CHAPTER

5

GEOGRAPHIC INFORMATION SYSTEMS, ENVIRONMENTAL JUSTICE, AND HEALTH DISPARITIES

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After studying this chapter, you should be able to

1. Describe some of the benefits and challenges of integrating biomedical and geographic perspectives to study childhood asthma.
2. Assess the role of differing exposure to urban environmental pollutants in creating or maintaining health disparities.
3. Identify specific roles that community organizations, medical centers, and academic institutions can play in the study of urban health conditions such as childhood asthma.

4. Assess different strategies for collecting data on the urban environment and analyze their strengths and limitations.

INTRODUCTION

In scientific research, the most interesting questions are very often at the interstitial zones and boundaries of disciplines, neither firmly within one or another. These are frequently the questions that go unasked or unanswered. They may also provide evidence that stimulates reconceptualization (e.g., physicians considering environmental aspects of asthma). One of the challenges of interdisciplinary research is to leverage input from many different disciplines. Embracing this challenge enables thinking about and solving problems in ways not possible using the methods and techniques of just a single discipline. In this chapter, we apply this approach to the study of asthma and air pollution in the Bronx, New York City. Our organizing framework for this chapter is based on two important themes: the *process* of interdisciplinary research (i.e., the benefits and challenges of an academic-medical-community partnership, which brought together expertise in geographic information science, clinical epidemiology, and street science), and the *outcomes* of interdisciplinary research (i.e., the enhanced understanding of the association between environmental conditions and asthma hospitalizations).

Environmental conditions are believed to contribute to producing and maintaining minority health disparities.[1] In the past four decades, numerous studies have demonstrated the existence of environmental injustices in the United States,[2, 3] and there have been efforts by communities and governmental agencies to define and advance environmental justice (EJ). The objectives of environmental justice include overcoming and rectifying past and present inequities—the now commonplace recognition that disadvantaged communities suffer a disproportionate share of toxic burdens and hazards.[4] Environmental justice refers to the conditions necessary to assure the right to a safe, healthy, productive, and sustainable environment for all, including biological, ecological, physical (both natural and human-made), social, political, aesthetic, and economic environments. The National Institute of Environmental Health Sciences (NIEHS) Strategic Plan for eliminating such disparities and injustices notes,

> *Both social and environmental exposures represent an important area of investigation for understanding and ameliorating the health disparities suffered by the disadvantaged of this nation . . . Recent results suggest that factors such as access to quality health care and individual lifestyle choices, e.g., smoking or alcohol consumption, are not the primary causative agents underlying disparate health outcomes for those of low SES [socioeconomic status]. Indeed, these findings act to shift research emphasis toward examination of mechanisms by which social and physical environments interact with SES to produce health disparities.*[5]

In the next sections, we set the stage for our study by providing a brief overview of three key foundations for our study: community-based participatory research, multilevel models of causation, and geographic information systems.

COMMUNITY-BASED PARTICIPATORY RESEARCH

Since the 1990s, there has been growing and convergent interest in minority health disparities and community-based participatory research (CBPR). Historically, research conducted in low-income areas and communities of color has rarely benefited and often harmed the communities involved. Because these communities were not included in the development of the research question and design, interventions often proved ineffective because they were not tailored to the concerns and cultures of those being recruited to participate.

In a study commissioned by the Agency for Healthcare Research and Quality, CBPR was defined as "a collaborative research approach that is designed to ensure and establish structures for participation by communities affected by the issue being studied, representatives of organizations, and researchers in all aspects of the research process to improve health and well-being through taking action, including social change."[6] CBPR also involved (a) "co-learning and reciprocal transfer of expertise by all research partners; (b) shared decision-making power; and (c) mutual ownership of the processes and products of the research enterprise." The study found that using CBPR improved research quality and enhanced community involvement and research capacity.

Israel and her colleagues at the Detroit Community-Academic Urban Research Center have outlined the following CBPR principles: (a) CBPR recognizes the community as a unit of identity; (b) builds on the strengths and resources within the community; (c) facilitates collaborative, equitable partnership in all phases of the research and is an empowering process; (d) promotes co-learning and capacity-building among all partners that attends to social inequalities; (e) integrates knowledge generation and intervention for the mutual benefit of all partners; (f) emphasizes the local relevance of public health problems and the multiple determinants of health and disease, including biomedical, social, economic, and physical environmental factors; (g) is cyclical, iterative, and long-term with research goals not always known at the beginning of work with a community; (h) disseminates findings and knowledge gained to all partners and involves them in dissemination; (i) addresses health from both positive and ecological perspectives; and (j) continues after the funding ends.[7, 8]

The advantages and rationale for CBPR include: (a) enhanced relevance and usefulness of the research findings to all partners involved; (b) improved quality and validity of research by engaging local knowledge and theory based on the experience of those involved; (c) strengthened research and program development capacity of all partners; (d) convening of diverse skills, knowledge, expertise, and sensitivities to address complex problems; (e) reduction of community mistrust of research; (f) bridge for culture gaps; (g) reduced fragmentation and increased contextualization of research; (h) employment for community partners; (i) reduced marginalization; and (j) improved health directly from interventions and indirectly from increased power and control over research process.[9] From the community's perspective, an empowering CBPR must also include the questioning of the political and economic underpinnings of the scientific research proposed, the methodology selected to conduct that research, and the decision-making process to determine where and how the research project is going to be conducted.

MULTILEVEL MODELS OF CAUSATION

Social characteristics vary systematically across communities along a number of dimensions, including socioeconomic status (e.g., poverty, wealth, education, occupation, etc.), family structure and life cycle (e.g., female-headed households, child density, etc.), residential stability (e.g., home ownership and tenure etc.), and racial and ethnic composition (e.g., residential segregation etc.).[10, 11] Evidence shows that the ecological concentration of poverty and inequality has increased in American neighborhoods during the 1980s and 1990s.[12, 13]

A growing body of multilevel research has examined community characteristics and individual-level health and has found mixed, often modest, but consistent evidence that links health outcomes to neighborhood context even when controlling for individual attributes and behaviors. Outcomes examined have included cardiovascular risk factors and mortality, low birthweight, smoking, all-cause mortality, and self-reported health status.[14, 15] Although ecological and observational study designs limit causal inferences, recent experimental studies, such as the Moving to Opportunity program, have confirmed that improving community environment leads to better health outcomes.[16] In summary, social and behavioral science research has found broad agreement (with causality and magnitude still at issue) that (a) much inequality persists between neighborhoods and local communities along multiple dimensions of socioeconomic status; (b) health problems tend to cluster together geographically in ecological units such as neighborhoods; (c) individual- and community-level predictors themselves interact in relation to health outcomes; and (g) the association of community context and health outcomes, especially all-cause mortality, depression, and violence, persists even when controlled for individual-level risk factors.[11]

ROLE OF GEOGRAPHIC INFORMATION SYSTEMS

We used geographic information systems (GIS) as the primary analytic tool in this study. GIS refers to a structured system of computer hardware, specialized spatial analysis and mapping software, spatial and nonspatial attribute data, and an informed analyst. Geographic information science (GISc) is a discipline grounded in geographic spatial analytic theory, requiring a myriad of spatial decisions and constant use of expert judgment, knowledge, training, and experience. GIS have been extensively used in public health research in recent years, including disease mapping for epidemiological studies, as well as mapping for planning and analyzing health services provision, health care administration, environmental health justice, health disparities, hazard and risk assessment, exposure analyses, and research of many other types of public health issues.[3, 17–32]

GIS can help the health researcher discover and analyze the spatial relationships among populations and their sociodemographic characteristics, health outcomes, patterns of diseases, and access or lack thereof to health care, as well as a host of other variables that may be spatially linked to health and specific locations and populations. Although GIS is becoming more common among health researchers, it is still not widely used due to lack of awareness of the potential analytic power of GIS and the steep learning curve required to use GIS in a meaningful way. Knowledge of the geographic aspects of health issues is very often crucial to fully understanding them, and the spatial perspective gives unique insights that cannot be obtained in any other way. Additionally, being a visual medium as well as an analytic tool, GIS is a means of incorporating, integrating, and enhancing the participatory research process with disparate groups. However, the extensive time and effort necessary for novice GIS users to become proficient was our reason for undertaking interdisciplinary research among geographers, medical professionals, and community advocates. Interdisciplinary research eliminates the need for everyone to be an expert in everything and makes it possible for everyone to have a sufficiently deep understanding of the basics to participate in a meaningful way in the research design and interpretation of results.

In the project described in this chapter, GIS was used to examine the spatial correspondence between the residence of people hospitalized for asthma and major sources of air pollution. The following section outlines some of the issues that must be resolved when using GIS for health research and the specific methodology used for this project to address and optimize these issues.

There are a number of limitations in using GIS for health research, such as spatial and attribute data deficiencies, the limits of ecological research designs, and methodological problems, especially those related to geographic considerations.[3, 33, 34] Geographic considerations include the delineation of the boundaries of the optimal study area, determining the level of resolution and the unit of spatial data aggregation, and estimating the areal extent of exposure, as well as the various problems encountered in trying to statistically analyze and summarize spatial data. Due to the principle of spatial autocorrelation, which states that data from locations near one another in space are more likely to be similar than data from locations remote from one another, spatial data are by their very nature not randomly distributed, as traditional statistical approaches require.[35] Spatial autocorrelation, which is a given in geography, becomes an impediment to the application of conventional statistical tests.

ENVIRONMENTAL JUSTICE AND HEALTH IN THE BRONX

The Bronx is the nation's poorest urban county and home to more than 1.3 million people.[36] Of New York City's five boroughs, the Bronx is the poorest and contains the highest percentage of black and Latino populations (85.5 percent) and the least well educated—37.7 percent of adults have not graduated from high school. The Sixteenth Congressional District in the South Bronx had the highest poverty rate (40.2 percent), lowest median income, and highest proportion of children living below poverty (50.1 percent) in the United States.

In addition to these economic disadvantages, residents of the Bronx bear severe environmental burdens. In New York City, as in many urban areas, minorities and poor people are more likely to be concentrated in or near industrial zones that typically carry higher environmental burdens than residentially zoned areas.

In the Bronx, many of the industries occupying these areas are waste related or pollute land in other ways. From the 1970s to the 1990s, other areas of New York City were gentrifying, and city planners were changing industrial zones into areas zoned for residential and commercial uses; however, during that same time period, the Bronx had many acres of residential land rezoned for industrial uses, and existing light industrial land was rezoned for heavier industrial uses.[37, 38] By decreasing the extent of industrial zones in the rest of the city and increasing those in the Bronx, the historical zoning changes virtually assured that industrial areas in the Bronx became home of many new noxious facilities such as waste transfer stations and hazardous materials storage centers. Although these rezoning actions may not be malicious or racist in intent, the effect of disproportionate environmental burdens remains, with highest exposures to pollutants in neighborhoods that are poorer and have higher proportions of blacks and Latinos than other city neighborhoods. Our study seeks to ascertain whether or not proximity to these disproportionate environmental burdens correspond to an increased risk for asthma hospitalization.

Geographic Scale and Context of the Project

The geographic extent (scale) of this study is Bronx County. The Bronx is the only borough of New York City located on the mainland, and therefore, it serves the important purpose of providing surface accessibility and connectivity with the city's four island boroughs and the counties of Long Island from the rest of the United States. As a result, the Bronx has one of the highest volumes of vehicular traffic in the nation.[39] The Bronx is approximately forty-two square miles, and it was selected as a study area primarily due to its high rates of asthma hospitalizations (approximately 7 hospitalizations per 1,000 people annually), high quantities of noxious land uses, and the availability of relatively complete and accurate asthma hospitalization data sets for this area.

Role of Asthma and Air Pollution in Health Disparities in the Bronx

Since 1980, asthma has become epidemic in low-income urban areas and is now the leading cause for hospitalization of children over one year of age. The precise causes of asthma are not known, and there may be a multiplicity of triggers. These include indoor and outdoor air pollution, pollen, allergies, and smoking or exposure to second-hand smoke.[40] Previous research has linked high concentrations of known air pollutants with morbidity (including hospitalization) and mortality from respiratory diseases, including asthma.[41, 42] Many researchers have investigated the link between outdoor air pollution and asthma in other cities and have demonstrated that exposure to major air pollutants, including ozone, sulfur dioxide, nitrogen dioxide, and suspended particulate matter, is related to asthma prevalence or hospitalizations.[42–48] Many of these studies focused on exposure based on proximity to roadways.[40–44, 46–49]

Asthma is the leading cause of preventable hospitalizations in New York City for both children and adults, and the Bronx has the city's highest rates of asthma hospitalizations and deaths.[50] Residents of the Bronx, especially children under the age of fifteen years, suffer from rates of asthma hospitalization that are among the highest in the nation.[50] In 1999, the asthma hospitalization rate for children was 70 percent higher in the Bronx than in New York City as a whole and 700 percent higher in the Bronx than for the rest of New York State (excluding New York City).[50] The asthma hospitalization rate for children in the Mott Haven/Hunts Point sections of the South Bronx is 23.2 per 1,000 children, which is more than double New York City's rate of 9.9 per 1,000 children.

On average, approximately 9,000 Bronx residents per year, nearly half of them children, were hospitalized for asthma for each of the five years studied, 1995–1999.[51] Asthma hospitalization rates for children in the Bronx doubled between 1988 and 1997, peaking in 1993. Although reductions in asthma hospitalization rates have been seen in children and young adults, there have been no changes in the past fifteen years in the asthma hospitalization rate of adults over thirty-five years of age.

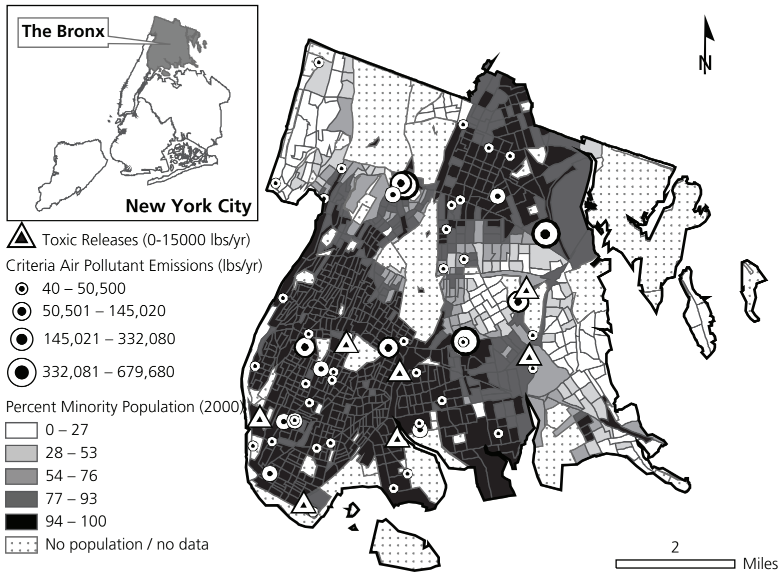
General air quality, however, has improved during the same time period. The Bronx also has many facilities that are known stationary sources of air pollution such as waste transfer stations and power plants as well as high quantities of pollution from mobile sources. Figure 5.1 shows that in the Bronx, pollution sources are concentrated in areas with high proportions of minority populations. We tested the hypothesis that there is a significant increase in asthma hospitalization rates in *microenvironments* for those residing near major sources of both mobile and stationary air pollution.

Research Partnership

Given the multiplicity of causes and consequences, solving the myriad environmental health issues facing the Bronx requires a partnership of community, academia, health professionals, and government. The South Bronx Environmental Justice Partnership (SBEJP) was developed in 2001 as a consortium of organizations, funded by NIEHS and led by a community organization, For a Better Bronx; a large clinical system, Montefiore Medical Center; a minority-serving educational institution, Lehman College; and a research-oriented medical school, Albert Einstein College of Medicine. The partnership's goal has been to improve the health and well-being of the people who live and work in the South Bronx by building capacity for and delivering community-driven environmental health research, education, and clinical and public health programs.

Community Partners For a Better Bronx (FABB) was founded in August 2004, evolving from the South Bronx Clean Air Coalition (SBCAC), which was founded in 1991 when several dozen community-based organizations, including churches and tenant, neighborhood, health, and civil rights groups, joined together to stop the operation

FIGURE 5.1 Major Stationary Sources of Air Pollution and Minority Population in the Bronx



Data sources: U.S. EPA, 2002; U.S. Bureau of the Census, 2000. Compiled by Juliana Maantay.

of a hospital-sponsored medical waste incinerator. SBCAC finally succeeded in closing it in June 1997. FABB now campaigns *against* large solid waste handlers, sludge processors, and fossil-fuel power plants and *for* sustainable community development initiatives, such as community-sponsored agriculture, community and rooftop gardens, "Green" buildings, solar energy, and an environmental youth corps. FABB brings first-hand experience to the partnership with local traffic and air pollution point sources.

Medical Partners Albert Einstein College of Medicine (AECOM) is the only medical school in the Bronx and the largest private medical school in New York State. AECOM is a premier basic science research institution with clinical affiliations not only in the Bronx but extending to Manhattan, Queens, and Long Island with a total enrollment of more than 800 medical and PhD students and a full-time and voluntary faculty of more than 3,000 physicians and researchers.

Montefiore Medical Center (MMC) is AECOM's university teaching hospital and provides more than 60 percent of the clinical training for all AECOM medical students. MMC is the largest hospital and health system in the Bronx. AECOM and MMC jointly sponsor the Institute for Community and Collaborative Health, which contributes administrative and clinical expertise and access to our study's hospitalization database.

Academic Partners Lehman College, City University of New York (CUNY) became CUNY's only four-year liberal arts college in the Bronx in 1968. Lehman's Department of Environmental, Geographic, and Geological Sciences sponsors a certificate program in GISc and brings technical expertise in GIS to the partnership. Research based in geographic information science (GISc) and environmental and health spatial analyses is conducted in the Urban GISc Lab.

Partnership Organization

The South Bronx Environmental Justice Partnership (SBEJP) has operated with funding from the NIEHS since 2001 with Montefiore Medical Center (MMC) serving as the grantee and For a Better Bronx (FABB) and Lehman College receiving subcontracts. Although this structure represents the organizational and administrative resources of the partners, it does not reflect the relative commitment to environmental justice or environmental health expertise of the partners. In fact, only FABB has a mission focused on promoting environmental justice, whereas AECOM, MMC, and Lehman have a variety of clinical, educational, and research goals. SBEJP has operated generally by consensus and has aims that include organizational development. Currently, meetings rotate between each partner's offices with a member of the host organization developing the agenda and chairing the meeting.

To better understand health disparities in the Bronx, we set out to explore whether environmental factors, such as poor outdoor air quality, could be shown to have a spatial association with the increased rates of asthma hospitalization in the Bronx. To conduct this multifaceted study, we needed to develop a team of experts in several fields as well as community-based scientists.

For the asthma and air pollution study, the academic, medical, and community-based organizations have joined together, and all three partners have been instrumental in crafting the methods for the analyses. The process of our collaboration and contribution of each partner is summarized in Table 5.1. In this project, geographic information systems were instrumental in the research design, and one of the strengths behind GIS is that it can take large amounts of data and examine complex interactions, making the complex visible and intelligible. GIS also provides an excellent foundation for meaningful community participation in research design, development of methodology, data needs assessment, data acquisition, and the actual analytic portions of the work. In other words, it permits the integration of local knowledge bases and "street science" into the more traditional health and environmental assessments.

METHODS

Community-Scale Assessment Techniques and Units of Analysis

Within Bronx County, not all areas are equally affected by high asthma hospitalization rates. Smaller geographic units may show contradictory trends regarding concentrations, hot spots, or prevalence. Therefore, we must look at the subcounty level to discern important differences and potential spatial correlations with air pollution sources. The unit of

TABLE 5.1. Phases of South Bronx Environmental Justice Partnership's Geographical Information Systems and Asthma Study and Partners' Contributions

Phase of asthma and GIS study	Role of collaborating partners	Description of analysis	Results
I: Proximity Analysis[a] I A—Use of census tract data as areal unit of analysis I B—Use of individual hospitalization and census block group as units of analysis	Community focused on influence of outdoor air pollution in asthma; Lehman conducted GIS analysis; Montefiore provided SPARCS data; funding from Einstein	Original creation of circular and linear "buffers" or "impact" zones and calculation of odds ratios inside vs. outside impact zones	Statistically significant increases in odds ratios for most exposures except MTRs for children and LAHs for both adults and children
II: Regression Analysis[b]	Einstein and Montefiore statisticians performed analysis to control for influence of poverty and racial/ethnic minority of original findings	Multiple regression analysis to determine contribution of minority and poverty status in relation to buffer zone exposure	Most hospitalization variance explained by minority and poverty status with 1% residual contribution from air pollution exposure
III: Multiple Exposure Analysis[c]	In response to FABB's concern about excess burden of multiple exposures, Lehman re-structured data and analyzed for zones affected by two or more sources of air pollution	Creation of "multiple exposure" buffer zones and calculation of odds ratios	Multiple exposure zones have higher odds ratios for hospitalizations than single exposure zones

IV: Dasymetric Population Mapping: Development of CEDS[d]	Analysis developed by Lehman in response to all partners' skepticism of original findings that proximity to Limited Access Highways (LAHs) were "protective" against asthma hospitalizations	Dasymetric analysis: Application of cadastral (tax assessment) database to calculating population distribution within block groups and calculation of odds ratios	Odds ratios for LAHs now show statistical significance; Odds Ratios increase for all individual, combined, and multiple exposure impact buffers
V: Loose-Coupling an Air Dispersion Model and the GIS[e]	Analysis developed by Lehman in response to concerns that circular "impact zones" were unrealistic and did not reflect local geography, prevailing winds, height of apartment buildings, etc.	Air dispersion modeling: Loose coupling air dispersion modeling estimates more accurate exposure plumes and, therefore, different "buffers"	Odds ratios increased for stationary point sources impact buffers

[a] Maantay, J. A. "Asthma and Air Pollution in the Bronx: Methodological and Data Considerations in Using GIS for Environmental Justice and Health Research" *Health and Place*. Special issue*: Linking Environmental Justice, Population Health, and Geographical Information Science*, 13 (2007): 32–56.

[b] Fletcher, J. *Report on the regression analysis of asthma hospitalization rates and proximity to major air pollution sources*. Bronx, NY: Albert Einstein College of Medicine, 2006.

[c] Maantay, J. A., Maroko, A. R., Porter-Morgan, H. "A New Method for Population Mapping and Understanding the Spatiality of Disease in Urban Areas." *Urban Geography*, 2008.

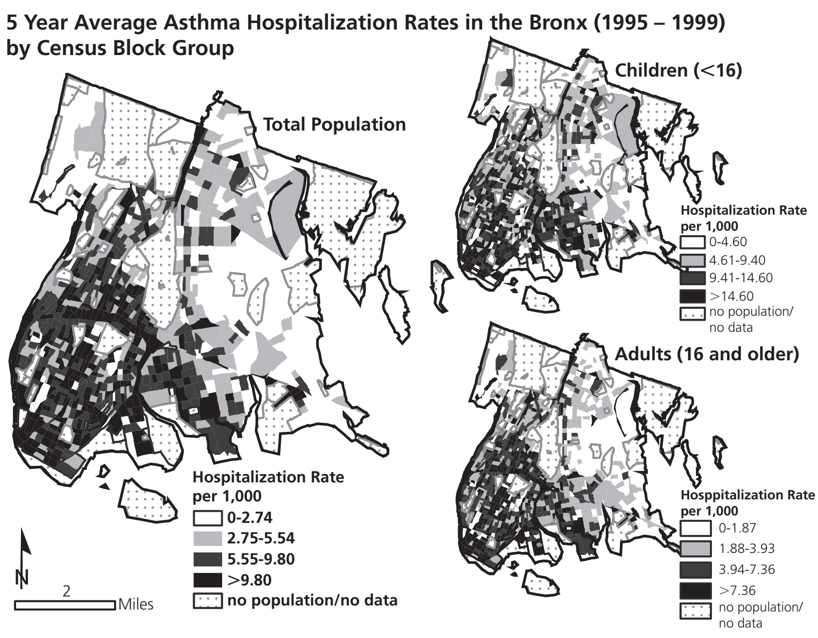
[d] Maantay, J. A., Maroko, A. R., and Herrmann, C. "Mapping Population Distribution in the Urban Environment: The Cadastral-Based Expert Dasymetric System (CEDS)." *Cartography and Geographic Information Science*. Special issue: *Cartography 2007: Reflections, Status, and Prediction*. 34 (2007): 77–102.

[e] Maantay, J. A., Tu, J., and Maroko, A. R. "Loose-Coupling an Air Dispersion Model and a Geographic Information System (GIS) for Studying Air Pollution and Asthma in the Bronx, New York City." *International Journal of Environmental Health Research*, 2008.

analysis for demographic and socioeconomic data is the *census block group,* the smallest census enumeration unit for which demographic and socioeconomic data are consistently available. The Bronx has 957 block groups, each containing an average of about 1,400 people.

The unit of analysis for the asthma hospitalization cases is the *individual patient record* for each admission, and this level of resolution was crucial in developing accurate rates of asthma hospitalization inside and outside buffered areas around polluting land uses, as described later. These individual hospital discharge records were drawn from the publicly available Statewide Planning and Research Consortium System (SPARCS) database of the New York State Department of Health. The home address of each individual hospitalized with a primary discharge diagnosis of asthma was geocoded to exact longitude and latitude with protections put into place to assure confidentiality and prevent back-coding. Rates were developed by dividing the number of asthma cases by the block group populations. Prior studies have used *census tract* data (a larger geographic unit than the block group) for both. The units of analysis for the environmental data are the individual polluting land uses and impact zones constructed around each. Figure 5.2 shows the spatial distribution of asthma hospitalization rates for various age groups.

FIGURE 5.2 Five-year Average Asthma Hospitalization Rates in the Bronx



Environmental Hazards and Pollutants Investigated

The locations of known sources of air pollution were used to derive approximations of the areas with poor air quality in the Bronx. In ascertaining which land uses are most likely associated with the suspected pollutants of concern for asthma, we decided to focus on major stationary point sources of air pollutants and the Toxic Release Inventories (TRIs) as well as mobile sources from major highways and truck routes as proxies for local areas of poor air quality.

Our GIS analysis used the publicly available TRI, maintained by the U.S. Environmental Protection Agency (EPA), which is a fairly consistent database and covers the entire United States. Facilities within certain Standard Industrial Classification (SIC) codes (e.g., chemical, printing, electronic, plastics, refining, metal, paper industries, etc.) must report their emissions and waste to the EPA if they meet certain conditions, such as manufacturing more than 25,000 pounds per year or using more than 10,000 pounds per year of one or more of the 650 listed toxic chemicals.[52] Because of the high thresholds in the reporting regulations, TRI includes only the largest users and emitters of toxic substances.

In many communities, TRI facilities and other listed major stationary point sources represent just one component of the total environmental burden, and many other facilities (which individually are below the reporting thresholds for quantities of emissions, use, or production of toxic chemicals and, thus, are not required to report to EPA) may contribute as much or more on a cumulative basis to the overall air emissions. Unfortunately, it is difficult to obtain reliable data about these facilities because they are not listed in a publicly accessible format and often do not receive any governmental oversight. Many smaller facilities, such as auto body painting and repair shops, electro-plating firms, waste transfer stations, and factories, also emit contaminants to the air, but these emissions for the most part remain undocumented and, thus, are difficult to incorporate into the analysis.

Another major contributor to air pollution, especially fine particulate matter, is the high level of truck traffic in the Bronx, which is especially prevalent in the industrial zones. It is not uncommon for 1,000 trucks to enter one solid waste transfer station each day, and there are more than a dozen such transfer stations in the Bronx.[53] Also of note, FABB has observed significant truck traffic on streets other than the truck routes designated by the Department of Transportation.

Although other vehicular traffic is a significant source of air pollution in the Bronx, it is more difficult than the major truck routes to isolate and quantify. Limited access highways, which carry in excess of 50,000 vehicles per day (average annual daily count), were selected to represent the most significant pollution sources from vehicular traffic in addition to trucks. The Hunts Point Terminal and Fulton Fish Markets are also located in the South Bronx, the major fish, meat, and produce wholesale exchange in the metropolitan area, resulting in more than 15,000 trucks per day.

Most researchers now consider air pollutants a risk factor for asthma, although the roles that specific air pollutants play in various respiratory illnesses remain unclear.[54, 55] However, if the general effects of air pollution, rather than the effects of specific pollutants, are examined, there is a large body of literature demonstrating their relationship to adverse respiratory events, suggesting that air pollutants are best treated as a whole. Therefore, air pollution in this article refers to the substances that constitute the pollutant mixture from traffic and industrial-related sources that has been associated with respiratory effects and typically includes particulate matter (e.g., PM_{10}, $PM_{2.5}$), volatile organic compounds (VOCs, e.g. benzene, acetaldehyde, tetrachloroethlene, toluene), NO_2 (nitrogen dioxide), SO_2 (sulfur dioxide), and O_3 (ozone). The locations of the stationary and mobile sources of these pollutants were mapped and examined in light of their spatial correspondence to areas of high asthma hospitalization rates.

Proximity: Analysis with GIS

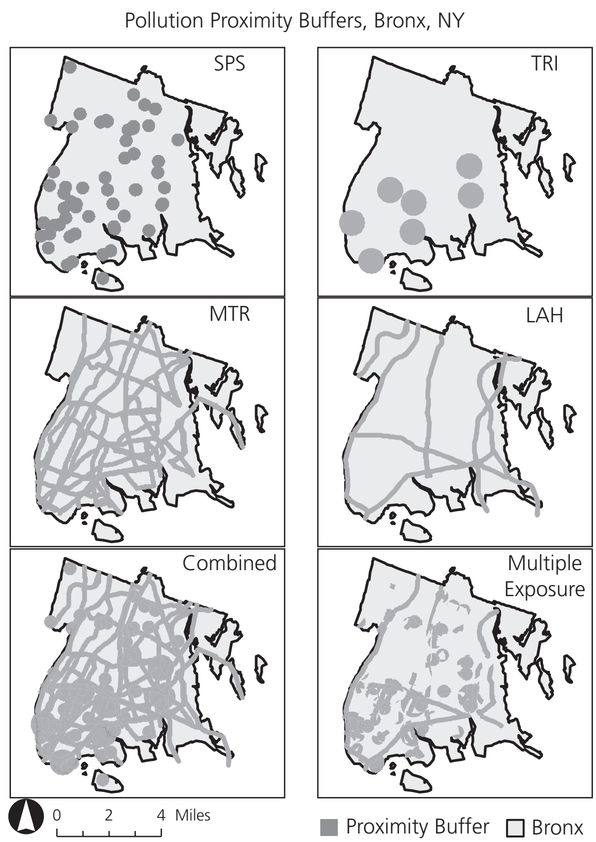
This study accounts for exposure to air pollution burdens by using proximity analysis to create impact zones around the TRI facilities (TRIs) and other listed major stationary point sources (SPSs) as a proxy for areas of elevated air pollution, as shown in Figure 5.3. Exposure to the pollution from truck traffic is accounted for by the creation of impact zones surrounding the major truck routes (MTRs), many of which traverse residential neighborhoods. Impact zones were also constructed around limited access highways (LAHs) to represent areas of elevated exposure from other vehicular traffic in addition to trucks.

The impact zones constructed for this study were based on distances established as standards by environmental agencies or used most often by other researchers as the area of greatest potential exposure from sources. One-half mile radius impact zones were constructed around TRI facilities;[56, 57] one-quarter mile radius impact zones around other major stationary point sources of criteria pollutants.[58] In addition, we created a 150-meter impact zone from roadway centerline around both LAHs and MTRs,[59, 60] the "distance within which concentrations of primary vehicle traffic pollutants are raised above ambient background levels."[61] The majority of similar studies found significant associations between traffic-related emissions and respiratory symptoms within the 100 to 200 meter range.[41, 62–64]

Each of these impact zone types constituted a separate layer that was then intersected with the asthma hospitalization layers. A layer of all the impact zones combined was also created and intersected as shown in Figure 5.3. Using the locations of the asthma hospitalization cases, it was possible to determine which cases fell within each of the four different impact zone types, as well as within their sum or "combined" buffer, by "clipping" (i.e., removing all the display elements that lie outside the boundary) the asthma layer by each of the five impact zone layers. The clip function was performed for total asthma hospitalization cases as well as for each of the age cohorts separately.

Rates based on the five-year average were calculated for the portions of the block groups within each type of impact zone and the combined impact zone. Because the locations of the asthma hospitalization cases are pinpointed with accuracy by latitude and longitude and are not aggregated by census tract or block group, it is possible to

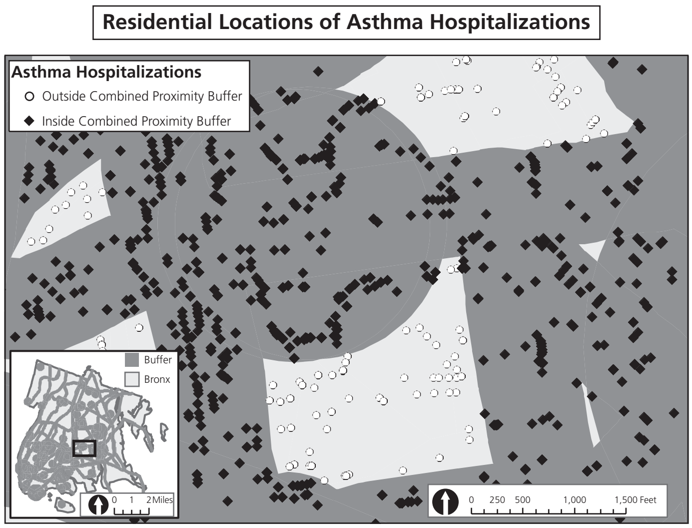
FIGURE 5.3 Pollution Proximity Buffers



derive rates for the block groups that can be differentiated by whether the portion of the block groups is in or out of the buffer, as shown in Figure 5.4. This would not be possible using data aggregated by enumeration unit (i.e., census tract) and is only feasible because individual patient record-level data were used.

To develop and compare rates inside and outside the impact zones, an interpolation process called "areal weighting" was performed on the census block groups. The boundaries of census block groups are not coincident with the buffer areas, and therefore, the population data for each tract or block group must be recalculated based on the portion of the tract or block group that falls within the impact zone. The census block groups that fall partially, but not totally, within a certain impact zone are weighted by the proportion of the area that falls within.[65, 66] For instance, if a tract or block group

FIGURE 5.4 Asthma Hospitalization Cases, In and Out of Buffers



Each dot represents the residence of one Bronx person admitted to the hospital for asthma in 1999. Some dots represent multiple admissions of the same person or multiple people admitted from the same address. The multiple cases are not shown as individual dots on the map, but have been included in statistical calculations. There were 8,188 hospital admissions in 1999: 5,876 of them from within the areas of the combined buffers and 2312 of them from the areas outside the buffers. Overall in 1999, a Bronx resident was 27 percent more likely to be admitted to the hospital for asthma if living within a buffer area than if living outside a buffer area.

Important note: the patient address locations shown on this map are derived from hypothetical data and do not represent actual addresses. Because of patient confidentiality requirements, the actual addresslocations could not be shown in a document for public dissemination, and this map is intended to illustrate only the methods used in the analysis. Actual address locations were, however, used by the researchers in the spatial analyses to derive the in- and out-of-buffer rates, odds ratios, and other statistical tests. The researchers were permitted to show only aggregated data (as opposed to record-level data) in any maps available to the public.

Data source: hypothetical data.

is exactly half within the impact zone, the ratio would be 0.5. These ratios are then applied to the population variables to get a reasonable estimate of the population within the impact zones.

The set of demographic and socioeconomic characteristics that we were interested in were quantified and mapped for the within-buffer population and compared to the outside-of-buffer population. The proportion of each variable within the impact zone is based on the proportion of area within the impact zone. Thus, the underlying assumption in this method is that the data for entire unit of analysis (in our case, the block group) are homogeneous, with its population spread evenly throughout, which obviously may not be the case, a limitation of this method. For instance, a large housing project in one corner of the tract would affect the accuracy of areal weighting, as would a large part of the tract being parkland or water, where people are unlikely to live.

Asthma hospitalization rates were developed by using the actual number of cases in each portion of the block group within the impact zones divided by the number of people estimated by areal weighting in that portion of the block group within the impact zones. As noted earlier, this is a simplification; however, considering the small areal extent of the typical Bronx block group, it appears to be reasonably accurate. Rates in and out of impact zones were calculated for the total population and the age cohorts separately, for each of the five years, and then calculated based on the five-year average.[67]

In general, the smaller the unit of data aggregation, the greater the likelihood of homogeneity and the more reliable the method of areal weighting. However, data disaggregation methods exist for obtaining more precise locations of populations, and these can be utilized to calculate better rates in and out of buffers, although these methods are more computationally demanding, time consuming, and require more detailed ancillary data. These data disaggregation methods are referred to as "dasymetric mapping." We developed a new population-mapping technique to improve the "denominator" to calculate more accurate rates.

The Cadastral-based Expert Dasymetric System (CEDS) is a model that uses both an expert system and dasymetric mapping to disaggregate population data (e.g., from the census) into much higher resolution data, giving a more realistic depiction of population locations and densities.[68] Dasymetric mapping entails using ancillary data sets to refine and redistribute the locations of some phenomena (e.g., population) to reflect their distribution more accurately. CEDS, for instance, uses data sets that mask off the areas where people tend not to live (e.g., parks and water bodies) and then redistributes the census populations throughout only the known inhabited areas rather than throughout the entirety of the census unit area (which often includes uninhabited areas). CEDS then uses tax-lot (cadastral) data, which in NYC is on average 150 times finer resolution than the census block group data, to further disaggregate the census population data, as described below.

The expert system is a computerized decision-making program, which has been instructed to "decide," based on heuristic rules and expert judgment, which among several variables in the tax-lot data set to use for disaggregating the census data to calculate the optimally accurate tax-lot-level population. CEDS can be used to reliably disaggregate population data as well as subpopulations such as racial/ethnic groups, age cohorts, income/poverty groups, and those with differing educational attainment levels. We recalculated our rates and analyses based on this more precise population denominator obtained by using CEDS and found more pronounced increases in hospitalization rates in impact zones.[68, 69]

FINDINGS

The results of the proximity and other GIS analyses are instructive in guiding our future research directions. The most noticeable visual aspect of the impact zones that were created around major air pollution sources is the extent of the Bronx that is covered. Approximately 66 percent of the Bronx's landmass falls within the impact zones (excluding major parkland and water bodies). Because the impact zones in this study represent those areas most affected by air pollution, a majority of the Bronx population may be exposed. According to calculations based on the areal weighting script, 88 percent of the people within the impact zones are minorities, and 33 percent are below the federal poverty level. This contrasts with 79 percent minorities in the areas outside the impact zones and 25 percent people below poverty. Even though the impact zones cover so much of the Bronx, there is still a disparity between the characteristics of the populations inside and outside the impact zones, indicating the likelihood of disproportionate environmental burdens.

In addition to the differences seen in poverty and minority status inside and outside the impact zones, there is also a difference in asthma hospitalization rates inside and outside the impact zones. Calculating odds ratios for the rates, we found that people living within the combined impact zones are 30 percent likelier to be hospitalized for asthma than people outside the impact zones, as shown in Table 5.2. Within some of the individual impact zones, such as TRI and major stationary point sources, asthma hospitalization rates were 60 and 66 percent higher, respectively, than if outside the impact zones. The odds ratios, in general, are higher for adults 16 years and older than for children 0 to 15 years. This is true for every type of impact zone and for nearly every one of the five years analyzed.

TABLE 5.2. Odds Ratio Ranges for the Five-year Study Period 1995–1999

Buffer type	Adults	Children	Total population
Combined	1.28–1.30*	1.11–1.17*	1.25–1.29*
Toxic release inventory	1.29–1.60*	1.14–1.30*	1.33–1.49*
Stationary point sources	1.26–1.66*	1.16–1.30*	1.23–1.32*
Major truck routes	1.07–1.17*	1.00–1.09	1.10–1.15*
Limited access highways	0.90–0.93	0.83–0.99	0.86–0.93

* Indicated results are statistically significant at $p < 0.01$.

Although the analysis found that people within the impact zones were much more likely to be hospitalized for asthma than those living outside the impact zones, the risks vary depending on the source of air pollution. Living within TRI and major stationary point source impact zone poses a higher risk than living within the limited access highway and major truck route impact zones according to the proximity and odds ratio analyses.

In looking at the number of observed cases versus the number of expected cases, based on the overall Bronx five-year average asthma hospitalization rate, the observed cases within the combined impact zones are higher than expected, and those in the areas outside the combined impact zones are lower than expected. A Standardized Incidence Ratio (SIR) was calculated by dividing the observed number of asthma hospitalizations by the expected number of asthma hospitalizations for each subpopulation as defined by impact zone state (inside or outside impact zone) and further refined by age cohort (all ages, 0–15, and 16+). The overall Bronx hospitalization rates were calculated by dividing the total number of asthma hospitalizations by age cohort by the appropriate susceptible populations of the Bronx. The resultant rates were then multiplied by each of the subpopulations to arrive at the expected numbers of hospitalizations. Our analysis confirmed that there was a statistically significant higher incidence of asthma hospitalizations within the impact zones than outside them for each age cohort examined.

Based on our initial analyses, the highways and truck routes seemed to have a protective nature regarding the likelihood of being hospitalized for asthma. This was counterintuitive to the findings of previous studies as well as to anecdotal information given to us by the community partners. Based on further "ground-truthing" type information given to us by the community partners, we realized that the results for these pollution sources might be an artifact of incomplete knowledge of where population was actually located, and hence arriving at incorrectly high denominators in these areas, resulting in artificially lower rates. By correcting this inaccurate denominator using the CEDS method as described earlier, we were able to show more realistic results that more closely conformed to prior studies and the community's experience with these areas.

IMPLICATIONS OF FINDINGS

The increased asthma hospitalization rates for both children and adults living in impact zones compared to their neighbors who did not suggests that local microenvironments and individual exposures are important in understanding the asthma epidemic and developing public health interventions that will reduce the adverse health effects of outdoor air pollution. The phases of our research have sought to improve the accuracy of our estimates of the asthma hospitalization rates for those exposed to stationary and mobile air pollution sources using proximity as our proxy for exposure. Each phase has made the odds ratios calculated comparing the risk of asthma hospitalization of those residing within impact zones to those living outside them both larger and more significant. Controlling for poverty and minority status diminished but did not eliminate the added risk arising from residential proximity to the four categories of air pollution. Studies measuring individual exposure and asthma symptoms, using portable sampling equipment and locating its specific measurements, could confirm our findings.

Limitations of Data and Analyses

Several data limitations are encountered with integrating health data in GIS. A basic data quality issue is data accuracy, and this takes two forms: positional accuracy and attribute accuracy. Both have substantial ramifications for the asthma and air pollution study. Positional accuracy refers to how close the location of a data point in a GIS reflects its true position in the real world. The incorrect identification of a data point's location can occur at the time of original measurement of the location or in subsequent data processing, such as change of projection and overlay analyses, and can result in erroneous data aggregation and spatial analysis. Attribute accuracy refers to how closely the data values describe the real-world entity's true attributes. Errors and inaccuracies in attribute data can occur due to inconsistencies in health event definitions and diagnoses as well as population indicators such as race or ethnicity.[70]

There are also data limitations more specific to this study, in addition to the general data limitations mentioned in the preceding paragraph. First, the asthma hospitalization data set contains only hospital discharges and not emergency room or office visits, asthma incidence, or asthma prevalence, so only the most severely ill and poorly managed proportion of the total population affected by asthma is represented in the analysis. Second, the locations of the major pollution sources are obtained from national databases and potentially have inaccuracies with locational attributes as well as nonspatial attributes because much of the information within these data sets is self-reported. Third, the demographic and socioeconomic data are derived from the U.S. Census, and there have been reports of serious undercounting of various populations, especially in dense urban areas. Such inaccurate population counts and locations have the potential to render inaccurate the disease rates developed from the census data. Additionally, the time periods of the data on environmental conditions and asthma hospitalization were not necessarily the same, primarily due to real-world difficulties involved in data acquisition. Table 5.3 provides information on data sources, time periods, variables, and data processing methods for the variables of interest.

General study limitations include the issues associated with ecological-level analyses. To avoid the ecological fallacy, we cannot infer any individual outcomes based on community or neighborhood characteristics. Also, the environmental data used (i.e., major air pollution sources) do not translate very well to individual exposures, and the spatial correlations found in the analysis do not imply causality, merely an association or relationship. Lastly, as mentioned earlier, asthma hospitalization data are not a proxy for asthma incidence, and hospitalization for asthma may reflect a failure to manage the disease or lack of access to primary and preventive care. Because of

TABLE 5.3. Data Sources for GIS Analysis

Data or variables	Source	Data processing method	Year
Asthma hospitalization data	New York State Dept. of Health SPARCS database	Geocoded	1995–1999
Toxic release inventory facility (TRI)	U.S. Environmental Protection Agency	Geocoded	2000
Other major stationary point sources (SPS)	U.S. Environmental Protection Agency	Geocoded	2002
Limited access highways (LAH)	U.S. Bureau of the Census	Selected street segments	2000
Major truck routes (MTR)	NYC Dept. of Transportation/Traffic Rules and Regulations	Selected street segments	2002
Zoning and land use	Lot Info by Space Track and NYC Dept. of Finance, RPAD (Real Property Attribute Data)	Spatially joined with property tax lots	2002
Demographic and socioeconomic data	U.S. Bureau of the Census	Spatially joined with census boundaries	2000
Street segments	U.S. Bureau of the Census	N/A	2000
Water bodies, parks, and other boundaries	U.S. Bureau of the Census	N/A	2000
Digital Orthophoto of NYC	NYC Department of Environmental Protection, NYCMAP	N/A	2000

these limitations, community advocates have now secured the inclusion of emergency department visits in the SPARCS database so that future analyses can consider both hospitalizations and ER visits.

Organizational Challenges

Power Differentials in the Partnership The asymmetry created by a large medical center and community-based organization (CBO) forming a partnership is exacerbated by the grant structure when the larger organization is also the grantee and the CBO is a subcontractor. For SBEJP, this has resulted in a significant power differential between MMC and FABB, reflected most dramatically in the process of distributing funds rather than in the amount of funds (which is now equally shared between FABB, Lehman, and MMC). Funds are transferred from NIEHS to MMC electronically, but several administrative steps are then required before FABB or Lehman can receive funds, including establishing internal fund numbers; generating, negotiating, and signing the subcontract; and invoicing MMC for services. Because grant funds constitute a large proportion of FABB's total operating budget, delays in the process have a profound impact on its staff and its cash flow. Attending to the bureaucratic paperwork consumes a disproportionate amount of precious staff time with the CBO always as "supplicant." Another example was the principal investigator's decision to ask the institutional partners (Lehman and Montefiore) to absorb a 10 percent funding cut without consulting FABB, which FABB experienced as paternalistic.

Differences in Foci or Interest, Time Commitments, and Investments FABB's staff are fully devoted to environmental justice efforts, although its SBEJP subcontract represents only one of FABB's funding sources. MMC and Lehman staff have only part-time commitments to SBEJP and, therefore, have many other time commitments. Although interest in academic publication is shared by all partners, FABB writes educational brochures, newspaper columns, and for magazines that reach the public, other CBOs, and EJ organizations, whereas Lehman and MMC are mainly interested in professional journals in their staff's various disciplines. Writing and publishing also compete with other, often more pressing organizational and political priorities.

Agenda Setting and Project Conceptualization The community partner was crucial in project conceptualization and in developing the initial working hypothesis that outdoor air pollution makes asthma worse, based on their long-term and immediate experiences. Historically, asthma researchers have focused on allergies and indoor air pollution, whereas FABB emphasized the importance of the multiple burdens in the community. As noted in Table 5.1, each partner contributed to the development and evolution of the study.

Integration of Local Knowledge Bases and Street Science with GIS Analysis Street science is defined as "a new framework for environmental health justice that joins local insights with professional techniques."[71] In this definition, traditional assessment methods and nonscientific contributions are not seen as mutually exclusive, but each is necessary for the complete realization of the other. By integrating local knowledge bases and community-specific ways of knowing with traditional analytic methods, both can be considerably improved, yielding not only more substantive results but results that will more likely be accepted by the community as their own.[72]

One kind of participatory research consists, in part, of nonscientist stakeholders informing the research in such a way that would not be possible by outside "experts" alone conducting the analyses. This is generally accomplished by community members providing intimate knowledge of the community or issue at hand, posing questions and gathering data that are particular or unique to the area, which would be virtually impossible for outsiders to obtain. Participatory research also involves all stakeholders together developing analytic methods that are appropriate to the community forming the geographic focus of the study. The ideal collaborative research goes beyond a *participatory* paradigm and addresses deeper institutional power dynamics and the hierarchy of knowledge that labels one body of knowledge and experience as nonscientific and another as scientific and recognizes the political and social context. For instance, the community partners suggested that we use GIS to examine not only the correspondence of individual pollution sources to asthma hospitalizations but also the impact of living within close proximity to more than one pollution source, which we did in the multiple exposure analysis. This analysis demonstrated even higher than expected hospitalizations among those residents living close to two or more pollution sources.

Data Collection and Analysis Community members provided important local knowledge and helped to collect sensitive data about the community in several ways, as shown in Table 5.4. Many of these local knowledge bases have been incorporated into the analysis of our asthma and air pollution study. Each phase of the analysis has been instructive in guiding our subsequent research directions and demonstrating the gaps and uncertainties that need further explanation and examination in our future research.

FABB also participated in meaningful ways in our analysis of GIS findings, not only with the review and critique of data collection and analytic methods but also with interpreting the results, giving guidance and offering tentative explanations based on local knowledge about anomalous findings from the research. FABB sought more discussion regarding the institutional and political implications of GIS research, the power dynamics of GIS research methodologies, and how CBPR and interdisciplinary research could be better tools for community empowerment and integrating historical, social, political, and economic perspectives.

Dissemination of Research Results One of the challenges in disseminating the results of our study is that publishing the findings in only academic and professional journals will not suffice. We must also find ways to present our results so that members of the affected community and other communities affected by high rates of asthma

TABLE 5.4. Community Contributions to Data Collection and Analysis

Variable of interest	Community contribution and impact on study
Truck routes	Databases obtained from the official sources, such as the Department of Transportation, were incomplete, according to community members who often witnessed trucks on local residential streets not designated as truck routes. Although suggested by FABB, resources did not permit enumeration of off-route trucking volume.
Active/inactive pollution sources	Of the stationary point sources of pollution that appeared on the federal lists, residents knew that some of the facilities were no longer active, and others were not properly reported as to emissions.
Actual location of residential areas within a block group	Areal weighting script used to calculate populations in portions of census block groups was based on the assumption of homogeneity of residential populations. The community had more specific knowledge of densities within block groups, such as the location of major housing projects, which influence the disease rates in and out of impact zones, and led to the dasymetric mapping phase of the study.
Buffer distances for highways	Standard guidelines for impact assessment assume that highways are at grade level, yet many highways in the Bronx are either elevated or below grade in cuts. Residents' knowledge of the differential impact of highway grade on the pollution that entered their house or street led us to reconsider standard buffer distances assigned to highways because grade affects the distance typical traffic-related pollutants travel.

and air pollution can understand and act on our findings. This includes developing culturally and linguistically appropriate maps, tables, charts, and risk communication materials, media, and a Web site for community presentations of these GIS findings to promote education and dialogue on appropriate public health and regulatory responses. Also of critical importance is communication of the study's findings to policy- and decision-makers and other government officials. We began this process with other

New York asthma researchers, environmentalists, and asthma advocates at a community forum at the New York Academy of Sciences in January 2007. We intend to organize similar forums in affected communities in the Bronx.

Making the Connection Between Environmental Justice and Environmental Health

This analysis found that people residing within the impact zones were not only much more likely to be hospitalized for asthma than those living outside the impact zones but also more likely to be minority and poor than those outside the impact zones. Previous research has suggested that socioeconomic status itself plays a role in diseases and deaths associated with air pollution.[73, 74] High asthma hospitalization rates reflect both minority and poverty status and high exposures to environmental pollution, and these factors are inextricably entwined.[75, 76] In hierarchical regression analysis, even after controlling for potential confounding factors, such as race/ethnicity and poverty status, the correlation between asthma hospitalization and proximity to air pollution sources remains significant. For instance, in examining the multiple exposure buffers, although race/ethnicity and poverty status account for most of the variance in the model, proximity to multiple sources of pollution remains significant ($R^2 = .429$; $p < .001$). Proximity to any major pollution source (residence within the combined buffers) yields similar results ($R^2 = .452$; $p < .05$).[77]

Poor people, those lacking access or means to health services, support, or resources, may be more likely admitted to the hospital for asthma because they may not receive ongoing preventive or disease management services. Regular access to doctors and medicine might reduce emergency room visits and hospital admissions for asthma, although the impact may vary by cultural background, educational attainment, or level of affluence, further illustrating the multiple determinants of asthma outcomes.

Although further analyses will clarify to what extent high asthma hospitalization rates are correlated with high environmental burdens, the fact remains that the populations in the Bronx in closest proximity to air pollution sources are also those with higher risk of asthma hospitalization and higher likelihood of being poor and minority. Regardless of whether the high asthma hospitalization rates are due to environmental causes or result primarily from poverty and other sociodemographic factors, the findings of this research point to a health and environmental justice crisis.

LESSONS ON INTERDISCIPLINARY APPROACHES TO URBAN HEALTH RESEARCH

Benefits and Challenges of the Partnership

As we have described, a major benefit of the interdisciplinary and organizational collaboration is the complementary knowledge, skills, and perspectives that each partner brings to the effort, none of whom could accomplish the research or its translation into public policy effectively on their own. Partners regularly share information that originates in disciplines, advocacy networks, and professional circles that enrich and broaden the perspective of all parties. We function as each other's eyes and ears in many forums where we would otherwise be unlikely to participate. Each partner brings different organizational and institutional resources that support the collaboration, not always in stereotyped roles, particularly as FABB staff have considerable expertise and training in environmental science, food justice, and endocrine disruptors, whereas the academic and clinical professionals have little knowledge and experience in these areas. The community partners keep the academic and clinical professionals up to date on major environmental justice controversies and challenges well before they reach the mainstream media and have risen to leadership positions in citywide coalitions, such as the New York Asthma Partnership. Despite the differences between partners, described previously, mutual respect and trust have developed over time, permitting more debate, problem solving, and reflection. The partnership is still far from achieving the ideal, and time for reflection and discussion remains a precious and limited resource.

Perspectives of the Stakeholders and Lessons Learned

Each organization contributes a unique perspective to the partnership. Lehman College, for example, brings an academic perspective that combines activism with teaching and research. SBEJP has provided an avenue to expand available support to conduct GIS research. Lehman staff arranged for FABB staff to receive formal training in a GIS certificate program, and the partnership has supported the development of a master's degree program in public health at Lehman College and a master's degree in GISc, focusing on environmental and health spatial sciences. The physicians and faculty of the Albert Einstein College of Medicine are both clinical and academic partners in SBEJP and are employed by Montefiore Medical Center. Most of SBEJP's efforts address environmental aspects of public health and, therefore, broaden the clinician's perspective beyond caring for individual patients and families. Our community partner FABB offers an ongoing dialogue with the Bronx community served by the medical center and its staff. Our clinicians are challenged by how to incorporate into practice and public policy our findings about the increased risk for asthma hospitalizations posed by geographic proximity to sources of stationary and mobile air pollution.

Within the community, SBEJP provides resources, both financial and intellectual, for the growth and development of FABB, which also maintains a community-academic partnership with the Mailman School of Public Health of Columbia University. The two partnerships are quite different and enrich FABB's capacity and community impact in different ways.

Like so many CBOs in impoverished communities, FABB suffers with being underresourced and understaffed in trying to address all of the aspects of environmental justice that face the South Bronx. FABB has sought to break the cycle of underfunding that affects community-based organizations, but this remains an unrealized goal. FABB has been eager to assure that "street science" is respected for its superior local knowledge as well as its desire to better integrate community expertise with more traditional forms of expertise. FABB has invested heavily in youth internships, teaching in neighborhood schools, and collaborating with other South Bronx organizations to promote its broad environmental justice agenda and has greatly influenced SBEJP's overall direction, activities, and research.

CONCLUSION

An interdisciplinary partnership has conducted important research with significant findings that should help focus attention on reducing stationary point and mobile sources of air pollution in urban areas. The work undertaken collaboratively in the partnership, especially regarding advances in technical methods, resulted in more robust findings, which became substantively more accurate in all four categories of major pollution sources investigated. The partnership contributed to an ongoing, iterative, and developmental process for improving the methodology and only began to integrate the local knowledge and expertise of community residents and advocates. Only if the findings of this research are incorporated into public policies at the community, neighborhood, borough, and citywide levels will we have achieved the community empowerment sought through such collaboration and CBPR.

SUMMARY

In this chapter, we examined the interdisciplinary research process and outcomes in a study of air pollution and asthma in economically distressed, mixed land-use neighborhoods in the Bronx, New York. We analyze how the unique contributions of our academic, medical, and community partners successfully integrated geographic information science, clinical epidemiology, and street science to reach a more robust understanding of the impact of local microenvironments and individual exposures on asthma rates. Results showed that people residing within high-impact pollution zones (especially stationary sources) were more likely to be hospitalized for asthma and to be minority and poor, even after results were controlled for sociodemographic characteristics and despite the limitations of data sources and methodologies. We discussed the challenges of, and lessons learned by, working in an intersectoral partnership (e.g., differing mandates, resources, and power) and the need for research findings and collaborative processes to be incorporated into neighborhood and citywide policy making to reduce pollutant sources and improve health care.

DISCUSSION QUESTIONS

1. What is the added value of studying childhood asthma from a biomedical and environmental perspective compared to either perspective alone?

2. What are the contributions and limitations of geographic information science (GISc) to increasing scientific understanding of the relationships between exposures or risk factors and disease?
3. In the case history the authors present, what roles did each participating organization play in the research? What unique contributions did each make to the research? What were some of the key challenges they faced, and how did the research team work to overcome them?
4. What are the contributions and limitations of community-based participatory research to solving environmental health problems facing urban communities?

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