Spatial Analysis of the Environment's Influence on Pediatric Asthma in Baltimore City using a Geographic Information System

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Abstract

The problem being addressed in this proposed study is the tendency of residents living in low-income, inner city, and minority neighborhoods being exposed to poorer air quality than residents living in upper-income, suburban, white neighborhoods. As a result of the poor environmental conditions, poor urban dwellers experience higher rates of respiratory diseases such as asthma in their communities. The purpose of this proposed project is to study the environmental factors that are associated with an increase in pediatric asthma and identify which of these factors can be found in Baltimore communities using a geographic information system. The location of possible sources contributing to high concentrations of asthma occurrences in Baltimore City such as brownfields and major roadways will be examined. In addition, racial and socioeconomic conditions found in Baltimore will be analyzed to see if they can be linked to asthma rates. The proposed project's methodology will consist of an exploratory analysis of the asthma geographic epidemiology in Baltimore. The literature currently states that areas of high urbanization experience more cases of asthma hospitalization than rural areas. Anticipated findings include having a high concentration of asthma occurrences in Baltimore's predominately black, poor, and inner city neighborhoods. Furthermore, these disadvantaged Baltimore neighborhoods will be located right next to sources of environmental pollution.

Problem Statement

The amount of children living in Baltimore city who are hospitalized for asthma "is 2-3 times the national rate" (Kimes et al, 2004, p. 142). Asthma cases found in Maryland are linked excessively to the poor and African-American populations living in Baltimore City (Blistein, 2002; Gupta, 2008; Magzamen, 2007). The problem being addressed in this proposed study is the tendency of residents living in low-income, inner city, and minority neighborhoods being exposed to poorer air quality than residents living in upper-income, suburban, white neighborhoods. As a result of the poor environmental conditions, poor urban dwellers experience higher rates of respiratory diseases such as asthma in their communities. Not much has been done

using geographic tools to visually document the possible environmental sources and reveal the spatial patterns of the respiratory sickness occurrences. Furthermore, little research has been done using spatial analysis to map possible causes of pediatric asthma. Most of the current studies involving spatial analysis of asthma in urban communities document children hospitalizations (Magzamen). Possible sources that are detrimental to respiratory health include exposure to brown fields and major roadways (Kimes; Litt, 2001; Magzamen).

Purpose of Proposed Research and Proposed Research Questions

The purpose of this proposed case study is to examine Baltimore City's environmental affects on pediatric asthma and to document the demographic trends and environmental causes of these asthma hospitalizations found using geographic information systems (GIS). The project will assess whether the asthma and environmental conditions in Baltimore City follow the general trends for other urban areas as stated by the literature by combining possible causes of asthma on a map. The proposed project emphasizes the environment's big impact on community health (Stair, Wooten, Raimi, 2008). For example, if one's environment is not healthy, he or she will be constantly exposed to toxins that will make him or her sick (Diez Roux, 2001). In addition, by focusing on the environmental conditions that are specific to Baltimore City that affect pediatric asthma, it will help shape environmental health policies for the city's particular needs. Giving the aforementioned purpose statement and the nature of the problem, the following questions are proposed:

• What built environmental factors affect rates of pediatric asthma?
• Where are the sources contributing to high concentrations of pediatric asthma occurrences located?
• What populations are affected the most by these built environment factors?

Significance of the Inquiry

Implementing computer applications like GIS to study health problems is a relatively new field (Dearwent, 2004; Khan, 2003; Lai & Mak, 2007). Researching on the environmental conditions in Baltimore City and its affect on pediatric asthma is significant for the following reasons:

• To note the problem area populations and neighborhoods in Baltimore City
• To see how health problems and geographic location can be connected spatially
• To close the gap between urban planning and public health

Summary of Analytic Framework for the Proposed Study

A conceptual framework is a method for displaying data in a graphic form that uses a map to show connections among concepts. Several characteristics make a framework a good theory for quantitative research methods in public health such as

this proposed study. Concept maps help the researcher frame the project and make it easier to find common themes in the literature. Analysis of the data will be easier as thematic patterns are revealed from concept mapping.

The proposed project will be based on Tobler's first law of geography. As used in Dearwent's (p. 27) project, Tobler stated, "everything is related to everything else, but close things are more closely related." The quote is saying that events that occur near each other are somehow connected with each other. The proposal will use this theory to see how the locations of pediatric asthma, brownfields, major roadways, race, and socioeconomic statuses in Baltimore city are associated with each other.

When studying community urban health, several features are commonly observed. Typically, community health studies are also usually centered around one disease. For this project, pediatric asthma rates in Baltimore city will be studied as provided by the Baltimore City Health Department. The framework will be explained in greater detail in an upcoming chapter.

Theory is important to study because it is necessary for a research project to be grounded in previously applied theory. Projects need theory to define a focus and for analysis. Without theory, the legitimacy of a project will be questioned.

Assumptions, Limitations, Delimitations, and Scope of Proposed Study

Assumptions

There are some assumptions to consider when conducting this study. The researcher is going to assume that the populations included in health research are not changing neighborhoods since much research has been done on these neighborhood emigrational patterns and health (Dearwent; Diez Roux). Also, as stated by Magzamen (3), an assumption can be made that "asthma cases are distributed non-randomly throughout a community." The proposed project will attempt to prove that asthma cases do not occur by chance.

Limitations

Several limitations will occur during this research project. In general, there will be a struggle with limited resources. Time will be a limit, as the researcher will only have 5 weeks to complete the proposal. Furthermore, during the upcoming school year when the project will be implemented, the researcher will be limited by the constraints of a full college course load. The data collected during the project will be small. According to Magzamen (9), "analyses of the impact of place on health outcomes frequently rely on observational data…. inference on the impact of environment on health-related outcomes has been somewhat limited". The researcher will use GIS data already provided by demographic organizations such as the U.S. Census and Baltimore City Health Department. Finally, the proposed project is also limited to basic geographic mapping and statistical tools.

Delimitations

There are many factors that the proposed project does not include. The project is not about how the environment affects of diseases other than asthma. Adults that suffer from asthma will not be studied in this proposed project. The proposed project is not about poverty or environmental health conditions in rural communities. The specific environmental conditions plaguing residents of Baltimore County or other areas in Maryland will not be examined. Most importantly, the proposed research project is not about reforming health policy change in Baltimore.

Scope

The boundaries of the proposed research project are constrained to several elements. The project will examine the asthma health conditions of children who live in Baltimore City. Also, the project is focused on the environmental conditions found in Baltimore City that lead to these asthma respiratory health issues such as brown fields and major roadways. Other factors that will be taken into consideration for the analysis are the racial make-up and socioeconomic conditions of Baltimore city. The time that the project will be implemented will be from 2009-2010. For spatial analysis, the geographic information system that will be used is ArcGIS 9.3. The proposed study will use data from the U.S. Census and Baltimore City Health Department to compare the previously stated variables among Baltimore zip codes using maps.

Definition of Terms

The study will use terms unique to the investigation. The following terms are defined to make clear what the researcher is examining:

1. **Brownfield.** "An abandoned and under-used commercial and industrial facility with real or perceived contamination." (Litt, p. ii)
2. **Built environment.** The phrase built environment refers to the man-made surroundings that provide the setting for human activity. The natural environment consists of living and non-living things occurring naturally on Earth. The project will take into considerations the built environment conditions that affect asthma rates in Baltimore City. (Magzamen)
3. **Geographic information system.** A geographic information system (GIS) is a system for storing and manipulating geographical information on computer. It allows users to question, interpret, and visualize data that reveal relationships, patterns, and trends in forms of maps, globes, reports, and charts. For this project, the GIS tool ArcGIS will be used to visually document environmental, socioeconomic, and racial makeup conditions in Baltimore city as it correlates to asthma rates. (ArcGIS)
4. **Medical geography**. Also known as geographic epidemiology. It "describes the study of the geographic distribution of disease." (Dearwent, p. 29)

5. ***Neighborhood***. "Neighborhoods" (as well as other geographically defined areas) are interdependent and interacting parts within larger wholes health-related differences across neighborhoods may be partly shaped by how neighborhoods relate to each other within the larger city structure…in emphasizing the social attributes of neighborhoods, we should not forget that neighborhoods are fundamentally places that exist in physical space and often differ markedly in environmental, service, and resource characteristics. (Diez Roux)

Analysis and Discussion of the Literature and Presentation of Analytic Framework

Asthma

The full causes of asthma and its increase are not yet fully understood. However, asthma can be described as an "inflammatory" sickness "that arises from deregulation of immune responses toward environmental stimuli. The bronchial tubes in the lungs are inflamed, restricting airflow in the mouth and nose. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible, either spontaneously or with treatment" (Magzamen, p. 24, 25). There are three main parts of asthma: enhanced bronchial activity - "wheezing after exposure to irritants" (Magzamen, p. 27), reversible airflow obstruction, and chronic inflammation of the airways.

In the United States alone, about seven percent of the youth are diagnosed with the chronic illness of asthma. A widespread phenomenon for America's children, asthma leads to hospitalization, disability, and absence from school. Studies show that low-income and minority children are more commonly found with asthma than other children. In fact, asthma is found more in children living in the city than in rural settings (Magzamen, U.S. Environmental Protection Agency, 2009). The growth of asthma found in children can be linked to "genetic and physiological factors and environmental exposures" (Magzamen, p. 1) from air pollution. Overall, adults are being affected by asthma in higher rates than children. Still, the proposal will focus on asthma found in children. One reason for this focus is that the majority of asthma cases are found in children. In addition, studying pediatric asthma will be more pertinent to this proposal since the environment affects pediatric asthma rates more than it affects adults with asthma (Magzamen, Lit, Dearwent).

About 90 percent of blacks in America live in cities. Youth residing in cities usually receive less adequate treatment for asthma. Studies show that rural children are at lower risk than city children. This leads to urban children, especially African-American children being hospitalized more for asthma related causes than other youth. As a result, black children have more cases of asthma than white children. In addition, Magzamen also states that rates of asthma can be linked to poorer socioeconomic conditions. He stated that living in poor neighborhoods and below poverty levels is associated with higher rates of asthma. This could be contributed to lack of funds for medical assessments and living near high exposures of air pollution.

Both the indoor and outdoor built environment can trigger asthma found in children in urban areas. Poor ventilation is the result of crowded and meager housing conditions in urban neighborhoods, which "can increase exposure to respiratory pathogens" (Magzamen, p. 5). These conditions generate an explosion in asthma activators like mold, dust mites, and tobacco smoke. In addition, studies have shown that cockroaches, rats, and other rodents are linked with aggravating asthma found in urban populations. According to Magzamen, many inner-city families have limited access to financial and informational materials to get rid of the interior asthma triggers.

Furthermore, air pollution surrounding the environment in urban areas are linked with the presence of asthma. Living near roadways and factory plants has been some of sources of environmental causes of asthma for inner-city people. It is assumed that environmental pollutants affect the urban poor and ethnic groups the most (Brimblecombe, 2001; Diez Rou; Kimes; Litt; Magzamen).

Air pollution caused by traffic has also been a concern for many urban communities. The following air pollutants are big worries for people with asthma since they hinder oxygen transfer: Particular matter (PM), sulfur dioxide (SO2), Ozone (O3), carbon monoxide (CO), and nitrogen dioxide (NO2) (Ayres, 2006; Burkhart, 2002; Morales, 1998). Overall, cities tend to have more levels of air pollution than rural areas because of higher exposure to major road pollution than rural areas. The built environment affects asthma more in urban areas as a result of more infrastructures such as roads and buildings and less vegetation. Unlike vegetation, the infrastructure helps keep environmental pollutants trapped in a city (Kimes; Sorensen, 2006).

Baltimore and Asthma

Baltimore is the largest city in Maryland. The racial composition of Baltimore City population is about 90% Caucasian and African-American when combined (U.S. Census). The amount of children living in Baltimore city who are hospitalized for asthma "is 2-3 times the national rate" (Kimes). Asthma cases found in Maryland are linked excessively to the poor and African-American populations living in Baltimore City (Baltimore City Health Department). As stated earlier, black children have more cases of asthma than white children (Magzamen).

GIS

In epidemiology, spatial analysis is defined as the study of how spatially based health statistics are connected to the way environmental, socioeconomic, and demographic characteristics are spread out geographically. Thus, spatial analysis is an important method for the proposed project in examining the relationship among pediatric asthma, environmental factors, and demographic conditions. An important tool for spatial analysis is called geographic information system (GIS). GIS is a system for storing and manipulating geographical information on computer. It allows users to question, interpret, and visualize data that reveal relationships, patterns, and trends in forms of maps, globes, reports, and charts (Lai, Khan, Magzamen).

GIS has three main uses when it comes to health applications. First, GIS can be used to expose the spread of disease such as asthma visually on a map. Second, these patterns of disease can be used to identify sources of causes of disease. Third, GIS can be used to discover the people who are affected by asthma and its related causes (Magzamen). Overall, GIS tools can be applied to tracking asthma occurrences in neighborhoods and documenting possible causes. For this proposal, it will help reveal the asthma problem areas found in Baltimore City visually on maps.

Strengths, Summary, and Implications of the Literature

Most of the literature went into thorough detail explaining what asthma is and how it affects the body. However, little research has been done that specifically describes that asthma conditions and causes that occur in Baltimore city. Many researchers have also noted how asthma how asthma affects certain populations the most. Also, though most of the literature mentions how the built environment affects asthma rates, most of the literature focused on indoor pollutants rather than outdoor pollutants. Finally, though the implantation of GIS to health is relatively new, many studies have extensively covered how the use of GIS can be beneficial to health research.

Overall, the literature states that asthma is a chronic lung disease that inflames the bronchial tubes and impedes breathing. The environment tends to affect children with asthma more than adults. Higher exposure to environmental pollutants leads to higher rates of asthma found in urban, African-American, and poor populations. Finally, the rates of asthma found in Baltimore city are higher than the national average's rates.

The implication for this proposed study is to try to improve public health for all residents in an urban community. The ideal situation would be that all people have access to healthy environments to lower their risk of disease. However, the researcher only advocates for people to live in a city if they know that the neighborhood they live in will be healthy. This is because moving into areas of poverty and destruction will negatively impact one's health greatly.

Presentation and Discussion of the Analytic Framework

The proposed project will be based on Tobler's first law of geography. As used in Dearwent's (p. 27) project, Tobler stated, "everything is related to everything else, but close things are more closely related." The quote is saying that events that occur near each other are somehow connected with each other. The proposal will use this theory to see how the locations of pediatric asthma, brownfields, major roadways, race, and socioeconomic statuses in Baltimore city are associated with each other.

When studying community urban health, several features are commonly observed. Typically, community health studies are also usually centered around one disease. For this project, pediatric asthma rates in Baltimore city will be studied as provided by the Baltimore City Health Department. Like in Magzamen's study,

this proposal will examine environmental, racial, and socioeconomic data in Baltimore city as provided by the U.S. Census. Similar to Litt and Magzamen's studies, environmental conditions that will be looked at are brownfields and major roadways in Baltimore city. Pediatric asthma rates between black and white children in Baltimore city will be compared since these races make–up 90% of the population in Baltimore city (U.S. Census). Also, pediatric asthma locations will be compared with the locations of between the rich and poor in Baltimore City to see if there are possible health disparities. Finally, when studying urban health, the methods of spatial analysis can be used to measure geographic locations of asthma and how it relates to environmental factors in a neighborhood using a geographic information system (Magzamen).

Research Design and Methodology
Purpose of Inquiry and Inquiry Questions
Methods for Collecting and Analyzing the Literature

Data Collection and Data Sources for Future Research

For the proposal, the University of Maryland College Park library's archives and databases will be used to collect data. The following data sources will be examined for analysis for this proposal: dissertations, demographic data, Baltimore City health data, public health journals, city guides, and U.S. Census data.

In the future research project, the following data collection strategies will be used. Diez Roux recommends studies on neighborhood to make use of both old and new data. As Diez Roux suggests, this study will attempt to connect current demographic and geographic data found from the Census to health data conducted by the Baltimore City Health Department. Since the Census does not provide data on specific neighborhoods, zip code boundaries will be used to compare the environmental, socioeconomic, and racial makeup conditions of Baltimore. Graphs will also be used to document the asthma data to decrease the chances of bias that occurs if maps are used (Diez Roux). This study will add something new by providing extended analysis comparing environmental, socioeconomic, and racial makeup in Baltimore city as it relates to pediatric asthma. Spatial analysis will be done to see if there is a correlation between the previous built environmental conditions and asthma occurrences in Baltimore City by overlaying all the previously stated variables on one map.

Data Analysis Strategies

The proposed project will consist of an instrumental explanatory case study methodology of the Baltimore community. For the future project, two possible methods of analysis could be used: spatial autocorrelation cluster analysis and multilevel logistic regression analysis. Spatial autocorrelation cluster analysis will be used to measure the frequency of asthma in Baltimore City. The multilevel logistic regression analysis will be used to measure the affect of the environmental conditions

on community respiratory health in Baltimore (Dearwent). The computer program ArcGIS 9.3 will be used to visually document the occurrences of allergies and asthma and the previously mentioned environmental conditions that cause them on maps.

According to Diez Roux, research done on neighborhood health should implement many types of research methods. For the best analysis, the proposed project will include varied neighborhoods, an upper class and lower class one, as Roux suggests in his study. Given that the proposed project will be quantitative, Roux (1785) suggests that the project "include data on both individuals and the areas in which they live." In addition to the previously stated environmental conditions, the following demographic data will be included in this study for analysis to link with asthma rates: racial composition and income levels Baltimore city. Diez Roux believes that a mixed methods study comparing neighborhoods in depth would be best. Thus, a qualitative case study with extensive literature review on the specific environmental conditions found in Baltimore city will also be conducted (Berg, 2009).

The proposed study will follow similar procedures taken on by Magzamen who has done a similar epidemiological study. A geographic information system will be used to examine the association among Census population data, geographic locations of pediatric asthma occurrences, and built environmental conditions in Baltimore, MD. The environmental aspects that will be examined include residential proximity to major roads and brownfields linked with causing asthma. Other factors linked with asthma occurrences such as income and race will also be studied in this descriptive exploratory analysis study (Magzamen).

Census tracts and block groups are frequently used in quantitative human population health studies in examining individual and group-level traits because of its set data units. The U.S. Census is a useful tool for this proposal for two reasons. Census tracts provide useful outline boundaries for analysis such as zip codes, roads, highways, and water feature boundaries. Also, the data from the U.S. Census is reliable because it has been collected for many years. "The census tract is a convenient geographic unit on which to base neighborhood measures due to the large amount of administrative data through the decennial census" (Magzamen, p.122). The use of classifying neighborhoods by Census Zip codes or census tracts is a tool highly used when examining health differences in urban communities.

Choropleth maps will be used to visually display the Census data. With choropleth maps, data value ranges are represented by color hues separated by boundary lines. Because of the data made available by the U.S. Census, choropleth mapping is a practical method to use for spatial analysis.

Land use information related to brownfields will be gathered from Litt's study on Baltimore. GIS will be used to combine land use planes with census data borders. Data on roadways will be gathered from the Census. The classification of the roadways used will be limited to major highways. This study will examine if there is a correlation between asthma occurrences in children and proximity

to traffic exhaust from railroads. As stated earlier, pediatric hospitalization, race, socioeconomic levels, and roadways will be the Census attributes studied in this proposal. Like in a previous study, "exposure to traffic exhaust will be determined by residential distance to" (Magzamen, p. 14) railroads using the buffering tool in ArcGIS.

To examine the association between locations of pediatric asthma and socioeconomic conditions, poverty level attributes in Baltimore city from the Census will also be used. "The burden of asthma among black children warrants particular attention" (Magzamen, p. 66, 67). Thus, this proposal will also focus on the disparity of asthma epidemiology between the white and black population in Baltimore City.

An exploratory analysis of the relationship between environmental factors and pediatric asthma occurrences in Baltimore will be conducted using a geographic information system. Furthermore, like in Magzamen's epidemiological study, the proposed project will utilize a GIS to examine the association between census socioeconomic data and hospitalization of children with asthma data. The objective will be to combine all the previously stated variables with urban pediatric asthma to see if they line up on a map. Like in the Magzamen study, the proposed project will test for the probability of environmental, socioeconomic, and racial influences on asthma rates using generalized estimating equations (GEE). The statistical software that will be used for analysis will be SAS.

Ethical Considerations

There are many ethical considerations that will be considered for the future research project. The researcher will attempt to make sure that the data presented is not misleading or incorrect. Also, the researcher will attempt to make sure that city of Baltimore is not blamed for the pediatric asthma hospitalizations found. Finally, the data reported about the pediatric asthma will remain confidential (Bowling, 2002; Neutens, 2002).

Anticipated Limitations of Research

One of the main limits of the future research will be finding environmental data that links corresponds to Baltimore city specifically. Due to limited time, the researcher will be limited to data already conducted or available on the environmental conditions in Baltimore. Thus, brownfields in Baltimore were chosen as an environmental factor because of the study done by Litt. Also, major roadways in Baltimore such as railroads were chosen as an environmental factor because the U.S. Census already provides this data. Also, since the U.S. Census tends to aggregate data by zip codes, this proposed project will be limited to pediatric and demographic data that is generalized for entire zip codes instead of individualized for neighborhood differences.

Findings, Conclusions, and Recommendations for Future Research

Findings from the Literature

The purpose of the proposed project is to examine and analyze the spatial patterns of pediatric asthma found in Baltimore City. Providing strong background knowledge for the project, the literature review offered a general overview of applying GIS applications to asthma conditions in urban communities. As stated previously, the following questions were proposed to study the relationship between built environment and pediatric asthma:

• What built environment factors affect rates of pediatric asthma?
• Where are the sources contributing to high concentrations of pediatric asthma occurrences located?
• What populations are affected the most by these built environment factors?

Kimes made several conclusions about asthma rates found in Baltimore city and environmental and socioeconomic conditions. He stated that as urbanization increases in an area, the rates of asthma increases because of the increase in built material and decrease in vegetation. Some of this can be linked to the traffic related pollution caused by transportation vehicles on roadways.

As stated by Magzamen, in general, the built environment has an association with asthma found in children living in city neighborhoods. In terms of major roadways, there was a positive correlation with pediatric asthma. Furthermore, Magzamen stated that highways had no correlation with pediatric asthma while living near interstates had a positive correlation. In terms of ethnicity and asthma, "black race was associated with increase odds of asthma" (Magzamen, p. 181). In terms of socioeconomics, the highest rates of poverty where linked with high rates of pediatric asthma hospitalizations. These findings can be contributed to blacks and the poor having less access to health resources.

The overall trend in asthma hospitalizations for the state of Maryland in 2004–2006 tended to be higher in urban areas. As a result, Baltimore City had one of the highest rates of asthma hospitalizations compared to other Maryland districts (Maryland Family Health Administration, 2008). In terms of asthma rates found in Baltimore City, the Baltimore City Data Collaborative and Goddard Space Center organizations provided the answers. According to their studies, the highest rates of pediatric asthma hospitalizations were found in the inner–city zip codes of Baltimore City in 2005. The outer edge zip codes of Baltimore City tended to have fewer rates of asthma hospitalizations. These findings all support the statement that asthma rates tend to be higher in areas of high urbanization.

Conclusions Based on Review of the Literature

Based on the literature, the environment cannot be the claimed as the main cause of asthma found in children. However, it can be said that asthma conditions found in urban youth can be highly influenced by the neighborhood conditions that the children live in. The trapped pollutants found in urban environments as a result of increased infrastructure can aggravate the asthma outbreaks found in children. Also, being a minority and a person of lower class will also increase a child's chance of being diagnosed with asthma because of their tendency to live in impoverished areas. However, as studies show, in Baltimore, "the way that people distribute themselves in Baltimore City is highly correlated to race, socioeconomic, and urban characteristics." Thus, it only makes sense that certain populations will have higher rates of asthma as they live in areas that high exposures of toxins.

Furthermore, though this study focuses on pediatric asthma in Baltimore, findings from this proposed project can helpful to many city neighborhoods. The project can encourage local health officials to work with urban planners to improve communities for residents of all races and economic backgrounds. As a result, everyone would live in neighborhoods that would not make him or her sick.

Recommendations for Future Research

For future research, more needs to be done discover other possible sources of pediatric asthma by the built environment in Baltimore City. The researcher would like to look into proximity to abandoned housing, industrial factories, and gas stations to see if those environmental factors can be linked with asthma. Also, a project needs to be implemented to locate the locations of these sources and put them on maps for more detailed spatial analysis. The researcher would also like to possibly keep track of asthmatic children who move out sick urban environments to see if their asthma conditions improve by living in healthier communities.

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