Asthma and Air Pollution in Baltimore City

ENVIRONMENTAL INTEGRITY PROJECT

ABELL FOUNDATION

DECEMBER 2017

ACKNOWLEDGEMENTS

This report was researched and written by Leah Kelly and Kira Burkhart of the Environmental Integrity Project (EIP).

EIP appreciates the support of the Abell Foundation in funding this report. We are grateful to the Maryland Department of Health for taking the time to issue the asthma datasets analyzed in this report and for responding to our questions relating to them. We also appreciate the assistance of Dr. Gwen Dubois of Chesapeake Physicians for Social Responsibility, who provided us with the Healthcare Cost and Utilization Project statistical brief referenced in this report.

THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project (http://www.environmentalintegrity.org) is a nonpartisan, nonprofit organization established in March of 2002 by former EPA enforcement attorneys to advocate for effective enforcement of environmental laws. EIP has three goals: 1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; 2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and 3) to help local communities obtain the protection of environmental laws.

For questions about this report, please contact EIP Director of Communications
Tom Pelton at (202) 888-2703 or
tpelton@environmentalintegrity.org.

PHOTO CREDITS

Cover: Fort Smallwood Complex. Photo by Doc Searls via Flickr

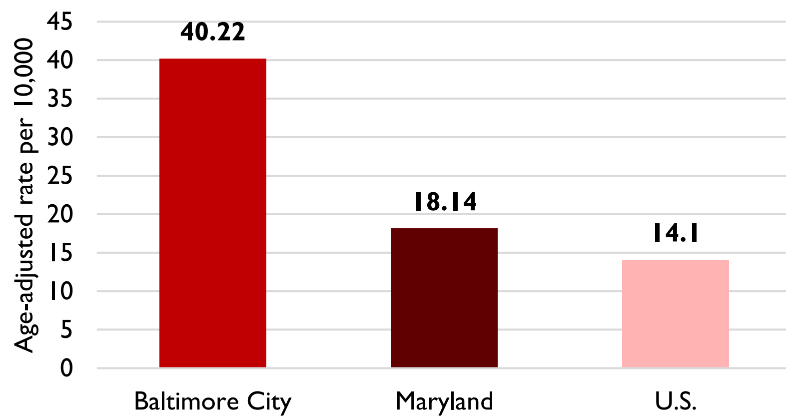
ASTHMA AND AIR POLLUTION IN BALTIMORE

Executive Summary

In 2010, Baltimore City's rate of asthma-related hospitalizations[1] was almost three times higher than the U.S. average and about 2.2 times higher than the average rate for Maryland. This is the most recent year for which hospitalization data can be compared at all three levels (national, state, and city), but more recent data indicates that this is still the trend. In 2013, the asthma hospitalization rate in Baltimore City was 2.3 times higher than the average rate for Maryland.

Emergency room visits due to asthma are also extremely high in Baltimore City compared with the state. In 2013, the average rate of asthma emergency room visits in Baltimore was 2.5 times the state average.

Figure ES-1. Comparison of Asthma Hospitalization Rates in Baltimore City, Maryland, and the United States (2010)



The Environmental Integrity Project ("EIP") examined recently released asthma data and found a potential association between asthma emergencies and some measures of local air pollution. Four out of the five Baltimore zip codes with the highest 2011[2] asthma hospitalization rates included smaller areas with very high relative exposure to toxic air pollution (95-100th percentile in the state), coming primarily from roadway vehicles. In addition, in two South Baltimore zip codes, there was a sharp drop in asthma hospitalization rates after 2009 that may have been influenced by steep pollution reductions at two nearby coal-fired power plants. Asthma hospitalization rates in the 21225 and 21226 zip codes fell from 2009-2013 by 57 percent in each zip code, which is more than 2.4 times the decrease in the city at large (23 percent) during these years and more than a national-level decrease from 2008 to 2012 (15.6 percent) found in a separate study. A state law, the Maryland Healthy Air Act, drove dramatic air pollution reductions in the area between 2008 and 2010 by requiring pollution control upgrades at the Brandon Shores and Herbert A. Wagner coal plants, which are located in the 21226 zip code and adjacent to the 21225 zip code.

---

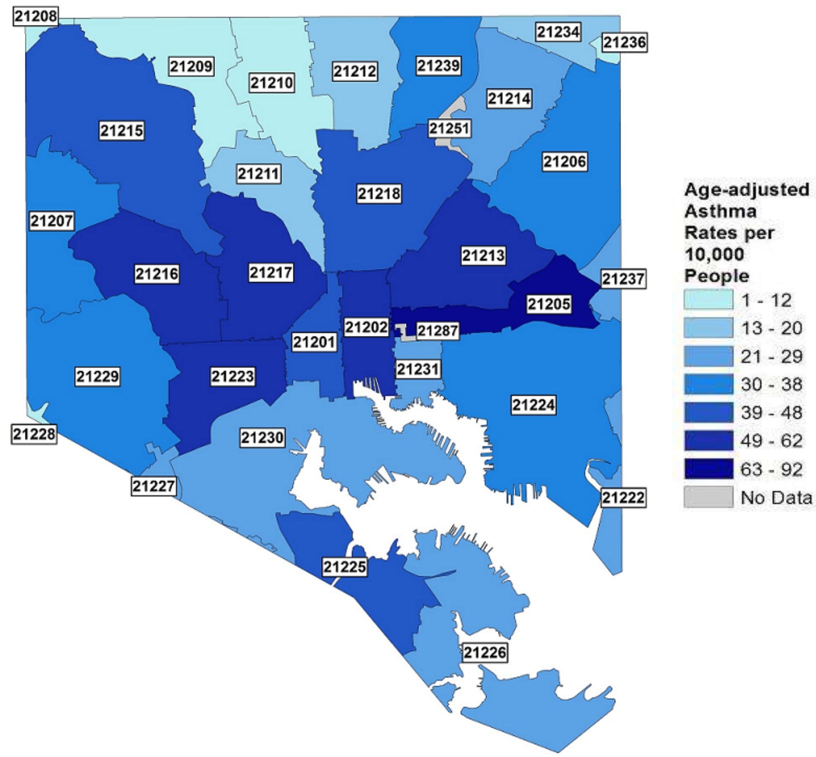
[1] The asthma hospitalization data described in this report is based on records of asthma hospital discharges. This covers persons who are admitted to the hospital (inpatients) for asthma, including those admitted through the hospital emergency department, but not persons who visit the emergency department for asthma and are treated and released (outpatients).

[2] 2011 is the most recent year for which we could compare toxic air pollution to hospitalization rates on a spatial scale.

We also found a very strong spatial correlation between asthma hospitalization and emergency room visits in Baltimore's zip codes and demographic measures of poverty, particularly median household income. This conclusion – that poverty and poor housing conditions have a major impact on asthma – was confirmed by a recent Kaiser Health News and Capital News Service report published in The Washington Post.[3]

Between September 2016 and May 2017, the Maryland Department of Health released the first sets of publicly available asthma data in the State of Maryland that can be analyzed by geographic areas smaller than counties. A set of zip code level data on asthma hospitalizations from 2000 through 2013 was made available in September 2016 and asthma emergency room visit data for the same years was published in April 2017.[4] Prior to this release, it had been known in Maryland's environmental health community that Baltimore City has much higher asthma rates than other counties in Maryland and that asthma is a severe health problem in Baltimore. However, data was publicly available only at the city level.[5] With the release of this new data, health advocates and members of the public can now identify the areas of the city with the highest asthma hospitalization and emergency room visit rates and begin to assess the factors that are driving these rates.

Figure ES-2. 2013 Baltimore City Asthma Hospitalization Rates by Zip Code



EIP analyzed these datasets and compared them to measures of air pollution in Baltimore City to assess whether there is any association between trends in air pollution and acute asthma events. Exposure to pollutants in the outdoor air, including ozone, sulfur dioxide, and particulate matter (or soot), has been shown to impair respiratory function and this can precipitate asthma attacks in those that already have the condition. Using data available from the U.S. Environmental Protection Agency ("EPA") and the Maryland Department of

[3] Bluth, Rachel, and Daniel Trielli. 2017. "Hospitals find asthma hot spots more profitable to neglect than fix." *The Washington Post*, December 4, 2017. Link: https://www.washingtonpost.com/national/health-science/hospitals-find-asthma-hot-spots-more-profitable-to-neglect-than-fix/2017/12/01/0d804ce2-b806-11e7-be94-fabb0f1e9ffb_story.html?tid=a_inl&utm_term=.7409ad4f5a10.

[4] The emergency room visit rates are discharge rates for patients who visit the emergency department because of asthma, including patients who are treated and released (outpatients) and patients who are admitted to the hospital through the emergency department (inpatients).

[5] Baltimore City is a county.

the Environment ("MDE"), we conducted a spatial assessment by comparing maps of the city asthma rates (like Figure ES-2) to maps of air pollution measures. We also compared asthma rates over time to trends in air pollution over time. Because our asthma mapping exercises clearly showed that the city's poorest neighborhoods have the highest rates of asthma, we performed a more limited analysis of the spatial correlation between asthma rates and measures of poverty in Baltimore.

Our goal was to assess the impact of these two factors - air pollution and poverty - on acute asthma events in Baltimore. We did not attempt to identify every condition that contributes to these events and its relative influence. Many variables contribute to high rates of asthma in Baltimore, including indoor asthma triggers like mold, pet dander, and cockroach and mouse allergens. It is beyond the scope of this report to assess the impacts of all of them.

Spatial Comparison

Figure ES-2 above shows the asthma hospitalization rates in Baltimore City by zip code in 2013, the most recent year for which we have data. For the sake of simplicity, we focused on hospitalization rate maps for our comparisons as they show rates of events that may be more serious[6] and they are very similar to the maps for emergency room visit rates. We mapped several indicators of air pollution in Baltimore's neighborhoods using a few different tools provided by the U.S. EPA. We found that four out of the five zip codes with the highest 2011 asthma hospitalization rates had smaller areas within their borders that were within the 95-100th percentile in the state (the red parcels in Figure ES-3 below) for respiratory risk from air toxics.[7] These zip codes were 21223, 21225, 21202, 21217, and 21201. We also found that, in the areas within the 95-100th percentile, roadway vehicle pollution contributed about 50 percent of the risk, which is more than twice the risk from any other category of pollution source.

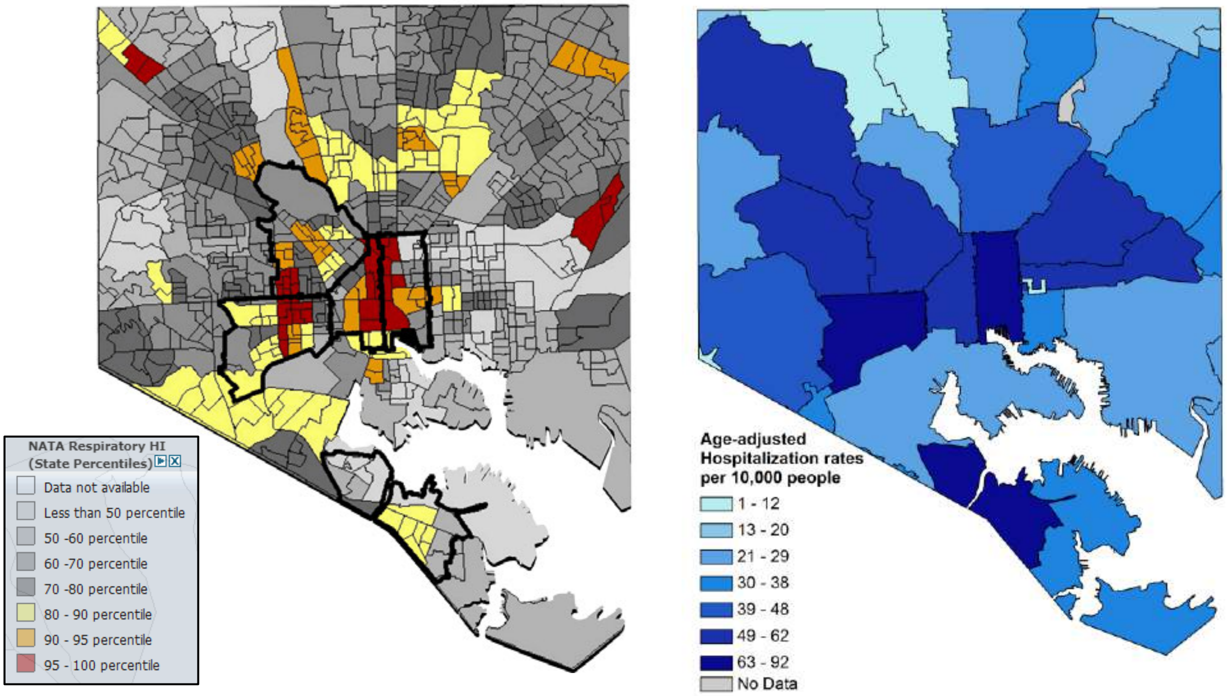
As could be expected, similar areas of overlap were shown when we compared the asthma hospitalization rate map to maps of ambient (outdoor) pollution concentrations from roadway traffic in Baltimore, using a different EPA tool, as illustrated below (Figure ES-4).

---

[6] The U.S. EPA has stated – with respect to data on hospitalization and emergency room visits for all respiratory issues – that "respiratory [emergency department] visits may represent potentially less serious, but more common outcomes."
U.S. Environmental Protection Agency. 2013. "Integrated Science Assessment for Ozone and Related Photochemical Oxidants." pg. 6-131. Link: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492.

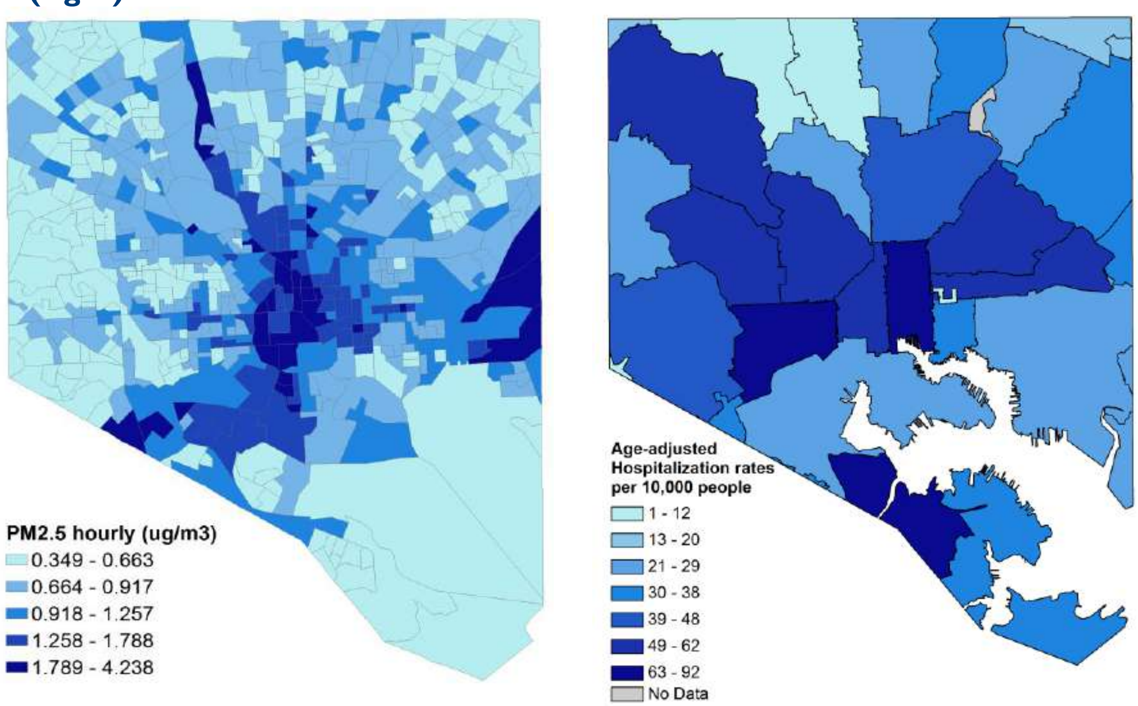
[7] EPA's EJSCREEN tool allows mapping of estimated health risks from toxic air pollution produced by EPA's National Air Toxics Assessment (NATA), which bases estimates on pollution data and modeling tools. These estimates are produced at the census tract level, which does not allow for a direct statistical comparison to the zip code level asthma data. We conducted this comparison using the 2011 asthma hospitalization rate map because NATA primarily uses emissions data from the year 2011. EIP superimposed the outlines of the five City zip codes with the highest asthma hospitalization rates in 2011. Those zip codes are 21223, 21225, 21202, 21217, and 21201.

Figure ES-3. 2011 Comparison of Respiratory Risks from Toxic Air Pollution (left) to Asthma Hospitalization Rates (right)



Note: Bold boundaries on Respiratory Risk map highlight zip codes with the five highest asthma-related hospitalization rates in 2011.

Figure ES-4. Comparison of Hourly PM2.5 Concentrations from Road Traffic Emissions (Peak Afternoon, Summer) (left) to 2011 Asthma Hospitalization Rates (right)



As discussed in more detail in the body of the report, we also found that measures of poverty, especially median household income, are strongly correlated at a spatial level with asthma hospitalization and emergency room visit rates in Baltimore. This is illustrated below in a comparison of zip code level maps showing asthma hospitalization rates and median household income (Figure ES-5). Scatter plots also show the strong statistical correlation (a negative correlation) between median household income and asthma hospitalization and emergency room visit rates (Figure ES-6).

Figure ES-5. 2013 Asthma Hospitalization Rates (left) and 2013 Median Household Income (right)

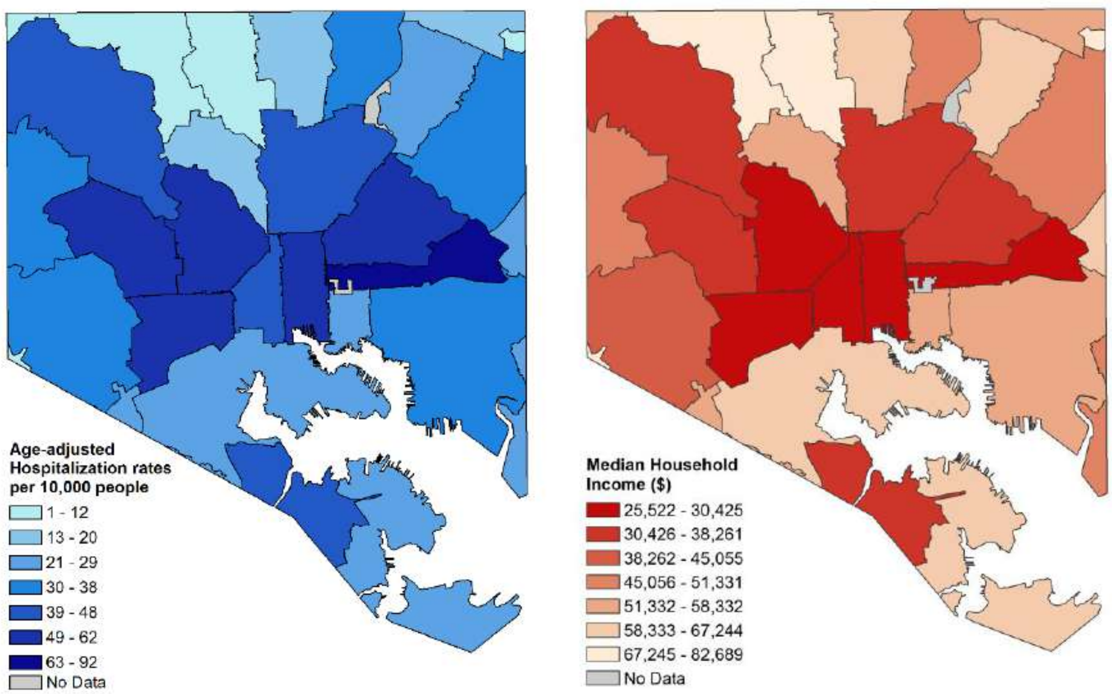
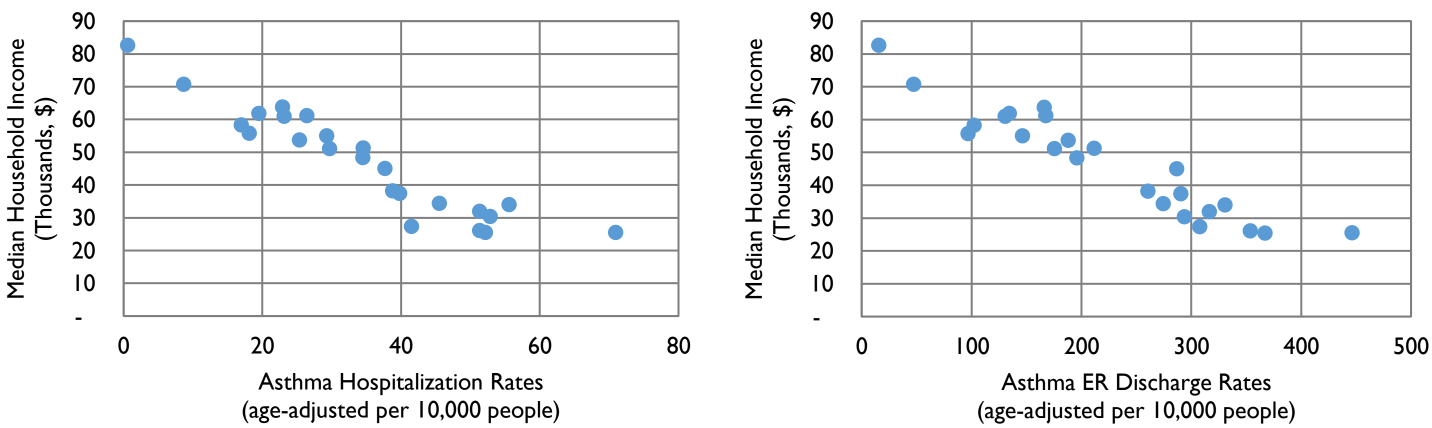


Figure ES-6. Scatter Plots of 2013 Median Household Income v. 2013 Asthma Hospitalization Rates (left) and 2013 ER Discharge Rates (right)



Trends Over Time

Baltimore's rates of asthma hospitalizations did not follow the same trend over time as rates of emergency room visits, as shown below in Figures ES-7 and ES-8. Rates of both generally rose from 2000 to 2009, although with different fluctuations. However, hospitalization rates began decreasing after 2009, while emergency room visit rates fluctuated during this period, including an increase between 2010 and 2011 and a decrease thereafter, ultimately reaching a rate in 2013 that was slightly less than in 2009 (4.7 percent less).

Figure ES-7. Baltimore City Asthma Hospital Discharge Rates, 2000-2013

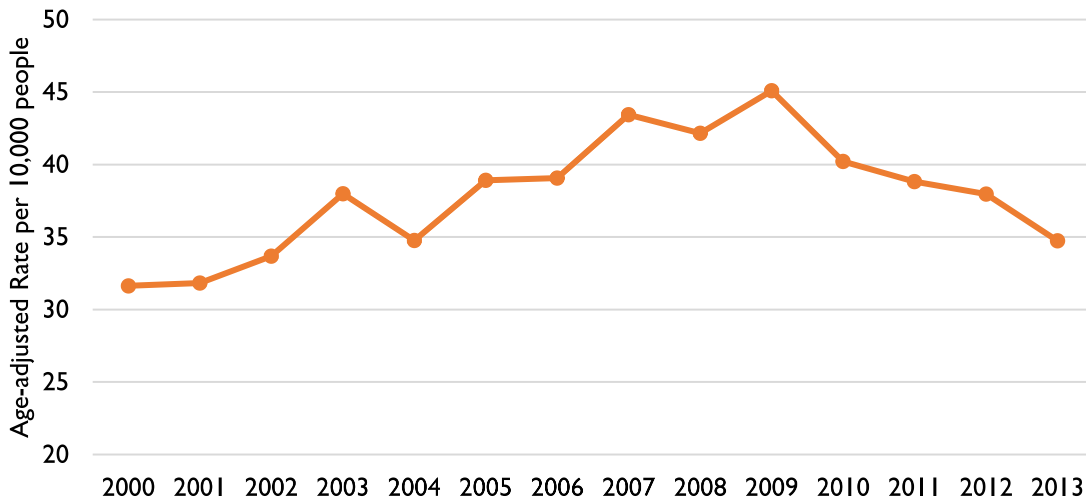
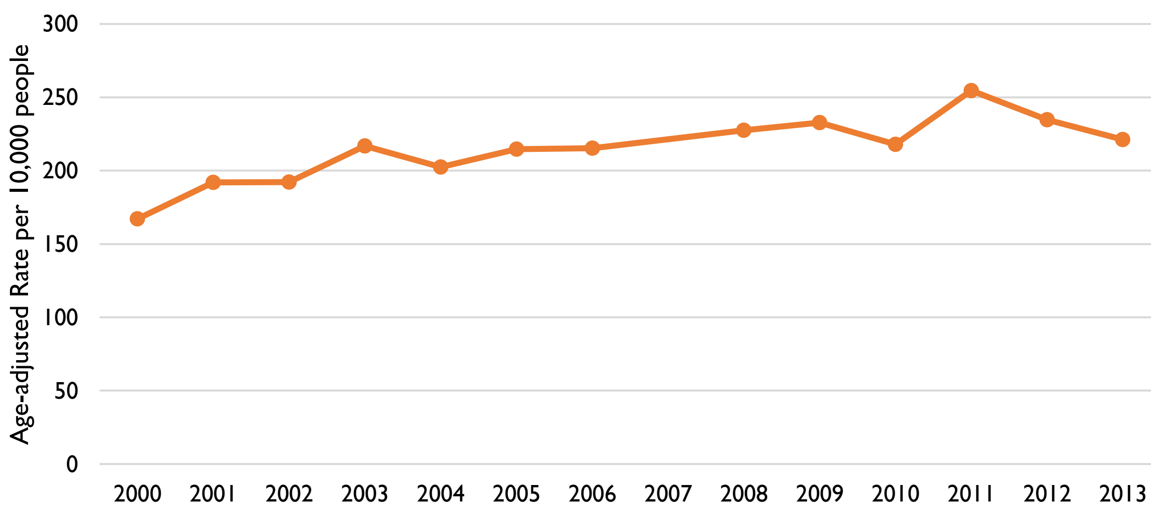


Figure ES-8. Baltimore City Asthma Emergency Room Discharge Rates, 2000-2013 (excluding 2007)[8]



[8] We were advised by the Maryland Department of Health that the 2007 ER data should not be used for trend purposes as it appears to be incorrect.

It appears that multiple variables affect asthma trends over time in Baltimore. [9] The divergence in hospitalization and emergency room visit trends after 2009 may have been influenced by post-recession economic and health care trends. A 2015 analysis of national-level data maintained by the Healthcare Cost and Utilization Project ("HCUP")[10] found that hospitalizations for potentially preventable conditions, including asthma, in adults decreased by 12.8 percent and that "treat and release" emergency room visits increased by 11.4 percent between 2008 and 2012.[11] For asthma, the researchers found that hospitalizations decreased by 15.6 percent between 2008 and 2012 and treat-and-release emergency room visits increased by 8.6 percent. They theorized that the changes may have been influenced by the recession and by the implementation of policies that penalized hospitals for high readmission rates "leading to more scrutiny over potentially preventable hospitalizations."[12]

EIP analyzed several measures of air pollution in Baltimore City for the period from 2000 through 2013, which are discussed in detail in the body of this report. A number of air pollution metrics declined substantially and fairly consistently during this period. Others fluctuated, showing spikes in different years. We did not find a consistent association between measures of air pollution and the city asthma rates. However, the post-2009 decrease in asthma hospitalizations may have been influenced by steep reductions between 2008 and 2010 in emissions from two coal plants located just south of the city in Northern Anne Arundel County. The decline in asthma hospitalization rates after 2009 was particularly sharp in the 21225 and 21226 zip codes near these plants, as discussed in more detail below.

Case Study: South Baltimore (Zip Codes 21225 and 21226)

Asthma hospitalization rates in the 21225 and 21226 zip codes in South Baltimore fell after 2009 much more sharply than in the city at large. Asthma hospitalization rates decreased in each of these zip codes by 57 percent from 2009 to 2013, which is more than 2.4 times the decrease in the city at large (23 percent) during these years. It is also much more than the national-level decrease from 2008 to 2012 found by researchers analyzing the HCUP database (15.6 percent). The trends for these two zip codes[13] and the city are shown below in Figure ES-9.

---

[9] Median household income, which is correlated with spatial asthma trends, does not appear to be correlated with trends over time, as discussed in more detail in the body of this report.

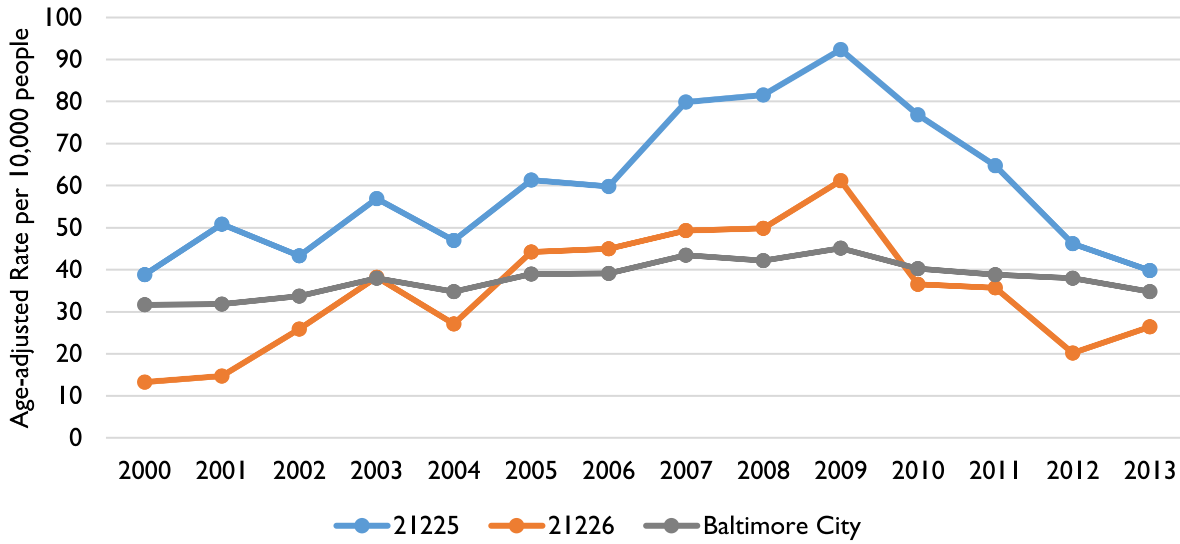
[10] HCUP is a family of health care databases and other information that is sponsored by the Agency for Healthcare Research and Quality, which is a division of the U.S. Department of Health and Human Services; Healthcare Cost and Utilization Project. 2017. "Fact Sheet." Link: https://www.hcup-us.ahrq.gov/news/exhibit_booth/HCUPFactSheet.pdf.

[11] Fingar, Kathryn R., et al. 2015. "Statistical Brief #195: Trends in Potentially Preventable Inpatient Hospital Admissions and Emergency Department Visits." Healthcare Cost and Utilization. pgs. 8-9. Link: https://www.hcup-us.ahrq.gov/reports/statbriefs/sb195-Potentially-Preventable-Hsospitalizations.pdf.

[12] *Id.*

[13] The fact that asthma hospitalization rates in the 21225 zip code are consistently higher over time than in the 21226 zip code is consistent with our finding that measures of poverty are closely correlated with spatial trends

Figure ES-9. Brooklyn (21225), Curtis Bay (21226), and Baltimore City Asthma Hospital Discharge Rates



Asthma emergency room visit rates did not experience the same steep drop after 2009, however. From 2009 through 2013, emergency room visit rates in the 21226 zip code increased by 7 percent and those rates in the 21225 zip code decreased by 19 percent, as shown in Table ES-1 below. At the city level, emergency room visit rates decreased slightly (by 5 percent) from 2009 to 2013. We were not able to analyze whether the decrease in hospitalization rates in these zip codes (or at the city level) was due to increasing "treat-and-release" emergency room visits, as the researchers analyzing the national-level HCUP data did, because we cannot identify these events separately from emergency room visits that result in admission. However, it does not appear that increasing treat-and-release emergency room visits was the primary reason for the decrease in hospitalizations in the 21225 and 21226 zip codes.

Table ES-1. Changes in Asthma Hospitalizations and Emergency Room Visit Rates from 2009-2013

	Hospitalizations	Emergency Room Visits
Baltimore City	-23%	-5%
Zip code 21225	-57%	-19%
Zip code 21226	-57%	+7%

The decrease in asthma hospitalization rates in the 21225 and 21226 zip codes may have been influenced by a rapid drop in emissions between 2009 and 2010 from two nearby coal plants. During these years, the Brandon Shores coal plant in Anne Arundel County, located just south of the city, added a suite of new pollution controls to its two coal-fired boilers, including flue gas desulfurization systems ("scrubbers") for sulfur oxides (SO_x) and mercury and baghouses for particulate matter (PM). These systems went into operation on one boiler

in Baltimore's asthma rates. Median household income in 2013 was about 63 percent higher in the 21226 zip code in 2013 than in 21225.

in December 2009 and on the other in February of 2010.[14] The Herbert A. Wagner coal plant, which is located at the same site as Brandon Shores, began using low-sulfur coal in 2010 to reduce SO_x emissions. Between 2009 and 2010, these new control measures reduced SO_x emissions from the two plants by 37,500 tons and particulate matter of a certain size (PM_{10}) by 546 tons. Prior changes had reduced nitrogen oxides (NO_x) emissions from these plants between 2008 and 2009.

All told, between 2008 and 2010, new control measures shaved off 44,792 tons of SO_x emissions, 9,945 tons of NO_x emissions, and 986 tons of PM_{10} emissions. These changes are shown by year below in Table ES-2.[15] The Brandon Shores and Herbert A. Wagner plants are located together at a complex called Fort Smallwood. Total pollution values per year in this table are for the Fort Smallwood complex.

Table ES-2. NO_x, SO_x, and PM_{10} Emissions from the Fort Smallwood Coal Plant Complex, 2008-2010

Year	Sulfur Oxides (SO_x) (tons)	Nitrogen Oxides (NO_x) (tons)	PM_{10} (tons)
2008	55,235	15,198	1093
2009	47,960	5,178	671
2010	10,443	5,253	125

The Fort Smallwood complex is located centrally in the 21226 zip code, which is partly in Baltimore City and partly in Anne Arundel County, and the 21225 zip code is the adjacent zip code to the Northwest. It appears that the dramatic reductions in pollution from the coal plants at Fort Smallwood may have played a role in bringing down rates of asthma hospitalizations in the Baltimore City zip codes closest to these plants.

While the post-2009 decline in asthma hospitalization rates certainly reflect an improvement for the 21225 and 21226 zip codes, more must still be done to reduce asthma in these areas. In 2009, the 21225 zip code had the highest asthma hospitalization rate out of every zip code in the city. In 2013, it was ranked 9th in the city, which is still relatively high, especially given how high city asthma rates are compared to the state. The 21226 zip code, which was 7th in the city for highest asthma hospitalization rates in 2009, ranked 16th in 2013.

Recommendations

Clearly, one of the main factors driving high asthma hospitalization and emergency room rates in Baltimore is poverty, which is linked to many conditions that can worsen asthma, including limited access to control medication and poor housing conditions. The

[14] Letter from Daniel Haught, Vice President, Baltimore Operations, Constellation Energy Power Generation ("CPSG"), to George Aburn, Director, Air & Radiation Management Administration, MDE (February 18, 2011). CPSG was the owner and operator of these plants at the time that the controls were installed. EIP had this letter in our electronic files; it was likely obtained in response to a past request to MDE under the Maryland Public Information Act.

[15] These emissions values are from the Maryland Emissions Inventory, which EIP requested from MDE under the Maryland Public Information Act. EPA's Clean Air Markets (CAM) database shows slightly different emissions values each year, but CAM also shows a drastic reduction in these pollutants from 2008 to 2010.

Environmental Integrity Project, as an environmental health advocacy organization, does not have answers to all of these problems. But reducing air pollution will likely have health benefits for the communities that are most affected by asthma emergencies. We are setting forth recommendations here for how state and city officials can take steps to further reduce air pollution that affects Baltimore.

1. State of the Art Pollution Controls Should Be Required for All Pollution Sources in the Baltimore Region

The pollution control upgrades, and subsequent emission reductions, at the Fort Smallwood coal plants were achieved because of the 2006 passage of a law called the Maryland Healthy Air Act. Our analysis suggests that these reductions may have improved asthma hospitalization rates in communities near the plant. State of the art pollution controls should be required on all pollution sources that affect the air that people breathe in Baltimore City. For example, MDE is currently setting new emission limits for NO_x for the Wheelabrator trash incinerator in South Baltimore (sometimes called the "BRESCO" incinerator), which is the largest stationary source of NO_x located within the city's borders. This plant emitted 1,141 tons of NO_x in 2016, making it the state's fifth largest emitter of that pollutant. NO_x emissions contribute to the formation of ground-level ozone, NO_2, and particulate matter in the air that people breathe. The BRESCO incinerator is also a major source of SO_x and a significant emitter of toxic air pollution.

MDE should set emission limits for this incinerator that will require the installation of new pollution controls at this plant, preferably state of the art controls. If MDE does not move forward quickly with a rule that requires significant emissions cuts at this facility, then the City of Baltimore, which also has legal authority to set emissions limits for this plant,[16] should consider setting its own limits.

2. MDE Should Apply Increased Scrutiny to Permit Applications for Air Pollution Sources In and Near Zip Codes with High Rates of Acute Asthma Events

When a new air pollution source is proposed in Baltimore (or any Maryland zip code with a high asthma rate), state officials should apply increased scrutiny to the permit application. Given the apparent association between SO_x emissions and asthma hospitalization rates in the areas near the Fort Smallwood coal plant complex, it makes sense for the state to conduct a particularly close review for new large sources of SO_x emissions.

There are a variety of ways in which MDE can more closely review the effect of a proposed pollution source on nearby communities. For certain sources, MDE can require the permit applicant to obtain neighborhood-specific air quality data if needed by installing air quality monitors in the communities closest to and/or downwind of the proposed pollution source.[17] This would allow a more precise evaluation of the potential effects of the new source. MDE also has some authority to take into account the air pollution impacts from mobile sources – for example, certain emissions from ships, which can be very large emitters

---

[16] Md. Code, Environment, § 2-104.
[17] U.S. Environmental Protection Agency. 1990. "Draft New Source Review Workshop Manual." pg. C-16. Link: https://www.epa.gov/sites/production/files/2015-07/documents/1990wman.pdf.

of SO_x[18] – that would service the proposed new facility. Enhanced opportunities for public input would make it more likely that any existing health conditions (in addition to asthma) in the nearby community that increase vulnerability to the adverse impacts of air pollution would be raised during the public comment period for the permit. For example, the EPA has found that there is adequate evidence that the adverse respiratory effects of ozone are made worse by an insufficiently healthy diet, particularly reduced intake of Vitamins E and C, as discussed in the section below on non-pollution factors that can affect asthma.

Depending on the results of the air quality impacts review, MDE could set more protective conditions in the final permit or, if permit requirements are not met, deny the permit. More protective permit conditions could include more stringent pollution control requirements and better monitoring, including ongoing air quality monitoring in nearby communities. If the proposed source is planning to meet any air quality requirements using pollution "offsets" from other facilities, MDE could require that those offsets be obtained from sources in the immediate vicinity of the new pollution source in order to ensure that local air quality is not degraded.[19]

3. The State of Maryland Should Reduce Emissions from Roadway Vehicles by Improving Public Transit Options in Baltimore

Air pollution from roadway vehicles appears to be disproportionately affecting some of the areas of Baltimore City that have the highest asthma hospitalization and emergency room visit rates. Increasing opportunities for Baltimore residents and commuters to take public transit will likely reduce the pollution burden on these communities. Baltimore's public transit system is notoriously outdated and inadequate, especially for a city that wishes to attract new residents and new businesses.

In 2015, Governor Larry Hogan canceled state plans to build the Red Line, which would have been a 14-mile subway and light rail line running from west to east in Baltimore. In addition to reducing air pollution,[20] this project was anticipated to provide enormous economic benefits to Baltimore. A 2009 study commissioned by the Baltimore City Department of Transportation found that the construction phase of the Red Line would have generated "$1.8 billion in economic activity in Baltimore City and create[d] or support[ed] 12,949 jobs earning $672.5 million in salaries and wages."[21]

This was a missed opportunity to reduce traffic congestion, and associated air pollution, in Baltimore while improving economic opportunities in the city. The state should undertake a

---

[18] Citations for this authority are provided in the Conclusion and Recommendations section of the body of this report.

[19] COMAR 26.11.17.03 (Requiring MDE to deny a permit for a new major source or a major modification in a nonattainment area unless "emission offsets will provide a positive net air quality benefit in the affected area . . . .")

[20] Without providing specific reduction figures, the Final Environmental Impact Statement Executive Summary (FEIS) for the project states that the Red Line is estimated "to decrease pollutant burdens" at the regional level by about 1.5 to 1.9 percent; The full FEIS was not available online; The Federal Transit Administration. 2012. "Red Line FEIS Executive Summary." pgs. ES-17, ES-23. Link: https://transportation.baltimorecity.gov/sites/default/files/Redline_executive%20Summary_feis.pdf.

[21] Clinch, Richard. 2009. "The Economic and Jobs Impacts of the Red Line Mass Transit System on Baltimore City." *The Jacob France Institute, University of Baltimore*. pgs. 5-6. Link: http://www.jacob-france-institute.org/documents/Red-Line-12-09.pdf.

review of how to reduce air pollution from roadway vehicles in the City of Baltimore, focusing on roadways in or near the city zip codes with the highest asthma rates. The Red Line should be considered an option as the state conducts this review.

4. The Maryland Department of Health Should Make Asthma Data Available by Community Statistical Area for Baltimore City

EIP is extremely appreciative of the time and resources that the Maryland Department of Health has expended in making available the zip code level asthma data discussed in this report. We are also very grateful to officials within the Department of Health for taking the time to provide helpful input in response to questions that we have raised about the data as we wrote this report. However, there is a way in which the asthma data could be made even more helpful to residents of Baltimore City.

The Baltimore Neighborhood Indicators Alliance ("BNIA)" tracks poverty and a number of other factors in the city at the level of community statistical areas, which are clusters of census tracts, and issues annual reports on this data called Vital Signs reports.[22] If possible without violating privacy requirements, the Maryland Department of Health should make asthma data available at this level for Baltimore City. This data would allow a direct comparison with many of the factors tracked by BNIA, such as measures of poverty and other measures relating to health and quality of life, including housing. Being able to make a direct statistical correlation would assist in identifying the factors that contribute most to the high asthma rates in Baltimore and could potentially identify any that might affect certain neighborhoods.

5. Officials and Local Universities Should Assist Baltimoreans to Obtain Community-Specific Air Quality Data Using Portable Monitors

As illustrated in the body of this report (Figure 27), only four official air quality monitors were located in Baltimore in 2013. Of these, only one was located in one of the city neighborhoods with the highest asthma hospitalization rates. Pollution levels can fluctuate from monitor to monitor, as shown below (Figure 28) in the graph comparing trends over time at three Baltimore City monitors for fine particles ($PM_{2.5}$). Having neighborhood-specific air quality monitoring data would be enormously helpful in determining whether certain neighborhoods within Baltimore are exposed to pollution hotspots and what the pollution levels might be in those areas.

If the state lacks the funding for these monitors, then local universities should explore options to fill in information gaps by gathering data on relative air pollution levels in different city neighborhoods.[23] Target areas within the city should be in zip codes shown in this report to have high asthma hospitalization and emergency room visit rates. Researchers should further consider sampling in neighborhoods with the lowest median household incomes, as identified by community statistical area based on BNIA's most recent Vital

[22] Baltimore Neighborhood Indicators Alliance and University of Baltimore. 2017. "Spring 2017 Vital Signs 15." Link: https://bniajfi.org/wp-content/uploads/2017/04/VS15_Compiled-04-12-17-08-41.pdf.
[23] Dance, Scott. 2017. "How clean is the air on your block? Baltimore citizen scientists build monitors to find out." *Baltimore Sun*, August 11, 2017. Link: http://www.baltimoresun.com/news/maryland/environment/bs-md-air-monitor-network-20170731-story.html.

Signs report, because of the strong spatial correlation between asthma rates and median household income at the zip code level.

Finally, as discussed in more detail in the body of this report, we recommend that monitors be deployed to measure pollutants including ozone, particulate matter, NO_x, and volatile organic compounds such as acrolein and benzene. EIP is already aware of one such effort for NO_x and ozone monitoring being implemented by researchers at Johns Hopkins under a grant from the EPA. As the sharp decrease in SO_x emissions at the Brandon Shores plant in 2009 and 2010 appears to have helped reduce asthma hospitalization rates in nearby Baltimore neighborhoods, we also consider it particularly important to increase monitoring of sulfur dioxide (SO_2), which is measured as a proxy for SO_x. We are pleased that MDE has been making plans to install an SO_2 monitor close to the Fort Smallwood complex,[24] which is still a large emitter of this pollutant even with the reductions that were achieved in 2010.

[24] Pacella, Rachael. 2017. "Riviera Beach Elementary proposed site for air quality monitor." *Capital Gazette*, September 22, 2017. Link: http://www.capitalgazette.com/news/ac-cn-air-quality-0923-story.html.

Table of Contents

Introduction

Asthma is well-recognized as one of the most severe health problems affecting residents of Baltimore City, Maryland. State and city officials and many members of the public have long been aware that asthma rates are much higher in Baltimore than in the State of Maryland as a whole.[25] However, until very recently, there was no large-scale set of data available to the public on asthma rates in Maryland in any areas smaller than counties (Baltimore City is a county). Thus, it was extremely difficult to analyze which neighborhoods within the city were most affected by asthma.

Between September 2016 and May 2017, the Maryland Department of Health ("Department of Health") publicly released two sets of zip code level data on asthma hospitalization events. Specifically, the Department of Health made available asthma hospital discharge data ("asthma hospitalizations") and asthma emergency department discharge data ("emergency room visits" or "ER visits") for the whole State of Maryland from 2000 through 2013 (again, at the zip code level). The Department of Health took this step partly in response to years of pressure from health and environmental advocates, including the Maryland Environmental Health Network, the Environmental Integrity Project, and Dr. Sacoby Wilson, the Director of the Community Engagement, Environmental Justice, and Health (CEEJH) program at the School of Public Health, University of Maryland. The Department of Health made the data available online via its user-friendly Environmental and Public Health Tracking portal, which allows members of the public to visualize the data using a mapping function[26] and to sort in different ways using a query function.[27]

This report analyzes the recently released asthma data for the City of Baltimore and further analyzes publicly available data on air pollution in the Baltimore area to assess whether there is a link between acute asthma events and air pollution in Baltimore City. The two types of asthma data analyzed in this report are briefly described below:

- **Hospitalization data.** This is discharge data for all patients who were admitted to a hospital (inpatients) for asthma, regardless of the department through which they were admitted.[28] This data was released by the Department of Health in September 2016.
- **Emergency room data.** This is discharge data for patients who visit the emergency department because of asthma, including patients who are treated and released

[25] The website of the Baltimore City Health Department states that "Baltimore's pediatric asthma hospitalization rate is the highest in Maryland and one of the highest in the nation. Asthma accounts for the greatest loss of productivity either through missed work days or school absenteeism."; Baltimore City Health Department. "Asthma." Link: http://health.baltimorecity.gov/node/454.
[26] Maryland Department of Health. Maryland Environmental Public Health Tracking. "Maps." Link: https://maps.health.maryland.gov/epht/.
[27] Maryland Department of Health. Maryland Environmental Public Health Tracking. "Queries." Link: https://maps.health.maryland.gov/epht/query.aspx.
[28] Email dated April 20, 2017 from Dr. Ann Liu, Chief, Center for Environmental & Occupational Epidemiology, Environmental Health Bureau, Department of Health, to Kira Burkhart, Senior Research Analyst, Environmental Integrity Project.

(outpatients) and patients who are admitted to the hospital through the emergency department (inpatients). This data was released by the Department of Health in April 2017.

There is some overlap between these two datasets because some patients are admitted to the hospital through the emergency department. With respect to how the two datasets differ, the U.S. EPA has stated – concerning data on hospitalization and emergency room visits for all respiratory issues – that "respiratory [emergency department] visits may represent potentially less serious, but more common outcomes."[29]

The purpose of this report is to analyze whether there may be a link between zip code level asthma rates in Baltimore City and measures of air pollution. We also assessed the influence of poverty on the distribution of asthma attacks in Baltimore's neighborhoods because it was immediately apparent to us, based on our mapping, that asthma rates were higher in the poorest areas of the city. We provide background information on other factors that can influence rates of asthma hospitalizations and emergency room visits. However, it is beyond the scope of this report to analyze the relative influence of all of the different factors that may be contributing to Baltimore's asthma hospitalization and emergency room visit rates.

Asthma and Air Pollution

Asthma is a chronic illness involving inflammation of the airways (bronchial tubes) leading to the lungs. For asthmatics, these airways are always inflamed, but certain triggers can cause increased inflammation and swelling of the muscles around the bronchial tubes, resulting in the symptoms associated with "asthma attacks": shortness of breath, wheezing, coughing, and chest tightness.[30]

Many different factors – including activities like exercise – can act as triggers. For those with allergic asthma, symptoms can be triggered by things that are not harmful to most people, like pet dander, pollen, mold, or cockroach or mouse droppings.[31] Other factors that can act as triggers include certain medications, emotional stress, viral and bacterial infections, acid reflux disease, and exposure to certain kinds of weather.[32] Irritants that can inflame the airways, but are not classified as "allergens" include tobacco smoke, strong odors or fumes, and air pollution.[33]

[29] U.S. Environmental Protection Agency. 2013. "Integrated Science Assessment for Ozone and Related Photochemical Oxidants." pg. 6-131. Link: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492.
[30] American Academy of Allergy Asthma & Immunology. "Asthma Overview." Link: http://www.aaaai.org/conditions-and-treatments/asthma.
[31] American Academy of Allergy Asthma & Immunology. "Asthma Triggers and Management." Link: http://www.aaaai.org/conditions-and-treatments/library/asthma-library/asthma-triggers-and-management
[32] *Id.*
[33] *Id.*; Asthma and Allergy Foundation of America. "Asthma, Allergens and Allergic Asthma." Link: http://www.aafa.org/page/allergic-asthma.aspx

Air Pollution as Asthma Trigger

Outdoor air (also called "ambient" air) in urban areas like Baltimore City frequently includes the pollutants nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone, and particulate matter or soot (PM). Pollutants like these come from many sources, like fossil fuel combustion from motor vehicles, power plants, and incinerators, and can contribute to adverse health effects, particularly in sensitive groups like children and the elderly. Over the last few decades, researchers have collected evidence supporting the idea that air pollution can worsen pre-existing asthma. These pollutants can damage, inflame, and/or constrict the airways which trigger asthma attacks in pre-existing cases.[34]

Specific pollutants that have been associated with increased asthmatic symptoms in scientific studies include particulate pollution, NO_2, ground-level ozone, SO_2, and the multi-pollutant category of traffic-related air pollutants. In 2015, researchers published a literature review and meta-analysis of 87 prior studies on the effects of short-term exposure (up to 7 days) to air pollution on asthma emergency room visits and hospitalizations. The authors concluded that "air pollutants were associated with significantly increased risks of asthma [emergency room visits] and hospitalizations."[35] Specifically, increases of 10 micrograms per cubic meter ($\mu g/m^3$) in fine particles ($PM_{2.5}$) were associated with increasing the risk of asthma-related hospitalizations or emergency room visits by 2.3 percent, and larger particulate matter (PM_{10}) increased risks by 1.1 percent.[36] For other pollutants, which typically exist at higher concentrations in the ambient air, an increase of the same amount (10 $\mu g/m^3$) was associated with increased risks of 1.8 percent for NO_2, increased risks of 1.1 percent for SO_2, and increased risk of 0.8 percent for ozone.[37] In addition, the study found stronger associations between short-term exposure to air pollution and asthma-related emergency room visits and hospitalizations in children and elderly populations.[38]

As noted above, certain populations, including children and the elderly, are especially vulnerable to the effects of air pollution. Multiple studies suggest that children may be more vulnerable to the effects of ambient air pollution than adults, although results have not always been consistent.[39] The reasons for this are likely that children have "higher ventilation rates, developing lung physiology, immature immune systems, and smaller . . . airways, resulting in proportionally greater airway obstruction from inflammation."[40] A study of children ages 5-17 between 2005 and 2011 in New York City found associations between ground-level ozone concentrations and asthma hospitalizations and emergency

---

[34] Guarnieri, Michael, and John R. Balmes. 2014. "Outdoor air pollution and asthma." *Lancet* 383: 1581-92.
[35] Zheng, Xue-yan, et al. 2015. "Association between Air Pollutants and Asthma Emergency Room Visits and Hospital Admissions in Time Series Studies: A Systematic Review and Meta-Analysis." *PLOS ONE*: 2. DOI:10.1371/journal.pone.0138146. Link: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0138146.
[36] *Id.*
[37] *Id.*; Carbon monoxide (CO) was also evaluated in the study but is not included here because, as the study authors note, the link between CO and asthma has not been studied as well and "the direct association between CO and asthma is . . . less clear." *Id.* at 16.
[38] *Id.* at 2; Lag time is the period of time between exposure and asthma exacerbations.
[39] Sheffield, Perry Elizabeth, et al. 2015. "Ambient ozone exposure and children's acute asthma in New York City: a case-crossover analysis." *Environmental Health* 14:25: 2. DOI 10.1186/s12940-015-0010-2.
[40] *Id.* at 1-2.

room visits. Specifically, an increase in ozone levels of 13 parts per billion ("ppb") was associated with an increased risk of 2.9-8.4 percent of emergency department visits for boys and 5.4-6.5 percent for girls. For girls, the same increase in ozone concentrations was also associated with an 8.2 percent increase in risk of hospitalization.[41]

Another study, known as the Southern California Children's Health Study, examined the impact of NO_2, ozone, and PM exposure from regional air pollution and traffic-related air pollution on children, by following five cohorts in sixteen communities. While the study did not focus on hospitalizations or emergency room visits, it did find that asthma symptoms were worsened by exposure to air pollution. The study found that children living in communities with higher concentrations of NO_2 and PM and diagnosed with asthma were more likely to have chronic and acute respiratory problems (e.g. bronchitis, phlegm, wheezing) than those exposed to lower levels of air pollution. The study's authors also found that increased air pollution (both regional and traffic-related) was associated with increased airway inflammation and negatively impacted lung development.[42]

Additionally, a 2010 report from the Health Effects Institute, an organization focused specifically on researching the health impacts from air pollution exposure, reviewed studies on the association of traffic-related air pollution and asthma-related symptoms, such as wheezing or coughing, and concluded there was sufficient evidence "to infer a causal association between traffic exposure and exacerbations [worsening] of asthma."[43]

Air Pollution and New-Onset Asthma

In addition to the demonstrated link between air pollution and worsening symptoms of existing asthma, some studies have indicated that exposure to air pollution may be linked to new-onset cases of asthma.

For example, the Southern California Children's Health Study found that, even at levels below the national air quality standards, air pollution is associated with asthma prevalence (having asthma as a condition) and incidence (new-onset asthma). Several of the cohorts showed increased prevalence in areas with higher concentrations of ambient NO_2 and an increased risk of new-onset asthma in children living closer to major roadways. Ozone was also associated with new asthma cases, although the association was also tied to exercise levels. Children who played sports in areas of high ozone concentrations were found to be more at risk of developing asthma than those who played no sports. The study also found that children with more airway inflammation, associated with regional and traffic-related air pollution, had an increased risk of developing asthma.[44]

Another study conducted in London found exposure to traffic-related air pollution, specifically NO_2, could be associated with decreased lung function in children, which would

---

[41] *Id.* at 1.

[42] Chen, Zhanghua, et al. 2015. "Chronic effects of air pollution on respiratory health in Southern California children: findings from the Southern California Children's Health Study." *J Thorac Dis* 7(1): 46-58.

[43] Health Effects Institute. 2010. "Special Report 17: Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects." Link: https://www.healtheffects.org/system/files/SR17Traffic%20Review.pdf

[44] Chen, *supra* note 42.

increase the risk of developing long-term respiratory ailments, such as asthma.[45] The Health Effects Institute report discussed above also "concluded that living close to busy roads appears to be an independent risk factor for the onset of childhood asthma."[46]

Respiratory Health Benefits from Reduced Pollution

EPA has quantified the health benefits from reducing emissions of $PM_{2.5}$ and nitrogen oxides (NO_x) and sulfur oxides (SO_x)[47] (as $PM_{2.5}$ precursors), including effects on exacerbation (worsening) of asthma and on hospital and emergency room visits because of respiratory problems. EPA's findings, which EIP has calculated based on reductions of 100 tons, are shown below in Table 1. This likely undercounts the total health benefits of SO_x and NO_x reductions because exposure to those pollutants in the ambient air (usually measured as SO_2 and NO_2) can have adverse health effects, as discussed above, that are in addition to health effects caused by exposure to $PM_{2.5}$, to which SO_x and NO_x contribute as precursors. Further, EPA's estimates are based on an average per ton benefit nationally, and does not reflect Baltimore City reductions specifically.

Table 1. Occurrence of Respiratory Health Effects Avoided per 100 Tons of $PM_{2.5}$, NO_x, and SO_x Reduced[48]

Emissions Source	Asthma Exacerbation	Respiratory Emergency Room Visits	Respiratory Hospital Admissions
Directly Emitted $PM_{2.5}$			
Electric Generating Units	42	0.83	0.41
Industrial Point Sources	87	1.6	0.8
On-Road Mobile Sources	300	2.4	1.1
NO_x (as a precursor to $PM_{2.5}$)			
Electric Generating Units	1.7	0.033	0.017
Industrial Point Sources	2.1	0.04	0.019
On-Road Mobile Sources	6.1	0.049	0.023
SO_x (as a precursor to $PM_{2.5}$)			
Electric Generating Units	26	0.21	0.11
Industrial Point Sources	13	0.25	0.13
On-Road Mobile Sources	7.4	0.11	0.053

[45] Barone-Adesi, Francesco, et al. 2015. "Long-term exposure to primary traffic pollutants and lung function in children: cross-sectional study and meta-analysis." *PLOS ONE.* DOI:10.1371/journal.pone.0142565.
[46] Health Effects Institute, *supra* note 43.
[47] Sulfur oxides (SO_x) is a category of gases and sulfur dioxide (SO_2) is used as an indicator or proxy for SO_x. The same is true of nitrogen oxides (NO_x) and nitrogen dioxide (NO_2).
[48] U.S. Environmental Protection Agency. 2013. "Technical Support Document. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors." Link: https://www.epa.gov/sites/production/files/2014-10/documents/sourceapportionmentbpttsd.pdf; EPA's estimates are based on national emissions, and represent the average benefit per ton for the entire country. Values represent estimated benefits (avoided morbidity) in 2016 for reducing emissions by 100 tons. Asthma exacerbation covers asthmatics age 6-18, whereas emergency room visits and hospital admissions measure benefits for all ages.

Non-Pollution Factors that Affect Asthma

As noted above, air pollution is one of many potential asthma triggers, which include viral and bacterial infections, pollen, mold, cockroach droppings, pet dander, acid reflux disease, emotional distress, and exposure to tobacco smoke. In addition, certain factors increase an individual's susceptibility to adverse effects from a given asthma trigger. For example, the EPA has found that there is adequate evidence that the adverse respiratory effects of ozone are made worse by an insufficiently healthy diet, particularly reduced intake of Vitamins E and C.[49]

It is beyond the scope of this report to analyze every factor that contributes to asthma hospitalization and/or emergency department visit rates in Baltimore City or elsewhere. However, it is important to note that the asthma attacks addressed in this report, which are severe enough to require hospitalizations and emergency room visits, have been shown to be influenced by the level and quality of preventative care available to a patient.

Some reports suggest that asthma hospitalizations and emergency department visits may track use of medication to control asthma and/or socioeconomic factors that may correspond with access to care. For example, a review of asthma data for child recipients of Medicaid in South Carolina, showed that use of "controller" medication (medication designed to control asthma and prevent acute incidents) was a significant predictor of emergency room visits and hospitalizations over the following 3, 6, and 12 month period. Specifically, the report's authors found that "patients who have controllers dispensed as less than half of their asthma medications are approximately 60 percent more likely to have an emergent care visit in the subsequent 3, 6, and 12 month time periods."[50]

In addition, a 2015 analysis by researchers using the Healthcare Cost and Utilization Project ("HCUP") - a national-level family of health care databases and other information that is sponsored by a division of the U.S. Department of Health and Human Services[51] - indicates that hospitalization rates and emergency department visit trends for multiple conditions may be driven by broader trends relating to health care and the national economy. Specifically, the report's authors found that, following the Great Recession, which began in December 2007, rates of hospitalizations for "potentially preventable" conditions in adults – meaning conditions that hospitalization and emergency room visits can often be reduced

---

[49] EPA, Integrated Assessment of Ozone, pages 8-35 to 8-36; *supra* note 28.

[50] Andres, Annie Lintzenich, et al. 2013. "Asthma Medication Ratio Predicts Emergency Department Visits and Hospitalizations in Children with Asthma" *Medicare Medicaid Res Rev* 3(4). Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4011648/.

[51] Specifically, HCUP is "a family of health care databases, software tools, supplemental files, reports, and other related products developed through a Federal-State-Industry partnership and sponsored by the Agency for Healthcare Research and Quality," which is within the U.S. Department of Health and Human Services; Healthcare Cost and Utilization Project. 2017. "Fact Sheet." Link: https://www.hcup-us.ahrq.gov/news/exhibit_booth/HCUPFactSheet.pdf.

through preventative care – decreased and the rates of "treat and release" emergency department visits[52] increased.[53]

From 2008 – 2012, for all potentially preventable conditions reviewed in the study, the rate of hospitalizations decreased by 12.8 percent and the rate of "treat and release" emergency room visits increased by 11.4 percent.[54] During this period, asthma hospitalizations decreased by 15.6 percent and emergency room visits increased by 8.6 percent.[55] The report's authors note that the recession was "associated with a decrease in inpatient stays as unemployment increased and access to health insurance decreased. For those who had health insurance during the [r]ecession, copayments and deductibles increased." They also note that "[r]ecent initiatives that penalize hospitals for high readmission rates are leading to more scrutiny over potentially preventable hospitalizations."[56] Thus, they conclude that "[a]lthough overall inpatient hospital stays have declined, increasingly patients are being seen in EDs and placed under observation, which may result in more individuals being discharged home rather than admitted as an inpatient."[57]

Asthma in Baltimore City

The most recent report on asthma in Maryland by the state Department of Health was issued in 2012 and uses datasets that are several years old. This report shows that, using 2008-2010 data, adults in Baltimore City had the highest average current prevalence of asthma (having the condition at the time polled) of any county in the state, at a rate about 38 percent higher than the state average.[58] Average lifetime prevalence of asthma (having had asthma at some point in one's life) for adults in Baltimore City for the same years was also high – approximately 14 percent higher than the state average – but not the greatest in the state. Dorchester and Calvert Counties had higher rates of adult lifetime asthma prevalence, and Caroline County had a rate equal to Baltimore City's.[59]

Asthma Mortality, Hospitalization, and Emergency Room Visits

Markers of the acute effects of asthma, however, show that Baltimore City has a much more significant asthma problem than the rest of Maryland. The 2012 Department of Health report measures average mortality from asthma using 2006-2010 data. This data shows Baltimore City as having an asthma mortality rate of 25.6 per 1 million people, which is

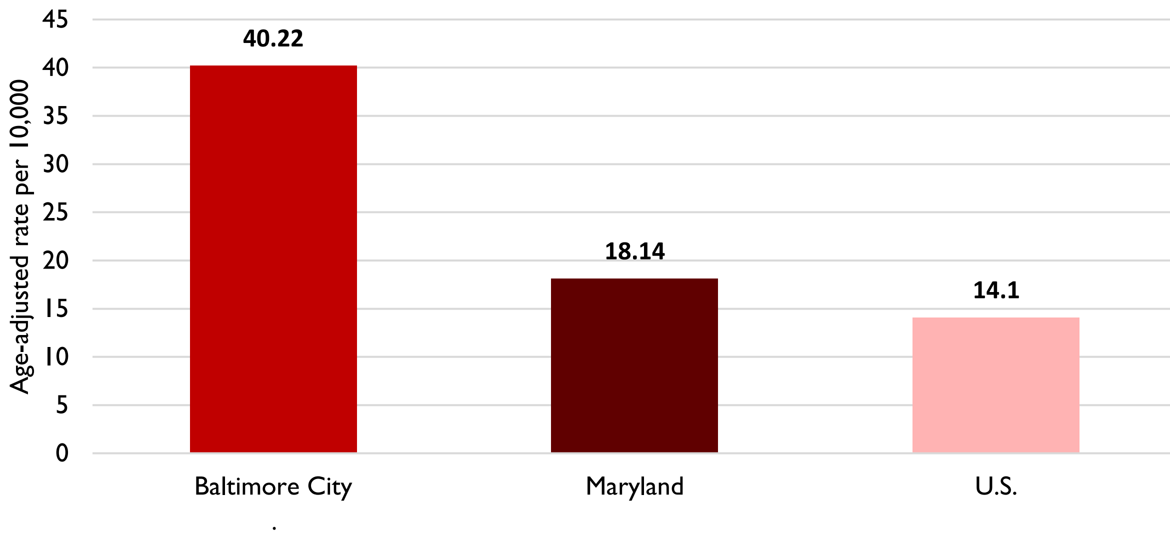
---

[52] "Treat and release" emergency department visits, in the study, were those that did not result in inpatient admission.
[53] Fingar, Kathryn R., et al. 2015. "Statistical Brief #195: Trends in Potentially Preventable Inpatient Hospital Admissions and Emergency Department Visits." Healthcare Cost and Utilization. pgs. 8-9. Link: https://www.hcup-us.ahrq.gov/reports/statbriefs/sb195-Potentially-Preventable-Hsospitalizations.pdf.
[54] *Id.* at 7.
[55] *Id.* at 8-9.
[56] *Id.* at 1-2.
[57] *Id.* at 2.
[58] Maryland Department of Health. 2012. "Asthma in Maryland 2012." pg. 55. Link: http://phpa.dhmh.maryland.gov/mch/Documents/Asthma%20in%20Maryland%202012.pdf.
[59] *Id.*

more than twice the state average rate and 23 percent higher than the rate of the next-highest county, Washington County.

Asthma hospitalization and emergency room visits in Baltimore City are also very high relative to the rest of the state. The zip code level asthma hospitalization and emergency room data released in 2016 by the Department of Health shows that, in 2013, the average rate of hospitalizations for Baltimore City[60] was 2.3 times the state-wide rate. In the same year, the average rate of asthma emergency room visits was 2.5 times the state average. Figure 1 below illustrates Baltimore City's asthma hospitalization rates in 2010 compared with Maryland rates and national rates.[61] 2010 is the most recent year for which we could find national hospitalization data to compare to state and city data.

Figure 1. Comparison of Asthma Hospitalization Rates in Baltimore City, Maryland, and the United States (2010)[62]



Figures 2 and 3 below show asthma hospitalization and emergency room visit rates respectively for Baltimore City from 2000 to 2013 compared with Maryland rates over the same period.

[60] For the purposes of this report, "Baltimore City" asthma hospitalization and emergency room discharge rates from the Maryland Environmental Public Health Tracking tool represents 25 zip codes that are mostly located in the city, and excludes 7 zip codes that are mostly located in other counties and only minimally within the City, as described in more detail in the Methodology and Data Caveats section of this report.

[61] Baltimore City and Maryland rates: Maryland Department of Health. 2011. "Asthma in Maryland 2011." pg. 62. Link: http://phpa.dhmh.maryland.gov/mch/Documents/Asthma_in_Maryland-2011.pdf; U.S. rate: *supra* note 58, pg. 37.

[62] National data: Centers of Disease Control and Prevention. "Most Recent Asthma Data." Link: https://www.cdc.gov/asthma/most_recent_data.htm; State and City data: Maryland Environmental Public Health Tracking Tool, *supra* note 27.

Figure 2. Baltimore City vs. Maryland Asthma Hospitalization Rates

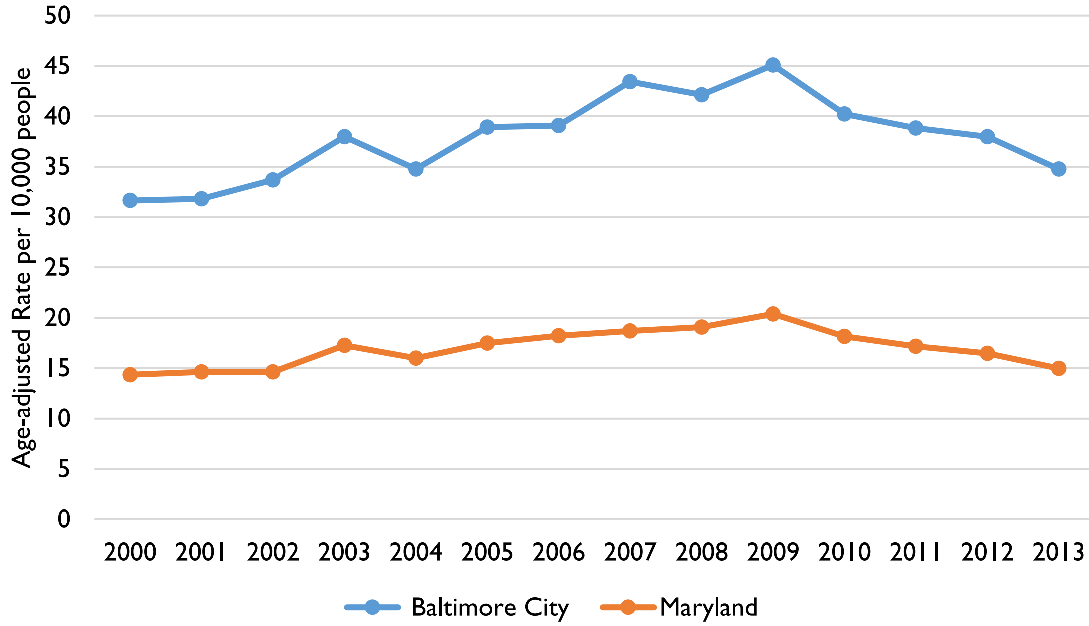
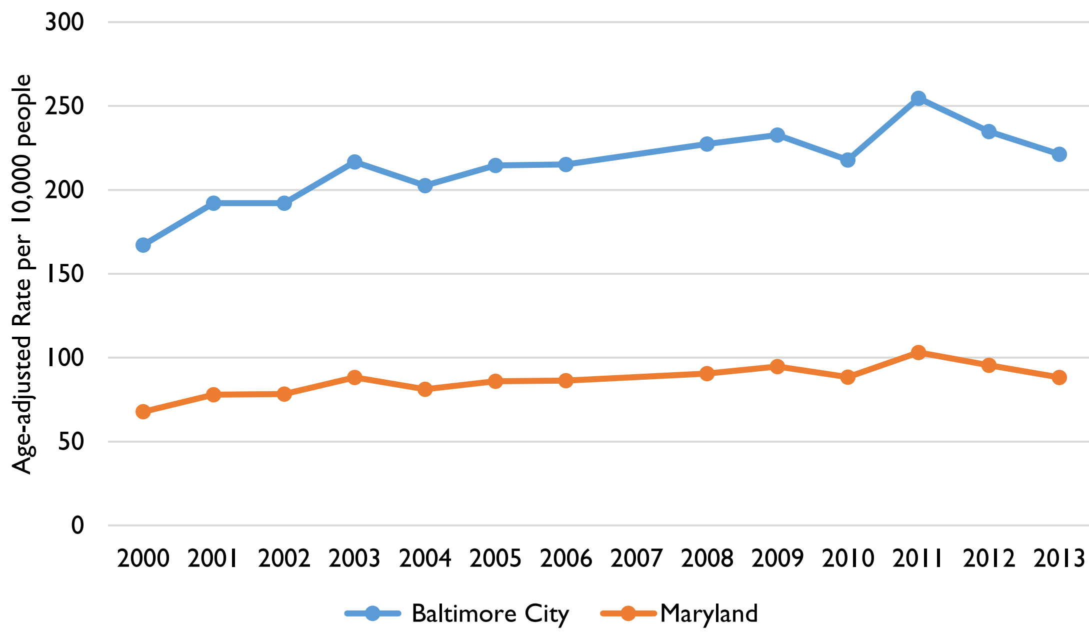


Figure 3. Baltimore City vs. Maryland Asthma Emergency Room Discharge Rates[63]



Childhood Asthma in Baltimore City

As discussed above, studies have suggested that children experience more serious symptoms of asthma than adults and that children are more vulnerable to the adverse effects of air pollution on asthmatic symptoms. The 2013 asthma hospitalization data shows that

[63] Data from the year 2007 is excluded from the graph showing asthma emergency room discharges. We were advised by the Department of Health that the 2007 data should not be used for trend purposes as it appears to be incorrect.

children ages 0-4 were hospitalized for asthma at a higher rate than most of the other age groups in Baltimore City and every group in Maryland as a whole (Table 2). However, some of the age groups with the highest asthma hospitalization rates were adults ages 40-49. In addition, the asthma hospitalization rates in Baltimore City are much higher than Maryland rates across all age ranges, with the exception of persons aged 20-29 and adults aged 55-64. (City data was not available for adults over 65.)[64] In other words, asthma hospitalizations appeared to be a problem for both children and adults in Baltimore City.[65]

Table 2. 2013 Baltimore City v. Maryland Asthma Hospitalization Rates by Age

Age range	Baltimore City (rate per 10,000 people)	Maryland (rate per 10,000 people)	Relative Difference*
0-4	4.85	1.94	150%
5-9	3.99	1.18	238%
10-14	1.59	0.56	184%
15-19	0.64	0.35	83%
20-24	0.57	0.35	63%
25-29	0.48	0.39	23%
30-34	2.30	0.45	411%
35-39	3.50	0.46	661%
40-44	7.72	0.73	958%
45-49	5.00	1.19	320%
50-54	2.42	1.4	73%
55-59	1.29	1.28	1%
60-64	0.40	1.06	-62%
65-69	No data	0.97	-
70-74	No data	0.79	-
75-79	No data	0.65	-
80-84	No data	0.59	-
85+	No data	0.63	-

*Relative difference = % that Baltimore City is higher than Maryland

Young children in Baltimore also visited the emergency room because of asthma at very high rates relative to other age groups and relative to other children in the state. For emergency room visits due to asthma, children ages 5-9 had the highest rates in Baltimore City (at 33.7 per 10,000 people), adults aged 40-44 had the second highest rate in the city (at 32.46 per 10,000 people), and children ages 0-4 had the third highest rate (31.93 per 10,000

[64] Baltimore City data is available for the 65+ age groups when querying EPHT for county-wide totals. However, to maintain consistency in our methods, EIP limited "Baltimore City" to 25 select zip codes. See footnote 60 and the Methodology and Data Caveats section of this report for more details.
[65] Our analysis for hospitalizations and emergency room visits by age considers the rate of incidents that occur within a given age category out of 10,000 people of any age. Thus, the rate for a given age category could be higher if the percentage of the population falling within that age category is higher in, for example, Baltimore City than in Maryland as a whole. However, the U.S. Census Bureau's American Community Survey estimates for 2013 indicates that the age breakdown between Maryland and Baltimore City was similar that year across age categories, with the greatest differences in the 20-24 year category (8.4 percent of the population in Baltimore and 6.8 percent of the population in Maryland), 25-30 year category (9.8 percent of the population in Baltimore and 7.0 percent of the population in Maryland) and 30-34 category (8.3 percent of the population in Baltimore and 6.8 percent of the population in Maryland).

people). These age groups also visited the emergency room because of asthma at much higher rates (13.61 per 10,000 people for ages 0-4 and 11.77 for ages 5-9) at the state level relative to other age categories (ranging from 0.91 to 6.29 per 10,000 people) at the state level as well. As with hospitalization data, emergency room visit rates in Baltimore were significantly higher than in the state as a whole across multiple age ranges. Baltimore City's asthma emergency room visit rates were over twice those elsewhere in the state in all age categories except for adults aged 50-64 and individuals aged 15-24. The greatest difference between city and state rates exists for adults ages 30-44, who had over six times the emergency room visit rates for asthma than adults of the same age in Maryland as a whole. Children in Baltimore ages 0-4 visited the emergency room because of asthma at a rate 2.35 greater than that of children of the same age in the state as whole. For ages 5-9, the Baltimore City rate was 2.86 times higher.

Table 3. 2013 Baltimore City v. Maryland Asthma Emergency Room Discharge Rates by Age

Age range	Baltimore City (rate per 10,000 people)	Maryland (rate per 10,000 people)	Relative Difference*
0-4	31.93	13.61	135%
5-9	33.70	11.77	186%
10-14	14.42	6.29	129%
15-19	6.33	5.42	17%
20-24	9.46	7.58	25%
25-29	13.08	5.89	122%
30-34	28.95	4.56	535%
35-39	26.67	4.16	541%
40-44	32.46	4.74	585%
45-49	16.01	5.71	180%
50-54	5.49	5.28	4%
55-59	2.11	3.94	-46%
60-64	0.66	2.76	-76%
65-69	No data	2.11	-
70-74	No data	1.46	-
75-79	No data	1.11	-
80-84	No data	0.94	-
85+	No data	0.91	-

*Relative difference = % that Baltimore City is higher than Maryland

We were unable to analyze childhood asthma by zip code. In order to address patient privacy concerns, data is suppressed by the state when the total number (counts) of hospitalizations or emergency room visits in any category is below certain thresholds. Because of this, there were significant data gaps in the zip-code level asthma data when it was broken down by age.

Asthma and Air Pollution in Baltimore – Spatial Trends

In order to assess whether there is an association between asthma rates and air pollution in different areas of Baltimore, we mapped asthma hospitalization rates and emergency room visit rates using the zip code level data released by the Maryland Department of Health in 2016 and 2017, and we compared those maps to maps of potential air pollution hotspots in the city. There are some important limits to what can be shown in this kind of analysis, most notably that no tool or dataset for mapping air pollution allows an assessment or visualization of the cumulative effects of all pollutants on an area. In fact, most tools assess only one pollutant from one type of pollution source. To map indicators of air pollution, we used an EPA tool that models respiratory health risks from toxic air pollution, EPA maps showing modeled pollution concentrations from roadway traffic, and maps that we created showing where emissions are released from power plants and other facilities.

We found that, for the most recent year that we could make this comparison, the zip codes with the highest rates of acute asthma events include, within smaller areas shown on the map, areas that have the highest respiratory risk from toxic air pollution. There is also a significant overlap between zip codes with high hospitalization and ER rates and areas with the highest relative pollution levels from roadway traffic (Figures 10, 12-14). Our ability to assess this was somewhat limited because the pollution mapping tools present outcomes at the census tract level, not the zip code level.

In addition, we conducted a separate spatial comparison between rates of acute asthma events and metrics of poverty. We found a strong correlation between measures of poverty, particularly median household income, and asthma hospitalization and emergency room visits rates. Thus, while poverty appears to be the primary driver of spatial trends in hospitalization and emergency room visit rates due to asthma in Baltimore City, air pollution, especially from roadway vehicles, seems to be making a bad situation worse in some of the poorest areas.

Asthma in Baltimore

In recent years, the Baltimore City zip codes with the highest asthma hospitalization rates have been in East Baltimore, West Baltimore, Northwest Baltimore, the downtown area in the heart of the city, and in the South Baltimore zip code of 21225 (Brooklyn and Cherry Hill). A map showing asthma hospitalization rates in the city in 2013 is provided below (Figure 4). Neighborhoods in North Baltimore, specifically 21209 (Roland Park) and 21210 (Mount Washington) had the lowest rates in the city and rates in Northeast Baltimore were also relatively low.

Figure 4. 2013 Asthma Hospital Discharge Rates by Zip Code

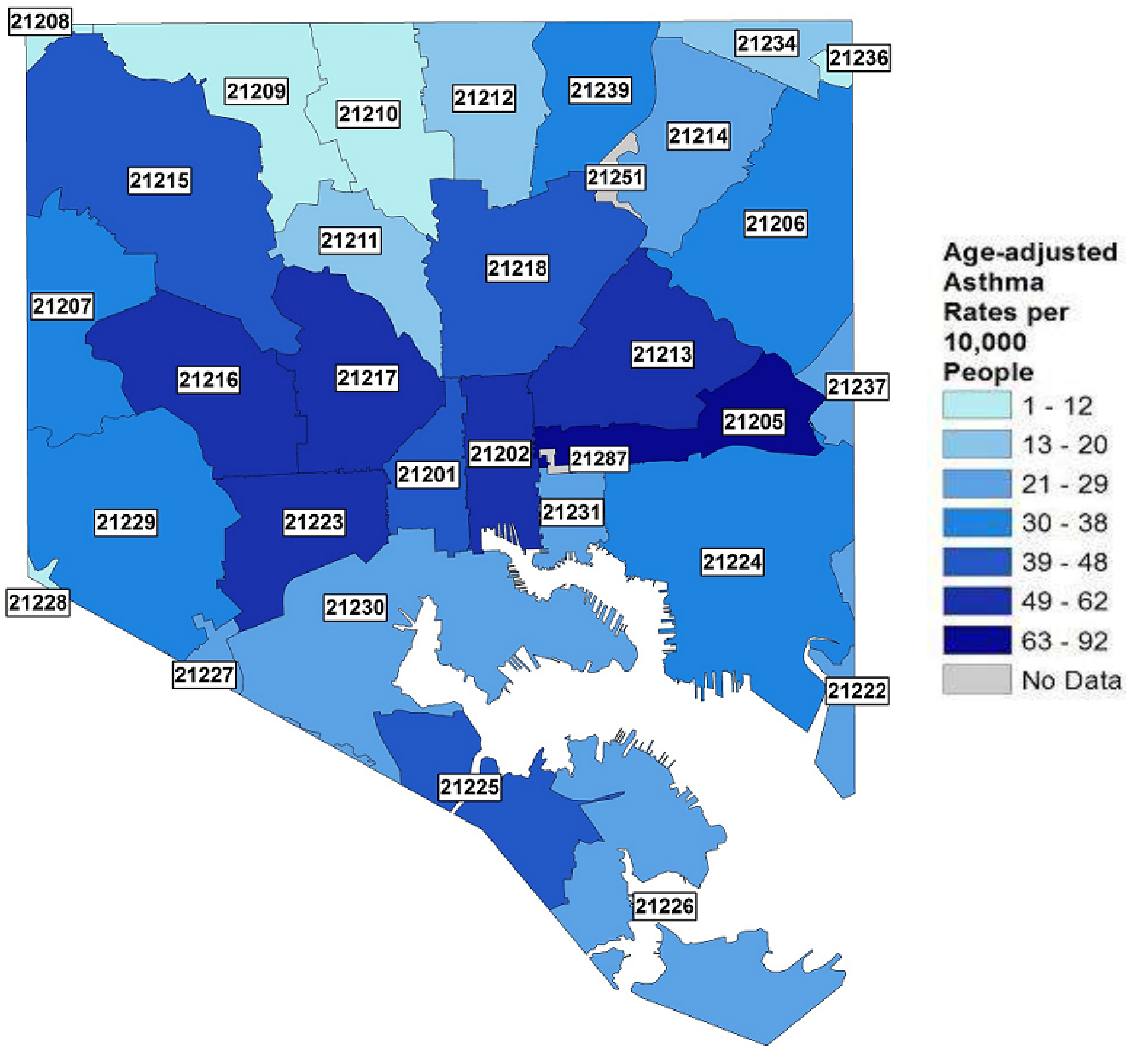
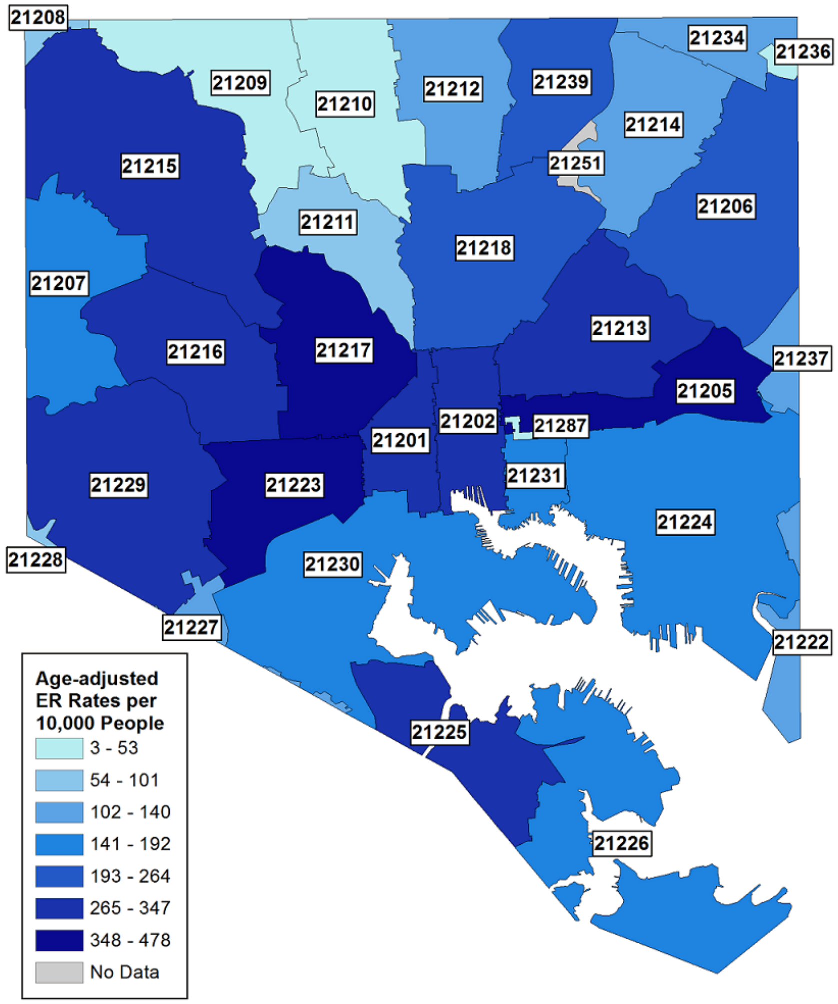


Table 4. 2013 Baltimore City Asthma Hospital Discharge Rates* by Zip Code

Rank	Zip Code	Rate	Rank	Zip Code	Rate	Rank	Zip Code	Rate
1	21205	70.9	11	21229	37.7	21	21227	22.9
2	21213	55.6	12	21239	34.5	22	21237	20.3
3	21202	52.8	13	21206	34.5	23	21212	19.5
4	21223	52.1	14	21207	29.7	24	21211	18.1
5	21216	51.3	15	21224	29.3	25	21234	16.9
6	21217	51.3	16	21226	26.4	26	21208	10.9
7	21215	45.5	17	21231	25.3	27	21236	9.7
8	21201	41.5	18	21222	23.6	28	21228	8.7
9	21225	39.8	19	21214	23.1	29	21209	8.6
10	21218	38.8	20	21230	22.9	30	21210	0.6

*Age-adjusted rate per 10,000 people

Figure 5. 2013 Asthma Emergency Room Discharge Rates by Zip Code



As shown above in Figure 5, spatial trends in asthma emergency room visits were very similar in Baltimore to those for asthma hospitalizations.

Comparison with Air Pollution Hotspots

We compared asthma rates in Baltimore with maps indicating potential air pollution hotspots in a few different ways. We did not attempt to map data from air quality monitors because these monitors are so widely spaced within the city and, thus, we relied on modeling tools and datasets from the U.S EPA. There is no tool that allows us to map the cumulative effects of all air pollutants in the aggregate. Almost every tool uses a pollutant-by-pollutant analysis method. In addition, almost every tool or data source looks at pollution from only one category of sources, such as roadway pollution or pollution from power plants and other stationary facilities. However, even with these constraints, mapping is still a useful tool for analyzing the effect of pollution on asthma rates in Baltimore. In addition, we are showing maps of hospitalization rates in Baltimore only in this section for simplicity and because the spatial trends are extremely similar for hospitalization and emergency department rates.

We found that the areas within the city that have the highest respiratory risk from air toxics appear to be located, for the most part, in zip codes with high rates of acute asthma events. A similar overlap is illustrated when comparing the asthma maps with maps showing pollution levels caused by roadway vehicles. However, we could not conduct an exact comparison between pollution maps, which present data at the census tract level, and asthma maps, which we could map only at the zip code level.

Respiratory Risk from Toxic Air Pollution

We mapped respiratory risks in Baltimore from toxic air pollution using EPA's Environmental Justice Screening and Mapping Tool ("EJSCREEN"),[66] which pulls data from EPA's National Air Toxics Assessment ("NATA"). The limitations of this tool are fully described in the Methodology and Data Caveats section of this report. It is important to note that NATA analyzes exposure only to a certain kind of pollutant: pollutants classified by the EPA as hazardous air pollutants, also referred to as air toxics. NATA does not address pollutants that are classified as "criteria pollutants," which include particulate matter, nitrogen oxides (NO_x), sulfur dioxide (SO_2), and ozone.[67]

A direct statistical comparison between EJSCREEN information and asthma hospitalization rates was not feasible because EJSCREEN utilizes census block groups and the asthma hospitalization data is at the zip code level. However, based on a visual comparison between maps[68] (Figure 6), it was clear that some of the areas with highest respiratory health risks (95-100th percentile) in the state from air toxics are in the city center and in small areas of West Baltimore, where zip code level asthma hospitalization rates are among the highest in the city. In fact, four out of the five zip codes with the highest asthma hospitalization rates had smaller areas within their borders that were within the 95-100th percentile in the state for respiratory risk from air toxics. [69] These zip codes were 21223, 21225, 21202, 21217, and 21201.

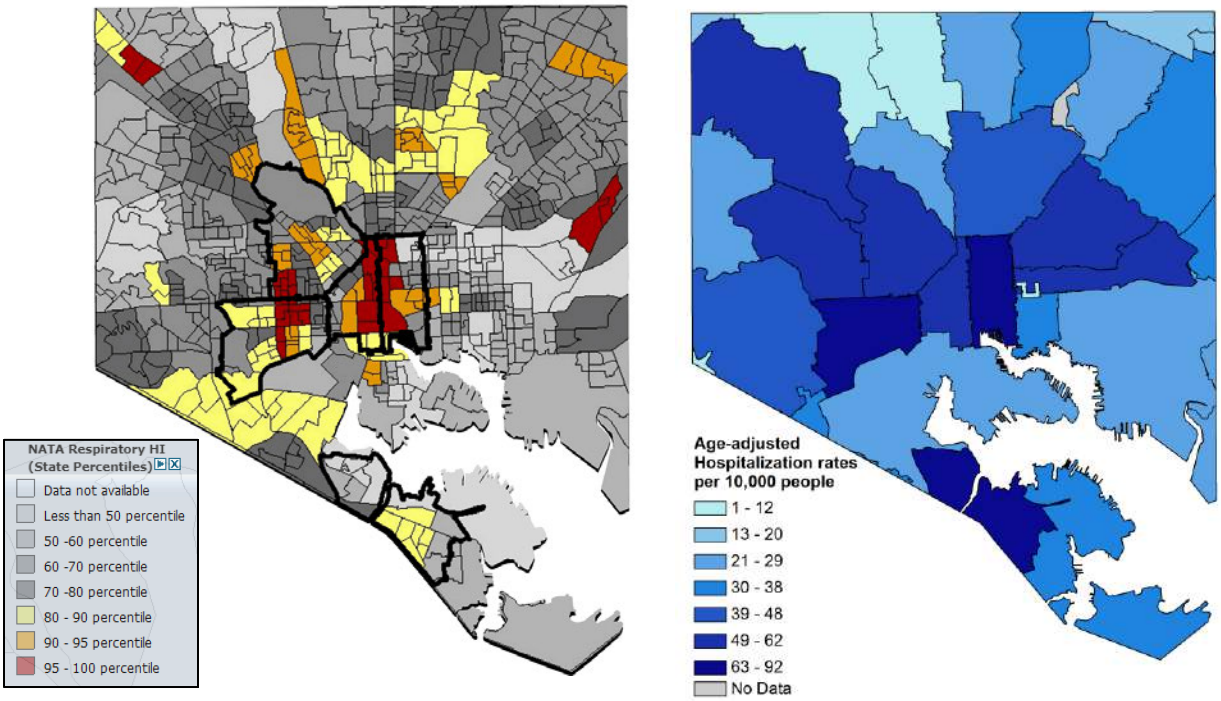
Areas of East, West, and South Baltimore with high asthma hospitalization rates were also in the 80-95th percentiles for respiratory risk from air toxics. However, there is a significant-sized area in Southwest Baltimore in the 80-90th percentile for health risks from air toxics and a sliver of Northwest Baltimore in the 90-95th percentile that are both in zip codes with

---

[66] U.S. EPA. Environmental Justice Screening and Mapping Tool. Link: https://ejscreen.epa.gov/mapper/.
[67] In general, criteria pollutants are emitted in much higher amounts by mobile and industrial sources and are subject to more requirements, including health-based air quality standards. Hazardous air pollutants are emitted in smaller quantities but can pose greater health risks – particularly of cancer and neurological disease - in small quantities. While NATA does not generally address criteria air pollutants, it does consider those pollutants which contribute to the formation of hazardous air pollutants.
[68] We conducted this comparison using the 2011 asthma hospitalization rate map because NATA primarily uses emissions data from the year 2011; U.S. EPA. 2015. "Technical Support Document: EPA's 2011 National-scale Air Toxics Assessment." pg. 17. Link: https://www.epa.gov/sites/production/files/2015-12/documents/2011-nata-tsd.pdf.
[69] EIP superimposed the outlines of the five City zip codes with the highest asthma hospitalization rates in 2011.

relatively low (for the city) asthma hospitalization rates. It is possible that the size of the zip codes is masking smaller areas with higher asthma rates within each code.

Figure 6. 2011 Comparison of Respiratory Risks from Toxic Air Pollution[70] (left) to Asthma Hospitalization Rates (right)



Note: Bold boundaries on Respiratory Risk map highlight zip codes with the five highest asthma-related hospitalization rates in 2011.

NATA also allows a user to analyze how much of the health risk in a given census tract is contributed by different kinds of sources. We conducted this analysis for each census tract in the city that was within the 95-100th percentile for respiratory risk (the red areas in Figure 6 above) and found that on-road mobile sources (road vehicles) contributed to, on average, 50 percent of the respiratory risk for air toxics in these areas. This is more than twice the average respiratory risk from air toxics contributed by any other category of source.

Pollution from Road Traffic

Although the NATA analysis is not comprehensive and is limited to respiratory risks from air toxics, it is likely that on-road vehicles are the largest contributor to the air pollution that people breathe in Baltimore. This is because there is significant traffic congestion in the area and because vehicle tailpipes, which are relatively close to ground-level, do not disperse pollution as widely as taller smokestacks.

We were able to map road traffic emissions using a tool made available by the University of North Carolina and the U.S. EPA called the Community LINE Source Model ("C-

[70] The respiratory risk map and legend were created by the EPA's EJSCREEN mapping tool, after selecting for environmental indicators and NATA Respiratory HI. EIP removed the areas outside of the City boundary.

LINE").[71] This tool is described in detail in the Methodology and Data Caveats of this report.[72] In summary, it uses EPA's emission factors, traffic data from the Highway Performance Monitoring System, and meteorological data to model air pollution from roadway sources. The user can conduct such modeling under a variety of scenarios. Because we were looking at contribution to acute asthma events (hospitalizations) we ran the model under the scenario that would show peak emissions: weekday hourly concentrations, during the PM peak/afternoon rush hour (4:00pm – 6:59pm), with average summer weather patterns. We mapped concentrations of NO_x, SO_2, $PM_{2.5}$, and Diesel-$PM_{2.5}$ in Baltimore City.

It is important to note that, while the C-LINE tool does estimate concentrations of pollution, it is most useful as a measure of where air pollution from vehicle traffic is the highest in the city. In addition, some pollutants are much more harmful in small amounts than others. For example, $PM_{2.5}$ – because it is so small that it can enter into the bloodstream through the lungs – poses a much greater risk to human health in small amounts than does NO_x or SO_2. In addition, diesel $PM_{2.5}$ likely poses an even greater risk because it is likely carcinogenic.[73] As was the case for the air toxics maps, we were not able to run a direct statistical comparison between the areas of the city with the highest emissions from roadway traffic and those with the highest asthma hospitalization rates because C-LINE provides estimates at the census tract level and the asthma data is at the zip code level. We are presenting the maps next to one another below to allow a visual comparison.

A separate map is provided below for each of the following pollutants from roadway traffic: $PM_{2.5}$, NO_x, SO_2, Diesel-$PM_{2.5}$. The map for $PM_{2.5}$ concentrations, which is the most harmful to human health of all of the criteria pollutants, is shown below in Figure 7 and compared with our map of 2011 asthma hospitalizations in Figure 8.[74] Maps for NO_x, Diesel-$PM_{2.5}$, and SO_2 are shown in Figures 9-11. Because we were mapping the same roadway network, the areas of the city affected were very similar for every pollutant that we

---

[71] University of North Carolina Institute for the Environment. 2017. Community Modeling and Analysis System. C-LINE v5.0. Link: https://www.cmascenter.org/c-tools/c-line.cfm.

[72] The University of North Carolina and EPA have also made available a different tool, C-PORT, that allows modeling of emissions from sources associated with ports, including truck, ship, and train emissions. EIP decided to focus this analysis on roadway traffic emissions because we determined that onroad emissions sources pose the greatest respiratory risk in Baltimore (see section "Respiratory Risk from Toxic Air Pollution") and C-LINE was limited to those emissions. See Methodology and Data Caveats section for more information about C-PORT.

[73] In 2012, the World Health Organization concluded that diesel engine exhaust is "carcinogenic to humans." In 1998, the State of California classified diesel particulate matter as a toxic air contaminant because of its potential to cause cancer. "Other agencies, such as the National Toxicology Program, the U.S. Environmental Protection Agency and the National Institute of Occupational Safety and Health, concluded that exposure to diesel exhaust likely causes cancer."; California Environmental Protect Agency Air Resources Board. "Summary: Diesel Particulate Matter Health Impacts." Link: https://www.arb.ca.gov/research/diesel/diesel-health_summ.htm.

[74] We selected the 2011 asthma map for the comparison because the C-LINE model uses meteorological data from 2011. C-LINE uses roadway traffic data from 2013. However, 2013 was an atypically cool summer in Baltimore, producing unusually low levels of pollution that form in heat and sunlight, such as ozone. *See* Maryland Department of the Environment. 2017. "Clean Air 2017 Progress Report" pg. 1. Link: http://mde.maryland.gov/programs/Air/Documents/MDCleanAirProgress2017.pdf;
Like ozone, $PM_{2.5}$ also forms more readily in hot summer weather. For this reason, we chose to use 2011 for the comparison as it is more representative of conditions in Baltimore.

mapped. The center of the city, which is exposed to pollution from the I-83 highway in addition to traffic congestion on non-highway roads, is shown to have the most area exposed to relatively high pollution levels from roadway emissions with additional areas of high pollution in Northwest Baltimore, East Baltimore, and Southwest Baltimore. The Northwest areas with relatively high modeled pollution levels appears to be most influenced by the path of I-83 and the East Baltimore tracts occur in the Hopkins Bayview area, which is ringed by I-95 and I-895. The areas of Southwest Baltimore with relatively high modeled pollution are those that are close to I-95 and/or I-895 in those areas.

Figure 7. Hourly $PM_{2.5}$ Concentrations from Road Traffic Emissions (Peak Afternoon, Summer)

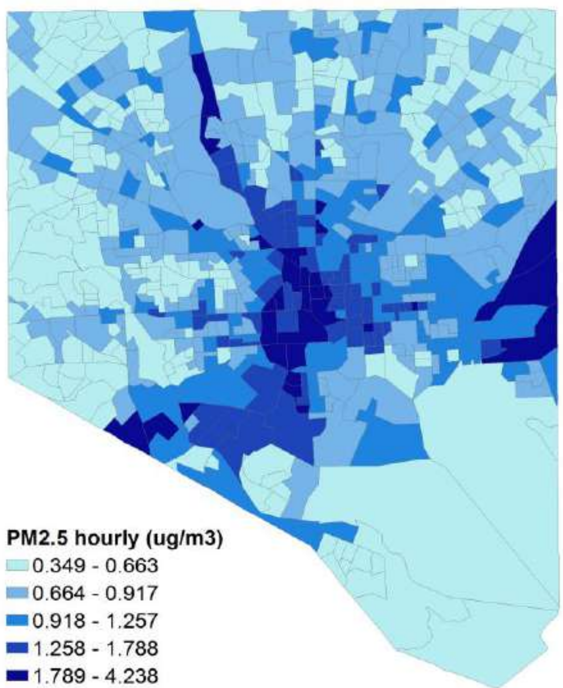
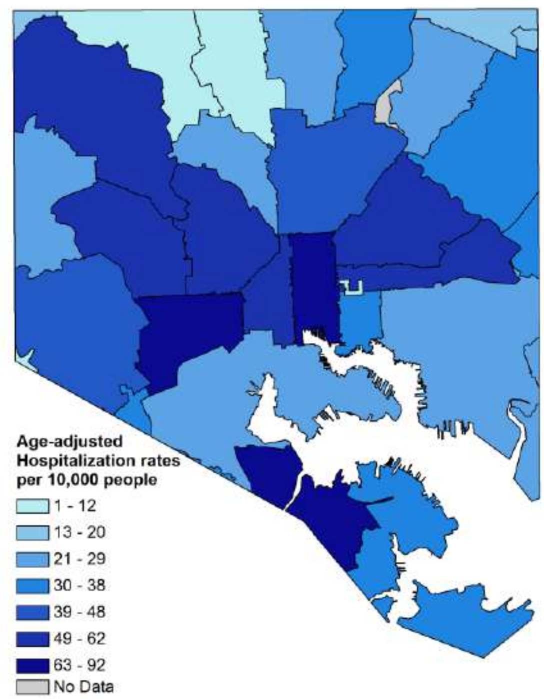


Figure 8. 2011 Asthma Hospital Discharge Rates



While the comparison is not exact because of the different geographic units used (census tracts v. zip codes), there is significant overlap between areas with relatively high roadway traffic pollution and high asthma hospitalization rates in the center of the city and in parts of East and West Baltimore.

Figure 9. Hourly NO_x Concentrations from Road Traffic Emissions (Peak Afternoon, Summer)

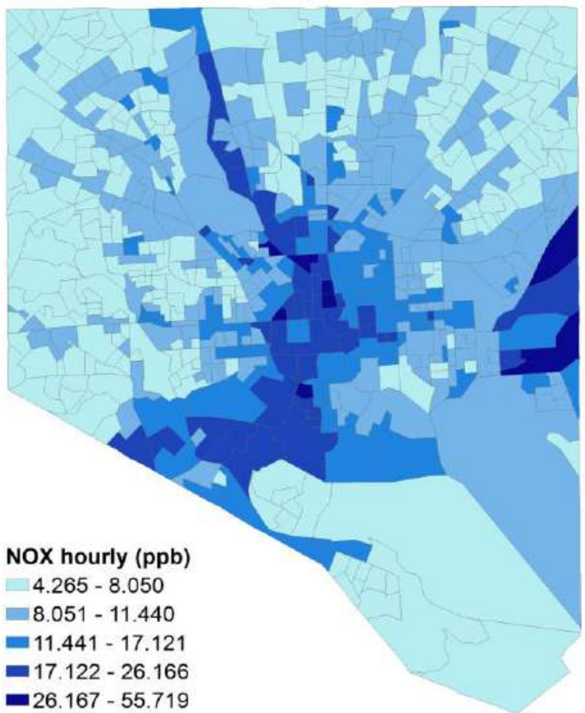


Figure 10. Hourly Diesel-$PM_{2.5}$ Concentrations from Road Traffic Emissions (Peak Afternoon, Summer)

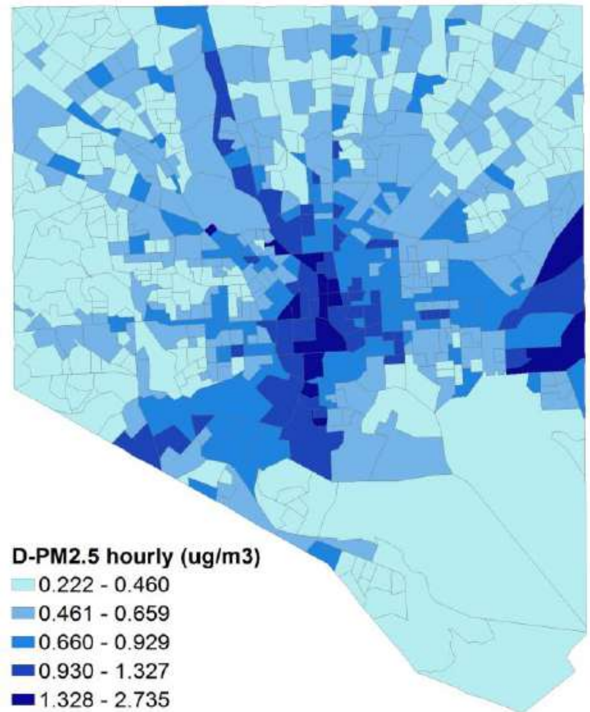


Figure 11. Hourly SO_2 Concentrations from Road Traffic Emissions (Peak Afternoon, Summer)

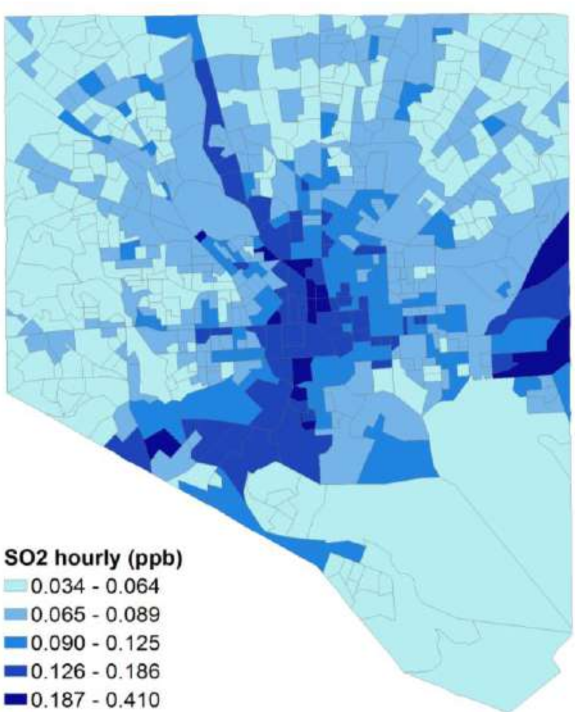
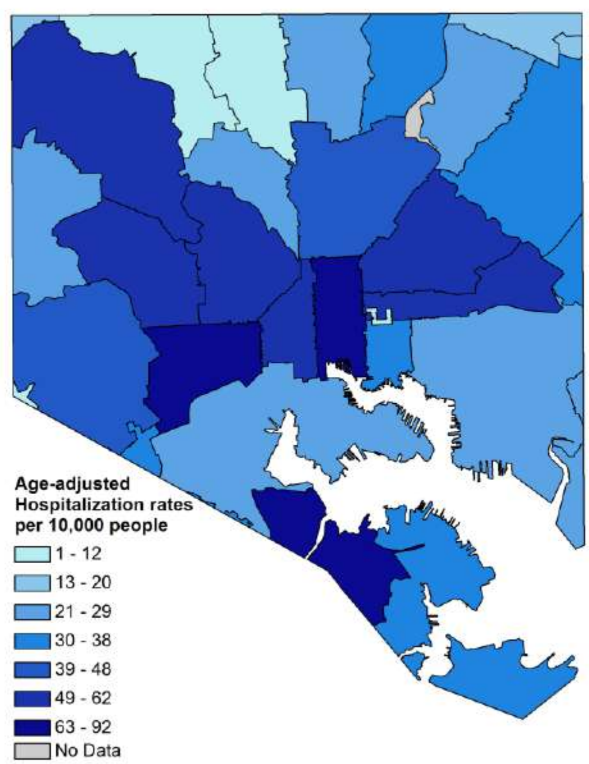


Figure 12. 2011 Asthma Hospital Discharge Rates



Pollution from Power Plants and Other Facilities

EPA does not provide a tool that allows users to model the dispersion of emissions from power plants and other large facilities.[75] The map of respiratory risks from air toxics (Figure 6) in the "Respiratory Risk from Toxic Air Pollution" section includes pollution from these facilities, but, as previously discussed, only health risks from toxic air pollutants (not criteria pollutants) are modeled. In order to provide a rough visualization of the location of large facility sources of criteria pollutants, we mapped the zip codes in which facilities that produce these emissions are located (Figures 13-15) using data from the National Emissions Inventory, an EPA dataset[76] that is described in more detail in the Methodology and Data Caveats section of this report. This is an extremely imprecise measure of air pollution from these plants, which can disperse differently depending on factors like stack height and wind direction.

In addition, we limited this presentation to emissions from facilities located within Baltimore City's borders. There are large sources of air pollution located just outside of the city. These include the Fort Smallwood coal plant complex, which is discussed in more detail in the section of this report on trends over time and is located in Anne Arundel County portion of the 21226 zip code. We did not include emissions from sources located outside of Baltimore City in the maps below because some large sources in the area, like the Charles P. Crane coal plant in Baltimore County, are in zip codes that are not even partly in Baltimore City. It would have been too difficult to present data for these sources as part of a map of Baltimore City.

In general, there is not a significant association between city zip codes with the highest emissions of criteria pollutants from stationary facilities and the zip codes with the highest asthma rates. The zip codes with the highest emissions from facilities in 2011 were 21230 (Westport/Morrell Park), which houses the Wheelabrator/Baltimore Refuse Energy Systems Company ("BRESCO") trash incinerator, and 21226 (Curtis Bay), which includes two industrial areas that house multiple pollution sources and are served by mobile pollution sources like trucks and trains. In 2011, the 21226 zip code ranked 14th in the city out of 31 zip codes with data in terms of highest asthma hospitalization rates and had an asthma hospitalization rate of 35.66 per 10,000 people. The 21230 zip code ranked 19th in the city with an asthma hospitalization rate of 27.76 per 10,000 people. However, it should be noted that the asthma hospitalization rates in both zip codes are still much higher than the state average rate in 2011 of 17.17 per 10,000 people.

---

[75] While the C-PORT mapping tool allows the user to manually add point sources emissions information to baseline data for port pollution sources, we did not use it to map pollution from point sources like incinerators and power plants because the tool was primarily created to visualize pollution from within ports/terminals. We would have had to manually add very detailed stack data – including exit temperature, exit velocity, inner stack diameter at top, and height – for each point source in order to include facility emissions in the model.

[76] We used the 2011 asthma map for the comparison because the National Emissions Inventory ("NEI") dataset is from 2011. NEI is assembled every three years, and a dataset is available for 2014. However, we do not have asthma data for any year more recent than 2013.

Figure 13. 2011 NEI NO_x Emissions

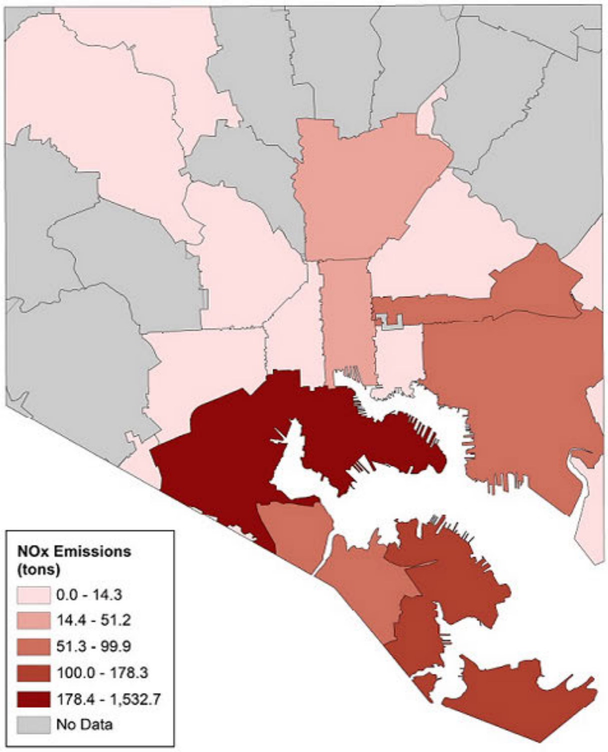


Figure 14. 2011 NEI SO_2 Emissions

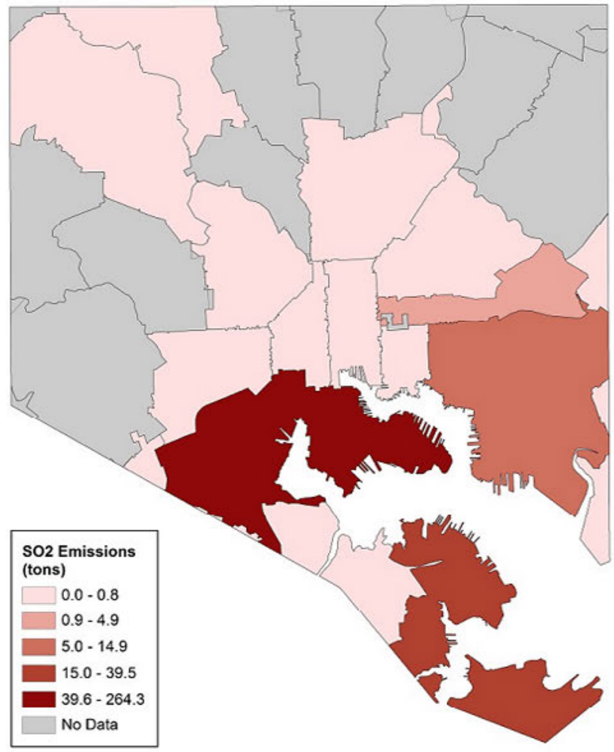


Figure 15. 2011 NEI $PM_{2.5}$ Emissions

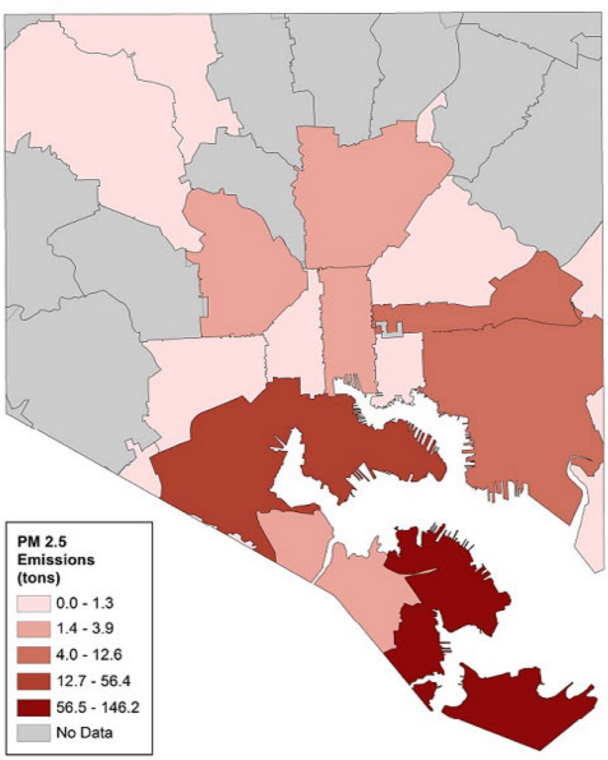
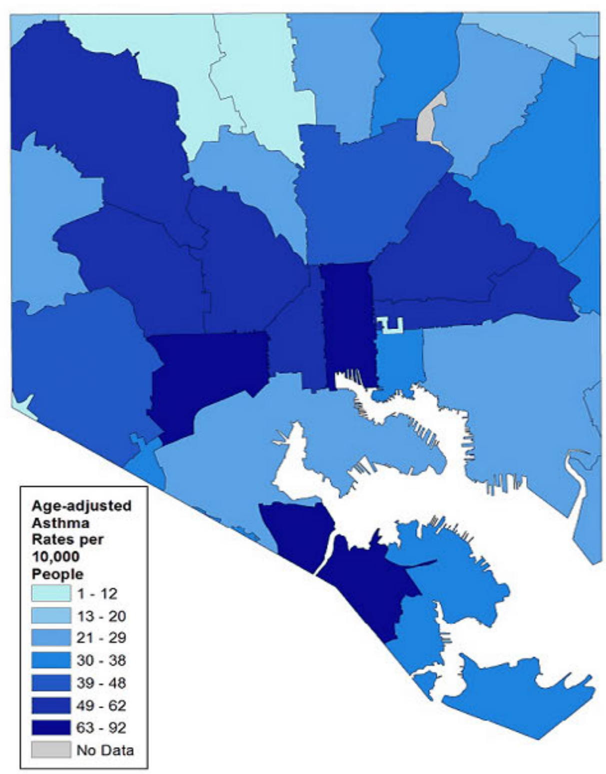


Figure 16. 2011 Asthma Hospital Discharge Rates



Asthma and Poverty in Baltimore

Because it was immediately apparent to us that the areas of the city with the highest asthma hospitalization rates were also those known to have high poverty rates, we conducted a limited additional analysis of this association. Using 2013 demographic data from the U.S. Census Bureau's 5-year American Community Survey, we analyzed how closely asthma hospitalization and emergency room visit rates correlate with seven demographic measures of poverty. These measures are: percent of population living in poverty, percent of childhood population living in poverty, median household income, percent uninsured, percent using Medicaid, percent uninsured or using Medicaid, and percent African American.[77] Table 5 below shows the correlation between each demographic category and asthma rates. Correlation coefficients are interpreted as showing stronger correlation the closer that they are to -1 or 1, and weaker correlation the closer that they are to 0.

Table 5. Correlation between Demographic Categories and Asthma Rates in Baltimore City at Zip Code Level[78]

Demographic Measure	Asthma Hospitalization Rates	Asthma ER Discharge Rates
% Poverty	0.79	0.86
% Poverty below 18 years	0.73	0.78
Median Household Income	-0.94	-0.95
% Uninsured	0.62	0.54
% Using Medicaid	0.94	0.95
% Uninsured or Using Medicaid	0.93	0.92
% African American	0.77	0.75

The three demographic measures that were most closely correlated with asthma rates in Baltimore were median household income (-0.94 for asthma hospitalization rates and -0.95 for emergency room discharge rates), percent of population using Medicaid (0.94 for asthma hospitalization rates and 0.95 for emergency room discharge rates), and percent of the population uninsured or using Medicaid (0.93 for asthma hospitalization rates and 0.92 for emergency room discharge rates). The scatter plots shown below (Figure 6) visualize the increase in asthma hospitalization and emergency room visit rates as median household income decreases. The other demographic indicators of poverty had slightly weaker, though significant, positive correlations with asthma rates (between 0.54 and 0.90). Scatter plots for the other demographic categories are provided in Appendix A. All of these demographic

[77] We chose to include percent African American among the demographics in this analysis because prior analyses by the Department of Health have found that asthma emergency room visit rates and hospitalization rates are significantly higher for Maryland residents who are Black/African American than for other racial groups; Maryland Department of Health. 2012. "Asthma in Maryland 2012" pgs. 35, 38. Link: https://phpa.health.maryland.gov/mch/Documents/Asthma%20in%20Maryland%202012.pdf; Baltimore City is 63 percent African American. U.S. Census Bureau. 2010 Census. Link: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml

[78] U.S. Census Bureau. 2009-2013 5-Year American Community Survey. "% Uninsured" describes the noninstitutionalized civilian population without insurance coverage.

measures are metrics of poverty, with the exception of percent African American.[79] These demographic metrics are not independent of one another.

Figure 17. Scatter Plots of 2013 Median Household Income v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)

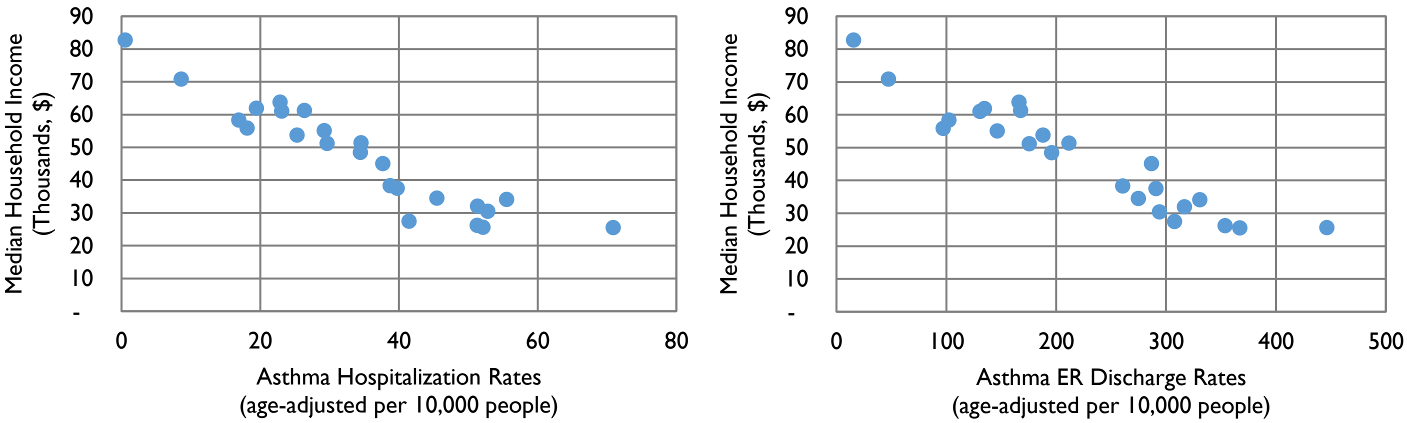
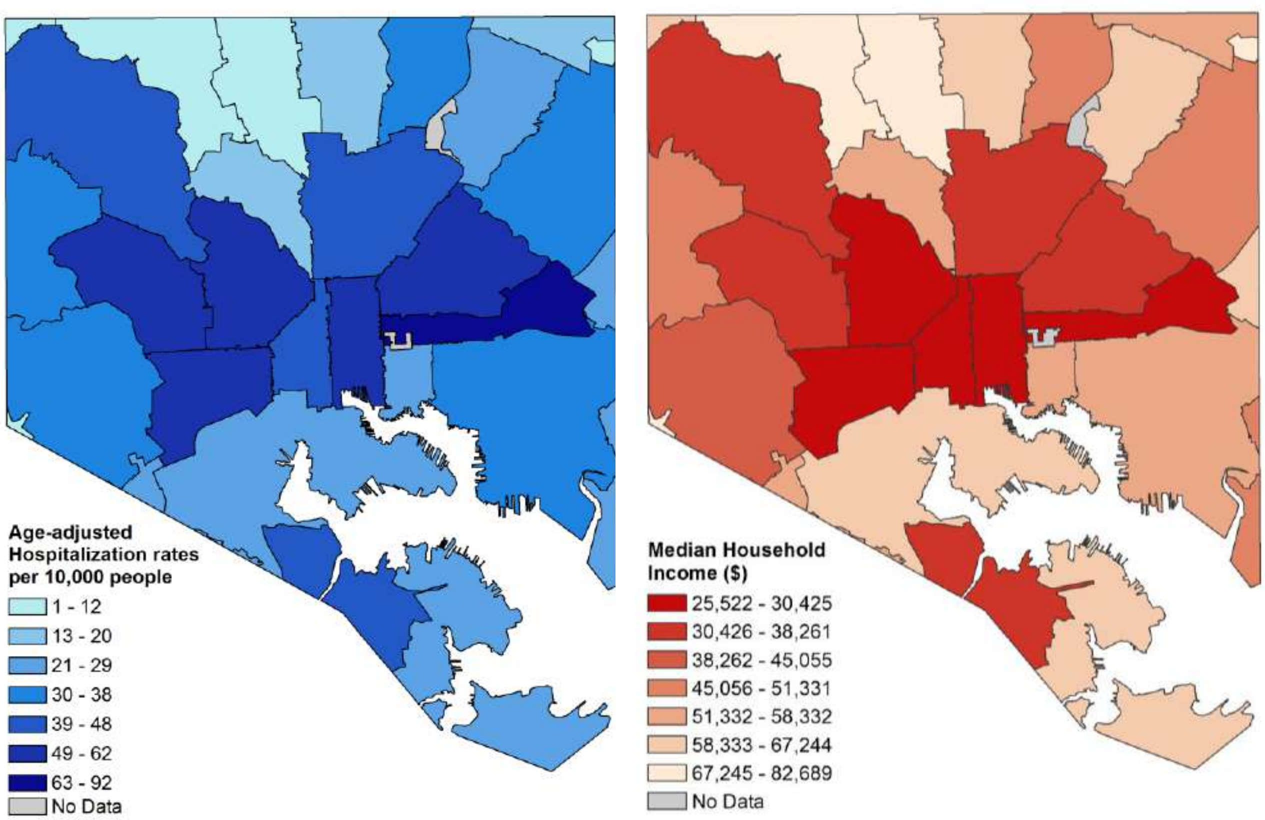
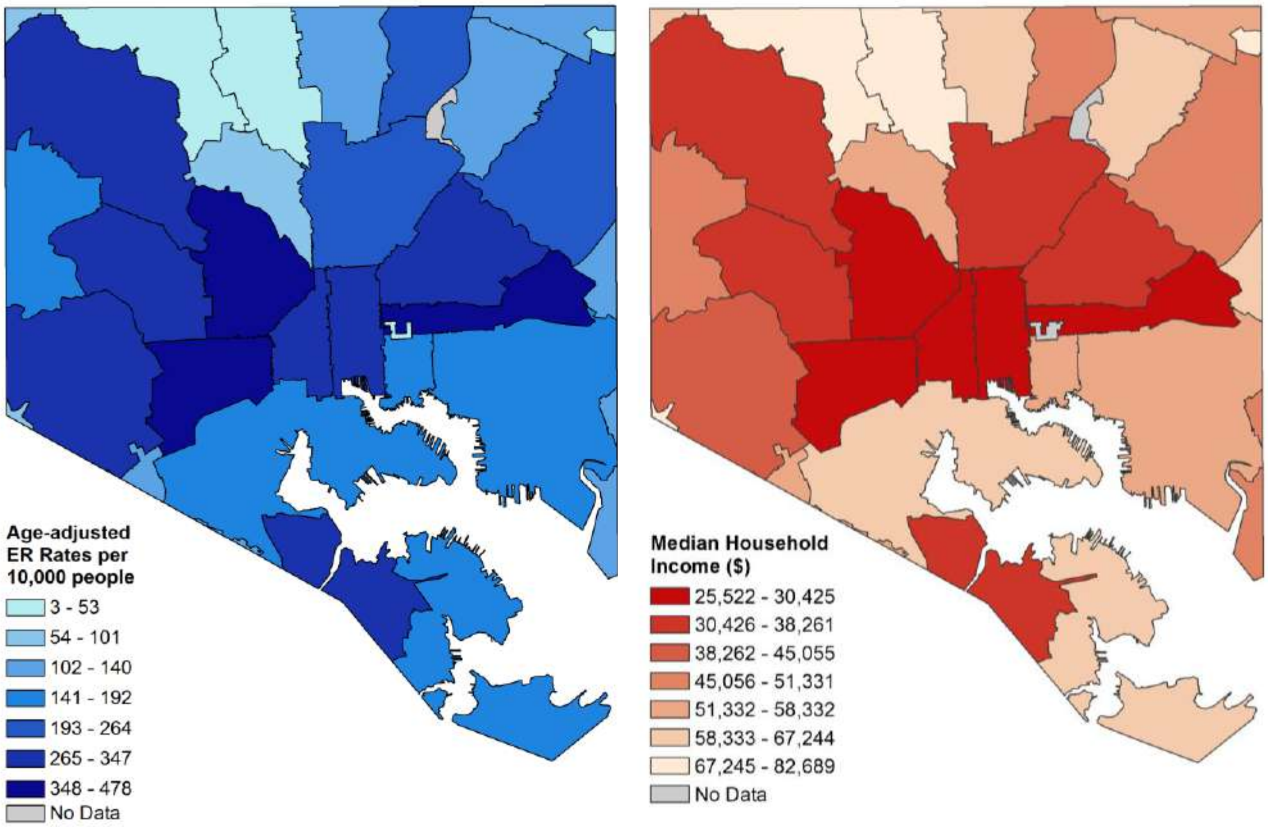


Figure 18. 2013 Asthma Hospitalization Rates (left) and 2013 Median Household Income (right)



[79] However, in Baltimore, it has been demonstrated that majority African American communities generally have high poverty and unemployment rates; Baltimore Neighborhood Indicators Alliance and University of Baltimore. 2017. "Spring 2017 Vital Signs 15." Link: https://bniajfi.org/wp-content/uploads/2017/04/VS15_Compiled-04-12-17-08-41.pdf.

Figure 19. 2013 Asthma Emergency Room Rates (left) and 2013 Median Household Income (right)



Asthma hospitalization rate maps from 2000 to 2013 are provided in Appendix B to this report and asthma emergency room rate maps from 2000 to 2013 are provided in Appendix C.

Asthma and Air Pollution in Baltimore - Trends over Time

Using all years for which data was available, 2000-2013, we looked at the trends in the city's asthma hospitalization rates and emergency room visit rates over time. We compared these trends to two measures of air pollution: emissions released into the air by nearby facilities and vehicles, and air quality data gathered by official monitors. Asthma hospitalization rates and emergency room visit rates followed different trends over time. Hospitalization rates generally rose from 2000 to 2009, peaking in 2009 and decreasing thereafter through 2013. Emergency room visit rates generally rose between 2000 and 2009, fell slightly from 2009 to 2010, increased from 2010 to 2011, and decreased between 2012 and 2013 (Figures 20-21).

We found a potential association between the decrease in asthma hospitalization rates starting after 2009 and a steep drop in emissions of sulfur oxides (SO_x) from facilities in the

Baltimore area between 2009 and 2010. As discussed in more detail below in the case study of the 21225 and 21226 zip codes, this decrease was especially sharp in areas near the Fort Smallwood coal plant complex, which installed a new suite of pollution controls in late 2009 and early 2010 in order to comply with the 2006 Maryland Healthy Air Act.

However, asthma trends were not consistently similar from 2000 through 2013 to trends over time in air pollution, which differed according to the pollution measure. In general, NO_x[80] and SO_x emissions[81] decreased from facilities and from mobile sources (like cars, trucks, trains, and boats) between 2000 and 2013. PM_{10} emissions decreased over time from facilities and $PM_{2.5}$ emissions from mobile sources remained relatively steady over time.

Air quality monitoring data, which is the best type of information on the pollution in the air that people breathe, is of limited use in analyzing city-level air pollution because there are few air quality monitors located within the city, leaving data gaps for many neighborhoods. The monitoring data that we have shows $PM_{2.5}$, SO_2, and NO_2 generally decreasing between 2000 and 2013, though with very different fluctuations along the way. By comparison, ozone levels remained relatively steady throughout the 2000-2013 time period, though it also decreased overall. We graphed trends for the toxic pollutant acrolein, which appears to be one of the most significant toxics in Baltimore. Data was only available starting in 2007, and it showed a spike at one monitor in 2009 and a different monitor in 2010.[82] However, there is some uncertainty with respect to the acrolein data, as discussed in more detail below.

Trends in Asthma Hospitalization and Emergency Room Visit Rates

As an initial matter, it is important to note that we analyzed the city-wide trend by using the Department of Health's query tool to aggregate rates for zip codes located at least partly in the city, with certain exceptions.[83] Thus, these rates may include individuals who live in a part of the zip code outside of the city boundary. The city-wide trend does not account for trends in individual zip codes, which varied. As discussed in more detail in the case study on the 21225 and 21226 zip codes, those areas experienced a sharp increase in asthma hospitalization rates between 2000 and 2009 and then a sharp decrease between 2009 and

[80] Nitrogen oxides (NO_x) is a group of gases, and nitrogen dioxide (NO_2) is used as a proxy for the group. Air quality monitoring data is measured as NO_2. Emissions data is submitted as NO_x to the Maryland Emissions Inventory and the National Emissions Inventory.

[81] Sulfur oxides (SO_x) is a group of gases, and sulfur dioxide (SO_2) is used as a proxy for the group. Ambient quality monitoring data is measured as SO_2. Emissions data are submitted is SO_x to the Maryland Emissions Inventory but as SO_2 to the National Emissions Inventory.

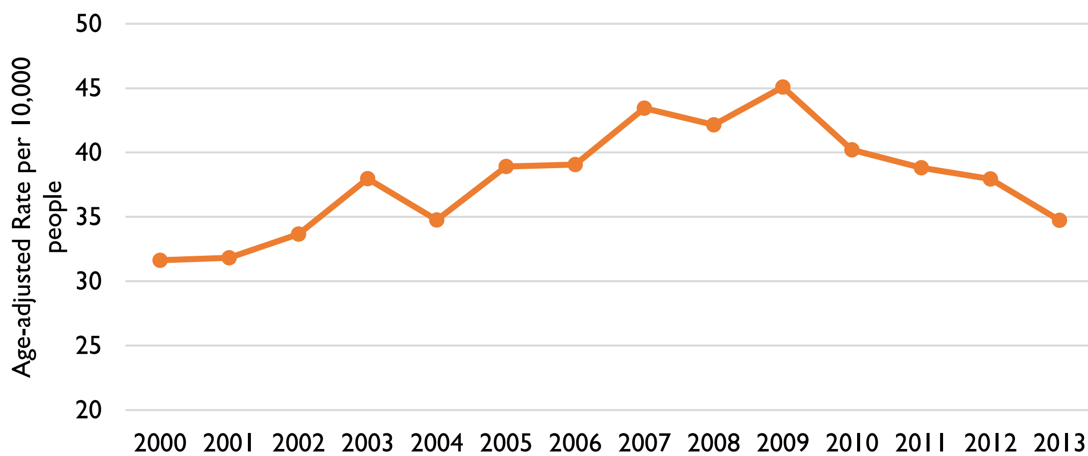
[82] Acrolein was measured at one Baltimore monitor from 2007 to 2013 and at another from 2007 to 2011.

[83] As described in more detail in the Methodology and Data Caveats section of this report, the state methodology for reporting county asthma hospitalization rates changed in 2008. The change relates to how the agency treats zip codes that are located in more than one county. Up until 2007, for such zip codes, the state allocated a portion of the asthma hospitalizations to each county. In 2008, it began apportioning the asthma hospitalizations in each such zip code to only one county. Thus, the Department of Health advised us not to compare Baltimore City hospitalization rates for periods before and after 2008. For this reason, we calculated our city rate using a consistent methodology that includes 25 of the 31 zip codes that have asthma hospitalization data within the City borders and excluding 6 zip codes that have only tiny slivers located within the City. The zip codes included and excluded are listed in the Methodology and Data Caveats section of this report.

2013. However, for several zip codes located in the center and the north of the city, asthma hospitalization rates remained more constant from 2000-2013. We were not able to analyze the trends in each separate city zip code and, therefore, we used a city-wide rate for the comparison to trends in air quality.

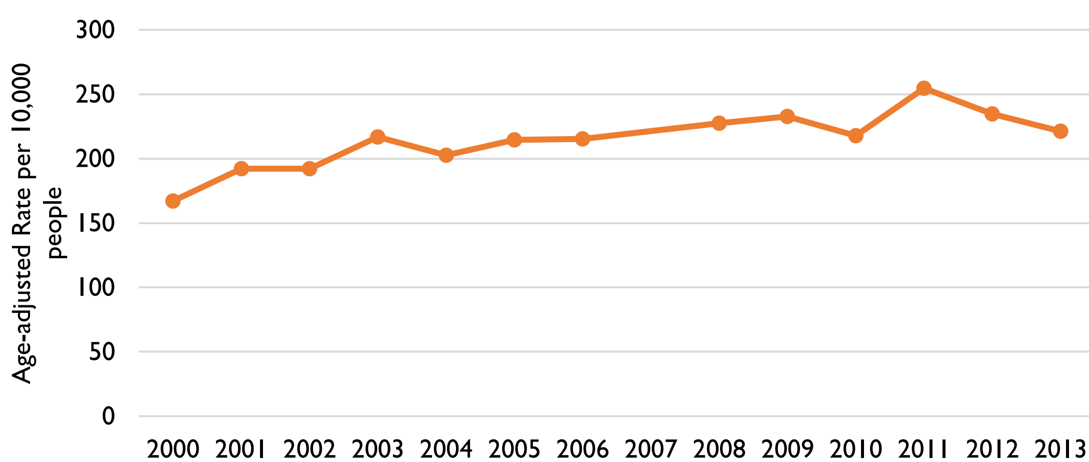
The overall trend in the city showed an increase in asthma hospitalization rates from 2000 to 2009 and a decrease from 2009 to 2013 (Figure 20). However, the increase from 2000 to 2009 was not consistent. Rates decreased from 2003 and 2004 and were about even between 2005 and 2006. Asthma hospitalization rates declined every year from 2009 and 2013.

Figure 20. Baltimore City Asthma Hospital Discharge Rates, 2000-2013



Like asthma hospitalization rates, emergency room rates generally rose from 2000 to 2009. However, unlike hospitalization rates, which began decreasing significantly after 2009, emergency room visit rates decreased slightly between 2009 and 2010, increased sharply between 2010 and 2011, and then decreased from 2011 to 2013.

Figure 21. Baltimore City Asthma Emergency Room Discharge Rates, 2000-2013 (excluding 2007) [84]



[84] As described above in footnote 63, data from the year 2007 is not shown in this graph.

The reason for the differing asthma dataset trends is not entirely clear. Unlike spatial trends, it does not appear that there is a correlation between the asthma trends and median household income in Baltimore City.[85] However, economic factors may have played a role in the trends, along with other conditions. As discussed above, researchers using the Healthcare Cost and Utilization Project ("HCUP"), a national-level family of health care databases and other information,[86] found that, in the years following the Great Recession, hospitalization rates for adults decreased for a number of potentially preventable conditions, including asthma, while national treat-and-release emergency room visit rates rose for those conditions. This included a finding that, from 2008-2012, asthma hospitalization rates decreased by 15.6 percent while treat-and-release emergency room visit rates rose 8.6 percent. The authors theorized that hospital admission policies and changes in patient access to insurance and/or ability to pay for admission may have resulted in more individuals being treated and released by the emergency department rather than being admitted to the hospital for a longer stay.[87]

In Baltimore, hospitalizations decreased 9 percent between 2008 and 2012. We were not able to identify "treat and release" emergency room visits because the Maryland dataset includes emergency room visits that result in inpatient admissions and does not allow the exclusion of these incidents. However, emergency room visit rates increased by 3 percent overall during the 2008-2012 period, which could also be seen as remaining relatively stable.

Air Pollution Trends

We used several measures to analyze air quality trends in Baltimore City from 2000 through 2013. An important distinction relating to types of data is that emissions of air pollutants from a stack or vent are different from concentrations of pollution in the air. Concentrations of pollution in the air are most directly related to air quality and to the pollution that people breathe in. Data on emissions of air pollution from smokestacks, vents, or vehicles provide information about pollution that enters the air, but it does not account for the fact that pollution disperses in the air differently depending on factors including the height of a smokestack, the pollutant itself, and wind speed and direction.

[85] Median household income in Baltimore generally increased between 2000 and 2008, decreased from 2008 to 2010, then increased slightly each year from 2010 to 2012 and increased more significantly from 2012 to 2013; Federal Reserve Bank of St. Louis. "Estimate of Median Household Income in Baltimore City, MD." Link: https://fred.stlouisfed.org/series/MHIMD24510A052NCEN; Maryland Department of Planning Maryland State Data Center. "Median Household Income for Maryland's Jurisdictions." Link: http://www.mdp.state.md.us/msdc/HH_Income/Household_Median_Income_SAIPE_Data_2013.pdf; This comparison is not exact as the median household income that we used was for Baltimore City and the asthma trend graphs that we created were based on 25 specific zip codes located all or partly in the City because of changes over time in how the Department of Health treated zip codes spanning multiple counties.

[86] Specifically, HCUP is "a family of health care databases, software tools, supplemental files, reports, and other related products developed through a Federal-State-Industry partnership and sponsored by the Agency for Healthcare Research and Quality," which is within the U.S. Department of Health and Human Services; *supra* note 51.

[87] HCUP, *supra* note 53, at pgs. 1-2.

Below, we discuss trends in emissions from power plants and other facilities, trends in emissions from mobile sources, and trends in ambient air quality data gathered by air monitors.

Facility Emissions Data

To show trends over time in emissions from plants and other non-mobile ("stationary") sources, we used data from the Maryland Emissions Inventory,[88] which is maintained by the Maryland Department of the Environment ("MDE") and consists of information reported each year by regulated facilities. We included in our analysis all facilities that report to the Maryland Emissions Inventory that are located within Baltimore City and certain additional sources located near the city that have been shown to or are very likely to (because of their size and proximity to the city) influence the city's air quality. This dataset includes, but is not limited to, emissions from the Fort Smallwood coal plant complex, which is the largest emitter in the area of several pollutants and is discussed separately below. The specific facilities included in this dataset are discussed in the Methodology and Data Caveats section of this report.

Figure 22. Annual NO_x and SO_x Emissions from Facilities In and Near Baltimore City

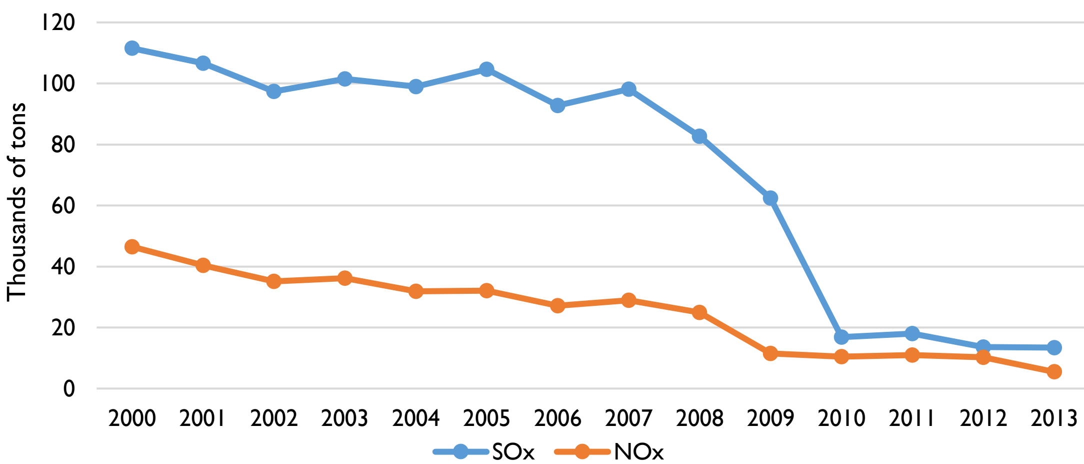


Figure 22 above shows emissions in or near Baltimore City of two pollutants, NO_x and SO_x, that can aggravate asthmatic symptoms. NO_x is the primary precursor to ground-level ozone, which, can also aggrativate asthma.[89] In addition, NO_x and SO_x are precursors for particulate matter, meaning they can form particulate matter through reactions in the ambient air in addition to particulates that are emitted directly from the stack.[90]

Annual emissions of NO_x and SO_x decreased gradually from 2000 through 2007. However, partly because of new air quality laws, annual emissions of both pollutants began decreasing

[88] EIP obtains annual Maryland Emissions Inventories through Public Information Requests from the Maryland Department of the Environment. Unlike later sections on mobile source emissions, EIP used Maryland Emissions Inventories, as opposed to EPA's National Emissions Inventories, for point source emissions because there is annual data available.
[89] See Introduction section of this report.
[90] U.S. EPA. Air Emissions Inventories. "Air Emissions Sources." Link: https://www.epa.gov/air-emissions-inventories/air-emissions-sources.

much more quickly between 2008 and 2010. The most dramatic decrease for SO_x was between 2009 and 2010, when emissions reduced by 45,556 tons. SO_x emissions also decreased by about 15,400 tons between 2007 and 2008 and by 20,318 tons between 2008 and 2009. NO_x emissions also declined substantially during these years, decreasing by 4,000 tons between 2007 and 2008, by 13,474 tons between 2008 and 2009, and by another 964 tons between 2009 and 2010.

All told, between 2007 and 2010, SO_x emissions were reduced by 81,269 tons or 83 percent and NO_x emissions decreased by 18,438 tons or about 64 percent. Both SO_x and NO_x continued to decrease from 2010 through 2013, though at a more gradual rate.

Figure 23. PM_{10} Emissions from Facilities In and Near Baltimore City

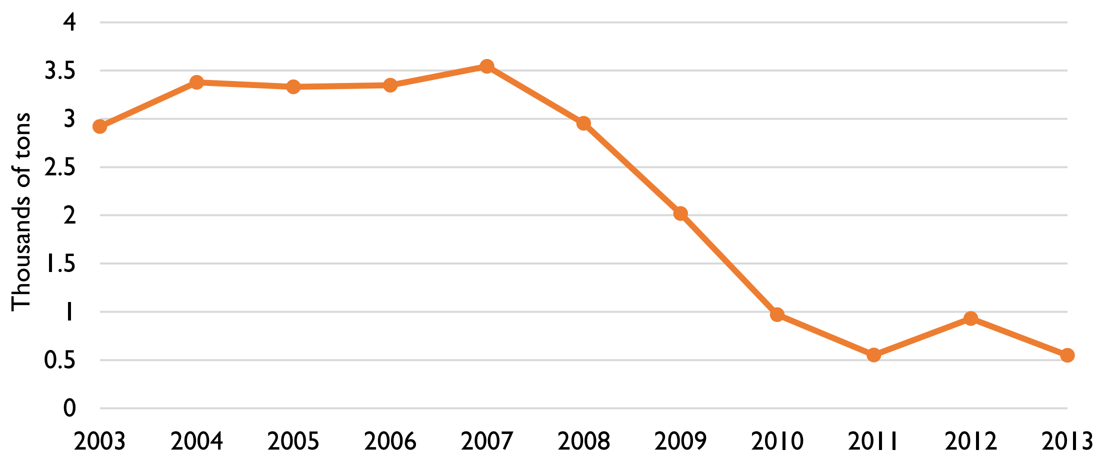


Figure 23 above shows the trend in emissions of particulate matter ten microns in diameter or smaller (PM_{10}).[91] PM_{10} data was not available until 2003. From 2003 through 2007, PM_{10} emissions increased by 624 tons (21 percent). However, as with SO_x and NO_x, there were significant reductions (2,600 tons or 72 percent) in PM_{10} emissions between 2007 and 2010. The greatest decrease between any two years was between 2009 and 2010, when PM_{10} emissions decreased by 1,050 tons (52 percent). Emissions increased slightly in 2012 but went down again in 2013.

These emission reductions were largely driven by the 2006 Maryland Healthy Air Act, which required "dramatic NO_x, SO_2, greenhouse gas, mercury, and other emission reductions."[92] These new requirements compelled major pollution control upgrades at the Brandon Shores coal-fired power plant, which is part of the Fort Smallwood complex in Northern Anne Arundel County, just south of Baltimore City. In 2009-2010, the Brandon Shores plant added a suite of new pollution controls to its two coal boilers, including flue gas desulfurization systems ("scrubbers") for SO_x and mercury and baghouses for PM. These systems went into operation on one boiler in December 2009 and on the other in

[91] The Maryland Emissions Inventory does not include emissions data for smaller-sized particles, which pose a greater risk to human health than PM_{10}; therefore, we are using PM_{10} as a marker of particulate emissions.
[92] Maryland Department of the Environment. 2017. "Maryland Clean Air: 2017 Progress Report." pg. 4. Link: http://mde.maryland.gov/programs/Air/Documents/MDCleanAirProgress2017.pdf.

February 2010.[93] The Herbert A. Wagner plant, which is also located at the Fort Smallwood complex, began using low sulfur coals in 2010 to reduce SO_x.[94] The emissions for each year from 2008 to 2010 for the Fort Smallwood complex are shown below in Table 6.[95]

Table 6. NO_x, SO_x, and PM_{10} Emissions from the Fort Smallwood Coal Plant Complex, 2008-2010

Year	Sulfur Oxides (SO_x) (tons)	Nitrogen Oxides (NO_x) (tons)	PM_{10} (tons)
2008	55,235	15,198	1,093
2009	47,960	5,178	671
2010	10,443	5,253	125

Decreasing emissions at the Fort Smallwood complex were responsible for most of the SO_x and NO_x reductions between 2008 and 2010 in our multi-facility analysis (67 percent and 65 percent, respectively) and almost half of the PM_{10} reductions (44 percent) were due to reductions in emissions at Fort Smallwood.

Mobile Source Emissions Data

We also analyzed trends in mobile source emissions, using data from the National Emissions Inventory (NEI), for NO_x, SO_2, and $PM_{2.5}$. As discussed in more detail in the Methodology and Data Caveats section of this report, EPA released NEI data annually for mobile sources from 2000-2002 and, thereafter, at three year intervals. Because the data indicates that EPA likely changed its methodology very significantly for estimating mobile source emissions between 2000 and 2002, we are limiting our analysis to 2002-2014.[96] During this period, NO_x decreased consistently between 2002 and 2011 and continued decreasing, though more slightly, between 2011 and 2014. SO_2 remained stable from 2002 to 2005, decreased sharply between 2005 and 2008, and then continued decreasing, though less rapidly, between 2008 and 2014. These trends are likely the result of new emissions standards passed by EPA.[97] $PM_{2.5}$, however, remained relatively stable from 2002-2014, with a slight jump in 2008.

---

[93] Letter from Daniel Haught, Vice President, Baltimore Operations, Constellation Energy Power Generation ("CPSG"), to George Aburn, Director, Air & Radiation Management Administration, MDE (February 18, 2011). CPSG was the owner and operator of these plants at the time that the controls were installed. EIP had this letter in our electronic files; it was likely obtained in response to a past request to MDE under the Maryland Public Information Act.

[94] *Id.*

[95] These emissions values are from the Maryland Emissions Inventory. EPA's Clean Air Markets ("CAM") database shows slightly different emissions values each year, but CAM also shows a drastic reduction in these pollutants from 2008 to 2010.

[96] NEI showed NO_x and $PM_{2.5}$ emissions from mobile sources as decreasing by more than 50 percent between 2001 and 2002 while SO_2 emissions more than double. No explanation appears available other than a change in the inventory methodology between those two years.

[97] EPA's Tier 2 standards for motor vehicles phased in new limits for sulfur levels in gasoline between 2004 and 2007 and new tailpipe standards for NO_x emissions from vehicles between 2004 and 2009' U.S. EPA. 1999. "Regulatory Announcement, EPA's Program for Cleaner Vehicles and Cleaner Gasoline." Link: https://nepis.epa.gov/Exe/ZyPDF.cgi/P1001Z9W.PDF?Dockey=P1001Z9W.PDF. Some of the difference in mobile source emissions over time could also be due to methodological changes over time in EPA's

Figure 24. NO_x Emissions from Mobile Sources 2002-2014 (Baltimore City)

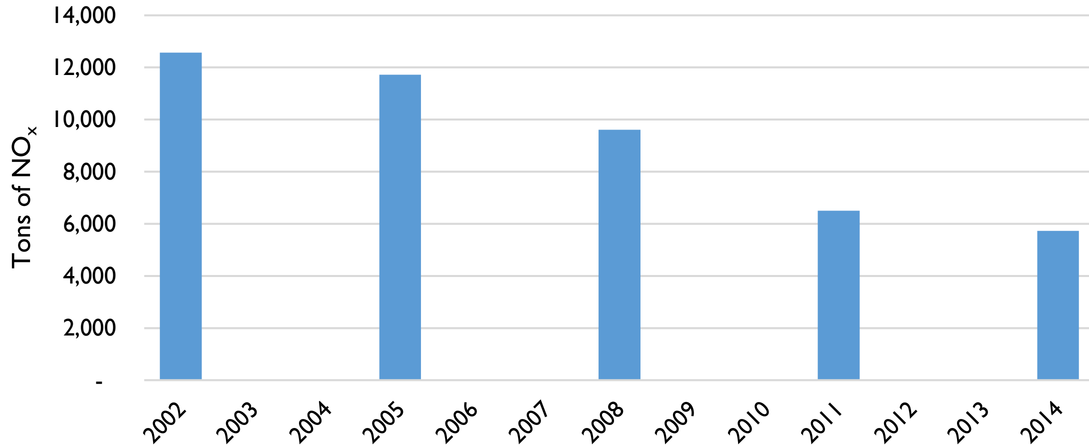


Figure 25. SO_2 Emissions from Mobile Sources 2002-2014 (Baltimore City)

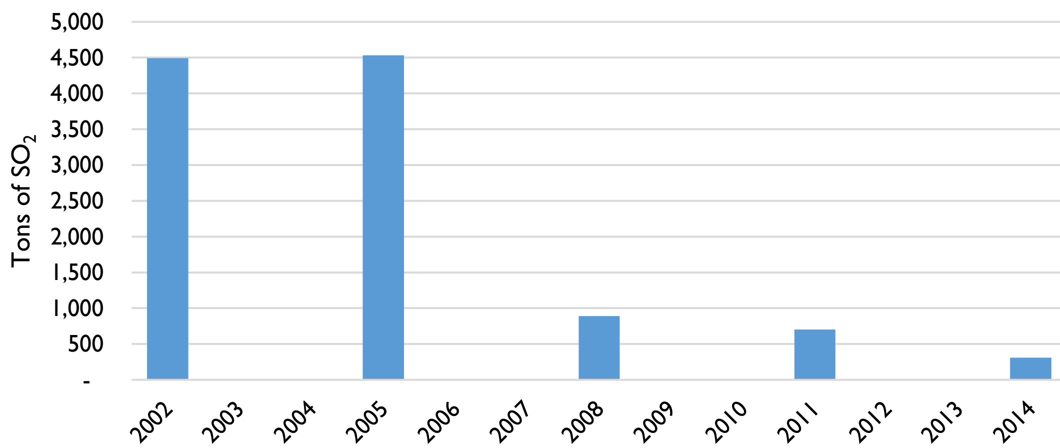
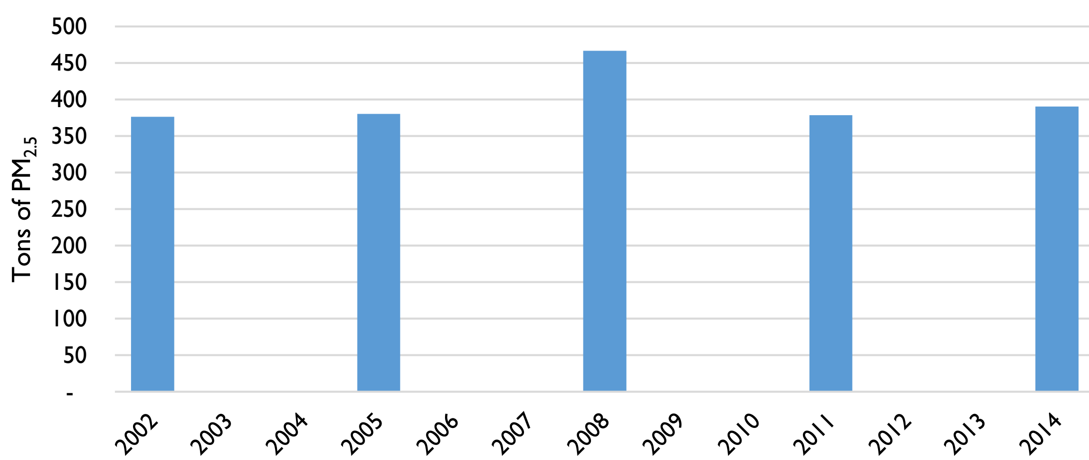


Figure 26. $PM_{2.5}$ Emissions from Mobile Sources 2002-2014 (Baltimore City)



National Emissions Inventory (NEI), although we did not identify any such changes during our analysis. See the Methodology and Data Caveats section of this report for more information about NEI.

It is more difficult to assess how mobile source emissions trends compare with asthma trends over time than it is to make this comparison for facility emissions because the mobile source data is available only at three-year intervals. However, the consistent reductions in NO_x and SO_2 do not correlate with the trends in the asthma rates, which increased overall from 2002 to 2009 for both asthma hospitalization and emergency room visit rates and then took different paths. However, it is possible that the trend in $PM_{2.5}$ emissions was somewhat similar to the asthma hospitalization rate trend if $PM_{2.5}$ emissions peaked in 2009, a year for which we do not have mobile source emissions data, and then declined. Because of the three-year interval, a peak in $PM_{2.5}$ is visible in the year 2008 but no data is available for 2009 (or 2010).

Air Quality Monitoring Data

The best possible data for showing air pollution concentrations, or air quality, is data captured by air quality monitors.[98] Unfortunately, these monitors are typically widely spaced in official monitoring networks for a number of reasons, including the fact that regulatory grade monitors are often quite expensive. Because there are few monitors located within Baltimore City, as illustrated below in Figure 27, it is difficult to use monitoring data to gauge city-wide trends. While there were three $PM_{2.5}$ monitors operating in the city in 2013, the most recent year for which we have asthma data, there was no SO_2 monitor operating in the city during the entire 2000 to 2013 period. In addition, the city's one air toxics monitor operating in 2013 did not measure many kinds of harmful air toxics, including lead. There was only one monitor for NO_2 during the 2000 to 2013 period and the one ozone monitor within the city did not begin operating[99] until 2006.[100]

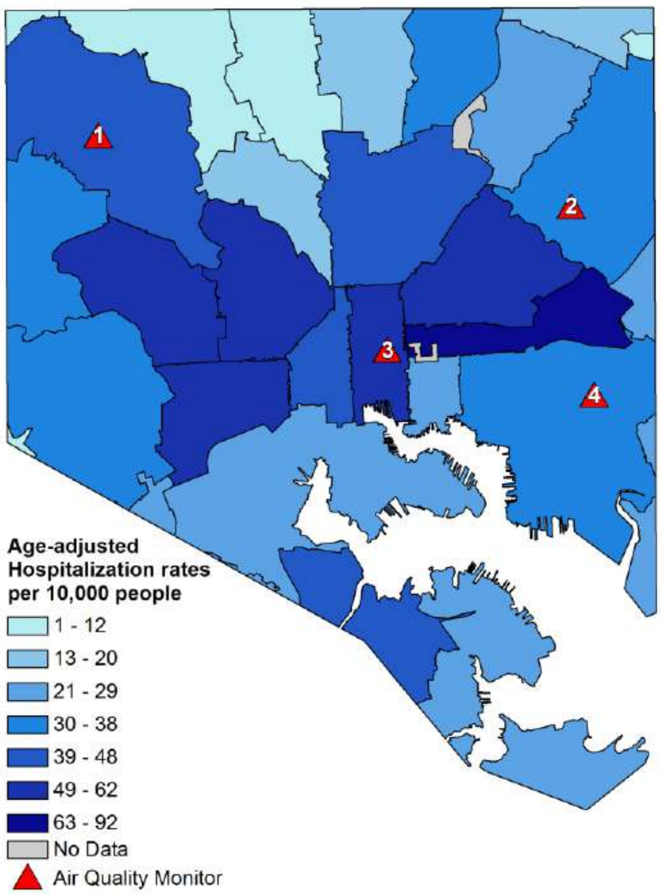
---

[98] U.S. EPA. Air Data. Outdoor Air Quality Data. "Monitor Values Report." Link: https://www.epa.gov/outdoor-air-quality-data/monitor-values-report.

[99] The Furley E.S. monitor began measuring ozone in August 2006, and only monitors from April to October each year. Prior to 2006, Baltimore City had two ozone monitors, one of which operated from 1995-2001, and the other from 2002-2003. See more details in ozone monitoring data gaps in the Methodology and Data Caveats section.

[100] This report addresses monitoring data only through the year 2013 because that is the most recent year for which asthma data is available. However, it is notable that ozone levels in Baltimore were higher in the years 2015, 2016, and 2017 than in the years 2013 and 2014, largely because the summers of 2013 and 2014 were atypically cool in Baltimore, reducing the formation of ozone.

Figure 27. State-Run Ambient Air Monitors Located in Baltimore City, Shown on 2013 Asthma Hospitalizations Map, and Pollutants Measured

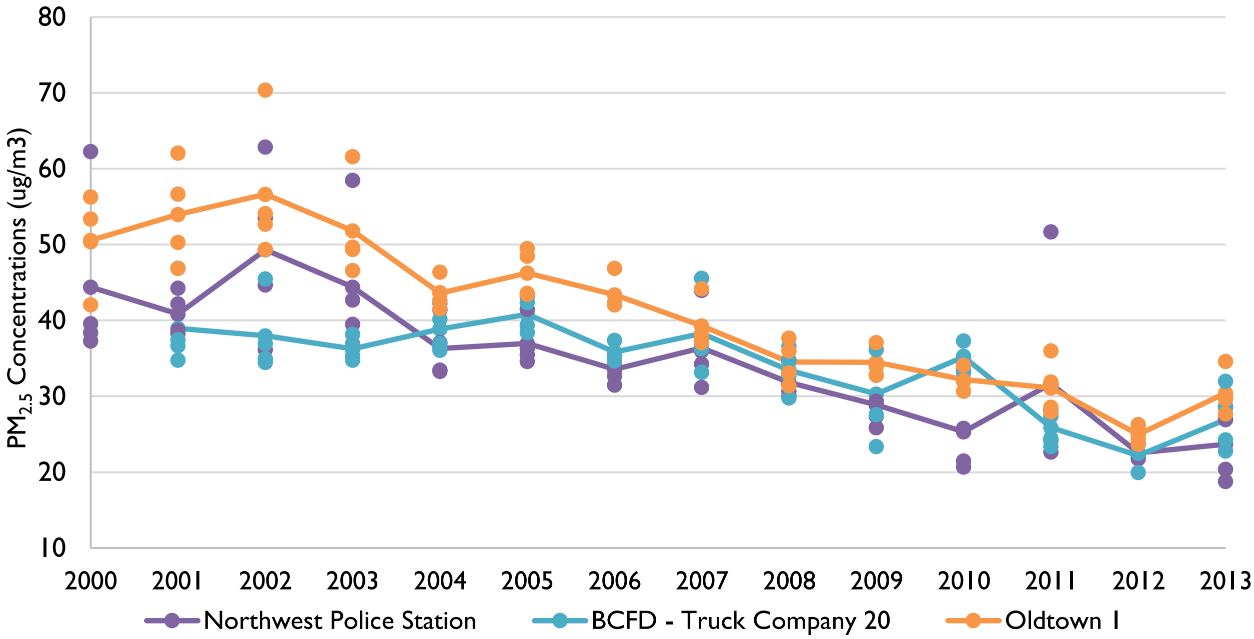


ID	Station	Pollutants Monitored
1	Northwest Police Station	$PM_{2.5}$
2	Furley Elementary School	Ozone
3	Oldtown Fire Station	Nitrogen Dioxide, Carbon Monoxide, PM_{10}, $PM_{2.5}$, Air Toxics (Volatile Organic Compounds)
4	BCFD Truck Company 20	PM_{10}, $PM_{2.5}$

Below, we present trend data from 2000 through 2013 for Baltimore City's $PM_{2.5}$ monitors and its ozone, NO_2, and toxics monitors. Because the ozone monitor did not start operating until 2006, we provide regional-level monitoring data for ozone from 2000 to 2013. We also provide trend data for SO_2 at the regional level because no SO_2 monitor was located in Baltimore City at any point during the 2000-2013 period.

$PM_{2.5}$

Figure 28. Four Highest Daily $PM_{2.5}$ Readings at Baltimore City Monitors



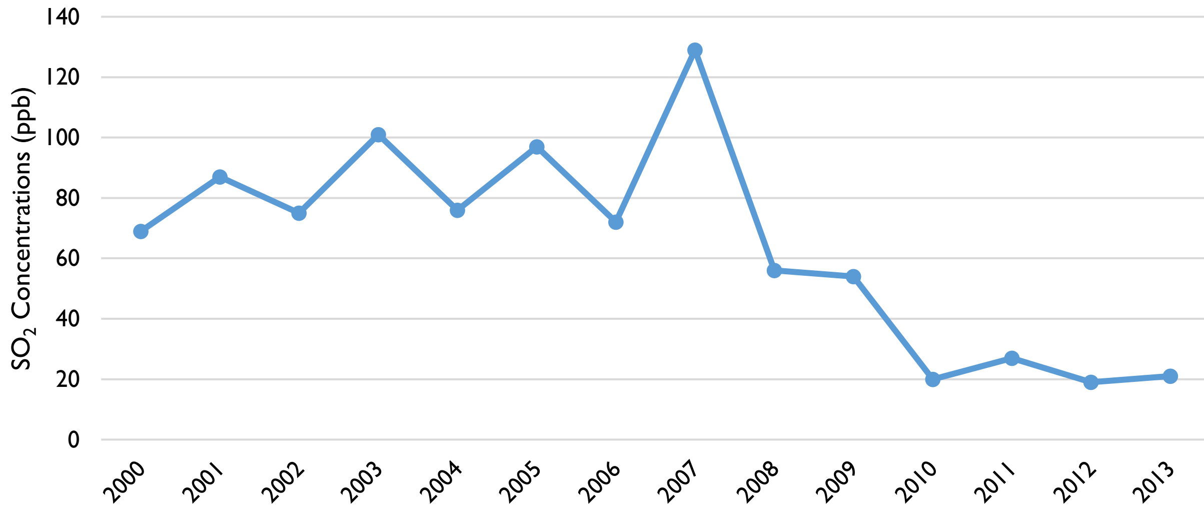
There were three $PM_{2.5}$ monitors located within the city in 2013. The Northwest Police Station and Oldtown monitors went into operation in 2000 and the BCFD Truck Company monitor started operating in 2001. EPA has set air quality standards for fine particle pollution on a daily basis and an annual basis. Since we are analyzing pollution that contributes to acute asthma events – hospitalizations and emergency room visits – we looked at daily (24-hour) monitor readings. Figure 28 above shows the four highest fine particle concentrations measured at each of these monitors from 2000-2013, and the average of those readings. The federal standard for daily $PM_{2.5}$ is not assessed based on the four highest readings each year but on the 98th percentile averaged over three years.[101] However, we believe that visualizing data in this way, especially given the three city monitors for this pollutant, likely gives the best sense of trends over time in daily $PM_{2.5}$ spikes in the city.

In general, the trend is a slight increase from 2000 to 2002 and then a steady decrease between 2002 and 2012, with a slight increase in 2005 and with additional fluctuations at the BCFD monitor and the Northwest Police Station monitor between 2009 and 2012. All three trend lines show increases between 2012 and 2013.

[101] U.S. EPA. "NAAQS Table." Link: https://www.epa.gov/criteria-air-pollutants/naaqs-table.

SO_2

Figure 29. Daily Maximum 1-Hour Sulfur Dioxide (SO_2) Readings (99th Percentile) at Baltimore CBSA Monitors



Because no monitor for SO_2 was located in Baltimore City during the 2000-2013 period, we used data from EPA for monitors located in the Baltimore core-based statistical area ("CBSA"). The Baltimore CBSA is Baltimore City and the five surrounding counties. EPA's Air Quality Statistics Report[102] provides the highest value each year for a given pollutant measured at any monitor in the CBSA. From 2003-2013, these values are all from a monitor located in Baltimore County, located a few miles west of the city, because that was the only SO_2 monitor in operation in the Baltimore CBSA during that time. The Air Quality Statistics Report provides data in a way that may be measured against EPA's air quality standards, without adding any multi-year averaging requirements. EPA's 1-hour SO_2 air quality standard looks at the 99th percentile of 1-hour daily maximum concentrations, averaged over three years. We are presenting data in this way in Figure 29 above, but without averaging over three years.

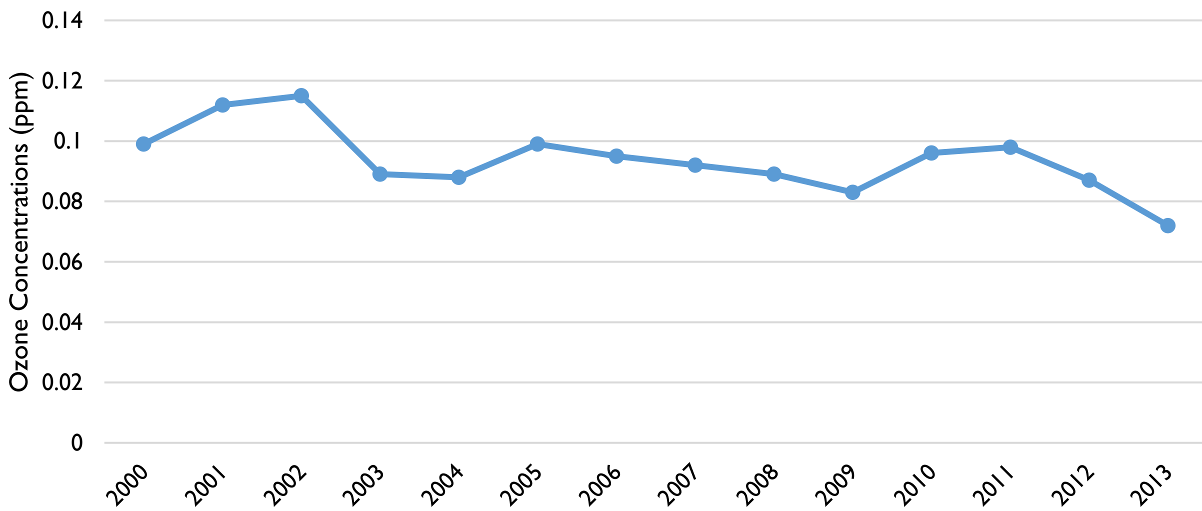
SO_2 levels fluctuated significantly between 2000 and 2006 with high readings in 2003 and 2005. A substantial spike was measured in 2007, followed by a sharp decrease in 2008. Levels held steady between 2008 and 2009, decreased significantly from 2009 and 2010, and experienced minor fluctuations thereafter. The decrease from 2009 and 2010 is likely due to emissions reductions at facilities including the Fort Smallwood coal plant complex, as described above, and the decrease between 2007 and 2008 could be related to reduction of mobile source emissions of SO_x. Though not as significant in total mass (tonnage) per year, SO_x from mobile sources is emitted from points, like vehicle tailpipes, that are typically closer to the ground than small smokestacks and can have a greater influence on the air that people breathe in smaller amounts. We do not have data that explains the 2007 spike in SO_2, but it could be related to mobile source emissions, for which we have no data for 2007.

[102] U.S. EPA. Air Data. "Air Quality Statistics Report." Link: https://www.epa.gov/outdoor-air-quality-data/about-air-data-reports#con.

Ozone

There is one ozone monitor in Baltimore City, but it has been in operation only since 2006. For this reason, we are presenting ozone trends over time using CBSA-level data for the Baltimore region from 2000 through 2013 and data from Baltimore City's one ozone monitor from 2006 through 2013.

Figure 30. Fourth Highest 8-Hour Ozone Concentrations in Baltimore CBSA Monitors

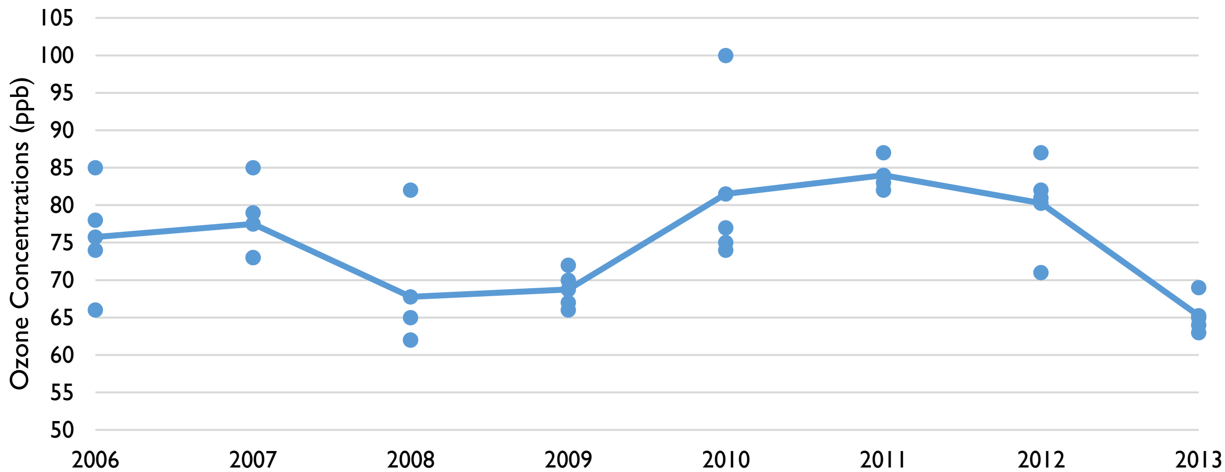


We used data for the Baltimore CBSA from EPA's Air Quality Statistics Report, which provides the fourth highest 8-hour reading per year read at any monitor within the CBSA.[103] There are multiple ozone monitors within the Baltimore CBSA (seven in 2013) and the highest-reading monitor is not always the same from year to year. As shown in Figure 30 above, ozone levels fluctuated throughout the 2000 to 2013 time period. They increased from 2000 to 2002, decreased significantly from 2002 to 2003, increased from 2004 to 2005, decreased slightly every year from 2005 through 2009, increased from 2009 to 2011 and decreased from 2011 to 2013.

Baltimore City's ozone monitor shows a similar trend for the period during it was operating: 2006 to 2013. For the Baltimore City ozone monitor, we visualized the top four 8-hour ozone concentrations measured each year. As shown in Figure 31 below, using this metric, ozone levels held relatively steady from 2006 to 2007, decreased in 2008, increased from 2008 to 2011, and decreased from 2011 to 2013.

[103] EPA's 8-hour ozone standard is measured based on the fourth-highest 8-hour reading averaged over three years.

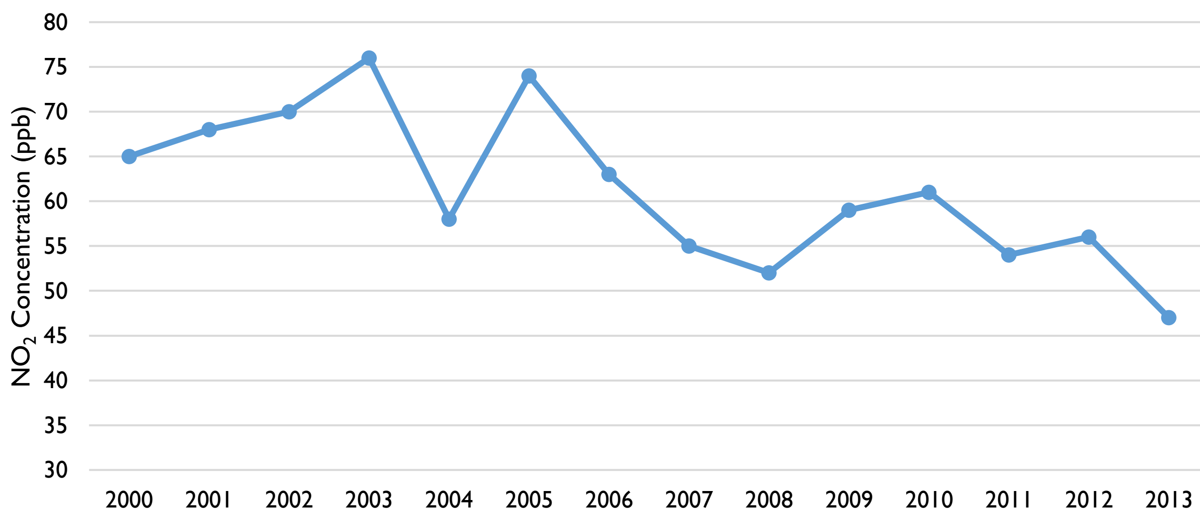
Figure 31. Four Highest Ozone Concentrations at Baltimore City Furley Monitor



Note: The points above represent the four highest ozone concentrations each year.

NO_2

Figure 32. Nitrogen Dioxide (NO_2) 98th Percentile 1-Hour Daily Max Values at Baltimore City Oldtown Monitor



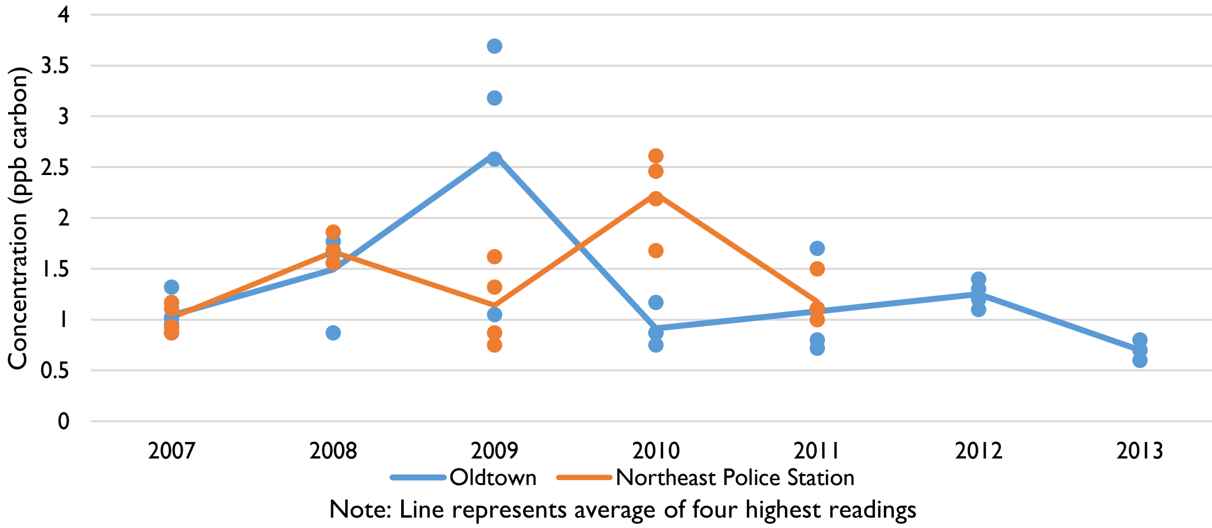
We graphed trends in NO_2 concentrations measured at Baltimore City's one monitor for that pollutant, looking at the 98th percentile of 1-hour daily maximum levels.[104] We chose to present the data in this way because data was available from EPA's Monitor Values Report only for the 98th percentile value each year and for the two highest readings per year, which were difficult to process visually when we graphed them. NO_2 readings increased from 2000 to 2003, decreased sharply in 2004, and then increased to about the prior level in 2005.

[104] EPA's standard is measured based on the 98th percentile of 1-hour daily maximum levels, averaged over 3 years.

From 2005 to 2008, there was a decrease each year, followed by increases from 2008 to 2010 and then a general decline from 2010 to 2013.

Air Toxics (Acrolein)

Figure 33. Air Toxics: Four Highest Daily Acrolein Concentrations at Baltimore City Monitors



Baltimore City's toxics monitor measures several pollutants. Using EPA's National Air Toxics Assessment (NATA) tool, we analyzed the toxic pollutants contributing most to respiratory risk in the city. NATA estimates that acrolein was contributing roughly 60-80 percent of the respiratory risk (the range is due to differing risks in different areas of Baltimore) in 2011.[105] Acrolein is produced by, among other things, burning fuels like oil and gasoline. Exposure to acrolein can occur due to proximity to vehicle exhaust,[106] which is consistent with our finding (also using NATA) that vehicle emissions were contributing most of the respiratory risk from air toxics in Baltimore.

Acrolein is measured in Baltimore City,[107] so we are presenting a graph of trends in acrolein levels over time (Figure 33 above), using the top four 24-hour levels measured each year from EPA's Air Data files.[108] It is also important to note that EPA's database identifies acrolein data from Baltimore as "unverified." This means there is some uncertainty about the accuracy of the data due to use of a monitoring method that could result in data that is biased high if the equipment is not properly cleaned before sampling, from acrolein growth within canisters, and/or variability in calibrating the systems.[109] Values were available for

---

[105] As described above and in the Methodology and Data Caveats section, the most recent year for which we have NATA information is 2011. Therefore, we conducted this analysis for the year 2011.
[106] U.S. EPA. 2009. "Acrolein: Hazard Summary." Link: https://www.epa.gov/sites/production/files/2016-08/documents/acrolein.pdf.
[107] NATA estimated that the toxic pollutant contributing the next-highest risk was acetaldehyde, but this pollutant is not measured in Baltimore City.
[108] U.S. EPA. Air Data. "Pre-Generated Data Files." Link: https://aqs.epa.gov/aqsweb/airdata/download_files.html.
[109] U.S. EPA. 2010. "Data Quality Evaluation Guidelines for Ambient Air Acrolein Measurements." Link:

Baltimore's Oldtown monitor from 2007 through 2013. The average of the four highest readings at this monitor rose slightly from 2007 to 2008, spiked in 2009, decreased from 2009 to 2010, a slight increase from 2010 through 2012, and decreased from 2012 to 2013. Acrolein data was also available for the Northeast Police monitor from 2007 to 2011. At this monitor, acrolein increased from 2007 to 2008, decreased from 2008 to 2009, increased significantly from 2009 to 2010, and decreased significantly from 2010 to 2011.

Case Study: South Baltimore (Zip Codes 21225 and 21226)

EIP has a longstanding relationship with individuals and groups that live and/or work in the South Baltimore neighborhoods of Curtis Bay and Brooklyn. These neighborhoods are located close to two large industrial areas, Fairfield and Hawkins Point, and air pollution and asthma have long been a concern to some residents of these neighborhoods. For this reason, we conducted an analysis that is specific to the zip codes that include these neighborhoods – 21225 and 21226 – to assess trends over time in asthma hospitalization rates and exposure to air pollution.

We found that trends in rates of acute asthma events in these two adjacent zip codes were very similar to one another. We also found that asthma hospitalization rates in each of these zip codes dropped by 57 percent between 2009 and 2013, which was over 2.4 times greater than the city-level decrease in asthma hospitalization rates from 2009 to 2013 (23 percent). This dramatic decrease in asthma hospitalization rates may have been influenced by pollution control technology upgrades at two coal-fired power plants at the Fort Smallwood complex, which is located in the 21226 zip code. These changes reduced SO_x emissions between 2009 and 2010 by 37,517 tons and PM_{10} emissions by 546 tons during the same period. Prior changes at the plants had also reduced NO_x emissions between 2008 and 2009. All told, between 2008 and 2010, emissions from the plants dropped by 44,792 tons of SO_x, 9,945 tons of NO_x, and 968 tons of PM_{10}.

https://www3.epa.gov/ttnamti1/files/ambient/airtox/20101217acroleindataqualityeval.pdf

Asthma Trends

Figure 34. Brooklyn (21225), Curtis Bay (21226), and Baltimore City Asthma Hospital Discharge Rates

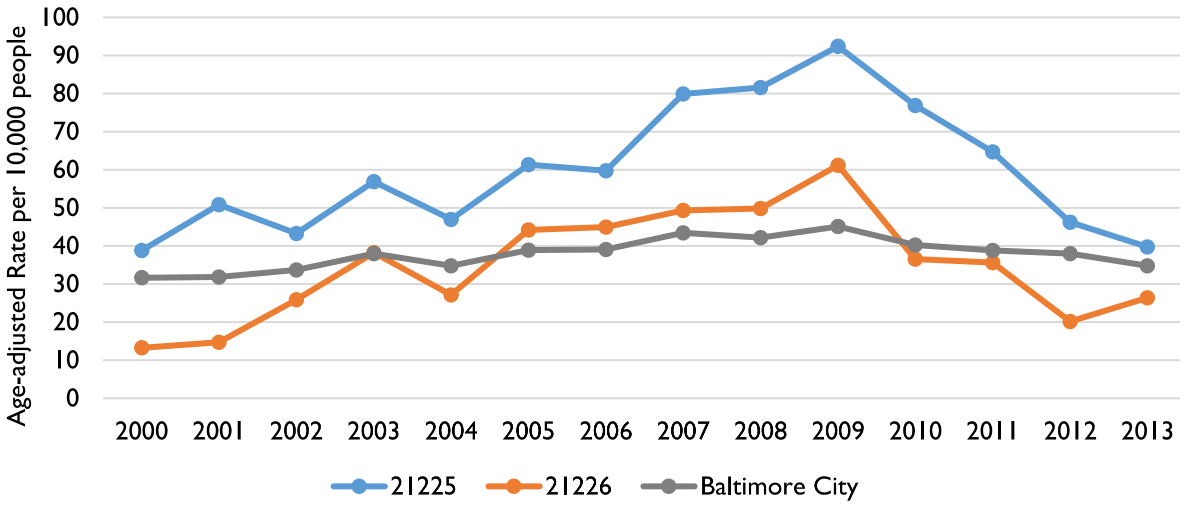


Figure 34 above shows trends in asthma hospitalization rates from 2000-2013 in the 21225 and 21226 zip codes and the city-wide rate. The fact that asthma hospitalization rates in the 21225 zip code were consistently higher over time than in 21226 is consistent with our finding, as stated above, that measures of poverty are closely correlated with spatial trends in Baltimore's asthma rates. Median household income in 2013 was about 63 percent higher in the 21226 zip code than in 21225 (Table 7). The 21226 zip code includes Curtis Bay, a low-income neighborhood in Baltimore City, but it also includes wealthier residential areas of northern Anne Arundel County. In addition, 21225 includes the Brooklyn and Cherry Hill neighborhoods of South Baltimore as well as the Brooklyn Park neighborhood in Anne Arundel County.

Table 7. 2013 Median Household Income in 21225 and 21226

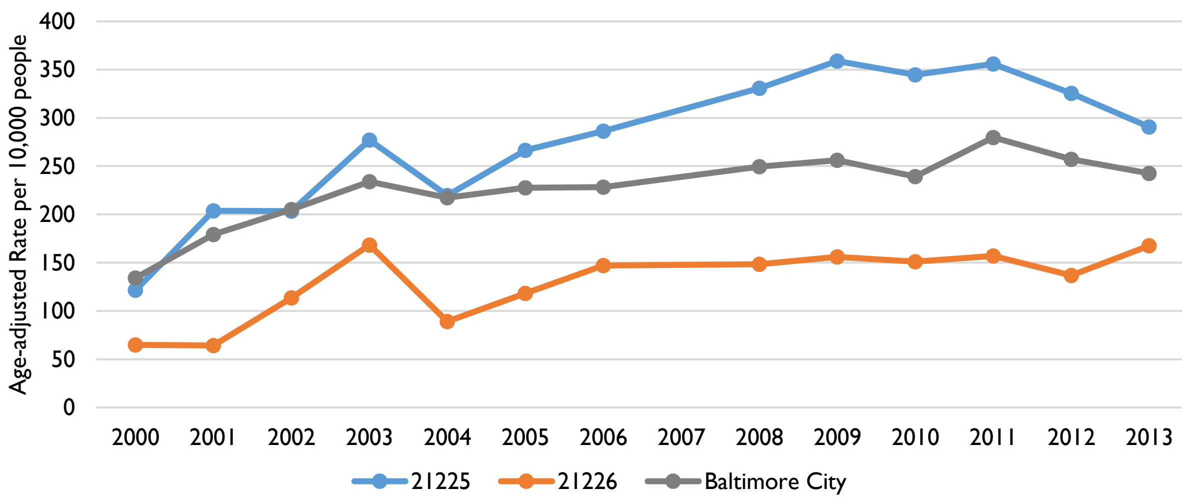
Zip Code	Total Population	Median Household Income
21225	34,015	$37,487
21226	7,707	$61,250

The trend over time in asthma hospitalization rates was very similar for both of these zip codes. In each, there was a significant, though uneven, increase in asthma hospitalization rates from 2000 to 2009 and a sharp decrease after 2009. In the 21226 zip code, there was also a slight increase from 2012 to 2013. The post-2009 drop in asthma hospitalization rates in these zip codes was significant enough that 21225, which had the highest asthma hospitalization rate out of all of the zip codes in the city in 2009, ranked 9th in the city in 2013 for highest asthma hospitalization rates. The 21226 zip code was 7th in the city for highest asthma hospitalization rates in 2009. In 2013, it was 16th.

As shown in Figure 35 below, the asthma emergency room discharge rate trend for the 21226 zip code was similar to that for the 21225 zip code, though not as similar as the asthma hospitalization rate trends were for the two zip codes. Emergency room visit rates increased in both zip codes from 2000 to 2003 and decreased significantly from 2000 to 2004. Between 2004 and 2009, rates steadily increased in 21225 and 21226.[110] Rates remained almost level from 2009 to 2011 in 21225 and 21226. Between 2011 and 2013, emergency room visit rates decreased in 21225. During this time, rates in 21226 decreased slightly and then increased.

Trends over time for asthma emergency room rates from 2000-2009 in the 21225 and 21226 zip codes were relatively similar to the trends in asthma hospitalization rates during these years, in that both showed an overall increase in rates between those years, although the increase was more steady for asthma emergency room rates and fluctuated more for hospitalization rates. However, emergency room visit rates did not decline sharply after 2009 in the 21225 and 21226 zip codes as hospitalization rates did.

Figure 35. Emergency Room Discharge Rates 2000-2013 - Brooklyn (21225), Curtis Bay (21226), and Baltimore City



We were not able to analyze trends in median household income for these zip codes because zip code level data was not available for years before 2010. However, as stated above in the section on city-level trends over time, median household income does not appear to correlate significantly with asthma trends in Baltimore over time. As also stated in that section, researchers using a national-level dataset (the Healthcare Cost and Utilization Project ("HCUP")) found that in the years following the recession, asthma hospitalization rates for adults decreased by 15.6 percent and treat-and-release emergency room visit rates for adults rose 8.6 percent.

There was no decrease in asthma rates in the 21225 and 21226 zip codes between 2008 and 2009. However, asthma hospitalization rates between 2009 and 2013 decreased by 57 percent in each of the 21225 and 21226 zip codes, a much greater decrease than the

---

[110] As stated above, we excluded 2007 data from the emergency room visit trends analysis at the recommendation of the Maryland Department of Health as the 2007 data appeared incorrect.

national-level drop between 2008 and 2012, and over 2.4 times greater than the city-level decrease in asthma hospitalization rates from 2009 to 2013 (23 percent). We are not able to analyze whether the decrease in these zip codes was due to increased treat-and-release emergency room visits, as the researchers theorized might be the case for the national HCUP dataset, because the Maryland dataset does not differentiate between treat-and-release emergency room visits and visits that result in admission. However, from 2009 to 2013, asthma emergency room visits in 21225 decreased by 19 percent and, in 21225, they increased by 7 percent. It appears unlikely that increased treat-and-release events were the sole cause of the post-2009 decrease in hospitalization rates in these zip codes.

Table 8. Change in Asthma Rates from 2009-2013

	Hospitalization Rate	Emergency Room Visit Rate
Baltimore City	-23%	-5%
Zip code 21225	-57%	-19%
Zip code 21226	-57%	+7%

Air Pollution Trends

There are no monitors located in the 21225 zip code or the 21226 zip code so we are not able to show neighborhood-level trends in air quality data over time.[111] We also do not have zip code level data on mobile source emissions, which likely have a significant influence in this area because of truck, train, and ship traffic associated with the adjacent Port of Baltimore and because tailpipes are closer to ground level, having a more direct effect on the air that people breathe. However, there are some large polluting plants in this area for which we have data. In general, the emissions trends for these plants is consistent with the Facility Emissions Data section of this report (for the city at large) largely due to the influence of the Fort Smallwood coal plant complex. As described in that section, emissions of NO_x and SO_x generally decreased from 2000 through 2007, decreased much more rapidly from 2008 through 2010, and then gradually declined from 2010 through 2013 (Figure 22). PM_{10} emissions increased from 2003 to 2004, remained relatively level from 2004 to 2007, decreased sharply from 2008 through 2011, increased in 2012, and then decreased in 2013 (Figure 23).

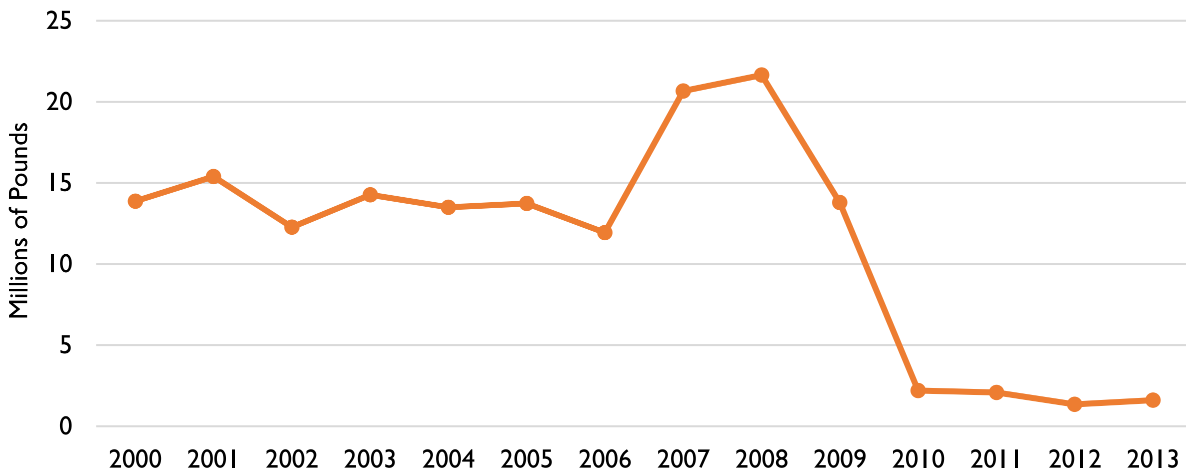
EIP also analyzed trends in toxic air releases within the 21226 zip code.[112] A report that we issued in 2011 found that the 21226 zip code had the highest toxic air releases from stationary facilities (using EPA's Toxics Release Inventory (TRI)) of any zip code in the

[111] EIP had fine particle monitors located in these areas intermittently from the summer of 2013 through the summer of 2015. However, because of technical concerns, we considered only the 2015 data to be reliable. While that data did indicate that pollution levels may be higher in this area than in the areas where the official state monitors are located, we cannot compare it to asthma hospitalization trends in South Baltimore on a multi-year basis; Environmental Integrity Project. 2016. "Citizen Air Quality Monitoring in Curtis Bay, Baltimore." Link: https://www.environmentalintegrity.org/wp-content/uploads/2016/11/PM2.5-Report.pdf; We also do not have asthma hospitalization data from 2015 as part of the dataset recently released by the Department of Health; that data is current through 2013.

[112] U.S. EPA. Toxics Release Inventory (TRI) Program. TRI Explorer. Link: https://iaspub.epa.gov/triexplorer/tri_release.chemical; Data includes both fugitive and stack emissions for all pollutants and facilities in 21226.

country in 2007 and 2008, falling to the number two zip code in the country in 2009.[113] Figure 36 below shows total toxic air releases in 21226 from 2000-2013 using TRI. Toxic air releases decreased overall from 2000 through 2006, with a slight increase in 2001 and slight decreases in 2002 and 2006. Spikes occurred in 2007 and 2008, followed by a substantial decrease from 2008 to 2009, an even larger decrease between 2009 and 2010, and relative stability thereafter.

Figure 36. Total Toxic Air Releases in 21226 Zip Code



While these pollution trends do not show a consistent association over time with asthma hospitalization or emergency room rate trends, the steep drop in asthma hospitalization rates in 21225 and 21226 between 2009 and 2010 occurred at the same time as dramatic reductions in emissions from plants in the 21226 zip code.

Between 2008 and 2010, new pollution controls and upgrades at the Fort Smallwood coal complex, which is located in the 21226 zip code and consists of two coal-fired power plants, dramatically reduced emissions of several pollutants from the plants. A suite of new pollution controls for SO_x, mercury, and PM was added to the two coal-fired boilers at the Brandon Shores plant, including wet flue gas desulfurization systems ("scrubbers") for SO_x and mercury and baghouses for PM. This system went into operation in December 2009 for one boiler at Brandon Shores and February 2010 for the other boiler.[114] The Herbert A. Wagner plant at the complex also began using low sulfur coals in 2010 to reduce SO_x.[115]

These changes reduced emissions from the Fort Smallwood complex between 2009 and 2010 by 37,517 tons of SO_x and 546 tons of PM_{10}. Prior changes at the plant had also reduced NO_x emissions between 2008 and 2009. All told, between 2008 and 2010, new controls at the plant shaved off 44,792 tons of SO_x emissions, 9,945 tons of NO_x emissions,

[113] Environmental Integrity Project. 2012. "Air Quality Profile of Curtis Bay, Brooklyn and Hawkins Point, Maryland." Link: http://www.environmentalintegrity.org/news_reports/documents/FINALBAYBROOKREPORT_003.pdf.
[114] Letter from Daniel Haught, Vice President, Baltimore Operations, Constellation Energy Power Generation ("CPSG"), to George Aburn, Director, Air & Radiation Management Administration, MDE (February 18, 2011). CPSG was the owner and operator of these plants at the time that the controls were installed.
[115] *Id.*

and 968 tons of PM_{10}. These changes are shown by year below in Table 9. [116] The new scrubbers on Brandon Shores were also largely responsible for the toxic release reductions between 2008 and 2010 shown in Figure 36 above, which were primarily caused by reductions in the pollutant hydrochloric acid (HCl). HCl emissions from the Fort Smallwood complex decreased by about 3,500 tons between 2008 and 2009 and by another 4,750 tons between 2009 and 2010.[117]

Table 9. NO_x, SO_x, and PM_{10} Emissions from the Fort Smallwood Coal Plant Complex, 2008-2010

Year	Sulfur Oxides (SO_x) (tons)	Nitrogen Oxides (NO_x) (tons)	PM_{10} (tons)
2008	55,235	15,198	1,093
2009	47,960	5,178	671
2010	10,443	5,253	125

Wind roses for BWI Airport, which is located about 10 miles to the west of Fort Smallwood,[118] show that the winds in the area are primarily westerly (blowing from west to east). However, the winds do blow in other directions as well.[119] The Fort Smallwood complex is located in the central, eastern part of the 21226 zip code, and the 21225 zip code is to the northwest of the plant.

Conclusion and Recommendations

Multiple scientific studies have shown that exposure to increased levels of air pollution can increase the risk of asthma hospitalizations and/or emergency room visits, especially in children, and some studies indicate that air pollution exposure may be linked to new-onset cases of asthma. However, asthma is associated with multiple variables. Other factors that can trigger asthma attacks including bouts of flu or cold, pet dander, cockroach and mouse allergens, and emotional stress. In addition, insufficient access to preventative care, specifically asthma controller medication, has been shown to increase the likelihood of asthma hospitalizations and emergency room visits.

We found that the areas of Baltimore City that are most affected by toxic air pollution – especially from roadway vehicle emissions – appear to be located inside the zip codes with the highest asthma hospitalization rates (Figures 6-11). Measures of poverty are strongly

---

[116] These emissions values are from the Maryland Emissions Inventory. EPA's Clean Air Markets (CAM) database shows slightly different emissions values each year, but CAM also shows a drastic reduction in these pollutants from 2008 to 2010.

[117] We used TRI for this analysis because the Maryland Emissions Inventory does not have pollutant-specific data for hazardous air pollutants during this period. Mercury emissions also dropped dramatically during this period at the plant as well, but inhalation of mercury is primarily associated with neurological impairment and not respiratory effects.

[118] Meteorological data from BWI Airport is used in official air quality modeling decisions for the Fort Smallwood plant; U.S. EPA. "Draft Technical Support Document: Area Designations for the 2010 SO2 National Ambient Air Quality Standard." pgs. 15, 26. Link: https://www.epa.gov/sites/production/files/2016-03/documents/md-epa-tsd-r2.pdf.

[119] *Id.*

correlated with rates of acute asthma events in Baltimore, meaning that it is likely a combination of factors – including poor housing conditions and lack of access to preventative care – that is driving the high hospitalization and emergency room visit rates in Baltimore. But pollution from roadway vehicles appears to be increasing the risk of these events in some of the neighborhoods that have the biggest problem with asthma.

The association among various factors that affect asthma rates was more difficult to analyze for trends over time. Asthma hospitalization rates and emergency room visit rates did not follow the same trends over time and neither consistently tracked any of the various measures of air pollution that we analyzed, which also showed differing trends. It is likely that asthma trends over time are influenced by multiple variables. Two factors that may have affected post-2009 hospitalization rates are shifting economic conditions caused by the Great Recession and hospital policies regarding patient admissions.

It also appears that the steep reductions in pollution in late 2009 and 2010 from two coal plants just south of the city may have influenced the post-2009 decrease in city asthma hospitalization rates. In the 21226 zip code, which includes the two plants at the Fort Smallwood complex, and the adjacent 21225 zip code, asthma hospitalization rates fell by 57% between 2009 and 2013, which is over 2.4 times the decrease in city rates (23%) during the same time period. Between 2009 and 2010, pollution upgrades at the two coal plants at the Fort Smallwood complex reduced emissions by 37,517 tons of SOx, and 546 tons of PM_{10}.

It is clear that one of the main factors driving high asthma hospitalization and emergency room rates in Baltimore is poverty, which is likely linked to many conditions that worsen asthma, including limited access to control medication and poor housing conditions. The Environmental Integrity Project, as an environmental health advocacy organization, does not have answers to all of these problems. But reducing air pollution will likely have health benefits for the communities that are most affected by asthma. We are setting forth recommendations here for how state and city officials can take steps to further reduce air pollution that affects Baltimore.

1. State of the Art Pollution Controls Should Be Required for All Pollution Sources in the Baltimore Region

The pollution control upgrades, and subsequent emission reductions, at the Fort Smallwood coal plants were achieved because of the 2006 passage of a law called the Maryland Healthy Air Act. Our analysis suggests that these reductions may have improved asthma hospitalization rates in communities near the plant. State of the art pollution controls should be required on all pollution sources that affect the air that people breathe in Baltimore City. For example, MDE is currently setting new emission limits for NO_x for the Wheelabrator trash incinerator in South Baltimore (sometimes called the "BRESCO" incinerator), which is the largest stationary source of NO_x located within the city's borders. This plant emitted 1,141 tons of NO_x in 2016, making it the state's fifth largest emitter of that pollutant. NO_x emissions contribute to the formation of ground-level ozone, NO_2, and particulate matter in the air that people breathe. The BRESCO incinerator is also a major source of SO_x and a significant emitter of toxic air pollution.

MDE should set emission limits for this incinerator that will require the installation of new pollution controls at this plant, preferably state of the art controls. If MDE does not move forward quickly with a rule that requires significant emissions cuts at this facility, then the City of Baltimore, which also has legal authority to set emissions limits for this plant,[120] should consider setting its own limits.

2. MDE Should Apply Increased Scrutiny to Permit Applications for Air Pollution Sources In and Near Zip Codes with High Rates of Acute Asthma Events

When a new air pollution source is proposed in Baltimore (or any Maryland zip code with a high asthma rate), state officials should apply increased scrutiny to the permit application. Given the apparent association between SO_x emissions and asthma hospitalization rates in the areas near the Fort Smallwood coal plant complex, it makes sense for the state to conduct a particularly close review for new large sources of SO_x emissions.

There are a variety of ways in which MDE can more closely review the effect of a proposed pollution source on nearby communities. For certain sources, if the existing monitoring network does not provide data that is representative of the geographic area of concern, MDE can require the applicant to obtain neighborhood-specific air quality data by installing air quality monitors in the communities closest to and/or downwind of the proposed pollution source.[121] This would allow a more precise evaluation of the potential effects of the new source. MDE also has some authority to take into account the air pollution impacts from mobile sources – for example, certain emissions from ships,[122] which can be very large sources of SO_x – that would service the proposed new facility. Enhanced opportunities for public input would make it more likely that any existing health conditions (in addition to asthma) in the nearby community that increase vulnerability to the adverse impacts of air pollution would be raised during the public comment period for the permit. For example, the EPA has found that there is adequate evidence that the adverse respiratory effects of ozone are made worse by an insufficiently healthy diet, particularly reduced intake of Vitamins E and C, as discussed in the section above on non-pollution factors that can affect asthma.

Depending on the results of the air quality impacts review, MDE could set more protective conditions in the final permit or, if permit requirements are not met, deny the permit. More

---

[120] Md. Code, Environment, § 2-104.

[121] U.S. EPA. 1990. "Draft New Source Review Workshop Manual." pg. C-16. Link: https://www.epa.gov/sites/production/files/2015-07/documents/1990wman.pdf.

[122] Letter from Charles J. Sheehan, Regional Counsel, U.S. EPA Region VI, to Michael Cathey, Managing Director, El Paso Energy Bridge Gulf of Mexico, L.L.C at 9 (October 28, 2003) (stating that the federal Clean Air Act definition of "stationary source" excludes only emissions from internal combustion engines, and "[t]hus, a vessel powered by external combustion engines would be a 'stationary source' for permitting purposes.") EPA New Source Review Workshop Manual ("NSR Manual") at A.18 ("As a result of a court decision in NRDC v. EPA, 725 F.2d 761 (D.C. Circuit 1984), emissions from vessels at berth ("dockside") [sic] not to be included in the determination of secondary emissions but are considered primary emissions for applicability purposes."); Texas Commission on Environmental Quality (TCEQ) Air Permit Reviewer Reference Guide, Major New Source Review – Applicability Determination (APDG 5881) ("TCEQ NSR Guide") ("Certain emissions from ships and barges located at berth are considered to be primary emissions and must be included in the PTE determination. These emissions include . . . the emissions from the ship's boilers used to support the transfer of materials between the vessel and shore facilities while the ship is docked.")

protective permit conditions could include more stringent pollution control requirements and better monitoring, including ongoing air quality monitoring in nearby communities. If the proposed source is planning to meet any air quality requirements using pollution "offsets" from other facilities, MDE could require that those offsets be obtained from sources in the immediate vicinity of the new pollution source in order to ensure that local air quality is not degraded.[123]

3. The State of Maryland Should Reduce Emissions from Roadway Vehicles by Improving Public Transit Options in Baltimore

Air pollution from roadway vehicles appears to be disproportionately affecting some of the areas of Baltimore City that have the highest asthma hospitalization and emergency room visit rates. Increasing opportunities for Baltimore residents and commuters to take public transit will likely reduce the pollution burden on these communities. Baltimore's public transit system is notoriously outdated and inadequate, especially for a city that wishes to attract new residents and new businesses.

In 2015, Governor Larry Hogan canceled state plans to build the Red Line, which would have been a 14-mile subway and light rail line running from west to east in Baltimore. In addition to reducing air pollution, [124] this project was anticipated to provide enormous economic benefits to Baltimore. A 2009 study commissioned by the Baltimore City Department of Transportation ("DOT") found that the construction phase of the Red Line would have generated "$1.8 billion in economic activity in Baltimore City and create[d] or support[ed] 12,949 jobs earning $672.5 million in salaries and wages."[125]

This was a missed opportunity to reduce traffic congestion, and associated air pollution, in Baltimore while improving economic opportunities. The state should undertake a review of how to reduce air pollution from roadway vehicles in the City of Baltimore, focusing on roads in or near the city zip codes with the highest asthma rates. The Red Line should be considered an option as the state conducts this review.

4. The Maryland Department of Health Should Make Asthma Data Available by Community Statistical Area for Baltimore City

EIP is extremely appreciative of the time and resources that the Maryland Department of Health has expended in making available the zip code level asthma data discussed in this report. We are also very grateful to officials within the Department of Health for taking the time to provide helpful input in responses to questions that we have raised about the data as

---

[123] COMAR 26.11.17.03 (Requiring MDE to deny a permit for a new major source or a major modification in a nonattainment area unless "emission offsets will provide a positive net air quality benefit in the affected area . . . .")

[124] Without providing specific reduction figures, the Final Environmental Impact Statement Executive Summary (FEIS) for the project states that the Red Line is estimated "to decrease pollutant burdens" at the regional level by about 1.5 to 1.9 percent; The full FEIS was not available online; The Federal Transit Administration. 2012. "Red Line FEIS Executive Summary." pgs. ES-17, ES-23. Link: https://transportation.baltimorecity.gov/sites/default/files/Redline_executive%20Summary_feis.pdf.

[125] Clinch, Richard. 2009. "The Economic and Jobs Impacts of the Red Line Mass Transit System on Baltimore City." *The Jacob France Institute, University of Baltimore*. pgs. 5-6. Link: http://www.jacob-france-institute.org/documents/Red-Line-12-09.pdf.

we wrote this report. However, there is a way in which the asthma data could be made even more helpful to residents of Baltimore City.

The Baltimore Neighborhood Indicators Alliance ("BNIA)" tracks poverty and a number of other factors in the city at the level of community statistical areas, which are clusters of census tracts, and issues annual reports on this data called Vital Signs reports.[126] If possible without violating privacy requirements, the Maryland Department of Health should make asthma data available at this level for Baltimore City. This data would allow a direct comparison with many of the factors tracked by BNIA, such as measures of poverty and also other measures relating to health and quality of life, including housing. Being able to make a direct statistical correlation would assist in identifying the factors that are most contributing to the high asthma rates in Baltimore and could potentially identify any that might affect certain neighborhoods.

In addition, this would allow a more precise evaluation of the effect of air pollution on different areas of the city. For example, EIP has heard anecdotally that residents of Curtis Bay, a neighborhood within the 21226 zip code, have reported very high rates of asthma in group discussions. However, especially high rates of asthma in this smaller area could be masked by the fact that zip code 21226 also includes wealthier areas of Anne Arundel County that may have lower asthma rates. Similar masking of smaller areas with especially high asthma rates may also be occurring elsewhere in the city because the data is presented at the zip code level.

5. Officials and Local Universities Should Assist Baltimoreans to Obtain Community-Specific Air Quality Data

As illustrated above in Figure 27, only four official air quality monitors were located in Baltimore in 2013. Of these, only one was located in one of the city neighborhoods with the highest asthma hospitalization rates. Monitoring data fluctuates from monitor to monitor, as shown above (Figure 28) in the graph comparing trends over time at three Baltimore City monitors for fine particles ($PM_{2.5}$). Having neighborhood-specific air quality monitoring data would be enormously helpful in determining whether certain neighborhoods within Baltimore are exposed to pollution hotspots and what the pollution levels might be in those areas.

Many, though not all, official monitors are fairly expensive to purchase. If the state lacks the funding for these monitors, then local universities should explore opportunities to fill in information gaps by gathering data on relative air pollution levels in different city neighborhoods. EIP and our partner groups have already been in touch with researchers from Johns Hopkins who are implementing one such effort for NO_x and ozone monitoring under a grant from the EPA.[127] We are hopeful that the data produced by the project will help to further demonstrate the relationship between air pollution and asthma rates in Baltimore.

---

[126] Baltimore Neighborhood Indicators Alliance and University of Baltimore. 2017. "Spring 2017 Vital Signs 15." Link: https://bniajfi.org/wp-content/uploads/2017/04/VS15_Compiled-04-12-17-08-41.pdf.
[127] Dance, Scott. 2017. "How clean is the air on your block? Baltimore citizen scientists build monitors to find out." *Baltimore Sun*, August 11, 2017. Link: http://www.baltimoresun.com/news/maryland/environment/bs-md-air-monitor-network-20170731-story.html.

Target areas within the city should be in zip codes shown in this report to have high asthma hospitalization and emergency room visit rates. Researchers should further consider sampling in areas with the lowest median household incomes, as identified by community statistical area based on BNIA's most recent Vital Signs report. There is a strong spatial correlation between asthma rates and median household income at the zip code level.

Finally, we recommend that such monitoring programs focus on pollutants that have been associated in studies with increased hospitalizations and/or emergency room visits due to asthma. As discussed in the Air Pollution as Asthma Trigger section of this report, these pollutants include ozone, PM, NO_x, and SO_2. As the sharp decrease in SO_x at the Brandon Shores plant in 2009 and 2010 appears to have helped reduce asthma hospitalization rates in nearby Baltimore neighborhoods, we also consider increased monitoring of SO_2 particularly important. We are pleased that MDE has been making plans to install an SO_2 close to the Fort Smallwood complex,[128] which is still a large emitter of this pollutant even with the reductions that were achieved in 2010.

In addition, toxic air pollution associated with vehicle traffic appears to be affecting smaller areas of the city within zip codes with high asthma rates. While EPA has recently flagged potential problems with some monitoring methods for acrolein, as discussed in more detail above, new and relatively inexpensive monitors have become available for monitoring the wider category of volatile organic compounds (VOCs), which includes acrolein. EPA recently approved use of inexpensive sorbent tubes for monitoring of volatile organic compounds (VOCs) like benzene, a carcinogen, in fence-line communities near oil refineries.[129] These tubes cost about $100 per probe for samples and can be programmed to record data over differ time periods (e.g. a week or two weeks), making them a practical and affordable option for researchers.

[128] Pacella, Rachael. 2017. "Riviera Beach Elementary proposed site for air quality monitor." *Capital Gazette*, September 22, 2017. Link: http://www.capitalgazette.com/news/ac-cn-air-quality-0923-story.html.
[129] DeWees, Jason M. 2015. "Refinery Fenceline Monitoring & Method 325A/B." PowerPoint Presentation. U.S. EPA. National Air Toxics Monitoring and Data Analysis Workshop. Link: https://www3.epa.gov/ttn/amtic/files/ambient/airtox/2015workshop/Petroleum%20Refinery.pdf.

Methodology and Data Caveats

Asthma-Related Hospital and Emergency Room Discharge Data

EIP used data obtained via the Maryland Department of Health's (MDH) Environmental Public Health Tracking (EPHT) tool for our analysis of asthma hospital discharge data and emergency room discharge data (sometimes referred to below as "ER data").[130] The tool allows users to query for multiple variables including age, zip code, gender, county, etc. The data was collected by the Maryland Health Services Cost Review Commission (MHSCRC) from inpatient and outpatient discharge medical records in 47 hospitals in Maryland. The asthma hospital discharge data we analyzed includes all patients who were admitted to one of the 47 hospitals (inpatients) for asthma, which includes patients admitted through the emergency room. It does not include persons who visited a hospital emergency department for asthma and were treated and released (outpatients). Alternatively, the asthma emergency room discharge data includes both individuals treated at an emergency room and released (outpatients) and individuals admitted to the hospital through the emergency department (inpatients). Because the ER data includes inpatients admitted through the emergency department, this subset would be counted in both the asthma hospital discharge data and the ER discharge data. MDH suppresses the data when there are fewer than 11 asthma-related discharges in any category shown in response to a query (such as in a given age range in a certain zip code) or the population for an area is under 500 people. Thus, even though there are thirty-one zip codes in total that have some portion of the zip code located within the city, for some years only 29 or 30 zip codes in total had available data because data was suppressed. Asthma-related discharge data includes counts, age-adjusted rates per 10,000 persons, and the 95 percent confidence interval for the age-adjusted rates.

We downloaded data at the zip code and state levels for our analysis for each year from 2000-2013, and selected for all races and genders. We excluded 2007 ER discharge data from our analyses due to potential errors with the data. The 2007 ER discharge rates were substantially lower than 2006 and 2008 data, and upon consulting with MDH, were informed the rates were inaccurate and unreliable. For our city-level analyses, we decided not to simply run a query for "Baltimore City" under the county variable. While there are 31 zip codes with asthma data located in Baltimore City, several zip codes are located partly in neighboring counties. From 2000 through 2007, MHSCRC separated the discharges in each zip code by the appropriate county. Beginning in 2008, the MHSCRC reported all cases for a zip code in a single county, regardless of whether the zip code was divided into multiple counties. Due to this methodological change, MDH advised us against using the trend shown by entering the "Baltimore City" query for the entire time period. Instead, we chose to select all of the zip codes that have asthma-related discharge data and are in or at least partially inside the city limits, with the exception of the following zip codes which were located mostly outside of the city: 21208, 21222, 21227, 21228, 21236, and 21237. The 25

[130] Maryland Department of Health. Maryland Environmental Public Health Tracking. Link: https://maps.dhmh.maryland.gov/epht/query.aspx.

zip codes included in our "city" analyses are: 21201, 21202, 21205, 21206, 21207, 21209, 21210, 21211, 21212, 21213, 21214, 21215, 21216, 21217, 21218, 21223, 21224, 21225, 21226, 21229, 21230, 21231, 21234, 21239, and 21287. Because we included zip codes that are located in more than one county (Baltimore City and another), our hospitalization rates may include some data for patients who are not city residents.

EIP also downloaded 2013 asthma-related discharge data by age group. When age group data was limited to the 25 zip codes listed above, we found there was no publicly available data for age groups 65 and older. City-level data is available for those age groups when selecting "Baltimore City" as a county, but we used the Baltimore City zip codes to maintain consistency in our analyses.

Spatial Trends

With the exception of the EJSCREEN Respiratory Risk maps, EIP used ArcMap 10.4 to create the maps used in this report. Screenshots were used to display the EJSCREEN maps. EIP used Baltimore City boundary shapefiles from the Maryland Department of Planning to mask the areas outside of the city in our final EJSCREEN maps.[131] These same boundaries were used to create maps showing asthma hospitalization and emergency room discharge rates, stationary source emissions, and demographic measures.

Asthma Maps

Using the asthma hospital and ER discharge data, EIP was able to map the rates by zip code. While the maps only display the area within the Baltimore City boundary, zip codes that span multiple counties represent rates for the entire zip code. Asthma data for zip codes that appear on the maps, but are predominantly located outside of the city boundary, may not be included in the city-level analysis for reasons mentioned in the "Asthma-Related Hospital and Emergency Room Discharge Data" section above.

Respiratory Risk from Toxic Air Pollution

EIP used the U.S. EPA's Environmental Justice Screening and Mapping Tool (EJSCREEN) to look at risk of adverse respiratory effects from air toxics.[132] Using the mapping tool, we selected the "NATA Respiratory Hazard Index" as an environmental indicator, and compared the results to the state. The environmental indicator category of EJSCREEN does not include demographic data, although that option is available as an "EJ Index." EIP did not produce original respiratory risk maps for this report. The respiratory risk map in Figure 6 is a screen shot of the map produced on EJSCREEN, although we cut the area beyond the city boundary out ourselves.

---

[131] Maryland Department of Planning. Maryland State Data Center. "2013/2014 Zip Code Maps with Roads." Link: http://www.mdp.state.md.us/msdc/Zipcode_map/2013/zip13idx.shtml.
[132] U.S. EPA. EJSCREEN. EPA's Environmental Justice Screening and Mapping Tool. Link: https://ejscreen.epa.gov/mapper/.

Because EJSCREEN's NATA indicators use census tracts[133], we cannot make a direct comparison with our asthma hospital discharge data, which can only be narrowed to the zip code level. Further, EPA states that the EJSCREEN results are susceptible to "substantial uncertainty," due to difficulty in making small area estimates, and also from limitations in emissions, ambient air pollution, exposure of individuals, and toxicity of pollutants. As a result, the tool can only provide a proxy for "actual health impacts."[134]

The environmental indicator selected for our analysis, the "NATA Respiratory Hazard Index," uses data from EPA's 2011 National Air Toxics Assessment and is limited to the risks from hazardous air pollutants. Criteria pollutants are considered only if they contribute to the formation of hazardous air pollutants. As with EJSCREEN, NATA also contains uncertainties in its estimates, particularly in smaller areas where there are fewer localized assessments (i.e. monitoring). Other limitations worth noting include underestimated ambient air concentrations for certain pollutants and the inability to accurately estimate emissions from a source's "short-term deviations such as startups, shutdowns, malfunctions, and upsets."[135]

National Emissions Inventory (NEI)

EIP created zip-code level maps of the location of facility emissions using the EPA's 2011 National Emissions Inventory (NEI).[136] This emissions inventory provides information on the amount of specific pollutants released into the atmosphere from power plants and other large point sources/facilities (see more information about NEI's other sources in the "Mobile Source Emissions Data" section below). It is important to note that the pollutants emitted from the point sources in these datasets disperse differently depending on factors such as stack height, weather patterns, and the pollutant itself. As such, this data cannot be used as a direct measure of air pollution in ambient air. It serves only to indicate the amount of pollution being released into the atmosphere.

EPA releases a new NEI every three years. Although a 2014 NEI dataset is available, we used 2011 data to coincide with asthma hospitalization data that was available to us from MDH. We analyzed the point source emissions data. The NEI combines emissions data from state, local, and tribal air agencies, EPA's Toxics Release Inventory (TRI), EPA's Acid Rain Program, and other data EPA collects for regulatory development. It includes criteria pollutants and hazardous air pollutants.

Because we cannot use this data to determine where the pollutant ends up or the level of pollution in the ambient air, EIP used NEI data to determine the amount of pollution being

---

[133] Generally, EJSCREEN indicators are calculated at the census block group level. However, NATA, PM, and ozone indicators are calculated at the census tract; U.S. EPA. EJSCREEN. "Limitations and Caveats in Using EJSCREEN." Link: https://www.epa.gov/ejscreen/limitations-and-caveats-using-ejscreen.

[134] *Id.*

[135] U.S. EPA. National Air Toxics Assessment. "NATA Limitations." Link: https://www.epa.gov/national-air-toxics-assessment/nata-limitations.

[136] U.S. EPA. Air Emissions Inventories. "2011 National Emissions Inventory (NEI) Data." Link: https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data.

emitted in Baltimore City zip codes. Using the facility information, we limited our facilities to those located within Baltimore City, aggregated the total emissions from each facility by zip code, and used the zip code totals as a measure of the source of the city's industrial air pollution.

EIP did not use Maryland Emissions Inventory (MEI) data for this analysis because we wanted to look at fine particulate ($PM_{2.5}$) emissions and sulfur dioxide emissions, which were not available in the MEI.

Pollution from Road Traffic

EIP used the Community LINE Source Model (C-LINE) tool to map the modelled impact of traffic on the city's air quality.[137] C-LINEv5.0 was developed by the University of North Carolina Institute for the Environment, and is part of their Community Modeling and Analysis System, for the U.S. EPA. The tool combines 2013 road and traffic data (e.g. annual average daily traffic, fleet mix, vehicle speed) from the Department of Transportation's Highway Performance Monitoring System, 2011 meteorological data, and emissions factors from the EPA Motor Vehicle Simulator model (MOVES-2014) to model pollution concentrations from road traffic. While C-LINE allows users to add or modify roads, as well as the traffic data, EIP did not make any changes to the baseline analysis.

C-LINE produces census-tract maps for primary criteria pollutants and some air toxics related to mobile sources. EIP limited the analysis to NO_x, SO_2, $PM_{2.5}$ and Diesel $PM_{2.5}$. The modeling tool allows the user to select multiple variables in regards to the pollution measure (e.g. hourly concentration, annual average concentrations, etc.), the specific pollutants, meteorological conditions, and emissions and vehicle mix/traffic volume. For each of the pollutants included in our analysis, we selected the following parameters for hourly concentrations:

Emissions parameters for vehicle mix and traffic volume
- **Day**: Weekday
- **Hour**: PM Peak (afternoon rush hour, 4:00 – 6:59 pm)

Meteorological conditions
- **Atmospheric stability**: Neutral
- **Season**: Summer
- **Wind direction**: Seasonal average

The Community Modeling and Analysis System also has a modeling tool to estimate emissions near ports (C-PORT). C-PORT expands on the on-road traffic modeling of C-LINE and incorporates emissions from sources at port terminals and railyards and also includes some major point sources. We limited our analyses to C-LINE, and not C-PORT, for several reasons. C-PORT only models emissions from additional sources (like industrial facilities) in select areas near the water designated as a terminal, and not the entire city, and is therefore not representative of all point sources in the city. While C-PORT includes the

[137] University of North Carolina Institute for the Environment. Community Modeling and Analysis System. C-LINEv5.0. Link: https://www.cmascenter.org/c-tools/c-line.cfm.

city-wide road network used in C-LINE, the additional point sources at the ports create an emphasis of high pollution concentrations near the water and makes it difficult to interpret pollution levels throughout the rest of the city. Further, the NATA data suggests onroad sources contribute the most to respiratory risks, and C-LINE allowed us to focus on just onroad sources.

Demographic Measures

2013 demographic data was obtained from the U.S. Census Bureau's 2009-2013 American Community Survey 5-year estimates.[138] EIP analyzed seven demographic indicators at the zip-code tabulation area (ZCTA) level: percent of population living in poverty, percent of population 18 years and younger living in poverty, median household income, percent uninsured, percent using Medicaid, percent uninsured or using Medicaid, and percent African American. The percentage of the uninsured population covers only the noninstitutionalized civilian population. The "percent African American" population covers individuals that identify as "African American alone," and does not include individuals of mixed race.

Using the zip-code level demographic and asthma data, EIP determined correlation coefficients for each measure. A correlation coefficient is a statistical measure used to measure the strength and type of relationship two measures have (e.g. median household income and asthma hospitalization rates). The coefficients range from -1 to +1, where values closer to -1 or +1 indicate a strong negative or positive linear relationship, respectively. Values closer to 0 suggest a weaker or no relationship.

Trends Over Time

Maryland Emissions Inventory (MEI)

EIP analyzed trends in facility emissions over time using data from the Maryland Emissions Inventory (MEI), which is similar to the NEI in many ways, but is issued every year unlike the NEI which is issued every three years.[139] Using this data, which EIP requested and received from the Maryland Department of Environment (MDE) under the Maryland Public Information Act, we were able to look at the trends in emissions from facilities in Baltimore City. The MEI includes SO_x, NO_x, VOCs, PM, Carbon Monoxide (CO), Total Suspended Particles (TSP), and Hazardous Air Pollutants (HAPs). We limited our analysis to SO_x and NO_x for 2000-2013 and PM_{10} for 2003-2013. Prior to 2003, PM data was combined with TSP, so we excluded it from the trend. HAP data reported to MEI from one of the largest pollution sources in the area, the Fort Smallwood coal plant complex, appeared extremely inconsistent over time. While the facility reported emissions from criteria pollutants from 2000-2009, the facility reported zero HAP emissions in this same

[138] U.S. Census Bureau. American FactFinder. 2009-2013 American Community Survey 5-year Estimates. Link: https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.
[139] EIP sends Public Information Act requests to the Maryland Department of the Environment for their annual emissions inventories.

period, then reported 2,300 tons of HAPs in 2010, and between 421-682 tons from 2011-2013. For this reason, we did not show trends over time for HAP emission.

We included all facilities located within Baltimore City. In addition to the facilities in Baltimore City, we included several other facilities near the city which have been shown to, or are very likely to, influence the city's air quality. These include all facilities reporting to the MEI that are located in the 21226, which include the Fort Smallwood coal plant complex. In addition, we included a the CP Crane coal fired power plant located in Baltimore County and the Sparrows Point Steel Mill, which was located in Baltimore County until it shut down in 2011.

Mobile Source Emissions Data

Mobile sources are sources of air pollution that move around, like trucks, trains, cars, and ships. EIP used EPA's NEI data to calculate mobile source emissions in Baltimore City from 2002 to 2014. The NEI has released emission data every three years since 2005. Annual NEIs are available from 1996 - 2005. Emissions data is provided to EPA from state, local, and tribal agencies, and includes criteria pollutants and precursors and hazardous air pollutant air emissions. The NEI has several data categories (SCC data files) in which they compile their emissions data, including point, onroad, nonroad, and nonpoint sources. Point sources cover large stationary sources, such as power plants and other industrial facilities; onroad sources include fuel-powered onroad vehicles, such as cars and trucks; nonroad sources include fuel-powered off-road vehicles, such as trains, ships, and construction equipment; nonpoint sources include small sources, such as asphalt paving. EPA uses models to calculate onroad and nonroad mobile emissions, using inputs provided by state, local, and tribal agencies. These models have regularly been updated for more accuracy, and may be responsible for some differences between years. [140]

From 2002 – 2005, we combined onroad and nonroad emissions, to determine total mobile source emissions. Beginning in 2008, EPA moved a number of source categories from the "nonroad" to "nonpoint" emissions categories, such as locomotive emissions and commercial marine vessel emissions. We isolated "mobile sources" from the nonpoint source emissions category, and combined these with onroad and nonroad categories to determine the total mobile source emissions. EIP's analysis determined annual mobile source emissions for NO_x, SO_2, and primary $PM_{2.5}$. Primary $PM_{2.5}$, which includes both filterable and condensable $PM_{2.5}$, measures only the particles that are released directly into the air and not particles formed due to chemical reactions in the air.

While NEI does make mobile source data available for the years 2000 and 2001, we limited our analysis to years 2002 and later. Data available for earlier years showed enormous changes in emissions between 2001 and 2002 for which no explanation appears available other than a change in the inventory methodology between those two years. Between those

[140] U.S. EPA. Air Emissions Inventories. "National Emissions Inventory (NEI)." Link: https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei. See Technical Support Documents for detailed methodology changes.

years, NEI showed NO_x and $PM_{2.5}$ emissions from mobile sources as decreasing by more than 50 percent while SO_2 emissions more than double.

In March 2017, EIP submitted a request to MDE under the Maryland Public Information Act requesting mobile source emissions from 2000-2013. MDE was unable to provide documents or data that showed annual mobile source emissions for the time period.

Monitoring Data

EIP analyzed trends in monitoring data from EPA's Air Quality Monitoring site from 2000-2013.[141] This site presents data that is captured by monitors run by MDE and the data is then submitted to EPA. MDE's monitoring network collects data on HAPs, carbon monoxide, lead, nitrogen dioxide, lead, ozone, PM_{10}, $PM_{2.5}$, and sulfur dioxide. EIP analyzed $PM_{2.5}$ data from the Northwest Police Station, Baltimore City Fire Department (Truck Company 20), and Oldtown monitors, which had consistent data over our time period of interest. (The BCFD began monitoring in 2001.) Using EPA's Monitor Values Report, we looked at the four highest $PM_{2.5}$ daily readings and calculated the average of those readings for each year to evaluate peak concentrations. Using the Monitor Values Report, we also calculated the average of the four highest concentrations of ozone at the Furley Elementary School monitor, the only ozone monitor in the city, and the 98th Percentile 1-Hour Daily Max nitrogen dioxide values at the Oldtown monitor. EIP also used Air Quality Statistics Reports to analyze ozone and sulfur dioxide concentrations in the Baltimore metropolitan area – specifically, the Baltimore-Columbia-Towson, MD core based statistical area (CBSA). For acrolein, we used data from EPA's Pre-Generated data files online, which contain raw pollution monitoring data rather than providing summary reports. There is some uncertainly with respect to this data. The monitoring method used to gather acrolein information is flagged as "unverified" in EPA's database, as the monitoring method used has, in some cases, resulted in a high bias.[142]

The Northwest Police Station monitor is located in Northwest Baltimore in the 21215 zip code, the Oldtown monitor is located near the city center in the 21202 zip code, and the BCFD monitor is located in East Baltimore in the 21224 zip code. There are no monitors in the 21225 or 21226 zip codes in South Baltimore. See Figure 27 for a map of the monitors in the city.

Toxics Release Inventory (TRI)

EIP used EPA's Toxics Release Inventory (TRI) to evaluate and show trends in toxic air releases in the 21226 zip code from 2000 through 2013. The data presented includes both fugitive and stack emissions for all pollutants and facilities in 21226 during these years. TRI likely underestimates, possibly by a significant amount, total toxic emissions from stationary sources, because of the rules governing whether or not a facility must report to TRI.

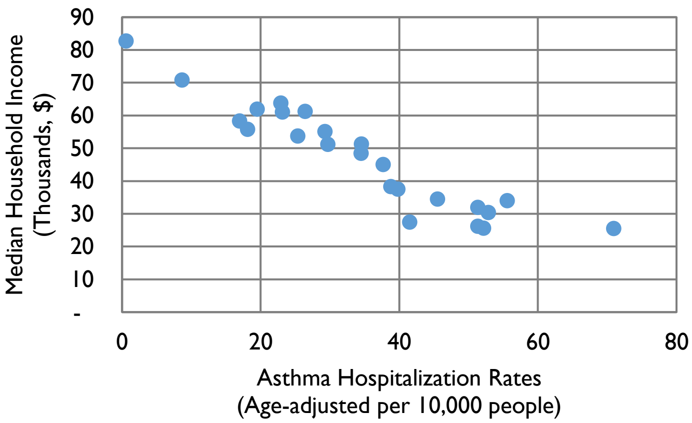
---

[141] U.S. EPA. Air Data. "Monitor Values Report." Link: https://www.epa.gov/outdoor-air-quality-data/monitor-values-report.
[142] U.S. EPA. 2010. "Data Quality Evaluation Guidelines for Ambient Air Acrolein Measurements." Link: https://www3.epa.gov/ttnamti1/files/ambient/airtox/20101217acroleindataqualityeval.pdf.

Specifically, facilities are required to report to TRI only if they: 1) have ten or more full-time employees or the equivalent; 2) have an NAICS code included in Section 313 of the Emergency Planning and Community Right-To-Know Act (EPCRA) or are a Federal Facility; and 3) manufacture, process, or otherwise use EPCRA Section 313 chemicals and chemical categories or exceed any non-PBT chemical reporting threshold by manufacturing or processing 25,000 pounds per toxic chemical or category per year, or otherwise use 10,000 pounds per toxic chemical or category per year (with the exception of 10 pollutants with very low thresholds).

Appendix A. Demographic Correlations

Figure A-1. Scatter Plots of 2013 Median Household Income v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)



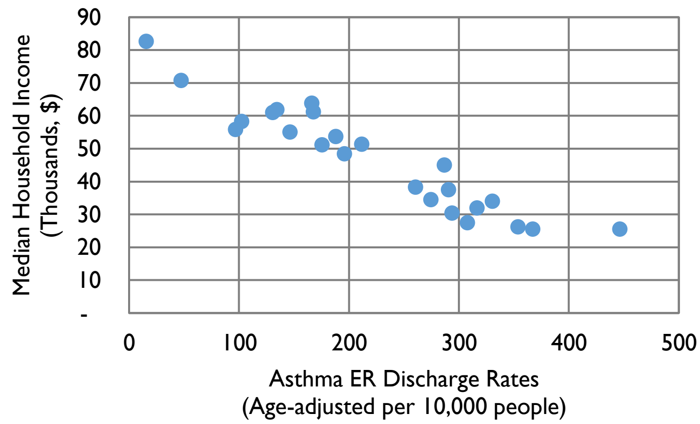
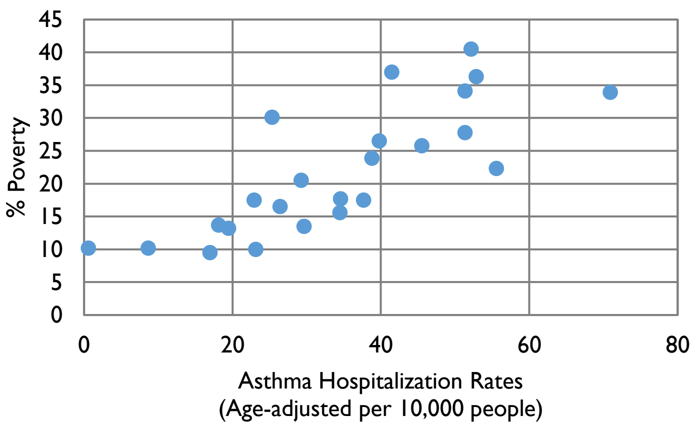


Figure A-2. Scatter Plots of 2013 Poverty Levels v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)



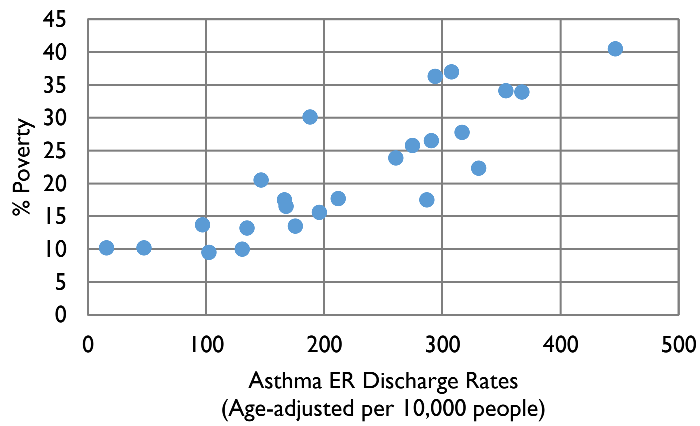
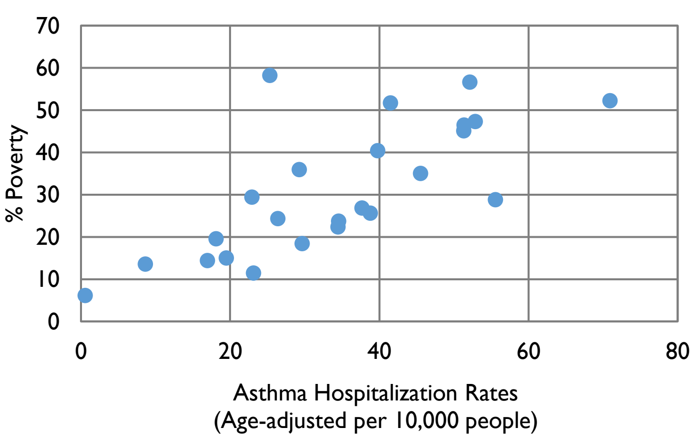


Figure A-3. Scatter Plots of 2013 Poverty Levels for the Population Under 18 years v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)



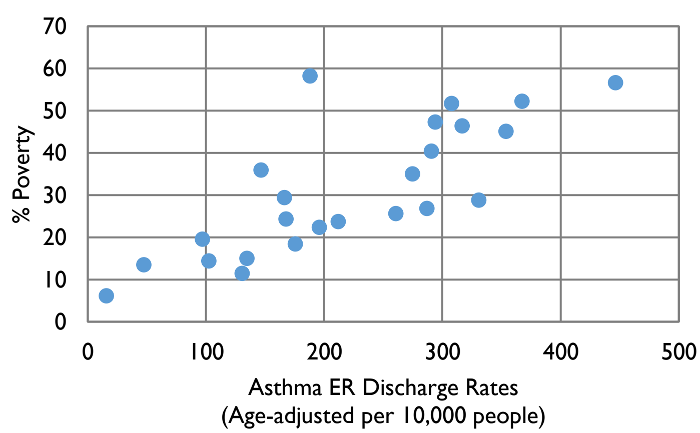


Figure A-4. Scatter Plots of 2013 Uninsured Population v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)

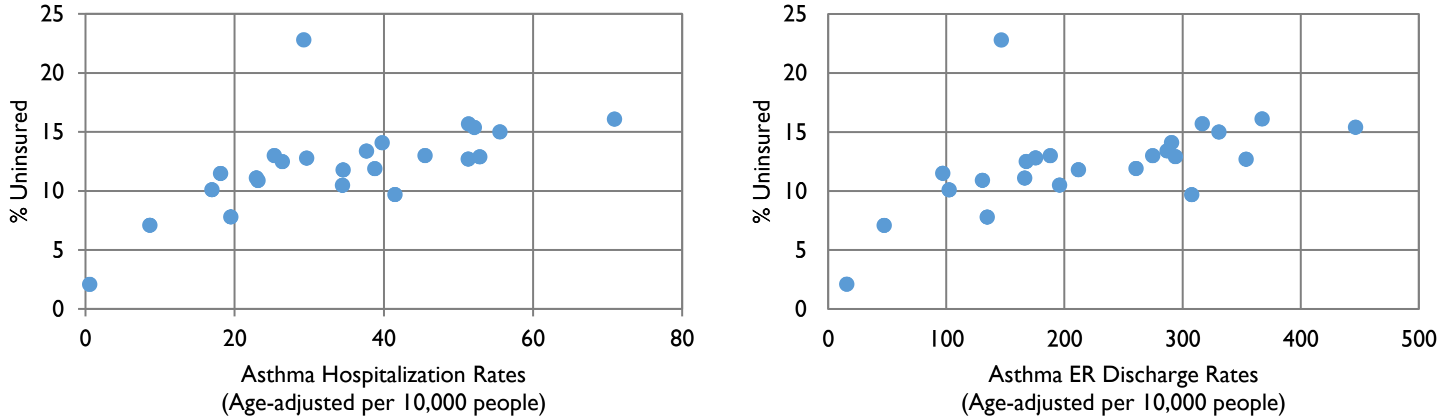


Figure A-5. Scatter Plots of 2013 Population Insured Through Medicaid v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)

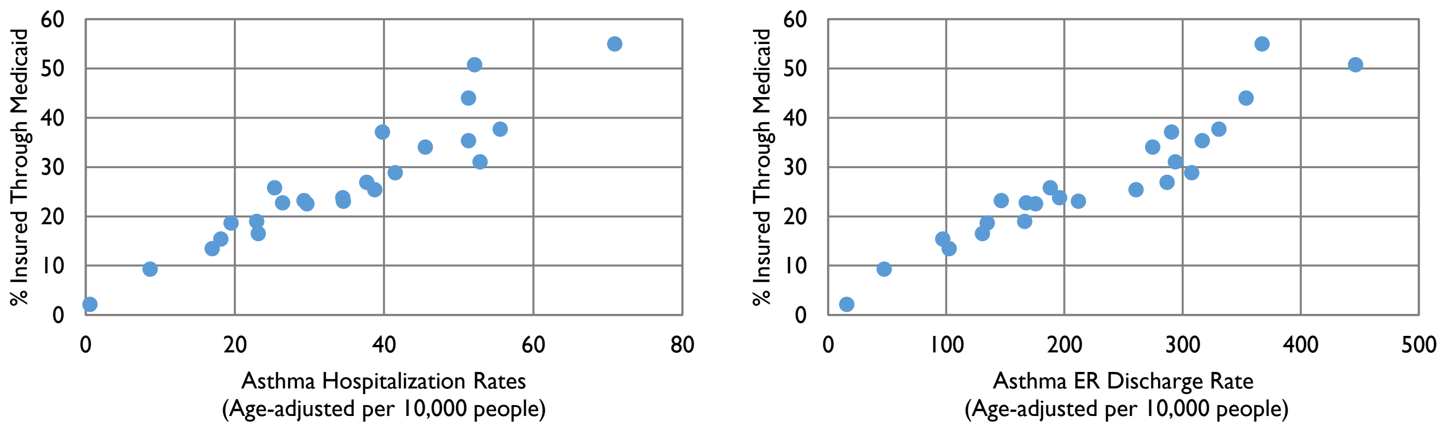


Figure A-6. Scatter Plots of 2013 Population Uninsured or Insured Through Medicaid v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)

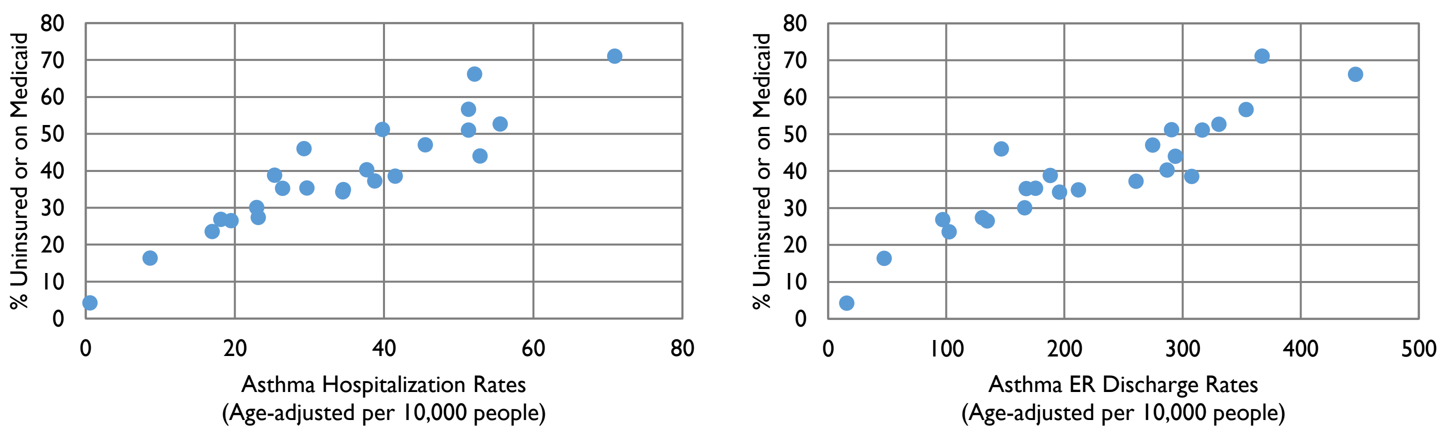
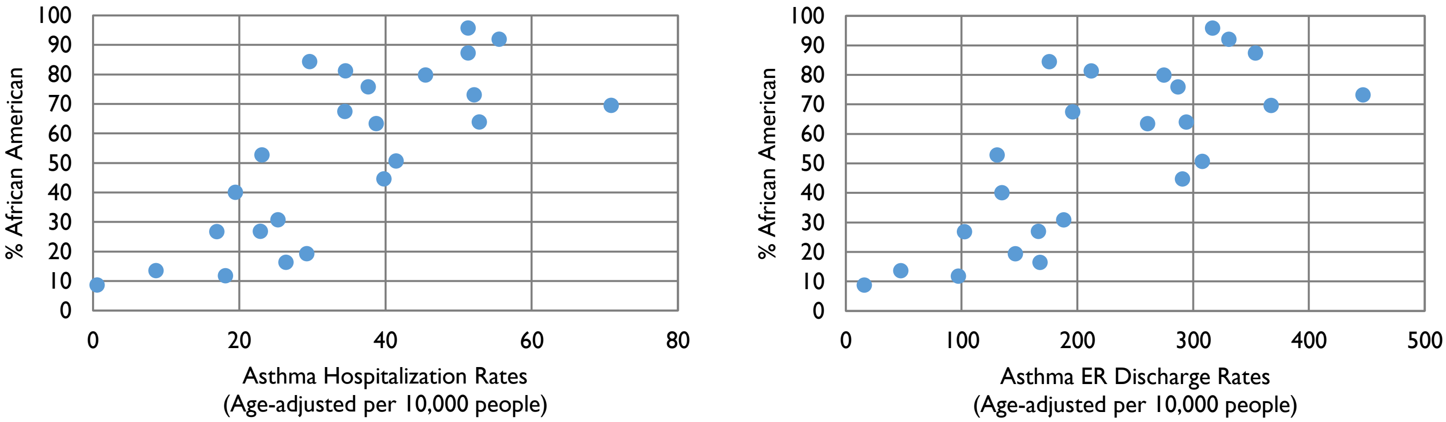
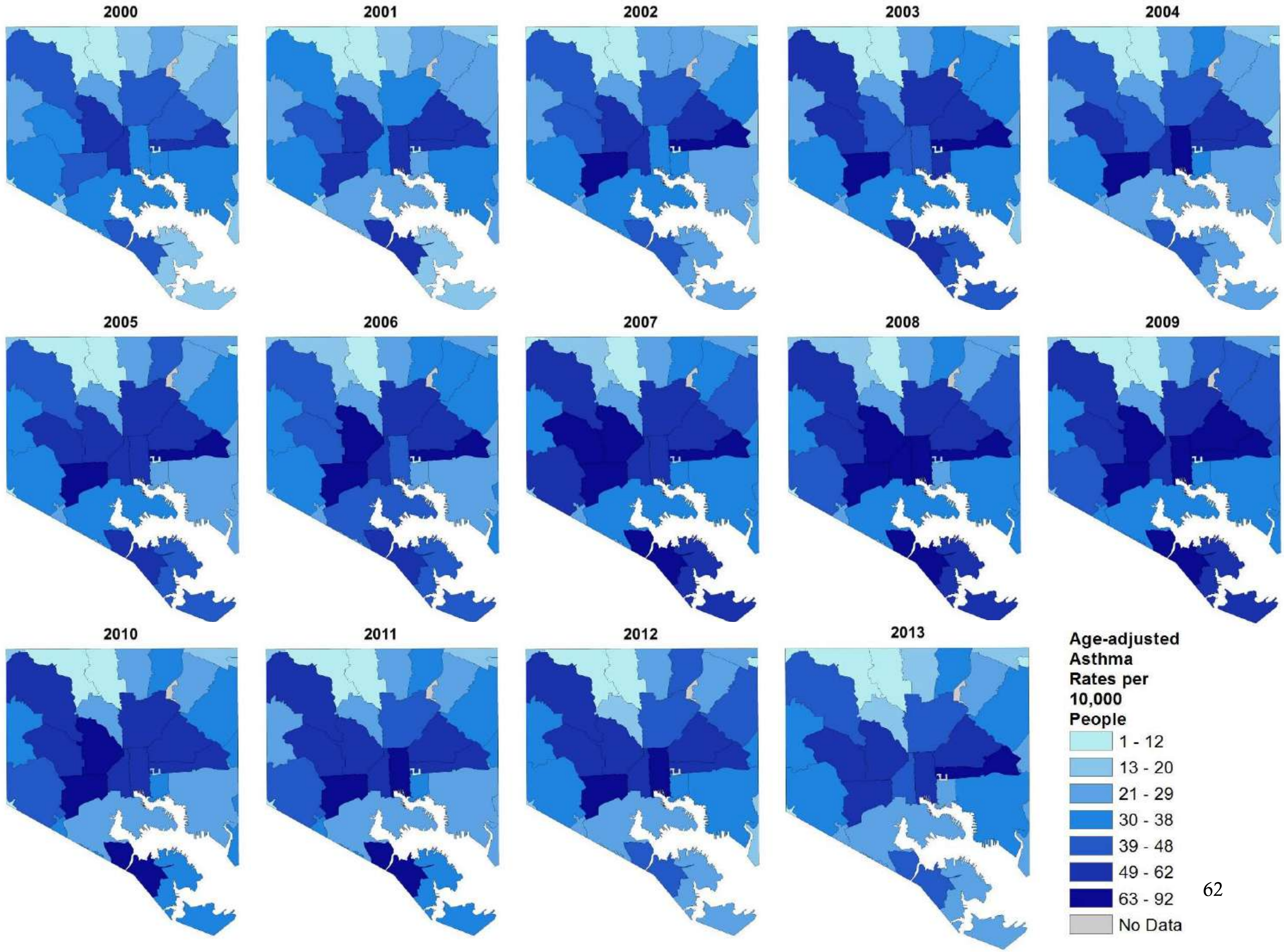


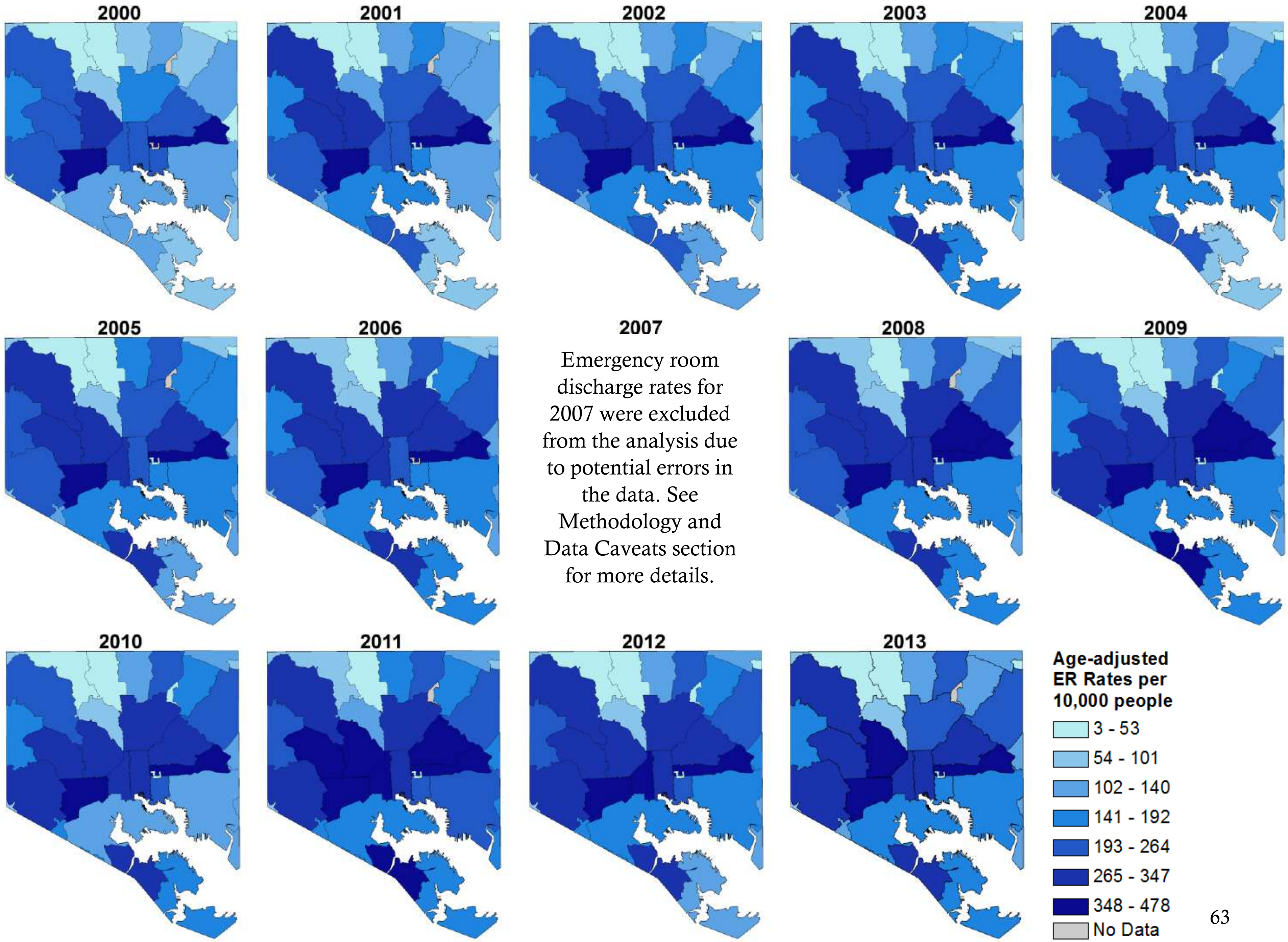
Figure A-7. Scatter Plots of 2013 African American Population v. Asthma Hospitalization Rates (left) and ER Discharge Rates (right)



Appendix B. Baltimore City Asthma Hospitalization Rates by Zip Code, 2000-2013



Appendix C. Baltimore City Emergency Room Discharge Rates by Zip Code, 2000-2013



ENVIRONMENTAL INTEGRITY PROJECT

1000 Vermont Avenue, NW
Suite 1100
Washington, DC 20005
202-296-8800
www.environmentalintegrity.org