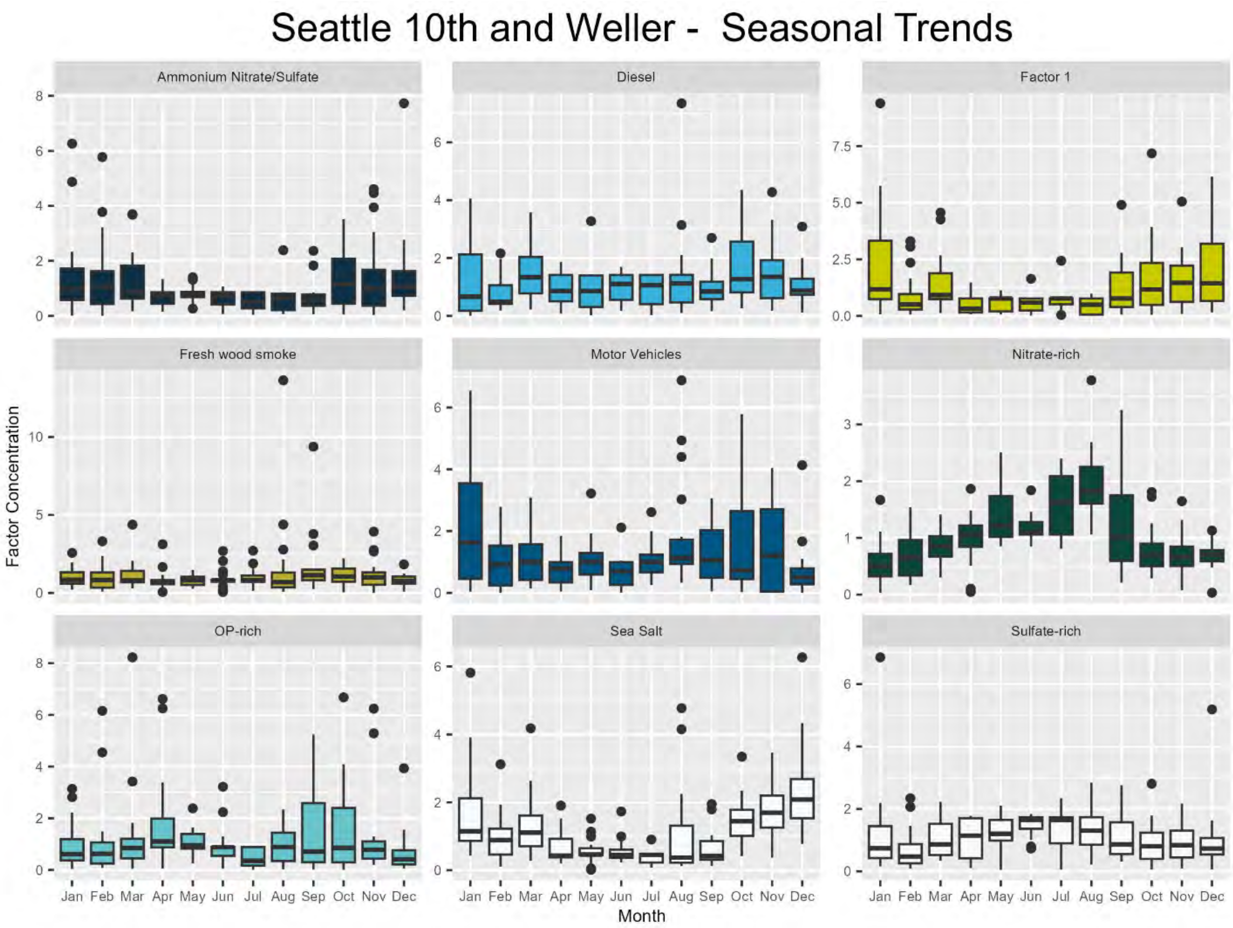


Figure K-7. Seattle Beacon Hill PMF Factor Pie Chart

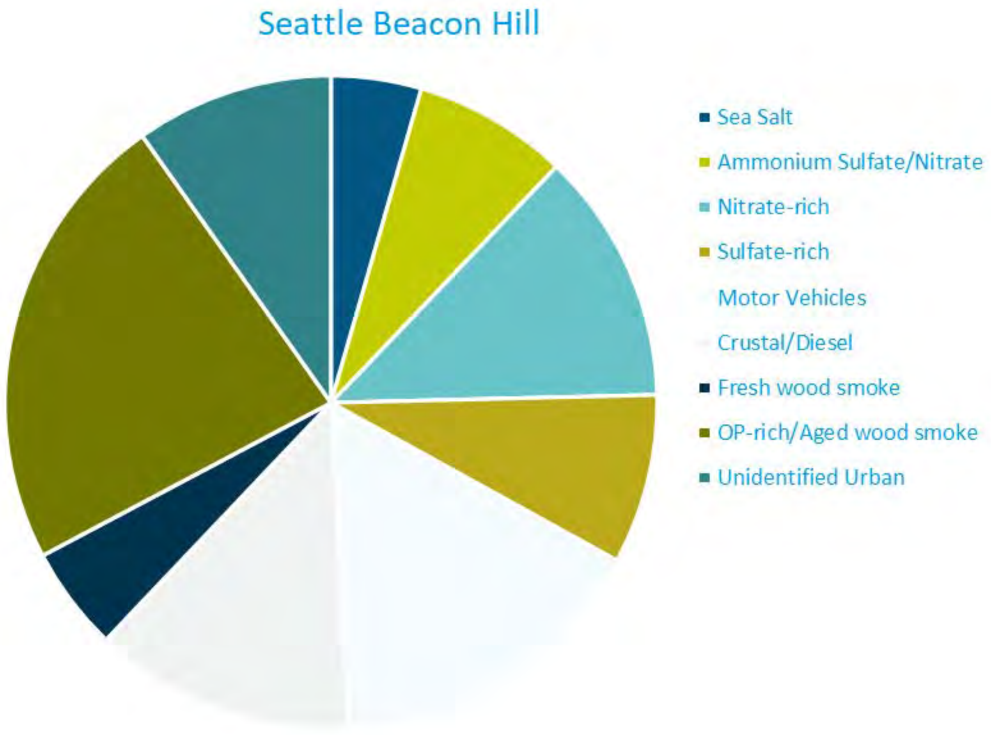


Figure K-8. Seattle Beacon Hill daily pollution roses for PMF factors

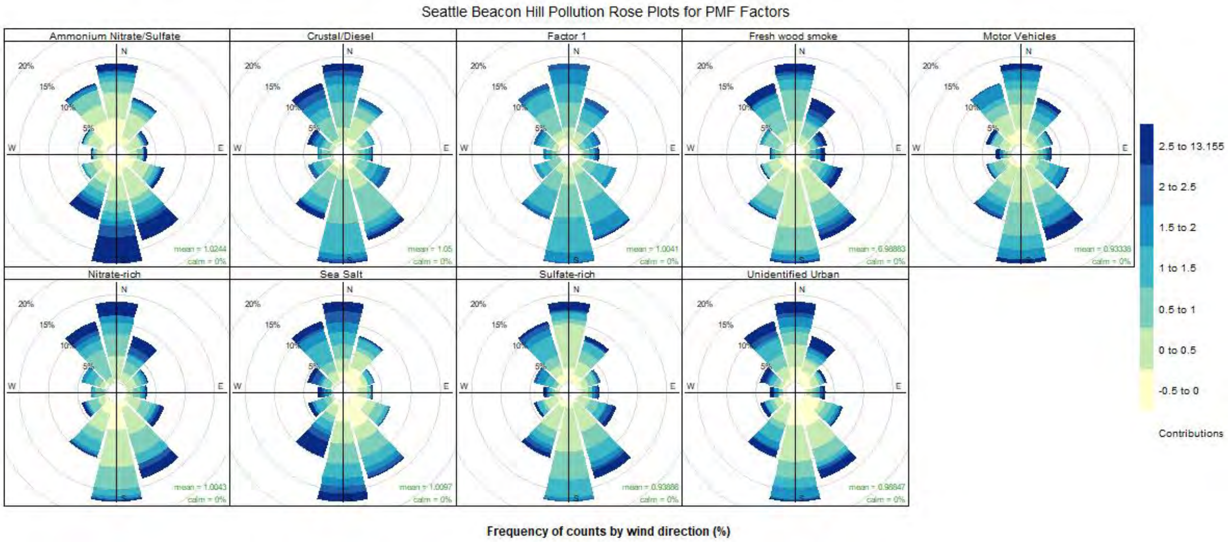


Figure K-9. Seattle Beacon Hill seasonal trend for PMF factors

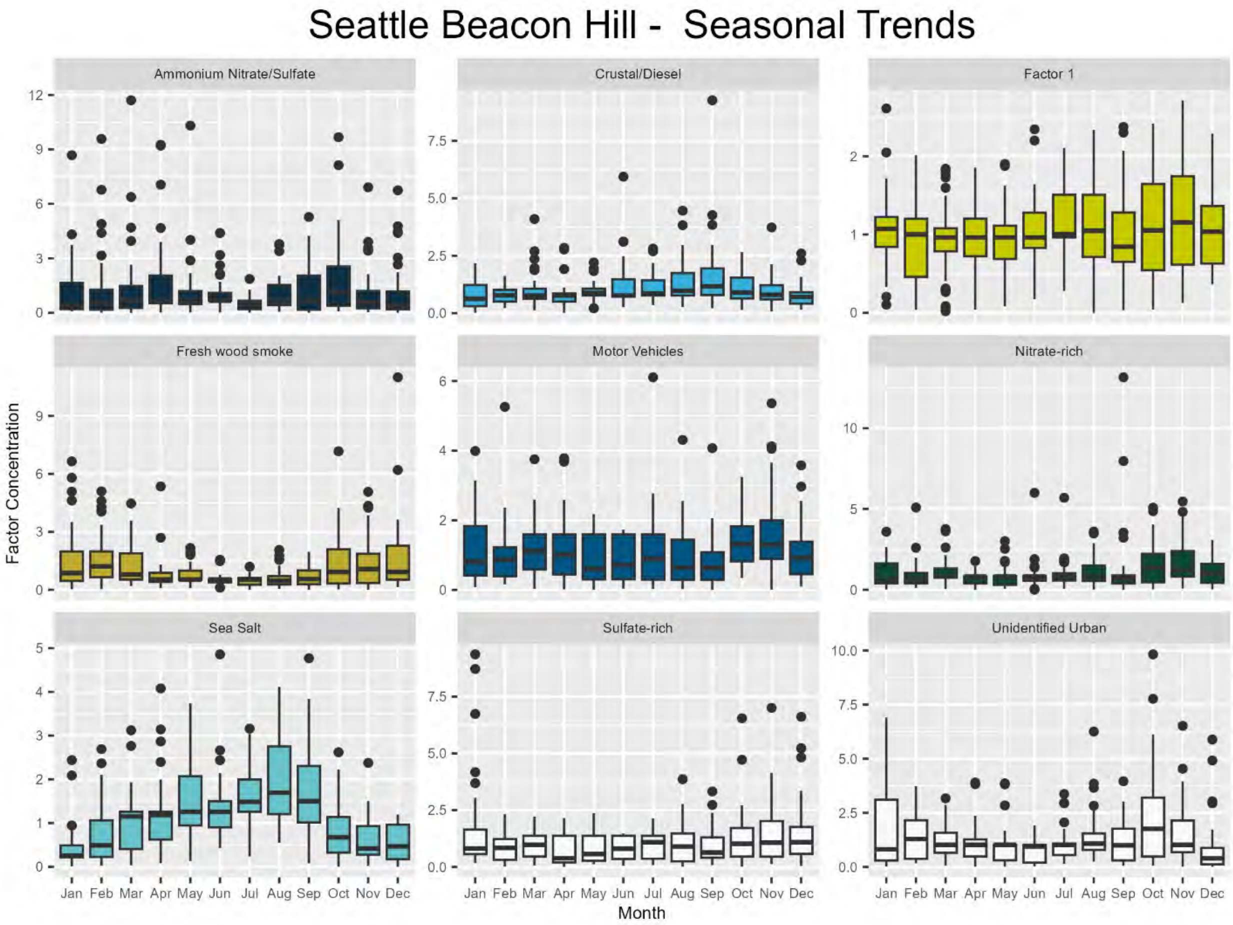


Figure K-10. Tacoma South L PMF Factor Pie Chart

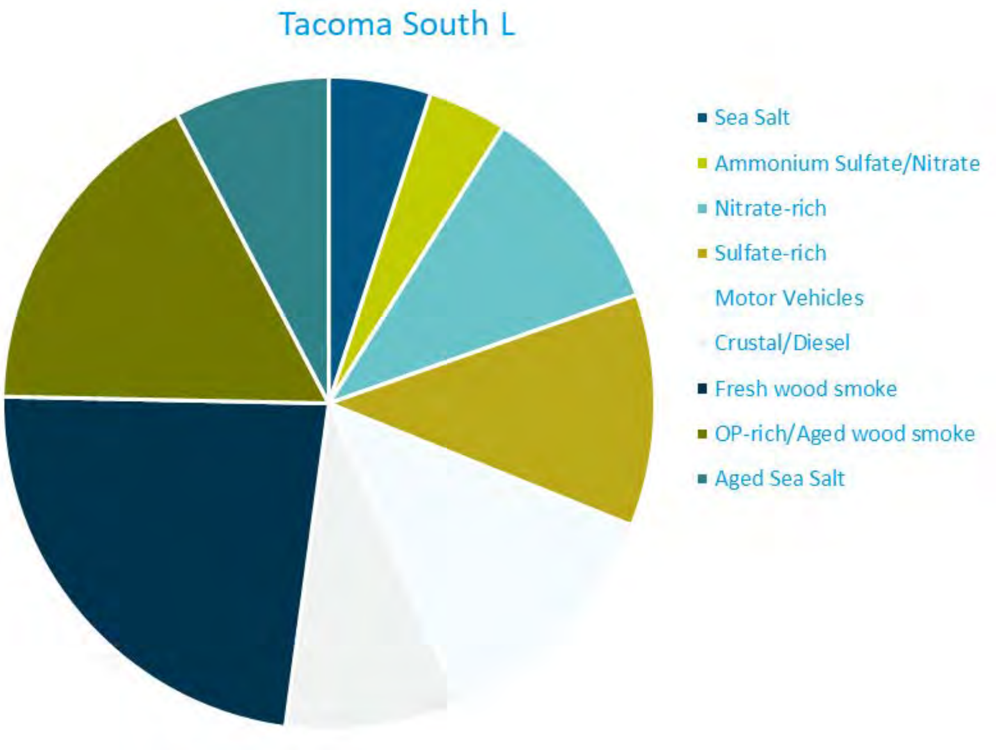


Figure K-11. Tacoma South L daily pollution roses for PMF factors

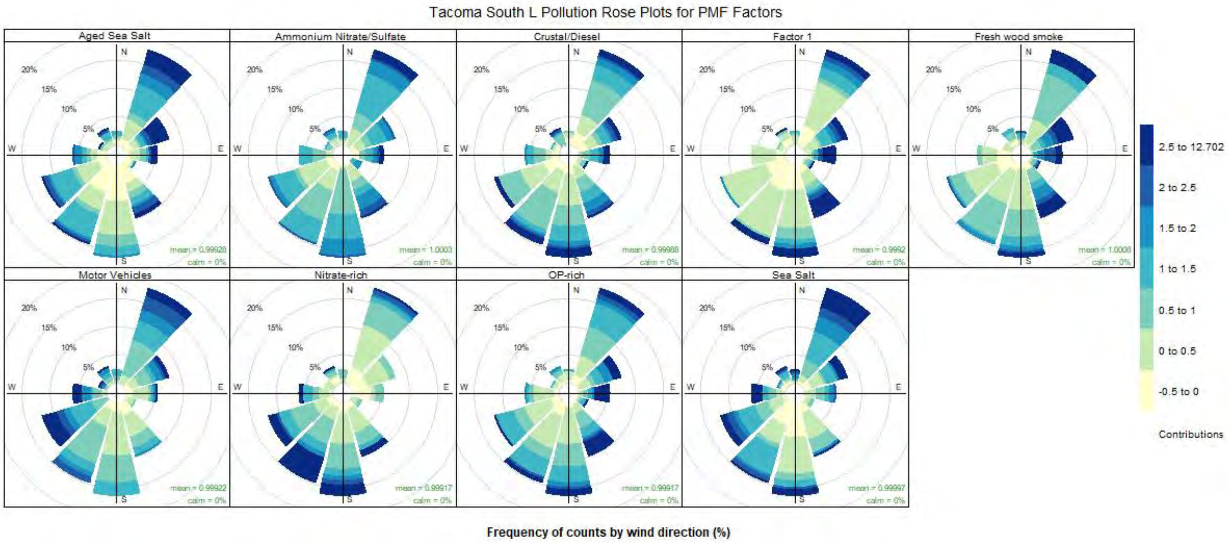


Figure K-12. Tacoma South L seasonal trend for PMF factors

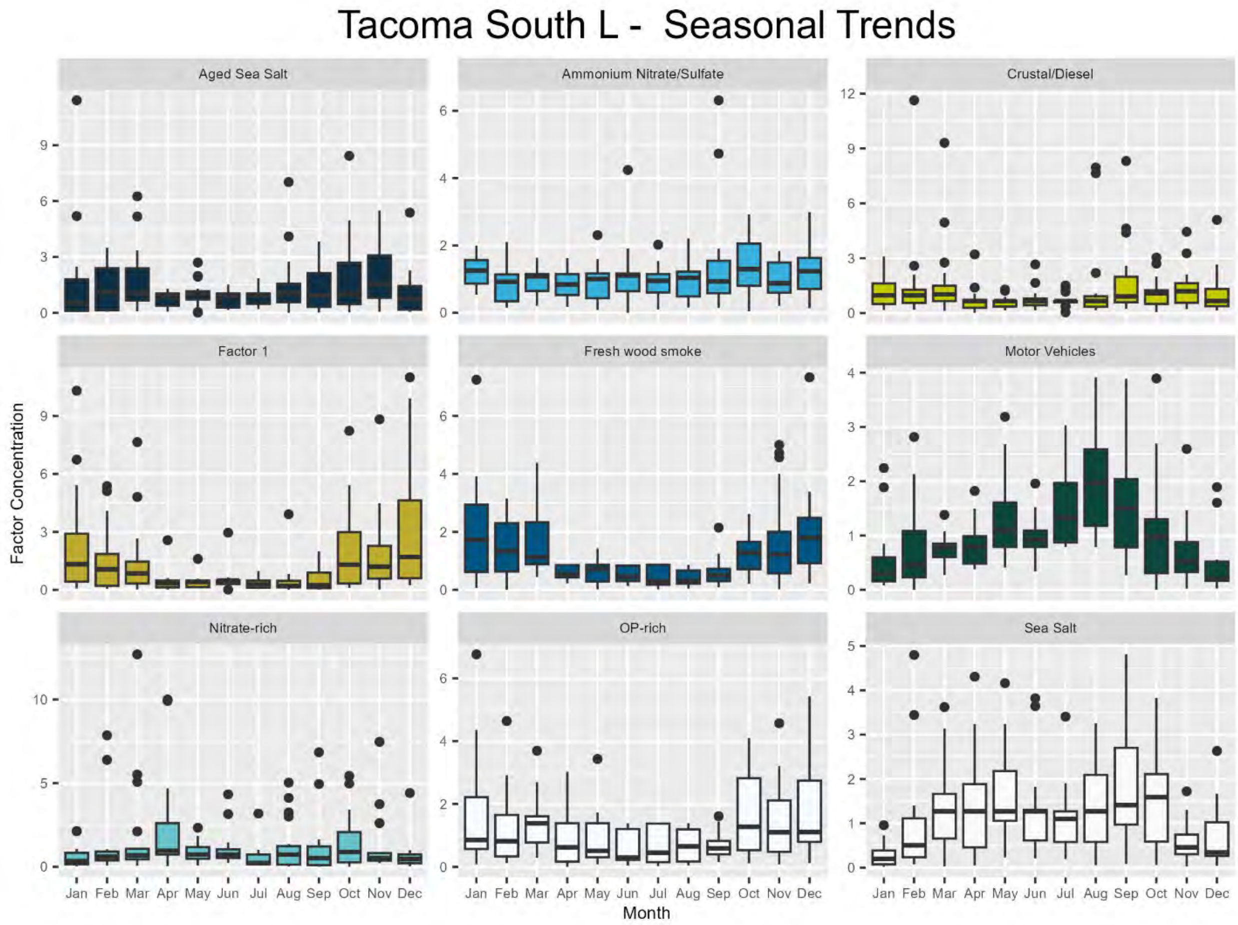


Figure K-13. Tacoma Tideflats PMF Factor Pie Chart

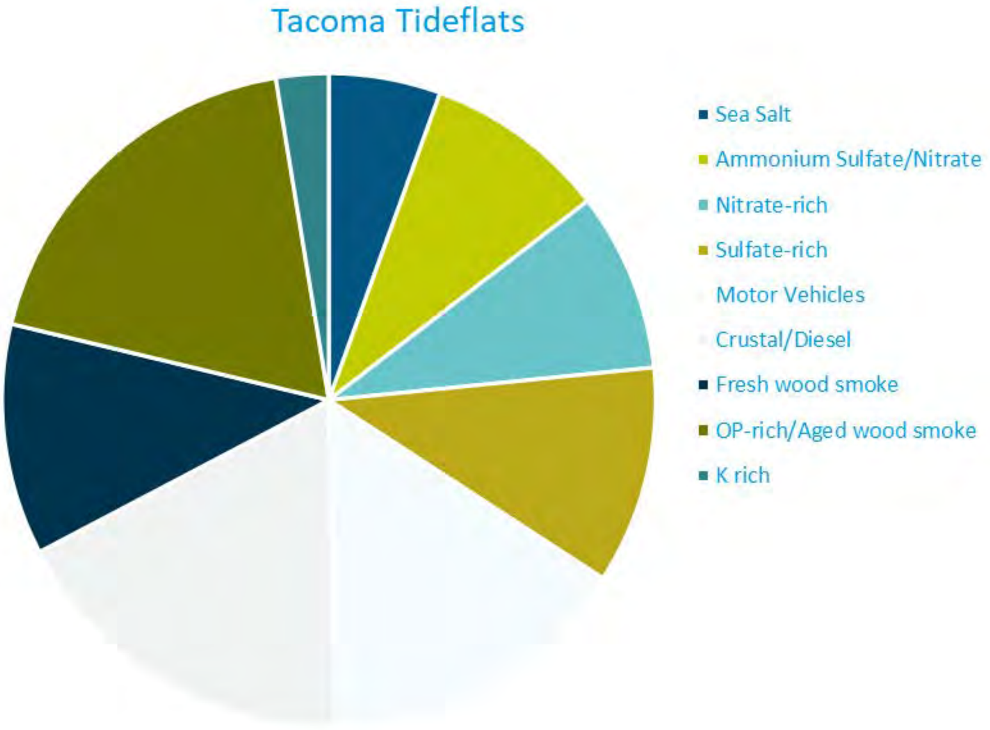


Figure K-14. Tacoma Tideflats daily pollution roses for PMF factors

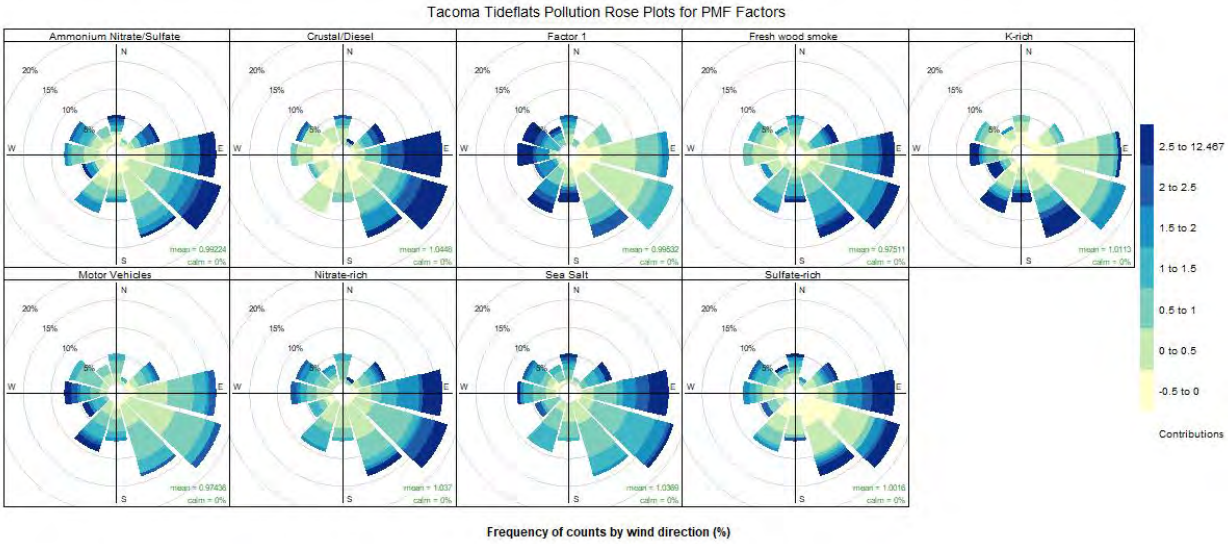
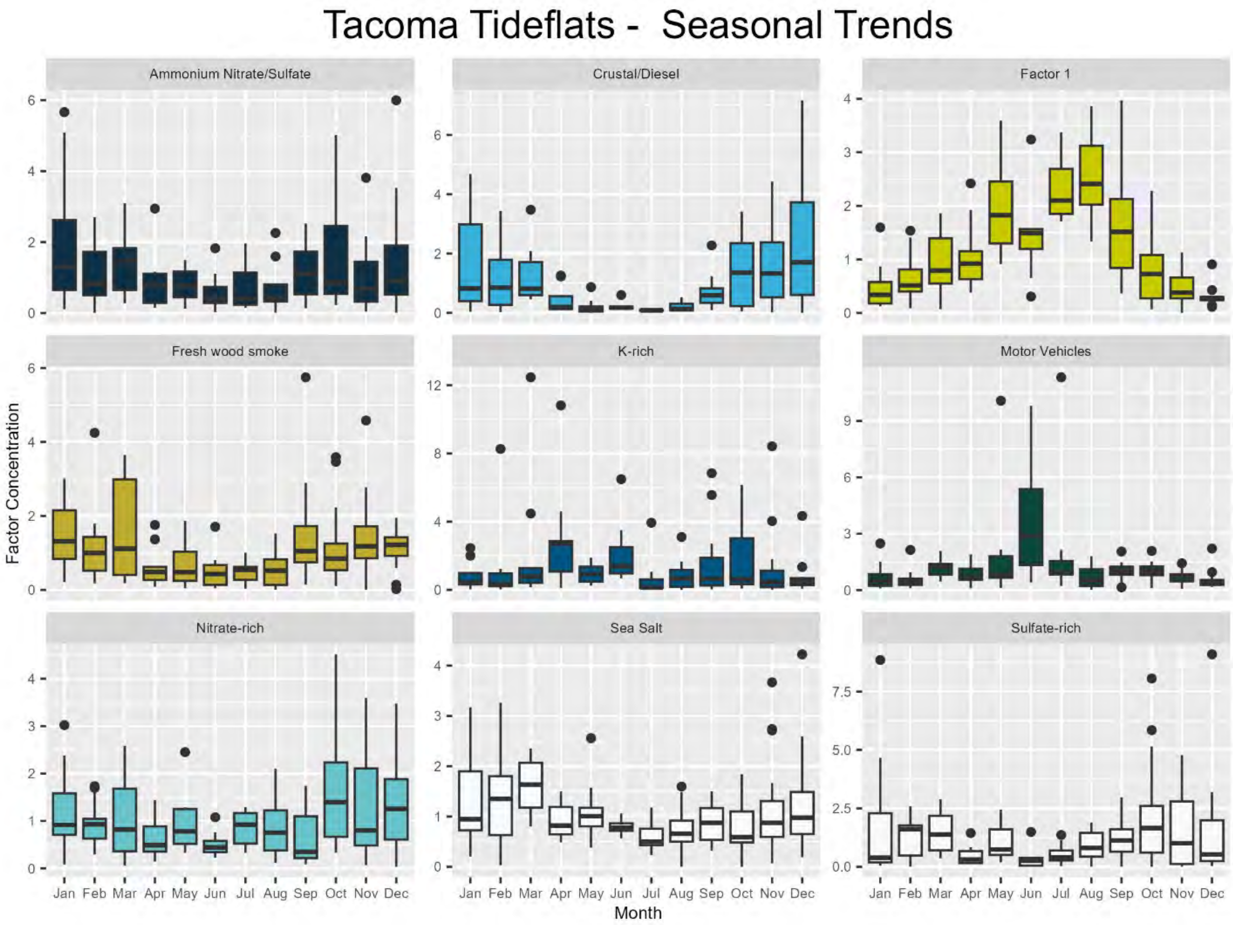


Figure K-15. Tacoma Tideflats seasonal trend for PMF factors

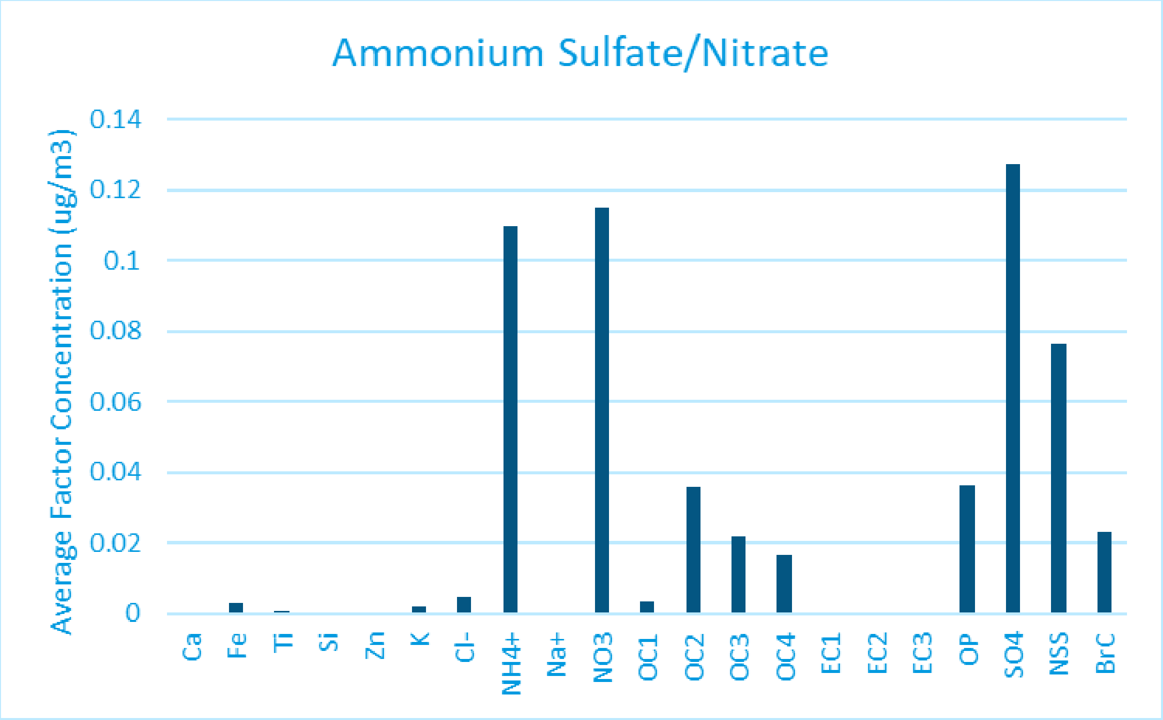


Factor descriptions:

Ammonium sulfate/nitrate:

The primary constituents in these factors were NH_4^+, NO_3^-, SO_4^{2-} and NSS. There were also contributions from higher-temperature OC components, pyrolyzed organic carbon (OP), and brown carbon (BrC). These factors represent 4-10% of $PM_{2.5}$ mass at the five sites, the highest concentrations being at Seattle Duwamish and Tacoma Tideflats, and lowest at Tacoma South L. The likely sources for these factors are oil refinery operations, wood combustion, and residual fuel oil. We were not able to verify any further because Nickel and Vanadium were not included in this analysis. Nickel and Vanadium have been used to confirm the identity of the residual fuel oil factor but could not be used in this analysis because they both did not meet the <MDL requirement. When increasing the number of factors in the PMF solution to 10 and 11, this factor did not split.

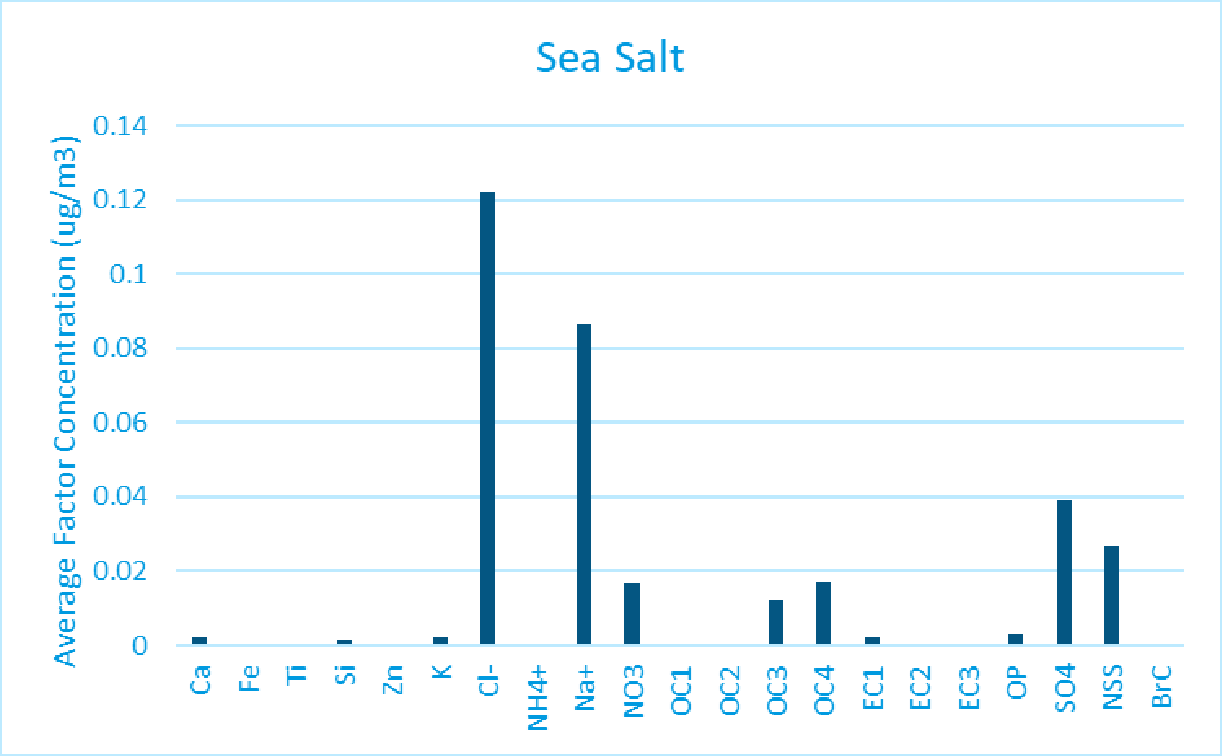
Figure K-16. Ammonium Sulfate/Nitrate Factor Profile



Sea Salt:

The sea salt factors were associated with the majority of Na^+ and Cl^-. These factors represent 4-8% of $PM_{2.5}$ mass at all sites, the highest concentrations being at Seattle 10th and Weller and Seattle Duwamish, and lowest at Seattle Beacon Hill.

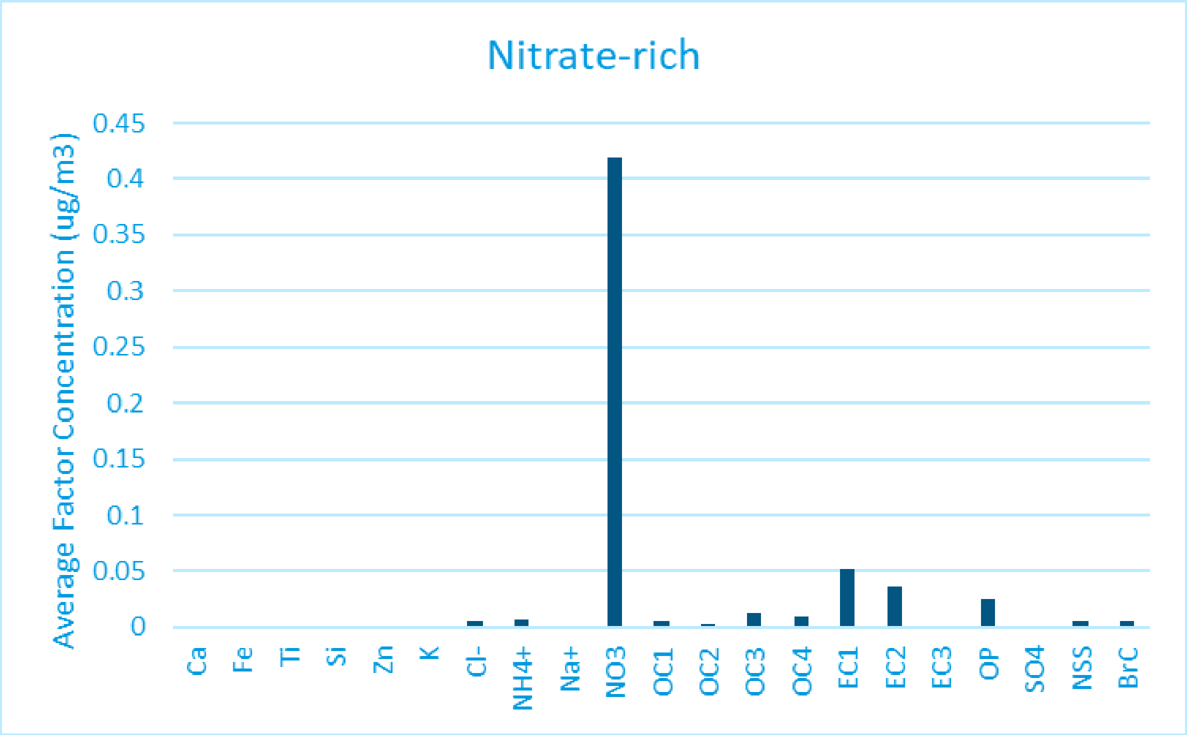
Figure K-17. Sea Salt Factor Profile



Nitrate-rich:

This factor was associated with high concentrations of NO_3^-, comprising between 9-21% of total $PM_{2.5}$ mass at the five sites. The highest proportion of $PM_{2.5}$ mass was at Seattle Duwamish at 21% and the other sites being between 9-12%. These factors are higher in winter for all sites, which is consistent with secondary nitrate. The presence of EC1, EC2 and OP also potentially suggests the presence of wood smoke.

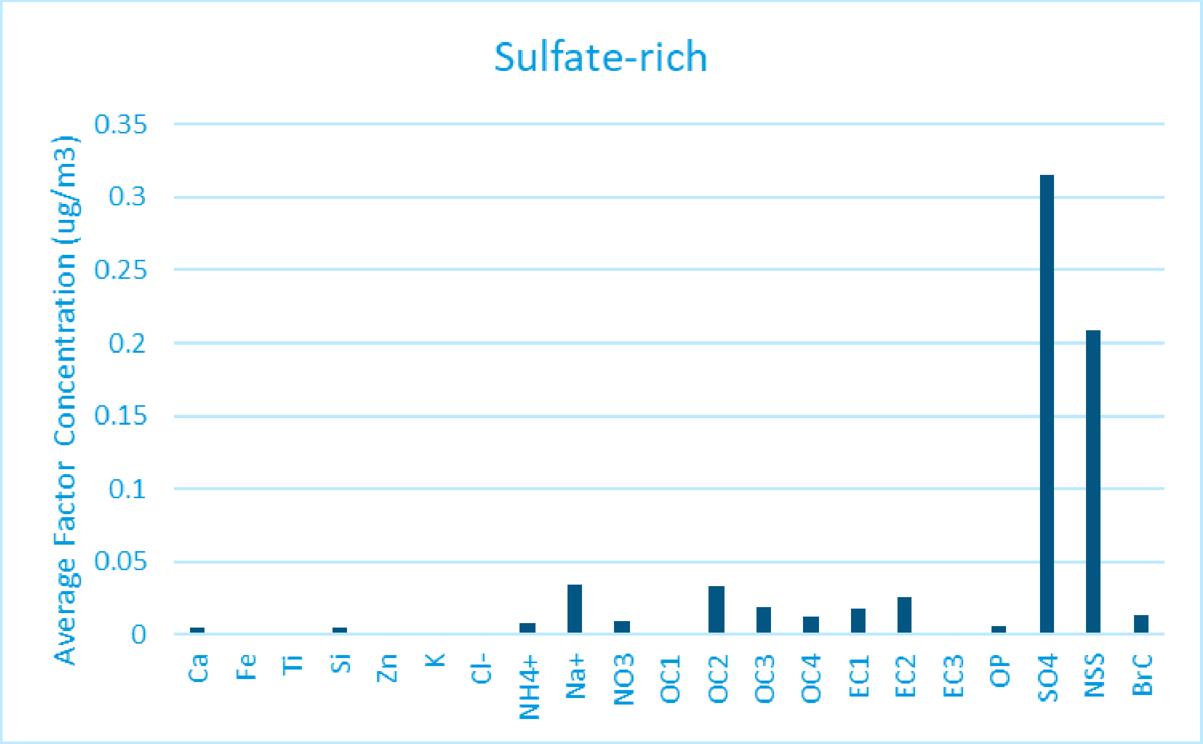
Figure K-18. Nitrate-rich Factor Profile



<u>Sulfate-rich</u>:

The sulfate-rich factors were associated with high concentrations of non-sulfate sulfur (NSS) and SO_4^{2-}. These factors comprised 8-15% of total $PM_{2.5}$ mass at the five sites, the highest being at Seattle Duwamish and Seattle 10th and Weller, and lowest Seattle Beacon Hill. The factors had higher concentrations during the summer for all sites. This seasonality is due to increased photochemical activity which forms secondary sulfate. There were also amounts of EC1 and EC2, likely due to maritime-related sources and fuel combustion. Past PMFs in the region have shown similar seasonality for factors assigned to maritime shipping.

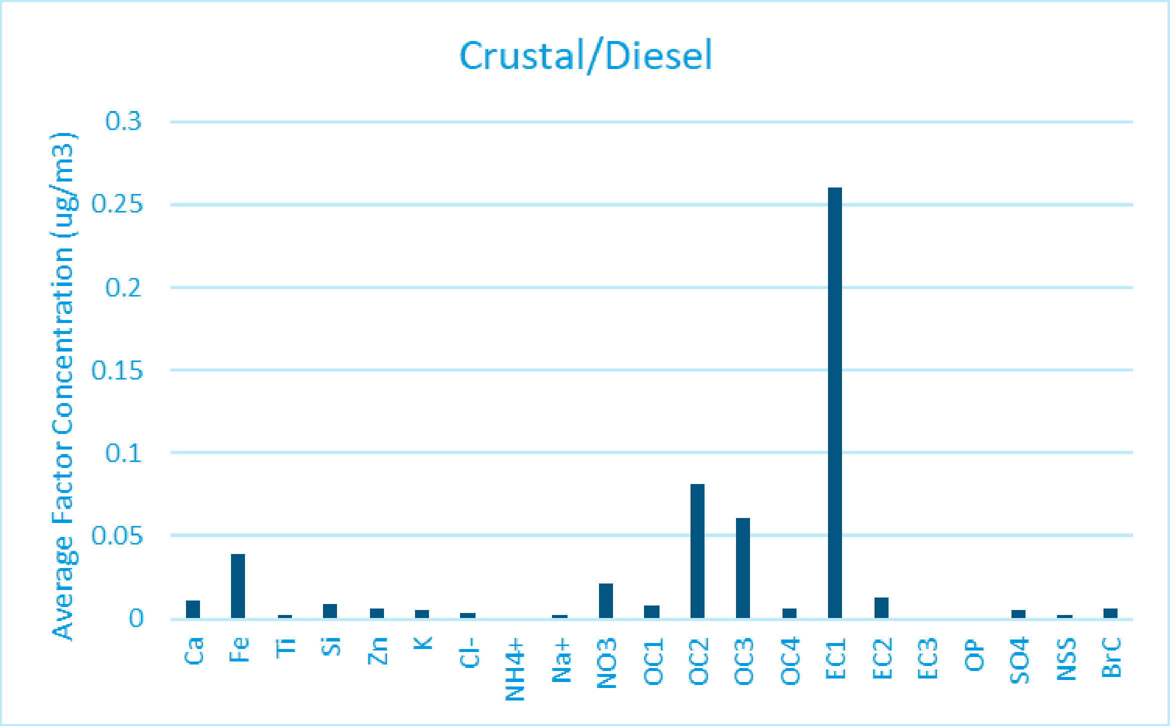
Figure K-19. Sulfate-rich Factor Profile



Crustal/Diesel:

These factors were a combination of diesel and crustal factors. It is characterized by high concentrations of EC1, some OC2 and OC3, and a majority of crustal elements Ca, Fe, Ti, Si, and Zn. These factors comprised 9-18% of total $PM_{2.5}$ mass at the five sites. The highest concentrations were at Tacoma Tideflats, likely due to increased truck traffic adjacent to our site during this study. During the study, there was an active dirt moving operation in which large dump trucks continuously passed within 20 feet of the site on a dirt road. The second highest concentration was at Seattle 10th and Weller, which is right next to I-5. When attempting to split this factor by running PMF with 10 or 11 factors, the factor did not split. Black carbon (BC) and nitrogen oxides (NO and NO_x/NO_y) are both markers of diesel emissions. BC and $NO/NO_x/NO_y$ were well correlated with these factors ($R^2 > 0.60$) at sites where they were measured. In addition, these factors were higher on the weekday compared to weekend, peaking Tuesday through Thursday. This weekday/weekend difference was least pronounced at the more residential sites, Seattle Beacon Hill and Tacoma South L, and most pronounced at Tacoma Tideflats.

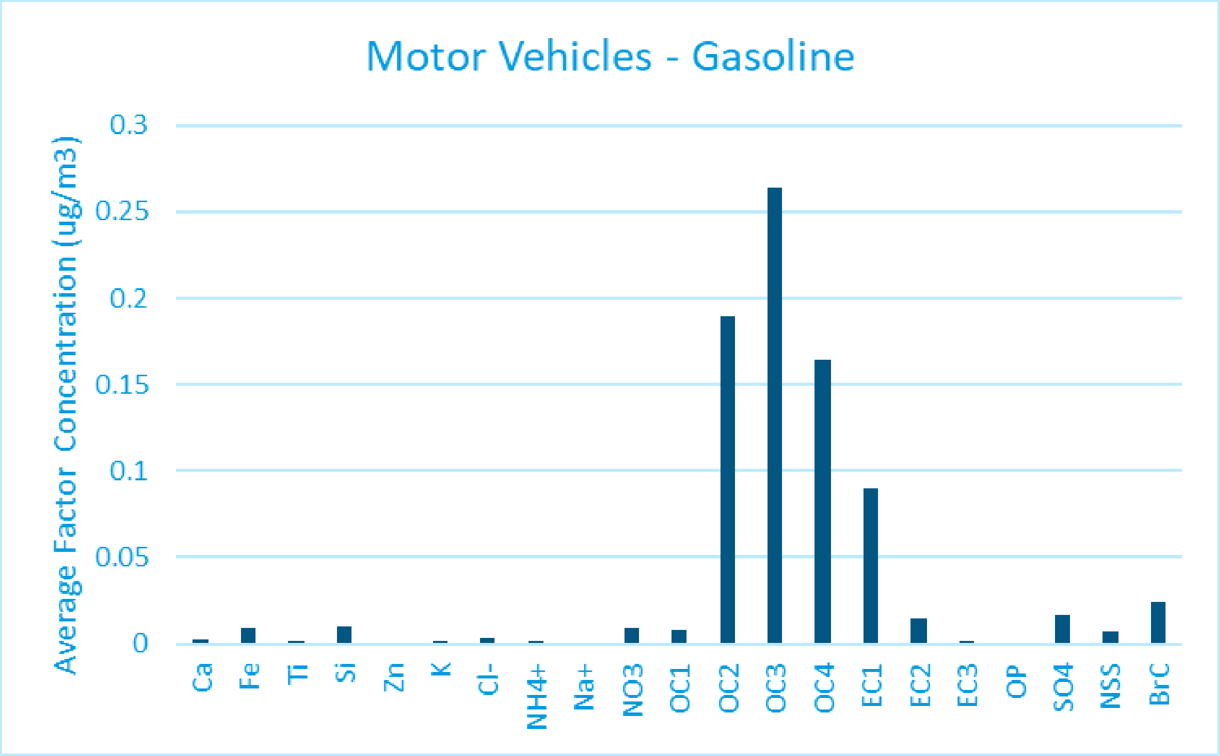
Figure K-20. Crustal/Diesel Factor Profile



Motor Vehicles - Gasoline:

The primary constituents in these factors were OC2, OC3, OC4, and EC1, and represented 12-17% of total $PM_{2.5}$ mass at the five sites. Highest concentrations for this factor were from Seattle Duwamish, Seattle 10th and Weller, and Tacoma Tideflats, with lower concentrations at the more residential sites Seattle Beacon Hill and Tacoma South L. The ratio between OC2, OC3, and OC4 in the factor profile is close to 1:2:1, which is characteristic of gasoline emissions. The factor also includes Fe which can come from tires and brakes, and Si which can come from re-entrained road dust.

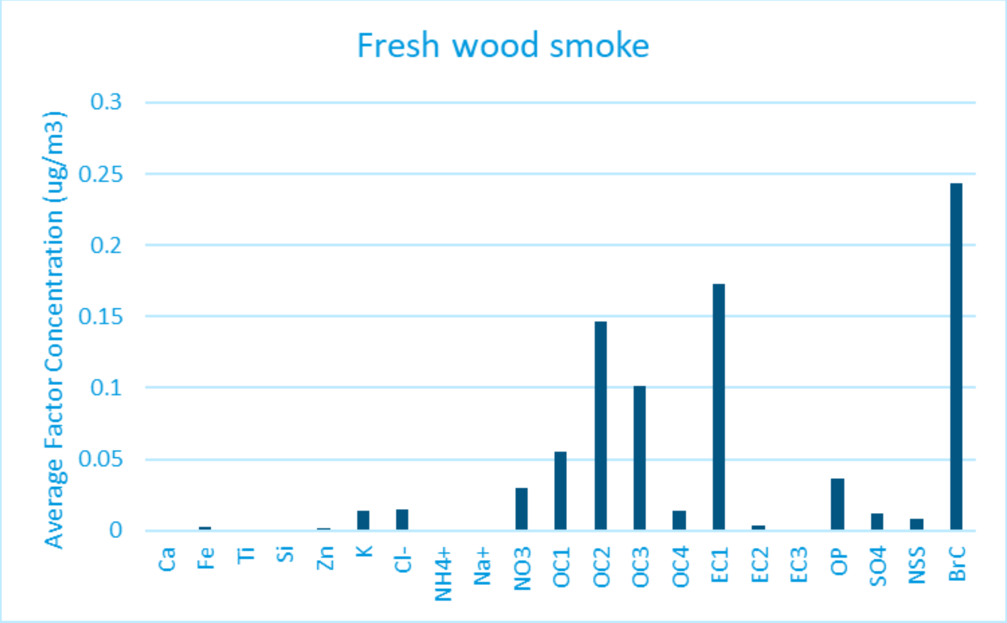
Figure K-21. Motor Vehicles - Gasoline Factor Profile



Fresh Wood Smoke:

The PMF factors associated with fresh wood smoke is characterized by high concentrations of lower temperature OC and EC fractions, significant portion of K, and brown carbon (BrC) at sites where BC/UV was measured. Concentrations peaked in the winter for most sites, consistent with the winter heating season. Average K/OC ratio was 0.043, similar to previous studies.[5,6] These factors comprise between 5-23% of total $PM_{2.5}$ mass at the five sites. The highest concentration by far was at Tacoma South L, with an annual $PM_{2.5}$ concentration of 1.42 $\mu g/m^3$. The fresh wood smoke factor is at Tacoma South L is significantly reduced compared to previous studies. Kotchenruther (2020) found wood smoke to contribute 3.53 $\mu g/m^3$ from 2015-2017 and 5.73 $\mu g/m^3$ from 2007-2009.[7] This continued reduction in fresh wood smoke $PM_{2.5}$ concentrations can be attributed to measures taken at the state and local level to reduce residential wood smoke PM emissions.

Figure K-22. Fresh Wood Smoke Factor Profile



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[5] Kotchenruther R. (2016). "Source apportionment of $PM_{2.5}$ at multiple Northwest U.S. sites: Assessing regional winter wood smoke impacts from residential wood Combustion". Amos Env 142:210-219.

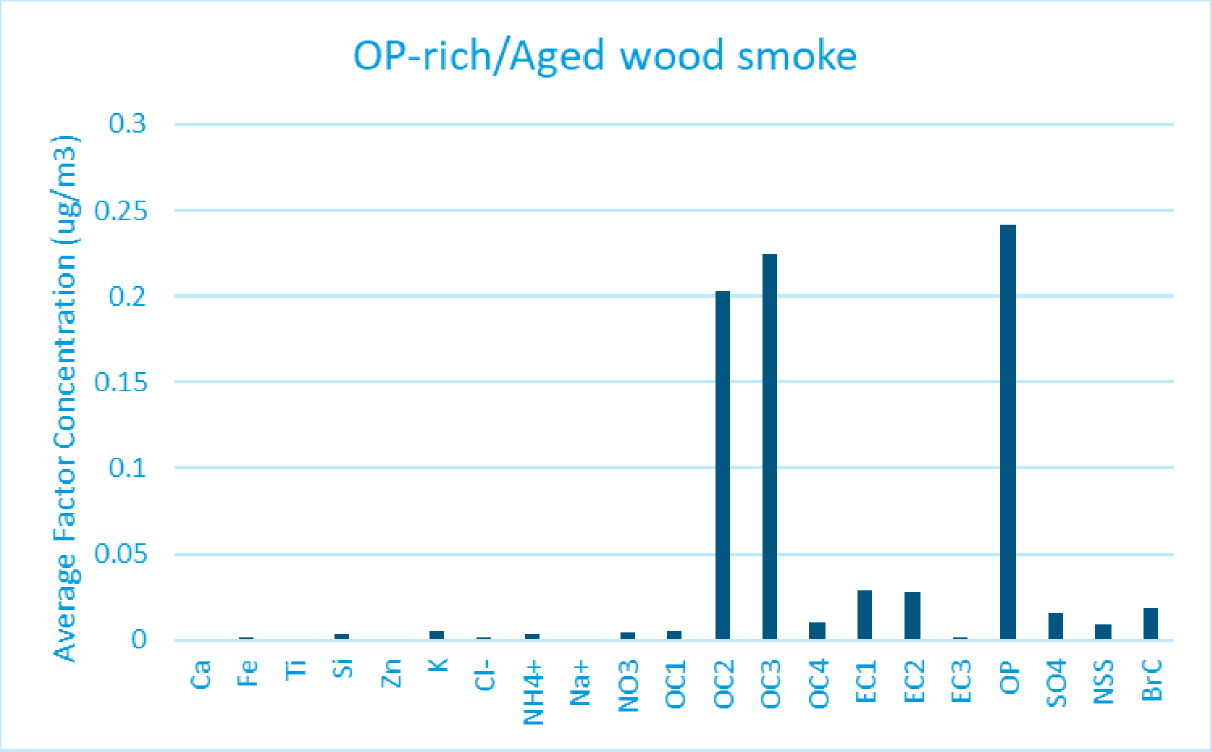
[6] Friedman B. (2020). "Source apportionment of $PM_{2.5}$ at two Seattle chemical speciation sites". J Air Waste Manag Assoc, 70:7, 687-699.

[7] Kotchenruther R. (2020). "Recent changes in winter $PM_{2.5}$ contributions from wood smoke, motor vehicles, and other sources in the Northwest U.S." Atmos Env 237:117724.

OP-rich/Aged Wood Smoke:

Thess factors were dominated by OC2, OC3, and OP, with some contributions from EC1, EC2, and BrC. They comprise between 7-23% of total $PM_{2.5}$ mass at the five sites. The highest concentrations are Seattle Beacon Hill, Tacoma South L, and Tacoma Tideflats. The lowest concentrations were Seattle 10th and Weller and Seattle Duwamish. Seasonal concentrations show a slight maximum in the winter. The factor is a mixture of aged wood smoke from winter wood home heating and wildfire smoke, and secondary organic aerosol formation. At most sites (expect Tacoma South L) the OP-rich factors correlated well with the fresh wood smoke factors ($R^2 >$ 0.5).

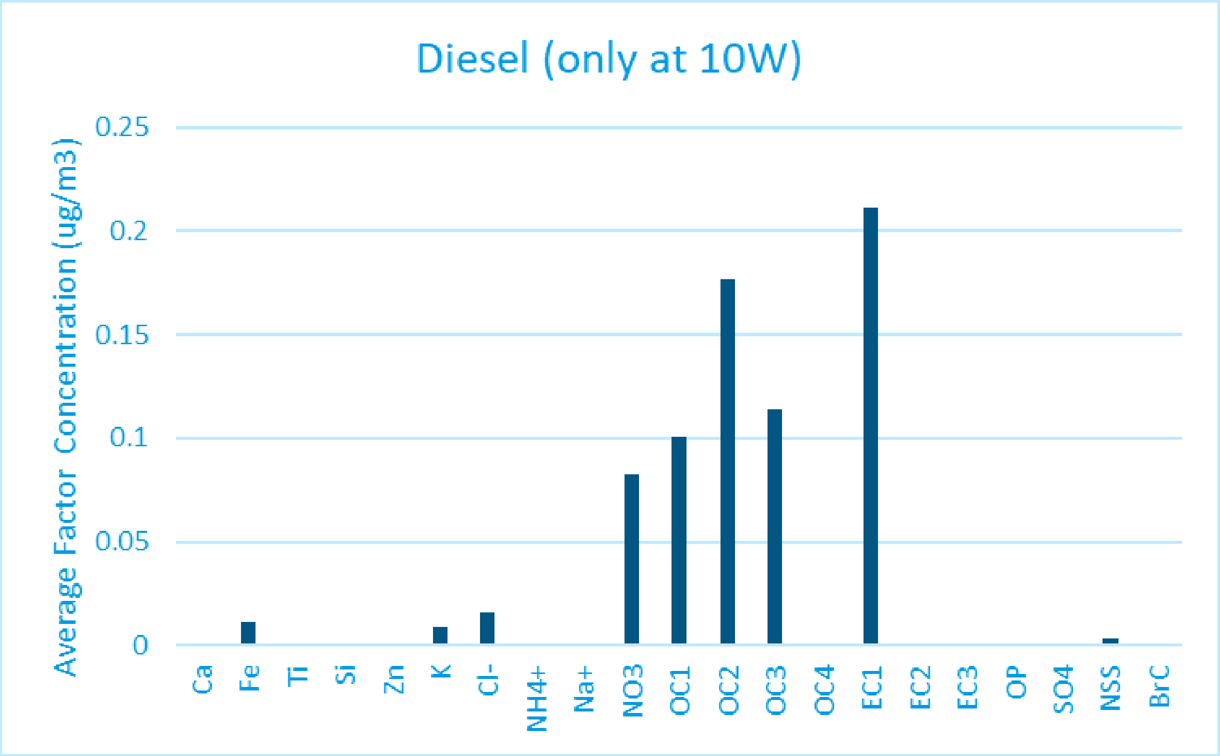
Figure K-23. OP-rich/Aged Wood Smoke Factor Profile



Motor Vehicles - Diesel:

This factor was found only at Seattle 10th and Weller. It comprised 11.9% of total $PM_{2.5}$ mass at Seattle 10th and Weller and was dominated by EC1, OC1, OC2, OC3, and NO_3, with contributions from Cl^-, Fe, and K. This factor was well correlated with BC ($R^2 = 0.61$), NO ($R^2 = 0.66$), and NO_2 ($R^2 = 0.52$), which are markers of diesel exhaust.

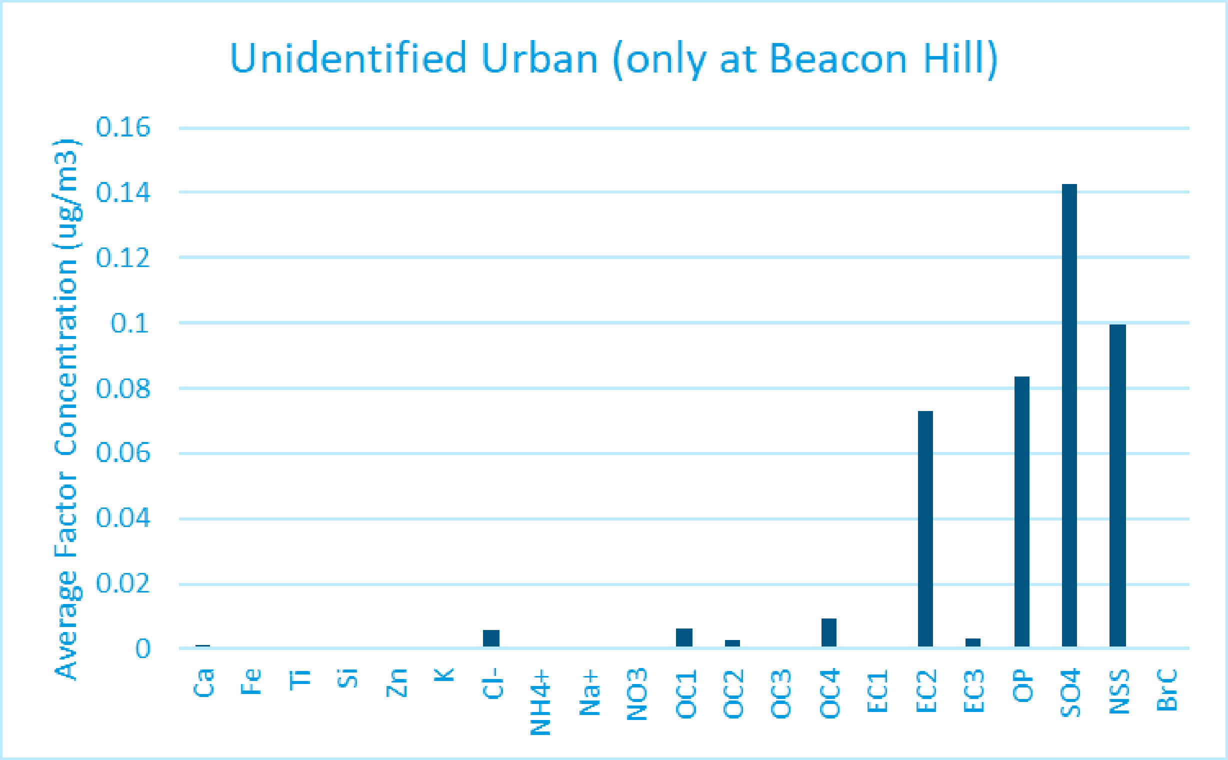
Figure K-24. Motor Vehicles - Diesel Factor Profile



Unidentified Urban:

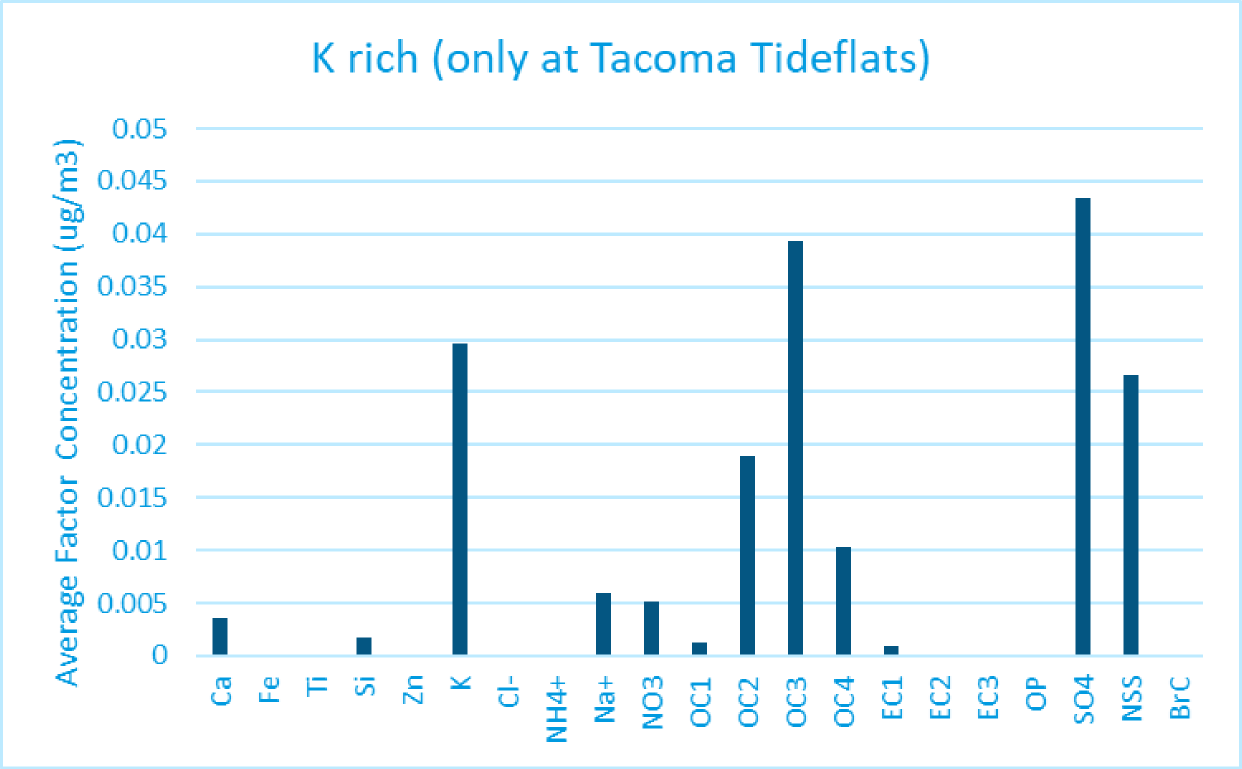
The Unidentified Urban factor was found only at Seattle Beacon Hill. It was dominated by EC2, OP, SO_4^{2-}, and NSS, and comprised 9.8% of total $PM_{2.5}$ mass. The source of this factor is unclear, but it is likely secondary organic aerosol from a variety of sources related to fuel combustion. There were no seasonal trends are observed.

Figure K-25. Unidentified Urban Factor Profile



K rich: The K rich factor was found only at Tacoma Tideflats. It is characterized by a majority of K, with contributions of higher temperature OC's, SO_4, and NSS. This factor only contributed 2.6% of $PM_{2.5}$ mass and the time-series were dominated by spikes in concentration during summer days. During these summer spikes no significant increase were observed in other PMF factors, BC, or $PM_{2.5}$, suggesting local firework activity. This factor was also found at Tacoma Tideflats by Friedman (2023).[8]

Figure K-26. K-rich Factor Profile



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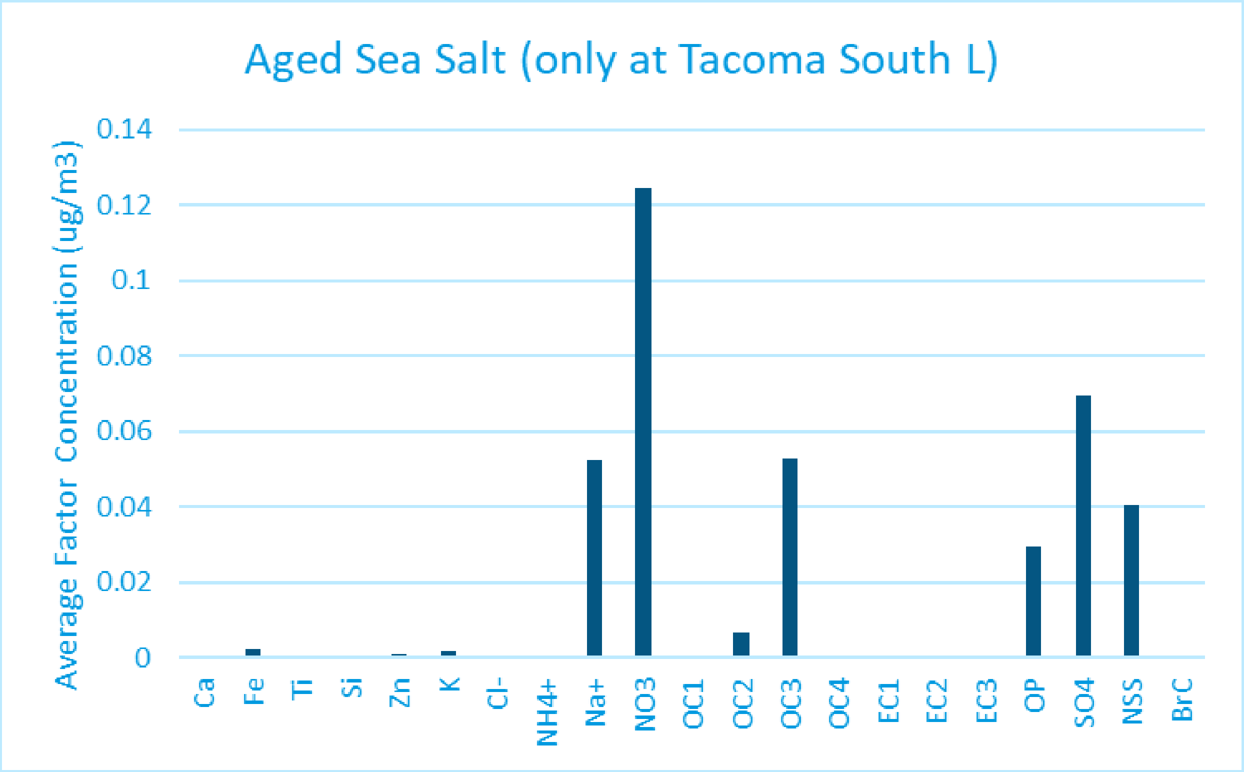
[8] Friedman, B. (2023). "Technical Report: Port of Tacoma Source Apportionment Study". WA Ecology, Publication 23-02-075.

Aged Sea Salt: This factor was only found only at Tacoma South L. It is nearly the same as the sea salt factor, except all of the Cl⁻ has been replaced with nitrate.

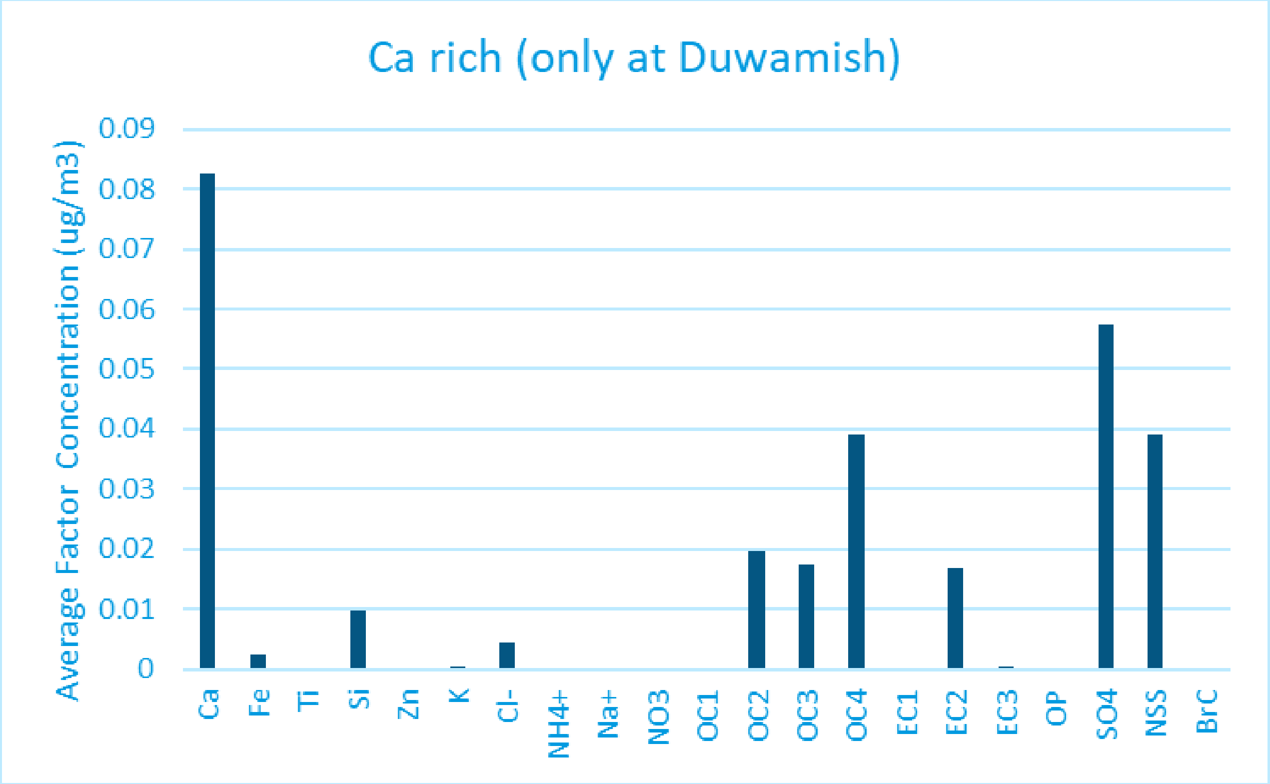
Figure K-27. Aged Sea Salt Factor Profile



<u>Ca rich</u>:

The Ca rich factor was only found at Seattle Duwamish and has the majority of Ca, as well as contributions from OCs, SO4 and NSS. This factor could be linked to cement production or other calcium rich operations and made up 6.5% of $PM_{2.5}$ at Duwamish. This factor has been found in previous studies at the Duwamish site.[9,10] Annual $PM_{2.5}$ concentration associated with this factor is similar to that in the 2013 study (0.40 μg/m^3 compared to 0.42 μg/m^3 in this study). In the 2008 study the factor annual average was 0.57 μg/m^3.

Figure K-28. Ca-rich Factor Profile



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[9] Kotchenruther R. (2013). "A regional assessment of marine vessel $PM_{2.5}$ impacts in the U.S. Pacific Northwest using a receptor-based source apportionment method". Atmos Env 68: 103-111.

[10] Hopke P., Kim E. (2008). "Source characterization of ambient fine particles at multiple sites in the Seattle area". Atmos Env 42:6047-6056.

Appendix L. Additional PMF analysis including air toxics

Additional source contributions were conducted using PMF by including air toxics data along with the speciation data for each site. There were some common sources and trends observed at the sites. For instance, motor vehicles and wood smoke were the biggest contributors at each site. During summer months, we observed higher production of secondary pollutants like ammonium sulfate, ammonium nitrate, formaldehyde, and acetaldehyde. There were some factors which were observed at only a few sites like acenaphthylene-rich factor and manganese-rich factor were observed only at Seattle Duwamish and Seattle Beacon Hill sites due to potential outliers. Below are the results from all the sites:

Seattle Duwamish: We used air toxics (carbonyls, VOCs, SVOCs, and PM_{10} metals) along with the speciation data at the Duwamish site for the additional PMF analysis. The ten factors were identified at the site out of which motor vehicles, wood smoke and secondary sulfate were the biggest contributors. Additionally, diesel and gasoline sources were identified based on the organic species. The SVOCs like benzo(a)anthracene, benzo(a)pyrene, Indeno(1,2,3-c,d)pyrene, benzo(b)fluoranthene are characteristic of gasoline emissions and SVOCs like anthracene, fluoranthene, fluorene, phenanthrene, pyrene are characteristic of diesel emissions. There were additional factors like Manganese rich factor and acenaphthylene rich factor, which were observed only at this site as mentioned earlier. Below is a pie-chart of the contributing factors.

Figure L-1. Seattle Duwamish additional PMF Factor Pie Chart

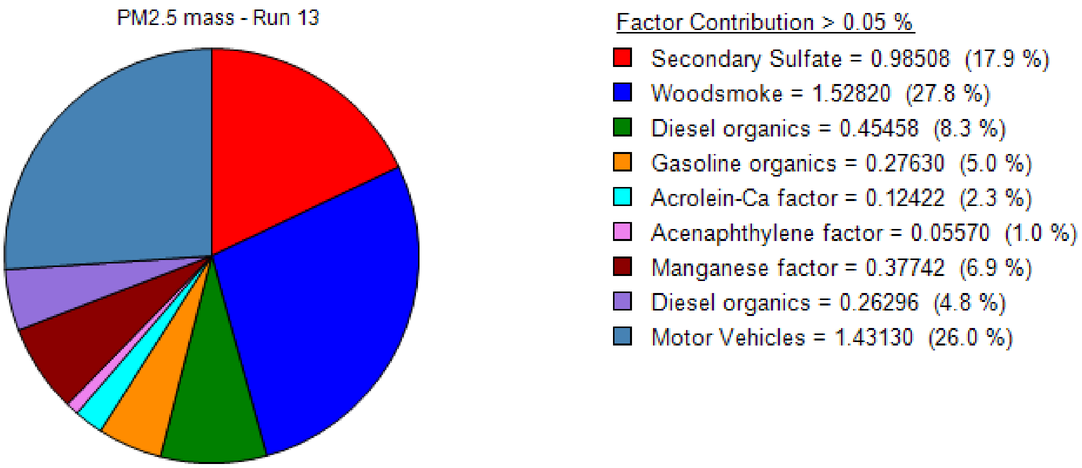


Figure L-2. Seattle Duwamish seasonal trend for PMF factors.

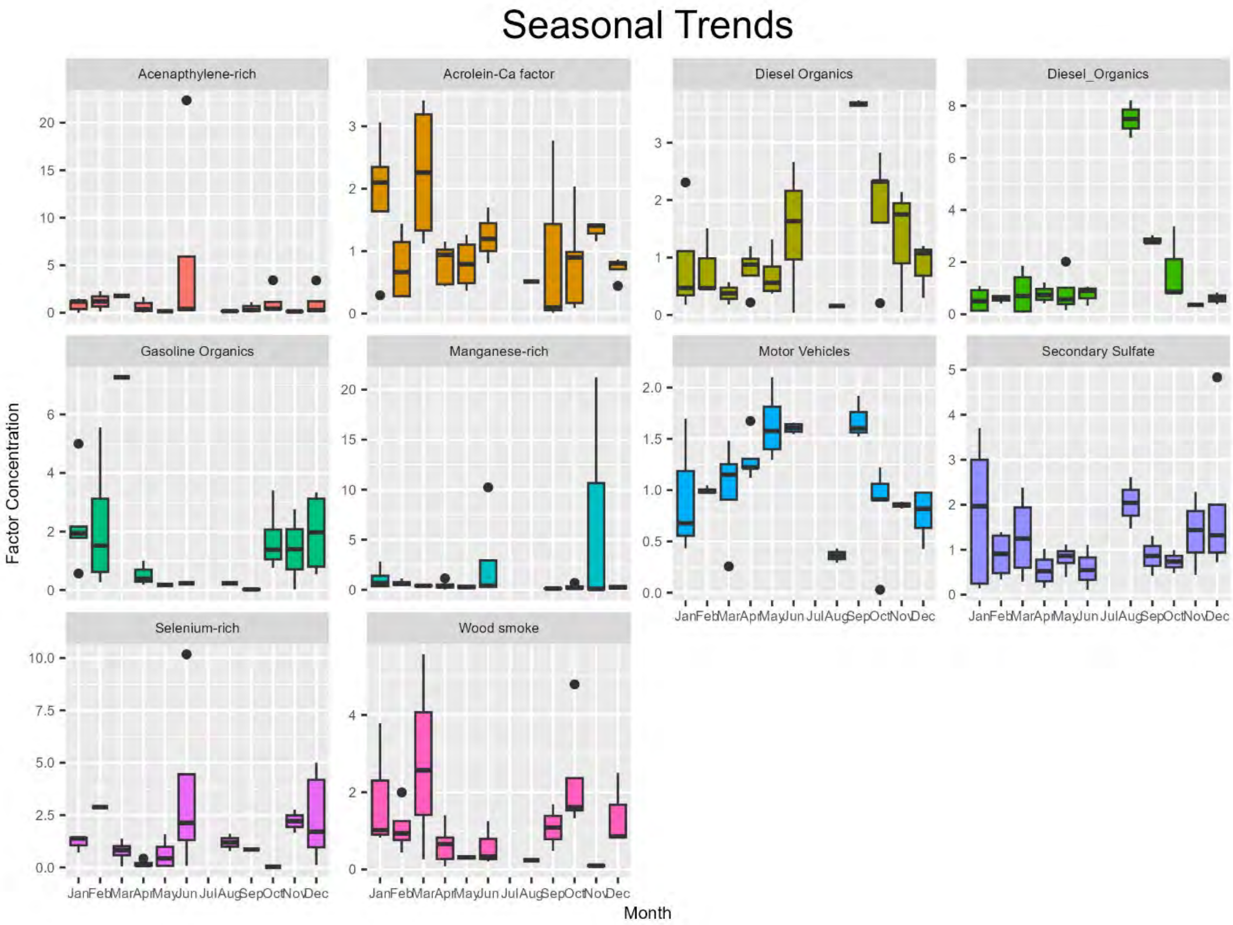


Figure L-3. Seattle Duwamish factor fingerprints PMF factors.

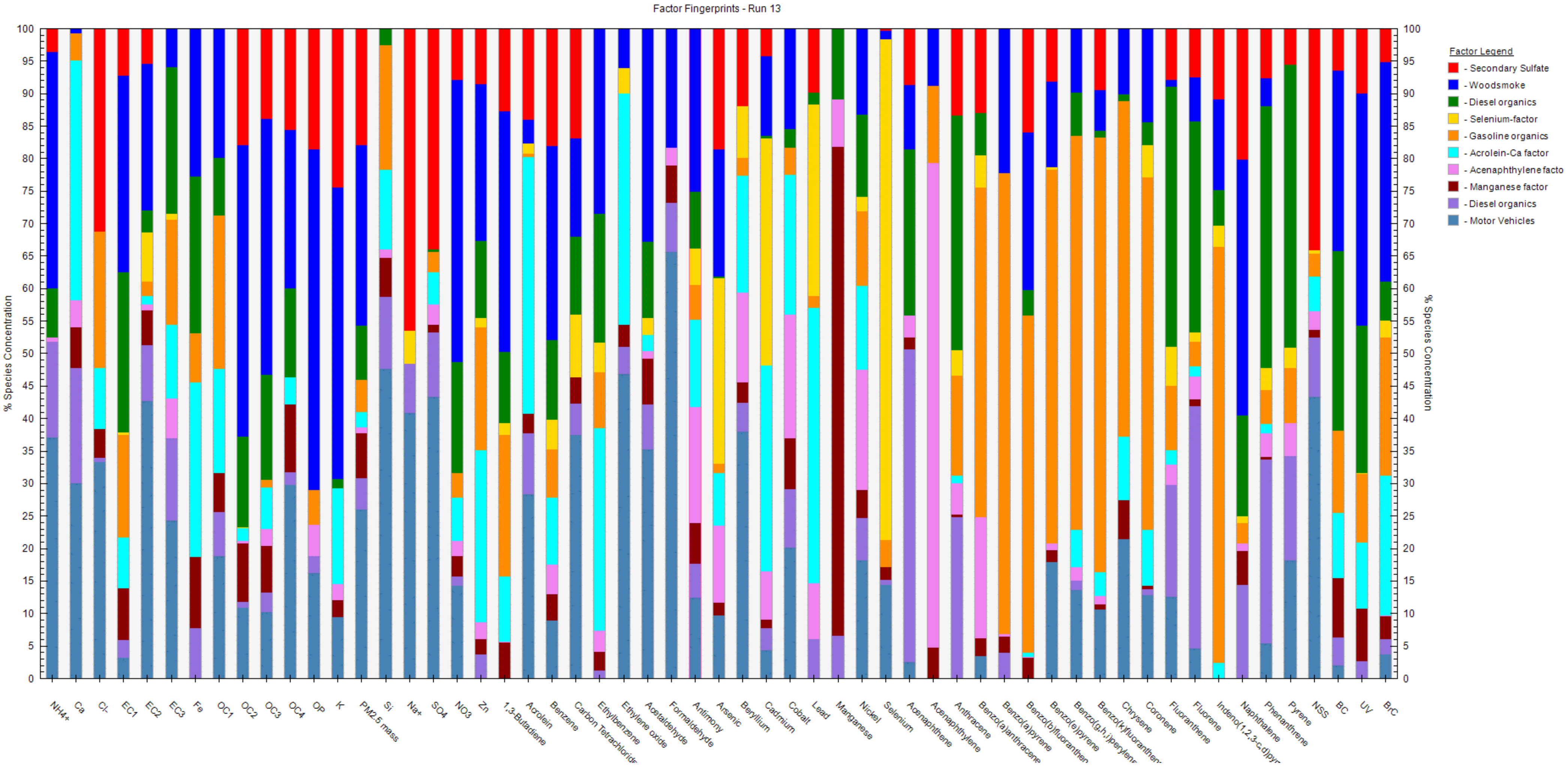
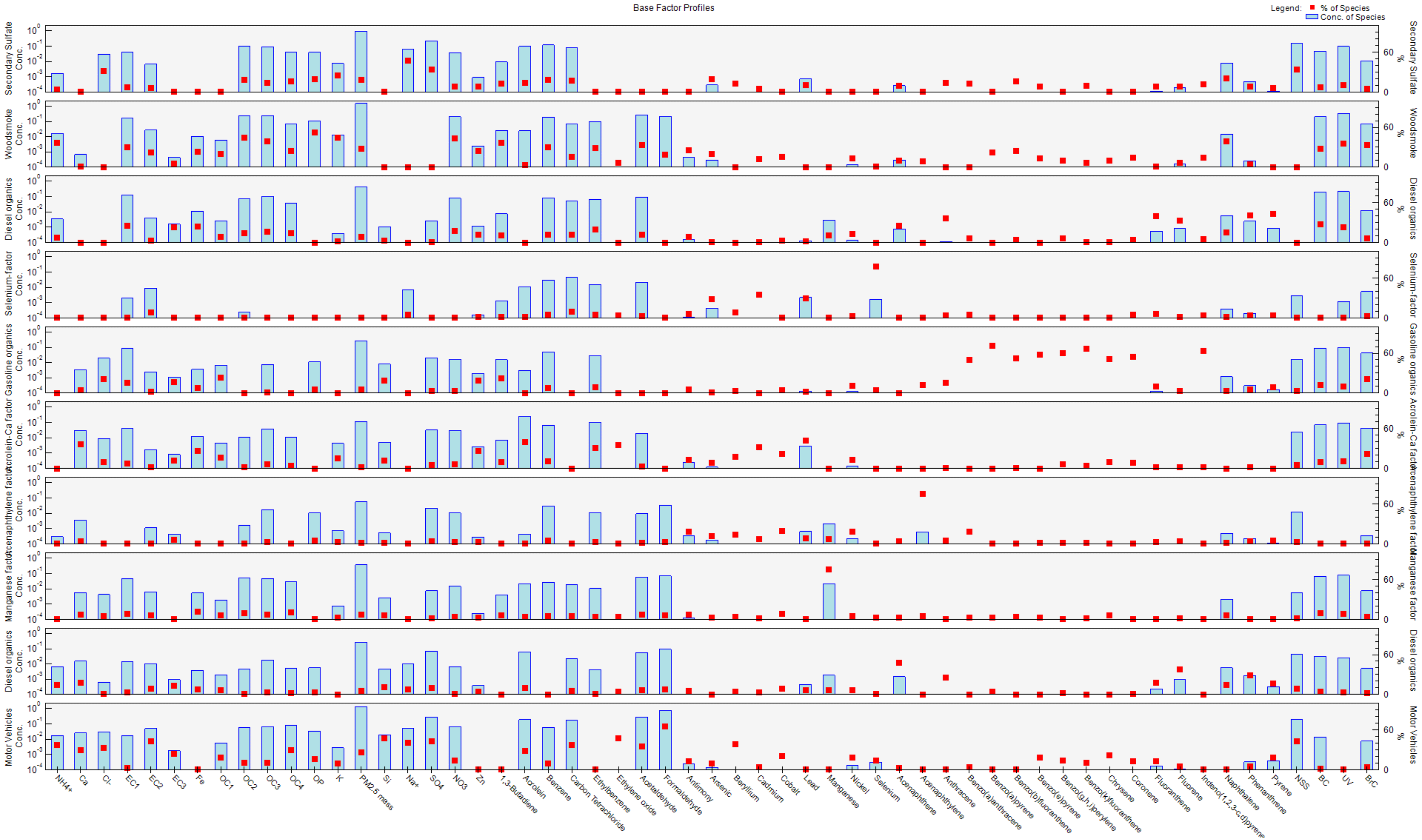


Figure L-4. Seattle Duwamish profiles and contributions for PMF factors.



Seattle 10th and Weller: We used air toxics (carbonyls, and VOCs) along with the speciation data at the 10th and Weller site for the additional PMF analysis. The nine factors were identified at the site out of which motor vehicles, wood smoke, ammonium nitrate and crustal/urban and were the biggest contributors. The site is a curbside location next to the I-5 and thus is heavily impacted by motor vehicles and the resuspension of dust which is reflected as crustal/urban source. Acrolein is also emitted from vehicle exhaust, tobacco smoke, and living near oil refineries, or pulp and paper mills. The acrolein-rich factor was highly correlated with the VOCs in the samples. Additionally, secondary sulfates, industrial solvents and sea salt were also identified based on the species signatures. Below is a pie-chart of the contributing factors.

Figure L-5. Seattle 10th and Weller additional PMF Factor Pie Chart

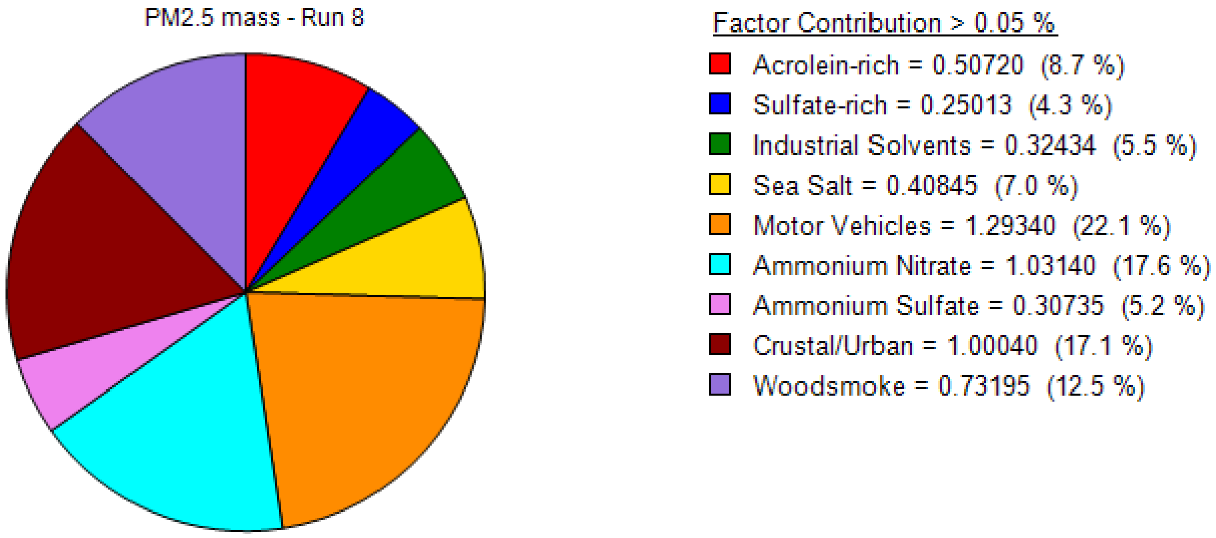


Figure L-6. Seattle 10th and Weller seasonal trend for PMF factors

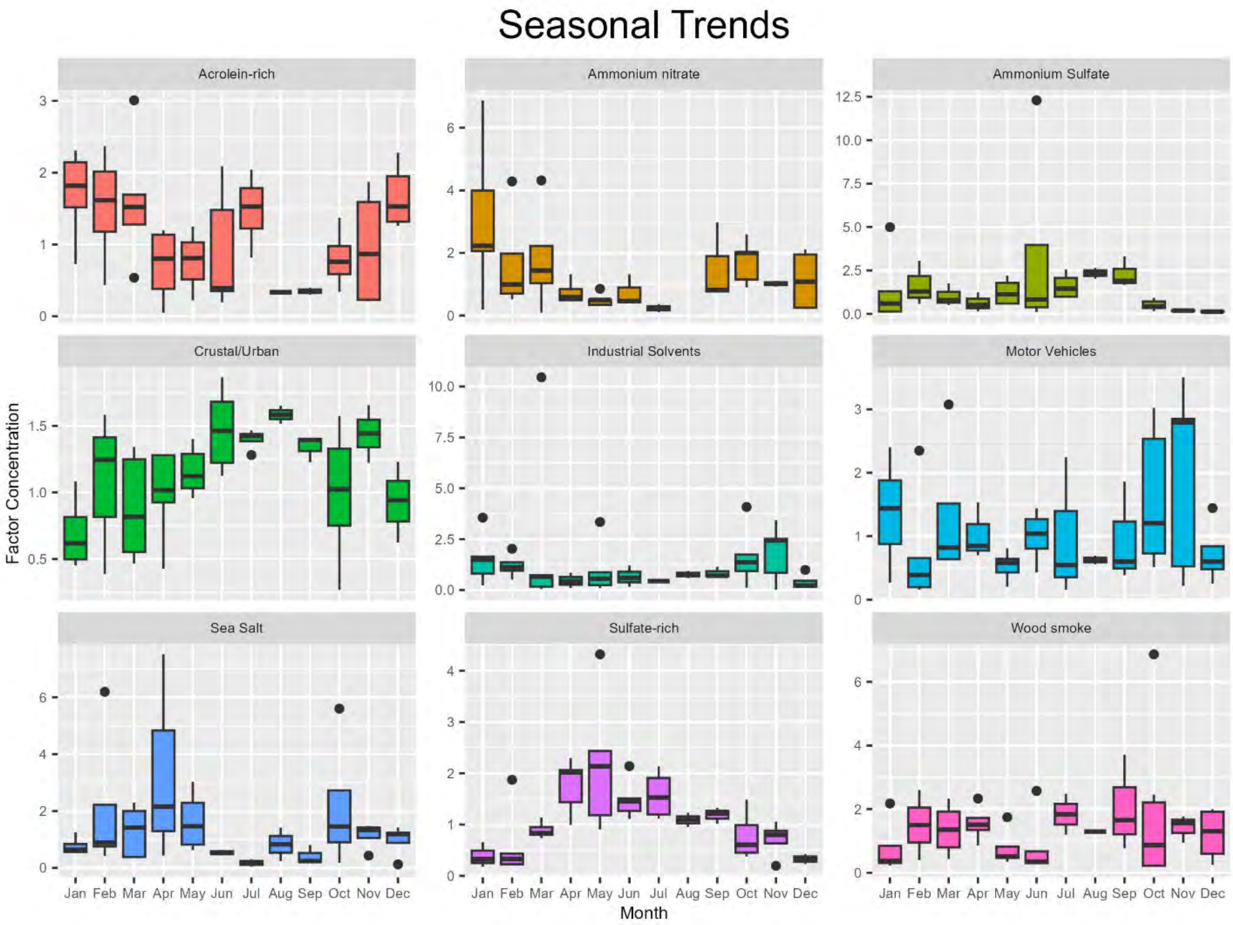


Figure L-7. Seattle 10th and Weller factor fingerprints PMF factors

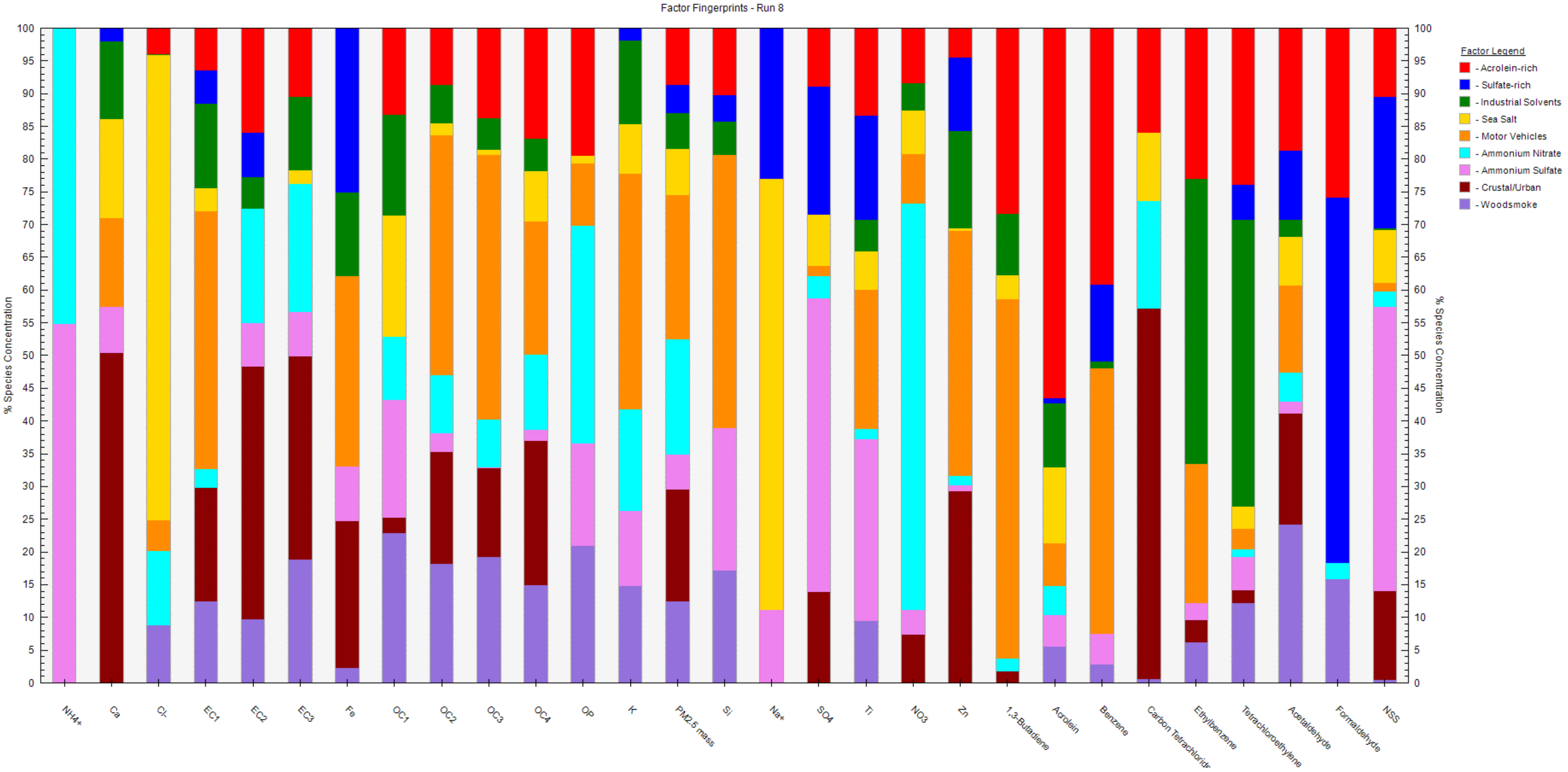
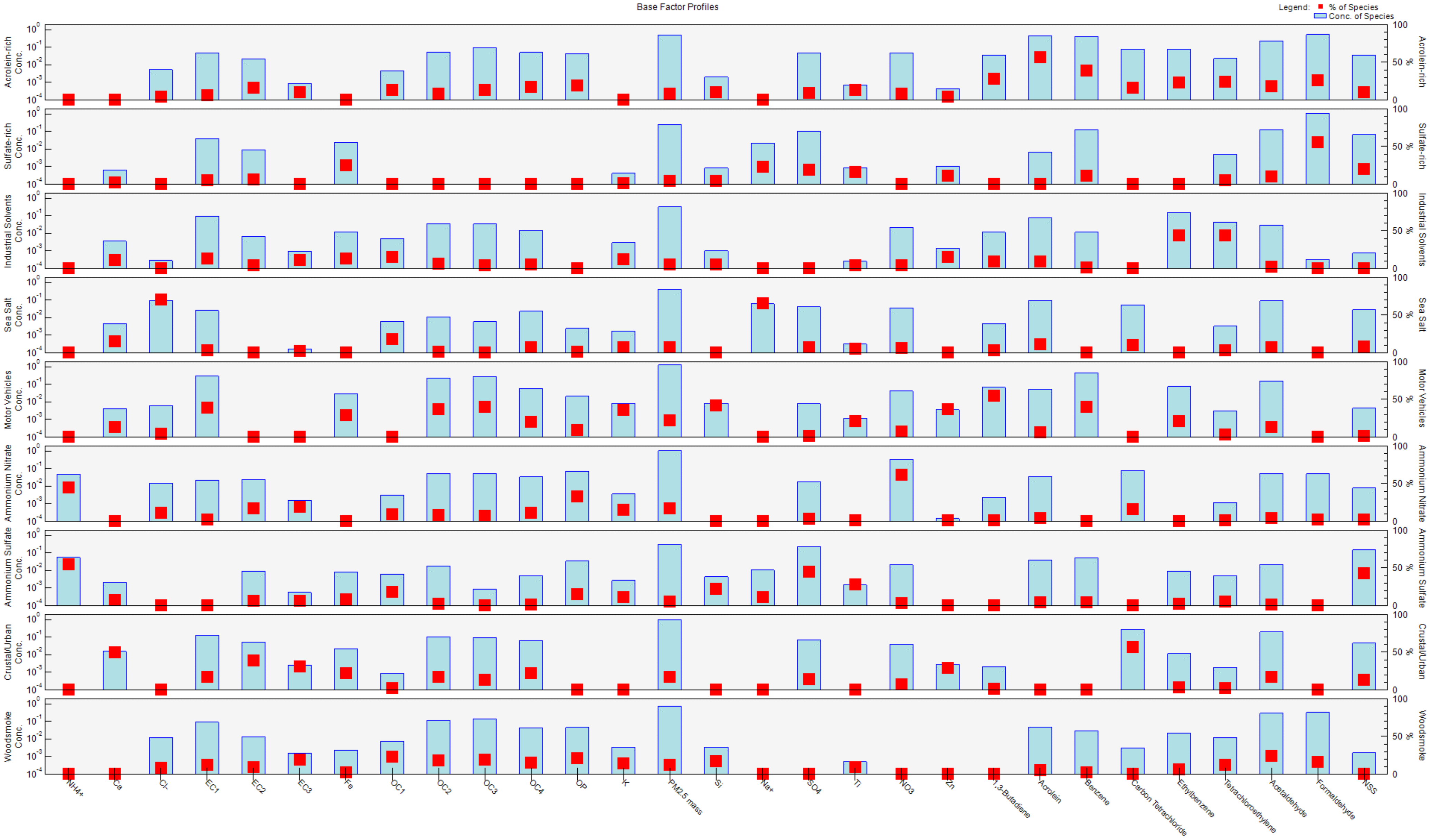


Figure L-8. Seattle 10th and Weller profiles for PMF factors



Tacoma South L: We used air toxics (carbonyls and VOCs) along with the speciation data at the Tacoma South L site for the additional PMF analysis. The nine factors were identified at the site out of which motor vehicles, wood smoke and secondary sulfate were the biggest contributors. This site is located in a residential area and is heavily influenced by wood smoke. There were additional factors like acrolein-rich factor which had high contributions of organics like carbon tetrachloride and benzene. Carbonyls acetaldehyde and formaldehyde were identified as a separate factor which showed high concentrations in summer as their production increase in high temperatures. Below is a pie-chart of the contributing factors.

Figure L-9. Tacoma South L additional PMF Factor Pie Chart

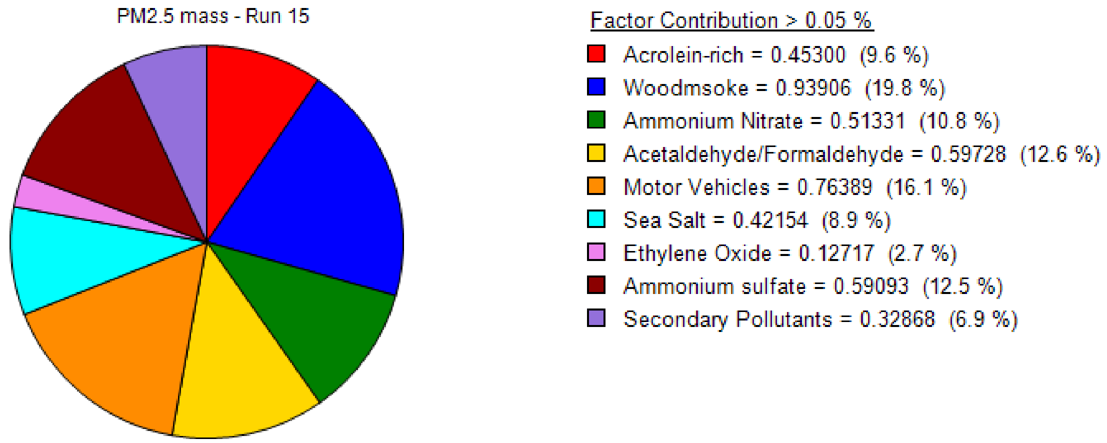


Figure L-10. Tacoma South L seasonal trend for PMF factors

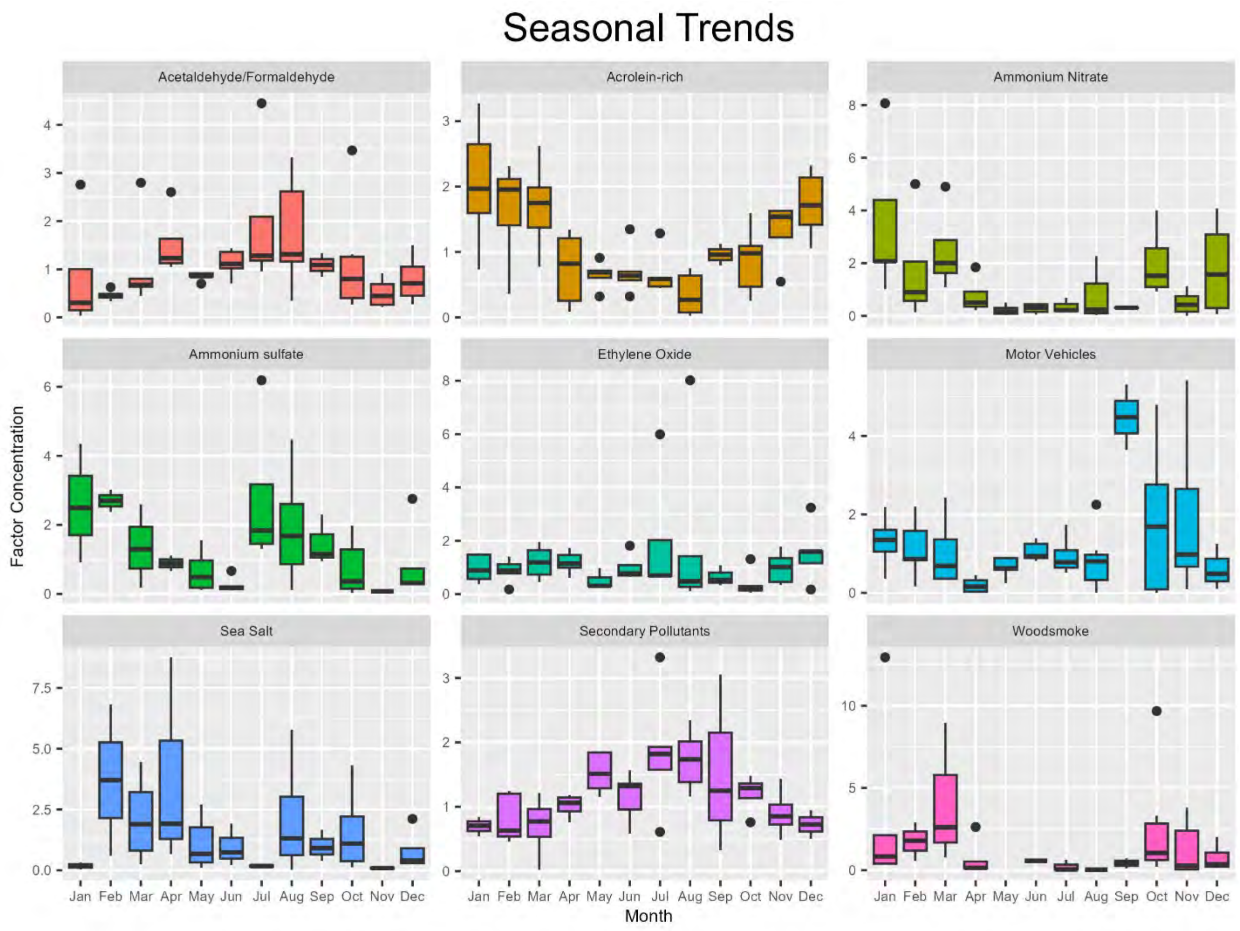


Figure L-11. Tacoma South L factor fingerprints PMF factors

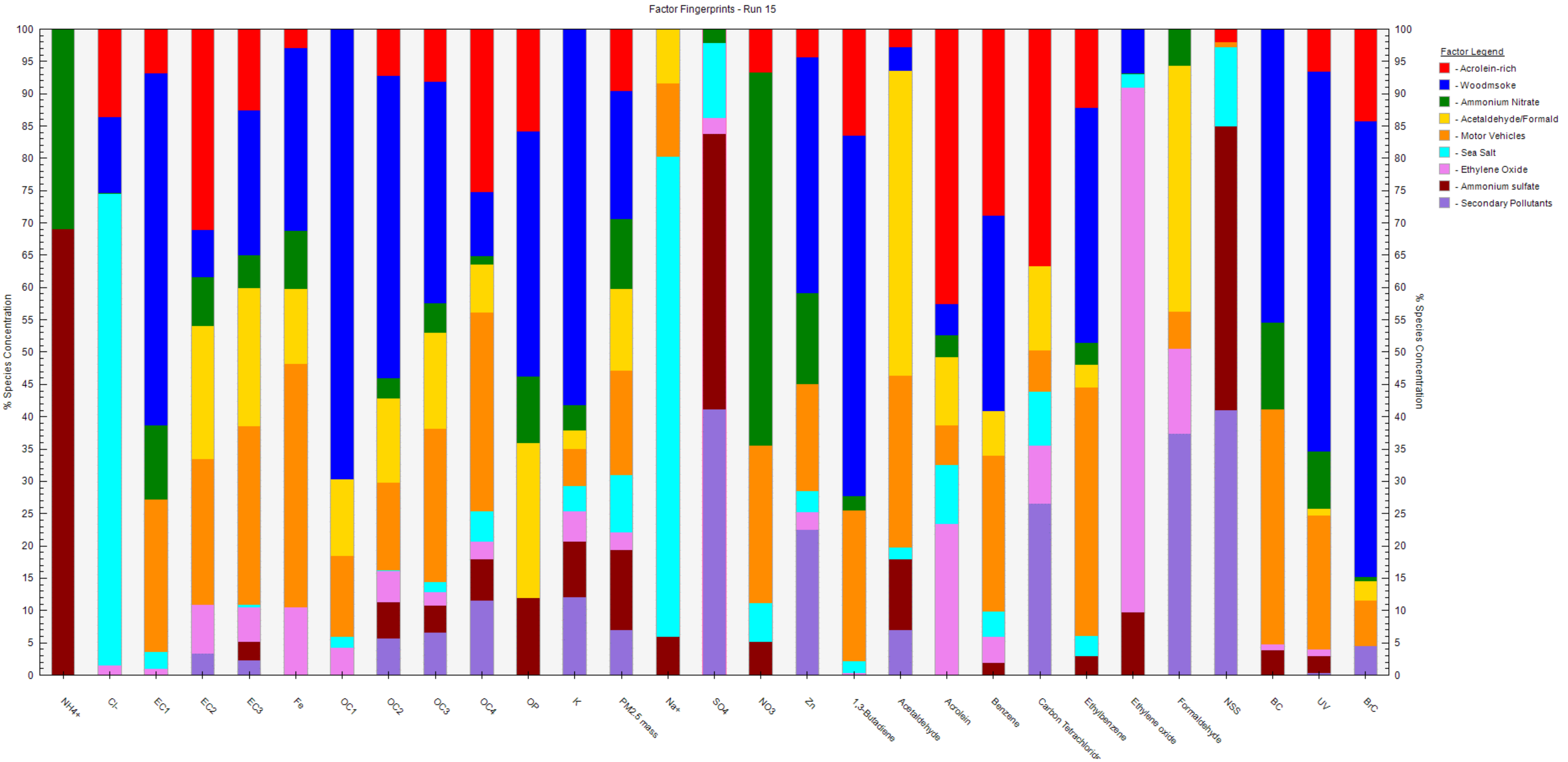
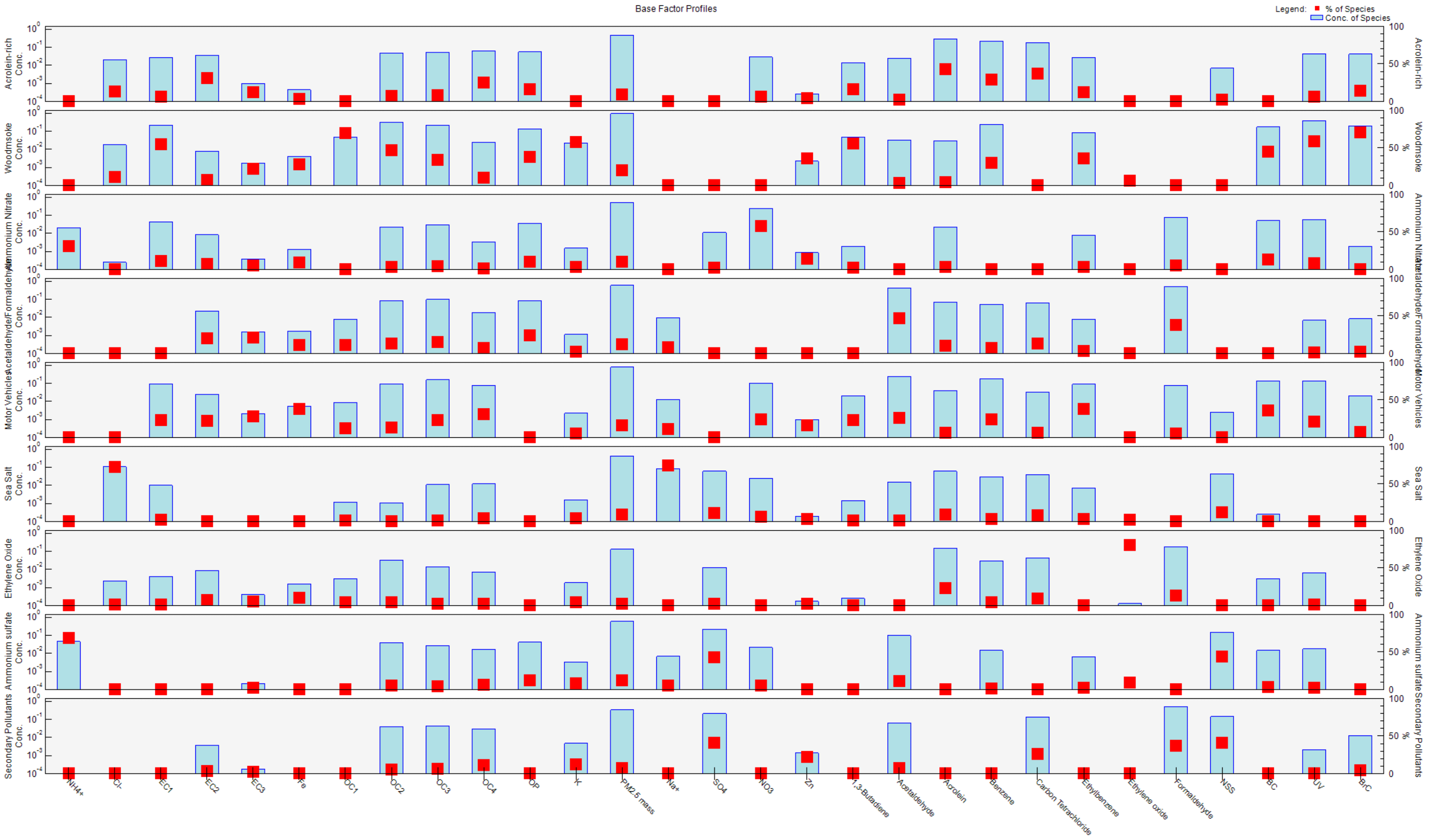


Figure L-12. Tacoma South L profiles and contributions for PMF factors



Seattle Beacon Hill: We used air toxics (carbonyls, VOCs, SVOCs, and PM_{10} metals) along with the speciation data at the Beacon Hill site for the additional PMF analysis. The ten factors were identified at the site out of which motor vehicles, wood smoke, Diesel and sea salt were the biggest contributors. With the help of VOCs and SVOCs, diesel and gasoline sources were identified. The SVOCs like benzo(a)anthracene, benzo(a)pyrene, Indeno(1,2,3-c,d)pyrene, benzo(b)fluoranthene are characteristic of gasoline emissions and SVOCs like anthracene, fluoranthene, fluorene, phenanthrene, pyrene are characteristic of diesel emissions. There were additional factors like Manganese rich factor and acenaphthylene rich factor, which were observed only at this site and at Seattle Duwamish sites. Below is a pie-chart of the contributing factors.

Figure L-133. Seattle Beacon Hill additional PMF Factor Pie Chart

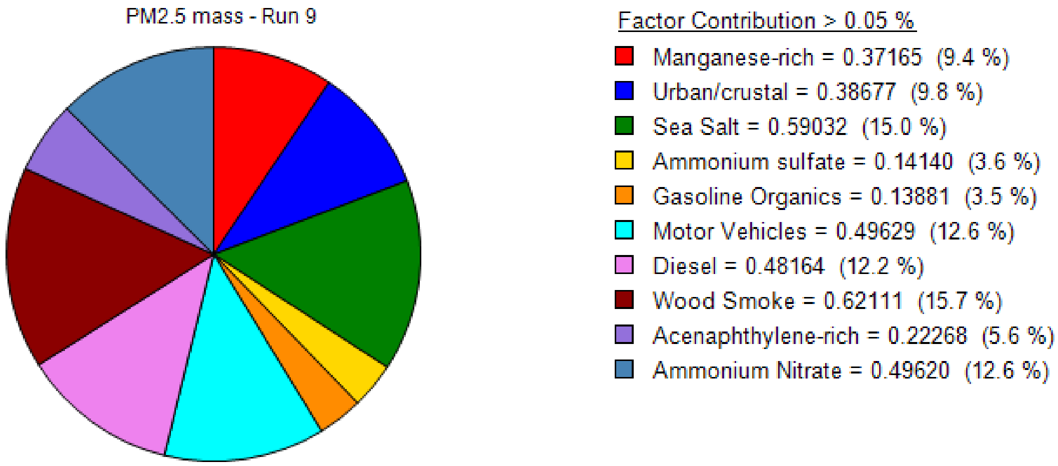


Figure L-14. Seattle Beacon Hill seasonal trend for PMF factors.

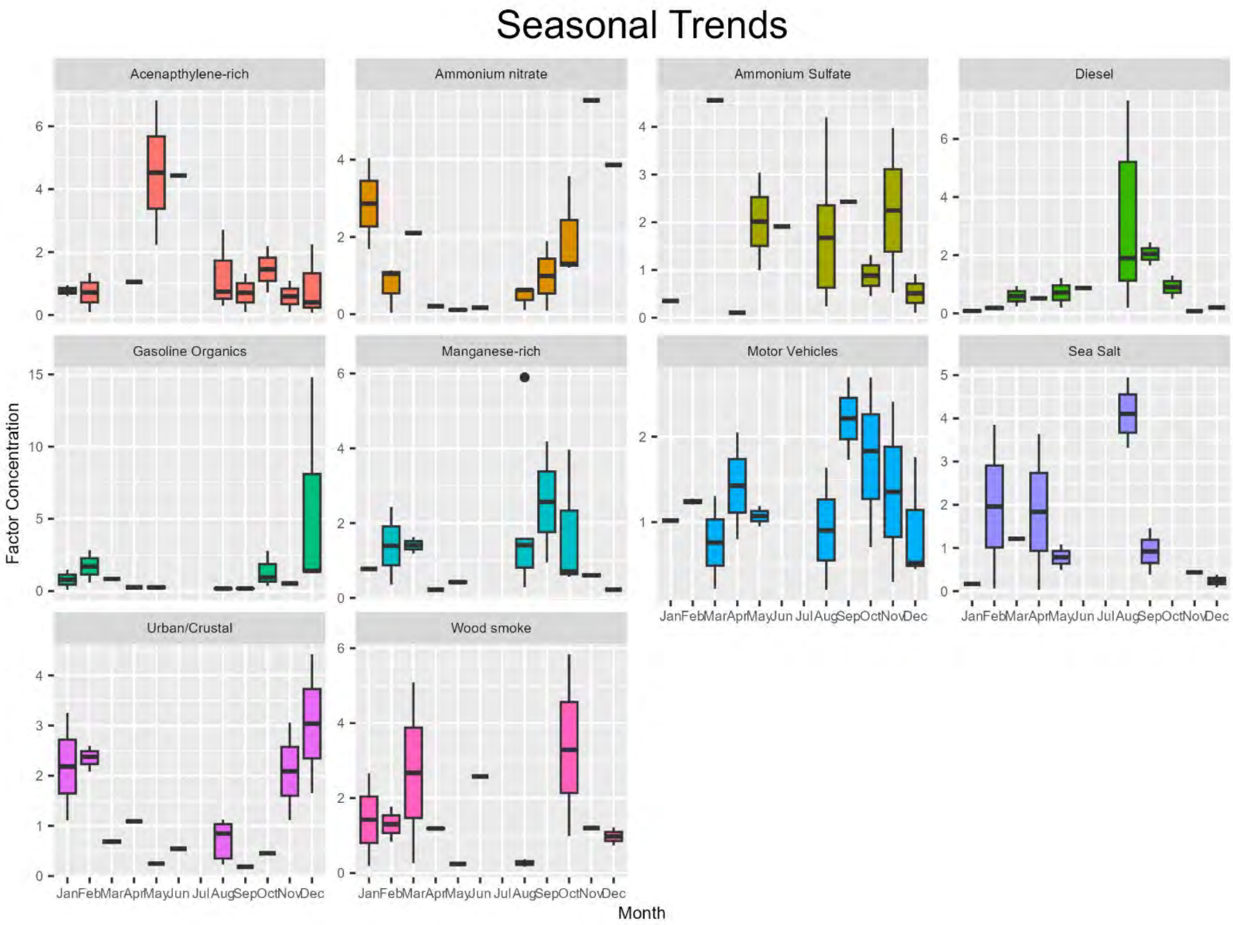


Figure L-15. Seattle Beacon Hill factor fingerprints PMF factors.

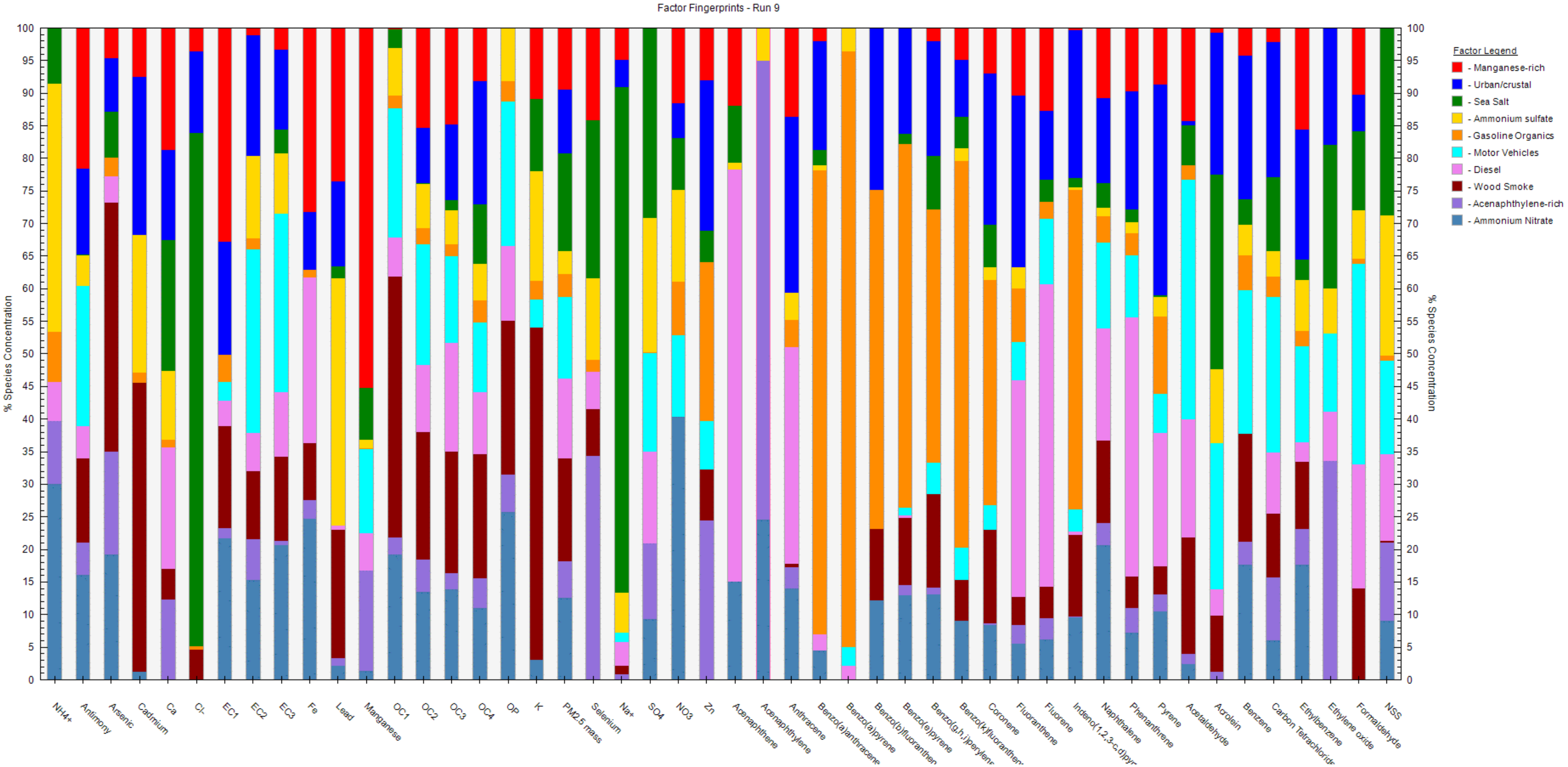
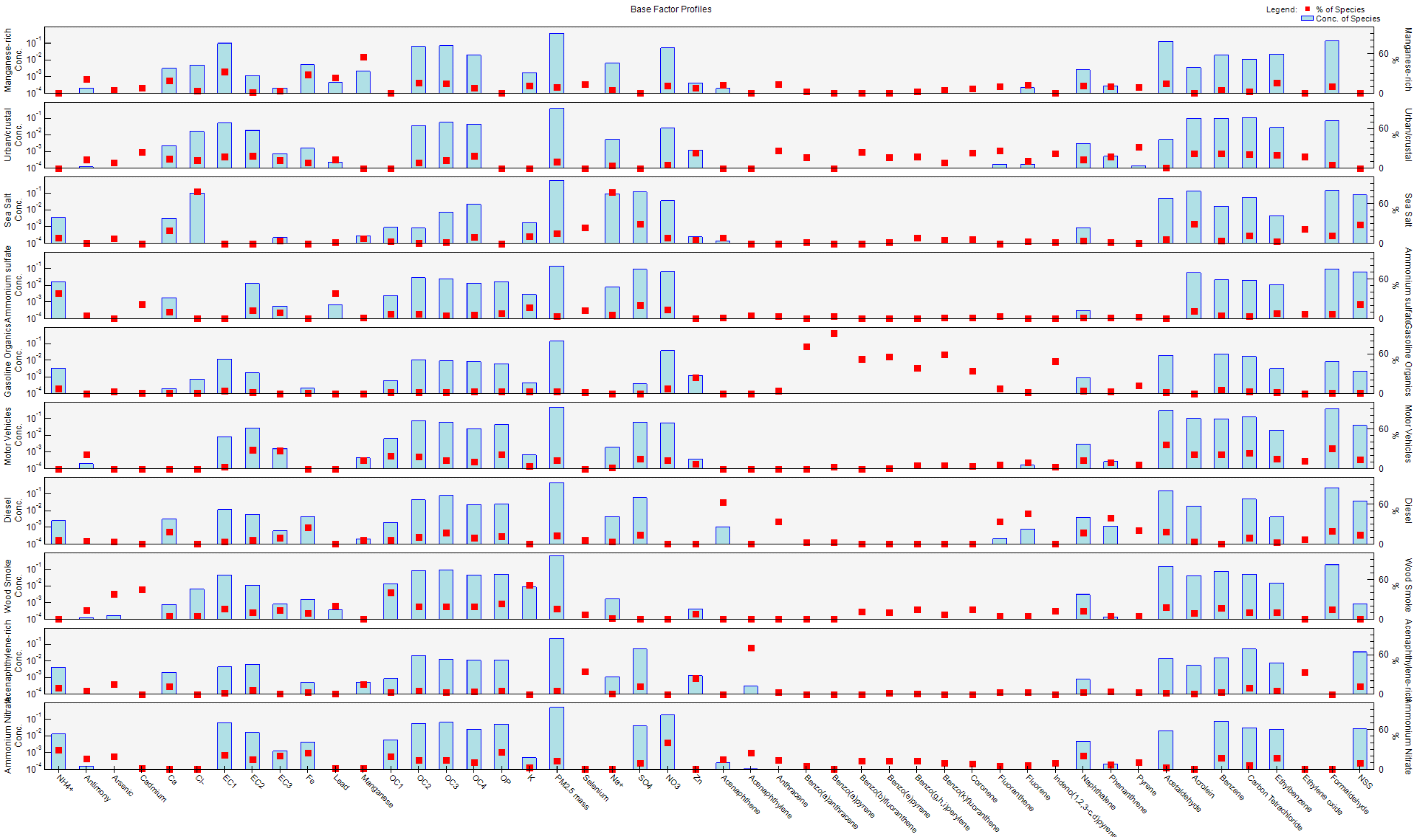


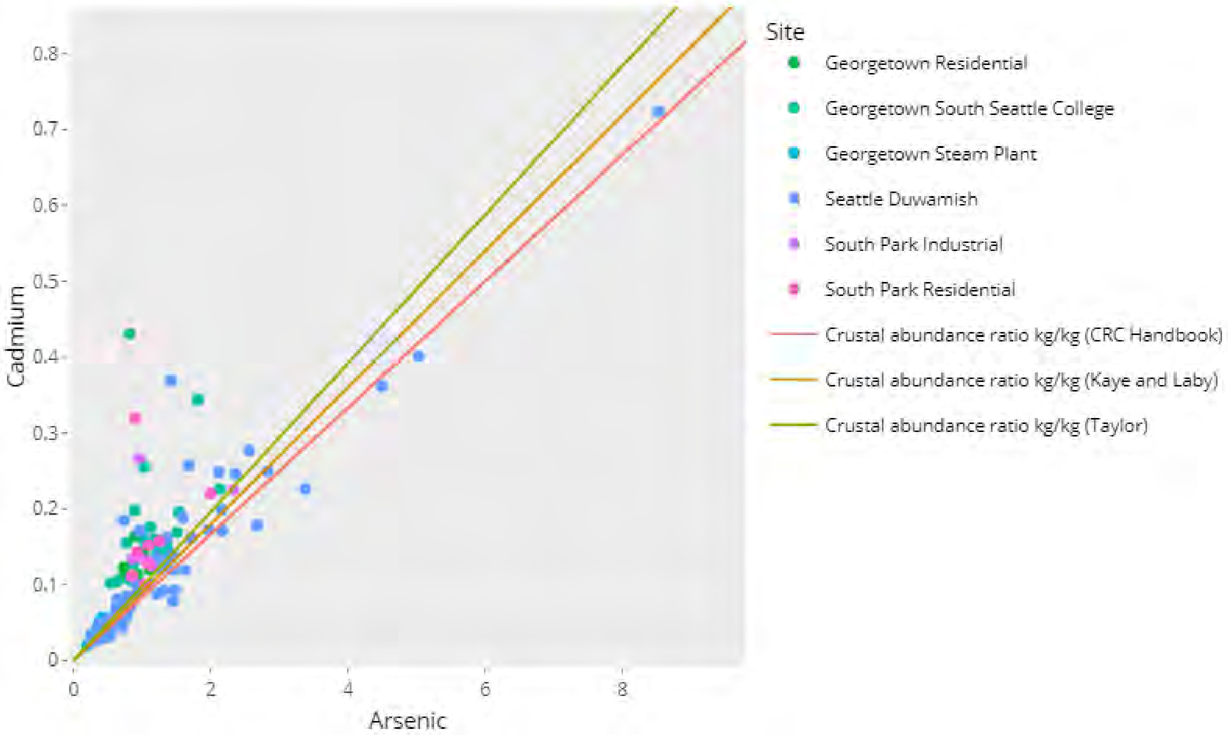
Figure L-16. Seattle Beacon Hill profiles and contributions for PMF factors.



Appendix M. Metal ratios compared to crustal abundance ratios

Figure M-1 below showed some correlation at the Seattle Duwamish monitoring site. The other locations had more limited number of samples covering a shorter time period but showed slightly higher cadmium to arsenic ratios. This may be seasonal in nature (those samples were collected in the summer), but we didn't investigate if this was related to seasonality.

Figure M-1. Arsenic vs cadmium concentrations for monitoring sites in the Duwamish Valley. The lines represent example crustal abundance ratios.



In Figures M-2 and M-3, arsenic vs lead and cadmium vs lead, showed somewhat stronger correlations to each other, as seen in the following figures.

Figure M-2. Lead vs Arsenic concentrations for monitoring sites in the Duwamish Valley. The lines represent example crustal abundance ratios.

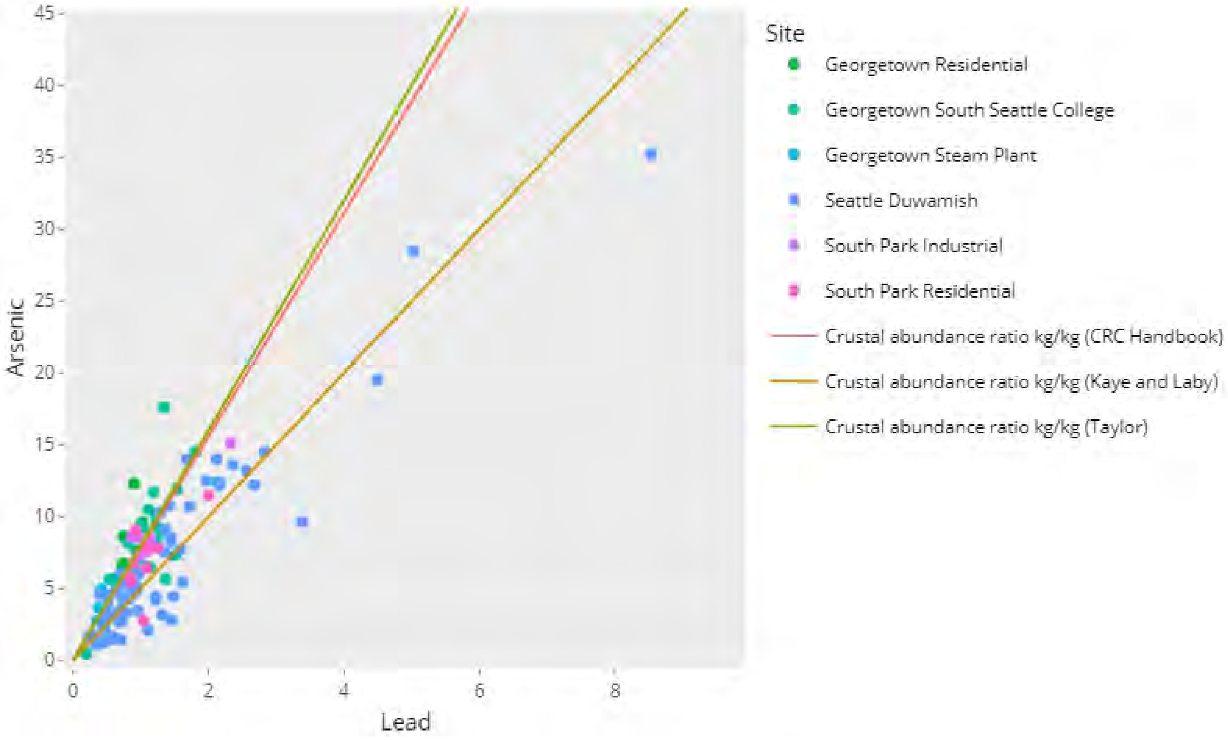
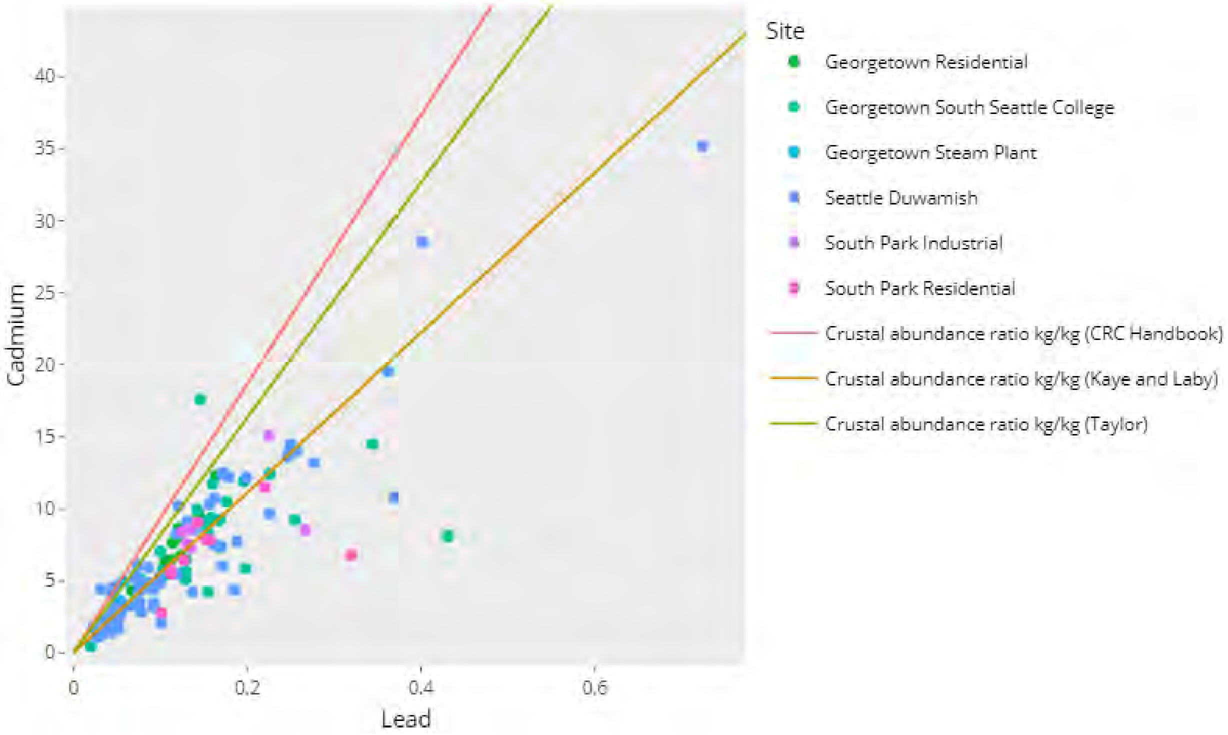


Figure M-3. Lead vs Cadmium concentrations for monitoring sites in the Duwamish Valley. The lines represent example crustal abundance ratios.



Appendix N. Single race graphs for average potential cancer risk from on-road diesel particulate matter

Figure N-11. Estimated average potential cancer risk from on-road diesel particulate matter by race – American Indian/Alaska Native.

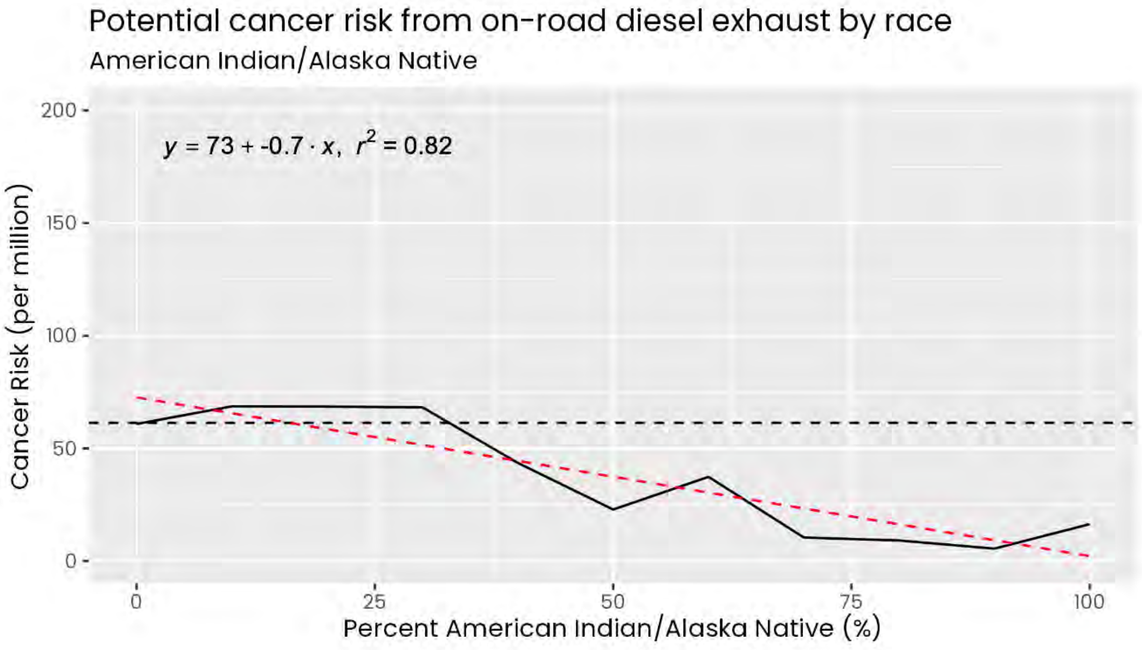


Figure N-22. Estimated average potential cancer risk from on-road diesel particulate matter by race – Asian.

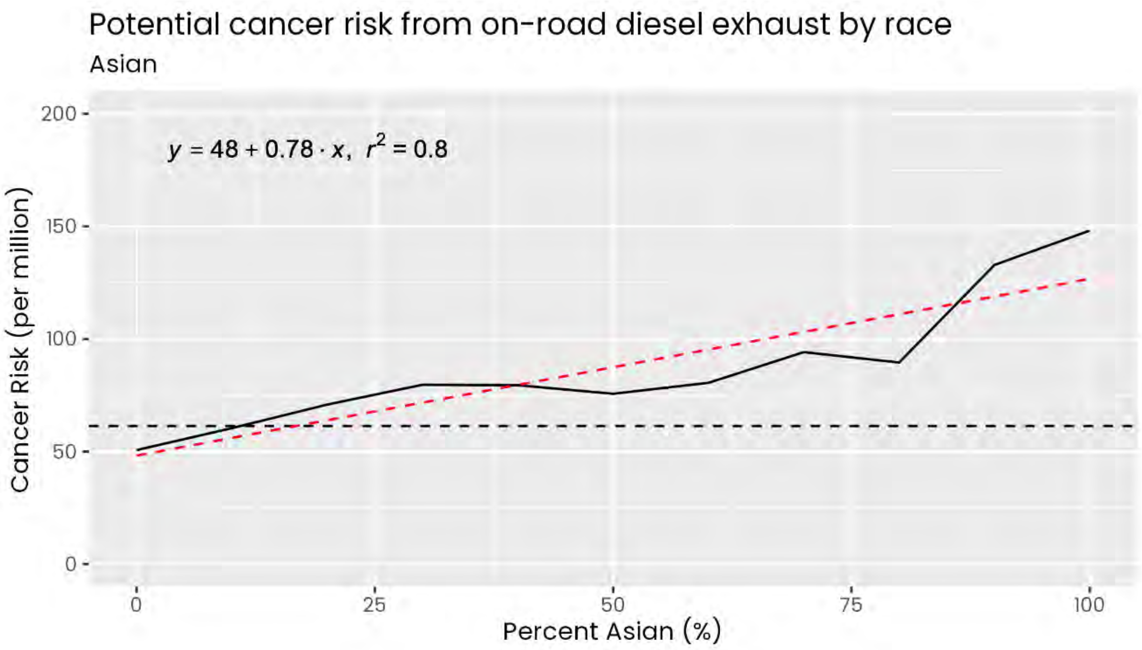


Figure N-33. Estimated average potential cancer risk from on-road diesel particulate matter by race – Black/African American.

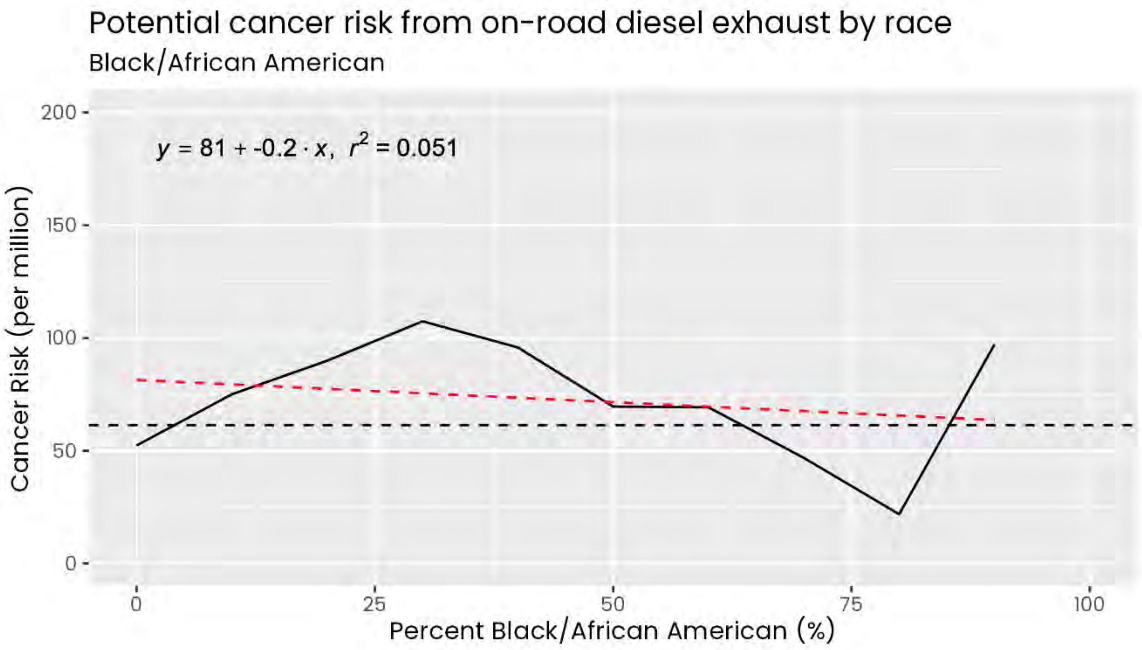


Figure N-44. Estimated average potential cancer risk from on-road diesel particulate matter by race – Multiple Races.

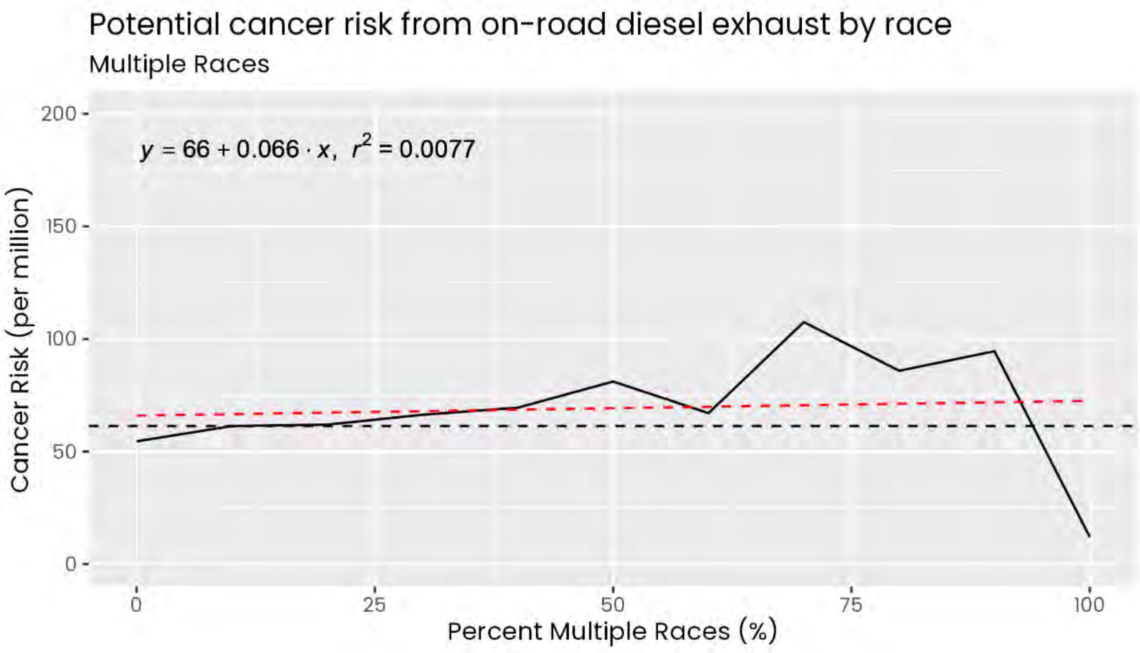


Figure N-55. Estimated average potential cancer risk from on-road diesel particulate matter by race – Native Hawaiian/Pacific Islander.

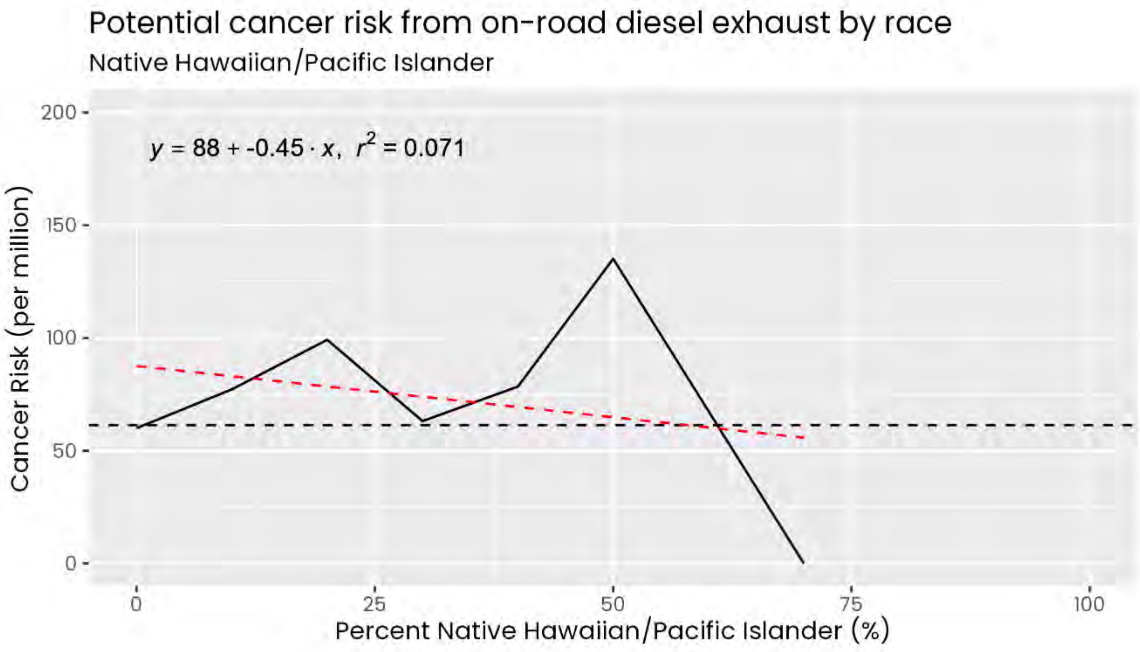
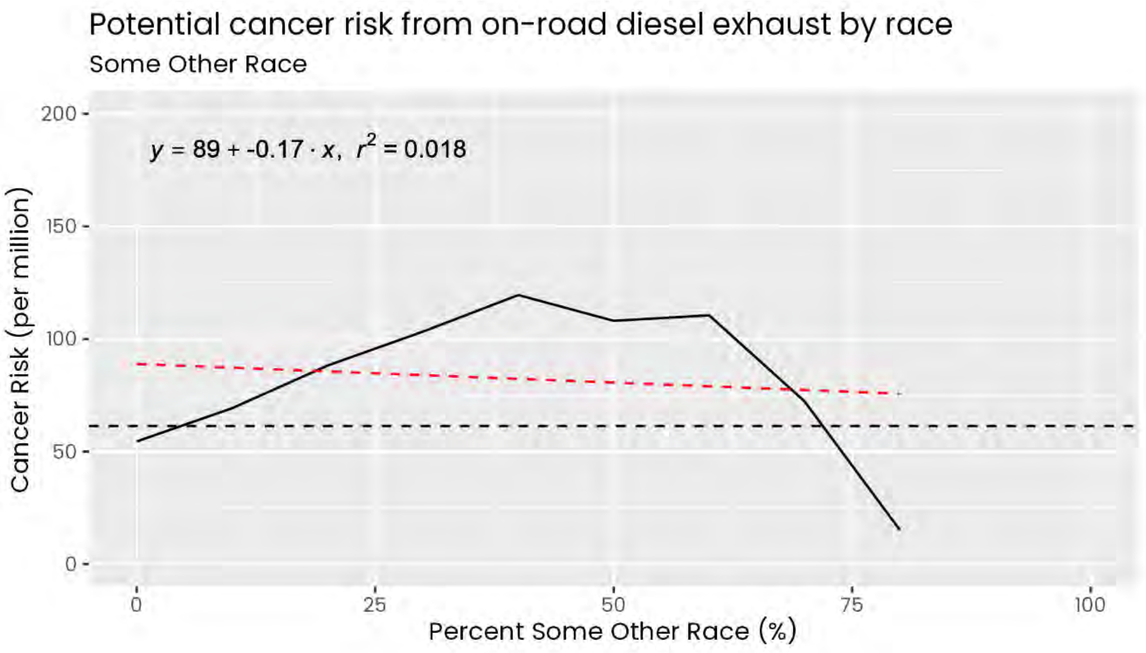


Figure N-66. Estimated average potential cancer risk from on-road diesel particulate matter by race – Some Other Race.



Appendix O. Box plots for PAHs

This section shows the box plots for PAHs. The dashed black line is the MDL. None of our sites had any PAH values above the MDL.

Figure O-17. Acenaphthene box plot.

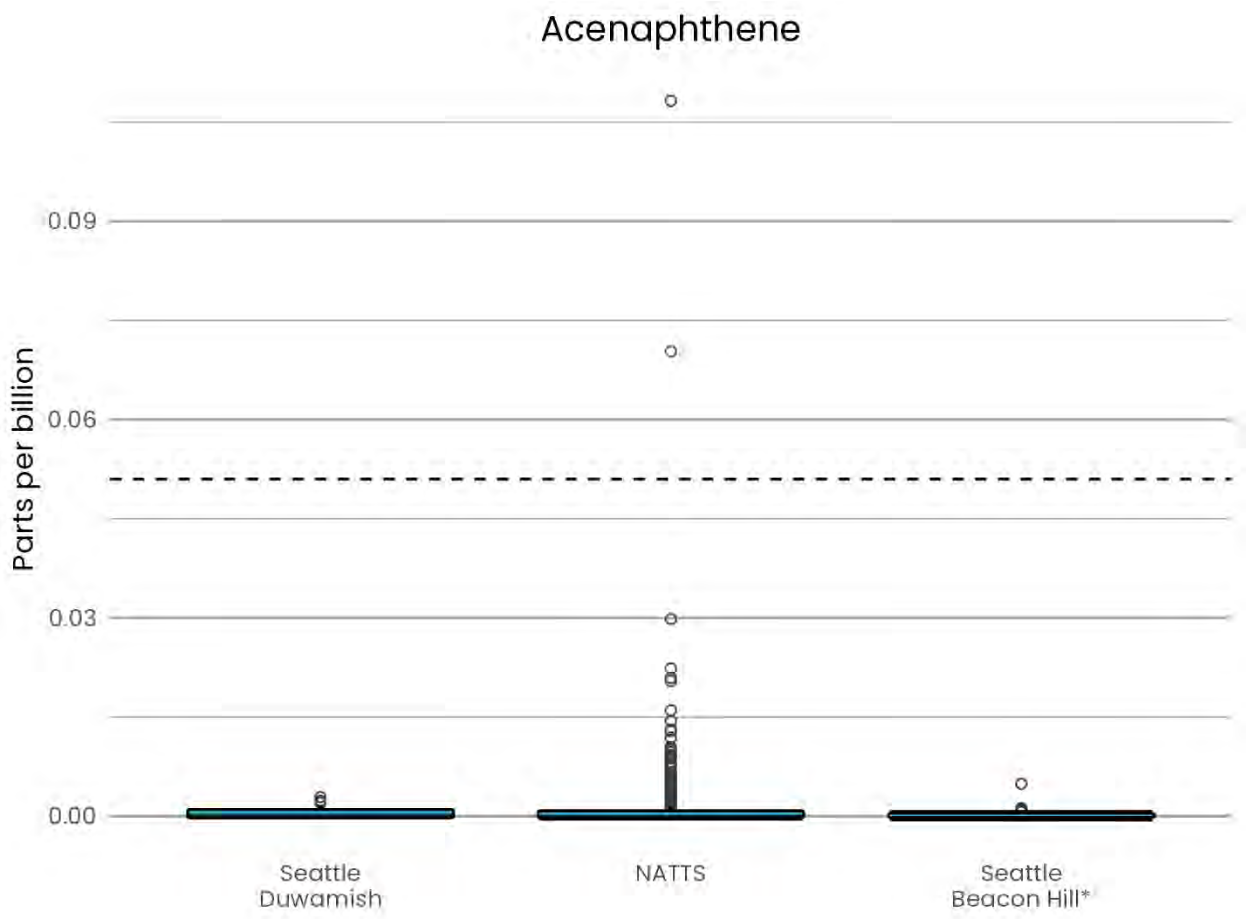


Figure O-28. Acenaphthylene box plot.

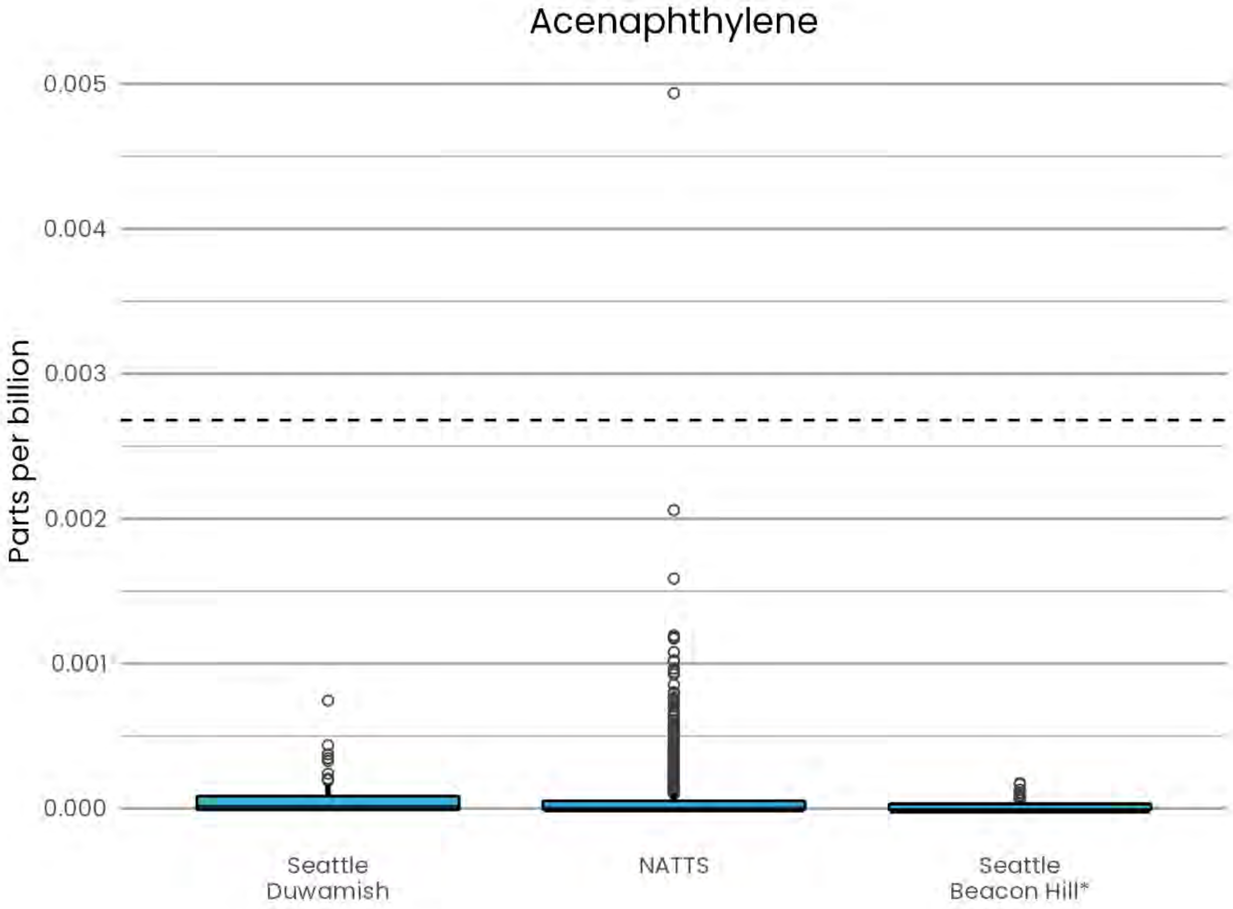


Figure O-39. Anthracene box plot.

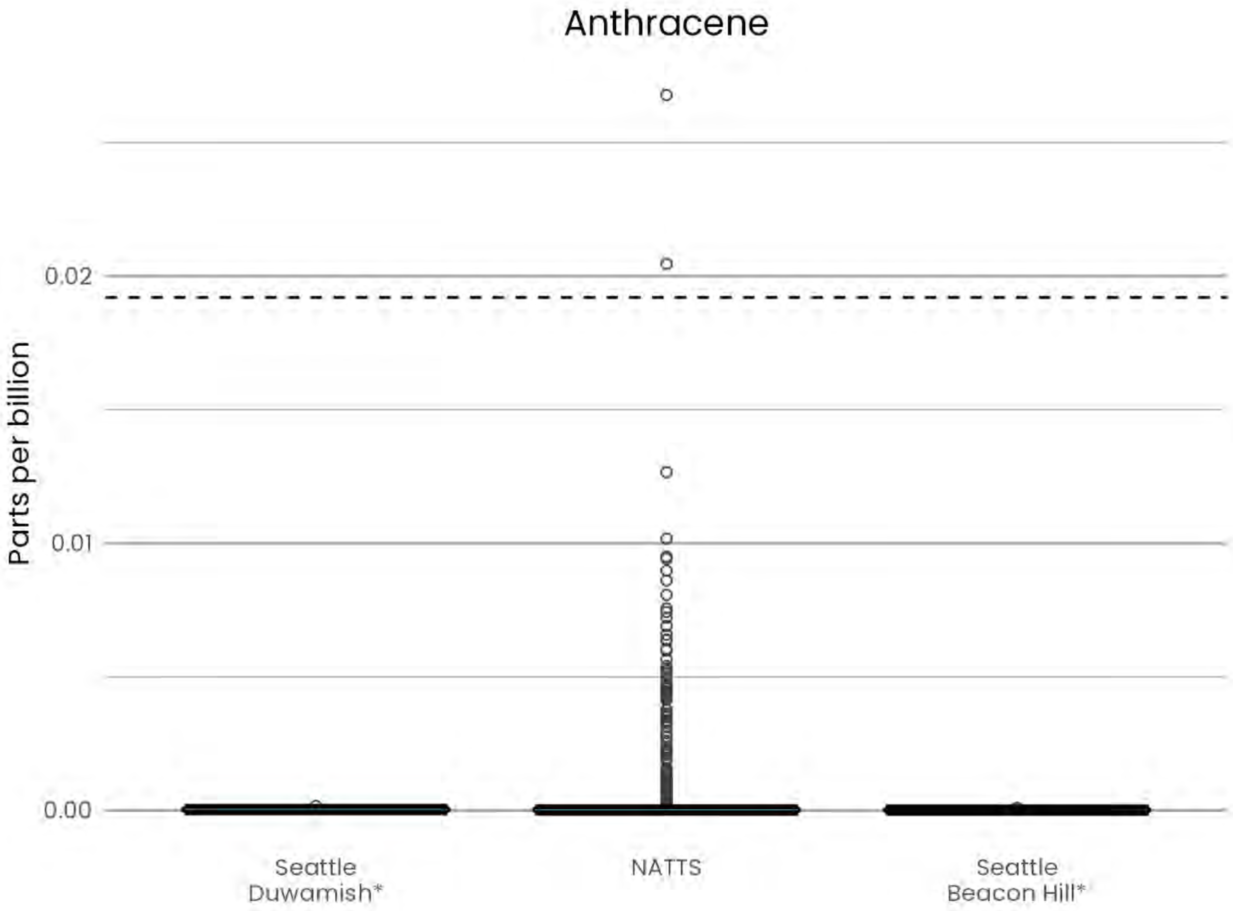


Figure O-410. Benzo[a]anthracene box plot.

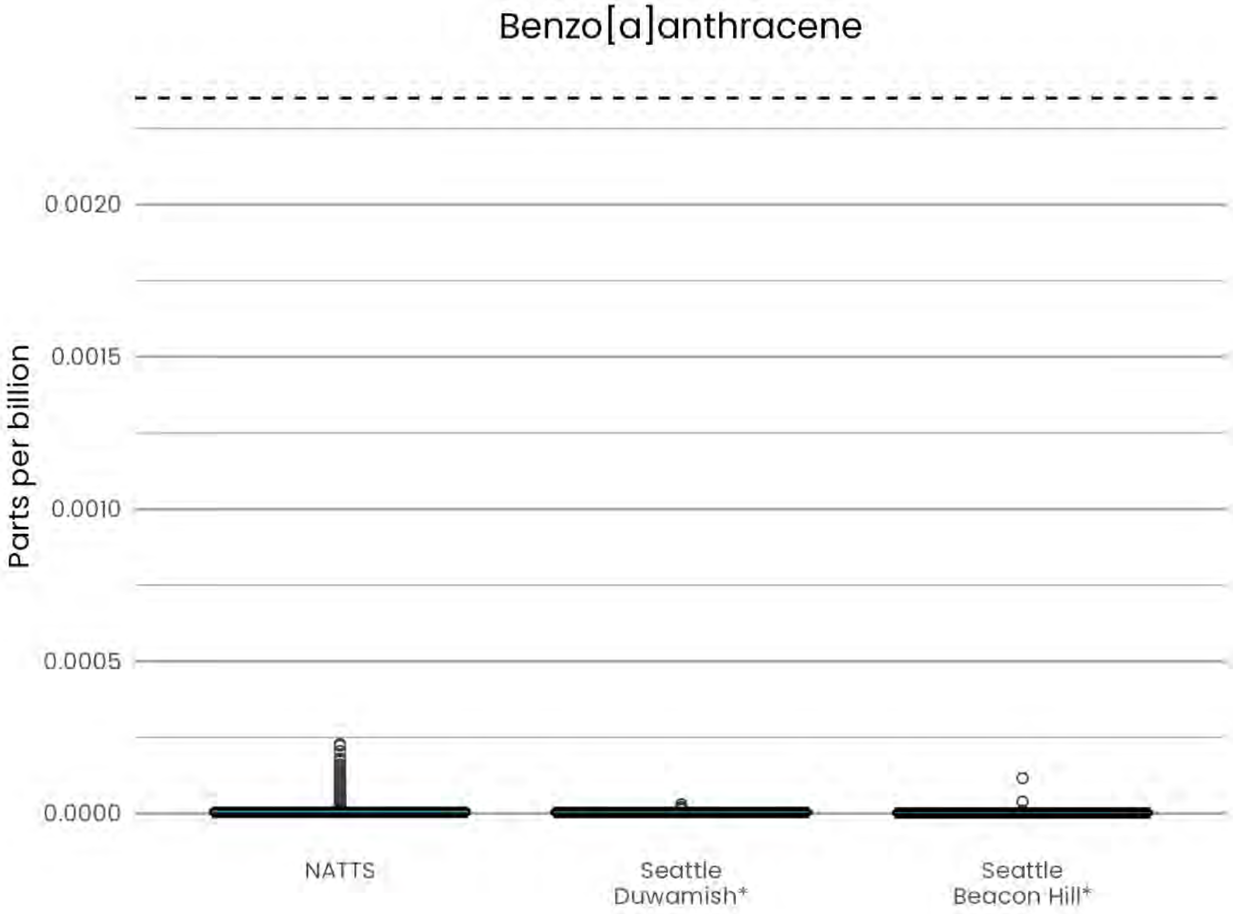


Figure O-511. Benzo[a]pyrene box plot.

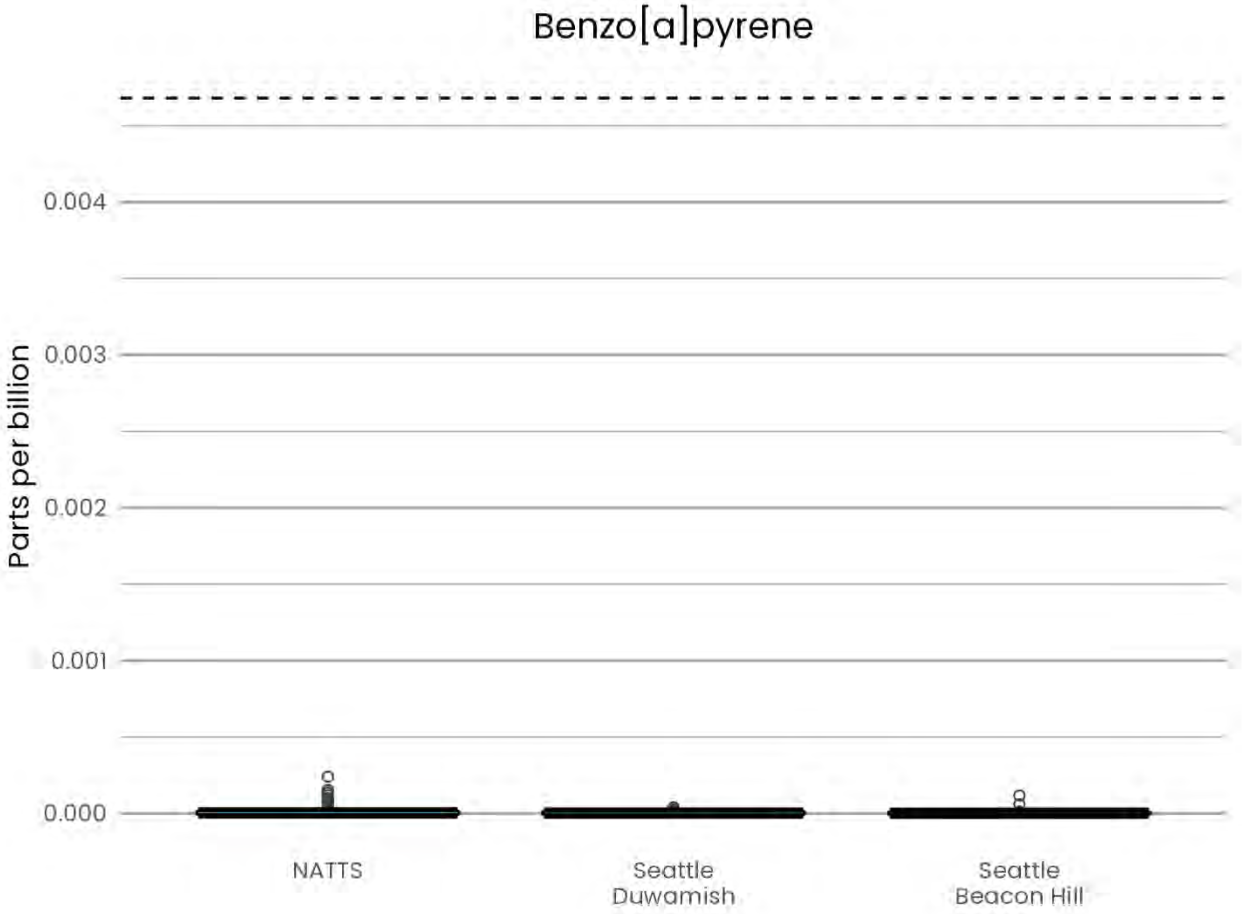


Figure O-612. Benzo[b]fluoranthene box plot.

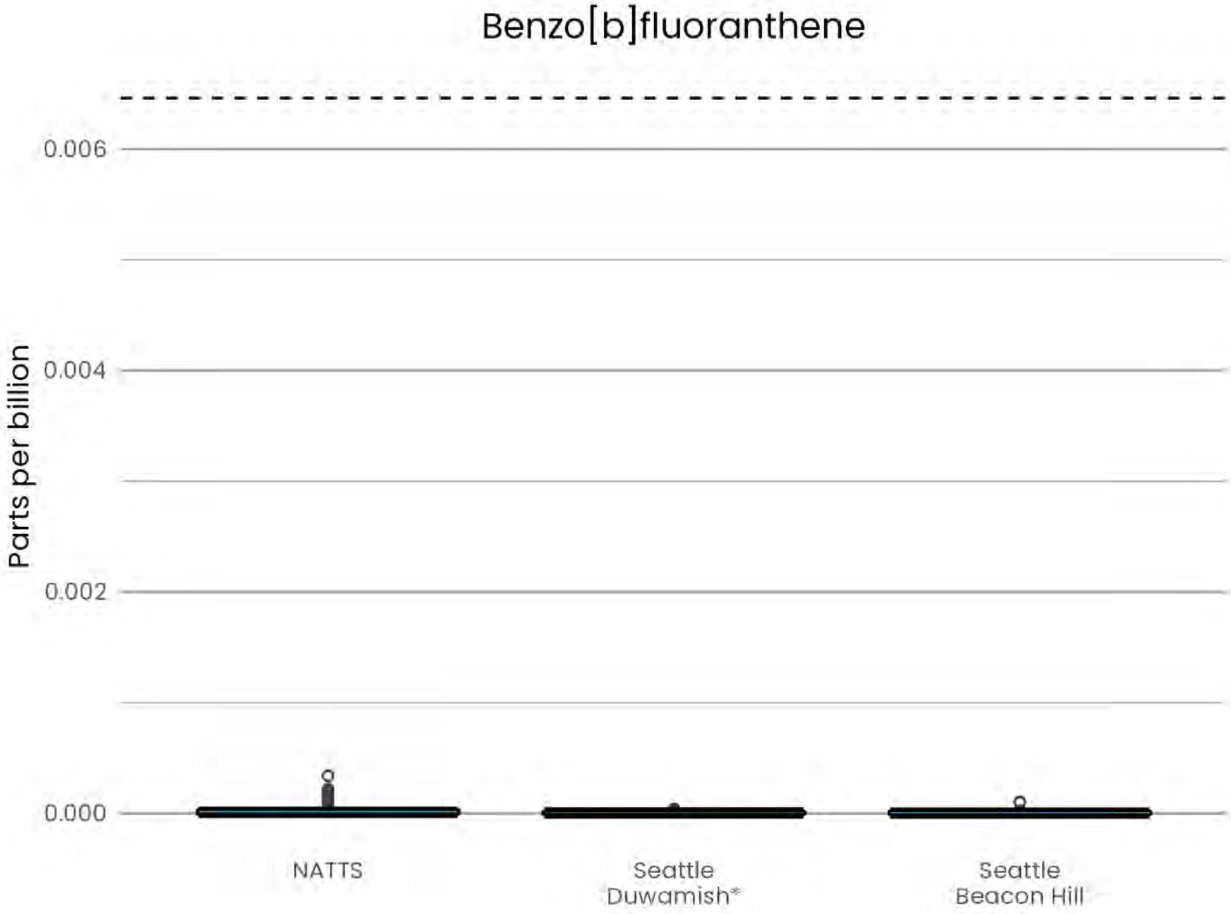


Figure O-713. Benzo[e]pyrene box plot.

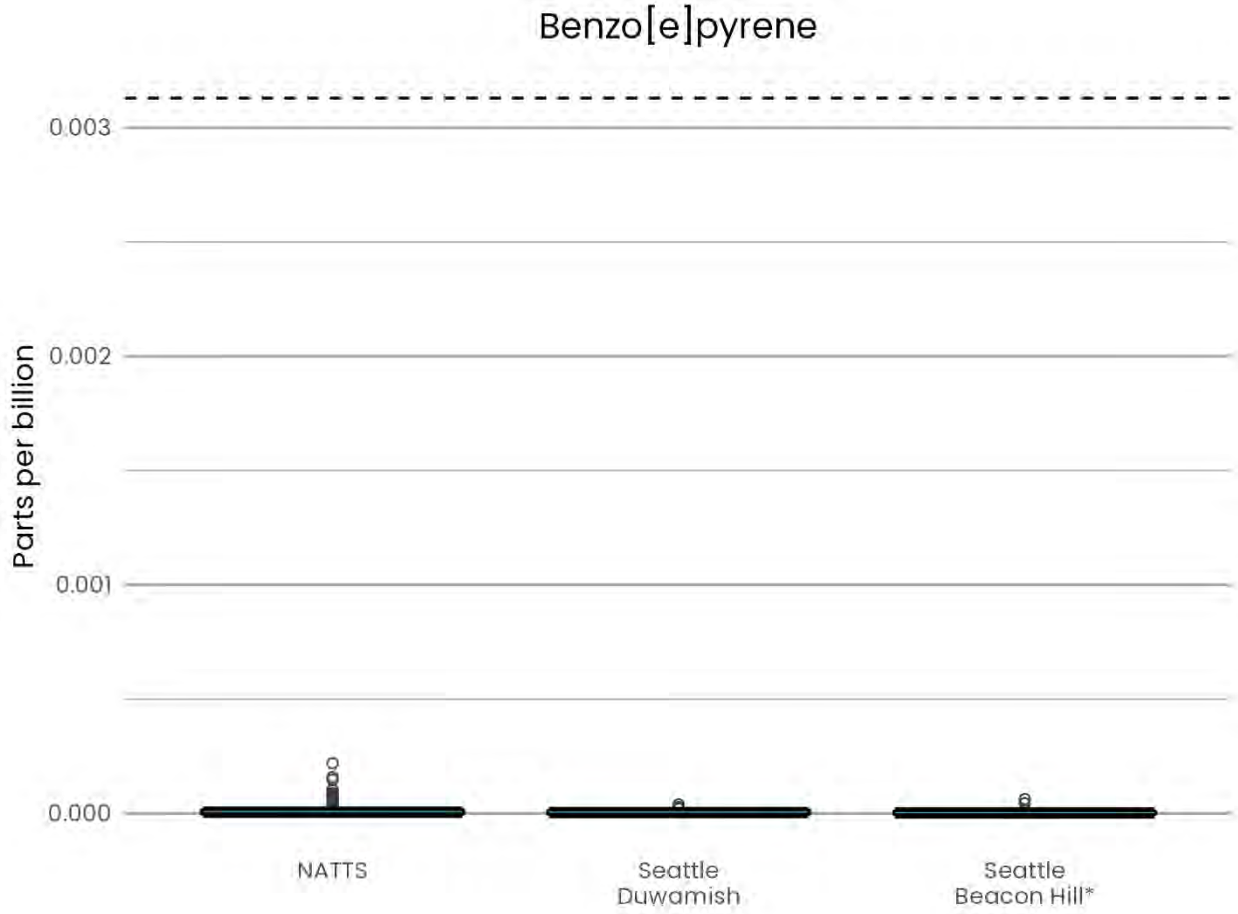


Figure O-814. Benzo[g,h,i]perylene box plot.

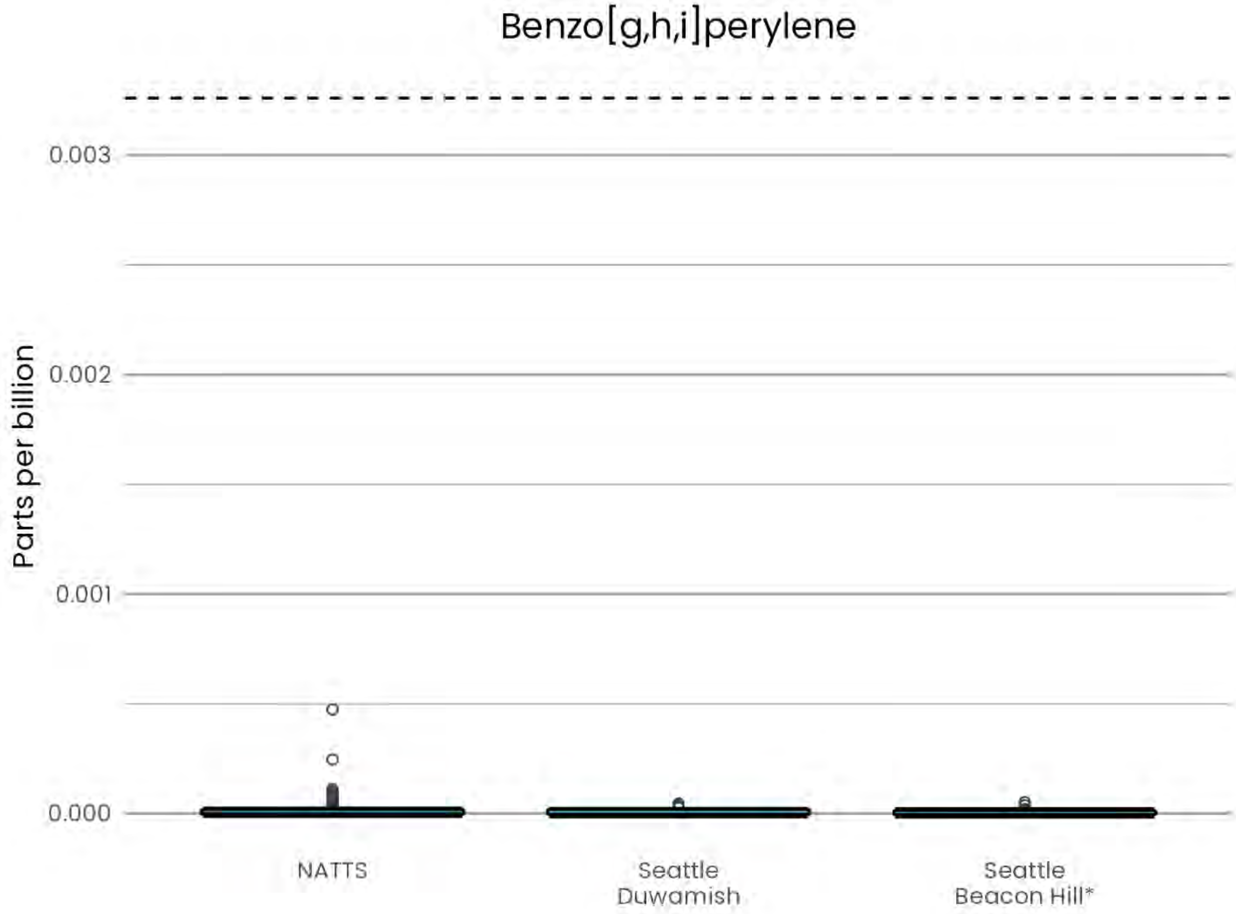


Figure O-915. Benzo[k]fluoranthene box plot.

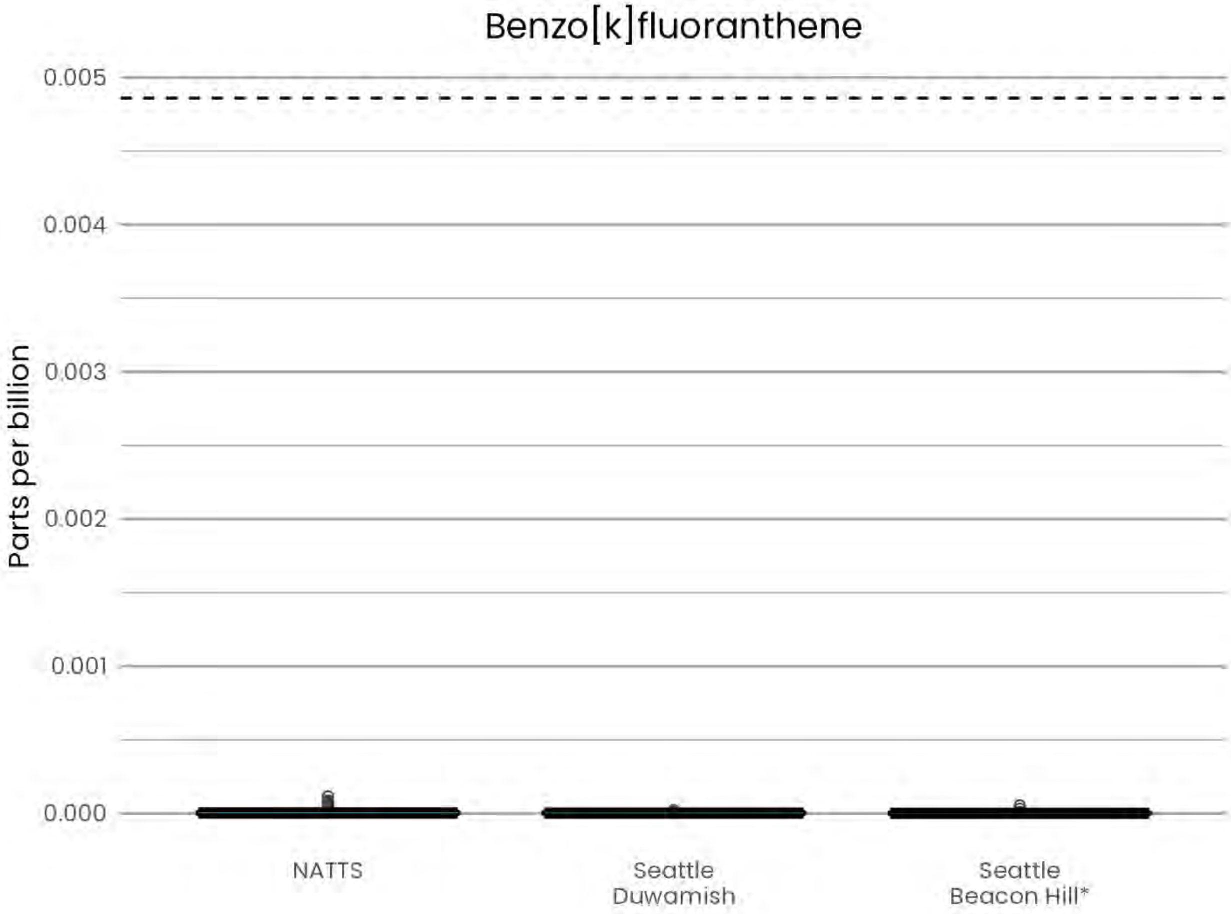


Figure O-1016. Chrysene box plot.

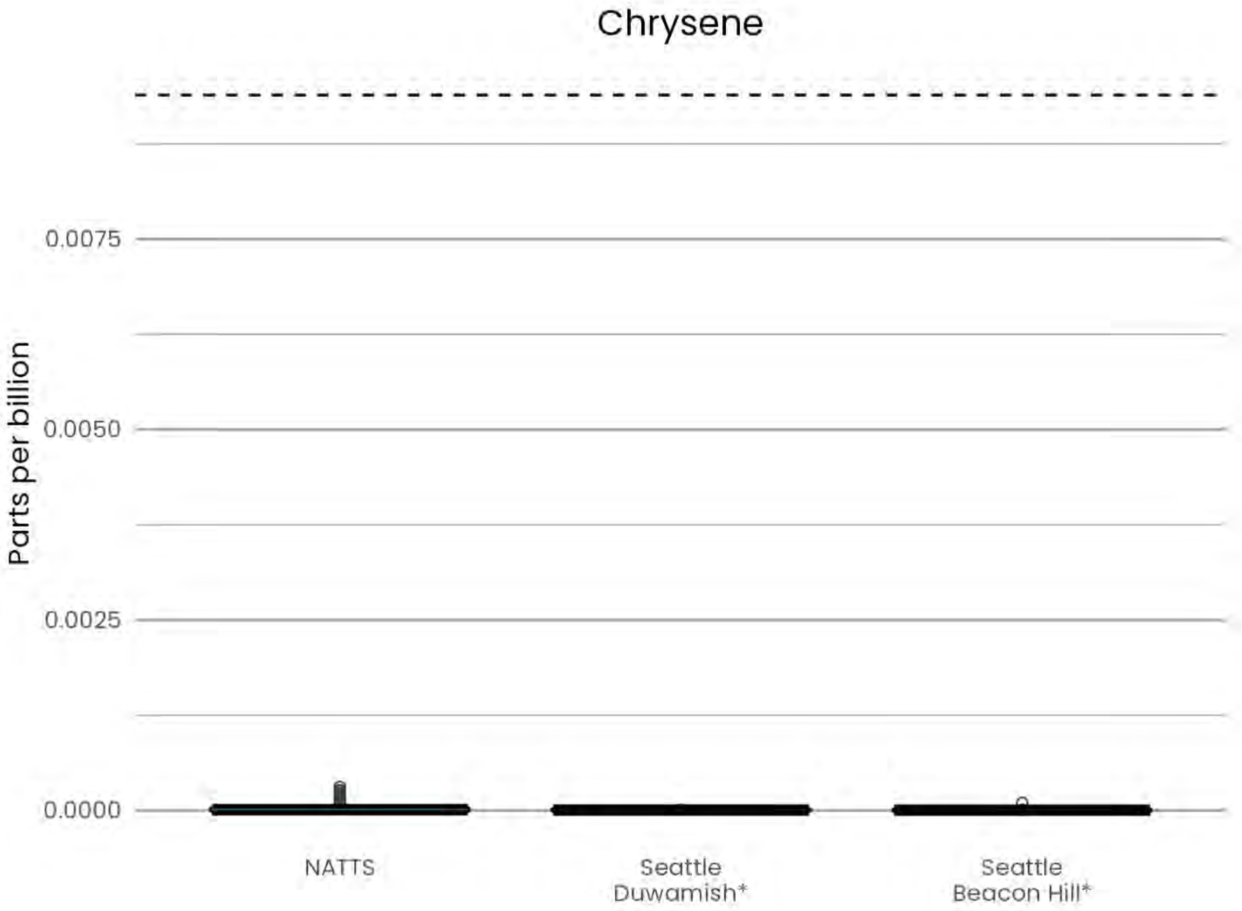


Figure O-1117. Coronene box plot.

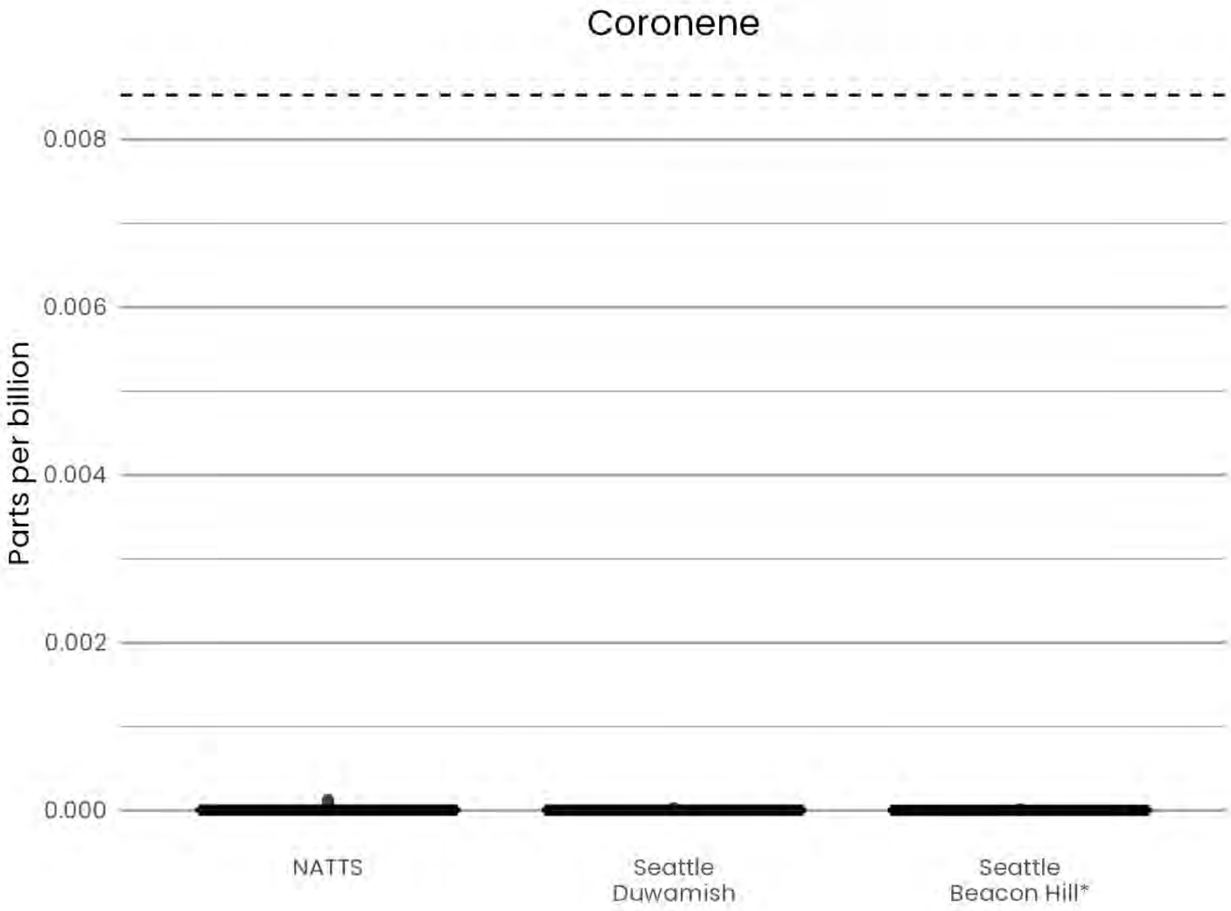


Figure O-1218. Dibenzo[a,h]anthracene box plot.

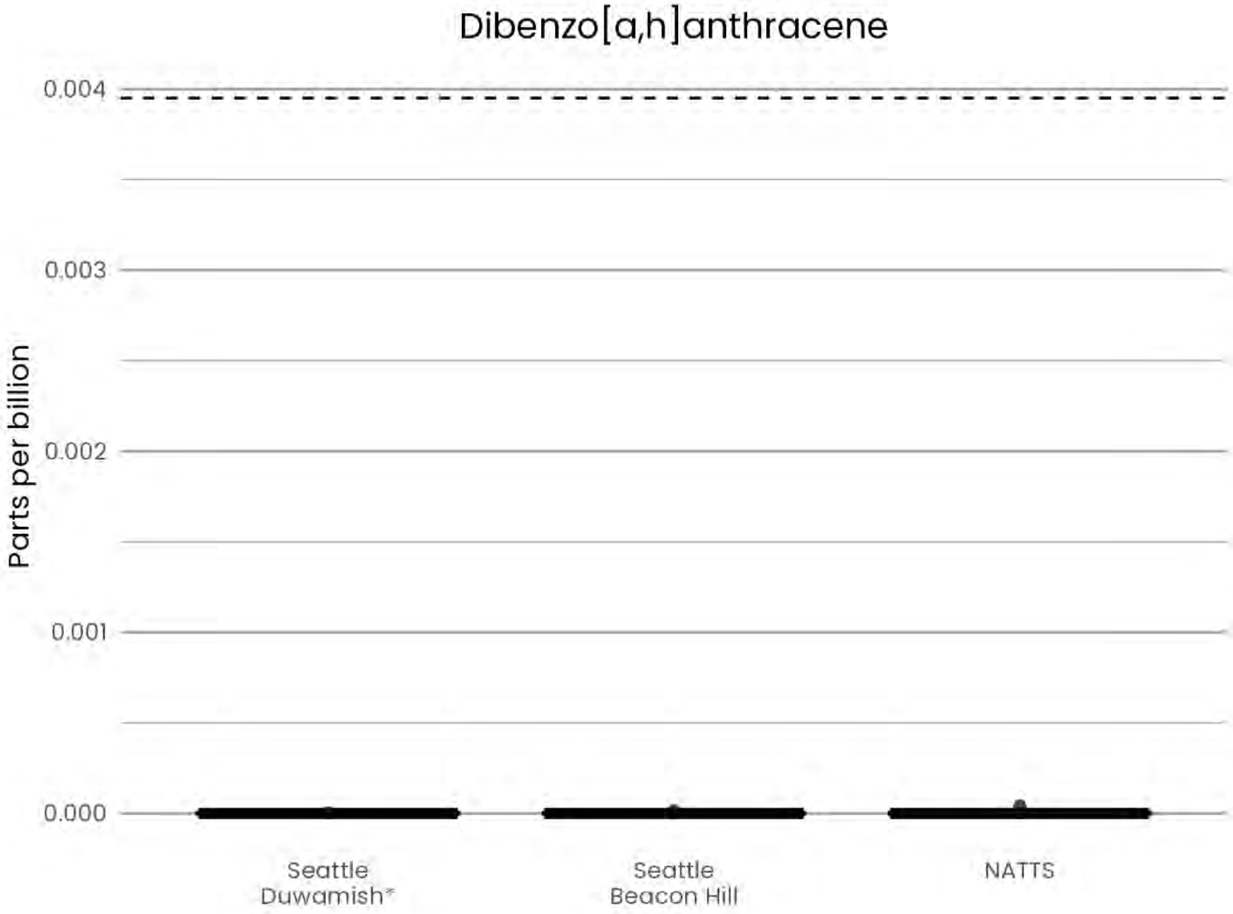


Figure O-1319. Fluoranthene box plot.

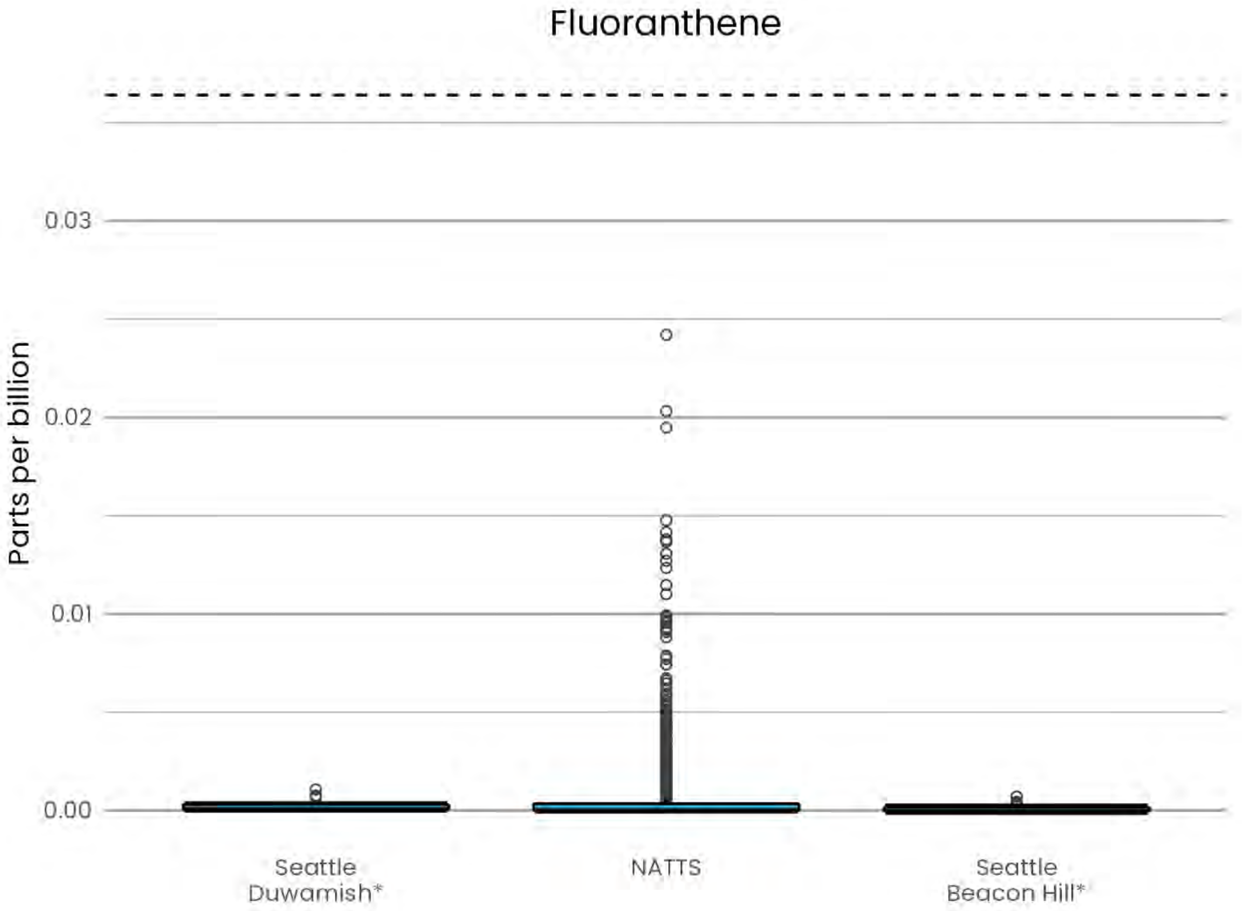


Figure O-1420. Fluorene box plot.

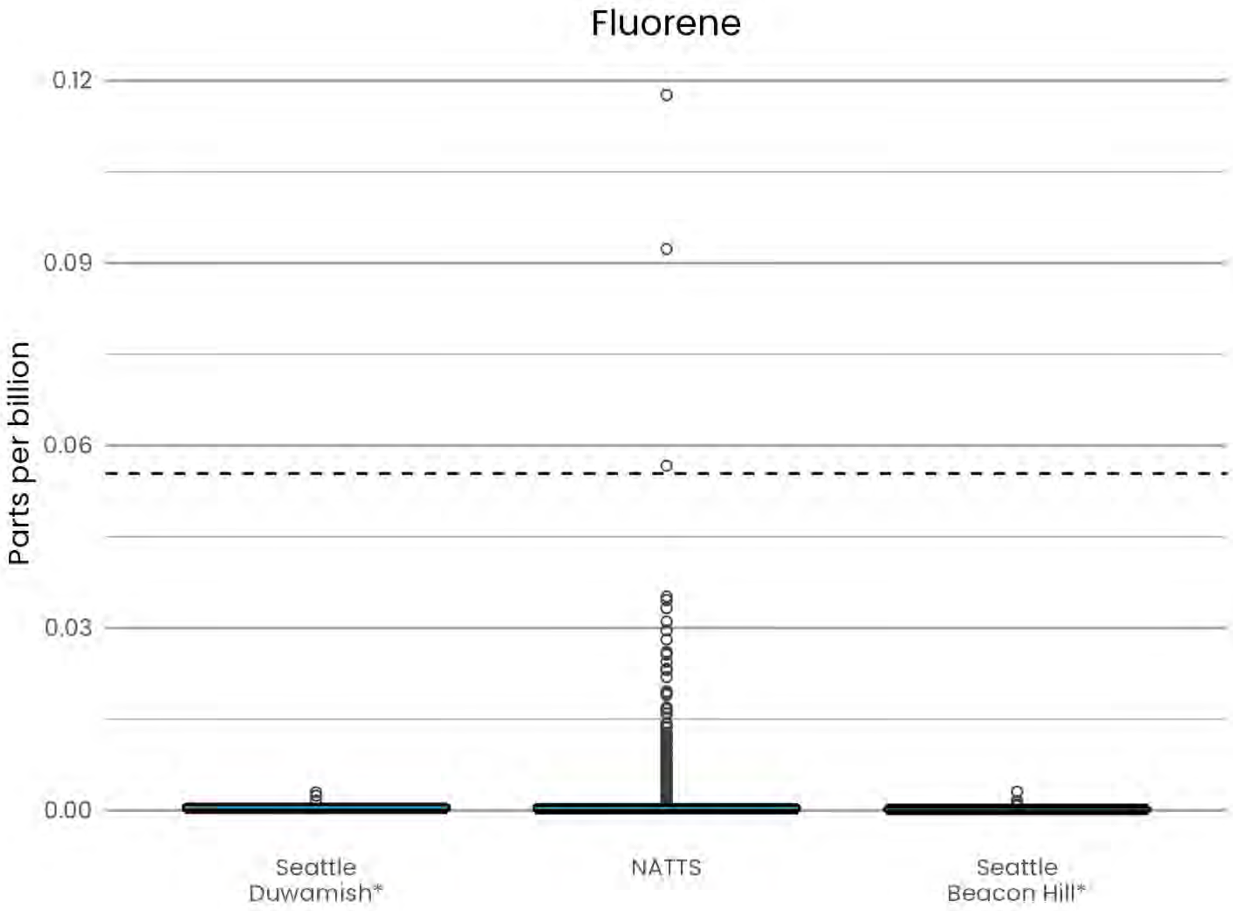


Figure O-1521. box plot.

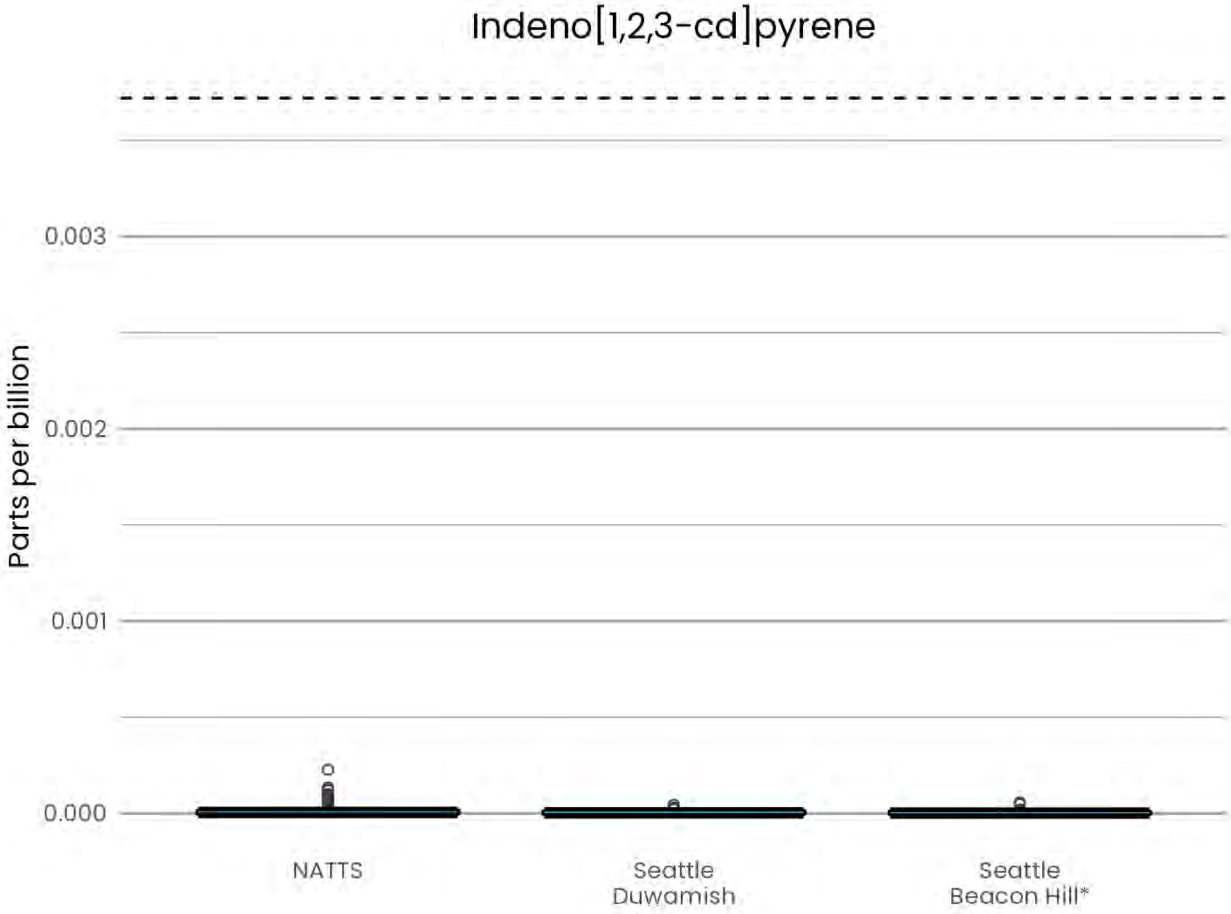


Figure O-1622. Naphthalene box plot.

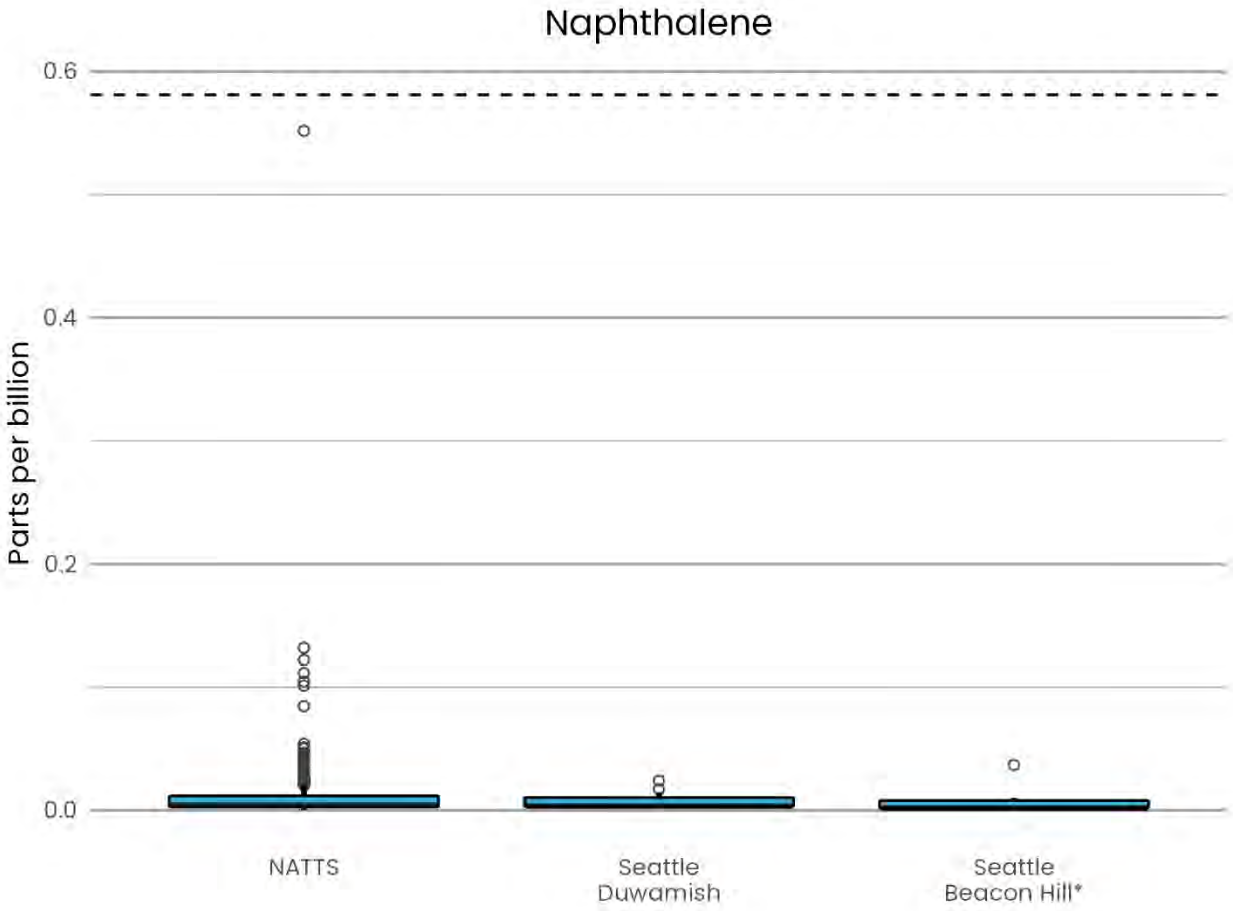


Figure O-1723. Perylene box plot.

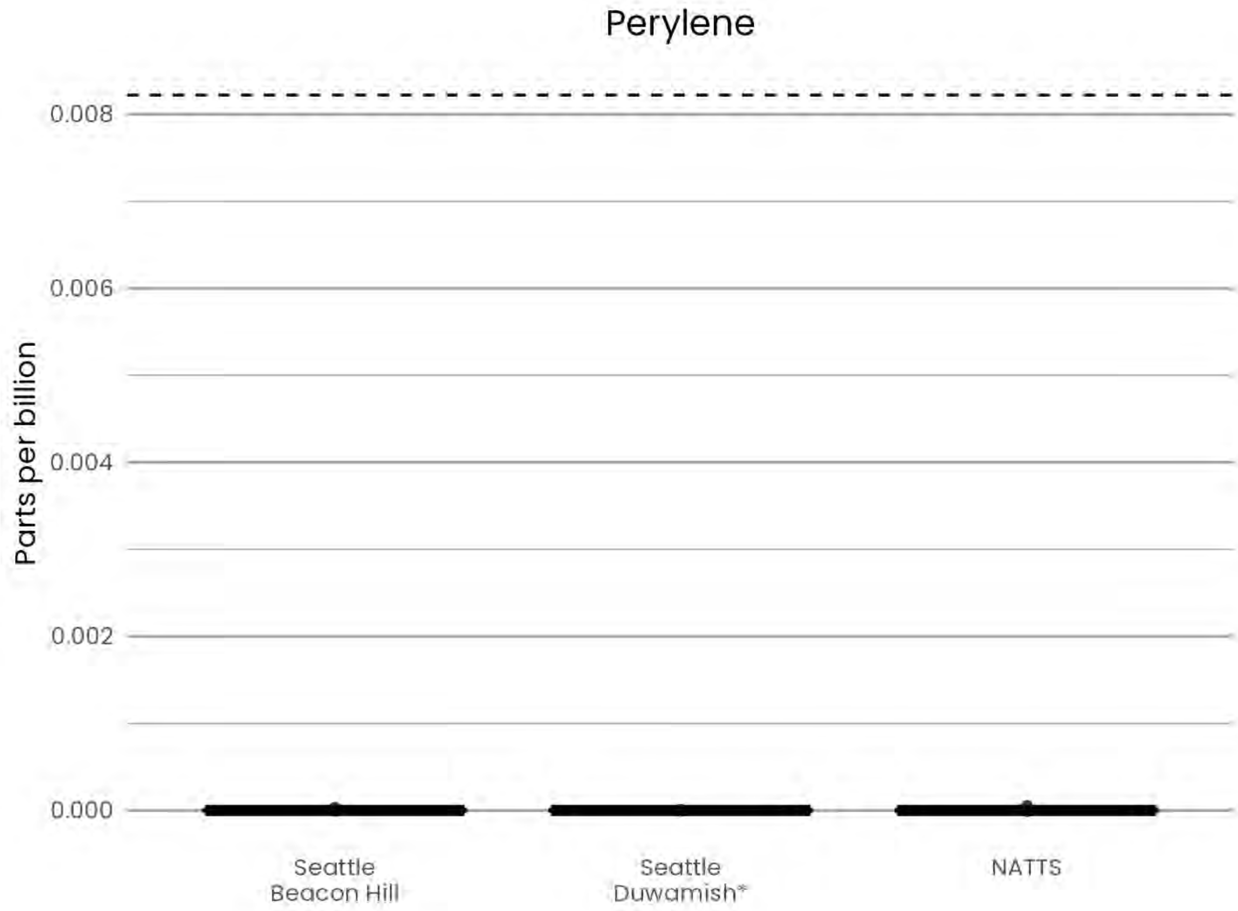


Figure O-1824. Phenanthrene box plot.

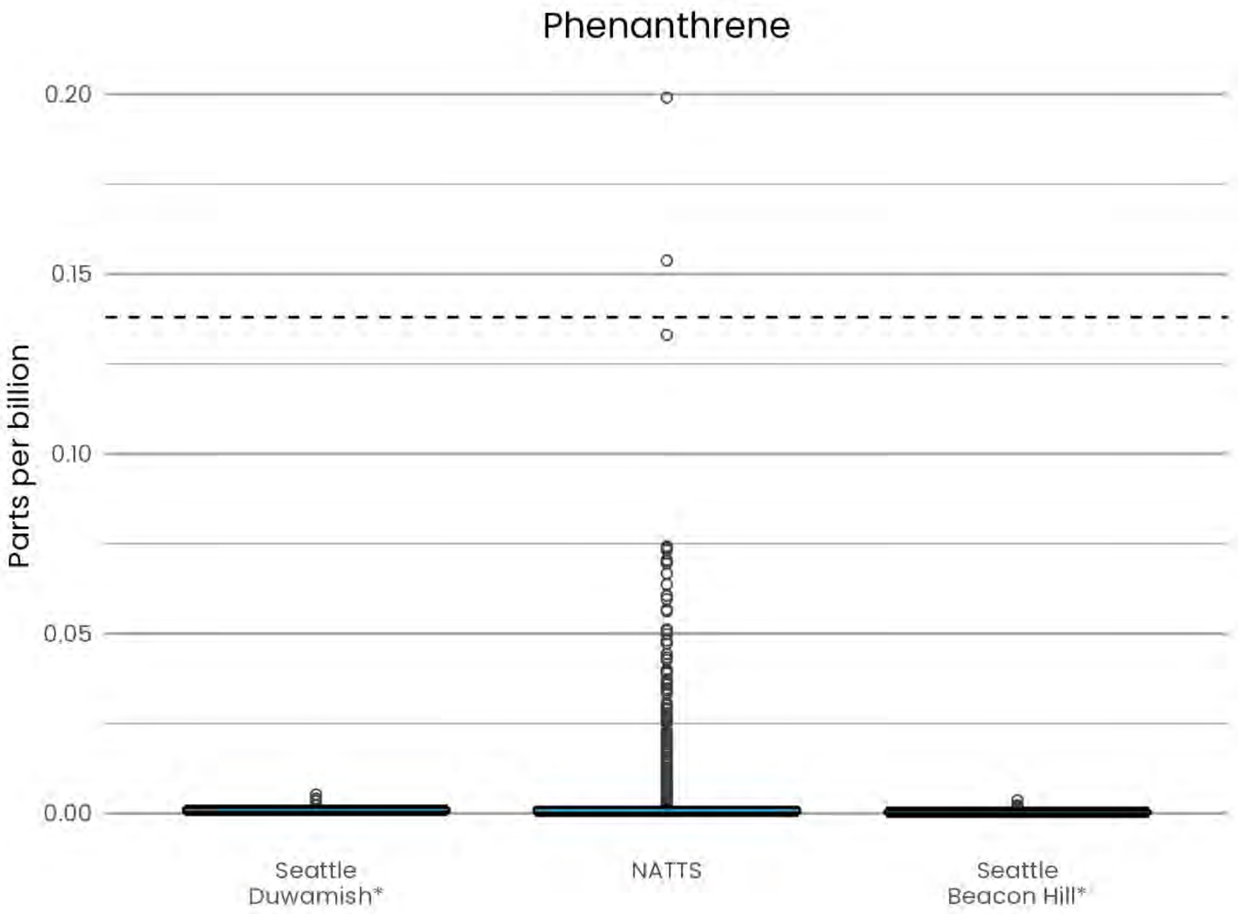
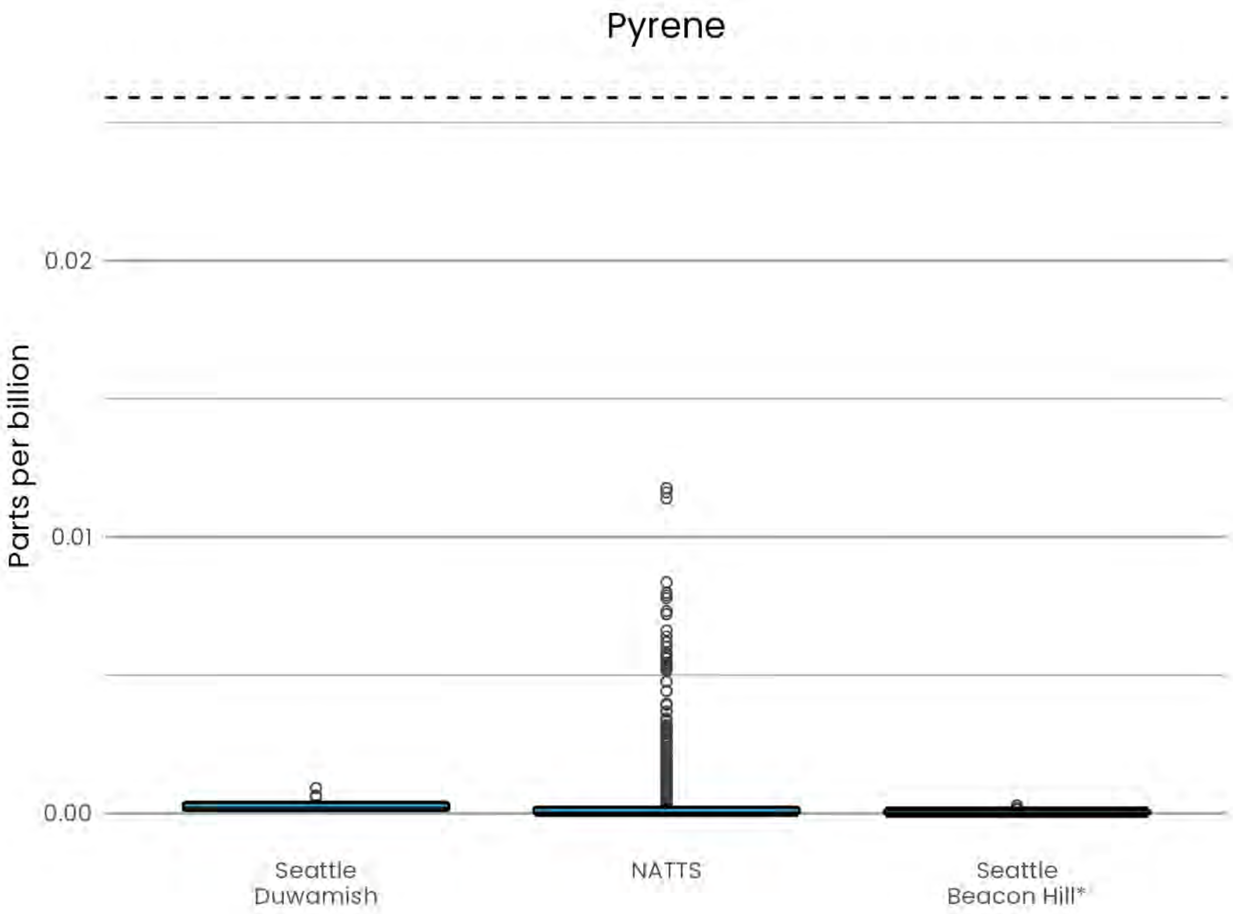


Figure O-1925. Pyrene box plot.



Appendix P. Summary statistics for fixed sites

This section contains summary statistics for the fixed sites. 5th is the 5th percentile, 25th is the 25th percentile and so on; 50th is the median; n is the number of samples.

Table P-126. Summary statistics for fixed sites.

Parameter	Site	5th	25th	Mean	50th	75th	95th	n	Units
1,3-Butadiene	10th & Weller	0.014	0.031	0.050	0.045	0.053	0.122	61	ppb
1,3-Butadiene	Beacon Hill	0.000	0.009	0.016	0.014	0.020	0.040	62	ppb
1,3-Butadiene	Duwamish	0.003	0.009	0.029	0.018	0.036	0.085	61	ppb
1,3-Butadiene	L St	0.005	0.009	0.038	0.015	0.047	0.126	63	ppb
1,3-Butadiene	S 36th St	0.004	0.022	0.039	0.029	0.050	0.098	62	ppb
1,3-Butadiene	Tideflats	0.004	0.009	0.029	0.016	0.031	0.106	65	ppb
Acenaphthene	Beacon Hill	0.00E+00	0.00E+00	2.71E-04	7.00E-05	2.45E-04	1.09E-03	59	ppb
Acenaphthene	Duwamish	0.00E+00	0.00E+00	5.72E-04	3.63E-04	7.98E-04	1.78E-03	56	ppb
Acenaphthylene	Beacon Hill	0.00E+00	0.00E+00	2.25E-05	3.11E-06	2.11E-05	1.10E-04	64	ppb
Acenaphthylene	Duwamish	0.00E+00	0.00E+00	7.80E-05	2.51E-05	7.54E-05	3.51E-04	57	ppb
Acetaldehyde	10th & Weller	0.463	0.555	0.690	0.630	0.774	1.070	60	ppb
Acetaldehyde	Beacon Hill	0.220	0.310	0.524	0.436	0.672	1.082	66	ppb
Acetaldehyde	Duwamish	0.238	0.329	0.507	0.413	0.603	0.985	59	ppb
Acetaldehyde	L St	0.253	0.323	0.536	0.427	0.552	1.108	62	ppb
Acetaldehyde	S 36th St	0.240	0.328	0.471	0.410	0.519	0.962	60	ppb
Acetaldehyde	Tideflats	0.273	0.365	0.564	0.475	0.705	1.041	60	ppb
Acrolein	10th & Weller	0.120	0.180	0.323	0.292	0.446	0.647	60	ppb
Acrolein	Beacon Hill	0.082	0.119	0.195	0.165	0.230	0.326	62	ppb
Acrolein	Duwamish	0.112	0.148	0.275	0.254	0.352	0.559	61	ppb
Acrolein	L St	0.095	0.156	0.276	0.250	0.345	0.596	62	ppb
Acrolein	S 36th St	0.116	0.189	0.298	0.257	0.417	0.578	60	ppb
Acrolein	Tideflats	0.090	0.162	0.350	0.302	0.464	0.794	65	ppb
Anthracene	Beacon Hill	3.91E-06	5.76E-06	1.76E-05	1.17E-05	1.73E-05	6.36E-05	63	ppb
Anthracene	Duwamish	0.00E+00	1.71E-05	4.09E-05	3.23E-05	6.04E-05	9.84E-05	56	ppb

Antimony	Beacon Hill	0.250	0.497	0.951	0.752	1.160	2.158	65	ng/m3
Antimony	Duwamish	0.628	0.927	1.793	1.325	2.185	4.428	66	ng/m3
Antimony	Tideflats	0.239	0.515	1.864	0.812	1.925	4.026	65	ng/m3
Arsenic	Beacon Hill	0.148	0.222	0.502	0.325	0.610	1.086	65	ng/m3
Arsenic	Duwamish	0.312	0.553	1.314	0.936	1.473	3.243	66	ng/m3
Arsenic	Tideflats	0.134	0.283	1.051	0.626	1.320	3.426	65	ng/m3
Benzene	10th & Weller	0.179	0.242	0.326	0.322	0.375	0.561	60	ppb
Benzene	Beacon Hill	0.060	0.090	0.135	0.127	0.167	0.247	62	ppb
Benzene	Duwamish	0.090	0.111	0.197	0.170	0.235	0.414	61	ppb
Benzene	L St	0.076	0.106	0.234	0.162	0.299	0.547	63	ppb
Benzene	S 36th St	0.116	0.138	0.229	0.188	0.267	0.432	62	ppb
Benzene	Tideflats	0.077	0.114	0.197	0.158	0.243	0.456	65	ppb
Benzo[a]anthracene	Beacon Hill	0.00E+00	9.25E-07	4.65E-06	1.51E-06	3.18E-06	7.95E-06	65	ppb
Benzo[a]anthracene	Duwamish	0.00E+00	1.80E-06	5.49E-06	3.18E-06	6.38E-06	1.83E-05	56	ppb
Benzo[a]pyrene	Beacon Hill	0.00E+00	4.28E-07	4.54E-06	1.01E-06	1.98E-06	1.10E-05	65	ppb
Benzo[a]pyrene	Duwamish	0.00E+00	1.04E-06	4.89E-06	1.80E-06	5.29E-06	2.10E-05	54	ppb
Benzo[b]fluoranthene	Beacon Hill	1.48E-06	1.89E-06	1.22E-05	2.57E-06	9.89E-06	5.58E-05	33	ppb
Benzo[b]fluoranthene	Duwamish	1.73E-06	2.43E-06	8.75E-06	4.03E-06	7.79E-06	3.51E-05	33	ppb
Benzo[e]pyrene	Beacon Hill	0.00E+00	1.39E-06	5.31E-06	2.11E-06	5.52E-06	1.32E-05	63	ppb
Benzo[e]pyrene	Duwamish	0.00E+00	2.38E-06	7.10E-06	3.70E-06	9.21E-06	2.38E-05	53	ppb
Benzo[g,h,i]perylene	Beacon Hill	0.00E+00	1.38E-06	5.37E-06	2.51E-06	6.08E-06	1.47E-05	61	ppb
Benzo[g,h,i]perylene	Duwamish	0.00E+00	2.09E-06	8.67E-06	3.62E-06	1.20E-05	3.20E-05	55	ppb
Benzo[k]fluoranthene	Beacon Hill	0.00E+00	0.00E+00	3.11E-06	8.85E-07	2.67E-06	9.19E-06	66	ppb
Benzo[k]fluoranthene	Duwamish	0.00E+00	7.61E-07	4.01E-06	1.56E-06	5.31E-06	1.49E-05	55	ppb
Beryllium	Beacon Hill	0.000	0.000	0.001	0.001	0.002	0.003	61	ng/m3
Beryllium	Duwamish	0.000	0.003	0.007	0.006	0.010	0.017	49	ng/m3

Beryllium	Tideflats	0.000	0.001	0.008	0.003	0.007	0.031	53	ng/m3
Cadmium	Beacon Hill	0.015	0.023	0.049	0.035	0.064	0.114	64	ng/m3
Cadmium	Duwamish	0.032	0.050	0.126	0.087	0.171	0.341	66	ng/m3
Cadmium	Tideflats	0.010	0.026	0.105	0.046	0.093	0.204	65	ng/m3
Carbon tetrachloride	10th & Weller	0.051	0.074	0.078	0.079	0.088	0.099	60	ppb
Carbon tetrachloride	Beacon Hill	0.074	0.078	0.084	0.082	0.089	0.099	62	ppb
Carbon tetrachloride	Duwamish	0.067	0.075	0.080	0.080	0.085	0.102	61	ppb
Carbon tetrachloride	L St	0.049	0.075	0.078	0.079	0.084	0.098	63	ppb
Carbon tetrachloride	S 36th St	0.066	0.077	0.080	0.079	0.085	0.098	62	ppb
Carbon tetrachloride	Tideflats	0.067	0.074	0.079	0.079	0.085	0.095	65	ppb
Chromium	Beacon Hill	4.412	5.210	6.004	6.090	6.870	7.556	65	ng/m3
Chromium	Duwamish	2.315	3.238	4.440	4.370	5.288	7.003	66	ng/m3
Chromium	Tideflats	1.694	2.210	2.986	2.540	3.555	5.912	65	ng/m3
Chrysene	Beacon Hill	0.000	0.000	0.000	0.000	0.000	0.000	22	ppb
Chrysene	Duwamish	0.000	0.000	0.000	0.000	0.000	0.000	19	ppb
Cobalt	Beacon Hill	0.030	0.050	0.079	0.073	0.100	0.162	65	ng/m3
Cobalt	Duwamish	0.050	0.095	0.192	0.154	0.237	0.458	66	ng/m3
Cobalt	Tideflats	0.027	0.057	0.207	0.105	0.256	0.530	65	ng/m3
Coronene	Beacon Hill	0.00E+00	1.06E-06	2.46E-06	1.49E-06	3.03E-06	6.82E-06	64	ppb
Coronene	Duwamish	0.00E+00	1.30E-06	4.75E-06	2.07E-06	5.78E-06	1.63E-05	55	ppb
Dibenzo[a,h]anthracene	Beacon Hill	0.00E+00	0.00E+00	6.36E-07	0.00E+00	0.00E+00	2.28E-06	66	ppb
Dibenzo[a,h]anthracene	Duwamish	0.00E+00	0.00E+00	3.47E-07	0.00E+00	0.00E+00	2.15E-06	57	ppb
Ethylbenzene	10th & Weller	0.034	0.046	0.079	0.062	0.089	0.179	61	ppb
Ethylbenzene	Beacon Hill	0.016	0.023	0.036	0.033	0.046	0.076	62	ppb
Ethylbenzene	Duwamish	0.020	0.040	0.098	0.063	0.120	0.220	61	ppb
Ethylbenzene	L St	0.012	0.020	0.059	0.033	0.076	0.200	63	ppb
Ethylbenzene	S 36th St	0.026	0.031	0.062	0.046	0.071	0.142	62	ppb

Ethylbenzene	Tideflats	0.016	0.026	0.061	0.043	0.083	0.158	64	ppb
Ethylene oxide	10th & Weller	0.000	0.055	0.112	0.088	0.116	0.282	29	ppb
Ethylene oxide	Beacon Hill	0.041	0.046	0.076	0.073	0.106	0.133	21	ppb
Ethylene oxide	Duwamish	0.041	0.061	0.106	0.075	0.154	0.217	27	ppb
Ethylene oxide	L St	0.039	0.054	0.140	0.078	0.117	0.462	32	ppb
Ethylene oxide	S 36th St	0.041	0.064	0.112	0.095	0.126	0.244	26	ppb
Ethylene oxide	Tideflats	0.030	0.050	0.127	0.090	0.132	0.395	31	ppb
Fluoranthene	Beacon Hill	2.55E-05	4.69E-05	1.04E-04	6.88E-05	9.22E-05	3.40E-04	64	ppb
Fluoranthene	Duwamish	8.21E-05	1.13E-04	2.15E-04	1.78E-04	2.40E-04	4.86E-04	56	ppb
Fluorene	Beacon Hill	7.43E-05	1.33E-04	3.27E-04	1.84E-04	2.86E-04	9.71E-04	64	ppb
Fluorene	Duwamish	1.77E-04	2.10E-04	5.33E-04	3.50E-04	6.91E-04	1.31E-03	56	ppb
Formaldehyde	10th & Weller	0.888	1.145	1.643	1.617	2.123	2.422	56	ppb
Formaldehyde	Beacon Hill	0.485	0.795	1.095	0.937	1.304	2.039	57	ppb
Formaldehyde	Duwamish	0.559	0.896	1.122	1.080	1.277	1.841	56	ppb
Formaldehyde	L St	0.565	0.744	1.142	1.027	1.324	2.200	59	ppb
Formaldehyde	S 36th St	0.447	0.672	1.029	1.002	1.222	1.892	57	ppb
Formaldehyde	Tideflats	0.613	0.939	1.245	1.214	1.530	2.121	56	ppb
Indeno[1,2,3-cd]pyrene	Beacon Hill	0.00E+00	9.39E-07	5.40E-06	1.92E-06	6.21E-06	1.55E-05	64	ppb
Indeno[1,2,3-cd]pyrene	Duwamish	0.00E+00	1.24E-06	6.91E-06	2.79E-06	9.43E-06	2.47E-05	56	ppb
Lead	Beacon Hill	0.490	0.965	1.747	1.270	2.270	4.336	65	ng/m3
Lead	Duwamish	1.428	2.843	6.770	4.575	9.370	14.375	66	ng/m3
Lead	Tideflats	0.493	0.962	4.000	2.025	5.735	14.600	65	ng/m3
Manganese	Beacon Hill	0.784	1.480	3.573	2.630	3.880	9.162	65	ng/m3
Manganese	Duwamish	2.903	5.133	23.224	10.900	16.825	31.475	66	ng/m3
Manganese	Tideflats	1.072	2.960	9.597	6.710	11.700	23.260	65	ng/m3
Mercury	Beacon Hill	0.002	0.003	0.006	0.005	0.008	0.013	65	ng/m3
Mercury	Duwamish	0.001	0.005	0.034	0.007	0.012	0.019	64	ng/m3
Mercury	Tideflats	0.000	0.005	0.009	0.008	0.012	0.018	64	ng/m3
Naphthalene	Beacon Hill	0.002	0.003	0.005	0.004	0.007	0.009	57	ppb

Naphthalene	Duwamish	0.003	0.004	0.007	0.006	0.009	0.015	47	ppb
Nickel	Beacon Hill	0.273	0.443	0.641	0.572	0.736	1.502	65	ng/m3
Nickel	Duwamish	0.457	0.776	1.604	1.305	1.933	3.828	66	ng/m3
Nickel	Tideflats	0.751	1.086	1.860	1.435	1.990	4.790	64	ng/m3
Perylene	Beacon Hill	0.00E+00	0.00E+00	6.15E-07	0.00E+00	0.00E+00	5.92E-07	66	ppb
Perylene	Duwamish	0.00E+00	0.00E+00	1.60E-07	0.00E+00	0.00E+00	9.45E-07	58	ppb
Phenanthrene	Beacon Hill	1.39E-04	2.44E-04	5.22E-04	3.32E-04	4.75E-04	1.85E-03	62	ppb
Phenanthrene	Duwamish	3.98E-04	5.00E-04	1.12E-03	8.47E-04	1.18E-03	2.78E-03	53	ppb
Pyrene	Beacon Hill	1.69E-05	3.12E-05	6.20E-05	4.95E-05	7.22E-05	1.71E-04	63	ppb
Pyrene	Duwamish	9.67E-05	1.57E-04	2.72E-04	2.58E-04	3.28E-04	5.39E-04	53	ppb
Selenium	Beacon Hill	0.026	0.092	0.228	0.170	0.267	0.651	65	ng/m3
Selenium	Duwamish	0.180	0.480	2.039	0.834	2.783	6.915	66	ng/m3
Selenium	Tideflats	0.020	0.066	0.147	0.124	0.216	0.312	64	ng/m3
Tetrachloroethylene	10th & Weller	0.005	0.007	0.017	0.010	0.015	0.028	61	ppb
Tetrachloroethylene	Beacon Hill	0.003	0.005	0.008	0.007	0.011	0.015	62	ppb
Tetrachloroethylene	Duwamish	0.005	0.010	0.020	0.017	0.024	0.044	61	ppb
Tetrachloroethylene	L St	0.004	0.006	0.013	0.009	0.016	0.034	63	ppb
Tetrachloroethylene	S 36th St	0.003	0.005	0.012	0.008	0.015	0.025	62	ppb
Tetrachloroethylene	Tideflats	0.005	0.007	0.016	0.011	0.021	0.038	65	ppb

Appendix Q. Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) model estimates

EPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) software can be used to estimate the daily lead exposure for children from different sources[11]. It is typically used for risk analysis near Superfund sites. However, by adjusting the air lead concentration to the level found at the highest site in our study (0.009 µg/m^3 at the South Park Industrial site), we can estimate the impact of lead exposure from air compared to other media. The other sources of lead that are modeled by IEUBK are diet, water, and ingestion of outdoor soil and indoor dust. The model then combines all of these inputs and calculates an estimated blood lead level. IEUBK comes with default parameters for each type of source. In the analysis presented below only the air concentration of lead was changed. IEUBK can output values for a number of different age ranges, from 6-12 months up to 6-7 years. In the analysis we performed, the 6-12 month age group had the highest estimated blood lead and will be the only group presented. The 6-7 year age group, which had the lowest estimated blood lead, had levels that were about 60%, or 1.2 µg/dL lower than the 6-12 month group.

Figure Q-127. Estimated daily lead intake for children 6-12 months.

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[11] Lead at Superfund Sites: Software and Users' Manuals, EPA, 2023. https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals.

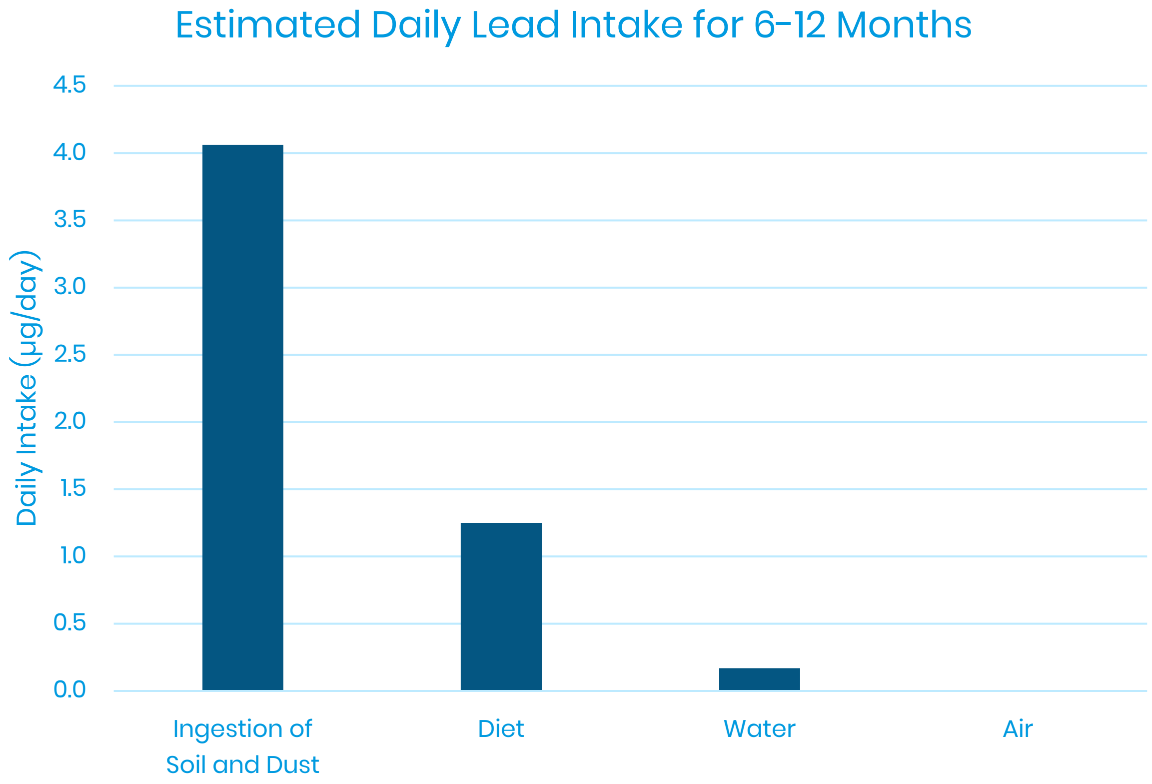


Figure Q-1 shows the estimated daily lead intake for children 6-12 months for different sources. Ingestion of outdoor soil or indoor dust was estimated at 4.1 µg/day. Diet was estimated at 1.2 µg/day. Water was estimated at 0.17 µg/day. And air was estimated at 0.003 µg/day. Smaller children breath in less air than larger children; and the 6-7 years group had an air intake of 0.011 µg/day. In this model, the amount of lead from air did not significantly contribute to the overall lead intake.

Seattle and Tacoma Air Toxics Study

We invite you to share your input

WHAT ARE AIR TOXICS?

Air toxics are a group of over 400 pollutants known or suspected to cause several health problems; including cancer and birth defects, as well as damage to lungs, immune systems, and nervous systems. In the Puget Sound region, the main health risks from air toxics come primarily from fine particles in diesel exhaust.

WHAT WE WILL BE STUDYING?

We will look at changes in air toxics levels over time including diesel exhaust sources, wood smoke, ethylene oxide (a newly prioritized air toxic), and metal emissions in industrial areas. We will estimate potential cancer risk from these air toxics.

WHY IS THIS STUDY IMPORTANT?

This study will gather important air quality data and help us better understand the health risks associated with air pollution in our communities. The final report will be released publicly so other organizations and agencies that serve the Duwamish Valley can access and utilize the data to determine where priorities are made in the community.

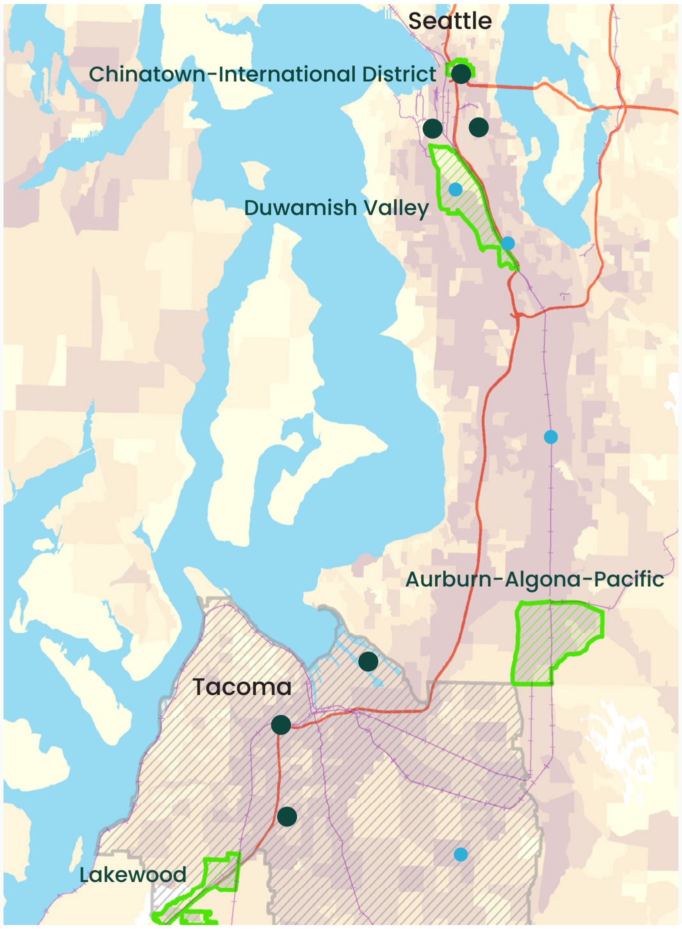
Seattle and Tacoma Air Toxics Study

COMMUNITY-DIRECTED SAMPLING + TIMELINE

We will complete a year of monitoring at two near-highway sites and two industrial sites in Seattle and Tacoma, and a residential site in Tacoma that has some of the highest levels of wood smoke in the region.

In addition, there is an opportunity for community-directed monitoring. This part of the study will include community members in the process of identifying locations of interest in the Duwamish Valley, and determining how often and for how long to monitor at certain sites.

The toxics monitoring will start in the summer/fall of 2021. After the monitoring period is complete, we will then interpret the data to screen for any potential health risks for the community. We expect the final results to be reported back to the community after monitoring is completed, in late 2022.



STUDY LOCATIONS

● Study Site

● Other Monitoring Station

▨ PM 2.5 Maintenance Area

▨ Focus Community

Environmental Justice Screening Score

Least Impacted 20%

Most Impacted 20%

WE INVITE YOU TO SHARE YOUR INPUT!

We want to include your input on where to monitor for air toxics in the Duwamish Valley. We will host a workshop on **Tuesday, August 17th** in South Park. We will also introduce information on air toxics, share recent moss study results, and hear your valuable input.

Register here. www.bit.ly/3eD1iOH

Fill out this survey to share your input and identify locations that you think should be prioritized.

Survey link. www.pscleanair.gov/DVAirToxics

Please contact us if you have any questions or concerns at ej@pscleanair.gov.

Region 9 - San Diego State University

Center for Community Energy and Environmental Justice

an EPA and DOE-Supported Environmental Justice Thriving Communities Technical Assistance Center

QUALITY ASSURANCE PROJECT PLAN (QAPP)

Quality Assurance Project Plan
For
San Diego State University
Center for Community Energy and Environmental Justice
an EPA and DOE-Supported Environmental Justice
Thriving Communities Technical Assistance Center

Region 9
June 2023 - May 2028
Cooperative Agreement # XJ-98T65801-0
EPA Office of Environmental Justice and External
Civil Rights

Prepared by: Paige Dawson
Center for Community Energy and Environmental Justice
SDSU Division of Research and Innovation
5500 Campanile Drive
San Diego, CA 92182
cceej@sdsu.edu
(619) 594-8287

Prepared for:
US EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105-3901

March 21, 2024

A2. APPROVALS

The following individuals have approval authority of this QAPP and will also receive a copy of the final, approved QAPP and any subsequent revisions. Sergio Morales, the Quality Assurance Manager for this project, is responsible for maintaining the official approved QAPP.

Center for Community Energy and Environmental Justice Executive Director:

Date: 4/23/2024

Center for Community Energy and Environmental Justice Quality Assurance Manager:

Sergio Morales

Date: 4/23/2024

USEPA Region 9 Grants Project Officer:

AllenWilliams, Dani
Digitally signed by AllenWilliams, Dani
Date: 2024.04.23 10:28:21 -07'00'

Date:

USEPA Region 9 Quality Assurance Manager:

Audrey L Johnson
Digitally signed by Audrey L Johnson
Date: 2024.04.22 12:35:01 -07'00'

Date:

Table of Contents

List of Tables and Figures

Figures

Tables

A4. Project Purpose, Problem Definition, and Background

A4.1. Problem Definition and Background

This Quality Assurance (QA) Project Plan has been prepared specifically for the use of secondary environmental data/information (that were originally collected for a different purpose) by the Center for Community Energy and Environmental Justice (CCEEJ) for the purpose of providing technical assistance related to environmental and energy justice for communities in EPA Region 9. The Center for Community Energy and Environmental Justice is part of the Federal Interagency Thriving Communities Network and delivers on the Biden-Harris Administration's Justice40 Initiative to ensure that 40% of the benefits of certain federal investments flow to disadvantaged communities. This part of the QA project plan describes how the project will be managed, organized and implemented.

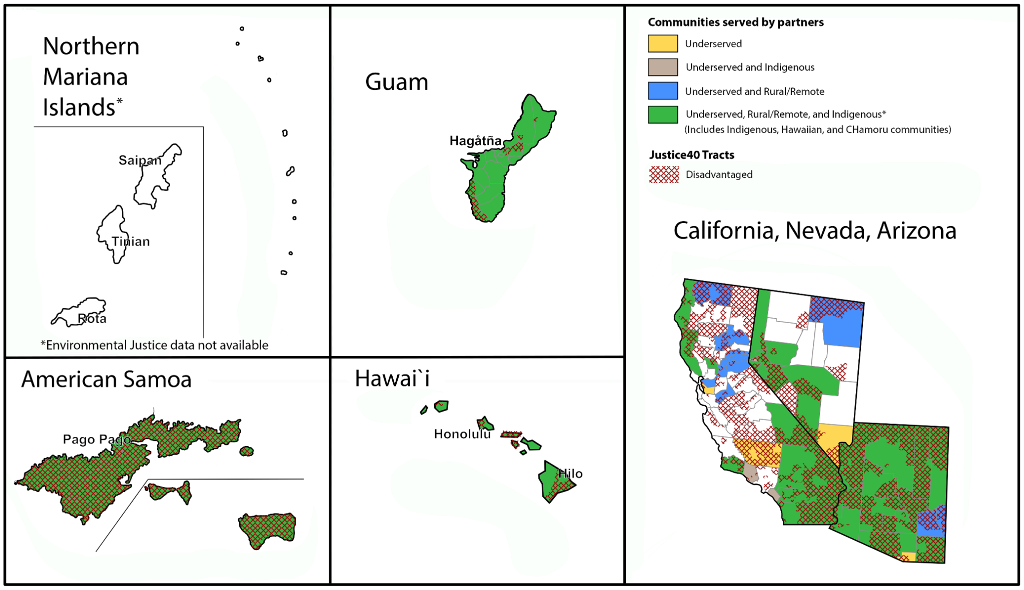
There are no other QA planning documents that have relevant requirements for this QAPP.

Historically, underserved communities have been disproportionately burdened by environmental hazards and health consequences and have faced environmental and energy justice challenges. These communities are often exposed to unhealthy land uses, poor air and water quality, dilapidated housing, lead exposure, and other environmental threats that drive health disparities. Many of these communities are also surrounded by social inequities such as job insecurity, underemployment, linguistic isolation, underperforming schools, noise pollution, crowded homes, face high energy burden or fossil fuel dependence, and lack access to healthy foods and transportation. In addition, they often lack adequate resources and experience to navigate complex grant application and award making processes and have been limited in their ability to have meaningful access to, and participation in, governmental decision-making processes that affect them, including those relating to environmental health and justice, and energy justice. The combination of environmental risks and social inequities creates a cumulative, disproportionate impact that hinders optimal environmental health and justice particularly for these communities.

Created by the Inflation Reduction Act under Clean Air Act Section 138, the Environmental and Climate Justice Program (EJC) allocated $2.8 billion dollars for the financial assistance to be implemented by the Environmental Protection Agency (U.S. EPA, Inflation Reduction Act Environmental and Climate Justice Program). This historical investment in environmental justice, along with the vast array of funding opportunities that extend beyond the EJC and EPA, creates a valuable opportunity for communities to build capacity and achieve environmental, energy, and climate justice. However, barriers such as lack of organizational capacity, inequitable access to resources, language barriers, unreliable internet access, and more, have the potential to inhibit the success of these investments. As one of the 17 Environmental Justice Thriving Communities Technical Assistance Centers (EJ TCTACs), the Center for Community Energy will address these barriers by providing free technical assistance to underserved communities in order to advance accessibility and equity for the communities that need it most. CCEEJ's environmental information operations (EIO) will be an essential element of the technical assistance provided to communities as it will provide a useful tool to help affected communities demonstrate the magnitude of environmental and energy justice issues. Understanding the magnitude of the issues will in turn aid in building communities' capacity to prioritize their needs, develop projects to address these issues, develop strong grant applications, and more.

A4.2 Project Overview and Purpose

Figure 1. Map of EPA Region 9 served by CCEEJ



Environmental and energy justice are integral components to protect human health and the environment, particularly in underserved, rural, remote, tribal, and indigenous communities. Building capacity in and providing technical support and assistance for communities often most vulnerable and affected by environmental challenges is essential to address environmental health and justice challenges. Hosted at San Diego State University, CCEEJ will serve to empower communities in EPA's Region 9 (California, Arizona, Nevada, Hawai`i, Guam, American Samoa, and the Northern Mariana Islands) by providing critical services to qualified community organizations. These services will provide eligible community organizations with the skills, support and capacity they need to meet community- defined priorities with community-driven actions and participate meaningfully in decision- making processes in areas related to energy and environmental justice. The mission of CCEEJ is to leverage and strengthen community assets by creating an accessible and inclusive in-person and virtual community center that builds capacity and provides technical assistance in energy and environmental justice centered around four unifying objectives:

1) **Engage in outreach and partnership building efforts** with the communities we will serve. This will include conducting community needs assessments, developing and implementing communication strategies and pathways to strengthen our network's existing partnerships, and expanding our network of community partners over time.
2) **Develop resources** to share across the network and serve community needs. Our hub partners will compile and integrate existing training materials and work to develop new materials to meet community needs identified during Objective 1 activities.
3) **Transfer knowledge and build community capacity**. Through the collaborative efforts of our hub and spoke partners, we will work with community partners to co-produce and co- generate training materials, conduct community training events, deliver of one-on-one services, establish and grow of the Community Knowledge Portal, and disseminate TCTAC resources through a variety of modalities to transfer knowledge and support communities in building capacity. The Community Knowledge Portal will include relevant regional grant opportunities.
4) **Evaluate, adapt, and innovate.** To ensure the SDSU TCTAC is meeting the needs of our client communities, we will evaluate our efforts on an ongoing basis, tracking qualitative and quantitative metrics of participant engagement and participating in rigorous internal and external evaluations. We will use the results of these annual evaluations to refine, adapt, and innovate our approaches to best serve our community partners.

Our grant-related support will include:
- Grant-getting capacity
- Strengthening a community's ability to identify, successfully apply for, and effectively manage grants related to environmental and energy justice
- Navigate government systems used in the grant process
- Knowledge of EnJ/EJ grants
- Knowledge and understanding of environmental and energy justice-related grant programs.

Using a hub and spoke model, CCEEJ will create a nexus of centralized expertise and coordination for each critical service to connect and empower eligible community organizations. Our hub and spoke model pairs established partners in each state/territory with hub partners who have the expertise and ability to coordinate, co-develop, share, deliver, and monitor key services while tracking and reporting qualitative (i.e., success stories) and quantifiable metrics of outcomes and outputs from the communities CCEEJ will serve.

No samples of primary information/data will be collected for this project. In order to achieve the previously-stated objectives, the project's EIOs will solely involve the use of existing data/information that were originally collected for a different purpose. The use of secondary environmental data will be directly linked to the following actions:

- Providing training on environmental (EJ) and energy justice (EnJ) screening tools for use in grant proposals along with EJ and EnJ assessments. Screening tools will include (but are not limited to):
    - EJScreen (Environmental Protection Agency)
    - Climate & Economic Justice Screening Tool (White House Council on Environmental Quality)
    - DOE Energy Justice Mapping Tool (Department of Energy)
    - Social Vulnerability Index (Center for Disease Control /Agency for Toxic Substances and Disease Registry)
    - CalEnviroScreen (California Office of Environmental Health Hazard Assessment)
    - Healthy Places Index (Public Health Alliance of Southern California)
- Producing guidance documents for EJ and EnJ analysis
- Provide support reviewing and commenting on environmental impact statements and permits and providing information on EPA regulations and policies
- Producing guidance for energy policy development
- Producing technical guidance on brownfields (providing technical support and assistance in navigating the redevelopment process, including redevelopment analyses, community engagement, and brownfields financing)
- Training communities on environmental program topics
- Development of the Community Knowledge Portal, which will serve as a community resource for data and information, training events, recording narratives, stories, music, art, and community oral histories.

The use of environmental data and information is integral to understanding EJ and EnJ issues and is an essential element of grant proposals addressing these issues. With this in mind, the primary purpose of the EIOs conducted by CCEEJ is to help achieve the primary goal of strengthening community organizations' capacity and effectiveness in applying to, managing and implementing EJ and EnJ grants and programs. The projected outcomes of the project's EIO actions will be 1) advanced community comprehension of environmental and energy justice issues in their region (including from a technical perspective) and 2) Ability for communities to be confident in using pre-existing data in the future (i.e., beyond the scope of their work with CCEEJ) to inform project/solution development, identifying priorities and action items, and/or to strengthen grant proposals that can provide the necessary resources to address EJ/EnJ issues. Leveraging existing data that meets the quality standards set forth in this document (and by the EPA) will provide community organizations with a valuable tool that can be used in grant proposals, project development, identifying priority areas, understanding EJ and EnJ issues from a technical perspective, and more. Secondary use of existing data will be the most effective in achieving our objectives for the following reasons:

1. Primary data collection is not in the scope, workplan, or budget of this project (and would take up a large amount of the limited resources that could be more effectively used for other project activities, such as community outreach and engagement)
2. Use of secondary data is more cost effective (both for this project and for communities who can continue to use these tools in the future) given that it requires less resources, funding, and time.
3. Secondary data provided to communities as a tool will already have gone through the rigorous screening process both by CCEEJ, as outlined in this QAPP, and by the agencies/experts/other entities who collected the data. This will also ease the burden on communities in the sense that they will not be required to invest additional time and resources (which is most often severely limited) in to confirming the integrity of data to be used in informing their environmental and energy justice efforts
4. Secondary data used by this project will already be presented in a more accessible manner (primarily with the use of screening tools).
5. Analysis and interpretation of this data, though originally conducted for a different purpose, will serve as a useful guide for how to apply this data in the context of a specific needs assessment, community project, grant proposal, and more.

The secondary data that will be used to inform the following environmental decisions:

- What environmental justice challenges should be prioritized in project planning (e.g., air pollution, brownfields, lead contamination, etc.)
- What methods might be the best option to address environmental justice issues
- What resources are available to address environmental justice issues
- What agencies to consult for advice and remedy
- What grant opportunities will be the best fit to fund the project
- What data points will the most salient to highlight in order to strengthen a grant proposal

Refer to Section A6 for discussion of the level of information quality needed in order to ensure that these environmental decisions are based on sound environmental information.

Table 1. Applicable Regulatory Programs and Standards

Regulatory Program	Executive Order/Section Number	Description
Advancing Racial Equity and Support For Underserved Communities Through The Federal Government	Executive Order 13985	A comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality.
Tackling the Climate Crisis at Home and Abroad	Executive Order 14008	Created the Justice40 Initiative, which established a goal of 40% of the overall benefits of certain federal investments–including those in climate change, clean energy and energy efficiency, clean transit, affordable and sustainable housing, training and workforce development, the remediation and reduction of legacy pollution, and the development of critical clean water infrastructure–flow to disadvantaged communities. Increased technical assistance and community engagement of disadvantaged communities was included as a benefit under Justice40 per the Interim Implementation Guidance for the Justice40 Initiative (M-21-28).
Clean Air Act	Section 138	Provides funding for financial and technical assistance to carry out environmental and climate justice activities to benefit underserved and overburdened communities.
Bipartisan Infrastructure Law	23 USC 101	Funds the Clean Energy Demonstration Program on Current and Former Mine Land (CEML) to demonstrate the technical and economic viability of deploying clean energy on current (operating) and former (abandoned or inactive) mine land, one of the priority areas of this program.

Annual Energy and Water Development and Related Agencies Appropriations Bill	H.R. 4394	Funds the DOE Office of Energy Efficiency and Renewable Energy (EERE) that is responsible for enabling renewable energy and end-use energy efficiency technology development and implementation.

A5. Project Task Description

Table 2. Summary of Project Tasks, Schedule, and Products

Task	Schedule	Description of the work to be performed	Products to be produced
Complete and submit QAPP for EPA approval	February 2024	Complete QAPP, send to EPA Project Officers for review and comment, submit to Region 9 Quality Assurance Manager for Approval	Official approved QAPP
Reviewing and commenting on environmental impact statements and permits, information about EPA regulations and policies	September 2023 - May 2028	Connecting communities with experts who can help review environmental impact statements (EIS) and permits and EPA regulations and policies in order to help communities understand (and comply with when necessary) technical documents. Technical support will take the form on 1-on-1 consultations and webinars/trainings (in person and virtual)	Publicly available documents and information providing guidance to communities (when applicable), recorded webinars/trainings of guidance (when applicable). Review of EIS and permits will include annotated documents of the community's EIS or permit that includes comments with feedback. Methods for these trainings will include presentations, providing examples of energy justice analysis projects, sharing pdf guides covering training content, and Q & A sessions to address specific questions from communities.
Producing guidance documents for energy justice and analysis	September 2023 - May 2028	Translating technical information into plain language to provide more accessible information to communities on energy justice-related policy, analysis, projects, etc. Technical support will take the form on 1-on-1 consultations and webinars/trainings (in person	Publicly available documents and information providing guidance to communities, recorded webinars/trainings of guidance (when applicable). Methods for these trainings will include presentations,

		and virtual)	providing examples of energy justice analysis projects, providing checklists for conducting energy justice analyses, sharing pdf guides covering training content, and Q & A sessions to address specific questions from communities.
Producing technical assistance guidance on brownfields	September 2023 - May 2028	Providing technical support and assistance in navigating the redevelopment process, including redevelopment analyses, community engagement, and brownfields financing. Technical support will take the form on 1-on-1 consultations and webinars/trainings (in person and virtual)	Publicly available documents providing guidance to communities, recorded webinars/trainings of guidance (when applicable). Methods for these trainings will include presentations, demonstrations on how to use tools, providing examples of successful brownfields projects, sharing pdf guides covering training content, and Q & A sessions to address specific questions from communities.
Training to communities on environmental program topics	September 2023 - May 2028	Providing technical support and assistance to communities on a variety of environmental program topics through the form on 1-on-1 consultations and webinars/trainings (in person and virtual). Guidance will focus on presenting community/environmental burdens, how to use pre-existing data in grant proposals, using screening tools such as the Climate and Economic Justice Screening Tool, EJScreen, CalEnviroScreen, DOE Energy Justice Mapping Tool, and more.	Publicly available documents providing guidance to communities, recorded webinars/trainings of guidance (when applicable). Methods for these trainings will include presentations, demonstrations on how to use tools, providing examples of related tasks and uses for pre-existing data, sharing pdf guides, and Q & A sessions to address specific questions from communities.
Creation of Community Knowledge Portal Database	December 2024	Gather EJ/EnJ data and information, training events, recording narratives, stories, music, art, and community oral histories to be stored	Community Knowledge Portal. This will be an online resource that provides a variety of information for

		in central portal that can be accessed by community members	communities to use, including products from all tasks listed in this table.

A6. Information/Data Quality Objectives and Acceptance Criteria

A6.1. Existing Data/Information Sources

Secondary data that will be used in this project will be identified with the assistance of the TCTAC program and our EPA Project Officers (e.g., sharing useful tools on data sources, holding orientations and training sessions on EJScreen, etc.) and our team members across the sub-recipient organizations in this project, who hold a vast array of knowledge and experience in the various sectors of energy and environmental justice (along with pre-existing data from past projects). Other potential methods for identifying data sources include conducting literature reviews, contacting other EJ/EnJ technical assistance providers, contacting state agencies, and online searches.

A6.2. Assessment for Inclusion of the Data Source

Once a data source has been identified, the team, under the supervision of the Executive Director (also identified as the Senior Project Operations Manager in this QAPP), will assess the integrity and appropriate use of the data source according to the acceptance criteria outlined in this QAPP (refer to section A6.2). During the review of the data source, limitations of the data will be assessed in order to determine appropriate (and inappropriate) uses of the secondary data as it pertains to specific EIOs, topics, and projects. Limitations will be accepted only in the event that the limitations are only specific for certain situations. For example, if a screening tool only provides data for specific parts of EPA Region 9 (e.g., CalEnviroScreen), the screening tool can still be used if it meets the acceptance criteria; however, it will only be used in the appropriate contexts (e.g., CalEnviroScreen will only be used when assisting California-based communities). In the event that limitations are accepted, the specific use(s) of the data source will be clearly outline in order to avoid the limitations inhibiting the effective use of the data source (i.e., the data source will only be used in contexts that aren’t exceedingly affected by the limitations). With approval of the Senior Project Operations Manager, this data source will be determined appropriate for the project’s EIOs, with a specific clarification on how this data source will be used in the project’s technical assistance activities. If there is disagreement over the validity of the data source, the team may consult with the Quality Assurance Manager who can determine whether the data source meets QAPP standards.

Table 3 documents data sources that have already been identified for potential use in this project. Throughout the course of this project, if additional secondary data sources are needed or identified, the team will assess the sources to determine the appropriate use of the data (if any) and will evaluate the source in accordance with data quality objectives, acceptance criteria, and the information laid out in Table 3. Once a new data source has been identified and confirmed for use, this table will be updated and stored in the project files. As necessary, the Quality Assurance Manager will ensure that this documentation is complete and the sources are in accordance with the processes described in this QAPP. If a discrepancy is identified, the Senior Project Operations Manager and the Quality Assurance Manager will determine a resolution and provide documentation within the project files.

In order to ensure the required quality of data, secondary data sources will be assessed both against the acceptance criteria outlined in section A6.2 and against the following general assessment factors:

- *Soundness* – extent to which the scientific and technical procedures, measures, methods, or models employed to generate the information are reasonable for, and consistent with, the intended application.
- *Applicability/utility* – extent to which the information is relevant for the project's intended use.
- *Clarity/completeness* – degree to which the information, assumptions, methods, QA, sponsoring organizations and analyses employed to generate the information are documented.
- *Uncertainty/variability* – quantitative and/or qualitative evaluation and characterization of the information, procedures, measures, methods, or models.
- *Evaluation/review* – extent of independent verification, validation, and peer review of the information or of the procedures, measures, methods, or models.

A6.3. Data Quality Objectives

For the purpose of this project, the two primary data quality objectives (DQO) include

- The data are as representative as possible of the location and/or socioeconomic, demographic, and environmental characteristics of the community that will be using the data
- The data are produced in accordance with established criteria and procedures for field sampling, sample handling and processing (if applicable), laboratory analysis (if applicable), and record keeping

A6.4. Acceptance Criteria

In order to be deemed appropriate and reliable secondary data for the purpose CCEEJ EIO operations, the data **must be specifically relevant to energy and environmental justice** and meet the following acceptance criteria, expressed in terms of the following data quality indicators (DQI):

- Precision
- Bias
- Accuracy
- Representativeness
- Comparability
- Completeness
- Sensitivity

6.4.5. Usability Assessment to Meet the Project Objectives

In addition to meeting the acceptance criteria listed above, the data source will be assessed to determine its adequacy in meeting the project objectives. After the Senior Project Operations Manager confirms that the data meets the acceptance criteria above, the team members conducting the relevant EIOs will assess the data, under the supervision of the Senior Project Operations Manager, to determine that it also meets project-specific criteria. The following project-specific criteria outlined below have been determined with the primary objectives of accessibility (i.e., the data can but translated in an accessible manner without requiring technical expertise), relevance (i.e., the data is relevant to communities in EPA Region 9 and the EJ/EnJ issues affecting these communities), and integrity (i.e., the data meets quality standards, comes from reliable sources, and presented in a transparent manner).

In order to be used in the project EIOs, the data source must meet *at least three* of the following **project-specific** criteria[1]:

- Data is presented in accessible manner (e.g., screening tools that are interactive and accessible for the layperson)
- Data is publicly available and presented in a transparent manner (i.e., the public has the ability to download datasets)
- Data is collected by a government entity (e.g., publicly available data screening tool)
- Data is the most up-to-date available
- Data meets government data quality standards
- Data is presented in a peer-reviewed publication
- Data is collected by an institution held accountable by Institutional Review Board (IRB) or other research ethical standards
- Data is collected by an entity that also has an approved QAPP
- Data has publicly available technical/overview document(s) outlining collection methods, limitations, potential uses, etc.

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[1] Given the different natures of the secondary data sources that will be used in this project, the threshold of criteria that needs to be met is lowered in order to allow for more flexibility in the sources that can be used. We believe this will not inhibit the integrity of the secondary data that is used due to the fact that the data must first meet the acceptance criteria listed above before being considered against the project-specific criteria.

Table 3. Currently Identified Existing Data Sources to be Used in EIOs

Data Source[2]	Data Type and Existing Data Uses Relative to Current Project	Project-Specific Acceptance Criteria	Factors affecting the reliability of data, and limitations on data use
EJScreen Mapping and Screening Tool - Environmental Protection Agency	Demographic, socioeconomic, and environmental information for a specific geographic area to highlight areas where vulnerable populations may be disproportionately impacted by pollution. Screening tool will be used to train community members how to leverage publicly available data in grant proposals and project development	● Data is presented in accessible manner ● Publicly available screening tool created by a government agency ● Data updated annually ● uses highest resolution data available ● Ability to download data ● Publicly available technical/overview document outlining collection methods, limitations, potential uses, etc. ● Data is collected by a government entity	● Limited in the scope and extent to which the information can be used for decisions. ● Data very limited for Pacific Islands ● Environmental indicators are mostly screening-level proxies for actual exposure or risk
Climate & Economic Justice Screening Tool - White House Council on Environmental Quality	Combination of socioeconomic and environmental data to identify "disadvantaged communities" (mostly for the purpose of J40 Initiative). Screening tool will be used to train community members how to identify “disadvantaged communities” in project planning, development, and grant applications.	● Data is presented in accessible manner ● Publicly available screening tool created by a government entity ● Uses EJScreen for some datasets/indicators ● Ability to download data	● Data very limited for Pacific Islands ● Less detailed/location specific ● Not as appropriate to use for energy justice issues

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[2] Refer to references for data source websites and technical documents (when available)

		• Data is collected by a government entity	
Energy Justice Dashboard - Department of Energy	Screening tool that overlays energy use/cost with other environmental and socioeconomic data to determine energy burden and EnJ issues. Screening tool will be used to train community members how to leverage publicly available data demonstrating energy justice and energy burden issues in grant proposals and project development.	• Data is presented in accessible manner • Publicly available screening tool created by a government agency • Ability to download data • Uses data from EJScreen • Data updated regularly • Data is collected by a government entity	• Less detailed/location specific • Less environmental indicators than other tools
Social Vulnerability Index - Center for Disease Control /Agency for Toxic Substances and Disease Registry	Overlays census data with public health data and CDC risk projections to help communities understand their risk to natural hazards that can be exacerbated by climate change. Screening tool will be used to train community members how to leverage publicly available data demonstrating climate justice issues in grant proposals and project development.	• Updated regularly • Data is collected by a government entity • Ability to download data • Publicly available technical/overview information outlining collection methods, limitations, potential uses, etc. • Has repository of peer-reviewed journal articles featuring the use of the screening tool	• No data for Pacific Islands • Less detailed/location specific (only displays data at the county level) • Not as appropriate to use for energy justice issues
CalEnviroScreen Mapping and Screening Tool - CA EPA / Office	Environmental, socioeconomic, and public health data to identify pollution- burdened census tracts for enforcement, training, and public outreach. Screening tool will be used to	• Data is presented in accessible manner • Publicly available screening	• Limited in the scope and extent to which the information can be used for

of Environmental Health Hazard Assessment	train community members how to leverage publicly available data in grant proposals and project development.	tool created by a government agency ● Data updated annually ● uses highest resolution data available ● Ability to download data ● Publicly available technical/overview document outlining collection methods, limitations, potential uses, etc.	decisions. ● Environmental indicators are mostly screening-level proxies for actual exposure or risk ● Data limited to California
Healthy Places Index - Public Health Alliance of Southern California	Environmental, socioeconomic, and public health data to identify community communities in need of public health and EJ-related investments. Screening tool will be used to train community members how to leverage publicly available data in grant proposals and project development.	● Data is presented in accessible manner ● Publicly available screening tool ● Has public document outlining ethical uses for screening tool ● Publicly available technical/overview document outlining collection methods, limitations, potential uses, etc. ● Meets data quality standards of government entities (who have used this tool for public health policy and project implementation)	● Data limited to California ● Data cannot capture rapid changes in population or its characteristics ● Includes less indicators of environmental justice issues than other screening tools (aside from public health data) ● Not as appropriate to use for energy justice issues
FEMA	Socioeconomic, geographic, and natural	● Data is presented in	● Data cannot capture rapid

Community Disaster Resilience Zones Viewer	hazard risk data used to assess community vulnerability and resilience to a variety of natural hazards. This mapping tool will be used to train community members on how to leverage publicly available data in grant proposals and project development, with a specific focus on issues related to climate justice and natural hazards.	accessible manner ● Publicly available screening tool ● Meets data quality standards of government entities ● Additional information on each map layer is available through external links	changes in population or its characteristics ● Not as appropriate to use for energy justice issues ● Harder to identify specific data points (most information displayed is based on an assessment of a large variety of variables that are not immediately displayed on the map) ● Data is very limited for Pacific Islands
EPA Science Inventory	Management system that stores, manages, and delivers a large variety of environmental data/information. This management system will potentially be used to identify specific studies, reports, and other information that inform communities in project planning, development, and grant proposals.	● Publicly available data/information ● Consistent with Federal Geographic Data Committee metadata content standards ● Ability to download data ● Updated regularly	● Not as easy to navigate as other data sources/screening tools ● Not helpful for “discovering” EJ data (i.e., database is only appropriate to use if you already know what data you need to focus on)
National Weather Service	Meteorological–provides information on current and past weather conditions, climate prediction and variability, local data/records, and more. This data source can be used to inform interpretation of weather patterns in relation to climate change and EJ/EnJ issues, which can in turn be used by communities in project planning, development, and grant proposals.	● Updated regularly ● Data is presented in accessible manner ● Publicly available tool created by a government agency	● Certain data points are highly technical (and not as accessible) ● Not all data is presented in an accessible manner ● Easier to find more recent data (i.e., takes more effort to identify trends)
National Oceanic	Meteorological/Climate data–provides	● Updated regularly	● Less detailed/location

and Atmospheric Administration (NOAA) / National Weather Service Climate Prediction Center	projections of future climate conditions that can be used to inform interpretation of weather patterns in relation to climate change and EJ/EnJ issues, which can in turn be used to communities in project planning, development, and grant proposals.	● Publicly available technical/overview document outlining collection methods, limitations, potential uses, etc. ● Data is presented in accessible manner with the use of maps ● Publicly available tool created by a government agency	specific (only displays data at national/state level) ● No data for Pacific Islands ● Focused on climate projections with less information on past trends (which are rather inferred by “above normal”/”below normal”)
NOAA National Centers for Environmental Information	Meteorological/Climate data–large inventory of data on a large variety of climate change-related issues. Data can be used to infer/assess climate justice and risk for communities which can in turn be used to communities in project planning, development, and grant proposals.	● Publicly available tool created by a government agency ● Data available for Pacific Islands ● Ability to download data ● Data vetted by National Research Council (NRC) standards ● Updated regularly	● Not as helpful for “discovering” EJ/Climate justice data data (i.e., database is only appropriate to use if you already know what data you need to focus on)
NOAA Office for Coastal Management Digital Coast	Socioeconomic, climate, oceanographic, and other environmental/ecological data. Data can be used to infer/assess climate justice and risk and natural hazard vulnerability for coastal and island communities which can in turn be used to communities in project planning, development, and grant proposals.	● Publicly available tool created by a government agency ● Data is presented in accessible manner via its organization into different topics, areas of concern, and offered trainings (on demand and live)	● Not relevant for use with non-coastal or island communities ● Not as easy to navigate as other tools ● Certain data points are highly technical (and not as accessible)

		● Updated regularly ● Ability to download data ● Data available for Pacific Islands	
Climate Mapping for Resilience and Adaptation mapping tool (DOE, DOI, FGDC, NASA, NOAA, USGCRP, USGS, White House CEQ, White House OMB, White House OSTP)	Climate, oceanographic, and other environmental/ecological data. Data can be used to infer/assess climate justice and risk and natural hazard vulnerability which can in turn be used to communities in project planning, development, and grant proposals. Primary focus areas for this tool include extreme heat, drought, wildfire, flooding, and coastal inundation.	● Publicly available tool created by a government agency ● Updated regularly ● Data is presented in accessible manner via maps and generated graphs and tables ● Ability to generate report on location in focus ● Data available for Pacific Islands	● Not as easy to navigate as other tools ● Certain data points are highly technical (and not as accessible) ● Information provided are predictions for future conditions and are not as focused on present conditions ● Data is very limited for Pacific Islands
EPA How's My Waterway? Mapping tool	Water quality data can be used to infer/assess water quality issues depending on the community's watershed. This can in turn be used by communities in identifying water quality threats/issues and sources, project planning, development, and grant proposals.	● Publicly available tool created by a government agency ● Updated regularly ● Data is presented in accessible manner via maps ● Data available for Pacific Islands	● Relevant use limited to water quality concerns ● Doesn't incorporate socioeconomic data ● Data less location specific (only presented at the watershed level)
Neighborhoods at Risk Mapping Tool	Socioeconomic data and climate variables that can be used to infer/assess climate justice and risk and vulnerability. This can in turn be used by communities in prioritizing action items, conducting vulnerability assessments, project planning, development,	● Publicly available tool that uses data provided by government entities ● Updated regularly ● Data is presented in	● Data not available for Pacific Islands (aside from Hawai`i) ● Relevant use limited to specific focus on natural hazard and climate change

	and grant proposals.	accessible manner via maps	vulnerability
Pre-existing data and information from partner organizations	Socioeconomic, public health, and environmental data from past reports, studies, and data collected by partner organizations (not for the purpose of this project). This will help our partner organizations leverage their experience and past work to provide effective technical assistance to communities with the support of existing data that is up to the data quality standards of the organization. Existing data will be used to help inform communities for project planning, development, and grant proposals.	● Additional insight in how the data was collected, managed, and stored ● Depending on the organization, data is collected by an institution held accountable by Institutional Review Board (IRB) or other research ethical standards ● Data is presented in accessible manner	● Might not be as accessible as other data sources/tools ● Doesn't cover every part of EPA Region 9
Data from published literature, reports, and handbooks	Socioeconomic, public health, and environmental data relevant to specific energy justice and environmental justice issues. Data will potentially be used to help inform communities in project planning, development, and grant proposals.	● Data is presented in a peer-reviewed publication ● Data is collected by an institution held accountable by Institutional Review Board (IRB) or other research ethical standards ● Data is the most up-to-date available	● Limited in the scope and extent to which the information can be used for decisions. ● Might not be as accessible as other data sources/tools
Data from state and local monitoring programs	Socioeconomic, public health, and environmental data that will potentially be used to help inform communities in project planning, development, and grant proposals.	● Publicly available data/information ● Meets data quality standards of government entities ● Data is potentially collected by an entity that also has an	● Might not be as accessible as other data sources/tools ● Might not cover every part of EPA Region 9

		approved QAPP - Data is collected by a government entity	
Existing maps, GIS layers, plots, photographs, or land surveys	Environmental data that can be used for project planning, particularly brownfields, land redevelopment, and other site-specific projects.	- Data is presented in accessible manner - Data is publicly available - Data is potentially collected by an entity that also has an approved QAPP	- Might not be relevant and/or available for all EJ/EnJ projects - Might not be as accessible as other data sources/tools

A7. Distribution List

QAPP Recipient	Title	Organization	Email	Version
Dani Allen-Williams	Lead Project Officer (PO) for SDSU TCTAC	Environmental Protection Agency	AllenWilliams.Dani@epa.gov	Final/ Approved and subsequent revisions
Michael Cloyd	Technical Project Officer for SDSU TCTAC	Environmental Protection Agency	Cloyd.Michael@epa.gov	Final/ Approved and subsequent revisions
Dr. Rebecca Lewison	Executive Director of SDSU TCTAC Senior Project Operations Manager	San Diego State University	rlewison@sdsu.edu	Final/ Approved and subsequent revisions
Sergio Morales	Quality Assurance Manager	San Diego State University	smorales3@sdsu.edu	Final/ Approved and subsequent revisions
Loren Halili	Project Coordinator for SDSU TCTAC	San Diego State University	lhalili@sdsu.edu	Final/ Approved and subsequent revisions
Paige Dawson	Program Manager for SDSU TCTAC Quality Assurance Officer	San Diego State University	pdawson@sdsu.edu	Final/ Approved and subsequent revisions
Michelle Roos	(Sub-grantee) Executive Director	Environmental Protection Network	michelle.roos@environmentalprotectionnetwork.org	Final/ Approved and subsequent revisions
Dr. Clark Miller	(Sub-grantee) Director	Arizona State University Center for Energy & Society	Clark.Miller@asu.edu	Final/ Approved and

				subsequent revisions
Scott Anders	(Sub-grantee) Administrative Director	University of San Diego Energy Policy Initiatives Center	scottanders@sandiego.edu	Final/ Approved and subsequent revisions
Nikki Cooley	(Sub-grantee) Co-Director	Institute for Tribal Environmental Professionals	Nikki.Cooley@nau.edu	Final/ Approved and subsequent revisions
Claire Weston	(Sub-grantee) Senior Program Manager	Center for Creative Land Recycling	claire.weston@cclr.org	Final/ Approved and subsequent revisions
Dr. Amber Pairis	(Sub-grantee) Founding Director and Lead Advisor	Climate Science Alliance	apairis@climatesciencealliance.org	Final/ Approved and subsequent revisions
Savannah North	(Sub-grantee) Director of Administration & Climate Initiatives	Public Health Alliance of Southern California	SNorth@phi.org	Final/ Approved and subsequent revisions
Dr. Tamara Wall	(Sub-grantee) Research Professor	Desert Research Institute	Tamara.Wall@dri.edu	Final/ Approved and subsequent revisions
Dr. Austin Shelton	(Sub-grantee) Director	University of Guam Center for Island Sustainability	shelton@uog.edu	Final/ Approved and subsequent revisions
Victoria Keener	(Sub-grantee) Co-Lead Investigator	Pacific Research on Island Solutions for Adaptation	vkeener@asu.edu	Final/ Approved and subsequent revisions

A8. Project Organization

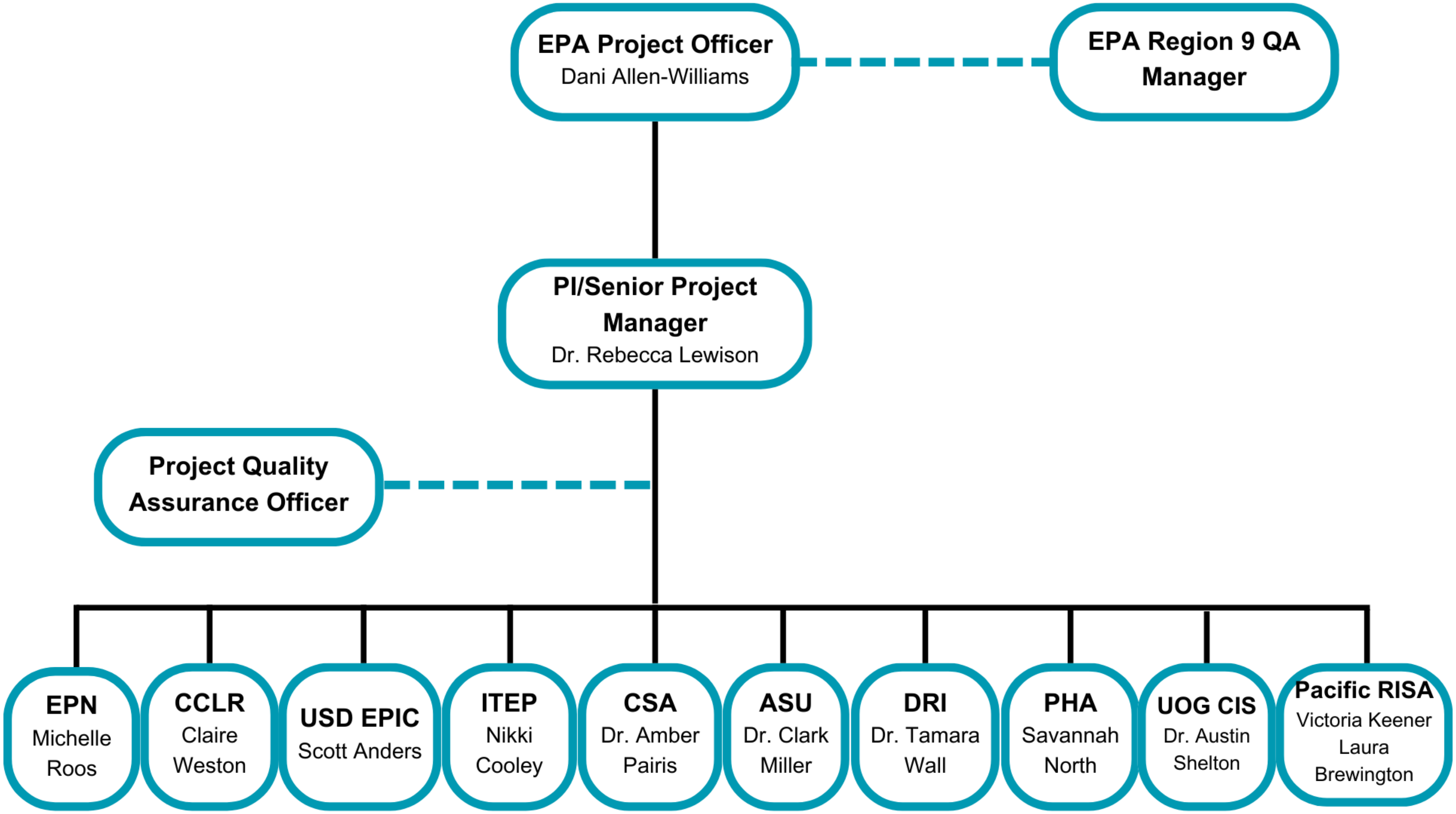
Table 4. General Roles and Responsibilities

Role	Individual in Role, Title, and Name	Roles and Responsibilities
Approval Authority for the QAPP	USEPA Region 9 Quality Assurance Manager	Review and approve the QAPP, has access and discuss quality-related issues with their organization's senior manager outside of their direct supervisory chain as necessary.
EPA Project Officer	Dani Allen-Williams, Lead Project Officer (PO) for SDSU TCTAC	Oversees development and subsequent revisions of QAPP prior to submitting to Region 9 Quality Assurance Manager
Senior Project Operations Manager	Dr. Rebecca Lewison, Executive Director SDSU TCTAC	Coordinating grant activities including communicating with the EPA and conducting the identification and evaluation of all existing data, compiling results, documenting progress, and writing the report and educational materials. The project manager is responsible for verifying the usability of the data and related information. Oversees environmental information operations of the team to ensure QAPP compliance. The Operations Manager or designee will not have authority to sign QAPPs for the QA Manager or designee, nor will the QA Manager or designee have authority to sign QAPPs for the Operations Manager or designee.
Sub-awardee conducting environmental information operations	Claire Weston Senior Program Manager at Center for Creative Land Recycling (CCLR)	Coordinate and oversee CCLR's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Sub-awardee conducting environmental information operations	Michelle Roos, Executive Director of Environmental Protection Network (EPN)	Coordinate and oversee EPN's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental

		information operations
Sub-awardee conducting environmental information operations	Scott Anders, Administrative Director of University of San Diego Energy Policy Initiatives Center (USD EPIC)	Coordinate and oversee USD EPIC's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Sub-awardee conducting environmental information operations	Nikki Cooley Co-Director of Institute for Tribal Environmental Professionals (ITEP)	Coordinate and oversee ITEP's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Sub-awardee conducting environmental information operations	Dr. Amber Pairis Founding Director and Lead Advisor of Climate Science Alliance (CSA)	Coordinate and oversee CSA's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Sub-awardee conducting environmental information operations	Clark Miller, Director of ASU Center for Energy & Society (ASU)	Coordinate and oversee ASU's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Sub-awardee conducting environmental information operations	Dr. Tamara Wall Research Professor at Desert Research Institute (DRI)	Coordinate and oversee DRI's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Sub-awardee conducting environmental information operations	Savannah North Director of Administration & Climate Initiatives at Public Health Alliance of Southern	Coordinate and oversee PHA's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental

	California (PHA)	information operations
Sub-awardee conducting environmental information operations	Dr. Austin Shelton Director of University of Guam Center for Island Sustainability (UOG CIS)	Coordinate and oversee UOG CIS's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Sub-awardee conducting environmental information operations	Victoria Keener and Laura Brewington Co-Lead Investigators of Pacific Research on Island Solutions for Adaptation (Pacific RISA)	Coordinate and oversee Pacific RISA's role in conducting environmental information operations while ensuring compliance with QAPP, reporting any issues to Project Operations Manager, communicating QAPP requirements to any team member assisting with environmental information operations
Project Quality Assurance Manager	Sergio Morales Program Coordinator Collaborative of Native Nations for Climate Transformation and Stewardship San Diego State University	Maintaining the official version of the QAPP. The QA Manager is also available for any necessary dispute resolution throughout the course of the project. This position is independent from the personnel who are conducting the identification and evaluation of the existing data/information. The Operations Manager or designee will not have authority to sign QAPPs for the QA Manager or designee, nor will the QA Manager or designee have authority to sign QAPPs for the Operations Manager or designee.
Quality Assurance Officer	Paige Dawson Program Manager Center for Community Energy and Environmental Justice San Diego State University	Technical lead creating the QAPP and monitoring QA activities.

Figure 2. Project Organization Chart[1]



[1] Solid lines within the organization chart indicate lines of authority; dotted lines indicate lines of communication.

Table 5. Sub-recipients Supporting Project and Role

Sub-Recipient	Specific EIO(s) to be supported
Environmental Protection Network	● Reviewing and commenting on environmental impact statements and permits, information about EPA regulations and policies ● Training to communities on environmental program topics
University of San Diego, Energy Policy Initiatives Center	● Producing guidance documents for energy justice and analysis ● Producing guidance for energy policy development ● Training to communities on environmental program topics
Arizona State University, Center for Energy & Society	● Training to communities on environmental program topics ● Producing guidance documents for energy justice and analysis ● Producing guidance for energy policy development
Center for Creative Land Recycling	● Training to communities on environmental program topics ● Producing technical guidance on brownfields (providing technical support and assistance in navigating the redevelopment process, including redevelopment analyses, community engagement, and brownfields financing)
Institute for Tribal Environmental Professionals	● Training to communities on environmental program topics
Climate Science Alliance	● Training to communities on environmental program topics
Public Health Alliance	● Training to communities on environmental program topics
Desert Research Institute	● Training to communities on environmental program topics
Pacific Research on Island Solutions for Adaptation	● Training to communities on environmental program topics
University of Guam Center for Island Sustainability	● Training to communities on environmental program topics

Table 6. Communication Pathways and Mechanisms

Description of Communication	Individual Responsible	Pathway & Timing	Mechanism
Elevating discrepancies within organization	QA Officer	Immediately upon identifying a discrepancy, the Quality Assurance Officer shall notify the Senior Project Operations Manager, the Project QA Manager, and the TCTAC team. The following procedures will follow: ● If discrepancy is identified by project personnel, they must immediately report to QA Officer, who will elevate the issue to the Project QA Manager and Senior Project Operations Manager ● Upon receiving report of discrepancy, Senior Project Operations Manager must coordinate with the Project QA Manager on the resolution of the discrepancy ● The Project QA Manager will facilitate any necessary dispute resolution ● Inform relevant stakeholders of discrepancy (in the event that the affected data has already been used in technical assistance activities) ● Discrepancy, correspondence, and subsequent resolution will be documented in the QAPP by the QA Officer in collaboration with the Project QA Manager and kept on file	Internal project meetings and direct communication via email
Elevating discrepancies within organization with contractors or subcontractors	Senior Project Operations Manager	Immediately upon identifying a discrepancy, the Senior Project Operations Manager will notify the EPA Project Officer and will work with them to determine resolution for the discrepancy. The following procedures will follow: ● The Senior Project Operations Manager will initiate communication and facilitate discussion ● The Senior Project Operations Manager will identify potential avenues for resolution ● The Project QA Manager will facilitate any necessary dispute resolution ● Discrepancy, correspondence, and subsequent resolution will be documented in the QAPP by the QA Officer in collaboration with the Project QA Manager and kept on file	Meetings and direct communication via email

QAPP non-conformances	QA Officer	Immediately upon identification of QAPP nonconformance, the QA Officer will notify the Senior Project Operations Manager, Project QA Manager, and team members involved in the EIOs. The Following procedures will follow: ● The Senior Project Operations Manager will initiation communication and facilitate discussion with the EPA Project Officer ● The Senior Project Operations Manager will identify potential avenues for resolution ● The Project QA Manager will assist with any necessary dispute resolution ● Description of non-conformance, correspondence, and subsequent resolution will be documented in the QAPP by the QA Officer in collaboration with the Project QA Manager and kept on file	Meetings and direct communication via email
Concurrence and approvals between project personnel	Senior Project Operations Manager	As needed based on project milestones, the Senior Project Operations Manager will request formal approval from project personnel. The following procedures will follow: ● Written approval of all parties must be updated in the QAPP by the Project QA Manager and kept on file	Internal project meetings and direct communication via email
Concurrence and approvals between contractor and organization responsible for Environmental Information Operations	Senior Project Operations Manager	As needed based on project milestones, the Senior Project Operations Manager will request formal approval from EPA Project Officers. ● Written approval of all parties must be updated in the QAPP by the Project QA Manager and kept on file	Internal project meetings and direct communication via email

A11. Personnel Training/Certification

Given that this project will only be using publicly available secondary data, no specialized training or certifications will be required for the environmental information operations. Key personnel selected to provide technical advice to this project were hired based on their expertise demonstrated on their resumes. With this in mind, all subrecipients have extensive professional and academic experience and expertise to make them qualified to conduct the environmental information operations outlined in this QAPP.

The EIOs in this project will not involve any Personally Identifiable Information.

A12. Documents and Records

Table 7. Documents and Records

Document or Record Name	How will the document or record be managed?
QAPP	Upon final approval, the QAPP stored in the shared Google Drive folder with our EPA Project Officers. The QAPP will also be made available to the CCEEJ team for review in order to ensure compliance. The QAPP file, along with all future revisions (if applicable) will be kept and maintained by the Project QA Manager for the entire duration of this project.
Existing data and information from other sources such as databases or literature	When necessary, existing data will be stored in the shared CCEEJ Google Drive for the team to access. Depending on the use of the data, summary of the data will also be condensed into shared documents that will in turn be produced in various training formats (handouts/”one pagers”, summary notes, presentations for trainings, etc.). The resources that were created from the use of this existing data will also be shared in the Community Knowledge Portal and potentially on the CCEEJ website. These documents will be kept for the entire duration of this project.
Email and other correspondence	Emails pertaining to QAPP activities, document approval, and other required EPA deliverables will be kept on file, both by the CCEEJ team (i.e., team members who are included in the emails) and the EPA Project Officers, in order to document compliance with all requirements set forth in the QAPP and cooperative agreement with the EPA.
Quarterly Reports	The CCEEJ team will prepare quarterly reports that will be sent to the EPA via email. These reports include: a brief project description, project tasks, objectives and accomplishments, description of the quality considerations (when applicable), funding status, upcoming events, and assistance required. The final version of each quarterly report will be shared both in the Shared Google Folder with our EPA Project Officers and also made available to the CCEEJ team through the shared CCEEJ Google Drive.

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Quality Assurance Project Plan (QAPP)

Dr. Kauneckis will be responsible for the overall quality assurance (QA) aspects of the project and general project data management. He will share responsibilities for the quality control (QC) of the project outputs with Lauren Boitel and Dave Ray. Dr. Kauneckis' has experience managing projects includes being PI on projects funded by the National Science Foundation, Department of Energy, United States Department of Agriculture, National Oceans and Atmospheric Administration, and others for over $3 million. Dr. Kauneckis is an Associate Professor at the Desert Research Institute (DRI), which relies on a combination of interval review of products and processes to ensure compliance with DoE and DoD QA/QC standards which will assist in proper data management.

Collection of primary data. Primary data will be collected from a system of local Purple Air Quality sensors. Purple Air maintains an online website with a map of all sensors and data visualization of sensor readings. Dr. Kauneckis will create metadata standards for project data, archive all sensor records, and provide data to community partners in a usable format. This will include locations, frequency of sensor data recordings, air quality characteristics, and other data streams recorded by Purple Air sensors. Since all data is intended for community engagement and education, it is not anticipated that scientific sampling procedures are necessary. If required, procedures for handling and custody of samples, including sample collection, identification, preservation, transport, storage, and accuracy of measurements can be verified and follow the standard procedures used by DoD and DoE, for example the Quality assurance (DOE O 414.1D; the Independent oversight and performance assurance program (DOE O 227.1); the Scientific and technical information management (DOE O 241.1B); the Occurrence reporting and processing operations information (DOE M 232.2) or the Environment, safety and health reporting (DOE O 231.1B) procedures. All the analytical method to be used will follow the applicable standard procedures described above for quality assurance (DOE O 414.1D), including acceptance criteria, calibration procedures and performance evaluation for the analytical instrumentation. The procedures for overall data reduction, analysis and reporting will agree with those proposed by the Scientific and technical information management (DOE O 241.1B) procedure.

Development or operation of environmental technology. The purpose of the technology developed within this proposal is to expand the existing Purple Air quality sensor network into East Las Vegas, which represents a gap in coverage, engage local communities in monitoring and understanding the uses of air quality data, provide STEM opportunities, and examine the impact of regular air filters changes on indoor air quality. A mobile air quality sensor will be developed to track air quality among mobile food vendors. The prototypes will be designed and deployed based on Dr. Kauneckis' experience and expertise using the best available technology from trustable suppliers. All the design and deployment stages will be recorded in log entries by Dr. Kauneckis as well as any change considered for the initial design along with the corresponding evidence of calculations for the modified specification in case of changes. The same QA/QC procedures described above will be used for the operation of environmental technology. The acceptability of the processes will depend on their performance for achieving the goals of this project and the assessment of their performance will be based on results obtained using the QA/QC protocols described above and the needs of project team members and community partners.

Region 1 - Health Resources in Action

QUALITY ASSURANCE PROJECT PLAN (QAPP)

Massachusetts Healthy Air Network: Monitoring and Building Capacity for Resilient Communities.

Quality Assurance Project Plan (QAPP)
For Collecting, Identifying and Evaluating
Existing Scientific Data/Information
EPA - 00A1105
February 2, 2024

A. Title: Massachusetts Healthy Air Network: Monitoring and Building Capacity for Resilient Communities.

The attached MA Healthy Air Network are hereby recommended for approval and commits the Environmental Protection Agency to follow the elements described within.

Stacey Chacker, Project Director — Phone: 617-279-2236
Health Resources in Action — email: schacker@hria.org
Signature: Stacy Chacker — Date: February 6, 2024

Krystal Pollitt, Ph.D., P.Eng., QA Manager [redacted]
Yale School of Public Health
Signature: K Pollitt — Date: February 6, 2024

Nora Conlon, QA Reviewer — Phone: 617-918-8335
US EPA — email: conlon.nora@epa.gov
Signature: *Nora J Conlon, Ph.D./s/* — Date: 02/07/2024

Alysha Murphy, EPA Air Technical Reviewer — Phone: 617-918-8381
US EPA — email: murphy.alysha@epa.gov
Signature: *Alysha D Murphy* — Date: 02/07/2024

Madeline Isenberg, MPH, Project Officer — Phone: (617)918-1271
US EPA Region 1- New England — email: isenberg.madeline@epa.gov
Signature: Madeline Isenberg — Date: 02/07/2024

A.2 TABLE OF CONTENTS -

C. ASSESSMENT AND OVERSIGHT

D. DATA VALIDATION AND USABILITY

A3 Overview

A.3.1 List of Acronyms

API	Application Programming Interfaces
DQI	Data Quality Indicator
DQO	Data Quality Objective
EPA	Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
PM	Particulate Matter
QA/QC	Quality Assurance/Quality Control
HRiA	Health Resources in Action
PHIWM	Public Health Institute of Western Massachusetts
O_3	Ozone
AQ	Air Quality
MAAP	MA Asthma Action Partnership
CBO	Community Based Organization
FBO	Faith Based Organization
MHAN	MA Healthy Air Network
EJ	Environmental Justice
MDEP	MA Department of Environmental Protection

A.3.2 Distribution List: The following organizations will receive a copy of approved QAPP and any subsequent revisions:

- US EPA Quality Assurance Office
- US EPA Project Officer – Madeline Isenberg
- *Project Partners:*
  - Public Health Institute of Western MA – Sarita Hudson and Francheska Bermudez
  - Yale University Schools of Public Health and Engineering - Dr. Krystal Pollitt and Dr. Dong Gao
  - Once we identify community-based organizations funded under this project, we will designate them, as well as their staff.

A.4 Project/Task Organization

A.4. 1. Roles and Responsibilities: Our project will have a design team (Table 1a) that meets to oversee implementation. We have also listed Key Partners who will participate as explained in Table 1b.

Table 1 – Design Team -

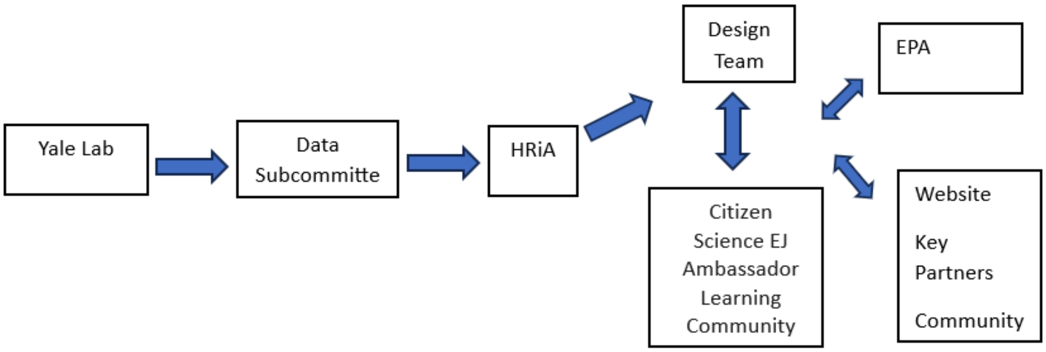
Position	**Responsibilities**
Health Resources in Action ● Stacey Chacker, Director, Policy and Practice ● Geri Medina, Senior Manager	Provide overall project management; convene partners agencies, coordinate educational and communication activities, including distribution of mini-grants and sensors. Stacey Chacker will be responsible for communicating with the EPA.
Public Health Institute of Western	Serve on Design Team and on committees relating to data, communications, and

Massachusetts ● Sarita Hudson, Senior Director ● Francheska Bermudez, Program Coordinator	evaluation; help to support the Ambassadors' Community and connect to Springfield, Chicopee, and Holyoke; co-support the Healthy Air Network website; and disseminate the website and other materials. Serve as a subject matter expert (SME) for community engagement for the project.
Yale University ● Dr. Krystal Pollitt ● Dr. Dong Gao	Dr. Krystal Pollitt will serve as our QA Manager, and be responsible for maintaining the official, approved QA Project Plan (that she will sign); she is independent of the group or team acquiring data. Yale will also on the Design Team and maintain the air sensor network in the Healthy Air Network ensuring sensors are routinely calibrated with EPA reference monitors to provide high-quality real-time measurements (QA/QC) of $PM_{2.5}$ mass and ozone concentration. Maintain a database of calibrated and cleaned data from all low-cost air sensors included in the network; share fine particulate matter ($PM_{2.5}$) and O_3 measurements on an interactive map that will be included on Healthy Air Network's website; serve as a SME for the project; provide training as part of the Ambassadors' Community; and disseminate the website, host webinars, and connect to cities about AQ monitoring.
EPA ● Madeline Isenberg, MPH	EPA, Project Officer

Table 1a: Other Key Partners:

Position	Responsibilities
MA Department of Environmental Protection ● Eva Tor, Deputy Regional Director	Work with our team at Yale University to use their established regional EPA approved monitors that utilize EPA certified measurement methodology to compare and aid in validating the data from the proposed basic monitors.
MA Department of Public Health Asthma Prevention and Control Program	Serve as Advisor as needed, provide data to ID EJ most burdened by asthma outcomes in MA, and promote and disseminate the project materials, webinars, and information to community partners and internal partners within MDPH.
EarthWatch Institute	Serve as Advisor as needed, and design and deliver educational workshops for the Ambassadors' Community, tailoring as needed, to specific communities.

A.4.2: Data Communication Pathway: HRiA is responsible for reporting, with contributions from other partners.



A.5 Problem Identification and Background: Our project will focus on Massachusetts. We are in the process of identifying which communities will be engaged as funded CBOs/FBOs. Other communities are being offered to connect their own sensors to our network.

$PM_{2.5,}$ and O_3 have been shown to contribute to morbidity for several chronic diseases including asthma, chronic obstructive pulmonary disease, cardiovascular disease, and most recently, COVID-19. $PM_{2.5}$, $O_{3,}$ and other outdoor air pollution predominantly impact communities of color.[2] NE has among the highest prevalence of current asthma in the country; in 2020, asthma rates for adults ranged from 10.6% to 12.1% across NE. Among children in 2019, prevalence ranged from 9.1% to 12.1% in Southern NE, 6.3% in Maine, and 9% in Vermont and New Hampshire.[4] In its Asthma Capitals 2022 Report, the Allergy Foundation of America named seven NE cities among the top 100 most challenging places in the U.S. to live with asthma, based on estimated asthma prevalence, ER visits due to asthma, and asthma-related fatalities. The cities are Springfield, MA (#52), Providence, RI (#58), Worcester, MA (#63), Hartford, CT (#69), Bridgeport, CT (#85), New Haven, CT (#90), and Boston, MA (#91).[5] Each is demographically diverse; 13%-38% of the populations of these cities are Black and 18%-47% are Latinx. Each also has high percentages of residents living in poverty, who are renters, speak a language other than English at home, and/or do not have a college education.[6] The American Lung Association's 2023 State of the Air report gave several counties in NE, particularly in Southern NE, poor or failing marks for AQ, and stated that people of color are 3.7 times more likely to be breathing the most polluted air compared to white people.[7] Similarly, low-income communities are more susceptible to $PM_{2.5}$ pollution than high-income communities; as racism contributes to and perpetuates financial instability within racial minority groups, they are more likely to have a lower socio-economic status, as well.[8]

The poorest and most marginalized EJ communities in MA suffer from poor ambient AQ due to multiple mobile and point sources including large inter-state and state highways, railroad lines running directly through residential neighborhoods, truck and bus depots, and industrial sites. In many of these communities, residences, schools, and playgrounds are immediately adjacent to highways, truck or bus depots, and industry. High levels of exposure are evidenced in the disproportionate rates of asthma experienced in cities, which are significantly higher than statewide and almost double the national rates (reference Table 3 below in EJ section). Furthermore, $PM_{2.5}$, $O_{3,}$ and other outdoor air pollution predominantly impacts communities of color.

Warming climate projections are expected to worsen AQ in communities. For example, according to data from the

Resilient MA Climate Change Clearinghouse and Northeast Regional Climate Center, the average annual temperatures in the MA portion of the CT River Basin are expected to rise by an estimated 3.88°F over the next three decades, with an average increase of 15 days above 90° each year[1] . Local ambient air temperatures will be even higher in the developed industrial areas of the prioritized EJ cities where the effects of urban heat island are already apparent relative to the surrounding neighborhoods. Rising temperatures increase the production of O_3 and the number of “unhealthy” days, thereby increasing morbidity for people with mentioned health conditions and exacerbate existing health disparities[2].

Existing monitoring networks across MA are limited. Low-cost sensor networks can supplement existing EPA/research monitoring networks and provide increased spatial and temporal resolution, capturing variations in local sources. The Healthy Air Network will provide opportunities to increase understanding of AQ in higher risk EJ communities, providing opportunities for highlighting periods with poor AQ. The PT will develop dynamic spatial models of $PM_{2.5}$ mass and O_3 concentrations using the calibrated real-time, low-cost air sensors. These models will integrate the calibrated low-cost sensor measurements, EPA monitoring and satellite data, as well as meteorological information.

For proper management of air quality, the availability of measurement data on the spatial and temporal distributions of pollution concentrations is critical. The deployment of low-cost sensors across a small geographic area has benefits to supplement traditional monitoring networks with additional spatial and temporal measurement resolution, if the data quality was sufficient. This would make it possible to answer new questions about the underlying causes of poor air quality, ensure more accurate modeling and prediction at local scales, enhance personal exposure monitoring on a neighborhood scale, improve the ability to identify the links between air quality and human health or environmental degradation, identify areas with elevated air pollutant levels, and enhance the ability to quantify the impacts of mitigation strategies.

A.6 Project Goals: MA Healthy Air Network builds on the Healthy Air Network is a project initiated by the PHIWM, Yale, and community partners in Western MA, and now includes HRiA and the MA Asthma Action Partnership (MAAP). The goal of MHAN is to foster knowledge and build capacity at the community-level to improve environmental health conditions in MA communities by expanding AQ monitoring, supporting a learning community, building a statewide universal platform, and disseminating results. MA Healthy Air Network will prioritize three EJ communities' where residents experience disproportionate challenges related to environmental exposures, racial and health disparities, socioeconomic factors, sources of pollution, and are most burdened by asthma, COVID-19, air toxic cancer risk, and other chronic health conditions related to high levels of $PM_{2.5}$ and O_3. To do this, MHAN will: provide funding and AQ sensors to three community (CBO) and/or faith-based organizations (FBO) from separate EJ communities; engage them in the MHAN Citizen Science EJ Ambassadors’ Learning Community Data, along with the three PVAQM EJ communities; and invite them to participate in the Data, Research/ Communications /Website, and/or Evaluation committee(s). The sensors will be installed by June 2024. The data is real time data collection with the sensors – directly streamed to the websites. The exact placement of where to place sensors is designed to be part of the project -- engaging with the community based organizations for site selections in the earlier part of 2024. The statewide platform – a mobile friendly website – will provide real-time, easily accessible, actionable data for any interested community monitoring $PM_{2.5}$ and O_3, highlight the EJ communities’ stories, and be available in English and Spanish. Finally, MHAN will organize a summit to share findings and data-to-action experiences from the EJ communities.

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[1] *Resilient Ma Action Team (RMAT)*. Mass.gov. (n.d.). Retrieved March 23, 2022, from https://www.mass.gov/info-details/resilient-ma-action-team-rmat

[2] J. M. J. T. (2021, September 21). *Air pollution: Everything you need to know*. NRDC. Retrieved March 23, 2022, from https://www.nrdc.org/stories/air-pollution-everything-you-need-know

A.7 Project and Task Description

1. Develop and support partnership structures to support the projects. Engage three community-based organizations (CBOs) and/or faith-based organizations (FBOs) in three separate Environmental Justice (EJ) communities to host calibrated sensors provided by MHAN and to participate in the Citizen Science EJ Ambassadors' Learning Community (hereinafter, Ambassadors' Community). MHAN will provide $30,000 and approximately 10 purple air sensors and one AirU sensor to each of three participating CBOs and/or FBOs from separate EJ communities. The CBOs/FBOs will each have a lead – and up to four members – participate in the Ambassadors' Community. MHAN will provide interactive virtual workshops to provide training on topics such as: a) why monitor -- AQ, public health, and the connection to the legacy of racism; b) strategically placing monitors near hotspots/getting buy-in from building owners; c) how to maintain a monitor/trouble shooting; d) communicating/using the data; and e) other topics that are identified by the cohort through discussion and polls. We will hold additional meetings to support technical assistance , exchanges/peer learning, strategizing, etc. Ambassadors will work in their own communities to place and maintain sensors, increase awareness about AQ in their community, and identify opportunities and/or take action based on their community priorities.

2. With the Design Team, enhance and maintain the Healthy Air Network universal website: This publicly available mobile friendly website provides real-time, local $PM_{2.5}$ and O_3 levels from all AQ sensors calibrated to the platform. The purpose of the platform is to build awareness, capacity, and understanding of AQ measures. For example, it may be useful to: a) develop local institutional policies (e.g., schools could develop "no outdoor recess" when $PM_{2.5}$ or O_3 are above certain designated levels); b) develop educational programs (e.g., clinicians or Community Health Workers could educate their patients with chronic respiratory or heart conditions about AQ); and c) advocate for or against something in their community (e.g., opposing the siting of a biomass plant, or advocating for electrification of bus fleets focusing on specific neighborhoods most impacted by poor AQ). It will also provide education linking the impacts of air pollution and AQ with climate/disaster resilience, tree-planting, and/or advocacy to address sources of air pollution.

3. Quarterly (or as needed) Committees: Data: The purpose will be to review data analysis, looking for patterns, opportunities for interpretation, hotspots, etc. We will encourage the use of this data – and hold up examples of data to action; 2) Research/Communications/Website: The purpose will be to: a) determine what to include on the MHAN website (based on results from surveys, interviews, and focus groups; and b) strategize messaging and provide feedback on developed materials. To facilitate development of AQ visualizations that are meaningful to the community, graphics detailing pollutant variation will be shared with the Ambassadors' Community, and will be tested in community stakeholder focus groups and/or interviews, to assure that the AQ information will be presented in an accessible manner and tailored to the cultural and socioeconomic attributes of residents; and 3) Evaluation: The purpose will be to contribute to evaluation design and feedback from the community focused on engagement, communications, data to action, etc.

4. Dissemination Campaign: The Healthy Air Network website will be linked to partners and Ambassadors' websites. We will develop a Dissemination Toolkit to build awareness, capacity, and understanding of AQ measures by providing sample newsletter articles, blogs, and tweets, and educational materials linking the impacts of air pollution and AQ with education on climate/disaster resilience, tree-planting, and/or advocacy to address sources of air pollution.

5. Healthy Air Network Summit: WE will organize a summit to share *lessons learned, best practices, strategies* and

results obtained over the course of the three-year project, including an analysis of findings to uplift Ambassador stories and data-to-action to network and plan together. All stakeholders will be invited to participate.

6. *Research/Communications/Website:* The purpose will be to: a) determine what to include on the MHAN website (based on results from surveys, interviews, and focus groups; and b) strategize messaging and provide feedback on developed materials. To facilitate development of AQ visualizations that are meaningful to the community, graphics detailing pollutant variation will be shared with the Ambassadors' Community, and will be tested in community stakeholder focus groups and/or interviews, to assure that the AQ information will be presented in an accessible manner and tailored to the cultural and socioeconomic attributes of residents; and

7. *Evaluation:* The purpose will be to contribute to evaluation design and feedback from the community focused on engagement, communications, data to action, etc.

8. Sensor Calibration, Deployment, Collection for Re-Calibration: Sensors will be calibrated on an on-going basis in groups of 10 to 40. Our plan is to have them deployed in the field by June 30, 2024. They will be collected for re-calibration on an as needed basis.

Project Activities	**Timeline**
1.1 Convene the PT monthly.	Q1-Q12
1.2 Convene the Advisory Committee quarterly; consult individually as needed.	Q1-Q12
2.1 Outreach to CBOs and/or FBOs through targeted communication about the MHAN Ambassadors' Community.	Q1-Q3
2.2 Engage CBOs and/or FBOs in the program. Provide $30,000/each, one AirU sensor and up to 9 Purple Air Sensors (sensors by June 30, 2024) to each to three participating CBOs and/or FBOs from separate EJ communities	Q4 – Q12
2.3. Outreach to 38 municipalities hosting 60 Purples provided by MDEP to invite them to have their sensors calibrated to the Healthy Air Network.	Q1-Q3
3.1 Enhance the Healthy Air Network universal platform and continue to do so.	Q1-Q12
3.2 Check in about useability of platform via Ambassador Community and focus groups and/or interviews with community members.	Q3-8
4.1 Develop workshop content for Ambassadors' Community.	Q4-Q11
4.2 Facilitate at least seven Ambassadors' Community workshops to provide support/strategy.	Q4-12
4.3 Obtain feedback from workshops through pre-and-post workshop survey.	Q4-12
5.1 Create and convene Data, Research/Communications/Website, and Evaluation Committees comprised of PT members, at least one representative from the Ambassadors' Community, and other stakeholders/advisors.	Q3-12
6.1 Develop a Dissemination Campaign and Toolkit, including sample social media post templates and images, newsletter language templates, and talking points.	Q4 – launch; then update bi-annually or as needed.
6.2 Obtain feedback from Dissemination Campaign through surveys, interviews, and focus	Q5-12

groups.	
6.3 Update MHAN's webpage/portal and promote via MAAP newsletter, social media, and partners' communication platforms and websites.	Q1 – Q12
7.1 Organize education summit to share MHAN project results and to strategize.	Q10-12
7.2 Obtain feedback from MHAN Summit through surveys and key informant interviews,	Q 12
7.3 MHAN to monitor progress and report to the EPA on a quarterly basis.	Q1-12
8. Sensor Calibration, Deployment, Collection for Re-Calibration	Q3 – Q12

A.8 Data Quality Objectives: Outdoor air quality will be monitored across specified cities in using up to 70 low-cost sensors. The deployment of low-cost sensors across this geographic area has benefits to supplement traditional monitoring networks with additional spatial and temporal measurement resolution, if the data quality is sufficient.

The low-cost sensors will be used as stationary monitors to characterize the spatial and temporal variability of the pollutants of interest. The accuracy and precision of the sensors will be evaluated against the regulatory instruments. To examine regional and seasonal variation in sensor responses, correction factors will be developed for this study, with separate correction factors for each site and season. These correction factors will be compared to see if a single statewide, year-round correction factor is suitable or if regional and/or temporal differences will be considered.

Regarding the questions to identify: a) - performance/measurement criteria for all information to be collected and acceptance criteria for information obtained from previous studies; b) representatives including project action limits and laboratory detection limits and; c) range of anticipated concentrations of each parameter of interest; and to describe the need for comparability and desired method sensitivity, the response is: the performance of the Purple Air sensor used in our project (PA-II) has been independently evaluated as part of previous EPA projects. Results are available here: http://www.aqmd.gov/aq-spec/sensordetail/purpleair-pa-ii. Sensors will only provide information once deployed in the community, not before. Collected measurements will be stored in our team's AWS database.

The funded groups will choose the location of sensors, in consultation with HRiA and Yale. In terms of intended data use – this will be determined by each partner community based organization, and other "owners" of sensors. The sensors may also be used for community near-source monitoring, community education and outreach, hotspot identification, and incident response, depending on the data quality. If the sensors are installed in educational institutions, such as schools, libraries, and museums, they will be intended to aid in air quality education and informal awareness. Sensors placed downwind of industrial facilities may be intended to identify and characterize emission hotspots. Sensors installed at residential locations can be used to assess air pollution exposure that potentially impacts the health of residents. Sensors placed in an area between regulatory monitors can better characterize concentration gradient between the different locations and serve as supplemental monitoring tools, if the data quality is sufficient. To meet the requirements of various objectives, quality control measures have been implemented to ensure the data quality of the low-cost sensors.

Table 2 – DQIs of accuracies, completeness, and representativeness for various objectives of sensor monitoring.

Intended use	Precision and Bias Error	Data Completeness	Rationale
Education and	<50%	=50%	Measurement error is not as important as simply

Information			demonstrating that the pollutant exists in some wide range of concentration.
Hotspot Identification and Characterization	<30%	=75%	Higher data quality is needed to ensure that not only does the pollutant of interest exist in the local atmosphere, but also at a concentration that is close to its true value
Supplemental Monitoring	<20%	=80%	Supplemental monitoring might have value in potentially providing additional air quality data to complement existing monitors. To be useful in providing such complementary data, it must be of sufficient quality to ensure that the additional information is helping to “fill in” monitoring gaps rather than making the situation less understood.

A.9 Training Requirements/Certification: Low-cost sensors for measuring outdoor air quality will be calibrated and operated by Dr. Pollitt’s research team at Yale University. All personnel from her research group will participate in training on standard protocol for operating these devices.

A.10 Documentation and Records: The approved QAPP and any updates will be shared with all organizations involved in the project by HRiA. The Yale team will notify all project staff working with the low-cost air sensors of any revisions/updates to the QAPP to ensure only the current version is used.

A file share accessible by the QA staff will be used to house the data and resulting analysis tools, outputs and reports. The file share is expected to include:

1) raw data downloaded from PurpleAir or TELLUS website;
2) programming codes for data cleaning, aggregating and analysis;
3) processed data;
4) analysis documents and visuals.

Dr. Krystal Pollit will serve as our QA Manager, and be responsible for maintaining the official, approved QA Project Plan (that she will sign); she is independent of the group or team acquiring data.

Reports generated in the project will be stored in the file share alongside the data and will be made available on request. The data will be stored for at least of the life of the project and will be backed up on Amazon Web Services (AWS). The primary storage location will be Dr. Pollitt's laboratory located at the Yale School of Public Health, 60 College Street, Room 510, New Haven, CT, 06520

HRiA will share the approved QAPP with identified EPA representatives and all project partners, as specified above.

B. MEASUREMENT AND DATA ACQUISITION

B.1 Sampling Process Design: *Low-Cost Sensors Selection.* Two types of low-cost sensors will be used to assess outdoor air, provided by the Healthy Air Network with this funding: PurpleAir PA-II-SD (https://www2.purpleair.com/collections/air-quality-sensors/products/purpleair-pa-ii-sd) and TELLUS AirU (https://shop.tellusensors.com/products/airu). Both these low-cost sensors provide estimates of $PM_{2.5}$ mass concentration. The AirU sensor additionally measures ambient ozone concentrations.

1) *Pre-Deployment Calibration of Low-Cost Sensors.* The aim of pre-deployment calibration is to try to identify all possible internal and external error sources of a sensor in an observed and/or controlled environment before deploying the sensor in the field. In this study, the sensors will be collocated with regulatory grade reference monitors in the target area for at least two weeks. A master sensor will be chosen based on its good correlation with the other sensors and will be installed at the EPA monitoring station for long-term air quality monitoring. Calibration factors will be derived between the master sensor and the other field sensors using linear regression methods, to standardize the raw signals of deployed sensors individually to the raw ones of the master sensor. The pre-deployment calibration factors will be used in the later post-deployment stage to transfer the calibration parameters acquired by the master sensor to all sensors.

2) *Low-Cost Sensor Deployment.* Twenty to 30 sensors will be distributed across selected geographies, where CBOs, FBOs, and or municipalities identify the need to expand the existing low-cost sensor network MA. We will have an additional – 20 sensors in reserve as replacements and/or to further distribute to other engaged partners in Western MA. To determine the suitable locations for sensor deployment, a weighted site selection analysis was performed by assigning varying importance levels to different factors such as traffic density, proximity to emission hotspots, and distribution of at-risk vulnerable populations. Deployment sites will reflect a variety of urban, suburban, and rural or green space areas, including potentially museums and libraries, schools or colleges, and residential homes (Figure 2). Communities will rank preferred locations and will be evaluate the availability WiFi/power. If a site becomes inaccessible, we will work with partners to identify an alternative location.

3) *Low-Cost Sensor Calibration and Evaluation.* Due to sensor drift over time and changes in the target environments, periodic post-deployment calibration is crucial to maintain consistency among distributed sensors and ensure data quality of long-term deployments. To accomplish this, one third of the sensors deployed will be collected every 6 months (in April or October when the meteorological parameters (temperature and relative humidity) and ambient pollutant levels change significantly). The collected sensors will be collocated with the master sensor and EPA reference instruments for two weeks for re-calibration and then be returned to original locations. Sensors with obvious seasonal drift are prioritized for calibration. The remaining sensor locations will be selected using the pollution contour map as guide. Sensors that monitor similar pollution levels and have similar land use characteristics are grouped together. Within each group, the sensors are further chosen based on the ease for sensor pickup. The data will be integrated and evaluated in hourly and daily averages. With established project DQOs, the quality of the data must be evaluated to ensure that it meets established performance requirements of our specific application. Our measurement is focused on PM2.5 mass concentration and no other critical information.

Each individual sensor will have its own calibration factor. Master sensors will be installed at DEP Air Monitoring Stations. The number of master sensors will be dependent on the communities participating in the project and the proximity of these communities to DEP stations. The specific DEP monitoring stations included in the project have yet to be determined. Once participating communities have been finalized, the specific reference grade monitors can be added to the QAPP. If more than one reference grade monitor is available at a DEP monitoring station, we will select the monitor that is most commonly available across all stations included in this project. Reference grade monitor selection will be conducted independently from the MA DEP air monitoring group as only one reference grade monitor is typically operated at each site for PM2.5 mass concentration and this data is publicly available.

While it may be possible for correction factor to mask a failing sensor if measurements have drifted, PM2.5 mass concentrations will offset. Given the regional nature of PM2.5 mass concentrations, any offset will alert our team that the sensor requires repair/replacement.

B.2 Sampling Methods: The PurpleAir and AirU low-cost sensors do not require any operation activities beyond installation and data telemetry. The sensor installation procedures were provided in Appendix A. Data is acquired through the Purple Air and AirU application programming interface (API) every two minutes for each sensor, ensuring a continuous and detailed data flow. This data is then securely stored on Yale's AWS database, which supports rigorous analysis and record-keeping. Data will be reviewed on a weekly basis to detect any sensor malfunction. This review process involves monitoring for data interruptions, which may arise from power outages or internet disconnections, and scrutinizing any significant fluctuations or inconsistencies in the data that fall outside expected ranges. We will cross-reference sensor data with nearby units to identify any discrepancies that could suggest malfunctioning. The impact of extreme weather or other environmental factors on sensor performance will also be considered. Sensor calibration will be performed at the Connecticut Department of Energy & Environmental Protection New Haven Criscuolo Park air monitoring station (EPA site number: 09-009-0027). Repairs will be performed at Dr. Pollitt's laboratory located at the Yale School of Public Health, 60 College Street, Room 510, New Haven, CT, 06520

B.3 Sampling Handling and Custody: The PurpleAir and AirU low-cost sensors perform in-situ measurements and do not produce any physical samples. No sample handling or chain of custody procedures are required.

B.4 Analytical Methods: The low-cost air sensors perform in-situ measurements and do not produce any physical samples which require analysis.

B.5 Quality Control: Our team will be focused on PM2.5 mass concentration measurements for this project. Temperature and RH will be measured by the air sensors and these measurements will be used to develop sensor-specific calibration factors. The PurpleAir and AirU both use Plantower PMS PM sensor to measure ambient $PM_{2.5}$ mass concentrations. Additionally, AirU sensors are equipped with semiconductor sensing units specifically designed for ozone measurement, which operate by reacting to ozone's presence, causing changes in electrical properties. Data reported by sensor channel(s) by deployed devices are reviewed on a weekly basis to identify data quality issues. Sensor data are flagged for several quality criteria, including data completeness, departure from a typical range of values or daily variation, and correlation with nearby sensors. Specifically, a departure from typical values is defined as readings that exceed more than 2 or 3 standard deviations from the historical means. Percentile-based criteria are also applied, flagging readings that fall into extreme percentiles (e.g., above the 95th or below the 5th) for further scrutiny. Detailed data evaluation criteria were given in Section D. Temperature and relative humidity information are evaluated only to determine if the readings display seasonal variation. If trouble shooting fails – the sensor will be taken down, and sent to the lab at Yale for repairs, and replaced with an alternative sensor if possible. QC statistics will be performed, including evaluation of precision, bias and assessment of outliers.

B.6 Equipment Testing, Inspection, Maintenance, and Calibration: The Healthy Air Network sensors, installed with this funding source, will include 'field' PurpleAir and AirU low-cost sensors that are located at sites across to be determined sites in MA. In addition to these 'field' sensors, we will also operate one 'master' PurpleAir and a 'master' AirU sensor. 'Masters' sensors will be located at EPA monitoring stations (Ware, MA and Liberty St. Springfield, MA) where reference $PM_{2.5}$ and ozone monitors are operated.

In preparation for installation of new ‘field’ PurpleAir and AirU low-cost sensors we conduct a pre-deployment calibration where the new sensors are placed for a minimum of two weeks at an EPA monitoring station to collocate with a designated ‘master’ sensor and regulatory grade reference air monitors (FRM/FEM). This pre-deployment calibration serves to verify the operational functionality of each ‘field’ sensor and to establish initial correction factors. These factors are derived by conducting a parallel comparison of the readings from each ‘field’ sensor with those of the ‘master’ sensor and the reference instruments, analyzed through detailed hourly measurements. From this comparative analysis, we derive unique correction factors for each ‘field’ sensor, standardizing their raw signals to align closely with the ‘master’ sensor, thereby ensuring accuracy and consistency across the sensor network. Following this pre-deployment calibration phase, the ‘field’ sensors are deployed at network sites. Concurrently, the ‘master’ sensor remains at the EPA station, which plays a crucial ongoing role in the calibration process. By continuously comparing its readings with the reference monitors, the ‘master’ sensor enables us to develop and refine a dynamic calibration model. This model, incorporating the initial correction factors, is periodically reassessed and applied to the ‘field’ sensors. This ongoing process accounts for any necessary adjustment due to changes in sensor behavior or environmental conditions, thus maintaining the long-term accuracy and consistency of our network’s data. The operating status of these ‘field’ sensors is continuously monitored in real-time through an online sensor dashboard.

To ensure ongoing accuracy and consistency, one third of the ‘field’ sensors will be collected from network sites every six months. These sensors will then be collocated at an EPA monitoring station for a two-week period alongside the ‘master’ sensors and regulatory grade reference air monitors. This collocation serves to evaluate the precision of measurements and measurement bias. Sensor maintenance generally is not required. If needed, a vacuum cleaner or compressed air can be used to clean out debris, insects, or spiders that may get into the bottom of the unit. If trouble shooting fails – the sensor will be taken down, and sent to the lab at Yale for repairs, and replaced with an alternative sensor if possible. The sensors which have failed or reached the lifespan of service will be replaced with new units. Replacement sensors will be stored in Dr. Pollitt's laboratory located at the Yale School of Public Health, 60 College Street, Room 510, New Haven, CT, 06520. Again, sensor installation and maintenance will be tracked using an online laboratory notebook managed by Yale.

B.7 Non-Direct Measurements: Temperature and RH will be measured by the air sensors and these measurements will be used to develop sensor-specific calibration factors. Meteorological information will be obtained from AccuWeather. We will not be deploying any sensors to measure this information.

B.8 Data Acquisition and Management: An overview of the acquisition and management of data from low-cost sensor is presented in Figure 3. PurpleAir and AirU low-cost sensors are connected to the Internet through local WIFI networks at their installed locations. Each partner community based organization will choose locations for their sensors, in consultation with our project team; our project team will identify the location of the sensor using a street address and geographic coordinates. Data is transferred in real time to PurpleAir or TELLUS website. Sensor data is acquired through API provided by each sensor company, stored by the Yale University team in a cloud-based centralized database platform. Within this platform, we utilize a standard data management pipeline, equipped with a data processing tool. This tool is crucial for cleaning and processing the sensor data. ‘Cleaning’ refers to the systematic removal or correction of erroneous data, which can arise from sensor malfunctions or environmental interferences. It also involves handling missing values and filtering out noise or other irrelevant information to ensure the reliability of our data. Beyond cleaning, the data processing tool also performs essential data transformation. It aggregates and normalizes the data and applies the calibration model to the cleaned raw data. Once processed, the cleaned and calibrated $PM_{2.5}$ mass and ozone concentrations are shared from the online platform on the Healthy Air Network website which includes interactive air quality visuals and community alerts. The data will be reviewed and downloaded to a local desktop computer at Yale University monthly for manual data review. Data will be shared with partner community based organizations during meetings, and/or as requested.

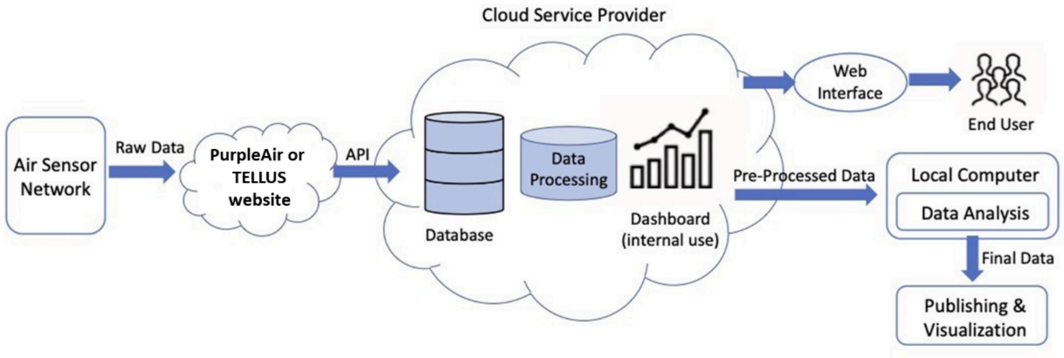


Figure 3. Overview of low-cost sensor data acquisition and management.

C. ASSESSMENT AND OVERSIGHT

C.1 Assessment and Response Actions: Data assessment will be performed to demonstrate that all air monitoring performed as part of the Healthy Air Network produces data that satisfies its intended use and is of defensible quality. The data will be assessed against the data quality objectives (DQOs) to determine whether the DQOs have been attained and that the data are adequate for their intended use. The assessment is an evaluation process used to measure the performance of the air quality sensor network or the suitability of sensor monitoring locations, and effectiveness of data collection and analysis operation.

We will implement an automated system to assess the performance of each air quality sensor. Dr. Pollitt's team will be responsible for data assessment. The assessment involves:

1) reviewing the DQO outputs to assure that they are still applicable and reviewing data collection documentation for consistency with the DQOs observing any potential discrepancies;
2) conducting data review to uncover potential limitations of using the data, to reveal outliers, and generally to explore the basic structure of the data;
3) selecting the most appropriate procedure for summarizing and analyzing the data, based upon the reviews of the performance and acceptance criteria associated with the DQOs.

Dr. Pollitt's will be responsible for response/corrective action which will be performed whenever a problem is observed such as warning flag, malfunction or whenever any performance assessment indicates the control limits have been exceeded. Following completion of a data assessment, results will be summarized in an email or memorandum to the Project Team and the US EPA Quality Assurance Office. Assessment findings will clearly specify if corrective action is necessary.

C.2 Reports to Management: Our project team meets monthly. HRiA will write reports and submit them to the EPA Project Officer on the schedule required.

The QA quality and issues will be routinely reported to all organizations involved in the project (See Table 1). These communications to the management chain can range from meetings to emails or memo notifications, to internal or external reports. The reports may include:

1) findings of quality system and performance audits and resolution;
2) progress with developing QA methods and oversight;
3) relevant changes to QA guidance, requirements or procedures;
4) comparisons with DQOs; and,
5) summary statistics of monitoring and QA activities.

Reports will be distributed to impacted staff from the appropriate branch.

D. DATA VALIDATION AND USABILITY

D.1 Data Review, Validation and Verification: Data review, validation and verification are assessment techniques used to accept, reject or qualify data in an objective and consistent manner. They are necessary for identifying data errors, biases, and unrealistic values before they are used for data assessments, trend analysis, modeling, or other uses. This section explains the process by which data is deemed usable for their intended purpose, that is, whether the agency has met its overall goals and whether the resulting data can be used with confidence.

Data review involves reviewing the procedures for sensor data analysis, including calibration, QC checks, and data processing and reduction. Verification can be defined as confirmation, through provision of objective evidence that specified requirements have been met. The data verification process involves the inspection, analysis, and acceptance of the data. Data validation is a routine process designed to ensure that reported values meet the quality goals of the environmental data operations. Data validation is further defined as examination and provision of objective evidence that the requirements for a specific intended use are fulfilled (e.g., QC checks are within the limits specified in the QAPP).

D.2 Validation and Verification Methods: The data review process is performed as a tiered approach (four levels) involving multiple staff. The four-tiered approach is inspired by established practices for review and validation of ambient air monitoring data as outlined in EPA-454/B-21-007 (August 2021). Data will be automatically screened at Level 0. During Level 1 to 3, data will be checked by the Yale Team, led by Dr. Krystal Pollitt resulting in high-quality data for sharing with the public.

Level 0 Validation is automated screening using pre-programmed data cleaning system with pre-defined set of rules. This is a continuous, daily process. At this stage, flags will be added to abnormal data, which may include but is not limited to 1) values that exceed predefined acceptable thresholds (such as negative values); 2) the time period during which sensors are offline due to power or internet failure; 3) repeating identical values for more than a few hours/days that can be flagged as suspect and require further investigation; 4) hourly values containing less than 75% of the data. This automated review process ultimately will increase the likelihood that erroneous data will be identified and appropriately addressed, while simultaneously reducing the work hours needed to manually evaluate data for certain criteria.

Level 1 Validation occurs daily. The goals of Level 1 data review are to distinguish measurements from measurement errors, interferences, or contamination and to document events that impact data quality. Level 1 validation includes, but is not limited to, the following activities 1) checks for extreme meteorological conditions and other notable or exceptional events (e.g., fireworks, rain, strong winds, nearby construction etc.); 2) collocation and calibration, and sensor replacement checks; 3) review of data warning indicators flagged during Level 0 automated screening.

Level 2 Validation is performed monthly and builds upon the previous levels. Examples of Level 2 validation include but are not limited to 1) review issues identified during Level 0 and Level 1 validation; 2) flag data for exceptional events or other criteria that were not accounted for during Level 0 and Level 1 validation; 3) verify the accuracy and completeness of the Level 1 review (e.g., look for any gaps in data collection, i.e., missing values, during the month) 3) check for consistency with expected data ranges (e.g., typical seasonal, weekly and diurnal pattern); 4) apply batch processing network calibrations as appropriate.

Level 3 Validation is performed quarterly, or more often if needed. This process is to ensure data is accurate, complete, comparable, and representative. The process includes 1) review issues identified during prior review; 2) assess data in terms of the DQIs (precision, bias, completeness, comparability, representativeness, sensitivity); 3) correlate suspect pollutant data with meteorological conditions (e.g., wind speed, rainfall, solar radiation, etc.); 4) compare data from nearby sites and compare to historical data as appropriate; 5) focus heavily on the data’s fitness for use, corresponding to DQOs.

D.3 Reconciliation with Data Quality Objectives: This section describes how the monitoring results obtained from this project will be reconciled with data quality objectives (DQOs) after having been reviewed, verified, and validated. Please refer to D2 for more details. The DQOs are the qualitative and quantitative statements that describe the intended use of the data, the types of data needed, and set tolerance limits on the amount of uncertainty in the data sets such that decision makers can use the resulting data with a knowledge of data limitations. The goal of this effort is to determine whether the programmatic goals have been achieved and how on-going reassessment and improvement in data quality can be achieved.

Reconciliation with the DQOs involves reviewing both routine and QA/QC data. It includes the review of DQOs in consideration of the sampling design and configuration, and data analysis methodology to ensure these are consistent with DQO needs. Findings, which indicate that programmatic objectives have not been met, will trigger further review of the impacted analysis methodology, with concurrent initiation of appropriate corrective action to correct outstanding issues.

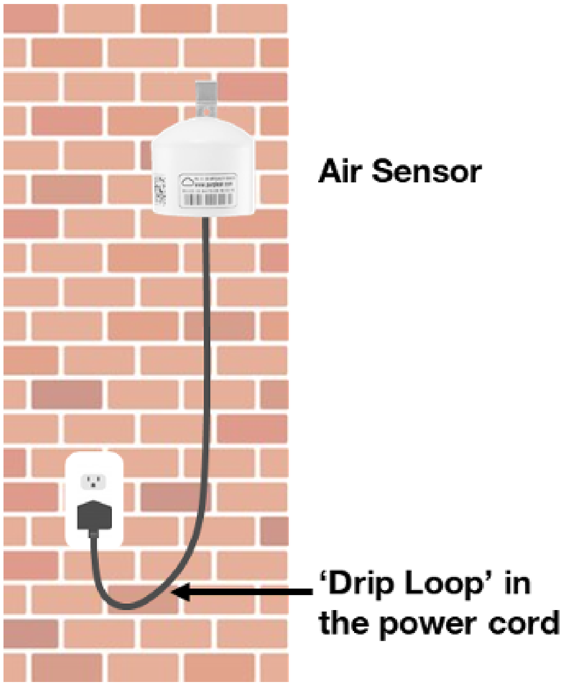
Reports to data users will include a section describing the limitations of measuring PM2.5 mass concentration using low cost air sensors.

APPENDIX A. DRAFT AIR SENSOR INFORMATION SHEET

What is needed to operate a low-cost air sensor?

Sensor Type. We will install two types of sensors across the Air Monitoring Network – each site will have either a PurpleAir Sensor or a AirU Sensor. Both are similar in size (about 4”x4”x4”) and weight (about 0.25 lbs). The power and

Wi-Fi requirements for the two sensors are also similar. Both types are capable of measuring $PM_{2.5}$, with AirU sensor offering the added capability of measuring ozone. Therefore, AirU sensors are prioritized to be placed in environments where a broader spectrum of air quality data is essential. This includes areas near industrial zones, regions prone to ozone fluctuations, or locations where comprehensive environmental data is necessary for ongoing research or public health monitoring. In regions with existing air quality monitoring infrastructure for ozone measurements, integrating AirU sensors will enhance our network's capability to provide a more complete air quality profile. The placement of the sensors will be balanced and widespread across the area of interest, ensuring a uniform coverage for air quality monitoring.



Finding a Site for the Sensor. The sensor should be placed:

- At least 6 ft above ground, avoiding exhaust or vents
- On a flat surface which accommodate screws for mounting
- In a protected location, like an eave
- Within 6ft of a power outlet
- In an accessible location for potential maintenance
- Within 100 feet of the Wi-Fi router
- In an area clear from other structures or devices

Mounting the Sensor. The sensor can be mounted with screws. The PurpleAir sensor requires a single screw attached into the metal mounting bracket. The AirU sensor requires four screws through the back wall of the housing case.

Power Connection. The sensors are powered using a micro-USB power adapter that provides 500 mA of current. The power requirement is low (about 1.5 W), which is estimated to cost less than 1 cent per month to run.

Ideally, the distance between the sensor and the power outlet should be as small as possible. The sensor power cord is water resistant (IP20) so it can be used outside but precautions must be taken to avoid water build up around the electrical outlet. There should be enough length in the power cord to create a drip loop – see the picture to the right.

Connecting to Wi-Fi. The air sensor needs a strong 2.4 GHz Wi-Fi signal - there should be more than 1 bar of signal strength. This typically requires that the air sensor be placed within 100 ft from the Wi-Fi router. The sensor will not work with a captive portal where manual acceptance of terms through an HTML page is required.
The air sensor is not capable of WPA-Enterprise where a certificate and/or username is needed to connect. The system administrator may need to allow access from the sensor's MAC address. The MAC address can be found on a sticker on the outside of the sensor's housing case.

The AirU sensor communicates using MQTT protocol, and it uses the following ports: 443, 8883, 8886, 123 (UDP). These


PurpleAir Sensor


AirU Sensor

ports must be open. Data packets will be sent every 2 minutes through mqtt.2030.ltsapis.goog:8883 and time.google.com:123. Over-the-Air firmware updates will be sent through ota.tetradsensors.com:443.

Low-Cost Air Sensor Installation Checklist

What is the sensor ID?	______________
List of people present for the installation.	______________ ______________ ______________ ______________
Contact information of the person who will be the contact point for any building/electricity issues.	*Name:* *Email:* *Phone:*
Contact information of the person who will be the contact point for any Wi-Fi issues.	*Name:* *Email:* *Phone:*
Confirm the sensor be installed in an area that avoids direct sunlight exposure (without using trees as a source of shade) and easily accessible in case of repairs?	
Will the sensor be installed at least 2 meters (6 ft, 7 in) away from other walls and obstacles to avoid corrupting the data?	
What is the height of the sensor above the ground?	______________m / ft
Confirm there is no overhead trees less than 10m (33 ft) away from the sensor that could potentially corrupt the data?	
Confirm there are no electric cables surrounding the sensor that could possibly disrupt the data?	
Will the sensor receive at least 270 degrees (or 180 degrees if adjacent to a wall) of airflow? If so, what is the degree of exposure?	______________degrees
Note any potential interferences (such as a new construction zone or increased traffic congestion) that may interfere with the sensor data.	
Confirm that the sensor was mounted properly?	
Confirm that you attached the power cable into the sensor's micro-power port and plugged the other end of the power cable into an electric outlet?	
Confirm that you created a "drip loop" with the power cord?	

What is the date/time of sensor installation?	
What is the address of the sensor’s location?	
What is the Latitude and Longitude of sensor’s location?	
Please take a photo of the sensor’s location.	

W**IFI Installation Instructions**: Each of the two air sensors that are being installed differ slightly in their WIFI setup.

AirU Sensor

1. Scan the QR shown on the right to download the Tetrad Connect App that will be used to setup the Wi-Fi connection on the air sensor. This app can also be download directly from GooglePlay or the App Store.

2. Once the Tetrad Connect App has been downloaded, open the app, and press “Provision Device”.

3. The app will now scan for available Wi-Fi networks. Find the name of your Wi-Fi network and enter the password. If you do not see the WI-FI network, select “choose a network” and other WI-FI names should appear.

4. You air sensor should now be connected to your Wi-Fi and will start uploading data to the internet.

PurpleAir Sensor

1. Once plugged into the power supply, check if the LED below the sensor will blink green a few times, then a blue light will blink periodically if the sensor is properly recording data.

   Note: If the blue light is blinking rapidly, then it’s indicating that the data is not being recorded properly. In this case, turn the sensor off and reconnect.

2. Using a Wi-Fi-enabled device (cell phone, tablet, or laptop), connect to the WiFi network called "AirMonitor xxxx" where xxxx is specific to the sensor. Your device may display an error like “Internet may not be available.” This is normal and you can proceed to the next step.

3. Once you have connected your device to the "AirMonitor xxxx" network, open an internet browser, type “192.168.4.1” in the search bar, and search.

4. A PurpleAir page will come up. Press/click on the “Wi-Fi Settings” link (see panel A in the picture below). Then select your personal Wi-Fi access name from the list, enter your password, and save (panel B). Your sensor will reboot to configure the settings (panel C).

5. Once the air sensor successfully connects to your Wi-Fi, it will start uploading data and the “AirMonitor_xxxx” network will no longer be available to connect via Wi-Fi.

Other helpful information about the PurpleAir Sensor:

- The "AirMonitor_xxxx" network is only available to connect to while the sensor isn’t configured to a Wi-Fi.
- If your sensor stops reporting data on the PurpleAir Map, perform a power cycle by unplugging the unit, waiting

10 seconds, and plugging it back in.

- If your sensor loses power, it will remain configured with the Wi-Fi information and automatically reconnect once the power comes back on as long as the SSID name and password remained the same.

Region 5 - Air and Radiation Division

QUALITY ASSURANCE PROJECT PLAN (QAPP)

U.S. E.P.A. Region 5 Air Sensor QAPP Guidance and Template

U.S. E.P.A. Region 5 Air Sensor QAPP Guidance and Template

August 2023

Acknowledgements:
This Quality Assurance Project Plan (QAPP) Guidance and Template is the product of the combined efforts of Environmental Protection Agency (EPA) Region 5 Air and Radiation Division (ARD) staff. The following individuals are acknowledged for their contributions:

State and Tribal Planning Section (STPS)	Air Monitoring and Analysis Section (AMAS)
Melanie Nowin	Rachel Kirpes
Camden Ogletree	Marta Fuoco
Alexis Hosna	

Purpose:
EPA recognizes the increasing interest in the use of air sensors, particularly by Tribal nations, community-based Environmental Justice organizations, and local air agencies. EPA defines air sensors as a class of non-regulatory technology that are lower in cost, portable, and generally easier to operate than monitors used for regulatory purposes. Due to the low cost of entry and relative simplicity, in addition to the ability to collect relatively quick or instant measurements in more locations, air sensors have become a popular way to educate the community about air quality, identify and characterize hotspots or emission sources, complement an existing network of regulatory air quality monitors, and conduct personal or group exposure studies. Like any environmental measurements, air sensor projects require Quality Assurance (QA).

Quality Assurance is a series of management activities, including planning, implementation, and assessment, necessary to ensure the quality and defensibility of the final product (e.g., air monitoring data). The project objectives dictate the level of QA required; therefore, data quality begins with well-defined objectives. A robust QA plan can help ensure defensible data by serving as a reference for current, past, and future project staff. A QA plan may include a Quality Management Plan (QMP), Quality Assurance Project Plan (QAPP), Standard Operating Procedures (SOPs), and other documents, checklists, or resources to guide planning, implementation, and assessment of the project. This document provides a QAPP template and guidance for common air sensor applications.

Before template use:
Prior to creating your Air Sensor QAPP, it is strongly recommended to read through EPA's Enhanced Air Sensor Guidebook[1]. The Guidebook is a comprehensive resource and is referenced throughout this document. Particularly relevant for QAPP development, Chapter 3, "Monitoring Using Air Sensors", describes the steps to plan and conduct an air sensor project (Guidebook Figure 3-1).

Additional sections in the Guidebook are valuable resources to inform project design and QA development. Prompts from *Appendix B: Questions to Consider When Planning for and Collecting Air*

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[1] https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CEMM&dirEntryId=356426

Sensor Data, and Sharing Your Results are included throughout the template to guide QAPP development. Other useful sections to review include:

Figure 3-3. Questions to Consider Before Purchasing an Air Sensor (pg. 50)
Chapter 4: Sensor Performance Guidance
Appendix A: Resources
Appendix C: Checklists
    C.1: What to Look for in an Air Sensor?
    C.2: What to Look for in Performance Guidance?

How to use the template:
The Guidebook identifies potential applications for air sensors in Chapter 1.1. A primary use of air sensors is for non-regulatory supplemental and informational monitoring applications. Other potential applications include mobile monitoring, personal exposure monitoring, and indoor air monitoring.

Table 1-1. Overview of Non-Regulatory Supplemental and Informational Monitoring Applications (NSIM) for Air Sensors (The Enhanced Air Sensor Guidebook)

Category	**Description**	**Common Examples**
Spatiotemporal Variability	Characterizing a pollutant concentration over a geographic area and/or time. *Is pollution higher in the morning at a location?*	• Daily trends • Gradient studies • Air quality forecasting • Participatory science • Education
Comparison	Analyzing differences and/or similarities in air pollution characteristics against a threshold value or between different networks, locations, regions, time periods, etc. *Does a location show high pollution levels, but other locations do not?*	• Hotspot detection • Data fusion • Emergency response • Supplemental monitoring
Long-term Trend	Characterizing changes in pollutant concentrations over a long time. *How did pollution concentrations change at a location over a 5-year period?*	• Long-term changes • Epidemiological studies • Model verification

EPA’s Quality Assurance guidance provides flexibility under a graded approach. This graded approach describes four QAPP Categories of air monitoring projects. Categories I and II include regulatory monitoring networks run by State, Local, and Tribal Air Agencies. Most air sensor projects will fall under Category III (Special Projects) or Category IV (Education and Outreach), recognizing that no low-cost air sensors have been approved to collect regulatory monitoring data. This template provides boilerplate language as an example of what to include in each of the QAPP elements for common applications under Category III, appropriate for any air sensor project collecting quantitative data. The following table summarizes which of the 24 QAPP elements are required for each Category under the graded approach. Category III requirements are highlighted; non-required sections are not included in this template.

QAPP Element	**QAPP Category Application**
A1 Title and Approval Sheet	I, II, III, IV
A2 Table of Contents	I, II, III
A3 Distribution List	I
A4 Project/Task Organization	I, II, III
A5 Problem Definition/Background	I, II, III
A6 Project/Task Description	I, II, III, IV
A7 Quality Objectives and Criteria for Measurement Data	I, II, III, IV
A8 Special Training Requirements/Certification	I
A9 Documentation and Records	I, II, III
B1 Sample Process (Network) Design	I, II, III, IV
B2 Sampling Methods Requirements	I, II, III
B3 Sample Handling and Custody Requirements	I, II, III
B4 Analytical Methods Requirements	I, II, III, IV
B5 Quality Control Requirements	I, II, III, IV
B6 Instrument/Equipment Testing, Inspection & Maintenance	I, II, III
B7 Instrument Calibration and Frequency	I, II, III
B8 Inspection/Acceptance Requirements for Supplies and Con.	I
B9 Data Acquisition Requirements for Non-direct Measurements	I, II, III
B10 Data Management	I, II
C1 Assessments and Response Actions	I, II
C2 Reports to Management	I, II
D1 Data Review, Validation, and Verification Requirements	I, II, III
D2 Validation and Verification Methods	I, II
D3 Reconciliation and User Requirements	I, II

Throughout the template, you will find instructional information, example language, and prompting questions. Instructions and prompts to guide QAPP development in each section are included in ***italics.*** Sample language or example text is included in some sections in **red text** and should be revised by the user. QAPPs are meant to be specific to a particular project, so the template prompts and example language should be used as a starting point to fully develop each section.

Revision History:

Version	Revision Date	Changes
0	5/17/22	New QAPP Guidance and Template Document
1	7/12/22	Reconciliation with guidance from Ambient Air Monitoring Graded Approach Memo and *Handbook for Citizen Science Quality Assurance and Documentation.*
2	5/1/23	Revisions to align with updated "Enhanced Air Sensor Guidebook"

References:

This document used a variety of references, examples, and concepts from various sources to attempt to create an all-encompassing guidance document that could be applicable to a large range of users. We acknowledge the following references:

1. U.S. Environmental Protection Agency, 2022. *The Enhanced Air Sensors Guidebook*, EPA 600/R-22/213, Office of Research and Development.
2. U.S. Environmental Protection Agency, 2001. *EPA Requirements for Quality Assurance Project Plans (QA/R-5)*, EPA/240/B-01/003, Office of Environmental Information.
3. U.S. Environmental Protection Agency, 2002. *EPA Guidance on Quality Assurance Project Plans (QA/G-5)*, EPA/240/R-02/009, Office of Research and Development.
4. U.S. Environmental Protection Agency, 2019. *Handbook for Citizen Science Quality Assurance and Documentation – Version 1*, EPA 206-B-18-001.
5. New Jersey Department of Environmental Protection, 2022. *Quality Assurance Project Plan for a Community Science Project: Air Quality Supplementary Network Monitoring Study*.
6. U.S. Environmental Protection Agency, 2019 *Air Quality Sensors – Long Term Performance Project*, D-EMMD-0031862-QP-1-0, Office of Research and Development
7. New Jersey Department of Environmental Protection, 2022. *Project Plan for a Community Science Project: Personal Exposure Monitoring Study – Group.*
8. New Jersey Department of Environmental Protection, 2022. *Project Plan for a Community Science Project: Personal Exposure Monitoring Study – Individual.*
9. New Jersey Department of Environmental Protection, 2022. *Project Plan for a Community Science Project: General Information and Education*.
10. New Jersey Department of Environmental Protection, 2022. *Quality Assurance Project Plan for a Community Science Project: Air Quality Hotspot Identification Study*.
11. U.S. Environmental Protection Agency, 2018. *Evaluation of Low-Cost Ambient Air Sensors in the Sun Valley Neighborhood in Denver, Colorado*, D-SED-0031824-QP-1-0, Office of Research and Development.
12. Pueblo of Santa Ana Department of Natural Resources, 2022. *Quality Assurance Project Plan (QAPP), Purple Air Ambient Air Quality Monitoring*, Environmental Division.
13. U.S. Environmental Protection Agency, 2023. *Quality Assurance Project Plan Template for Purple Air Projects,* Region 10 Air and Radiation Division.

INSTRUCTIONS:

Provide the project title, name of the organization conducting the project, and personnel with approval authority. Approval authorities typically include the project organization and regulating authorities such as EPA. Provide the revision number and date in the header if this is a revision to a previously approved QAPP.

Quality Assurance Project Plan
for
<< Project Title >>
<<Affiliated Program & Associated Assistance Agreement Number>>

Prepared by
<< Grantee Name and Address >>

Prepared for
U.S. E.P.A. Region 5, Air and Radiation Division
77 W. Jackson Blvd., Chicago, IL 60604

Approvals:

This QAPP is approved by the undersigned and effective on the date of last EPA signature.

_________________________________ Date: __________________

<<Name>>, Project Manager
<<Organization Name>>

_________________________________ Date: __________________

<<Name>>, QA Officer
<<Organization Name>>

_________________________________ Date: __________________

<<Name>>, Project Officer
U.S. E.P.A. Region 5, Air and Radiation Division

_________________________________ Date: __________________

<<Name>>, Technical Reviewer
U.S. E.P.A. Region 5, Air and Radiation Division

_________________________________ Date: __________________

<<Name>>, Quality Assurance Reviewer
U.S. E.P.A. Region 5, Air and Radiation Division

Acronyms:
AQI – Air Quality Index
ARD - Air and Radiation Division (U.S. EPA Region 5)
CAA - Clean Air Act
DQI - Data Quality Indicator
DQO - Data Quality Objective
EPA - Environmental Protection Agency
QA - Quality Assurance
QAM - Quality Assurance Manager
QAPP - Quality Assurance Project Plan
QC - Quality Control
SOP - Standard Operating Procedure

Table of Contents

INSTRUCTIONS:

Update this Table of Contents with the section/subsections of the QAPP document and all figures, tables, and appendices. Provide associated section/subsection numbers and pages so that all information may be readily found in the document.

A. PROJECT MANAGEMENT

A.1 Title and Approval Pages - See pages 1-2

A.2 Table of Contents **-** See pages 3 - 5.

A.4 Project Organization

INSTRUCTIONS:

Clarifying roles and responsibilities sets expectations and can help prevent future miscommunications. Identify the individuals and organizations participating in all major aspects of the project and discuss their specific roles and responsibilities. Include program or project management, personnel responsible for conducting project activities, the project QA manager, and points of contact and associated organizations for all consultants, contractors, and/or laboratories. Whenever possible (depending on the size of the organization), ensure that the project QA manager is independent of the staff generating the data.

Provide a concise organization chart (Figure A-1) showing the relationships and lines of authority/ communication for all named people and organizations.

Consider the following questions:

- *Have you established clear roles and responsibilities for those involved in the project?*
- *Who will be the primary contact if others have questions about the data?*

Below is some example language to consider including. Please revise/edit the information, as appropriate, and ensure the name of the individual associated with each title is presented.

Project Manager will be the responsible official for this project overseeing the overall project and budget, as well as tasking contractors with work required to complete this project. (Pronoun(s)) will communicate project needs to the contractor's project manager.

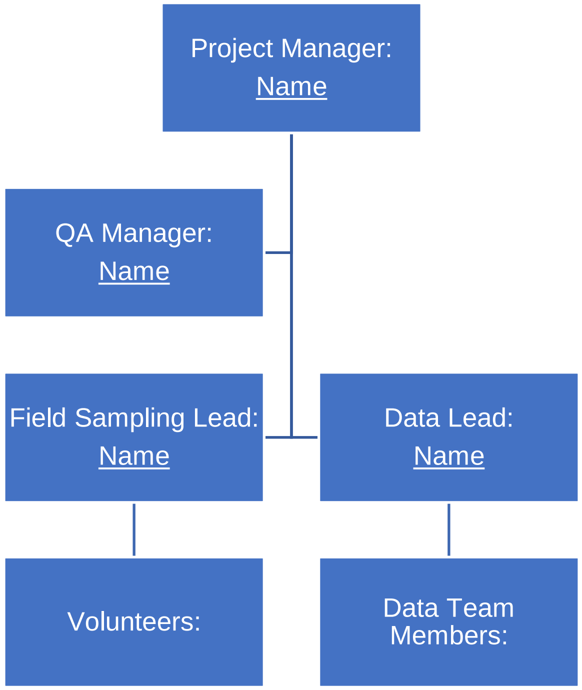
QA Manager or Designee will be responsible for reviewing and approving the QA Project Plan. (Pronoun(s)) may provide technical input on proposed sampling design, analytical methodologies, and data review, but will not be involved in data generation. (Pronoun(s)) may assist with coordinating laboratory services.

Contractor (or Sub-Grantee) Project Manager will have overall responsibility for assigning appropriate personnel to complete the tasks included in this plan. (Pronoun(s)) will ensure that the project budget is adhered to. (Pronoun(s)) will communicate with the Project Manager on work accomplished in this plan and any problems or deviations that need to be resolved.

Field Sampling Lead will be responsible for assigning field technicians to their specific tasks and objectives. (Pronoun(s)) will have overall responsibility for all field activities. (Pronoun(s)) will report to the Contractor Project Manager.

Data Lead will be responsible for data collection, storage, analysis, and quality control.

Other Key Project Positions –



A.5 Problem Definition/Background

INSTRUCTIONS:

State the specific environmental problem or question to be investigated. Include sufficient background information to provide an historical and scientific perspective for the current project. Describe decisions to be made, actions to be taken, or outcomes expected from the information to be obtained. Identify regulatory information, applicable criteria, action limits, etc necessary to the project. Identify the reasons for conducting the work and/or the current lack of information relating to the project. You can also mention any previous studies or data you may be comparing your project to if it applies. Cite any sources used here.

Consider the following questions:

- *What is the purpose of the project and the question you want to answer?*
- *What existing research and data are available to help answer your question?*
- *What pollutants will you measure? If you are interested in a particular source of air pollution, have you checked that your selected pollutant is relevant to that source?*
- *Will you contact the state/local/tribal air monitoring agency during the planning phase to obtain their input and recommendations?*
- *Are you expecting any agencies (local/state/federal/tribal) to use your data or results? Have you spoken with the agencies to understand if that is possible?*
- *Will you consider alternative ways to answer the questions using other data sources besides air sensors (e.g., traffic counts, health data, existing monitoring data)?*
- *Have you clearly defined your purpose for monitoring and expected outcomes? Is collecting air sensor data the best way to achieve these outcomes?*
- *Will you publish your results or create any public communication materials?*

(*Town*) is located in (*specific area of state*) with a population of (*town population*). In (*location),* there are several sources of air pollution. (*Specific neighborhood*) is located in a(n) (*rural, residential, commercial, or industrial*) part of (*town*) where there is a *(describe the source, i.e., a factory, highway, etc.*) and has the potential to impact local communities in the area *(add any important things in this area that are impacted like a school, hospital, residential area, high walking traffic, wildlife, etc).* The nearest State/Tribal-operated regulatory monitor(s) is/are (distance) away.

The pollutant(s) of concern is/are (*pollutant(s)*). (*Potential source)* may be a potential health hazard for the community because (*pollutant(s)*) can have negative health impacts such as (*examples & cite source*). Ambient air quality data can be collected using low-cost air sensors and, with the proper oversight, could be used to identify a hotspot source in (location). This study will collect environmental data using (*air sensor*) to measure (*pollutant(s)*) concentrations in (*location/town*) and will be used to answer the following questions:

- Are (*pollutant(s)*) concentrations are higher in one area of town than the other. If so, why?
- Does this area experience particularly high (*pollutant(s)*) concentrations that may not be detected by the closest tribal- or state-operated monitor?
- Am I exposed to high levels of (*pollutant(s)*) on my bike commute to work?

A.6 Project/Task Description and Schedule

INSTRUCTIONS:

Provide a summary of the work to be detailed in the remaining sections of this QAPP and the schedule for implementation. Include an overview of the pertinent work activities (field sampling, types and locations of samples to be collected, measurements/analyses, data evaluation, etc.), products/reports to be generated, and a targeted schedule for each activity/report (including timeline from QAPP development through final report writing). Discuss resource and time constraints, as applicable.

Consider the following:

- *Where will you collect the measurements?*
- *What will be the location of the sensor(s) (e.g., latitude, longitude, elevation, and height of the sensor from ground level)?*
- *Will you take the measurements at a fixed site or mobile platform (e.g., on a car, on a person)? What type of environmental conditions will they represent?*
- *Is there additional support that would be helpful (e.g., data analysis or interpretation support, collocation assistance)?*

Project Location:
Measurements for [*pollutant*] will be taken in [*describe study area/town/etc*] The first sampling site is located [*describe location*] and is upwind of the potential pollution source. The second sampling site is located [*describe location*] and is downwind of the potential pollution source. The third sampling site is located [*describe location*] and is collocated with *[describe monitor]*. Measurements will be taken [*number of times]* a day for [*duration*] on these dates [*list or write out dates and times*] to measure [*e.g. compare different times of day]*.
[*insert a map image here with labeled sites and a caption*].

Post-Measurement Analyses:
Describe if the sensor data will be accessed via a real-time dashboard or downloaded for analysis. If applicable, include data management, protocols, record keeping, and Quality Assurance method for post-measurement analyses.

Project Timeline:
In the table below, list all major project activities that will be performed during the course of the project. Organize this information in any way that best fits your project plan.

Activity	[Year]											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Project Planning												
QAPP development												
Field Sites Selected												
Sensors Prepared and Tested												

Training and Log sheets prepared												
Sensors Deployed												
Data Collection												
Data Analysis												
Quality Assurance Checks												
Final Report Writing												
Presentations												

A.7 Quality Objectives and Criteria for Measurement Data

INSTRUCTIONS:

Describe the data quality objectives for the project, identify the targeted action limits/levels, and define the associated data quality acceptance criteria/measurement performance criteria. Flexible data quality objectives are typically acceptable for informational or investigative sensor projects.

These sections are the core of the QAPP document, as they define what environmental data is needed for the project and how that data will be qualified for use.

A.7.1 Objectives and Project Decisions

Describe how the project objectives provide answers to the problem. Include the tasks that will collect information to address the problem. Why are sensor measurements needed to address the problem? What measurements are required and what do they represent (e.g. indoor vs outdoor, hyper-local scale of sensor data, comparison to AQI or local air quality trends and patterns).

A.7.2 Action Limits/Levels

Describe the anticipated range of concentrations of each parameter of interest. Specify the tolerable limits on the probability of making a decision error due to uncertainty in the data (how much measurement uncertainty can be tolerated in the data set?).

Consider the following:

- *What actions might you take depending on the research, data, or air monitoring results?*
- *What are the expected levels for the pollutant in the location of interest, including background and peak concentrations, seasonal and day/night trends, and spatial variability*

Additional considerations for $PM_{2.5}$ sensors include:

- Moderate uncertainty is acceptable in translating sensor measured $PM_{2.5}$ levels to the AQI and exploring trends and patterns.
- EPA scientists have found that air sensors often report data that overestimates, or underestimates pollutant concentrations compared to the permanent or temporary instruments that are operated in the same location.
- Sensors, without the use of the EPA correction equation, measure the same trends in $PM_{2.5}$ concentrations as collocated monitors, but they tend to overestimate the $PM_{2.5}$ mass concentrations and respond nonlinearity at high smoke concentration (>200 µg/m3).
- For the sensor data used in the Fire and Smoke Map, EPA has applied an extended U.S.-wide correction equation, developed by EPA scientists, that reduces the bias in the sensor data. The corrected data are more closely comparable to the permanent and temporary monitor data.

A.7.3 Measurement Performance Criteria/Acceptance Criteria

Data Quality Indicators (DQIs) are quantitative or qualitative characteristics associated with the collected data (i.e. calculated statistics). DQIs ensure that the data are accurate, well-managed, and are appropriate for meeting the project objectives. List the DQIs for the project, provide brief definitions for each, and explain how the acceptance or performance criteria for each DQI will be measured or determined.

Acceptance or performance criteria are designed to evaluate and control various phases (sampling, preparation, analysis) of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the DQIs. Any data not meeting these criteria should be invalidated and excluded from the dataset.

Projects that or solely educational or for informational awareness may use qualitative DQIs. Quantitative DQIs are appropriate for all investigative projects where quantitative results will be measured and communicated.

If you need additional resources to help determine DQIs or to learn more about what DQIs are and how they are measured, please refer to the Air Sensors Guidebook. Chapter 3.4.1: Target Pollutant and Sensor Performance

Suggested DQIs for sensor projects include:

- ***Precision** – the ability of a measurement to consistently be reproduced under identical conditions.*
- ***Bias** – systematic error in a measurement, or the difference between a measurement and the true value.*
- ***Comparability** – the extent to which data from one data set can be compared directly to another data set.*
- ***Completeness** – the amount of data that must be collected in order to achieve the goals and objectives of the project.*
- ***Measurement Range** – the lowest and highest pollutant concentrations a sensor can measure. May also include the range of linearity, the concentration range where sensor response is linear to pollutant concentration.*

Revise the following table as needed for your specific project.

DQI	Acceptance/Performance Criteria
Precision	Collocated sensors (and/or multiple channels in a device) are within 70% or 5 µg/m^3 of each other
Bias	A correction factor must be applied to the sensor data to reduce MAE below 20% (The EPA nation-wide Purple Air correction equation or a project-specific equation developed through collocation with a regulatory monitor).
Comparability	R^2 is greater than 80% between collocated sensors
Completeness	An hour of data is considered complete if at least four of six (67%) of 10-minute windows are complete. A day of data is considered complete if 75% of the hourly data are complete. Complete data is valid (meets precision and bias goals).
Measurement range	The manufacturer reported detection limit is sufficient to meet the project objectives and measure expected concentrations for action levels. The sensor has a linear response across the expected concentration range, or can be corrected (e.g. with the EPA Purple Air extended correction for wildfire smoke).

A.9 Documents and Records

INSTRUCTIONS:

Describe the process for distributing the most current approved QAPP, as well as any revisions/updates, to appropriate project staff.

Identify due dates for quarterly/semi-annual and final grant progress reports submitted to EPA. Describe what data summaries, analyses, actions, etc will be included in the grant reports.

Identify any other project records to be maintained, how and where the records will be stored, who will have access, and the length of time of storage. This may include information generated in the field (e.g., field forms, well development & sampling logs, field logs, chain-of-custody forms, etc.), sensor data files, assessment/oversight reports, interim progress/status reports, final data reports, etc. Include protocols for handling any personal identifiable information (PII) that may be collected (e.g. locations of sensors installed at private residences).

Describe the type of information and format to be included in technical reports (for example: perhaps it will be summarized in a data base and/or Excel spreadsheet with all supporting information to be retained in a project file). Describe any analyses to be performed on the data.

Describe the structure and management of the electronic data, including location of files, and how they are backed up/version control maintained. Describe the process to ensure data file consistency and data reporting standards, including identifying what metadata will be recorded.

For ARP grant projects:
Describe the strategy to ensure that the collected data is useable, accessible to the public, and will be shared with appropriate stakeholders (e.g., local government) and local communities in a practicable amount of time. Data and/or related observations must be shared throughout the lifetime of the project and not only after the project is at or near completion.

Consider the following:

- *Will you read the data from the screen or store it in an electronic format?*
- *How will you name the data files so that you can keep track of where and when they were collected? What type of file or database will you use to store the data?*
- *How will you track the data if you transfer it to others to analyze?*

See Chapter 3.7.3 Data Management System and Appendix D (Guidebook)

B. DATA GENERATION AND ACQUISITION

B.1 Sampling Design (Experimental Design)

INSTRUCTIONS:

Describe the overall design of the project's data collection activities to achieve the stated objectives. Provide rationale for the design and selection of sampling locations, measurements/analytical parameters, potential sources of variability, etc. and any supporting assumptions. Include maps depicting sampling locations. Summarize the type, frequency, and duration of each measurement type, along with the associated QC samples to be collected in the field.

Consider the following:

- *Have you developed a plan for your monitoring activities?*
- *What instrument/sensor will you use (i.e., manufacturer, model, etc.)? Will these be new devices, older, or refurbished?*
- *What, if any, additional local data or observations will you collect (e.g., wind measurements, site photos, global positioning system (GPS) coordinates, activity logs, event logs, health information)?*
- *How long will you make your measurements (e.g., two weeks, two months)?*
- *How will you select the site? What criteria or guidelines will you use?*
- *What type of conditions will the measurements represent (e.g., outdoor, indoor, occupational)?*
- *How will you differentiate the source you are trying to measure from the background pollutant concentrations?*

See Section 3.5: Setup: Locating Sites for Air Sensors (Guidebook)

B.2 Sampling Methods

INSTRUCTIONS:

Describe the procedures for collecting field samples, as well as the associated field QC samples. Identify the sampling methods and equipment and describe why each method was chosen. For continuous monitoring, indicate averaging times and how instruments will store and maintain raw data or data averages. Describe how the sampling methods related to the stated objectives.

Include a brief description of how the sensor operates, what parameters are measured, and identify any assumptions or calculations made to produce the reported values. Describe how the sensors will be deployed and operated to avoid contamination, reduce interferences, and ensure data quality. If multiple sensors will be deployed, describe how each sensor and associated data will be tracked.

Consider the following:

- *Do you have procedures and instructions so that measurements are taken in a consistent way (e.g., developed standard operating procedures)?*
- *Will any obstructions nearby affect the airflow around the sensor?*
- *What nearby emission sources (e.g., roadways, industrial facilities) might affect the sensor measurements?*
- *Are there other potential local sources near your site (e.g., dust from unpaved roads, parking areas, street-sweeping activity) that might affect your measurements?*
- *Might anyone nearby be smoking (e.g., cigarettes, cigars) when and where you are collecting the measurements?*
- *Will there be any periodic events (e.g., construction, fireworks, fires) that could affect the data?*

If information is available in standard operation procedures (SOPs), include in the appendices and reference here. If the SOPs provide options, ensure that the option(s) selected for the current project are identified in the text.

Revise the following table as needed for your specific project.

Sampling Location	**Sampling Schedule**	**Parameter**	**Field QC Samples**	**Averaging Period**	**Sampling Location Objective**
(Name of location) – Use 1 row for each sampling location	*Frequency and duration of sampling.*	*(Pollutant and sensor type)*	*(Describe the method & frequency for each field QC check)*	*(# of samples taken in this location, based on specified data averaging period)*	*(Define objective for sampling at this location)*

B.3 Sample Handling and Custody

INSTRUCTIONS:
This section is only required if physical samples (e.g. air sampling canisters, filters, sorbent tubes) will be collected as part of the project.

All sensors will collect real-time direct measurements of ambient air pollutants and thus, no physical samples will be collected or tracked.

B.4 Analytical Methods

INSTRUCTIONS:

Describe the data analysis tools (e.g. R, Excel, ArcGIS) that will be used and the statistical functions employed in data analysis. Statistics could include descriptive (number of observations, mean, median, standard deviation, standard error, 95% confidence interval (CI), minimum, maximum, variance, quantiles, interquartile range, coefficient of variation, variance box plots, time series, distributions (histograms), bar charts, and bivariate plots (fit Y by X)) or inferential functions (t tests, least squares linear regression modeling, ordinary least squares regression, coefficient of determination (R2), ANOVA/ANCOVA, and multivariate analyses). Identify where analyses will be documented.

If information is available in standard operation procedures (SOPs), include these in the appendices. If these documents provide options, ensure that the option(s) selected for the current project is identified in the QAPP text and is clearly understood by all necessary project personnel.

Consider the following:

- *Do you need software to analyze the data (e.g., Microsoft Excel, R, Matlab, Python)? Does someone on your team have the skills needed to use the required software?*
- *How will you analyze the data (e.g., create a scatterplot, create a time series plot, compare with meteorological measurements)?*

B.5 Quality Control Requirements

INSTRUCTIONS:

Quality Control (QC) is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements. QC activities are used to ensure that measurement uncertainty can be estimated and is less than the measurement quality objectives so that the DQOs can be met.

Identify the required QC checks for both the field sampling methods and measurements/analyses. State the frequency for each type of QC check, the acceptance criteria, as well as the associated corrective action if the acceptance criteria are not met. Identify procedures and formulas for calculating applicable QC statistics.

If information is available in standard operation procedures (SOPs), include these in the appendices and reference here. If these documents provide options, ensure that the option(s) selected for the current project is identified in the QAPP text and is clearly understood by all necessary project personnel. Summarize the information pertinent to the QC checks in the QAPP.

Consider the following:

- *What procedures will you use to ensure that the sensors measure high-quality data?*
- *What quality control (QC) criteria must the sensor data meet?*
- *Will you have Standard Operating Procedures (SOPs) (i.e., detailed written instructions and directions on how to perform a technical activity so that measurements are obtained in a consistent way)?*
- *Will you average the data, and if so, how? How will you account for missing data, negative values, and extreme outliers?*
- *What software will you use to process and QC your data (e.g., Microsoft Excel)?*
- *How will you correct or adjust the air sensor data?*
- *How will you document any changes or adjustments to the data?*
- *Will you use consistent data qualifiers to "flag" data that do not meet QC criteria?*
- *Will you document if there are any persistent problems with the data or significant downtime?*
- *How will you record and resolve any data problems?*
- *How will you ensure that each parameter has the correct units?*
- *How will you document the time standard [e.g., local standard time (LST), Coordinated Universal Time (UTC)]?*

Revise the following table as needed for your specific project.

QC Activity	**DQI**	**Frequency of QC Checks**	**Acceptance Criteria**	**Corrective Action**
Confirm sensor is reporting data to online map	completeness	(daily/weekly/ monthly)	75% of hourly data are complete	Check Wi-Fi connectivity and power connection
Compare sensor results to nearby sensors or regulatory monitor	comparability	monthly		Check for physical debris in sensor and remove if present. Recalibrate sensor via co-location.

B.6 Instrument/Equipment Testing, Inspection, and Maintenance

INSTRUCTIONS:

Identify all instruments that need periodic maintenance, testing, or inspection. Describe how inspections and acceptance testing of instruments and their components will be performed and documented. Describe or reference how periodic preventive and corrective maintenance of *measurement or test equipment will be performed. Identify the equipment and/or systems requiring periodic maintenance.*

See Appendix C.3: How to Maintain Your Air Sensor? (Guidebook)

B.7 Instrument/Equipment Calibration and Frequency

INSTRUCTIONS:

Describe how calibration of the sensors will be performed and documented. Describe any proposed methods for harmonization (comparison and calibration between different sensor units) and/or collocation with a reference monitor. Identify the frequency of calibration (e.g. collocation prior to data collection, dynamic calibration throughout the project period, monthly harmonization with neighboring sensors).

Identify any published correction factors that will be applied to the data (e.g. EPA's nationwide PurpleAir correction factor) or describe the process for developing a calibration equation based on harmonization and/or collocation efforts. Identify any additional measurement parameters that will be included in a correction factor (e.g. T, RH).

Describe who will have access to raw data and calibrated/corrected data, including what data will be publicly available.

Consider the following:

- *Will you collocate (i.e., place nearby) your sensor near reference monitors or other trusted measurement systems to evaluate their performance? If so, where will you collocate and how will you process and show your results?*
- *Will you make any adjustments, corrections, or calibrations to the data after collection? Will you document the methods and techniques used?*
- *How will you store raw, unedited data from the sensors? How will you document how data was processed or corrected?*

See Chapter 3.6: Setup: Collocation and Correction (Guidebook)

B.9 Data Acquisition Requirements (Non-Direct Measurements)

INSTRUCTIONS:

Identify any types of data needed (for project implementation or decision making) that are obtained from non-direct measurement sources such as existing data from another project, auxiliary data from local or regional sources, photographs and maps, literature files, or historical databases.

Describe the purpose for the original data collection and its relevance to the current project.

Discuss how the data will be used. Describe the process to determine if the data is of acceptable quality for the current project and/or if there are any limitations on its use.

Consider the following:

- *What, if any, additional data sources will you draw from (e.g., meteorological data from the National Weather Service, regulatory air monitoring data from a state/local/tribal air monitoring agency)? Where will those data come from and how will they be integrated with the measurements you are making?*

Revise the following table as needed for your specific project.

Existing Data or Study	**Data Source**	**How Data Will Be Used**	**Acceptance Criteria**
(Pollutant) Concentration data in *(units)*	*(Abbreviate source citation here, full citation will be in References section)*	This data will be used to *(briefly state how it will be used, i.e., supplement measured data, compare measured data, show how concentrations have changed)*	This data is relevant because it is the same pollutant measured in the same area from *(time/year)* and has a reliable, peer-reviewed source.

D. DATA REVIEW AND USABILITY

D.1 Data Review, Verification, and Validation Requirements

INSTRUCTIONS:

Describe how the results will be reviewed, including deviations from the QAPP, SOP, and/or project objectives. Describe how any issues or data anomalies will be identified and resolved. How will the results and any limitations of the data be communicated?

Describe the data verification process. Address conformance of collected data with QC goals. What documentation will be used for data assessment? Examples of records commonly included in the verification process include instrument logs or bench notes; instrument readouts (raw data); calculation worksheets; quality control (QC) results; internal laboratory checklists, and field logbooks and datasheets. Describe how accepted, qualified, and rejected data will be identified. Include data qualifiers if appropriate.

State the criteria used to review and accept, reject, or qualify project data. Describe the data validation process. Validation may address:

- *how field sample collection, handling, and field analysis were performed*
- *the procedures used for data recording and management including electronic or manual transfer, data entry or transcription, calculations, and use of data from other datasets*
- *evaluation of appropriate ranges of data*
- *the name of the person, identified by title, responsible for data validation*

Describe how the sample results (which have already been reviewed, verified, and validated/evaluated) obtained from the project will be reconciled with the project objectives and measurement performance criteria/acceptance criteria.

Describe how the data will be summarized or analyzed (e.g., qualitative analysis, descriptive statistics, or inferential statistics) to meet project objectives. If descriptive statistics are proposed, list how the data will be summarized (e.g., mean, median, standard error, or minimum and maximum values). If an inferential method is proposed, include an indication of what is specifically proposed (hypothesis test, confidence interval, or confidence limit).

E. REFERENCES

1. <<Cited Reference #1 >>
2. << Cited Reference #2 >>
3. <<Citied References #3>>

FIGURES:

Figure A-1. Organization Chart

<< add >>

Figure B-1. Site Map with Sampling Locations

<< add >>

APPENDICES

APPENDIX A. Field Documentation

A-1. Equipment/Instrument Manual
A-2. Standard Operating Procedures
A-3. Field Data Forms

APPENDIX B. Data Evaluation

B-1. Data Evaluation/Documentation Form