The Spatial Variability of Asthma and its Link to the Distribution of Aerosols in the Atmosphere:

Correlation and Analysis

Written By:

Marquise McGraw, Bronx H.S. of Science

Mita Singh, Bronx H.S. of Science

Contributors:

Leon Abbo, Bronx H.S. of Science

Autumn Anderson, Bronx H.S. of Science

Faculty Advisor:

Mr. Mitch Fox, Bronx H.S. of Science

Research Scientist:

Dr. Barbara Carlson, NASA GISS

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Introduction

It has long been hypothesized that certain conditions in the environment tend to aggravate human health. Asthma is one disease that is hypothesized to meet this criterion. Its causes have yet to be pinpointed, but it is suspected that its prevalence is somehow related to the environment. It is important to study the causes and factors that affect asthma because while asthma was rare in 1900, it has now grown into an epidemic. There are more than 15 million people affected in the United States and up to 10 times as many around the world[1].

It is currently hypothesized in the scientific community that particulate matter may have an impact on the prevalence of asthma. Particulate matter (PM) are extremely tiny aerosol particles that have been shown to adversely affect one's health. In fact, for every 10 microns of PM which existed in a certain area, the death rate rose 0.5%[2]. Increasing evidence has shown that a rise in the levels of particulate matter can aggravate existing asthma, while evidence that PM can promote the induction of asthma is limited[3]. PM in ambient air has been associated with increased emergency room visits and medication use by asthmatics as well[4]. Other aerosols, such as NO_2, and SO_2, are also theorized to have some sort of effect on asthma.[5]

In this research project, we focused on finding a connection between the spatial distribution of asthma and the spatial distribution of these three aerosols in the atmosphere. It is hypothesized that there is a direct correlation between aerosols and asthma. We intended to see if this hypothesized relationship was true in New York as we compared asthma rates with spatial aerosol distribution in the Bronx, Brooklyn, Manhattan and Queens. The following questions were considered:

- How does the prevalence of asthma differ between the boroughs of New York City?
- How does asthma prevalence differ between the schools surveyed?
- What factors could account for these differences?
- Can increased particulate matter in the atmosphere be correlated to an increase in the prevalence of asthma?

In order to do this a survey was distributed in seven schools around the city in May 2001 to determine the prevalence of asthma within each school and each borough. The data, drawn from a sample size of 1,404 New York public school students, were sorted and analyzed by school and borough. This data was then compared with hospitalization data obtained from the State Health Department and the EPA to determine whether there was truly a spatial relationship between aerosols and asthma.

Background

In a person who has asthma, at times the circular smooth muscles of the branching air tubes of the lungs, the bronchi, go into spasm so that the bronchi are narrowed and the passage of air is impeded[6]. It is often easier to breathe in than out and the lungs become inflated and cannot be easily emptied. A wheeze on breathing out is a regular feature of an asthma attack. The most common type is allergy-induced asthma, but asthma can also be induced by infection, emotional factors, occupational factors, exertion, and temperature[7]. No one knows for sure why the prevalence of asthma is on such a steep climb but research shows that it is possible that many of the following factors might be acting to cause this to occur:

- Increased rates of maternal smoking
- Changes in our diet (less fresh food, less fish, more processed/ refined food)
- Changes in our environment (more clustered, less ventilated homes)
- Changes in furnishings (which, together with reductions in ventilation, expose us to potentially greater quantities of dust mites)
- Alterations in the type and frequency of certain infections to which we were exposed in early life (might infections in early life beneficially stimulate our immune system and suppress asthma?)
- Changes in outdoor pollution exposure [8]

It is also important to examine the social impacts of asthma. Students with asthma miss the highest number of school days, don't do as well as their peers on tests and often feel dejected, depressed and unfocused because of this delicate condition[9]. Adults are also affected by the strict regime required to keep asthma under constant check. Many feel depressed because of the fact that they have to spend large amounts of money on asthma medication, must take the same medicines day in and day out and must limit their activities so that they don't aggravate their condition.

Atmospheric aerosols are very fine particles suspended in the air. They are formed by the dispersal of material at the Earth's surface (primary aerosols), or by reaction of gases in the atmosphere (secondary aerosols). They include sulfates and nitrates from the oxidation of sulfur dioxide and nitric oxide respectively. Natural aerosols, which also include sea salt and volcanic dust, are probably four to five times more than man made ones on a global scale[10]. Although making up only one part in a billion of the mass of the atmosphere, they have the potential to significantly influence the amount of sunlight reaching the Earth's surface, and therefore climate[11].

Like greenhouse gases, aerosols influence the climate. Atmospheric aerosols influence the transfer of energy in the atmosphere in two ways: directly through the scattering of sunlight, and indirectly through modifying the optical properties and lifetimes of clouds. The scattering of sunlight by aerosols is clearly demonstrated in the aftermath of a major volcanic eruption, when exceptionally colorful sunsets can be witnessed. The volcanic pollution results in a substantial reduction in the direct solar beam, largely through scattering by the highly reflective sulfuric acid aerosols. Overall, there is a net reduction of 5 to 10 percent in energy received at the Earth's surface[12]. An individual eruption may cause a global cooling of up to 0.3ºC, with the effects lasting anywhere from one to two years[13].

However, estimating the impact aerosols will have on longer-term global climate is complex and uncertain. This is largely because of the fact that the geographical distribution of aerosols is highly variable and strongly related to their sources[14]. The best estimates of global cooling attributable to man-made aerosols are based on computer models. These show that the global cooling effect of man-made aerosols could offset the warming effect of increased greenhouse gas concentrations by as much as 30%[15]. The variable distribution of aerosols however, makes calculation of a global average difficult. Nevertheless, it is likely that aerosols may slow the rate of projected global warming during the 21st century[16].

Another type of aerosol comes from human activities. A large fraction of human-made aerosols come from the burning of biomass and fossil fuels. The concentration of human-made sulfate aerosols in the atmosphere has grown rapidly since the start of the industrial revolution. At current production levels, human-made sulfate aerosols are thought to outweigh the naturally produced sulfate aerosols[17]. The concentration of aerosols is highest in the northern hemisphere where industrial activity is centered[18]. The sulfate aerosols absorb no sunlight but they reflect it, thereby reducing the amount of sunlight reaching the Earth's surface. Sulfate aerosols are believed to survive in the atmosphere for about 3-5 days[19]. The sulfate aerosols also enter clouds where they cause the number of cloud droplets to increase but make the droplet sizes smaller. The net effect is to make the clouds reflect more sunlight than they would without the presence of the sulfate aerosols. It is also believed that the additional aerosols cause polluted clouds to last longer than non-polluted clouds[20].

Even though it is unclear how aerosols affect the human body in order to increase the prevalence of asthma, it is quite clear that they can aggravate it. Asthma is a global problem that has worsened throughout the United States, but most markedly in low-income urban areas[21]. Even though the theory that suggested that increased amounts of pollution resulted in increased amounts of asthma has been discarded, it is now suspected that NOX compounds released by the burning of fossil fuels in a particular area directly affect the prevalence of wheezing in 13-14 year olds in that same area[22].

Methodology

The problem that was analyzed has two dimensions to it. First, the relationships, if any, within the data from the asthma survey must be determined. Second, the data from the EPA, regarding aerosols in the atmosphere for the year 2000 must be analyzed for specific trends. Finally, the relationships in both the asthma proportions and the aerosol concentrations must be compared in order to determine trends or distributions common to both which would provide a link between the aerosols and asthma prevalence.

The data from the asthma survey was organized and analyzed based on school. Once we obtained statistics for those data, all the school data sets were combined to make one combined data set, with sample size (n) = 1404. This was sorted by borough, and the data were analyzed based on borough. EPA data regarding three types of aerosols known to aggravate asthma, PM 10, SO_2, and NO_2 were obtained for the year 2000, averaged and sorted by borough. Then, an overall comparison was made in order to obtain a conclusion.

Analysis of Survey Data

Data were compiled from seven schools throughout four of the five boroughs, excluding Staten Island. The asthma surveys were randomly administered to adolescents anywhere between 12 and 18 years of age within each school. Surveys completed by adults, or that were not legitimate in other ways were discarded. The proportion of students surveyed who indicated that they had asthma was obtained for each of the seven data sets.

Is there evidence of a spatial distribution of asthma between the seven schools themselves?

The two schools sampled in Queens, Townsend Harris and MAST High School yielded the lowest prevalence levels, 9.1% and 11.1% respectively. The Bronx High School of Science was sampled in order to obtain data for the Bronx. Unfortunately, the majority of the students who attend Bronx Science reside in Queens, and therefore, it was not a very good representation for the Bronx data set. The prevalence level obtained from Bronx Science was 12%.

In Manhattan, samples were taken from Urban Peace Academy (UPA), Frederick Douglass Academy (FDA). and Health Professions H.S. There was 15.5% prevalence at UPA. At FDA, asthma was 21% prevalent. At Health Professions, located in lower Manhattan, a similar level of prevalence was obtained, 19.0%. In Brooklyn, the sample came from Arthur Somers Junior High School, from which was obtained a prevalence level of 18.0%. Unfortunately, since Somers is a middle school, all its students come from one specific Brooklyn area. This may have introduced a possible bias into the results.

The mean overall proportion of students with asthma in the sample was determined to be 15.1%. The median was 15.5%, indicating that half the samples are expected to be below this level, and half the samples above this level. A 95% confidence interval was obtained for the true mean proportion of adolescents with asthma in NYC, which is (13.2%, 16.9%). This was somewhat compelling evidence of spatial distribution between the seven schools. The overall range of the school data fell within twelve percentage points. This large spread showed significant variation between the seven schools. This can observed in Chart 1: School vs. Proportion of Students with Asthma, in the Appendix. A statistical test, the chi-square test for independence was performed, which yielded a p-value of virtually zero. In this test, the null hypothesis stated the proportions of students with asthma in the school were independent of school, and the alternative hypothesis stated the prevalence levels depended on the school from which they originated. The test is designed to show whether there is a significant difference between the obtained proportions. With all of this, there was extremely strong evidence of the widespread variation in school asthma prevalence rates, and it was concluded that with regard to these seven schools, asthma is spatially distributed based on the location of the school.

Is there a significant difference in asthma prevalence between these four boroughs?

The data from all seven data sets were combined in order to account for the fact that students can reside outside of the borough in which they attend school. Data were sorted by borough, and a borough-by-borough analysis was conducted. Staten Island was neglected because of the extremely small sample size obtained from that borough (n = 2).

In Queens, once again, the lowest level of asthma prevalence was obtained, 10.6%. A 95% confidence interval gives (8%, 13%), with n (sample size) = 527. The other boroughs seem to be approximately uniform in their distribution of asthma prevalence. For students residing in the Bronx, the proportion of prevalence obtained was 18.3%, along with a 95% confidence interval of (11.4%, 25.3%), n = 120. For students residing in Brooklyn, a prevalence level of 17.1%, and a 95% confidence interval of (13.7%, 20.5%), n = 477 were obtained. Finally, in Manhattan, a prevalence level of 18.9% with a 95% CI of (14.3%, 23.5%) was obtained, with n = 280.

A second chi-square test for independence was conducted. The null hypothesis stated that asthma prevalence was independent of the borough in which the student lived, and the alternative hypothesis stated that the proportion of prevalence was dependent on the borough of student's residence. With all four boroughs in the test, a p-value was obtained of virtually zero. The test was repeated, excluding Queens, and the p-value was determined to be .629. This proved two things: one, that the proportion of asthma prevalence in Queens was significantly less than that in the other boroughs, and that the proportion of asthma in the other boroughs given by the sample is most likely relatively uniform. Chart 3 provides this information in a visual format. It was observed that Manhattan, the Bronx, and Brooklyn, which geographically lie in a north-south direction to each other, had similar proportions of asthma prevalence. However, moving toward Queens and farther eastward yields a significantly decreasing proportion of asthma prevalence.

Analysis of EPA Aerosol Data

Data were collected from the EPA AIRData Database[23] and analyzed to see if any relationship existed between the amount of aerosols in the atmosphere and asthma. This data were measured from a set of EPA stations located all across the city. The annual means of the data were used for the purposes of this investigation. The three types of aerosols for which the EPA had sufficient data for this analysis were sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter smaller than 10 microns (PM 10).

The data were graphed in order to analyze the spatial distribution of aerosols. In Chart 5, Queens was excluded from analysis because there was no EPA data on PM in Queens. In Chart 6, Brooklyn was excluded because there was no information on NO_2 concentration in Brooklyn.

Staten Island was neglected due to the fact that it was neglected in the sampling for the asthma survey.

What trends are observed in the measurements of PM 10 from borough to borough?

A decrease in particulate matter was observed when moving from the Bronx southward through New York City, as was shown by Chart 6, Combined SO_2 and NO_2 concentrations in the City. PM vary widely within a range from 15.9 ug/m^3 to 22.05 ug/m^3, or 6.15 ug/m^3, as seen in Chart 5, Particulate Matter Distribution. The Bronx has the highest PM 10 concentration. This supports the hospitalization data from the New York State Health Department (see Chart 4). However, in the survey, Manhattan had the highest proportion of asthma sufferers. If PM 10 concentration truly influenced asthma prevalence, then the distribution should more closely resemble that of Chart 2, Borough vs. Asthma Prevalence. The two distributions clearly do not share a common trend, but this is by no means enough information to conclude that PM 10 concentration does not influence the prevalence of asthma.

What trends are observed in the levels of SO_2 and NO_2?

It was observed that the highest levels of SO_2 and NO_2 are concentrated in Manhattan. The Bronx came in second, and Queens once again had the lowest levels of these aerosols. This was consistent with the data that we obtained in the asthma survey. The spatial distribution was the same as that obtained in the asthma survey as well. However, without data on Brooklyn, any conclusions made must be made with caution. Since the spatial distributions appear the same, it appears logical to conclude that SO_2 and NO_2 levels in the atmosphere influence the prevalence of asthma.

Discussion and Conclusions

It was determined that asthma prevalence levels were the highest in the Bronx, Brooklyn and Manhattan and significantly lower in Queens. These differences can possibly be explained by referring to the general environment of each of these boroughs. Manhattan, Bronx and Brooklyn are all urban areas with elevated levels of pollution, cramped living quarters and inadequate ventilation. All these factors increase exposure to PM, dust mites and contaminated air, which can greatly affect susceptibility to asthma. Queens is generally a suburban area that has relatively less buildings and more single unit housing. This leads to increased amounts of exposure to fresher and more natural air. Studies have shown that people who spend more time outdoors are less susceptible to having asthma attacks. (cite a study or omit this)

The significant differences between the Health Department hospitalization data[24] and the survey data can be explained by a number of factors (see Chart 4). Most people with asthma do not end up at hospitals unless they had a severe attack; most people choose to go to their medical doctor to obtain proper treatment. Some of the people living in the city might not go to see a doctor at all and just continue to bear the burden of having asthma without treatment.

The significant differences shown in Chart 3, which compared the results of two different methodologies used to obtain the prevalence statistics by borough (averages of school data within the borough, or a combined data set), can be explained by the fact that the Bronx High School of Science is not a typical zoned high school. Two-thirds of the students who attend Bronx Science are from Queens, and therefore, this school does not accurately reflect the Bronx population. In addition, biases included in the Townsend Harris data set (because permission had to be obtained in order for students to take the survey) and the Arthur Somers JHS data set (because most of the students came from the same area in Brooklyn) could have skewed our survey results. This could also explain why the overall spatial variations do not show the same pattern as with the Health Department hospitalization data.

It has been concluded that with respect to the schools, spatial variation existed according to geography. When asthma prevalence by borough was analyzed, similar proportions were obtained for the three boroughs to the west of Queens. However, moving eastward decreases the proportions of asthma, SO_2, NO_2, and PM, all simultaneously. In addition, the SO_2 and NO_2 levels increased in the same boroughs where there was increased prevalence, and decreased in the same boroughs with decreased prevalence. This leads to the conclusion that not only is asthma spatially distributed around the city, but it is linked somehow to the spatial distribution of aerosols as well.

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