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Citizen Science Air Monitoring in the Ironbound Community

Office of Research and Development
National Exposure Research Laboratory

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Disclaimer

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Acronyms and Abbreviations

ACE	Air, Climate, and Energy Program
AC	alternating current
CAG	community action group
CARE	Community Action for a Renewed Environment
CSAM	Citizen Science Air Monitor
ºC	degrees Celsius
DC	direct current
EJ	Environmental Justice
EPA	Environmental Protection Agency
FEM	Federal Equivalent Method
FDMS	Filter Dynamics Measurement System
FRM	Federal Reference Method
GB	gigabyte
ICC	Ironbound Community Corporation
kg	kilograms
lpm	liters per minute
Li-ion	lithium ion
m	meters
NAAQS	National Ambient Air Quality Standards
NCore	National Core
NEMA	National Electrical Manufacturers Association
NJDEP	New Jersey Department of Environmental Protection
NO_2	nitrogen dioxide
ORD	Office of Research and Development
O_3	ozone
PM	particulate matter
$PM_{2.5}$	fine particulate matter
ppb	parts per billion
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
RARE	Regional Applied Research Effort
RH	relative humidity

SCC	sharp cut cyclone
SD	secure digital
T	temperature
TEOM	Tapered Element Oscillating Microbalance
$\mu g/m^3$	micrograms per cubic meter
µm	micrometers
USB	Universal Serial Bus
V	volt

Executive Summary

Background

The Environmental Protection Agency's (EPA) mission is to protect human health and the environment. To move toward achieving this goal, EPA is facilitating identification of potential environmental concerns, particularly in vulnerable communities. This includes actively supporting citizen science projects and providing communities with the information and assistance they need to conduct their own air pollution monitoring efforts. The Air Sensor Toolbox for Citizen Scientists[1] was developed as a resource to meet stakeholder needs. Examples of materials developed for the Toolbox and ultimately pilot tested in the Ironbound Community in Newark, New Jersey are reported here. The Air Sensor Toolbox for Citizen Scientists is designed as an online resource that provides information and guidance on new, low-cost compact technologies used for measuring air quality. The Toolbox features resources developed by EPA researchers that can be used by citizens to effectively collect, analyze, interpret, and communicate air quality data. The resources include information about sampling methods, how to calibrate and validate monitors, options for measuring air quality, data interpretation guidelines, and low-cost sensor performance information. This Regional Applied Research Effort (RARE) project provided an opportunity for the Office of Research and Development (ORD) to work collaboratively with EPA Region 2 to provide the Ironbound Community with a "Toolbox" specific for community-based participatory environmental monitoring in their community.

Study Objectives

This collaboration provided for community-based participatory environmental monitoring of the particulate matter size fraction 2.5 micron ($PM_{2.5}$) and gaseous nitrogen dioxide (NO_2), as pollutants chosen jointly by the ORD, Region 2, and the Ironbound Community using an environmental sensor pod designed by ORD for the particular needs of the community. ORD provided technical commentary on the general research study plans developed by the Ironbound Community/Region 2 and provided data analysis expertise concerning data summarization options ultimately shared with the community. The primary objective of this effort was to develop the approach (Toolbox) needed to support such activities and ensure its success. The ultimate goal of these cumulative efforts was the estimation of local pollution levels by the efforts of citizen scientists and determination of the lessons learned associated with the use of a low-cost sensor pod for environmental monitoring.

Methods

Scientists worked closely with the Ironbound Community Corporation (ICC) to

- Jointly develop a study design to monitor air quality;
- Assist the community in selecting pollutants to monitor;
- Provide novel environmental sensors, in-person technical training, and written

[1] http://www2.epa.gov/air-research/air-sensor-toolbox-citizen-scientists-resources

directions for sensor use;
- Establish quality assurance procedures needed to ensure high yield of useable data;
- Assist with establishment of data analysis tools, selection of data summarization tools, and technical expertise in presenting air quality data summaries to meet the needs of the general public.

Results

An extensive dataset containing spatially and temporally resolved air quality measurements collected from four portable sensor pods incorporating $PM_{2.5}$ and NO_2 sensors was developed as a community asset. Working in concert with ORD and Region 2 partners, the sensor pods were collocated with Federal Equivalent Method (FEM) monitors under ambient monitoring conditions. Regression algorithms from collocated reference comparisons were used to establish a normalized data set for all measures and time points. The sensor pods operated by citizen scientists following only a day of hands-on training provided for extensive air quality monitoring to be performed in numerous citizen-selected locations throughout a wide area of the Ironbound Community. The extensive data collections, in concert with quality assurance procedures of the effort, ensured data of sufficient depth and value were available to inform the community about spatial and temporal variability of the pollutants of interest. Local pollutant concentrations were then compared to other settings as part of EPA's effort to raise community awareness of key data findings. In total, the data provided for an improved upon knowledge base concerning estimates of $PM_{2.5}$ and NO_2 concentrations for the Ironbound Community.

Conclusion

EPA aims to address environmental health concerns of vulnerable populations in its research programs, and integrating community-based citizen science efforts is a major goal of the Agency. The Air Sensor Toolbox's technical resources developed for the Ironbound Community represent an example for use by other communities across the country in developing their own air monitoring programs in areas where pollution is a concern. As such, the pilot effort provided EPA an opportunity to work directly with a highly motived citizen science organization, develop a collaboratively agreed upon research plan, and introduce advanced technology to the citizen scientists to meet their needs. The ICC pilot project provided useful lessons in how to improve coordination between the Agency and communities, the types of tools and technologies needed to assist communities, and how the lessons learned from this pilot study might be applied to future efforts.

1.0 Introduction

There exists a strong desire by the general public to collect environmental data of importance to their family or community[2,3]. This desire is driven by a wide variety of factors, including concerns citizens have about known or perceived local pollution sources. The recent introduction of lower cost environmental monitors and sensors into the public domain has increased citizens' awareness of tools that may be available which would give them the opportunity to collect environmental data for their own use[4,5,6,7]. However, most citizens do not have the technical training to operate environmental monitors with a great deal of understanding on the proper procedures[8,9], thwarting citizens from collecting environmental data. In addition, most of the lower cost environmental monitors that citizens would obtain for their use have not been evaluated for their performance characteristics so that the data obtained by such devices have a high probability of being less than adequate. It is the desire of the Environmental Protection Agency (EPA) to promote citizen involvement in areas associated with environmental education and awareness. It is also EPA's desire to investigate sensor technologies and to determine their usefulness for a wide variety of potential applications[10,11]. The project reported here has helped EPA achieve both of these desires by developing a framework and tools for citizens in a select community to participate in environmental monitoring using technologies to which they previously did not have access.

EPA's Office of Research and Development (ORD) as part of its Air, Climate, and Energy (ACE) program area on emerging technologies (EM-3), has ongoing research involving a wide array of emerging technologies and their application to solving complex environmental research.

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[2] McKinley, Duncan C., et al. "Investing in citizen science can improve natural resource management and environmental protection." *Issues in Ecology* 19 (2015).

[3] Dickinson, J.L. and R. Bonney (Eds.). 2012. Citizen Science: Public Participation in Environmental Research. Cornell University Press, Ithaca.

[4] The Changing Paradigm of Air Pollution Monitoring. Emily G. Snyder, Timothy H. Watkins, Paul A. Solomon, Eben D. Thoma, Ronald W. Williams, Gayle S. W. Hagler, David Shelow, David A. Hindin, Vasu J. Kilaru, and Peter W. Preuss. *Environmental Science & Technology* 2013 *47* (20), 11369-11377

[5] Kaufman, A.; Brown, A.; Barzyk, T.; Williams, R. The Citizen Science Toolbox: Air Sensor Technology Resources. EM, September 2014, 48-49.

[6] Preuss, P. and French, R. A Sensor World. EM, January 2014, 20-24.

[7] White, R.M.; Paprotny, I.; Doering, F.; Cascio, W.E.; Solomon, P.A.; Gundel, L.A. Sensors and 'Apps' for Community-Based Atmospheric Modeling. EM, May 2012, 36-41.

[8] Williams, R.; Watkins, T.; Long, R. Low-Cost Sensor Calibration Options. EM, January 2014, 10-15.

[9] Williams, R., Vasu Kilaru, E. Snyder, A. Kaufman, T. Dye, A. Rutter, A. Russell, and H. Hafner. Air Sensor Guidebook. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/159 (NTIS PB2015-100610), 2014.

[10] EPA's Air Sensor Toolbox for Citizen Scientists: http://www.epa.gov/air-research/air-sensor-toolbox-citizen-scientists.

[11] EPA's Draft Roadmap for Next Generation Air Monitoring: http://www.epa.gov/sites/production/files/2014-09/documents/roadmap-20130308.pdf.

This includes development and evaluation of select environmental sensors as well as their integration into select research opportunities that better define their capabilities to meet a wide variety of monitoring needs[12].

EPA Region 2 had a desire to facilitate community-based participatory environmental monitoring associated with the Ironbound Community as an opportunity to establish successful practices associated with such efforts. EPA Region 2 has an established Citizen Science Program designed to help engage and empower communities to collect their own data and advocate for their own environmental concerns. These efforts are focused on assisting Citizen Science groups, particularly those in Environmental Justice (EJ) communities, by providing them with tools and technical guidance to help promote and advance needed air-monitoring projects. Citizen Science projects have been remarkably successful and contributions from citizen scientists have become a developing tool for expanding scientific knowledge and literacy, especially for disenfranchised EJ communities. Region 2 support to the Ironbound project included project management, assistance with site selection, assistance with quality assurance project plan (QAPP) development and review, equipment calibration and modification, community volunteer training, assistance with equipment deployment, equipment collocation with State reference monitors, and equipment repair.

EPA's ORD collaborated with EPA Region 2 and the Ironbound Community Corporation (ICC) in this project funded through the Regional Applied Research Effort (RARE) Program. RARE projects are designed to respond to high-priority research needs, address a wide variety of environmental issues, and foster interaction between EPA regions and the ORD[13]. This specific RARE project included direct community involvement, with a focus on citizen science and community-based air monitoring.

1.1 Ironbound Community

The Ironbound Community is comprised of about 50,000 residents, the majority of which are minorities. Citizens in this northeast area of New Jersey live in a community potentially impacted by a wide variety of environmental pollution sources. The Ironbound Community has an established history and interest in conducting limited environmental monitoring campaigns but is lacking technical expertise and equipment to perform environmental monitoring related to some of their ongoing concerns[14,15]. Many of the residents suffer from both poverty and living in close proximity to industry, combined with the impacts of transportation arteries, such as highways and rail lines, that further add to the burden of pollution on local residents. It is reported that 25% of the children living in this community suffer from asthma, three times the state average[16]. Figure

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[12] EPA's Air Research Web Page: http://www.epa.gov/air-research.

[13] https://www.epa.gov/sites/production/files/2015-10/documents/rare_factsheet_102015.pdf

[14] https://sites.google.com/a/ironboundcc.org/ironboundcare/

[15] http://www.epa.gov/sites/production/files/2015-03/documents/citizen_science_toolbox_ironbound_community_fact_sheet.pdf

[16] Presentation: Community Based Participatory Research: Newark, NJ. Molly Greenberg, Ironbound Community Corporation: http://www3.epa.gov/citizenscience/NJ/2b-Greenberg-AirMonHealthSurvey.pdf.

1-1 shows the location of the Ironbound Community in relation to the Newark Liberty Airport, the Port of Newark and the NCore Reference Monitor Station.

The community is aware that high densities of roadways and industrial operations might lead to exposure to a variety of airborne pollutants, such as nitrogen oxides, sulfur oxides, particulate matter, and air toxics. Pollution sources often tend to be concentrated in low-income urban areas because of urban land use practices. The community is concerned about the health consequences of poor air quality, including high disease rates for respiratory and cardiovascular conditions and potentially cancer[16 above4].

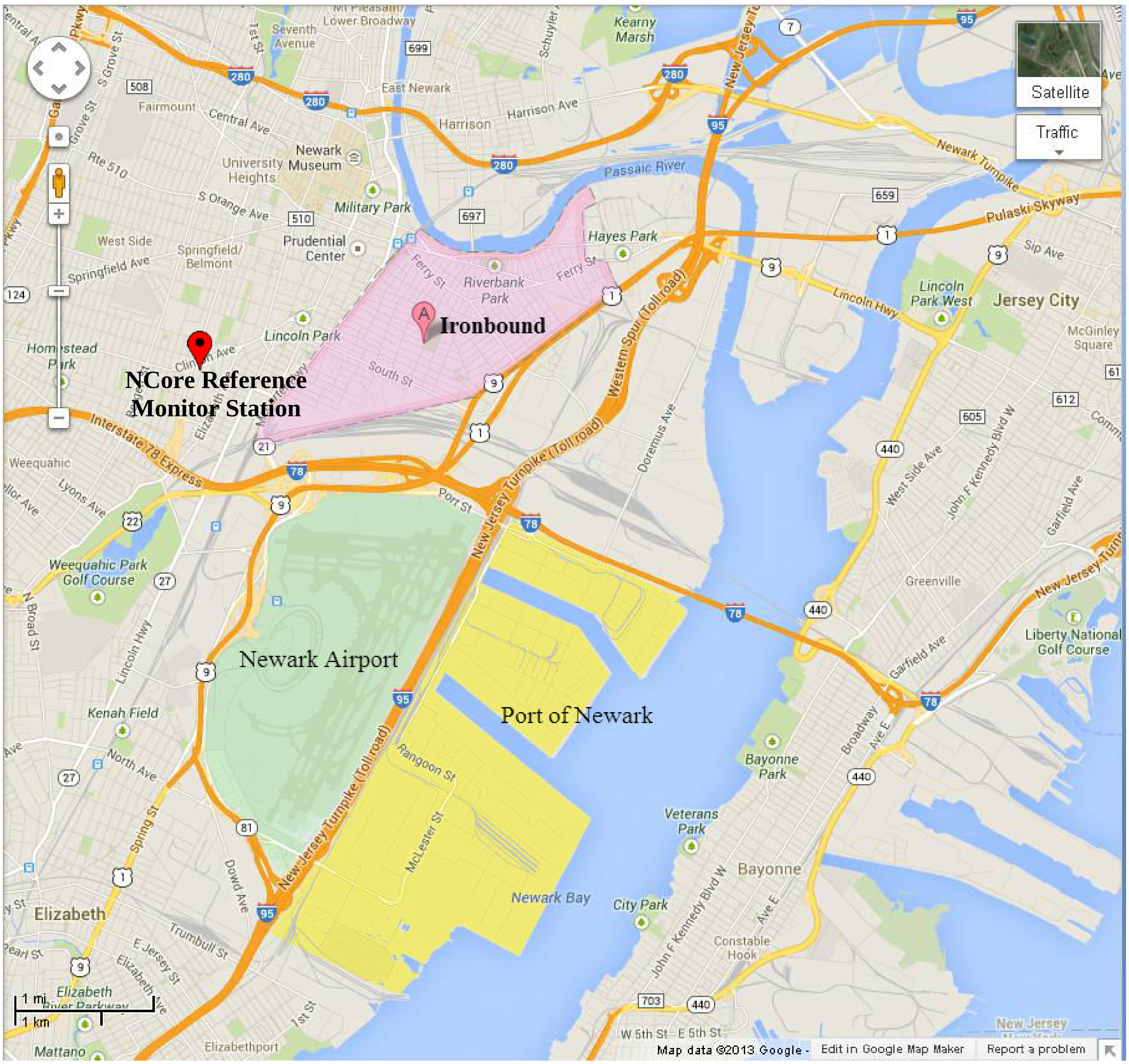

Figure 1-1. Map of the Ironbound Community.

Figure 1-2. Images of a railway (top) and industrial facilities (bottom) in the Ironbound Community.

1.2 Citizen Science and Air Monitoring

The term 'citizen science' refers to the collection and analysis of data by members of the general public, typically as part of a collaborative project with professional scientists. Citizen science engages people in decision making processes, promotes collaboration, brings fresh perspectives into decision making, fosters environmental stewardship, spreads knowledge, answers local community questions of concern, incorporates local and traditional knowledge, builds awareness of an organization's mission, improves science literacy, and builds expertise[17]. Communities are increasingly becoming involved in citizen science projects that involve open collaboration, address real-world problems, identify research questions, collect and analyze data, interpret results, make new discoveries, develop technologies and applications, and solve complex problems. Interest in this area is extremely high with a recent event sponsored by the EPA detailing a wide range of environmental issues citizens were trying to address through their own efforts[18].

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[17] McKinley, Duncan C., et al. "Investing in citizen science can improve natural resource management and environmental protection." *Issues in Ecology* 19 (2015).

[18] Community Air Monitoring Training: A Glimpse into EPA's Air Sensor Toolbox: http://www.epa.gov/air-research/community-air-monitoring-training.

Air quality monitoring represents a very high technical hurdle. This is true not just for professional scientists but also for citizen scientists. While the professional title of the individual responsible for conducting such efforts might change, the basic requirements needed to ensure such efforts are being done properly cannot change. Simply put, data collected of poor quality only complicates the goal of assessing environmental conditions. Poor quality data presented to others (such as a governing authority, industrial concern, etc.) has the unintended consequences of ultimately reflecting negatively on the presenting organization and loss of credibility in the discussion being voiced.

As documented in the EPA's Air Sensor Guidebook[19], not only does one need to have extensive knowledge of the air pollutants of interest to design a monitoring strategy, the strategy must be sophisticated enough to ensure that the proper technology is being applied and that data quality assurance procedures are in place to meet data quality objectives. While this sounds like an almost unachievable barrier, this project sought to address those issues directly. The first step in this pilot project was to provide air quality training to the citizen scientists who led the effort. Second, the citizen scientists were provided advanced air quality instrumentation using low cost sensor components assembled by the EPA and known to operate in a well-characterized fashion. Last, EPA (ORD, Region 2) and the citizen scientists together defined quality assurance objectives targets, developed a QAPP, and then assessed the raw data versus acceptance criteria to develop a useable database for project summarization. ORD provided expertise in review, analysis, and summaries of the data collected by the ICC. Table 1-1 summarizes each groups' objectives for the project.

Table 1-1. Project Objectives.

Group	Objectives
ICC	1. Characterize near-road/near-source high-concentration areas
	2. Determine potential impact on nearby residences (including multi-level housing)
	3. Investigate locations of multi-level (roadways + elevated rail) sources
EPA Region 2	1. Develop 'how-to' documentation
	2. Examine potential for sensor loan program for public use
	3. Use community validated documentation for local Air Sensor Toolbox
EPA ORD	1. Develop Air Sensor Toolbox for Citizen Scientists – sensor 'how-to' documentation, community-based participation, developing a research plan, interpreting measurements, making decisions
	2. Explain uncertainty and variability, benefits and limitations

[19] Williams, R., Vasu Kilaru, E. Snyder, A. Kaufman, T. Dye, A. Rutter, A. Russell, and H. Hafner. Air Sensor Guidebook. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/159 (NTIS PB2015-100610), 2014.

2.0 Materials and Methods

ORD collaborated with Region 2 and the ICC on communicating the goals of the project to all parties as it was initiated and conducted. The project took advantage of information gained from ORD's ACE sensor evaluation research task (ACE 143)[20,21,22] with respect to a knowledge base of applicable low cost sensors to be used, the state of technology on energy systems to power the sensor pod, and data storage/data recovery components that would minimize citizen scientist concerns about technical competency to handle such duties. Specific aspects of these challenges are defined in depth in Section 2.2. Select environmental monitoring was performed by the ICC community members, with the resulting data visualized using Microsoft Excel. A local ICC liaison was identified as the primary point of contact between ORD, Region 2, and the ICC. The primary focus of the work was on environmental education and providing the ICC first-hand experience in using low cost sensors as a means to investigate air pollutant sources of concern.

ORD provided four sets of customized air pollution sensors after consulting with the ICC on their source pollutants of greatest concern. Standard operating procedures developed to meet citizen science technical comprehension for the device were created, as well as quality assurance guidelines regarding sensor use and data validation. The latter was not the traditional QAPP used by EPA, since ORD was not involved in the direct collection of environmental measures, but rather, a Region 2-developed quality assurance guidance document aimed toward citizen science based activities. Region 2's QAPP guidance was specifically aimed at the Region's Citizen Science program. It complies with EPA Quality Assurance (QA) requirements, but streamlines existing guidance, using a template format, and includes a citizen science project example[23]. This document has utility far beyond the normal QAPP, and provides greater benefit to all parties.

The ICC/Region 2, in consultation with ORD, developed a research plan (study design) involving the citizen scientist monitoring approach. The ICC/Region 2 implemented the data collection strategy as defined directly above. This involved a multi-seasonal approach (February through July 2015). No personal monitoring or residential indoor monitoring was performed as per the fully agreed-upon partner study design.

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[20] Williams, R., R. Long, M. Beaver, A. Kaufman, F. Zeiger, M. Heimbinder, I. Hang, R. Yap, B. Acharya, B. Ginwald, K. Kupcho, S. Robinson, O. Zaouak, B. Aubert, M. Hannigan, R. Piedrahita, N. Masson, B. Moran, M. Rook, P. Heppner, C. Cogar, N. Nikzad, and W. Griswold. Sensor Evaluation Report. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/143 (NTIS PB2015-100611), 2014.

[21] Williams, R., A. Kaufman, and S. Garvey. Next Generation Air Monitoring (NGAM) VOC Sensor Evaluation Report. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/122 (NTIS PB2015-105133), 2015.

[22] Williams, R., A. Kaufman, T. Hanley, J. Rice, and S. Garvey. Evaluation of Field-deployed Low Cost PM Sensors. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/464 (NTIS PB 2015-102104), 2014.

[23] http://www3.epa.gov/region02/citizenscience/pdf/citsci_air_attach_b_form.pdf

2.1 Pollutants of Interest

The Ironbound community was interested in learning more about the pollution potentially caused by near-road sources. Therefore, ORD suggested that the two best pollutants to measure based on their particular needs, study resources, and available low cost sensor technologies, were fine particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2).

PM consists of particles of various sizes such as soot, smoke, dirt, and dust. These particles are often generated and released into the air from combustion sources such as power plants, automobiles, and fires, along with industrial and agricultural processes. PM can adversely affect breathing and aggravate respiratory and cardiovascular conditions, with the smallest particles posing the greatest health risk. PM also contributes to atmospheric haze that reduces visibility. PM data values and discussion mentioned throughout the remainder of this report refers explicitly to the $PM_{2.5}$ size fraction. $PM_{2.5}$ is a National Ambient Air Quality Standards (NAAQS) criteria air pollutant that states are required to monitor[24].

NO_2 is a highly reactive gas that can irritate the lungs and cause bronchitis, pneumonia, and other respiratory problems. NO_2 is also a NAAQS criteria pollutant that states are required to monitor[24]. NO_2 pollution is both man-made and naturally occurring. It occurs naturally as a result of atmospheric processes. It also forms from fuel combustion and forms quickly from automobile emissions. Therefore, significant increases in NO_2 concentrations are often found near major roadways. Power plants and other industrial processes also emit NO_2. Table 2-1 describes source types and health effects for $PM_{2.5}$ and NO_2. More information about these air pollutants are reported elsewhere[25].

Table 2-1. Pollutants, source types, and health effects.

Pollutant	Source Types	Health Effects
$PM_{2.5}$	Combustion activities (motor vehicles, coal power plants, wood burning, etc.) Certain industrial processes	• Nonfatal heart attacks • Irregular heartbeat • Aggravated asthma • Decreased lung function • Respiratory symptoms such as irritation of the airways, coughing, or difficulty breathing • People with heart or lung diseases, children, and older adults are the most likely to be affected
NO_2	Combustion activities, especially from vehicles; higher near roadways	• Adverse respiratory effects • Airway inflammation in healthy people • Increased respiratory symptoms in people with asthma

[24] http://www3.epa.gov/ttn/naaqs/criteria.html

[25] http://www.epa.gov/airquality/urbanair/

2.2 Citizen Science Air Monitor (CSAM)

Early discussions with the ICC and their desire to conduct citizen science air quality monitoring resulted in EPA developing the low cost sensor pod for the effort. Specific needs are defined in Table 2-2.

Table 2-2. CSAM design requirements.

Specification Requirement	Design Response	Key Features
Continuous $PM_{2.5}$	Thermo DataRam 1200 Nephelometer, 1 second time averaging capable	Well established light scattering sensor with capability to operate with an inline 2.5-micrometer (µm) cyclone size selective inlet. The modified version of the SKC AirCheck Model 52 provided needed 1.5 liter per minute (lpm) intake flow rate[26,27].
Continuous NO_2	Cairpol CairClip NO_2/ozone (O_3) Universal Serial Bus (USB) sensor	Capabilities previously established in ORD-based chamber evaluations[28]. A low volume teflon adapter was affixed to the inlet of the device to allow for calibration and intake snorkel connections.
Portable but rugged	Modular features	National Electrical Manufacturers Association (NEMA) box configurations separately housed the sensor pod and battery supply that were connected via cable for ease of use and transport. A modified aluminum tripod stand was used to support air intakes at 1 meter above the base with simple fasteners for set-up/take down ease of use.

[26] Williams, R., Rea, A., Vette, A., Croghan C., Whitaker, D., Wilson, H., Stevens, C., McDow, S., Burke, J., Fortmann, R., Sheldon, L., Thornburg, J., Phillips, M., Lawless, P., Rodes, C., Daughtrey, H. The design and field implementation of the Detroit Exposure and Aerosol Research Study (DEARS). Journal of Exposure Science and Environmental Epidemiology, 19: 643-659 (2009).

[27] Reed, C.H., Rea, A., Zufall, M., Burke, J., Williams, R., Suggs, J., Walsh, D., Kwok, R., and Sheldon, L. Use of a continuous nephelometer to measure personal exposure to particles during the U.S. EPA Baltimore and Fresno panel studies. Journal of the Air and Waste Management Association, 50:1125-1132 (2000).

[28] Williams, R., R. Long, M. Beaver, A. Kaufman, F. Zeiger, M. Heimbinder, I. Hang, R. Yap, B. Acharya, B. Ginwald, K. Kupcho, S. Robinson, O. Zaouak, B. Aubert, M. Hannigan, R. Piedrahita, N. Masson, B. Moran, M. Rook, P. Heppner, C. Cogar, N. Nikzad, and W. Griswold. Sensor Evaluation Report. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/143 (NTIS PB2015-100611), 2014.

Specification Requirement	**Design Response**	**Key Features**
Rechargeable battery and land power options sufficient for 7 days unattended full-time operation	12 volt (V) lithium-ion (Li-ion) battery pack and equally capable alternating current (AC) (115 V) connection options	The selected Li-ion battery pack provided for 9 days non-attended operational cycles. Simple plug-in recharge features. AC power linkages used transformed 115V plug-in adapters. Assembled units required professional electrical safety review and approval for design features and non-professional operation.
Snorkel options for air intakes	Small diameter (< 30 second flow duration) Teflon intake lines with direct connection to $PM_{2.5}$ and NO_2 sensors	Easy on/off non-reactive transfer lines (tubing) allowed direct calibration of NO_2 sensor and sampling distances up to 0.7 meters (m) from CSAM unit. Tubing provided means for through window unit deployment.
Precipitation resistant	NEMA encasement with grommet features for protruding components	NEMA casement provided weather resistant close and lock mechanism allowing deployment in rain/snow. Hinged rain cover provided secondary precipitation protection above CSAM unit during severe weather events when interior electronics might be exposed. Rubber gaskets on hinged interior access door provided wind-blown precipitation protection. Aluminum materials (NEMA/tripods/rain shields) reduced overall unit mass and were rust resistant.
Internal data storage	8 gigabyte (GB) secure digital (SD) card	Removable SD card provided for easy data recovery following each event. Used card was returned to study office while replacement card was inserted into slot. CSAM indicator lights illuminated when SD card was properly inserted to avoid data loss to missing memory card.
Ease of use data recovery application	Excel executable	An Excel macro developed specifically for the CSAM provided for minimal technical training.

Specification Requirement	Design Response	Key Features
Simple on/off operation	Keyed on/off switch	Removable key provided for security of device. Movement to off position stopped data collections. Movement to on position reinitialized all sensors and data storage time stamps for new data run.
Ease of use calibration features	Excel macro with updatable cells for sensor response values	Capable of being updated with new calibration inputs.

The Citizen Science Air Monitor (CSAM) is an air monitoring system designed for measuring $PM_{2.5}$ and NO_2 pollutants simultaneously, and is capable of producing representative data following calibration and quality assurance review. It is not recognized as a Federal Reference Method/Federal Equivalent Method (FRM/FEM) reference monitor used for regulatory monitoring to assess attainment. It represents a device capable of producing representative data following calibration and quality assurance review.

This self-contained system consists of a CairPol CairClip NO_2 sensor, a Thermo Scientific *personal* DataRAM $PM_{2.5}$ monitor, and a Honeywell temperature (T) and relative humidity (RH) sensor (HIH-4602-C). The CSAM's design provides for easy data retrieval from all three devices in a single step through a key-lock access door[29,30]. The sensors are powered by rechargeable lithium ion phosphate batteries (Stark Power 12V 20Amp-Hour Part number SP-12V20-EP), which were capable of maintaining nominal 12 volt (V) power for a week in the field. Data were stored on a secure digital (SD) card, which were then uploaded to a personal computer and viewed via a pre-designed Microsoft Excel macro also stored on the SD card. Electrical safety review of all components by a licensed institution (Intertek. 1950 Evergreen Blvd Suite 100. Duluth GA, 30096. 679-775-2400) insured that the basic design of the CSAM was deemed intrinsically safe when operated as per EPA operating guidelines. Figure 2-1 shows the inside of the CSAM and its separate components. Figure 2-2 shows a CSAM unit assembled with tripod, weather shielding, and battery case.

While the CSAM achieved its primary design specifications as to being capable of operation with minimal technical training under a wide variety of deployment conditions for long periods of time (> 7 days unattended), such specifications did not necessarily equate to a unit being lightweight and easily transported under all conditions. The CSAM had a mass of ~ 7 kg, its attachable battery box had a mass of ~ 10 kilograms (kg), and its tripod stand had a mass of ~ 9

[29] Williams, R.W., T. M. Barzyk, and A. Kaufman. Citizen Science Air Monitor (CSAM) Quality Assurance Guidelines. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/008, 2015.

[30] Williams, R., T. Barzyk, and A. Kaufman. Citizen Science Air Monitor (CSAM) Operating Procedures. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/051, 2015.

kg. While the individual or combined mass of all CSAM components was not excessive for normal research instrumentation EPA research teams often encounter with field monitoring equipment, it did represent a challenge to some of the citizen scientists who participated in such activities, especially when units had to be secured on rooftops or other non-ground-based locations. Simpler (smaller/lighter) monitoring devices might have been developed, but as of the initiation of this project, especially with respect to the power requirements, the selected components offered the best compromise on ease of use, established performance features with true $PM_{2.5}$ size fractionation, calibration capability, and long unattended operational periods.

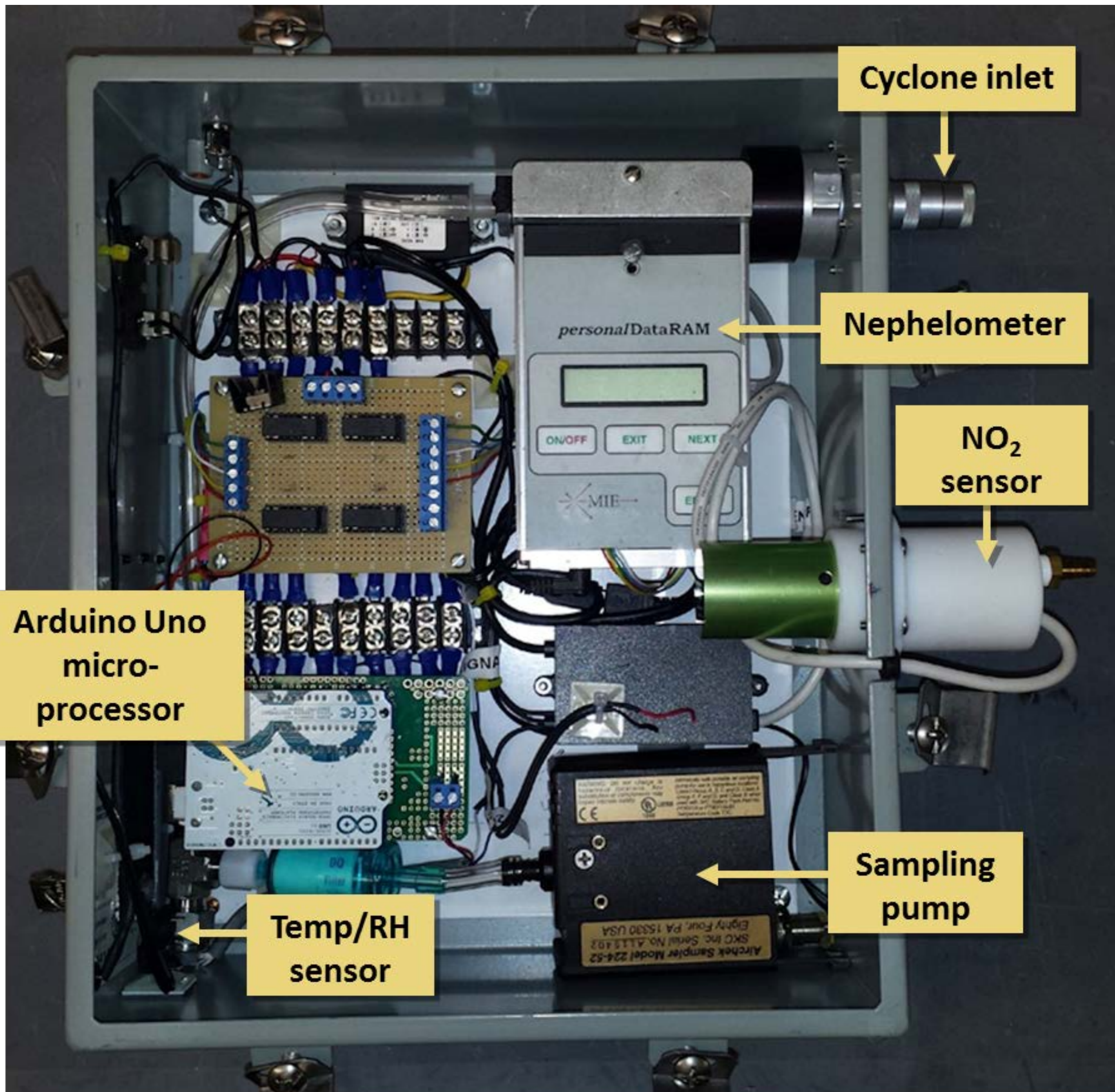

Figure 2-1. The inside of the CSAM and its separate components.

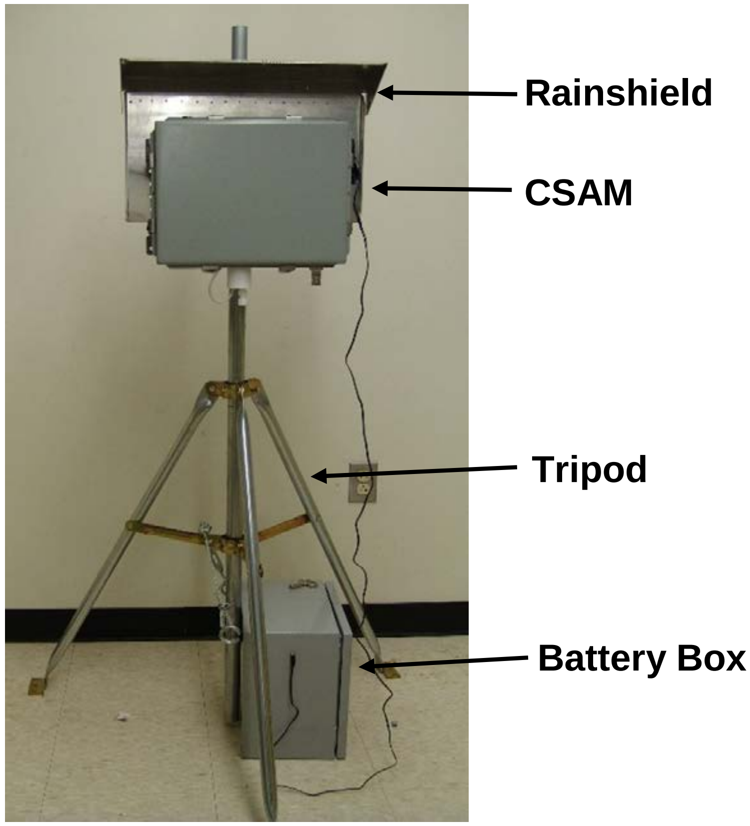

Figure 2-2. CSAM unit assembled with weather shielding, tripod, and battery case.

The CSAM-PM component measures real-time $PM_{2.5}$ in micrograms per cubic meter ($\mu g/m^3$) using a Thermo Scientific *personal* DataRAM nephelometer, a device that uses light to measure the concentration of suspended particles in a liquid or gas. A modified SKC AirChek 52 personal sampling pump draws air into the nephelometer. Modifications consisted of removing its battery pack and powering it directly from the CSAM energy harness. The nephelometer used a BGI sharp-cut cyclone (SCC) inlet (SCC 1.062), which excluded particles above a mean aerodynamic diameter greater than 2.5 microns, allowing only "fine" particles ($PM_{2.5}$) to be sampled. The CSAM-PM had a detection limit of 0.1 $\mu g/m^3$.

CSAM measurements of NO_2 were made using a CairPol CairClip NO_2 sensor[31]. The CairClip used a gas-specific inlet filter combined with dynamic air sampling in an integrated system to measure real-time gas concentration in parts per billion (ppb). The CSAM- NO_2 unit's detection limit (the lowest concentration the instrument was likely to detect) was approximately 5 ppb NO_2 as determined in a previous EPA research study[32]. The sensor was "tuned" by the manufacturer to be more responsive to NO_2, as compared to other oxides such as O_3. Even so, the

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[31] http://www.cairpol.com/index.php?option=com_content&view=article&id=41&Itemid=156&lang=en

[32] Williams, R., R. Long, M. Beaver, A. Kaufman, F. Zeiger, M. Heimbinder, I. Hang, R. Yap, B. Acharya, B. Ginwald, K. Kupcho, S. Robinson, O. Zaouak, B. Aubert, M. Hannigan, R. Piedrahita, N. Masson, B. Moran, M. Rook, P. Heppner, C. Cogar, N. Nikzad, and W. Griswold. Sensor Evaluation Report. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/143 (NTIS PB2015-100611), 2014.

output of the device under field conditions might have potentially represented a cumulative response to such pollutants to some unknown degree. Field experience in other studies has indicated that simple subtraction of the non-wanted O_3 response has sometimes yielded excellent agreement of the NO_2 estimates versus Federal Reference Methods (FRMs)[33]. For the present study conducted during mostly winter-spring seasonal periods where typical O_3 concentrations are historically well below 10 ppb in the study area, results would indicate minimal O_3 impact on data quality for the NO_2 measurements. Collocated CSAM versus reference monitor agreement as reported in the Results section are provided to support the selection of this particular NO_2 sensor.

The CSAM also contained a Honeywell temperature and RH sensor (HIH-4602-C). Temperature (ºC) and RH (% at ºC) data were recorded along with the $PM_{2.5}$ and NO_2 concentration data. The recommended operating ranges for temperature and RH were 0–40 ºC (32–104 ºF) and 0–90% RH (with no formation of water droplets), respectively. These measurements were taken in-line with the $PM_{2.5}$ air monitoring components. Table 2-3 summarizes measurement units reported by each CSAM component.

Table 2-3. Measurement units reported by each CSAM component.

Measurement	Reporting Unit
$PM_{2.5}$ concentration	Micrograms per cubic meter ($\mu g/m^3$)
NO_2 concentration	Parts per billion (ppb)
Temperature	Degrees Celsius (ºC)
Relative humidity (RH)	Percent (%) at ºC

It should be noted that a manufacturing issue with the SKC pump occurred that had not been previously reported by SKC. Even though new pumps were integrated into the CSAM units, which should have provided for thousands of hours of nominal performance, a new “metallic-bearing lubricant” had been applied to the primary motor of the pumps. It was reported to EPA that a new provider of these pump components had not reported to SKC the inclusion of metallic-bearing materials as part of the manufacturing process. This metallic lubricant appeared to interfere with the electronic control circuits of the pumps after they had been operating for a few days, interrupting the ability of the units to maintain pre-established flow rates, as evidenced by wild fluctuation of flow with no operator involvement or adjustment of the set point potentiometer. Table 2-4 describes pump replacement history.

[33] http://www.epa.gov/air-research/sensor-technology-state-science

Table 2-4. CSAM pump replacement history.

CSAM Pump Replacement History

CSAM #1	CSAM #2	CSAM #3	CSAM #4
100% up time	replaced 1/27/15	replaced 1/27/15	replaced 3/10/15
	replaced 4/14/15		

Some damage to the CSAMs occurred while they were in transit from their manufacturing location in Research Triangle Park, NC to the EPA Edison New Jersey office. As a result, pelican cases were purchased and used to ensure safety and protection during transport. A wooden base was designed to secure the tripod. The citizen scientists setting up and monitoring the CSAMs at field locations were trained on how to change and recharge the CSAM's battery, set up the unit properly at its outdoor or indoor location, initiate data collection, and retrieve and process the data. The CSAM is designed to run for one week (continuously for 7 days) on a fully charged battery. Therefore, the operator visited the test site at least once a week to replace and/or recharge the battery, download data, and inspect the unit's functionality.

2.3 Technical Training

ORD scientists provided a day-long technical training session to the ICC to demonstrate the proper use and maintenance of the CSAM units. The first half of the training involved a project overview followed by a demonstration of how to assemble the CSAM units. The project overview included discussion of the pollutants measured, data considerations related to the benefits and limitations of the sensors, and information about the context of measurements, including sources, sites, potential exposures, and interpretation. During the assembly example, ORD scientists demonstrated how a CSAM would be assembled in the field. They indicated the location, features, and specific purpose of each CSAM internal component and explained how the components work together to measure air quality. The stand, rain shield and battery box were placed in the correct orientation for field operation. Next, the CSAM cover was removed and each internal component was named and described. Then, the electrical input connector was displayed, including information on how to use either the battery connection or the alternating current/direct current (AC/DC) adapter. They emplasized battery and electrical safety measures, including the importance of users ridding themselves of static electricity by making contact with a grounded component of the monitoring stand before touching the internal components. The second half of the training provided the ICC staff and volunteers a hands-on opportunity to work as teams to disassemble and reassemble the four units on display, giving them a sound understanding of proper assembly through a complete cycle of start-up, take down, and data recovery. ORD scientists provided guidance and feedback during this process. Once units were reassembled, the training proceeded to demonstrate the process of data collection, including how to transfer datasets via a removable SD card plugged into a personal computer. Trainees were instructed on proper techniques for transporting and moving the units and best practices for siting units for proper function and data collection. Lastly, ORD trainers explained how to troubleshoot in case of disturbances in the unit's operation, cold weather events, or other potential errors. Refer to Appendix A, Attachment D for more information.

2.4 Quality Assurance/Quality Control

There were two quality assurance project plans (QAPPs) developed for this project, one citizen science QAPP (i.e., 'How-To' document) that has the potential of being easily transferable to other locations and regions, and one project-specific QAPP (i.e., research design for the Ironbound Community). The project specific QAPP used Region 2's streamlined QAPP template specifically designed for citizen scientists. It included specifics such as monitoring locations, maintenance schedule, accessibility, measurement duration per location, technology requirements, and data responsibilities. Refer to Appendices A and B for more information.

Study QA procedures are detailed in Table 2-5 and include a comprehensive plan to assess CSAM performance prior to the deployment and then repeatedly throughout.

Table 2-5. Study QA features.

QA component	Responsible party	Specifics	Results	Outcome
Laboratory assessment during fabrication	EPA contractor staff examined NO_2, $PM_{2.5}$, RH, temperature sensors and active pumping system laboratory and calibrated all components under controlled conditions over expected operational range. Response algorithms were established and embedded in Excel executable file.	Direct in-line or chamber challenge of sensors by EPA contractor staff using approved operating procedures and reference materials (e.g., gases).	Linear range of NO_2 device established (0 to 200 ppb), DataRam algorithm correctly reporting zero concentration when blank tested. RH and temperature (T) sensors established linear response over full manufacturer's range. SKC pump produced stable (precision error < 10% flow operation from 0 to 4 lpm).	CSAM achieved expected operational requirements needed for deployment goals (range, linearity, response features, precision).
Pre-deployment audit	Region 2 EPA staff examined all CSAMs upon shipping receipt. Repeated inline audits of NO_2 sensor response using in-house gas manifold under known conditions. Team established active pumping system precision.	NO_2 gas manifold with snorkel tube was used to deliver challenge over 3 orders of magnitude directly to CSAM. Automated flow rate monitors were used to establish SKC pump stability.	NO_2 sensor were shown to be linear over full range. New response algorithm inputs were updated in Excel executable file. Some SKC pumps were shown to exceed flow stability requirements. Pumps were recalibrated under known test conditions and in some cases replaced if stability was not achieved.	Shipping units to Region 2 offices from the ORD laboratory resulted in some failures of the CSAMs (e.g., loose components, disconnect of hoses/electrical unions). It was evident that greater structural integrity of certain internal CSAM components was needed to ensure efficient transport.

Collocation with Federal Equivalent Method monitors	Region 2 and ICC	ICC, in concert with EPA Region 2 staff, collocated all 4 CSAM units at the New Jersey Department of Environmental Protection (NJDEP)'s NCore station at the Clinton Avenue Firehouse in Newark, NJ. Units were operated for 7 continuous days.	Regression coefficients were established between each CSAM unit and reference measurements.	Comparisons revealed good to excellent agreement with NO_2 measurements with $PM_{2.5}$ comparisons more variable. RH and temperature sensors revealed greater offset from reference measures for some of the individual CSAMs. Cumulative review of the dataset as a whole indicated failure of the active pumping system in some CSAMs was occurring.
Weekly performance audits	ICC	Audit/calibration of active pump system for zero (blank) output pf the DataRam and flow rate stability at needed set point.	ICC reported reoccurrence of flow rate stability errors and inability of some CSAMs to hold their flow rate set point.	ORD and Region 2 staff subsequently reviewed SKC pump performance. New lab audits were performed on select units indicating an issue with the new pumps. Direct conversation with SKC revealed a new manufacturing process for this model pump had been started which ultimately resulted in the poor performance we observed. Ultimately, all pumps were replaced by

				the end of the study, but repeated failures prior to establishment of the reason impacted data completeness.
Raw data review and normalization	ICC and ORD	ICC developed data collection logs indicating operational status of each unit for each time period. ORD summarily integrated established time points of data quality issues pinpointed by ICC into data exclusion schemes. Region 2 and ORD developed regression normalization algorithms following collocation testing.	Data exclusion was performed upon raw data where pump failure incidences were noted. Regression algorithms from collocated reference comparisons were used to establish normalized data set for all measures and time points.	Normalization algorithm revealed only minimal "correction" of NO_2 raw data was needed while multifold correction was needed to normalize raw $PM_{2.5}$ estimates.

2.5 Collocation and Sensor Calibration to Federal Stations

An initial performance audit/calibration of the CSAM sensors was performed following their development (e.g., flow rate, linear response, zero air response). A summary inspection/re-audit was performed by Region 2 (Edison, NJ) staff upon transfer of the CSAMs to their possession. The four CSAM units were collocated by EPA Region 2 with monitors at the National Core (NCore) site maintained by the New Jersey Department of Environmental Protection (NJDEP). This site is part of the ambient air monitoring network in fulfillment of the National Ambient Air Quality Standards (NAAQS) established by the U.S. EPA, and therefore must meet federal requirements for performance. Air monitoring network sites are designed to measure maximum pollutant concentrations, assess population exposure, determine the impact of major pollution sources, measure background levels, determine the extent of regional pollutant transport, and measure secondary impacts in rural areas.

The NCore station at the Newark Firehouse (Figure 2-3) includes monitors for both NO_2 and $PM_{2.5}$, and thus provided an opportunity to compare and calibrate the CSAMs with federally validated and approved technologies. CSAM units ran continuously for approximately one week (04/07/2015 – 04/14/2015). NCore monitors took continuous measurements of NO_2 using a TECO 42i sampler, and continuous $PM_{2.5}$ using an R&P 1400 TEOM (Tapered Element Oscillating Microbalance)-FDMS (Filter Dynamics Measurement System).

Continuous measurements from the CSAM and NCore monitors were compared over time, as displayed in Figures 2-4 through 2-7. Example output of timestamp comparison between individual CSAM units and NCore measurements was conducted. Contemporaneous measurements were plotted against each other to determine the degree of variance from a 1:1 agreement (i.e., perfect agreement is represented by a slope of 1 in the resulting regression equations). While the CSAM units showed consistent relative agreement with the NCore monitors, following trends, peaks, and troughs (especially NO_2 measurements following calibration), there was disagreement between absolute measures. Therefore, the regression equations were applied to all CSAM measurements in order to correct for these discrepancies (more variability in agreement between CSAM and NCore monitors were observed for $PM_{2.5}$ measurements). Each CSAM unit differed in its respective variance from the reference measurement, so a specific regression equation was determined for each unit. These regression equations are shown in Table 2-6, and unless otherwise noted, all measurement results include these corrections. Several large deviations occurred during data collection due to pump failures in the CSAM units. These measurements were disregarded from the regression analysis.

Figure 2-3. Four CSAM samplers were deployed on the roof of NJDEP's NCore station at the Clinton Avenue Firehouse in Newark, NJ.

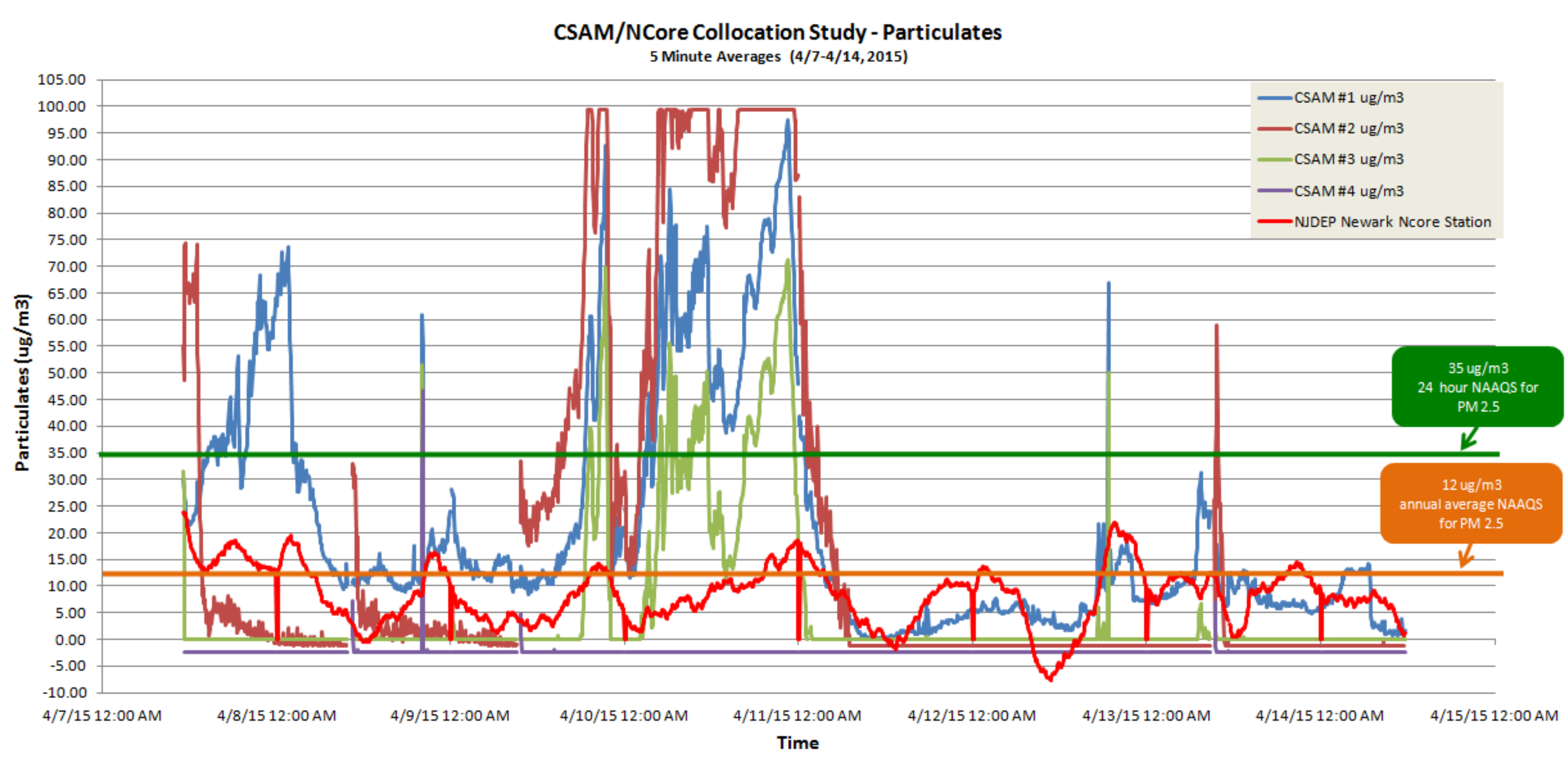


Figure 2-4. CSAM/NCore Collocation Study Particulates.

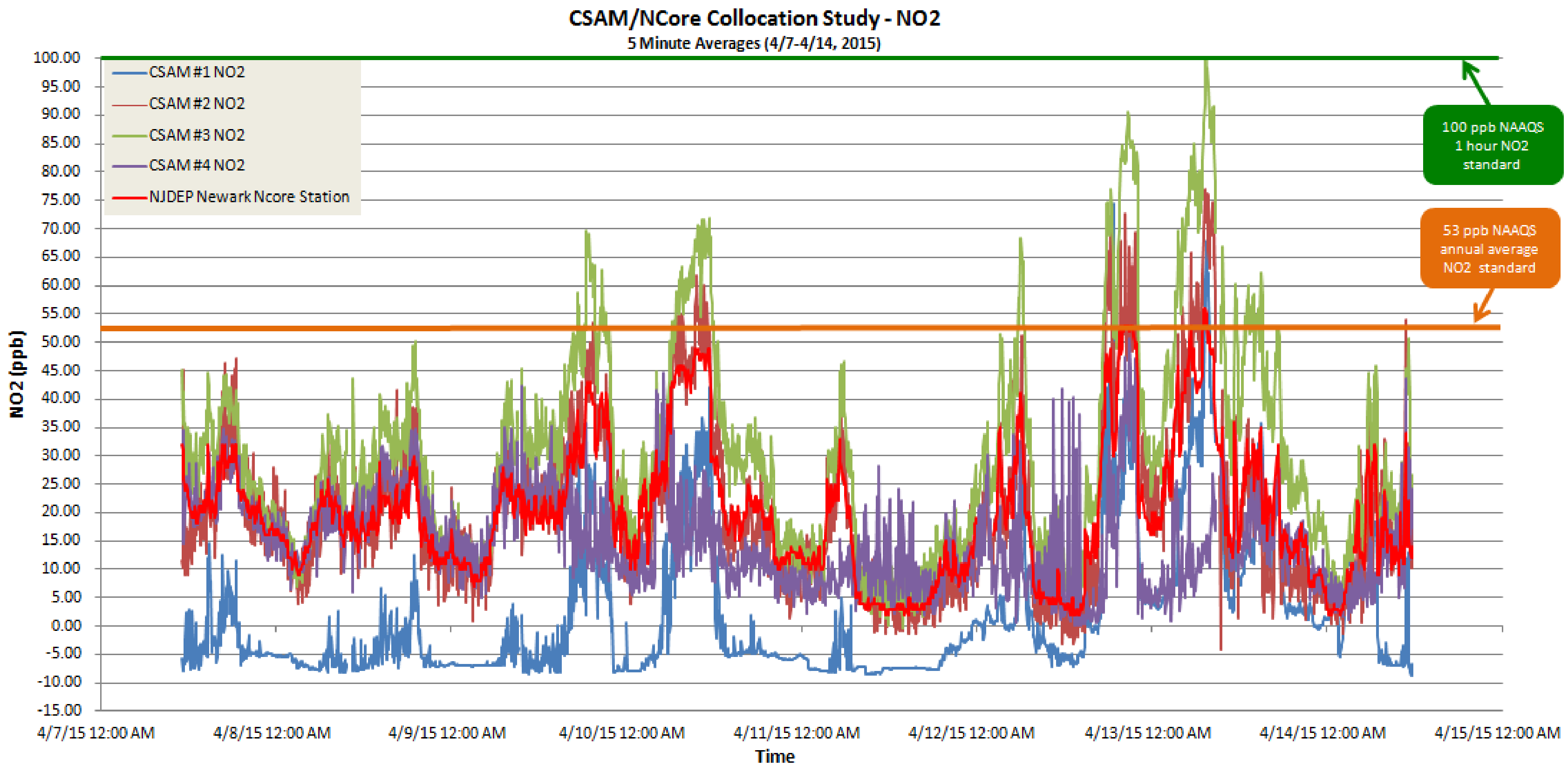


Figure 2-5. CSAM/NCore Collocation Study NO_2.

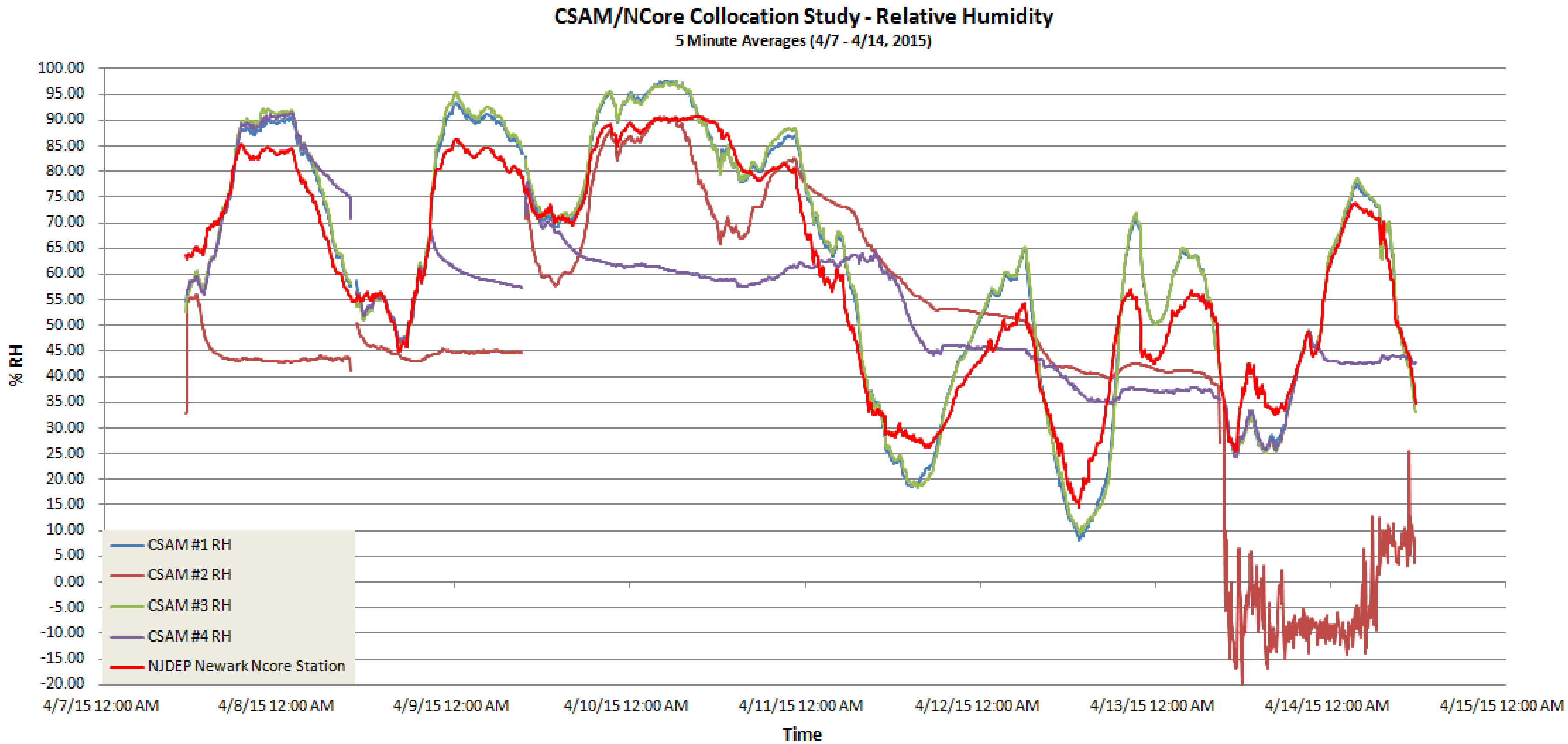


Figure 2-6. CSAM/NCore Collocation Study Relative Humidity.

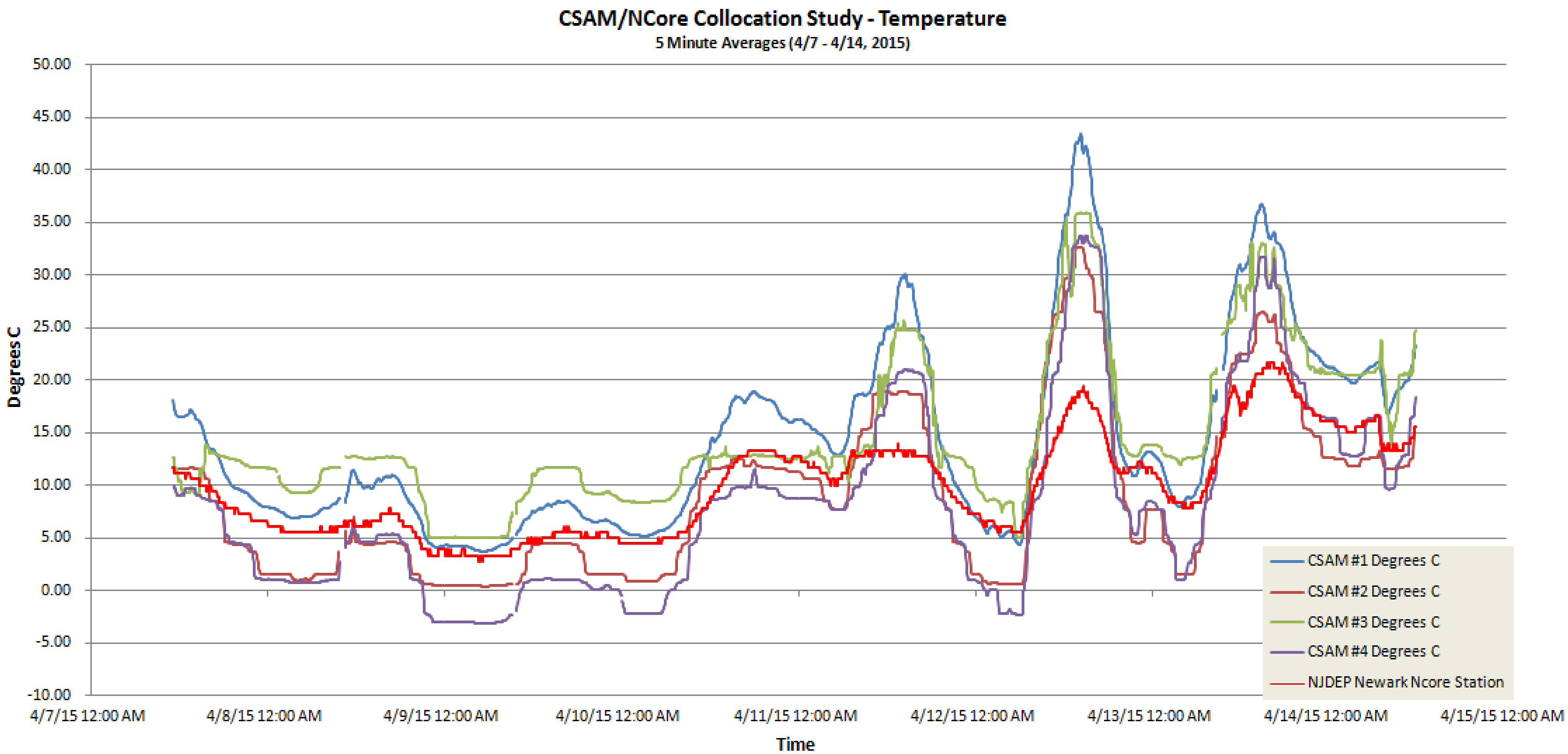


Figure 2-7. CSAM/NCore Collocation Study Temperature.

Regressions were based on the continuous, collocated measurements of the CSAM and NCore monitors. Since pump failures affected the CSAM readings, results were separated by day in order to identify time periods when both CSAM and NCore devices showed generally good agreement in their temporal trends (i.e., to exclude erroneous data to the best of our abilities). An example regression for 04/12/2015 is provided in Figure 2-8. The most ideal regressions equations were identified for each CSAM, and the selected regression equations are shown in Table 2-6. These equations were applied to all CSAM measurements in order to correct for sensor deviations from the NCore units. This resulted in a normalization of data response from the individual CSAMs in relation to collocated NCore monitors. Due to pump failure during collocation trials, we were unable to develop an individual calibration for Unit 4. In its place, an average regression based upon performance of Units 1 and 3 was applied for that particular unit.

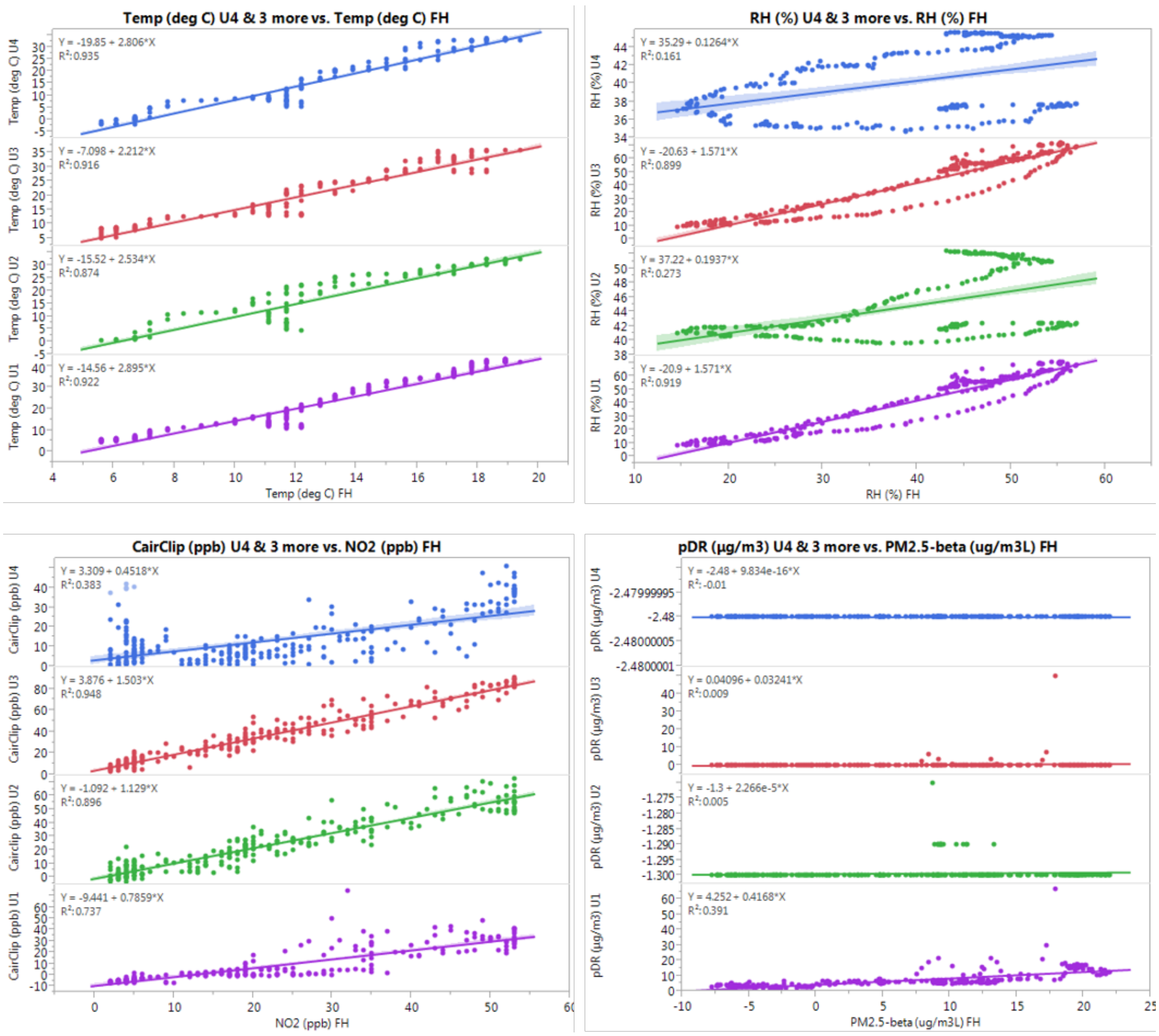


Figure 2-8. Example regressions from one day (04/12/2015) of the collocation.

Table 2-6. Regression equations selected for each sensor in each unit to normalize CSAM measurements to NCore monitor results.

		T	RH	NO_2	$PM_{2.5}$
U1	Date/Time	4/13/2015	4/8/2015	4/10/2015	4/11/2015; 12:15AM-5:05AM
	R^2 Value	0.943	0.982	0.776	0.814
	Regression Equation	-6.697 + 1.888*X	-9.178 + 1.182*X	-20.76 + 0.9267*X	-20.69 + 3.112*X
U2	Date/Time	4/13/2015	4/9/2015; 9AM-11:55PM	4/10/2015	4/11/2015; 12:15AM-5:05AM
	R^2 Value	0.932	0.877	0.901	0.760
	Regression Equation	-10.37 + 1.654*X	-43.89 + 1.467*X	-5.144 + 1.181*X	-32.52 + 4.894*X
U3	Date/Time	4/12/2015	4/8/2015	4/12/2015	4/11/2015; 12:15AM-1:50AM
	R^2 Value	0.916	0.982	0.948	0.614
	Regression Equation	-7.098 + 2.212*X	-12.75 + 1.244*X	3.876 + 1.503*X	-73.04 + 4.882*X
U4	Date/Time	4/13/2015	4/7/2015	4/8/2015	N/A
	R^2 Value	0.951	0.977	0.618	N/A
	Regression Equation	-12.25 + 1.865*X	-48.7 + 1.642*X	1.178 + 1.033*X	- 46.87 + 3.997*X (**)

(**) Representative average normalization response based upon collocation trials of Units 1 and 3

2.6 Deployment Plan

Site considerations for the four CSAM sensors included taking into account accessibility for the community liaison or the community action group representative, consideration for potential theft or vandalism, and meteorology. ICC had the full responsibility for site selection and deployment to meet the agreed upon study design. Other considerations included proximity to indoor (or other) sources that might influence the resulting outdoor air measurements. Examples included efforts not to place monitors in close proximity to kitchen exhausts or building heating system exhausts. Likewise, the study participants were trained to understand that tobacco smoke and other combustion sources could have an impact on sensor readings. Therefore, since the goal of the study was to understand outdoor concentrations of targeted pollutants, community members sought out locations where such interferences would be excluded or minimized.

ICC worked with its community members to deploy all four CSAM units simultaneously throughout the study. Deployment typically coincided with weekdays when residents were available to receive the instrumentation, with the intention of a two-week sampling time, which was achieved in most cases. Deployment was conducted from February 12, 2015 to July 30, 2015. ORD was involved in an onsite support contractor change during the study, which affected the ability of ICC to maintain a constant deployment scheme as the community liaison position was partially funded via that mechanism. That contractor change resulted in approximately a six-week hiatus (from May 11, 2015 to June 25, 2015) in sampling, during which time no measurements were recorded. Figure 2-9 shows the approximate locations of 15 of the 21 locations. Others were not included because data were not captured due to pump failures.

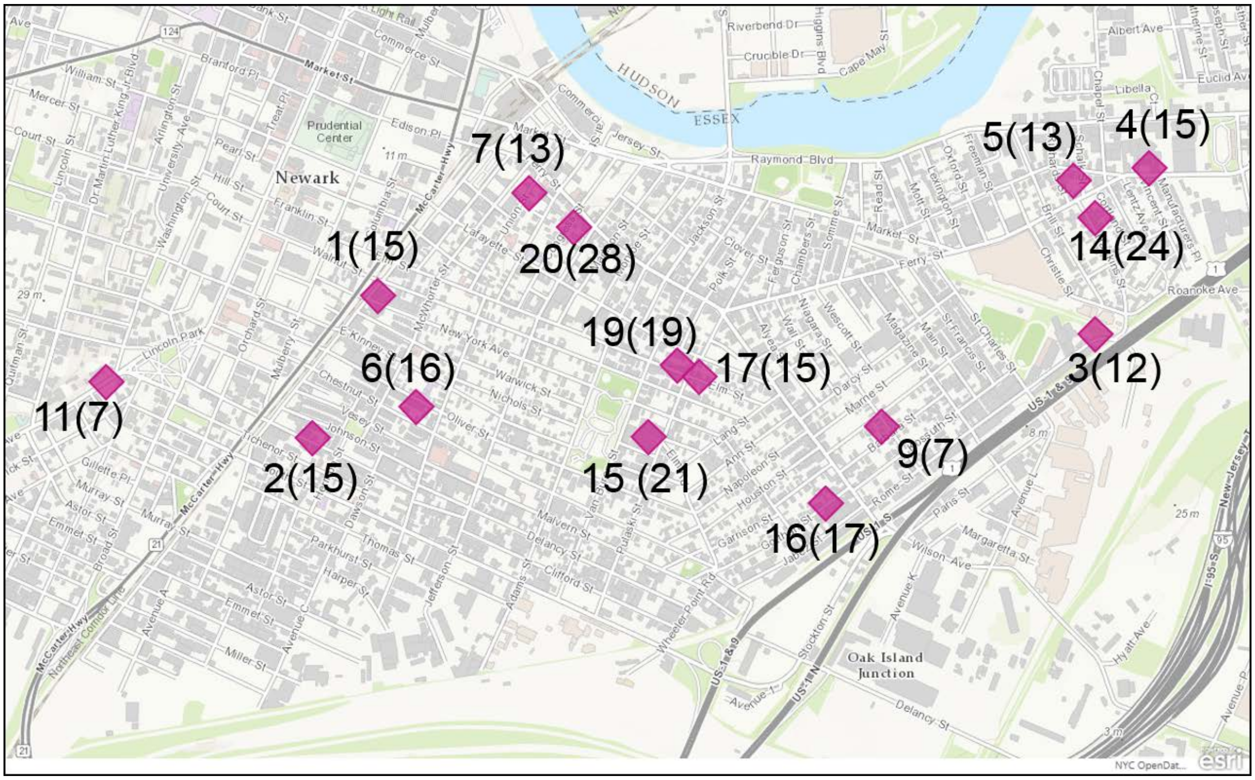


Figure 2-9. Deployment Plan – Location # (Sampling Days).
*Addresses have been offset to nearby streets to protect personal information.

2.7 Community Liaison Duties

The community liaison was responsible for developing a deployment and maintenance schedule, understanding the technology (software and hardware), and storing and sharing data. CSAM maintenance duties included swapping or charging and replacing batteries on a specific schedule, data download via SD card, and transferring CSAM units to different monitoring sites. It was anticipated that 20-30 minutes per week would be necessary to collect data and change the battery for each unit. In terms of accessibility, physical or social requirements included the ability to access residents’ homes, access rooftops, and/or climb ladders.

3.0 Results and Discussion

3.1 General Findings

Overall, the CSAM units were stable in all weather conditions (wind, rain, show, changes in temperature), with the exception of one incident where rain entered the monitor. This could have occurred due to extreme wind causing rain droplets to enter at an unexpected angle. The sensors were highly sensitive to measuring pollutant concentrations, with only minimal time periods (<24 hours) where pollutant concentrations were not detected. Data storage and data recovery hardware and software were robust. The simple turnkey design of the CSAM enabled a single day of training to be sufficient for proper use in the field by ICC staff and volunteers. They operated the sensors without any reported safety issues throughout the entire study. Sensors were physically located either indoors or outdoors, and with either battery or land power. Sensors located indoors due to accessibility needs were operated with a low volume snorkeling system designed specifically for the CSAMs so that outdoor air was actually the air stream being monitored. Typically, this represented the snorkeling tube being inserted through window passages. In the case of battery power, the battery life was more than sufficient for one week of operation. Recharging the batteries was simple, as was the switch from land power to battery power and vice versa.

There were some technical issues that arose throughout the study, which is not unusual for field studies. Minor CSAM damage occurred during transport from the manufacturing location in Research Triangle Park, North Carolina to EPA's Edison office in New Jersey, which needed to be repaired before deployment. Some users reported that the monitoring stands and battery power supplies were heavy and therefore difficult to transport to certain siting locations. Repeated pump failures (flow rate stability) developed after the units cleared initial EPA testing. Brand new air pumps were used to replace the old pumps, but there was a change in the manufacturing process that was unknown by the manufacturer that resulted in part failure and subsequent data loss. On one occasion there was a battery unit that failed to recharge. Overall, the CSAM units performed very well, with the exception of these issues.

Table 3-1 presents a summary of findings for each location and CSAM unit, including sampling times, data flags, and summary statistics for NO_2, $PM_{2.5}$, T, and RH. Data were flagged green, yellow, or red; green indicates that no problems were found with the data collection, and red indicates a lack of data due primarily to hardware issues. Yellow-flags indicate that data collection may not have been as robust as expected; for example, several yellow-flagged periods recorded a low temperature differential throughout the time period, and/or a high overall temperature as compared to outdoor conditions. These were typically during times when the units were placed indoors with the snorkel tube extending outdoors, and so may indicate some indoor sampling may have accidentally occurred or mixed with the outdoor readings. To date, the true reason for the yellow flags is inconclusive, but warrants examination before implementing similar studies that use this technique.

Table 3-1. Summary of sampling locations and CSAM units, including sampling times, data flags, and summary statistics for NO_2, $PM_{2.5}$, T, and RH.

				PM (µg/m³)			NO2 (ppb)			T (°C)	RH (%)
Location & Sensor Unit	Time Period (N)	Use of Snorkel (Y/N)	Green/Yellow/Red Flag (Reason)	Mean (Std Dev)	Median	Upper 95% Mean	Mean (Std Dev)	Median	Upper 95% Mean	Mean (Std Dev)	Mean (Std Dev)
L1 U1	2/12-2/24 (3568)	N	G (OK; 2/16?)	12.2 (5.7)	10.5	12.4	33.2 (24.7)	21.7	34.0	0.0 (4.0)	51.1 (15.0)
L1 U1	2/25-2/27 (874)	N	G (OK)	11.6 (2.2)	11.4	11.7	47.2 (24.5)	41.8	48.9	1.8 (2.5)	49.9 (8.1)
L2 U2	2/12-2/24 (3564)	Y	Y (High T; Low ΔT)	13.2 (4.2)	11.9	13.4	10.2 (9.8)	5.3	10.5	20.5 (1.0)	26 (7.6)
L2 U2	2/25-2/27 (881)	Y	Y (High T; Low ΔT)	13.0 (3.1)	12.2	13.2	13.4 (9.7)	10.1	14.0	21.0 (0.9)	34.2 (1.9)
L3 U3	2/12-2/24 (3590)	N	G (OK)	19.4 (4.0)	17.8	19.5	18.3 (15.4)	14.1	18.8	-1.3 (5.3)	48.1 (18.9)
L4 U4	2/12-2/24 (3465)	Y	Y (High T; Low ΔT) R (PM N/A)	N/A	--	--	17.8 (15.0)	14.0	18.3	16.0 (2.6)	37.7 (4.4)
L4 U4	2/25-2/27 (829)	Y	Y (High T; Low ΔT) R (PM N/A)	N/A	--	--	22.2 (10.9)	22.6	22.9	16.6 (1.0)	38.6 (0.9)
L5 U1	3/3-3/16 (4040)	Y	Y (High T; Low ΔT)	12.1 (4.4)	11	12.3	13.8 (0.8)	13.5	13.8	17.6 (0.8)	25.0 (8.1)
L6 U2	2/28-3/16 (4654)	Y	Y (High T; Low ΔT)	13.9 (6.2)	13.1	14.1	4.6 (2.4)	5.0	4.7	15.6 (1.9)	37.8 (8.5)
L7 U3	3/3-3/16 (4004)	N	G (OK)	20.1 (5.8)	18.9	21.1	27.2 (18.9)	23.1	27.8	6.1 (4.2)	55.8 (20.8)
L8 U4	3/2-3/16	Y	R (Pump Failed)	N/A	--	--	N/A	--	--	N/A	N/A
L9 U1	3/18-3/25 (2287)	N	G (OK)	10.4 (4.8)	8.6	10.5	27.5 (4.8)	8.6	28.4	7.8 (3.7)	39.6 (17.7)
L10	3/17-4/6	Y	Data?								
L11 U3	3/18-3/25 (1709)	Y	G (OK)	16.6 (2.2)	15.9	16.7	8.7 (11.4)	3.8	9.2	9.4 (1.6)	25.4 (6.2)
L12 U4	3/18-4/6	Y	Data?								
L13 U1-4	4/7-4/15 (≈2000)	N	G Collocation Reported Separately								
L14 U1	4/21-5/12 (6048)	Y	G (OK)	10.8 (5.1)	8.9	10.9	38.2 (31.7)	24.2	39.0	19.5 (3.2)	34.7 (10.0)
L15 U2	4/21-5/11 (5680)	Y	Y (High T; Low ΔT) R (PM N/A)	N/A	--	--	15.1 (18.7)	6.2	15.6	19.8 (0.4)	42.3 (9.7)
L16 U3	4/24-5/11 (4915)	Y	G (OK)	16.6 (4.1)	15.0	16.7	22.0 (18.3)	18.6	22.5	13.2 (2.8)	46.9 (14.5)
L17 U1	6/25-7/10 (2279)	Y	Y (6/29-7/1; 7/5-7/10)	10.9 (3.3)	10.3	11.1	27.0 (15.4)	23.4	27.7	19.9 (3.0)	53.9 (14.4)
L18 U2	[6/25-7/14]	N	R (Card taken; battery unplugged)	N/A	--	--	N/A	--	--	N/A	N/A
L19 U3	6/25-7/14 (5439)	Y	G (OK)	16.2 (2.6)	15.0	16.3	4.0 (8.6)	1.6	4.3	18.3 (1.7)	51.2 (7.8)
L20 U4	6/16-7/14 (5328)	Y	Y (6/16-6/26) R (PM N/A)	N/A	--	--	5.2 (6.7)	3.1	5.3	22.4 (3.3)	63.8 (9.3)
L21 U3	7/30 (31)	N	G (OK)	16.6 (0.6)	16.5	16.8	1.0 (4.1)	-0.5	2.5	19.5 (0.6)	62.4 (3.5)

3.2 $PM_{2.5}$ Results

$PM_{2.5}$ demonstrated a moderate degree of variability between locations, with the lowest mean of 10.4 μg/m^3 at location 9, and the greatest mean of 20.1 μg/m^3 at location 7 (note: these were not contemporaneous measurements). The 90th percentile values ranged from a low of 14.8 μg/m^3 at location 9 as well, and the greatest value of 31.8 μg/m^3 also at location 7. The overall average $PM_{2.5}$ from all locations and time periods was 14.5 μg/m^3, and overall the 90th percentile value was 20.3 μg/m^3. A geospatial map of $PM_{2.5}$ is presented in Figure 3-1. The figure reports a combination of 12 select locations previously described in Table 3-1 having either "green" or "yellow" flagged data completeness records. Temporal graphs for Locations 7 and 9 are presented in Figure 3-2.

The overall trend of $PM_{2.5}$ across locations and time primarily seems to reflect general ambient conditions, as sites did not deviate significantly between each other. However, certain sites did indicate a potential effect from localized sources. The five locations with the greatest average $PM_{2.5}$ values (from high to low) were locations 7, 3, 11, 16, and 19, ranging from 20.1-16.2 μg/m^3 (with 90th percentile values being greater still). The remainder of the sites ranged from 14.7-10.4 μg/m^3, demonstrating enough of a difference between the two groups to warrant further investigation into local contributions to $PM_{2.5}$.

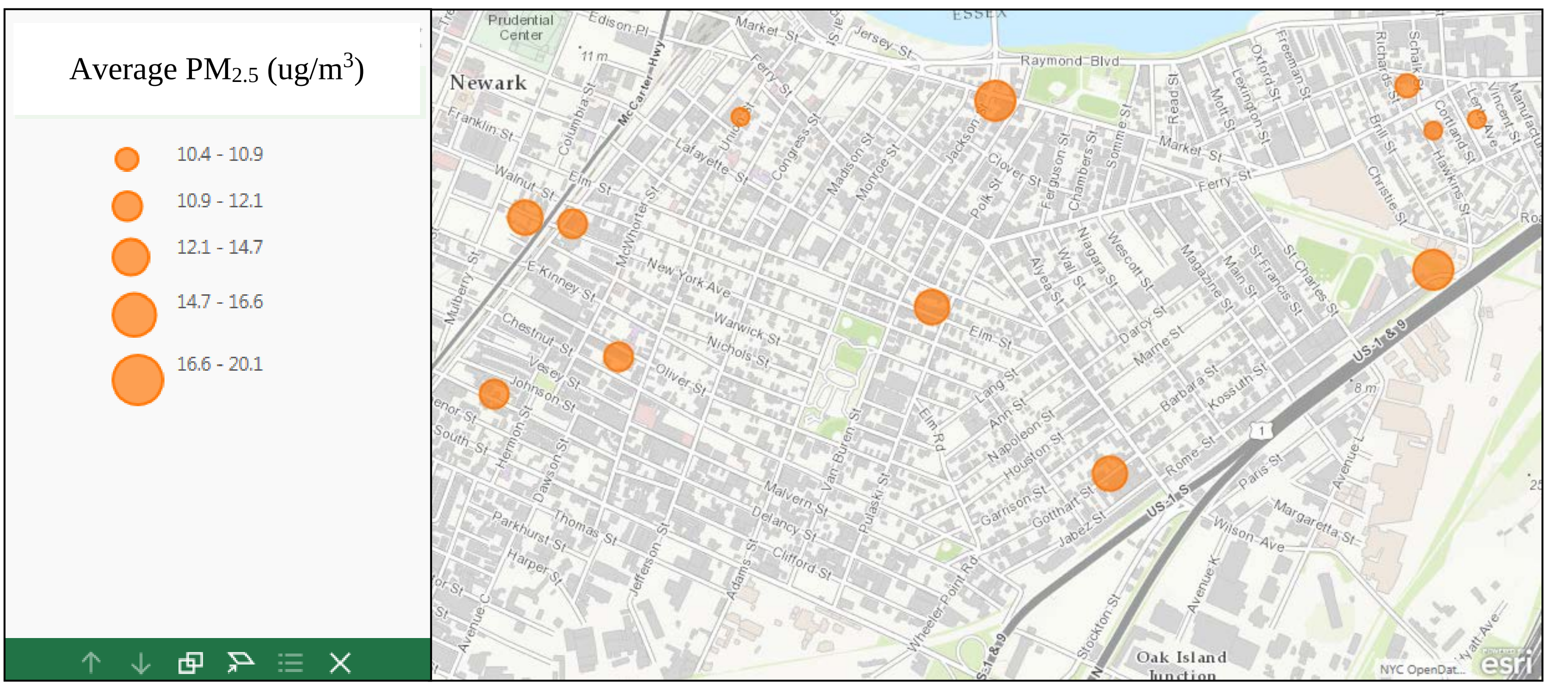


Figure 3-1. Average $PM_{2.5}$.

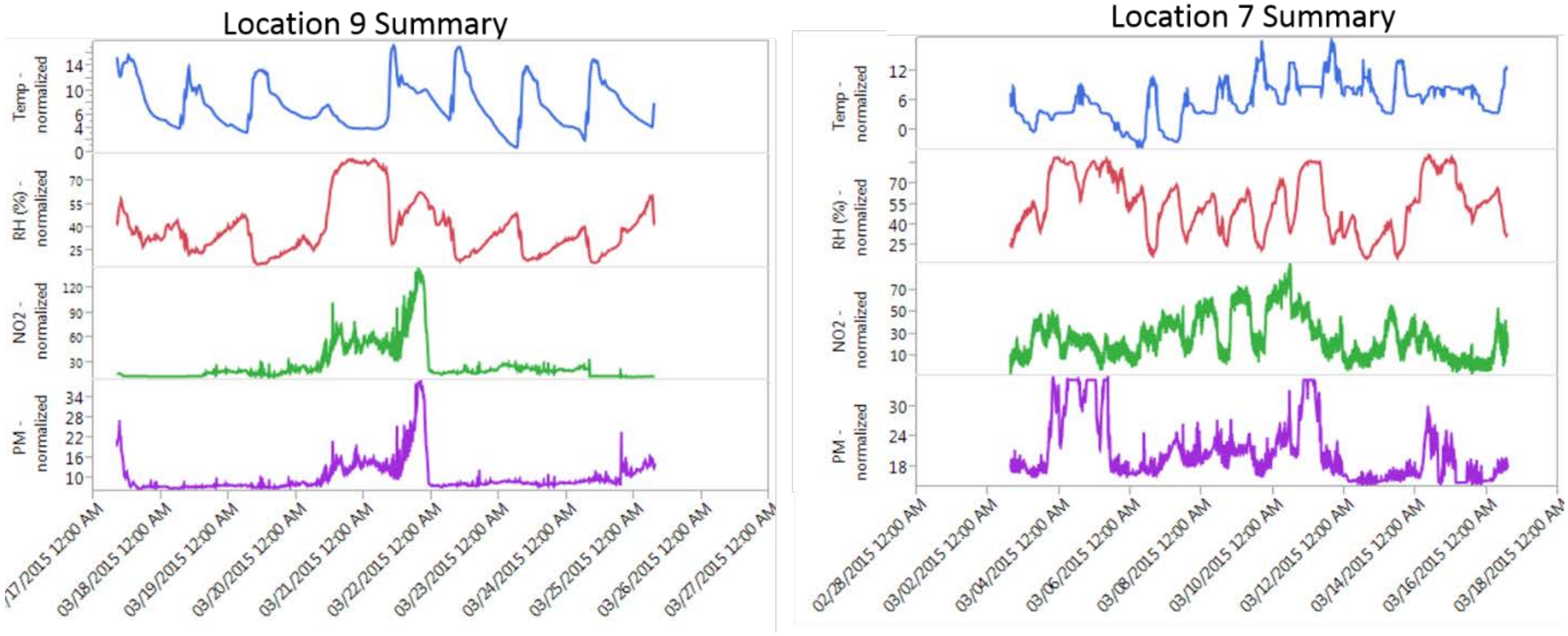


Figure 3-2. Temporal measurements for Location 9 and 7, representing the least and greatest average $PM_{2.5}$ measurements, respectively.

3.3 NO_2 Results

As expected, NO_2 showed greater variability between locations than $PM_{2.5}$. Locations near major transportation corridors seemed to record the highest values, although a detailed analysis of source contributions was not performed. For example, location 9, though recording the lowest average $PM_{2.5}$, actually was one of the top 5 sites for NO_2, likely due to its proximity to McCarter Highway. Average NO_2 ranged from a low of 4 ppb at location 19, to a high of 41.4 ppb at location 1. The 90th percentile value ranged from a low of 13.4 ppb at location 20, and a high of 87.4 ppb at location 14. The overall average NO_2 from all locations and time periods was 18.9 ppb, and overall 90th percentile value was 40.4 ppb.

As noted, there was a marked difference in NO_2 measurements between different sites. Sites with relatively higher values retained those patterns throughout their sampling times (i.e., their greater averages were not driven by singular excursions or outliers). The top five 90th percentile values were 87.4, 80.8, 56.2, 56.2, and 49.7 ppb recorded at locations 14, 1, 9, 7, and 16, respectively. In contrast, the lowest five 90th percentile values were 8.1, 13.4, 15, 16.2, and 26.8 ppb at locations 6, 20, 5, 19, and 2, respectively. However, some of these lower sites were flagged as yellow and should be considered with caution. Nonetheless, the discrepancy between the higher and lower groups indicates a strong potential connection to localized conditions, especially with respect to major roadways. Even so, a full understanding of all local source impacts, including roadways, has not been defined as a result of this pilot study. Temporal trends for locations 19 (lowest average) and 1 (highest average) are presented in Figure 3-4.

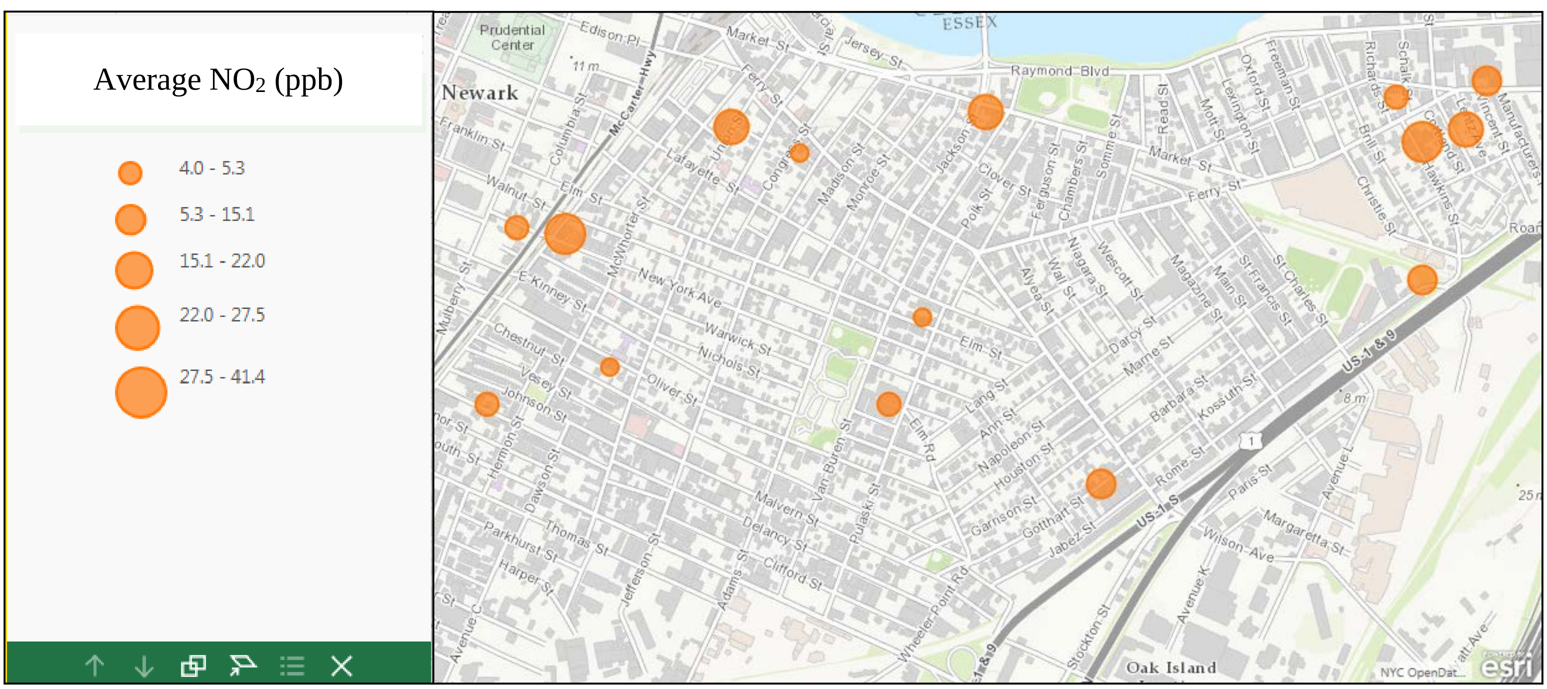


Figure 3-3. Average NO_2.

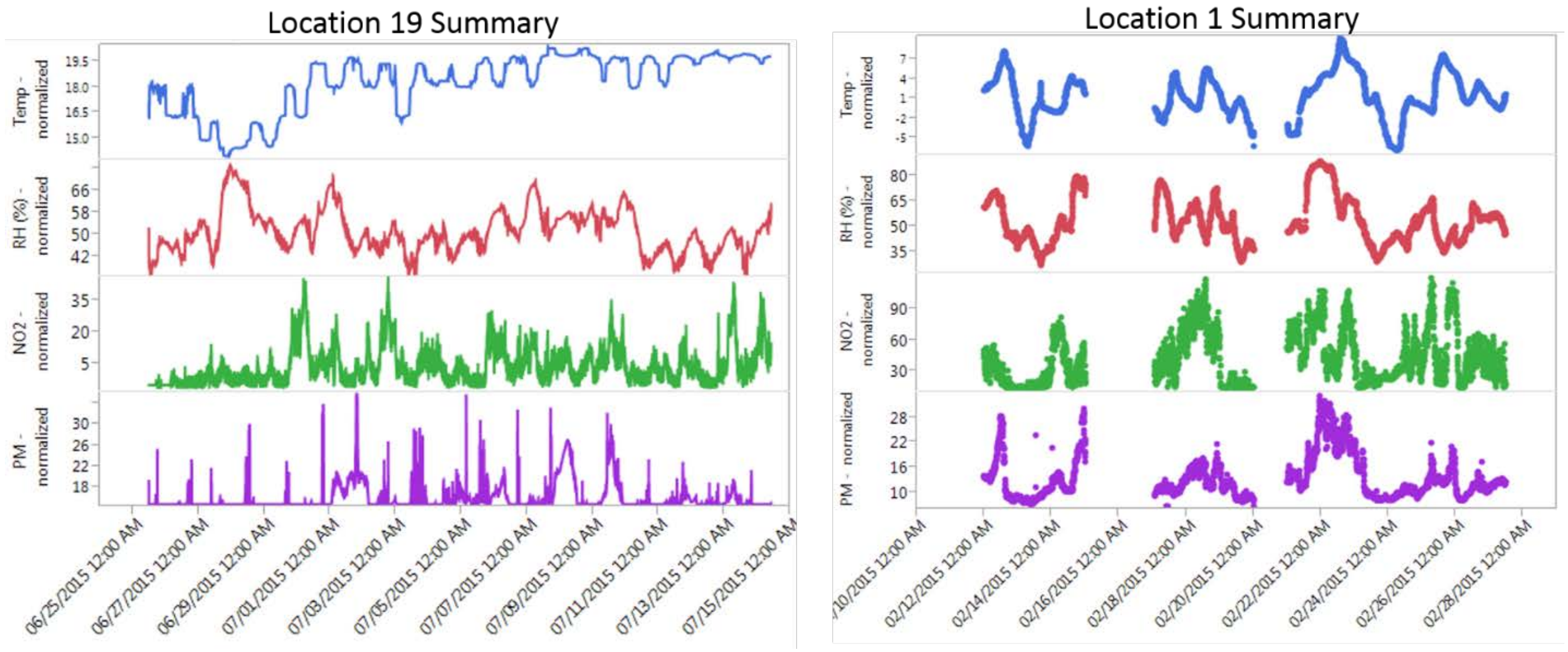


Figure 3-4. Temporal measurements for Location 19 and 1, representing the least and greatest average NO_2 measurements, respectively.

3.4 General Discussion

The CSAM units proved to be a reliable method of collecting air quality information. The two technical challenges included the previously unknown manufacturing defect in the pumps and data quality possibly related to the snorkel tubes (the potential for which was discussed prior to deployment). Despite these issues, participants were able to collect a wealth of temporally- and geospatially-resolved data to assess local air quality conditions. Whereas technical issues were often quickly identified and resolved, interpretation and communication of results proved to be a more challenging aspect throughout the project to its conclusion. This section describes the process and eventual approach taken to characterize the data and deliver an appropriate scientific message that also resonated with the various viewpoints of the different stakeholders: ICC, the EPA Region, and EPA ORD.

CSAM results generally demonstrated that $PM_{2.5}$ concentrations were more indicative of ambient air quality, and NO_2 concentrations were potentially affected by nearby sources (e.g., roadways). However, since no source apportionment analyses were performed, these interpretations were based primarily on geospatial trends and patterns. Future work may include a temporal analysis of NO_2 (i.e., rush hour versus off-peak traffic conditions) and/or coupling measurements with a near-road air quality model and source apportionment model in order to delineate traffic effects, but this was not performed in this project.

Aside from the general geospatial interpretations, one of the primary questions was about how the data relates to personal exposures and potential impacts. Since the measurements were non-regulatory (i.e., they were not Federal Reference Method or Federal Equivalent Method measurements), their interpretation related to impacts was not clear. Also, even though the CSAM units had a stationary aspect to them (i.e., left in place for up to two weeks), it was important to note and convey that they are not equivalent to or representative of stationary regulatory monitors. Therefore, their measurements cannot be interpreted in the same way. Interpretation of results relied primarily on comparisons between the locations, rather than on determining what the actual concentration values meant with respect to potential impacts.

It was generally agreed that results related more to 24-hour standards than annual averages, but even this was not a direct comparison. We could not compare the CSAM results to the NAAQS 24-hour standards because the methodological and technical discrepancies were too great. In order to put some context on the actual measured values, we compared them to 24-hour averages based on one year of data for other cities. This was simply to provide some scale to the results as to whether they were relatively high, low, or average. Results were not on the highest end of the scale, but nor were they the lowest, and examination of 90^{th} percentiles and upper-bound values indicated that the air quality resided with some of the more polluted cities that were compared. Given that the Ironbound measurements were taken primarily in winter or cold months, the potential for higher summertime values could increase these estimates as well as provide a more complete annual picture of air quality conditions.

Geospatial examination (especially of NO_2) did tend to highlight near-road areas as potential for concern. These findings would support more careful examination of exposure and associated risk, as well as help identify areas to target exposure reduction actions. $PM_{2.5}$

concentrations did not indicate that ambient air quality was exceedingly high, although it was not so low as to warrant no further consideration. One of the early goals was to use the data to isolate specific areas to target near-source effects. In this respect, data collected here could be used to target sensor placement in order to determine near-source contributions and their effect on localized background concentrations (i.e., hotspot identification). To date, this has not yet been performed.

Based on these considerations, communicating results relied more on aspects of geospatial distribution and general trends, rather than on the potential impacts resulting from measured concentrations. Results are informative to identify areas for further study or education and outreach, or to target future citizen science measurement campaigns. Targeted exposure and risk assessment lie outside the scope of what the CSAM can provide. This project successfully engaged citizens in data collection of air quality measurements, identified geospatial trends in $PM_{2.5}$ and NO_2, and put the community air quality into context with that of other cities. In particular, air quality monitoring instrumentation and study design considerations previously unknown to the community was provided. In turn, the community partner exhibited zeal in using the new technology, a devotion to conducting research within the quality assurance guidelines, and a desire to communicate knowledge learned to its stakeholders. Participants were able to use this information to formulate ideas for future studies, such as saturation monitoring with passive sensors (for source attribution), air quality in the context of other issues (e.g., water quality and contaminated land), examination of health incidence clusters, and an overall cumulative environmental assessment to examine a combined range of issues.

4.0 Lessons Learned

An essential aspect of this project was to establish a trusting and collaborative relationship with the ICC community action group (CAG). This should be the first step in any citizen science research collaboration. Projects like these are also well served by early communication between all partners, especially the state, if any collocation of monitors is desired. Because the ICC was already a well-established CAG and had conducted prior air quality monitoring efforts, they were well suited to conduct a successful air monitoring project. The staff and volunteers had experience working together. EPA Region 2 had also previously worked with the ICC on a Community Action for a Renewed Environment (CARE) project, so there was already a base relationship established. Multiple phone and web conferences occurred before the initial visit to the Ironbound Community by ORD and Region 2 scientists. The first visit included a 'meet and greet', a shared meal, and a tour of the community, highlighting areas of concern related to air pollution and potential sources. Following this visit, the three parties worked together to develop a study design. Roles and responsibilities were established for each individual involved in the project, but for future projects it is recommended that this occur earlier in the process. This is an important step in order to manage expectations and ensure there is no confusion regarding roles and responsibilities. This information was also a necessary component of the QAPP. Region 2 assisted the ICC in completing the QAPP. Many of the sections were easy to complete because Region 2 already had a citizen science QAPP template available for modification to the specific project[34]. The initial plan for data analysis was for the ICC to analyze and summarize the data collected. As the project proceeded, it became clear that the ICC would benefit from EPA assistance in this area. ORD scientists ultimately analyzed and summarized all of the data in a coordinated effort with all of the research partners. The data summary and interpretation was shared in multiple meetings via PowerPoint presentations containing graphs and figures showing each unit, location, dates monitored, and results. This data was ultimately shared with the general public in a community meeting on November 13, 2015, where ORD and Region 2 scientists communicated the project goals, design, and results to attendees.

This project proved to have many successes and opportunities for growth/learning lessons. Emerging technologies were developed to meet citizen science needs and made to operate in a user-friendly mode. The turnkey on/off design of the CSAM provided a simple interface for citizens. Though well-designed and engineered, the technology was not foolproof. There were some technical difficulties at times, but they were mostly due to circumstances outside of EPA's control associated with a component failure. EPA found that it is important for all parties to understand the benefits and limitations of the data before and throughout the research project, and how it can and cannot be used. Data review was extensive and required EPA involvement. Furthermore, determining what the data mean represented a key question. ORD scientists had to assist the ICC in data analysis and interpretation. Overall, citizen scientists in this pilot project operated sophisticated equipment and successfully engaged in extended air quality monitoring campaigns. They also followed an approved study design and QAPP. The ICC represents a well-

[34] http://www3.epa.gov/region02/citizenscience/pdf/citsci_air_attach_b_form.pdf

informed, highly engaged community action group, and this collaboration helped to understand our respective roles (ICC/Region/ORD) in citizen science.

4.1 Value of Citizen Science Data

Citizen science has contributed to science for hundreds of years. With the introduction of low-cost technologies, citizens now have the potential to learn more about their local and personal environments. Data collected by citizens can identify and isolate high-concentration pollution areas. It can also paint a picture and give an overall representation of air quality in a specific community. Taking measurements over time can help citizens find areas that fluctuate between high and low concentrations due to local sources.

While citizen-collected data have many potential uses, there are some limitations. It cannot pinpoint specific sources of emissions, but it can find areas affected by local sources, such as major roadways. It cannot determine health impacts of pollution, but it can isolate most-affected areas in order to target health improvement strategies. The value of these contributions should not be overlooked.

It is important to acknowledge that while informative, citizen science sensors are not directly comparable to regulatory sensors. The technologies are different, and regulatory monitors are left in place for long periods of time with frequent checks. In addition, regulatory standards (for enforcement) are calculated in a specific way.

EPA plays an important role in citizen science. EPA scientists can help citizens understand how citizen-collected data can be used, what information it provides, and how results can drive decision making, especially at the local level. In addition, EPA can participate, educate, facilitate partnerships, technically assist, analyze and interpret results, and recommend actions – but, by law, citizen science measurements cannot be used to mandate regulatory actions.

4.2 Ironbound Citizen Science Accomplishments

The Ironbound community and ICC staff and volunteers played a large role in the success of this project. They independently established a team of citizen scientists to conduct the air quality monitoring. They successfully received and conducted training on a sophisticated monitoring system, the CSAM. They engaged the community and established monitoring location agreements that met the study design requirements. They also independently operated the monitors to meet quality assurance guidelines and obtained sufficient data collection when the sensors were operating at their potential. All of these accomplishments led to the ultimate success of the project.

Appendix A: Quality Assurance Project Plan

Ironbound Citizen Science Air Monitoring Collaboration
US EPA ORD, US EPA Region 2, and Ironbound Community Corporation
Regional Applied Research Effort (RARE)
Project: Quality Assurance Project Plan
February 4, 2015

Ironbound Citizen Science Air Monitoring Collaboration

US EPA Regional Applied Research Effort
US EPA Office of Research and Development (ORD), US EPA Region 2, Alion Science and Technology, Ironbound Community Corporation (ICC)

Effective Date of Plan: February 4, 2015

Prepared by: ______________________________
Molly Greenberg, MSW
Ironbound Community Corporation, Community Program Manager

Approved by: ______________________________
Patricia Sheridan, EPA Region 2 NJ, Citizen Science Liaison & QA Officer

Approved by: ______________________________
Avraham Teitz, EPA Region 2 NJ, Community Technical Support

Approved by: ______________________________
Ron Williams, EPA ORD Technical Advisor

Approved by: ______________________________
Tim Barzyk, EPA ORD Principal Investigator

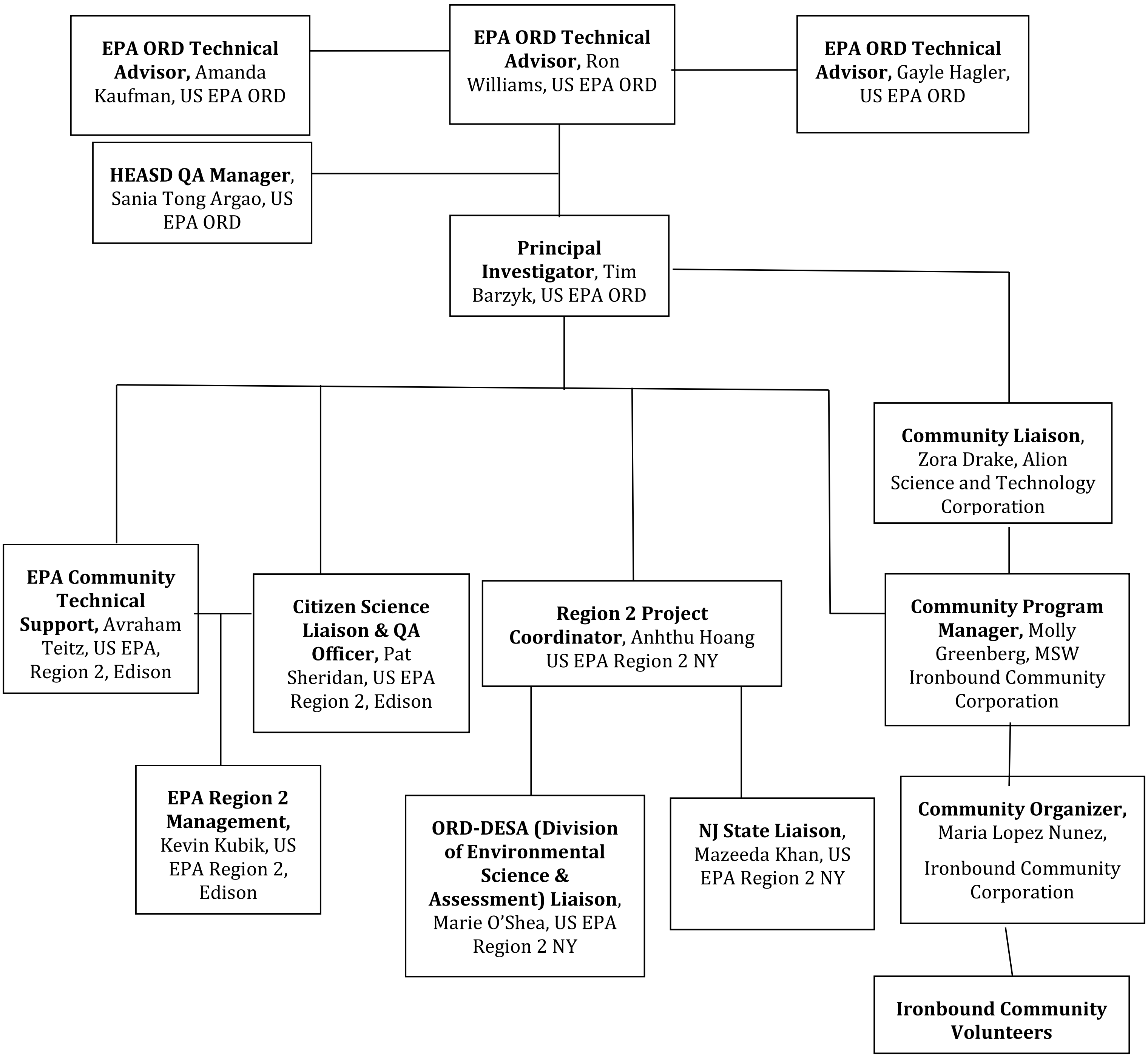
Approved by: ______________________________
Anhthu Hoang, EPA Region 2 NY Project Coordinator

Concurrence by: ______________________________
Sania W. Tong Argao, EPA ORD HEASD QA Manager

Project Organization Chart

Figure 1 shows the organization chart for this project. For more detailed information about the roles and responsibilities for this project, please see Table 1 below and Attachment A.

Figure 1. Project Organization Chart



Project/Task Organization

Table 1. Roles and responsibilities of key project personnel.

Name	Contact Information	Organizational Affiliation	Title	Responsibilities
Molly Greenberg, MSW	mgreenberg@ironboundcc.org	Ironbound Community Corporation	Community Project Manager	1. Coordinate with EPA partners on the development of Citizen Science protocols for community air monitoring. 2. Characterize near-road/near-source hotspots, determine potential impact on nearby residences (Inc. vertical gradients); and roadways at different gradients 3. Work with Community Volunteers to review and validate equipment/study SOPs and toolbox materials 4. Support the project by organizing and conducting outreach to facilitate community involvement in study-related needs such as design, data collection, analysis, and report back 5. Prepared the QAPP document
Maria Lopez Nunez	mlopeznunez@ironboundcc.org	Ironbound Community Corporation	Community Organizer	1. Coordinate the community volunteers, downloading of data, and the moving of the sensors
Community Volunteers		Ironbound Community		1. Support study needs including equipment handling and maintenance, data collection and management, provide community updates 2. Review and critique SOPs and Citizen Science toolbox documentations 3. Update study partners on progress and challenges related to monitoring
Anhthu Hoang	Hoang.Anhthu@epa.gov	EPA Region 2 ORA/OSP-EJ, NY	Region 2 Project Coordinator	1. Coordinate study activities 2. Ensure communication between project staff and partners regarding, among other things, project progress and needs, sharing documents, data reporting, and technical assistance.
Mazeeda Khan	Khan.Mazeeda@epa.gov	EPA Region 2 CASD, NY	NJ State Liaison	1. Ensures NJ DEP is aware of the Region 2/ICC RARE study and apprised of its progress
Marie O'Shea	OShea.Marie@epa.gov	EPA Region 2 DESA, NY	ORD-DESA Liaison	1. Provide support regarding issues related to RARE funding 2. Advise study staff and partners regarding DESA and ORD related issues

Table 1. Roles and responsibilities of key project personnel. (continued)

Name	Contact Information	Organizational Affiliation	Title	Responsibilities
Patricia Sheridan	Sheridan.Patricia@epa.gov	EPA Region 2 DESA, Edison	Citizen Science Liaison, QA Officer	Advise study partners on Citizen Science issues such as QAPP development and sensor best practices.
Avraham Teitz	Teitz.Avraham@epa.gov	EPA Region 2 DESA, Edison	EPA-Community Technical Support	1. Training ICC volunteers on the use of the sensors and the data download; 2. Participate in the collaborative site selection process; 3. Site tour and presentation; 4. Trouble-shoot future download/maintenance issues as they arise.
Kevin Kubik	Kubik.Kevin@epa.gov	EPA Region 2 DESA, Edison	EPA Region 2 Management	Provide R2 Leadership input as appropriate
Tim Barzyk (EMRB)	Barzyk.Timothy@epa.gov	EPA ORD	Principal Investigator	Develop citizen sensor *toolbox* – compile how-to documents/tools related to sensors, siting, and analysis; develop guidance for local scale applications (e.g., best practices).
Ron Williams (EMAB)	Williams.Ronald@epa.gov	EPA ORD	EPA ORD Lead Technical Investigator	Develop citizen sensor *toolbox* – provide guidance on developing how-to documents, examples of best practices, and sensor applications. Advise on sensor use and operation, measurement uncertainty/variability, and environmental considerations (e.g., cold, heat, precipitation).
Amanda Kaufman	Kaufman.Amanda@epa.gov	EPA ORD	EPA ORC Technical Advisor	Develop citizen sensor *toolbox* – review documents, tools, and resources for toolbox; review R2/ICC practices; advise on sensor operation and operational considerations.
Gayle Hagler	Hagler.Gayle@epa.gov	EPA ORD	EPA ORC Technical Advisor	Develop citizen sensor *toolbox* –provide expertise on sensor applications related to various pollutants and types of environmental assessments.
Sania Tong Argao	Tong-Argao.Sania@epa.gov	EPA ORD	Human Exposure & Atmospheric Sciences Division (HEASD) QA Manager	Review and provide concurrence on the project QAPP.
Zora Drake	drake.zora@epa.gov	Alion Science and Technology	Community Liaison	1. Attend training at EPA offices for: a. Equipment handling & maintenance b. Data collection & management 2. Provide technical support and supervision for Community Project Manager 3. Act as liaison between project technical team, ICC, and community volunteers

For more information, please see Attachment A for further information about the project, roles, and responsibilities.

Background and History

"The Ironbound" neighborhood is located in the East Ward of Newark in Essex County, New Jersey. It is roughly four square miles east of Newark's Pennsylvania Station, bounded by highways (Routes 1 & 9, 21, 78, NJ Turnpike), waterways (Passaic River, Newark Bay), Newark Airport and Port Newark/Elizabeth Marine Terminal. Located in and comprising most of the City's East Ward, the Ironbound gets its name from the rail tracks that once surrounded the area on three sides. The community has a population of more than 50,000 people and is one of the most densely populated and diverse areas of the city, with two-thirds of the population being foreign born. Seventy five percent of those over the age of five speak a foreign language at home, typically Portuguese or Spanish. Educational attainment levels are relatively low with 55% of those over 18 without a high school diploma. Census tracts in the Ironbound neighborhood range from 25% - 55% of households below the poverty level. There are hundreds of public housing tenants in three public housing complexes (more than 700 units of public housing, 75% of the residents are African American and all low income) living in closest proximity to industrial land uses and hazardous sites like the Diamond Alkali Superfund site and highways like the Turnpike.

Ironbound is an environmental justice neighborhood, which suffers from the concentration of environmental burdens resulting from past and current industrial activities that lead to cumulative environmental and health impacts. Although the community still has the remnants of its old manufacturing base (e.g., chemical and paint manufacturers), many more of the pollution sources today are derived from unregulated or non-traditional sectors like scrap metal yards, backup power generation, goods movement related industries (e.g., trucking companies, highways, waste treatment or incineration), and long term cleanup projects like the Passaic River dredging. These diverse pollution sources require more comprehensive and innovative approaches to gaining up to date community level monitoring data and using that to further identify, and mitigate risks than the standard, single media-based approaches of the past.

Problem Definition and Project Objectives

Problem Definition

According to the EPA, citizen science is a form of research that enlists the public in collecting a wide range of environmental data to expand scientific knowledge and literacy. Knowing the numerous sources of pollution in Ironbound, there has been little on the ground air monitoring by either the state New Jersey Department of Environmental Protection or the federal Environmental Protection Agency. Therefore, the Ironbound Community has looked to citizen science as a means to get better community level data and highlight the need for additional monitoring as well as increase the priority given to environmental justice communities like Ironbound. The Ironbound Community Corporation (ICC), working in collaboration with EPA's Office of Research and Development (ORD) and Region 2, will use stationary air monitors to gain invaluable data about the impacts from a disproportionate number of mobile sources, also taking into account areas in the community with sources of vertical gradients of mobile pollution. The monitors will provide data for particulate matter (PM) and nitrogen dioxide (NO_2), which are the air pollution components most associated with mobile emissions.

Project Objectives

The primary goal for this project is to have Ironbound community volunteers take outdoor air monitoring measurements of PM and NO_2 using the Citizen Science Air Monitor (CSAM) air monitoring system in order to understand what exposures of urban air pollution affect the environmental justice Ironbound community.

During the course of this project, each of the partners will work towards fulfilling the following objectives:

> **Ironbound Community Corporation**: Characterize near-road/near-source hotspots; Determine potential impact on nearby residences (including vertical gradients) and roadways at different gradients near sensitive receptors such as public housing next to ground-level truck routes and an above-grade/elevated railroad and highway. Engage the community on citizen science and air monitoring.
>
> **EPA Region 2**: Develop a standard operating procedure (SOP) and a one-page *how-to-use* brochure for using the Citizen Science Air Monitoring kit. Develop sensor loan program for public use that includes timeframes, source types, # monitors/loan, SOP, and related materials.
>
> **EPA Office of Research and Development**: Develop the Citizen Science Toolbox that compiles tools, methods, sensor and environmental considerations, and best practices for conducting citizen science environmental assessments.

Data Users

The data collected from this project will be used by ICC as initial data to help characterize the correlation between near roadside sources of air pollution and their potential impacts on the Ironbound Community. ICC and EPA will be analyzing the data and comparing it to the only stationary monitor in Newark, NJ.

The pilot of this project in the Ironbound Community has a short timeline. The process will enhance ICC's organizing around protective zoning, increasing greenspace, advocacy for the least polluting trucks, and stopping new sources of pollution from being built in the community. The results from the air monitors will potentially show the need for more extensive testing.

Project Location

Working in conjunction with residents, ICC plans to target the locations for the sampling where there is high exposure to mobile sources nearby major roadways to vulnerable populations, children and seniors. Sampling will ideally be at each location for up to or as close to two weeks, and with exact locations being finalized once the date for release of the instruments is confirmed. ICC is planning to start with the identified first two rounds of monitoring as listed in Table 2 (see locations marked with 1 or 2). Using the data from that initial month, ICC will hone in on the locations where increases in PM and NO_2 numbers are seen and then try to locate air monitors near those places for the next round of monitoring. Table 2 and Figure 2 list and show possible monitoring sites, respectively. ICC has reached out to different residents throughout the neighborhood about being possible locations for the air monitors. It is known that these monitors are designed for outdoor use, but siting considerations may necessitate placement of the monitor assembly indoors with a snorkel tube leading outdoors for outdoor air sampling (e.g., through a window). It is noted that in an urban environmental justice location, the placing of outdoor monitors can present a challenge. Therefore, ICC and EPA will take into account any potential quality of data impacts that may occur due to indoor placement and the use of a snorkel tube for some of the sensors. For more information about the Ironbound location, see the attached Ironbound Cumulative Impacts CARE Maps, Attachment B – Map of the Ironbound Community, Attachment B1 – Facilities Emitting Hazardous Air Pollutants in East Ward, Newark NJ and Nearby South Kearny, and Attachment B2 – 2002 NATA Predicted Statewide Diesel Concentrations in New Jersey.

*Tables 1 and 2 were omitted due to sensitive information on siting locations.

Table 3 below shows the general schedule for the project.

Table 3. Project Schedule

Activities	Organization/Group responsible for activity completion	Timeframe work will be done
Preparation of QAPP	Molly Greenberg, MSW ICC Community Project Manager	January 2015- Submit QAPP February 2015- Approved QAPP
Review and Assist with Preparation of QAPP	Pat Sheridan, Citizen Science Liaison & QA Officer, US EPA Region 2 Edison	January/February 2015
Grant Oversight	Zora Drake, Alion Science and Technology Timothy Barzyk, EPA Work Assignment Contract Officer	October 2014 – March 2015
Approval of QAPP	Pat Sheridan, EPA Region 2 Edison	February 2015
Procurement of Equipment	Sam Garvey, Alion Science and Technology	March 2015
Equipment re-assemble, testing, repair, and recalibration	Avraham Teitz, US EPA Region 2	Upon receipt of equipment (January 2015)
Sample Collection and Analysis	Molly Greenberg, Maria Lopez Nunez, & Community Volunteers Ironbound Community Corporation; Avraham Teitz to provide technical assistance as needed	February 2015-April 2015

Activities	Organization/Group responsible for activity completion	Timeframe work will be done
Data Evaluation	Ironbound Community Corporation; Tim Barzyk, EPA ORD, available for consultation and technical assistance	February 2015-April 2015
Preparation of Final Deliverables	Ironbound Community Corporation; Tim Barzyk, EPA ORD, available for consultation and technical assistance	April 2015

Existing Data

The Ironbound Citizen Science Air Monitoring Collaboration, Regional Applied Research Effort is being piloted in this project and new raw data is to be collected. Therefore, there is not any existing data so this section is not applicable in this QAPP.

Quality Objectives

For information about the data quality objectives, see pages 1-5 (especially Table 2) in the Citizen Science Air Monitor (CSAM) (Attachment C), and for more project specific objectives see Attachment D ICC_EPA_RARE Training Agenda, including Section 5 (Data Collection) and Section 7 (Output Datasets and Software). In addition to the data quality objectives listed in Table 2 for each measurement, the flow rate at the CSAM-PM inlet should be 1.5 L/min ± 10%.

One of the aspects of this project that ICC and EPA will be evaluating is the data quality resulting from the sensors when placed indoors and using a tube to collect outdoor samples. Ironbound is a unique urban community. Although we are densely populated, Ironbound has maintained a neighborhood look. There are not many apartment buildings or fire escapes for outdoor siting of sensor assemblies. Therefore, we are planning to test the efficiency of the monitors when the measuring devices (actual sensors) are operating inside a building, but using a small tube (i.e., snorkel tube) to collect outdoor samples (e.g., by extending the tube out a window).

Equipment List and CSAM Set Up & Operation

For equipment list information, see Attachment C: Citizen Science Air Monitor Section 1: Verifying CSAM Performance (pg. 4 -5) and Section 2: Field Operation (pg. 16).

For information on performance checks, software installation, CSAM set up, and maintenance by an experienced operator, see Section 1: Verifying CSAM Performance (pg. 4-15) of the Citizen Science Air Monitor Operating Procedure (Attachment C).

For information on field operation of the CSAM by the volunteer citizen operators, see Section 2: Field Operation (pg. 16-27) of the Citizen Science Air Monitor Operating Procedure (Attachment C). Information in this section includes battery changing/charging, CSAM on location set up, routine data collection, and processing data.

Instrument Calibration and Maintenance – Alion, EPA, and ICC Responsibilities

Alion Science and Technology and EPA ORD are responsible for completing the initial calibration of the monitors. EPA Region 2 Edison performs quality assurance and quality control calibrations. EPA Region 2 Edison along with the Ironbound Community Corporation performs field calibrations while the monitors are being collocated with the New Jersey State Department of Environmental Protection's Newark stationary air monitor. While the monitors are in the community, ICC performs daily flow checks and coordinates collaboration in the field. ICC is also responsible for daily operations of the monitor including battery maintenance and EPA Region 2 Edison will support ICC as needed. EPA Region 2 Edison is responsible for the maintenance of the monitors. General information about calibration and maintenance can be found in Attachment C: Citizen Science Air Monitor - Recording Performance Check Data (pg. 9 -10), Conducting the Performance Check (pg. 11 – 15), and Battery Changing and Charging (pg. 16-20).

Data Collection Methods

ICC will be responsible for setting up the CSAM units. ICC will document the location, dates, and other relevant information of monitor placement in Field Data Sheets (below) and then consolidate the information into a central repository, such as a master spreadsheet or file folder, at the main office or other accessible location.

For information about the data collection methods, see Section 2: Field Operation in Attachment C: Citizen Science Air Monitor Operating Procedure starting on page 16. Note that battery changing/charging info begins on page 16 of the CSAM Operating Procedure document while CSAM set up procedures begin on page 20 followed by Routine Data Collection procedures starting on page 23. The Ironbound Air Monitor Locations mentioned in Table 2 and Ironbound RARE Possible Monitoring Sites in Figure 1 show where air monitoring data is planned and potentially planned on being collected. Site selection and positioning requirements for the CSAM unit can be found in the CSAM Quality Assurance Guidelines as referenced in the CSAM Operating Procedures manual. Table 4 shows the Community Field Data Sheet to be used during sample collection by ICC when installing the sensors at the siting locations.

Table 4. Ironbound Citizen Science Air Monitoring Collaboration Community Field Data Sheet

Ironbound Citizen Science Air Monitoring Collaboration Community Field Data Sheet (Ironbound Community Corporation)					
Name:					
Address:					
Describe Location (nearby industries, childcare centers, restaurants, etc.):					
Date:	**Time**	**Battery Status** (Changed)	**Calibration Number**	**Flow Rate**	**General Observations of the day/location** (Bad Smell, lots of trucks, etc.)
1.					

2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					

Analytical Methods*

*This section only needs to be completed when sample analysis by a laboratory is applicable to the project.

No laboratory will be used to analyze the samples since the equipment being used will provide the data without further laboratory analysis. Additional information about the pollutants being monitored can be found in Attachment C: Citizen Science Air Monitor pages 2-3.

Data Evaluation

At the onset of the project, CSAM units will be co-located with established Federal Reference Methods (FRMs) in order to determine the consistency and precision of CSAM monitors. As data is collected from the field, it will be screened for anomalous readings by examining temporal trends and outliers. CSAM results will be compared to ambient FRM measurements from the local air monitoring station by establishing and comparing regression equations based on at least seven days of data; while exact replication of values is not expected, this will provide a baseline to identify outliers or otherwise inconsistent readings. CSAM measurements will also be examined as related to meteorological parameters, such as temperature, relative humidity, and precipitation to analyze any confounding issues. Also, a comparison between sampling with and without snorkel tubes will be performed. The combination of these analyses will ensure that collected data conforms to the accuracy expected of the CSAM units.

Training and Specialized Experience

Training

Alion Science and Technology and EPA will provide one in person training for ICC staff and community volunteers to go over the CSAM Operating Procedure manual and the mechanics of using the monitors. EPA Region 2 NJ will be available as needed for further instruction or help. EPA ORD also offered webinar based training if needed/wanted by the community. See Attachment D: ICC_EPA_RARE Training Agenda for training-related information.

Personnel/Group to be Trained	Description of Training	Frequency of Training
Ironbound Community Corporation staff and community volunteers	Representatives from Alion Science and Technology and EPA will go to Newark and work with community to show them the instruments, go over the manual, and allow for community to take the instruments apart and put them together while answering any of their questions	*Training will be on January 22, 2015 prior to the instruments being turned over to the community*

Specialized Experience

Person	Specialized Experience	Years of Experience
Molly Greenberg, MSW Environmental Justice Policy Manager Ironbound Community Corporation	Currently a co-PI for an EPA STAR project where asthmatic children ages 9-14 carry micro aethalometers. Coordinated a citizen science project taking VOC grab samples. Is coordinating a second round of citizen science VOC grab samples.	4

Data Management

Data management information can be found in Attachment C: Citizen Science Air Monitor pages 24-27, Processing Data. ICC will collect and store all data collected from the CSAM units on at least one (preferably two for backup) hard drive at their local office; this includes raw data as well as the CSAM Excel Data Analysis files. ICC can send data through email as electronic files to Region 2, ORD, or other collaborators as needed. ICC will develop a file naming convention to ensure consistency between file names, and include the site location and CSAM unit # (dates are automatically recorded, and not required in the file names); an example is, CSAM_Unit1_Site2 (with site number being documented as well).

Data Review and Usability Determination

Data Review

Table 5 shows the field activities needed to help ensure quality assurance for the project, and the related data review tasks associated with those activities. ICC is responsible for the field activities and data review tasks during installation of CSAM units and collection of data.

Table 5. Field Activities and Associated Data Review Tasks Required for Quality Assurance

Field Activity to Check	Data Review Tasks
Monitoring of site activities	Daily visits to site locations • Check battery/power • Check CSAM integrity not compromised • Visual/audible inspection of equipment Check in with resident volunteers • Ensure no issues with sensor placement • Confirm appropriate operation followed Calibration of monitors (as needed; by Region) Field Data Sheet • Collect and fill information in Field Data Sheet • Note any special considerations or issues
Field QC samples performed correctly	Step by step following of CSAM procedures • Downloading of data • Follow up if needed with EPA
Measurements performed correctly	Data check in with EPA • On a periodic basis (TBD by ICC after data collection has begun), ICC will check in with Region 2 and ORD regarding data collection, and review any potential issues or discrepancies
Calibrations performed correctly	Information documented on Field Data Sheet
Evaluate any deviations from QAPP or SOPs to determine the impact to the data and project objectives	Follow up with community volunteers • Confirm operations are proceeding as planned • Note any issues regarding installation or operation of CSAM units Check in with Community Organizer • Community Organizer will compile any relevant details or notes regarding CSAM operation as reported by volunteers Check in with EPA • On a periodic basis (TBD by ICC), check in with EPA regarding CSAM operations and progress

Data Usability

This project is a pilot for use of these monitors by community volunteers and is collaborative effort with EPA ORD, EPA Region 2, and ICC. Therefore, ICC will work with EPA to identify and address any possible issues with the data. Data that does not fully comply with QC criteria or QAPP requirements will be explained, and any resultant limitations on data use will be fully discussed in any final documents.

ICC has been informed by EPA that the sensors were designed for use as outdoor samplers. Indoor placement and the use of a snorkel tubes (the 1' long ¼" o.d. x 1/8" i.d. tubes provided by the EPA ORD contractor) will affect the data quality of the PM fine sensor due to flow and wall effects, and it could potentially negatively impact the NO_2 results, due to the inability of the sample air to diffuse to the sensor. As it is not known what the exact affects will be, the plan is to evaluate the data and see if any adjustments need to be made prior to including the data in any final deliverables.

Reporting and Final Deliverables

ICC will work with community partners and EPA ORD on the use and reporting of the data. Expected outputs (final deliverables) for this project include:

- Collection of "on the ground" data from the CSAM air monitors, which will help inform the Ironbound community about the many concerns that they have about local poor air quality. This information may possibly be helpful for future interventions.
- Excel CSAM Data Analysis spreadsheets from each air monitoring location; sharing with EPA Region 2 and ORD on a periodic basis (TBD by ICC) via email.
- Raw data text files from each air monitoring location of the PM, NO_2, temperature, and humidity results.
- Temporal trends of pollutant concentrations and basic data analysis (comparison of sites, sensor units, averages, variability, day/evening concentrations, etc.)
- Identification of potential hotspots of pollution

Note that some of that the information about how the data can be used and how the data will be reported will need to be determined after evaluation of the data that has been collected. There is no current format for reporting the final data set planned. This is a new pilot project, and therefore, much is not known about what can be interpreted or derived from the actual results from this type of community volunteer type air monitoring.

According to the contract guidelines of this project, ICC reports to Alion Science and Technology by providing a short narrative on the project's accomplishments and a monthly invoice. A copy of these reports will be shared with the EPA ORD Principal Investigator by Alion.

Attachment A:

IRONBOUND CITIZEN SCIENCE COMMUNITY AIR MONITORING COLLABORATION
ROLES AND RESPONSIBILITIES

II. Partnership Objectives (Jan, 2014 – Jan, 2016):

Partner	Point(s) of contact	Objective
ICC	Molly Greenberg [Program Manager]	Characterize near-road/near-source hotspots Determine potential impact on nearby residences (incl. vertical gradients) Locations of multi-level (vertically-intersecting) sources (public housing next to ground-level truck route and elevated/above-grade rail lines and highways)
EPA Region 2	Anhthu Hoang Marie O'Shea Avi (Avraham) Teitz Mazeeda Khan Pat Sheridan Kevin Kubik	Develop SOP and one-pager how-to-use brochure Develop sensor loan program for public use (timeframes, source types, # monitors/loan, SOP, etc.) Use/community validated documentation for local Citizen Science toolbox
EPA ORD	Tim Barzyk [EMRB] Ron Williams [EMAB] Amanda Kaufman	Develop citizen sensor *toolbox* – how---to---use; community---based participation; local scale applications (e.g., hotspots); data management options/tool use Uncertainty/variability; etc.

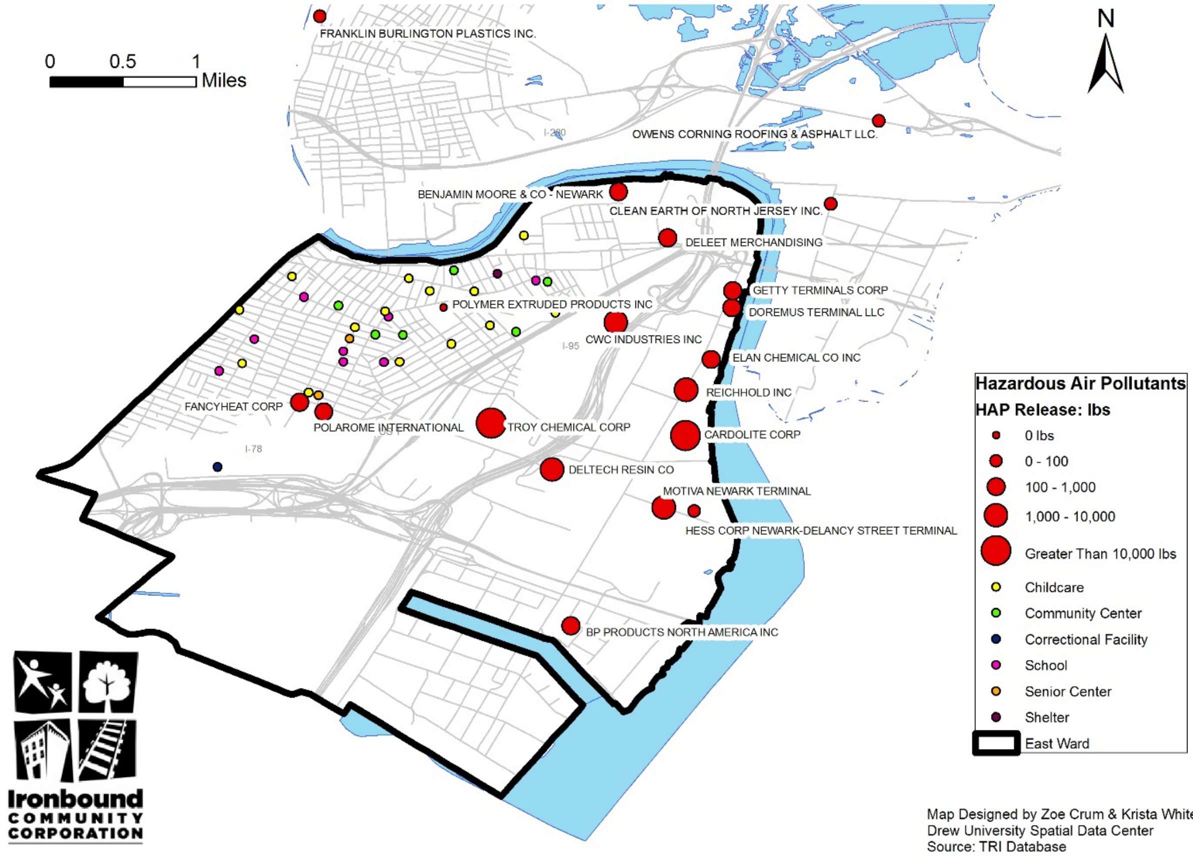
III. Scope: Geographical and Temporal (Areas of Study and Timelines)

Project Staff	Affiliation	Role	Responsibility
Molly Greenberg [Program Manager]	ICC	Community Partner Project Manager	Oversee activities of Community Liaison and Volunteers
Drew Curtis	ICC	TBD	TBD
TBD	Ironbound Community Contractor	Community Liaison	1. Attend training at EPA offices for: a. Equipment handling & maintenance b. Data collection & management 2. Provide technical support and supervision for Community Liaison 3. Work with Community Volunteers to review and validate equipment/study SOPs and toolbox materials 4. Act as liaison between project technical team, ICC, and community volunteers 5. Support the project by organizing and conducting outreach to facilitate community involvement in study---related needs such as design, data collection, analysis, and report back
Non-defined	ICC	Community Volunteers	1. Support study needs including equipment handling and maintenance, data collection and management, community updates 2. Review and critique SOPs and Citizen Science toolbox documentations 3. Update study partners on progress and challenges related to monitoring
Anhthu Hoang	EPA Region 2 ORA/OSP---EJ, NY	Region 2 Project Coordinator	1. Coordinate study activities 2. Ensure communication between project staff and partners regarding, among other things, project progress and needs, sharing documents, data reporting, etc.
Mazeeda Khan	EPA Region 2 CASD, NY	NJ State Liaison	Ensures NJ DEP is aware of our study and apprised of our progress
Marie O'Shea	EPA Region 2 DESA, NY	ORD---DESA Liaison	1. Provide support regarding issues related to RARE funding 2. Advise study staff and partners regarding DESA and ORD related issues

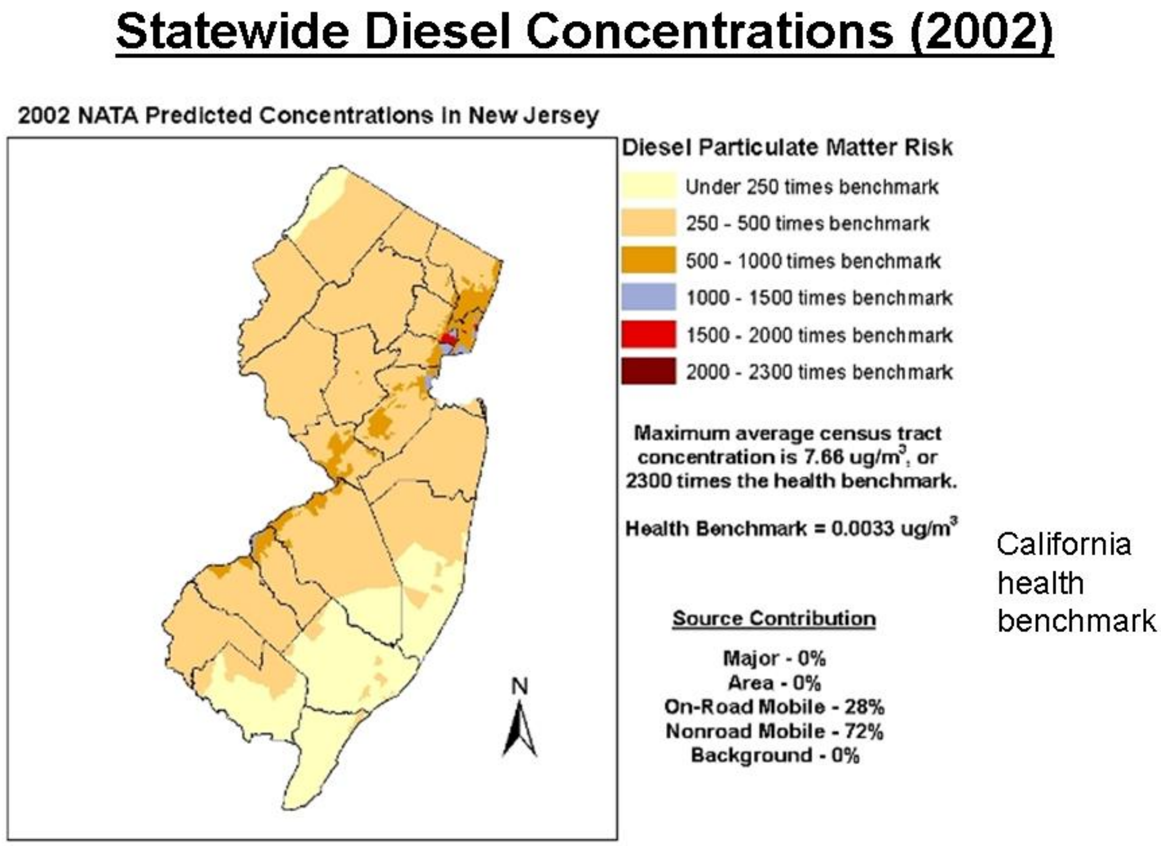
Pat Sheridan	EPA Region 2 DESA, Edison	Citizen Science Liaison	Advise study partners on Citizen Science issues such as QAPPS development, etc.
Avraham (Avi) Teitz and Mustafa Mustafa	EPA Region 2 DESA, Edison	EPA---Community Technical Support	1. Work with ICC on site selection a. Conduct site visit to ICC to scope potential sites given ICC's data objectives and technology restrictions b. Report to study partners potential sites, identifying tradeoffs 2. Train and provide technical assistance ICC contractors (and other representatives as appropriate) and Community Volunteers on project---related technical needs a. Handling and maintenance of monitoring equipment b. Equipment handling documentation: chain of custody, calibration, battery change, etc. c. Data collection and management, including development and following QAPPS, etc. Respond to questions and advise ICC contractor and Community Volunteers on equipment handling and maintenance e. May need to make periodic site visits to ensure project---related equipment are in good working order and set up is appropriate for project data needs d. Work with ICC contractor and Community Volunteers to troubleshoot equipment problems and assist to repair resources as needed
Kevin Kubik	EPA Region 2 DESA, Edison	EPA Region 2 Management	Provide R2 Leadership input as appropriate
Tim Barzyk (EMRB)	EPA ORD	Principal Investigator	1. Manage contractor work assignment related to instrument assemblies, citizen science toolbox, and community liaison. 2. Maintain milestones and documentation related to RARE progress. 3. Facilitate interaction between technical requirements and community---specific needs. Provide mid-way study status report at a general Ironbound Community partners meeting
Ron Williams (EMAB)	EPA ORD	EPA ORD Technical Advisor	Provide technical expertise on instrument assemblies as related to project objectives, and input on citizen science toolbox.
Amanda Kaufman	EPA ORD	EPA ORD Technical Advisor	Provide expertise in assembling citizen science toolbox Conduct in-person technical training on CSAM units

Attachment B – Map of the Ironbound Community

Attachment B1 – Facilities Emitting Hazardous Air Pollutants in East Ward, Newark NJ and Nearby South Kearny



Attachment B2 – 2002 NATA Predicted Statewide Diesel Concentrations in New Jersey.



SOURCE: http://www.nj.gov/dep/airtoxics/Diesel02.htm

United States Environmental Protection Agency

EPA/600/R-15/051

Attachment C - Citizen Science Air Monitor (CSAM) Operating Procedure

CITIZEN SCIENCE AIR MONITOR (CSAM)

Operating Procedures

Office of Research and Development
National Exposure Research Laboratory

Contents

Introduction

Citizen Science Air Monitor (CSAM)

The Citizen Science Air Monitor (CSAM) is an air monitoring system designed for measuring nitrogen dioxide (NO_2) and particulate matter (PM) pollutants simultaneously. This self-contained system consists of a CairPol CairClip NO_2 sensor, a Thermo Scientific *personal* DataRAM $PM_{2.5}$ monitor, and a Honeywell temperature and relative humidity (RH) sensor. The CSAM's design provides for easy data retrieval from all three devices in a single step through a key-lock access door.

These operating procedures explain what you need to do to collect quality data using the CSAM for your monitoring project. Two sets of procedures are detailed here. Procedures for verifying proper operation of the CSAM are provided in Section 1 and should be performed only by an experienced operator. The Section 2 procedures are for the field operation of the CSAM by citizen volunteers.

Pollutants Measured and Their Sources

NO_2 is a highly reactive gas that can irritate the lungs and cause bronchitis, pneumonia, and other respiratory problems. NO_2 pollution is both man-made and naturally occurring. It occurs naturally as a result of atmospheric processes. It also forms from fuel combustion and forms quickly from automobile emissions. Therefore, significant increases in NO_2 concentrations are often found near major roadways. Power plants and other industrial processes also emit NO_2.

PM consists of particles of various sizes such as soot, smoke, dirt, and dust. These particles are often generated and released into the air from sources such as power plants, industrial and agricultural processes, automobiles, and fires. PM can adversely affect breathing and aggravate respiratory and cardiovascular conditions, with the smallest particles posing the greatest health risk. PM also contributes to atmospheric haze that reduces visibility.

For more information on these air pollutants visit the U.S. Environmental Protection Agency's Web site at http://www.epa.gov/airquality/urbanair/.

CSAM Components

Figure 1 shows the inside of the CSAM and its separate components. Each component is detailed in the following subsections. The experienced operators conducting the performance checks will need a thorough understanding of these components, while a general familiarity of instrument operation should be sufficient for the citizen volunteer operators, who likely will not need to access the inside of the CSAM. Understanding the components that comprise the CSAM, however, will help the citizen scientists evaluate the quality of collected data and identify operational problems. Table 1 lists the measurement units reported by each component.

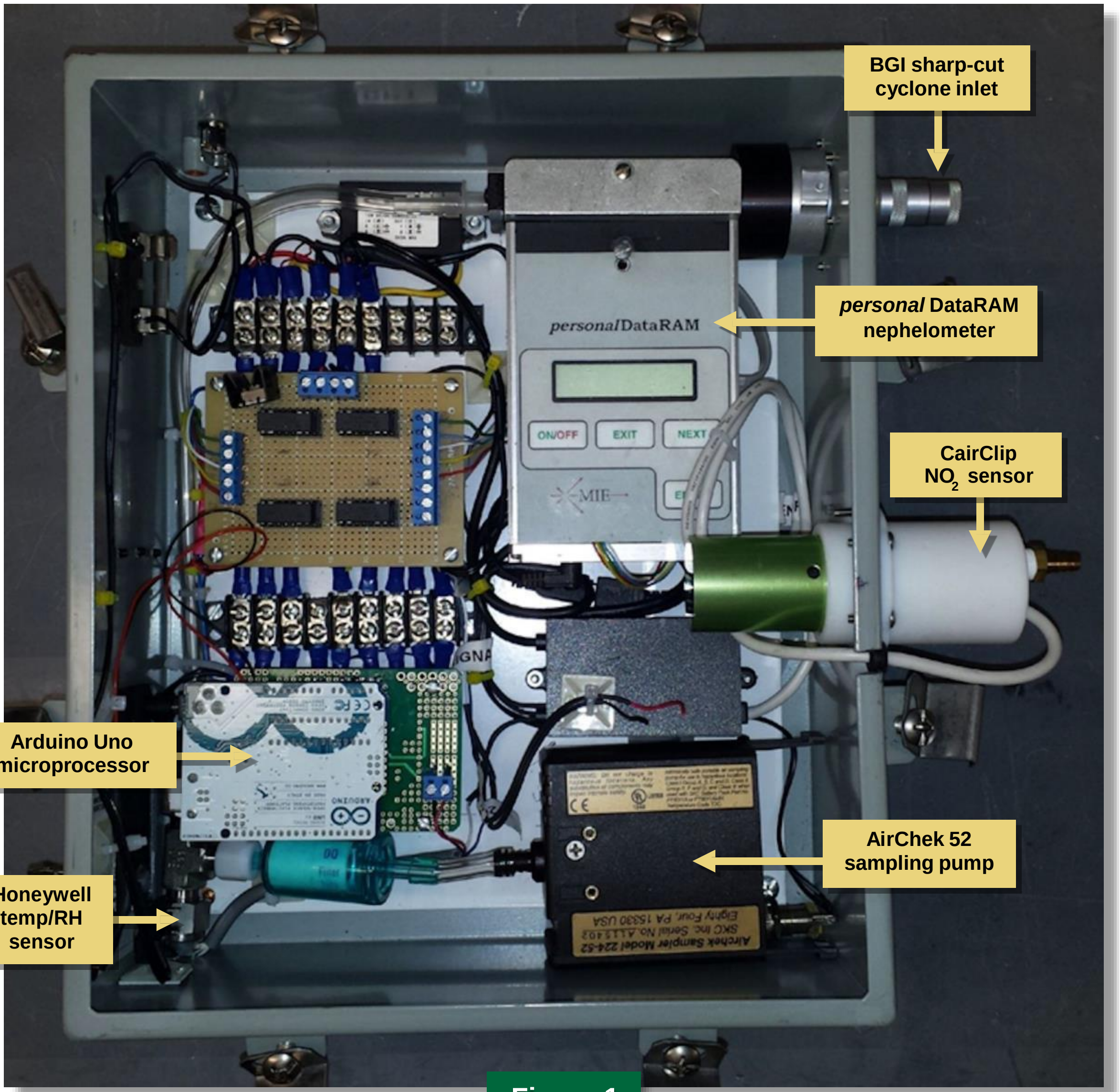


Figure 1

Measurement	Reporting Unit
NO_2 concentration	Parts per billion (ppb)
PM concentration	Micrograms per cubic meter ($\mu g/m^3$)
Temperature	Degrees Celsius (°C)
Relative humidity (RH)	Percent (%) at °C

Table 1

CSAM-NO_2

CSAM measurements of NO_2 are made using a CairPol CairClip NO_2 sensor. The CairClip uses a gas-specific inlet filter combined with dynamic air sampling in an integrated system to measure real-time gas concentration in parts per billion (ppb). The CSAM-NO_2 unit's detection limit—the lowest concentration the instrument is likely to detect—is approximately 20 ppb NO_2.

CSAM-PM

The CSAM-PM component measures real-time PM in micrograms per cubic meter (μg/m^3) using a Thermo Scientific *personal* DataRAM nephelometer, a device that uses light to measure the concentration of suspended particles in a liquid or gas. Air is pumped to the nephelometer by an SKC AirChek 52 personal sampling pump. The nephelometer uses a BGI sharp-cut cyclone inlet (SCC 1.062), which excludes particles with a diameter above a certain size. In this case, the CSAM-PM samples for $PM_{2.5}$, which consists of particles less than 2.5 micrometers in diameter, or "fine" particles. Fine particles come from all types of combustion activities, such as motor vehicles, power plants, and wood burning, and pose the greatest health risk because they can lodge deeply in the lungs. The CSAM-PM unit operates at a flow rate of 1.5 liters per minute (L/min). It is important to understand that a change in flow rate will change the diameter of the particles being sampled and thus affect data quality. If a change in flow rate is noted, the unit should be removed from operation, and an experienced operator should perform the flow rate check and adjustment detailed in Section 1. The CSAM-PM has a detection limit of 0.1 μg/m^3.

Temperature and Relative Humidity

The CSAM also contains a Honeywell temperature and RH sensor (HIH-4602-A/C series). Temperature (ºC) and RH (% at ºC) data are recorded along with the PM and NO_2 concentration data. The recommended CSAM operating ranges for temperature and RH are 32–104 ºF and 0–90% RH (with no formation of water droplets), respectively. Abrupt changes in temperature and RH can affect the performance of your CSAM, particularly the CSAM-NO_2 sensor component. Therefore, temperature and RH data collected concurrently with concentration data can help you recognize any performance issues caused by environmental conditions.

Microprocessor

Data from all components—PM, NO_2, and temperature and RH—are collected and stored using an Arduino Uno microprocessor. The Arduino Uno has a USB connection and a power jack. This microprocessor uses software developed by EPA to allow operators to retrieve all data from the unit in one easy step. Data will be stored on a secure digital (SD) memory card located in the microprocessor that the citizen operators access and remove for data download as described in Section 2.

Section 1: Verifying CSAM Performance

The procedures in this section should be carried out only by an experienced operator.

The performance checks and maintenance procedure described in this section will help make sure the CSAM produces the desired results during the study. It is recommended that an experienced operator conduct the performance checks before deploying the instrument in the field and after it is removed from the field at the end of the study. In addition, the filter of the CSAM-NO_2 component should be changed by an experienced operator. If at any time a citizen volunteer operator suspects a CSAM is not functioning properly, it should be removed from operation and undergo troubleshooting, maintenance, and performance checks as described in this section.

What You Will Need

Included in CSAM Package

- CSAM
- Secure digital (SD) card (standard size)
- SD card reader
- AC-DC adapter with power supply cable or CSAM battery pack
- USB cable
- Macro-enabled Microsoft Excel spreadsheet created specifically for processing CSAM data (on accompanying CD)
- High-efficiency particulate air (HEPA) filter with tubing attached for PM zero drift check
- Rotameter for flow rate measurement with tubing attached
- CSAM Monitoring Record
- Red dongle (for CairClip maintenance – see procedure)

Not Included

- Personal computer (PC) running a Windows operating system (preferably Windows 7 or greater)
- Arduino software (to be downloaded from the Arduino web site – see procedure)
- Microsoft Excel
- Long Phillips screwdriver (for CairClip maintenance – see procedure)
- Flat-head screwdriver (to adjust PM flow rate – see procedure)
- Source of NO_2
- Teflon tubing (and proper fittings) for NO_2 zero and span drift check

CSAM Performance Checks

Table 2 identifies the recommended checks—zero and span drift for the CSAM-NO_2, flow rate and zero drift for the CSAM-PM, temperature, and RH—and the acceptable ranges for accuracy and precision for CSAM applications. Zero and span drift checks verify that the monitor is functioning within the operating range and that it responds with the desired sensitivity to changes in input concentration. The flow rate check verifies the rate at which the sample gas flows through the instrument. The flow rate is checked using a flow meter to ensure that the monitor is receiving the proper amount of air to yield a representative sample.

Measurement (Sensor)	Performance Check	Accuracy	Precision	Corrective Action (by an Experienced Operator)
NO_2 concentration ($CSAM-NO_2$)	Zero/span drift	± 20%	± 20%	Perform calibration and troubleshooting
PM concentration (CSAM-PM)	Flow rate	1.5 L/min ± 10%	± 10%	Adjust set screw on pump
	Zero drift	< 20% of ambient following local aerosol normalization	± 10%	Perform troubleshooting
Temperature/RH (Honeywell sensor)	Compared with local data*	± 5% (temp) ± 10% (RH)	± 2% (temp) ± 5% (RH)	Perform troubleshooting

*The following web sites are sources of local weather data:
http://www.weather.com/weather/hourbyhour/l/USNJ0355:1:US
http://w1.weather.gov/obhistory/KEWR.html

Table 2

Software Installation and CSAM Setup

To conduct the performance checks, you must first download and install the Arduino software on a computer and then connect the computer to the CSAM so that the recorded data for each check are available for manual entry at the end of each check.

Procedure: Download and Install the Arduino Software

1. Go to the Arduino web site at http://arduino.cc/en/Main/Software to begin your download.
2. On the **Download** tab (Figure 2), click **Arduino 1.0.6**.
3. On the next screen (Figure 3), click **Windows Installer**.
4. Read the license agreement and click the **I Agree** button (Figure 4).
5. When the **Arduino Setup: Installation Options** window opens (Figure 5), make sure all the boxes are checked and click **Next**. These should already be checked by default.

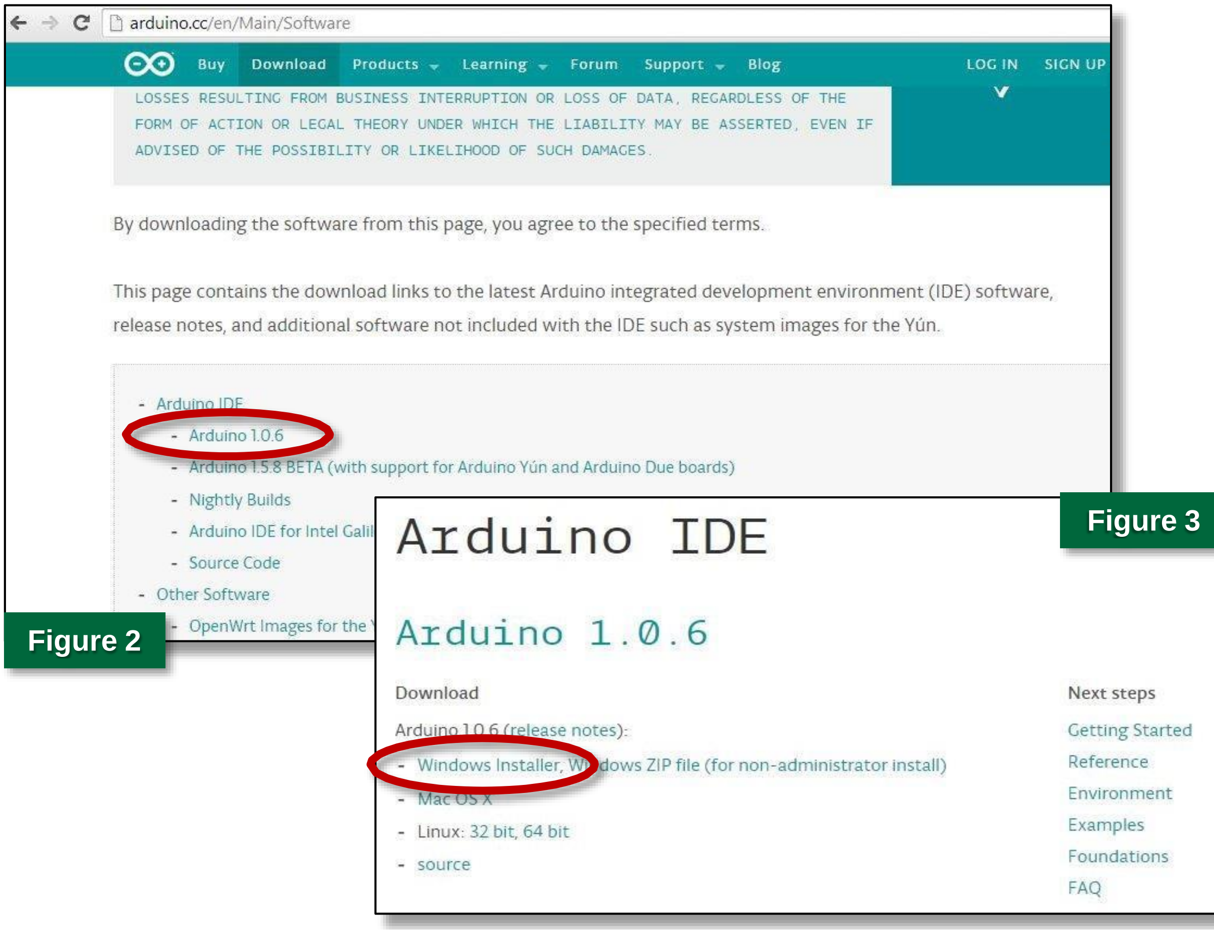


Figure 2

Figure 3

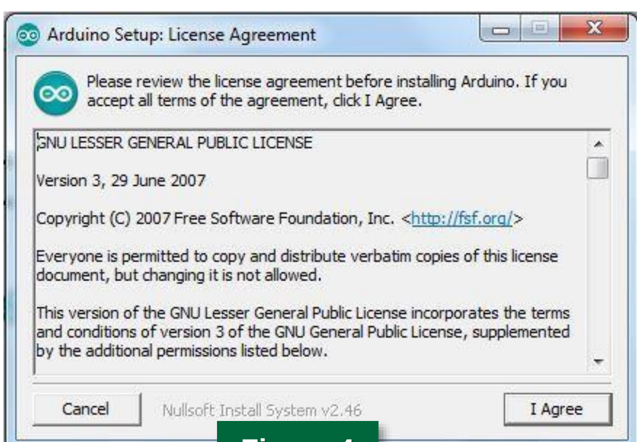


Figure 4

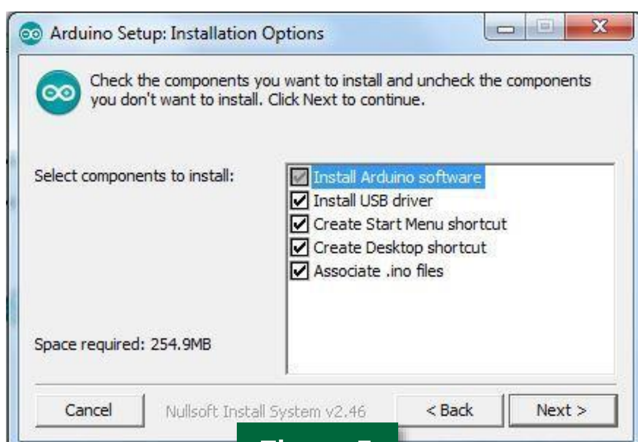


Figure 5

6. In the **Arduino Setup: Installation Folder** window (Figure 6), click **Install** to install the software at the default location.
7. When prompted (Figure 7), click **Install** to complete installation.

Consult the Arduino instructions at www.Arduino.cc/en/guide/Howto if you encounter any problems with installation.

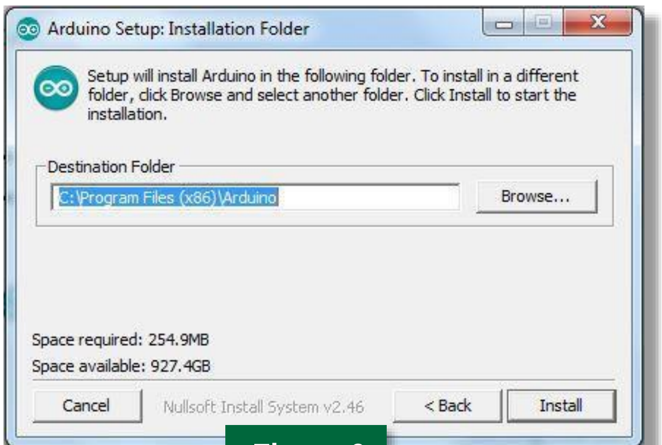


Figure 6

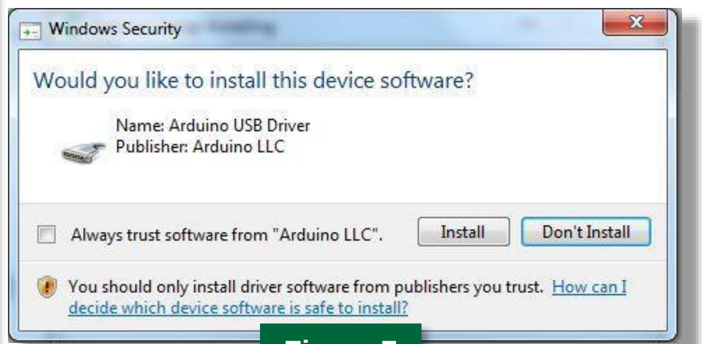


Figure 7

Procedure: Set Up the CSAM

1. Turn on the CSAM by plugging the power supply cable into the CSAM and connect to a wall outlet with the AC adaptor or to the battery case as shown in Figure 8.
2. Open the access door (Figure 9) and make sure the SD card is in the SD card slot (Figure 10).

   Note: The access door switch, as shown in Figure 10, detects when the door is opened and shuts down the power to the unit. You will need to apply consistent pressure to the switch to simulate the door being closed. This can be done by wedging folded up paper between the switch and the case.

Cautions

- Always get rid of static electricity before touching electronics by touching a metal object such as the CSAM case. Certain clothing (e.g., wool sweaters) are known to generate static electricity.
- Do not touch circuitry or wiring while the CSAM is running.

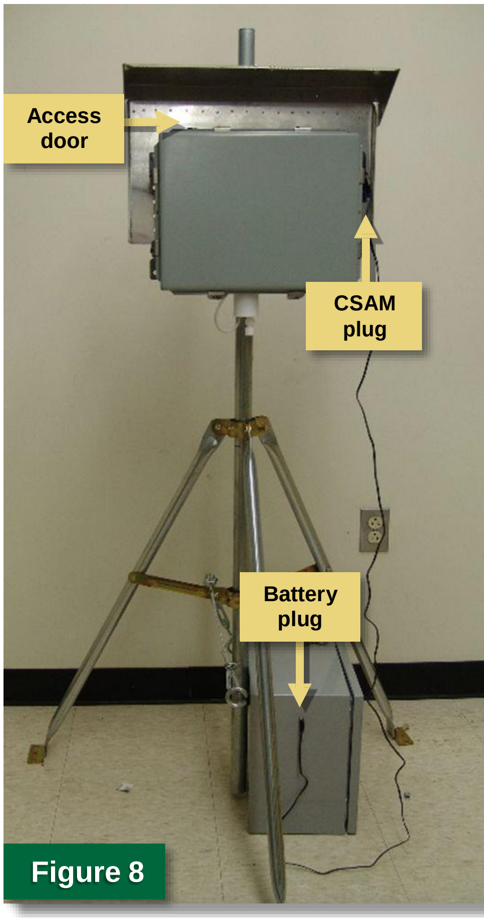


Figure 8

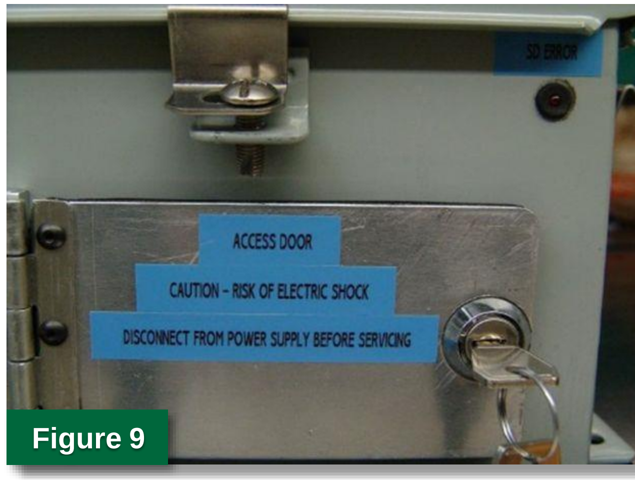


Figure 9

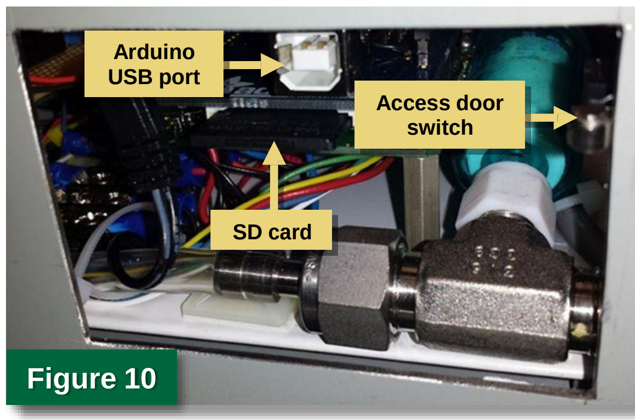


Figure 10

3. Connect a USB cable to the Arduino USB port (Figure 10) and to a computer with the Arduino software.
4. Launch the Arduino software by clicking on the Windows desktop icon that was created during installation.
5. On the **Tools** tab, click **Serial Port** in order for the software to detect the connected CSAM (Figure 11).
6. Click the magnifying glass in the top right corner (Figure 11) to open a window where the data are reported on the screen in 5-minute averages, as shown in Figure 12.

The CSAM is now ready to record performance-check data as described in the following procedures.

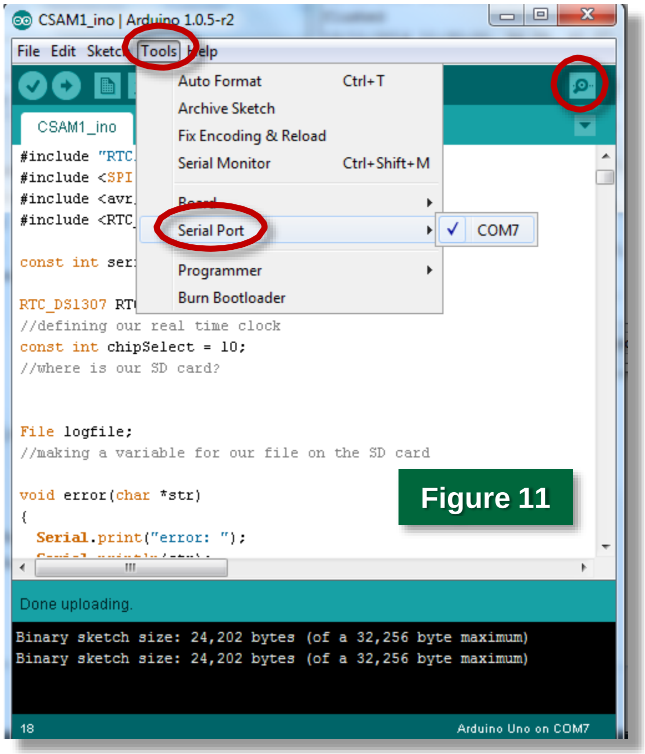


Figure 11

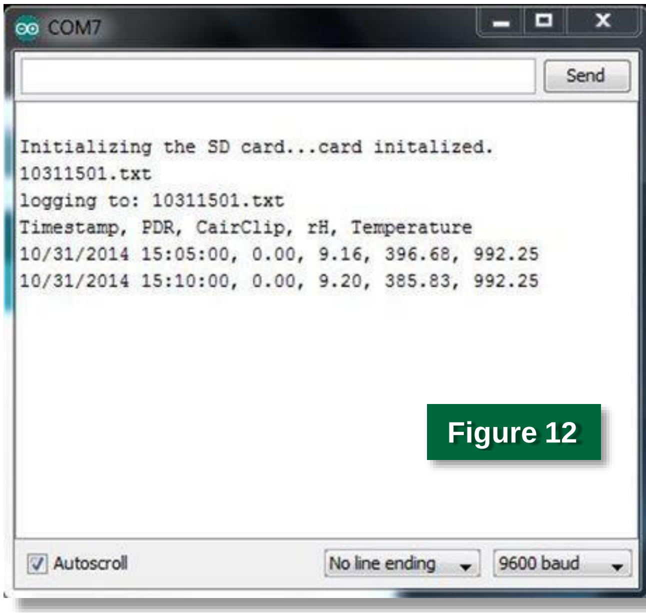


Figure 12

Recording Performance Check Data

A CD with a Microsoft Excel macro-enabled spreadsheet, **CSAM Data Analysis [Serial No. XX].xlsm**, accompanies each CSAM (Figure 13). The CSAM unit's two-digit serial number is part of the file name so that the spreadsheet can easily be matched with its associated unit if more than one CSAM is deployed in the field.

This spreadsheet was created specifically for entering CSAM performance-check data and processing field data relative to the performance data. It is recommended that acceptable performance of each CSAM unit be verified at the beginning and the end of the study, and space is provided for both start and end checks. However, if no check is performed at the end of the study, the processing macro, activated by clicking the **Load Data, Perform Calculations, Graph Processed Data** button, will assume that both start and end check data are identical.

Each sensor—PM, NO_2, and temperature/RH—has four cells associated with it:

- **Zero/Low Voltage:** sensor output in millivolts (mV) while sensor is exposed to zero or a very low level of what the sensor measures.
- **Zero/Low Set Point:** concentration corresponding to the zero/low voltage output.
- **Span Voltage:** sensor output at 80% of its full measurement range in millivolts.
- **Span Set Point:** concentration corresponding to the span voltage output.

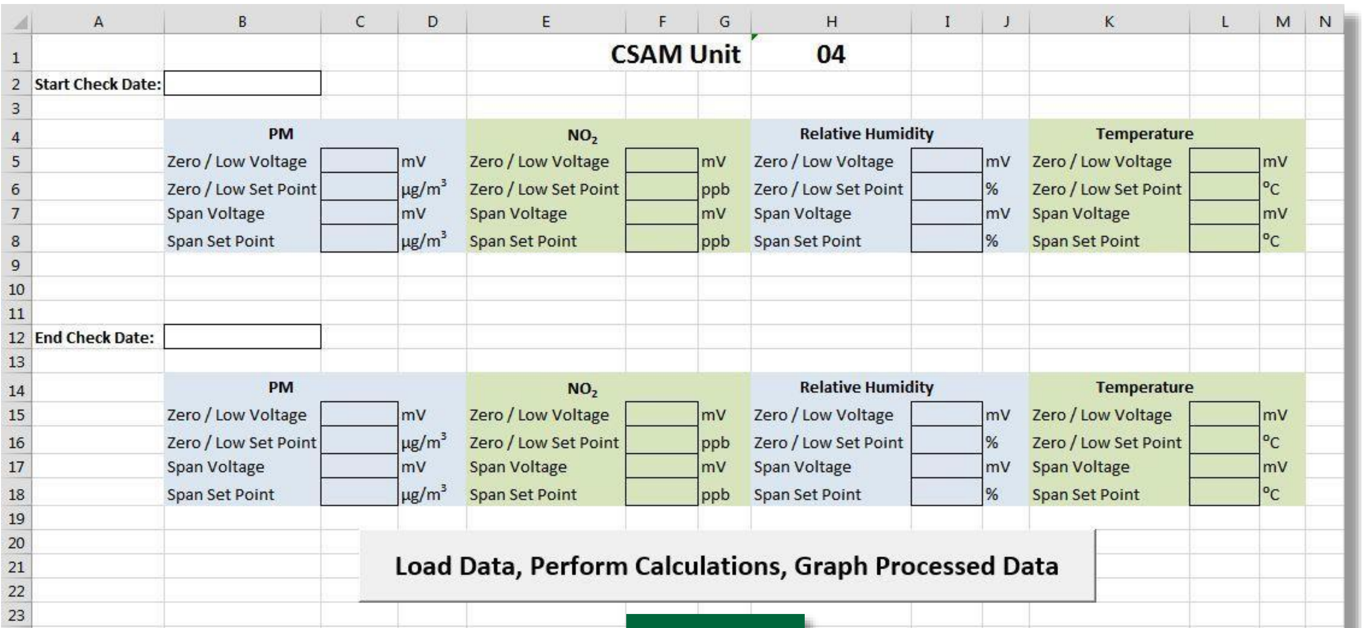


Figure 13

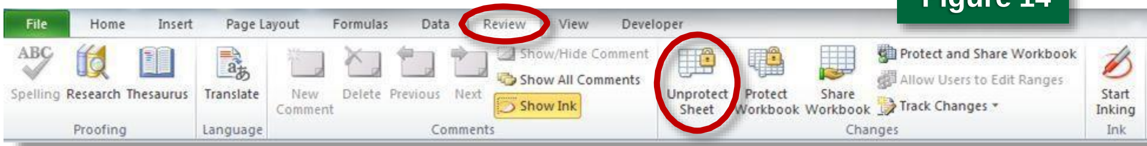
At the end of each performance check, the experienced operator should manually enter the information into the appropriate spreadsheet cells. It is also recommended that the performance information be recorded in a laboratory notebook and on the CSAM Monitoring Record (see the CSAM Quality Assurance Guidelines). After the performance data has been entered, the citizen scientists can then use the spreadsheet to load and process the collected data. The spreadsheet automatically interprets the voltage data produced by the CSAM and converts it to the measurement units required for processing and analyzing the data (NO_2 [ppb], PM [µg/m^3], temperature [°C], and RH [% at °C]).

The spreadsheet is locked for editing to prevent accidental modification. While the sheet is locked, only the **Load Data, Perform Calculations, Graph Processed Data** button is functional, and the rest of the sheet cannot be manipulated. Project leaders should use the default password to unlock the file for entering performance-check data and then relock the file, creating a new password, before citizen scientists use it to process the collected field data, as described in the following procedures.

Procedure: Unlock Spreadsheet

1. On the **Review** tab, click **Unprotect Sheet**, as shown in Figure 14.

Figure 14



2. When prompted for a password (Figure 15), enter the default password "**CSAMXX**," where XX is the two-digit serial number of the unit.
3. Click **OK**.

The spreadsheet is now ready for entering data.

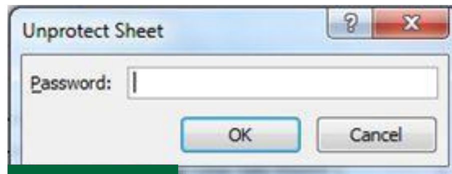


Figure 15

Procedure: Relock Spreadsheet and Create New Password

1. On the **Review** tab, click **Protect Sheet**, as shown in Figure 16.

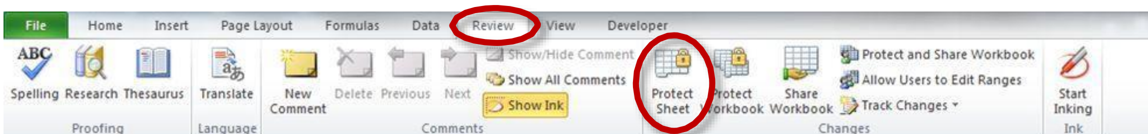


Figure 16

2. In the **Protect Sheet** dialog box, make sure **Select unlocked cells** is checked (Figure 17).
3. Enter a password in the **Password to unprotect sheet** field.
4. Reenter the password when prompted, as shown in Figure 18.

The spreadsheet is now ready for use by the citizen scientists.

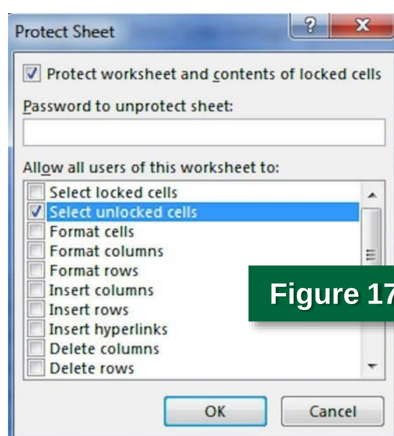


Figure 17

Conducting the Performance Checks

The following procedures are to be performed while the CSAM is running and connected to a computer with the Arduino software installed and open, as described in the CSAM Setup section above, and the **CSAM Data Analysis [Serial No. XX].xlsm** spreadsheet open. The date of the checks should be typed into the appropriate spreadsheet cell, either **Start Check Date** or **End Check Date**.

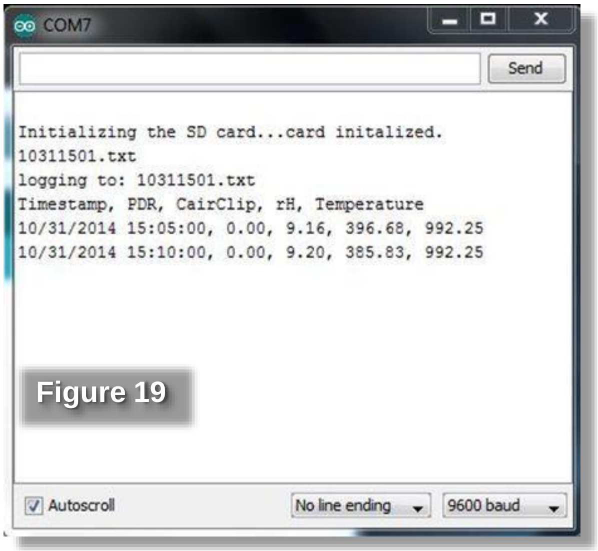


Figure 19

During each check, the voltage values (mV) are reported on the Arduino software screen in 5-minute averages, as shown in Figure 19. The voltage values to be entered in the spreadsheet for each check will be the last values listed on the screen at the end of the designated testing period. The PM span voltage and concentration values and all temperature and humidity data are preset in the spreadsheet.

Procedure: Check CSAM NO_2 Zero and Span

1. Use the supplied tubing to attach the unit to a source of zero air for the zero check (Figure 20) and allow the unit to sample for 15 minutes.
2. Record the final zero voltage and concentration values in the appropriate spreadsheet cells and on the CSAM Monitoring Record or other project documentation.
3. Attach the unit to a source of NO_2 (Figure 20) using Teflon tubing at a concentration that is 80% of full range (upper range limit 250 ppb) for the span check and allow the unit to sample for 15 minutes.
4. Record the final span voltage and concentration values in the appropriate spreadsheet cells and on the CSAM Monitoring Record or other project documentation.
5. If the results do not meet the quality assurance requirements listed in Table 2, return the CairPol CairClip to the manufacturer for calibration.

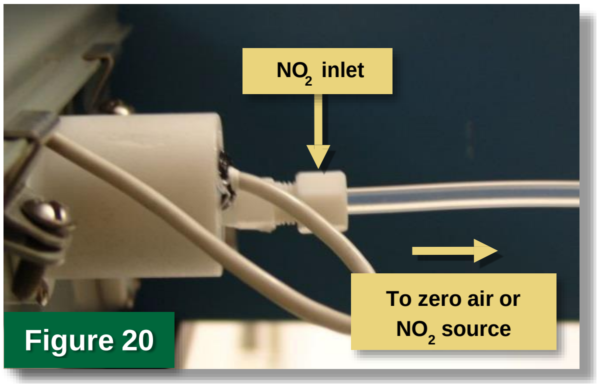


Figure 20

Procedure: Check CSAM PM Flow Rate

1. Attach the flow adaptor to the PM cyclone inlet, as shown in Figure 21, by fitting it over the inlet and pressing until it fits securely.
2. Connect the supplied rotameter with tubing attached to the CSAM-PM inlet (Figure 22).
3. Allow the unit to sample at least 5 minutes or until the flow rate is stable within 1.5 L/min ± 10%.
4. If the value is outside the specified 1.5 L/min ± 10% limit, adjust the flow rate using the set screw on the AirChek pump (Figure 23). Turn the screw clockwise to increase flow and counterclockwise to decrease the flow.
5. After each adjustment allow the flow to stabilize for 5 minutes and reevaluate.
6. Record the final flow rate on the CSAM Monitoring Record or other project documentation.

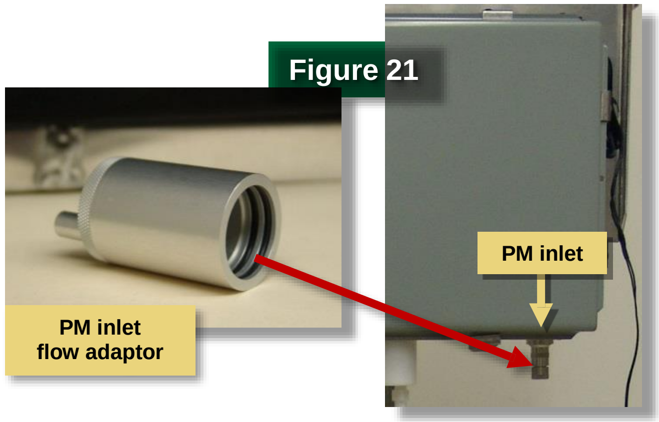


Figure 21

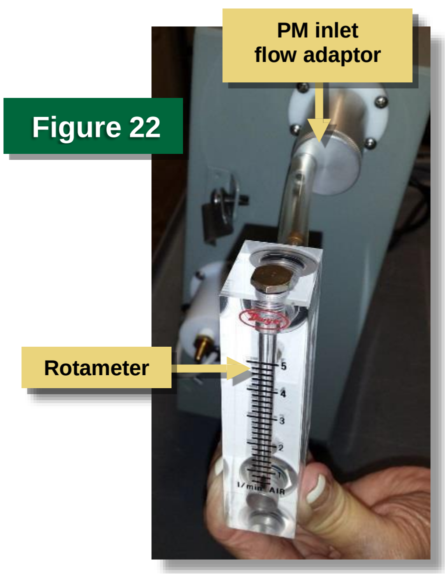


Figure 22

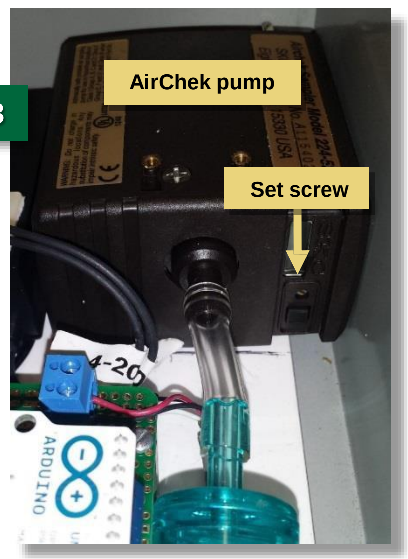


Figure 23

Procedure: Check CSAM PM Zero

1. If not already in place, attach the flow adaptor to the cyclone as shown in Figure 21 in the previous procedure.
2. Connect the supplied HEPA filter with tubing attached to the CSAM-PM inlet (Figure 24).
3. Allow the unit to sample through the filter for 15 minutes.

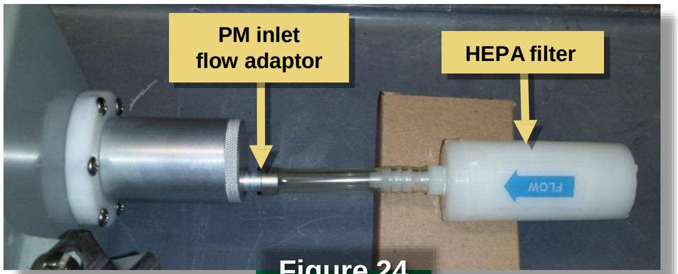


Figure 24

4. Record the final zero voltage and enter zero (0) for the concentration value in the appropriate spreadsheet cells and on the CSAM Monitoring Record or other project documentation.

CSAM-NO_2 Maintenance

If the CSAM-NO_2 (CairClip) is regularly exposed to dust, it is recommended that the removable filter be changed every 4 months. The filter comes premounted in its holder and is removed and replaced as a single unit (Figure 25). The CairClip is contained in a protective Teflon sleeve on the CSAM. In order to perform this procedure, the CSAM must be opened and the CairClip removed from the protective sleeve.

Figure 25


Procedure: Change CSAM NO_2 Filter

1. Disconnect the CSAM from its power supply.
2. Remove the CSAM cover using a Phillips screwdriver to loosen the screws of the brackets and then sliding the brackets off the cover edges.
3. Hold onto the white mini USB cable on the front of the CSAM to prevent its fitting from working loose, and from inside the CSAM gently wiggle the CairClip backwards until it comes out of the sleeve (Figure 26).
4. Disconnect the mini USB cable.

5. Insert the red dongle provided with the CSAM into the CairClip as shown in Figure 27. The dongle prevents the small fan inside the device from turning.

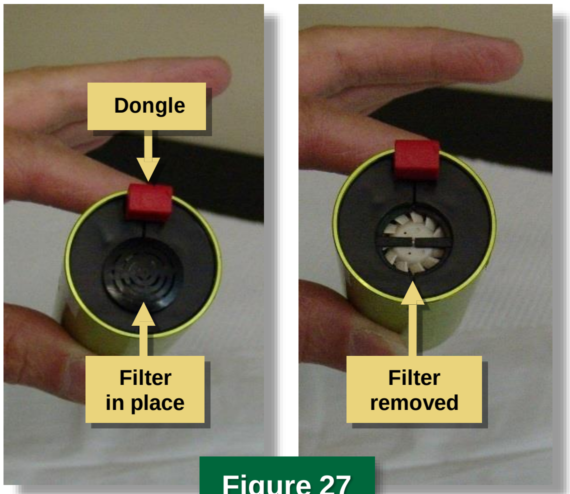


Figure 27

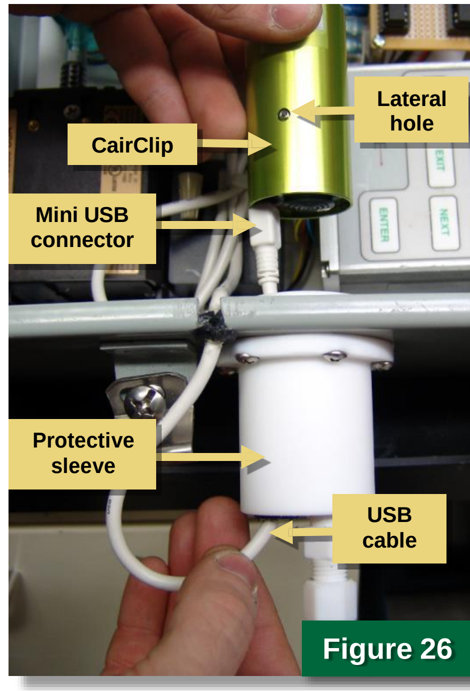


Figure 26

6. Remove the filter/filter holder assembly from the back of the CairClip by gently pulling the filter holder with your fingers.
7. Place a new filter/filter holder assembly into the opening and gently press until it is secure.
8. After changing the filter, remove the red dongle and reconnect the mini USB cable to the CairClip.
9. Align the USB plug with the cable insertion hole, and while feeding the mini USB cable gently into the hole, reinsert the CairClip into the protective sleeve and gently but firmly press the CairClip into the sleeve hole until it can go no further. Be sure the lateral hole, shown in Figure 26 remains outside of the sleeve.
10. Close the unit by replacing the cover on the CSAM, refitting its brackets, and tightening the screws.
11. Note the date of the filter change in a laboratory notebook or other designated project documentation.

Section 2: Field Operation

These procedures are expected to be carried out by volunteer citizen operators.

Field operation of the CSAMs is expected to be carried out by volunteer citizen scientists. The citizen scientists setting up and attending to the CSAMs at field locations need to know how to change and recharge the CSAM's battery, set up the unit properly at its outdoor or indoor location, initiate data collection, and retrieve and process the data. The procedures in this section detail the activities required for using the CSAM successfully for field data collection and retrieval.

The CSAM is designed to run for one week (continuously for 7 days) on a fully charged battery. Therefore, an operator should visit the test site at least once a week to replace and/or recharge the battery, download data, and inspect the unit's functionality.

What You Will Need

Included in CSAM Package

- CSAM
- Access door key
- Two standard size secure digital (SD) cards
- SD card reader
- AC-DC adapter with power supply cable or CSAM battery pack
- USB cable
- Macro-enabled Microsoft Excel spreadsheet created specifically for processing CSAM data (on accompanying CD)
- High-efficiency particulate air (HEPA) filter
- Teflon tubing and proper fittings (indoor setup)
- Metal tubing protector (indoor setup)
- Rain shield (outdoor setup)
- Tripod (outdoor setup)
- Battery charger

Not Included

- Personal computer (PC) running a Windows operating system (preferably Windows 7 or greater)
- Arduino software (to be downloaded from the Arduino web site – see procedure)
- Microsoft Excel
- Weatherstripping (indoor setup)
- 9/16-inch socket driver
- Laboratory tape
- Permanent marker

Battery Changing and Charging

Changing and charging any battery should be performed with caution. The batteries used in the CSAM (LiFePO4) carry a large amount of energy in a very small space. A damaged battery can potentially cause explosion, fire, or burns. Inspect the batteries carefully on site visits, and replace any battery that exhibits signs of malfunction such as smoke, excess heat, foul odor, etc. Always completely remove the batteries from the battery case before charging.

Cautions

- Always get rid of static electricity before touching electronics by touching a metal object such as the CSAM case.
- Do not short circuit the red (+) and black (-) terminals with any metal tools or objects.
- Do not get the batteries wet.
- Do not heat the batteries above 60 ºC (140 ºF) or expose it to fire.
- Do not disassemble, crush, or modify the batteries.
- Stop using a battery if you detect any unusual condition such as excess heat or foul odor, or if you observe any physical damage.
- Do not charge the battery while it is powering the CSAM.
- Never charge the batteries while they are inside the battery case.

Procedure: Change Battery

1. Unplug the CSAM from the battery case (Figure 28).
2. Unlock both the top and bottom of the battery case with the key provided (Figure 29). The case contains two batteries labeled with a date written on laboratory tape, two red cables, two black cables, and mounting hardware.

Figure 28


Figure 29

3. Check the date on the battery labels (Figure 30). If the CSAM is not expected to be visited again before the date labeled on the batteries, the batteries must be changed.
4. Making sure not to short circuit the red (+) and black (-) terminals with any metal tools or objects, disconnect the batteries from the unit by first disconnecting the black wire from each battery (1, 2) and then the red wire from each battery (3, 4), as shown in Figure 30.

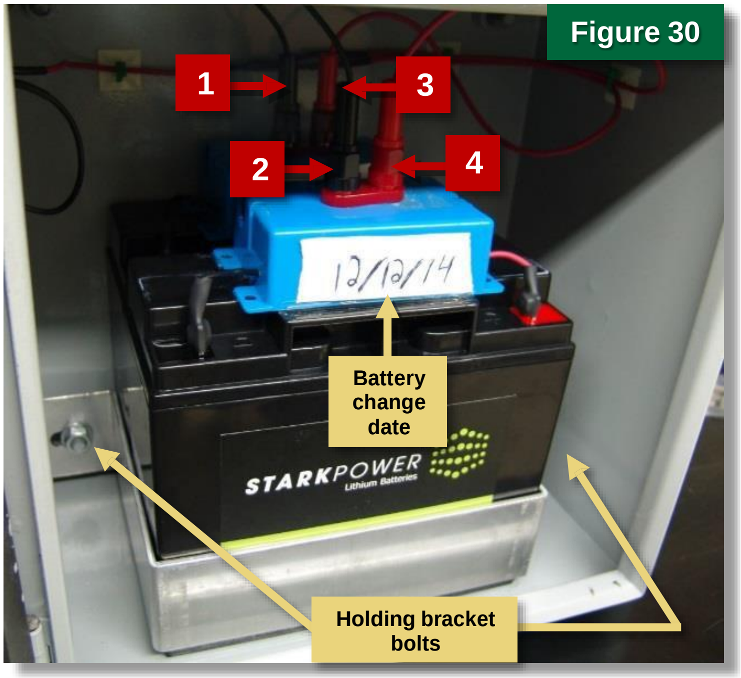


Figure 30

5. Loosen the bolts on the holding bracket by turning them counterclockwise using a 9/16-inch socket driver (not provided) until the bracket is loose enough for the batteries to be lifted out of the case (Figure 31).
6. Remove the batteries from the case and set them aside.
7. Take two fully charged batteries out of the boxes used for transport.
8. Using laboratory tape and a permanent marker such as a Sharpie, add a label with a date 7 days in the future. This date is the latest these batteries should be attempted to be used without being replaced or recharged.

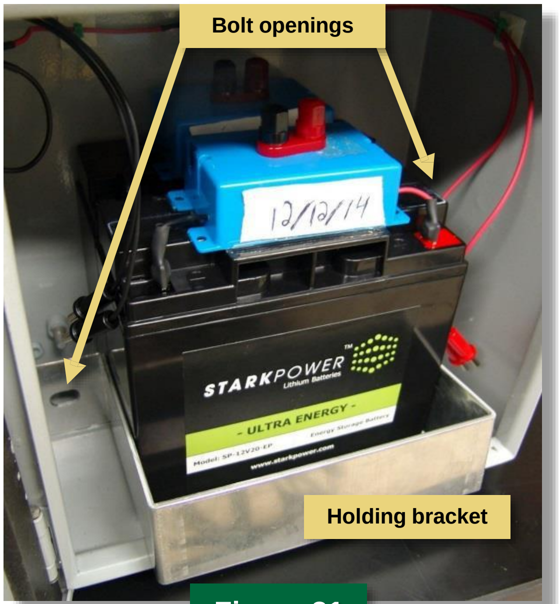


Figure 31

9. Place the two fully charged batteries into the battery case, and place the holding bracket around the bottom of the batteries, as shown in Figure 31.
10. Insert the bolts in the openings in the holding bracket and tighten by turning them clockwise using the 9/16-inch socket driver until the batteries are held firmly in place.
11. Connect the batteries to the unit by first connecting the black wire from each battery (1, 2) and then the red wire from each battery (3, 4) as shown in Figure 30.
12. Place the depleted batteries in the empty boxes that contained the fully charged batteries for transport to the recharging location.
13. Close and lock the battery case.
14. Plug the CSAM into the battery case to resume operation.
15. Log the time and date of the battery change in the field operations notebook or other designated project documentation.

Procedure: Charge Battery

1. Place the battery to be charged on a flat surface that is free of clutter or debris within the provided charger's reach of a standard 110 V AC wall outlet.
2. Making sure not to short circuit the red (+) and black (-) terminals with any metal tools or objects, connect the black charger cable to the black (-) terminal and the red charger cable to the red (+) terminal.
3. Plug the charger into the 110 V AC standard wall outlet (Figure 32). When the LED on the charger turns green, the battery is fully charged. This can take up to 20 hours per battery, but does not require constant supervision.
4. When the battery is fully charged, unplug the charger from the wall before disconnecting the battery.
5. Disconnect the black charger cable from the black (-) terminal and the red charger cable from the red (+) terminal, making sure not to short circuit the terminals with any metal tools or objects.

Cautions

- Always connect the charger to the battery before plugging it into the wall outlet.
- After the battery is fully charged, be sure to unplug the charger from the wall outlet before disconnecting the battery.

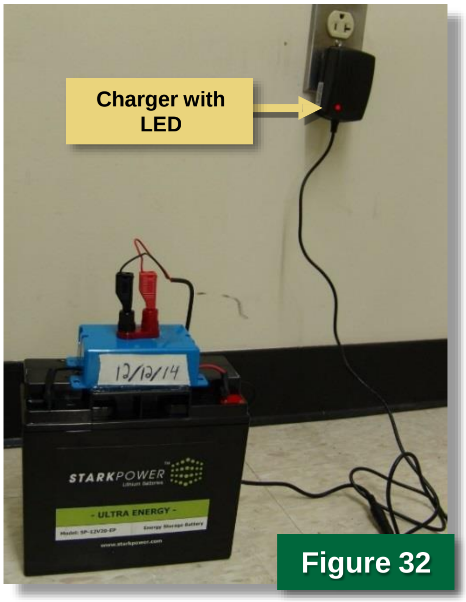


Figure 32

6. Label the battery “Full Charge” with the date using laboratory tape and a permanent marker.
7. Place the battery in the battery box for storage and transport.
8. Repeat as needed until all batteries are fully charged.

CSAM Setup

The CSAM can be set up for outdoor or indoor use. See the Quality Assurance Guidelines for site selection and positioning requirements for the CSAM unit. Sites should be selected by the project team at the beginning of the project. The procedures provided here are for an outdoor rooftop or ground location or for indoor window placement. The required equipment differs for each location, as noted in “What You Will Need” at the beginning of this section.

Procedure: Place on Rooftop or Ground

1. Select a flat roof or ground location that has no obstructions within at least 3 meters (10 feet) of the equipment. It should not be placed under trees or where water from gutters or down spouts would impact it.
2. Make sure no electrical or physical hazards are in the immediate vicinity of the setup. Select a location that is at least 1 meter from any vertical wall if at all possible so that air flow around the monitor is not impeded.
3. Unfold the tripod, insert the mast pole into the top hole of the tripod, and extend the mast downward until it rests on the surface of the rooftop or ground (Figure 33).
4. Screw in the two sets of fasteners around the mast until it is held securely.
5. Place the battery box at the bottom of the tripod and secure it to the tripod mast using the cable with turnbuckle. The cable should be placed over a tripod brace, as shown in Figure 33, and connected to the eyebolts on the battery case to prevent the setup from tipping or blowing over. The cable can be tightened or loosened using the turnbuckle.
6. Once the tripod is secure, install the rain shield on the mast approximately 5 feet above the surface of the roof by sliding the mast through the back of the shield and tighten the bolts on the back (Figure 34) until the rain shield is secure.
7. Lift the top of the rain shield and push it backwards so it is out of the way when installing the CSAM.

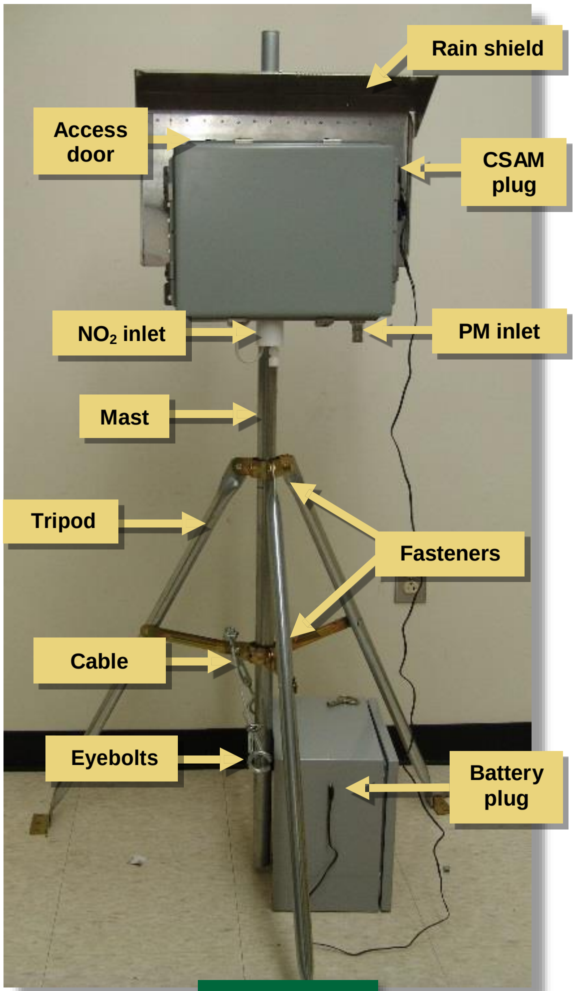


Figure 33

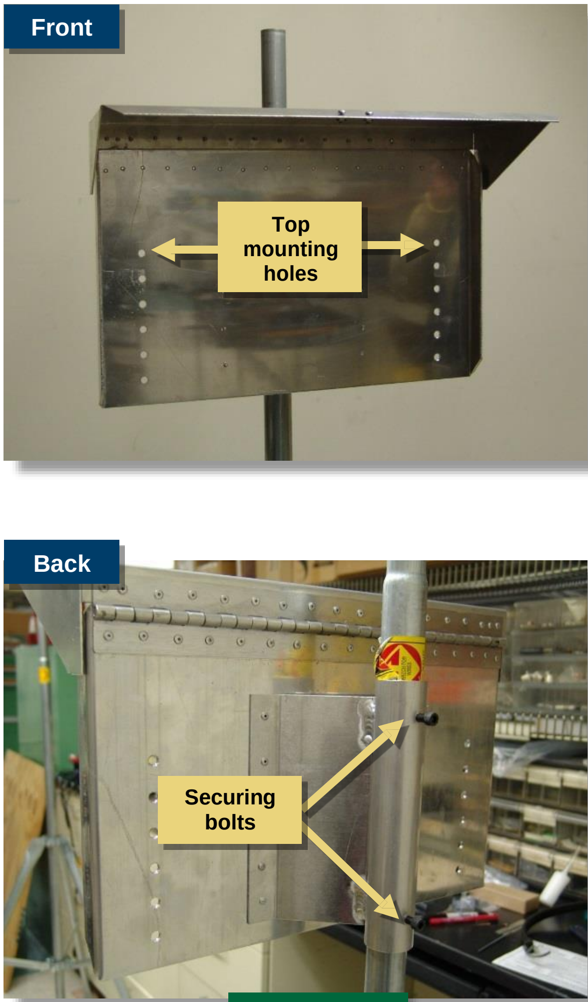


Figure 34

8. Fasten the CSAM in the top mounting holes of the rain shield (Figure 34) by placing the bolts provided through the top mounting brackets of the CSAM (Figure 34). The PM and NO_2 inlets should be pointing downwards and the access door should be on top as shown in Figure 33. Make sure the CSAM is centered over one of the tripod legs to stabilize the setup and keep it from tipping over.

9. When ready to initiate data collection, plug the CSAM into the battery case.

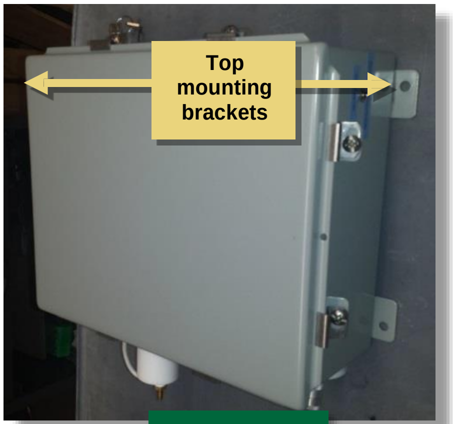


Figure 35

Procedure: Place in Window

1. Place the CSAM unit on a flat, stable surface near a window.
2. Connect the provided Teflon tubing to the NO_2 inlet as shown in Figure 36. Teflon or stainless steel is the preferred tubing choice.
3. Connect the adaptor to the PM Inlet (Figure 37), and then attach the provided tubing, as shown in Figure 38.

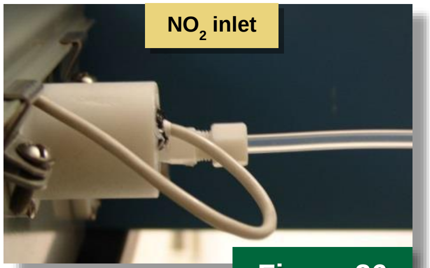


Figure 36

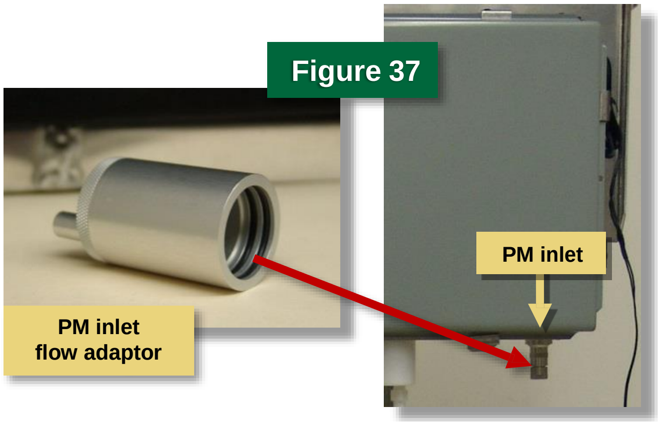


Figure 37

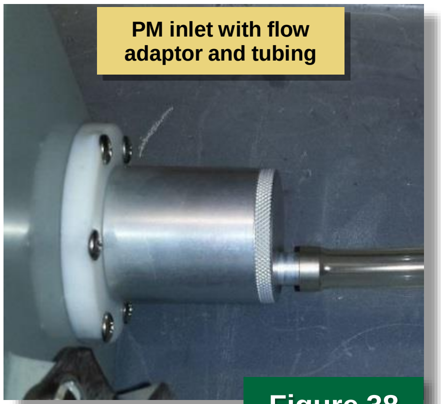


Figure 38

4. Open the window and run the sampling lines through the metal tubing protector, as shown in Figure 39, so that the ends of the sampling lines are outside the window and the tubing protector rests on the window sill. The tubing protector will prevent damage (such as crushing or crimping) to the sampling lines when the window is closed.


Figure 39

5. Fill the opening between the sill and window sash with weatherstripping (not provided) as needed to prevent outside air from getting inside.
6. When ready to initiate data collection, plug the CSAM into the battery case or use the provided AC adaptor (Figure 40) to connect to a wall outlet.


Figure 40

Routine Data Collection

Once the CSAM is set up properly, data collection can begin. The CSAM can collect data continuously for 7 days on battery power. The unit automatically saves data files every 24 hours at midnight, with file names based on the date and time (military) data collection began. For example, the file name 12080000.TXT denotes that sampling for a 24-hour period began on December 8 (1208) at midnight (0000). The following procedures will guide you through initiating data collection and retrieving and processing the data.

Procedure: Collect Data

1. Connect the CSAM to a power supply either by plugging the AC-DC adaptor into a wall outlet or by plugging it into the CSAM battery pack.
2. Use the key provided with the CSAM unit to open the access door (Figure 41).
3. Make sure the SD card is inserted properly into its slot (Figure 42). The LED at the top right of the access door (Figure 41) will light up if the card is not inserted correctly.
4. Close and lock the access door and put the key in a secure location.

The CSAM will begin taking data automatically. You should hear the pumps making a quiet buzzing sound.

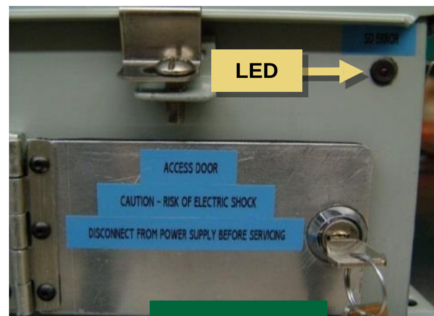


Figure 41

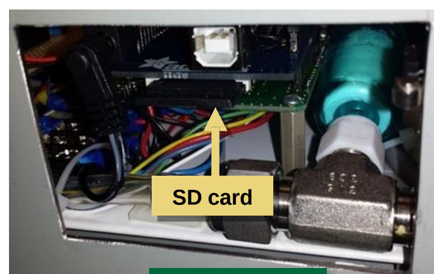


Figure 42

Procedure: Retrieve Data

Note: This procedure is required only if the CSAM unit will continue collecting data in the field. If the unit is being removed from field operation, data retrieval can be carried out at the data processing location.

1. Disconnect the CSAM from its power supply.
2. Open the access door (Figure 41). The CSAM will cease monitoring.
3. Pull out the SD card (Figure 42) for transport to the data processing location.
4. Insert a new SD card into the slot. If not properly inserted, the LED at the top right of the access door (Figure 41) will illuminate.
5. Close and lock the access door to resume sampling.

Processing Data

This procedure explains how to create a new Excel spreadsheet for processing and interpreting your collected data. A CD with a Microsoft Excel macro-enabled spreadsheet, **CSAM Data Analysis [Serial No. XX].xlsm**, accompanies each CSAM (Figure 43). This spreadsheet was created specifically for processing field data relative to the performance-check data, which allows you to assess the quality and usability of the collected data. The CSAM unit's two-digit serial number is part of the file name so that the spreadsheet can easily be matched with its associated unit if more than one CSAM is deployed in the field.

The CSAM Data Analysis spreadsheet contains the performance-check data recorded at the start, and possibly the end, of the study by an experienced operator. You will use this spreadsheet in combination with the data text files generated by the CSAM to create the data-processing spreadsheet, as described in the procedure below. The spreadsheet is locked so that the performance-check data cannot be accidentally changed. The **Load Data, Perform Calculations, Graph Processed Data** button is the only active part of the spreadsheet and is all that is needed for creating the spreadsheet containing the processed data.

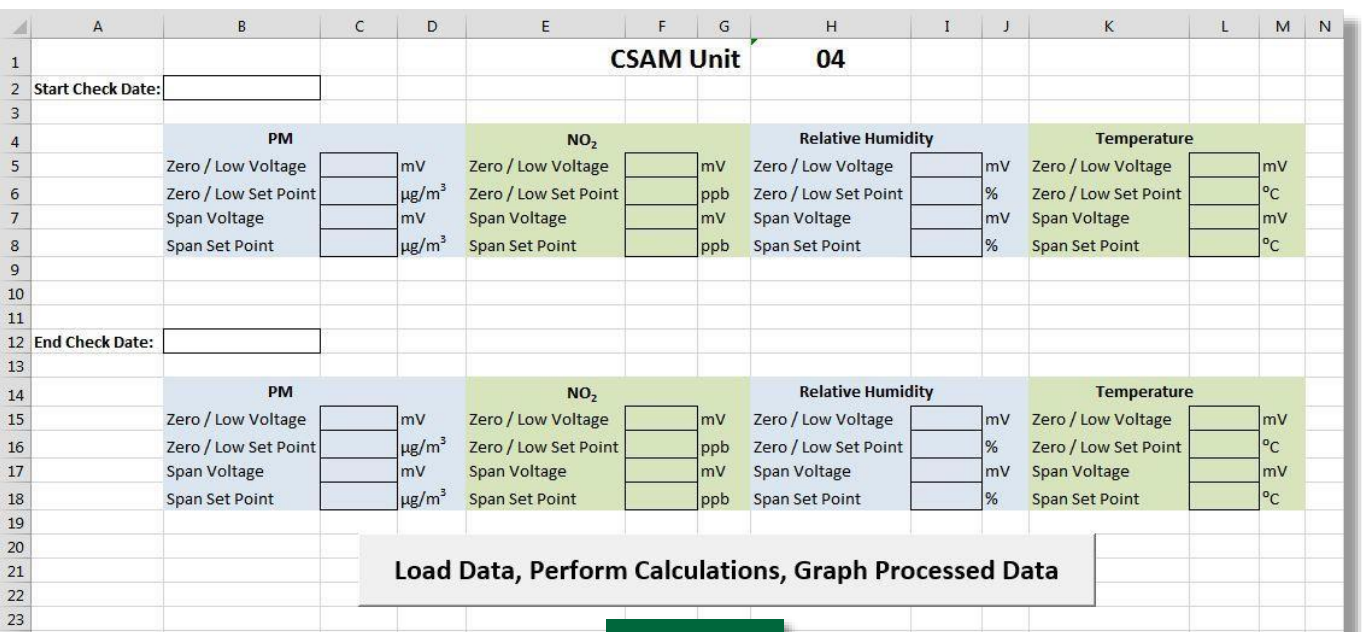


Figure 43

The new spreadsheet created during this procedure will be saved automatically in a folder named **CSAM Output** in your main **Documents** folder. The spreadsheet file name will be based on the time and date the spreadsheet was created. The example file used here to explain this procedure is named **(2014-Dec-17)14.36.37.ProcessedDataFile.xlsx.**

This spreadsheet automatically converts the voltage data (raw data) produced by the CSAM to the measurement units (final data) required for interpreting the data (NO_2 [ppb], PM [µg/m^3], temperature [°C], and RH [% at °C]). The generated spreadsheet has multiple tabs:

- The **Files** tab (Figure 44) lists the data text files, in order by date and time created by the CSAM, that were selected to be processed. This tab also shows where the newly created spreadsheet was saved, i.e., **Net My Documents\CSAM Output**.

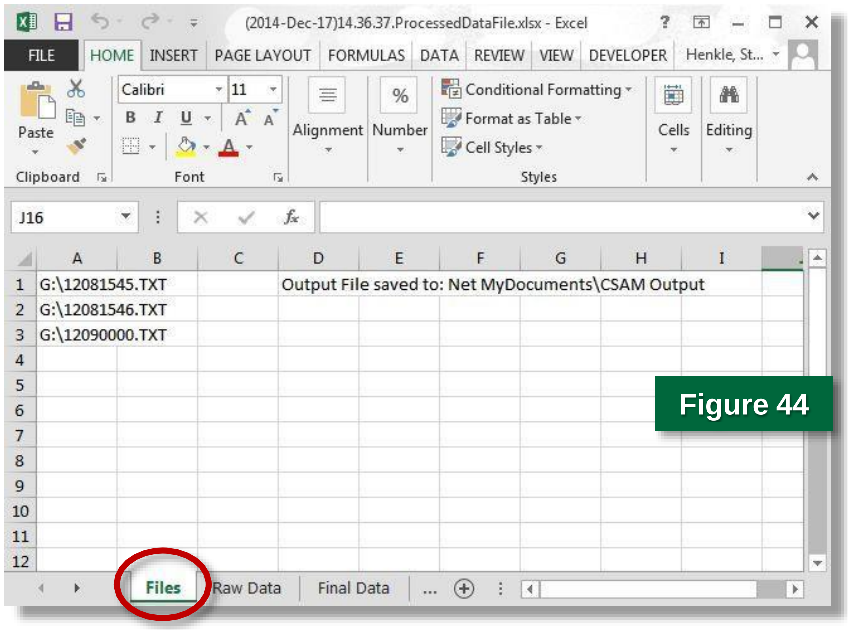


Figure 44

- The **Raw Data** tab (Figure 45) shows the data recorded by the CSAM in its originally collected format using the CSAM's programmed voltage values (mV).

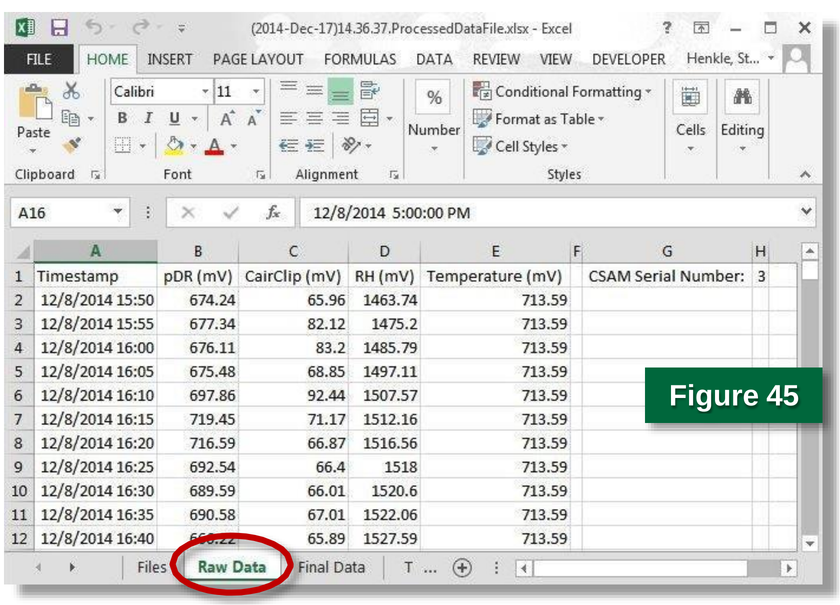
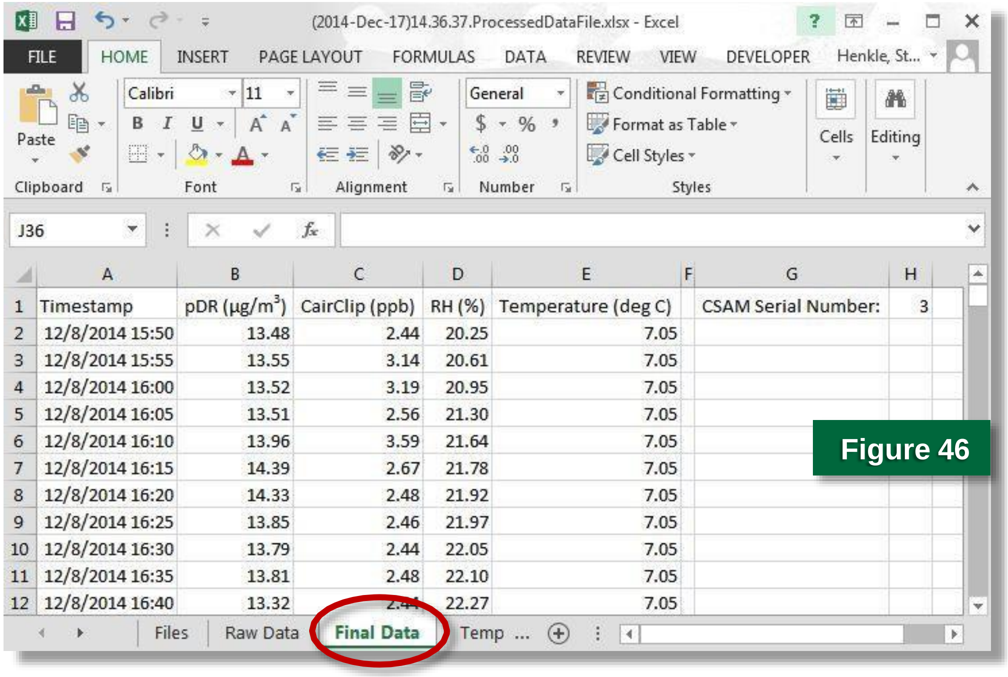


Figure 45

❖ The **Final Data** tab (Figure 46) contains the processed data from all sensors reported in the concentration and temperature and RH units needed for understanding the data.



	A	B	C	D	E	F	G	H
1	Timestamp	pDR (µg/m³)	CairClip (ppb)	RH (%)	Temperature (deg C)		CSAM Serial Number:	3
2	12/8/2014 15:50	13.48	2.44	20.25	7.05			
3	12/8/2014 15:55	13.55	3.14	20.61	7.05			
4	12/8/2014 16:00	13.52	3.19	20.95	7.05			
5	12/8/2014 16:05	13.51	2.56	21.30	7.05			
6	12/8/2014 16:10	13.96	3.59	21.64	7.05			
7	12/8/2014 16:15	14.39	2.67	21.78	7.05			
8	12/8/2014 16:20	14.33	2.48	21.92	7.05			
9	12/8/2014 16:25	13.85	2.46	21.97	7.05			
10	12/8/2014 16:30	13.79	2.44	22.05	7.05			
11	12/8/2014 16:35	13.81	2.48	22.10	7.05			
12	12/8/2014 16:40	13.32	[illegible]	22.27	7.05			

Figure 46

❖ The last four tabs—**Temperature, RH, CairClip,** and **pDR**—contain full-page graphs of the data from each sensor. As an example, the graphed data from the RH sensor is shown in Figure 47.

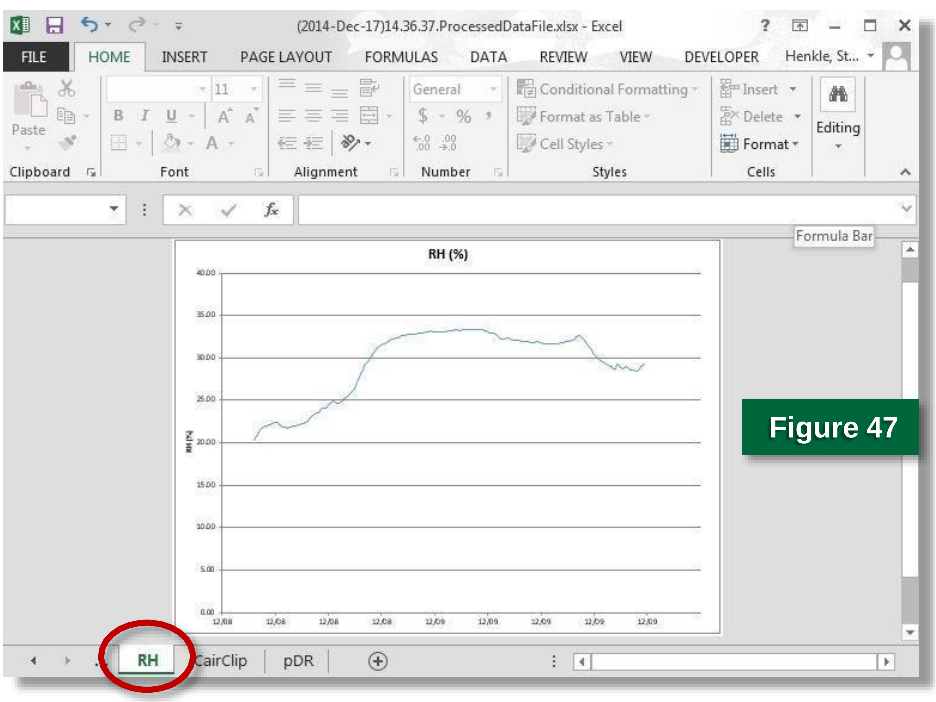


Figure 47

Procedure: Process Data

1. Plug the provided SD card reader into the computer using a USB cable (Figure 48).
2. Insert the SD card into the reader.
3. Create a new folder on your computer to contain the files.
4. Using Windows Explorer, transfer the files from the SD card to the newly created folder.
5. After transferring the files, pull the SD card out of the reader and reserve it for the next use with the CSAM.
6. Open the **CSAM Data Analysis.xlsm** macro-enabled Excel spreadsheet (Figure 43).
7. Click the **Load Data, Perform Calculations, Graph Processed Data** button.

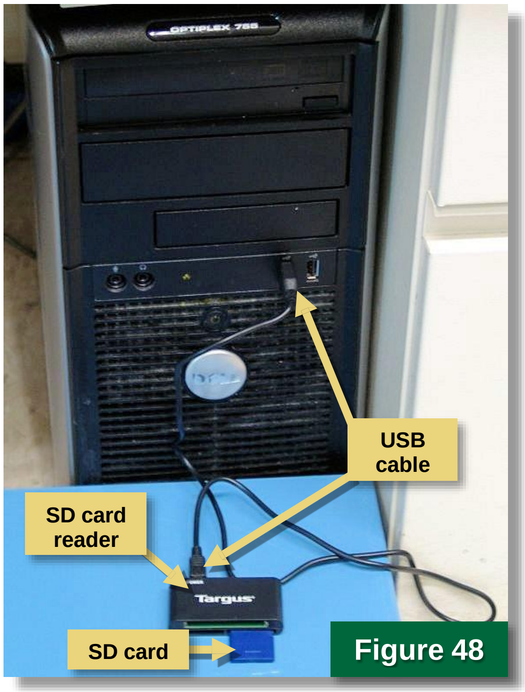


Figure 48

8. When prompted, select all the CSAM data files you want to process at once by holding down the **Shift** or **Control** keys while clicking each file.
9. Click **OK**. The new spreadsheet file of processed data will be created in your main **Documents** folder as described above.

For Additional Help

CairPol, Technical Data Sheet CairClip NO_2, http://www.cairpol.com/images/pdf/NO2/technical%20datasheet%20no2%2015072013.pdf, last accessed October 30, 2014.

Thermo Scientific Personal DataRAM pDR-1000AN Instruction Manual, http://www.envirosupply.net/manuals/ThermoElectron_PersonalDataRAM_pDR-1000AN-1200.pdf, last accessed December 17, 2014.

Thermo Scientific Personal DataRAM pDR-1000AN Monitor brochure, http://www.thermoscientific.com/en/product/personal-dataram-pdr-1000an-monitor.html, last accessed December 17, 2014.

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Attachment D ICC_EPA_RARE Training Agenda

Agenda for January 22 CSAM Training

ICC, EPA Region 2, EPA ORD

Time	Activity
9:30---9:45	Project Overview
9:45---10:30	Assembly Example
10:30---11:00	Components and Flow
11:00---11:30	Battery and Electrical Safety
11:30---12:15	Data Collection
12:15---1:00	Lunch
1:00---2:30	Re---Assembly Practice
2:30---3:30	Output Datasets and Software
3:30---4:00	How to Move Instruments
4:00---4:30	Siting Considerations
4:30---5:00	Troubleshooting and FAQs

Agenda is subject to change; times are estimates. Overview in morning; hands-on experience in afternoon.

1. **Project Overview**
    a. Pollutants measured
    b. Data considerations (e.g., benefits/limitations of sensors)
    c. Context of measurements – sources, sites, potential exposures, interpretation, etc.
2. **Assembly Example**
    a. One CSAM unit will be unboxed and ready for assembly with all components laid out in a manner to easily demonstrate how a CSAM would be assembled in the field.
    b. Starting with the monitoring stand itself, describe its features, caveats, and how other parts integrate with it.
    c. Assemble the stand, rain shield and place a battery box in its normal position and describe its features, caveats, and integration with other parts.
3. **Components and Flow**
    a. Next, take the cover off a CSAM unit and describe its features to the group. Work first on the outside of the box. Name each part and its function. Describe how to use each part (and when).
    b. Next, name and describe each component of the electrical input connector. Describe how people can use either the battery connection or the AC/DC adapter. Talk about electrical safety and the components of the interior. Describe where energized circuits are and how one should always be cautious around any energized circuits. Indicate no beverages should be handled when working with the CSAM (open or closed). Indicate that users should get rid of static electricity before they do anything with the unit. Show them how to get rid of static electricity by making contact with a grounded component of the monitoring stand. This is especially vital before touch the Arduino and the data card.
    c. Next, name and trace (visually with your finger) how air comes into the CairClip. Describe how this is an active sampler and air is pulled into the unit through the Teflon fitting/snorkel tube.
    d. Show how the snorkel tube would be connected. Instruct them that Teflon Swagelok fittings need to be handled carefully and that all they need to do is turn it until is it snug (finger tight). Make sure that you have the proper Swagelok ferrule and nut on the Teflon tubing; otherwise, you will not be able to show how the tubing is actually connected. The ferrule should be set in advance at the proper depth before attempting to show this action.
    e. Describe the fact that there is a short time delay between air coming into the tubing and it being detected. You should be able to describe this in exact seconds after the units are challenged in the lab. They will need this offset value, which should be approximately ~ 1 minute.
    f. Describe how there is an internal particulate matter filter in the CairClip and that it has to be changed every 4 months if it was operating 24 hours/day. Show where that filter is located and how to get to it. There is no way of determining when the filter needs changing (there is no diagnostic) but the 24 hr/4 months rule should be applied. This would equate to ~ 2880 hours of sensor run time. Describe the fact that to zero or calibrate the CairClip, one would have to either place the device in a

chamber or provide challenge gas to it via the snorkel tubing.

g. Trace the flow of particles into the BGI cyclone through the pDR to the HEPA filter and the SKC pump. Describe the fact that the intake of the cyclone is not visible. Describe how a cyclone works and that the "cup" should be removed and blown out at least monthly. They may or may not actually see large particles in the cup under normal use.
h. Instruct about the need to ensure proper connections between the cyclone, pDR, pump, and all tubing. The interior of the unit should be inspected after every 7 days of operation as a general practice to check for good connections, wiring harnesses, etc.
i. Instruct on how they should connect a zero calibration device to the cyclone. Say that it is needed to both check flow rate as well as to perform the zeroing activities.
j. With the CSAM now energized, demonstrate how to adjust flow rate to 1.5 lpm. Next, show how to do a zeroing activity. Show how the snorkel tube must be connected to the calibration cap for it to be used.
k. Closing up the CSAM unit, show how to connect it to a stand.

4. **Battery and Electrical Safety**
    a. Connect the unit to a power supply (battery box). With one of the other CSAM battery boxes, show how to recharge the li-ion batteries and for how long they should be recharged.
    b. Describe the recharge time and general safety considerations associated with any recharge event (excessive heat, smoke, melting of wires, etc) should be checked for each time a recharge event takes place.
    c. Describe the fact that li-ion batteries are different from standard lead---acid batteries and behave differently (poorly) if taken to too low a power state.
    d. For the purposes of this work, a 7-day operation schedule should be used.
5. **Data Collection**
    a. Using the Operating Procedure, work through each step of data collection and data recovery.
    b. Talk about the operation of the door, the micro---switch, and the SD card.
    c. Indicate the automatic start and stop of the unit when the door is closed or open.
    d. Instruct on what a pDR measures (light scattering) and that an algorithm (internal) has been established for the unit to estimate ug/m^3 of $PM_{2.5}$. Even so, they should establish a regression equation using data from the CSAM (24-hr averages) with the local air monitoring station involving at least 7 days of operation (7 data points). The resulting equation should then be applied to the raw CSAM data when they use it to "normalize" the response to local aerosol properties.
    e. Ensure that one of the SD cards in one of the CSAM units has data on it. Show how to pull out the card from the circuit.
    f. Talk about the SD card reader and its connection to a PC.
6. **Re-Assembly Practice**
    a. Disassemble all instruments during lunch, and then have participants re-assemble them
    b. Take the unit you assembled during the class apart and then have participants assemble the unit in good working order. Start first with the physical stuff

(stand/rain shield, battery box) and then integration of the CSAM unit on the stand.

   c. Go through a complete cycle of start-up, take down, data recovery, etc.

7. **Output Datasets and Software**
   a. Working through the operating procedure, instruct on how to download the Arduino software.
   b. Demonstrate how the zero and calibration macro components work. Describe the fact that putting in the wrong values in that step would have serious impacts on the data as the macro uses that information to establish the algorithm being applied.
   c. Recover the data file and execute the macro so that data is visualized.
   d. Discuss how the data file should be saved.
   e. Discuss cleaning the SD card (deleting the original file) only after duplicate copies of the original data exist preferably on two devices (it could be two flash drives, one computer/one flash drive, two computers, etc).
8. **How to Move Instruments**
   a. Describe sensitivity of scientific instrumentation
   b. Discuss best practices for handling, packing, and assembling CSAM units
9. **Siting Considerations**
   a. Discuss siting of CSAM with respect to intake tubes
   b. Discuss installation of units to ensure proper collection of measurements
10. **Troubleshooting and FAQs**
    a. What happens in very cold weather?

Appendix B: CSAM Quality Assurance Guidelines

United States
Environmental Protection
Agency

EPA 600/R-15/008

CITIZEN SCIENCE
AIR MONITOR (CSAM)

Quality Assurance Guidelines

Office of Research and Development
National Exposure Research Laboratory

Contents

The Citizen Science Toolbox

Many communities in the United States are potentially impacted by a wide variety of environmental pollution sources. The U.S. Environmental Protection Agency (EPA) encourages communities to advocate for environmental and public health mitigations and to raise awareness of air pollution issues. To this end, EPA promotes citizen science to involve citizens in collecting environmental data of importance to their families and communities.

The Ironbound Community Corporation (ICC) Community Advisory Board (CAB) in Newark, NJ, is committed to improving air quality for thousands of Newark residents who suffer from potential cumulative impacts of major industrial and port-related pollution sources on human health and the environment. EPA Region 2, the EPA region that serves Newark, has been a leader in EPA's efforts to promote citizen science. For this project, these two groups—the ICC CAB and EPA Region 2—are working together to initiate a community-based environmental monitoring study.

As part of this study, EPA is developing a Citizen Science Toolbox that contains the tools and information needed for the ICC CAB citizens to collect pollution data for nitrogen dioxide (NO_2) and particulate matter (PM), two types of air pollution that can have significant adverse health effects. Citizen volunteers will use a monitoring device called the Citizen Science Air Monitor (CSAM), which was designed and constructed by EPA for use by citizen volunteers. The documentation in this project's Citizen Science Toolbox was created specifically for use of the CSAM and includes an operating procedure, which provides information on how to set up the instrument and collect and process data, and these quality assurance (QA) guidelines, which offer basic information and considerations for collecting meaningful data. EPA Region 2 personnel will provide technical support as needed to the ICC CAB throughout the project.

This collaborative project will benefit both the Newark community and EPA. It will help the ICC CAB identify pollutants in its community that are of concern for both human health and the environment. The effort also will further EPA's aims of building community capacity for conducting environmental monitoring studies and will form the foundation for Region 2's Air Sensor Loan Program that will enable other community groups with similar concerns about air pollution in their neighborhoods.

What Is Quality Assurance?

Quality assurance is the process by which you determine if the environmental data collected in your monitoring project are credible and usable. The quality assurance process involves several steps, which EPA has termed PIE—Planning + Implementing + Evaluating. Each piece of PIE is vital to achieving quality results from your project. These quality assurance guidelines focus on specific CSAM requirements and are not meant to fully capture everything you need to know about conducting a credible air monitoring study. To learn more about planning and implementing your project and assuring the quality of the collected data, visit the following EPA web pages:

- Air Sensor Toolbox for Citizen Scientists—general tools and information for conducting a Citizen Science air monitoring project (http://www.epa.gov/heasd/airsensortoolbox).
- EPA's *Air Sensors Guidebook*—what sensor users need to understand if they are to collect meaningful air quality data (http://www.epa.gov/airscience/docs/air-sensor-guidebook.pdf).
- EPA Region 2 Citizen Science—guidelines for planning–implementing–evaluating and developing a quality assurance project plan (http://www.epa.gov/region2/citizenscience)

CSAM Components

The CSAM simultaneously measures NO_2 and PM along with temperature and relative humidity (RH). NO_2 and PM are pollutants of concern in the ambient environment because of the adverse health risks they pose, as described below. (For more information on these air pollutants visit http://www.epa.gov/airquality/urbanair/ and http://www.epa.gov/air/criteria.html.) While the CSAM is designed for easy operation and retrieval of data for all measurements at once (see the CSAM Operating Procedure), the unit consists of several components that generate the data. Citizen volunteers will not need to operate each component of the CSAM separately, but a general knowledge of the components that make up the CSAM will aid in understanding the requirements for data quality. Figure 1 shows the inside of the CSAM unit and its separate components. Each of these components is described in detail in the following subsections. Table 1 lists the measurement units reported by each component.

CSAM-NO_2

NO_2 is a highly reactive gas that can irritate the lungs and cause bronchitis, pneumonia, and other respiratory problems. NO_2 pollution is both man-made and naturally occurring. It occurs naturally as a result of atmospheric processes. It also forms from fuel combustion and forms quickly from automobile emissions. Therefore, significant increases in NO_2 concentrations are often found near major roadways. Power plants and other industrial processes also emit NO_2.

CSAM measurements of NO_2 are made using a CairPol CairClip NO_2 sensor (http://www.cairpol.com/index.php?option=com_content&view=article&id=41&Itemid=156&lang=en). The CairClip uses a gas-specific inlet filter combined with dynamic air sampling in an integrated system to measure real-time gas concentration in parts per billion (ppb). The CSAM-NO_2 unit's detection limit—the lowest concentration the instrument is likely to detect is approximately 20 ppb NO_2.

CSAM-PM

PM consists of particles of various sizes such as soot, smoke, dirt, and dust. These particles are often generated and released into the air from sources such as power plants, industrial and agricultural processes, automobiles, and fires. PM can adversely affect breathing and aggravate respiratory and cardiovascular conditions, with the smallest particles posing the greatest health risk. PM also contributes to atmospheric haze that reduces visibility.

The CSAM-PM component measures real-time PM in micrograms per cubic meter (μg/m^3) using a Thermo Scientific *personal* DataRAM nephelometer, a device that uses light to measure the concentration of suspended particles in a liquid or gas. Air is pumped to the nephelometer by an SKC AirChek 52 personal sampling pump. The nephelometer uses a BGI sharp-cut cyclone inlet (SCC 1.062), which excludes particles with a diameter above a certain size. In this case, the CSAM-PM samples for $PM_{2.5}$, which consists of particles less than 2.5 micrometers in diameter, or “fine” particles. Fine particles come from all types of combustion activities, such as motor vehicles, power plants, and wood burning, and pose the greatest health risk because they can lodge deeply in the lungs. The CSAM-PM unit operates at a flow rate of 1.5 liters per minute (L/min). It is important to understand that a change in flow rate will change the diameter of the particles being sampled and thus affect data quality. If a change in flow rate is noted, the unit should be removed from operation, and an experienced operator should perform the flow rate check and adjustment detailed in the CSAM Operating Procedure. The CSAM-PM has a detection limit of 0.1 μg/m^3.

Temperature and Relative Humidity

The CSAM also contains a Honeywell temperature and RH sensor (HIH-4602-A/C series). Temperature (ºC) and RH (% at ºC) data are recorded along with the PM and NO_2 concentration data. The recommended operating ranges for temperature and RH are 0–40 ºC (32–104 ºF) and 0–90% RH (with no formation of water droplets), respectively. Abrupt changes in temperature and RH can affect the performance of your CSAM, particularly the CSAM-NO_2 sensor component. Therefore, temperature and RH data collected concurrently with concentration data can help you recognize any performance issues caused by environmental conditions.

Microprocessor

Data from all components—PM, NO_2, and temperature and RH—are collected and stored using an Arduino Uno microprocessor. The Arduino Uno has a USB connection and a power jack. This microprocessor uses software developed by EPA to allow operators to retrieve all data from the unit in one easy step. Data will be stored on a secure digital (SD) memory card located in the microprocessor that the citizen operators access and remove for data download as described in the CSAM Operating Procedure.

CSAM

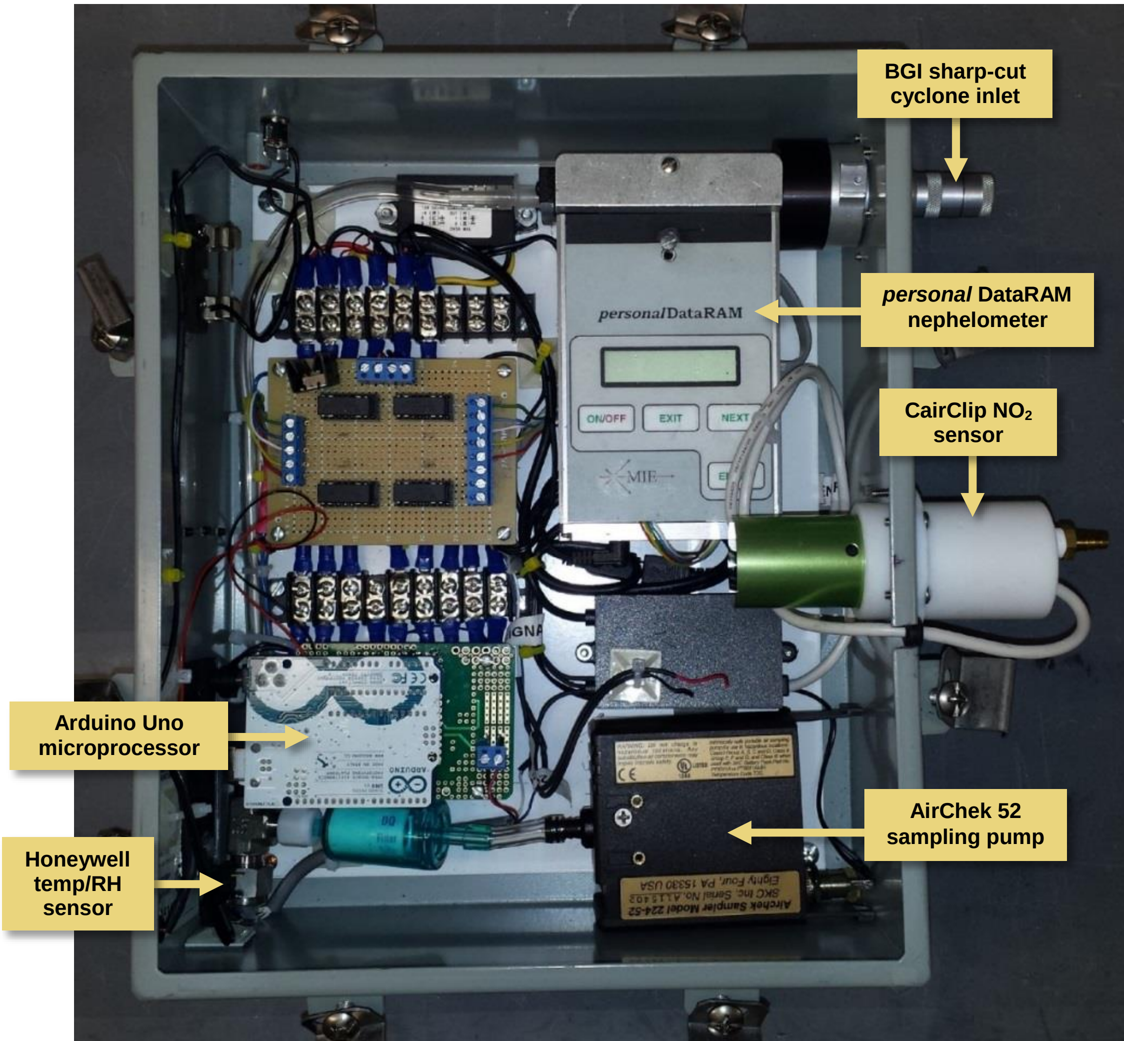

Figure 1

Measurement	Reporting Unit
NO_2 concentration	Parts per billion (ppb)
PM concentration	Micrograms per cubic meter (µg/m^3)
Temperature	Degrees Celsius (°C)
Relative humidity (RH)	Percent (%) at °C

Table 1

Important Considerations for Air Monitor Placement

Appropriate placement of air monitoring devices is critical for collecting useful data. Air pollution concentrations can vary considerably due to factors such as proximity of the pollutant sources, buildings and other obstructions, and atmospheric conditions. For these reasons, you must plan monitoring locations carefully to make sure the collected data are representative of the community you are monitoring and that meet your study objectives. EPA Region 2 and the Ironbound CAG will work together to identify the CSAM locations for this study. The following are some important considerations for choosing representative sampling sites:

- **Local atmospheric conditions.** Factors such as rain, wind, sunlight, clouds, temperature, and humidity can affect your CSAM data.
    - Make sure the unit is protected from the effects of weather using the individual EPA-developed aluminum shields that accompany your CSAM unit.
    - Temperature and humidity can particularly affect the performance of the CSAM. The recommended operating ranges for temperature and RH are 0–40 ºC (32–104 ºF) and 0–90% RH (with no formation of water droplets), respectively.
    - Wind speed and direction can also affect CSAM measurements. For example, stagnant air can lead to pollutant concentrations that gradually increase, whereas strong winds can decrease concentrations by spreading pollutants over a larger area. Higher winds can also lead to higher concentrations of other pollutants such as dust. Wind direction can affect your results by increasing or decreasing concentrations depending on whether your air monitor is located upwind or downwind of the prevailing wind at the time of data collection. Understanding the effects of wind can aid in choosing a monitoring site and in recognizing when your results might have been affected by wind.
- **Primary or secondary source.** Some pollutants are emitted directly by a source (primary pollutants), while others are formed as the products of chemical reactions in the air (secondary pollutants). Primary pollutants are often more localized (i.e., near the source) and can have a greater variability over distances than secondary pollutants. It is important to consider whether a pollutant of interest is primary or secondary when deciding where and how to collect monitoring data. More information can be found at: http://www.epa.gov/air/criteria.html.
- **Location of pollutant sources relative to the pollutant of interest.** NO_2 and PM, for instance, might have much higher concentrations closer to a roadway as both come from automobile emissions. If you want to find out how a roadway influences NO_2 and PM concentrations, you could locate one CSAM close to the road and one some distance downwind of the roadway to determine the changes in concentrations.
- **Location of the air monitor relative to the exposed population.** If the aim of your study, for example, is to measure the impact of industrial emissions of NO_2 and PM on a

particular neighborhood, the CSAMs could be placed within the neighborhood at varying distances from the facility rather.

- **Air flow.** Make sure air flows freely to your CSAM unit by placing it far enough away from the ground (at least 1 meter above the surface) and away from building surfaces, trees, or any other obstructions to flow (ideally at least 1 meter away).
- **Reactions and interferences.** Sensors can experience interference from other chemicals in the atmosphere, as well as heat and cold, which can lead to erroneous concentration estimates. Avoid placing the CSAM near sources of heat or cold and gases that can react with the pollutant of interest. Possible interferences for the CSAM-NO_2 component include high concentrations of chlorine (a commonly used disinfectant for swimming pools) and ozone (often formed during warm, dry, and cloudless days with low wind speeds).

EPA's *Air Sensor Guidebook* provides additional details and considerations for choosing sites for air monitoring studies (http://www.epa.gov/airscience/docs/air-sensor-guidebook.pdf).

Performance Goals

The performance of an air sensor or instrument describes its overall ability to measure air pollution. For your data to be useful in meeting any objective, be sure your expectations for the data collected with the CSAMs are well defined. These expectations are the *performance goals* of the measurement system. The quality of data collected with sensors can vary greatly depending on sensor design and performance characteristics as well as your deployment strategy. In addition, acquiring meaningful data relies on proper operation and response of the air monitoring instrument, which must be checked and maintained regularly to continuously produce quality results. The following subsections describe general performance considerations you should keep in mind while conducting an air monitoring study, the level of quality assurance needed based on your intended application, and specific CSAM performance requirements.

Performance Characteristics That Affect Data Quality

A broad range of performance-related characteristics can affect data quality. The performance characteristics listed in Table 2 are applicable to air monitoring systems in general. A familiarity with these characteristics will allow you to assess if your air monitoring device is generating usable data throughout the study.

Evaluating Data Quality	
Performance Characteristic	**Assessment**
Bias	Is measurement routinely high or low with respect to the true value?
Precision	How repeatable is the measurement?
Calibration	Does device respond in a systematic fashion as concentration changes?
Detection limit	How low and high will the device measure successfully?
Response time	How fast does the response vary with concentration change?
Linearity of response	What is the linear or multilinear range?
Measurement duration	How much data do you need to collect?
Measurement frequency	How many collection periods are needed?
Data aggregation	Value in aggregating data (e.g., 1 second, 1 minute, 1 hour)
Selectivity/specificity	Does it respond to anything else?
Interferences	How does heat and cold affect response?
Sensor poisoning and expiration	How long will the sensor be useful?
Concentration range	Will the device cover expected highs and lows?
Drift	How stable is the response?
Accuracy of timestamp	What response output relates to the event?
Climate susceptibility	Does RH, temperature, direct sun, etc., impact data?
Data completeness	What is the uptime of the sensor?
Response to loss of power	What happens when it shuts down?

Table 2

All of the concepts described above are discussed in detail in the Air Sensor Guidebook (http://www.epa.gov/airscience/docs/air-sensor-guidebook.pdf).

An understanding of the following terms is helpful in setting your performance goals and assessing whether the collected data meet these goals:

- **Accuracy:** Accuracy is the overall agreement of an instrument's measurement to the true value obtained with an accepted reference method. Accuracy is a measure of the *bias*, or systematic error, in a system.

  Accuracy = average value - true value

- **Precision:** Precision refers to how well the sensor reproduces the measurement of a pollutant under identical circumstances.

  Precision = (standard deviation / average of replicates) x 100,

  where standard deviation is the range of variation in the measurements taken and replicate samples are two or more samples taken from the same place at the same time.

You should be aware that a sensor's accuracy and precision can change over time. For example, exposure to rapidly changing temperatures or humidity might lead to a gradual change in response, also known as *drift*.

Tables 3,4,and 5 show manufacturer's specifications for the CairClip NO_2 sensor, the *personal* Data RAM (PDR) PM sensor, and the AirChek 52 sampling pump.

Table 3

CAIRPOL
MINIATURE AIR QUALITY MONITORING SYSTEMS
P061D.OZ.Technical.Data Sheet.NO2.160812

Technical Data Sheet CairClip NO_2 (preliminary version)

(document prone to modifications)

Range	0-250 ppb (0-240 ppb analog)
Limit of detection (1, 2)	20 ppb
Repeatability at zero (1, 2)	+/- 7 ppb
Repeatability at 40% of range (1, 2)	+/- 15 %
Linearity (1, 2)	< 10%
Uncertainty	< 30% (2, 3)
Short term zero drift (1, 2, 4)	< 5 ppb / 24 H
Short term span drift (1, 2, 4)	< 1% FS (5) / 24 H
Long term zero drift (1, 2, 4)	< 10 ppb / 1 month
Long term span drift (1, 2, 4)	< 2% FS (5) / 1 month
Rise time (T10-50) (1, 2)	< 90s (180s if large variation of RH)
Fall time (T10-50) (1, 2)	< 90s (180s if large variation of RH)
Effect of interfering species (1)	Cl_2: around 80% Reduced sulphur compounds : negative interference O_3 : possible interferences if high concentration
Temperature effect on sensitivity (2)	< 0.5 % / °C
Temperature effect on zero (2)	+/- 50 ppb maximum under operating conditions
Maximum exposure	50 ppm
Annual exposure limit (1 hour average)	780 ppm (NO_2)
Annual exposure limit (1 hour average)	180 ppm of oxidant species (O_3 eq.)
Operating conditions	- 20°C to 40°C / 10 to 90% RH non-condensing 1013 mbar +/- 200 mbar
Recommended storage conditions	Temperature: between 5°C and 20°C Air relative humidity: > 15% non-condensing Ambient air free from O_3
Power supply (6)	5 VDC/200 mA (rechargeable by USB via PC or 100 V-240 V/5 V 0.8 A-1.0 A with adapter)
Communication interface	USB, UART Analog (UART & 4-20 mA / 0-5 V converter)
Dimensions	Diameter: 32mm - Length: 62mm
Weight	55g
Protection	IP42 (according IEC60529)
Electrical certification	ETL Intertek 4003892 Conform to UL Std. 61010-1 Certified to CSA Std. C22.2 N°. 61010-1 CE
Parameters Set up / Downloading	CairSoft

[1] According to our operating conditions during tests in laboratory: 20°C +/- 2°C / 50% RH +/- 10% / 1013 mbar +/- 5%
[2] Values possibly affected by exposures to high gradients of concentration
[3] In accordance with the Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe
[4] Full scale continuous exposure
[5] FS = Full Scale
[6] The complete discharge of a device (screen turned off) can lead to a deterioration of its performances
For an optimal quality of use, please keep the Cairclip in a vertical position in accordance with indications on the device

Any use of the sensor not complying with the conditions specified in herein, including exposures, even short ones ,to environments other than ambient air, to dry and / or devoid of oxygen air or other atmosphere not composed in majority of air, even during calibration, will invalidate the warranty.

Main options	CairTub: autonomy 21 days CairNet: wireless communication & battery powered by solar panel Software: CairSoft, CairMap, CairWeb

Office : CAIRPOL
ZAC du Capra
55, avenue Emile Antoine
30340 Méjannes les Alès - France

Tel: +33 (0)4 66 83 37 56
Fax: +33 (0)4 66 61 82 53
info@cairpol.com
Web site: www.cairpol.com

SARL au capital de 354 200€ - N° Siren : 492 976 253

_personal_DataRAM (PDR) Manufacturer's Suggested Specifications

Concentration Measurement Range	0.0001 to 400 mg/m^3
Scattering Coefficient Range	1.5 x 10^{-6} to 0.6 m^{-1} (approx.) @ λ=880 nm
Precision / Repeatability Over 30 Days (2-sigma)	±2% of reading or ±0.005 mg/m^3, whichever is larger, for 1-sec averaging time ±0.5% of reading or ±0.0015 mg/m^3, whichever is larger, for 10-sec averaging time ±0.2% of reading or ±0.0005 mg/m^3, whichever is larger, for 60-sec averaging time
Accuracy	±5% of reading ± precision
Resolution	0.1% of reading or 0.001 mg/m^3, whichever is larger
Particle Size Range of Maximum Response	0.1 to 10 μm
Operating Environment	14 to 122 F (-10 to 50 C), 10 to 95% RH non condensing

Table 4

AirChek 52 Personal Sample Pump Manufacturer's Suggested Specifications

Flow Range	1000 to 3000 ml/min
Flow Control	Holds constant flow to ± 5% of set-point after calibration
Compensation Range	1000 ml/min up to 25 ins water back pressure 2000 ml/min up to 25 ins water back pressure
Temperature	Operating: 32 to 113 F (0 to 45 C)
Humidity	0 to 95% non-condensing
Noise Level	62.5 dBA – pump without case

Table 5

Sensor Performance Goals for Citizen Science Applications

The aim of your project and the intended use of its data will dictate your performance goals. EPA has suggested the following broad application areas, or tiers, for citizen science projects:

- Education and information (Tier I): uses sensors as teaching tools

- Hotspot identification and characterization (Tier II): uses fixed locations and/or mobile sensor systems to map pollutants and determine emission sources
- Supplementary network monitoring (Tier III): uses air sensor systems to complement an existing network of air quality monitors
- Personal exposure monitoring (Tier IV): uses sensors in applications to monitor a person's exposure to air pollution, often to evaluate the impact of air pollution on health
- Regulatory monitoring (Tier V): uses sensors to monitor pollutants to determine if an area is in compliance with the National Ambient Air Quality Standards

Each tier requires progressively more detailed technical considerations and higher data quality expectations. These tiers are listed and briefly described in Table 6. Note that only Tiers I through IV are listed and discussed here as no low-cost sensors, including the CSAM unit, meet the regulatory monitoring requirements. For more information on these tiers and potential air monitoring applications, see EPA's *Air Sensors Guidebook* (http://www.epa.gov/airscience/docs/air-sensor-guidebook.pdf).

Tier	Application Area	Pollutants	Precision and Bias Error	Data Completeness	Rationale
I	Education, information, and community organizing and advocacy	All	< 50%	≥ 50%	Measurement error is not as important as simply demonstrating that the pollutant exists in some wide range of concentration.
II	Hotspot identification and characterization	All	< 30%	≥ 75%	Higher data quality is needed here 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.
III	Supplementary network monitoring	Criteria pollutants and air toxics including VOCs	< 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.
IV	Personal exposure monitoring	All	< 30%	≥ 80%	Many factors can influence personal exposures to air pollutants. Precision and bias errors suggested here are representative of those reported in the scientific literature under a variety of circumstances. Error rates higher than these make it difficult to understand how, when, and why personal exposures have occurred.

Table 6

CSAM Performance Checks

The CSAM requires several performance checks, conducted by Region 2 technical staff, to make sure the instrument will produce the desired results during the study. It is recommended that these checks be performed before deploying the instrument in the field and after it is removed from the field at the end of the study. If at any time, an operator suspects a CSAM is not functioning properly, it should be removed from operation and returned to Region 2 technical staff.

Table 7 identifies the three recommended checks—zero and span drift for the CSAM-NO_2 and flow rate and zero drift for the CSAM-PM—and the acceptable ranges for accuracy and precision for CSAM applications. This information is being provided to citizen scientists for informational purposes only. Only an experienced operator should perform these procedures before sensors are distributed. Zero and span drift checks verify that the monitor is functioning within the operating range and that it responds with the desired sensitivity to changes in input concentration. The flow rate check verifies the rate at which the sample gas flows through the instrument. The flow rate is checked using a flow meter to ensure that the monitor is receiving the proper amount of air to collect a representative sample.

Measurement (Sensor)	Performance Check	Accuracy	Precision	Corrective Action (by an Experienced Operator)
NO_2 concentration (CSAM-NO_2)	Zero/span drift	± 20%	± 20%	Perform calibration and troubleshooting
PM concentration (CSAM-PM)	Flow rate Zero drift	1.5 L/min ± 10% < 20% of ambient	± 10% ± 10%	Adjust set screw on pump Perform troubleshooting
Temperature/RH (Honeywell sensor)	Compared with local data*	± 5% (temp) ± 10% (RH)	± 2% (temp) ± 5% (RH)	Perform troubleshooting

*The following web sites are sources of local weather data:
http://www.weather.com/weather/hourbyhour/l/USNJ0355:1:US
http://w1.weather.gov/obhistory/KEWR.html

Table 7

Range

Environmental pollutants are often present in very low concentrations, particularly when measurements are being made far from the source of the pollution. The CSAM is most useful when it is able to measure its target pollutants over the full range of concentrations commonly found in the atmosphere. The expected operational range for the CSAM-NO_2 is 20–200 ppb, and for the CSAM-PM it is 0.1–200 $\mu g/m^3$. If you think your CSAM is not functioning properly, return the instrument to EPA Region 2 for assessment.

Calibration

Some sensors come with an "expiration date," after which its measurements are likely no longer accurate. The expiration date indicates when the device requires *calibration*. Calibration is the process of checking and adjusting an instrument's measurements to ensure it is reporting accurate data. During the calibration process, the response of the instrument is compared with a known reference value.

The life expectancy of the CSAM is 1 year. After this time, the unit might begin producing unreliable results. The CSAM-NO_2 (CairClip) is delivered calibrated and does not need recalibration for 1 year as long as the sensor maintains the operating conditions listed in its data sheet (Table 3). The CSAM-PM is also delivered calibrated. Remember, however, that the CSAM-PM operates at a flow rate of 1.5 L/min and that a change in the flow rate will change the diameter of the particles being sampled. If you detect a change in the flow rate, return the instrument to EPA Region 2 for a flow rate adjustment.

Service Schedule

Air monitoring devices require careful care and maintenance to ensure proper functionality and reliable performance. The rate that an air monitoring device requires service depends on its power supply (battery) capabilities and the amount of data that can be safely stored before data are overwritten or lost. Once the CSAM is set up and attached to a power source, it is expected to sample continuously until a volunteer operator returns to the site to download data. The CSAM is designed to run for one week (continuously for 7 days) on a fully charged battery. Therefore, an operator should visit the test site at least once a week to download data, inspect the unit's functionality, and replace and/or recharge the battery.

The filter in the CSAM-NO_2 (CairClip) needs to be changed every 4 months if it is regularly exposed to dust (or more frequently if exposed to large quantities of dust). The filter should be changed only by an experienced operator, as described in the CSAM Operating Procedure.

Documents and Records

Each activity associated with a monitoring project influences the value of the project's results. Therefore, it is important to maintain thorough documentation in order to use the results to make meaningful technical interpretations and judgments. This project requires experienced operators to carry out certain project activities, such as conducting performance checks at the beginning and end of the study, while other activities, such as field site visits and data downloads, will be performed by citizen volunteer operators. All project participants are responsible for carefully documenting their activities throughout the study.

Briefly described here are the types of records you should keep to ensure your project is well documented. These suggestions and examples provide a starting point for record keeping, but your project team should determine the documentation requirements for the project as an integral part of the planning process. Developing a quality assurance project plan, or QAPP, is recommended during the planning stages. A QAPP provides a "blueprint" for conducting and documenting a study that produces quality results. EPA Region 2's Citizen Science web page (http://www.epa.gov/region2/citizenscience) provides helpful information and a template for developing a Citizen Science QAPP.

At a minimum, you should consider the following documentation as crucial to producing meaningful results:

- A Microsoft Excel spreadsheet created specifically for processing the CSAM data is included in the Citizen Science Toolbox for this project. Data collected by both experienced operators and citizen volunteers should be entered in this spreadsheet. The CSAM Operating Procedure details how to use the spreadsheet to enter data for both performance checks and routine field data collection.
- Performance-check activities should be recorded in a bound notebook by the experienced operator performing the check. All notebook entries should be made in black, permanent ink and initialed and dated by the person making the entry. Changes or corrections to data should be indicated with a single line through the original entry so that the original entry remains legible. All changes should be explained, dated, and initialed. In addition, all performance-check information, both pre- and post-test, should be provided to the citizen scientists so they can enter that information in the sampling log sheet, as shown in the example in Table 8.
- Field data collection records for each CSAM unit and site should be kept in a bound notebook as for the performance checks and entered on a prepared sampling log sheet stored in a loose-leaf binder. The example log sheet shown in Figure 5 can be used or modified as needed for your project. The experienced operator will provide the pre- and post-test information for instrument performance and this information will be a part of the macro that is provided with each CSAM unit.
- All equipment maintenance and calibration forms should be kept in a project file by the project leader until the end of the project or a date determined during project planning.

All hard-copy and electronic files of project data and documents should be maintained by the project leader. Records stored or generated by computers should have hard-copy or write-protected electronic backup copies. The project leader is responsible for making sure each project participant has the most current versions of any pertinent documents they need to carry out their assigned tasks, such as these quality assurance guidelines and the operating procedure.

Table 8

CSAM Monitoring Record

CSAM unit #: ____________ Date: ____________ Data recorded by: ____

Test location (description): ____

Fresh batteries installed? Yes ☐ No ☐

If yes, date: ____________

Data logging interval: _______ min Operation mode: AC power ☐ Battery ☐

Start date: ____________ End date: ____________

Start time: ____________ End time: ____________

Total run time: ___________ hours

Pre-test Instrument Setup

$PM_{2.5}$ zero check Performed by: ________________________ Date: ____________

$PM_{2.5}$ flow rate check Performed by: ________________________ Date: ____________

NO_2 zero and span check Performed by: ________________________ Date: ____________

Post-test Instrument Operations

Data downloaded Yes ☐ No ☐ File name: _____________________________________

Performed by: ____ Date: _____________

Comments

For Additional Help

CairPol, Technical Data Sheet CairClip NO_2, http://www.cairpol.com/images/pdf/NO2/technical%20datasheet%20no2%2015072013.pdf, last accessed October 30, 2014.

Thermo Scientific Personal DataRAM pDR-1000AN Monitor brochure, http://www.thermoscientific.com/en/product/personal-dataram-pdr-1000an-monitor.html, last accessed October 30, 2014.

U.S. Environmental Protection Agency, Citizen Science Toolbox, CSAM Operating Procedure, October 2014.

U.S. Environmental Protection Agency, Air Sensor Toolbox for Citizen Scientists http://www.epa.gov/heasd/airsensortoolbox, last accessed November 18, 2014.

U.S. Environmental Protection Agency, What Are the Six Common Air Pollutants? http://www.epa.gov/airquality/urbanair/, last accessed September 19, 2014.

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