From Asthma to AirBeat: Community-Driven Monitoring of Fine Particles and Black Carbon in Roxbury, Massachusetts

Penn Loh, Jodi Sugerman-Brozan, Standrick Wiggins, David Noiles, and Cecelia Archibald

Alternatives for Community & Environment, Inc., Roxbury, Massachusetts, USA

Asthma is an ongoing environmental justice concern in Roxbury, an urban neighborhood of Boston, Massachusetts. Residents, especially local youth, were the first to investigate the potential links between high asthma rates and air pollution, particularly from diesel buses and trucks. A youth-led march for clean air and community air monitoring projects drew governmental and media attention to these problems. In 1998, a collaboration of environmental justice, government, and research groups came together to develop a real-time air pollution monitoring system known as AirBeat. This community-based participatory research project was designed to answer community questions about whether there are pollution "hot spots" in Roxbury and the degree to which diesel emissions are contributing to health problems. AirBeat measures and reports levels of $PM_{2.5}$ (particulate matter with a mass median aerodynamic diameter ≤2.5 µm), ozone, and black carbon on an hourly basis. These data are accessible via a website, telephone hotline, and a flag warning system. AirBeat is successful because community residents and organizations participate as equal partners with an equitable share of funding. The project also promotes a community sense of ownership and pride. Dozens of youth have developed leadership and scientific skills. The media have extensively covered the project as a community victory. The data support the claim that Dudley Square in Roxbury is a hot spot for air pollution. This information is now being used to advocate for alternative fuel transit buses and other clean air measures. Finally, this project has strengthened community partnerships with research and governmental institutions.
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Background

In this article we describe the AirBeat project and analyze this community-based research effort from the perspective of the community-based participants. AirBeat is a real-time air monitoring system that measures levels of $PM_{2.5}$ (particulate matter with a mass median aerodynamic diameter ≤2.5 µm), black carbon, and ozone and reports these through a website, telephone hotline, and flag warning system. The AirBeat partners include Alternatives for Community & Environment (ACE), Harvard School of Public Health (HSPH), Massachusetts Department of Environmental Protection (DEP), Northeast States for Coordinated Air Use Management (NESCAUM), and Suffolk County Conservation District (SCCD).

Asthma and Environmental Justice

The AirBeat project was initiated to address concerns in Roxbury, Massachusetts, about high asthma rates and other respiratory illnesses related to air pollution. Roxbury is a predominantly low-income community of color located in the heart of Boston. Like many inner-city communities, there is wide recognition among residents that asthma is affecting families in epidemic proportions. Asthma hospitalization rates in 1997 in this neighborhood of 60,000 people were the highest in the state—almost 5 times the state average (*1*). In March 2001, two young people 12 and 16 years of age from the community died in the same week as a result of acute asthma attacks (*2*) (Figure 1).

Though asthma has been a problem for many years, it is only in the last 5 years that asthma has been framed as a problem of environmental health and environmental justice. Our organization, ACE, has been part of a growing grassroots environmental justice movement in Boston that has expanded the asthma issue from a medical problem for the individual to an environmental problem for the whole community. A number of environmental justice issues have been driven by concerns over asthma, including excessive traffic and automobile emissions, particularly from diesel vehicles, substandard housing, poor air quality in schools, and limited access to quality health care. Based in Roxbury, ACE has been building the power of lower income communities and communities of color in Greater Boston to eradicate environmental racism and to achieve environmental justice since 1993.

Youth, especially, have been key environmental justice leaders in Roxbury. Through ACE's Roxbury Environmental Empowerment Project (REEP), youth identify and solve environmental and public health problems in their communities through an in-school curriculum and after-school internship program. It was REEP youth, after learning about high asthma rates, who began to ask why Roxbury and surrounding neighborhoods were suffering so much from this disease.

In 1996, REEP youth at several schools began mapping various sources of air pollution in Roxbury, including nail and hair salons, solid waste facilities, and bus and truck depots. One of the major findings was that there were more than 15 bus and truck depots garaging more than 1,150 diesel buses and trucks within 1.5 miles of Dudley Square, a major commercial and residential hub in Roxbury (*3*). Though they also found a high concentration of other polluting facilities, these students chose to focus on diesel buses and trucks for several reasons. First, diesel vehicles are among the dirtiest polluters on the road and are especially high emitters of fine PM, which can penetrate deeply into the lungs and trigger asthma attacks. Another reason was that diesel transit buses are operated by a government agency, which can be held accountable to the community.

This work culminated in an "Anti-Idling Day" in October 1997. Working with ACE lawyers, the youth learned that there was a Massachusetts law limiting engine idling to only 5 min. More than 75 students from Nathan Hale Elementary, Greater Egleston Community High School (GECHS), and Community Academy (a high school)

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Address correspondence to P. Loh, Alternatives for Community & Environment, Inc., 2343 Washington St., 2nd Fl., Roxbury, MA 02119 USA. Telephone: (617) 442-3343. Fax: (617) 442-2425. E-mail: penn@ace-ej.org

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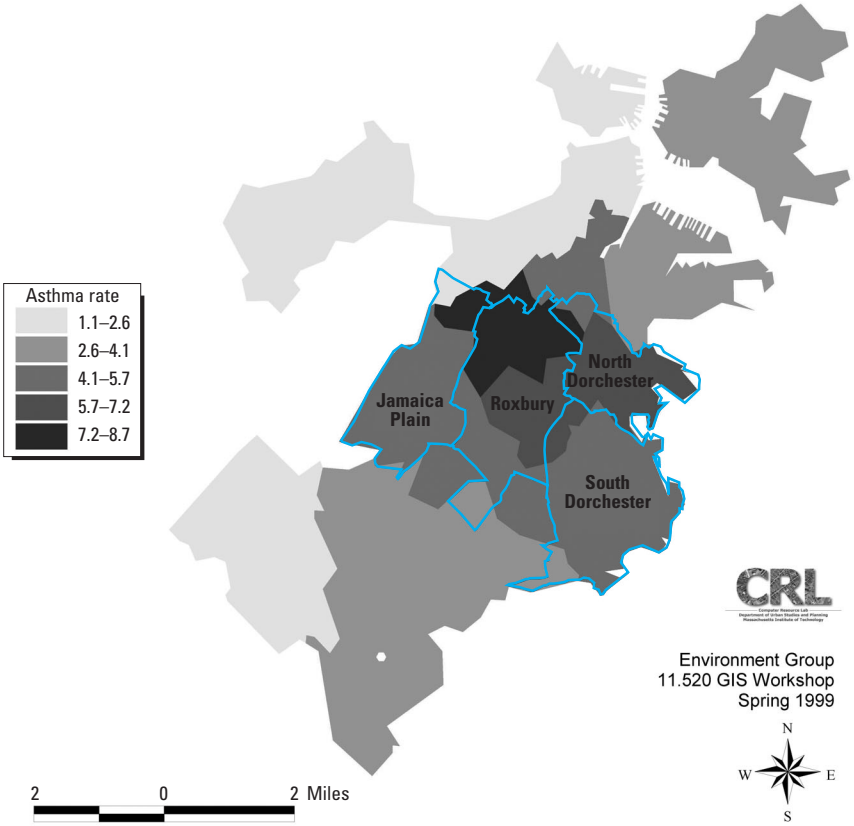

Figure 1. Asthma hospitalization rates across Boston's neighborhoods, 1994–1996. Rates are average annual rates per 1,000 people. Data represent the number of hospital discharges with the diagnosis of asthma. Data from Boston Public Health Commission (*11*).

decided to educate their community about the law, which was not enforced. They marched in the street, handing out pollution "tickets" to educate drivers about the law and about how idling affects health. This action drew significant newspaper and television coverage and the support of top-level environmental officials. Anti-Idling Day also launched a new effort, the Clean Buses for Boston coalition, to advocate for the replacement of the public transit system's diesel bus fleet with cleaner, alternative-fueled buses.

Particulate Air Monitoring in Roxbury

At the same time that these youth brought attention to the link between asthma and air pollution, other community groups were also working with ACE to address these issues. In spring 1997, ACE worked with several community groups in Greater Boston to conduct pilot fine-particulate monitoring projects. With technical support and equipment from HSPH and NESCAUM, ACE trained residents to collect particulate samples. Residents of the Egleston Square Neighborhood Association (ESNA) conducted an all-day monitoring project collecting simultaneous samples of PM_{10} (particulate matter with a mass median aerodynamic diameter ≤10 µm) and $PM_{2.5}$ at a busy intersection and in a resident's backyard off the main street. As expected, the data showed that the levels of PM at the busy intersection were higher than those in the backyard. But the residents gained much more than just a day of data. They learned how particulate pollution is monitored and gained confidence in developing their own hypothesis that air pollution "hot spots" might be contributing to high rates of asthma.

The youth Anti-Idling Day and community monitoring projects captured the attention of state environmental officials in several ways. First, demands were made directly to state officials to enforce the idling law. Second, newspaper and television coverage elevated the issue to a community priority. Third, community groups sought to collaborate with environmental officials at the city, state, and federal levels as well as with academic and research institutions that lent scientific credibility. Thus, in late 1997, the DEP approached ACE, ESNA, and the Committee for Boston Public Housing to ask for our assistance in siting a $PM_{2.5}$ monitor in Roxbury as part of a new network to determine the state's compliance with the $PM_{2.5}$ standards of the U.S. Environmental Protection Agency (U.S. EPA) set earlier that year. Before then, there were no official state air monitors in Roxbury. After examining several sites, the DEP chose to site its monitor in Dudley Square, one block from the busiest bus station in the public transit system. This decision to site a monitoring station in Roxbury, along with the relationships developed in the process, led to the formation of the AirBeat project team.

AirBeat: More than a Monitor

AirBeat Team

The AirBeat team was convened in early 1998 and includes ACE, DEP, HSPH, NESCAUM, and SCCD. This collaboration applied for and successfully received funding for a 2-year project from the U.S. EPA Environmental Monitoring for Public Access and Community Tracking (EMPACT) program. The project was titled "Time-Relevant Communication of Ozone and Particulate Air Pollution Data: A Pilot Project to Raise Public Awareness and Promote Exposure Reduction" (*4*).

As described above, all the partners except for SCCD had already developed successful working relationships. SCCD had been working with ACE on a community mapping project but had not previously worked with the other partners. SCCD comprises five elected residents of Suffolk County serving on a voluntary basis and has an office in Roxbury.

SCCD was the lead agency in the application to the U.S. EPA and assumed responsibility for project management. ACE was the lead partner in community education and outreach. HSPH and DEP were responsible for setting up and operating the monitors. NESCAUM developed the data management center and the website for the project.

The development of the proposal itself took more than 6 months, with the partners meeting at least monthly, often at ACE's office in Roxbury. During this proposal-writing period, further trust was developed, and ground rules were established for how to work together. The community-based partners ACE and SCCD demanded that the project provide equitable resources, especially for the public education and communication components of the project, to ensure that the data would be accessible by residents. A website as the only means of data access was not acceptable, given the lower rates of computer ownership in the community. SCCD

in particular emphasized the need for the project to build capacity in the community, including ownership of the monitors and the training and hiring of local residents and youth where possible. ACE pushed the project to focus on research questions that were already established by youth and community groups. These questions included the following:

- To what extent are diesel vehicle emissions contributing to high asthma rates and other health problems?
- Does Dudley Square have elevated levels of air pollution compared with other areas of Boston?

Objectives

The objectives of the project, as stated in the final proposal, were to

- deploy a reliable configuration of real-time monitors for PM, ozone, and black carbon (a marker of diesel emissions);
- develop a data management center to aggregate, standardize, and archive the data from the monitors and to provide quality assurance;
- develop multiple communication venues to ensure widespread access to these data;
- promote use of these data by community residents to improve daily decisions to reduce harmful effects of air pollutants;
- strengthen partnerships among community institutions receptive to learning about and using air quality data, such as schools, community health centers, and housing developments; and
- bolster the community's effectiveness in shaping local policies for transportation, development, and construction projects affecting air pollution.

Results

Monitoring and Data Management System

Monitors that continuously measure ozone, $PM_{2.5}$, and black carbon were successfully installed and are now operating on the monitoring site (*5*). In addition, there is a meteorologic station as well as other DEP monitors for carbon monoxide, sulfur dioxide, nitrogen oxides, $PM_{2.5}$, and particulate speciation. The data from the monitors are downloaded via modem to a computer at NESCAUM's office in downtown Boston, subjected to quality assurance, and stored for use by the data communication venues. The AirBeat monitors are now maintained as part of the DEP's regular operations at the site. DEP technician Damon Chaplin is a local resident of the community who regularly gives tours of the site to curious passersby and to students from area schools.

Communication Venues

Website. Three systems for disseminating the data from the AirBeat monitors were developed, while a fourth is still being pursued. The first is the website (*6*).

This website reports data on a daily, weekly, and monthly basis. It also is linked to a live "hazecam" photo of downtown Boston. Except for black carbon, the data are reported using the U.S. EPA Air Quality Index (AQI) rather than in absolute concentrations (Figure 2). The site also contains related information on regional ozone, adverse health effects, pollution sources, actions to reduce exposure, and links to other websites. In spring 2001, the site received an average of 42 hits per day.

Telephone. The second system is a telephone hotline (617) 427-9500. Callers first hear the current AQI for ozone and $PM_{2.5}$. Using the telephone keypad, callers can obtain the specific index level as well as the worst levels for today and yesterday. The voice of the hotline is that of Cecelia Archibald, an 18-year-old ACE youth intern.

Third, ACE's youth interns and students from GECHS designed and established their own Air Quality Flag Warning System. Flags matching the colors of the U.S. EPA AQI (*7*) are hoisted in Dudley Square and Egleston Square each morning. The color of the flag indicates the AQI for $PM_{2.5}$ or ozone, whichever is higher. Red corresponds to an AQI of 100 or above, meaning unhealthy for sensitive groups or unhealthy for all. A yellow flag corresponds to an AQI between 50 and 100, meaning moderate. A green flag indicates an AQI from 0 to 50 and means that the air quality is healthy or good. More than 25,000 people pass through Dudley Square bus station each day, which is across the street from the air quality flag. In Egleston Square the flag is visible from a major school bus stop and school dropoff and loading area.

The fourth venue for data dissemination is through local radio and television weather reports. Although none of the stations have yet to integrate AirBeat data into their weather reports, we have approached the major stations and have initial interest from the local cable news channel. We chose to develop this venue based on an initial youth survey in 1999 of about 80 residents in Dudley Square. The survey found a high level of concern about air pollution and asthma but only limited understanding about the sources of air pollution (*8*). Although 50% of respondents had family members with asthma, only 10% were aware that the state had installed an air monitor in the area, and only 33% knew what PM was. The survey also found that almost three quarters would like to learn about air quality data from the television.

Community Education

One of the most important results was raising the level of knowledge within the community of air pollution levels and health impacts. One of the premises of AirBeat was that data are only useful to the community if they are widely accessible and residents have the knowledge to interpret them. Through AirBeat, educational programs were designed for various audiences.

Youth education and training. Youth are often the most impassioned and articulate spokespeople for community issues. On the basis of REEP's past experience, youth are

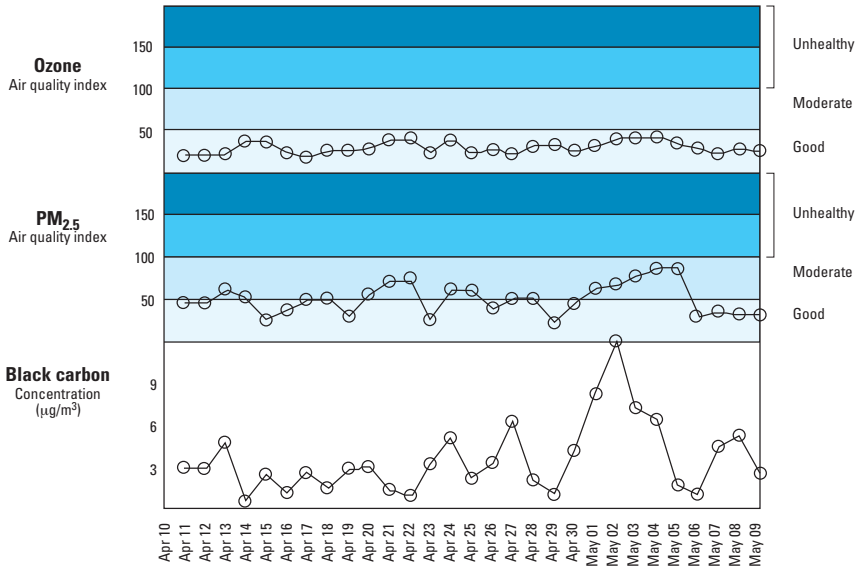

Figure 2. Graph of AirBeat data from April 10 through May 9, 2001 (*6*).

highly effective at educating their community on asthma and air quality issues. For this project, REEP integrated the AirBeat system into its curriculum on air pollution and health. The curriculum includes workshops on how air pollution is produced, the adverse health effects of different types of pollution, and a focus on particulates and asthma. This curriculum was delivered to more than 300 students from five area schools. These students also toured the monitoring site, guided by DEP staff person Damon Chaplin.

By intensively training a group of youth, we expanded the ability of the project team to do more outreach. As detailed below, youth played leading roles in reaching out to all of the other audiences. But more important, the youth themselves became active members of the project team and developed entirely new communication venues that were not part of the original proposal. GECHS students conceived and developed the flag warning system. The REEP interns added the AirBeat monitoring site to their environmental justice tours of Roxbury. This site is a powerful example of what the community can achieve and is in stark contrast to the other sites on the tour, which include a major diesel bus garage, a former electroplating facility, and a run-down public park.

Community leaders and general public. The project also promoted broad awareness of AirBeat through two public events that were well covered by the local media. The first was the public launch of AirBeat in November 1999. The second event was the unveiling of the flag system in Dudley Square in June 2000. This second event was held across from Dudley bus station, which allowed more passersby to learn about the monitoring system. This was an intentional strategy we employed to build more community sense of ownership over the system. More than 150 people attended these events. The numerous government agency and elected officials who attended these events helped further the public awareness of the project.

Local resident outreach. Youth have also been the main conveyors of information on AirBeat for other Roxbury residents. Workshops, flyers, and surveys have all been used to inform and educate the local community. The youth survey in 1999 was conducted not only to ascertain what people knew about air quality but it was also an opportunity to inform people that an air monitoring station had been sited in the community (*8*). The interns also developed a single-page flyer about AirBeat, advertising its existence, purpose, and ways to access the data.

AirBeat was also integrated into more than 50 workshops conducted in the community by ACE staff and youth. These workshops were conducted with tenants at local housing developments in the Dudley Square area, students in area schools, community health center programs, and at community conferences.

Disputes over message. In the process of communicating AirBeat's purposes and its data to the public, the project team experienced tensions around communicating the links between asthma and outdoor air pollution. Some of the research partners felt that the community partners and the media overstated the degree to which diesel pollution contributed to or caused asthma. They felt the public was being misled into believing that diesel pollution was the main source of the asthma problem. Although ACE was always careful to state that outdoor air pollution and diesel emissions trigger asthma attacks and that there is no scientific certainty about the causes of asthma, the media message often did not reflect that distinction. As a result, many residents that we talked to did not make a distinction between cause and exacerbation of asthma.

This tension, however, helped community and research partners learn valuable lessons. As a community organization accountable to residents, we learned that we have to be responsible in our communication of risk and that we had to include other major factors such as smoking and indoor air pollution in the asthma problem in our communications. The research partners learned more about how residents actually perceive the problem and that these perceptions should not be minimized or dismissed. Community residents are not so much interested in conclusive scientific proof of a causal link between asthma and diesel emissions as they are about acting to decrease public health threats.

Application of Data to Community Problem Solving

In addition to people using the data for daily decision making, one of the objectives of AirBeat is to provide data for community problem solving on air pollution. ACE staff and youth compiled an air quality factsheet that analyzes the data available so far and provides background information on air pollution (*9*).

The average $PM_{2.5}$ concentration for the 15-month period from September 1999 to December 2000 was 14.9 µg/m^3 (*9*). This level is just under the U.S. EPA average annual standard of 15 µg/m^3. In terms of the combined AQI for $PM_{2.5}$ and ozone, air quality was "good" (AQI ≤ 50) for 58% of the time and "moderate" for the other 42% (*9*).

These data are also helping to answer the question of whether Dudley is a local air pollution hot spot. Many residents believe that diesel bus and truck emissions are a significant factor in Dudley's air quality. We compared data from AirBeat with data from identical $PM_{2.5}$ and black carbon monitors at HSPH, just over a mile away from Dudley (Figure 3). Preliminary analysis shows that $PM_{2.5}$ levels in Dudley are 15–20% higher than those at the Harvard site, whereas black carbon levels are about 22% higher in Dudley (*9*). During morning and afternoon rush hours, black carbon levels are 25–30% higher (*9*). These data begin to confirm suspicions that Dudley is a hot spot for $PM_{2.5}$ and that diesel emissions significantly increase the pollution levels.

This information was presented by REEP interns David Noiles and Stanley Wiggins to more than 30 community residents and city officials at a workshop on the city-sponsored Dudley Square Transportation and Air Quality Study in January 2001. After this presentation, David and Stanley provided recommendations to the study team for decreasing air pollution. Many of their recommendations were adopted in the final study, including enforcement of the anti-idling law in Dudley Square, conversion of diesel transit buses to compressed natural gas, relocation of a local transit bus yard, and upgrading of transit service to Dudley Square (*10*).

Long-Term Outcomes

Harder to measure and quantify, but perhaps the most important benefits of this project, are the long-term outcomes. These include the growth of the individuals involved in the project, the perceptions within the community of its own strength, and the lasting partnerships among the project team.

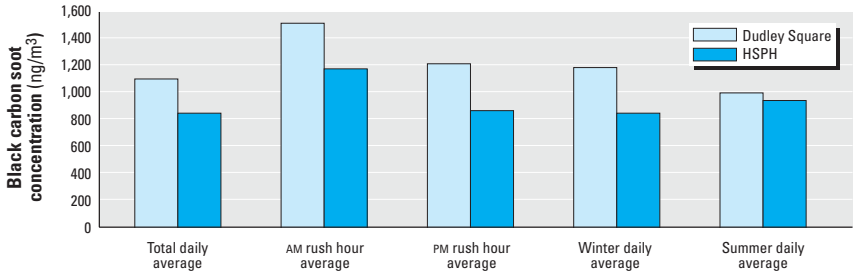

Figure 3. Graph comparing black carbon soot levels measured in Dudley Square and HSPH.

Youth Empowerment

Perhaps of all the participants in this project, the ones who benefited the most were the youth. The four REEP interns at ACE and the several classes from GECHS involved in this project not only became knowledgeable about air pollution and monitoring, but exercised key leadership skills such as public speaking, strategizing, and educating others. They were recognized by government officials and the media for their leadership role and expertise. In effect, this project helped them become the local experts.

According to Cecelia Archibald, 18 years old:

> What I'm most proud of is I learned a lot about air pollution and what I learned can really help the community. Even people without computers can call and find out what the air quality is and choose how to spend their day.

Stanley Wiggins, 18 years old, says,

> I consider the air monitor to be our greatest accomplishment because it gives us concrete, visual evidence as to why Roxbury is overburdened by air pollution.

Frederick George, 20 years old, reflects on his experience in AirBeat:

> We have done great work so far, but now it is time to take it to the next level. Now it is time to really reduce the sources of pollution in our neighborhood and lower the asthma rates in Roxbury once and for all.

Community Ownership and Pride

The project also has long-term outcomes affecting the way community residents view their own community. All too often, Roxbury and other urban neighborhoods are portrayed negatively as crime-ridden areas about which no one cares. This project emphasized the community's leadership role. Residents saw their own youth as the experts. Well-respected community organizations received funding and played central roles in the project. These successes were then applauded and held up as models by the U.S. EPA, locally elected officials, and other government officials. At the site itself, the chief technician is a community resident.

There is immense pride that Roxbury was able to develop a resource that no one else has. This pride is rooted in the perception that the project is "owned" by the community, rather than a project that is brought in by outside entities. This pride is itself a resource for the community in other struggles.

According to Matthew Goode, the AirBeat project's principal investigator and commissioner of SCCD:

> An additional benefit of the AirBeat project is its potential as a vehicle for transfer of technology to members of urban communities. Involvement of high school youth is an important point of departure for this goal.

Community–Research Partnerships

Finally, the project has strengthened the relationships among the project team members. This project was possible only because of the relationships and trust that had been developed in the years leading up to the actual project. Now this trust is magnified by the success of the project. Trust, which is very difficult to build and very easy to lose, is one of the key long-term benefits of AirBeat.

Lessons Learned for Community-Based Participatory Research

On the basis of our experience in this project, we have learned there are many values to community-based participatory research that extend far beyond the immediate research results. The most important outcomes are the increased capacities of individuals and organizations in the community to understand the complexities of the problem and to organize and advocate for policy changes that will result in real health and environmental benefits. Participating in setting the research questions and guiding the project as equal partners help promote a greater sense of ownership over the problem. Rather than seeing themselves as victims requiring an outside savior, they begin to see themselves as the key change agents.

In our work, we defined the problem as excessive adverse health effects of asthma due to poor air quality. Instead of only seeking more health care, we also focused on changing the underlying environmental conditions. The community-based research partnerships that we pursued were built on this definition of the problem. AirBeat helped and is continuing to support our hypothesis that Roxbury has areas of relatively high air pollution and that diesel emissions are a major contributor of air pollution in Dudley Square.

AirBeat was successful as a community-based research project for two key reasons. First, the relationships we established were equitable from the start, which developed the trust necessary for productive collaboration. The research partners understood their role as resources to help educate the community about the links between air pollution and health. The project and the research questions were not conceived first by researchers but by the community. When a proposal was developed and funding sought, the community partners were equal participants and received an equitable share of the funding.

The second key reason for AirBeat's success was the degree to which we promoted community ownership of the project. The outreach and education components of the project were conducted by respected and well-established community groups. Local youth were trained and became an important part of the project team. The media were used to portray the project as a community victory. Even the state agency's main staff person for maintaining the site was a local resident. All these strategies helped to counter the negative impressions that residents often have about research projects conducted in the community by predominantly White researchers. In fact, the project is now a source of pride for the community.

On the basis of these lessons learned, we have several recommendations for researchers pursuing community-based partnerships:

- Community-based organizations must be equal partners in all phases of the research project, especially in the definition of the research agenda, and receive an equitable share of funding.
- Community education and outreach should be integrated into project from the beginning and, to the extent possible, be delivered by community-based institutions, so equal value can be given to local knowledge and residents can be educated about the purpose of the project.
- Projects should seek to involve technical people from the community and/or researchers of color to help bridge the gap between researchers and community and to serve as role models for youth.
- Projects should be made visible in the community and through the media to spark interest in the project and help community take ownership of the project.

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