



# Air pollution exposure assessment at schools and playgrounds in Williamsburg Brooklyn NYC, with a view to developing a set of policy solutions

Ana Maria Carmen Ilie<sup>1,2</sup> · Norma McCarthy<sup>3</sup> · Leslie Velasquez<sup>4</sup> · Masoom Moitra<sup>4</sup> · Holger Michael Eisl<sup>2</sup>

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## Abstract

Community science offers unique opportunities for non-professional involvement of volunteers in the scientific process, not just during the data acquisition, but also in other phases, like problem definition, quality assurance, data analysis and interpretation, and the dissemination of results. Moreover, community science can be a powerful tool for public engagement and empowerment during policy formulation. This paper aims to present a pilot study on personal exposure to fine particulate matter (PM<sub>2.5</sub>) and raises awareness of the hazards of air pollution. As part of data acquisition conducted in 2019, high school students gathered data at their schools, schoolyards, and playgrounds using low-cost monitors AirBeam2. The data was automatically uploaded every second onto the AirCasting mobile app. Besides, a stationary network of air monitors (fixed stations) was deployed in the neighborhood to collect real-time ambient air concentrations of PM<sub>2.5</sub>. Students involved in the project attended workshops, training sessions, and researched to better understand air pollution, as part of their science class curriculum and portfolio. This air quality monitoring was incorporated into the “Our Air/Nuestro Aire” — El Puente grassroots campaign. The main goals of this campaign included sharing the data collected with the community, engaging academic partners to develop a set of policy and urban design solutions, and to be considered into a 5-point policy platform.

**Keywords** Air quality · Community science · Grassroots campaign · Policy solutions · PM<sub>2.5</sub> · Science class curriculum

## Introduction

It is well-established that particulate matter (PM) has adverse effects on human health and the environment (Dockery et al. 1993; Samet et al. 2000; Nel 2005; Pope and Dockery 2006; Posfai and Buseck 2010). Studies on school-age children indicated that PM is associated with adverse effects

on respiratory function (Horak et al. 2002; Peacock et al. 2003; Moon et al. 2009). Children are particularly vulnerable to the harmful effects of air pollution because of immature lung defenses, narrower airways, higher inhalation rates, and higher metabolic rate of oxygen consumption per unit of body weight (Salvi 2007; Santamouris et al. 2008). Children are also believed to be more susceptible than adults to the adverse health effects of poor indoor air quality (IAQ) due to their higher metabolic demands and higher minute ventilation rates, which increases their exposures (Bluyssen 2016; Mendell and Heath 2005). Prior studies have often focused on indoor and outdoor air pollutants (Buonanno et al. 2013; Crilley et al. 2016; Godwin and Batterman 2007; Laiman et al. 2014; Mazaheri et al. 2016; Ramachandran et al. 2005; Rivas et al. 2014; Stranger et al. 2008; Zhang and Zhu 2012). There are many existing participatory models, such as participatory-action research, community-based participatory research, action research, street science, and ethnographic action research (Hughes 2008; Waterman et al. 2001; Corburn 2005; Dick 2006; Schein 2008), which encompass many of the key principles of these participatory

✉ Ana Maria Carmen Ilie  
ailie@mines.edu

<sup>1</sup> Center for Experimental Study of Subsurface Environmental Processes (CESEP), Department of Civil and Environmental Engineering, Colorado School of Mines, Golden, CO 80401, USA

<sup>2</sup> Barry Commoner Center for Health and the Environment, Queens College, City University of New York, Flushing, NY 11367, USA

<sup>3</sup> El Puente Academy for Peace and Justice High School, Brooklyn New York City, NY 11211, USA

<sup>4</sup> El Puente Community-based Organization, Brooklyn, New York City, NY 11211, USA

approaches. 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; Minkler 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). Building social capital for sustainable development requires not only collective action by a community but also participatory policymaking (Gerometta et al. 2005; Seyfang and Haxeltine 2012; Wakefield et al. 2001; Agyeman and Angus 2003). Most of the community science projects have the objective of raising awareness and increasing community engagement, as well as making sure that the results are used in policy debates. This ensures that people are monitoring for good data which will be relevant and used by policymakers (Conrad and Hilchey 2011). In 2007, the New York City Department of Health and Mental Hygiene (Health Department) established the New York City Community Air Survey (NYCCAS), the largest ongoing urban air monitoring program of any US city. NYCCAS, which began collecting data in December 2008, is a collaboration between the Health Department and Barry Commoner Center for Health and the Environment (BCCHE) at the Queens College of the City University of New York. This project provides data to help inform OneNYC, the city's sustainability plan, track changes in air quality over time, and estimate exposures for health research. NYCCAS has become vital to the city's understanding of the variation in pollution exposures within NYC, 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 high-frequency data collection by citizens, (Eisl and Ilie 2018).

This pilot study, a part of the NYCCAS project, aims to focus on personal exposure to fine particulate matter (PM<sub>2.5</sub>) using low-cost sensor technology, in collaboration with a community-based organization El Puente, in Brooklyn — Williamsburg neighborhood, New York City. El Puente is a community human rights institution that promotes leadership for peace and justice through the engagement of members (youth and adults) in the arts, education, scientific research, wellness, and environmental action. Founded in 1982 by Luis Garden Acosta, El Puente currently integrates the diverse activities and community campaigns of its Center for Arts and Culture and its Community Health and Environment Institute (CHE) within its three neighborhood Leadership Centers and its nationally recognized public high school, the El Puente Academy for Peace and Justice. El Puente's mission is to inspire and nurture leadership for

peace and justice (<https://elpuente.us/>). El Puente's proposal was accepted to be the first of our two-community air quality monitoring pilots and creating a lasting impression with their knowledge of local air quality issues, particularly relating to PM<sub>2.5</sub>, as well as their goal to use the air quality monitoring network to expand measuring air quality outside of parks to identify potentially safer areas for playgrounds and greenspace in Southside Williamsburg. Utilizing the information collected through the community 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. Specific aims of this project focused on increasing community engagement in accessing, collecting, and communicating air quality data, thus providing tools to better inform communities on air quality issues, and advocating for clean air. The data provided additional spatial and temporal insights on pollution levels beyond the existing NYCCAS program and regulatory methods in New York City. Based on the data collected, to mobilize community members and gain support, a petition was created that demanded action from elected leaders and city agencies to improve air quality in Williamsburg. The petition not only raised awareness of air pollution and demanded immediate action from elected officials, but also connected the issues of air quality and systemic racism as a crisis and provided a way forward through a 5-point platform that was put together by El Puente's Green Light District in consultation with residents, experts, community leaders, and more, through the "Our Air" campaign. The main goals of this campaign included sharing the data collected with the community, engaging academic partners to develop a set of policy and urban design solutions.

## Methodologies

### Study area

The study area is in Southside Williamsburg, Brooklyn neighborhood (NYC), which is prone to a high rate of asthma and cardiorespiratory diseases (Keirbek et al. 2011). 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 (BQE). The Southside community of Williamsburg — Los Sures is a historically low-income, Latino community that is in the process of being gentrified, exacerbating the inequalities, already faced by the community. El Puente, a community-based organization headquartered in Williamsburg, has a mission 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

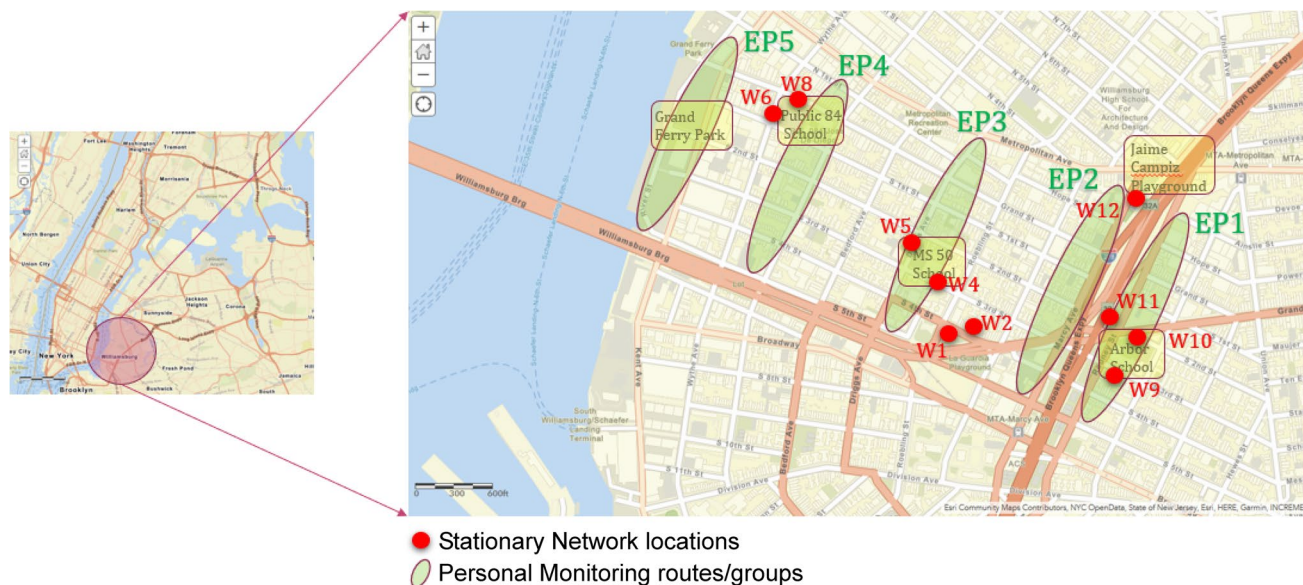
and environmental health (<https://elpuente.us>). Williamsburg is served by several NYC subway routes, and there are three physical lines through the neighborhood, (MTA 2021). The Williamsburg Bridge with a high traffic volume crosses the East River to the Lower East Side of NYC. Several bus routes terminate at the Williamsburg Bridge/Washington Plaza, and many other bus lines also run through the neighborhood (MTA 2020). A concern at various levels of the community regarding health risks, attributed to air pollution due to traffic, 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 as well (Barrett 2010; Fuller et al. 2013; Chin et al. 2014). Many researchers discovered that broader fears of living in a “toxic” and potentially polluted environment resulted in anxiety and apprehension among community residents (Brody et al. 2009; Wing et al. 2008; Brody et al. 2009; Kondo et al. 2014; Svendsen et al. 2014; Barzyk et al. 2016).

El Puente was involved in this study focusing on the assessment of personal exposure to fine particulate matter, in Southside Williamsburg, characterized by high-volume traffic with playgrounds and parks located right next to the Williamsburg Bridge and BQE, as shown in Fig. 1. The main areas of interest were mostly schools, schoolyards, and playgrounds where the students and kids spend most of their outdoor activities, which includes Middle School-50 El Puente community school, William Sheridan playground, Public School 84, Brooklyn Arbor School — schoolyard,

Rodney playground, La Guardia Playground, and Jaime Campiz playground.

### Pilot study goals

El Puente community, volunteers, and students focused on measuring air quality outside of parks to identify potentially safer areas in Southside Williamsburg. Their goal was to understand if there was a measurable difference in air quality between the parks and other areas of the neighborhood and to determine the relative safety of recreational areas in the neighborhood. Measuring air quality through the stationary network and personal monitoring would allow to study air quality across a broader area and compare air quality within the community. This process helped El Puente to identify hotspots that deserve attention, as well as find safer areas, where new recreational areas could be located. Multiples studies can be found in the literature which addresses community concerns around local specific problems, like air pollution (Bleviss 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 community science projects (Silvertown 2009; Bonney et al. 2009; Dickinson and Bonney 2012; Irwin 1995; Greaves and Lishman 1980; Wilsdon et al. 2005; Stilgoe 2009; Irwin 2001; English et al. 2017). The objectives of this community science project were as follows:



**Fig. 1** Study area in Williamsburg, Brooklyn (NYC) with the green, highlighted areas showing the personal monitoring routes, and the stationary network locations identified with the red markers

- Focus on gaining a better understanding of the air quality at the community level, hourly/daily  $PM_{2.5}$  averages
- Engage Williamsburg’s Southside 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 air quality monitors 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 particulate exposure in public spaces around the neighborhood
- Develop policy recommendations based on findings
- Disseminate results to the community through events, forums, and/or an art campaign

### Study design

The development of this pilot study was divided into three different phases, such as planning, research, and action. Each of these phases was broken down into different sub-sections. The planning phase involved formulating the objectives of the study, as well as developing a research strategy to meet those goals, as shown in Fig. 2. The next step was to draft a plan for collecting data, including the identification of key components of the study, determining the instrumentation involved, and providing information on their calibration and validation.

When building research projects for community-based organizations, it is important to provide them with monitors that make accurate measurements and are user-friendly. The use of these technologies potentially offers individuals and community groups the opportunity to gather accurate personal exposure data at a specific location (Nieuwenhuijsen et al. 2014, 2015; Steinle et al. 2013). Many in-person meetings were conducted at the El Puente Headquarters to discuss research priorities with BCCHE and DOHMH. The project also involved walking around the Williamsburg

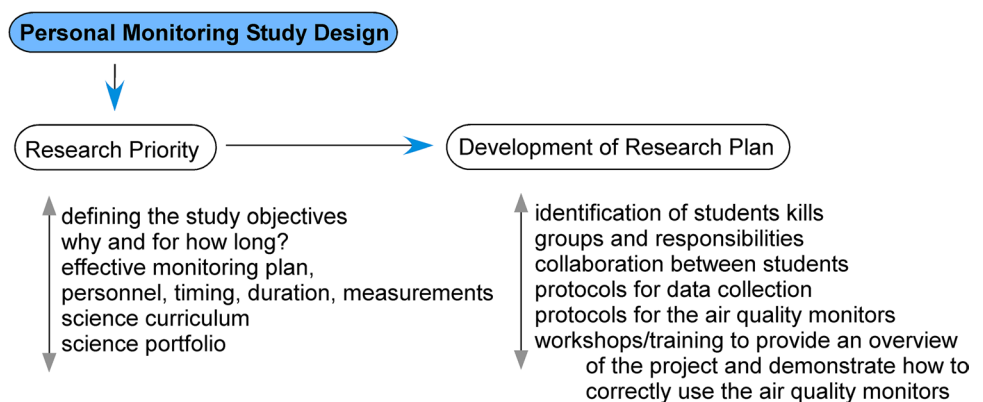
neighborhood, to identify potential locations for the stationary network monitoring system, which was built and deployed by the researchers at BCCHE. A map of suggested stationary monitoring sites was prepared by El Puente and BCCHE, to justify the importance of the location, identifying all sites which were related to the children’s exposure to poor air quality. The last phase of the project involved the dissemination of knowledge gained from the study. Conclusions were generated from the results obtained, and suitable recommendations were provided for future action into a 5-point policy platform.

### El Puente for Peace and Justice High School — science class, curriculum, and portfolio

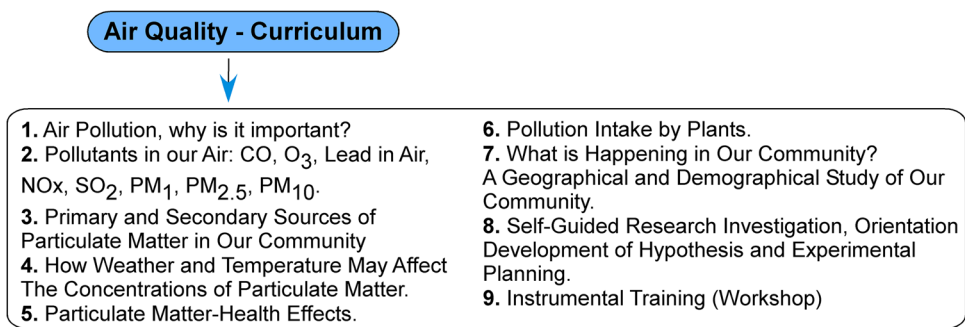
As a part of personal monitoring stage, high school students participated in the data collection, using the AirBeam2 low-cost sensor technology. Key targets for the data collection on  $PM_{2.5}$  exposure were schools and playgrounds near major roadways based on El Puente community concerns. The students attended workshops and training sessions organized by BCCHE and conducted deep research to better understand air pollution in their community as part of their high school curriculum and portfolio, organized by their Science Teacher class and BCCHE. The “*Air Quality Project Curriculum*,” as shown in Fig. 3, was created to support student learning about sources of particulate matter, possible health effects in the community, and to train on the subject. The curriculum consisted of nine guided lesson units in which several presentations and information were given by the academic facilitator. Some of the guided unit lessons and presentations included information about air pollution, primary and secondary sources of fine particulate matter, and how weather conditions might affect the pollutants in the air at a certain location, and pollution’s impact on individual health, the ecosystem, and the community itself.

The curriculum incorporated feedback from each student in the form of a written scientific research portfolio which became the assessment tool. The scientific research

**Fig. 2** Personal monitoring study design



**Fig. 3** Air quality project — curriculum



portfolio, as shown in Fig. 4, fulfilled a graduation requirement. Every student communicated in a written form about their experimental findings.

The portfolio was written and presented to three teachers of the school community called the “graduation committee” who were trained to assess each student’s written portfolio and oral presentation using a New York State assessment rubric, a tool used to interpret and grade students’ work, (<http://www.performanceassessment.org/>).

BCCHE conducted workshops and training at the El Puente and High School as a part of their science class. The workshops consisted of an introduction to the Barry Commoner Center mission and the influence of Barry Commoner into the Citizen Science projects in the 1970s who was considered as the Father of the Modern Environmental Movement (Kuzmiak 1991). Some of the discussed topics included air quality history, as well as discussions about Empedocles, the Pre-Socratic Philosopher, and his theory about the elements earth-air-fire-water, how they relate to each other, and how pollutants can affect these elements. The students were kept engaged throughout the presentations by questions about Air Quality and Air Pollution in London, New Delhi, Bangkok, and New York City. This discussion broadened their perspective on pollution issues all over the world and why air quality is critical,

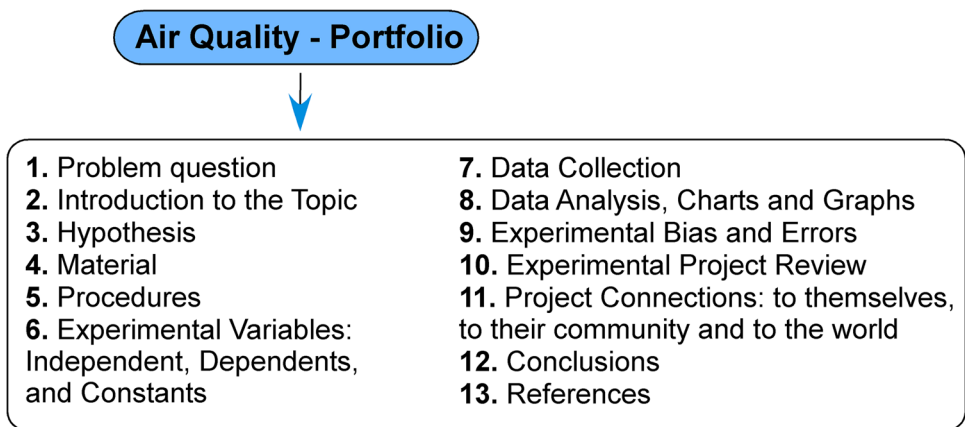
as well as air pollution and long-term effects on the planet as far as global warming is concerned.

Throughout the project, BCCHE organized training to keep everyone 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 during the training included:

- When and for how long the students should go out to collect data?
- How do weather conditions affect the monitoring activities?
- Improving communication with the students by creating a WhatsApp group
- Improving the data collection on the routes assigned for each group
- Reminding project participants to follow the 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

Recommendations were provided to the students as a part of the process to ensure that high-quality data was acquired during the personal monitoring sessions. They had to ensure

**Fig. 4** Scientific research portfolio



that the air monitor (AirBeam2) was housed outside a bag and avoid any movement while the data was collected. A primary reason to avoid holding the monitors in their hands was due to the body impact on the temperature sensor. Students were also asked to maintain a certain distance to the intake of the monitor to ensure consistency in the measurements.

### Data collection and protocols

The air quality monitoring protocols were developed by BCCHE and finalized after several discussions with the El Puente community and the high school students. Students learned how to use the AirBeam2 monitor, which is a wearable air monitor that measures  $PM_1$ ,  $PM_{2.5}$ ,  $PM_{10}$ , temperature, and humidity, and maps, graphs, and crowd source pollution exposures in real time via the AirCasting Android app and AirCasting website. A similar case study using this air monitor has been described in detail in Ilie et al. (2021). With a focus on the most important locations, five different fixed sites (stationary network) with many internal locations were identified for air quality monitors (AQMs) 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 and higher volume traffic. For each site, location coordinates were provided, and lamppost or flag poles were identified that were suitable for deploying a monitor. A comparison between personal monitoring data to the stationary network data (fixed stations) provided a better understanding of breathing levels and how accurate the personal monitoring data was to the stationary network monitors. The AirBeam2s were calibrated by the manufacturer itself and validated in the field against FEM/FRM instruments by BCCHE at DEC Queens College, NYC. Two different teams of 25 students each divided into five groups (EP1 through EP5) were created for the personal monitoring sessions, and the devices were named according to the group itself, to track the data collected from a specific route, systematically. These routes were selected so that  $PM_{2.5}$  concentration maps could be built at a high spatial resolution. Each route had three stops that were near a stationary monitoring network 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 a map, and the groups had to follow the directions and stay on their designated route. In each group, every student had a specific role such as a student in charge of a timer, counting the number of cars passing by each location every 3 min for a total of 15 min; counting the number of trucks passing by each location; recording the temperature; making observations such as odors,

nearby constructions, weather, wind, and other factors that may affect their results; checking the AirBeam2 monitor and the mobile phone; and lastly, recording all information provided by the previous members of the group. At the end of each session, students determined the average levels of  $PM_{2.5}$  for each location, average count of passing vehicles, temperature, and humidity and visualized data in the form of charts and graphs. Students could interact within their study groups as well as family members and community, to analyze data and develop a better understanding. Throughout the project, many discussions between BCCHE and the science teacher were held on the science class project for an improved curriculum focused on air quality.

### Data analysis

Data processing, analysis, and data visualization were conducted by BCCHE, as well as by the high school students during their science class curriculum. Air pollution patterns in the Williamsburg neighborhood were determined through fixed monitoring stations via ten air quality monitors (AQM) which were built, deployed, and maintained by BCCHE. Air pollution patterns were determined also through the personal monitoring sessions where the data was collected by the El Puente community, from spring 2019 through fall 2019 academic sessions. Pollution data with timestamps and GPS coordinates were collected, and sampling routes (EP1–EP5) were specially designed to cover the areas of “hot spots,” such as major roads and highways. The personal monitoring data collected every minute was interpreted as the EPA pilot study on minute readings for the particulate matter measurements. Specifically, the “Low, 0–29  $\mu\text{g}/\text{m}^3$ ” and “Medium, 30–69  $\mu\text{g}/\text{m}^3$ ” sensor messages corresponded to sensor readings that stay in the same range for at least an hour or more. Anything less could have been caused when an emissions source was temporarily nearby (Keating et al. 2016). The study emphasized exploratory data analysis, which included a structured process to handle raw quantitative information, and cleaning the dataset. Other steps included handling missing information, removing outliers, and generating visualizations to communicate results. Data from the 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, and data comparison between all stationary network units and personal monitoring groups, to identify which location(s) presented the highest  $PM_{2.5}$  concentrations. This data analysis plan developed by BCCHE provided insights into the data collected throughout the study. Proper data interpretation and analysis helped in making decisions and focusing on future strategies.

## Results and discussion

### Summary of PM<sub>2.5</sub> monitoring data in Williamsburg

The first session of personal monitoring data acquisition started on March 11, 2019 and was held bi-weekly through November 2019. A summary of results from each group is shown in Fig. 5, which includes the dates when the personal monitoring sessions were held along with the hourly average PM<sub>2.5</sub> concentrations. The results are categorized for each month separately to get a better understanding of monthly variation, and concentrations higher than 10 µg/m<sup>3</sup> are highlighted with a darker shade of green. The duration of each session was at least an hour long. All the five groups with five different routes monitored the area at the same time, so a wider range of data could be acquired in the Williamsburg neighborhood, and a group-wise comparison could be made. The

PM<sub>2.5</sub> concentration range was between 0.03 and 27.35 µg/m<sup>3</sup>, categorized as “low” according to an EPA pilot study (Keating et al. 2016). The PM<sub>2.5</sub> concentrations were almost the same at all locations with the only discrepancy observed on April 19th at EP5 with a value of 27.35 µg/m<sup>3</sup> due to construction on the road. Proximity to an emission source is an important consideration because high short-term spikes in local PM<sub>2.5</sub> concentrations can occur (Keating et al. 2016). Personal exposure studies are critical alongside microenvironment and ambient studies to get a better understanding of the health risks posed by fine particulate matter in the urban transport microenvironment and for making informed decisions to manage and reduce the health risks (Kaur et al. 2007). Based on the literature, it has been shown that pavement position and the side of the road walked upon also lead to significant differences in the level of pedestrian exposure to most pollutants (Kaur et al. 2005).

**Fig. 5** Summary of personal monitoring PM<sub>2.5</sub> hourly data

Datetime	EP1 Avg. PM <sub>2.5</sub>	EP2 Avg. PM <sub>2.5</sub>	EP3 Avg. PM <sub>2.5</sub>	EP4 Avg. PM <sub>2.5</sub>	EP5 Avg. PM <sub>2.5</sub>
3/11/2019		8.30	7.51	7.21	
3/20/2019				6.48	5.08
3/25/2019	12.26	10.83	10.32	11.45	
3/27/2019	3.84	3.26		2.78	
3/29/2019				4.63	3.35
4/1/2019	1.83	1.93	1.50	0.83	
4/3/2019	5.78	5.76	5.07		5.59
4/4/2019			5.15	5.64	
4/8/2019			7.98	7.37	8.67
4/10/2019	0.54	0.30		0.25	0.20
4/11/2019	3.19			4.66	
4/15/2019	0.20		0.03		
4/17/2019					
4/19/2019				8.94	27.35
4/25/2019			10.63	10.36	
4/29/2019			2.70		1.88
5/6/2019	3.88	6.02		2.56	
5/15/2019	2.37	2.57	4.58	10.55	
5/20/2019	17.20	17.40	13.30	9.15	
5/22/2019	2.63	2.33	1.82		
5/29/2019	12.75	13.37	10.69	7.33	
6/3/2019	0.03	2.62	4.87	4.62	
7/8/2019				7.24	
7/9/2019			9.04	9.04	
7/11/2019			9.37		
7/16/2019			9.16	10.39	9.96
8/1/2019			4.06	4.18	4.70
9/18/2019	3.60		2.65	3.14	
9/20/2019	5.28		3.74	4.47	
9/25/2019	7.85		7.55		
9/27/2019	9.39		9.39	8.90	
10/4/2019	0.60		0.07	0.68	
10/11/2019	2.49		0.89	1.92	
10/17/2019	0.82		0.27	0.10	
10/18/2019	1.22	1.22	0.33	4.71	
10/23/2019	2.39	2.68		1.11	
10/24/2019	2.53	2.78	1.47		
10/30/2019	10.73	10.69		7.86	

## Traffic count

Data from personal monitoring groups (EP) and Stationary Network (SN) at seven different locations were compared to understand the impact of vehicles like moving cars, idling cars, and trucks, on the  $PM_{2.5}$  concentration levels, as shown in Table 1. A higher number of moving cars and trucks were observed at W2 — El Puente Headquarters close to Williamsburg Bridge ramp and W12 — Jaime Campiz Playground, close to Brooklyn-Queens Expressway (BQE). This leads to more than  $3 \mu\text{g}/\text{m}^3$   $PM_{2.5}$  concentration readings observed on the personal monitoring data. It is interesting to note that the highest concentration for stationary networks occurs at the W6 — Public 84 School location where traffic does not seem to have much influence. Other factors like weather conditions, long-range transportation of  $PM_{2.5}$ , close construction, could be attributed to this observation.

Three different locations W9, W10, and W12 show more than  $4 \mu\text{g}/\text{m}^3$   $PM_{2.5}$  concentration measured by personal monitoring as well as corresponding higher levels on stationary network data. The data indicate a clear correlation between traffic and higher concentration levels for certain locations, although certain other factors contributed to the increased  $PM_{2.5}$  concentration levels. Students were surprised to find out that they could potentially be exposed to high levels of air pollution when vehicles were idling as well. Understanding how highly circulated streets impact the community on their daily journey trips is a true challenge that can give a clear insight on how the eco-neighborhood needs to be reconfigured to protect its inhabitants (Mihăiță et al. 2019). Walking in heavily trafficked environments appears to lead to an order of magnitude difference risk of exposure exacerbated by traffic, weather conditions, hotspots, and the general ambient conditions (Greaves et al. 2008).

## Personal monitoring sessions compared to the stationary network

To understand the quality of data acquired from personal monitoring sessions, a comparison was made against the stationary network, as shown in Fig. 6.

These monitoring approaches provided more information on air pollution that can be added at the neighborhood data

level and helped explain variabilities in exposure, as several studies (Sarnat et al. 2012; Peters et al. 2014) showed that monitoring can give additional insights into spatial variability and exposure assessment, at a resolution of street level and even within-street level.

The  $PM_{2.5}$  concentrations of the personal monitoring were observed to be similar to the stationary network. The highest concentration was found to be  $9.16 \mu\text{g}/\text{m}^3$  occurring close to the Williamsburg bridge and the ramp into the BQE, due to the high volume of traffic. The data was found to be consistent with NYCCAS LUR annual data report (<https://nyccas.cityofnewyork.us/nyccas2021v9/report/2>; Ilie and Eisl 2019).

## Personal monitoring map, spring, and fall sessions

During the monitoring sessions, students were able to investigate the  $PM_{2.5}$  data in real time onto the AirCasting app. Using Tableau, a data visualization software, all routes were put together to show the average  $PM_{2.5}$  based on latitude and longitude. The data was organized and averaged for spring and fall sessions, as shown in Figs. 7 and 8, respectively. Lower  $PM_{2.5}$  concentrations were represented by purple, and higher concentrations were shown by green and red. These maps helped the community to identify where the highest or lowest levels of air pollution were recorded along their route.

Spring sessions included the data gathered in March, April, and May 2019 and provided an opportunity to gather a good amount of data on all routes created for the personal monitoring groups, which further made it possible to create a richer picture of the air quality in the neighborhood, as shown in Fig. 7. Average  $PM_{2.5}$  concentrations were calculated for the fall session, occurring during September and October 2019 and are shown in Fig. 8. Based on the EPA pilot study, the “high” values were considered above  $70 \mu\text{g}/\text{m}^3$ .

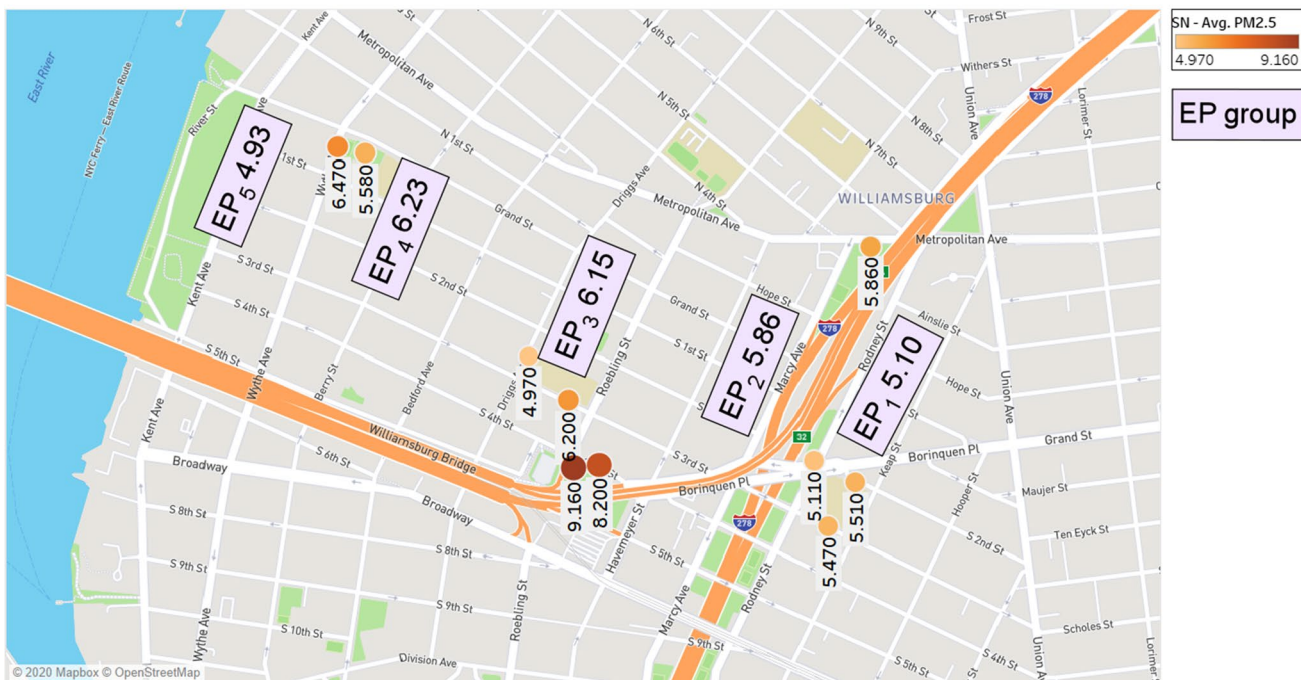
There were two locations in Williamsburg with high values of  $PM_{2.5}$  concentration. The first instance occurred at the W12 location or Jaime Campiz Playground which is along the exit from the BQE and attracts a lot of truck traffic entering Williamsburg. The second location occurred at the W6 location or Public 84 Schoolyard which is a busy road connecting the north and south parts of the Williamsburg neighborhood. On the other routes, the  $PM_{2.5}$  concentrations

**Table 1** Comparison of personal monitoring data (EP) with a stationary network (W2) along with traffic count

	EP_W2	EP_W4	EP_W5	EP_W6	EP_W9	EP_W10	EP_W12
EP	3.31	2.83	2.94	2.21	4.48	5.02	4.06
SN	2.88	1.95	2.21	4.98	2.95	3.13	2.27
Cars	3201.00	924	713	753	355	881	3717
Idling	665.00	105	62	76	20	127	883
Trucks	430.60	27	88	23	26	1	709

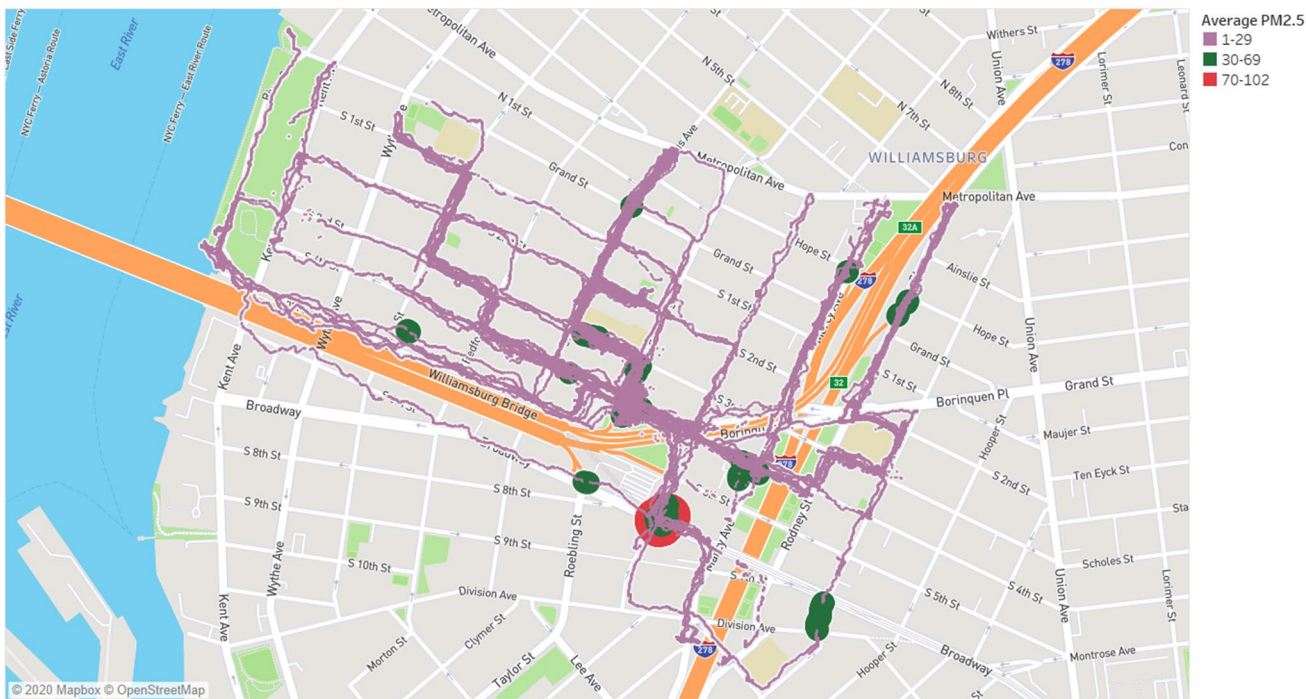


Stationary Network & Personal Monitoring, Avg. PM<sub>2.5</sub>



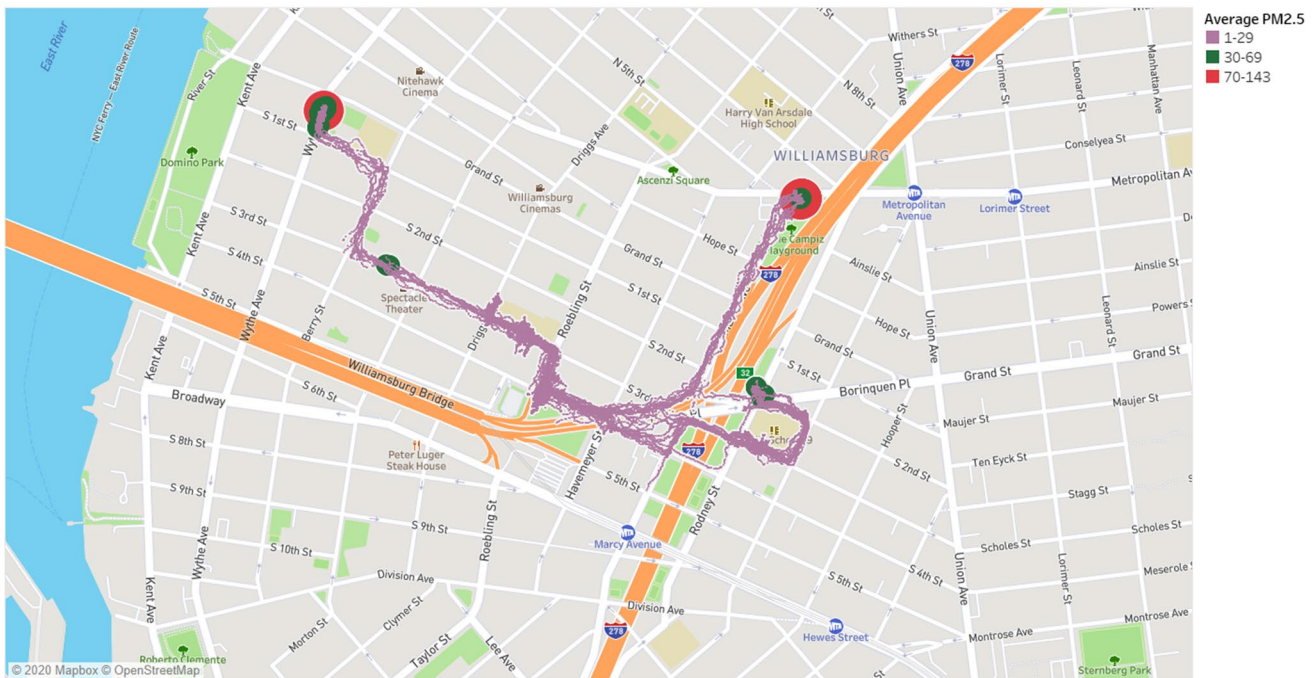
**Fig. 6** Comparison of average PM<sub>2.5</sub> concentration between personal monitoring data (EP) and stationary network (SN) based on specific locations in Williamsburg

Personal Monitoring - Spring 2019



**Fig. 7** Map depicting routes taken during personal monitoring sessions along with average PM<sub>2.5</sub> concentrations taken from March to May 2019

## Personal Monitoring - Fall 2019



**Fig. 8** Map depicting routes taken during personal monitoring sessions along with average PM<sub>2.5</sub> concentrations taken from September to November 2019 (fall season)

ranged between 1 and 29  $\mu\text{g}/\text{m}^3$ . Rivas et al. (2018) have shown the average school-hours daily concentrations in an outdoor school environment which ranged between 10 and 111  $\mu\text{g}/\text{m}^3$  for PM<sub>2.5</sub>. One of the strengths of participatory approaches is that the research is an empowering process in which information is gathered to promote action (Israel et al. 1998), such as the case studies presented by Minkler et al. (2008), where communities that were subject to the effects of various polluted conditions generated environmental information and used it to improve environmental health policies. The most important aspects of the air pollution monitoring design were that the El Puente community, academic institutions, and high school students worked on data acquisition, data analysis, identifying air pollution hot-spots, and finding solutions for better air quality which was presented on the 5-point policy platform.

### A 5-point policy platform of solutions

This pilot study was incorporated into the “Our Air/Nuestro Aire” — El Puente grassroots campaign. The main goals of this campaign included sharing the data collected with the community, engaging academic partners to develop a set of policy and urban design solutions. Community members were engaged through events, forums, and workshops; multiple plays were presented and numerous visual arts

pieces to promote the campaign. Leaders and partners were engaged to build support for the “Our Air/Nuestro Aire” project. Public officials and community leaders who represent South Williamsburg/Los Sures and Bushwick communities were called to come together and take action to reduce the air pollution in the parks and open spaces so that the community will not continue to suffer from the most dangerous effects of pandemics like COVID-19 which has now exposed the deadly results of the lack of prompt action, resources, and policies ensuring clean air for families and neighbors. COVID-19 virus attacking respiratory systems has been a wake-up call for the Williamsburg community. The recognition of inequity needs to transform into policy and action, and our air quality monitoring program was used to educate the public about environmental conditions, influence policy design and decision-making process to ensure compliance with environmental regulations, and assess the effects of anthropogenic influences (Mitchell 2002). 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). The low-cost air pollution sensors created 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). Considering the ongoing public health issues,

a 5-point Action Platform was implemented which is community-led, centered on self-determination, and follows a holistic approach to preparedness and resilience, as outlined below:

- *The right to breathe clean air*: mitigate vehicular pollution, strategic circulation and access, and community-led development of Brooklyn Queens Expressway (BQE)
- *Health as a human right*: strengthens the public health-care system, develops and launches a culturally responsive bilingual Community Health Platform, invests in and reinforces community-led emergency healthcare programs
- *A community-led resiliency & public health emergency taskforce*: self-determination centered and holistic approach, including building capacity and tools to exchange resources, facilitate recovery, relief, and preparedness efforts, during and in the aftermath of public health emergencies and disasters; commit to sustainable and long-term community-controlled mechanisms by conducting feasibility studies and investing in initiatives like community land trusts and credit unions
- *Greening for a safe future*: funding to build and maintain green infrastructure in open and public spaces to mitigate air pollution, fund tree planting programs in partnership with schools and local, community organizations, reduce asphalt and concrete, and increase permeable surfaces in existing open spaces in parks and plazas like LaGuardia Playground and Continental Army Plaza. These measures would not only improve air quality but also reduce extreme heat by providing shade and reducing surface-level temperatures and reducing the incidence of flooding by increasing permeable surfaces.
- *Cultural organizing, community education, and mobilization*: awareness of the impact of air pollution on health; tools and practices that promote health, living, and nutrition; provide free internet for every household and safe, common spaces at local community organizations and cultural institutions for Wi-Fi

The main part of the “Our Air/Nuestro Aire” grassroots campaign has been to educate and raise awareness on the health crisis and environmental issues in the Williamsburg community through a multimedia campaign. Social media and digital organizing techniques were used in addition to educating and mobilizing our community through a series of focus group sessions, training, workshops, and presentations at school parent-teacher association (PTA) meetings, senior citizen centers, classes at local schools, parks, markets, libraries, and at El Puente program sites. The events included a wide range of engagement strategies, such as theatre performance, an overview of the historical environmental and

health issues in the community, presentations of the air monitoring process and preliminary findings, and breakout groups to discuss and provide recommendations. Each of these events also included the circulation of a petition (paper and digital <https://elpuente.us/our-air-nuestro-aire>) to call on decision-makers for immediate action and raise awareness among community members who frequent the highly polluted open spaces in the neighborhood. We estimate that we have reached roughly 5000 people across all our events. Part of the advisory committee meetings focused on mobilizing the community residents and developing support and consensus among diverse stakeholders by building cross-sector coalitions. Representatives of multiple city agencies like the Parks Department, the Department of Health, and the Department of Transportation were engaged along with a variety of experts and stakeholders. Several meetings were planned to discuss on progress of the project, findings, and next steps in terms of data analysis, community mobilizing/organizing, and the policy platform implementation. Technical and academic experts and community members were engaged in these advisory committee meetings.

## Conclusion

This pilot study conducted with a focus on air quality monitoring at the neighborhood level leads to multiple benefits to the society by increasing awareness of air pollution in their immediate vicinity as well as providing recommendations for improvement of air quality. To gain insights related to fine particulate matter concentrations, the study provided increased knowledge of air quality in Southside Williamsburg. Areas of concern were identified, through the stationary network and personal monitoring sessions. A comprehensive data analysis with fine-scale monitoring helped create a rich dataset useful for addressing public health uncertainties. As a part of community science, the act of monitoring pollution themselves could facilitate learning and increase their awareness of environmental issues by changing the public attitude towards science and the environment. Through this work, residents can have access to informational tools that can help them understand the distribution of health outcomes because of air pollution, identify areas with the highest PM<sub>2.5</sub> concentration, and avoid harmful exposures to their bodies, modifying their travel plans accordingly. Measuring air quality through personal monitoring allowed El Puente community-based organization and El Puente Academy high school students to analyze air quality across a broader area and compare air quality within the neighborhood, helping them to identify other unsafe areas that deserve attention. Planning school travel routes helped in reducing

exposure for children daily, so that personal monitoring exposure data can give rise to more generalized exposure patterns which can eventually be used for optimizing personal choices. 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 new low-cost technology, AirBeam2 air monitors, to collect and summarize environmental data. Consistent results were obtained from this pilot study when compared to the already existing dataset in the Williamsburg area collected by NYC-CAS (seasonal and annual patterns); this provided reliable exposure information. It was beneficial for the El Puente community to understand the hourly/diurnal patterns from the personal monitoring sessions and stationary network as compared to the seasonal/annual data from NYCCAS. Based on the stationary network data, the La Guardia playground which is located right next to the Williamsburg Bridge and BQE ramp presented higher PM<sub>2.5</sub> levels than other locations, which still raised some concerns, since most of the families spend their time with the kids. Based on the data collected, to mobilize community members and gain support, a petition was created that demanded action from elected leaders and city agencies to improve air quality in Williamsburg. The petition not only raised awareness of air pollution and demanded immediate action from elected officials, but also connected the issues of air quality and systemic racism as a crisis and provided a way forward through a 5-point platform that was put together by El Puente's Green Light District in consultation with residents, experts, community leaders, and more, through the "Our Air" campaign. While the issue of air quality has plagued the Williamsburg neighborhood for decades, the emergence of COVID-19 in the middle of this project served as a shocking reminder of the health disparities that have existed in the communities for decades, and the deadly effects of these disparities. The fact that in a city Latinx and African American/Black families have death rates twice as high as White families provides further evidence that neighborhoods with existing air quality and respiratory issues are suffering and will continue to suffer unless this issue is addressed on an urgent basis by our elected, private stakeholders and community leaders.

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