The NYC Air Pollution Control Code

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1. Introduction

In 2015, the New York City Council added section 24-149.4 of Title 24 to its Administrative Code. This code, called the **New York City Air Pollution Control Code** (AirCode), went into effect on May 6, 2016, to "preserve, protect, and improve the air resources of the City" (NYC Business.gov, AirCode). In general, the AirCode is a legal law that regulates the emission of pollutants in New York City. The code covers regulating emissions such as asbestos; refuse burning equipment, incinerators, and crematoriums; demolitions; and other potentially hazardous tasks that industrial, commercial, cultural, and manufacturing establishments may perform.

Even with the policy's enactment in 2016, the **complaints and health risks** associated with air pollution remain an issue for many New Yorkers. Air pollution is associated with many adverse health effects and diseases, such as asthma and other respiratory illnesses, as well as circulatory, neurological, gastrointestinal, and urinary problems.

Further, the **burden of air pollution may be felt differently** across the various neighborhoods of NYC, and given the nature of segregation in the City, it can be said that this burden may fall on the residents of various race groups and socio-economic statuses in a disparate manner. We aim to study this disparity in conjunction with whether the code actually reduced air pollution–specifically in terms of the factors that are indicative of air quality.

There's a **gap in the literature** in regard to this air code, especially in evaluating its impact. Unlike air quality studies in the City, few papers focus on this specific code, and there's been no evaluation team established for it. We aim to assess its effectiveness to offer insights to help inform future policy decisions.

2. Literature Review

a. Air Pollution in NYC

The **Clean Air Act** (CAA) (1970; most recent major amendment in 1990) is a federal law that regulates air emissions from both stationary and mobile sources in the United States. Under it, the Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS). It requires states to develop state implementation plans (SIPs) to meet these standards, particularly in industrial areas. These standards are necessary to safeguard public health and to regulate hazardous air pollutants. According to a 2018 analysis, the original legislation and CAA revisions may have contributed to a 60% decline in manufacturing industry emissions between 1990 and 2008.

NYC has recently taken some steps to more strictly regulate air pollution, including passing legislation to control emissions from various sources, such as idling vehicles, school buses, and other diesel-fueled vehicles. Beginning in 2000, the Metropolitan Transit Agency (MTA) in NYC began deploying compressed natural gas, hybrid electric, and low-sulfur diesel buses to reduce urban air pollution. Broadening the understanding of the purview of sources of air pollution, beyond transportation, the City's first sustainability strategy, PlaNYC 2030, was introduced in 2007 by Mayor Michael R. Bloomberg of New York City, to improve the environment and the quality of life of New Yorkers. The Plan included a proposal for a local air quality study to: *"(1) characterize spatial variance in street-level concentrations of combustion-related pollutants and local emission sources; (2) inform City-led emission reduction initiatives; and (3) provide exposure estimates for epidemiological studies"* (Matte, 2013, p. 223). The NYC Community Air Survey was born out of this Plan.

The **NYC Community Air Survey** (NYCCAS), the largest thorough street-level air monitoring survey in the United States, was started by the Mayor's Office of Long-Term Planning and Sustainability (OLTPS) and the NYC Department of Health and Mental Hygiene to understand the City's current boiler installations. The first study was conducted in 2008 (The New York City Community Air Survey, Results from Winter Monitoring 2008-2009), however, even in 2013, there were just 3 regulatory nitrogen oxide (NO) monitors, 3 sulfur dioxide (SO2) monitors, 5 ozone (O3) monitors, and only 2 out of the 23 $PM_{2.5}$ monitors measured chemical constituent concentrations. Matte et al. (2013) point out, *"This limited spatial resolution is especially important because intraurban gradients in exposure to combustion pollutants can be greater than between-city differences and these gradients are associated with adverse health outcomes, including cardiovascular and respiratory disease, mortality, and the exacerbation of asthma and chronic obstructive pulmonary disease."*

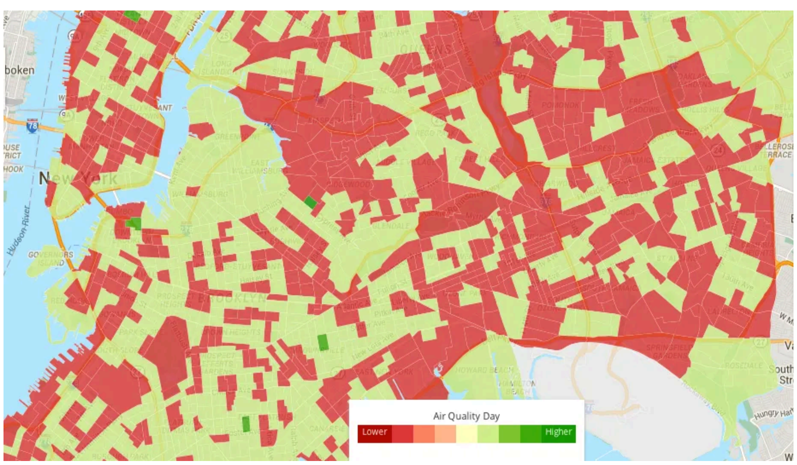
Before PlanNYC, the EPA and the Department of Environmental Conservation (DEC) carried out air pollution monitoring by looking at overall average concentrations on a large regional scale, *which was better suited to depict general trends than to measure human exposure.* To further understand neighborhood-level variances, the Mayor's OLTPS and the NYC Department of Health and Mental Hygiene agreed to obtain an enhanced measurement of human exposure to air pollutants in PlanNYC. It was acknowledged that not all New Yorkers were equally affected by changes in air quality, despite tremendous advances in this area. One of the ways it acknowledges this is in the context of premature mortality by stating in its goal (NYC Health, 2018), *"The Plan for a Strong and Just City is to ensure that all New Yorkers live a long and healthy life. Premature mortality is closely tied to neighborhood poverty, which, in New York City, correlates with communities of color that have long undergone structural and historical oppression. Under the OneNYC plan for 2040, the City has committed to reducing the premature mortality rate by 25%."* Thus, to enhance the air quality and, by extension, the health of New Yorkers in every community, it was necessary to instill better and more accurate monitoring of human exposure to air quality.

The NYCCAS focuses on several pollutants. Except for black carbon, our analysis will focus on the following pollutants (and Carbon Monoxide, whose presence in the atmosphere may result in ozone air pollution): (page 224 of the Code)

- **Fine Particulate Matter ($PM_{2.5}$):** A significant portion of this pollutant comes from outside the City. Local sources of it include commercial cooking, heating fuel, electric power generation, construction equipment, and other off-road mobile sources.
- **Black Carbon (BC):** This pollutant makes up a small portion of overall $PM_{2.5}$, but it makes up 75% of PM from diesel exhaust.
- **Nitrogen Oxide (NO):** A common marker of vehicular traffic and on-road mobile sources, this pollutant accounts for 30% of all kinds of Nitrogen Oxide emissions (NO_x) in NYC (including NO2, which is a part of our analysis). Additionally, the residential and commercial fuel combustion sector produces 25% of NO_x emissions compared to 3% nationally.
- **Ozone (O_3):** This secondary pollutant tends to have higher concentrations in suburban neighborhoods outside Manhattan. It is only measured in the summer to capture the seasonal peak in NYC.
- **Sulfur Dioxide (SO_2):** This pollutant is produced from electrical power plants and large industrial facilities. For NYC, residual heating fuel used in large commercial and residential buildings is a main source. It is only measured in the winter in NYC.

While the crux of our analysis does not include data from the strictly bi-annual results of the NYCCAS, we feel its history and implementation are important in understanding the data that informed the creation and subsequent implementation of multiple environmental policies in the City, like the Clean Heat Program and the AirCode.

In 2012, the NYC **Clean Heat Program** went into effect which mandated that any newly installed boilers would have to burn at heating oil #2, an ultra-low sulfur, lower-polluting grade oil as compared to the previously used heating oils #4 and #6 (which are called residual heating oils). A Columbia University study (Zhang et al., 2021) found that the program, which fully went into effect in 2016, when oil #6 was banned, was effective in reducing air pollution (and associated pollutants such as PM2.5, NO2, and SO2) and was effective in both low- and high-income neighborhoods.



The reality of air pollution in NYC in 2016 was **varied across boroughs**. An October 2016 Medium article called '*This Air Quality Map of NYC Shows How Screwed Your Lungs Are'* reported on the City's air quality with the BreezoMeter, a tool that can be accessed through the Google Maps API. The tool indicated that the City's air quality looked something like this. The image goes to show that an analysis at the borough, if not a more granular level, is *necessary to ensure we have a more holistic understanding of air quality and its impact on the City.*

When assessing air quality in New York City, it is crucial to keep in mind its geographic and environmental characteristics. NYC has a land area of nearly 800 km^2 and its population is over 8 million. Taking the similarities and differences across boroughs into account is crucial in understanding a particular locale's air quality. Staten Island's West Shore was known for its industrial activities, like oil refinery and construction in the late 20th century. The Bronx also had industrial expansion, as evident in the establishment of Hunts Point Industrial Park, which hosts over 800 businesses. For Brooklyn, *"the worst offender* [in 2016] *is the area along* *the water near Bay Ridge and the Brooklyn Army Terminal, a large complex of warehouses, offices, piers, docks, cranes, rail sidings and cargo loading equipment in Sunset Park"* (Medium).

New York City's Air Pollution Control Code is part of a **broader national and global conversation about the growing awareness of air pollution's impact on public health and climate change, particularly in the last half-century**. The American Cancer Society Cancer Prevention Study (CPS-II) was one of two studies crucial to the 1997 debate on the National Ambient Air Quality Standard (NAAQS) for fine particulate matter in the US (Krewski, 2009). The original study looked at mortality in adults starting in 1982 and a follow-up study on the same cohort was done from 1982-2000, increasing the follow-up period from 11 to 18 years. This follow-up study had approximately 360,000 participants in areas that have adequate PM2.5 monitoring for 1980 and 500,000 participants in areas with adequate PM2.5 monitoring in 2000. The study looked at causes of death from death certificates, and neighborhood-level covariates (like poverty level), and created long-term average exposure variables from PM2.5 data from 1979-1983 and 1999-2000. Then they used the standard Cox proportional-hazards model (sometimes including variation to allow for random effects) to calculate hazard ratios for various cause-of-death categories associated with the levels of air pollution exposure in the cohort.

Krewski and colleagues performed this analysis at the national level but also conducted an analysis specifically for New York and Los Angeles. For NYC, land-use regression models were created to estimate exposure to PM2.5 using concentrations averaged over 3 years, or over winter months for 1 year. Data for these estimates came from the 1999-2001 daily monitoring data of 62 monitors through the U.S. EPA Air Quality Subsystem or AQS; the same database where we got our data for our analysis. This data was combined with land-use data from a variety of geographic sources like trafficking counting systems and local government planning and tax assessment maps to assign estimated exposure to the participants (Krewski, 2009, p. 2). Based on their Cox regression modeling and analysis, Krewski et al. calculate causal estimates for the rates and hazard ratios of various health outcomes in the New York City population due to PM2.5 and Ozone. Variances for the estimates are also broken down by neighborhood (Krewski, 2009, p. 46-58).

The estimated results of their Cox regression model are what the New York City Department of Health and Mental Hygiene bases their yearly estimates of deaths due to PM2.5 on the *"About the Measures"* subsection in their Environmental Health Data Portal: The estimate of deaths is calculated with the *"estimated annual number of all-cause deaths associated with the difference in air quality for indicator years relative to modeled natural background..[and] the chronic all-cause mortality risk estimate, from Krewski."*

b. What is Air Pollution, exactly?

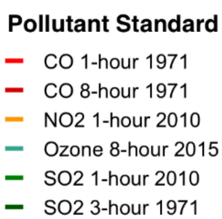
"Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere" (World Health Organization). It is quantified by the Air Quality Index. In the US, the AQI is the EPA's index for reporting air quality that can be thought of as *"a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern"* (AirNow.gov). The EPA has established a national AQI standard for the five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter, including PM2.5 and PM10), carbon monoxide, sulfur dioxide, and nitrogen dioxide.

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

The AQI is measured using a formula that incorporates the levels of the pollutants mentioned above (see Appendix). Generally, an AQI value of 100 corresponds to the short-term national ambient air quality standard to ensure the protection of public health. Metropolitan Statistical Areas (MSAs) with a population of more than 350,000 are required to report the daily AQI to the EPA. Many more areas report it as a public service.

There are various ways in which pollutant emission standards are determined, and they are regularly updated by the EPA. In further analysis, one might note that some visualizations have the following legend:



The 2 levels of CO reflect the time over which the levels of CO have been averaged over w.r.t. the standard as established in 1971; while the 2 levels of SO2 reflect the revised standard of SO2 levels permissible according to those established in 1971 and 2010. More detailed information about these standards can be found here.

c. Disparate Impact of Air Pollution

The presence of PM2.5 is associated with an **increased risk** of asthma, heart attack, and heart failure, with higher risks for asthma attacks among females, children under 14 years old, and patients requiring hospitalization (Weber, 2016). NYC health officials estimate that fine particulate matter contributes to nearly 2,000 premature deaths, 3000 annual deaths, and more than 6,000 hospital visits per year (New York City Trends in Air Pollution and its Health Consequences, 2013). These particles are largely black carbon, but the ones that spew out of tailpipes also have nitrogen oxides and polycyclic aromatic hydrocarbons in them which are harmful. A study (Perera, 2021) estimated that there was a 23% improvement in PM2.5 levels during the COVID-19 shutdown months compared to the average levels in 2015–2018. It claims that if this trend had continued for 5 years, it could have led to thousands of avoided cases of illness and death, with associated economic benefits from \$31.8 billion to \$77 billion. A similar study (Shukla, 2022) identified the potential health outcomes and monetary benefits of various policy areas of focus in five policy scenarios, including commercial cooking regulations and fleet electrification. It found that a combination of such policies, the *"citywide sustainable policy implementation"*, could prevent hundreds of premature deaths annually, with health benefits ranging from \$2B to \$5B. Research (Harvey, 2021) has even been done on how fine particulate matter can affect incidences of preterm births. Trasande, along with New York University colleagues Patrick Malecha and Teresa Attina, took data on air pollution from the EPA and data on preterm births from the Centers for Disease Control and Prevention (CDC) and used previous research on the risks of preterm birth associated with exposure to particulate matter to estimate how many premature babies were caused by pollution exposure in 2010.

Health disparities across various groups due to air pollution are also a well-studied topic. One study (Dressel, 2022) looked at how much nitrogen dioxide (NO2) pollution varies in different neighborhoods in the New York City−Newark area during a project called LISTOS (the 2018 NASA Long Island Sound Tropospheric Ozone Study). It found that NO2 pollution is higher in neighborhoods where more Black and African American, Hispanic / Latino and Asian people live compared to neighborhoods with mostly non-Hispanic / Latino White people. It also found that NO2 pollution is worse in neighborhoods with lower incomes and higher poverty rates. When researchers looked at both race and income together, they found that NO2 pollution was even higher. Disparities have also been found (Kheirbek, 2016) in the context of motor vehicle emissions and PM2.5 levels. Findings showed that these emissions contribute to over 300 deaths annually in NYC, along with nearly 900 emergency department visits and hospitalizations for respiratory and cardiovascular diseases. Disparities in PM2.5 exposures were observed across neighborhoods, with higher impacts in areas with high traffic density and poverty rates.

On the other hand, it should be noted that some policies aimed at improving air quality in NYC have shown **positive effects for those from low-income communities**. A simulation study (Johnson, 2020) on the potential air quality benefits of New York City's plan to reduce greenhouse gas (GHG) emissions by 80% by 2050 points to the potential for there to be 10 times fewer asthma emergency department visits in low-income neighborhoods compared to the wealthiest neighborhoods, even though median declines in ambient PM2.5 across the neighborhoods were similar.

d. The Code

The passing of the 2016 AirCode by the New York City Council and Mayor Bill De Blasio was the largest update to the air code in 35 years (Total Food Service, 2015) and greatly extended the regulation of air pollution across many city sectors. Overall, the Code puts regulations on any device or practice that can emit fumes into the City's air. It covers:

- Refuse-burning equipment, incinerators, and crematoriums
- Work permits and certificates of operation
- Asbestos
- Emission standards including those for Internal Combustion Engine (ICE) vehicles, demolition dust, nitrogen oxides, wood-burning heaters, cook stoves, and more
- Equipment and apparatus: use and maintenance, including use of boilers, engine idling, and alternative fuel buses
- Fuel standards
- Enforcement including violation notice processes and criminal penalties

We go into further detail below:

Refuse-burning: Refuse-burning equipment, incinerators, and crematoriums cannot be installed (with the following exceptions) without further licensing approval from the City:

1. Hospitals, biological laboratories, and other medical facilities
2. Equipment operated by the Department of Sanitation in connection with sewage treated for energy generation
3. Sanitation for solid waste
4. Crematoriums for human or animal remains

Asbestos and Dust: A 5-page subchapter of the AirCode is dedicated to asbestos alone. No one is allowed to spray or handle any substance containing asbestos, whether it be inside or outside a building during its construction, alteration, or repair (Air Code - NYC Business, n.d., p.21). Essentially, any work involving asbestos, including its removal, needs approval and permits from the City. Similarly, when it comes to dust, particularly in construction, no one can generate dust without the proper precautions and permits from the City. If approved, actors must still do all they can to prevent the dust from becoming airborne, like by using wetting procedures (Air Code - NYC Business, n.d., p.27). Buildings also cannot be demolished without permits as well.

Boilers: All boilers, including water boilers, have to pass a combustion efficiency test and all boilers have to be registered. Registrations are valid for 3 years and registrations that have expired for a year or more are considered canceled.

Open fires: Some open fires are allowed, like in picnic areas and barbecue pits specifically designated for such use in City parks or provided for under certain laws provided they are no larger than 10 feet and use charcoal and/or gas burners. Other exceptions include fire department training forests approved by the commissioner, as well as entertainment productions approved by the fire commissioner.

Stationary engines and vehicle idling: No one is allowed to emit a visible air contaminant from the internal combustion engine of a motor vehicle for more than 10 seconds if the vehicle has moved continuously for more than 90 yards.

Commercial charbroilers and cook stoves: Restaurants that use wood or coal-fired cooking appliances (pizza ovens, grills, and smokers) and/or char-broilers to cook over 875lbs of meat per week have to be outfitted with emission control devices approved by the Department of Environmental Protection. Without the device, restaurants will not be approved for permits. When the code went into effect in 2016, the mandate on control devices was for all new installations, although there was a grace period until 2020 to retroactively outfit existing installations. Cooking appliances with this machinery turns out to be crucial. According to Bill Welch, an air quality researcher at UC Riverside, *"The average diesel-engine truck on the road today would have to drive 10 miles on the freeway to put out the same mass of particles as a single charbroiled hamburger patty"* (Total Food Service, 2015).

Besides wood-burning ovens for cooking, the code also banned wood-burning heaters (Air Code - NYC Business, n.d., p.30). Other regulations include not allowing emissions from odorous air contaminants, steam, or water vapor that could create health hazards, not allowing emissions that are darker than certain colors on the standard smoke chart, not allowing architectural coatings and solvents unless they are in compliance with volatile organic compound limits set forth in the Code, and not allowing the use of fireplaces as the primary source of heat unless the building's normal primary heat source is inoperable due to power outages, natural disasters, and other events in that vein (Air Code - NYC Business, n.d., p.29). The type of firewood permissible in these fires is also stipulated in the Code. There are several other details and parameters in the Code that we do not have the capability to go over in this document.

The main takeaway that we hope to convey with this summary is that the Air Pollution Control Code covers a wide array of subjects that could, intentionally or unintentionally, **impact the air** New Yorkers breathe every day; and that essentially any work that is prohibited outright needs to be **registered** with the City, **approved** by the City Commissioner of Environmental Protection, and have the **proper permits** to impact the air quality in a certain way. Overall, the Department of Environmental Protection can issue fines or even shut down establishments for violations or continual non-compliance. We encourage the reader to read the full Code, which can be found in the New York City Administrative Code, Title 24 of Environmental Protection and Utilities, Chapter 1: Air Pollution Control at nyc.gov. We believe that AirCode's sweeping changes across multiple industries and sectors may have aided New York City in gaining momentum toward a sustainable reduction in air quality.

Relatedly, the City also passed updates to its Construction Codes on May 6, 2016, to complement the new provisions in the AirCode. Updates included revisions to the *"General Administrative provisions"*, about demolitions and work regarding asbestos, the *"Building Code"*, in regards to fireplaces and dust, and the *"Mechanical Code"*, regarding fireplaces and solid fuel burning appliances.

3. Research Questions

a. How did the NYC Air Pollution Control Code of 2016 affect **AQI and pollutant levels** and how did this vary by vulnerable groups, race groups, and locations?
b. How did the NYC Air Pollution Control Code of 2016 affect **health outcomes** of NYC residents and how did this vary by vulnerable groups, race groups, and locations?
c. How did the NYC Air Pollution Control Code of 2016 affect the **number and nature of air quality complaints** and can this impact be broken down by indoor v/s outdoor air complaints?

What the code puts restrictions on	What the code aims to do	Our parameters of study *(RQ#)*
Refuse-burning	• Improve air quality • Improve health outcomes	Air Quality: • NO2 • SO2 • Ozone • PM2.5 • CO • AQI *(RQ1)* Health Outcomes: • Deaths, Asthma Emergency Room visits, Respiratory Hospitalizations, and Cardiovascular Hospitalizations due to PM2.5 • Asthma Emergency Room visits and Asthma Hospitalizations (general rates and numbers) • Preterm Birth Rates; Infant Mortality rates; Low Birthweight rates; Live Birth rates and numbers, include rates for moms on Medicaid *(RQ2)*
Boilers		
Open fires		
Commercial charbroilers and cook stoves		
Asbestos and Dust		Number and nature of air quality complaints *(RQ3)*
Stationary engines and vehicle idling		

"emission[s] into the open air of any harmful or objectionable substance, including but not limited to smoke, soot, fly ash, dust, fumes, gas, vapors, odors or any products of combustion or incomplete combustion resulting from the use of fuel-burning equipment or refuse burning equipment is a menace to the health, welfare, and comfort of the people of the City"

4. Data

We relied on several sources of data in our evaluation. From the United States Environmental Protection Agency (EPA), we were able to get particulate-specific daily levels which we used to examine changes and trends in air quality over our study period. In addition to particulate daily data, we were also able to get daily data on the AQI from the EPA. These pre-generated data files are grouped by parameter– particulates, toxins, criteria gasses, and AQI.

In order to determine disadvantaged neighborhoods, we pulled data from the U.S. Census Bureau. This included data on common poverty indicators such as median household income level, percentage of population below the poverty line, education level, child-dependency ratio, old-age dependency ratio, and the overall racial and ethnic composition or percentages for each UHF 42 neighborhood. Aside from the more obvious demographics that may indicate an underprivileged community like median income and educational attainment– how do dependency ratios work as poverty indicators? These dependency ratios measure the number of dependents aged zero to 14, the child-dependency ratio, and over the age of 65, the old-age dependency ratio, compared with the total population aged 15 to 64 (Hayes, 2019). Thus, these act as indicators that the working population in that neighborhood faces a greater burden to support and provide the social services or needs of children and older persons.

Moving on to our health outcomes data, we were able to get estimates on hospitalizations and visits to the emergency room for illnesses specifically related to air quality. These estimates were pulled from the Environmental and Health Data Portal which is hosted by New York City's Department of Health and Mental Hygiene's Bureau of Environmental Surveillance and Policy. These estimates are detailed above in our discussion of the Krewski et al. paper.

Finally, in order to answer our third research question and examine air quality complaints following the code's enactment, we used data from the NYC OpenData portal. This was a dataset of all 311 Service Requests from 2010 to the present. This data comes from New York's 311 Customer Service Center which allows NYC residents to call in with service requests such as performing an inspection or addressing a problem. We were able to filter this data down to only calls related to air quality complaints or issues.

5. Methodology

One of our goals was to get daily air quality data at a smaller, local / community level across the boroughs. Ideally, we wanted to get daily air-quality site monitoring data from every zip code in the City for every single pollutant that makes up AQI. However, the daily AQI and pollutant data available on the EPA website have several limitations: not every pollutant gets measured in every single zip code. Additionally, even if a pollutant gets measured in a zip code, there might not be a measure for that pollutant in that zip code every day.

In order to get the most localized data without having to parse around major missing data issues, we decided to look at air particulate rates based on "United Hospital Fund"(UHF) Neighborhoods. UHF neighborhoods are groups of geographically similar communities categorized by zip codes into new neighborhood conglomerates.

Each zip code in the City is designated to one of 42 “neighborhoods”, known as the UHF 42 neighborhoods. These 42 adjoining zip code areas are *“designated to approximate New York City Community Planning Districts”*. The UHF 42s are often combined even further down to make 34 neighborhoods, otherwise known as the UHF 34s, to increase the statistical power of the neighborhood sample size.

We found 18 unique monitoring sites from the Environmental and Health Data Portal that collected data for the EPA’s daily AQI from 2013 to 2019, our study period for all analyses, for the 5 New York City counties (Bronx, Brooklyn, Manhattan, Kings, Richmond). Within these data, 13 unique UHF 42 neighborhoods and 11 unique UHF 34 neighborhoods were represented based off of the sites’ zipcodes (the dataset provides the full address and longitude-latitude of the monitoring sites). However, as previously stated, not all sites were represented uniformly across the time period. Thus, we chose to delve into UHF 42 sites which had relatively more data. This approach also guided us in determining the neighborhoods for which we needed to filter the pollutant data from the EPA’s data portal, which contained even sparser information, given that the EPA only has 7 monitors across the city (refer to the Appendix for further details).

As far as the methods for our analysis, we conducted a robust before-and-after analysis methodology, leveraging the power of time-series plots and data to scrutinize our targeted outcomes. This involves an examination of data points across time intervals which allows us to determine patterns, trends, and any fluctuations concerning the implementation of the policy. For modeling particulate data for our time series analysis, we used locally estimated scatterplot smoothing (LOESS). We were interested in capturing the changes in average-scaled pollutant concentrations across the years and this non-parametric regression method allowed us to fit a smooth curve to our huge set of data points for daily particulate levels. In a time series analysis, these regressions help with visualizing long-term trends while preserving important short-term fluctuations–such as the seasonal fluctuations we see with air pollutants.

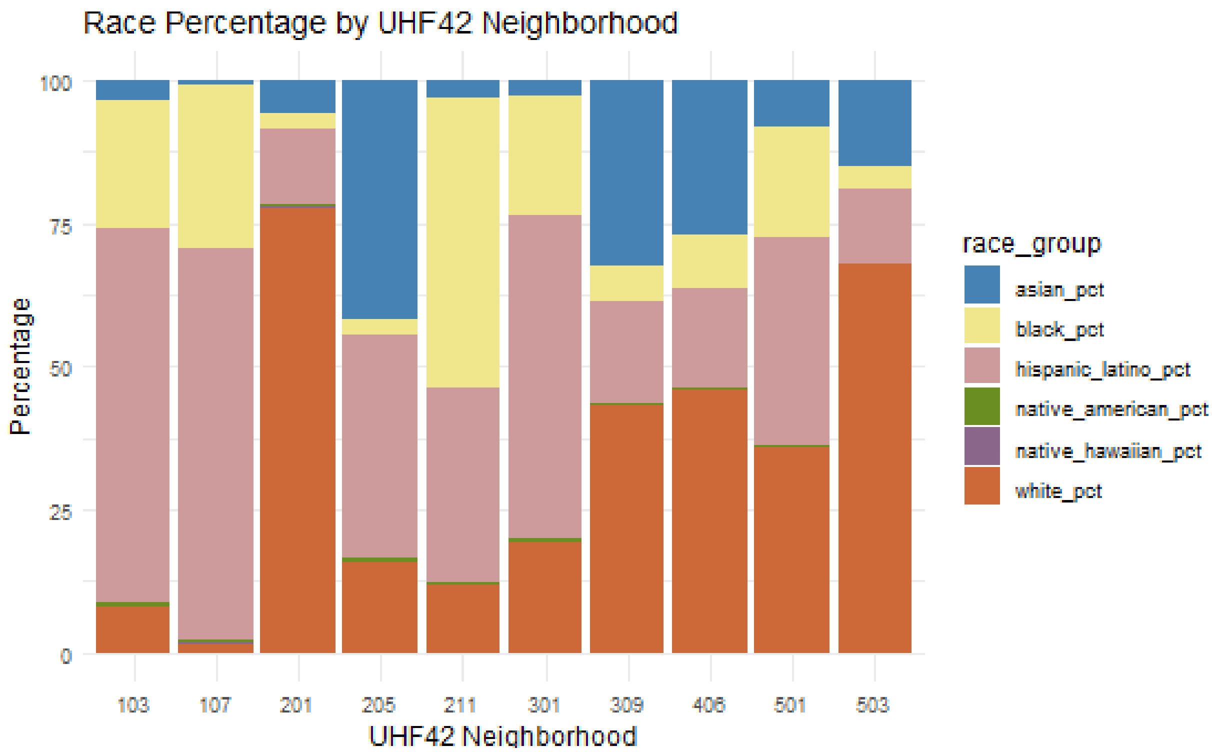
To accompany our time series analysis, we also look at the spatial distribution of our outcomes to delve into the geographical dimension of our data. In particular, the spatial units we looked at included neighborhoods and the latitude and longitude of air quality complaints. This exposed patterns in the spatial data, thus, allowing us to identify disparities in the distribution of negative air quality outcomes across different geographic locations. This method is especially useful in understanding the potential ethical implications of air regulations in historically segregated neighborhoods.

And finally we of course did extensive descriptive analyses of our outcomes related to air pollution as well. This method helped us describe trends and relationships between our data. Primarily, our descriptive analyses facilitated the creation of visualizations of our data through graphs, charts, and tables– which made for more accessible or more interpretable findings.

UHF 42 (code)	Borough	Description	Addressed (in-depth) in RQ#	Classified as a*
Fordham - Bronx Park (103)	Bronx	● Hispanic / Latino-dominant ● Low-income decile ● Mid-child dependency ratio	RQ1 and RQ2	Vulnerable group
Washington Heights - Inwood (301)	Manhattan	● Hispanic / Latino-dominant ● Mid-income decile ● Low child dependency ratio	RQ1 and RQ2	Vulnerable group
Fresh Meadows (406)	Queens	● White-dominant ● High-income decile ● Mid-child dependency ratio	RQ1 and RQ2	Not a vulnerable group
Willowbrook (503)	Staten Island	● White-dominant ● High-income decile ● Low to mid-child dependency ratio	RQ1	Not a vulnerable group
Hunts Point - Mott Haven (107)	Bronx	● Hispanic / Latino-dominant ● Low-income decile ● Mid-child dependency ratio	RQ2	Vulnerable group
Greenpoint (201)	Brooklyn	● Hispanic / Latino, White, Asian-dominant ● High-income decile ● Low child dependency ratio	RQ2	Not a vulnerable group
Sunset Park (205)	Brooklyn	● Hispanic / Latino-dominant ● Mid-income decile ● Mid-child dependency ratio	RQ2	(Unsure)
Williamsburg - Bushwick (211)	Brooklyn	● Black and Hispanic / Latino-dominant ● Low to mid-income decile ● Mid-child dependency ratio	RQ2 and RQ3	Vulnerable group

Chosen UHF 42 sites and the associated RQ's they are studied in

**We identify vulnerable groups to make effective comparisons amongst demographically differing neighborhoods and their associated air quality, health outcomes, and complaints*



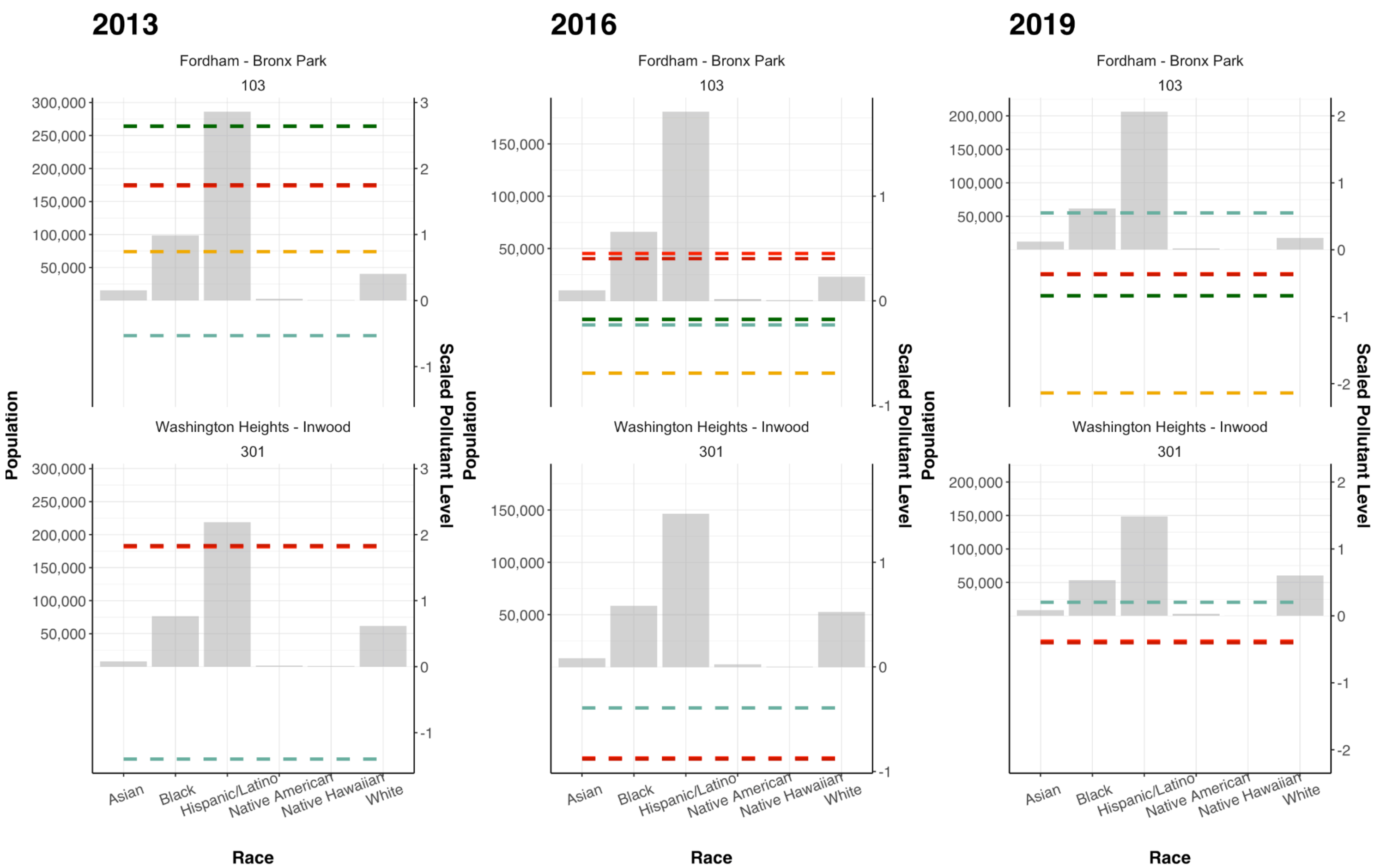
A breakdown of the racial demographics of our selected UHF 42 sites

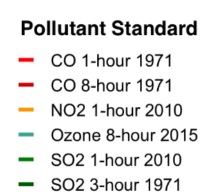
6. Results

a. RQ1

<u>*Pollutants*</u>

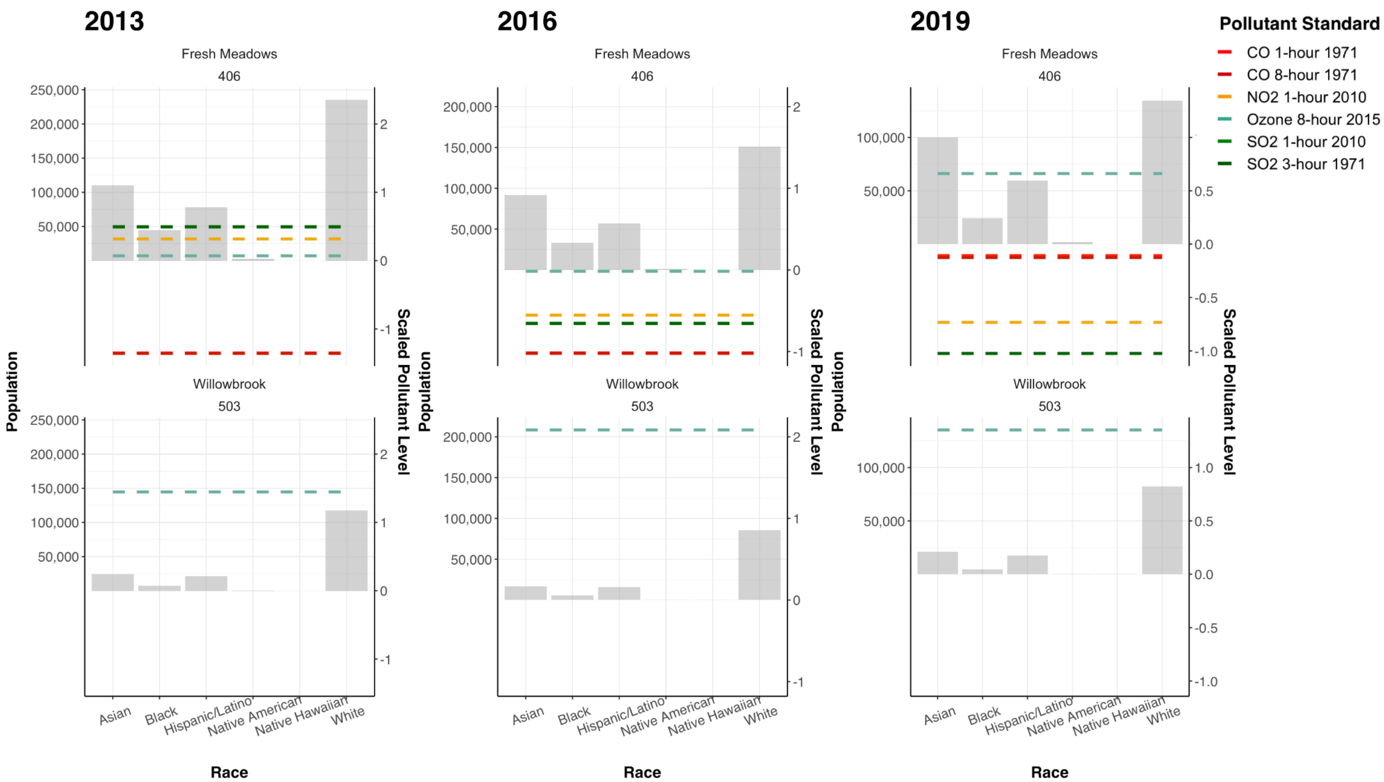
Over the years, for **Fordham**, a Hispanic / Latino-dominant neighbourhood, we see a steady decrease in the scaled amount of NO2, SO2, and CO. It is difficult to make similar judgements for **Washington-Heights - Inwood,** also a Hispanic / Latino-dominant neighbourhood due to lack of data.



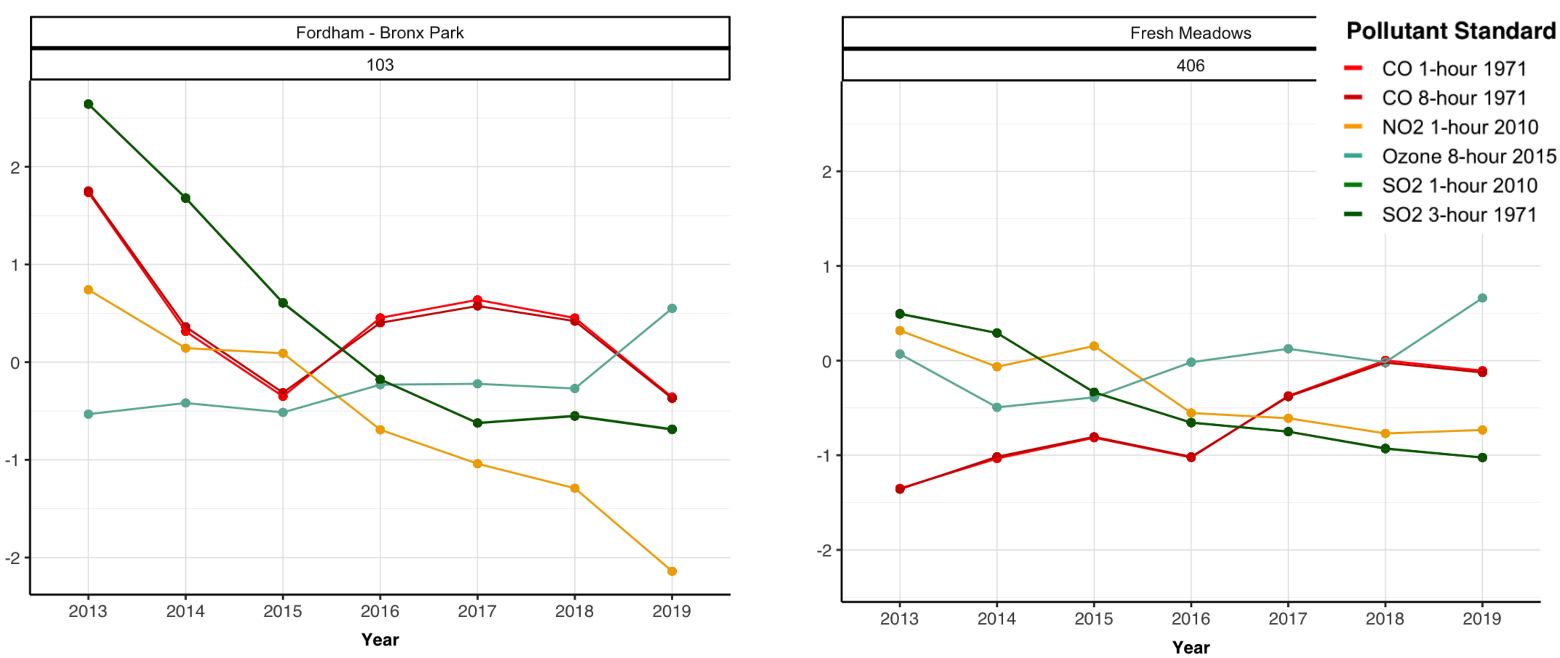


Similarly, we can evaluate pollutant trends for less vulnerable neighborhoods such as **Fresh Meadows** and **Willowbrook**, both White-dominant neighborhoods. Over the years, for Fresh Meadows, we see a steady decrease in the scaled amount of NO2, and SO2, but increasing trends for CO. It is difficult to make similar judgements for Willowbrook due to lack of data.

It is worth noting that scaled ozone levels increased for all the 4 neighbourhoods discussed here.

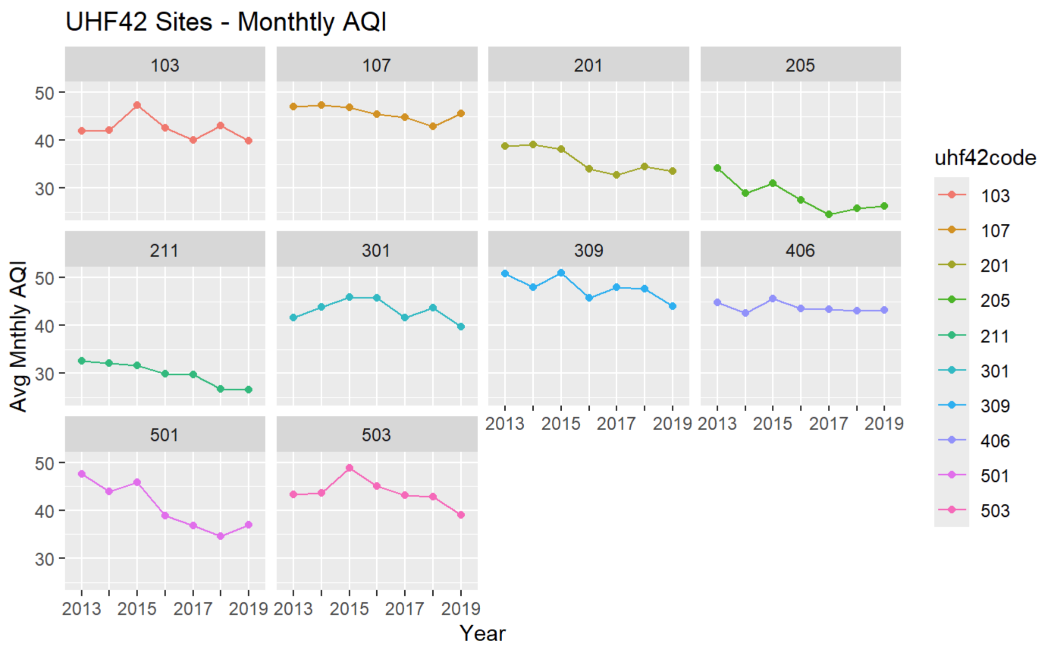


However, the pollutant levels in both these UHFs have different 'starting values'. So, although the differences across time **within** the UHFs may not be particularly indicative of evidence of a difference in pollutant outcomes in White (Fresh Meadows) and Hispanic / Latino (Fordham) -dominant UHFs, it is worth exploring trends **across** UHFs. It appears that the decrease in pollutants is **more pronounced** in Fordham.

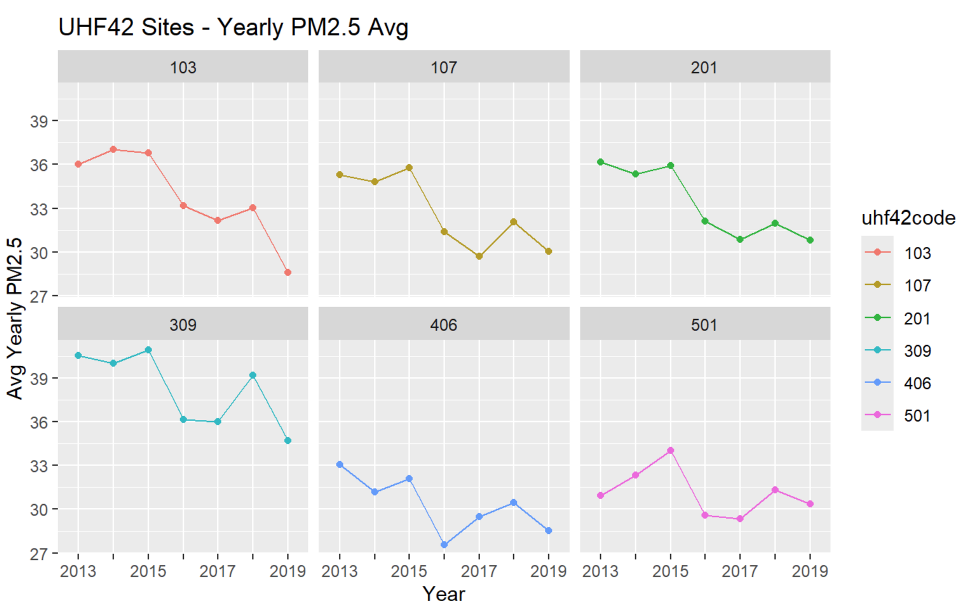


AQI

When we look at the yearly AQI averages across UHF 42 sites, almost all had lower yearly averages of AQI in 2019 than in 2013. However, the yearly average in 2019 as compared to 2016 is a different story across sites. 9 sites had their 2019 yearly average be below their 2016 yearly average. However, UHF 42 107, UHF 201, and UHF 406 had 2019 AQIs that were either the same or less than 0.6 their 2016 AQIs. The difference between these two statistics seems negligible. Additionally, many sites saw a slight increase in AQI in 2018 (see Appendix for monthly break-down).



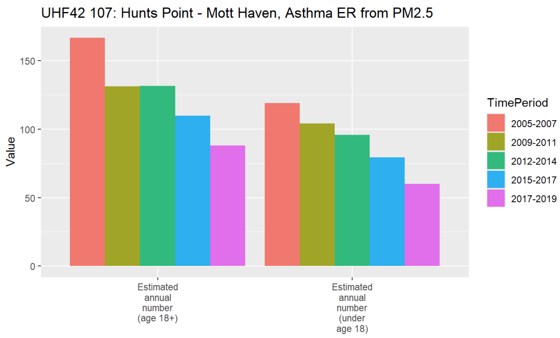
PM2.5

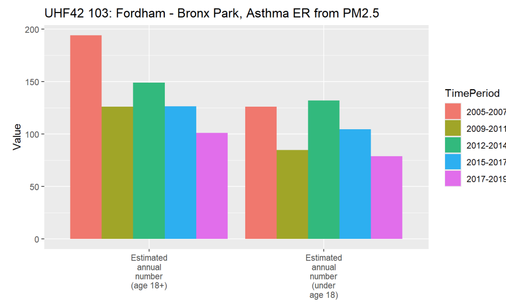


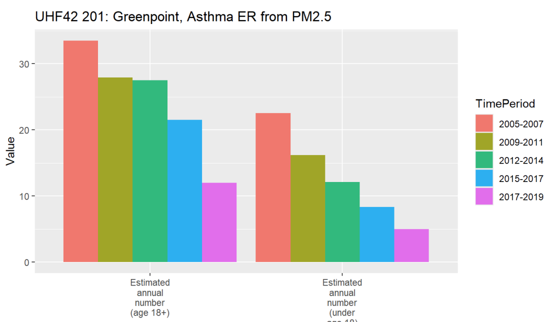
When we look at the yearly PM2.5 averages across UHF 42 sites, we again see a decrease. Out of our 11 UHF 42 sites which had a reliable amount of data, only 6 had PM2.5 data. The most decrease, however, seems to be from 2015 to 2016, during the final year when the Clean Heat Program had to go into full effect. It was also the year before the AirCode went into effect. While rates overall continued to decline a bit from 2016-2017, it was not at the rate from 2015-2016. All sites reported an uptick in yearly PM2.5 from 2017 to 2018. 2 UHF 42 sites saw a lower yearly level of PM2.5 in 2019 than in 2016. However, all saw levels increase in 2018. We believe that the steep drop from 2015 to 2016 could have been due to the elimination of residual heating oil use from the Clean Heat Program and the regulations put in place by the AirCode could have helped perpetuate the PM2.5 decline.

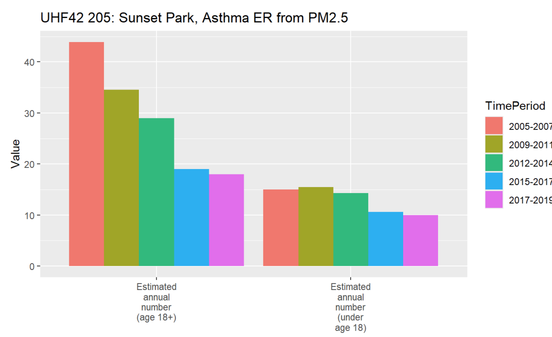
b. RQ2

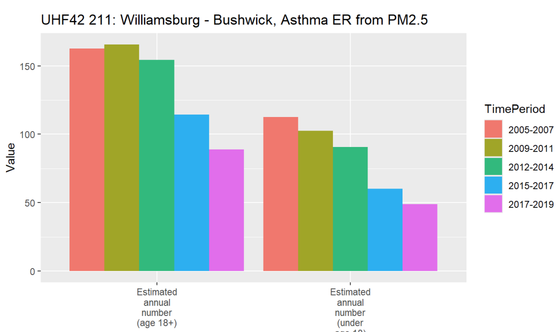
While we do not have all the PM2.5 rate data for every UHF site, the Environment and Health Data Portal still provides estimates for health outcomes related to PM.2.5 for *all* UHF 42 sites. As mentioned above in the Literature Review, these are estimates; we believe they follow plausible statistical procedures. At the same time, their results should not be taken in absolute terms but rather as general trends. Below we show PM2.5 health-related outcomes from the UHF sites listed in Question 1. To see the trends for all UHF 42 sites which had a reliable amount of data, please refer to the Appendix.

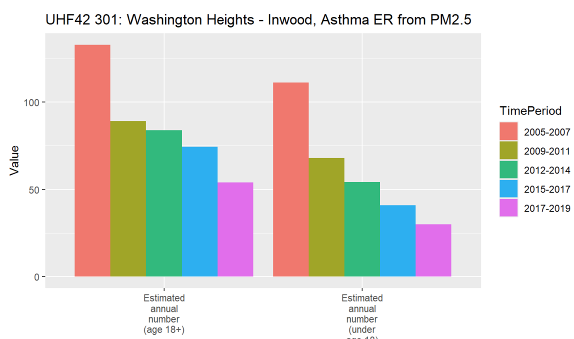


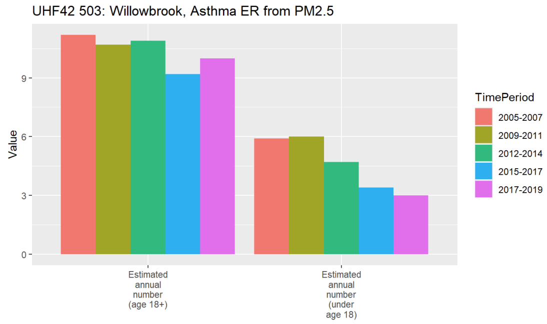








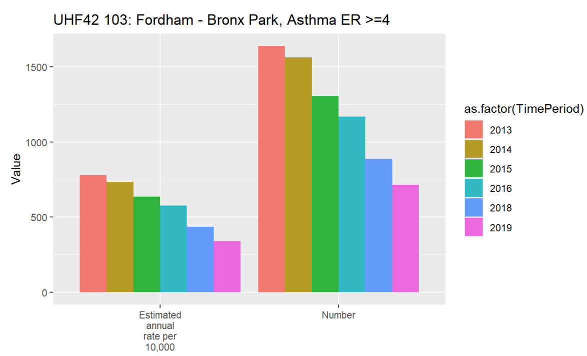


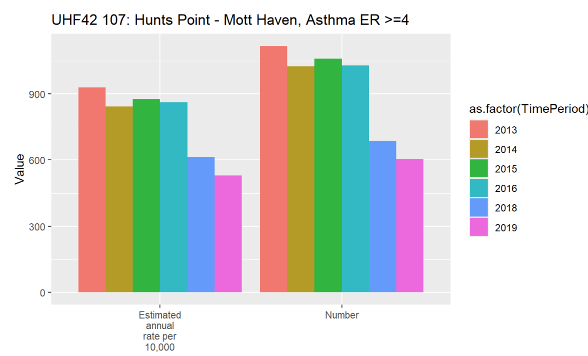


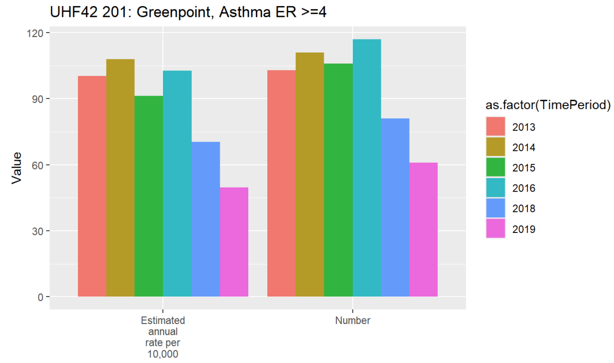
While there is a general trend of estimated number and estimated annual rate of asthma hospitalizations due to PM2.5, the rates of decline (outside of 2005-2007, which is beyond our spatial analysis), are greatest in the blue 2015-2017 years, and the purple 2017-2019 years. Similar trends are seen for Deaths due to PM2.5, Respiratory Illnesses due to PM2.5, and Cardiovascular Hospitalizations due to PM2.5.

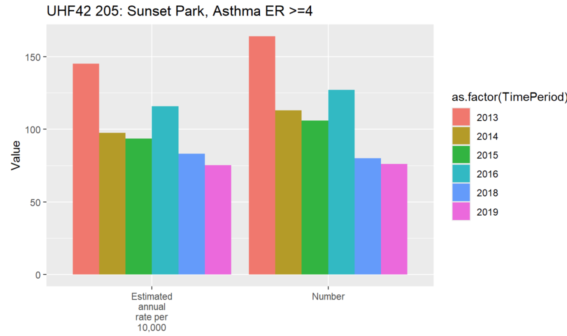
These changes are apparent across age groups as well. While not specifically related to PM2.5, the EHP reports estimated rates and empirical numbers for asthma ER visits and asthma hospitalizations for all causes for 3 age groups. Ages under 4, ages 5-17, and ages 18 and up. Please note that in this data set, however, the year 2017 and sometimes, the year 2015 were missing.

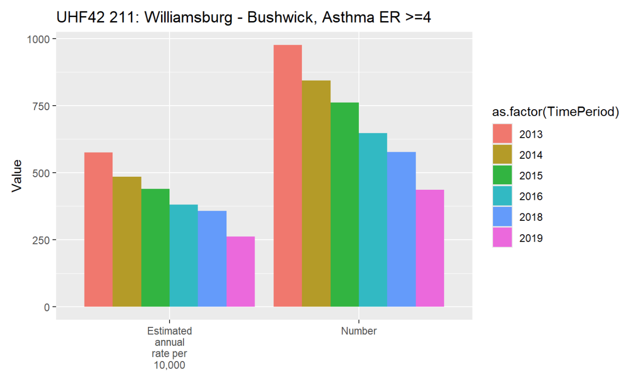
Below, we show these rates and numbers for the smallest and most vulnerable of New Yorkers: children ages 4 and under. You can see that again, some of the steepest drops in rates and numbers occurred in the years 2018 and 2019, post AirCode passing. Additionally, we note that the scales for each UHF are not uniform across. The predominantly POC, lower-income neighborhoods of 103, 107, 205, and 211 have their asthma ER visits on the top 4 highest scales compared to higher-income, predominantly White neighborhoods; 201, 406, and 503, which have the 3 lowest scales.

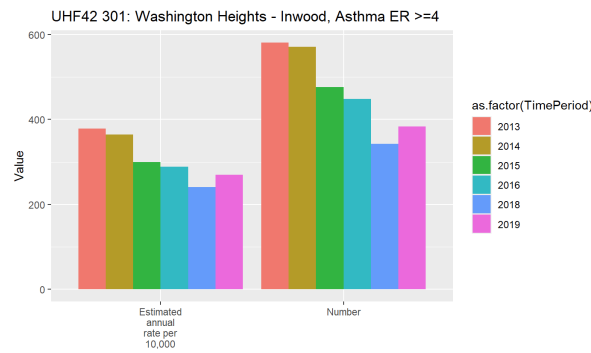


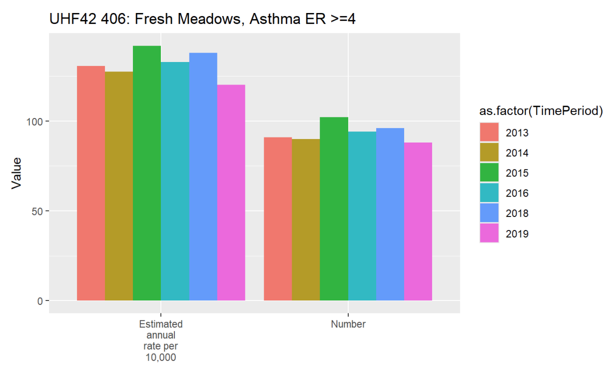


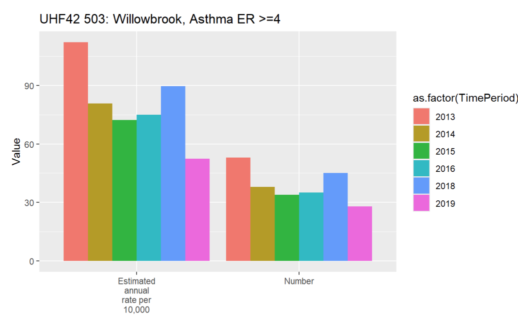






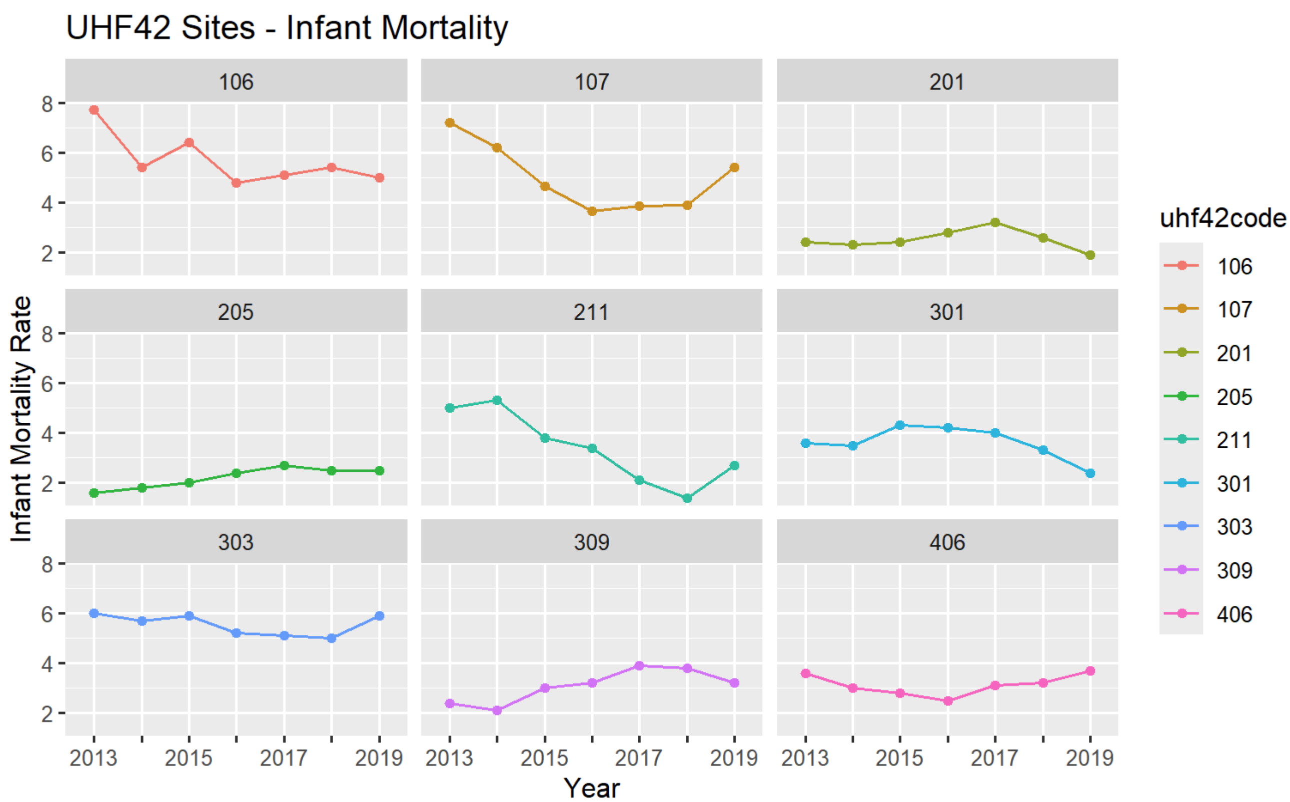






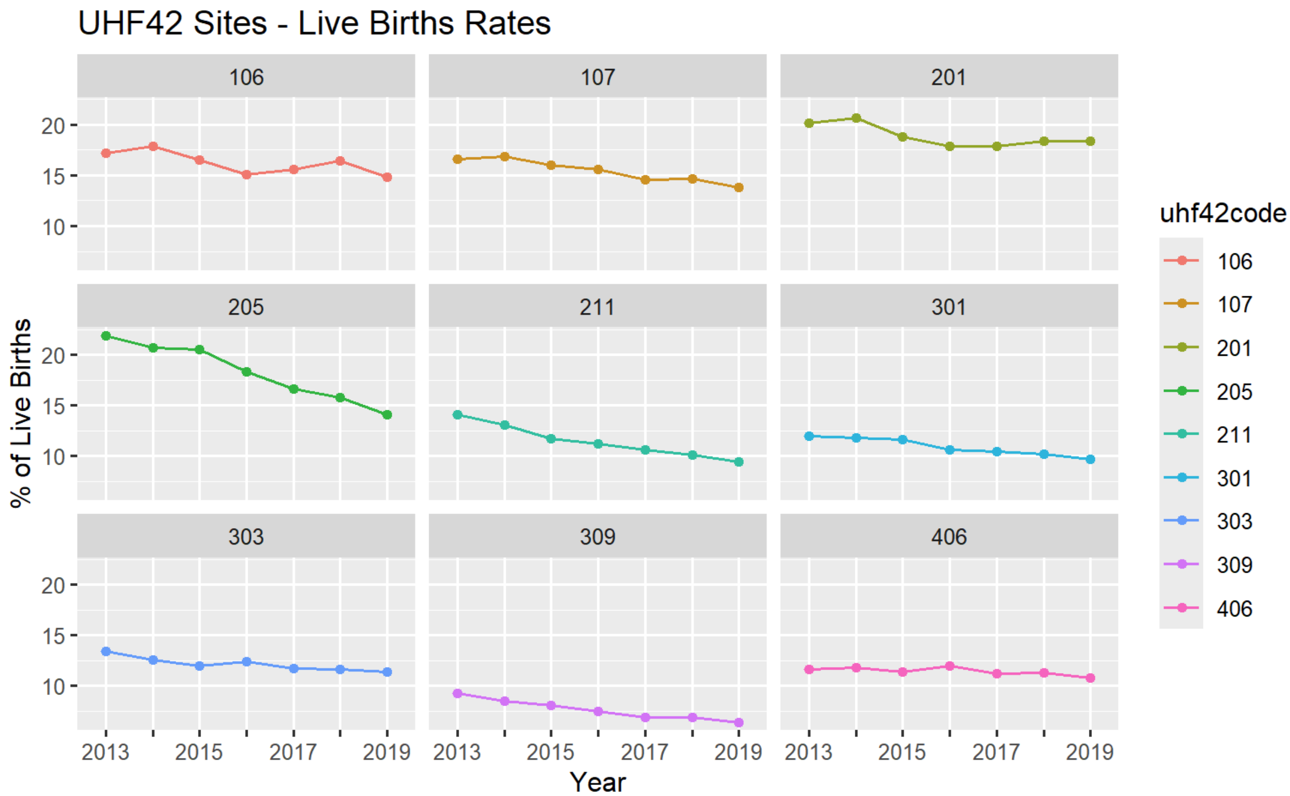
These charts show us that disparities in health outcomes between race and socio-economic standards persist beyond even what the Air Control Code helped to mitigate.

Lastly, we were curious to see if the Code had any effect on birth outcomes. We downloaded the data from a repository that the Citizens Committee for Children of New York maintains, which they collect from the New York City Department of Health and Mental Hygiene Vital Statistics Summary reports at nyc.gov. The data reports statistics by borough and listed communities/neighborhoods, not explicit UHF 42 sites. Out of the total 18 UHF 42 sites that we analyze throughout this paper, we matched 9 communities with 9 UHF 42 neighborhoods. We would also like to note that this data grouped Williamsburg and Greenpoint (Brooklyn) into one community block and Bushwick was listed as its own community. This is reversed from the UHF 42 neighborhood groupings which list Williamsburg and Bushwick together as one UHF 42 neighborhood (211) and list Greenpoint as its own UHF42 neighborhood (201). Although all 3 communities show similar levels of poverty, this is an important distinction from our previous analysis. For this birth outcome analysis, "Williamsburg/Greenpoint" will represent UHF-42 201 and Bushwick will represent UHF-42 211.



Overall, it does not look like the Code's passing coincided with a decline in negative birth outcomes across the city. Some negative birth outcomes increased after 2016, like in infant mortality for UHF's 107 or Hunts-Point/ Mott Haven in the Bronx. UHF 406 (Fresh Meadows, Queens) also saw an incline. On the other hand, UHF's 201, 211, and 301 from our previous descriptions above did see a decline in infant mortality. Similar up-and-down trends were seen for low birth weights and preterm-births (see Appendix).

Additionally, there is a general downward trend in the number and rates of live births across the UHF 42 neighborhoods. This pattern appears even before the Code's passing in 2016.



To us, it is inconclusive if the Air Code is related to the various up-and-down patterns in birth outcomes that were seen across these UHF 42 neighborhoods. We do not see a clear relationship between air quality in NYC and negative birth outcomes in this analysis. To see further analysis on low birth weight rates and live birth numbers, please see the Appendix.

c. RQ3

For the last leg of our evaluation of the 2016 AirCode, we were interested in exploring the impact of the code on air pollution complaints in the City. Understanding the patterns and trends in air complaints can provide valuable insights into the effectiveness of the code's regulations and their implementation; thus, shedding light on the overall air quality management efforts and their outcomes. These complaints come from New York's 311 Customer Service Center—from which we were able to derive all air quality-related complaints. These complaints can be further categorized based on whether the air quality issue occurred indoors or outdoors. Based only on what is covered by the code, we will look at indoor air quality complaints specifically related to asbestos exclusively. In terms of outdoor air quality complaints, we will analyze all types of complaints, whether explicitly addressed by the code or not. This allows us to assess and compare the changes in complaints covered by the code with those that are not.

To begin, let us first examine how the number and nature of outdoor air quality complaints changed over time. Prior to 2016, we found an increasing trend in the total number of outdoor air quality complaints. This climbing rise reached a peak in 2016 with about 9000 complaints. Then, in 2017 we see a plunge in total complaints to about 7600 and another drop to 7300 in the following year, 2018. We can examine the composition of complaint types in Figure A. The actual counts are broken down by complaint type in Table A.

Number of Complaints Across Years

Complaint Type	2013	2014	2015	2016	2017	2018	2019
Air: Dust, Construction/Demolition (AE4)	1512	1793	1845	1917	1793	1547	1531
Air: Odor, Nail Salon (AD8)	38	47	44	62	78	80	121
Air: Odor, Sweet From Unknown Source (AZ1)	16	23	43	34	42	15	37
Air: Odor/Fumes, Dry Cleaners (AD1)	25	13	28	30	18	17	6
Air: Odor/Fumes, Restaurant (AD2)	855	866	970	1017	876	884	882
Air: Odor/Fumes, Vehicle Idling (AD3)	1595	1806	2589	3348	2512	2637	3682
Air: Open Fire, Construction/Demolition (AC4)	1	0	5	1	0	0	0
Air: Other Air Problem (Use Comments) (AZZ)	638	675	700	562	452	414	305
Air: Smoke, Chimney or vent (AS1)	1701	1380	1672	1302	1425	1297	982
Air: Smoke, Other (Use Comments) (AA5)	3	6	14	11	5	10	1
Air: Smoke, Residential (AA1)	7	2	16	7	1	0	0
Air: Smoke, Vehicular (AA4)	408	518	573	538	490	488	325

Table A.

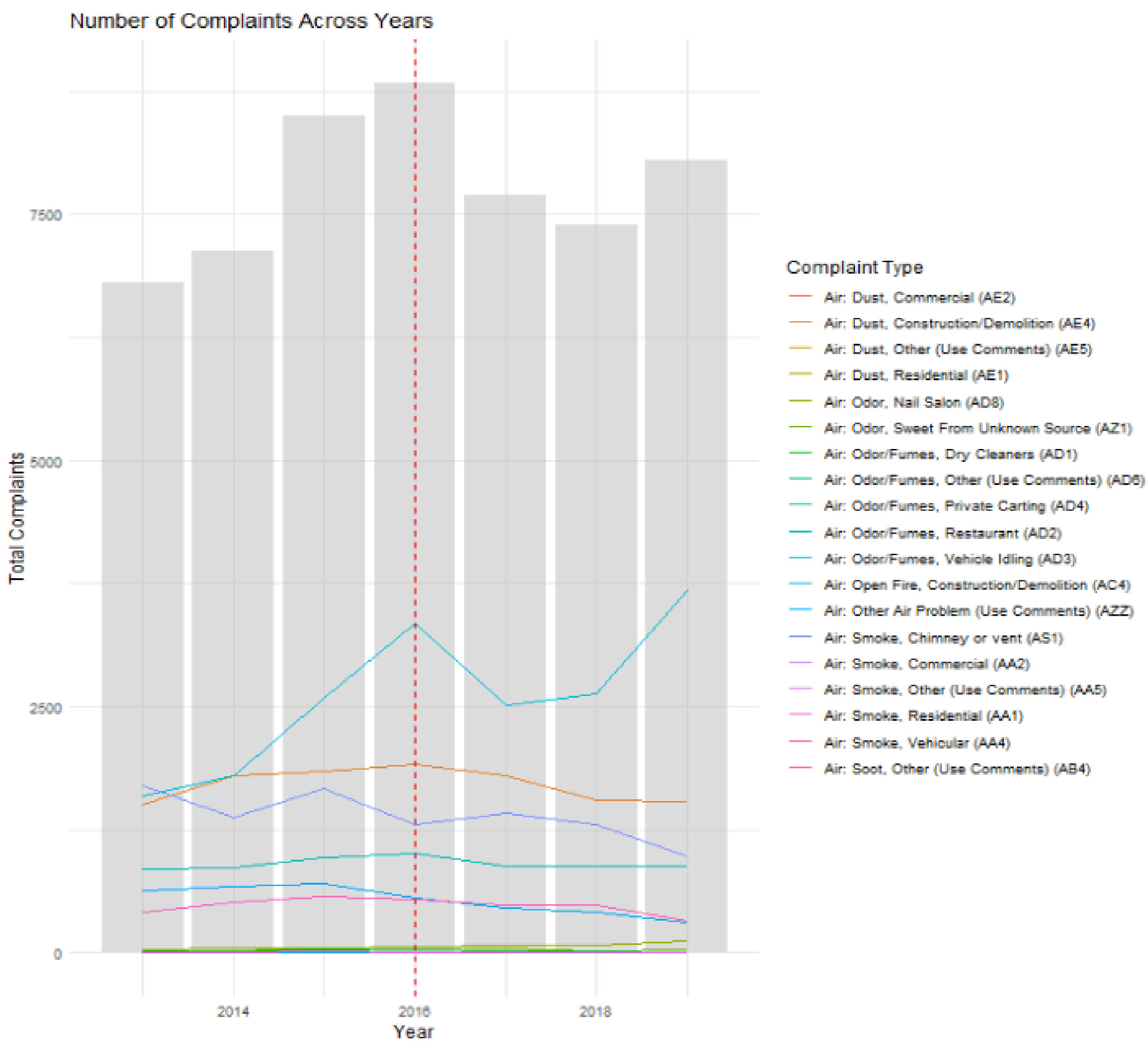


Figure A.

In Figure A, the topmost line corresponds to Vehicle Idling, indicating that it accounts for the majority of complaints. This category exhibits the most significant and immediate reduction in total complaints. We suspect this significant decrease in complaints is due to enforcement of the code. In particular, the code's subsection on the restrictions on idling of engines details this enforcement and declares that "*in addition to the department and the police department, the department of parks and recreation and the department of sanitation shall have the authority to enforce subdivision a of this section and shall have the power to issues summonses, appearance tickets and/or notices of violation for violations of such subdivision"* (Air Code - NYC Business, n.d., p.34). The second line from the top in the figure represents complaints related to dust from construction and / or demolition sites. Here, we observe another noticeable decrease, albeit not as pronounced as in the Vehicle Idling category. The immediate decrease dropped by about 200 complaints following the enactment of the code.

Other complaint types of interest—that is, those that are also covered by the code—include odor / fumes from restaurants (covered in the code's discussion of commercial charbroilers and cook stoves) of which which we also see a significant decrease in by about 200 complaints. We also see a few outliers such as "Air: Open Fire, Construction/Demolition (AC4)” and “Air: Smoke, Other (Use Comments) (AA5)”, which have very few complaints across all years. This could imply either a low prevalence of these issues or underreporting. Overall, we found an immediate decrease across all complaint types specifically at the timepoint of code enforcement.

We may now examine indoor air quality, or more precisely asbestos complaints. Subchapter 5 of the Air Code regulates asbestos installers and the methods of installation. To get a sense of the distribution of asbestos complaints before the code, we plotted the coordinates of each service call related to asbestos made in 2016. After an examination of several different demographic variables such as educational attainment and racial / ethnic percentage by Census Tract, we found that the spatial distribution of asbestos complaints prior to the code most strikingly resembles the distribution of predominantly Black communities. This hotspot of asbestos complaints in Brooklyn overlaps with an area with a high percentage of Black residents—this overlap is captured in Figure B.

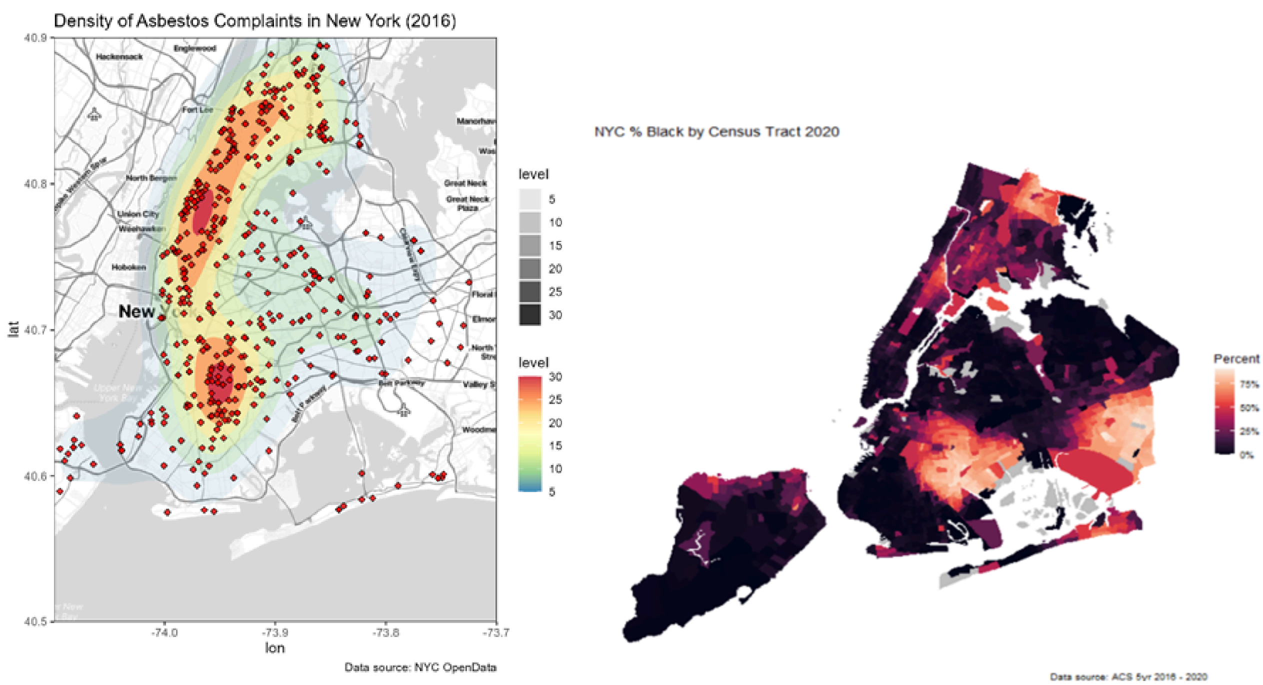


Figure B.

This is especially concerning as the negative health impacts including cancer-related to asbestos are well-researched and documented (Berry et al., 2022). This spatial analysis reveals an inequitable distribution of environmental burdens. And if Black communities are disproportionately affected by asbestos exposure, it could exacerbate existing health disparities. With this motivation in mind, let’s get into the impact of the code on the total number of asbestos complaints. A time series plot of daily asbestos complaints from 2013 to 2019 reveals an immediate (albeit maybe short-lived) greater protection of public health and safety as we saw an immediate decrease in asbestos complaints in Figure C.

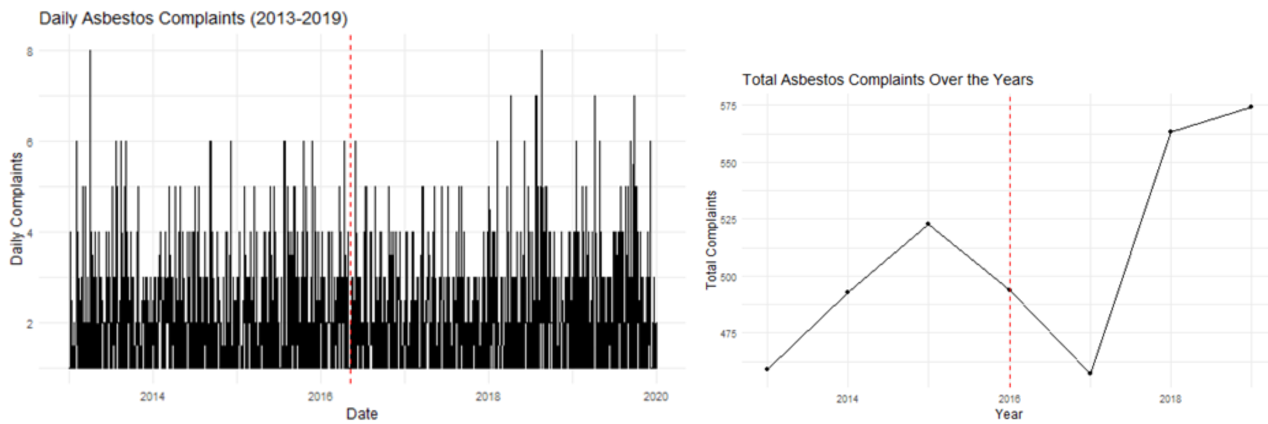


Figure C.

This decrease may be difficult to visualize using daily counts so we can take another look at yearly counts also found in Figure C. It would be remiss to not acknowledge the spike in complaints between 2017 and 2018. In 2018, NYC added the Asbestos Control Program that further refined the regulations surrounding renovations, repairs, demolitions, and constructions that involve asbestos-containing materials. These rules and regulations included an asbestos project notification known as the Asbestos Reporting and Tracking System (ARTS) E-file system (Title 15, Chapter 1 of the Rules of the City of New York, n.d.). From this system, we were able to determine that concurrent with the jump in complaints there was also a jump in projects that involved asbestos from about 100 to 3000 projects. This intuitively makes sense—the more asbestos projects going on, the more potential complaints.

Overall, we saw an immediate decrease in asbestos complaints following the code's enactment—but was this decrease equally felt across all New Yorkers? Or were there disparate outcomes depending on where you live? To investigate this, we again plotted the coordinates of asbestos complaints and found that following 2016, there was some alleviation in complaints in Black communities as these asbestos complaint hotspots moved away from Brooklyn and toward Manhattan in 2017 and 2018. The spatial distribution of asbestos complaints over time can be found in the Appendix.

We can examine this further by looking at one neighborhood in Brooklyn—and more specifically, within the hotspot for asbestos complaints that we identified earlier. The UHF neighborhood we will focus on is UHF 211, or Williamsburg-Bushwick. This neighborhood is characterized by a predominately Black and Hispanic / Latino community, a low to mid-income decile, and a mid-child dependency ratio. We can repeat our descriptive analysis of air complaints across all of NYC for just this UHF neighborhood as seen in Figure D.

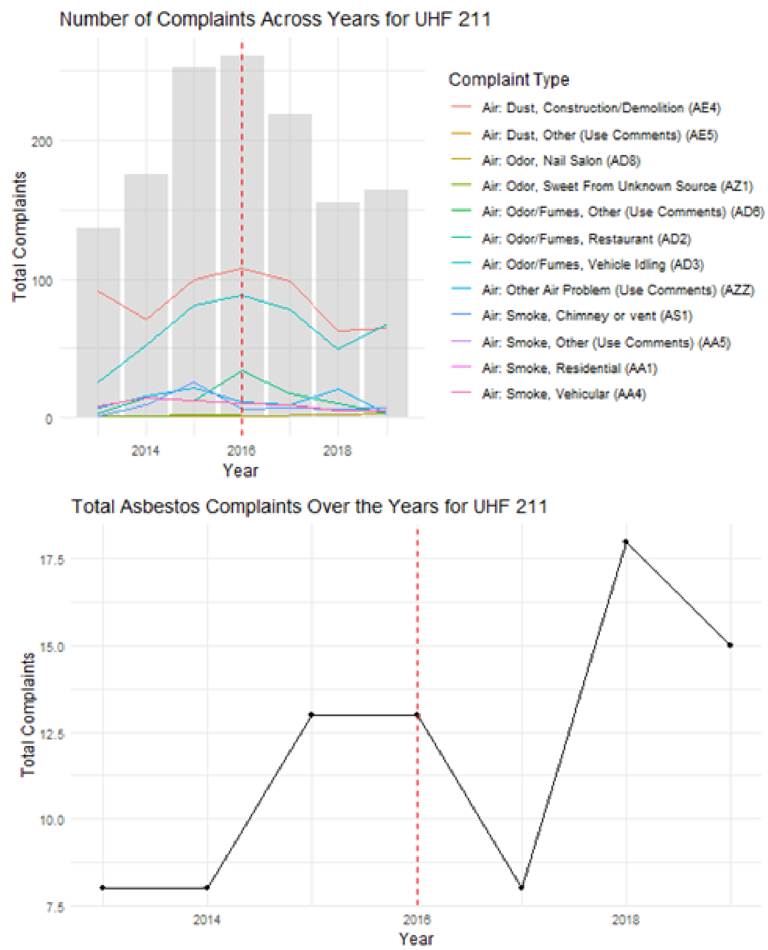


Figure D.

We find similar results as the city-wide complaint analysis. Specifically, we see a dramatic decrease in asbestos complaints following the 2016 code. We also see decreases in complaints concerning Vehicle Idling and Dust from Construction / Demolition. Dissimilarly, dust from construction / demolition makes up more of the total air quality complaints which might be indicative of location differences—for instance, Brooklyn and Queens are both seeing a boom in residential construction projects during the study period (Walker, 2018).

In conclusion, post-implementation of the 2016 AirCode, we observe reductions in all air quality complaint types, both indoor and outdoor, explicitly addressed by the code. Moreover, we verified that these reductions were experienced by the same disadvantaged neighborhoods previously bearing the brunt of this environmental burden. It appears that, to some extent, the air code has mitigated these inequitable environmental challenges.

7. Ethical Implications / Concerns / Policy Implications

Our comparative analyses of affluent and disadvantaged neighborhoods have subtly pointed to the ethical considerations surrounding air policy. As stated by author Kristen Fedak, *"Air pollution exposure is distinct by virtue of its involuntary nature from other more voluntary disease risk factors (e.g., diet, alcohol, and tobacco)"* (Fedak, 2018). This highlights the crucial aspect that individuals often cannot control their exposure to air pollution. Therefore, research on air pollution plays a vital role in upholding the ethical principle of protecting the public interest and vulnerable populations.

Our first concern is the variations in monitoring sites and their air quality assessment. We were restricted in which monitors we could include in our analysis due to an inequality among monitoring sites which underscores disparities in access to accurate environmental data. The monitors are unequal in which particulates they measure and how often they take measurements—making for inconsistent data across all neighborhoods. Addressing these discrepancies is essential to ensure that air quality assessments and research are ethical, comprehensive, and equitable for all communities. Moreover, it calls for an examination of the socioeconomic factors influencing the placement and maintenance of monitoring stations. Thus, highlighting the need for environmental justice and equity in environmental monitoring practices.

Further concerns we have surround the enforcement of the code. The code outlines more strict rules and regulations and the entities that enforce them—but could there be disproportionate enforcement of the code? Perhaps the code is more strictly enforced in neighborhoods with a history of over-policing, for example with vehicle idling, than other neighborhoods. This raises equity and justice issues if some groups are facing criminal penalties, fines, and imprisonment, at unfair rates compared to other groups.

A final ethical concern is of course one of our outcomes of interest; the disproportionate negative health outcomes related to poor air quality. Despite seeing health outcomes specifically related to air quality get better across all neighborhoods, the scale of the persistence of negative health outcomes was not equal. Thus, disparities remain in the reduction of health-related burdens; this emphasizes the need for more interventions to address the unequal distribution of health benefits. All in all, air quality is one small part of the bigger puzzle of environmental, health, and socioeconomic disparities between NYC neighborhoods.

In sum, not only do we need ethical policy but ethical air pollution research as well. This requires more data and equivalent means of measuring across all neighborhoods. Other ways to conduct ethical research include collaborating with community stakeholders and incorporating community-based participatory research approaches to enhance the relevance and validity of research findings. Ultimately, ethical air pollution research should aim to promote environmental justice and equity by advocating for policies, programs, and / or interventions that address the needs and concerns of all communities, particularly those most vulnerable to the adverse effects of air pollution.

8. Conclusion

We saw decreasing trends in particulate matter and AQI in general and we hypothesize that it's possible that the decrease may have been more drastic for Hispanic / Latino-dominant neighborhoods compared to White-dominant ones. It is difficult to determine if the NYC AirCode is the sole contributor in the general reduction of breathing-related health illnesses. However, its combined efforts with the Clean Heat Project may have made a difference. Finally, over the time period of our analysis, we saw a decrease across all complaint types *explicitly related to the code* (Asbestos, Vehicle Idling, and Dust from Construction/Demolition). This trend was especially noticeable in neighborhoods that were previously disproportionately affected by these conditions.

9. Limitations / Recommendations

Overall, since this analysis was descriptive in nature, we have not and cannot attribute the trends we noticed to solely the passing of the AirCode. Isolating or attributing air quality improvements solely to a single policy or program is always a challenge due to various international, national, and municipal efforts aimed at combating climate change concurrently.

We also would like to delineate the limitations that we and our analyses faced in answering each of our research questions. For RQ1, we had missing particulate data in that not all monitors were uniformly measuring the same particulates over similar periods of time. Thus, we were only able to do analyses where and for those locations where particulate monitors were present, ultimately limiting our ability to make comparisons amongst a wider variety of neighborhoods with more demographic heterogeneity. For answering RQ2, we relied on health outcome *estimates* from previous work, rather than empirical numbers as we could not locate such data on rates of asthma during the time frames of our analysis (except for adults; all other timeframes were either until 2013 / 2014 or started in 2017 and after). Additionally, it should be noted that when it comes to hospitalizations at the other age breakdowns, the data for 2017 data was missing. Finally, in regards to RQ3, it should be noted that it might be unrealistic to assume that people across all neighborhoods have the same 'threshold' in deciding to make a complaint. One might be living in very poor air quality conditions and not call in with a complaint (due to lack of awareness, resources, etc.) while someone else may be living in an area with relatively better air quality but still call in. Relatedly, some communities may feel disenfranchised and fearful of the potential repercussions of making a complaint, further skewing the aforementioned 'thresholds'.

We have several recommendations for future air policy and air pollution research. In further research, we recommend integrating various urban datasets to gain insights into the complex relationships between vegetation, weather, public health, and other variables that may be helpful in gaining a better understanding of the various other ways the code may have made a difference. The foremost recommendation is to have more consistent data across all sites. Not only do not all monitors measure the same particulate matter, but some do not consistently measure throughout the year–that is, not all sites were represented uniformly across the time period. Thus, we were limited in our evaluation to only UHF 42 sites which had more data–costing us representation across all of NYC. We believe in future research this pitfall can be avoided by equally maintaining working monitors across all sites. The lack of consistent data raises concerns as it might potentially reflect socioeconomic factors of communities. This leads us to the overarching theme of our evaluation which is that policy should consider the effects on various communities; what works for one community might not work for another. We also believe the work in this report just calls to the gap in literature–more specifically, the lack of evaluation as to whether the code was truly effective. What were the city's benchmarks or checks for whether this code was practical and worthwhile?

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11. Individual Contributions

Marlee:

- Cleaned AQI code from the EPA database and helped determine which UHF 42 sites did not have missing data
- Handled tackling and writing up RQ2
- Helped to conduct literature review research on the AirCode itself, its history, and health outcome calculations from the Environmental Health Portal
- Created charts and plots of health outcome data and AQI and PM2.5 rates
- Wrote up literature review on code and history of Air Code

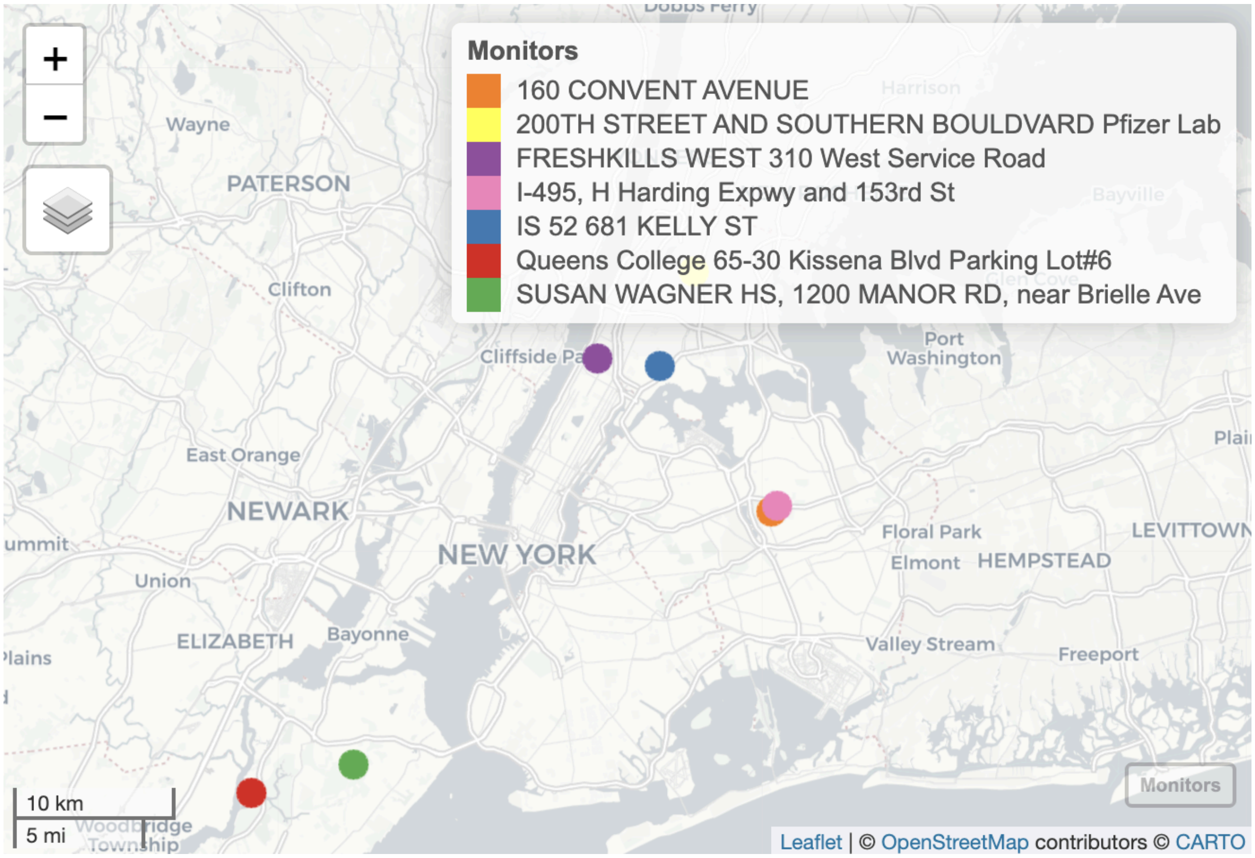
Hailie:

- Helped with visualizing the Census data from the US Census Bureau and getting the defining characteristics/demographics of each UHF neighborhood in our evaluation
- Handled tackling RQ3, this included descriptive analysis, visualizations, making maps/plotting latitude and longitude data
- Helped with writing and editing the Conclusion, Data, Methodology, and Limitations/Recommendations sections
- Put together all the citations for the references sections

Saumya:

- Helped with cleaning the Census data from the US Census Bureau and Pollutant data from the EPA's website
- Handled tackling RQ1, and making time series plots for the same
- Provided scaffolding for, edited, and helped smooth out the Literature Review, Conclusion, and Limitations/Recommendations sections
- Added tables to the document which help make the connection between our research questions and what the code covers more concrete
- Added all our analyses to a Quarto Document

12. Appendix



EPA's pollutant monitoring sites

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}.$$

Where I_p = the index for pollutant p

C_p = the truncated concentration of pollutant p

BP_{Hi} = the concentration breakpoint that is greater than or equal to C_p

BP_{Lo} = the concentration breakpoint that is less than or equal to C_p

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

Formula to calculate AQI

Asbestos Complaint Distribution Over Time

UHF 34 NBHOOD Code	2013	2014	2015	2016	2017	2018	2019
	YEAR						
201		x	x	x	x	x	x
205	x	x	x			x	x
211		x	x	x		x	x
301		x	x	x	x	x	x
303							
402	x						
309310	x	x	x	x	x	x	x
404406	x	x	x	x	x	x	x
501502		x	x		x	x	
503504		x	x	x	x	x	x
105106107	x	x	x	x	x	x	x

UHF 34 NBHOOD Code	2013	2014	2015	2016	2017	2018	2019
	YEAR						
201	1						
205				1	1		
211	3				1		
301	1						
303	11	10	10	11	8	9	9
402		4	4	5	9	7	8
309310							
404406							
501502	1			5			1
503504	1						
105106107							

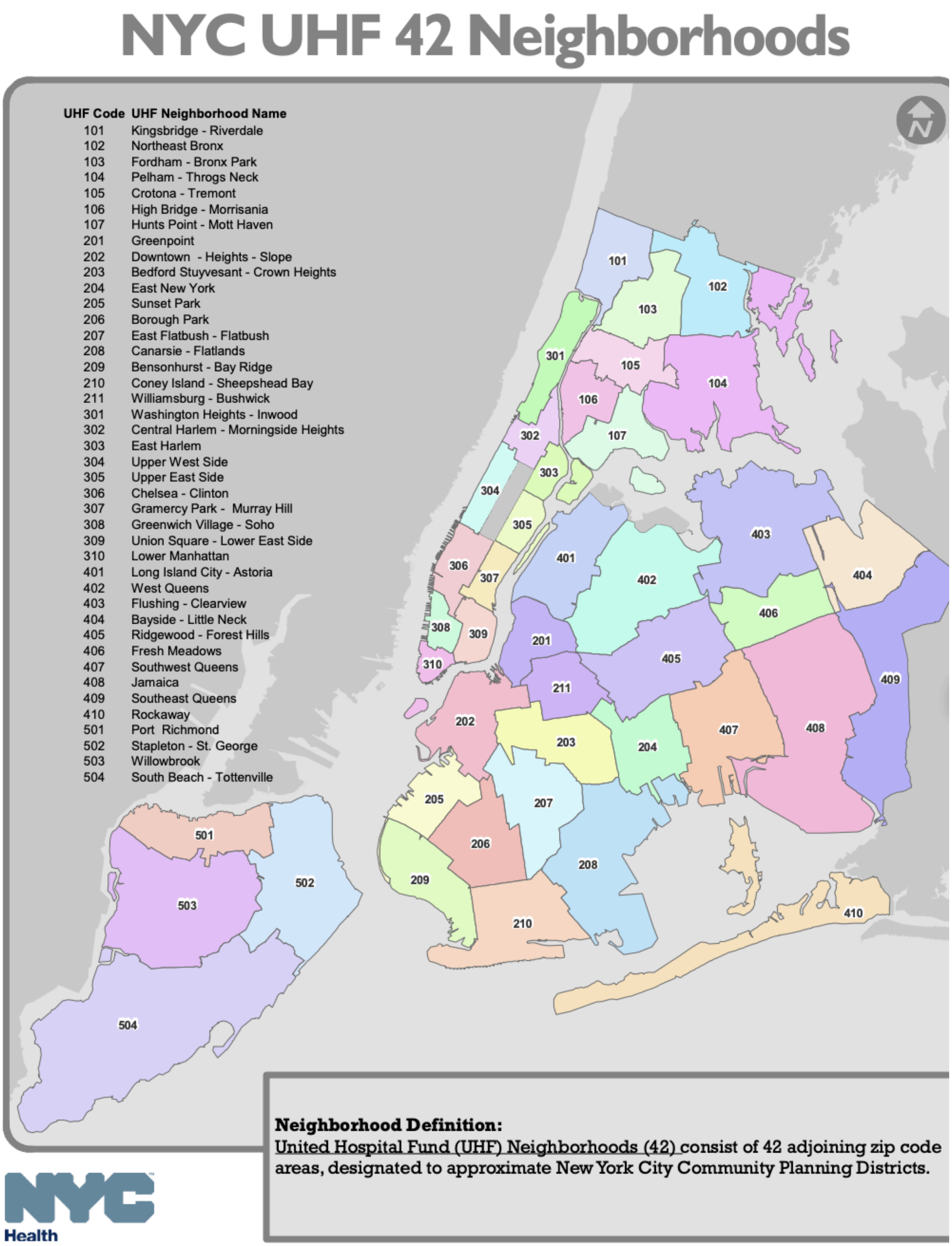
UHF 42 NBHOOD Code	2013	2014	2015	2016	2017	2018	2019
	YEAR						
103	x	x		x	x	x	x
106	x						
107	x	x	x	x	x	x	x
201		x	x	x	x	x	x
205	x	x	x			x	x
211		x	x	x		x	x
301		x	x	x	x	x	x
303							
309	x	x	x	x	x	x	x
402	x						
406	x	x	x	x	x	x	x
501		x	x		x	x	
503		x	x	x	x	x	x

x = "No months present with 0 data points for that year"

UHF 42 NBHOOD Code	2013	2014	2015	2016	2017	2018	2019
	YEAR						
103			1				
106		1	5	2	3	3	8
107							
201	1						
205				1	1		
211	3				1		
301	1						
303	11	10	10	11	8	9	9
309							
402		4	4	5	6	7	10
406							
501	1			5			1
503	1						

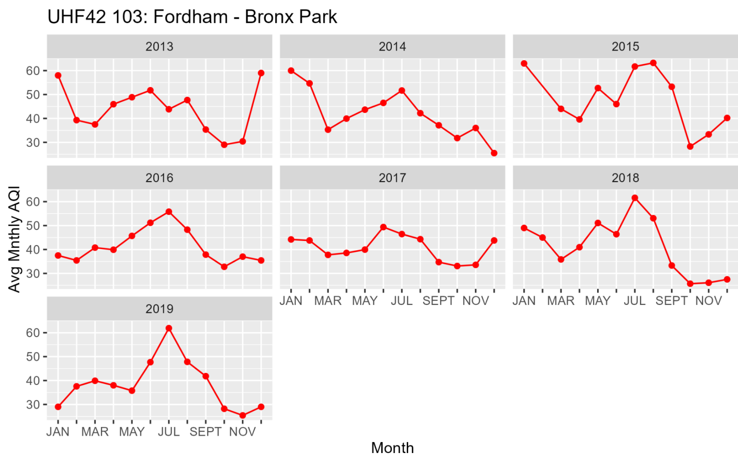
How many 0s (months without a data point) in a year

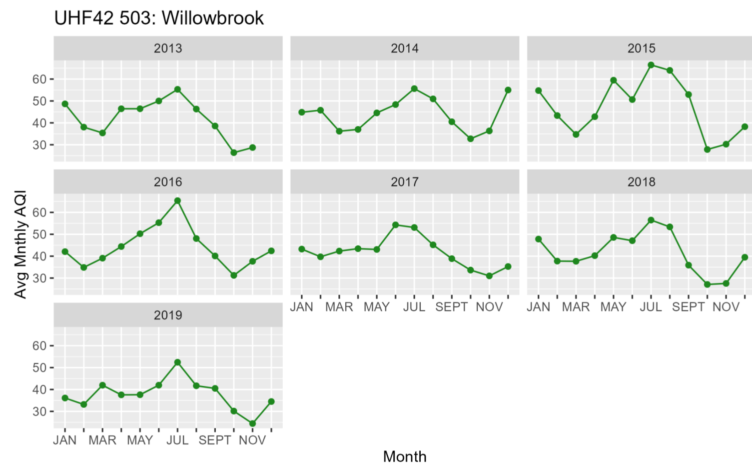
2 charts showing what sites did not have missing data during the months of a particular year and if data were missing, how many months were missing data in that given year. Based on this analysis, we decided that we had enough data to do pollutant data (and cross it with other location-based outcome data) for 10 UHF 42 sites and 9 UHF 34 sites

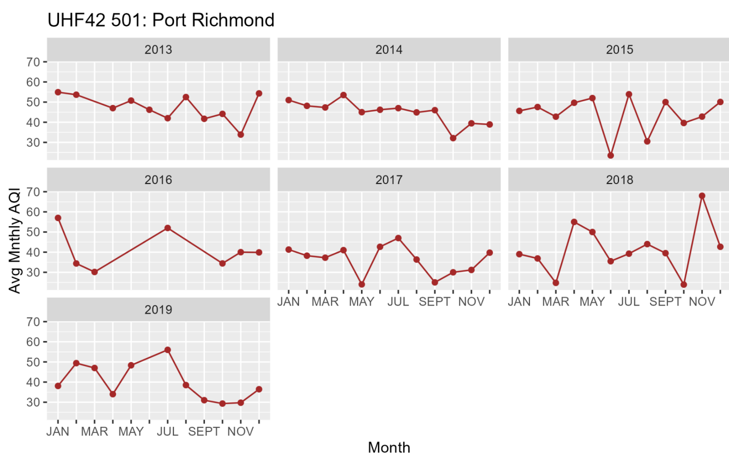

NYC UHF 42 Neighborhoods
UHF Code UHF Neighborhood Name
101 Kingsbridge - Riverdale
102 Northeast Bronx
103 Fordham - Bronx Park
104 Pelham - Throgs Neck
105 Crotona - Tremont
106 High Bridge - Morrisania
107 Hunts Point - Mott Haven
201 Greenpoint
202 Downtown - Heights - Slope
203 Bedford Stuyvesant - Crown Heights
204 East New York
205 Sunset Park
206 Borough Park
207 East Flatbush - Flatbush
208 Canarsie - Flatlands
209 Bensonhurst - Bay Ridge
210 Coney Island - Sheepshead Bay
211 Williamsburg - Bushwick
301 Washington Heights - Inwood
302 Central Harlem - Morningside Heights
303 East Harlem
304 Upper West Side
305 Upper East Side
306 Chelsea - Clinton
307 Gramercy Park - Murray Hill
308 Greenwich Village - Soho
309 Union Square - Lower East Side
310 Lower Manhattan
401 Long Island City - Astoria
402 West Queens
403 Flushing - Clearview
404 Bayside - Little Neck
405 Ridgewood - Forest Hills
406 Fresh Meadows
407 Southwest Queens
408 Jamaica
409 Southeast Queens
410 Rockaway
501 Port Richmond
502 Stapleton - St. George
503 Willowbrook
504 South Beach - Tottenville
Neighborhood Definition:
United Hospital Fund (UHF) Neighborhoods (42) consist of 42 adjoining zip code areas, designated to approximate New York City Community Planning Districts.
NYC Health

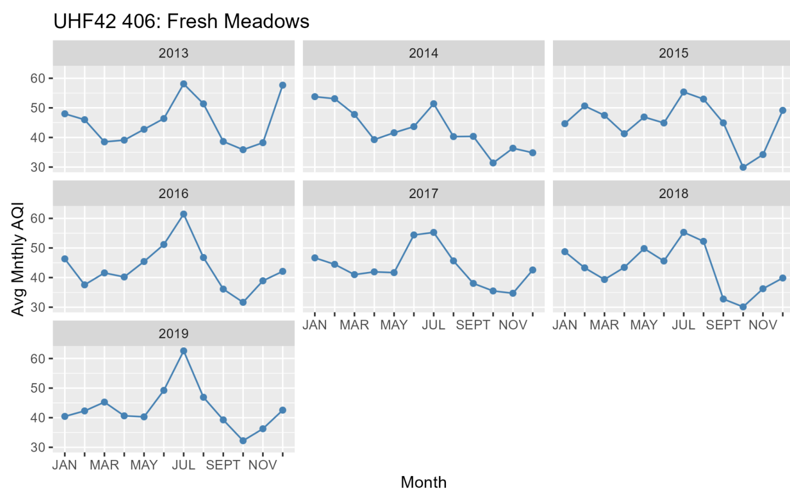
UHF 42 Map

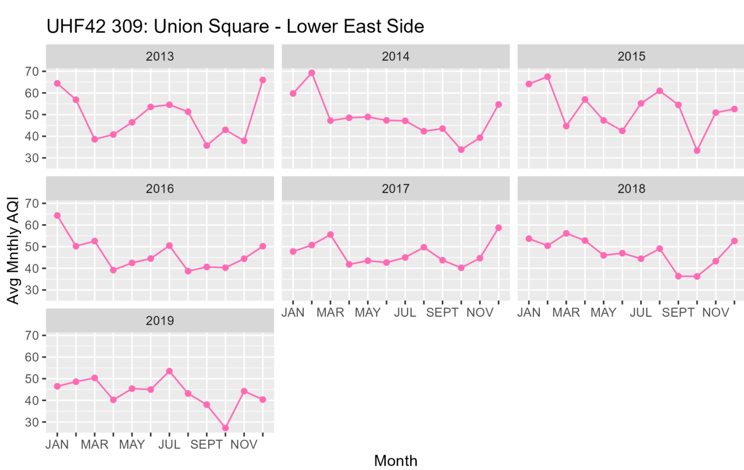
AQI by month per site

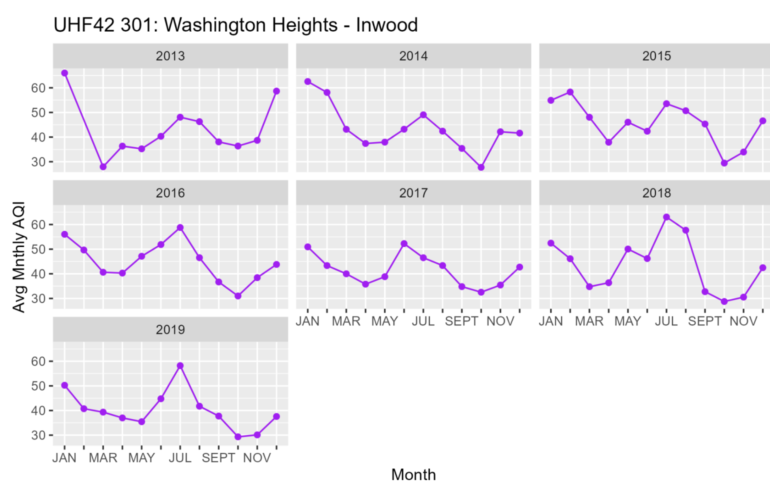




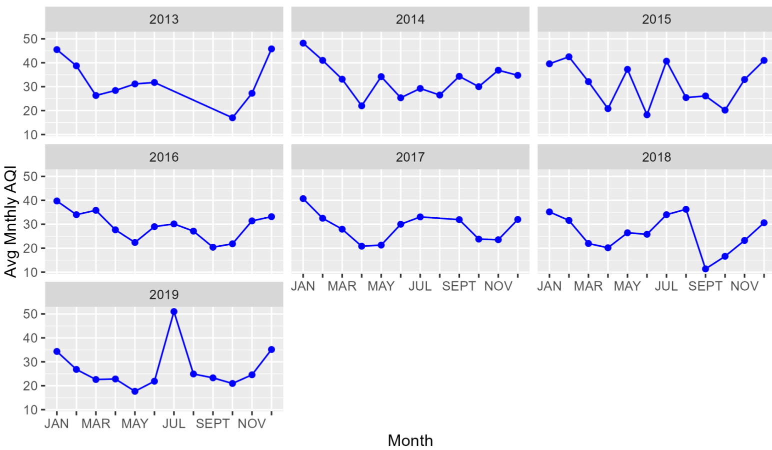




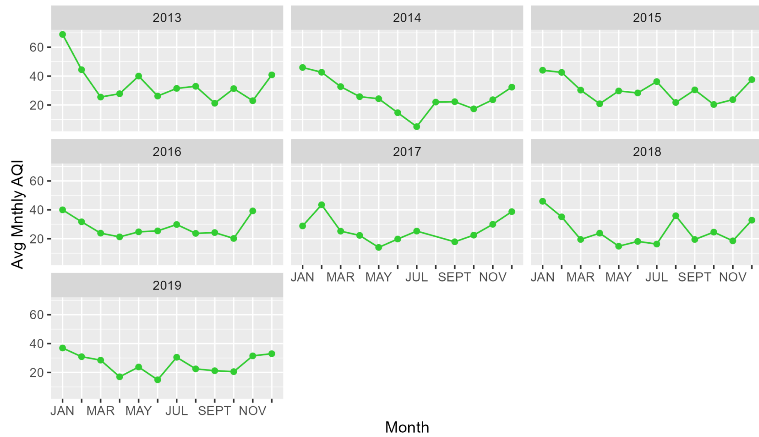




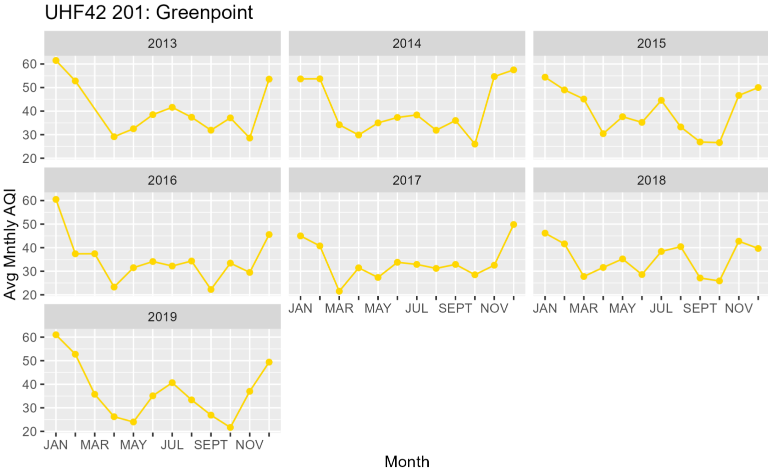
UHF42 211: Williamsburg - Bushwick



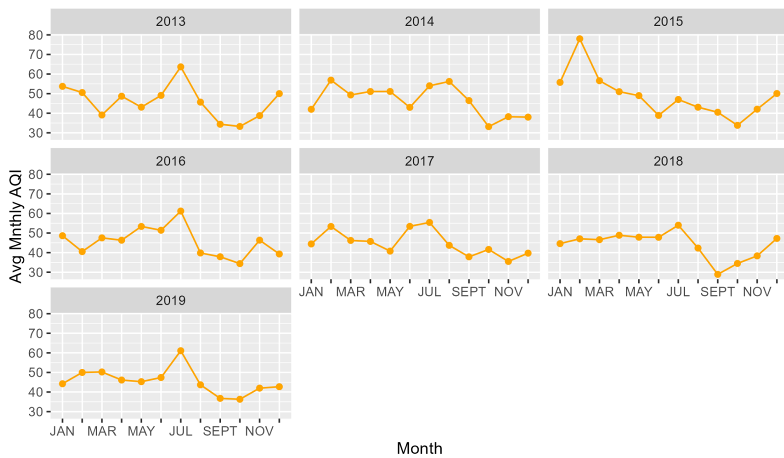
UHF42 205: Sunset Park



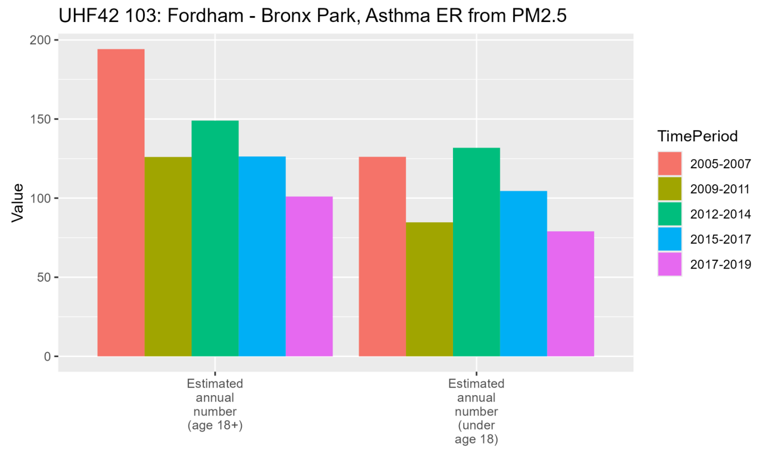
UHF42 201: Greenpoint

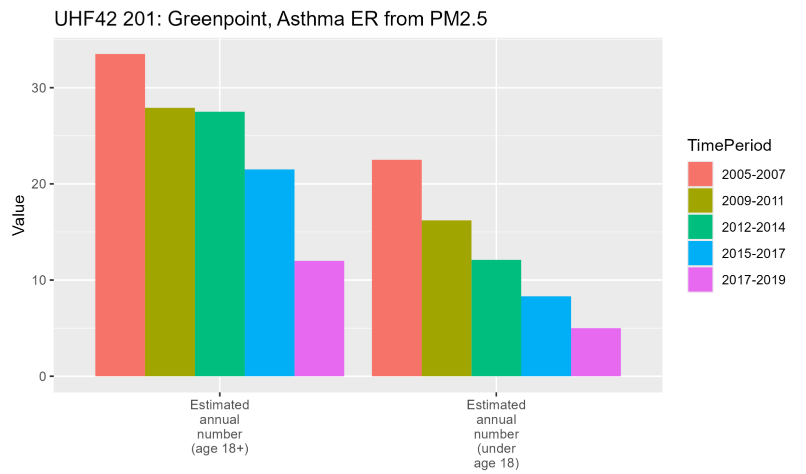


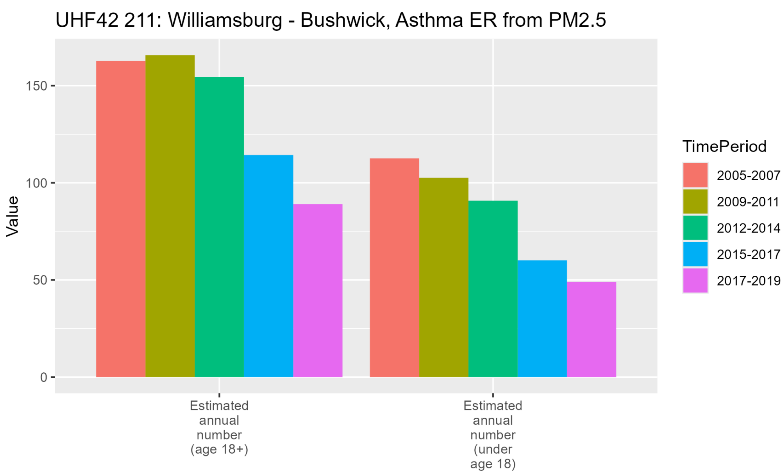
UHF42 107: Hunts Point - Mott Haven

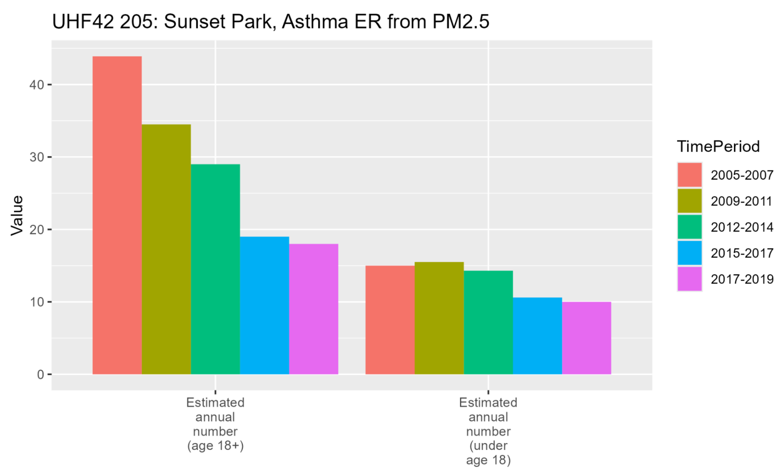


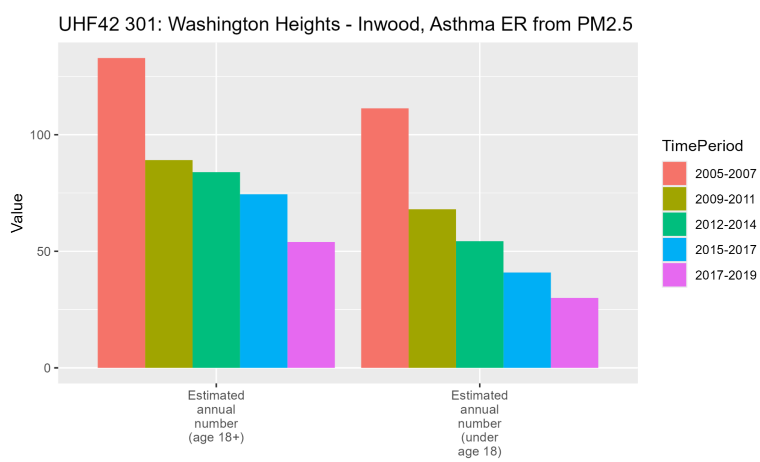
ASTHMA ER visits due to PM2.5

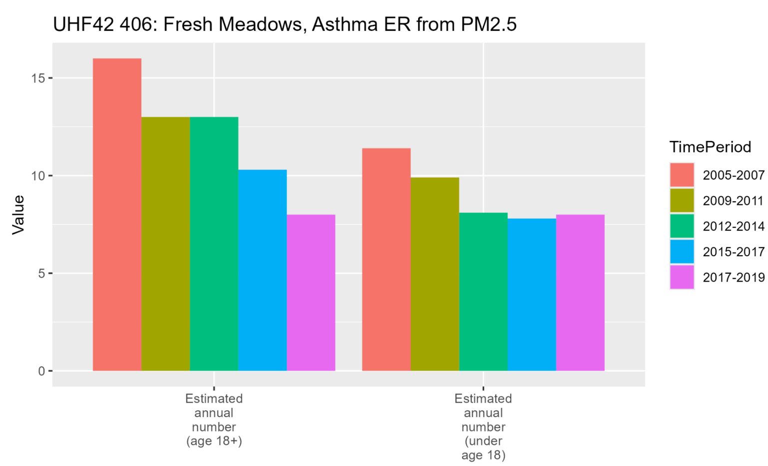


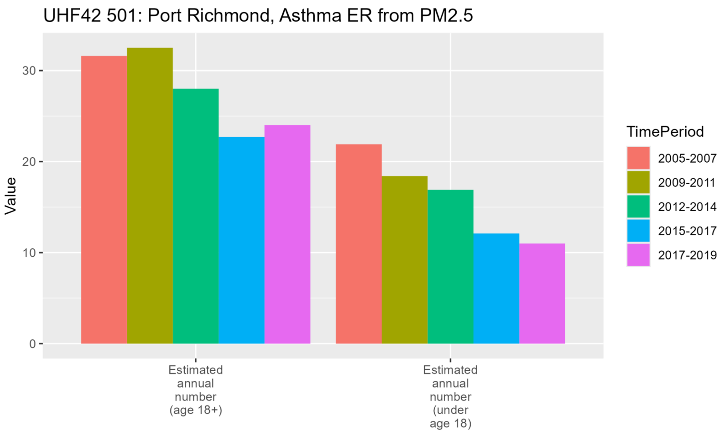


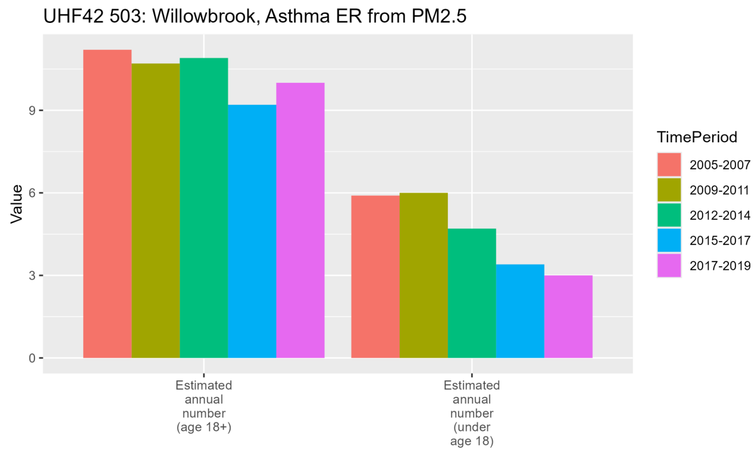


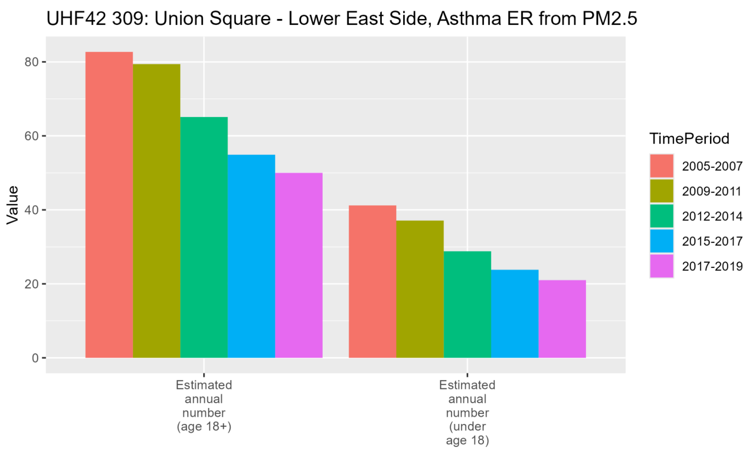




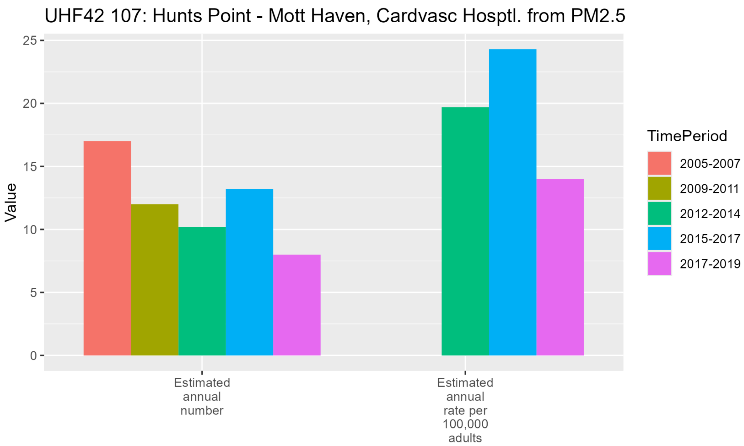


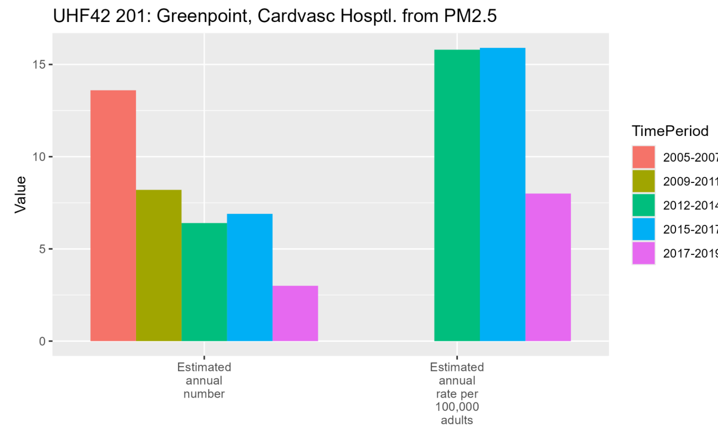

UHF42 501: Port Richmond, Asthma ER from PM2.5
Value
0
10
20
30
Estimated annual number (age 18+)
Estimated annual number (under age 18)
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

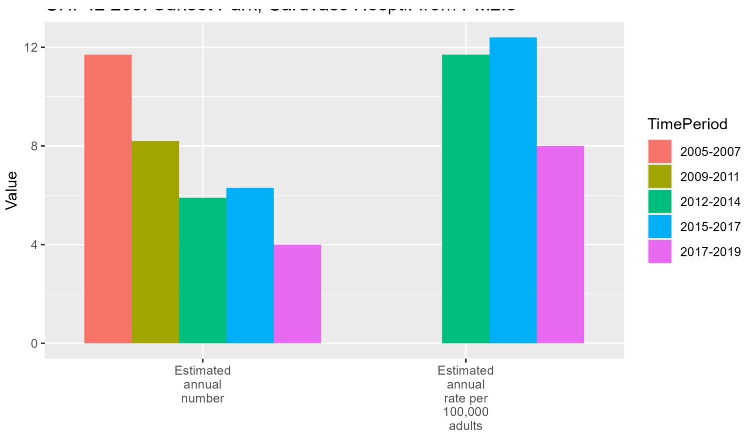

UHF42 503: Willowbrook, Asthma ER from PM2.5
Value
0
3
6
9
Estimated annual number (age 18+)
Estimated annual number (under age 18)
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

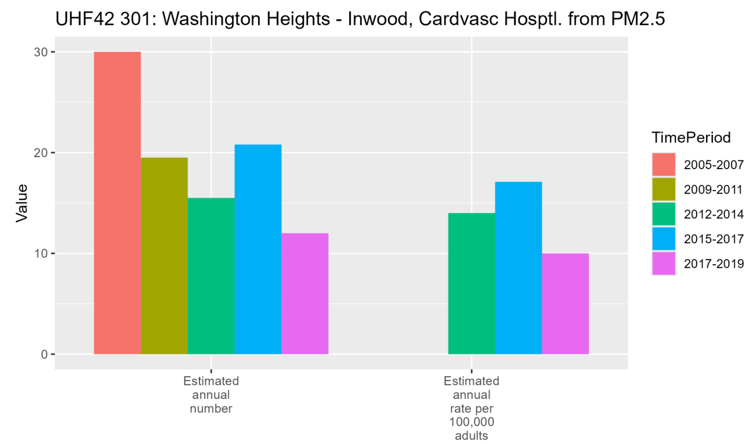

UHF42 309: Union Square - Lower East Side, Asthma ER from PM2.5
Value
0
20
40
60
80
Estimated annual number (age 18+)
Estimated annual number (under age 18)
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

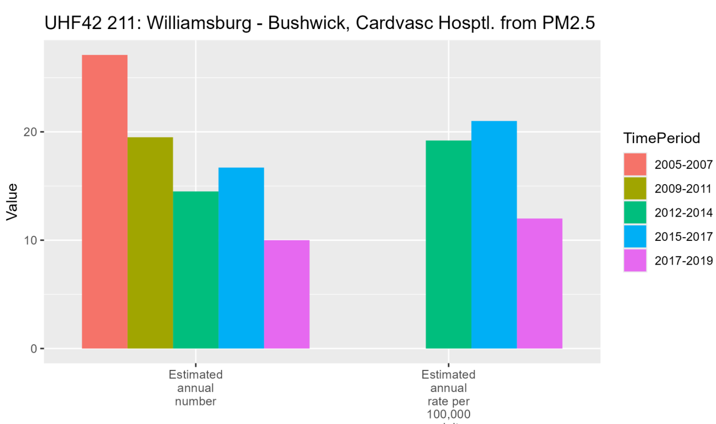
CARDIOVASCULAR hospital visits due to PM2.5

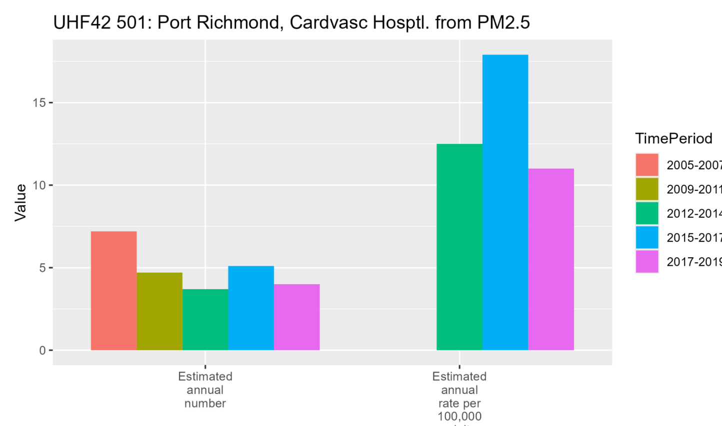


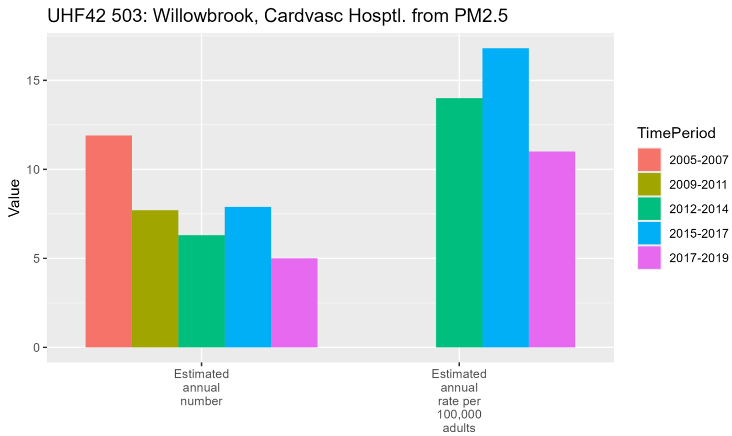


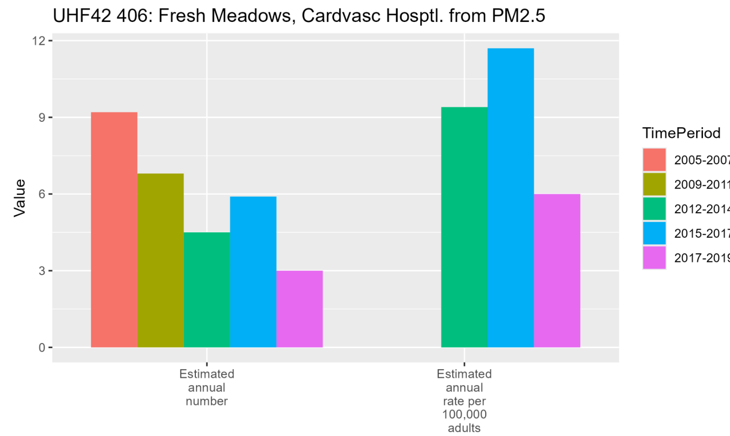




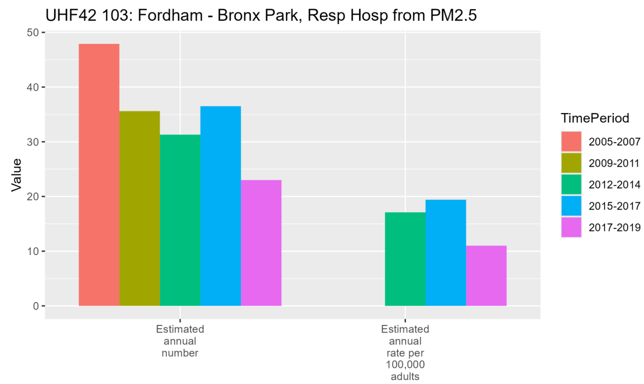


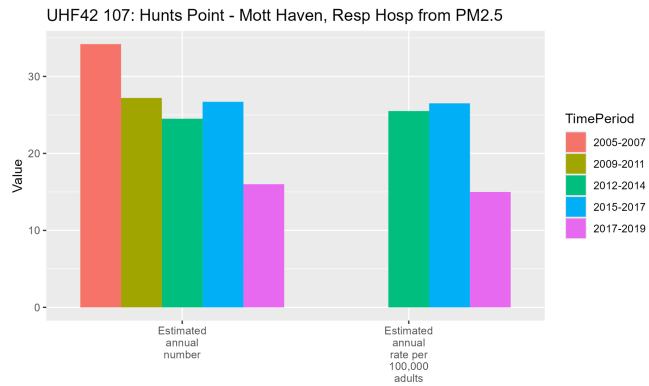


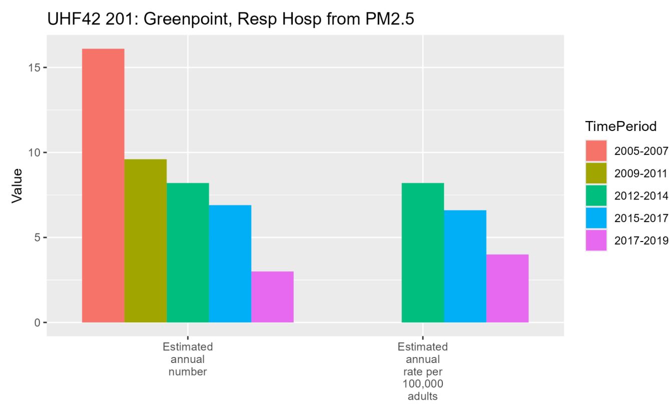

UHF42 503: Willowbrook, Cardvasc Hosptl. from PM2.5
Value
0
5
10
15
Estimated annual number
Estimated annual rate per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

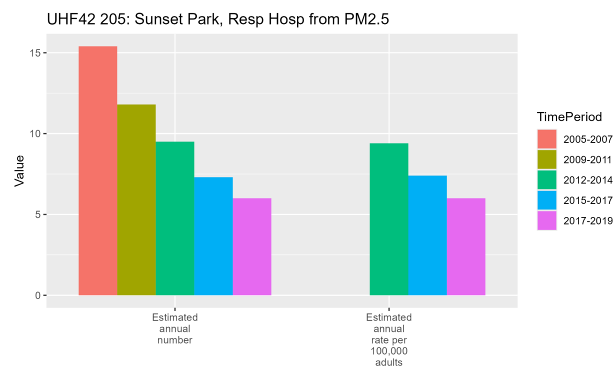

UHF42 406: Fresh Meadows, Cardvasc Hosptl. from PM2.5
Value
0
3
6
9
12
Estimated annual number
Estimated annual rate per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

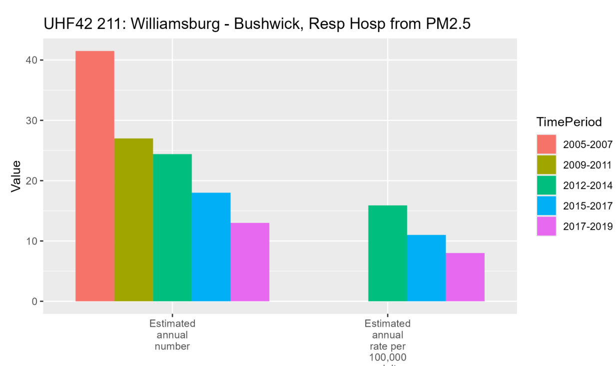
RESPIRATORY hospitalizations due to PM2.5 (age 20+)

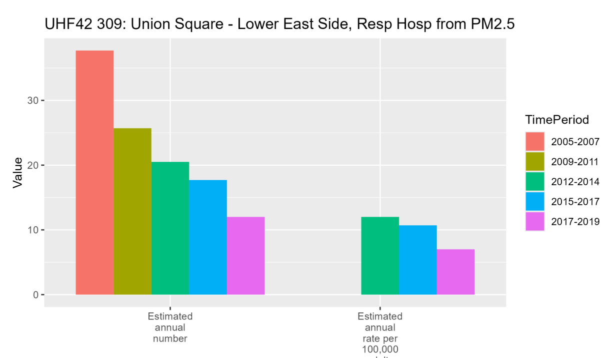


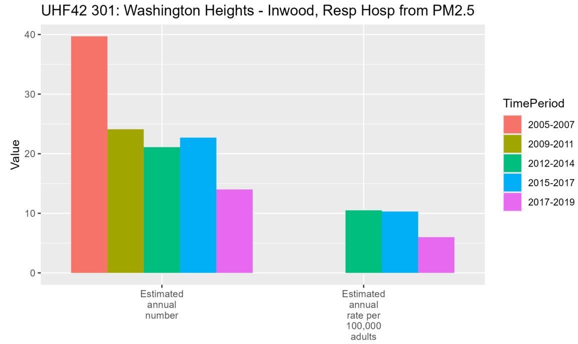


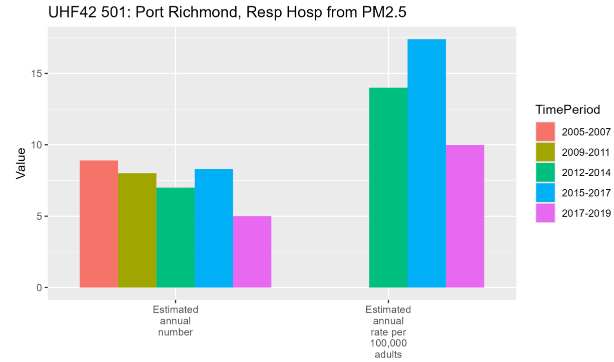


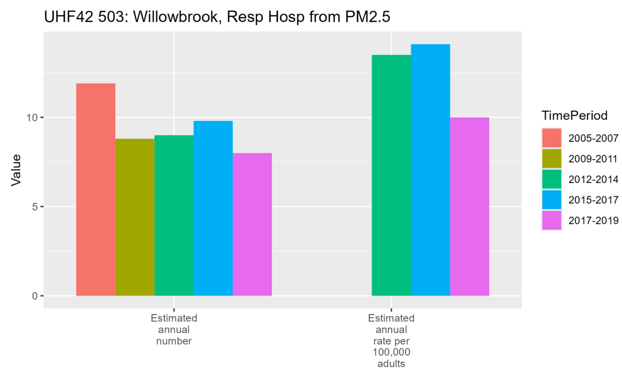


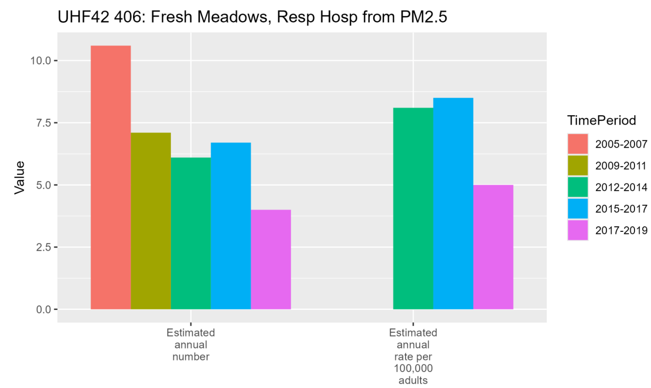




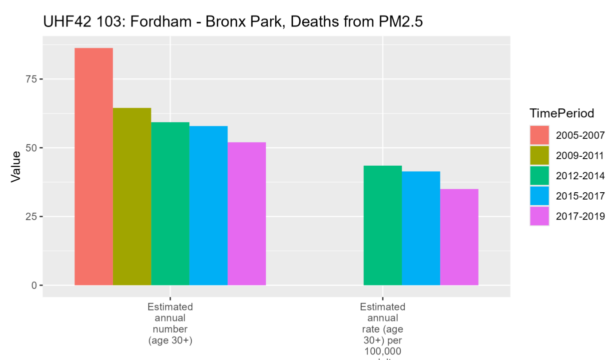


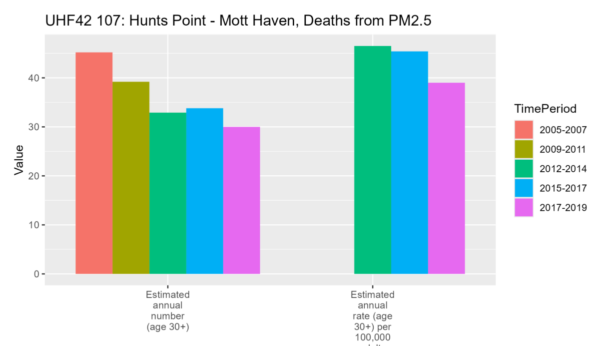


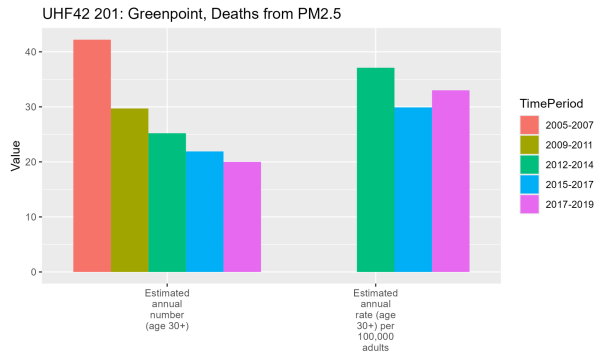


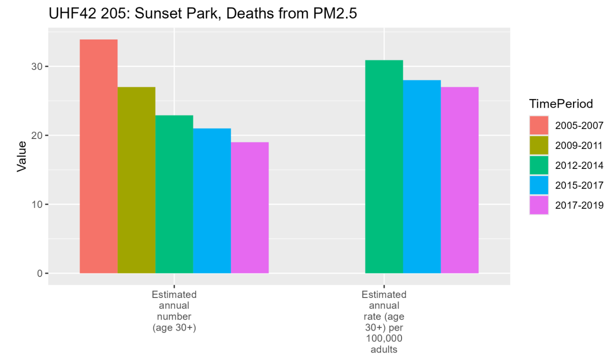


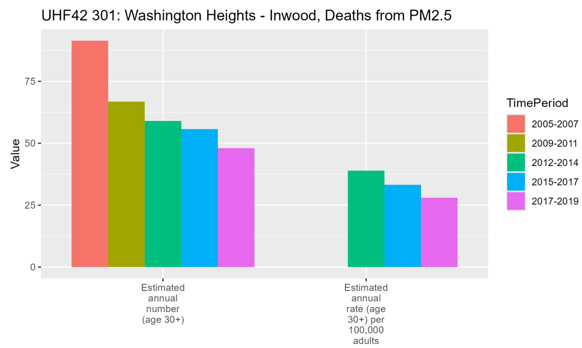
DEATHS due to PM2.5

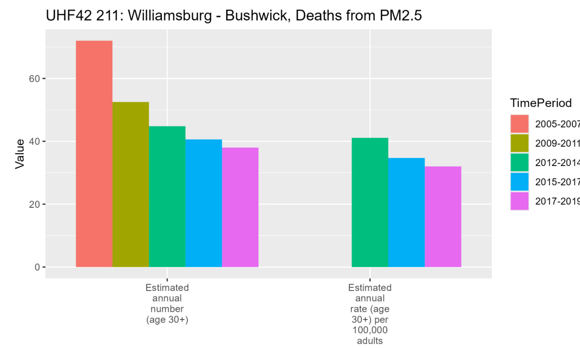


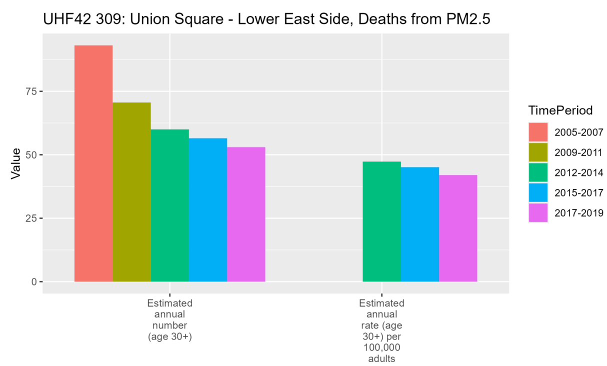


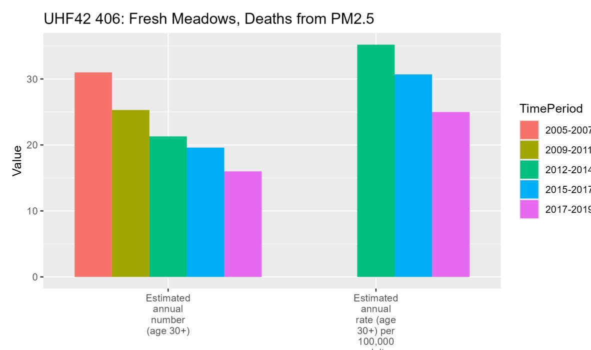

UHF42 201: Greenpoint, Deaths from PM2.5
Value
0
10
20
30
40
Estimated annual number (age 30+)
Estimated annual rate (age 30+) per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

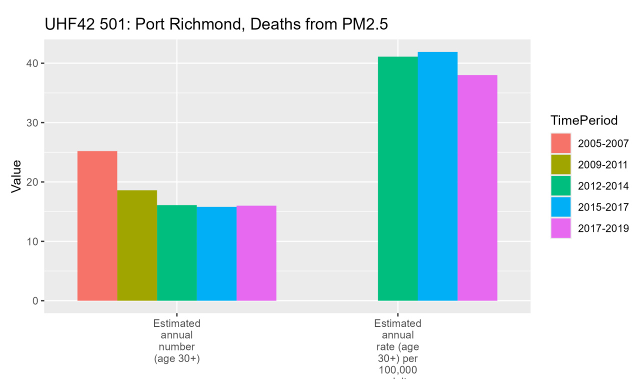

UHF42 205: Sunset Park, Deaths from PM2.5
Value
0
10
20
30
Estimated annual number (age 30+)
Estimated annual rate (age 30+) per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019


UHF42 301: Washington Heights - Inwood, Deaths from PM2.5
Value
0
25
50
75
Estimated annual number (age 30+)
Estimated annual rate (age 30+) per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

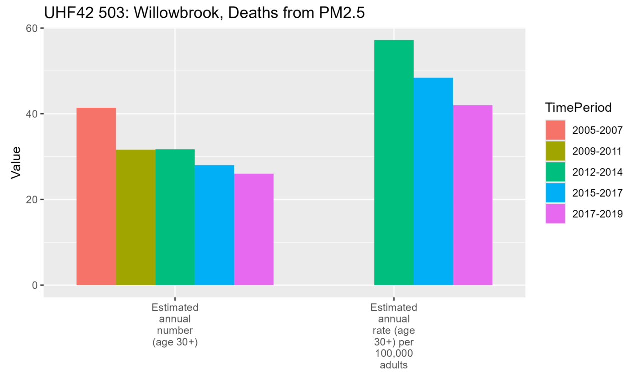

UHF42 211: Williamsburg - Bushwick, Deaths from PM2.5
Value
0
20
40
60
Estimated annual number (age 30+)
Estimated annual rate (age 30+) per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

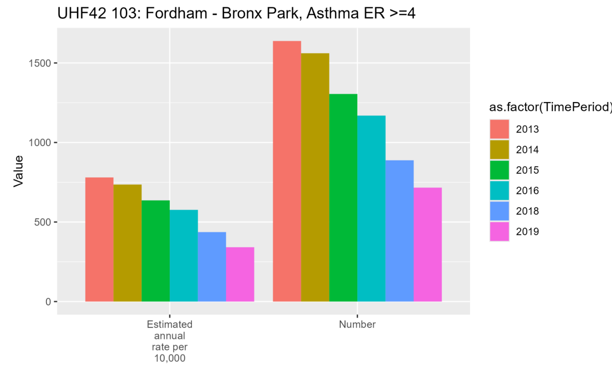

UHF42 309: Union Square - Lower East Side, Deaths from PM2.5
Value
0
25
50
75
Estimated annual number (age 30+)
Estimated annual rate (age 30+) per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

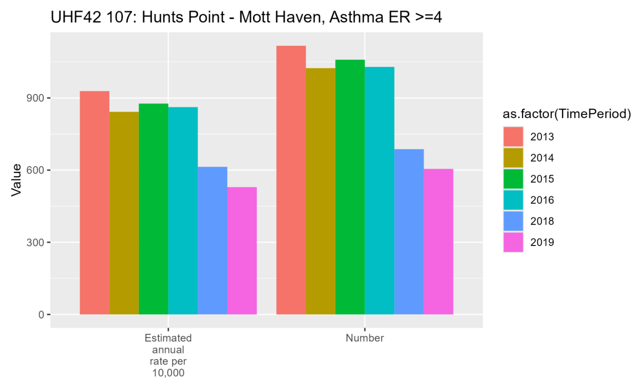

UHF42 406: Fresh Meadows, Deaths from PM2.5
Value
0
10
20
30
Estimated annual number (age 30+)
Estimated annual rate (age 30+) per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

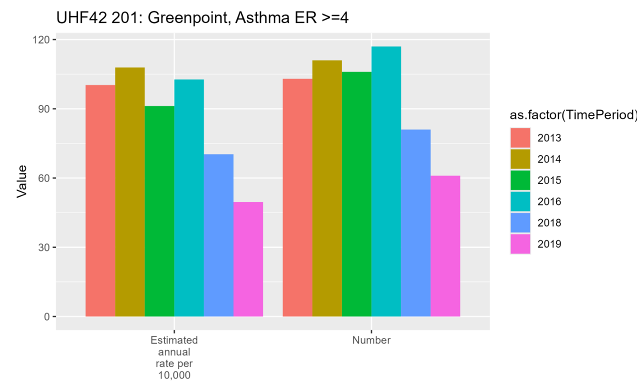

UHF42 501: Port Richmond, Deaths from PM2.5
Value
0
10
20
30
40
Estimated annual number (age 30+)
Estimated annual rate (age 30+) per 100,000 adults
TimePeriod
2005-2007
2009-2011
2012-2014
2015-2017
2017-2019

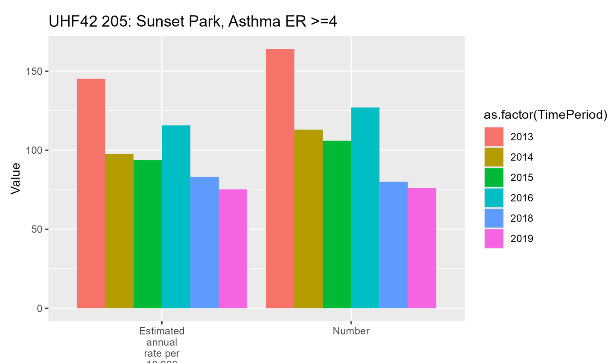
ASTHMA Emergency Department visits (4 and under)

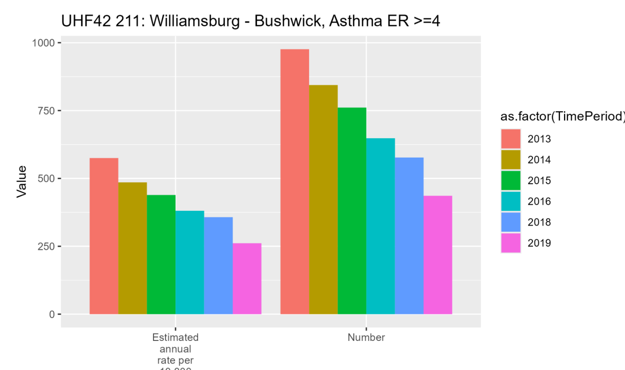




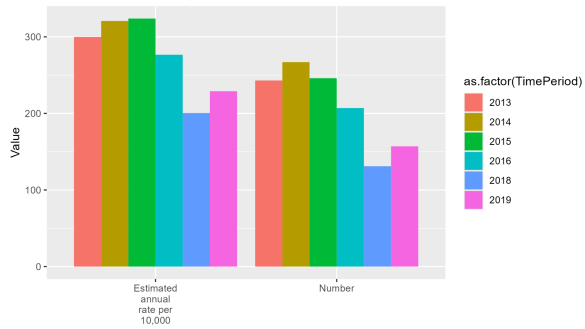




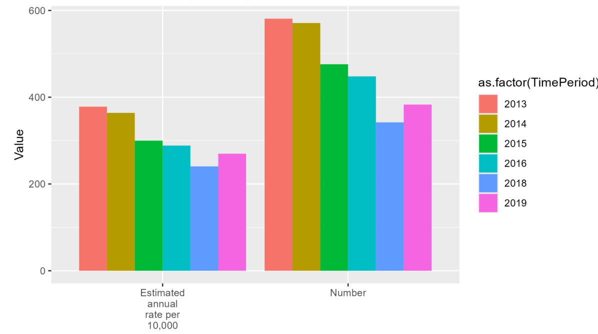




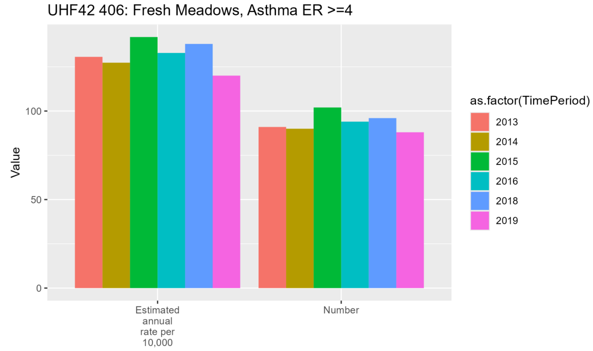
UHF42 309: Union Square - Lower East Side, Asthma ER >=4



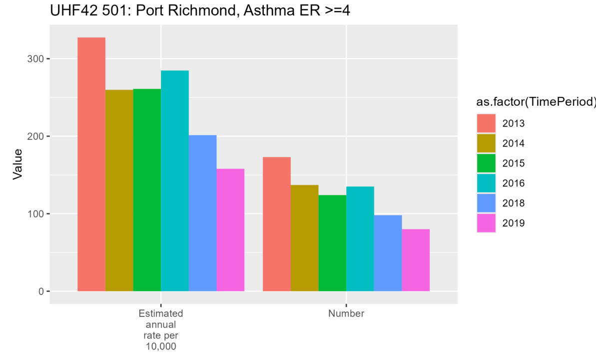
UHF42 301: Washington Heights - Inwood, Asthma ER >=4



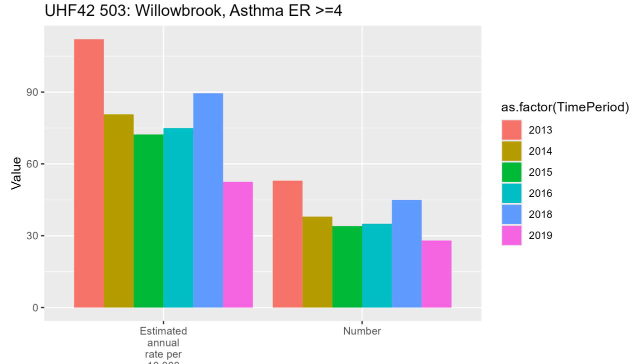
UHF42 406: Fresh Meadows, Asthma ER >=4



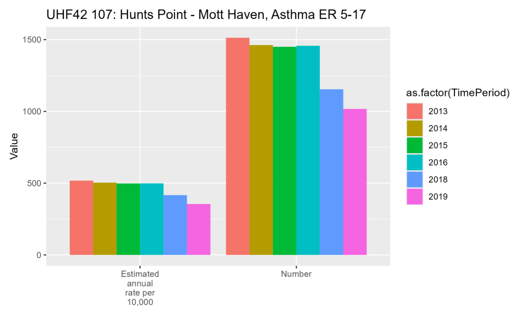
UHF42 501: Port Richmond, Asthma ER >=4

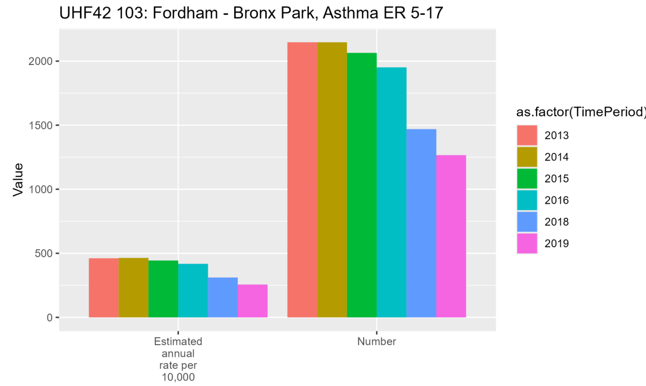


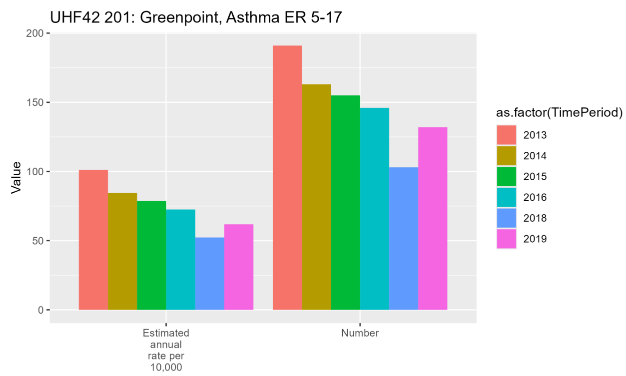
UHF42 503: Willowbrook, Asthma ER >=4

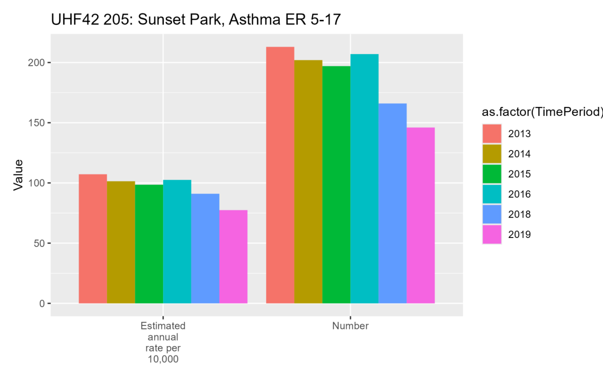


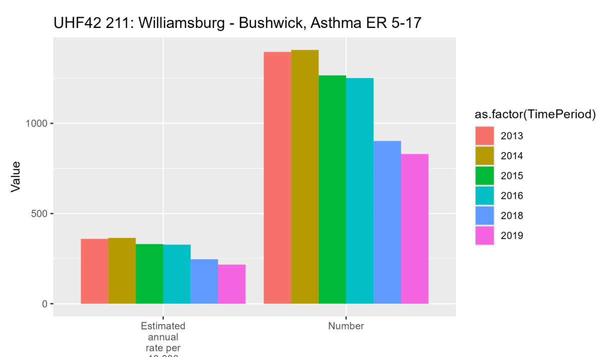
ASTHMA Emergency Department visits (5-17)

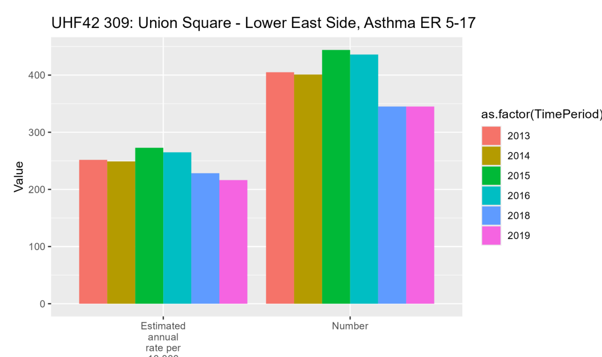


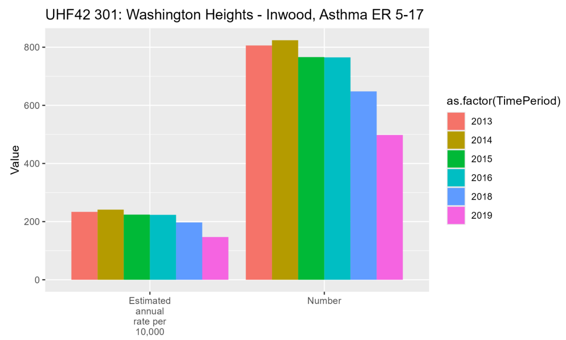


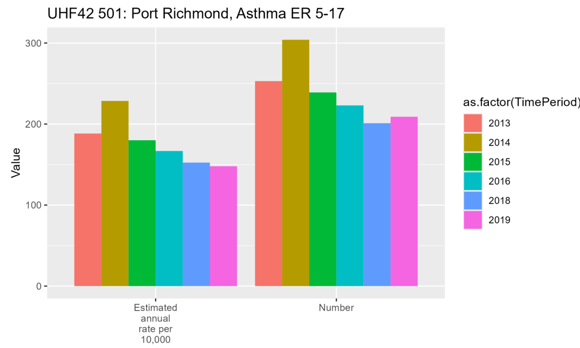


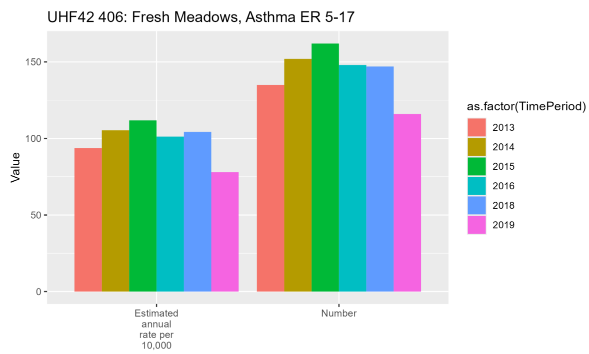


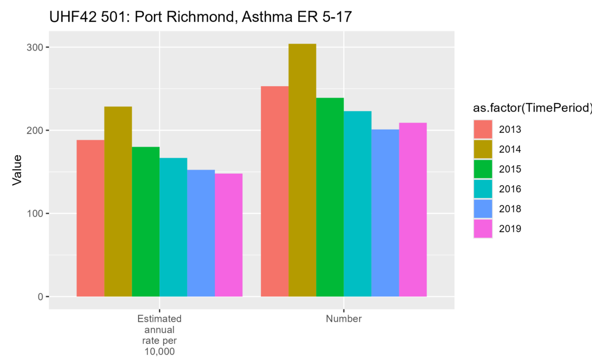


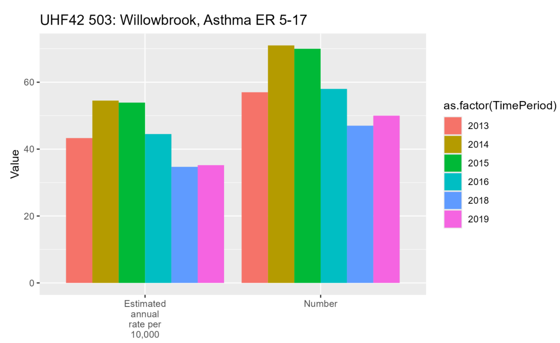



UHF42 301: Washington Heights - Inwood, Asthma ER 5-17
Value
0
200
400
600
800
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

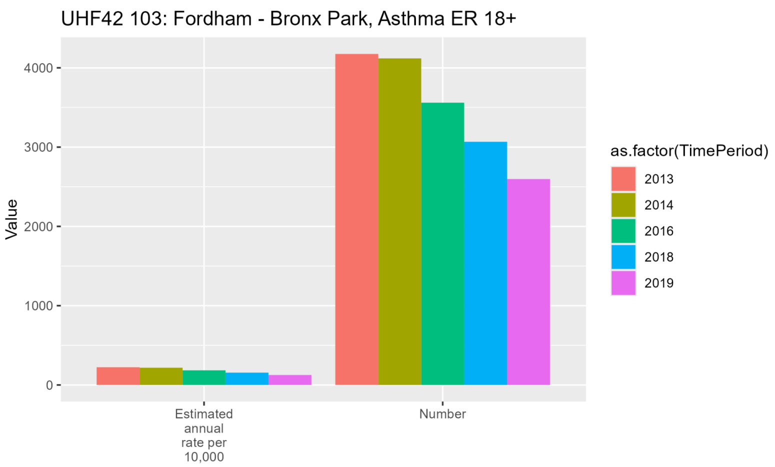

UHF42 501: Port Richmond, Asthma ER 5-17
Value
0
100
200
300
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

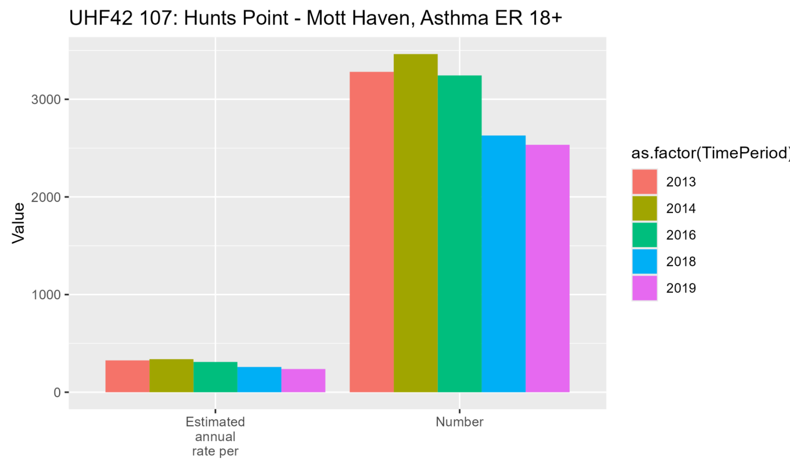

UHF42 406: Fresh Meadows, Asthma ER 5-17
Value
0
50
100
150
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

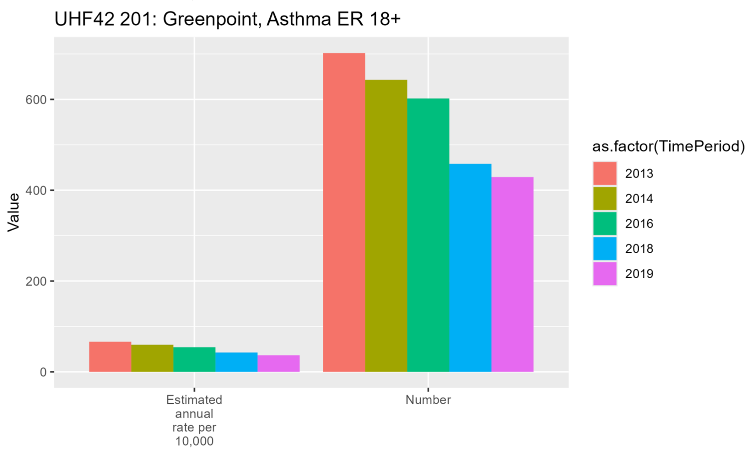

UHF42 501: Port Richmond, Asthma ER 5-17
Value
0
100
200
300
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

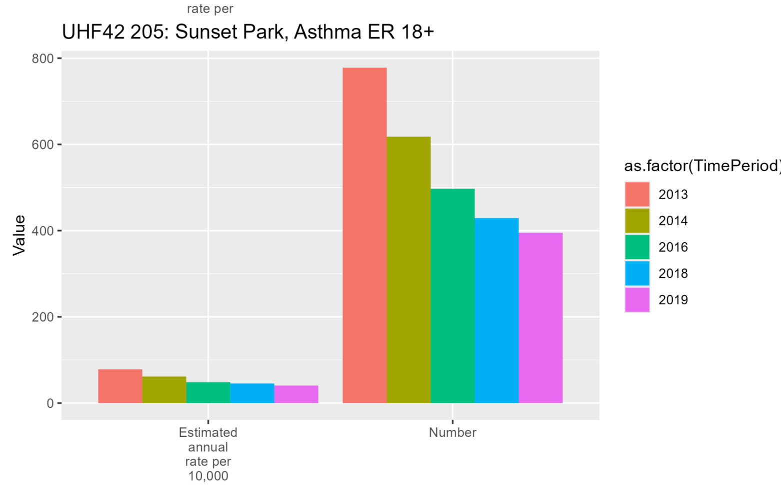

UHF42 503: Willowbrook, Asthma ER 5-17
Value
0
20
40
60
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

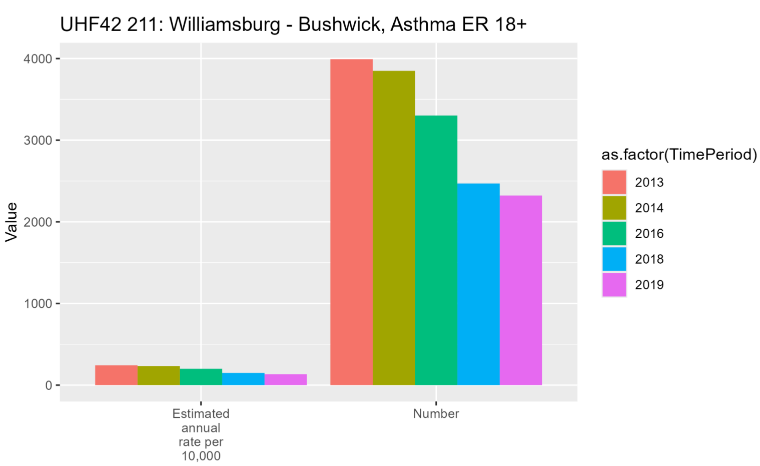
ASTHMA Emergency Department visits (18+)

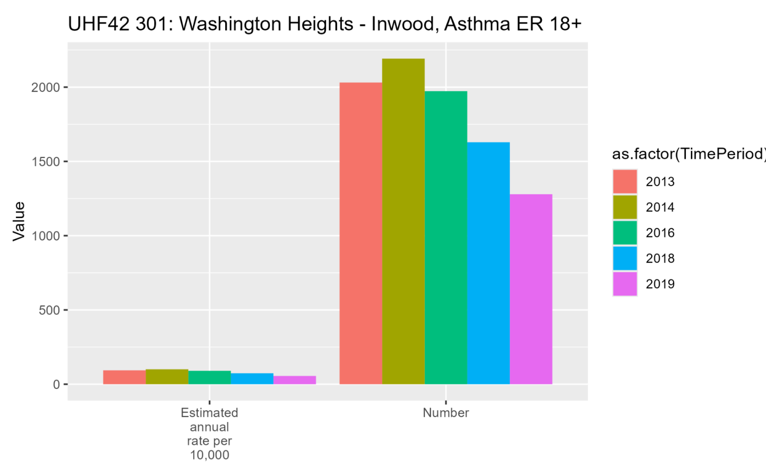


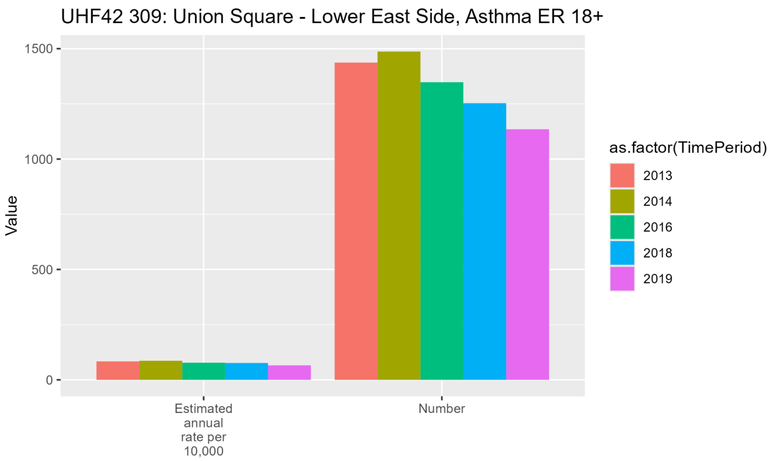


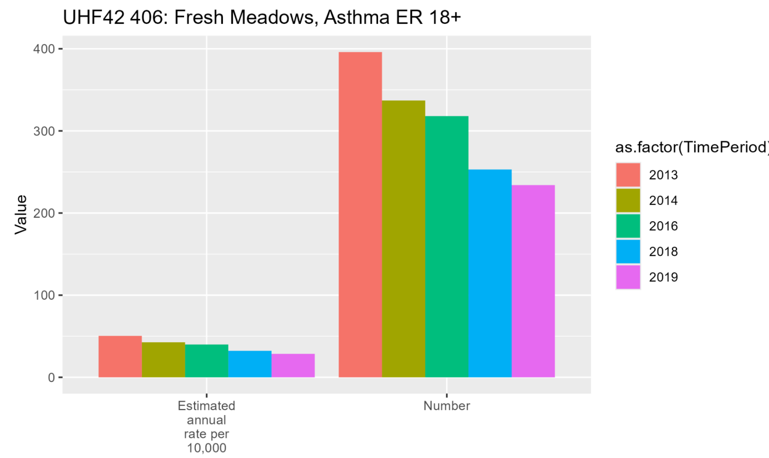


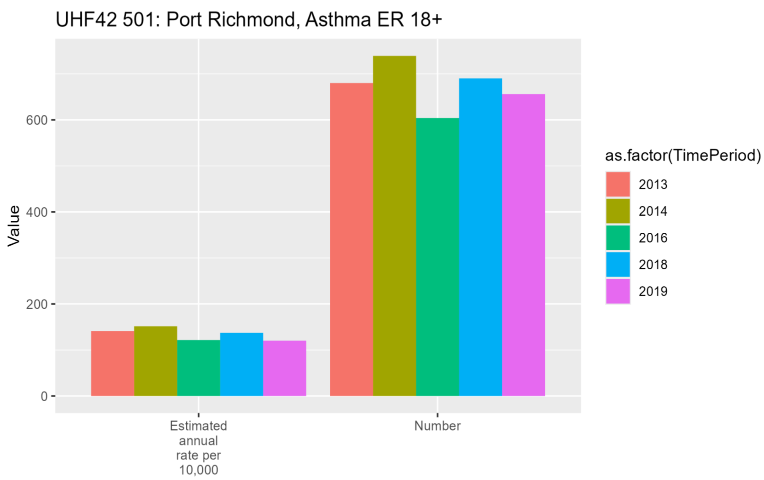


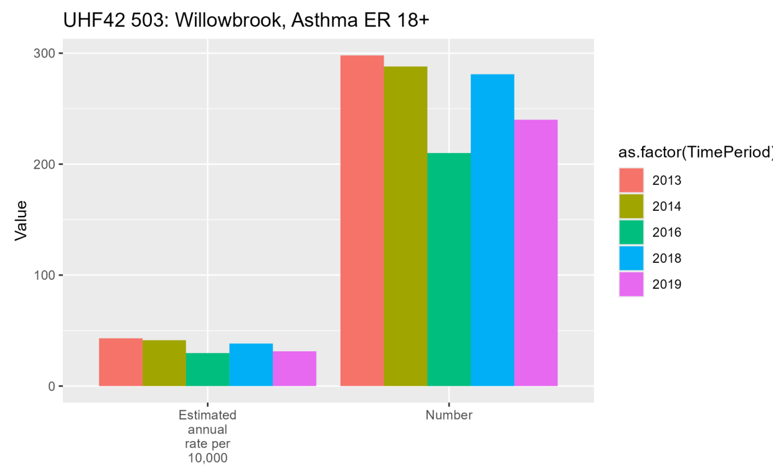




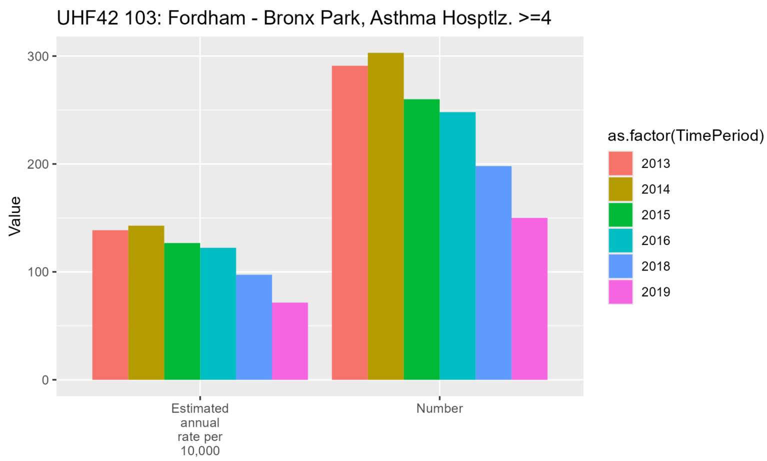

UHF42 309: Union Square - Lower East Side, Asthma ER 18+
Value
1500
1000
500
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

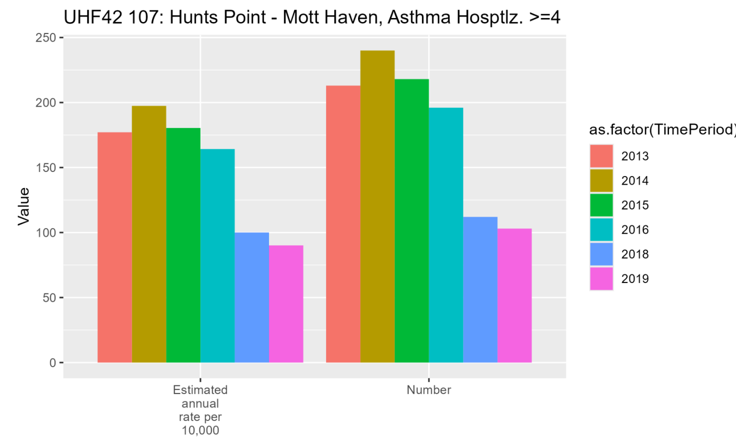

UHF42 406: Fresh Meadows, Asthma ER 18+
Value
400
300
200
100
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

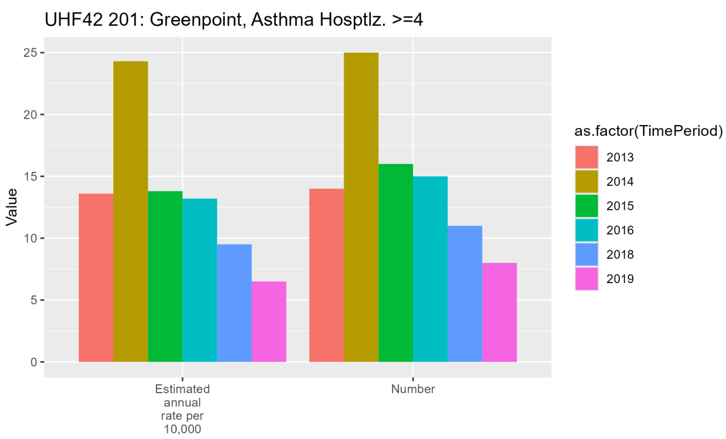

UHF42 501: Port Richmond, Asthma ER 18+
Value
600
400
200
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

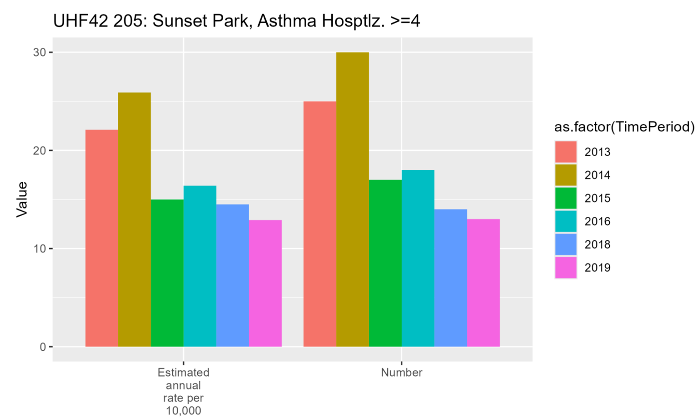

UHF42 503: Willowbrook, Asthma ER 18+
Value
300
200
100
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

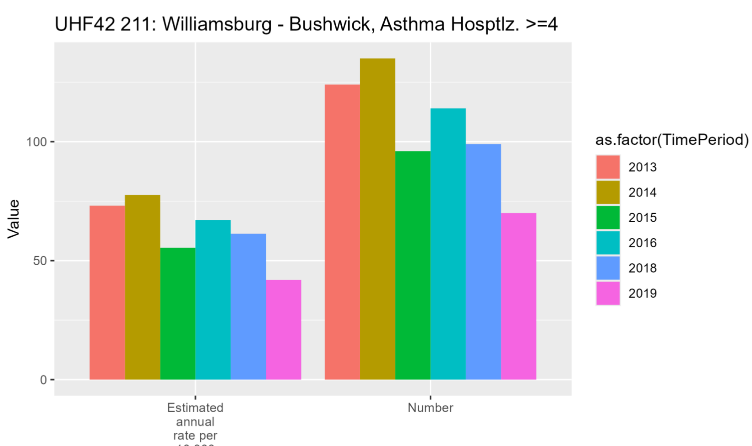
ASTHMA hospitalizations (4 and under)

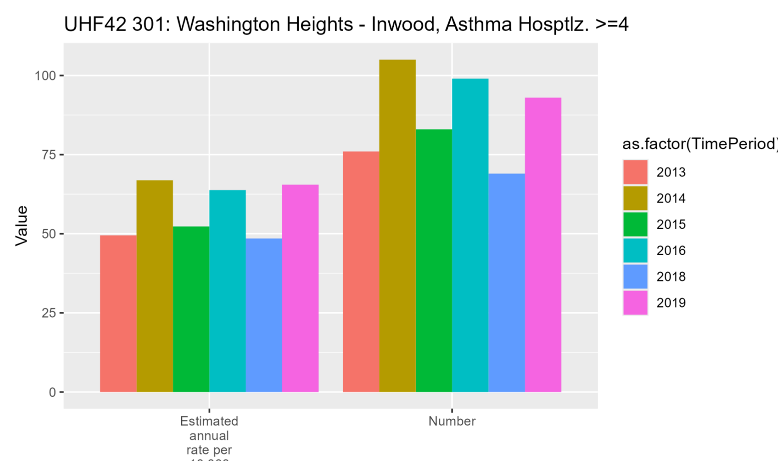


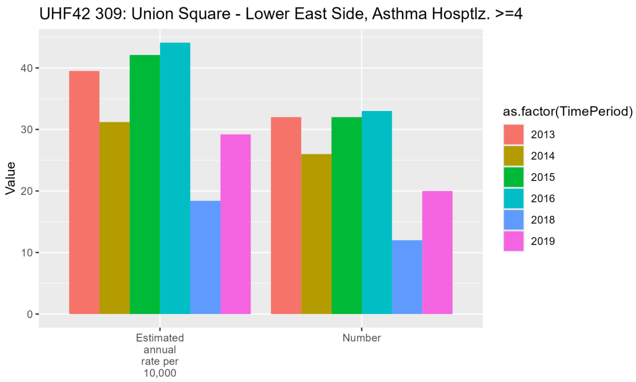


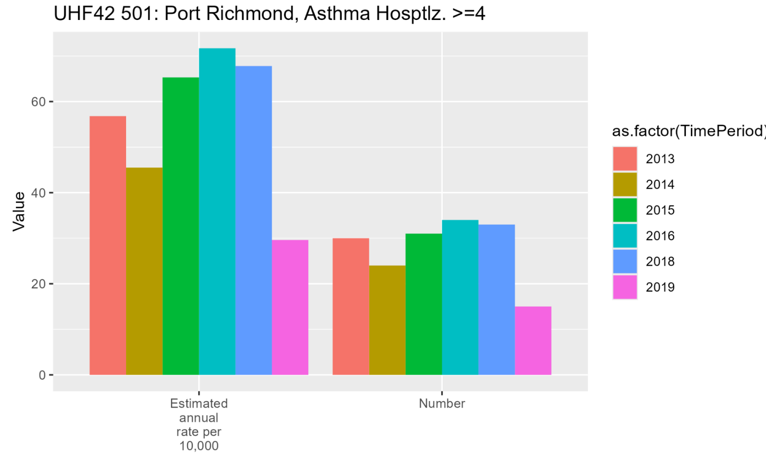


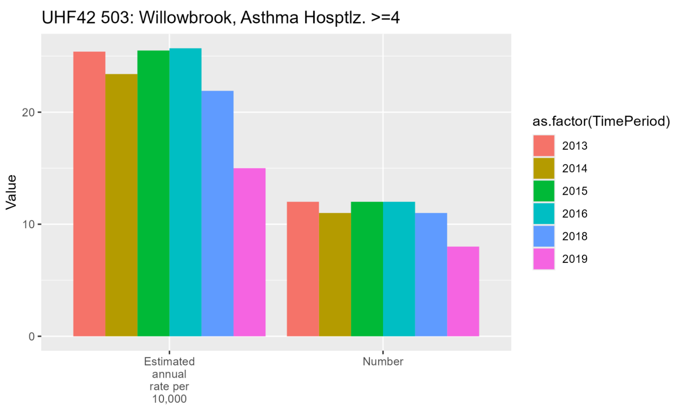




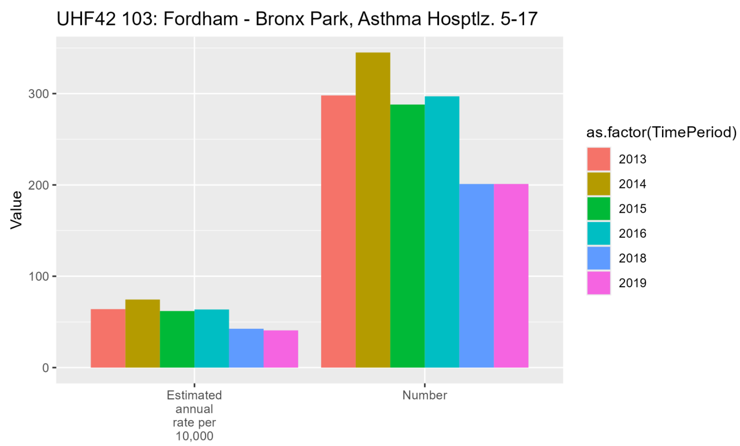


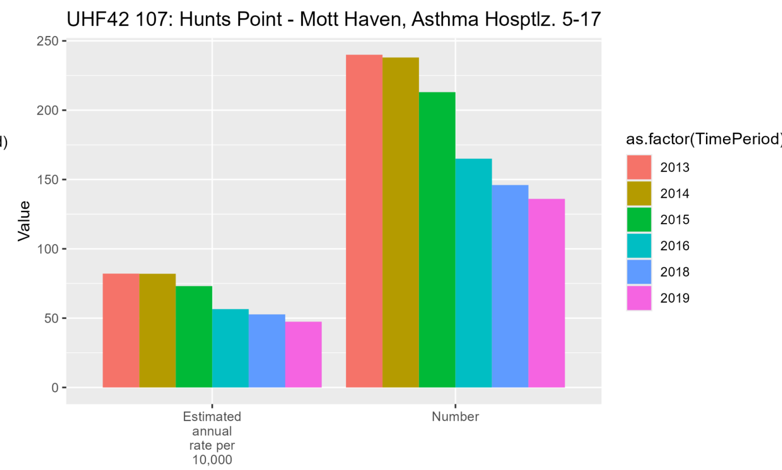

UHF42 309: Union Square - Lower East Side, Asthma Hosptlz. >=4
Value
0
10
20
30
40
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

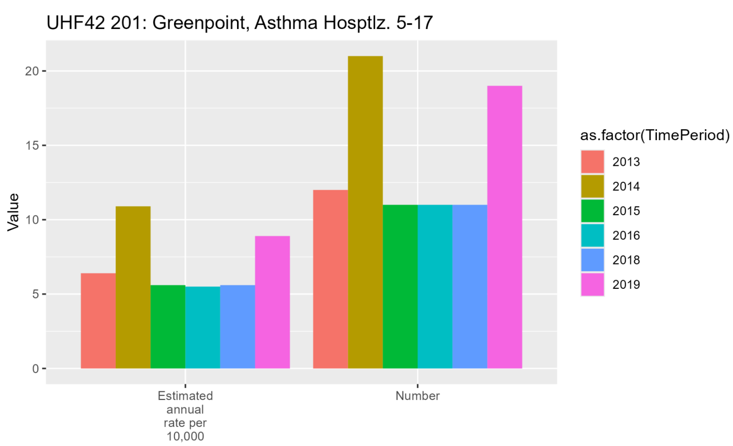

UHF42 501: Port Richmond, Asthma Hosptlz. >=4
Value
0
20
40
60
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

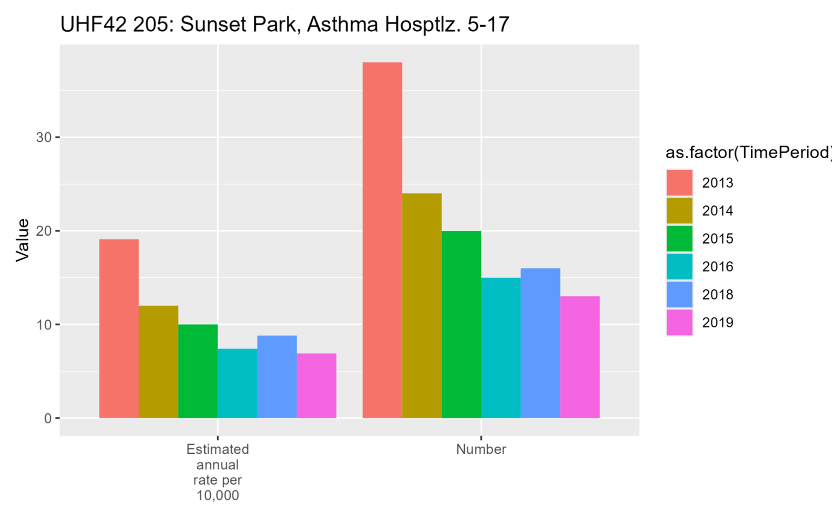

UHF42 503: Willowbrook, Asthma Hosptlz. >=4
Value
0
10
20
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2015
2016
2018
2019

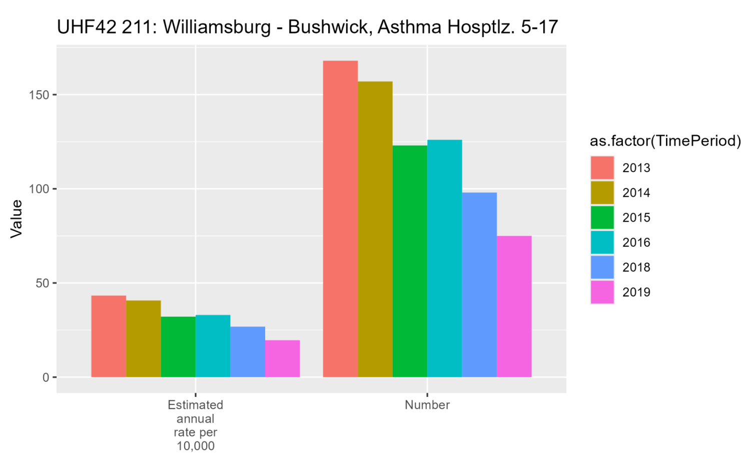
ASTHMA hospitalizations (5 and 17)

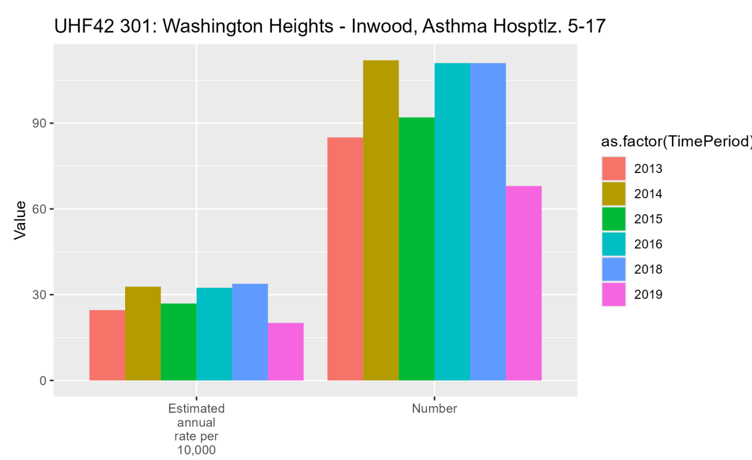




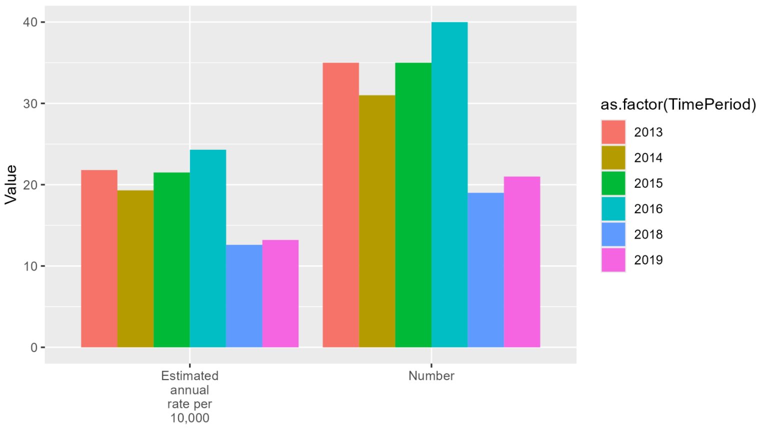




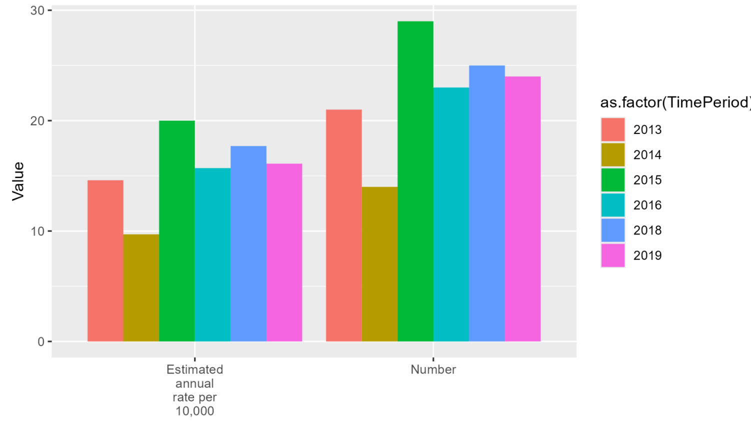




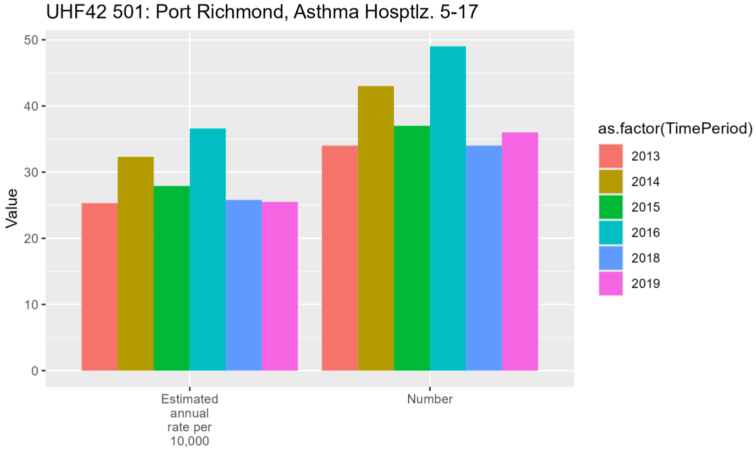
UHF42 309: Union Square - Lower East Side, Asthma Hosptlz. 5-17



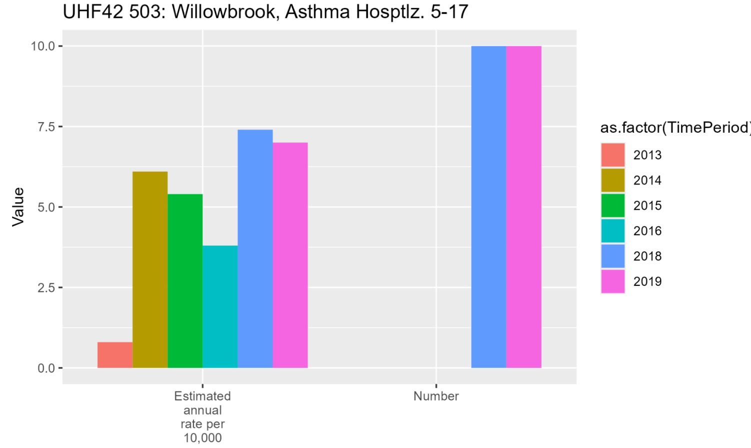
UHF42 406: Fresh Meadows, Asthma Hosptlz. 5-17



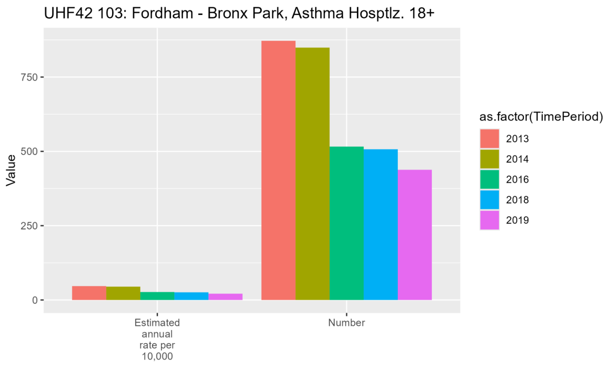
UHF42 501: Port Richmond, Asthma Hosptlz. 5-17

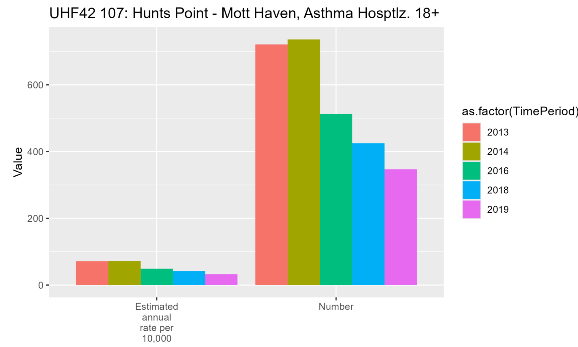


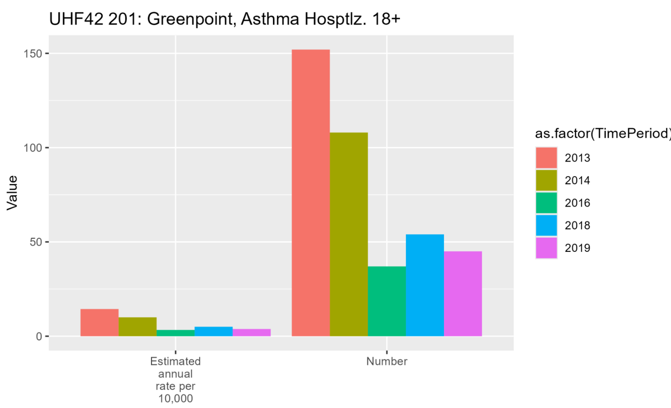
UHF42 503: Willowbrook, Asthma Hosptlz. 5-17

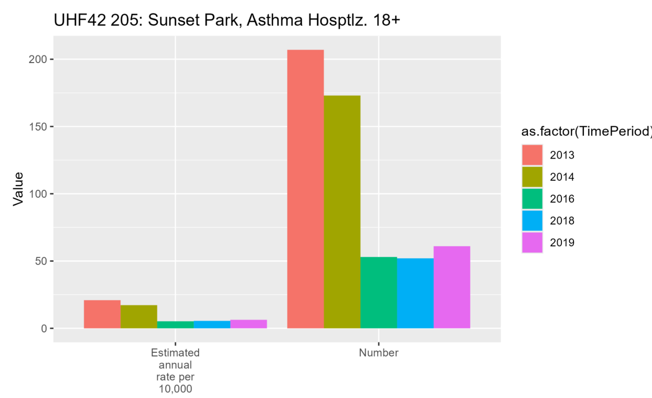


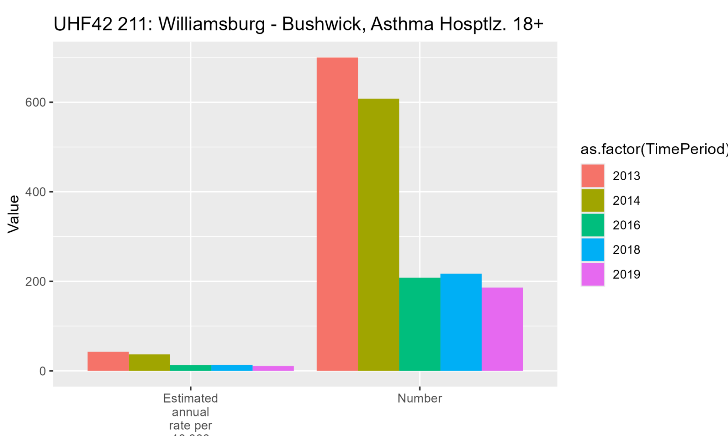
ASTHMA hospitalizations (18+)

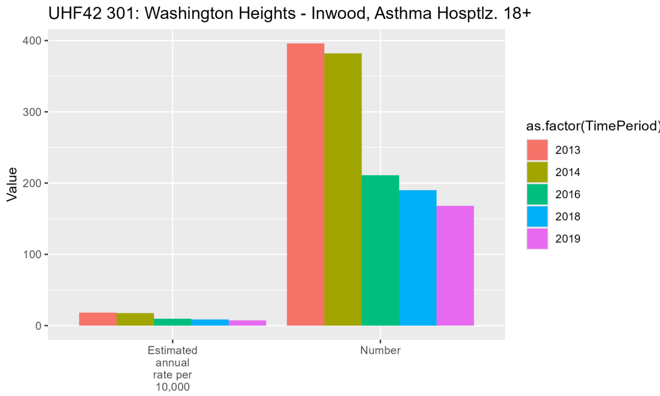


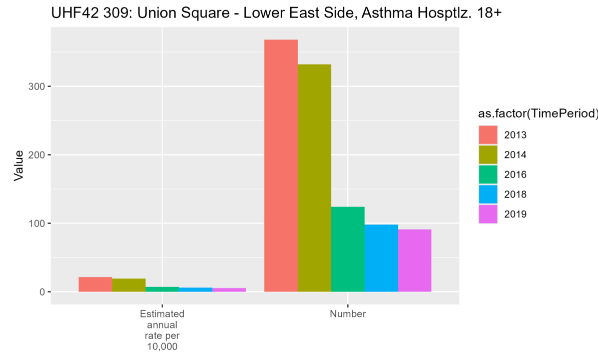


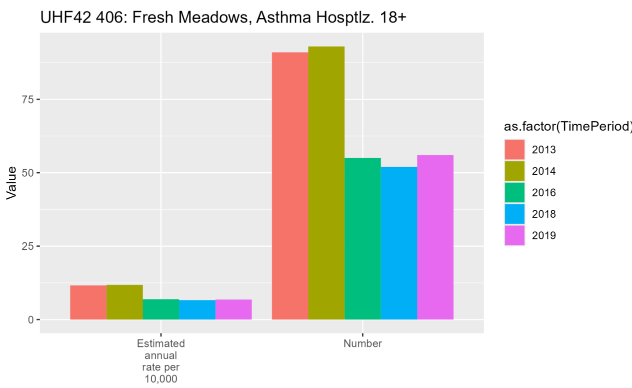


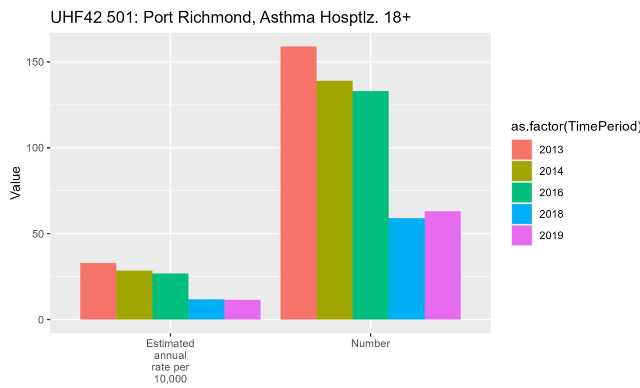


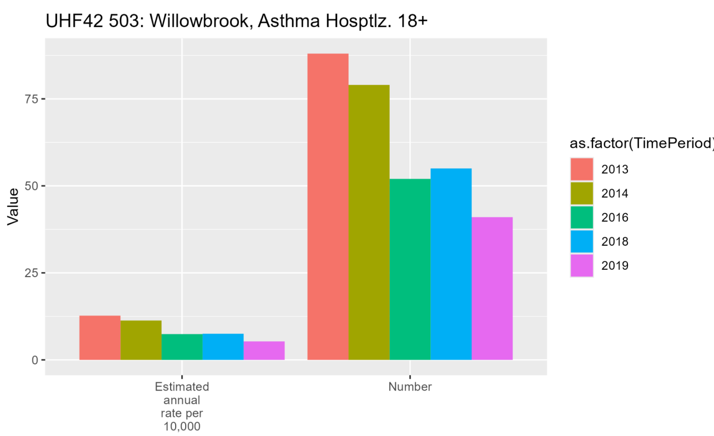



UHF42 301: Washington Heights - Inwood, Asthma Hosptlz. 18+
Value
400
300
200
100
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

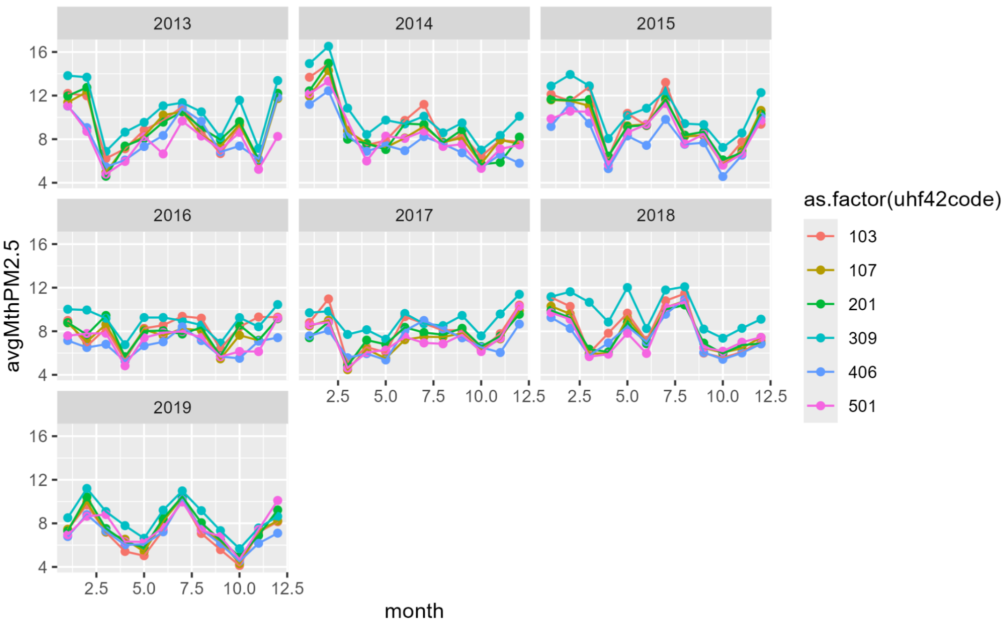

UHF42 309: Union Square - Lower East Side, Asthma Hosptlz. 18+
Value
300
200
100
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

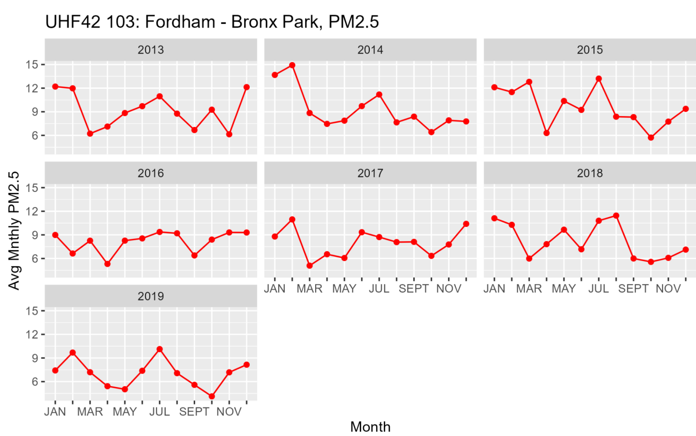

UHF42 406: Fresh Meadows, Asthma Hosptlz. 18+
Value
75
50
25
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

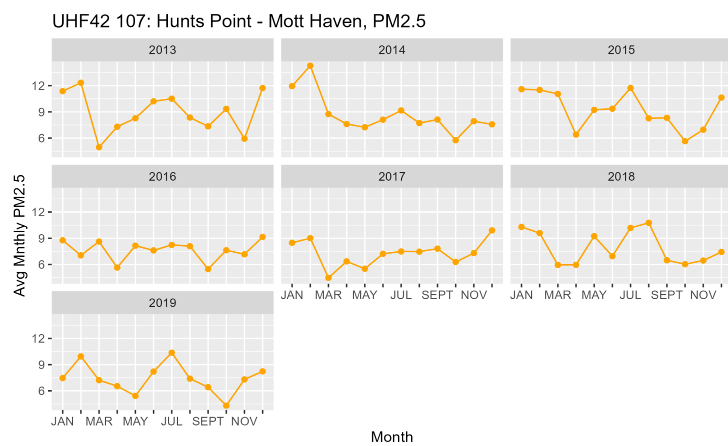

UHF42 501: Port Richmond, Asthma Hosptlz. 18+
Value
150
100
50
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

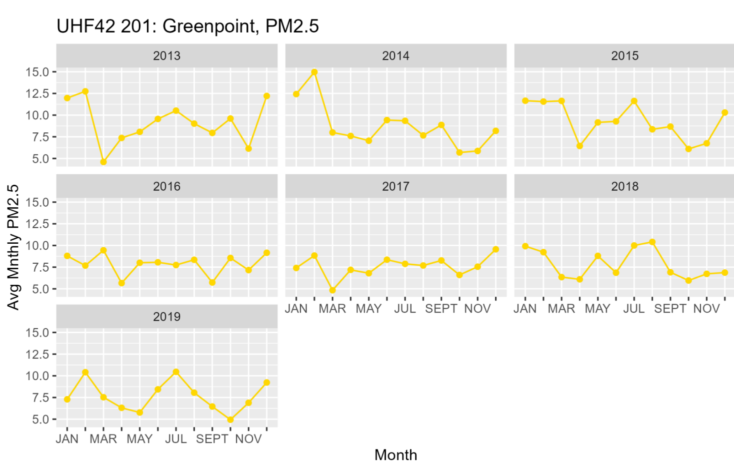

UHF42 503: Willowbrook, Asthma Hosptlz. 18+
Value
75
50
25
0
Estimated annual rate per 10,000
Number
as.factor(TimePeriod)
2013
2014
2016
2018
2019

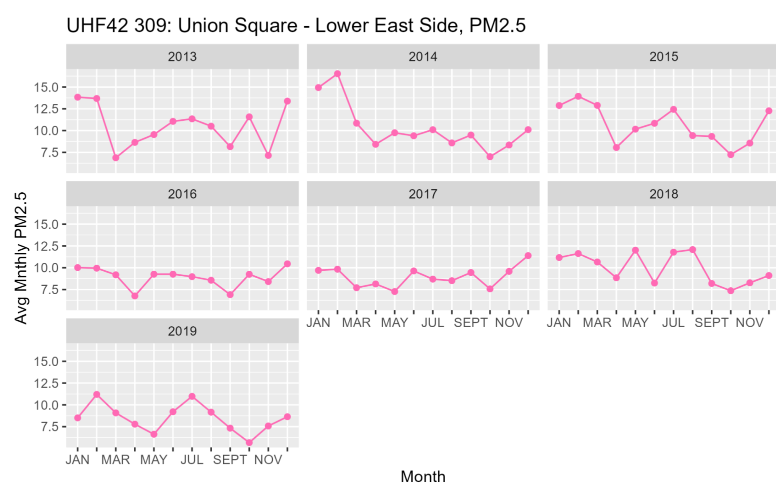
PM2.5 by UHF42 by month

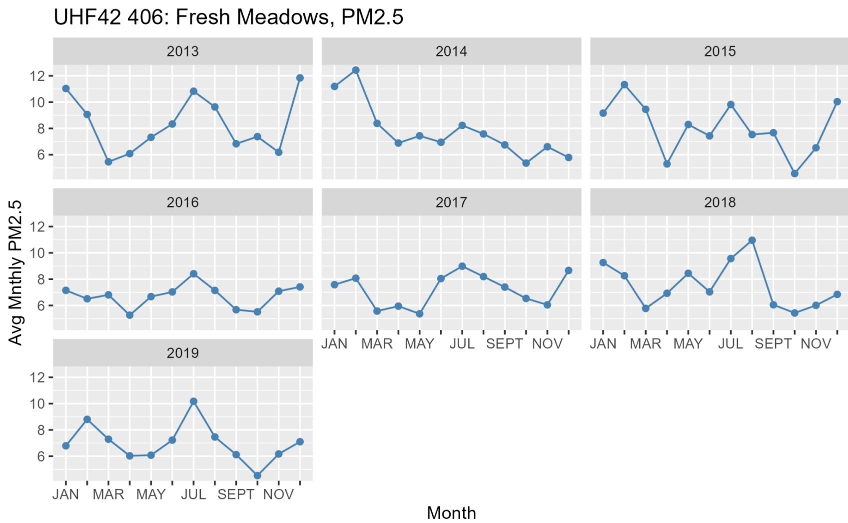


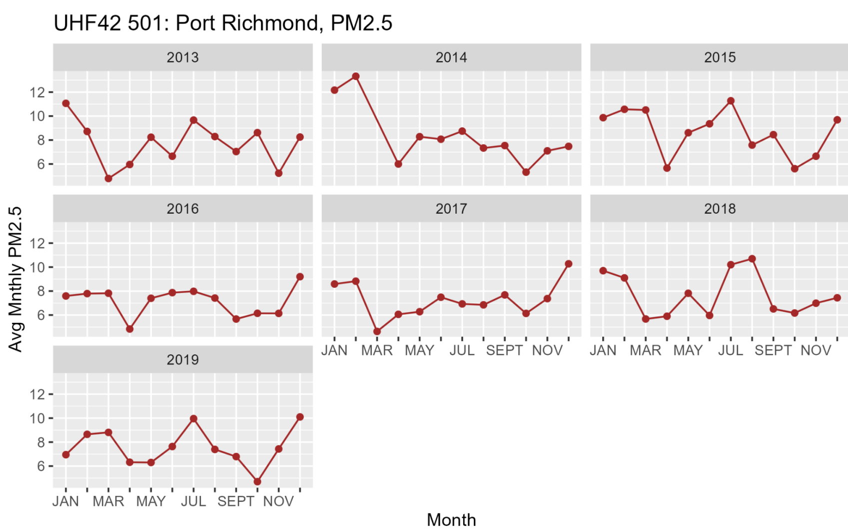




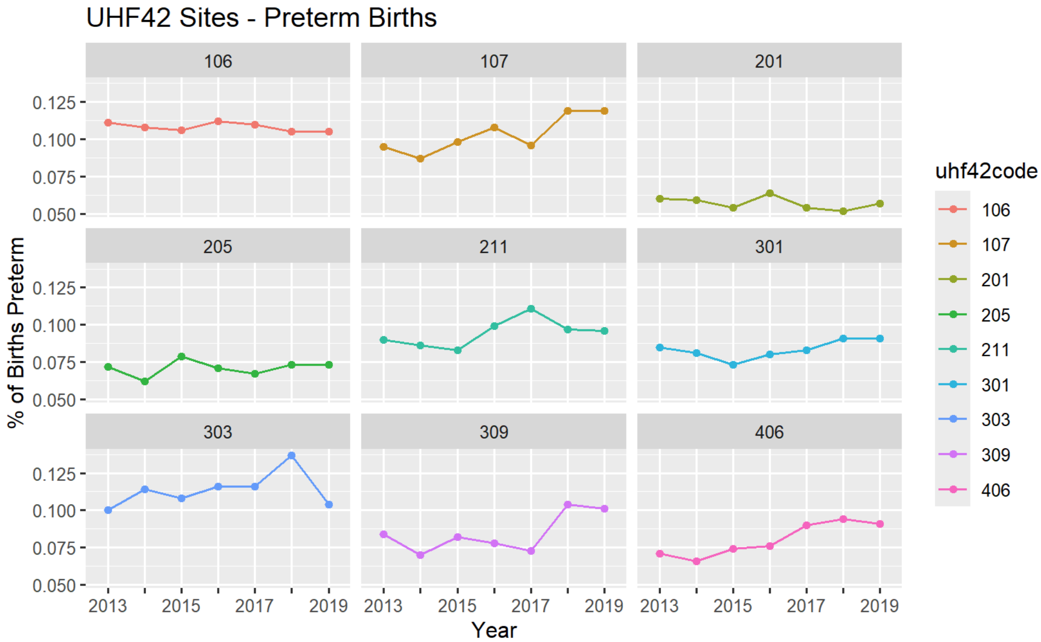




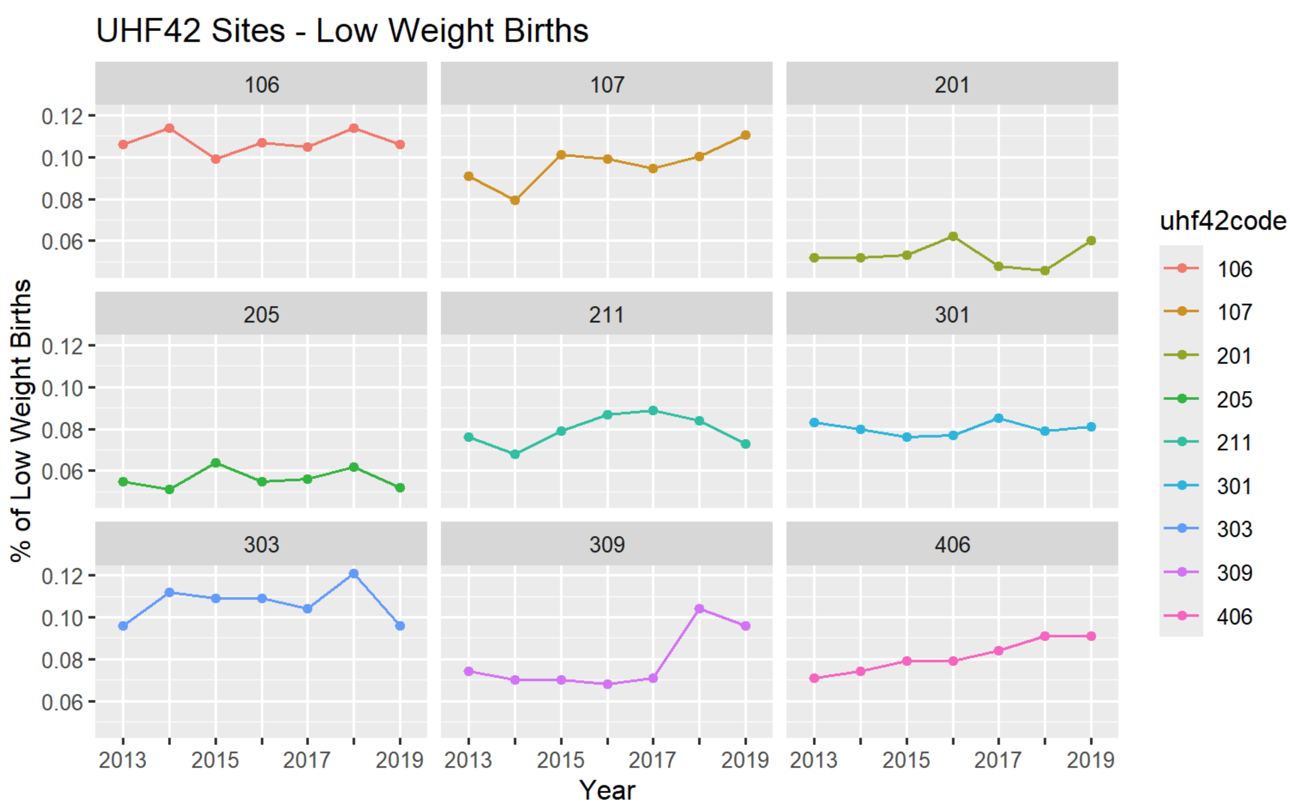

UHF42 406: Fresh Meadows, PM2.5
2013
2014
2015
2016
2017
2018
2019
Avg Mnthly PM2.5
12
10
8
6
JAN MAR MAY JUL SEPT NOV
Month


UHF42 501: Port Richmond, PM2.5
2013
2014
2015
2016
2017
2018
2019
Avg Mnthly PM2.5
12
10
8
6
JAN MAR MAY JUL SEPT NOV
Month

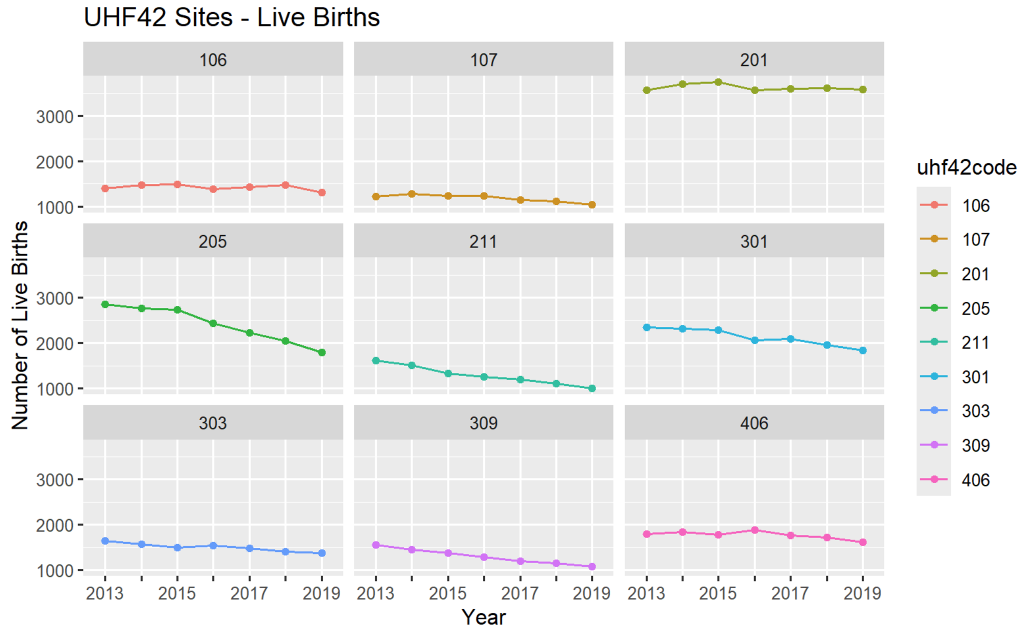
Pre-Term Births



Low Birth Weight Rates



Live Birth Numbers



Live Births to Mothers on Medicaid