Barry Commoner Center For Health and the Environment

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QUEENS COLLEGE

Air Quality Citizen Science Research Project in NYC

Toolkit & Case studies

Youth Ministries for Peace and Justice

NYC Health

EL PUENTE LEADERS FOR PEACE & JUSTICE

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Table of Contents

Table of Contents

Table of Contents

Background

Traditional approaches to air quality monitoring typically involve regulatory agencies that utilize expensive and complex stationary equipment, maintained by trained staff, to provide the type of highly accurate data needed to demonstrate attainment with federal air quality standards. While this type of monitoring is a vital component to air quality management, in urban areas these monitors are often deployed at, only, a limited number of rooftop locations. Though intended to track urban scale trends in pollution levels, the placement of these monitors is not spatially dense enough to characterize intra-urban spatial variation in air quality, due to local emission sources such as traffic. To address this limitation, in 2007 the New York City Department of Health and Mental Hygiene (NYC DOHMH) in partnership with the Barry Commoner Center for Health and the Environment (BCCHE), located at Queens College—City University of New York (CUNY), launched the New York City Community Air Survey (NYCCAS), a high-density monitoring network designed to assess spatial variation over longer-term air pollution exposures (seasonal and annual average) at the neighborhood-level. NYCCAS uses less expensive monitoring technology than the traditionally employed technology that meets federal requirements for NAAQS-attainment determination (Federal Reference Methods), thus trading high temporal resolution (achieved through more expensive monitoring methods) with increased spatial coverage (achieved by using larger numbers, of lower cost and easier to deploy instruments). Despite not qualifying as a federal reference method, these instruments have undergone extensive quality assurance and testing, and have been demonstrated to provide accurate and reproducible results. NYCCAS has become vital to the City's understanding of the variation in pollution exposures within New York City, and its sustained operation relies on trained lab and field staff to collect and analyze air quality data. In recent years, technological advancements in air quality monitoring have brought to market many lower-cost, easy-to-use, real-time portable air quality sensors, which provide exciting opportunities for additional data collection, (Eisl and Ilie, 2018).

Background

Simultaneously, there is a growing field of 'citizen scientists', non-scientists engaged in specific issues who collect or analyze data to contribute to scientific research or advocate for environmental or public health improvements. The NYCCAS team expanded into this area of community engagement and community based participatory research by developing air quality "citizen-science" toolkits that include how-to guides for accessing available data on emission sources, designing neighborhood air pollution surveys using new, low-cost technologies, and sharing data online. This project provides valuable outcomes for both DOHMH and the community, with the key objective that citizen science can be done by persons without specialized training and experience. Specific aims of this project include:

- Increase citizen engagement in accessing, collecting, and communicating air quality data, thus providing tools to better inform communities on air quality issues.
- Provide communities with information for advocating for clean air.
- Increase data collection in communities that can offer additional spatial and temporal data on pollution levels beyond existing NYCCAS and regulatory methods. These data can offer valuable insights into gradients near major sources and temporal characteristics that contribute to chronically high levels of pollution in many neighborhoods.
- Produce data for research efforts aimed at combining data from low-cost sensor networks with data from existing NYCCAS or regulatory monitoring networks. These statistical fusion techniques can help develop more spatiotemporally resolved exposure maps of air pollution exposure and inform how the City and other researchers use sensor data in the future.
- Develop data systems that allow for remote uploading of data to servers or citizen uploading of air quality data.

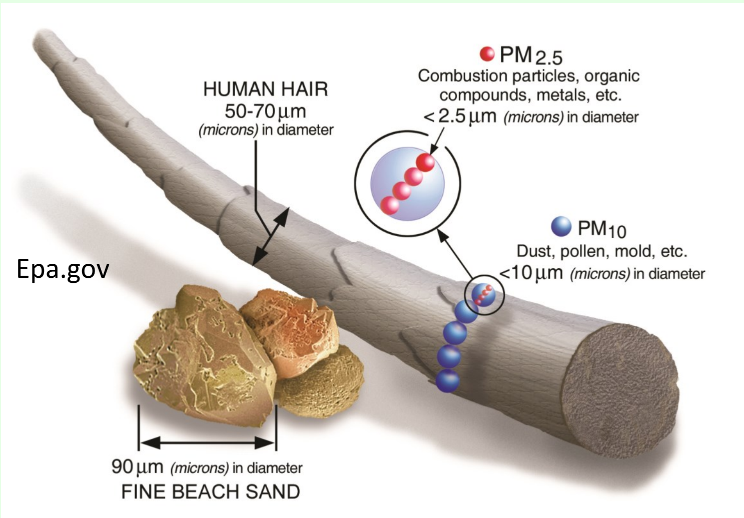
INTRODUCTION

Air Quality in New York City

Urban air pollution is generally caused by a wide variety of emission sources including traffic, industry, and commercial/residential fuel combustion, and is comprised of a complex mixture of gaseous and particulate air contaminants such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), fine particulate matter ($PM_{2.5}$) (defined as particles with aerodynamic diameters ≤2.5 µm), and ground-level ozone (O_3). Epidemiological studies suggest potential associations between short and long-term exposure to criteria air pollutants and increased morbidity, mortality, and hospital admissions for various cardiovascular and pulmonary diseases, including strokes, in addition to associations with overall decreased life expectancy. Evaluation of long-term air monitoring data and the characterization of ambient $PM_{2.5}$ can aid in improving the understanding of the state of air quality and understanding sources of particle pollution within urban areas. Mass concentration is the current standard metric for measuring and controlling particulate matter (PM) exposure. Based on the epidemiology and the resulting guidance of international organizations (e.g., WHO, 2000; IARC, 2013), national legislation in many developed countries specifies fixed thresholds, limits, and/or target values for PM mass concentrations. In the U.S., air quality is regulated using National Ambient Air Quality Standards (NAAQS) that set limit values for PM with aerodynamic diameters less than 10 and 2.5µm (PM_{10} and $PM_{2.5}$, respectively). Air quality in NYC has, generally, improved since the 1970s (NYC Gov.). Based on an analysis of an approximately 15-year period, Rattigan et al (2016), reported substantial decreases in $PM_{2.5}$ mass (30–40% decrease in annual mean values) and other major components across New York since the early 2000s. Furthermore, New York City Community Air Survey (NYCCAS) project data reports show a decline in annual average $PM_{2.5}$, NO_2, NO, and BC levels of 18%, 23%, 28%, and 18%, respectively, between the first year of monitoring (2009) and the most recent year (2017). Higher levels of $PM_{2.5}$ continue to be observed in areas of higher traffic density, building density, and industrial areas, like Williamsburg and many neighborhoods in the Bronx.

Air Pollution—$PM_{2.5}$

Air pollution occurs when chemicals, fumes, particulate matter, odor, or biological materials introduced into air exceed safe limits and cause harm to the health of humans, animals, plants, and other living organisms, or cause damage to inanimate objects (Sarkar, 2015). These materials can be in the form of solid particles, liquid droplets, or gases and are called pollutants. Pollutants, which are directly emitted from plants or motor vehicles into the atmosphere, e.g., ash, particulate matter, sulfur dioxide, or carbon monoxide, are called primary pollutants. While secondary pollutants result from an interaction or chemical reaction of primary pollutants, e.g., the formation of smog or depletion of the stratospheric ozone layer. Air pollutants are dispersed throughout the world's atmosphere in concentrations high enough to gradually cause serious health problems. Particulate matter or more precisely suspended particulate matter (SPM) are fine solid particles suspended in a gas. Particulate matter is both naturally available in the atmosphere and man-made. Particle pollution includes PM_{10} inhalable particles, with diameters that are generally 10 micrometers and smaller, and $PM_{2.5}$ fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller. Furthermore, the combustion of fossil fuels in power plants generates significant amounts of particulate matter (Sarkar, 2015).



Health Effects of Air Pollution

Long-term exposure to particulate matter can result in heart disease, decreased lung function, exacerbation of asthma, and lung cancer, amongst other cardiovascular and pulmonary conditions. Especially fine particulate matter ($PM_{2.5}$) has been shown to influence the frequency and severity of many respiratory and cardiovascular diseases (Rom and Samet, 2006; Pope et al., 2004; Peters et al., 2001; Norris et al., 1999). $PM_{2.5}$ also increases inflammatory proteins and heart rate variability (HRV) in healthy individuals (Samet et al., 2009). One study indicated that diesel exhaust gases and particulates tended to lead to lung disorders and higher daily mortality (Calabmse et al., 1981, Dockery et al., 1992). To track the effect of ambient air pollutants, such as $PM_{2.5}$, on public health, accurate measurements of concentrations are vital. $PM_{2.5}$ concentration measured by the United States Environmental Protection Agency's (U.S.EPA's) national ground-based ambient air pollutant network provides a foundation for air pollution monitoring.

The Role of Citizen Science

In its June 2014 update, the term citizen science was officially added to the Oxford Dictionary and defined as:

"Scientific work is undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions".

New technology and citizen science projects are growing trends in addressing community concerns around local specific problems, such as air pollution (Blevis, 2007; Brynjarsdottir et al., 2012; Dickinson and Bonney, 2012; DiSalvo et al., 2009-2010; Irwin, 1995; Mankoff et al., 2007; McKinley et al., 2015). Science education and participatory democracy are the major outcomes of citizen science projects (Silvertown, 2009; Bonney et al., 2009; Dickinson et al., 2012; Irwin, 1995; Bernard and Gordon, 1980; Wilsdon et al., 2005; Stilgoe, 2009; Irwin, 2001; English et al., 2017). Lower-cost and easy-to-use air pollution sensors provide citizens and communities with opportunities to monitor the local air quality that can directly impact their daily lives (www.citi-sense.eu). As they gather this information, they become more educated and informed about air quality in their community, which allows them to become more conversant on potential air quality issues and better positions them to develop community-based strategies to reduce air pollution exposures to protect their health (Snyder et al., 2013). Widespread data collection and data sharing, using new sensors is already occurring (http://airqualityegg.com/; http://aircasting.habitatmap.org/). However, challenges remain regarding the use of sensors and sensor data, chiefly sensor data quality, and derivation of meaningful information from data sets (Snyder et al., 2013).

Citizen Science-based and Air Pollution Projects

Concern at various levels of the community regarding health risks attributed to air pollution is a primary motivator for community-based participatory research air monitoring (Minkler et al. 2012). Furthermore, disease burdens surrounding asthma, cardiovascular disease, and cancer risk are leading causes of community concern (Yip et al. 2004; Lewis et al. 2005; Brown et al. 2006; Barrett 2010; Fuller et al. 2013; Chin et al. 2014). Many researchers discovered that broader fears of living in a "toxic" environment resulted in anxiety and apprehension among community residents. In particular, concerns stemmed from people being close to potential pollution sources (Wing et al. 2008; Brody et al. 2009; Kondo et al. 2014; Svendsen et al. 2014; Barzyk et al. 2016). Many of the project areas were located within a few miles of major industrial and transportation corridors with point sources such as oil refineries, unconventional oil and gas facilities, concentrated animal feeding operations, and non-compliant auto body and paint shops (Wing et al. 2008; Minkle et al. 2010; Macey et al. 2014). Nonstationary sources of concern were mostly from the truck, rail, and marine industries (Brody et al. 2009; Garcia et al. 2013; Truax et al. 2013). Citizen science projects have shown the most success, in communities where strong partnerships exist among academic institutions, a state or federal agency, and the community, as demonstrated in North Charleston, South Carolina, by collaborators who assessed trends in local ambient particulate matter (Svendsen et al. 2014). Similarly, the Detroit Exposure and Aerosol Research Study (DEARS) has been seminal in pointing out factors that affect exposures to particulate matter and sources of local air toxics—cars, trucks, factories, and power plants (Williams et al. 2012). While in Newark the Ironbound community collaborated with the EPA to conduct community-based air monitoring using the recently developed Air Sensor Toolbox (Barzyk et al. 2016).

Citizen Science-based and Smart Sensors Network - SSN

A wide range of SSN applications have been developed in recent years, in which smart sensor devices are embedded in interconnected devices to sense, monitor, measure, communicate, and exchange information. This enables the collection, processing, analysis, and dissemination of valuable information gathered in various industrial environments (Da-Xu L et al, 2014; Echanobe J et al, 2014; Gubbi et al, 2013). Smart sensors are devices that detect & measure, exchange information, transmit useful collected information, and automatically assign roles to manage, deploy, and schedule the behaviors of industrial apparatuses over a network. Environmental monitoring can be defined as the systematic sampling of air, water, soil, and biota to observe and study the environment, as well as to derive knowledge from this process (Artiola et al., 2004; Wiersma, 2004, Ilie and Vaccaro, 2017). Monitoring can be conducted for many purposes, including to establish environmental "baselines, trends, and cumulative effects" (Mitchell, 2002), to test environmental modeling processes, to educate the public about environmental conditions, to inform policy design and decision-making, to ensure compliance with environmental regulations, to assess the effects of anthropogenic influences, or to conduct an inventory of natural resources (Mitchell, 2002). Monitoring programs can vary significantly in scope, ranging from community-based monitoring on a local scale to large-scale collaborative global monitoring programs such as those focused on climate change (Conrad & Daoust, 2008; Lovett et al., 2007). Monitoring is a "fundamental component of environmental science and policy" (Lovett et al., 2007) and thus needs to be conducted under a rigorous application of the scientific method (Artiola et al., 2004). Many community projects in air pollution monitoring programs are growing, using air pollution sensors that are relatively cheap and easy-to-use (Dutta et al. 2009; Devarakonda et al. 2013a; Hagler et al. 2014; Jiao et al. 2015b; Duvall et al. 2016). These low-cost sensors create new opportunities for community-based organizations to collect air pollution and to achieve policy changes (Kruger and Shannon 2000; Lakshminarayanan 2007; Miller-Rushing et al. 2012).

How to create your own *"Air Quality Citizen Science"* Project?

The development of an 'Air Quality Citizen Science' Project can be divided into three different phases—planning, research, and action. Each of these phases can be broken down into different sub-sections. The planning phase involves formulating the objectives of the study, as well as developing a research strategy to meet those goals. The next step is to draft a plan for collecting data, including the identification of key components of the study, determining the instrumentation involved, and the data collection frequency. Data generation is followed by data validation. An exploratory analysis of the data can provide insights into the characteristics of the data quality. The last phase of the project involves the dissemination of knowledge gained from the study. It is important to generate conclusions from the results obtained from the analysis and provide suitable recommendations for future action.

PLANNING PHASE

IDENTIFY A RESEARCH PRIORITY 1

DEVELOPMENT OF RESEARCH PLAN 2

RESEARCH PHASE

DATA ANALYSIS PLAN 3

DATA VALIDATION DATA ANALYSIS 4

ACTION PHASE

DATA DISSEMINATION 5

DISCUSSIONS CONCLUSIONS 6

IDENTIFY A RESEARCH PRIORITY 1

Project objectives and research questions need to be clear and concise before study commencement. Simple questions such as why and how long we monitor must be at the forefront of all discussions to achieve project consensus, which without it can lead to the eventual demise of the project (Minkler, 2014). Moreover, effective monitoring plans need to include consideration of personnel, location, timing, duration, and the nature of measurements (Williams et al., 2014c). Depending on the question the community aims to answer, several strategies may be needed to assess air quality, particularly in communities with multiple sources of air pollution (Snyder et al., 2013).

Some of possible questions include:

- Why is Air Quality Monitoring important?
- What is the purpose of monitoring?
- What are your goals and what you hope to accomplish?
- Which low-cost sensor technology is suitable for your scope and study area?
- What resources are available and how do they fit in your project objectives?

Multiple studies in the field of Air Quality Citizen Science are available for reference purposes. A few of which are listed below:

https://www.epa.gov/citizen-science/examples-citizen-science-projects-supported-epa#a1

https://www.habitatmap.org/

https://scistarter.org/

http://making-sense.eu/projects/

https://ivan-imperial.org/air

http://www.aqmd.gov/aq-spec/evaluations

https://www.citizenscience.gov/catalog/#

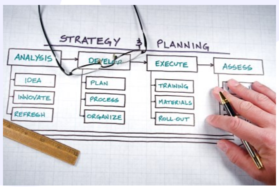
DEVELOPMENT OF RESEARCH PLAN 2

A well-organized research plan is critical. Participant’s resources and skills must be identified at the beginning of the project. Each member of the project should be aware of the responsibilities tied to the overall objectives of the study. Collaboration is very important for a successful citizen science project, so face to face meetings with all participants to discuss the progress of the project is essential. Furthermore, keeping track of the progress or status of each of the tasks needed to achieve the goals, is paramount.

For a Research Plan you must consider:

◊ *Project objectives*

◊ Monitoring Approaches/Methodologies



◊ *Protocols/Workshops*

DEVELOPMENT OF RESEARCH PLAN 2

Project Objectives

Here are some questions which you can consider as a part of the Research Plan:

- Interested in identifying pollution hot spots and relating them to specific sources?
- Interested in monitoring on one specific location or multiple locations? e.g. schools, schoolyards, playgrounds, gardens, open public spaces or highways, main roads, busy traffic intersection, etc.
- Interested in knowing the level of pollution exposure for an individual on a daily basis?
- Interested in seeing changes in air quality during rush hours?
- Interested in looking into peak/frequency concentrations caused by trucks or buses passing by at a certain location?
- Which technologies are you going to use and how do you plan to calibrate and validate the low-cost sensors data?
- How will you organize your curriculum, or conduct a workshop/training?
- How will be high-frequency data going to be stored? Is there enough expertise available to stream the data for real-time analysis purposes?
- Who is going to have access to the data collected?
- How will the team members be selected and what different responsibilities will be assigned to them?
- Has the cost of initial setup, calibrations, repairs, and regular maintenance of the air monitors been considered?

Questions related to equipment life span, electronic waste, and technological upgrades may need to be added in a research plan. Many researchers find these questions important in a citizen science research project (Graham et al. 2011; Snyder et al. 2013; Newman et al. 2012; Kumar et al. 2015; Mattingly et al. 2016).

Monitoring approaches/ Methodologies

- Employing simple monitoring, scientifically appropriate methods, and incorporating training into all aspects of these projects are other important steps (Conrad and Hilchey, 2010). Detailed descriptions of air sampling methods can be found in the American Industrial Hygiene Association text (DiNardi, 2003) and the Air Pollution Control Technology Handbook (Schnelle and Brown, 2002). We briefly define a few monitoring approaches:
- Fixed site monitoring measures air quality with static instruments at a given location. This approach permits controlled sampling for a large array of equipment regardless of the size or weight. The equipment can also be protected from harsh weather while maintaining adequate power supply. Furthermore, it provides a broad representation of an entire neighborhood although spatial variability and time activity factors can be lost with such a method since exposures vary as people move from one microenvironment to the other.
- Mobile monitoring is typically performed with equipment housed in trailers, cars, and even backpacks, which are moved around to different locations.
- Personal monitoring refers to air sampling conducted on individuals to capture their specific exposures, typically, within their breathing zones. Residential and school monitoring consists of any air measurements taken in proximity to a home or school whether outside or inside.

Projects that focus on local air pollution hot spots may consider using sensors that allow for mobile monitoring (Schnelle and Brown 2002). The Community Action Against Asthma (CAAA) in Detroit collected outdoor and indoor particulate matter concentrations at two community schools, combining fixed site and school monitoring to help address community concerns (Yip et al. 2004). Thanks to these monitoring approaches more information on air pollution can be added at the neighborhood data level and help explain variabilities in exposure (Sarnat et al. 2012).

Cellphone and other portable devices can collect data that can be easily retrieved (Willett et al., 2010; Graham et al., 2011; White et al., 2012; Castell et al., 2015). Peters et al., (2014) showed that mobile monitoring can give additional insights in spatial variability and exposure assessment, at a resolution of street level and even within-street level. The citizen science toolbox provides all information necessary about emerging air sensor technologies (Kaufman et al., 2014). Zhuang et al. 2015, included low-cost particle sensors in their personal air quality monitoring devices to improve the environmental awareness of individuals. Seto et al. 2009, demonstrated that personal-scale dust sensing can be used for asthma prevention and management. Finally, by exploiting these low-cost particle sensors with human mobility, portable air quality systems have shown promise in enabling participatory sensing for finer-grained environmental analysis at different scales (Budde et al., 2013, Devarakonda et al., 2013). For community air monitoring, many sensors evaluations have been conducted by the EPA and by the South Coast Air Quality Management District (http://www.aqmd.gov/aq-spec/evaluations), which presented detailed summaries on recent sensor costs and performance during the laboratory and field testing. Interested communities can factor in cost, study objectives, and purposes of the data to help with sensor selection and refer to the “Air Sensor Guidebook - EPA.”

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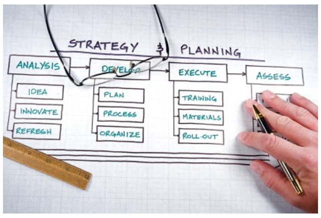


Protocols/Workshops

Create a workflow with all tasks which should include:

- workshop and training to provide an overview of the project and demonstrate how to correctly use the air quality monitors
- data collection process and protocols

You need to consider the following questions as well:

- How long will each task take?
- Is there any scheduling conflict with the volunteers (for example, academic calendar especially for high school students or budget year)?
- Do you consider building your own website or Facebook/Twitter/Instagram page with an open-source content and sharing all activities considered in the project?
- How will you communicate with your community?

DATA ANALYSIS PLAN 3

An enormous amount of information on air quality is currently available, in the form of scientific publications as well as public awareness communications. The first step is to understand what is already known and available. Data quality is the most important task for a successful project. You need to ensure that high standards of data acquisition are met, and that the data collected aligns well with the overall project goals.

<u>Data collection plan:</u>

Planning

Collecting data

Data Processing

DATA ANALYSIS PLAN 3

Planning

Before starting to collect data, you might consider questions like:

- Does the data already exist?
- Will you need to incorporate data from outside sources to meet your project goals?
- Who is responsible for managing the data?
- What type of data are you collecting?
- How will the data be collected?
- How will the data quality be evaluated?
- Is there any database available for data storage?
- How will the data be analyzed?

Evaluate what type of data you will collect, how to collect it, and what additional resources you will need. In your plan you should address:

- standards, responsibilities, and methods for data collection
- data description and structure
- data evaluation, quality assurance, and quality control
- statistical analysis

Collecting Data

Creating a "Sampling Protocol" is the best way to help volunteers understand the process of data acquisition. In this protocol the following information will be included:

- Which pollutants are you going to measure?
- Which monitor are you using and how is it going to be used?
- What is the duration of data acquisition?
- How will the data be processed and displayed on visualization dashboards?
- How you plan to analyze the data to better understand the variability of pollutants measured within the community area?

As a part of personal monitoring, it is important to be aware and think about the following environmental factors which can affect the data:

- Is there any visible dust in the air near the monitor?
- Is there any construction going on near the monitor?
- Evidence of frequent smoking near the monitor?
- Are there many trees in the area?
- Are there any highways nearby?
- Did a car, bus, truck pass by during data collection?

Volunteers typically record their observations in notebooks or take photos to obtain supplemental information with the monitoring data. The more meticulous your volunteers are in collecting data, the more credibility the project will have, and the less work will be required to filter and clean-up data later.

Data Processing

Data processing occurs when data are collected and translated into usable information, (https://www.talend.com/resources). Data processing is usually performed by data scientists since it is important for data processing to be done correctly so as not to negatively affect the data output. The output or "processed" data can be obtained in different forms like image, graph, table, vector file, audio, chart or any other desired format depending on the software or method of data processing used. Different types of output files obtained as "processed" data:

Plain text file – Most of these files are user-readable and easy to comprehend. Very negligible or no further processing is needed with these types of files. These are exported as notepad or WordPad files.

Table/spreadsheet – This file format is most suitable for numeric data. Having digits in rows and columns allows the user to perform various operations like filtering & sorting in ascending/descending order to make it easy to understand and use. Various mathematical operations can be applied when using this file output.

Charts & Graphs – The option to present the output in the form of charts and graphs is handy and is now a standard feature in most software. This option is beneficial when dealing with numerical values reflecting trends and patterns of growth/decline.

Maps/Vector or image file – When dealing with spatial data the option to export the processed data into maps, vector and image files is of great use. Having the information on maps is of particular use for urban planners who work on different types of maps.

Other formats/raw files – These are the software specific file formats that can be used and processed by specialized software. These output files may not be a complete product and require further processing. Thus, there will be a need to perform multiple data processing steps.

DATA VALIDATION DATA ANALYSIS 4

Scrutiny of scientific principles and methods is critical for a successful project. A quality assurance/quality control program encompasses all phases of ambient air sampling and data analysis. For example, all monitoring data, collected throughout the project, must be compared to federal reference methods (EPA; Williams et al., 2014a; Williams et al., 2014b; Williams et al., 2015a; Williams et al., 2015b; Duvall et al., 2016). Co-locating monitoring instruments to perform an inter-instrument comparison and simultaneous sampling can help address the non-comparability of results (Williams et al., 2014c). There may also be challenges with data fragmentation due to equipment failure, baseline drift, power interruptions, and interferences (Whitelaw et al., 2003). Multiple computer programs—including open source options—are available to automatically transmit, verify, and validate data (EPA, 2003). It is important to include competent scientists in the project to ensure appropriate handling of technical details in data management (e.g., identifying and correcting potential problems during the process of collecting data).

To interpret the air quality measurements obtained from low-cost sensors, the EPA has developed a messaging system to enable the public to understand how short-term air quality measurements relate to local air quality and personal exposures (EPA, 2016b; Mannshardt et al., 2016). Community partnerships can consider these resources to aid in data interpretation. Data analysis is defined as a process of cleaning, transforming, and modeling data to discover useful information for decision-making. The adequate interpretation of the air monitoring results is dependent on the study's clearly defined objectives and research questions that are meaningful to the individual and the community (Paulos et al., 2009).

DATA VALIDATION DATA ANALYSIS 4

Data analysis is the step where the cleaned and aggregated data are imported into analysis tools. These tools allow you to explore the data, find patterns in it, and ask and answer what-if questions, such as:

- average annual/seasonal/monthly/weekly/daily/hourly concentrations
- the average concentration in a holiday period
- average pollutant concentration during peak hours or off-peak hours
- average concentration during week-day/ weekends

Check with the local or state air monitoring agency to verify and validate the data in a form of an external check.

DATA DISSEMINATION 5

Citizens should have access to the data so that they can make positive changes in their daily commuting routines (Morello-Frosch et al., 2009). Citizens should be more engaged in local environmental decision-making and meaningfully use the data for pollution reduction strategies (Brown et al. 2006). Today, technology provides numerous options for real-time data retrieval and dissemination. Community-based organizations should maintain and share the data in a way that people can find, understand, and use it in a variety of technical and non-technical contexts.

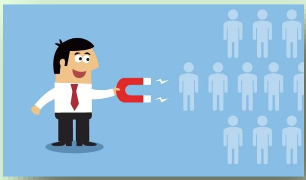
When you share the data:

- Figure out who will need your data or want to see it, that is researchers, journalists, policymakers or a community.
- Consider how you can present and interpret your results to make it clear and understandable to your volunteers and other audiences. Translate results into plain language, use simple graphs and offer map-based visual tools when appropriate.
- Provide the simplest possible tools or methods for data visualization, evaluation and comparison, summary or abstraction (such as maps or GIS, statistical summaries and charts and graphs), and data download (such as CSV files for custom query results, as well as compressed packages of pre-selected, documented data).
- Make your data available for public use beyond your own immediate needs, in accordance with federal requirements for open data and open access.

CONCLUSIONS 6

Plans for discussions and conclusions:

- How many stationary networks have been deployed, where and for how long?
- Comparison to DEC data – is the $PM_{2.5}$ data gathered by the low-cost monitors true or do you see a difference when collecting real-time data on a hyper-local scale?
- When looking at the bar graphs based on daily/hourly averages, do you see that the pollutant levels are decreasing or increasing? When and at which location?
- How are the pollutant levels compared to other parts of the city?
- How does the personal monitoring data compare to the stationary network data?
- Were hotspots located that were not already identified by other studies?
- Were there any places with good air quality identified?



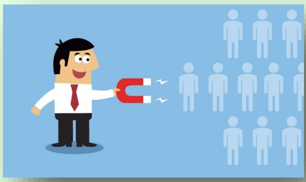
Solicitation for Pilot Community Air Quality Monitoring Network

Program Description

BCCHE, in partnership with DOHMH, sought to understand how academic institutions, city governments, and community groups can work together to increase air quality monitoring within communities using citizen-collected data and to enable communities to understand air pollution and its sources. In collaboration with two community-based organizations (CBOs), BCCHE created a pilot community-based air quality monitoring network, whereby community members and project partners designed and implemented a stationary network to collect and share local air quality data using AirBeam2 sensors. The CBOs selected received a stipend of $10,000 each to help mobilize volunteers for active participation in the project. Utilizing the information collected through citizen science in conjunction with current city-wide air quality monitoring efforts, this partnership created a richer picture of neighborhood-level variation in air quality and thus provided communities with a better understanding of the air quality in their neighborhood.

Pilot Study Goals:

1. Create partnerships among local government, academic institutions, and community groups centered on air quality assessments
2. Increase community awareness of local air quality, its determinants, and air pollution-related health risks
3. Increase citizen participation in acquiring, interpreting, and communicating air quality data
4. Help develop methods for citizen air quality monitoring that can be scaled to other communities
5. Develop strategies for disseminating information to the public and air quality monitoring community



Criteria for selecting a CBO as project partner

- Well-embedded in a local NYC neighborhood
- Demonstrates an interest in air quality and a commitment to using air quality data
- Has the capacity to mobilize a group of community volunteers to operate/maintain a stationary network to effectively characterize pollution levels in the neighborhood with multiple AirBeam2 monitors
- Is willing to work collaboratively with pilot partners
- Has staff member(s) that can take the lead on the project and function as the main liaison with pilot partners.

Proposals required the following:

- Description of CBO's concerns with air quality in their neighborhood.
- Description of the CBO in terms of number of people they serve and size of the neighborhood they cover.
- Explanation of how the CBO meets the selection criteria.
- Explanation of how the community stipend (approximately $10,000) will be spent (i.e. hiring staff, paying for extra staff time, volunteer incentives, etc.).
- What previous air quality studies/analyses and findings have been performed by the CBO in this community/area if any?
- Describe previous work with volunteers and relative knowledge of air quality.

Case Studies

El Puente (Williamsburg, Brooklyn) proposal was accepted to be the first of our two-community air quality monitoring pilots. We were impressed with their knowledge of local air quality issues, particularly relating to $PM_{2.5}$, as well as their goal to use the network to expand measuring air quality outside of parks to identify potentially safer areas for playgrounds and greenspace in Southside Williamsburg. Their goal was to understand if there was a measurable difference in air quality between the parks they have previously studied and other areas of the neighborhood, to determine the relative safety of recreational areas in the neighborhood. Their previous study focused exclusively on air quality in four parks located adjacent to the Brooklyn Queens Expressway in Williamsburg. While this project helped to demonstrate that air pollution in these parks exceeded national air quality standards, and suggested that locating parks next to the Brooklyn Queens Expressway is unsafe, it only represented air quality in one part of the neighborhood. Measuring air quality through the stationary network would allow El Puente to study air quality across a broader area and compare air quality within the community, helping them to identify hotspots that deserve attention, as well as safer areas (places with good air quality), where new recreational areas could be located. Their intended project area was the Southside of Williamsburg. El Puente typically defines this neighborhood as being bordered by Metropolitan Avenue to the North, Union Avenue to the East, Division Avenue to the South, and the East River waterfront to the West. With these boundaries, the area of the Southside is about 0.55 square miles. This area is central to the Southside neighborhood and includes areas of interest such as M.S.50 El Puente Community School, William Sheridan playground, Grand Street Ferry Park, and Domino Park. Since this area includes recreational facilities, particularly for young people, El Puente believed it was especially important to understand the air quality, and therefore the health risks for the community.

Youth Ministries for Peace and Justice (YMPJ, the Bronx) proposal was accepted to be the second community to partake in our air quality monitoring pilot project. We were impressed with their knowledge of local air quality issues. YMPJ sought to gather baseline data that showed how the air quality would change over the next ten to fifteen years as the Governor launches a $2 billion-dollar investment in the redevelopment of the Sheridan Expressway. The Sheridan Expressway redevelopment is expected to remove thousands of trucks from the local streets. YMPJ believes baseline data will demonstrate the impact of the new infrastructure on the air quality over the long term. The study will demonstrate how the City's transportation network impacts respiratory health outcomes for community residents in one of the poorest Congressional districts in the country. Ideally, they would like to do monitoring before, during, and after construction. The project area is along the Cross Bronx Expressway, the Bruckner Expressway, Southern Boulevard, and Zerega Avenue. The neighborhoods surrounded by these three highways, known as the "Toxic Triangle," are exposed to elevated levels of air pollution due to the high traffic density on the highways and local roads, thus severely impacting the living conditions of the local population.

El Puente Williamsburg

Ana MC Ilie
PHOTOGRAPHY

Williamsburg, Brooklyn (NYC)

The case study focuses on the Southside Williamsburg in Brooklyn, which is in New York City (NYC). It is a community with a population of roughly 50,000 people located within approximately one square mile around the Williamsburg Bridge and the Brooklyn Queens Expressway. The Southside community of Williamsburg, Brooklyn is a historically low income, Latino community that is in the process of being gentrified, exacerbating the inequalities the community already faces. Williamsburg's Southside is a historic environmental justice community, facing multiple severe risks.

El Puente

El Puente's mission is to inspire and nurture leaders for peace and justice through the activist engagement of youth and adult members in the arts, education, scientific research, and community and environmental health. Founded in 1982 by Luis Garden Acosta, El Puente was created as a response to an epidemic of gun violence among young people in the Southside of Williamsburg, Brooklyn. Since then, El Puente has led several successful grass-roots campaigns related to environmental and social justice, including stopping the develop-ment of a 55-story incinerator, the reforesting of the Southside, and closing down half of Radi-ac, New York City's only hazardous chemical and nuclear storage facility. El Puente's success can be attributed to its ability to inspire and support community members to act as leaders through holistic leadership development programs. Such programs gave rise to community groups such as El Puente's Toxic Avengers and CAFE (the Community Alliance for the Environ-ment). Through achievements like co-founding the New York City Environmental Justice Alli-ance, publishing a peer-reviewed scientific article in the American Journal of Public Health, and leading a recent pilot study of air contamination in Southside playgrounds, El Puente has become a widely respected institution within North Brooklyn and a nationally recognized leader for social, cultural, and environmental justice.

PLANNING PHASE

RESEARCH PHASE

ACTION PHASE

Case study setup

The community was involved in all aspects of the study, ranging from project design to implementation. Members of the community and high school students participated in both defining the study objectives and the collection of air quality data using low-cost sensor technology (AirBeam2) based on personal monitoring procedures. Key targets for the data collection on $PM_{2.5}$ exposure included schools and playgrounds near major roadways. Project participants attended workshops and training sessions to better understand air pollution in their community and to learn how to use low-cost sensor technology (AirBeam2) to collect and analyze environmental data. BCCHE provided expertise in review, analysis, and summaries of the data collected by the El Puente community.

AirBeam2 (https://www.habitatmap.org) is a wearable air monitor that maps, graphs, and crowdsources your pollution exposures in real-time via the AirCasting Android app and AirCasting website. AirBeam2 is slimmer, lighter, and more accurate; can measure PM_1 and PM_{10} in addition to $PM_{2.5}$, has a higher upper detection limit, is weather resistant to accommodate outdoor installations, and can communicate over 2G GSM and WiFi 2.4GHz in addition to Bluetooth 2.0. An Android device is required to configure the AirBeam2.

The AirCasting platform was built as an open-source, end-to-end solution for collecting, displaying, and sharing health and environmental data using your smartphone. The platform consists of wearable sensors that detect changes in your environment and physiology, including a palm-sized air quality monitor called the AirBeam2, the AirCasting Android app, the AirCasting crowd mapping website, and wearable LED accessories.

PLANNING PHASE

Assessment of Pollution exposure. **1**

Development of Research Plan **2**

RESEARCH PHASE

Data Analysis Plan **3**

Data Validation
Data Analysis **4**

ACTION PHASE

Data Dissemination **5**

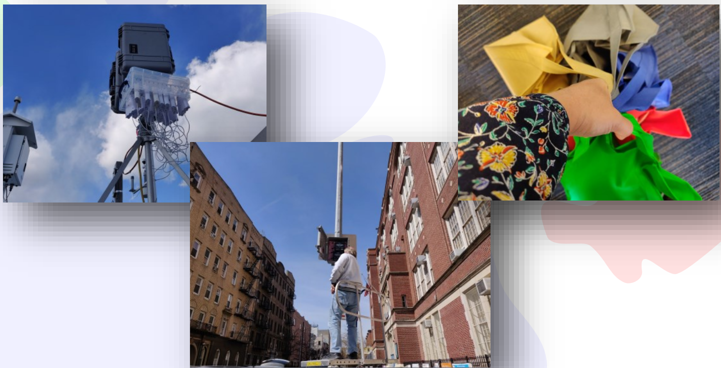
Discussions
Conclusions **6**

1 Assessment of Pollution exposure.

Barry Commoner Center for Health and the Environment (BCCHE) - Queens College and Department of Health and Mental Hygiene (DOHMH) in collaboration with El Puente (Leaders for Peace and Justice) have started this pilot study to better characterize the air quality in South Side Williamsburg neighborhood. This Air Quality Citizen Science research project aimed to provide better awareness and understanding of local hotspots of fine particulate matter ($PM_{2.5}$) concentrations in Williamsburg, Brooklyn neighborhood, which is prone to a high rate of asthma and cardio-respiratory diseases. A key component of the project was to involve the local population in all aspects of the study, ranging from project design to implementation. Members of the community and high school students participated in both defining the study objectives and the collection of air quality data using low-cost sensor technology (AirBeam2) based on personal monitoring procedures. Key targets for the data collection on $PM_{2.5}$ exposure included schools and playgrounds near major roadways. Project participants attended workshops and training sessions to better understand air pollution in their community and to learn how to use low-cost sensor technology to collect and analyze environmental data. In addition to personal monitoring activities, a fixed site monitoring network, using low-cost Airbeam2 devices, was set up at 11 locations in the Williamsburg neighborhood, which provided real-time $PM_{2.5}$ air concentrations that were transmitted to a cloud server. Tableau software was used for data visualization. Before the use of low-cost sensor technology for personal monitoring and the fixed-site network in the project area, an assessment of the performance of all Airbeam2 instruments was performed under ambient conditions at the Queens College-based regulatory monitoring site, operated by the New York State Department of Environmental Conservation (NYSDEC). Preliminary data indicated distinct spatial patterns of $PM_{2.5}$ concentrations in the project area of the South Side Williamsburg neighborhood.

Development of Research Plan 2

- ◊ *Project objectives*



- ◊ *Methodologies*

- ◊ *Protocols & Workshops*

Development of Research Plan 2

Project Objectives

The project was initiated with a kick-off meeting in August 2018 in collaboration with El Puente and the Department of Health and Mental Hygiene (DOHMH). The purpose of the meeting was in-person introductions of team members across El Puente, BCCHE, and DOHMH partners, discussion of project deliverables and to gain an understanding of El Puente's local air quality concerns. Some of the areas discussed included a brief introduction to the air pollution problem in the Williamsburg neighborhood, previous studies on air pollution, and the effects poor air quality might have on health. During the meeting, most polluted areas (hotspots) were identified to chart an air quality plan.

- The primary objective of the study was to focus on gaining a better understanding of air quality at the community level.
- Engage Williamsburg's Southside community in order to raise awareness of the impacts of air pollution and to gain community investment and participation in the project
- Mobilize volunteers to collect air quality data using AirBeam2s in order to characterize the exposure to air pollution and to identify any additional local sources of pollution
- Use data from personal monitoring, previous studies, community knowledge, and NYCCAS data to identify locations for stationary monitoring sites around outdoor public spaces
- Deploy a stationary network using AirBeam2 to collect real-time air quality data around public spaces. Use the co-location of higher quality sensors to ensure data quality.
- Analyze the data to better understand the level of particulate exposure at public spaces around the neighborhood
- Develop an initiative using research findings to identify areas of better air quality or additional problem areas and develop policy recommendations based on findings.
- Disseminate results to the community through an event, forums, and/or an art campaign.

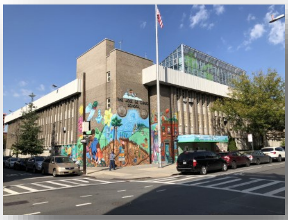
Development of Research Plan 2

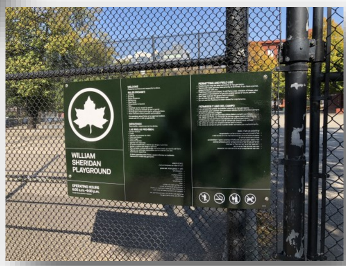
Methodologies

Site Visit - Stationary Network

Further in-person meetings were conducted at El Puente to discuss research priorities and walk around the Williamsburg neighborhood to identify potential locations for the stationary network. Apart from community concerns, discussions related to children's exposure to poor air quality around their schools, schoolyards, and playgrounds were also conducted. After we walked through the study area a map of suggested stationary monitoring sites was made with justifications for why the location was important. It was decided to install a high-quality Thermo Scientific pDR-1500 aerosol monitor at the El Puente Headquarter for data validation purposes. Visual analysis was performed to assess the suitability for an AirBeam2 Stationary Network. An attempt to find locations of power supply and Wi-Fi connectivity was conducted so that AirBeam2 could run continuously and transmit data in real-time. Since it was difficult to find a solution for the power supply at selected locations, it was decided to use batteries as a source of power and pre-installed SIM cards for connectivity.

As a process of personal monitoring, a plan was drafted to have volunteers collect data around areas of interest in Williamsburg. The data ideally should be collected at least 3 times per week and for five minutes at each location. A comparison between personal data to the stationary network could provide a better understanding of breathing levels and how accurate the data is to the stationary network. Field data sheets were made so that volunteers could take notes and information related to traffic, some passing trucks, any odor, any construction activity, any public smoking, or any other kind of information necessary for the interpretation of data. The volunteers were also required to take pictures.





Development of Research Plan 2

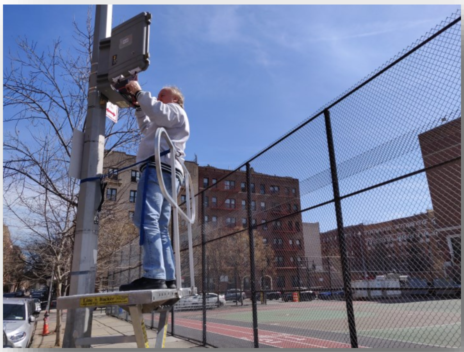
Site Visit - Stationary Network

Based on the previous kick-off meeting, certain areas of interest were identified by El-Puente which included three schools, schoolyards, and playgrounds, as shown in figure 1. With a focus on the most important locations, five different sites with many internal locations were identified for air quality monitors (AQM) using Airbeam2. For example, the entrance to one of the schools was selected as a target location along with the schoolyard, due to higher student activity in those areas. For each site, suitable lamppost or flag poles locations for the deployment of air monitoring equipment were identified and their GPS coordinates were determined.

Figure 1. Map of Williamsburg area indicating 12 locations for the stationary network.

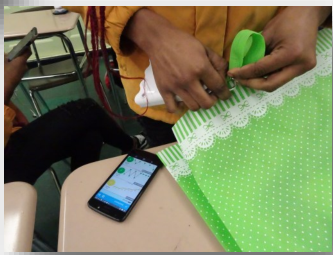
Stationary Network - Deployment at Queens College DEC site

The AirBeam2s were deployed at the Department of Environmental Conservation (DEC) site - Queens College, for three weeks before deployment in Williamsburg and referenced against FEM (R&P Tapered Element Oscillating Microbalance—TEOM, method 701 & 702) and FRM (TEI 2025i Method 145) instruments. Field data sheets were prepared in the lab. A unique ID was assigned to each location where AQM was deployed. The AirBeam2 devices were configured in cellular mode using the Ting and Mint SIM cards. Moreover, they were configured to run as a fixed session through the AirCasting App using Motorola mobile phone. Data was collected at the DEC site for three other weeks at the end of the project. This 'co-location' procedure at DEC site helps us to better understand the accuracy of the low-cost sensors.



Stationary Network - Deployment in Williamsburg

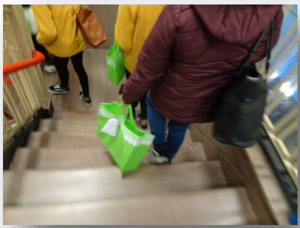
As a first step towards the deployment of AQM, it was ensured that the equipment had their batteries completely charged. Once on location, a metal plate was installed directly on the lamp posts which was further hooked to the Pelican box which houses the AirBeam2s. Each battery was placed inside the housing and secured with a bungee cord. The AirBeam2 was switched ON and it was made sure that the data was streaming onto the AirCasting web-site. Each unit was locked for safety reasons. The AQM units started to collect data in Williamsburg in January (W2), March (W4-W6-W10), and August (W1- W3-W5-W7-W8-W9-W11-W12). All THE AQM run simultaneously in August – September – October 2019.

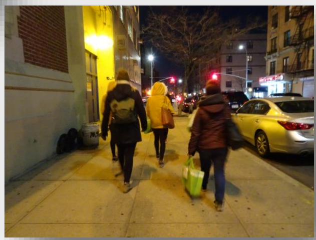


Personal Monitoring

The participants were recruited by El Puente who proposed the measurement routes. The volunteers were composed of students from El Puente After-School Program, El Puente Academy High School, and internship students from Queens College - BCCHE. The first session of data acquisition was started on March 11th, 2019 and was held bi-weekly through November 2019. Five groups (EP1 through EP5) were created for personal monitoring. Each group had a minimum of 2 volunteers and the devices were named according to the group itself, to track the data collected from a specific route, regularly. Ideally, the same volunteers were assigned to the same route, to make it easier for them to understand the route and report relevant events associated with it.

The volunteers participated in the data collection process through the AirCasting app and online interactive data visualizations on the AirCasting website. These routes were selected in a way so that air pollution maps could be built at a high spatial resolution and be able to derive exposure to pollutants from these maps. For each measurement, readings were required to be taken during morning and evening to obtain a wide range of values and better characterize the pollution levels. However, due to the unavailability of the volunteers in the earlier phase of the project, measurements were only taken during the evening. Each path had to be traveled back and forth through the same route. Each route had six stops that were near a stationary monitoring station or a subset point, and area source indicated as a special concern (e.g. major truck routes, ongoing construction, traffic congestion points, highway interchanges, and transportation facilities). The area where the data needed to be collected was marked for each group on the map and the groups had to follow the directions and stay on their designated route.





Development of Research Plan 2

Each step of the personal monitoring process is shown in the figure 2. A brief description is also provided. The first step involves signing in to take out the required material and making sure it is all available for performing the data acquisition. This includes access to AirBeam2, Mobile Phone, Map, and all necessary for taking notes. The second step was performed to make sure the proper connection between the AirBeam2 and the mobile phone was successfully established. To make sure data was consistently recorded, the volunteers were required to enter the Session Number and AirBeam ID. Once the volunteers were made aware of the specific route, data was collected for the required time interval. At the end of the session, volunteers had to return all the equipment and sign a form indicating it was returned then upload the data onto the AirCasting website. El Puente took the responsibility to charge all devices at the end of each session.

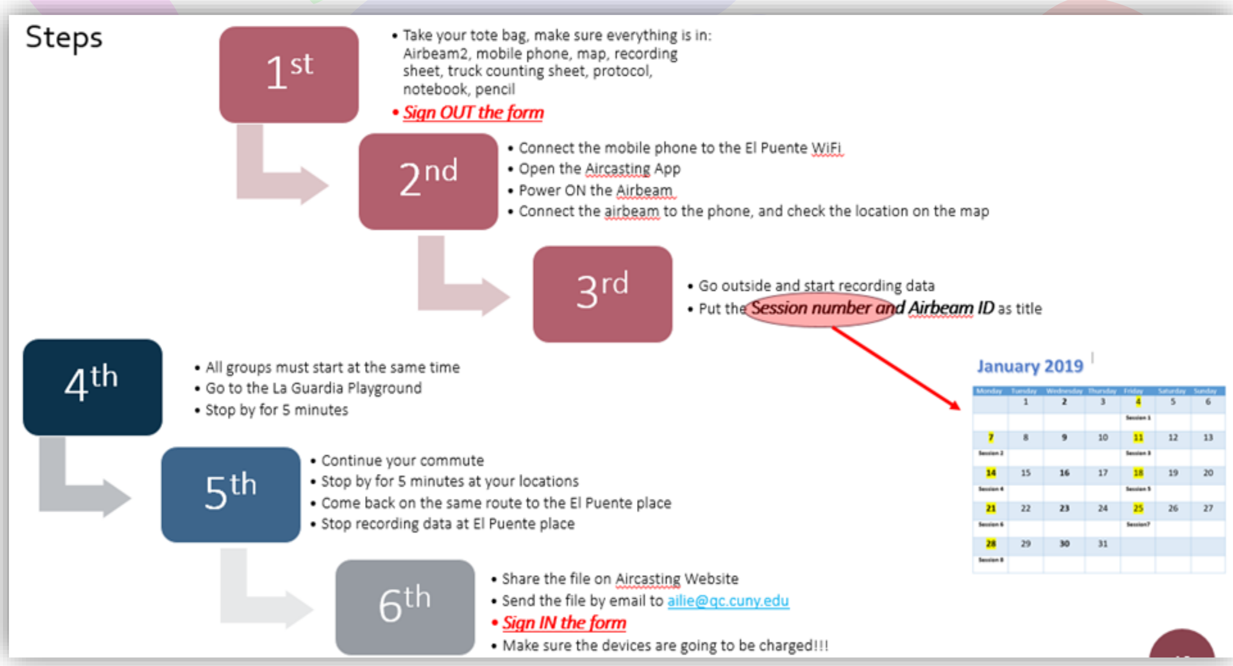
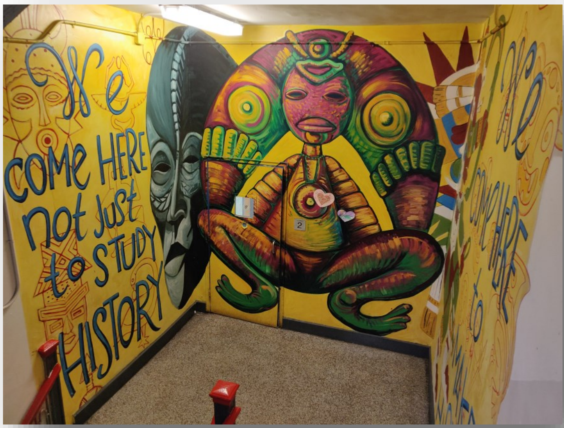
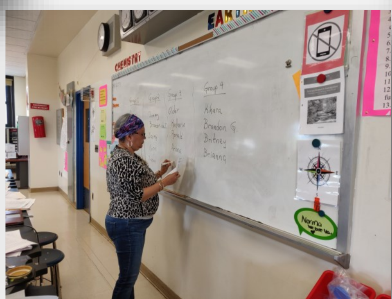


Figure 2. Steps of the personal monitoring process.

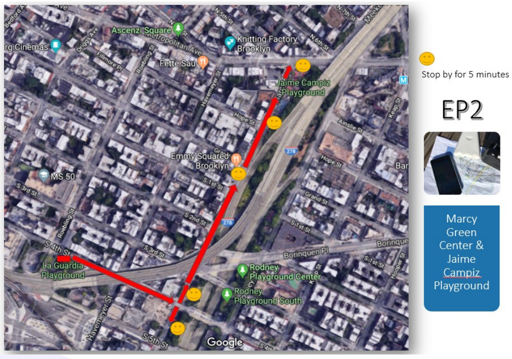


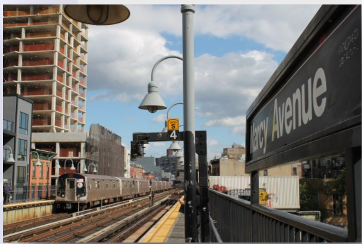
Development of Research Plan 2

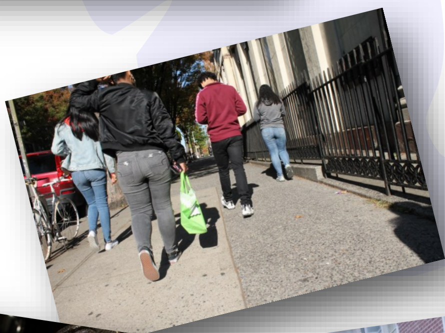
As a part of the personal monitoring plan, several meetings were conducted with the science teacher partaking in the science project at the El Puente Academy for Peace and Justice High School, before the start of the monitoring sessions. Discussions with the teacher related to the Science project were held for an improved curriculum focused on air quality. Two different groups of 25 students each (Team F and Team G) were selected for personal monitoring sessions, based on their interest in the air quality project. Based on the student's availability, a timeline was proposed for personal monitoring. The measurements were required to be taken twice a week during morning and afternoon. An introductory session was organized for the students to give them an overview of the project, air pollution, and background information on the particulate matter including their sources and health effects. The students were trained on how to use AirBeam2 and how to analyze the data. These groups followed the same routes of the El Puente volunteers' groups so that we could obtain more information on those important streets. Each group comprised of 5 students and a mentor. They had to follow the same steps El Puente volunteers' groups had to as mentioned in the previous section.



The route where the data needed to be collected for the Group EP1-EP2 is shown on these maps.

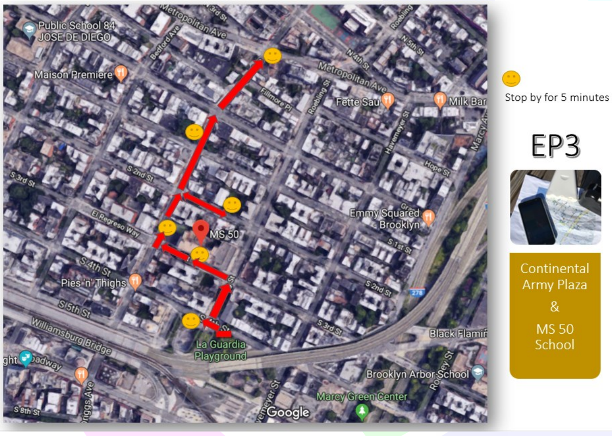


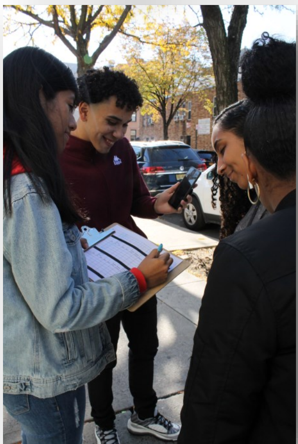




Development of Research Plan 2

The route where the data needed to be collected for the Group EP3-EP4 is shown on these maps.





The route where the data needed to be collected for the Group EP5 is shown on this map.

Protocols

Air Quality Monitor (AQM) protocol

Due to safety and liability issues, only BCCHE staff was involved in the process of assembling of the portable, power-independent Airbeam2-based real-time PM2.5 monitoring units. The primary components of the Air Quality Monitor (AQM) included two PS-6580 - 6V 58AH Sonic Rechargeable batteries, a step-down adjustable voltage power converter, and an AirBeam2 for recording particulate matter concentrations. The secondary components of the AQM included: a DC power jack/connector, power extension, charge cable, printed circuit board, screw terminal blocks, SIM card for data transmission to the AirCasting website, rubber bungee strap with S-Hooks, foam, resistant PVC (gray board), and plates, see figure below. The equipment is mounted inside a watertight and crushproof polypropylene case (Pelican Model 1550NF silver case, exterior dimensions 16 in L x 13 in W x 6.9 in D). The complete unit weighs approximately 45 lbs. and was mounted on a lamppost, ten to twelve feet above ground using a permanently installed lockable mounting plate that enables rapid deployment. The batteries were fixed on a PVC board with the rubber bungee strap with S-Hooks and connected to the PCB board through the screw terminal blocks. The circuit was soldered on the PCB board, which includes the step-down adjustable voltage power converter. The converter drops the 6V battery output to 5V to meet the power requirements of the AirBeam2 monitor.

Build your own Prototype, follow the next steps:

1. On the back of the Pelican case 15500 measure the midpoint of the top crest. (About 7 ¼”)

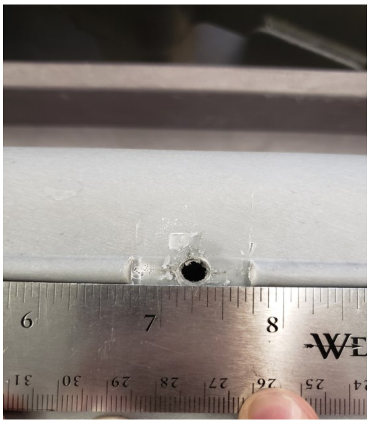
2. Draw a straight guide line down the middle of the case

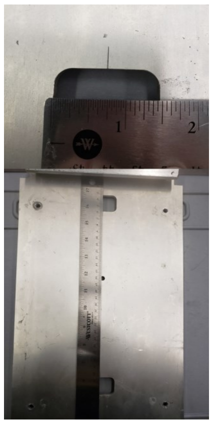
3. Measure ½ inch from the midpoint on both sides and cut away the entire 1 inch section of the ridge. Make sure a 1” washer fits, cut away excess material until it sits flat.

4. Using a 9/64 drill bit make a pilot hole in the center of the gap created, then use a ¼ drill bit to make the hole.

5. On the metal backing plate measure the midpoint of the two large holes on the back side.

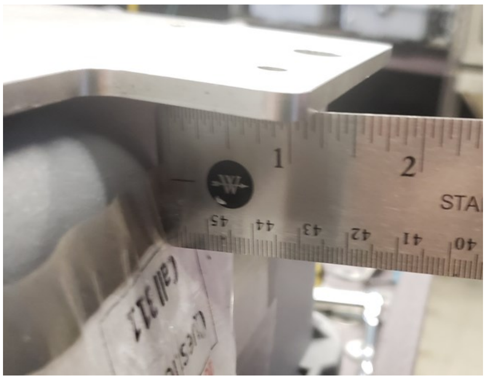
6. Make sure that the measurements line up perfectly with a straight edge or ruler





7. Line up the midpoint lines on the back plate with the guideline from step 2 leaving at least a 1” gap between the end of the case and the end of the plate.

8. While applying pressure to the back plate, using a ¼” drill bit use the 4 holes in the corners as a guide to make the holes in the case. Use the drill to make a small divot, then move the plate away to make the full hole. Do this in a crisscross manner and use a screw to hold the plate in place.



9. Put the template gray board on top of the new gray board and clamp them together with as many clamps as possible keeping them as even as possible. Use a small 9/64” bit to make pilot holes and a ¼” bit to make the final holes for the 8 holes on the sides.

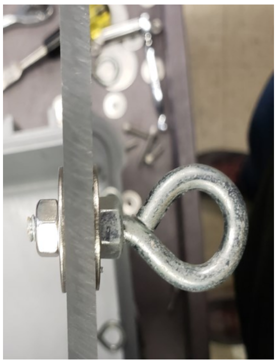
Note: The top and bottom are not equal so label which side is which.

10. Put the gray board in the Pelican case, and use something like packing foam to hold it tight against the bottom.

11. Flip the case over and use the top center, and bottom two holes as guides to drill into the gray board with a ¼” bit.

12. Use a 5/16” bit to make these three holes bigger

13. Add the eyebolts to the 8 side holes on the board. Thread a nut all the way to the top of the bolt and add a washer, then on the other side add another washer and nut. Use a socket wrench to tighten down.



14. Apply silicone caulk around all 5 holes in the back of the case. The middle two holes get 2 washers each so be sure to apply a layer between the washers.

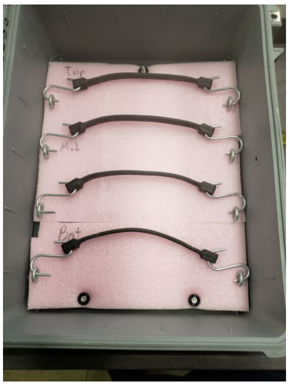
15. Add the back plate and screws

16. Apply silicone caulk to the inside of the case as well. Tighten down all 5 nuts using 2 sock-et wrenches. Allow at least 24 hours for the caulk to properly cure.

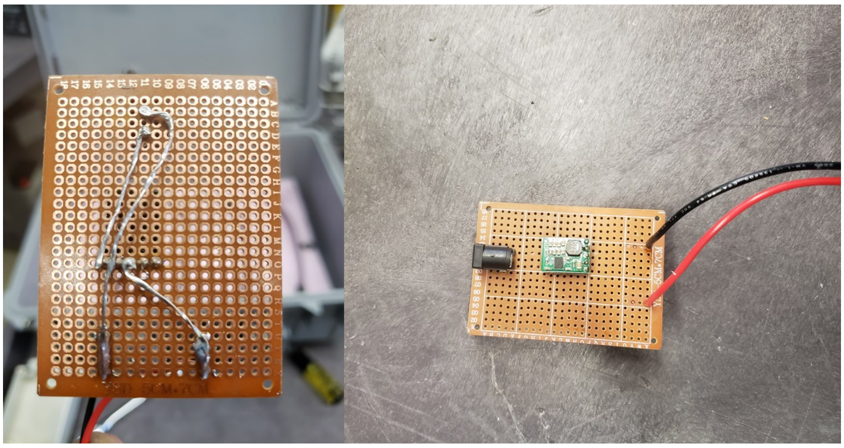
17. Insert the gray board and add the foam and straps. Tighten down with 3 thumb nuts.

18. Drill a large hole in one side of the plastic housing and cut out a piece of the top on the other side. Use a file to smoothen it out and make the hole as wide as possible.

Note: Co-located units will need two holes in the same side



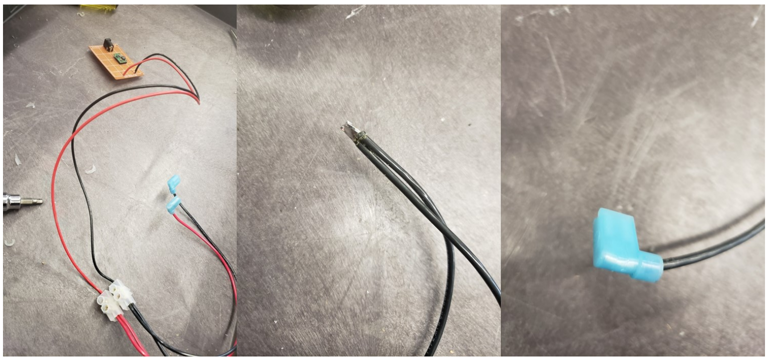
19. Solder the step down board together. First solder the jack to the board, then the 5 pin riser, and finally the positive and negative wires. Then wire them together as shown. Make sure to keep the polarity correct or else the board will short out and be ruined.



20. Insert the positive and negative wires from the step down board into one end of the terminal box and screw down tight.

21. Solder the ends of two pieces of 14 gauge wire together and insert them into the other side of the terminal box, screw down tight.

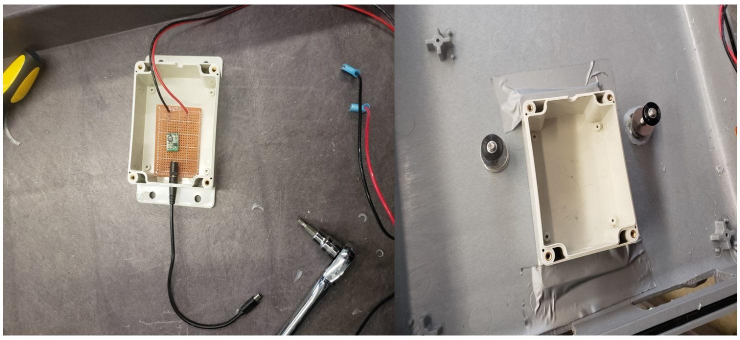
22. Strip the remaining 4 ends of the wire, and put an angled spade terminal on and crimp it using a crimping tool.

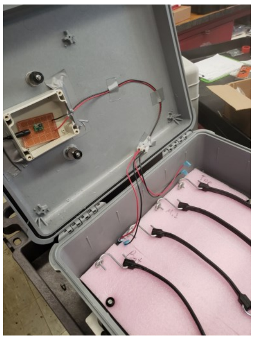


23. Insert the board into the plastic housing, and thread the power cable through the hole. Plug it into the jack.

24. Mount the plastic housing to the case using duct tape

25. Tape down the wires to the plastic housing, and tape down the remaining wires.





Development of Research Plan 2

Lead-Acid Battery Safety and Battery Acid Spill Cleanup Procedures

Prepared by the Barry Commoner Center for Health and the Environment (BCCHE) & Environmental Health and Safety (EHS), Queens College, City University of New York.

1. Purpose and scope

This procedure describes the safety requirements that apply to lead-acid battery packs under normal and emergency conditions. All Barry Commoner Center for Health and the Environment (BCCHE) personnel that use, store, and dispose lead-acid battery packs must review and follow this procedure.

2. Lead-acid battery hazards

Lead-acid batteries contain sulfuric acid, which is corrosive and can burn and damage the skin and other body tissues. Lead-acid batteries produce hydrogen gas, especially during charging. Hydrogen is explosive at concentrations between approximately 4% and 75% by volume with air.

Batteries are heavy and require proper handling to lift them safely.

Lead is toxic to human health and is considered an environmental pollutant.

Workers must have the proper personal protective equipment:

- acid resistant gloves,
- eye/face protection,
- rubber apron,
- Lab coat.

3. Battery recharging

Recharging should be done only in a location with adequate ventilation to disperse fumes given off during charging. Prohibit smoking, open flames, sparks, welding and electric arcs in recharging locations. Ensure recharging area is equipped with fire extinguishers, materials for absorbing spilled electrolyte and emergency shower and eyewash stations in case of an electrolyte splash.

Follow these safety procedures for charging batteries:

A. Ensure the proper charger is being used for the particular kind of battery.

B. Connect the cables of the charger to the battery while the charger is OFF!

C. Hook-up the positive cable on the charger to the positive terminal on the battery. Hook up the negative cable on the charger to the negative terminal on the battery.

D. Set the charger to the slowest charge rate.

E. Observe the battery temperature, voltage and current during charge (never overcharge a battery)

F. Shut off the charger when disconnecting the battery.

G. After charging, allow the battery to cool down

4. Leaking cells

Know what to do in the event of an emergency. Damaged cells can leak electrolyte, which consists of a sulfuric acid solution (typically at a 35% concentration). Sulfuric acid is a corrosive that can damage the skin and eyes.

4.1 Before attempting to deal with leaking lead-acid batteries, don proper personnel protective equipment:

- acid-resistant gloves,
- eye/face protection,
- lab coat

Ensure that emergency wash water is immediately available.

If your skin or eyes are exposed to the battery electrolyte, immediately rinse affected body parts with water and seek immediate medical attention for injuries.

4.2. Spilled electrolyte should be neutralized before being cleaned up. Spilled electrolyte from lead-acid batteries can be neutralized with an approved acid neutralizer, such as Spill-X-A Acid Neutralizer or baking soda. Absorbent should be collected with corrosion-resistant plastic tools and materials. Area shall be rinsed with water once acid has been neutralized.

4.3. Damaged batteries and spill cleanup materials should be collected in a suitable container that is properly labeled. A five-gallon plastic container with lid is suitable for storage and transportation. Container must be labeled as hazardous waste, damaged lead acid battery.

5. Waste Management and Transportation

Intact Lead-acid batteries that are spent or otherwise considered waste, cannot be disposed as regular trash and must be recycled and managed as universal waste. Damaged, swollen or leaking batteries must be managed as a hazardous waste. Batteries should be transported in a manner that prevents short circuit or other abusive conditions. All exposed terminals must be taped or enclosed to prevent short circuiting. Do not mix incompatible batteries in the collection container and replace the container lid.

Battery acid spill cleanup procedure: Step-by-step approach

Required materials:

- Neoprene gloves
- Safety goggle
- Acid resistant shoe covers and apron
- Baking soda
- Vermiculite/cat litter
- Bucket(s)/Container(s)
- Plastic bags
- Broom
- Dustpan

Procedure:

1. Place Safety Cones around the area where the battery dropped, and the acid spill occurred.
2. Keep the public away from the area.
3. Retrieve the Battery Spill Kit from the vehicle.
4. Wear neoprene gloves, safety goggles, and acid resistant shoe covers and apron.
5. Spread the baking soda on the battery and any areas around it that might have been in contact with acid, working from the outside in.
6. Pick up the damaged battery and place in bag. Seal bag tightly, then place in the bucket/ container.
7. Spread more baking soda on the ground where the acid has spilled.

8. When the acid stops fizzing, put vermiculite/kitty litter on the spill.

9. After all of the acid has been absorbed, sweep up everything with the broom and pour residue into bag. Seal bag and place in bucket.

10. Rub baking soda between gloves over bucket to remove excess acid.

11. Remove gloves without touching the outside, and place in another bag and put in bucket. If the shoe covers have come into contact with the acid remove them BEFORE removing the gloves and place it in the bag.

12. Close the bucket.

Fill out an INCIDENT REPORT DOCUMENT(s), as shown in figure 3.

LABORATORY INCIDENT REPORT AT QUEENS COLLEGE/CUNY

INCIDENT INFORMATION:

Date: .... Location: ....

Nature of Incident: .... PPE (Yes/No): ....

Name of Person(s) Involved: .... Department: ....

Clean-Up Done? .... By Whom? ....

Description of the Circumstances (use back if needed): ....

....

....

....

Action Taken:

Injury (Yes/No): . . . . . Describe: ....

Person(s) Injured: .... Department: ....

First Aid (Yes/No): .... Ambulance acc./dec./ ....

Reported by: Instructor, ... Telephone #: ....

Remarks: ....

Reported to: .... Date: ....

Reported to: .... Date: ....

Figure 3. Incident report document.

AirBeam2 Protocol

The AirBeam2 uses a light scattering method to measure $PM_{2.5}$. Air is drawn through a sensing chamber wherein light from a laser scatters off particles in the airstream. This light scatter is registered by a detector and converted into a measurement that estimates the number of particles in the air. Via Wi-Fi or cellular, these measurements are transmitted to the AirCasting server every minute where they are mapped and graphed, as shown in figure 4. Via Bluetooth, these measurements are communicated every second to the AirCasting Android app, which maps and graphs the data in real-time on your smartphone before sending it on the AirCasting website. When recording a mobile session, these measurements are communicated once a second to the AirCasting Android app via Bluetooth. When recording a fixed session, these measurements are communicated once a minute to the AirCasting website via WiFi or cellular. At the end of each mobile AirCasting session, the collected data is sent to the AirCasting website, where the data is crowdsourced with data from other AirCasters to generate heat maps indicating where PM concentrations are highest and lowest.

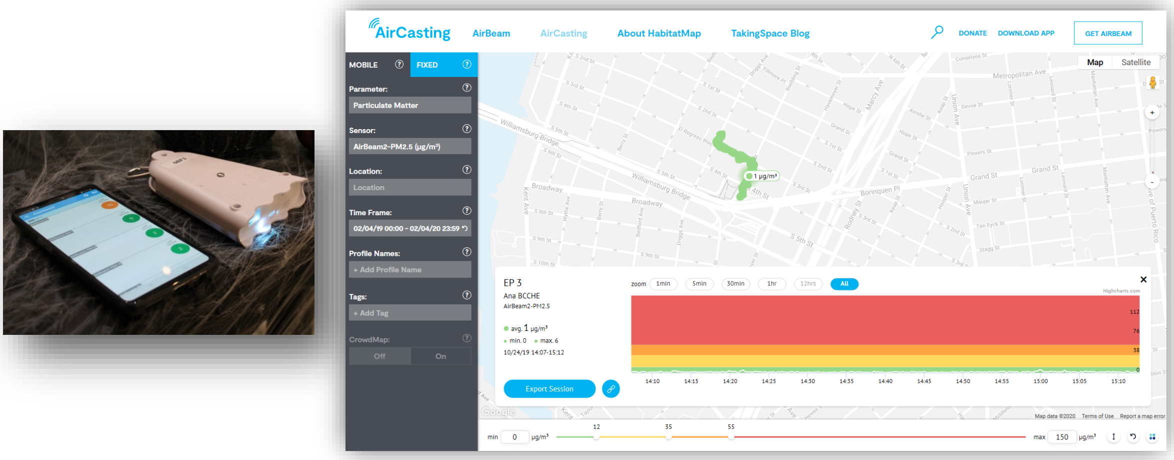


Figure 4. AirBeam2 and AirCasting website (www.habitatmap.org)

AirBeam2 Protocol, follow these steps:

1. When to use AirBeam2

AirBeam2 can be used in environments with a humidity of less than 90% and a temperature range from -10°C to 60°C (14°F to 140°F).

Note: During the winter, you must start recording directly outside, do not go inside while you record data.

During the summer, if you start your measurements in a cold, air conditioned room and go outside to warmer temperatures, do not consider the first 5 minutes of recorded data when conducting your analysis. Rapid fluctuations in environmental conditions yields inconsistent data.

2. Powering on AirBeam2

AirBeam2 has a 2000mAh 3.7V rechargeable lithium battery. When the battery is fully charged, AirBeam2 can operate for 10 hours. The battery charges via a USB C port, which can also be used to power AirBeam2 directly. The battery charging indicator (see diagram below) turns solid green when AirBeam2 is charging and turns off when AirBeam2 is either fully charged of unplugged, as shown in figure 5.

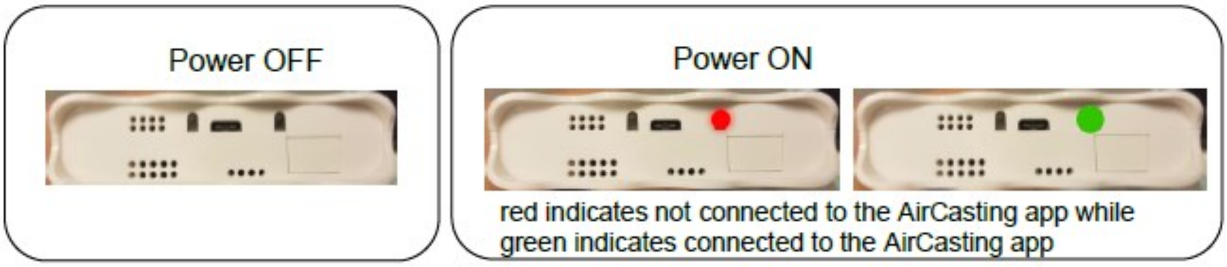


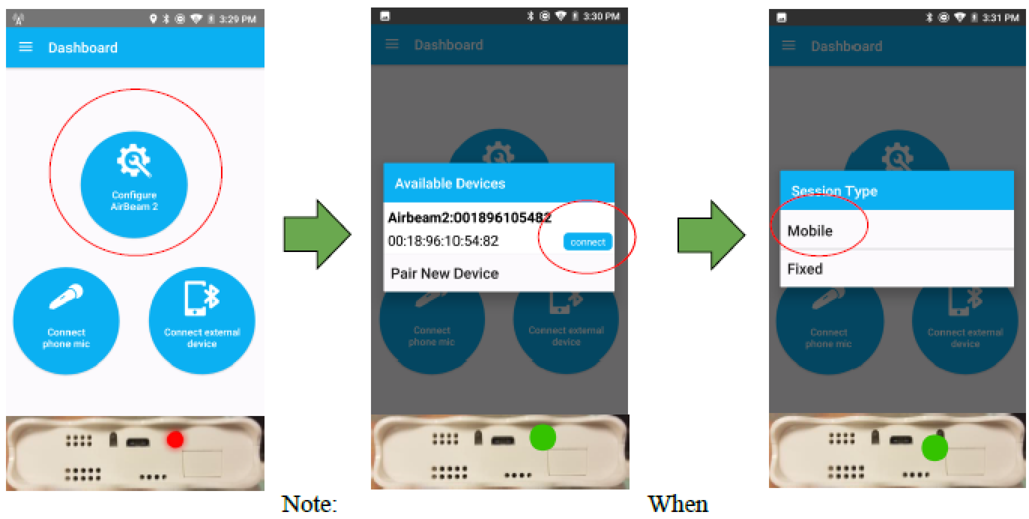
Figure 5. Powering ON the AirBeam2.

While recording a mobile session, measurements are communicated once a second to the AirCasting app via Bluetooth. The Android device must stay within 10 to 20 feet of AirBeam2 to maintain the Bluetooth connection and receive data from AirBeam2.

Note: While operating AirBeam2 be sure to keep the PM sensor intake and PM sensor exhaust fee from obstructions.

3. Connecting to an Android device

To connect AirBeam2 to an Android device, first open the AirCasting app. Then, power on AirBeam2 by pressing the power button until it clicks inward. Once AirBeam2 is powered on, proceed with the following steps, as shown in figure 6:



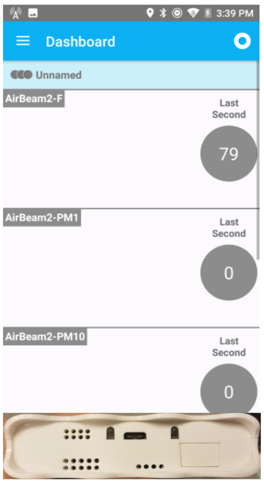
1) On the Dashboard, select *Configure*

2) When AirBeam 2.0 shows a green light, select *Connect*

3) Select *Mobile*

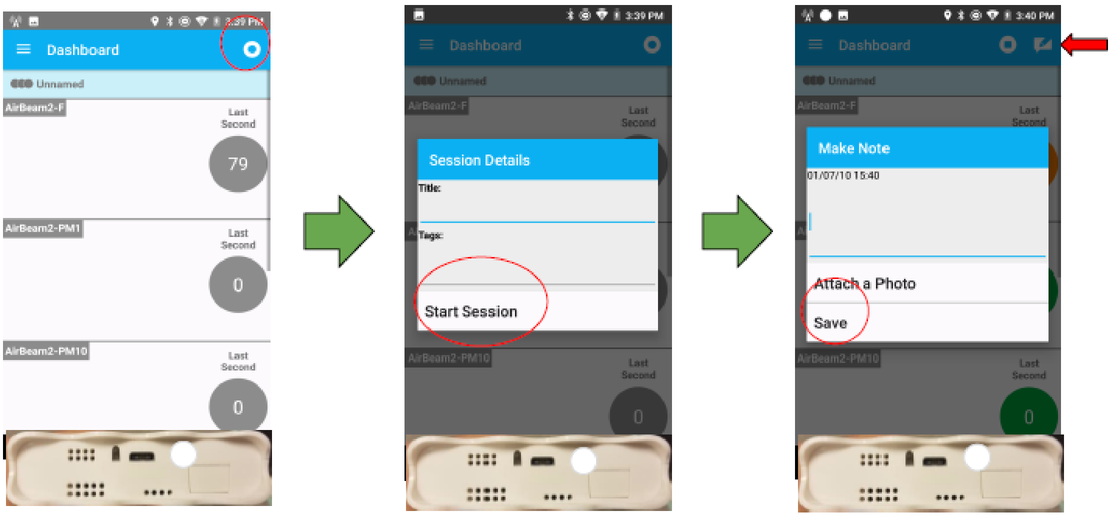
Figure 6. Connecting AirBeam2 to an Android device.

If the AirBeam2 and the Android device are successfully connected, AirBeam2 will show a white light and the Dashboard will display all parameters as demonstrated below:



4. Begin to record data

To begin recording data, proceed with the following steps:



1) On the Dashboard select the circle in the upper right hand corner

2) Title the entry and select *Start Session*

3) To add notes or photos to the entry select the pen icon in the upper right hand corner and *Save* accordingly

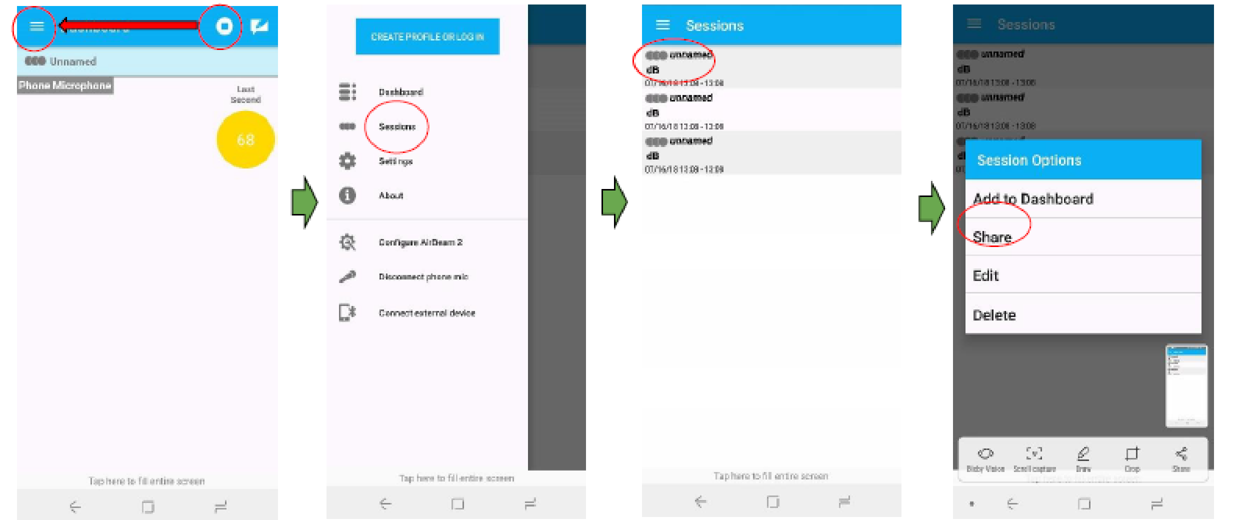
Figure 7. Begin recording data.

When you go outside with the AirBeam2, it will no longer be able to connect to your WiFi network; however, the on-board GPS will still save your location no matter where you go. At the end of the day, try to connect your Android device to WiFi and upload the data to the AirCasting app or share the data file via email.

Note: On the dashboard you have the option of viewing the parameter that you prefer as either a graph or a map.

5. Stop AirCasting and share the file

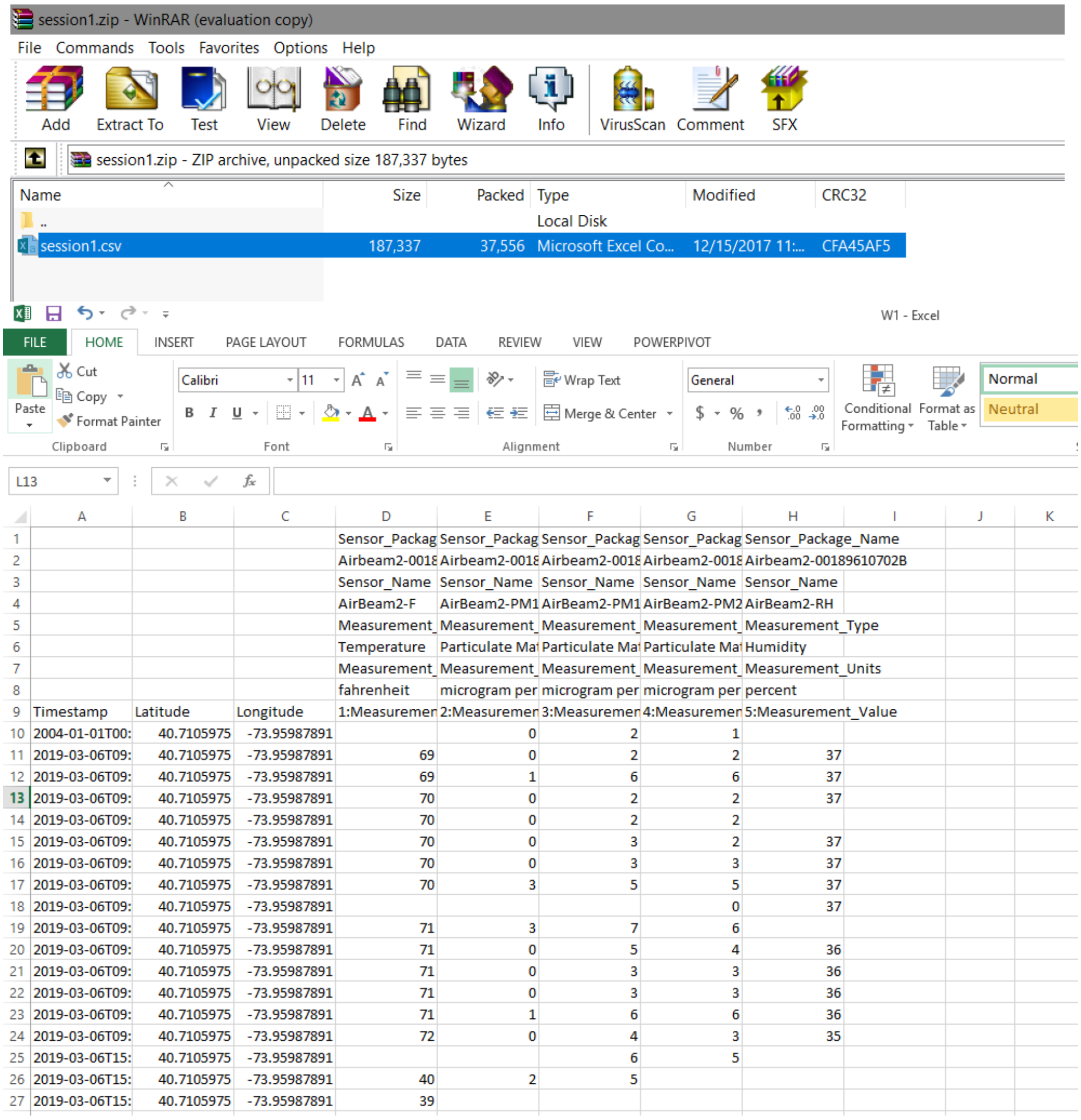
To share the file, you must stop the session and follow the prompts to share accordingly.



1) Select stop by tapping the circle icon then open the menu in the upper left hand corner	2) Select Sessions	3) Select the desired session	4) Select share to open the share menu and share via mode of choice e.g. email, Bluetooth, Google Drive, ect.

Figure 8. Stop recording and share the file.

Once the file is received, it can be downloaded as a winzip file. Open it in Excel with eight columns: A timestamp, B latitude, C longitude, D - H all parameters recorded (F, PM_1, PM_{10}, $PM_{2.5}$, RH).



	A	B	C	D	E	F	G	H
1				Sensor_Packag	Sensor_Packag	Sensor_Packag	Sensor_Packag	Sensor_Package_Name
2				Airbeam2-0018	Airbeam2-0018	Airbeam2-0018	Airbeam2-0018	Airbeam2-00189610702B
3				Sensor_Name	Sensor_Name	Sensor_Name	Sensor_Name	Sensor_Name
4				AirBeam2-F	AirBeam2-PM1	AirBeam2-PM1	AirBeam2-PM2	AirBeam2-RH
5				Measurement_	Measurement_	Measurement_	Measurement_	Measurement_Type
6				Temperature	Particulate Ma	Particulate Ma	Particulate Ma	Humidity
7				Measurement_	Measurement_	Measurement_	Measurement_	Measurement_Units
8				fahrenheit	microgram per	microgram per	microgram per	percent
9	Timestamp	Latitude	Longitude	1:Measuremen	2:Measuremen	3:Measuremen	4:Measuremen	5:Measurement_Value
10	2004-01-01T00:	40.7105975	-73.95987891		0	2	1	
11	2019-03-06T09:	40.7105975	-73.95987891	69	0	2	2	37
12	2019-03-06T09:	40.7105975	-73.95987891	69	1	6	6	37
13	2019-03-06T09:	40.7105975	-73.95987891	70	0	2	2	37
14	2019-03-06T09:	40.7105975	-73.95987891	70	0	2	2	
15	2019-03-06T09:	40.7105975	-73.95987891	70	0	3	2	37
16	2019-03-06T09:	40.7105975	-73.95987891	70	0	3	3	37
17	2019-03-06T09:	40.7105975	-73.95987891	70	3	5	5	37
18	2019-03-06T09:	40.7105975	-73.95987891				0	37
19	2019-03-06T09:	40.7105975	-73.95987891	71	3	7	6	
20	2019-03-06T09:	40.7105975	-73.95987891	71	0	5	4	36
21	2019-03-06T09:	40.7105975	-73.95987891	71	0	3	3	36
22	2019-03-06T09:	40.7105975	-73.95987891	71	0	3	3	36
23	2019-03-06T09:	40.7105975	-73.95987891	71	1	6	6	36
24	2019-03-06T09:	40.7105975	-73.95987891	72	0	4	3	35
25	2019-03-06T15:	40.7105975	-73.95987891			6	5	
26	2019-03-06T15:	40.7105975	-73.95987891	40	2	5		
27	2019-03-06T15:	40.7105975	-73.95987891	39				

Figure 9. Data recorded in a WinZip file.

6. AirCasting website

When recording a mobile AirBeam2 session, you can share your data on the website at http://aircasting.org/

Click MAPS and a new window will be opened.

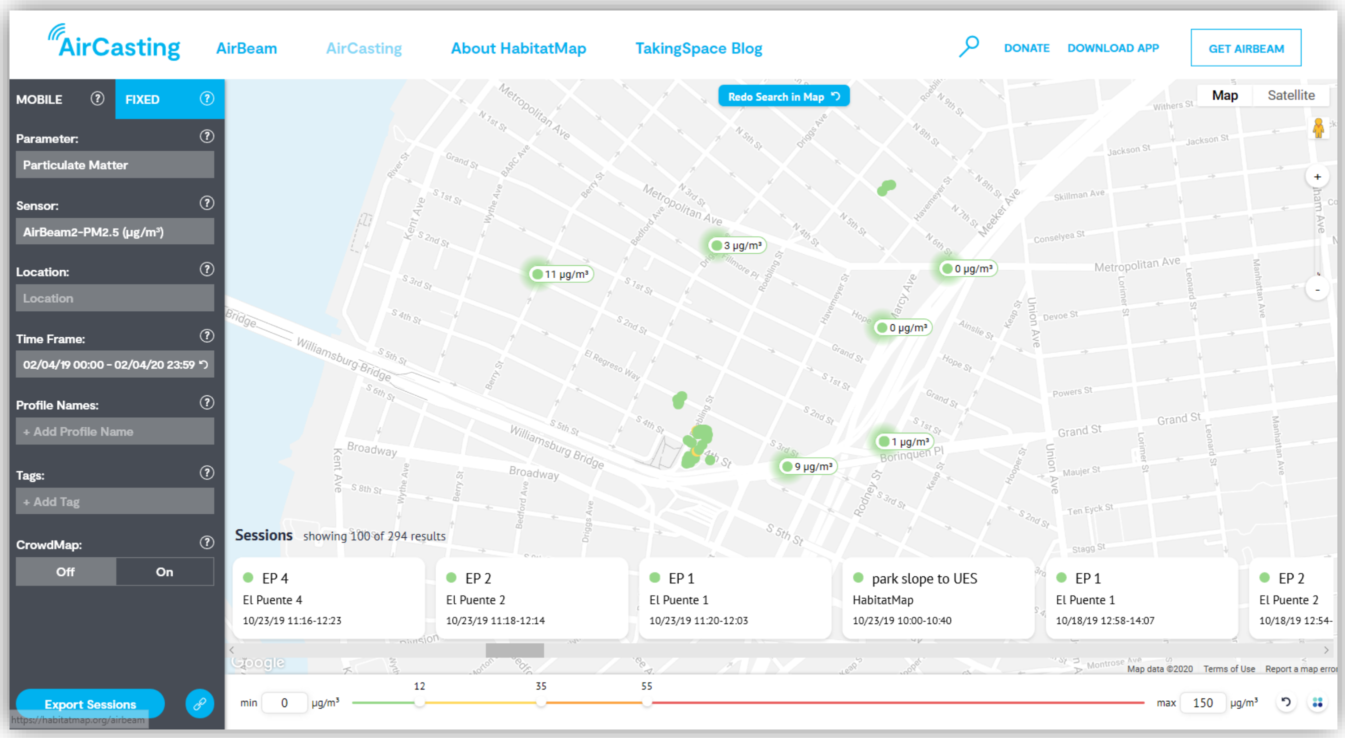


Figure 10. AirCasting website.

In the upper left corner of the window, you can view Mobile sessions and Fixed Sessions.

To view your own data, click Mobile sessions, specify the Profile name or ID of the Airbeam2 device.

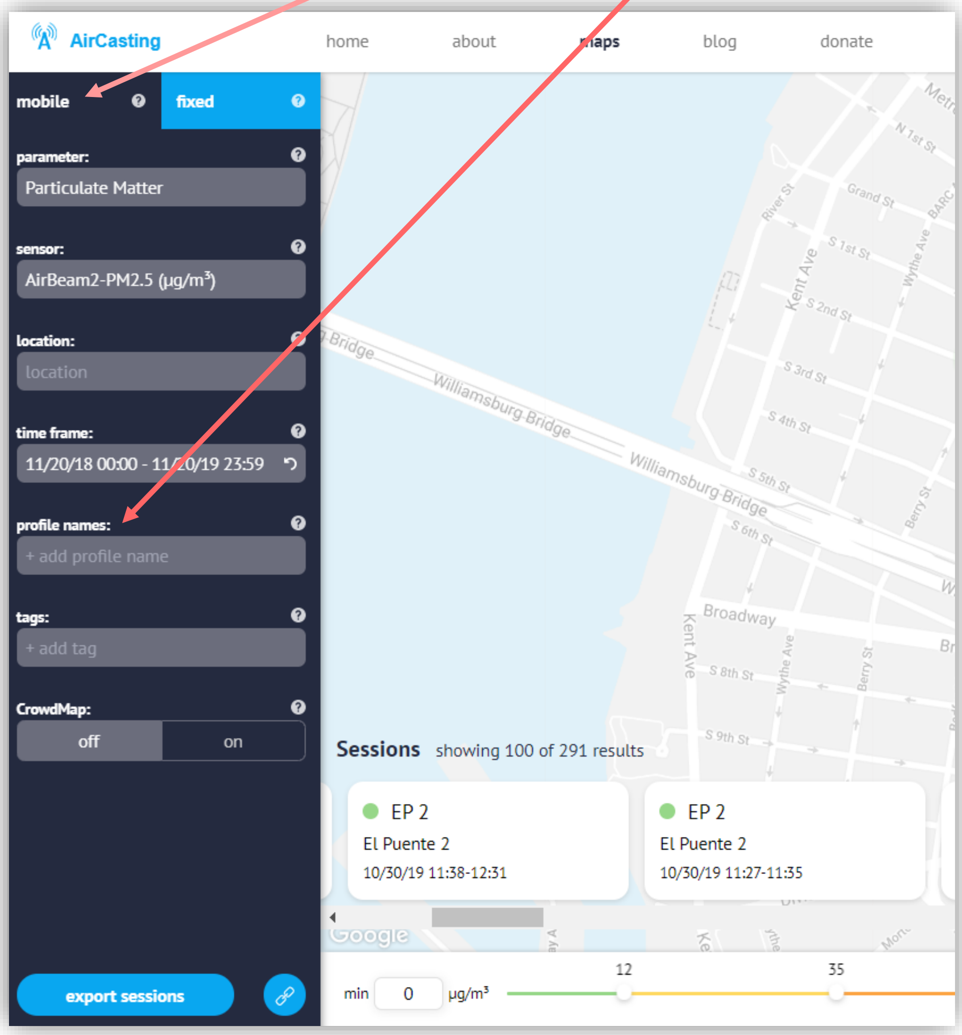


Figure 11. AirCasting website, mobile and fixed sessions.

AirCasting organization (http://aircasting.org/) records all fixed and mobile sessions from the AirBeam device. BCCHE uses the AirCasting Application Programming Interface (API) to retrieve the data from the AirCasting database: https://github.com/HabitatMap/AirCasting. The API Python script pulled data from the AirCasting database into a PostgreSQL database residing at BCCHE. To develop the various aggregate reports, we used Tableau Desktop accessing the PostgreSQL database. The parameters measured by the AirBeam2 include temperature, relative humidity, and particulate matter or PM_1, $PM_{2.5}$, and PM_{10}. It can communicate over 2G GSM and Wi-Fi 2.4 GHz in addition to Bluetooth 2.0. These measurements are transmitted every minute to the AirCasting server via cellular connection, where they are mapped and graphed.

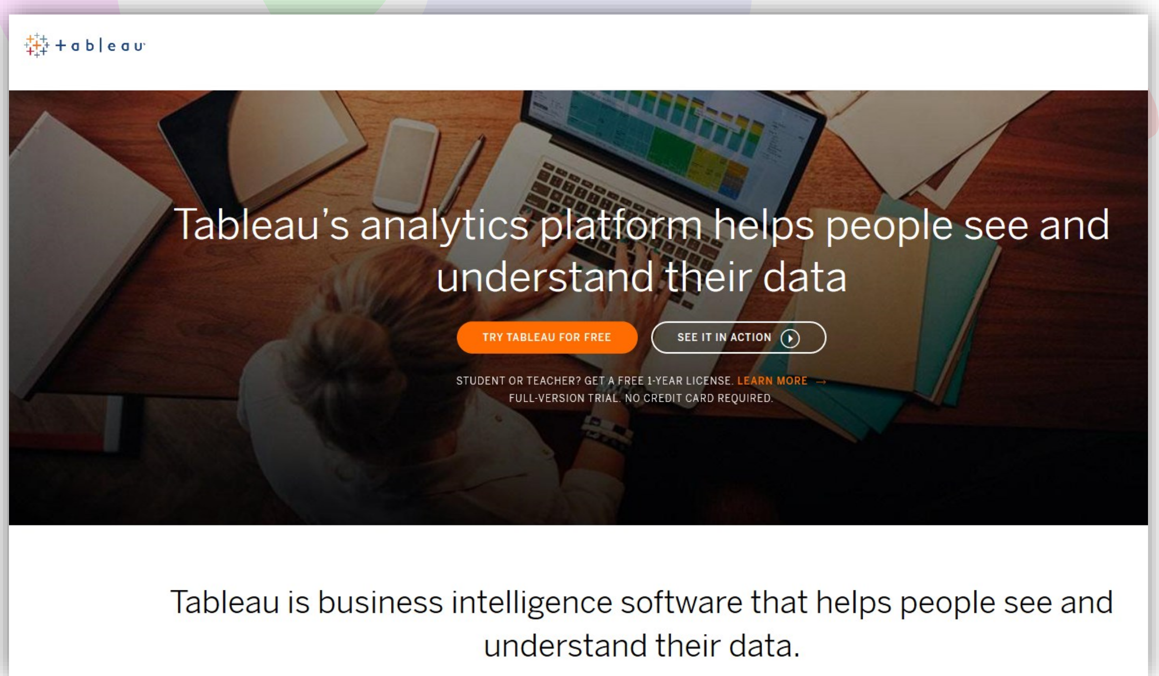
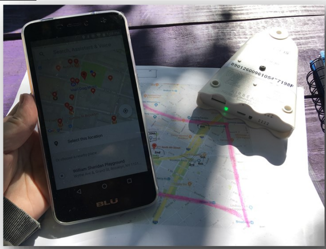


Figure 12. Tableau software. Student or teacher? Get a free 1-year license.

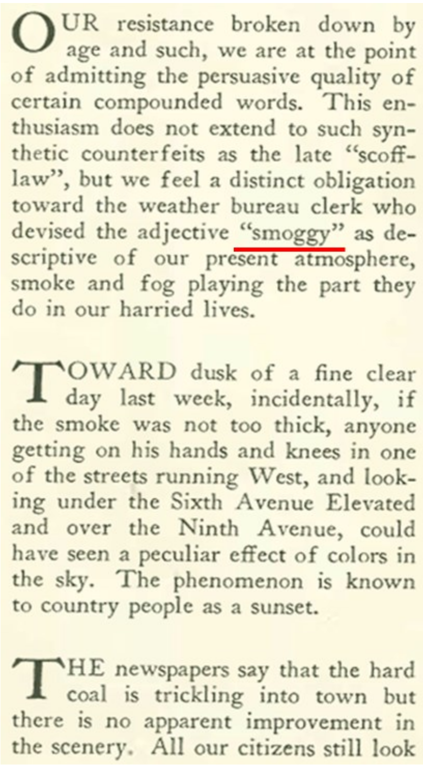


Development of Research Plan 2

Workshop at El Puente Headquarters

The first workshop for Air Quality Citizen Science Project was conducted in October 2018 at El Puente Headquarters in Williamsburg, NY. Participants were invited to attend through various channels including emails, messages, flyers, and promotion by El Puente community-based organization.

The workshop consisted of an introduction to the Barry Commoner Center and the influence of Barry Commoner into the Citizen Science projects in the '70s who is considered as the Father of the Modern Environmental Movement. Discussions with the community included topics like air quality history, Empedocles the Pre-Socratic Philosopher, and his theory about the elements Earth-Air-Fire-Water and how they relate to each other and how pollutants can affect them.



OUR resistance broken down by age and such, we are at the point of admitting the persuasive quality of certain compounded words. This enthusiasm does not extend to such synthetic counterfeits as the late "scofflaw", but we feel a distinct obligation toward the weather bureau clerk who devised the adjective "smoggy" as descriptive of our present atmosphere, smoke and fog playing the part they do in our harried lives.

TOWARD dusk of a fine clear day last week, incidentally, if the smoke was not too thick, anyone getting on his hands and knees in one of the streets running West, and looking under the Sixth Avenue Elevated and over the Ninth Avenue, could have seen a peculiar effect of colors in the sky. The phenomenon is known to country people as a sunset.

THE newspapers say that the hard coal is trickling into town but there is no apparent improvement in the scenery. All our citizens still look

The participants learned about 'smog' which was a term used for the first time in February 1926 in New York City, the result of homes and businesses burning soft coal, which produced far more smoke than the hard variety which had limited supply. The media including editors at The New Yorker tried their best to make light of the situation. It is also interesting to note that the word "smoggy" was considered by the editors to be a relatively new term. The participants were kept engaged throughout the presentation by being asked questions about Air Quality and Air Pollution.

Development of Research Plan 2

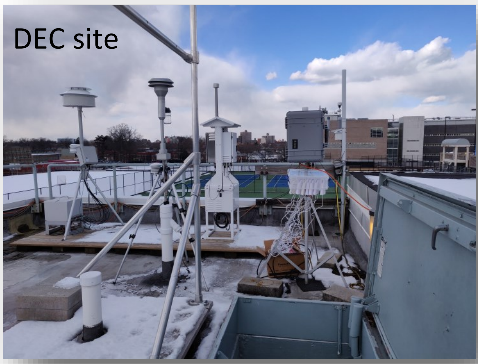
The presentation included a section about pollutants focusing on particulate matter, their definitions – characteristics based on size and dimension – chemical composition – sources – and their health and environmental effects. Another section presented the latest news on air pollution and what scientists have done to improve the environment. Furthermore, the positive impact of the NYCCAS project towards the improvement of air quality in NY was discussed with participants. However, there are still some neighborhoods where air quality is a concerning matter in terms of high levels of pollutants, specifically in neighborhoods with high traffic density, building density, and industrial areas, like Williamsburg. The final part of the presentation was dedicated to an overview of the current project, which addressed the following questions:

- Why are we doing an Air Quality project?
- How are we going to make it possible?
- What type of useful and valid data do we need to collect or use?
- Where locations should be focused on data acquisition?
- What resources do we need?
- How will the information be useful to the community?

Development of Research Plan 2

Throughout the project, we organized meetings to keep everybody informed about the progress of the study and address issues related primarily to the implementation of the personal monitoring campaign. Examples of topics that were deliberated included:

- When and for how long the students should go out to collect data;
- How weather conditions might affect the monitoring activities;
- Improving communication with the students creating a WhatsApp group;
- Improving the data collection on the routes assigned for each group;
- Reminding project participants to follow the BCCHE protocols during the personal monitoring sessions, emphasizing the importance of taking notes and pictures while collecting air monitoring data;
- Discussing quality assurance and quality control issues during data collection and data analysis; and
- Organizing/preparing data analysis workshops with study participants.



Data Analysis Plan 3

Data Analysis Plan

Air pollution patterns in the Williamsburg neighborhood were determined through fixed monitoring stations (DEC sites, NYCCAS sites, pDR 1500 - Real Time (RT) sites, and 11 sites of the AirBeam2 stationary network) and personal monitoring. The Stationary Network started to collect data in January 2019 through November 2019. The Personal Monitoring started to collect data in March 2019 through November 2019.

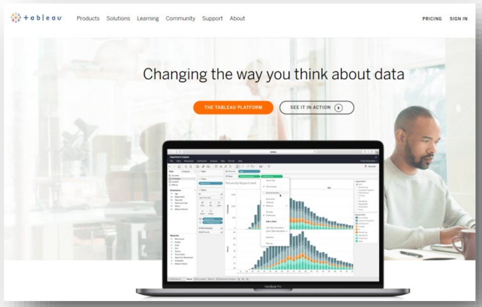
Air pollution monitoring using these fixed stations suffers from the low spatial resolution of the data, which may lead to an inaccurate assessment over the whole study area. Personal monitoring was included to fill this gap and better characterize the air quality in the neighborhood. Compared to fixed monitoring stations, mobile devices measure pollution close to the people affected by it, or close to the vehicles producing it. They offer a high spatial and temporal resolution, albeit concentrated on specific routes and specific periods (e.g., rush hour). Pollution data with timestamps and GPS coordinates were collected using the Airbeams2, and sampling routes (5 groups, EP1 - EP5) were specially designed to cover the areas of "hot spots," such as major roads and highways. In the beginning, we proposed that each route has six stops near a stationary monitoring station or a subset point, and the data was recorded for 5 minutes at each stop. Subsequently, we decided to have 3 stops along the routes at the schools and schoolyards with data recordings lasting 15 minutes at each stop.

Data Analysis Plan 3

Data Analysis objectives

The primary reason for data analysis is to understand the hidden patterns in the dataset through a statistical approach by obtaining useful information and identifying the relationship between variables and sources. The study emphasizes exploratory data analysis, which includes a structured process to handle raw quantitative information, cleaning the dataset, collinearity between variables, and feature selection. Other steps include handling missing information, imputation, removing outliers, and generating visualizations to communicate results. This study can help us provide insights into the data collected throughout this study. Proper data interpretation and analysis can help in making decisions and focusing on future strategy. The data from Stationary Network and Personal monitoring was subject to:

- Exploratory Data Analysis
- Descriptive statistics (hourly/daily/weekday/monthly)
- Correlation Analysis, scatter plots
- Time series Based Visualization
- Regression Analysis, data validation
- Personal monitoring data compared to the Stationary Network
- Comparison between all Stationary Network units, in order to identify which location(s) present the highest PM concentrations
- Comparison between all Groups (Personal Monitoring data), in order to identify which route(s) present the highest PM concentrations



Data Analysis Plan 3

Data-Preprocessing and Exploratory Data Analysis (EDA):

A database was created to bring together the data collected from different sources (DEC sites, NYCCAS, RT, and AirBeam2s) and was analyzed using the Tableau software.

[NOTE: The Tableau Desktop Version (www.tableau.com) can be downloaded at ***no cost*** for students and teachers. The online version, “Tableau Public: Free Data Visualization Software” (www.public.tableau.com) is free and can allow anyone to connect to a spreadsheet or file and create interactive data visualizations for the web].

EDA is important to understand the relationship between variables once the pre-processing is complete. Graphical representation of data will be in the form of scatter plots and bar charts to help identify the underlying distribution in the data. Since the data in this study is time-series based, multiple indexing procedures are applied for decomposing the data into three distinct components – trend, seasonality, and noise. The processing of signal components in the data to identify patterns and critical events is essential to this study.

Statistical Analysis

This is a part of descriptive statistics where the objective is to present data in a meaningful way for simple interpretation and observe hidden patterns. Understanding the correlation between the variables is critical for pattern recognition. Correlation analysis is a statistical evaluation method that can be used to study the relationship between numeric and continuous variables. An example of such a method is Pearson’s correlation. This step helps in understanding the changes occurring between different variables and how they impact others over some time. A descriptive data analysis study is required to identify the patterns in the dataset from different locations for a better understanding of the events.

An overview of the existing Air Quality condition in Williamsburg—DEC sites

According to EPA, the relative $PM_{2.5}$ concentrations in Greenpoint/Williamsburg were found to be the highest in comparison to the rest of NYC and Brooklyn covering the years 2010-2016, as illustrated from the bar charts in Figure 13 and Figure 14 below. The trend was observed from the measurements taken during summer and winter season. The data was obtained from different instruments running in NYC, deployed at multiple DEC sites. For the same time period, data from NYC and Brooklyn does not show any discrepancy and are very similar to each other. It is interesting to observe the cyclic nature in Williamsburg during winter.

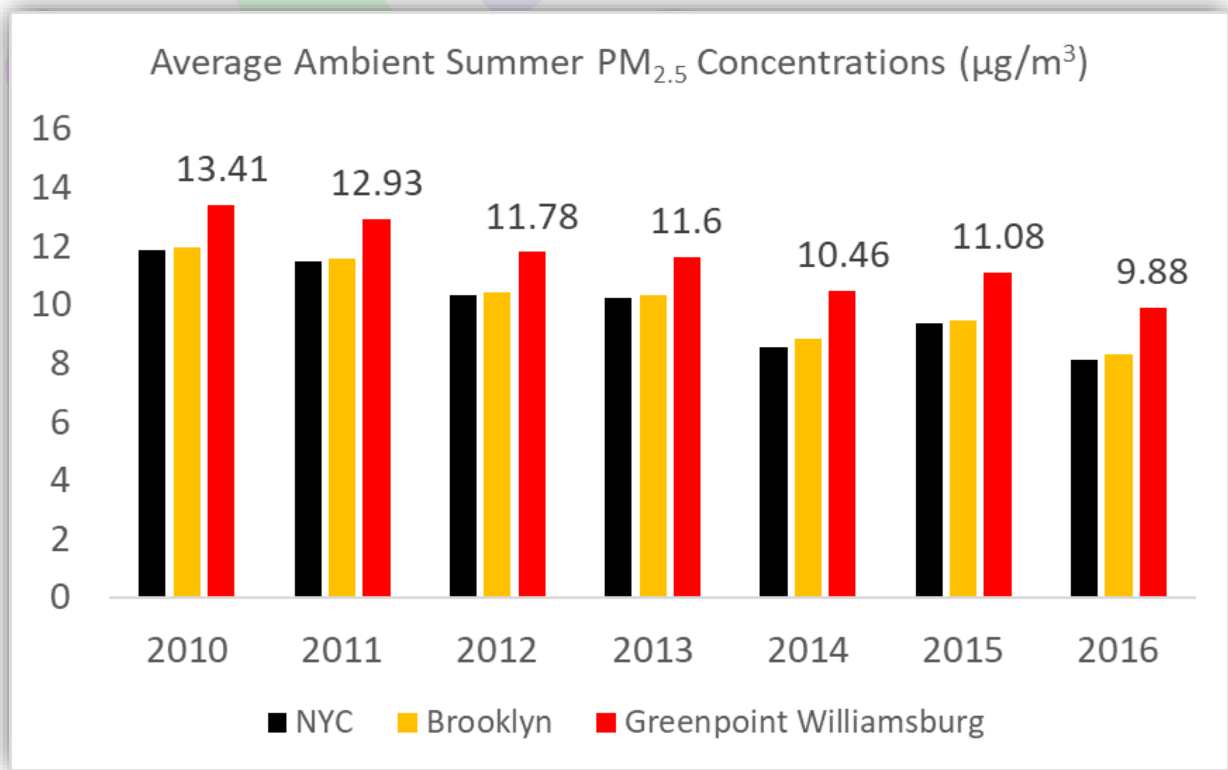


Fig.13 Bar chart with average concentrations in summer for different neighborhoods in NYC

Although the Williamsburg neighborhood PM concentrations, shown by the red bar in Figure 14 is the highest, also show a positive downward trend during summer indicating an improvement in air quality. This steady decrease can be attributed to the use of better energy practices and cleaner fuel consumption. This is the primary reason behind selecting Williamsburg for an Air Quality Citizen Science study so that a thorough in-depth analysis can be performed based on which recommendations could be provided for improvement of overall air quality in the area.

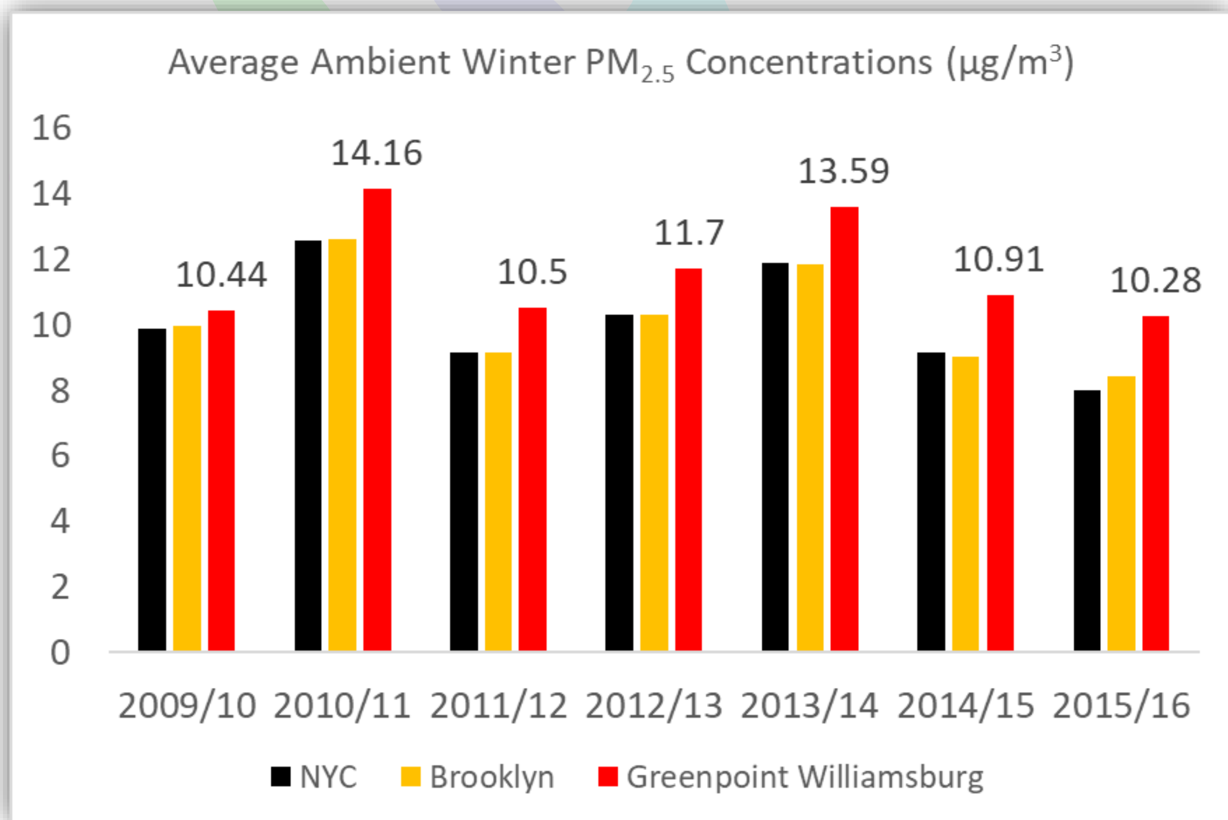


Fig.14. Bar chart with average concentrations in winter for different neighborhoods in NYC

An overview of the existing Air Quality condition in Williamsburg – NYCCAS LUR 2017

Annual average $PM_{2.5}$ concentrations were also obtained from the NYCCAS Land Use Regression (LUR) model for 2017 (see Figure 15 below), showing annual average concentrations of 8.65 $\mu g/m^3$ for the El Puente project area with the highest concentrations (>9 $\mu g/m^3$) observed along the BQE.

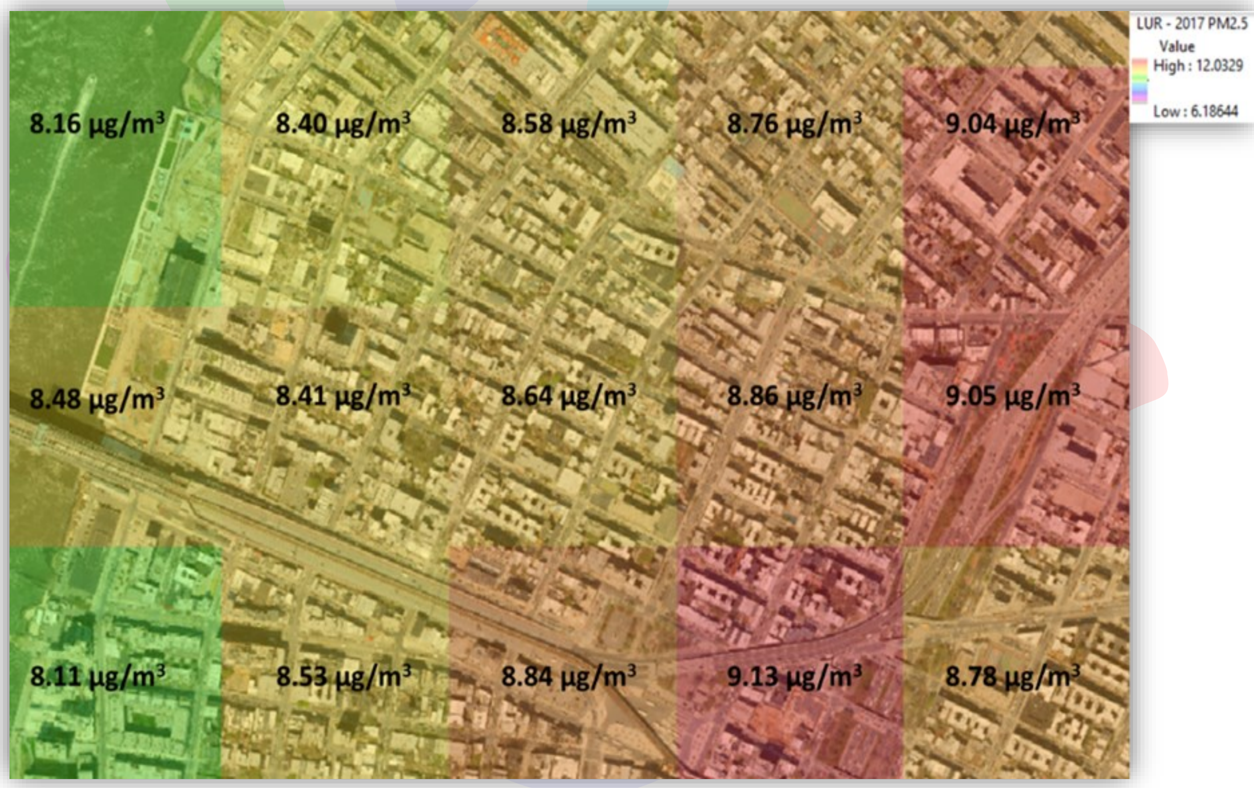


Fig.15. Annual Average $PM_{2.5}$ concentrations in the El Puente neighborhood based on 2017 NYCCAS Land Use Regression (LUR) data.

Data Validation 4

QA/QC Validation based on data collected at the Queens College DEC site

The idea behind co-location is to understand the measurements taken from two different instruments at the same location. In this study, measurements of PM concentrations were obtained from FEM and AirBeam2, at the DEC site. Data were collected both, before and after the deployment in Williamsburg for 3 weeks. For each location shown by an ID on the x-axis in Figure 16, a regression analysis was carried out to compare the results between FEM and Airbeam2. Linear regression R-Squared (R2) scores are plotted on the y-axis of this plot. An improvement in regression scores can be observed from this plot. Based on R2 a strong agreement can be observed between FEM and AirBeam2.

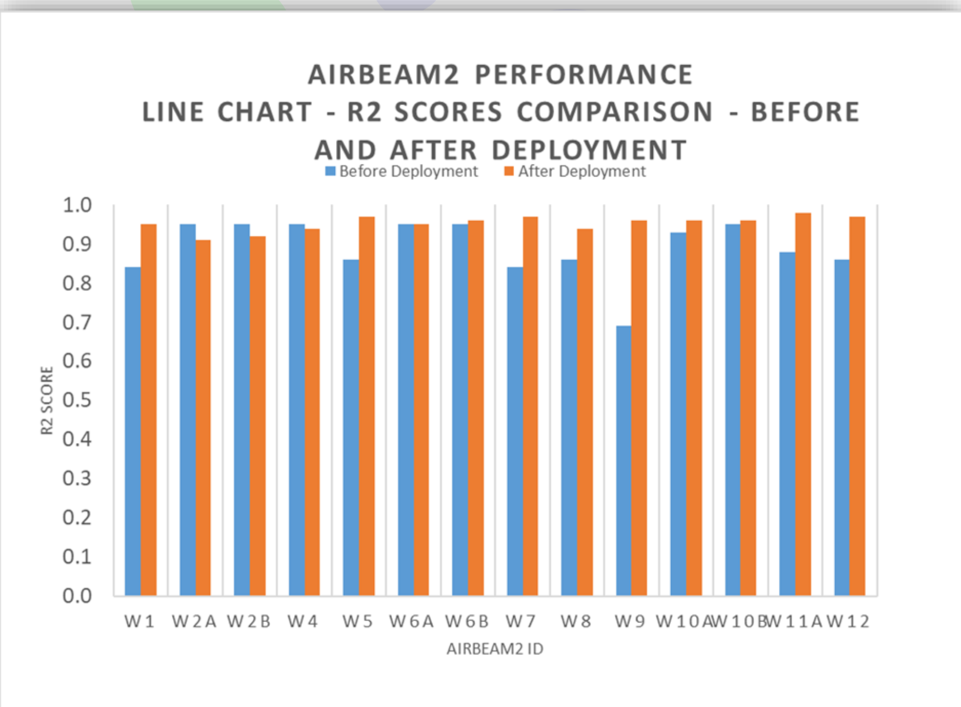


Fig.16 A comparison of R^2 scores in the form of a Bar Chart obtained from Linear Regression between FEM and AirBeam2 ($PM_{2.5}$ $\mu g/m^3$) concentrations, for each location, before and after deployment (Ilie and Eisl, 2019).

Colocation/Validation at El Puente Headquarter pDR1500 (RT) —AirBeam2

The Real-Time unit with the pDR-1500 instrument was installed in Williamsburg at El Puente (South 4th St Brooklyn, NY). The unit collected data every 15 minutes from May 2019 through November 2019. Based on the analysis, the average $PM_{2.5}$ concentrations were found to be 10.08 µg/m^3. To understand the relationship between the AirBeam2 data and pDR-1500 data, deployed at the same location (lamppost), a scatter plot was plotted in Figure 17. With a co-efficient of determination value (R2) of 0.81, the model can explain the variance in the response data well around its mean value. This statistical measurement imparts confidence to the measurements taken from the AirBeam2s and hence could be used with confidence in locations where pDR-1500 installation is not feasible.

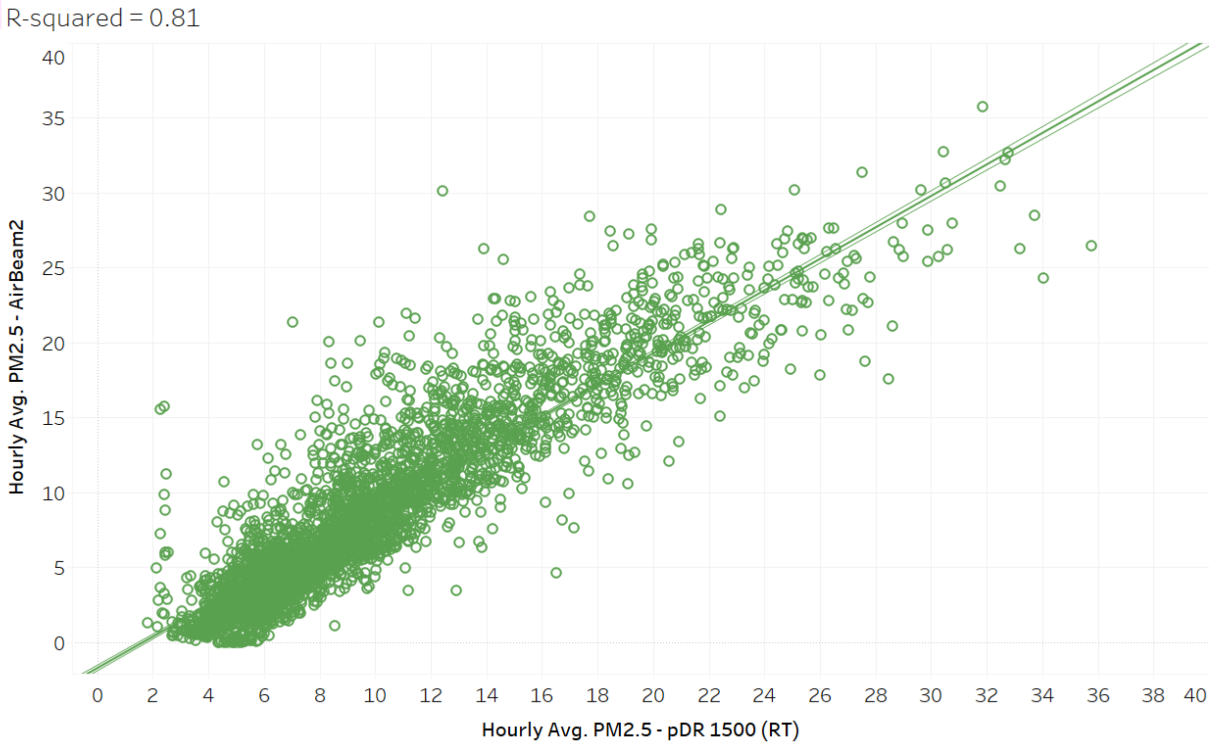


Fig.17. Regression model between AirBeam2 (W2) and Real-Time pDR-1500 data.

Monthly average: AirBeam2 (W2) and pDR 1500 (RT)

The monthly average of $PM_{2.5}$ concentrations for AirBeam2 (location El Puente Headquarter W2) and pDR-1500 aerosol monitor (RT) is plotted in the form of a bar-chart as shown in Figure 18. For the initial few months during the period from May-July, the values seemed to be aligned with each other. However, from August onwards, the concentrations measured by the real-time instrument were higher, and the differential between the values kept on increasing. Justification can be provided for this observation by considering the different measurement designs/configurations for each instrument. A real-time instrument is configured to measure only $PM_{2.5}$ concentrations through an inlet-particle sorting cyclone serving as a separator, whereas an AirBeam2 is designed to measure $PM_{2.5}$, PM_{10}, and PM_1 concentrations together.

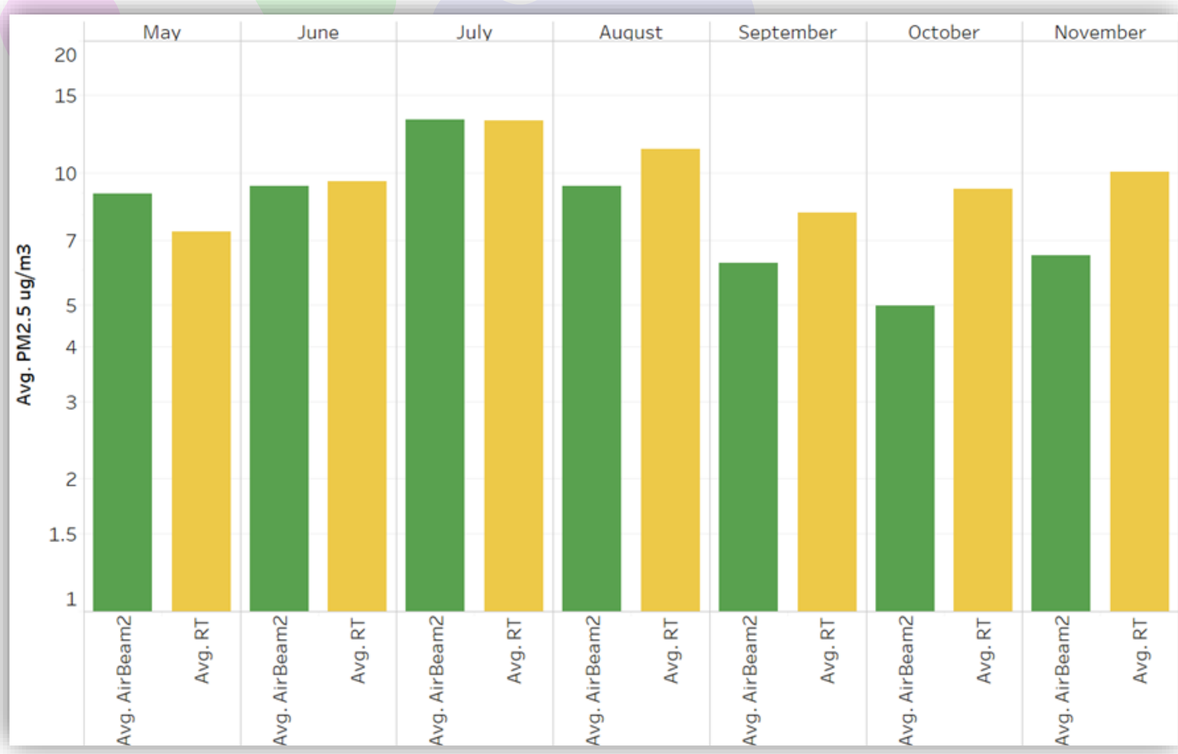


Fig.18 Monthly averages for data obtained from AirBeam2 and pDR-1500 aerosol monitor during a period of May to November 2019.

__Weekly average: AirBeam2 (W2) and pDR 1500 (RT)__

To understand the differences between the instruments, it is imperative to go into further details and analyze the data weekly. Weekly averages for the same time between May to November are plotted in Figure 19. There is an increasing trend for both measurement devices beginning Monday and which reaches a peak on Wednesday.

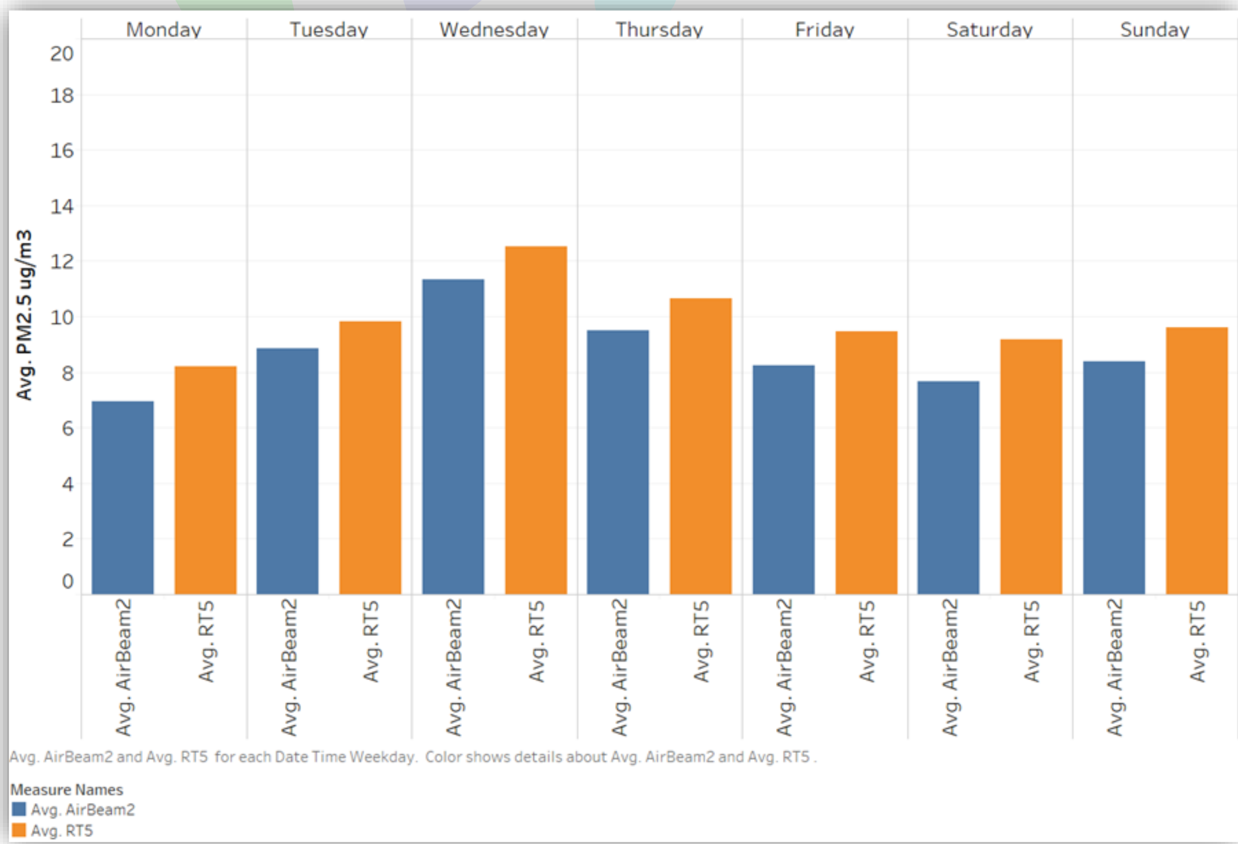


Fig.19. Weekday averages for data obtained from AirBeam2 and pDR-1500 instruments during a period of May to November 2019.

<u>*Daily average: AirBeam2 (W2) and pDR 1500 (RT)*</u>

Due to the high frequency of the data collected during the study, it was possible to zoom daily and understand the differences in values and trends with time for both AirBeam2 and RT data. The data is plotted as a time-series plot in Figure 20. High fluctuations can be observed for the entire period. Besides, high differentials of 10-15 µg/m^3 occur between the values for the same month. Furthermore, there are durations when a spike in $PM_{2.5}$ concentrations occurs, reaching as high as 30 µg/m^3 around mid-August. The National Ambient Air Quality Standards (NAAQS) under EPA regulations is 35 micrograms (one-millionth of a gram) per cubic meter air (µg/m^3) for the average of 24-hours. Looking at the overall data, the highest concentrations were still under the limit of 35 µg/m^3 as per EPA regulations.

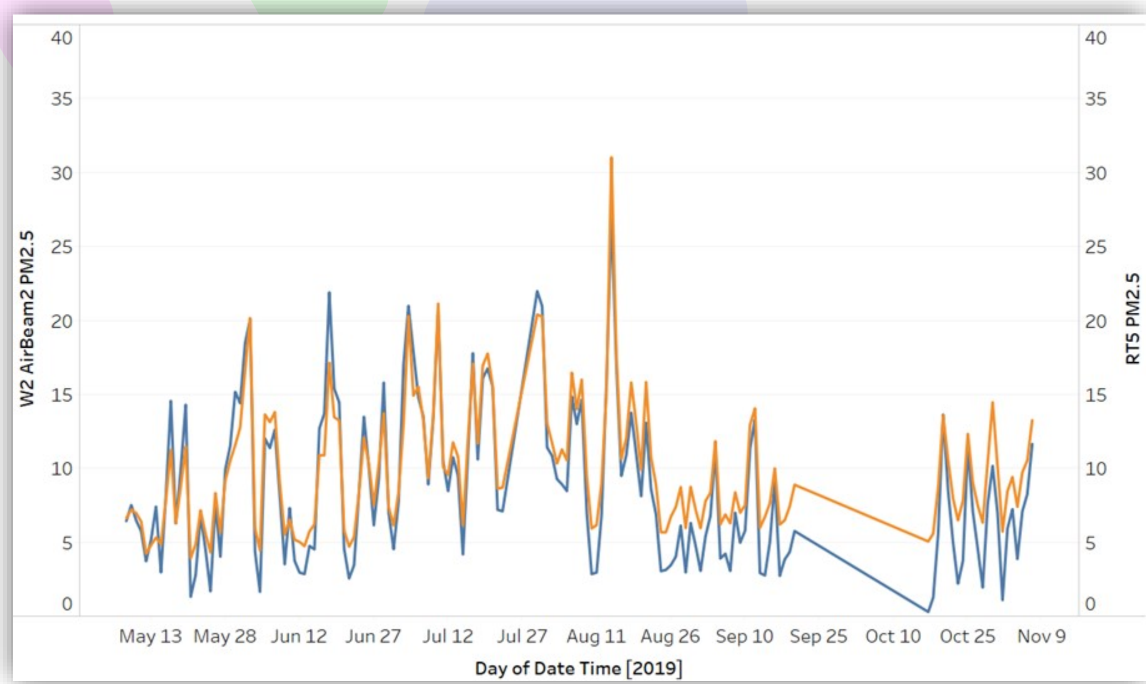


Fig.20. Daily averages from AirBeam2 (blue color) and pDR-1500 (orange color) during a period of May to November 2019. NOTE: The data gap from September 15 to October 15, 2019 is due to malfunctioning of the pDR-1500 instrument.

AirBeam2 data pattern compared to the closest DEC monitoring site

Monthly averages: AirBeam2 at W2 (El Puente Headquarters) and FRM at JHS126.

Figure 21 shows the monthly average of $PM_{2.5}$ concentrations for AirBeam2 (W2) and FRM $PM_{2.5}$ Sampler (Sampling Method 145 – R&P Partisol 2025i). The concentrations measured by AirBeam2 at W2 are generally higher compared to the FRM data from the JHS126 monitoring site. The differences may be explained by the fact that the W2 monitoring site is on a lamp post close to emission sources compared to the JHS126 monitoring site with the FRM Particulate Sampler mounted on the rooftop of the school building.

Fig.21. Monthly average of $PM_{2.5}$ concentrations for AirBeam2 and FRM for a period of January to August 2019.

AirBeam2 data pattern compared to the closest DEC monitoring site

Weekly averages: AirBeam2 (W2) and FRM (JHS126)

Data obtained from AirBeam2 and FRM PM2.5 Sampler (Sampling Method 145 – R&P Partisol 2025i) is also analyzed weekly and averages for the same time between January and August are plotted in Figure 22. At W2 the highest levels were observed on Wednesday and the lowest values were observed on Monday. At the JHS126 FRM, the highest levels were observed on Monday and Wednesday and the lowest values were observed on Sunday.

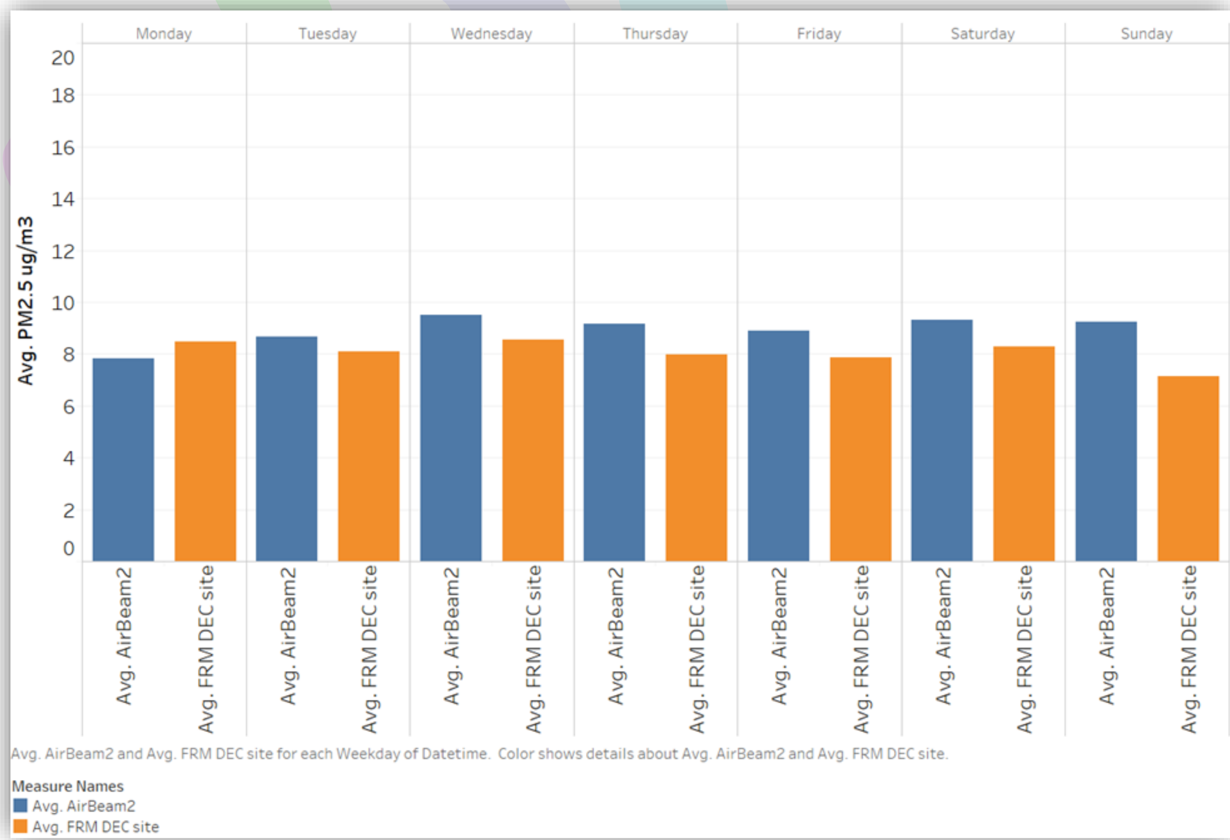


Fig.22. Weekday average of $PM_{2.5}$ concentration for AirBeam2 and FRM for a period of January to August 2019.

AirBeam2 data pattern compared to the closest DEC monitoring site

Daily averages: AirBeam2 and FRM

The data is plotted as a time-series plot in Figure 23. High fluctuations can be observed for the entire period and different trends can be seen for each device. Several spikes in $PM_{2.5}$ concentrations occur reaching as high as 30 µg/m^3 in February for W2 located on the main road (Williamsburg). The PM levels are lower at the FRM DEC site at the school. Looking at the overall data, the highest concentrations were still under the limit of 35 µg/m^3 as per EPA regulations.

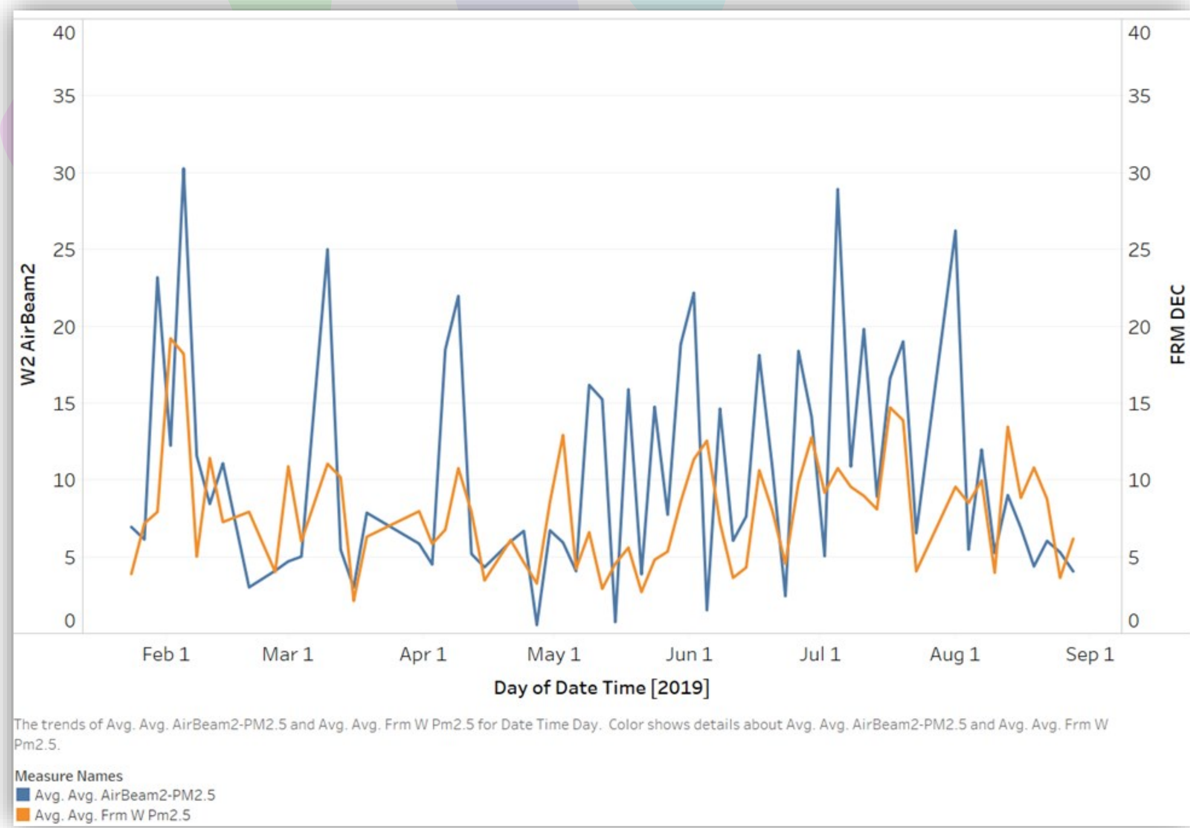


Fig.23. Time series plot of concentration measured daily from AirBeam2 and FRM during a period of May to November 2019.

<u>AirBeam2 data pattern compared to the NYCCAS LUR 2017</u>

A comparison of data collected from this study, from both personal monitoring (averages of all sessions) and the stationary network (averages March to November 2019), was compared to NYCCAS LUR model results from 2017, which were discussed earlier in Figure 24.

[NOTE: This exercise should serve only as illustration of the opportunity for community-based citizen science projects to compare their data to the findings of the NYC's air surveillance program (NYCCAS).] A "correct" comparison was not possible for two key reasons: (1) NYCCAS LUR-2019 data were not available for the analysis and (2) the data collection period of AirBeam2-based stationary network combined with the personal monitoring activities were too short to adequately compare the two data sets.

Fig.24. Annual $PM_{2.5}$ averages from Land Use Regression (LUR-2017) model along with daily/ sessions measurements from AirBeam2, (NYCCAS 2017; Ilie and Eisl, 2019).

QA/QC Validation based on data collected from two AirBeam2s at same location

Two co-located AirBeams2 were housed inside the same pelican box, as shown in Figure 14. Some of the locations selected for validation purposes included El Puente Headquarter, Public 84 schoolyard, Brooklyn Arbor Schoolyard, and Jaime Campiz Playground.

The following procedures/steps need to be implemented to understand if the data do the match between the AirBeam2 sensors.

- Observe the sensor signal response and make sure it is not noisy.
- Data for different locations need to be recorded for the same time interval and cross-checking is required to make sure the duration matches.
- Descriptive Statistics have to be calculated which summarizes the quantitative nature of the measurements and includes the following parameters:

  Count – This is related to the frequency of the measurements and gives an idea about the number of data points generated for any time interval

  Mean – This estimation of central tendency gives an idea about the average value of different measurements

  Standard Deviation – This parameter gives an idea about the spread of the data and can be calculated as the average distance between the mean value and each measure ment of the sample.
- Based on the data generated during the process, a linear regression yielding R2 can be generated which is a statistical parameter describing the variance between the measurements of the two AirBeams2.

Data Analysis Results 4

QA/QC Validation based on data collected from two AirBeam2s at same location

An example of a summary analysis using descriptive statistics is shown in the Table 1. Some of the observations from the table include:

- A similar count can be observed between the pair of instruments for the same location (using W2 as an example), denoted by W2a and W2b. A similar conclusion cannot be said about the location W6 where a big difference in the count is present.
- Regarding the mean and standard deviation, locations W2 and W6 provide consistent results while significant difference occurs in the estimate of the mean for location W10.

	W2a PM2.5	W2b PM2.5	W6a PM2.5	W6b PM2.5	W10a PM2.5	W10b PM2.5
count	269086.00	275110.00	83998.00	137775.00	174296.00	191040.00
mean	8.46	8.62	7.35	7.08	6.28	7.91
std	6.55	6.64	6.09	6.11	5.37	5.72
R2	0.94		0.95		0.91	

Table 1. AirBeam2 co-location process, descriptive statistics.

QA/QC Validation based on data collected from two AirBeam2s at same location

Going deeper into the reasoning behind the variance in statistical measurements, it can be observed from the Figure 25, that location W10b had an AirBeam2 with a noise in sensor signal.

Figure 25. AirBeam2, W10b noise in sensor signal.

Another example of noise in sensor signal is shown for location W7 in the Figure 26 which was discarded during the data analysis process.

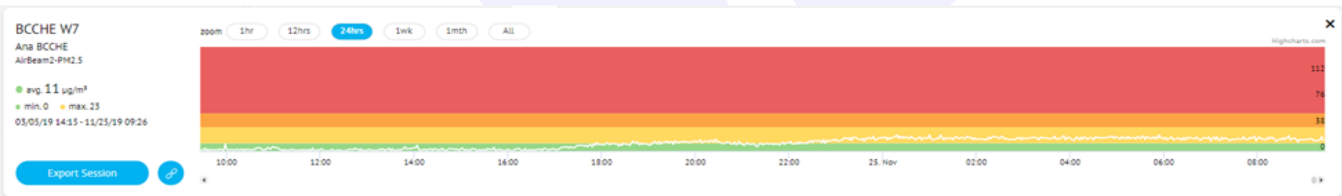


Figure 26. AirBeam2, W7 noise in sensor signal.

Daily/weekday /monthly/seasonal patterns in the Project area - Williamsburg

The area of interest for the study was divided into three subcategories - schools, schoolyards, and playgrounds. A map of Williamsburg shown in Figure 27, shows twelve different locations where air quality measurements were taken. The locations were further divided into separate groups as indicated by different clusters based on which the data analysis will be carried out. Location W3 no longer had a running unit because it was vandalized right after it was deployed to the location. Unit W7 run close to unit W12 since it could not be deployed at the entrance to Public 84 School due to construction. Keep in mind that there is a margin of error associated with the value measured by the instrument.

ID UNIT	LOCATION UNIT
W1	LA Guardia Playground
W2	El Puente Headquarter
W3	Continental Army Plaza
W4	*MS 50 School*
W5	
W6	*Public 84 School (W6) - William Sheridan Playground (W8)*
W8	
W9	*Brooklyn Arbor School*
W10	
W11	Rodney Playground
W12, W7	Jaime Campiz Playground

Fig.27. Map of Williamsburg area indicating 10 locations where air quality measurements were taken.

<u>*$PM_{2.5}$ diurnal patterns in Williamsburg study area*</u>

A scatter plot was generated with the average $PM_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 28. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 7.22 $\mu g/m^3$ and 13.05 $\mu g/m^3$ as indicated by the minimum and maximum measurements, shown as numbers on the plot itself. Lowest concentrations were obtained during the non-rush hour which was evident from the bottom-most blue points for each day. The average concentrations were very similar daily except for the spike, which was observed mid-week during Wednesday, reaching the highest value around 13 $\mu g/m^3$, during the morning rush hour. A similar jump in the concentration can be observed for Thursday, although it tapers down as the workweek comes close to an end, indicated by relatively lower concentrations on Friday and Saturday.

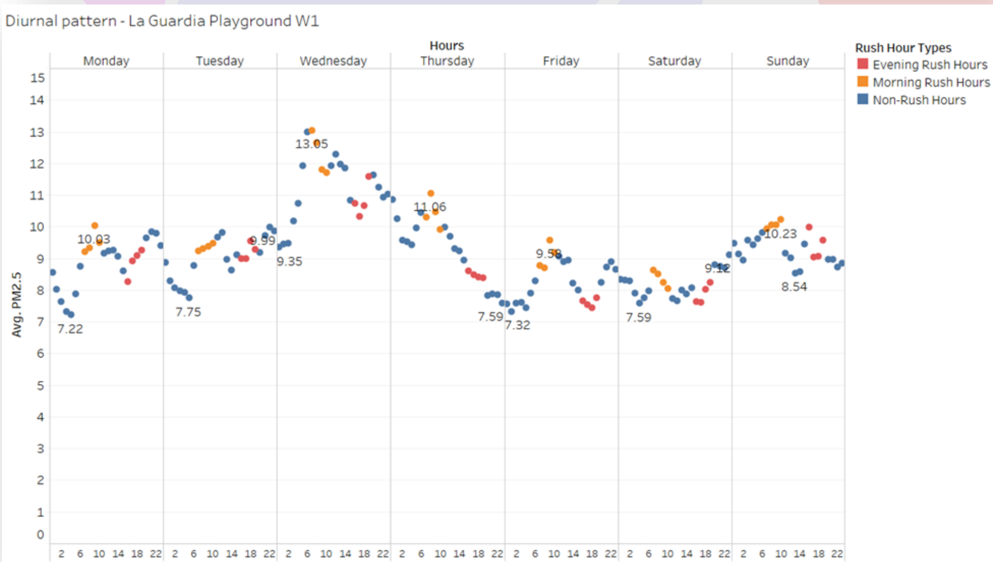


Figure 28: Diurnal patterns at La Guardia Playground W1.

PM

<u>*$PM_{2.5}$ diurnal patterns in Williamsburg*</u>

A scatter plot was generated with average $PM_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 29. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 5.92 μg/m^3 and 11.06 μg/m^3 as indicated by the minimum and maximum measurements, shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were very similar daily except for the spike, which was observed mid-week during Thursday, reaching the highest value around 11.06 μg/m^3, during the morning rush hour. Relatively lower concentrations are on Monday at the El Puente Headquarters.

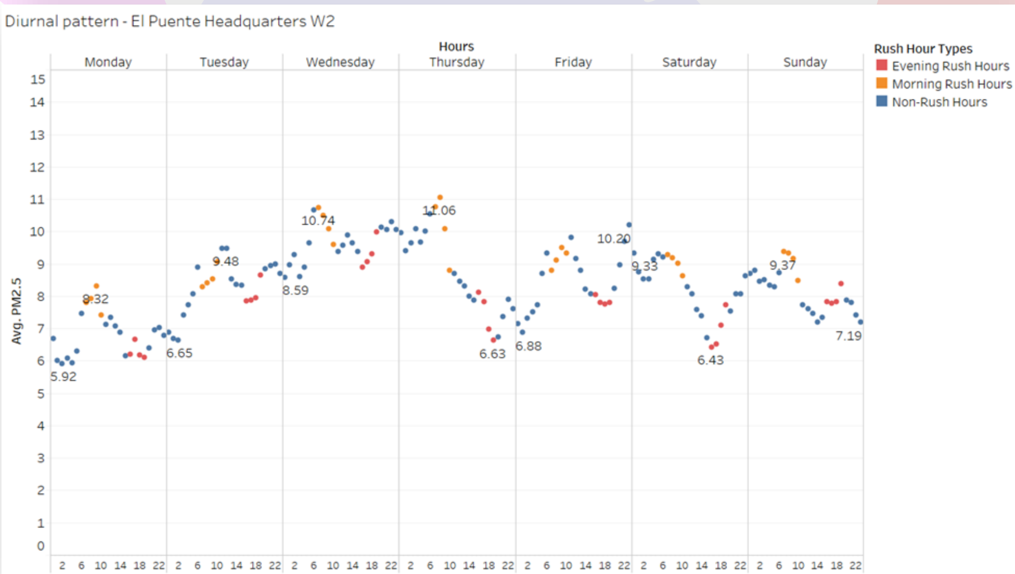


Figure 29: Diurnal patterns at El Puente Headquarters W2.

PM$_{2.5}$ diurnal patterns in Williamsburg

A scatter plot was generated with average PM$_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 30. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 4.57 µg/m^3 and 8.02 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were very similar daily except for the spike, which was observed mid-week during Thursday, reaching the highest value around 8.02 µg/m^3, during the morning rush hour.

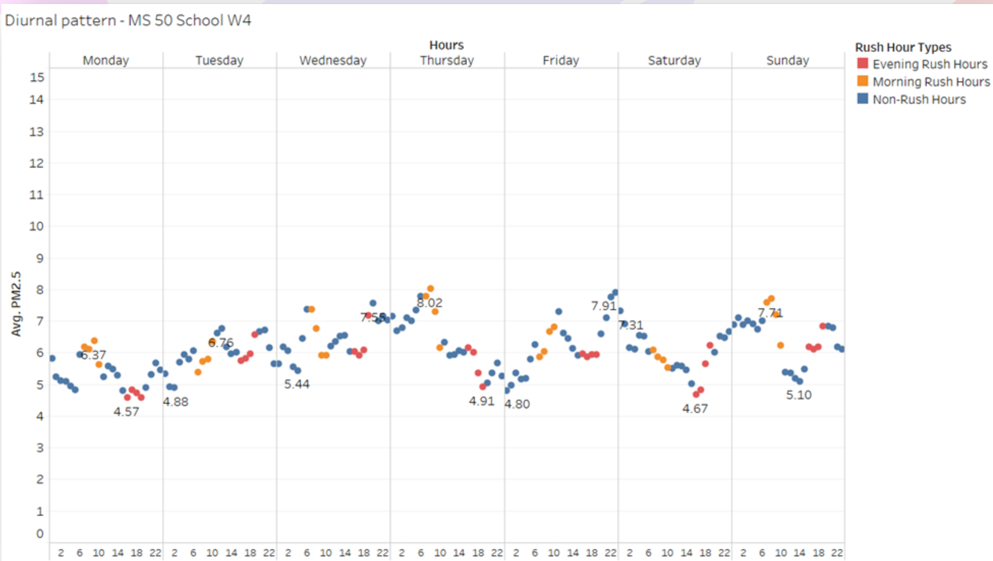


Figure 30: Diurnal patterns at MS 50 School W4.

Data Analysis Results 4

PM$_{2.5}$ diurnal patterns in Williamsburg

A scatter plot was generated with average PM$_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 31. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 2.73 µg/m$_3$ and 9.58 µg/m$_3$ as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the non-rush hour which was evident from the bottom-most blue points for each day. The average concentrations were different daily with a spike, which was observed mid-week during Wednesday, reaching the highest value around 9.58 µg/m$_3$, during the morning rush hour. Relatively lower concentrations were observed on Friday and Saturday.

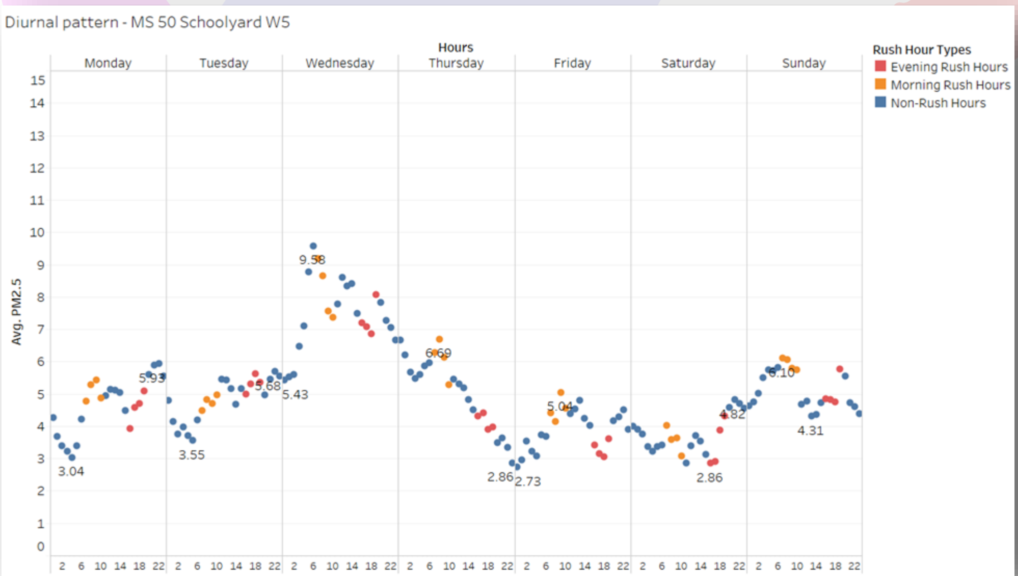


Figure 31: Diurnal patterns at MS 50 Schoolyard W5.

$PM_{2.5}$ diurnal patterns in Williamsburg

A scatter plot was generated with average $PM_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 32. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 4.07 μg/m^3 and 9.76 μg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were a little different daily with the spike, which was observed mid-week during Thursday, reaching the highest value around 9.70 μg/m^3, during the morning rush hour. Relatively higher concentrations were on Tuesday, Wednesday, and Thursday at this location. Relatively lower concentrations were observed on Monday.

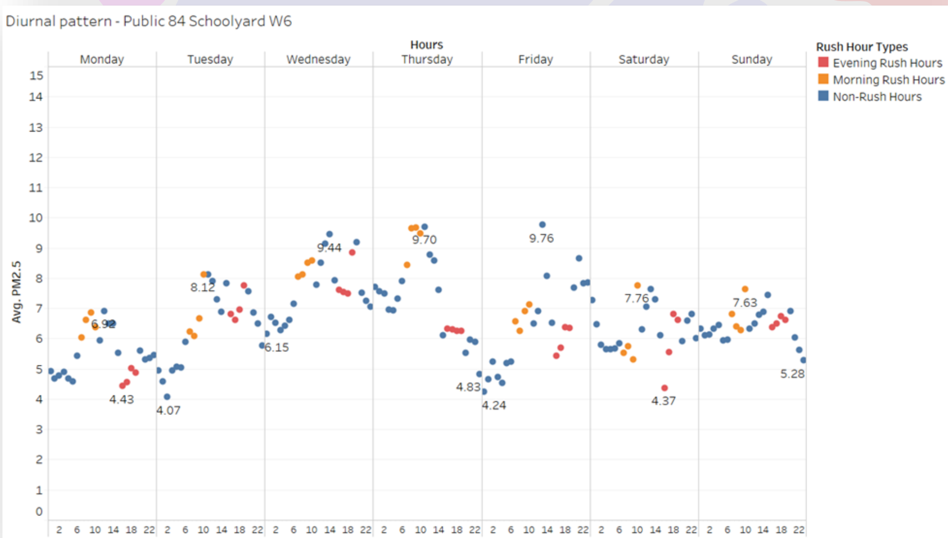


Figure 32: Diurnal patterns at Public 84 Schoolyard W6.

PM2.5 diurnal patterns in Williamsburg

A scatter plot was generated with average $PM_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 33. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 2.57 $\mu g/m^3$ and 10.39 $\mu g/m^3$ as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were a little different daily with the spike, which was observed mid-week during Wednesday, reaching the highest value around 10.39 $\mu g/m^3$, during the non-rush hour. Relatively lower concentrations were observed on Saturday.

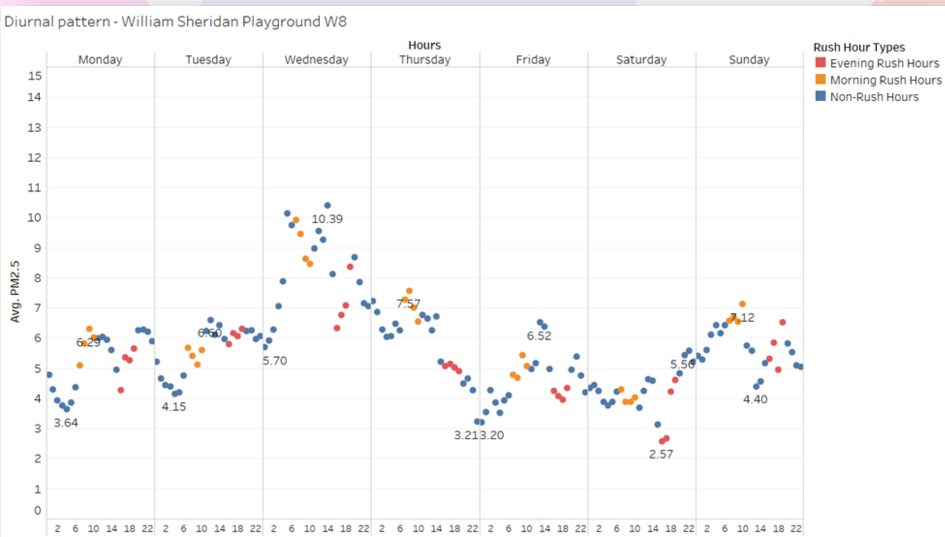


Figure 33: Diurnal patterns at William Sheridan Playground W8.

$PM_{2.5}$ diurnal patterns in Williamsburg

A scatter plot was generated with average $PM_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 34. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 3.03 μg/m^3 and 11.18 μg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were a little different daily, which was observed mid-week during Wednesday, reaching the highest value around 11.18 μg/m^3, during the morning rush hour. Relatively lower concentrations were observed on Friday and Saturday.

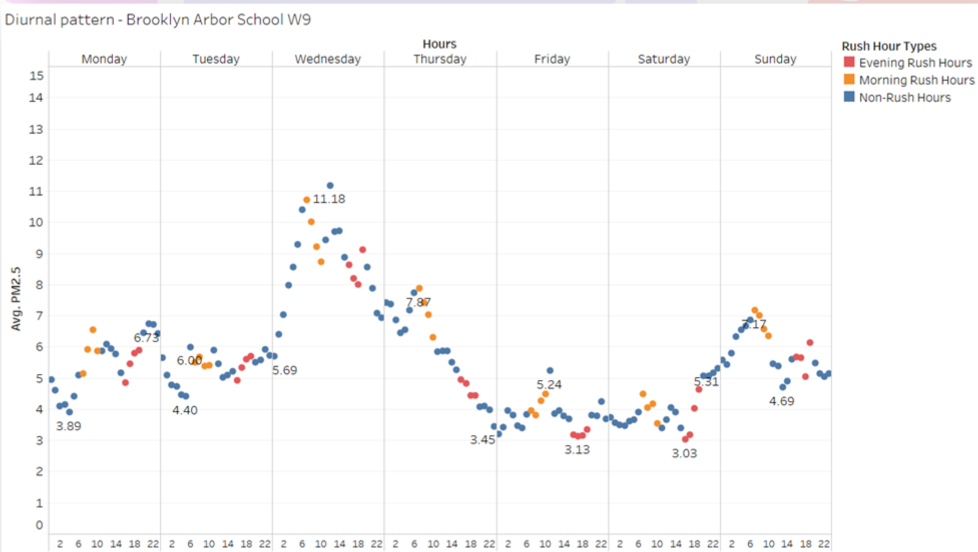


Figure 34. Diurnal patterns at Brooklyn Arbor School W9.

PM$_{2.5}$ diurnal patterns in Williamsburg

A scatter plot was generated with average PM$_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 35. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 2.48 µg/m^3 and 8.88 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were very similar daily except for the spike, which was observed mid-week during Wednesday, reaching the highest value around 8.88 µg/m^3, during the morning rush hours.

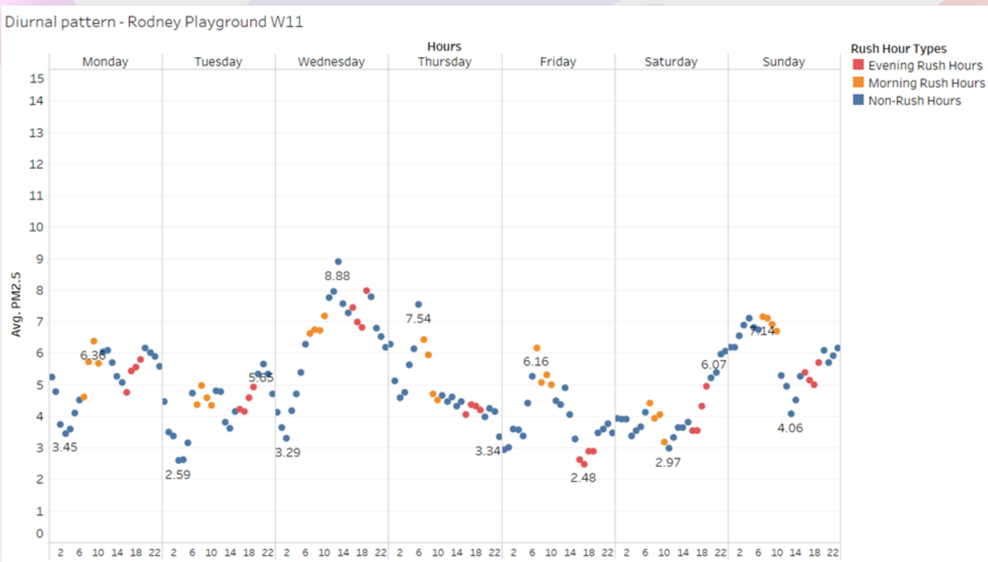


Figure 35: Diurnal patterns at Rodney Playground W11.

PM$_{2.5}$ diurnal patterns in Williamsburg

A scatter plot was generated with average PM$_{2.5}$ concentrations on the y-axis and time on the x-axis, as shown in Figure 36. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 3.18 µg/m^3 and 10.64 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were a little different daily with the spike, which was observed mid-week during Wednesday, reaching the highest value around 10.64 µg/m^3, during the morning rush hour. Relatively lower concentrations were observed on Friday and Saturday.

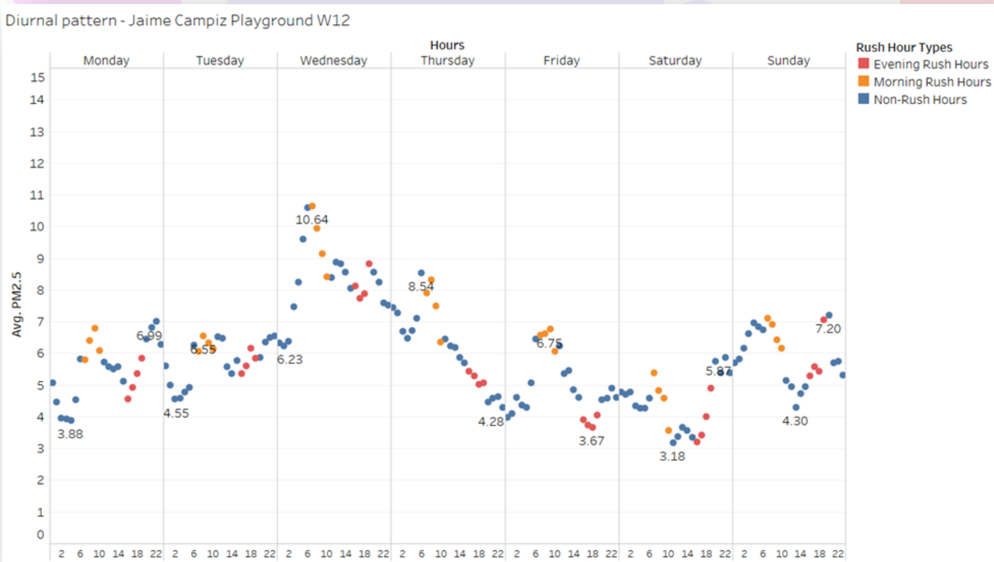


Figure 36: Diurnal patterns at Jaime Campiz Playground W12.

<u>Daily averages: Locations W2, W4, W6, W10 (These units were running simultaneously from March to November 2019)</u>

Due to the high frequency of the data collected during the study, it was possible to zoom in daily and understand the differences in values and trends with time for each location. The data was plotted as a time-series plot in Figure 37. Different colors indicated different Airbeam2 IDs (also denoting different locations). The National Ambient Air Quality Standard (NAAQS) under EPA regulations is 35 micrograms (one-millionth of a gram) per cubic meter air (µg/m^3) for the average of 24-hours. As observed from the data in the Williamsburg area, no location exceeds the limit of 35 µg/m^3 for 24 hours.

High fluctuations can be observed for the entire period of March through November. There are durations where $PM_{2.5}$ concentrations spike, reaching as high as 27 µg/m^3 at the beginning of March and May and mid-August. The $PM_{2.5}$ concentrations were relatively lower in September. Measurements taken at different locations exhibited very similar behavior with the occurrence of peaks and troughs at the same time indicated by the overlap of different lines. Although significant spikes in the concentrations were observed for certain periods, the measurements were still under the limits of EPA regulations, as mentioned earlier.

Daily averages: Locations W2, W4, W6, W10

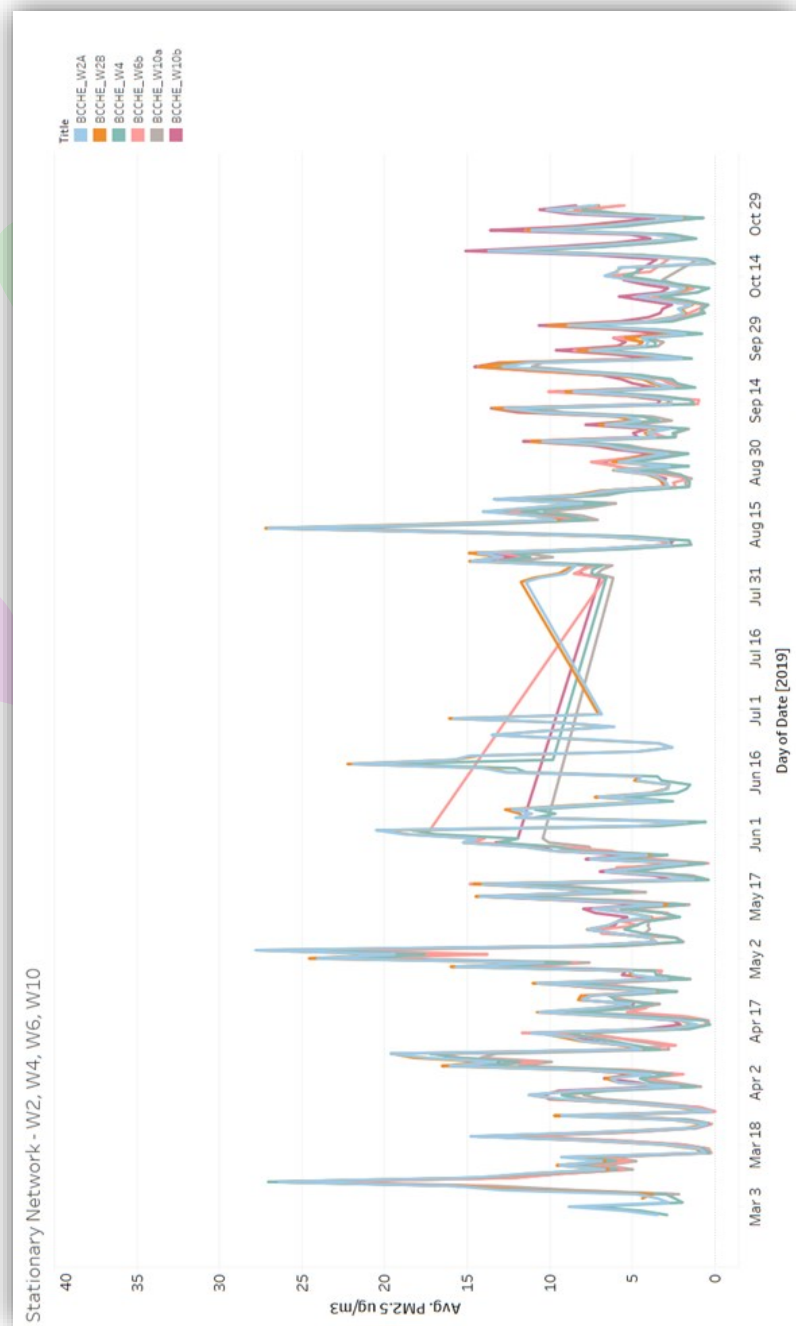


Fig. 37. Daily averages of $PM_{2.5}$ concentrations for different locations in Williamsburg.

Monthly averages: Locations W2, W4, W6, W10

The monthly average of $PM_{2.5}$ concentrations for W2, W4, W6, W10 were plotted in the form of a line-chart shown in Figure 38, where a comparison was made between data from different months. The data for each month was also divided into averages for each week day, for higher precision. Different colors indicated different Airbeam2 IDs (also denoting different locations). The highest concentration was observed for the month of August with an increased average value during the week, reaching the highest concentration of 16.90 µg/m^3 on Wednesday. Looking at the overall data, the highest concentrations were still under the limit of 35 µg/m^3 as per EPA regulations. An analysis of the highest concentrations for the remaining months is also discussed in the section below.

- In March unit W2 (S 4th St Brooklyn) recorded the highest average value of 9.66 µg/m^3, on Saturday.
- In April, the highest concentration levels were 10.14 µg/m^3 occurring on Tuesday and Friday at locations W10 (Brooklyn Arbor School – schoolyard) and W2 (S 4th St Brooklyn).
- In May the highest levels were 12.51 µg/m^3 on Thursday at location W2
- In September the highest levels were 8.52 µg/m^3 on Wednesday at location W10
- In October the highest levels were 7.69 µg/m^3 on Wednesday at location W10

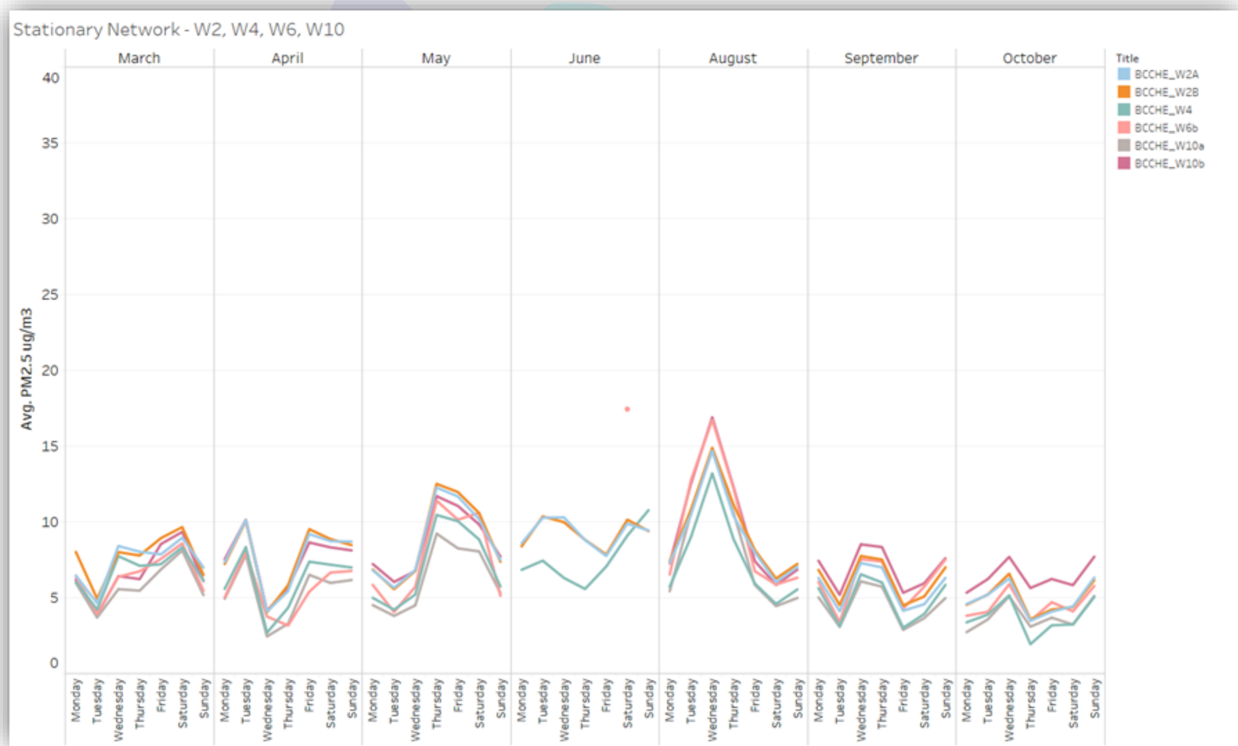


Fig.38. Monthly averages for W2, W4, W6 and W10 shown as a time series plot for a period of March to October 2019, (Ilie and Eisl, 2020).

Daily averages: Locations W1, W2, W4, W5, W6, W8, W9, W10, W11, W12

A time series plot of all locations with daily average concentration was presented in Figure 39. The high-frequency data allowed an understanding of the differences in values and trends with time for each location. There were durations when the spike in $PM_{2.5}$ concentration occurs, reaching as high as 27.22 µg/m^3 around mid-August at location W2. Although the seasonality of the time series trend indicated similar peaks and troughs indicating high fluctuations, the range of concentrations was narrow. Certain locations, for example, W1 (red line color in the plot, W1 located close to the Williamsburg Bridge and BQE), reported the highest concentration throughout the monitoring period compared to monitoring sites that were located at larger distances from high-traffic highways (e.g. W5).

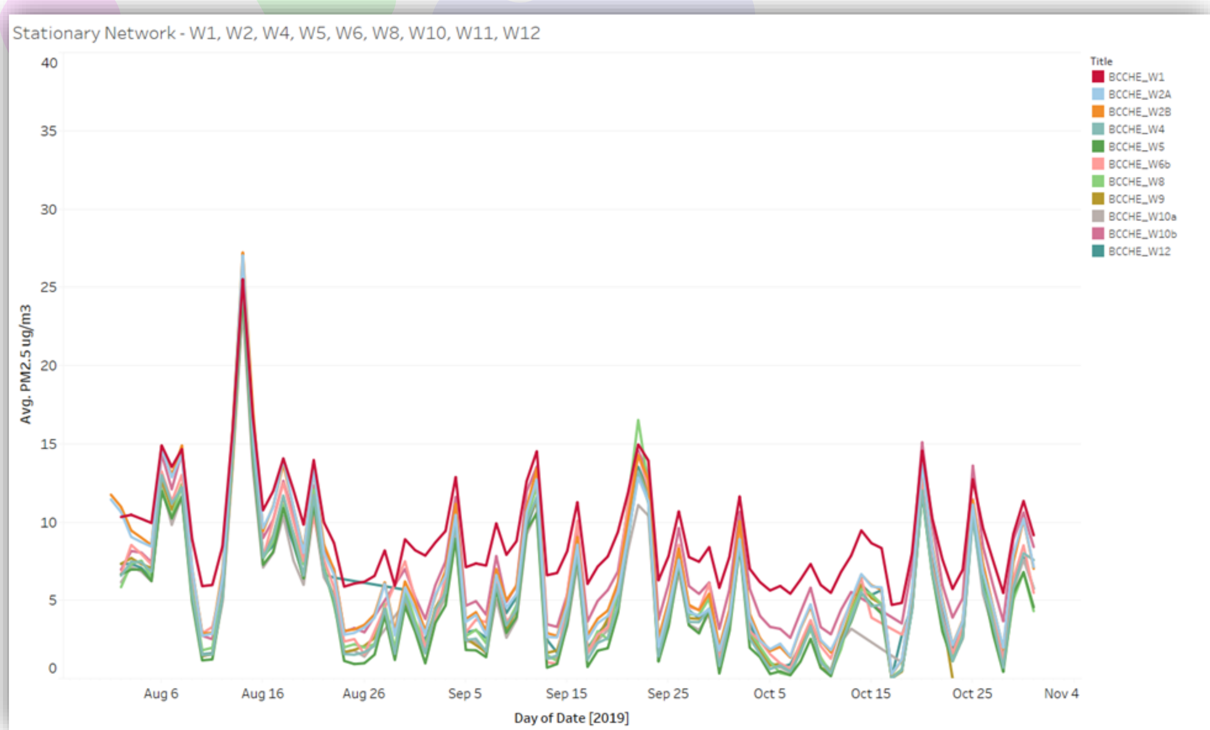


Fig.39. Daily averages of $PM_{2.5}$ concentration for all locations indicating the fluctuations shown by the peaks and troughs, (Ilie and Eisl, 2019).

Monthly averages: locations W1, W2, W4, W5, W6, W8, W9, W10, W11, W12

The monthly average of $PM_{2.5}$ concentrations for locations W1, W2, W4, W5, W6, W8, W9, W10, W11, and W12 were plotted in the form of a line chart in Figure 40, where a comparison was made between data from different months. The data for each month was also divided into averages from each day. It can be observed that on average, a higher concentration was observed in August, with an increased value occurring mid-week, reaching the highest on Wednesday. Overlapping trends with high seasonality for different locations were observed in this case as well. The monthly analysis of the averages is discussed in the following section.

- In August the highest level was around 16.90 µg/m^3 on Wednesday at location W10.
- In September the high levels were around 10 µg/m^3 on Wednesday and Thursday at location W1 (La Guardia Playground).
- In October the high levels were around 9 µg/m^3 on Wednesday and Sunday at location W1.

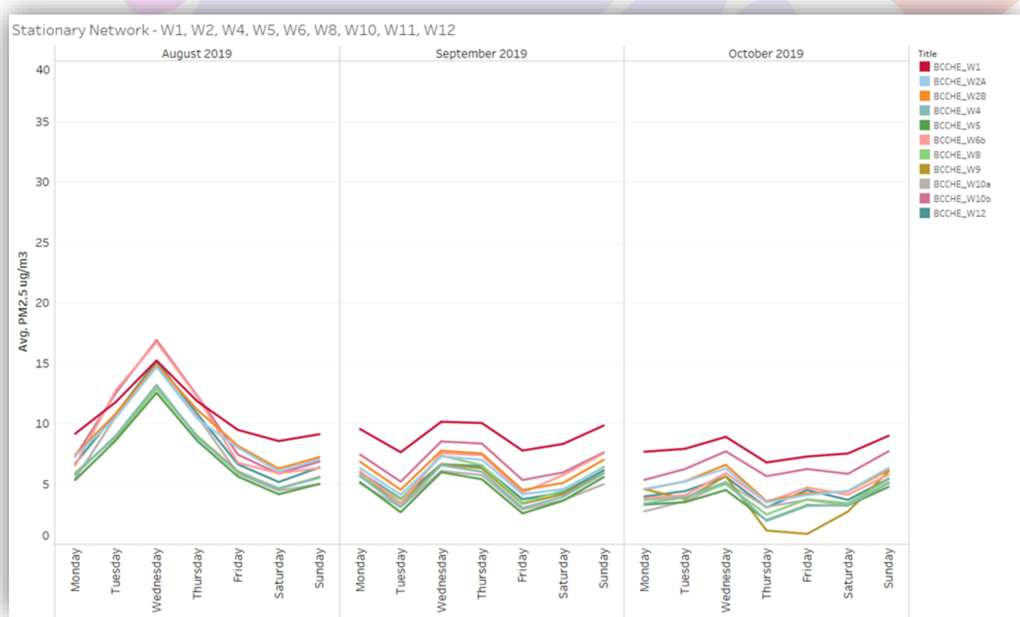


Fig. 40. Monthly averages of $PM_{2.5}$ concentrations (Ilie and Eisl, 2019).

Weekday Average $PM_{2.5}$ *concentrations – Stationary Network*

In the bar chart shown in Figure 41, weekday averages of $PM_{2.5}$ concentrations for August, September, and October are shown. The results were divided into four different categories in which the study locality was divided – school entrance, schoolyard, South 4th St, and Playgrounds. As seen in Figure 18, an average, higher $PM_{2.5}$ concentrations were observed near South 4th St in Williamsburg. Higher concentrations were observed near the W1 zone at the La Guardia playground close to the Williamsburg bridge and BQE. Due to decreased activity of the traffic during the weekends, a lower concentration of $PM_{2.5}$ was observed at most locations during that time.

There were two locations at school entrances - W4 and W9. These locations presented different $PM_{2.5}$ levels, when weekday averages were considered. Although both locations weere on 3rd St in Williamsburg, location W4 was near the feeder road leading to Williamsburg Bridge and the BQE and it is considered the main road. This was the primary reason why these two locations had higher concentrations. It was also observed that location W4 had higher $PM_{2.5}$ concentration levels during the weekends while location W9 had higher levels on Wednesdays.

There were three locations at schoolyards, W5, W6, and W10. These locations presented almost similar $PM_{2.5}$ concentrations. At the W5 location, $PM_{2.5}$ levels were lower in general with the highest levels occurring on Wednesdays. Both W6 and W10 locations presented high $PM_{2.5}$ values on weekends and Mondays.

Weekday Average PM$_{2.5}$ *concentrations – Stationary Network*

There were three locations at playgrounds, W1, W8 and W12. Locations, W8, and W12 had higher PM$_{2.5}$ concentrations observed on Wednesdays and Thursdays. Looking at the relative concentrations for the playgrounds, location W1 had the highest concentration among the three locations. With the highest values of more than 11 µg/m^3 observed during Wednesday. Explanation can be provided for this observation since W1 was located very close to BQE and was next to a feeder road leading to the Williamsburg Bridge.

Higher concentrations were observed for South 4th St when compared to other locations.

This analysis of grouping the locations into four different categories helped us understand the commonalities between the data.

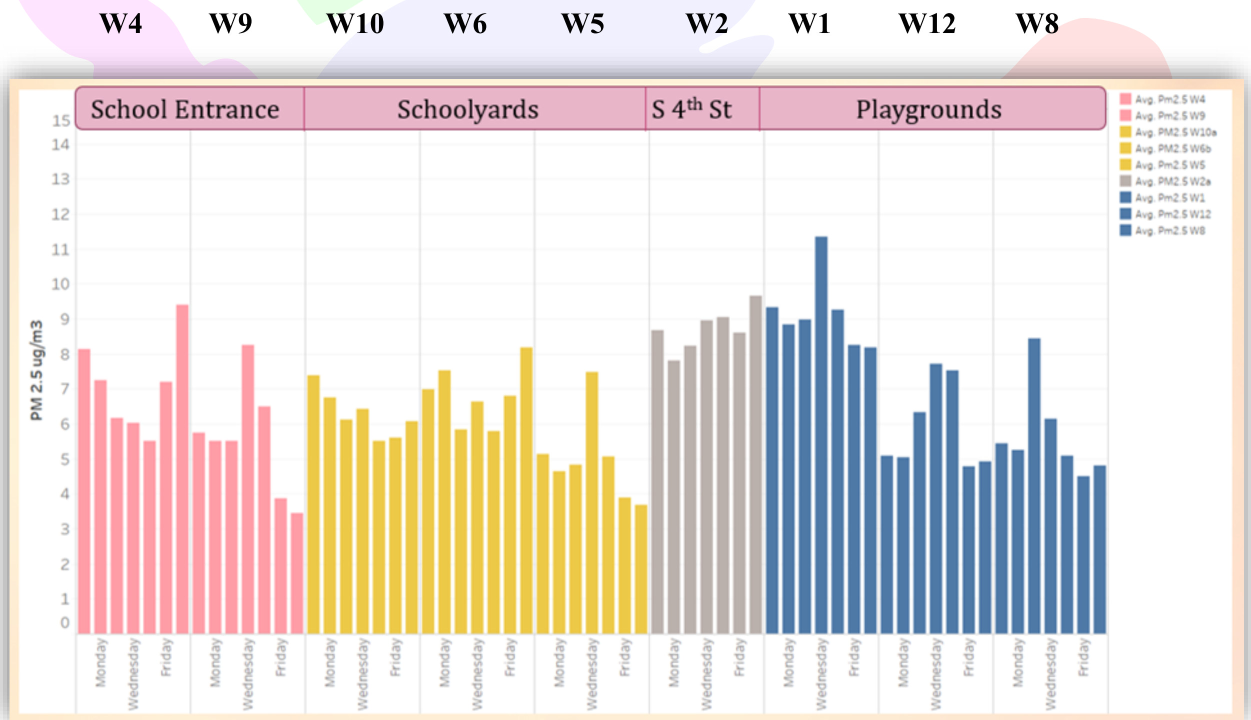


Fig.41. Weekday averages grouped into 4 different categories, (Ilie and Eisl, 2019).

Monthly Average $PM_{2.5}$ *Concentrations – Stationary Network*

Looking deeper into the monthly analysis for Stationary networks, data from different locations was plotted in Figure 42, for different Airbeam2 IDs for each month. As seen from the plot, the spike which was observed in August was primarily due to the increased concentration on South 4th St, and near the playgrounds. The data also showed that the concentration range varied from 3.5 μg/m^3 to 10.5 μg/m^3.

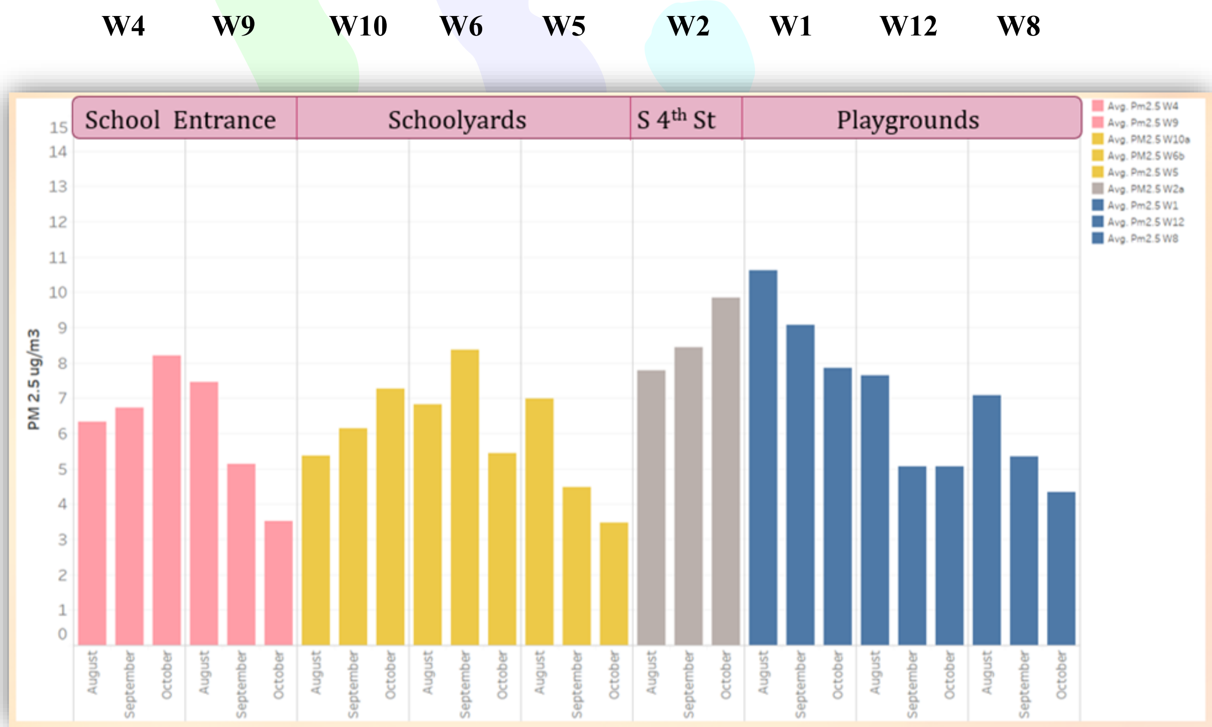
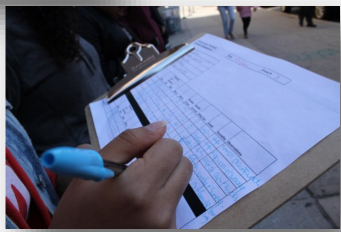


Fig. 42. Monthly averages obtained from Stationary Network grouped into 4 different categories, (Ilie and Eisl, 2019).



<u>Personal Monitoring – car/truck counting – Stationary Network</u>

To understand the impact of vehicles like moving cars, idling cars and trucks, on the $PM_{2.5}$ concentration levels, data from seven different locations were shown in Figure 43, as a clustered bar chart. The average $PM_{2.5}$ concentrations measured from personal monitoring (EP) and Stationary Network (SN) were plotted on the left y-axis, while the count of vehicles on the right y -axis. A higher number of moving cars and trucks were observed at W2 and W12, as shown by the gray-colored bars. This leads to more than 3 µg/m^3 $PM_{2.5}$ concentration readings seen on the personal monitoring data. It was interesting to note that the highest concentration for stationary networks occured at W6 where traffic did not seem to have much influence. Other factors like construction could be attributed to this observation. Three different locations – W9, W10, and W12 showed more than 4 µg/m^3 $PM_{2.5}$ concentration measured by personal monitoring as well as higher levels on stationary network data. This chart indicated a clear correlation between traffic and higher concentration levels for certain locations, although there were certain other factors which contributed to the increased $PM_{2.5}$ concentration levels, like weather conditions and the long-range transport of the particles.

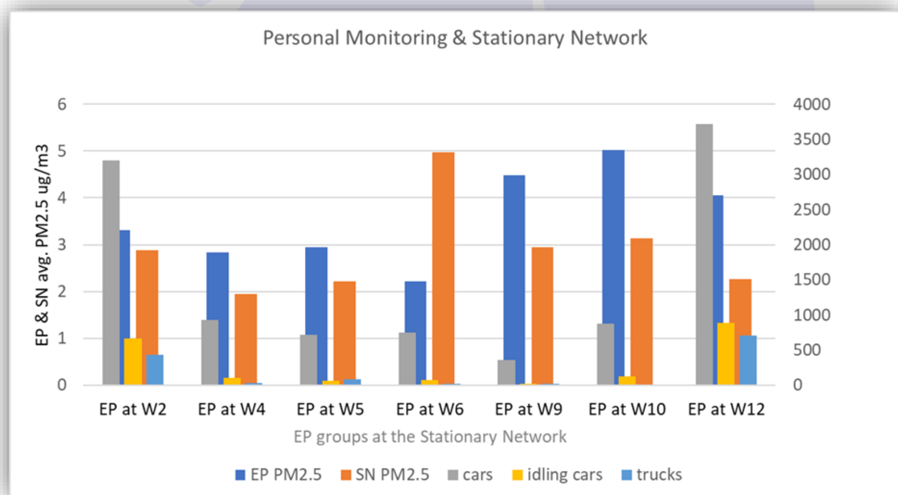


Fig. 43. Personal monitoring data (EP) compared to the stationary network (SN).

July 24th Poster presentation at the Our Air launch program

On July 24th El Puente celebrated their birthday and honored founder Luis Garden Acosta by launching their new project Our Air! / ¡Nuestro aire! This project united artists, youth activists, community advocates, residents, elected leaders, academic partners (Queens College - BCCHE), parents, and schools to study neighborhood air quality, develop solutions to improve environmental conditions, and advocate for the right to clean air and green open spaces through art and activism. At this program launch, we presented the project objectives and preliminary results on air quality in the Williamsburg neighborhood.

A Close-out meeting

A close-out meeting was held at the El Puente Headquarter with BCCHE and DOHMH research team members to discuss key findings of the air quality monitoring project. The brief discussion included an analysis of results and conclusions. Consistent results were obtained from the Citizen Science Project when compared to the already existing dataset in the Williamsburg area collected by NYCCAS and DEC.

The NYCCAS data showed a seasonal pattern while diurnal patterns were observed with the stationary network, with low variance observed at the locations. In the neighborhood where the study was conducted, the emissions sources were mainly from traffic which drove patterns in air pollution in the city.

It was beneficial for the community to understand the diurnal patterns from the Stationary Network as compared to the seasonal data from NYCCAS. Even though it was known from previous studies that the traffic was pretty much constant throughout, it was necessary to understand from the diurnal data that no inherent pattern exists.

Based on Stationary network data, the La Guardia playground was still higher on $PM_{2.5}$ levels than other locations, which still raised some concern. It was mentioned to the community that the $PM_{2.5}$ was not ideal for characterizing the traffic source since the $PM_{2.5}$ could come from the surroundings as well as from other neighborhoods. Other pollutants like NO_2 would have been a better marker for traffic, but due to highly complicated instrumentation, it was not performed. In conclusion, the issue of the high traffic volume will still exist due to the location of BQE in the current neighborhood. Once the congestion pricing goes into effect in 2021, Williamsburg Bridge will convert to a toll bridge and thus changes in traffic patterns should be expected.

A Close-out meeting

The NYC saw improvements in fuel consumption and actual heating, but no action was taken concerning the traffic patterns from on-road and off-road construction trucks or vehicles. To find a complete solution and make an effort to the improvement of air quality, it is important to identify and quantify the sources, because measuring the pollutants without having an idea about where these are coming from would not lead to accurate analysis. One of the recommendations is to conduct a transportation study in the Williamsburg neighborhood with the help of the Department of Transportation (DOT).

Discussions 6

El Puente goal was to understand if there was a measurable difference in air quality between the parks previously studied and other areas of the neighborhood, to determine the relative safety of recreational areas in the neighborhood. The community was interested specifically in identifying other unsafe areas that deserve attention, as well as safer locations where new recreational areas could be proposed to be placed. The data analysis carried out for the sensor measurements collected from the Stationary Network (August – November 2019) showed little variance in the $PM_{2.5}$ concentrations at the schoolyards and playgrounds. According to the EPA, in 2016, the $PM_{2.5}$ concentration average was found to be around 10 µg/m^3 in Williamsburg and 8 µg/m^3 in NYC and Brooklyn. As for the closest FEM DEC site to Williamsburg, its $PM_{2.5}$ average was around 8.29 µg/m^3 (May 2019 – August 2019). Annual $PM_{2.5}$ concentration averages for 2017 were obtained from the NYCCAS project and the average value was around 8.65 µg/m^3, with the highest values observed along the BQE Expressway at around 9.13 µg/m^3. In this pilot study, measurements of $PM_{2.5}$ concentrations were taken from FEM and AirBeam2, at the DEC site for data validation. The data were collected both, before and after the deployment in Williamsburg for 3 weeks. Based on the R^2-value a strong agreement was observed between FEM and AirBeam2. For data validation purposes, in Williamsburg, a Real-Time unit pDR-1500 was installed at El Puente (S 4th St Brooklyn, NY). The unit collected data every 15 minutes from May 2019 through November 2019. Based on the analysis the average $PM_{2.5}$ concentration was found to be 10.08 µg/m^3. Based on the R^2 a strong agreement was observed between pDR-1500 and AirBeam2. A comparison of data collected from this pilot study, from both personal monitoring and stationary network, was performed with NYCCAS LUR model results from 2017. Personal monitoring and stationary network (2019) PM2.5 averages were found to be around 6 µg/m^3, while NYCCAS LUR (2017) PM2.5 averaged 8.50 µg/m^3.

Discussions Conclusions 6

Based on the time series analysis of the collected data it can be concluded that the Stationary Network provided us more precise information on diurnal patterns by going into the details of hourly measurements while NYCCAS study was more focused on the identification of seasonal patterns. The diurnal pattern was determined, for example, W1 location (located close to the Williamsburg Bridge and BQE), reported the highest concentration throughout the monitoring period compared to monitoring sites that were located at larger distances from high-traffic highways (e.g. W5). Regarding the diurnal pattern, higher concentrations (>7 µg/m^3) were observed at the locations W1-W2-W6 during both rush hours and non-rush hours. On the other hand, lower concentrations (below 7 µg/m^3) were observed at the locations W4-W5-W8-W9-W11-W12. On an average basis, lower concentrations were observed on Saturday at locations W5-W9-W8-W11-W12. For locations W1-W2-W6-W8-W9-W12 peaks in PM$_{2.5}$ concentration occurred, reaching as high as 11 µg/m^3 on Wednesdays. In Williamsburg daily PM$_{2.5}$ concentration average was around 12 µg/m^3, using the data collected from all AQM units (August – November 2019). There were durations when the spike in PM$_{2.5}$ concentration occurred, reaching as high as 27.22 µg/m^3 around mid-August at the El Puente Headquarter location close to the Williamsburg Bridge and BQE. Mean concentrations in Williamsburg varied from 3.2 to 12 µg/m^3 on the weekdays and 3 to 10 µg/m^3 on the weekends. Higher concentrations were also observed near the W1 zone which lies close to the La Guardia playground. An investigation of the relationship between traffic counts and air pollutants was also conducted in Williamsburg at the stationary network locations. The data revealed that the highest number of cars was around 4000 at the Jaime Campiz Playground (W12) leading to higher PM$_{2.5}$ concentration levels when compared to other locations during personal monitoring sessions. Looking at the overall data, the highest concentrations were still under the limit of 35 µg/m^3 as per EPA regulations.

YMPJ the Bronx

Ana MC Ilie

PHOTOGRAPHY

Case Study YMPJ

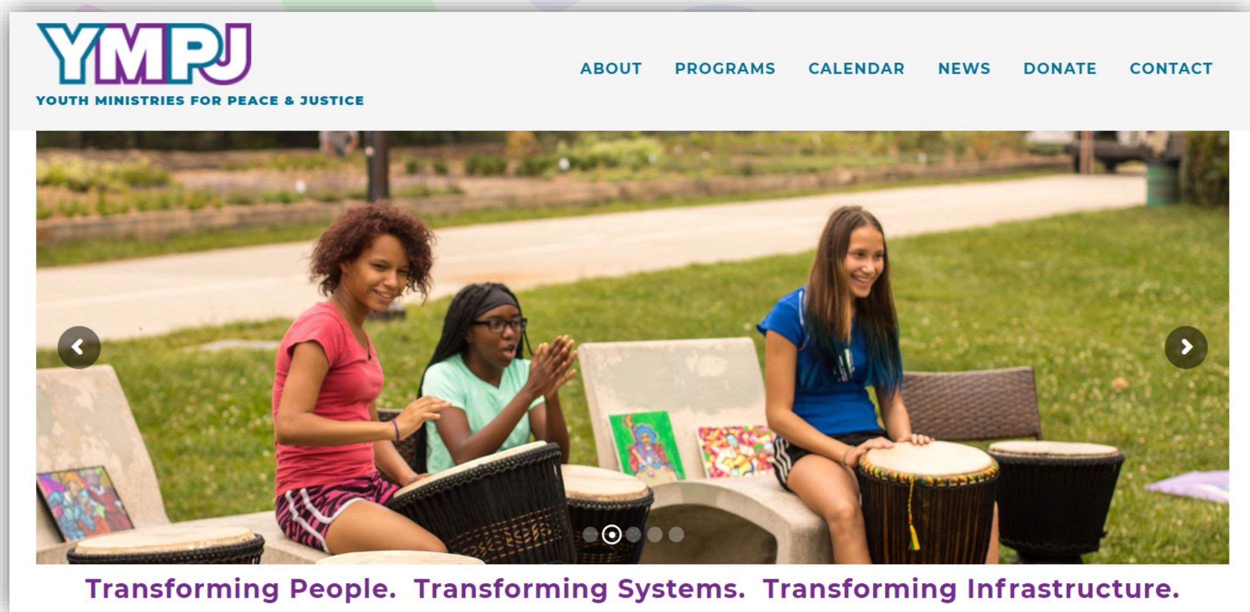
The Bronx (NYC)

The Bronx is a borough of New York City, the third-most densely populated county in the United States with a population of 1,432,132 according to 2018 records. The South Bronx has large volumes of heavy vehicle traffic passing through it along several major highways which creates pollution that can impact the health of residents in this area. Besides, some multiple local industries and facilities generate truck traffic, including Hunts Point Wholesale Markets (world's largest wholesale market), a municipal sewage sludge processing plant, a privately-owned sludge drying plant, as well as nineteen public and private waste transfer stations. The area also hosts a municipal wastewater treatment plant and many manufacturing facilities which also help add on to the traffic in the area. All this traffic results in high concentrations of truck activity and diesel emissions in the proximity of schools and residences in the South Bronx.

Case Study YMPJ

The Bronx (NYC)

The mission of Youth Ministries for Peace & Justice (YMPJ) is to rebuild the neighborhoods of Bronx River and Soundview/Bruckner Boulevard in the South Bronx by preparing community members to become prophetic voices for peace and justice. YMPJ accomplishes this through political education, spiritual formation, youth development, and community development and organizing. YMPJ's mission includes assisting low-income immigrant communities in need of legal and social services to assist them with obtaining citizenship and becoming self-sufficient members of the Bronx community, in addition to organizing the community to act in ways that benefit their interests.



PLANNING PHASE

RESEARCH PHASE

ACTION PHASE

Case Study Setup

The community was involved in all aspects of the study, ranging from project design to implementation. Key targets for the data collection of PM2.5 exposure included all those areas near major roadways and expressways. Project participants attended a workshop to better understand air pollution in their community and to learn how to use low-cost sensor technology to collect environmental data.

Youth Ministries for Peace and Justice

PLANNING PHASE

Assessment of pollution exposure. 1

Development of Research Plan 2

RESEARCH PHASE

Data Analysis Plan 3

Data Validation
Data Analysis 4

ACTION PHASE

Data Dissemination 5

Discussions
Conclusions 6

Assessment of Pollution exposure. 1

The Barry Commoner Center in collaboration with YMPJ (Youth Ministries for Peace and Justice) has started a pilot study to better characterize the air quality in the Bronx. The primary objective was to better understand the community's exposure to poor air quality coming from the Sheridan expressway where thousands of trucks pass by every day towards the commercial area in Hunts Point. Another objective is to engage with people who are exposed and impacted by the poor air quality in these areas of interest and raise awareness of the health hazards of air pollution. In this pilot study, we focused on understanding the $PM_{2.5}$ concentrations in the Bronx, a borough that is characterized by a high rate of asthma and cardio-respiratory issues due to the presence of high levels of particulate matter in the atmosphere. The study area is located exactly between the three main highways known as the "toxic triangle."

Participants attended a workshop to better understand air pollution in their community and to learn how to use the Airbeam2 devices to collect measures of fine particulate matter. Key targets for the data collection on $PM_{2.5}$ exposure included schools and playgrounds near the major roads and expressways. A fixed-site monitoring network, using low-cost Airbeam2 devices, was set up at thirteen locations in the Bronx, which provide real-time $PM_{2.5}$ air concentrations that were transmitted to a cloud server. Tableau software has been used for data visualization. Before the use of low-cost sensor technology for the fixed-site network in the project area, an assessment of the performance of all Airbeam2 instruments was performed under ambient conditions at the Queens College-based regulatory monitoring site.

Development of
Research Plan
2

Research Plan

◊ *Project objectives*

◊ *Methodologies*

◊ *Workshops*

Development of Research Plan 2

Project Objectives

The project was initiated with a kick-off meeting in August 2019 in partnership with YMPJ and the Department of Health and Mental Hygiene (DOHMH). The purpose of the meeting was in-person introductions of team members across YMPJ, BCCHE—Queens College, and DOHMH partners, discussion of project deliverables, and gain an understanding of the Bronx's local air quality concerns. Some of the areas which were discussed included a brief introduction to the air pollution problem in the Bronx neighborhood, previous studies on air pollution, and the effects poor air quality might have on health.

The objectives of this pilot study:

- Characterize the ambient air quality of the South Bronx, having high concentrations of diesel trucks and waste transfer facilities
- Engage the South Bronx community to raise awareness of the impacts of air pollution and to gain community investment and participation in the project
- Mobilize volunteers to collect air quality data using AirBeam2s to characterize the exposure to air pollution and to identify any additional local sources of pollution
- Deploy a stationary network using AirBeam2 to collect real-time air quality data.
- Analyze the data to better understand the level of air pollution
- Disseminate results to the community through an event, forums, and/or and art campaign.

Development of Research Plan 2

Methodologies

Site Visit - Stationary Network

Further in-person meetings were conducted at YMPJ to discuss research priorities and walk around the South Bronx to identify potential locations for the stationary network. A map of suggested stationary monitoring sites was made with justifications to why a unit should be located there. The visual analysis was performed to assess the suitability for an AirBeam2 Stationary Network. As a process of personal monitoring, a plan was drafted to have the volunteers collect data around areas of interest, and twenty-seven groups were created to cover all of the study areas. Field data sheets were made so that volunteers could take notes related to traffic, the number of passing trucks, any odors, any construction activity, any public smoking, or any other kind of information necessary for the interpretation of data.

Personal Monitoring

The participants were recruited by YMPJ who proposed the measurement routes. The volunteers were a part of the YMPJ after School Program. One session of personal monitoring was conducted during the workshop. Twenty-seven groups (B1 through B27) were created for the personal monitoring but unfortunately, no sessions were conducted by the volunteers.

AirBeam2s - Deployment at Queens College DEC site

All AirBeam2s instruments were deployed at the DEC site (Queens College) for three months and referenced against a FEM instrument before they were deployed to the South Bronx, as shown in Figure 37. They were deployed in the Bronx area in September 2019 and run continuously through November 2019. A unique ID was assigned to each location where an AQM unit was deployed to. At the end of the project as a 'co-location' procedure was performed between the AirBeam2s and FEM DEC for one week to validate the data. The low-cost monitors were protected from severe weather conditions using a plastic container that held multiple monitors together, as shown in the Figure below.

Stationary Network - Deployment in the Bronx

Five different sites, with many locations, were identified along the Sheridan Expy, Cross Bronx Expy, and Bruckner Expy, as shown in Figure 44. For each site, location coordinates were provided and lamp-post was identified. The deployment process followed the same rules as in Williamsburg.

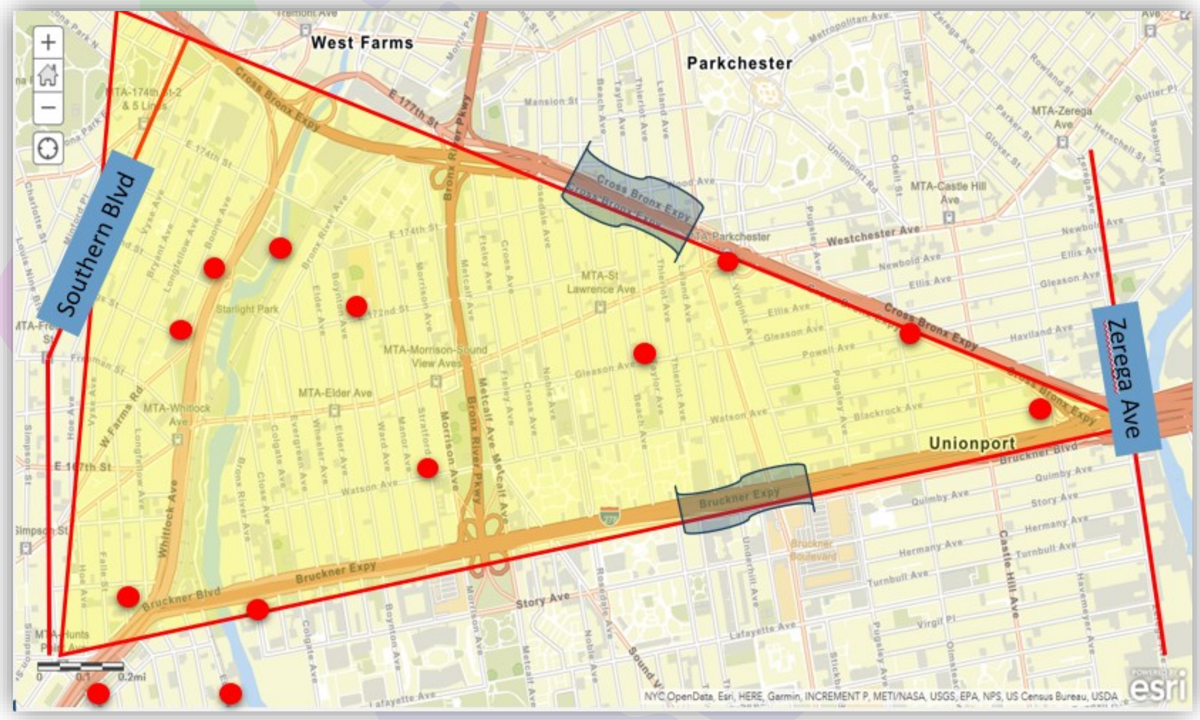


Fig. 44. Map of the Bronx area indicating 13 locations for the stationary network.

Development of Research Plan 2

Workshop

The first workshop for Air Quality Citizen Science Project was at the YMPJ office in the Bronx, NY. Participants were invited to attend through various channels of communication which included emails, messages, word of mouth, flyers, and promotion by YMPJ community-based organization. The workshop consisted of an introduction to the Barry Commoner Center and the influence Barry Commoner, the Father of the Modern Environmental Movement, had on Citizen Science projects in the 1970s. The participants were kept engaged throughout the presentation by being asked questions about Air Quality and Air Pollution. The presentation had a section about the pollutants focusing on particulate matter, their definitions – characteristics based on size and dimension – chemical composition – sources – and their health and environmental effects. The positive impact of the NYCCAS project on the improvement of air quality in NY was also discussed with the participants. Although there are still neighborhoods where the air quality is a concerning matter due to the high levels of pollutants. Especially neighborhoods with high traffic density, building density, and industrial areas, like the South Bronx. The final part of the presentation was dedicated to the overview of the current project where the following questions were discussed:

1. Why are we doing an Air Quality project?
2. How are we going to make it possible?
3. What type of useful and valid data do we need to collect or use?
4. Where locations should be focused for data acquisition?
5. What resources do we need?
6. How will the information be useful to the community?

An overview of the existing Air Quality condition in the Bronx.

According to EPA, the relative $PM_{2.5}$ concentrations in the Bronx were around 6 μg/m^3, as illustrated from the bar charts in Figure 45, where 2017 to 2019 data is shown. The data was obtained from the closest DEC site in the Bronx, IS74 (FEM—R&P Tapered Element Oscillating Microbalance [TEOM]—Method 701 & 702). The data did not show any discrepancy and the averages $PM_{2.5}$ for the IS74 FEM site appears to be very similar from year to year.

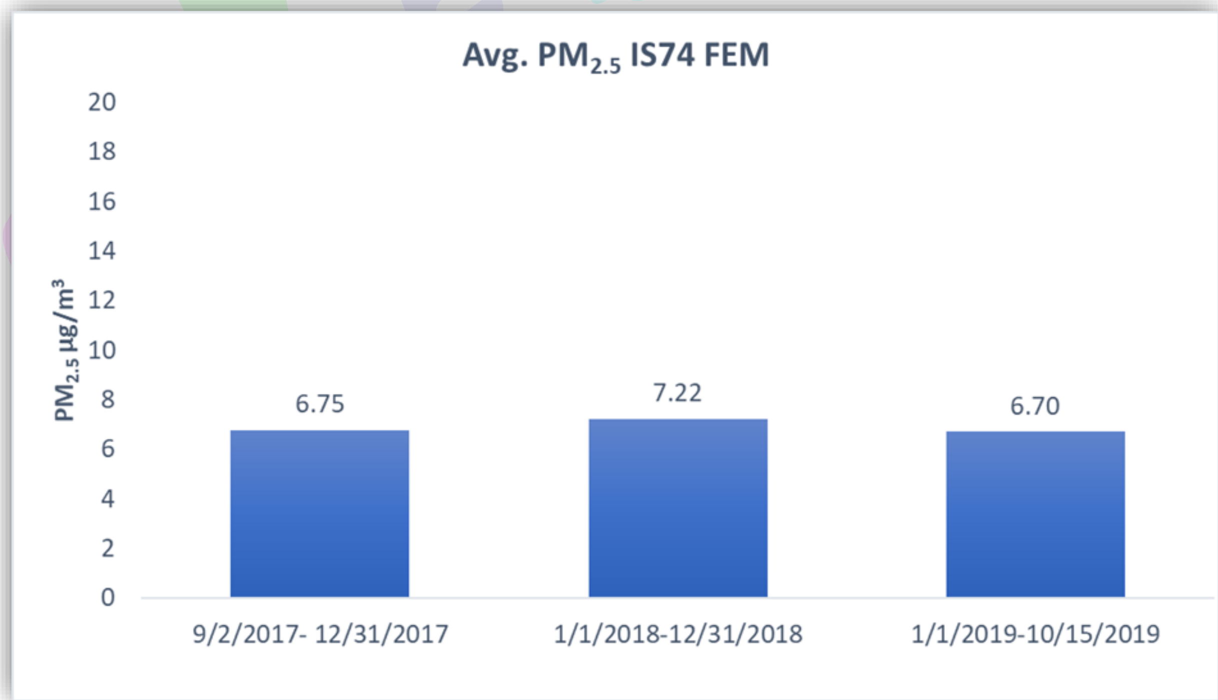


Fig.45. Annual average $PM_{2.5}$ concentrations at IS74 (DEC site) in the Bronx, 2017 to 2019.

NYCCAS LUR annual average for 2017

Annual $PM_{2.5}$ concentration averages for 2017 were also obtained from NYCCAS and are shown in the form of a Land Use Regression (LUR) model in Figure 46, where the data from a specific location was analyzed and shown in the form of a grid distribution. The average value was found to be around 8 µg/m^3 and the highest values were observed in Hunts Point, as indicated by the red zone.

Fig.46. $PM_{2.5}$ concentration levels obtained from Land Use Regression (LUR) model.

QA/QC Validation based on data collected at the QC DEC site – the Bronx

The idea behind co-location was to understand the measurements taken from two different instruments at the same location. In this study, measurements of $PM_{2.5}$ concentration were taken from FEM and AirBeam2, at the Queens College DEC site. The data were collected both, before and after the deployment in the Bronx. For each location shown by an ID on the x-axis in Figure 47, a regression analysis was carried out to compare the results between FEM and Airbeam2. Linear regression R^2 scores were plotted on the y-axis of this plot. Based on R^2 a strong agreement was observed between FEM and B1A – B4A – B5 – B6 – B8 – B9 – B12 – B13 AirBeam2. The B3 – B4B – B7 – B10 – B11 AirBeam2s did not have a strong agreement after deployment in the Bronx, thus the data were not considered in the data analysis. This could have been caused by the sensors malfunctioning, due to the 6V battery power pack using a step-down voltage, thus influencing the five-voltage needed for the sensor.

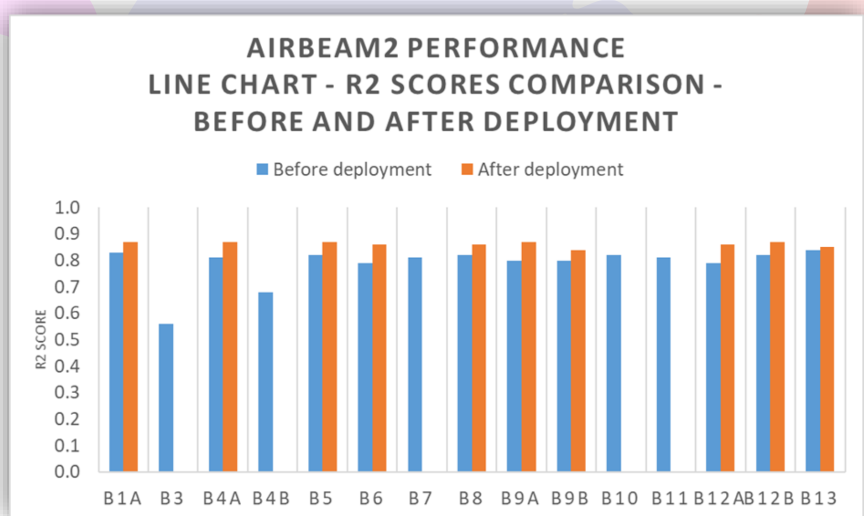


Fig. 47. A comparison of R^2 scores obtained from Linear Regression between FEM and Air-Beam2 $PM_{2.5}$ concentrations, (Ilie et al., 2020).

AirBeam2 data pattern compared to the closest DEC monitoring site

Monthly average: AirBeam2 (Bronx8) and FEM DEC (0.37 miles SE from the Bronx8)

The monthly average of $PM_{2.5}$ concentrations for AirBeam2 (Bronx8) and FEM are shown in Figure 48. The concentrations measured by AirBeam2 were slightly higher. Explanation can be provided to this observation by the distance between the monitoring sites and the variability of the AirBeam2 instruments.

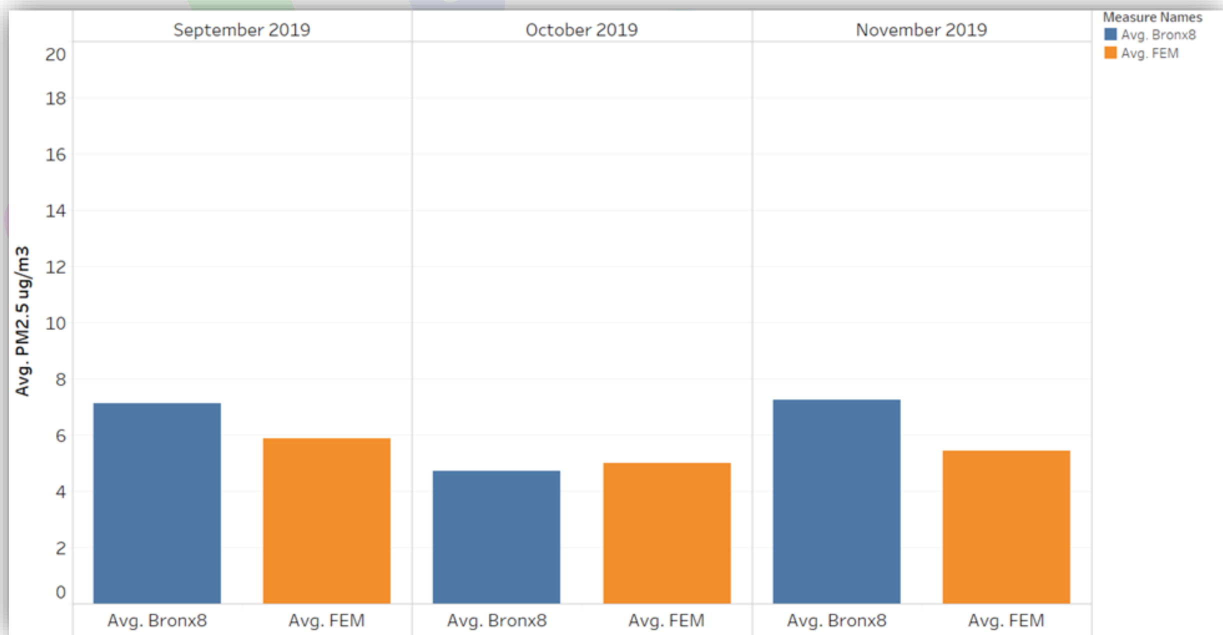


Fig. 48. Monthly average of $PM_{2.5}$ concentrations for AirBeam2 and FEM for a period of September to November 2019, (Ilie et al., 2020).

AirBeam2 data pattern compared to the closest DEC monitoring site

Weekday average: AirBeam2 (Bronx8) and FEM DEC

Data obtained from AirBeam2 and FEM was also analyzed weekly and averages for the same time between September and November 2019, the plot is shown in Figure 49. The highest values for FEM measurements were seen on Sundays and Mondays and the lowest values were observed on Tuesdays and Fridays. When looking at the Bronx8 measurements the same trend was observed.

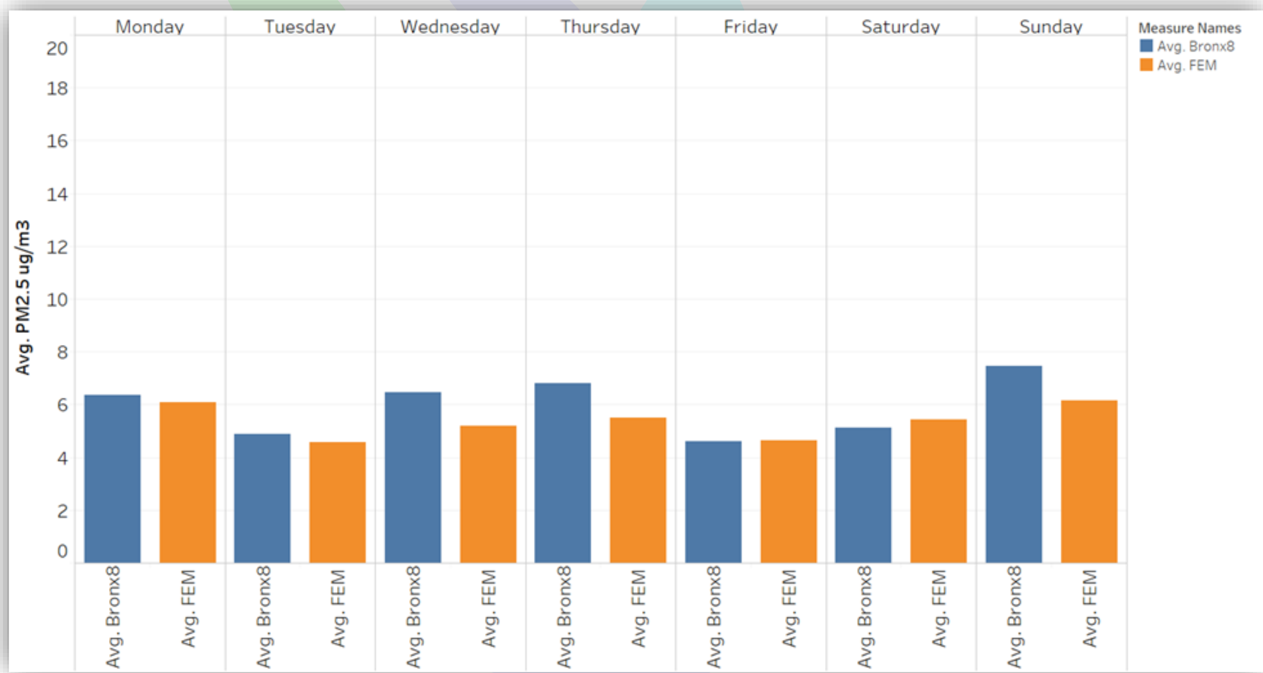


Fig. 49. Weekday average $PM_{2.5}$ concentrations for AirBeam2 and FEM locations, September to November 2019, (Ilie et al., 2020).

AirBeam2 data pattern compared to the closest DEC monitoring site

Daily average: AirBeam2 (Bronx8) and FEM DEC

Average daily concentrations obtained from Bron8 (AirBeam2) and IS74 (FEM DEC site) were plotted as a time series for the same time between September and November 2019 in figure 50. Small fluctuations were observed throughout the period and both instruments had the same trend line. Several spikes in $PM_{2.5}$ concentrations were observed, with the highest one being 37 µg/m^3 in October at IS74 which is in South Hunts Point. Overall, it was observed that the DEC FEM location had lower $PM_{2.5}$ concentration levels than the Bronx8 location.

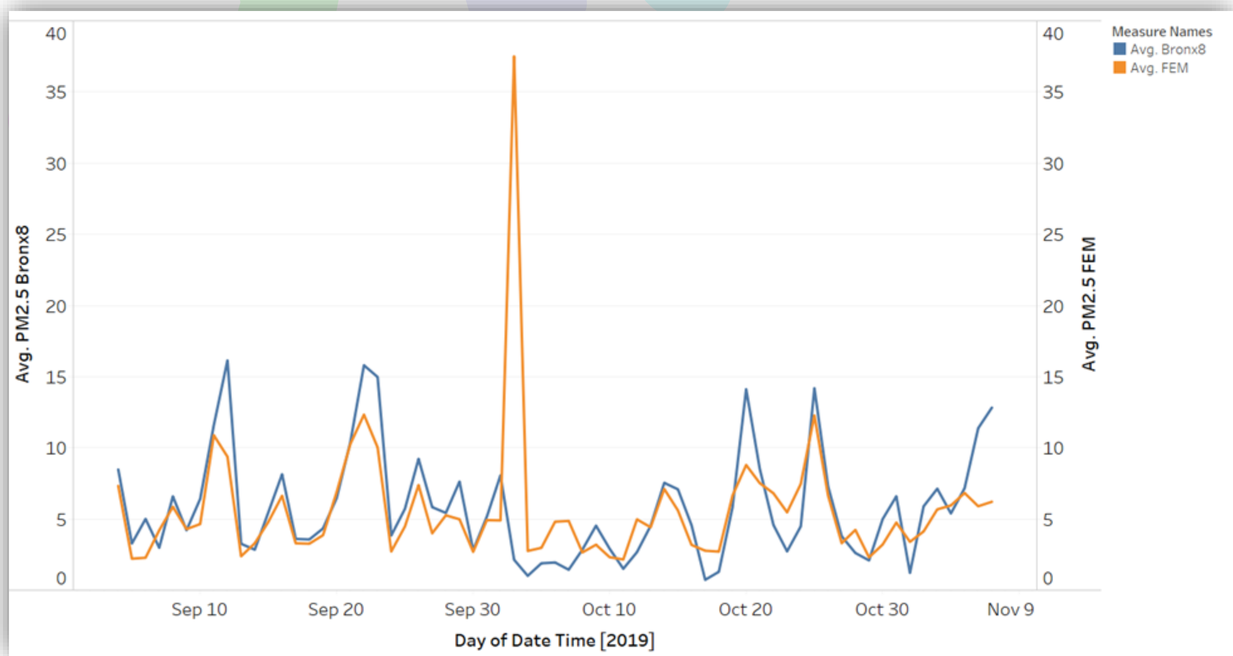


Fig.50. Average daily concentrations at Bronx8 (AirBeam2) and IS74 (DEC), September to November 2019, (Ilie et al., 2020).

AirBeam2 data compared to the NYCCAS LUR

A comparison of data collected from the Bronx stationary network, was performed with NYC-CAS LUR model results from 2017, as shown in figure 51. Differences were observed for most of the sites. NOTE: This exercise should serve only as an illustration of the opportunity for community-based citizen science projects to compare their data to the findings of the NYS's air surveillance program. A "correct" comparison was not possible for two key reasons: (1) NYCCAS LUR-2019 data were not available for the analysis and (2) the data collection period of AirBeam2-based stationary network combined with the personal monitoring activities were too short to adequately compare the two data sets.

Fig.51. Concentration levels obtained from Land Use Regression (LUR) model along with measurements from AirBeam2 at different locations in the Bronx, (Eisl et al, 2019).

Data Analysis
Results 4

Daily/weekday /monthly/seasonal patterns in the Project area – the Bronx

A map of the Bronx study area is shown in Figure 52, which shows 13 different locations where air quality measurements were taken. Most of the sites were along the Sheridan Expressway, the area of interest of YMPJ, and sites along with the Cross Bronx and the Bruckner expressway. It is important to note that the Bronx2 unit never ran since we could not deploy it due to construction.

#	Location	Unit ID
1	Public School 195	BRONX 01
2	Starlight Park	BRONX 02
3	Fannie High/Middle School	BRONX 03
4	Whitlock Avenue Station	BRONX 04
5	James M. Kieran Junior High School schoolyard	BRONX 05
6	Soundview Market place	BRONX 06
7	Rocking the boat	BRONX 07
8	Bruckner Expy (close by Point CDC)	BRONX 08
9	Public school 75 schoolyard	BRONX 09
10	Virginia Park	BRONX 10
11	Junior High School 125 Henry Hudson Schoolyard	BRONX 11
12	Public School 36 Unionport schoolyard	BRONX 12
13	Bruckner Expy	BRONX 13

Fig.52. Stationary AirBeam2 monitoring sites in the Bronx (n=13).

Diurnal patterns in the Bronx study area

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x-axis, as shown in Figure 53. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 1.32 µg/m^3 and 8.19 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the morning-evening rush hour and non-rush hour which was evident from the bottom-most yellow-red-blue points for each day. The average concentrations were a little different daily with the spike, which was observed on Monday, reaching the highest value around 8.19 µg/m^3, during the evening rush hour. Relatively lower concentrations were observed on Friday and Saturday.

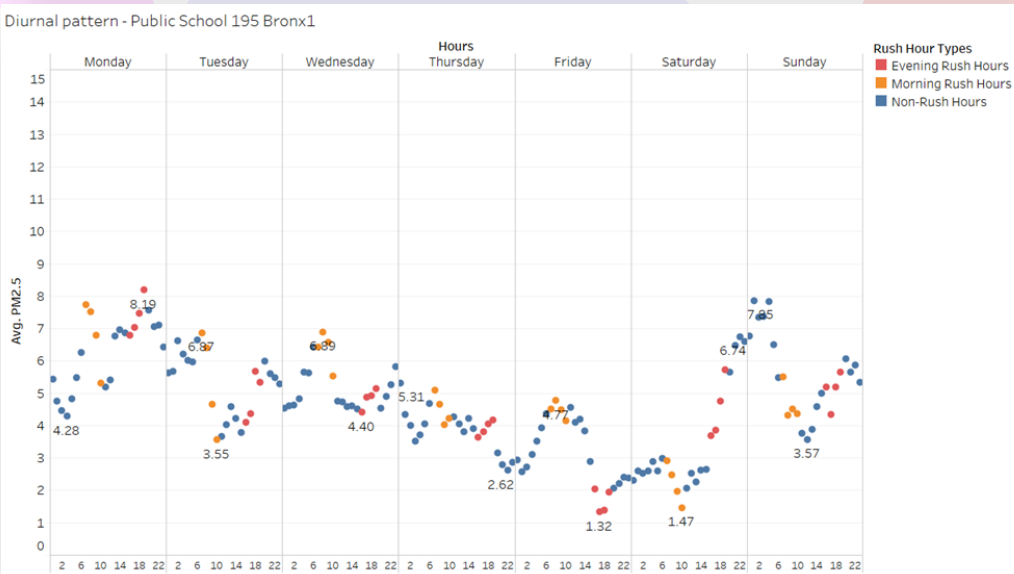


Figure 53: Diurnal patterns at Public School Bronx1.

__Diurnal patterns in the Bronx study area__

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x -axis, as shown in Figure 54. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 1.85 µg/m^3 and 8.48 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were a little different daily with the spike, which was observed on Monday, reaching the highest value around 8.19 µg/m^3, during the evening rush hour. Relatively lower concentrations were observed on Friday and Saturday.

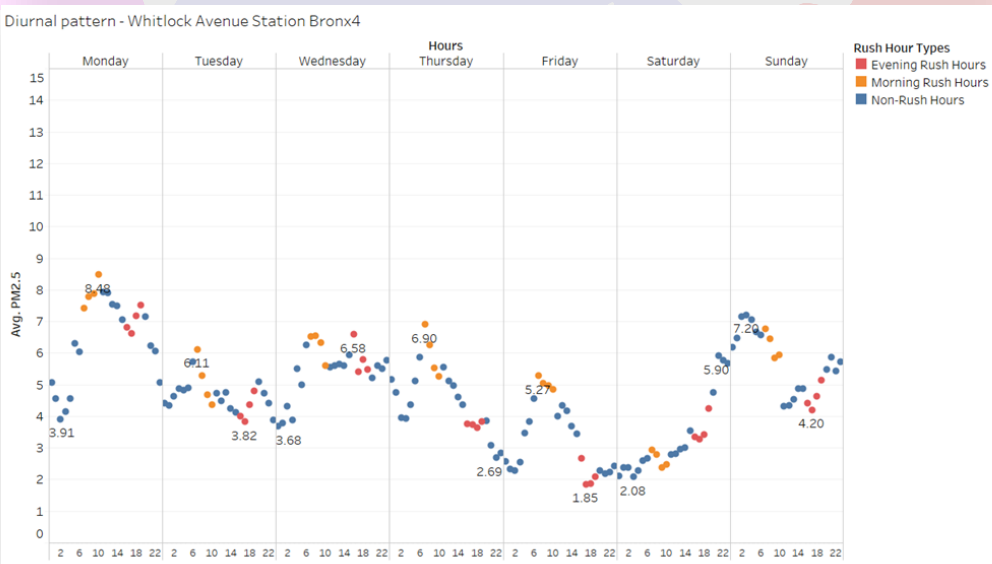


Figure 54 : Diurnal patterns at Whitlock Avenue Station Bronx4.

Diurnal patterns in the Bronx study area

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x -axis, as shown in Figure 55. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 1.27 µg/m^3 and 6.78 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the morning-evening rush hour and non-rush hour which was evident from the bottom-most yellow-red-blue points for each day. The average concentrations were a little different daily with the spike, which was observed on Monday and Sunday, reaching the highest value around 6.78 – 6.77 µg/m^3, during the evening rush hour and non-rush hours respectively. Relatively lower concentrations were observed on Friday and Saturday.

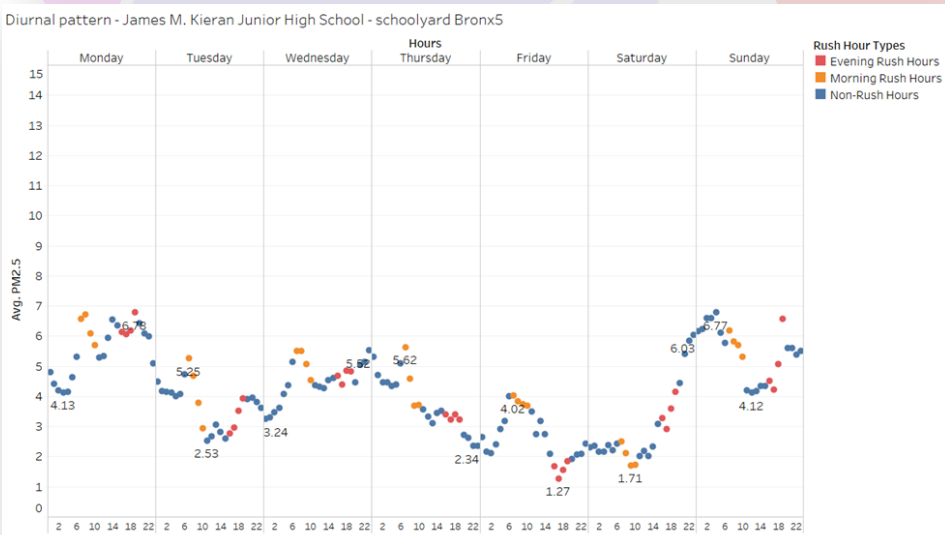


Figure 55: Diurnal patterns at James M. Kieran Junior High School - schoolyard Bronx5.

Diurnal patterns in the Bronx study area

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x-axis, as shown in Figure 56. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 0.84 µg/m^3 and 9.72 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were very similar daily with the spike, which was observed on Monday, reaching the highest value around 9.72 µg/m^3, during the morning rush hour.

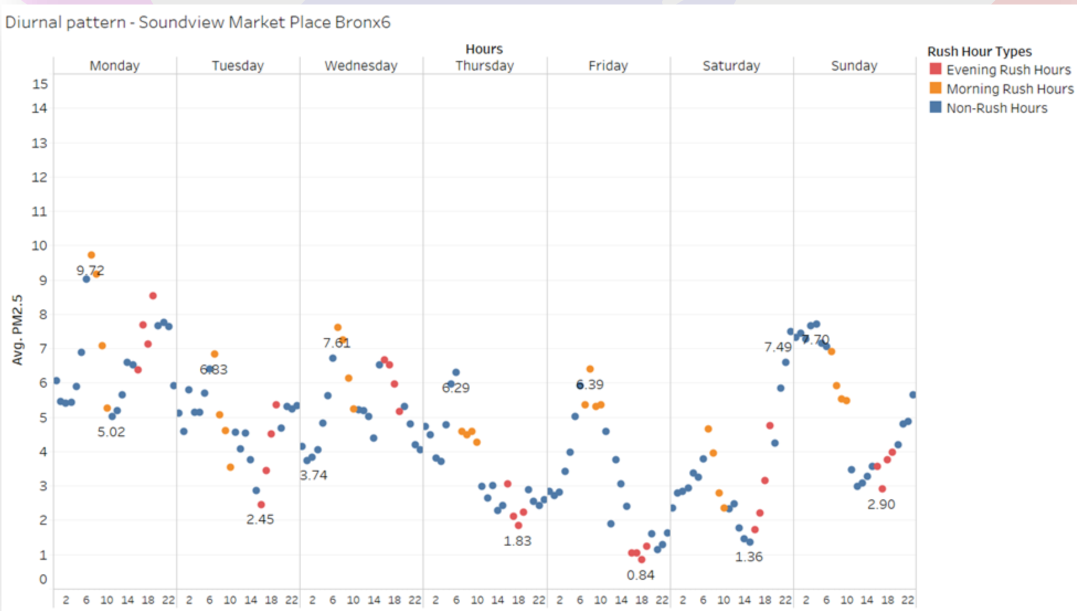


Figure 56: Diurnal patterns at Soundview Market Place Bronx6.

Diurnal patterns in the Bronx study area

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x-axis, as shown in Figure 57. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 2.54 µg/m^3 and 10.27 µg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were very similar daily with the spike, which was observed on Monday, reaching the highest value around 10.27 µg/m^3, during the morning rush hour.

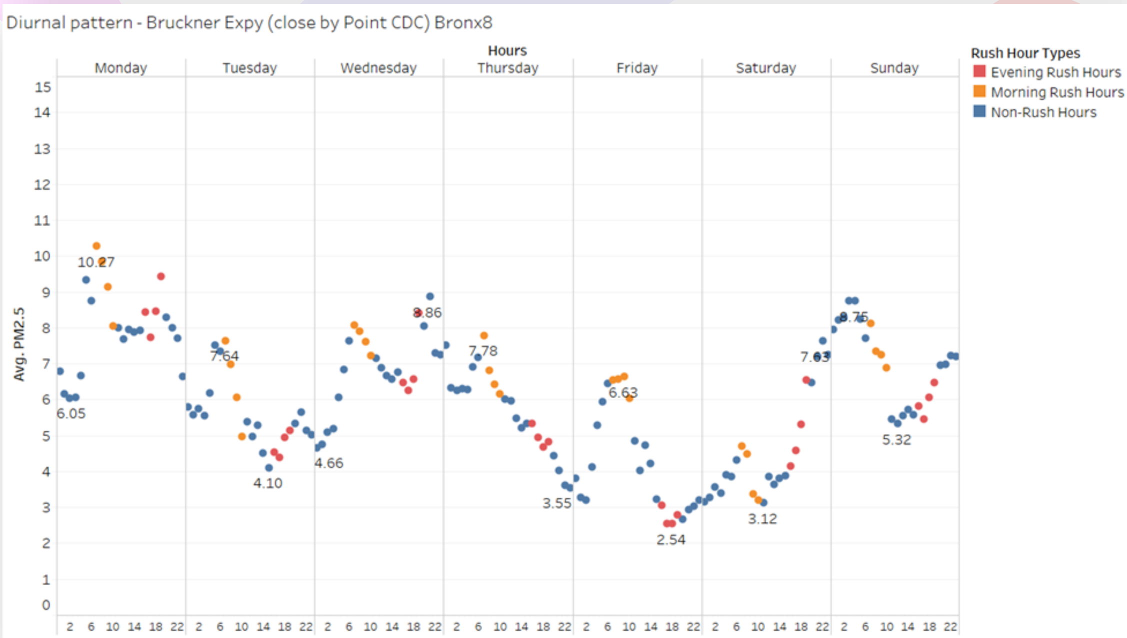


Figure 57: Diurnal patterns at Bruckner Expy (close by Point CDC) Bronx8.

Diurnal patterns in the Bronx study area

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x-axis, as shown in Figure 58. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 1.28 $\mu g/m^3$ and 11.10 $\mu g/m^3$ as indicated by the minimum and maximum measurements, shown as numbers on the plot itself. Lowest concentrations were obtained during the evening rush hour and non-rush hour which was evident from the bottom-most red-blue points for each day. The average concentrations were very different days with the spike, which was observed on Monday and Wednesday, reaching the highest value around 10.31 – 11.10 $\mu g/m^3$, during the evening rush hour and non-rush hour. Lower concentrations were observed on Friday and Saturday.

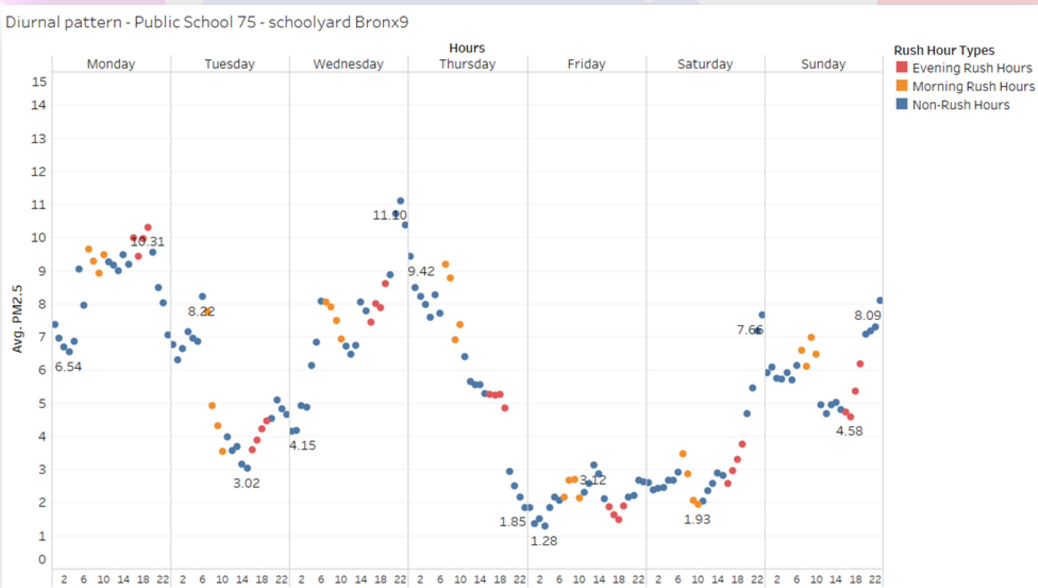


Figure 58: Diurnal patterns at Public School 75 - schoolyard Bronx9.

Diurnal patterns in the Bronx study area

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x -axis, as shown in Figure 59. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 0.86 μg/m^3 and 7.77 μg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the morning/evening rush hour and non-rush hour which was evident from the bottom-most yellow-red-blue points for each day. The average concentrations were a little different daily with the spike, which was observed on Monday and Wednesday, reaching the highest value around 7.61 – 7.77 μg/m^3, during the evening rush hour and non-rush hour. Lower concentrations were observed on Friday and Saturday.

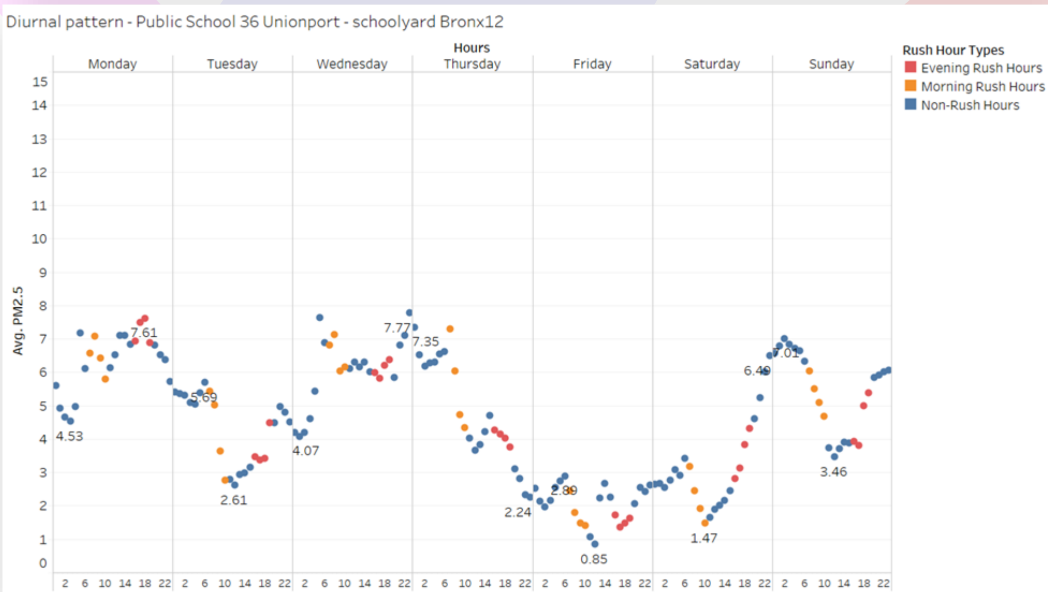


Figure 59: Diurnal patterns at Public School 36 Unionport – schoolyard Bronx12.

Diurnal patterns in the Bronx study area

A scatter plot was generated with average $PM_{2.5}$ concentration on the y-axis and time on the x-axis, as shown in Figure 60. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different times during the day and divided into three categories – morning rush hour, evening rush hour, and non-rush hour. The range of concentration for the entire week was between 3.40 μg/m^3 and 9.71 μg/m^3 as indicated by the minimum and maximum measurements shown as numbers on the plot itself. Lowest concentrations were obtained during the morning/evening rush hour and non-rush hour which was evident from the bottom-most yellow-red-blue points for each day. The average concentrations were very similar daily with the spike, which was observed on Monday and Sunday, reaching the highest value around 9.31 – 9.71 μg/m^3, during the morning rush hour and non-rush hour. Lower concentrations were observed on Friday and Saturday.

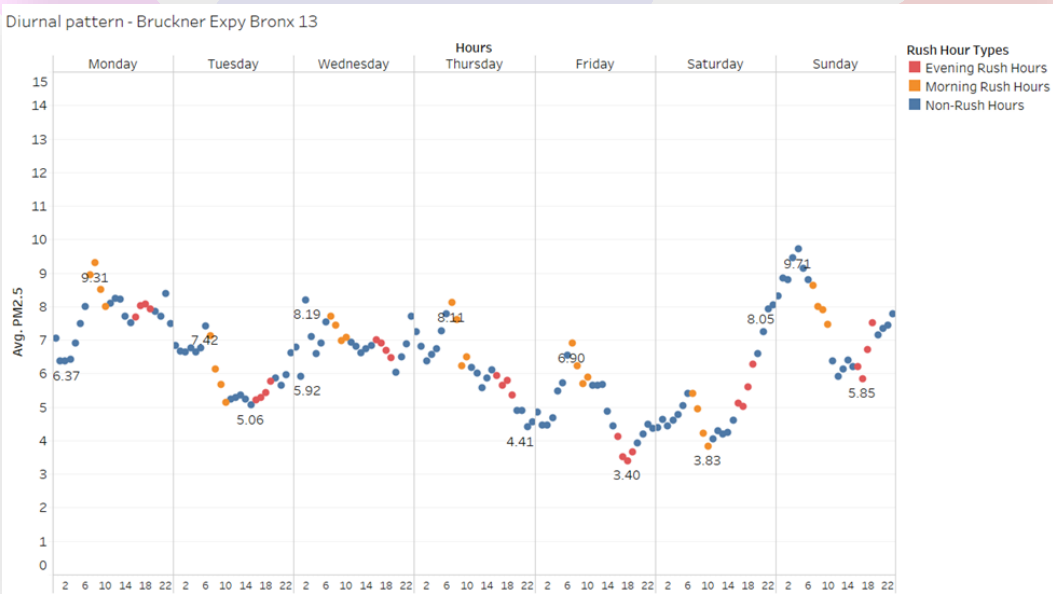


Figure 60. Diurnal patterns at Bruckner Expy Bronx13.

Data Analysis Results 4

Daily averages: Bronx1 – Bronx13

Due to the high frequency of the data collected during the study, it was possible to zoom daily and understand the differences in values and trends with time for each location. The data was plotted as a time-series plot in Figure 61. Each Airbeam2 ID (also denoting different locations) had a different color associated. The National Ambient Air Quality Standards (NAAQS) under EPA regulations is 35 micrograms (one-millionth of a gram) per cubic meter air (µg/m^3) for the average of 24-hours. As observed from the data in the Bronx area, no location within the studied area exceeded the limit of 35 µg/m^3 for 24 hours.

High fluctuations were observed for the entire period of September through November of 2019. There were spikes in $PM_{2.5}$ concentrations throughout this period, reaching as high as 17 µg/m^3 at the end of September and October. The concentrations were relatively lower at the beginning of October. Measurements taken at different locations exhibited very similar behavior with the occurrence of peaks and troughs at the same time indicated by the overlap of different lines. Although significant spikes in the concentrations were observed for certain periods, the measurements were still under the limits of EPA regulations, as mentioned earlier.

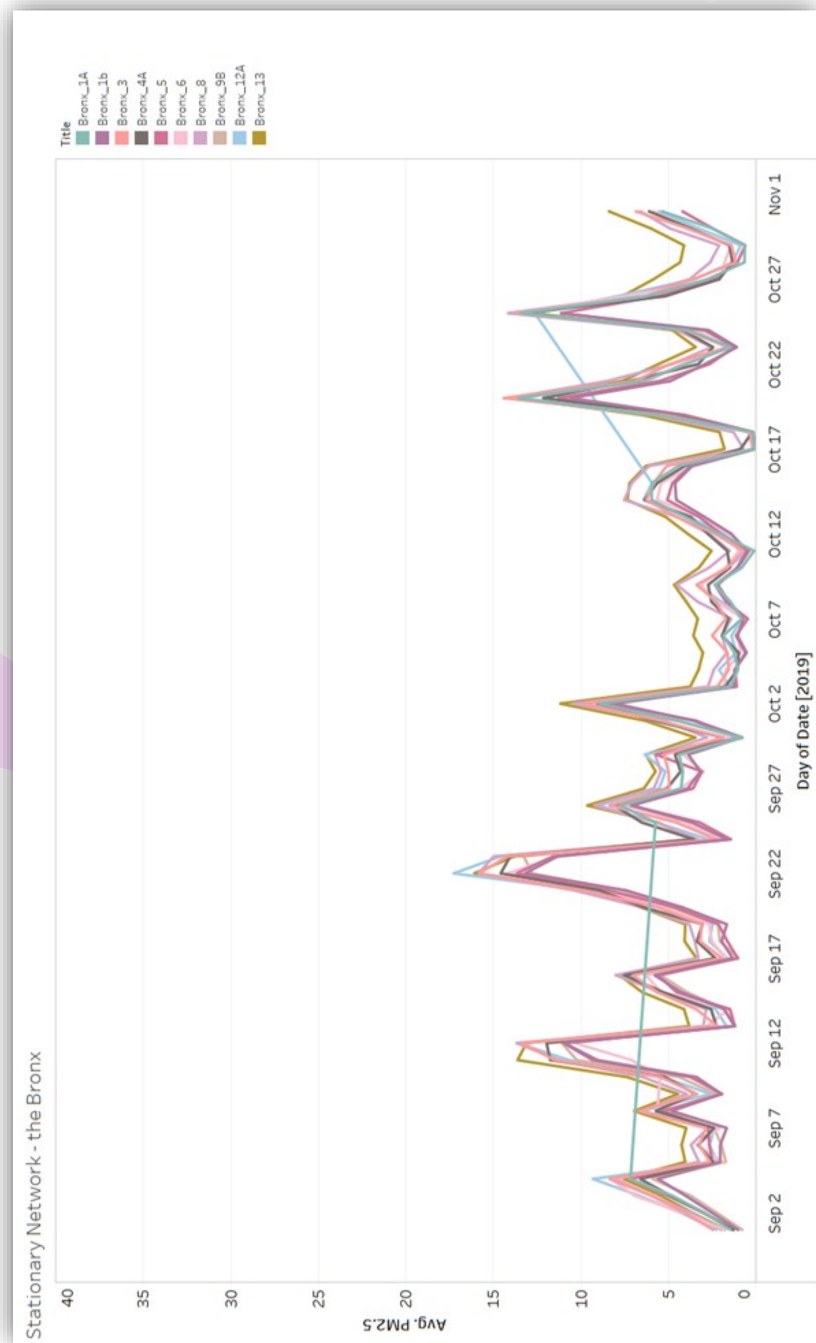


Figure 61. Daily averages of the Bronx stationary network, September to November 2019, (Ilie et al., 2020).

Monthly averages: Bronx1 – Bronx13

- The monthly average concentrations for Bronx1 – Bronx13 were plotted in the form of line chart in Figure 62, where a comparison was made between data from different months. The data for each month was divided into averages from each day, for higher precision of the measurements. Looking at the overall data, the highest concentrations were still under the limit of 35 μg/m^3 as per EPA regulations and the maximum average peak was about 11 μg/m^3.
- In September the highest $PM_{2.5}$ levels were around 9 μg/m^3 on Thursday at the Bronx13 location.
- In October the highest levels were around 6 μg/m^3 on Wednesday at the Bronx13 location.

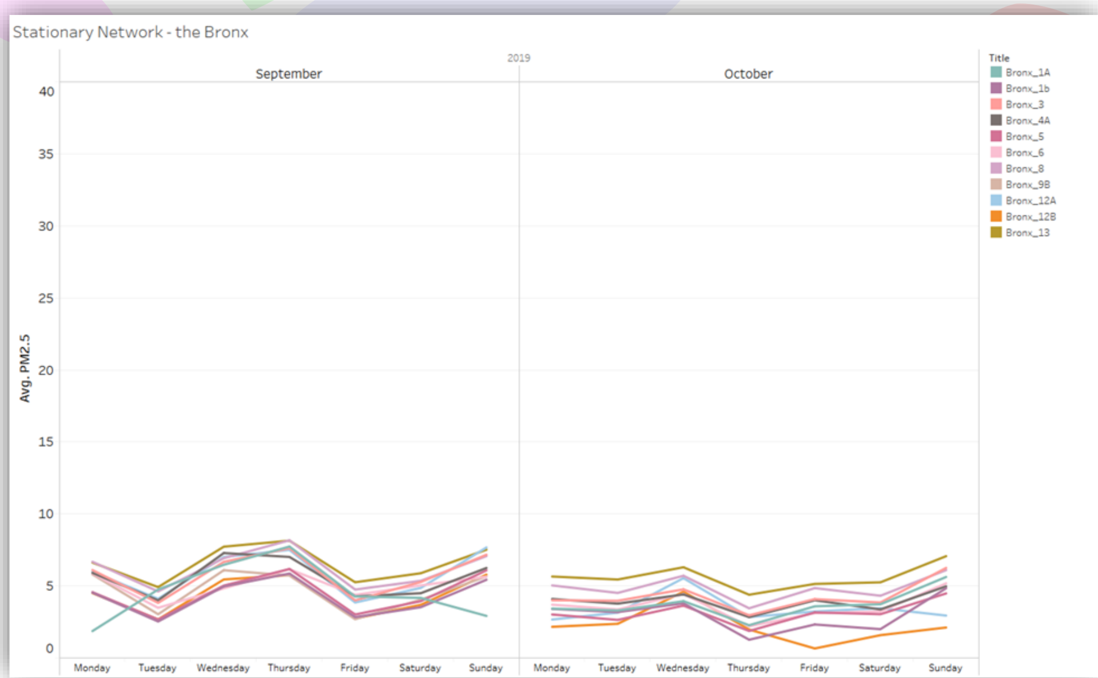


Fig.62. Weekday averages of the Bronx stationary network, September to November 2019

Discussions Conclusions 6

YMPJ seeks to gather baseline data that shows how the air quality will change in the redevelopment of the Sheridan Expressway where will remove thousands of trucks from the local streets. The project area is along the Cross Bronx Expressway, the Bruckner Expressway, Southern Boulevard, and Zerega Avenue, an area also known as the “toxic triangle”.

According to the EPA, from 2017 to 2019 the $PM_{2.5}$ average in the Bronx was found to be around 6 µg/m^3. The closest FEM DEC site to the Bronx, the $PM_{2.5}$ average was found to be around 5.37 µg/m^3 (September 2019 – November 2019).

Annual $PM_{2.5}$ concentration averages for 2017 were obtained from the NYCCAS project and the average value was found to be around 8.29 µg/m^3 and the highest values were observed in Hunts Point 9.26 µg/m^3.

In this pilot study, measurements of $PM_{2.5}$ concentrations were taken from FEM and AirBeam2, at the DEC site for data validation. The data were collected both, before and after the deployment in the Bronx for 3 months and 1 week respectively. Based on R^2 a strong agreement was observed between FEM and AirBeam2.

A comparison of data collected from this pilot study, from the stationary network, was performed with NYCCAS LUR model results from 2017. The stationary network (2019) $PM_{2.5}$ average was found to be around 5.50 µg/m^3 compared to NYCCAS LUR (2017) $PM_{2.5}$ averages of 8.50 µg/m^3.

In the Bronx daily $PM_{2.5}$ average was around 10 µg/m^3, using data collected from all AQM units from September to November 2019. There were durations when the spike in $PM_{2.5}$ concentration occurred, reaching as high as 17 µg/m^3 at the end of September and October. While mean $PM_{2.5}$ concentrations in the Bronx varied from 3 to 7 µg/m^3 on the weekdays and 3 to 6 µg/m^3 on the weekends.

Williamsburg data pattern compared to the Bronx data pattern

Daily averages: Williamsburg – the Bronx

A comparative analysis was carried out between the data collected from Williamsburg and the Bronx, as shown in Figure 63. There was an overlap between the values, as indicated by the peaks and troughs occurring at the same time. Similar concentration levels with very low variation between the daily averages indicated that the general air quality was similar in the two different locations. For both locations, the highest average took place around the third week of September 2019.

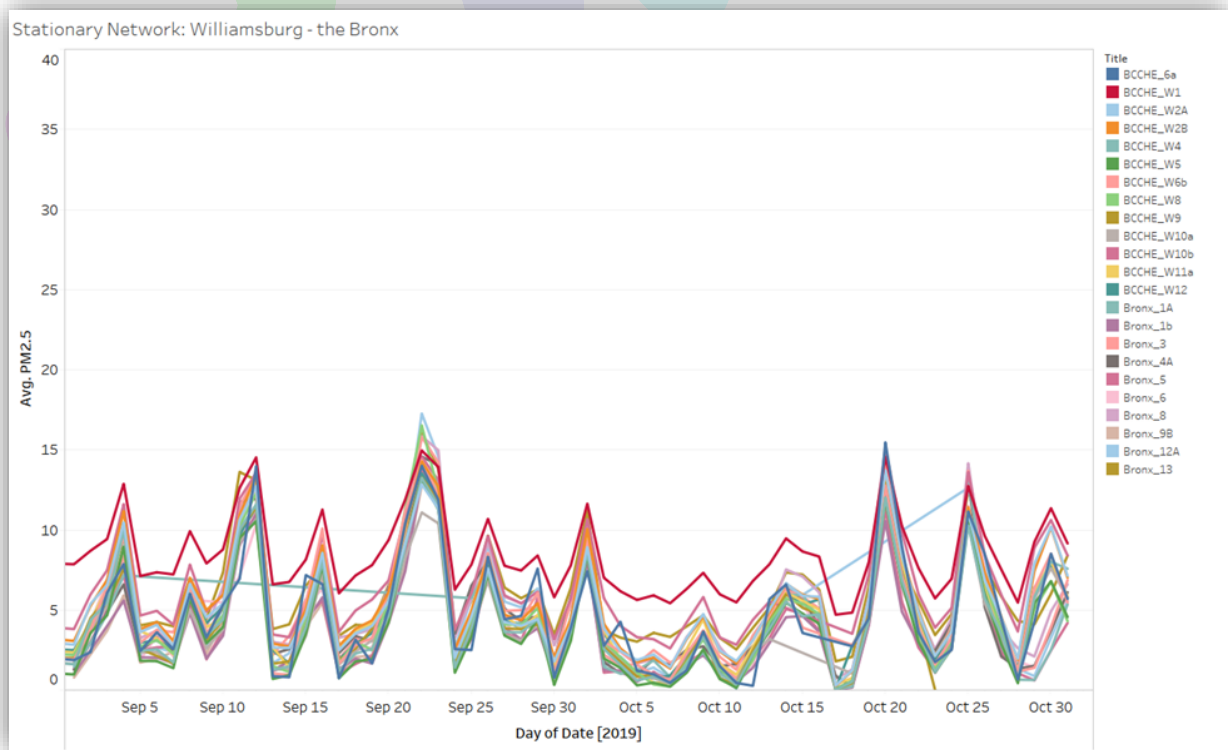


Fig. 63. Time series plot for comparison of data from Williamsburg and the Bronx.

Conclusions 6

Monthly averages: Williamsburg – the Bronx

During September and October, data was collected from AQM installed at both locations – Williamsburg and the Bronx. As observed from Figure 64, very similar trends exhibited at both the locations with a small range of $PM_{2.5}$ variations. In Williamsburg high $PM_{2.5}$ levels were at W1 location or La Guardia Playground (W1 red line color on the plot).

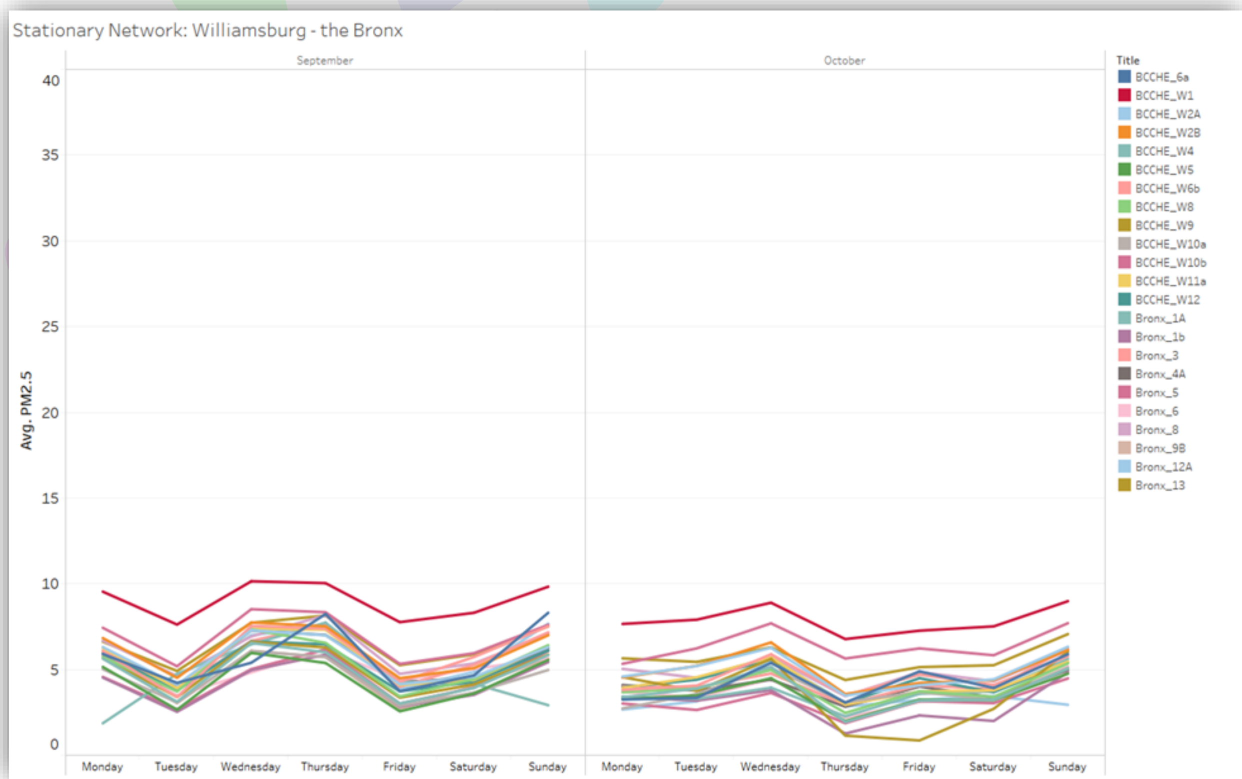


Fig. 64. Monthly averages plotted as line charts to compare data from Williamsburg and Bronx.

Conclusions 6

Diurnal patterns: Williamsburg – the Bronx

A comparative analysis was carried out between the data collected from September to November 2019, from Williamsburg and the Bronx study area, as shown in Figure 65. A scatter plot was generated with an average $PM_{2.5}$ concentration on the y-axis and date time on the x-axis. The time scale was further broken down into each hour and every day of the week. The points were colored based on the different time during the day and divided into three categories – morning rush hour, evening rush hour and non-rush hour.

- The range of concentrations for the entire week in Williamsburg study area were between 2.67 $\mu g/m^3$ and 8.15 $\mu g/m^3$ as indicated by the minimum and maximum measurements shown as numbers on the plot itself.
- The range of concentrations for the entire week in the Bronx study area were between 3.68 $\mu g/m^3$ and 8.66 $\mu g/m^3$.

The average concentrations were very similar in both neighborhoods daily except for the spike, which was observed mid-week during Wednesday, reaching the highest value around 8.15 $\mu g/m^3$ in Williamsburg, and during the weekend reaching the highest value around 8.65 $\mu g/m^3$ in the Bronx.

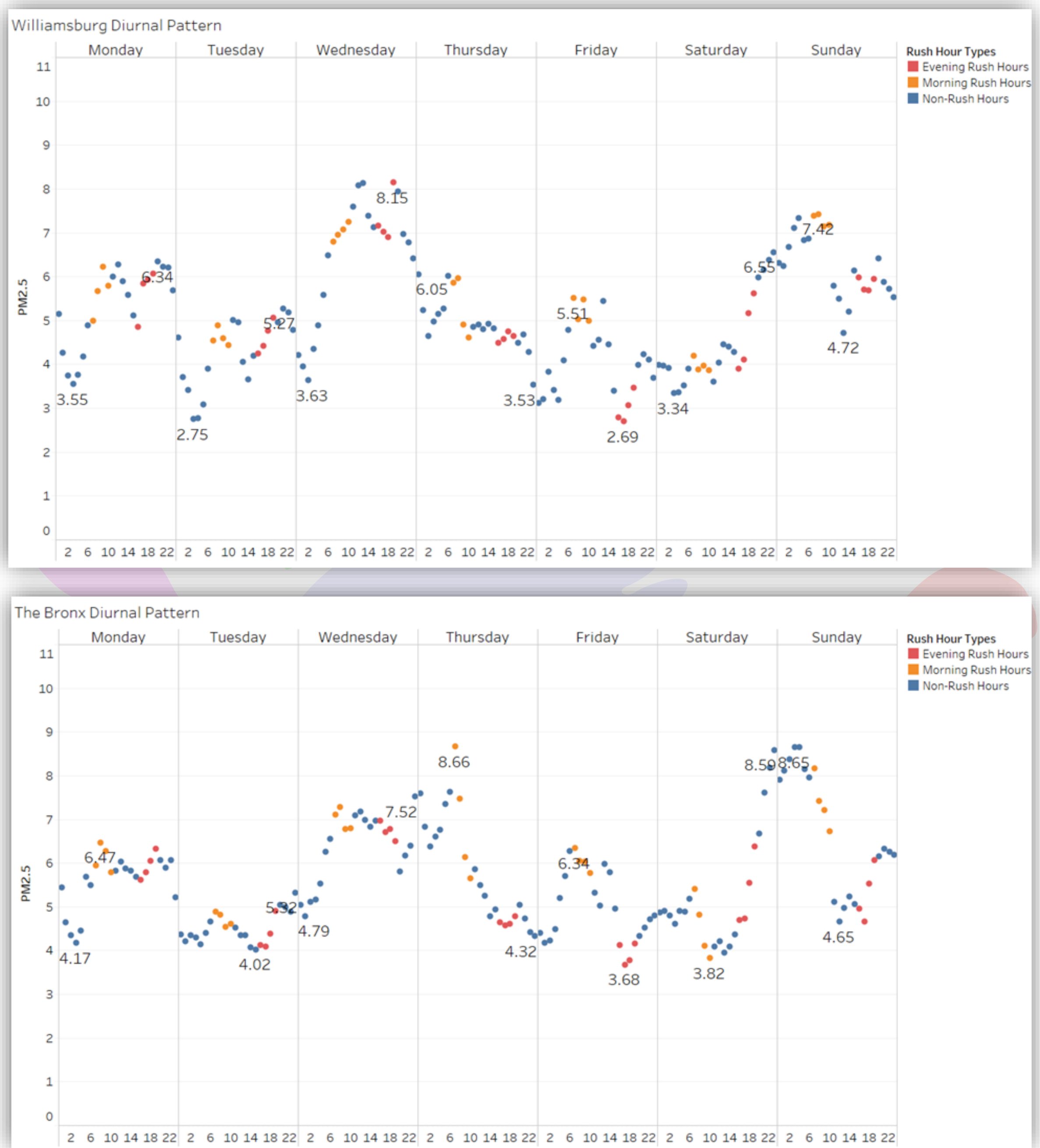


Fig. 65. Diurnal patterns avg. PM2.5 in Williamsburg and in the Bronx study area.

Discussions and Conclusions

Utilizing the information collected through citizen science in conjunction with current city-wide air quality monitoring efforts, this partnership created a richer picture of neighborhood-level variation in air quality and provided communities with data and appropriate context to better understand their local air quality. While the NYCCAS study provided seasonal data patterns, the Stationary Network (low-cost monitors) gave us diurnal pattern information on pollutant levels by delving deeper into $PM_{2.5}$ concentrations on an hourly scale for multiple locations. As a follow-up study from the NYCCAS project, the objectives behind this Citizen Science project were not just to address the gaps and concerns associated with institutional monitoring, but also to raise awareness of air quality on a community level. It focused on improving community-level engagement through direct public interaction and emphasized the importance of collaboration and establishing the best practices for a scientific study when conducting a citizen science project. Which was only possible with the direct involvement of the communities who are impacted by the existing environmental challenges in the areas studied. In this pilot study, an emphasis was laid on understanding the $PM_{2.5}$ concentrations in Southside Williamsburg and the “toxic triangle” in the South Bronx, which is characterized by a high rate of asthma and cardio-respiratory issues due to the presence of higher levels of particulate matter in the atmosphere. The negative side of the high-volume traffic due to the Williamsburg Bridge, bus depot, commercial areas, and main highways in both neighborhoods is evident. Also, the presence of schools, playgrounds, and parks right next to these areas of high emissions is concerning. As part of the community-level engagement, high school students participated in collecting air quality data by using AirBeam2 low-cost monitors as a personal monitoring procedure to characterize the exposure to air pollution near areas of concern. As a part of raising awareness and disseminating knowledge, workshops and training were conducted to help students better understand air pollution levels in their community and learn how to use the Airbeam2 devices to collect and summarize environmental data.

Discussions and Conclusions

Due to the rise of community-based air quality monitoring projects around the country, a consensus highlights the success of these programs. A primary reason behind the surge can be attributed to higher public awareness and willingness to act for improving environmental conditions. Although public data shows some improvement in air quality levels in recent years, there are potential health risks caused by higher levels of particulate matter concentration, which still need to be addressed. Fixed site monitoring for air quality has been the conventional approach in the past, but with recent developments in technology, single and multi-pollutant low-cost sensors have proved to be a viable solution. Providing a simple user-friendly design, low-cost sensors have allowed citizen scientists to gather data more easily. With this technology, we have ushered in the next era of air quality monitoring by directly involving citizen scientists to be a part of the process.

Understanding the spatial and temporal scales at which air quality affects people is critical for maintaining the overall health of a community. Due to the high cost and technical requirements associated with regulatory-grade instrumentation like the Federal Reference Method (FRM) and Federal Equivalent Method (FEM), multiple challenges were encountered during installation at multiple locations. This work intended to explore the feasibility of using low-cost instrumentation and hardware to create a more accessible platform for measuring air quality. Based on the trade-off analysis for accuracy and cost, low-cost monitors have proven to be a good alternative for measuring air pollutant concentrations. Besides, the collaboration with NYSDEC and having access to the DEC monitoring location were invaluable during the design and testing phase of the low-cost air quality monitoring units (Housing unit + AirBeam2 + cellular data acquisition system). The result was a prototype for a low-cost air quality monitoring system named 'Air Quality Monitor' (AQM), proposed in this project. In which each prototype obtained a unique ID at each location.

Discussions and Conclusions

The low-cost AQM provided the opportunity of many devices being installed at multiple locations to increase the spatial and temporal resolution of monitoring or surveillance areas. The approximate cost for AQM unit consisting of two AirBeam2 instruments costs approximately $2,000 whereas the cost for a typical FEM or FRM instrument amounts to approximately $25,000. This highlights the monetary advantage of using low-cost instruments to increase the spatial and temporal resolution of monitored and/or surveillance areas. With a savings of 92% for the same number of units used in a FEM-FRM study, the low-cost AQM provides the opportunity of many devices being installed at multiple locations.

The prototype discussed in this work provides a low-cost alternative to existing systems for air quality monitoring. AirBeam2 illustrates the advantage of low-cost sensor platforms by helping drive down the cost of data acquisition and providing more insights into the air quality network. Due to higher spatial resolution, a more comprehensive analysis of urban environments is made possible through the proposed monitoring system. The personal exposure data, collected through personal monitoring devices, can give rise to more generalized exposure patterns that can eventually be used for optimizing personal choices or policy measures.

Challenges

Challenges and Limitations

During the planning and implementation of this citizen science project, the research team was confronted with several challenges, which are addressed in this section. The conclusions are divided into three sub-sections that follow the same structure as the case studies discussed earlier in this report. For a successful study in the future, it is important to understand the reasons behind them and to take adequate steps to overcome these limitations in future projects.

1. Planning Phase

To identify potential locations for the stationary network, several meetings were conducted at El Puente. It was difficult to identify the locations for the installation of low-cost units AQM, since the Williamsburg area is dominated by the BQE and Williamsburg Bridge. To ensure high -quality data acquisition through low-cost monitors, another challenge was regarding the location of high-quality Thermo Scientific pDR-1500. The availability of power supply for the instrument as well as concerns about vandalism led to the installation of the sensor at the El Puente Headquarters. There are different technologies used by regulatory agencies and citizen science monitors which had to be addressed for data quality and validation purposes. Another important limitation was related to the inability to use current low-cost sensors for source apportionment studies, which was done by using a filter-based system in previously conducted NYCCAS project. Some administrative hurdles were encountered during the recruitment process which delayed the community engagement process. As a result, only eight 8 student volunteers could be recruited and participated in the project.

Challenges

Challenges and Limitations

2. Research Phase

For the personal monitoring phase, the plan was to have the volunteers collect data at least three times per week, but the data acquisition inconsistently took place with measurements taken only twice a week. Weather conditions posed a challenge for the volunteers, with students being unable to go out and collect data during either extreme cold or hot temperatures. It was difficult to engage the volunteers on data interpretation, with no workshop being conducted for data analysis. Keeping volunteers engaged throughout the project and have them follow the BCCHE protocols was a difficult task with many students leaving the project after a few sessions. This resulted in the personal monitoring data with intrinsically lower quality since the protocols were not strictly followed by volunteers. There were few communications issues observed between with community and volunteers.

Regarding the instrumentation limitations due to the battery-powered systems and same-day deployment, it was a difficult task to run all AQM simultaneously. Some of the other challenges included the electronics and systems integration (step-down chip), and power issues – battery power supply, swapping out batteries and the maintenance of the AQM, units.

3. Action Phase

As soon as preliminary results were conveyed to the communities, they wanted to portray data in a way that confirmed their suspicions. They wanted to take immediate action before data and findings were validated and finalized. Some of the challenges were related to confirming the results of the citizen science-based air monitoring program to the project objectives. More long-term planning is required to acquire a significant amount of data, perform detailed analysis, draw conclusions, and developing strategies for the near future.

Benefits

One of the main objectives of this citizen science project was to conduct community-based air quality monitoring to raise awareness about local air pollution and assisting communities in developing strategies for improvement. The study also created opportunities to leverage limited governmental resources by utilizing citizen scientists to help to fill environmental data gaps. The project provided learning opportunities for the communities and thus raised awareness on pressing environmental issues in their neighborhoods. For example, residents have full access to the data and reports produces by this project, which will help them to better understand health outcomes due to air pollution, identify pollution hotspots and hopefully avoid harmful exposures wherever possible.

In sum, the study provides detailed information on the Air Quality in Southside Williamsburg and the "Toxic Triangle" in the South Bronx. Areas of concern were identified that had otherwise not been identified before (areas with higher $PM_{2.5}$ concentration). Detailed data analysis with fine-scale monitoring created a rich dataset that helps address public health concerns.

Accomplishments

The Air Quality Citizen Science Research project included a detailed description of two pilot studies with target areas in Williamsburg and the Bronx and the purpose of addressing local air quality concerns. Detailed monitoring plans were developed for both stationary monitoring networks and personal monitoring activities using low-cost AirBeams2 sensor technology. Knowledge transfer was carried out by conducting workshops to inform, teach, and train the public on various aspects of the project. Data dissemination was carried out through public events, seminars, and conferences. This air quality citizen science toolkit is an instruction manual to perform comprehensive air quality studies, which includes information on sensor deployment, maintenance of sensors, data acquisition methods/techniques, and guidance for data analysis.

Dissemination

ABSTRACTS, Events include: conferences, meetings, symposia, workshops

- Ilie A.M. C. and Eisl H.M., **2020.** *Are Low-Cost Monitors Good Enough to Help People Understand Poor Air Quality in their Neighborhood?* Association of Environmental & Engineering Geologists 2020 Virtual Annual Meeting. Abstract poster presentation. https://www.aegannualmeeting.org/
- Ilie A.M. C., Eisl H.M. and Heimbinder M., **2020.** *Development of a Power-Independent Low-Cost Particulate Monitor for Air Quality Monitoring in the Bronx – New York City.* 3rd Conference of the Arabian Journal of Geosciences, Sousse Tunisia. Abstract oral presentation. https://cajg.org/
- Ilie A.M. C. and Eisl H.M., **2019.** *Air Quality Citizen Science Research Project in Williamsburg, NYC.* AGU 2019 San Francisco, California. Abstract oral presentation. https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/599543
- Eisl H., Ilie A.M.C. and Johnson S., **2019.** *Performance assessment of low-cost stationary PM2.5 sensor networks, deployed in Brooklyn and the Bronx, New York.* Air Sensors International Conference California. Abstract poster presentation. https://asic.aqrc.ucdavis.edu/poster-presentation-abstracts
- Eisl H.M. and Ilie A.M. C., **2018.** *The role of Citizen Science Projects in the context of information made available by the New York City Community Air Survey.* Air Sensors International Conference California. Abstract oral presentation. https://asic.aqrc.ucdavis.edu/
- Rice M., **2018**. *City government, academia, and local communities: Cooperative approaches to citizen data collection.* Air Sensors International Conference California. https://asic.aqrc.ucdavis.edu/

Dissemination

PEER REVIEWED ARTICLES

- Ilie A.M. C., Eisl H.M. and Heimbinder M. (paper submitted, accepted and under review). *Development of a Power-Independent Low-Cost Particulate Monitor for Air Quality Monitoring in the Bronx – New York City.* Advances in Science, Technology & Innovation - Springer Journal.

- Ilie A.M.C., McCarthy N., Eisl H.M. and Velasquez L. (paper to be submitted, Sustainable Cities and Society - Elsevier Journal). *Air Pollution Exposure Assessment at Schools and Playgrounds in Williamsburg, Brooklyn, NYC.*

- *Ilie A.M. C., and Eisl H.M. (paper to be submitted, Journal of Computer Science and Technology—Springer). Python programming language for a Citizen Science - Air Quality Monitoring Research Project.*

- Ilie A.M.C., Eisl H.M., Heimbinder M. and Christophersen M., (work in progress paper). *Performance Assessment of Low-Cost Air Quality Monitors for Fine Particulate Matter Monitoring in a Citizen Science Research Project.*

- Ilie A.M.C., Eisl H.M., Rice M, Olson C., and Johnson S. (work in progress paper). *Community-based participatory in Air Quality Monitoring Network – Pilot Studies in New York City.*

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Morgan, Patricia, Maresa interns students
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John D. and I were part of a large abolitionist community right here in Williamsburg. This place has a long history in the struggle for peace & justice
Prepárense . . .
THANKS GUYS, WE'LL TAKE IT FROM HERE!
Ana MC Ulie
PHOTOGRAPHY

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