A Visual Exploration of Air Pollution Across New York City

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***Abstract*— Air pollution poses significant health risks to urban populations, with varying exposure levels and vulnerabilities across neighborhoods. This project aims to develop a visualization dashboard that analyzes air quality indicators across New York City, using comprehensive surveillance data from NYC Open Data. The dashboard can feature time series analyses, comparative charts, and thematic maps to highlight trends and disparities in pollutant exposure over time and geography. The goal is to determine where and when the worst air quality areas are occurring and why that is happening.**

I. INTRODUCTION AND RELATED WORK

This project aims to comprehensively analyze New York City's air quality from 2005 to 2022, shedding light on critical trends across neighborhoods. By examining emergency room visits, hospitalizations, and deaths linked to ozone and PM2.5 exposure, alongside data on boiler emissions (nitrogen oxides, PM2.5, and sulfur dioxide), outdoor air toxics (benzene and formaldehyde), nitrogen dioxide, and the miles a vehicle travels annually, we seek to paint a detailed picture of the health impacts of air pollution. The study focuses on the five boroughs—Bronx, Brooklyn, Manhattan, Queens, and Staten Island—paying particular attention to neighborhoods with a history of industrial activity and their potential role in sustaining higher pollution levels. Additionally, we aim to uncover how seasonal variations, such as summer heatwaves or winter inversions, exacerbate air quality issues and affect vulnerable populations. We hypothesize that the air quality during the summer months will worsen due to wildfire season. This analysis will help us understand whether certain communities face a disproportionate burden and how environmental inequalities manifest in an urban landscape. Another hypothesis we plan to investigate is that specific neighborhoods consistently will have higher pollution and, therefore, worse air quality due to close proximity to industrial areas and/or high-traffic zones. Ultimately, our investigations and findings can inform targeted interventions, policy recommendations, and community-driven solutions to improve air quality and protect public health across New York City.

Air pollution and its health impacts have been extensively studied, highlighting its significant consequences for urban populations. Research consistently identifies PM2.5 and ozone as key contributors to respiratory and cardiovascular diseases, as well as premature deaths. In New York City, studies show that PM2.5 and ozone levels are driven by emissions from vehicles, industrial activities, and fossil fuel combustion. Vulnerable groups, like children, older adults, and individuals with pre-existing health conditions, are disproportionately affected. These findings align with this project's focus on the implications of air quality trends on public health in NYC neighborhoods. [3] [4]

The use of spatial and temporal data to analyze environmental health disparities has been demonstrated in studies that use public health indicators. For instance, air quality models and health impact methodologies have been applied to estimate changes in illness and mortality rates associated with improved air conditions. This approach mirrors our effort to use thematic maps and time series analyses to identify trends and disparities in pollutant exposure across New York City's boroughs. Furthermore, previous works exploring seasonal variations in air pollution support our hypothesis that summer months exhibit poorer air quality due to phenomena like wildfires and increased ground-level ozone formation. These seasonal patterns have been shown to exacerbate health outcomes, particularly in urban areas with high traffic density and industrial activities. By building on these studies, our project aims to provide insights for mitigating air pollution's impact on vulnerable populations in

NYC. The integration of historical data with neighborhood-specific analyses advances the understanding of environmental health inequalities and supports targeted interventions. [1] [6]

II. BACKGROUND INFORMATION

The dataset used for this project provides comprehensive information on New York City air quality surveillance, capturing various metrics across neighborhoods, time periods, and geographic boundaries. Each record in the dataset is uniquely identified with a Unique ID, and the type of measured value is classified by an Indicator ID and its corresponding Name. Geographic granularity is emphasized through columns like Geo Type Name, which specifies the level of geography (e.g., boroughs, community districts), and Geo Place Name, which identifies neighborhoods. A Geo Join ID is included to facilitate mapping and thematic visualizations. Temporal details are captured with columns such as Time Period, Start Date, and Data Value, which provide insights into the timeframe, start date, and actual air quality measurements. This dataset allows for a multifaceted analysis of air quality trends across NYC, offering a robust foundation for visualizing and understanding environmental health disparities.

Here, we clarify features that may lead to confusion. Our dataset shows a difference between emergency room visits and hospitalizations. For example, “asthma emergency visits” and “asthma hospitalizations.” An emergency room visit can lead to hospitalization, but the difference lies in that an ER visit is for immediate care where you are in the triage stage. Hospitalization means you are admitted to stay for a period of time for further medical treatment. The features are measured using different units, and in Table 1, we have displayed which features use which units.

Feature Types	Units for Measurement
Annual vehicle miles traveled	Per square mile
Emergency visits, Hospitalizations, Deaths	Per 100,000 adults and/or children
Fine Particles	mcg/m3
Nitrogen Dioxide, Ozone	ppb
Outdoor Air Toxics	µg/m3

Table 1. Features and their Units

III. DATA VISUALIZATIONS

Our dataset includes three types of data: emissions, annual vehicle miles traveled, and deaths and hospitalizations. In Figure 2, you can see the breakdown of these categories and also the distribution of the subcategories within the categories. This is important to note because of our further analysis on the air quality data values, and in some graphs, we take an average of all the air quality data values, regardless of the category. Since these categories have different units, we cannot pay particular attention to the numbers in each graph, but the yearly trends are important to analyze.

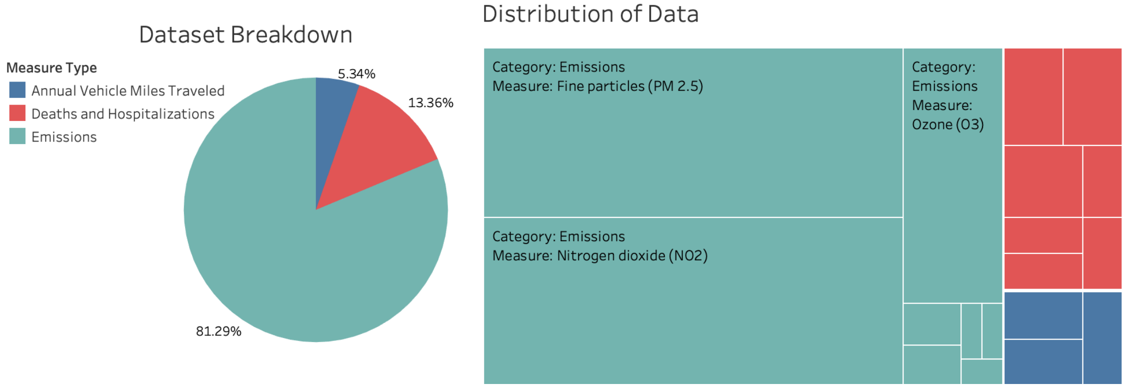

Fig. 2. Air Quality Dataset

One of our hypotheses was that seasonal variations impact air quality. We predicted air quality would worsen during the summer months due to wildfire season. Figure 3 shows the total average air quality values from 2009 to 2022 for each Winter and Summer season. This graph can create discrepancies with comparisons because the winter season overlaps two years. When comparing the two seasons, should we compare the winter that occurred before or after the summer season? For example, do we compare Summer 2009's air quality with the 2008 to 2009 Winter or the 2009 to 2010 Winter season? There is no correct answer, but being aware of both changes is important. In Figure 3, it is shown that a majority of the time, the summer air quality is worse than in the winter. Specifically, after the summer of 2014, our hypothesis consistently holds true. This can be attributed to increased ground-level ozone formation, which we will analyze further in this section.

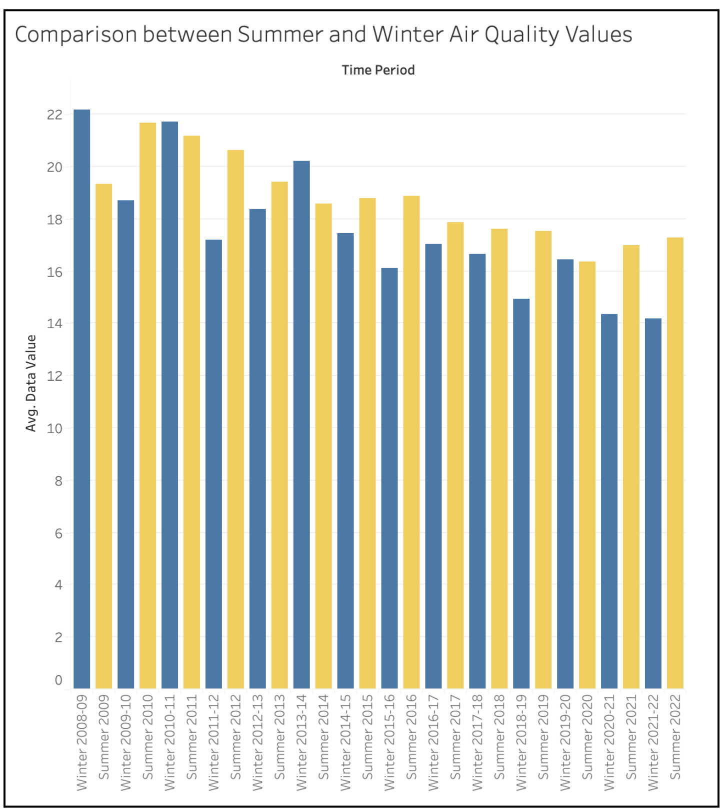

Fig. 3. Comparison of Seasonal Air Quality Values

Another hypothesis was that specific neighborhoods consistently have higher pollution and, therefore, worse air quality due to close proximity to industrial areas and/or high-traffic zones. Figure 4 compares NO2 levels with fine particle levels in 2008 and 2022. These graphs show that these levels have a positive linear correlation; Manhattan, specifically Midtown, has the highest levels, and they have decreased and improved from 2008 to 2022. Our hypothesis is proved to be correct because "Manhattan as well as industrial areas and areas of high building traffic density in the outer boroughs" have relatively higher levels [5]. Parts of the western Bronx community, including Fordham and University Heights, as well as Highbridge and Concourse, also have worse air quality levels due to "high densities of residual fuel oil boilers and truck traffic" [5]. It is important for citizens in those communities to be warned about these conditions.

2008 *2022*

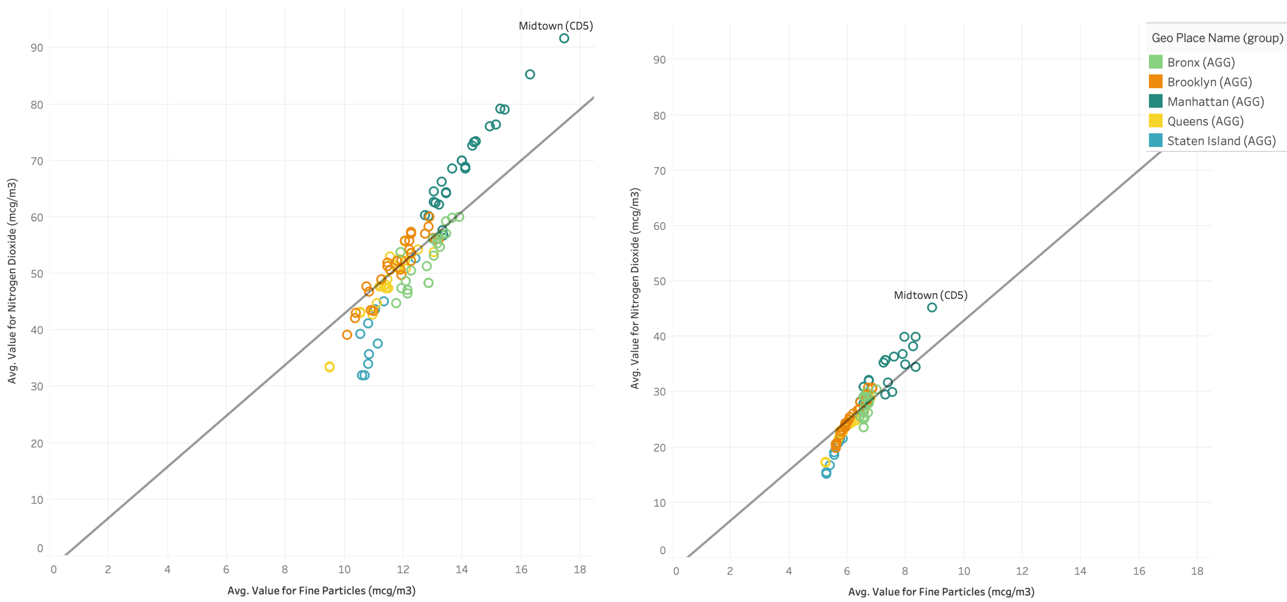

Fig. 4. Avg NO2 Levels compared to Avg Fine Particle Levels (mcg/m3)

In the data so far, air quality values seem to be improving and decreasing from 2009 to 2022. Ozone values, however, are worsening. There are higher levels of ozone in the summer because of the heat, and it is predicted that ozone levels will continue increasing each summer due to climate change and global warming [6]. In Figure 5, the maps also display that Manhattan has the lowest ozone values in comparison to the other boroughs. In every other type of air quality measurement, we notice Manhattan always has the worst air quality levels. This is due to Manhattan's high density of traffic. Combustion emissions release high levels of NO2, which react with ozone and reduce ozone concentrations [2].

Summer 2009 *Summer 2022*

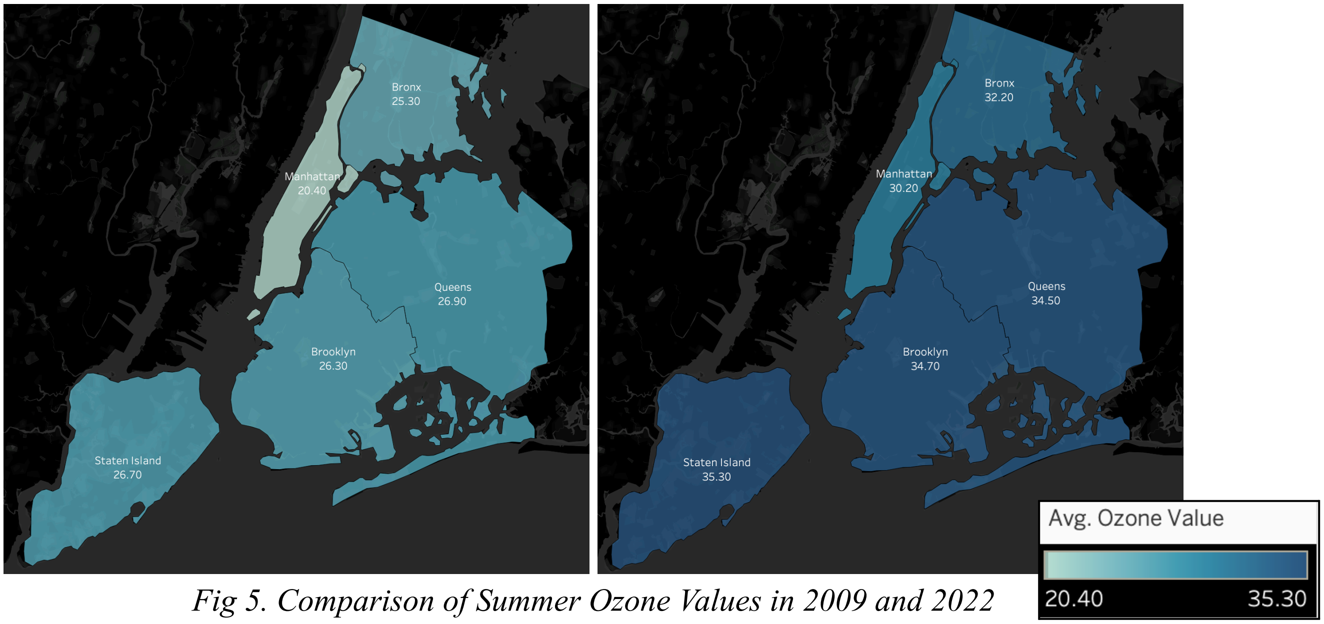

Fig 5. Comparison of Summer Ozone Values in 2009 and 2022

Similarly to the ozone levels, the average number of annual vehicle miles also increases throughout the years. In Figure 6, we can see this is mainly due to cars. After analyzing the ozone values, we expected the annual miles traveled in Manhattan to be the highest out of all the boroughs because combustion emissions release high levels of NO2, which is what reduces ozone concentrations, and Manhattan had the lowest ozone values. Annual vehicle miles traveled and ozone values will have a negative correlation by borough. This means that the ozone values are the lowest in Manhattan, but the annual vehicle miles traveled are the highest in Manhattan. Ozone values and annual vehicle mileage, however, have a positive correlation when you disregard the separation by borough and just analyze the numbers over the years.

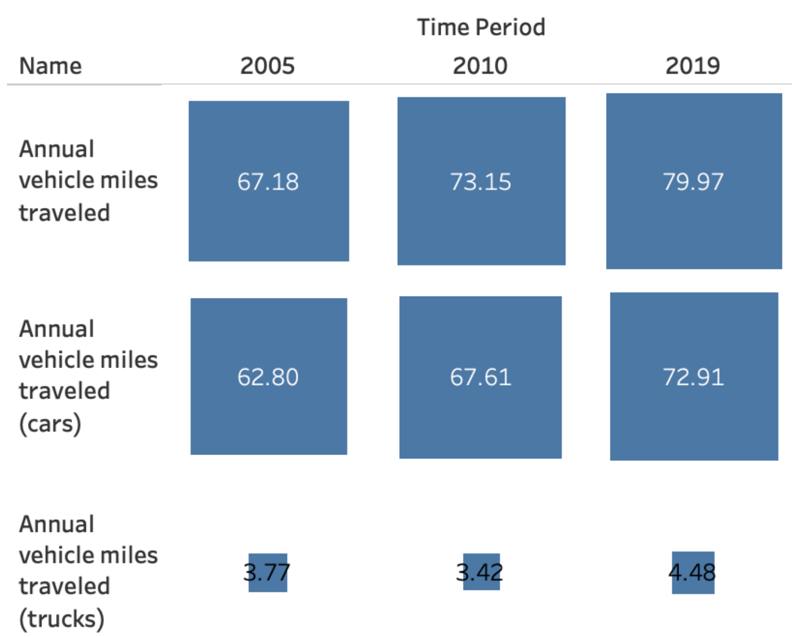

Fig 6. Annual Vehicle Miles Traveled from 2005 to 2019

IV. CONCLUSION

The goal of this project is to improve air quality, but how? Reducing the annual miles traveled by using public transportation such as trains or buses into the city rather than driving will reduce emissions. This project demonstrates the power of data visualization in understanding the complexities of air quality across New York City. By analyzing metrics like PM2.5, ozone, NO_2, and health-related indicators, we uncovered clear trends and disparities in pollutant exposure. Seasonal variations, such as elevated summer ozone levels exacerbated by heat and wildfires, highlight the impact of climate change on urban air quality. Spatial analyses reveal that Manhattan's dense traffic often correlates with higher levels of certain pollutants, although it also exhibits lower ozone levels due to the chemical interactions involving NO_2 emissions.

While progress has been made in reducing some pollutants, the persistent challenges posed by increasing ozone levels and localized pollution in industrial and high-traffic neighborhoods underline the need for targeted interventions. Reducing vehicle miles traveled through expanded public transportation and sustainable urban planning can significantly decrease emissions. Community-driven policies addressing environmental inequalities are vital to protecting vulnerable populations and ensuring a healthier future. Our findings emphasize the importance of continued monitoring and analysis of air quality data to inform policy decisions. Future work could expand this research to assess the effectiveness of existing measures and explore innovative strategies to mitigate urban air pollution, paving the way for cleaner cities.

V. REFERENCES

Dataset:

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