Comparison of fine particulate matter and ozone levels in zip code areas of New York City with different child asthma burdens

M. Solorzano[1], J. Stingone[2], A. R. Rentas[1] & L. Claudio[2]
[1]*Universidad Metropolitana, San Juan, Puerto Rico*
[2]*Mount Sinai School of Medicine, New York, New York, USA*

Abstract

Previously our group found that asthma hospitalization rates in zip code-defined communities of New York City correlate with higher proportions of low income and minority populations in a community. We showed that low-income minority communities have 21 times higher asthma hospitalization rates than more affluent communities in New York. In this work we investigate the relation between asthma burdens, in terms of prevalence and hospitalization rates, and ambient levels of these air pollutants in NYC. Asthma prevalence was determined in schools within each zip code using a parent-response survey. We classified NYC zip codes in three different categories taking into account their asthma burdens: High, Medium or Low. Four zip code areas (study areas) were selected in order to carry out the air pollution exposure comparison: two from high, one from medium and one from low. We compared 1999 to 2003 pollution data from air monitoring stations (AMS) operated by New York State Department of Environmental Conservation (NYSDEC), and located within a 1.5 mile radius of our study areas defined by zip codes. Asthma prevalence among the schools ranged from 7.79% to 36.2%. Prevalence correlated with socioeconomic measures in the study populations. There were no statistically significant differences in PM2.5 and ozone levels between study areas, as measured by the AMS that could explain the asthma burdens disparities in our study areas. We concluded that race/ethnicity and the median household income of the community were strong predictors of asthma prevalence. No differences were detected in the levels of PM2.5 and ozone in these communities, which suggests similar exposure. It is possible that the air pollution data provided by the NYSDEC Air Monitoring Network does not represent an accurate assessment of exposure to ambient levels of the air pollutants studied.
Keywords: child asthma, GIS, ozone, pm2.5, monitoring, prevalence, health disparities, low income.

1 Introduction

Just et al. [14] completed a panel study to assess the short-term effects of photo-oxidant and particulate pollution on the health of medically diagnosed asthmatic children. Incident asthma attacks significantly correlated at lag 0 with moderately high ozone (O3) levels ($p=0.02$) given that the model included significant interactions between O3 and pollen or temperature. In the same study, O3 was associated with changes in lung function as daily peak expiatory flow (PEF) variability increased by 2.6% with an increase of 10 μg/m^3 of 0-4 mean O3 concentration ($p=0.09$). Ozone has been associated with, asthma exacerbation, chest symptoms, medication use and decreases in lung function (Thurston et al. [24]), shortness of breath (Ostro et al. [22]) in children with asthma. White [25] studied emergency visits to the Grady Children's Hospital in Atlanta in the summer of 1990, and reported a 37% increase in hospital emergency visits for asthma after 6 days when the ozone level exceeded 0.11 ppm. Recent studies suggest that if more than mild exercise is imposed, asthmatic subjects show increased SRaw to a 2-hr exposure to 0.4 ppm O3 (Ball et al. [2]). Exposure to O3 has been associated to increased hospital admissions and emergency visits in Atlanta (Bates [4]). Restrepo et al. [23] measured air pollution levels at three different locations in the South Bronx of New York City and compared these to air data from the New York State Department of Environmental Conservation (NYSDEC) air monitoring stations, at four different sites, where they are located at about 15 m above ground. Restrepo's air monitoring was performed at 4m above ground by a mobile laboratory placed in a van. The air pollution levels monitored in this study included PM2.5, O3, Sulfur Dioxide (SO2), Nitrogen Dioxide (NO2) and Carbon Monoxide (CO). The South Bronx is mostly a low-income minority community (60% Hispanic, 39%African-American) and with a big traffic density (Restrepo et al. [23]). It is crossed by a number expressways and its annual average daily traffic for the time of the study was between 75,000 and 150,000 vehicles. They found that the PM2.5 levels measured by the van were higher for some days to those reported by the NYSDEC but lower for others. In terms of O3 the levels measured by the van were similar (August/November) or lower (December) to the NYSDEC data. Restrepo et al. [23] argue that their results are explained by the facts that PM2.5 and O3 are regional pollutants and that O3 levels are expected to be lower closer to the ground because of reaction with nitrogen monoxide (NO) generated by cars.

Recent studies by our team showed that asthma hospitalization rates have a strong spatial and socioeconomic component in New York City (Claudio et al. [7]). A number of explanations have been given for these differences (Faye et al. [10]) including poor housing conditions (Krieger and Higgins [16]), disparities in socioeconomic status and health care access (Halfon and Newacheck [13]), disparities in indoor air quality (Koenig et al. [15]), low literacy skills or inadequate health literacy and disparities in asthma management (AMA [1]). Although a number of studies have explored the relationship between ambient air pollution and asthma, some authors indicate that air pollution is still underappreciated as a contributor to asthma exacerbations. Other studies have also found a strong correlation between child asthma prevalence and hospitalization rates with a correlation factor of about 0.6 significant at the 0.001 level (Claudio, [unpublished data]).

According to the 2000/2001 Report on Social Indicators from the New York Department of City Planning, the population of New York City on April, 2000, was 8,008,278, according to census data (NYCDCP [19]). In year 2000, New York City's racial/ethnic diversity was striking with white non-Hispanics accounting for about 35 percent of the population, Hispanics 27 percent, Black non-Hispanics 24.5 percent, 1-in-10 New Yorkers was Asian and Pacific Islander non-Hispanic, and those with a multiracial non-Hispanic background accounted for 2.8 percent of the population (NYCDCP [19]). The Hispanic population became the largest minority in 2000 (NYCDCP [20]). Asthma studies revealed striking geographical, ethnic, racial aspect of asthma hospital admission rates or hospitalizations in New York City in the past. Studies by De Palo [8] found an average citywide annual hospital admission rate of 681 per 100,000 between 1989 and 1991. However, Bronx and Manhattan had the highest admission rates and admissions ratio for Hispanics was 1,003 per 100,000, 810 per 100,000 for blacks and 242 for whites (De Palo [8]).

New York City experienced an increase in asthma morbidity and mortality in the early 1990s (Garg et al. [11]). In the year 2000, asthma hospitalization rate in New York City reached the lowest point since 1990. Although these figures are encouraging, asthma remains a great problem in New York City. A report from the NYC Department of Health and Mental Hygiene (DOHMH) revealed that in 2000, NYC children were nearly twice as likely to be hospitalized for asthma as children in the United States as a whole. In addition, the DOHMH report indicates that, in 1999, school-based asthma prevalence among children 4-5 years old was more than twice as high among children residing in low-income areas than among children residing in high-income areas. Furthermore, the report points the Bronx as the borough with the highest overall rates of asthma hospitalizations, deaths and prevalence among children and among adults (Garg et al. [11]). NYCs population is racially diverse although the white non-Hispanics are the largest group accounting for 35%. Results from previous studies indicated that zip code areas with the largest minority population had the highest asthma hospitalization rates in New York City (Claudio et al. [7]).

Several explanations, such as socioeconomic status and health care access, have been offered for disparities in asthma hospitalization rates as well as asthma prevalence in NYC (Halfon and Newacheck [13]). In this study we examined whether differences in exposure to air pollution are at the bottom of these disparities. We assessed air pollution levels at different locations within NYC and how they varied through time. We were interested in any geographical differences in the air pollution levels that might be behind differences in air pollution exposure. A number of air pollutants, particularly ozone and PM2.5 have been associated with child asthma exacerbation (White et al. [25]; Gent et al. [12]). We were concerned whether differences in exposure to these pollutants were related to the child asthma burdens disparities observed within NYC. For that purpose, we assessed what was the impact of geographical location on child exposure to O3 and PM2.5 within NYC, and, we examined whether areas previously found to have higher asthma burdens where getting more pollution on a general basis. We already found different children asthma prevalence and hospitalization rates in schools located in several zip codes within NYC. Air pollution data, including ambient PM2.5 and ozone levels, is available from the air monitoring network managed by the NYSDEC. As part of this network, a number of air pollution monitors are based at different locations within New York City as part of New York's State Implementation Plan mandated by the Environmental Protection Agency (EPA). We compared ambient levels of O3 and PM2.5 at locations where marked child asthma burden disparities were observed, using air pollution data records from a number NYSDEC air monitoring stations.

2 Methodology

In this work we used the child asthma prevalence data from a previous study by Claudio et al. (unpublished). The authors obtained the data from a parent-response survey carried out at public schools. The asthma prevalence data from those schools was used as a proxy of the asthma prevalence of the zip code area the schools were located at. For this study we used PM2.5 and ground ozone levels from air monitoring sites managed by NYSDEC. The air pollution data was obtained from EPA through the Freedom of Information Act. The NYSDEC runs an air monitoring network for the criteria pollutants (SO2, NO2, O3, PM2.5, PM10, CO) as well as a number of hazardous pollutants.

We selected four (4) PM2.5 monitors and two (2) O3 monitors from this network. Since the selection of the geographical unit of analysis, or Modifiable Area Unit Problem (MAUP), may have consequences in the results of spatial relationship epidemiological studies (Maantay [17]), we decided to establish zip code areas as the geographical unit for our analysis. We had asthma prevalence data from public school students from a previous study per zip code area. About 70% of the students in those schools lived and went to school in the same zip code area. In addition, recent epidemiological studies have used zip code areas as the geographic unit of analysis with successful results (Jones et al, 2004). In order to select our study areas we choose a few zip code areas with different child asthma prevalence. In addition, we wanted to select air-monitoring sites for PM2.5 and ozone that were located inside those zip code areas or within a distance of 1 mile from the area boundary. For the study area and AMS selection we created the maps in Figure 1 using geographical information system tools from ArcGIS 9.0 software package (Redlands, CA).

After reviewing the air monitoring data from the EPA and the NYSDEC we found that recorded data varied from monitor to monitor and from year to year. As a consequence, there were some periods of time between the years 1999 to 2003 that didn't have pollution data available. In addition, there is a high variability in the air sampling frequency performed by the air monitoring stations. Some of the AMS perform measurements on a daily basis while others do so every three or six days. We also found a marked variation in the sampling frequency throughout the year. Another fact to consider in the analysis was that EPA assigns a code to the air pollution values derived from the air monitoring sampling in those days when there has been an incident during the sampling process. These incidents may be scheduled or unexpected, such as machine malfunction, and may have repercussions in the actual values measured by the air monitors. In order to compare the ambient levels of PM2.5 and ozone from AMS to AMS we decided to plot together the pollutant concentrations or sampling values measured in each of them. Also we carried out a statistical analysis of the data using SAS 9.0 (SAS Institute, Cary, NC) as well as an ANOVA test to compare the annual means of the PM2.5 ambient levels recorded by the selected air monitoring stations. The same was done for the ozone levels.

3 Results and discussion

In this study we compared air pollution levels from different state managed air monitors in NYC. Our main objective was to compare PM2.5 and O3 ambient levels in areas with child asthma prevalence disparities. With this objective we wanted to examine the possible relationship between child asthma and air pollutant levels. Using the child asthma prevalence, child asthma hospitalizations, zip codes, and AMS sites we created the maps in Figures 1A and 1B illustrating children asthma prevalence within NYC as well as the AMS monitoring sites in this study.

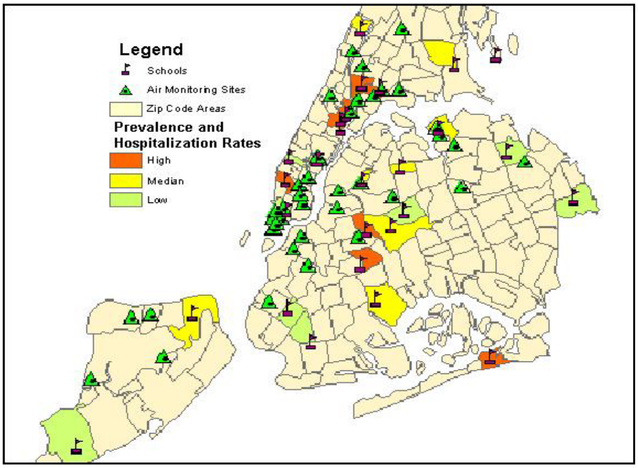

Figure 1A: Map of AMS, Schools and Asthma Burdens per Zip Code Area.

We extrapolated child asthma prevalence from the public schools to the corresponding zip code areas, we classified zip code areas according to asthma prevalence (low, medium, and high) and we also added AMS and school locations. The study from which we got the asthma prevalence data wasn't widespread enough to make assumptions about the geographic component of asthma prevalence in NYC as a whole. Nevertheless, we notice that children asthma prevalence (defined as the number of children who had asthma) varies according to geographic location, at least in the zip code areas sample. The zip code areas with the highest child asthma prevalence are located in four (4) zones: South Bronx/East Harlem, west Midtown Manhattan, Queens/Brooklyn border and a zip code area in south Queens. In some cases, high, median and low prevalence zip codes are adjacent or pretty close together. However, not many inferences can be made by looking at the spatial distribution of our zip code areas because of their small number. The trends we observe may be misleading since we don't know what the situation is in the remaining zip code areas in terms of asthma prevalence. Nevertheless, we can say that, for example, the high prevalence zip codes are located in places that are mentioned in literature as receiving extra volumes of traffic related pollution or having air pollution problems, such as South Bronx (Maciejczyk et al. [18]) and the Queens/Brooklyn border (NYCDOT [21]).

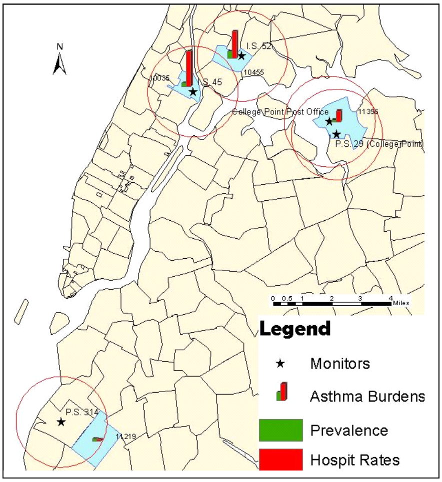

Figure 1B: Map of the Study Area and Selected Air Monitoring Sites.

Ground ozone levels showed very similar patterns at the two selected Air Monitoring Stations in years 2000, 2001, 2002 and 2003. In November and December 1999 there where observable differences in ground ozone levels at the selected AMS in terms of the occurrence of concentration peaks. However, levels stayed at or below .03 ppm in both locations during those 2 months. These concentrations are well below the 0.12 ppm EPA standard. These low concentrations may be explained by the lower solar radiation during winter.

Many O3 concentration peaks from both AMS match both temporally and quantitatively in those years. Data showed the expected seasonal pattern of the

O3 levels, reaching higher ambient concentrations in summer months, such as June and July, with higher solar incidence, and lower ones in winter months (December, January, February). The results of the O3 levels statistical ANOVA analysis shown in Table 1 demonstrate that the mean values of both air monitoring sites are very similar for the periods of study.

Table 1: Ozone levels statistical analysis.

Period of comparison	Station	Number of daily values	Minimum	Maximum	Mean (ppm)	Std. deviation	One-way ANOVA	
							F	p
1999	CPPO	54	0	0.003	0.009	0.007	8.10	0.0053
	I.S. 52	53	0	0.002	0.006	0.006		
2000	CPPO	294	0	0.007	0.015	0.0107	0.24	0.6213
	I.S. 52	303	0	0.007	0.015	0.0103		
2001	CPPO	210	0	0.04	0.014	0.0104	0.00	0.9728
	I.S. 52	212	0	0.05	0.014	0.0109		
2002	CPPO	302	0	0.05	0.018	0.0114	1.52	0.2179
	I.S. 52	305	0	0.05	0.017	0.0124		
2003	CPPO	305	0	0.05	0.016	0.0104	0.00	0.9948
	I.S. 52	293	0	0.06	0.016	0.0115		

The results of the PM2.5 statistical analysis are summarized in Table 2. We performed an ANOVA test and it showed that there wasn't a significant difference in the analyzed periods ($p > 0.5$) although the F test scored slightly higher than 1 for the period from Jan-Jun Sept-Dec 2001.

4 Conclusions

Our results and analysis showed that all studied areas have a similar exposure to ambient ozone and PM2.5. These results are similar from those of recent studies (Bari et al. [3]; DeGaetano and Doherty [9]; Restrrepo et al. [23]). Bari et al. [3] studied the concentrations and seasonal variation of various air pollutants including PM2.5 at monitoring sites in Manhattan and the Bronx from 1999 to 2000. Their results suggest a regional component of PM2.5 mass at those sites. They also indicate that local sources seem to have only small contributions to PM2.5 mass. This is in contrast with the results of other studies that indicate that motor vehicle emissions are one of the chief contributors to within-community variations in ambient pollution levels, particularly for PM2.5 (Chu [6]). Nevertheless, we decided it was worth examining this fact at a broader inner-city scale taking into account the fact that asthma prevalence levels vary from place to place within NYC.

Table 2: PM2.5 levels statistical analysis.

Period of comparison	Station	Number of values	Minimum	Maximum	Mean (ppm)	Std. deviation	One-way ANOVA	
							F	p
1999	P.S. 29	12	4.1	16.2	9.8	4.413	0.19	0.6711
	I.S. 52	12	4.8	18.1	10.57	4.409		
Jan-Apr 2000	I.S. 45	25	5.2	38.1	14.04	7.476	0.4	0.6726
	I.S. 52	23	3.5	40	14.056	8.594		
	P.S. 29	25	5.8	34.8	12.37	6.724		
Apr-Dec 2000	I.S. 45	86	4.2	62.2	16.03	10.183	0.7	0.5532
	I.S. 52	78	3.8	41.6	15.31	8.655		
	P.S. 29	81	2.8	45.8	14.43	9.097		
	P.S. 314	83	2.7	74.4	16.48	10.601		
Jan-Jun and Sep-Dec 2001	I.S. 45	97	3.9	36.5	14.44	7.73	1.62	0.1842
	I.S. 52	95	3.8	36.5	14.9	7.61		
	P.S. 29	96	2.7	37.3	13.15	7.49		
	P.S. 314	93	3.8	38	15.48	7.73		
Jun-Aug 2001	I.S. 45	22	4.9	51.3	18.63	11.43	0.37	0.695
	P.S. 29	20	4.3	50.6	16.51	11.09		
	P.S. 314	21	7.1	51.2	19.48	11.73		
Jan-Mar 2002	I.S. 45	21	6.1	35.5	14.99	6.52	0.17	0.9189
	I.S. 52	21	5.5	36.9	14.78	7.03		
	P.S. 29	21	4.7	34.2	13.65	6.95		
	P.S. 314	21	6.6	29.5	14.78	5.93		
Jan-Dec 2002	I.S. 45	105	3.8	77.6	14.79	9.82	0.01	0.9934
	I.S. 52	105	2.6	79.7	14.69	9.96		
	P.S. 314	105	3.1	86.4	14.85	10.02		
Jan 2003	I.S. 45	8	5.9	23.0	11.58	5.18	0.14	0.8666
	I.S. 52	8	7.1	23.3	11.62	5.19		
	P.S.	8	7.3	25.6	12.85	5.67		

The unexpected results from our comparison ought not to be misinterpreted. They don't indicate at all that air pollution doesn't have an impact in the health of asthmatic children in our study areas. However, our results seem to support other explanations of geographic and socioeconomic child asthma prevalence differences observed within NYC and nationwide such as poor housing conditions (Krieger and Higgins [16]), socioeconomic status and health care access (Halfon and Newacheck [13]), disparities in indoor air quality, disparities in asthma management, low literacy skills or inadequate health literacy (AMA [1]). Perhaps the most important findings of our study is the fact that air monitoring stations located at considerable distance within NYC and this may hamper recording localized differences in air pollution levels.

Although we worked with a relatively small number of air monitors we can see a redundancy trend in the data of ambient levels of PM2.5 and ozone. If this was the case for all the monitors within the city, then there could be the possibility of relocating the monitors to avoid redundancy. Whatever the case might be the protocols for the location of the AMS should also consider, for example, information available from asthma reports. Incorporating child asthma hospitalization rates into that protocol would definitely benefit this susceptible population.

References

[1] Ad Hoc Committee on Health Literacy for the Council on Scientific Affairs, American Medical Association (AMA). Health literacy: report of the Council on Scientific Affairs. Ad Hoc Committee on Health Literacy for the Council on Scientific Affairs, American Medical Association. Journal of the American Medical Association, Vol. 281, 552-557, 1999.

[2] Ball, B. et al. *Pulmonary responses in asthmatics performing light exercise in clean air (air) and 0.16 ppm ozone (O_3).* American Review of Respiratory Disease, Vol. 147, A640, 1993.

[3] Bari, A. et al. Regional sources of particulate sulfate, SO2, PM2.5, HCl, and HNO3, in New York, NY. Atmospheric Environment, Vol. 37, 2837–2844, 2003.

[4] Bates, D.V. (1995). The effects of air pollution on children. Environmental Health

[5] Perspectives Supplements, (Vol. 103) Issue Supplement 6, p. 49.

[6] Chu, S.-H. PM2.5 episodes as observed in the speciation trends network. Atmospheric Environment, (Vol. 38) pp. 5237-5246, 2004.

[7] Claudio, L. et al. Socioeconomic Factors and Asthma Hospitalization Rates in New York City. Journal of Asthma, Vol. 36, No.4, 343-350, 1999.

[8] De Palo, V.A. Demographic influences on asthma hospital admission rates in New York City. Chest, Vol.106, No.2, 447-51, 1994.

[9] DeGaetano, A. T. and Doherty, O. M. Temporal, spatial and meteorological variations in hourly PM2.5 concentration extremes in New York City, Atmospheric Environment, Vol. 38, 1547–1558, 2004.

[10] Faye, V.J. et al. The Use of Spatial Statistics to Identify Asthma Risk Factors in an Urban Community. Pediatric Asthma, Allergy & Immunology, Vol. 17, No. 1, 3-13, 2004.
[11] Garg, R. et al. Asthma Facts, Second Edition. New York City Department of Health and Mental Hygiene, 2003.
[12] Gent, J. F. et al. Association of low-level ozone and fine particles with respiratory symptoms in children with asthma. Journal of the American Medical Association, Vol. 290, No. 14, 1859-1867, 2003.
[13] Halfon, N. and Newacheck, P.W. Childhood asthma and poverty: differential impacts and utilization of health services. Pediatrics, Vol. 91, 56-61, 1993.
[14] Just, J. et al. Short-term health effects of particulate and photochemical air pollution in asthmatic children. European Respiratory Journal, Vol. 20, 899–906, 2002.
[15] Koenig, J.Q. et al. Pulmonary effects of indoor- and outdoor-generated particles in children with asthma. Environmental Health Perspectives, Vol. 113, No. 4, 499-503, 2005.
[16] Krieger, J. and Higgins, D.L. Housing and Health: time again for public health action. American Journal of Public Health, Vol. 92, 758-768, 2002.
[17] Maantay, J. Mapping environmental injustices: pitfalls and potential of geographic information systems in assessing environmental health and equity. Environmental Health Perspectives, Vol. 110, Suppl. 2, 161-171, 2002.
[18] Maciejczyk, P.B. et al. Ambient pollutant concentrations measured by a mobile laboratory in South Bronx, NY. Atmospheric Environment, Vol. 38, 5283-5294, 2004.
[19] New York City Department of City Planning (NYCDCP). 2000/2001 Report on Social Indicators. DCP# 02-12, 2001.
[20] New York City Department of City Planning (NYCDCP). 2002 Report on Social Indicators. DCP# 03-06, 2002.
[21] New York State Department of Transportation (NYSDOT). Traffic volume report for Bronx County. www.dot.state.ny.us/tech_serv/high/count.les/bronx.pdf, 2001.
[22] Ostro, B. et al. Air pollution and exacerbation of asthma in African-American children in Los Angeles. Epidemiology, Vol. 12, 200–208, 2001.
[23] Restrepo, C. et al. A comparison of ground-level air quality data with New York State Department of Environmental Conservation monitoring stations data in South Bronx, New York. Atmospheric Environment, Vol. 38, 5295–5304, 2004.
[24] Thurston, G.D. et al. Summertime haze air pollution and children with asthma. American Journal of Respiratory Critical Care Medicine, Vol. 155, 654–660, 1997.
[25] White, M.C. et al. *Exacerbations of childhood asthma and ozone pollution in Atlanta*. Environmental Research, Vol. 65, 56-68, 1994.