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Urban asthma and the neighbourhood environment in New York City

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Abstract

Asthma is now the leading cause of emergency room visits, hospitalizations, and missed school days in New York City's poorest neighbourhoods. While most research focuses on the influence of the indoor environment on asthma, this study examines the neighbourhood effects on childhood asthma, such as housing and ambient environmental hazards. Using Geographic Information Science (GIScience) we identify neighbourhoods with elevated concentrations of childhood asthma hospitalizations between 1997 and 2000 in US census tracts, analyze the sociodemographic, housing characteristics, and air pollution burdens from stationary, land use and mobile sources in these areas. The paper reveals the importance of distinguishing the specific and often different combinations of poor housing conditions, outdoor air pollution and noxious land uses that contribute to the high incidence of asthma in impoverished urban neighbourhoods.

Keywords: Asthma; Neighbourhood environment; Housing; Land use; Geographic information science

Introduction

Urban asthma is frequently described as one of America's fastest growing epidemics. The epidemic is particularly acute among poor, African-American and Latino children living in urban neighbourhoods. While the national prevalence of childhood asthma in 1999 was approximately 7% for all children under 15-years old, African-American children living below the poverty line were 15–20% more likely to have asthma (CDC, 2002). In large urban areas, the prevalence of asthma is even more severe. For instance, in New York City 17% of children have experienced asthma-like symptoms at some point in their lives (New York City Department of Health (NYC DOH), 1999). Children living in poor New York City neighbourhoods bear the heaviest burden of the disease and are three times more likely to be hospitalized for asthma as children who live in wealthy neighbourhoods (NYC DOH, 2003; Claudio et al., 1999). Asthma is the leading cause for emergency room evaluations, pediatric hospitalizations, and school absenteeism in New York City (NYC DOH, 2003).

Numerous factors are believed to be behind the distribution of urban asthma. Residential exposures, including environmental tobacco smoke and in-home allergens common in poor quality housing, such as mold

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and cockroach allergens, are consistently associated with the development and exacerbation of asthma (Sears, 1997; Weiss et al., 1993). Exposure to outdoor air pollutants, including ozone (O_3), particulate matter (PM) and hazardous air pollutants (HAPs), are also known risk factors for developing respiratory diseases, including asthma (Strachan, 2000; Gent et al., 2003; Delfino et al., 2003). While traditional asthma epidemiology has focused on individual and family level risk factors, many of the suspected contributors to asthma (both its onset and triggering once one has the disease) have contextual or neighbourhood effects. Neighbourhood physical characteristics frequently associated with asthma include poor housing quality and disproportionate environmental pollution burdens regularly found in low-income, minority urban neighbourhoods (Mott, 1995; Krieger and Higgins, 2002).

Increasingly, public health researchers have shown that neighbourhood or area characteristics may be related to health independently of individual-level attributes (Diez Roux, 2001; MacIntyre et al., 2002). The emerging field of social epidemiology emphasizes that both physical and social characteristics of neighbourhoods, such as persistent poverty, residential segregation, psychosocial stress, unemployment, inadequate transportation, lack of affordable food stores, unsafe recreation spaces, high crime rates, biased policing, concentrated environmental hazards, and social networks, are important for understanding population distributions of disease and well being (Kawachi and Berkman, 2003). This view of public health suggests that disease is not determined entirely by an individual's biologic composition, or ''who you are,'' or social context, or ''where you are,'' but rather both/and; so, who you are depends in part on where you are. However, with a few exceptions, the relationships between the physical characteristics of urban neighbourhoods and asthma have rarely been studied (Ledogar et al., 2000; Brugge et al., 2003; Wright and Fisher, 2003). Additionally, the few studies focusing on neighbourhood characteristics and asthma tend to examine one neighbourhood without performing cross-neighbourhood comparisons.

This paper seeks to assess the neighbourhood effects on childhood asthma hospitalization rates in New York City by analyzing the environmental characteristics of neighbourhoods that may be contributing to the onset and triggering of the disease and comparing across different neighbourhoods throughout the City. We aim to investigate the role of the physical neighborhood environment on childhood asthma hospitalization rates in New York City with a research premise that neighborhoods are important units for studying the contextual effects on health because their physical, social and economic characteristics all help structure the health status of populations living in them. Thus, the theoretical thrust behind our study is that the relationship between health and place is undeniable, but particular aspects of this relationship, including mechanisms and weight of particular neighborhood characteristics, have been inadequately explored.

While asthma hospitalization data are limited because they tend to reflect who seeks emergency treatment and do not necessarily represent asthma prevalence, these are the only asthma data currently available at the neighbourhood scale for all of New York City. Using childhood asthma hospitalization rates for the years 1997–2000 aggregated by US Census tracts, we analyze the relationship of asthma hospitalization rates and socio-demographic factors, neighbourhood housing quality, and environmental exposures such as polluting facilities, noxious land uses, and mobile-source air pollution. The purposes of the study are to identify, using Geographic Information Science (GIScience) techniques, New York City neighbourhoods with consistently high asthma hospitalization rates (some of the highest rates ever recorded in the United States) and analyze some of the neighbourhood-specific hazards, including housing and environmental exposures, frequently associated with urban asthma. A goal of this research is to better direct asthma management and prevention policies aimed at the neighbourhood and metropolitan scale.

Methods

Using GIScience methods, we analyse and map the spatial distribution of social and physical characteristics that appear to affect population health both within and across different neighborhoods in the same city. In order to combine mapping with spatial statistical tools, we selected GIScience methods. GIScience includes numerous analytic tools missing in other commonly used neighborhood-effect research methods, such as multilevel analyses, including techniques for spatially defining ''neighborhoods,'' analyzing the spatial distributions of hazards within selected areas (as opposed to just across areas and levels) and mechanisms for the ''smoothing'' of disparate point data to estimate the spatial distribution of hazardous exposures across small-areas (Mark, 2000).

This study uses cluster analysis and multiple data sets to define neighbourhoods with elevated asthma hospitalization rates in New York City. We then analyze the socioeconomic and physical characteristics of neighbourhoods with elevated asthma hospitalization rates, focusing on housing and environmental conditions. Our research methods recognize some key challenges confronting analyses of neighbourhood effects on health (MacIntyre et al., 2002). One challenge is defining "neighbourhood." We define neighbourhood using a spatial scan statistic that identifies adjacent US census tracts with elevated asthma hospitalization rates. We call these disease cluster areas "neighbourhood hotspots". A second methodological challenge is recognizing that neighbourhoods are only one level at which health is influenced, albeit an understudied level. Our research acknowledges the importance of an ecologic approach to health, where susceptibility and resistance to disease operates simultaneously at multiple levels, from individual, to family, to neighbourhood, to state, to nation. Finally, we recognize that our methods are limited because they fail to capture the dynamic and continual interaction between compositional ("who you are") and contextual ("where you are") characteristics for understanding health. However, while our study avoids the ecologic fallacy, we focus on neighbourhood characteristics because most researchers tend to fall victim to the "atomistic fallacy"—capturing individual-level data but ignoring the geographic and contextual characteristics of neighbourhoods (Diez Roux, 2001).

Asthma data

Asthma hospitalization data for the years 1997 through 2000 were obtained through INFOSHARE (http://www.infoshare.org) for the 2106 census tracts in New York City. This program consolidates hospitalization data obtained from the New York State Department of Health, Statistics Planning and Area-wide Research Council (SPARCS). The International Classification of Disease, Ninth Revision, Clinical Modfication (ICD-9-CM) diagnosis code 493 was used to identify asthma hospitalization discharge diagnosis. Asthma hospitalization rates per 1000 persons were calculated for ages 0–14 years for all census tracts for each year from 1997 to 2000. An average hospitalization rate per 1000 persons 0–14 years was generated using the calculated annual rates.

Demographic data for all census tracts in New York City were obtained from 2000 US Census File SF3a. In order to capture an area's socioeconomic status, we calculated the median household income, the percentage of the population in poverty, and the mean household rent. Race and ethnicity data for percentage of the population white, African–American, and Latino (non-white Hispanic) were also calculated.

Variable selection

Our study variables were selected to test whether the built environments of neighborhoods, including housing quality, location of hazardous air polluting facilities and noxious land uses, correlated with childhood asthma (Jackson, 2002). Our variables were selected to go beyond the conclusions of most asthma studies of urban neighborhoods: the lower the income and higher the percentage in poverty, the higher the likelihood of asthma. The variables reflect our hypothesis that material and social resources and assets, including income and wealth, act as fundamental causes of disease disparities and that greater specification of these resources, or lack thereof is necessary (Link and Phelan, 1996). We seek to respond to Macintyre et al. (2002) who note that the majority of studies investigating the neighborhood effects on health have concluded that "rather than there being one single, universal 'area effect on health' there appear to be some area effects on some health outcomes, in some population groups, and in some types of areas" (Macintyre et al., 2002: 128). Thus, our selection of variables is aimed at investigating the combination of small-area effects on asthma and to specify whether aspects of the built environment operate differently across neighborhoods in the same city with similar asthma hospitalization rates.

Housing data

Housing characteristic data were obtained for the percentage of units subsidized and public, the age of the housing stock, and the condition of units and buildings. We gathered data on public housing to capture the number of residents living on public assistance. The age and condition of residential buildings data were gathered with the assumption that older and substandard housing would be more likely to contain known triggers of asthma, such as mold and mildew, cockroach and rodent dander, and dust mites. The age and housing quality data were obtained from the New York City Housing Vacancy Survey for 1996 and the data on public housing units were obtained from the "Type of Housing–Public Housing, 1998" from the US Department of Housing and Urban Development (HUD). Both of these data sets are published with the publicly available 2000 US Census Data (http://www.census.gov/hhes/www/housing.html).

Environmental load profile

Environmental hazards data were obtained from multiple sources and compiled to create a composite area measure called the environmental load profile (ELP). The ELP was generated to estimate harmful respiratory exposures at the neighbourhood level. Since actual air monitoring is sporadic or non-existent at the neighbourhood scale, we used three proxies, stationary source polluting facilities, noxious land uses, and truck routes.

In order to estimate the respiratory burden from stationary source air pollution, we gathered data for all facilities emitting some pollution into the air from the US Environmental Protection Agency (EPA), Aerometric Information Retrieval System (AIRS) Facility Subsystem (http://www.epa.gov/enviro/html/airs/airs_query_java.html). These data include small stationary air polluting facilities such as boilers in apartment buildings and drycleaners. We also gathered data on air polluting facilities from the US Environmental Protection Agency (EPA), Toxic Release Inventory (TRI) system (http://www.epa.gov/tri). These are large facilities that emit larger amounts of toxic pollutants into the air than those in the AIRS database. Finally, we gathered data from the New York State, Department of Environmental Conservation, on the location of all the Municipal Waste Transfer Stations (WTS) in New York City. These are facilities that transfer residential, commercial and construction waste that is collected throughout the city to large long-haul trucks that ship the waste for landfill disposal outside the city. The air pollutants emitted by WTS are not monitored, but these facilities tend to have trucks queuing along neighboring streets waiting to dump their loads, trucks constantly entering and exiting, and front-loading construction equipment inside—all of which can generate a significant amount of air pollution. These data were aggregated and mapped by census tract and a facility density per square mile was calculated for each tract.

A second variable of the ELP included environmental burdens from potentially polluting land uses. Since data are not collected on the potential environmental health impact from living near land zoned for manufacturing or industry, we developed a dataset that contained all the potentially polluting land uses in each census tract. These potentially noxious land uses included areas zoned for heavy or light manufacturing ("M-zones") and/or contained one of the following uses; gas stations, repair garages, power plants, sub-stations, sewage treatment plants, bus depots, rail yards, and vacant property. These data were obtained from the New York City, Department of City Planning, *Bytes of the Big Apple* (http://www.nyc.gov). A density figure for each census tract of the number of potentially polluting land uses per square mile was calculated and defined as the composite variable "land use burden".

The third component of the ELP aimed to capture mobile source air pollution from diesel exhaust. Diesel particulate matter is a known hazardous air pollutant and triggers asthma attacks (Kinney et al., 2000). Since actual ambient air monitoring data at the neighbourhood level does not exist for diesel or particulate matter, we again used a proxy variable. In order to estimate mobile source air pollution, we gathered data on all truck routes within the city designated by the New York City, Department of Transportation (http://www.ci.nyc.ny.us/html/dot/html/trans_maps/truckroutes.html). Truck routes were selected because the majority of diesel particulate air pollution in New York City comes from trucks, not automobiles or buses. Similar to the other ELP variables, we calculated the density of truck route miles per square mile for each census tract. We called this proxy variable "truck route density."

Data analysis

Defining neighbourhood asthma hotspots

All data were entered into a Geographic Information System using Arcview software from Environmental Systems Research Inc., (http://www.esri.com). The first stage involved determining the location of asthma "neighbourhood hotspots," or neighbourhoods with consistently elevated asthma hospitalization rates for children under 14-years old. We defined a hotspot as contiguous census tracts where the observed asthma hospitalization rate exceeded the expected rate with a 90% confidence interval. Hospitalization rates were expressed as the number of hospital admissions with ICD-9 codes for asthma per 1000 residents under 14-years old.

We used *SatScan 3.5* (Kulldorf, 2003) to calculate several different hotspots using varied inputs. The Kulldorf Spatial Scan Statistic is a means to identify contiguous areas where the total number of cases within that area is significantly greater than would be expected given the population. The Kulldorf Spatial Scan Statistic has been used in fields as diverse as policing and public health on scales from the local to the national (Jefferies, 1998; Jemal et al., 2002). We used several iterations with different parameters to identify areas with consistently elevated asthma hospitalization rates. Different iterations included varying parameters such as limiting the population to those under 14-years old, including covariates such as race and income, changing the maximum hotspot size, and using data from 1997 to 2000 for each year individually as well as a collective average.

Throughout all these iterations, certain areas were consistently identified as having statistically significant high rates of asthma hospitalizations relative to the population. As expected and shown in Fig. 1, asthma hospitalizations for the years 1997–2000 were not randomly distributed throughout the city but were geographically clustered into four primary hotspots which we define as "neighbourhood hotpots" and they included: (1) South Bronx, (2) Morrisania/Belmont (3) Central/East Harlem, (4) Central Brooklyn. While these four areas contain 14% of the total population in the Bronx, Manhattan, Queens, and Brooklyn, they account for over 44% of the asthma hospitalizations for children 14 years and younger.

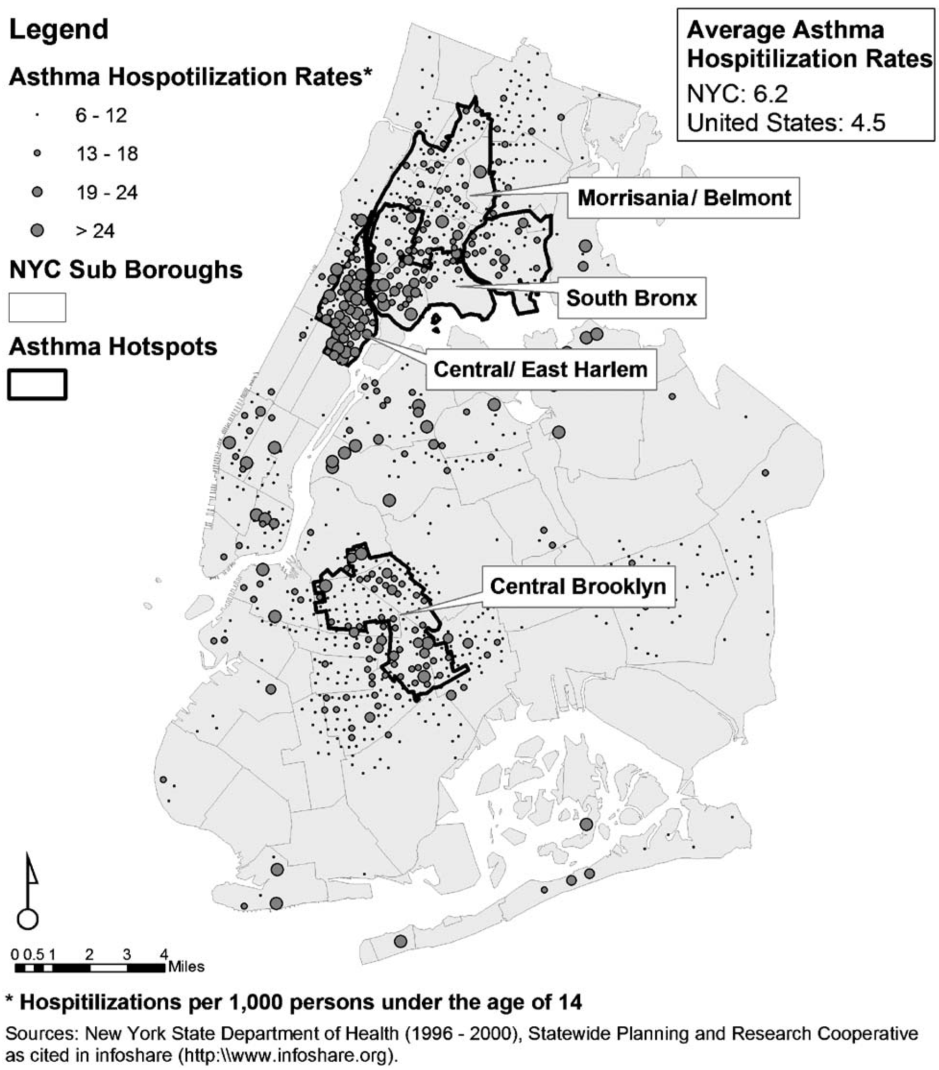

Fig. 1. Neighbourhood asthma hotspots, New York City, 1997–2000.

Using the asthma hospitalization hotspots as our ''neighbourhoods'' of study, we analyzed the demographic, housing and environmental characteristics within each hotspot, across all hotspots, outside all hotspots and across the entire study area (New York, Kings, Queens and Bronx Counties).

Neighbourhood characteristics

Asthma hospitalization rates for all children 0–14 years old between 1997 and 2000 in our ''hotspot'' neighbourhoods were 12.4 per 1000 persons, nearly three times the national average of 4.2 per 1000 persons and twice the NYC average of 6.4 per 1000 persons (NYC DOH, 2003) (Table 1). These rates are consistent with earlier studies by Carr et al. (1992) that found the annual hospitalization rate in New York City between 1982 and 1986 was 3.9 per 1000 and Claudio et al. (1999) who calculated a rate of 4.6 per 1000. Our findings indicate that the neighbourhoods of Central and East Harlem have had the highest asthma hospitalization rates in the city from 1997 through 2000. These findings are consistent with earlier studies claiming that Harlem has some of the highest asthma hospitalization rates in the United States (De Palo et al., 1994) and recent studies showing that this trend continues today (Findley et al., 2003; Citizens' Committee for Children of New York, 2000).

Table 1
Under 14 asthma hospital admits per 1000 under 14 population

	Hospitalization rate per 1000 persons under 14 years				
	1997	1998	1999	2000	Avg.
All Brooklyn, Manhattan, Queens and Bronx	8.82	6.42	7.65	5.86	7.19
All Hotspots	15.93	11.27	12.61	9.85	12.41
Central Brooklyn	14.74	9.71	11.81	9.37	11.41
Central/East Harlem	19.73	19.01	21.18	13.82	18.43
Morrisania/Belmont	15.47	8.95	10.25	9.16	10.96
South Bronx	15.75	11.50	11.89	9.22	12.09
Outside of Hotspots	6.35	4.74	5.93	4.48	5.37

Source: New York State, Department of Health, Statistics Planning and Area-wide Research Council (SPARCS).

Table 2
Socioeconomic and housing characteristics of neighbourhoods in New York City

Neighbourhood	Black (%)	Hispanic (%)	Median household income ($)	Percentage persons below poverty line (%)	Percentage public housing (%)	Dilapidated & deteriorating buildings (%)
All Brooklyn, Manhattan, Queens and Bronx	27.59	27.85	39,395	21.48	7.84	6.48
All Hotspots	48.77	50.31	21,665	37.60	22.70	11.05
Central Brooklyn	61.72	35.86	22,053	38.15	29.60	15.82
Central/East Harlem	60.17	35.34	20,601	35.94	31.97	17.19
Morrisania/Belmont	34.12	59.52	21,556	39.21	15.43	9.80
South Bronx	36.81	61.23	21,886	36.50	14.50	4.76
Outside of Hotspots	23.31	22.62	43,246	17.73	4.45	5.60

Sources: 2000 US Census File SF3a. New York City Housing Vacancy Survey for 1996; "Type of Housing–Public Housing, 1998" 2000 US Census Data (http://www.census.gov/hhes/www/housing.html).

Asthma and sociodemographic data

To understand how the neighbourhood socioeconomic characteristics of our four hotspots compared to areas outside the hotspots, we analyzed data on race/ethnicity, household income, and poverty (Table 2). We found that hotspot residents are almost twice as likely to be African–American and/or Latino. Over 60% of residents in the Harlem and Brooklyn hotspots are African–American and 60% of the residents in the two Bronx hotspots are Latino.

The median household income for residents in all hotspots is $21,665, roughly half that of those living outside of hotspots, $43,246. Over half the households in the hotspots make less than $25,000 per year, compared with 32% living outside the hotspots. Only eight percent of families in the hotspots have incomes above $75,000 per year, compared with over 25% of families living outside the hotspots. Almost 38% of hotspot residents are living below the poverty line, compared to less than 18% of those living outside the hotspots.

Finally, we grouped the census categories of population black and Hispanic to create a variable of the percentage of the population that is "minority." In order to show the distribution of asthma hospitalizations by race and ethnicity, we categorized census tracts as "predominantly minority" when 40% or more of the population was African American or Hispanic. Our map of these data and median household income, reveal that all our neighbourhood asthma hotspots are in areas with a high percentage of minority and low-income populations (Fig. 2).

Housing affordability and quality

The housing characteristics of those living in neighbourhoods with elevated asthma hospitalization rates were also analyzed. Residents in hotspots are five times as likely to be living in public housing than residents outside the hotspots (23% versus 4.45% respectively). Roughly one-third of the housing units in the Harlem

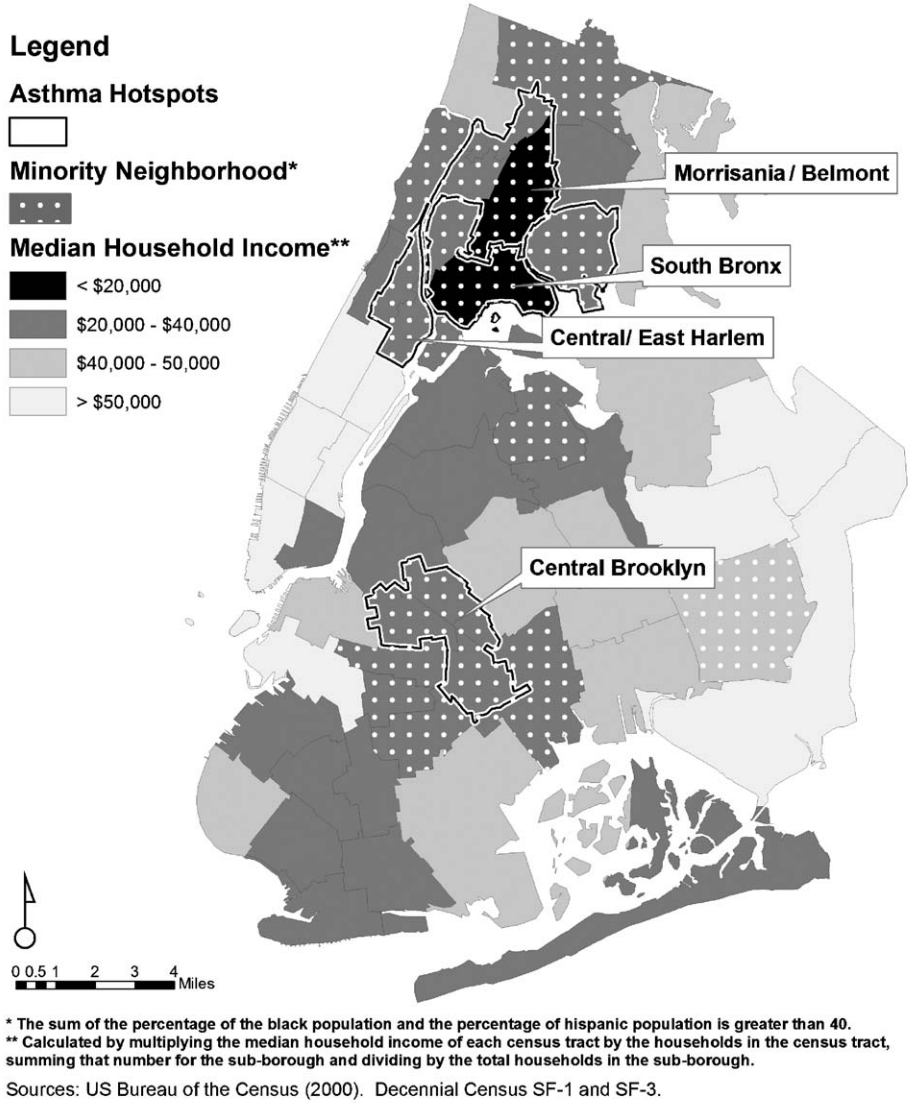

Fig. 2. Minority population, household income & neighbourhood asthma hotspots, New York City, 1997–2000.

and Brooklyn hotspots are in publicly run housing projects. Of the non-subsidized units, over 52% of residents pay less than $600 per month in rent, as compared to 24% of residents outside the hotspots. In Central/East Harlem, over 68% of residents pay less than $600 per month in rent while city-wide the average rent is between $1000 and $1250.

As compared to the areas outside the hotspots, over three times as many housing units in the hotspots were classified as dilapidated. Dilapidated housing was particularly acute in the Harlem hotspot, where 11% of all housing units were classified as dilapidated as compared to a citywide average of only 5.6%. This means that residents are living in buildings classified by building inspectors as virtually ''unlivable.'' Dilapidated buildings in the Harlem and Brooklyn hotspots (17% and 16%, respectively) were a particularly severe problem. This implies that close to one-fifth of residents in these neighbourhoods are living in homes that do not provide safe and adequate shelter and include such major structural defects as missing walls and roofing, boarded-up or missing windows, sloping, sagging and missing flooring, and other structural defects that ''cannot be corrected by normal maintenance'' (US Census, 2000) (Fig. 3).

Environmental load profile (ELP)

The density of air pollution sources was also analyzed and was as severe a hazard as the dilapidated housing.

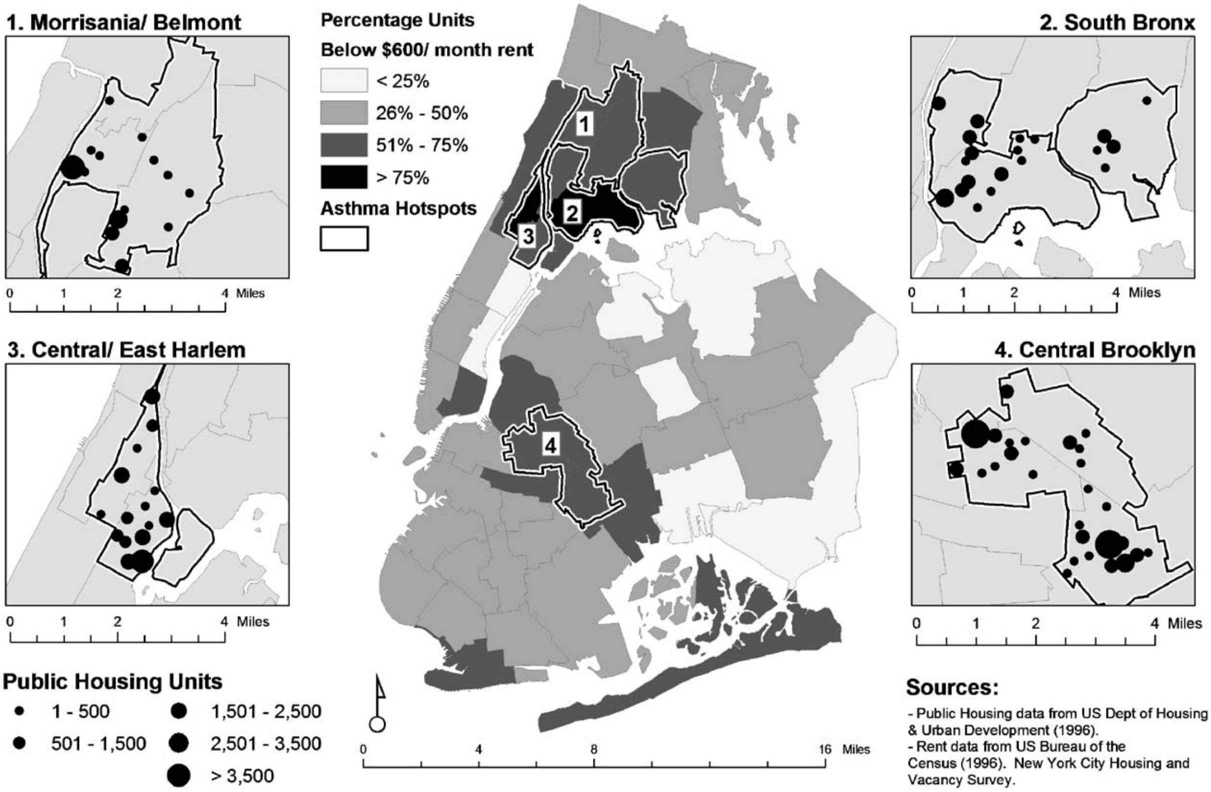

Fig. 3. Neighbourhood asthma hotspots, average rent & public housing in New York City.

Table 3
Neighbourhood asthma hotspots and environmental load

Neighbourhood	Air polluting facilities[a] (# per sq. mile)	Density of polluting land uses[b] (# land uses per sq. mile)	Truck route density[c] (miles linear roadway per sq. mile)
All Brooklyn, Manhattan, Queens and Bronx	15.84	261.99	25.97
All Hotspots	18.97	548.24	46.18
Central Brooklyn	15.31	990.61	14.46
Central/East Harlem	19.20	449.76	7.13
Morrisania/Belmont	16.34	394.76	82.85
South Bronx	23.36	383.66	55.81
Outside of hotspots	15.40	222.10	23.15

[a]Includes the following air polluting facilities: US Environmental Protection Agency, Aerometric Information Retrieval System (AIRS) Facility Subsystem (http://www.epa.gov/enviro/html/airs); Toxic Release Inventory (TRI) System (http://www.epa.gov/tri), and; New York State, Department of Environmental Conservation, Municipal Waste Transfer Stations.

[b]Includes manufacturing zoned zoned land, including land classified for use as, gas stations, repair garages, power plants, substations, sewage treatment plants, bus depots, rail yards, and vacant property (New York City, Department of City Planning, *Bytes of the Big Apple*).

[c]Source, New York City, Department of Transportation (http://www.ci.nyc.ny.us/html/dot/html/trans_maps/truckroutes.html).

Since actual monitoring data was not available at the neighbourhood scale across all study areas, we used proxy measures for air quality. According to our indicators, the type and intensity of potential air pollution varied across the four neighbourhoods. For example, in East/Central Harlem and the South Bronx, stationary air pollution sources were particularly concentrated while in Central Brooklyn there are four-times as many polluting land uses than in the other neighbourhoods (Table 3). In the Morrisania/Belmont section of the Bronx, mobile source air pollution from trucks, reflected in the density of roads designated as truck routes, accounts for the majority of the environmental pollution load in this area. We also found that polluting facilities clustered in neighbourhoods adjacent to our asthma 'hotspot' communities. This dynamic was especially apparent in Brooklyn along the Queens border with Long Island City, where we found the highest concentration of air polluting facilities for all of New York City in the neighbourhoods of Greenpoint and Long Island City, which are to the west/north west, up-wind, and adjacent to the Central Brooklyn asthma hotspot (Fig. 4).

To assess the relationship between asthma hospitalization rates and the socioeconomic and physical neighbourhood factors, Pearson correlation coefficients were calculated for each neighbourhood hotspot and outside all hotspots (Table 4). The strongest positive correlations were found between asthma hospitalization rates and the percentage of African–Americans, Latinos, and residents living in public housing. We also found a positive correlation with the percentage of dilapidated and deteriorating housing, and the density of polluting facilities, land uses, and truck routes. These values compared to a strong inverse correlation between asthma hospitalization rates and median household income.

Discussion

This study has shown a positive correlation between a set of social and physical neighbourhood characteristics and asthma hospitalization rates for urban children living in New York City neighbourhoods. These characteristics include low median household income, high percentage minority, public and inadequate housing, and multiple environmental pollution burdens. We have also mapped some of our results to visually display the relationships between asthma hospitalization rates and selected neighbourhood characteristics. We discuss

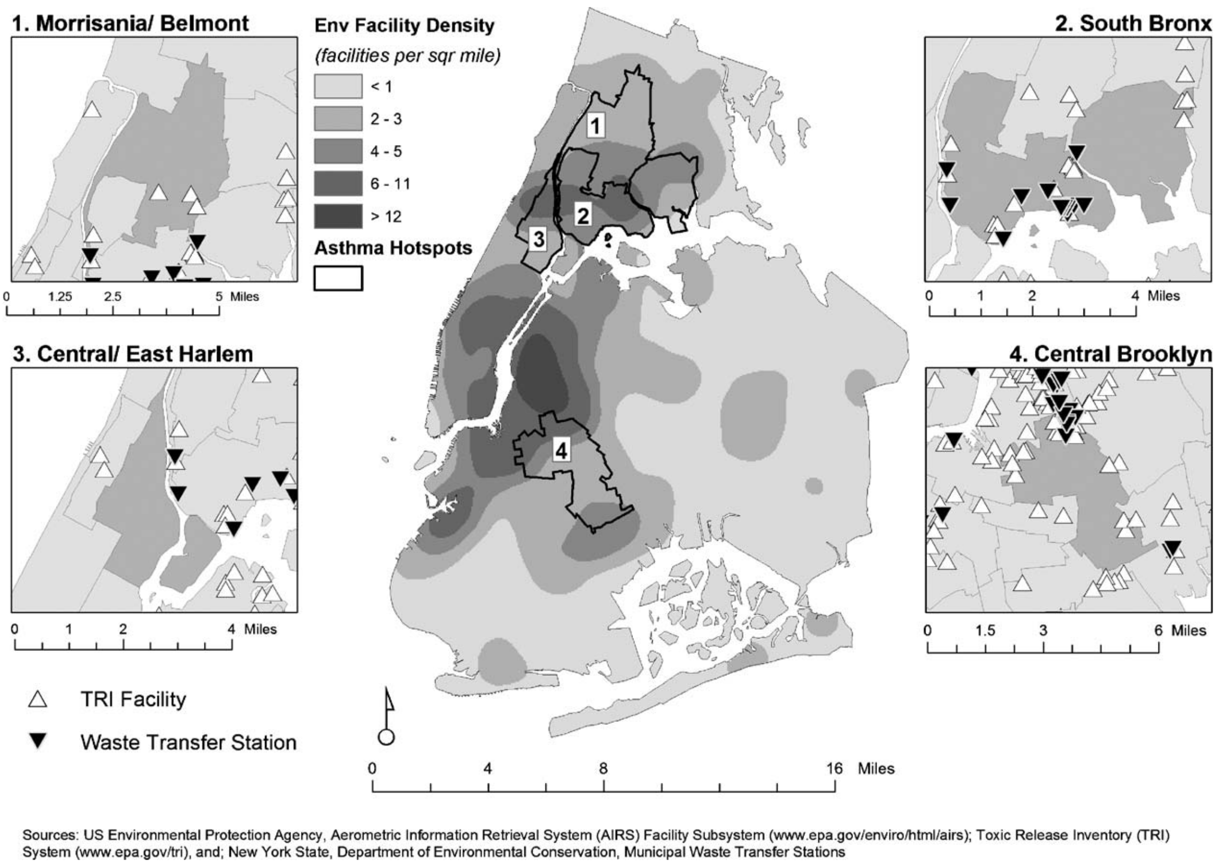

Fig. 4. Air polluting facilities & neighbourhood asthma hotspots, New York City.

Table 4
Correlation coefficients for asthma hospitalization rates, socioeconomic, and physical characteristics of neighbourhood hotspots in New York City

Neighbourhood	Median household income	Percentage African–American	Percentage Latino (Hispanic)	Percentage public housing	Percentage dilapidated/ deteriorated housing	Density of air polluting facilities	Density of polluting land uses	Density of truck routes
Inside all hotspots	−0.788	0.813	0.743	0.668	0.588	0.587	0.681	0.553
Central Brooklyn	−0.509	0.436	0.821	0.701	0.805	0.402	0.924	0.349
East/central Harlem	−0.806	0.782	0.843	0.816	0.731	0.826	0.470	0.117
Morrisania/Belmont	−0.672	0.687	0.528	0.632	0.599	0.353	0.436	0.928
South Bronx	−0.653	0.712	0.833	0.602	0.226	0.840	0.408	0.867

the implications of our findings in the remaining section of the paper.

Contribution to social epidemiology

Our study has extended work in social epidemiology by not only showing how GIScience can be used to incorporate ecological variables into contextual analyses but by highlighting that the contextual factors that may be driving health disparities can differ across disadvantaged neighborhoods in the same city. While most contextual studies tend to reinforce the notion that neighborhood deprivation, however measured, is bad for health, our work has emphasized the importance of geographic specification by highlighting how different neighborhood characteristics appear to exert a stronger influence on health across impoverished neighborhoods in New York City. Our study has also revealed how methods from multiple disciplines, including social epidemiology, geography and urban planning, can be combined to study the neighborhood effects on health. Using an interdisciplinary research approach we highlighted how, for example, spatial clustering techniques can simultaneously analyze and map toxic exposures and disease in small-geographic areas.

Our finding that there is a strong relationship between asthma hospitalization rates, low median household income and high percentage minority neighbourhood population, is not surprising. Previous studies by Carr et al. (1992), Claudio et al. (1999), De Palo et al. (1994), and the New York City Department of Health (1999) all found similar relationships. One explanation for these robust findings is that families with low incomes tend not to have access to primary care physicians or health insurance, thus they might use the hospital for primary care. The frequency of hospitalization visits might be compounded when minority residents receive substandard treatment while in the hospital (McDermott et al., 1996; Zoratti et al., 1998; Lieu et al., 2002).

A recent study by Ford et al. (2001) in Harlem found that poor residents relied on the emergency room and hospital care even when they had access to primary care. This study found that despite having a regular source of care, 69% of respondents identified the hospital as their preferred source of care for asthma. Among residents that had visited their primary care physician in the past year for asthma, 82% also visited the emergency room more than once in the same year for asthma treatment. These findings are consistent with other studies noting that poor inner-city residents, even when they have health care, are likely to visit the hospital for acute care (Lara et al., 2003). Thus, being poor and whether or not you have access to primary health care does not entirely explain why residents of certain neighbourhoods have elevated asthma hospitalization rates.

Housing conditions

Having a low-income, being a minority *and* living in substandard housing appear to be strong neighbourhood predictors of asthma hospitalizations. Deteriorating and dilapidated housing is likely to increase resident's exposure to indoor air pollutants known to trigger asthma, such as rodent and cockroach allergens, mold, mildew, and dust mites (Rauh et al., 2002). Substandard housing conditions may contribute to increased exposure to nitrogen dioxide, from inadequately vented or poorly functioning combustion appliances, and volatile organic compounds, emitted from particle board and floor coverings, both of which are associated with asthma. Housing classified as deteriorating or dilapidated reflect the extreme conditions of unhealthy shelter—boarded-up windows, burned-out apartments, and over-crowding—and the chronic hazards, such as cracks in walls and ceilings, leaky pipes, unrepaired water damage, and inadequate heating, associated with neglect and disrepair. These chronic conditions contribute to known asthma triggers, such as mold spore growth. Dangerous and unhealthy housing conditions, even in a wealthy city such as New York, remain a serious and all too common feature of low-income urban neighbourhoods (Krieger and Higgins, 2002).

Unsafe, deteriorating housing can also act as a social determinant of health. Dilapidated conditions often contribute to overall housing instability, the fear of homelessness, and chronic stress that acts as both an asthma trigger and a leading indicator of overall health (Krieger and Higgins, 2002; Fullilove, 1998). Run-down housing in a neighbourhood can become a place for criminal activity and violence. To avoid these unsafe outdoor conditions parents may be forced to keep their children indoors in substandard housing, increasing the likelihood of exposure to asthma allergens. The fear of violence, both outside and inside unlit hallways and elevators of large public housing developments, can contribute to psychosocial stress. Neighbourhoods with dilapidated housing often attract illegal dumping of municipal, construction and hazardous wastes, which can harbor pests that infest homes, further exacerbating asthma risks.

Environmental exposures

Our findings documenting the neighbourhood "environmental load" are also consistent with prior studies documenting that poor and minority communities have higher concentrations of polluting facilities and harmful air pollutants, such as diesel particulate matter that lodges in the lungs and contributes to respiratory disease (Kinney et al., 2000; Olden, 1996). A study by the American Lung Association found that over half of pediatric asthma cases occur in areas in non-attainment of EPA's air quality standards and that urban populations are disproportionately impacted (American Lung Association (ALA), 2001).

As noted above, our study of the neighbourhood burden from air pollution was limited because actual monitoring data at this scale do not exist. However, our proxy variables, density of stationary source air polluting facilities, polluting land uses, and truck routes for estimating mobile-source air pollution, confirm that the environmental pollution burden in the study neighbourhoods is particularly severe as compared to the rest of the city. Our findings have important implications for future neighbourhood-level studies and for environmental regulation more generally.

By estimating at the potential air pollution contributions from multiple sources, our study has highlighted the importance of studying the multiple environmental hazards in neighbourhoods and the cumulative burden chronic exposures to these hazards can place on susceptible populations, such as children. Urban neighbourhoods, particularly those with low-income populations and a majority of people of colour, tend to have many small polluting facilities that do not emit enough pollutants to be monitored by a regulatory agency but taken together represent a significant hazardous exposure for residents. Thus, estimating the pollution burden from noxious land uses, in addition to air quality monitoring, is necessary for understanding neighbourhood environmental hazards.

Land use patterns in most US cities are driven by zoning rules. Maantay (2001) has shown in a study of zoning in New York City from 1961 through 1998, that the zoning of land uses has changed significantly over this period and, perhaps more importantly to this study, that industrial zones have large residential populations in them that tend to be poor and minority. In this same study, Maantay reaches the conclusion that noxious land uses concentrate in minority and poor neighbourhoods not by chance, but by discriminatory public policies. There is a wealth of data in urban planning that supports the notion that zoning has historically been used as an exclusionary and discriminatory land use tool (Babcock, 1966). Our analysis of potentially noxious land uses reveals that these uses tend to cluster in areas with elevated asthma hospitalization rates, but more work needs to be done to estimate the environmental pollution burden from land use patterns.

By underscoring the importance of studying multiple environmental hazards at the local-level, this study challenges the current environmental policy system that regulates pollution with a "geographically neutral" approach. Currently, environmental regulations in the US place controls on specific hazardous agents or pollutants (e.g., lead, asbestos, radon), industries, or, less frequently, the route of exposure (e.g., drinking water, ambient air). In the case of each of these scenarios, the cumulative exposure burden from multiple hazardous agents nor the health effects of local zoning and land use regulations are considered. Our findings highlight the importance of considering multiple pollutants and sources, and the need to devise regulatory strategies that can address neighbourhood-level environmental pollution burdens.

Study limits

As noted in the introduction, our study is limited by the fact that we use asthma hospitalization data as a surrogate for asthma prevalence. Since we were concerned with neighbourhood characteristics, the hospitalization data we obtained did not include individual patient information. Associations we observe from neighbourhood characteristics may not necessarily hold true for specific individuals. Our hospitalization data also did not allow us to screen-out multiple admissions of the same patient, so results are the number of admissions, not asthmatic patients in a neighbourhood. However, hospitalization data at the census tract level are the only data available city-wide and the only data that allow for cross-neighbourhood analyses. Finally, our study could have been strengthened if actual air pollution monitoring data were available at the neighbourhood scale. In the absence of these data, we were forced to develop proxy variables for outdoor air pollution burdens.

These limits also reflect a reality faced by many researchers and public health agencies in urban areas across the US. The methodology outlined here provides one example for how public health researchers constrained by funding and/or lack of data can perform analyses of neighbourhood effects on health. This type of study, while admittedly incomplete, will continue to be important because it can speak directly to decision-making that occurs along pre-existing political boundaries.

Conclusions

This study has shown that neighbourhood context does matter for understanding the distribution of childhood asthma hospitalization rates in New York City. Our study has shown that an ecological approach is necessary for both studying and developing intervention strategies to address urban asthma. Understanding the neighbourhood effects on urban asthma will continue to require the use of emerging GIScience tools, some of which have been employed here. However, more detailed investigation are required to fully parse-out the contextual and compositional characteristics that contribute to urban asthma. This study has sketched a study approach and revealed some new findings, but further work is needed to address the growing epidemic of urban asthma.

References

American Lung Association (ALA), 2001. Urban air pollution and health inequities: a workshop report. [Congresses] Environmental Health Perspectives 109 (Suppl 3), 357–374.

Babcock, R., 1966. The Zoning Game: Municipal Practices and Policies. University of Wisconsin Press, Madison.

Brugge, D., Vallarino, J., Ascolillo, L., Osgood, N.D., Steinbach, S., Spengler, J., 2003. Comparison of multiple environmental factors for asthmatic children in public housing. Indoor Air 3 (1), 18–27.

Carr, W., Zeitel, L., Weiss, K.B., 1992. Variations in asthma hospitalization and death in New York City. American Journal of Public Health 82, 59–65.

Citizens' Committee for Children of New York, 2000. Keeping Track of New York City's Children. Citizen's Committee for Children, New York.

Claudio, L., Tulton, L., Doucette, J., Landrigan, P.J., 1999. Socioeconomic factors and asthma hospitalization rates in New York City. Journal of Asthma 36, 343–350.

De Palo, V.A., Mayo, P.H., Friedman, P., Rosen, M.J., 1994. Demographic influences on asthma hospital admission rates in New York City. Chest 106 (2), 447–451.

Delfino, R.J., Gong Jr., H., Linn, W.S., Pellizzari, E.D., Hu, Y., 2003. Asthma symptoms in Hispanic children and daily ambient exposures to toxic and criteria air pollutants. Environmental Health Perspectives 111 (4), 647–656.

Diez Roux, A.V., 2001. Investigating Neighbourhood and Area effects on health. American Journal of Public Health 91, 1783–1789.

Findley, S., Lawler, K., Bindra, M., Maggio, L., Penachio, M.M., Maylahn, C., 2003. Elevated asthma and indoor environmental exposures among Puerto Rican children of East Harlem. Journal Asthma 40 (5), 557–569.

Ford, J.G., Meyer, I.H., Sternfels, P., Findley, S.E., McLean, D.E., Fagan, J.K., Richardson, L., 2001. Patterns and predictors of asthma-related emergency department use in Harlem. Chest 120 (4), 1129–1135.

Fullilove, M.T., 1998. Promoting social cohesion to improve health. Journal of American Medical Womans Association 53, 72–76.

Gent, J.F., Triche, E.W., Holford, T.R., Belanger, K., Bracken, M.B., Beckett, W.S., Leaderer, B.P., 2003. Association of low-level ozone and fine particles with respiratory symptoms in children with asthma. Journal of the American Medical Association 290 (14), 1859–1867.

Jackson, R., 2002. The impact of the built environment on health: an emerging field. American Journal of Public Health 93 (9), 1382–1384.

Jefferies, E.S., 1998. A Multi-method Exploration of Crime Hot Spots: SaTScan Results. National Institute of Justice, Crime Mapping Research Center.

Jemal, A., Kulldorf, M., Devesa, S., Hayes, R., Fraumeni, J., 2002. A geographic analyses of prostate cancer mortality in the United States, 1970–89. International Journal of Cancer 101, 168–174.

Kawachi, I., Berkman, L.F., 2003. Neighbourhoods and Health. Oxford University Press, Oxford.

Kinney, P.L., Aggarwal, M., Northridge, M.E., Janssen, N.A., Shepard, P., 2000. Airborne concentrations of PM(2.5) and diesel exhaust particles on Harlem sidewalks: a community-based pilot study. Environmental Health Perspectives 108 (3), 213–218.

Krieger, J., Higgins, D.L., 2002. Housing and health: time again for public health action. American Journal of Public Health 92, 758–768.

Kulldorf, M., 2003. SatScan 3.5, Software for the Spatial and Space-Time Scan Statistics. National Cancer Institute, Bethesda.

Lara, M., Duan, N., Sherbourne, C., Halfon, N., Leibowitz, A., Brook, R.H., 2003. Children's use of emergency departments for asthma: persistent barriers or acute need? Journal of Asthma 40 (3), 289–299.

Ledogar, R.J., Penchaszadeh, A., Garden, C.I., 2000. Asthma and Latino cultures: different prevalence reported among groups sharing the same environment. American Journal of Public Health 90, 929–935.

Lieu, T.A.P., Lozano, J.A., Finkelstein, F.W., Chi, N.G., Jensvold, A.M., Capra, C.P., Quesenberry, J.V., Farber, H.J., 2002. Racial/Ethnic variation in asthma status and management practices among children in managed medicaid. Pediatrics 109 (5), 857–865.

Link, B.G., Phelan, J.C., 1996. Understanding sociodemographic differences in health—the role of fundamental social causes. American Journal of Public Health 86, 471–473.

Maantay, J., 2001. Zoning, equity and public health. American Journal of Public Health 91, 1033–1041.

Macintyre, S., Ellaway, A., Cummins, S., 2002. Place effects on health: how can we conceptualise, operationalise and measure them? Social Science and Medicine 55 (1), 125–139.

Mark, D., 2000. Geographic information science: critical issues in an emerging cross-disciplinary research domain. URISA Journal 12 (1), 45–54.

McDermott, M., Silva, J., Rydman, R., Giachello, A.L., Yarzagaray, E., Robinson, D., Peragallo, N., Barquero, H., Arrom, J.O., 1996. Practice variations in treating urban minority asthmatics in Chicago. Journal of Medical Systems 20 (5), 255–266.

Mott, L., 1995. The disproportionate impact of environmental health threats on children of color. Environmental Health Perspectives 103 (Suppl 6), 33–35.

New York City Department of Health (NYC DOH), 1999. Asthma Facts. Community Health Works. Department of Health and Mental Hygiene, NewYork.

New York City Department of Health and Mental Hygiene (DOH), 2003. Asthma can be controlled. NYC Vital Signs 2, 1–4.

Olden, K., 1996. Effects of air pollution on African-American and other minority populations. Otolaryngology—Head & Neck Surgery 114 (2), 255.

Rauh, V.A., Chew, G.L., Garfinkel, R.S., 2002. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. Environmental Health Perspectives 110 (suppl. 2), 323–327.

Sears, M.R., 1997. Epidemiology of childhood asthma. Lancet 350, 1015–1020.

Strachan, D.P., 2000. The role of environmental factors in asthma. British Medical Bulletin 56 (4), 865–882.

US Census, 2000. New York City Region. Housing & Vacancy Survey (Local Census): Bureau of the Census, US Department of Commerce.

Weiss, K.B., Gergen, P.J., Wagener, D.K., 1993. Breathing better or wheezing worse? The changing epidemiology of asthma morbidity and mortality. Annual Review of Public Health 14, 491–513.

Wright, R.J., Fisher, E.B., 2003. Putting asthma into context: community influences on risk, behavior, and intervention. In: Kawachi, I., Berkman, L.F. (Eds.), Neighborhods and Health. Oxford University Press, New York, pp. 233–262.

Zoratti, E.M., Havstad, S., Rodriguez, J., Robens-Paradise, Y., Lafata, J.E., McCarthy, B., 1998. Health service use by African Americans and Caucasians with asthma in a managed care setting. American Journal of Respiratory & Critical Care Medicine 158 (2), 371–377.