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Comparison of PM2.5 Pollution in New York City and Mexico City

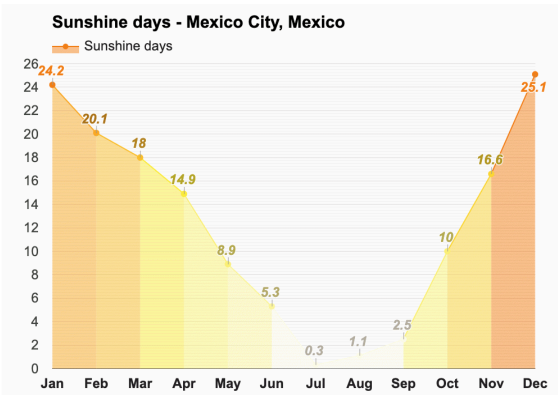
Problem

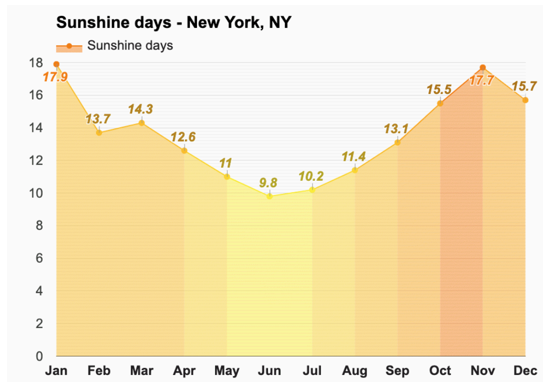
Despite similar population numbers, Mexico City has historically poor air quality, where New York City does not. Most notably: Mexico City's PM2.5 level consistently exceeds human health standards because of its geography and urban planning.

Background Knowledge

Particulate matter is the airborne liquid and solid particles within our atmosphere. This matter is quantified by size. There are many sources which produce Particulate Matter or the pollutants which will eventually develop into it. Some great primary examples given by the CDC are "smoke from fires and emissions (releases) from power plants, industrial facilities, and cars and trucks" (CDC, 2019). Primary sources of this pollutant are those which directly produce and release PM 2.5. There are so many more examples than these, however, these are some of the most common we experience in our day to day lives. The common secondary sources are sulfate, nitrate, and secondary organic aerosols (Hao, 2020). PM 2.5 is one of, if not the, most concerning size of Particulate Matter. The particles which make up this size of PM are sometimes called 'fine particles' as they are smaller than 2.5 micrometers. PM 2.5 is so miniscule that it can travel deep into your lungs, and sometimes even enter your bloodstream. An excerpt from EHP states that, "ambient fine particulate matter (PM2.5) exposure, currently considered the leading environmental risk factor globally, is estimated to be associated with 4.2 million premature deaths … [and] updated for 2016, the PM2.5 disease burden estimate includes 4.1 million deaths" (Anenburg, 2018). Taking all of this into account it is prevalent that PM 2.5 is a very concerning pollutant and becomes a greater concern when considering those with respiratory problems. According to the CDC, 1 in 12 people in the US have asthma (CDC, 2011). The irritants in an asthmatic person's lungs may cause an asthma attack, more severe than usual, and if the necessary equipment is not available for aid, it is likely to be fatal. (CDC, 2011)

Winter is the worst time of year for air pollution in Mexico City. In the winter Mexico City experiences an average of 20-28 sunshine days, compared to 0-2 sunshine days in the summer months. Mexico City sits at an elevation of 7349 feet. The lower atmospheric oxygen levels at this altitude cause higher emissions. Intense sunlight turns these into higher-than-normal smog levels. In turn, the smog prevents the sun from heating the atmosphere enough to penetrate the inversion layer. The inversion layer acts as a lid over the city trapping and condensing pollutants inside. New York's summer and winter are traditionally more polluted than the spring and fall. This trend is attributable to unique winter weather, including cool air inversions, and summer weather, including abundant sunshine that creates atmospheric ozone from precursor gases.

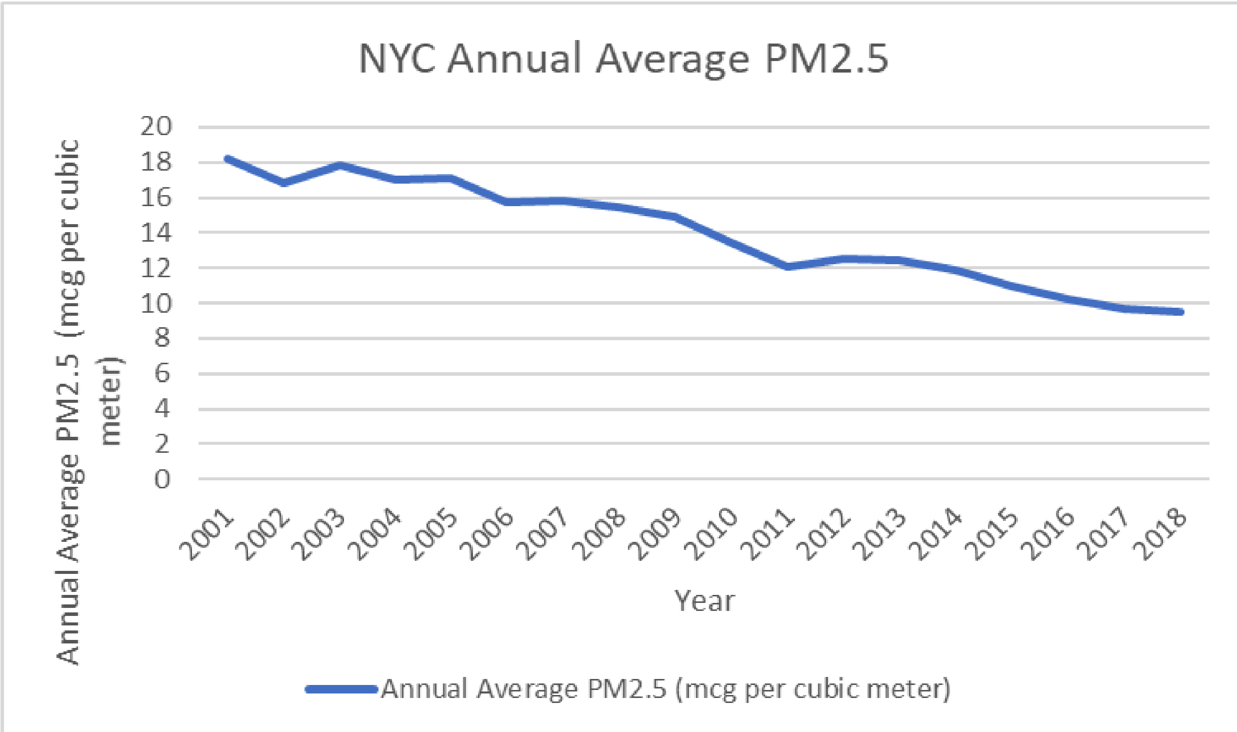




Hypothesis

Our prediction is that both New York City and Mexico City will have a downward trend in PM2.5 levels. To compare the cities, NYC is predicted to have less PM2.5 pollution than Mexico City because of their vehicle and public transportation habits and lower amounts of SO2 in the atmosphere.

Graphs



Graph 1: The data which was plotted is the annual average level of PM2.5 in the atmosphere in New York City. (United States Environmental Protection Agency (EPA) Air Quality System (AQS) Data)

Figure 1: The figure above juxtaposes the data for the population, employment, and transportation in New York City recorded throughout different years. This data allows interpretation of the trends of the populace as well as both emission heavy and non-emission transportation.
(https://www.nyc.gov/html/dot/downloads/pdf/nyc_greendividend_april2010.pdf.)

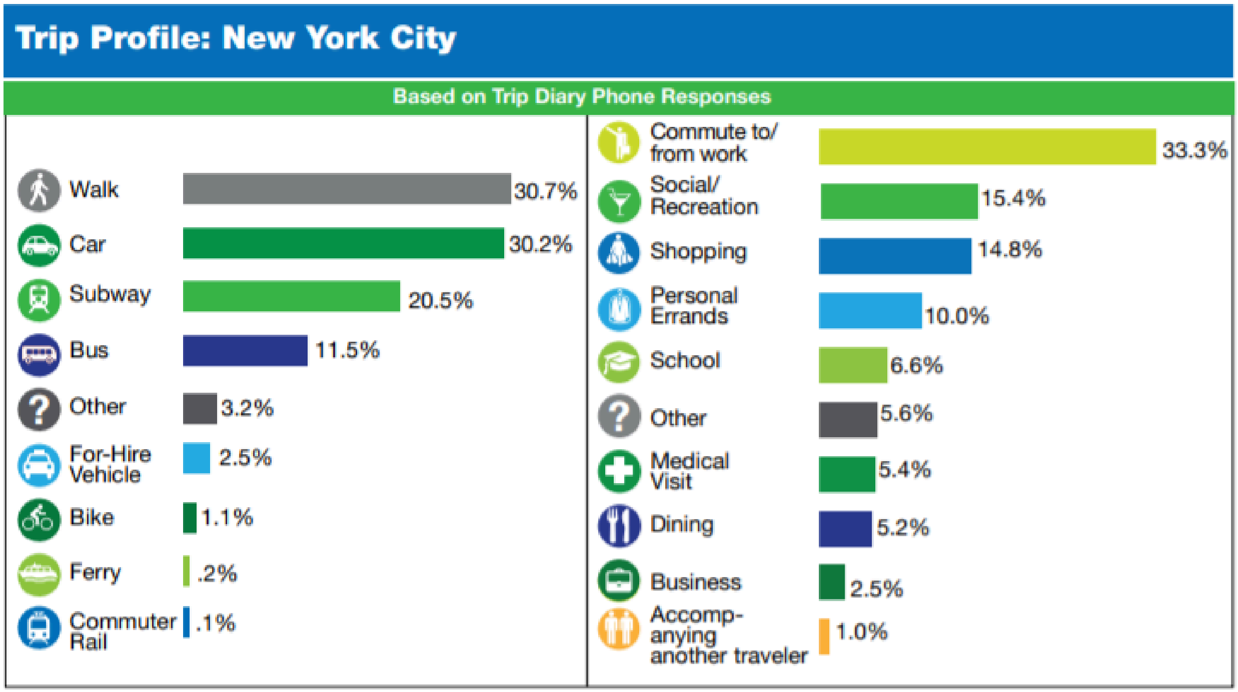


Figure 2: the relationship between the way's the people in New York City travel. Rather than showing the difference between differing years, this figure shows the proportions between each form of transportation, as well as the destination each of these trips are to. (https://www.nyc.gov/html/dot/downloads/pdf/nyc_greendividend_april2010.pdf.)

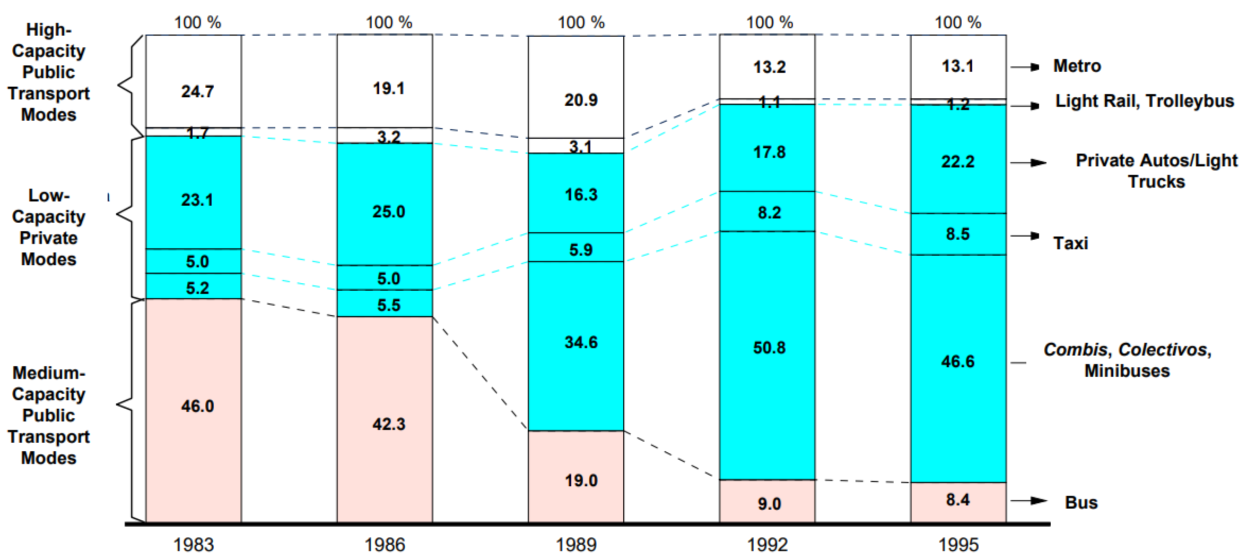
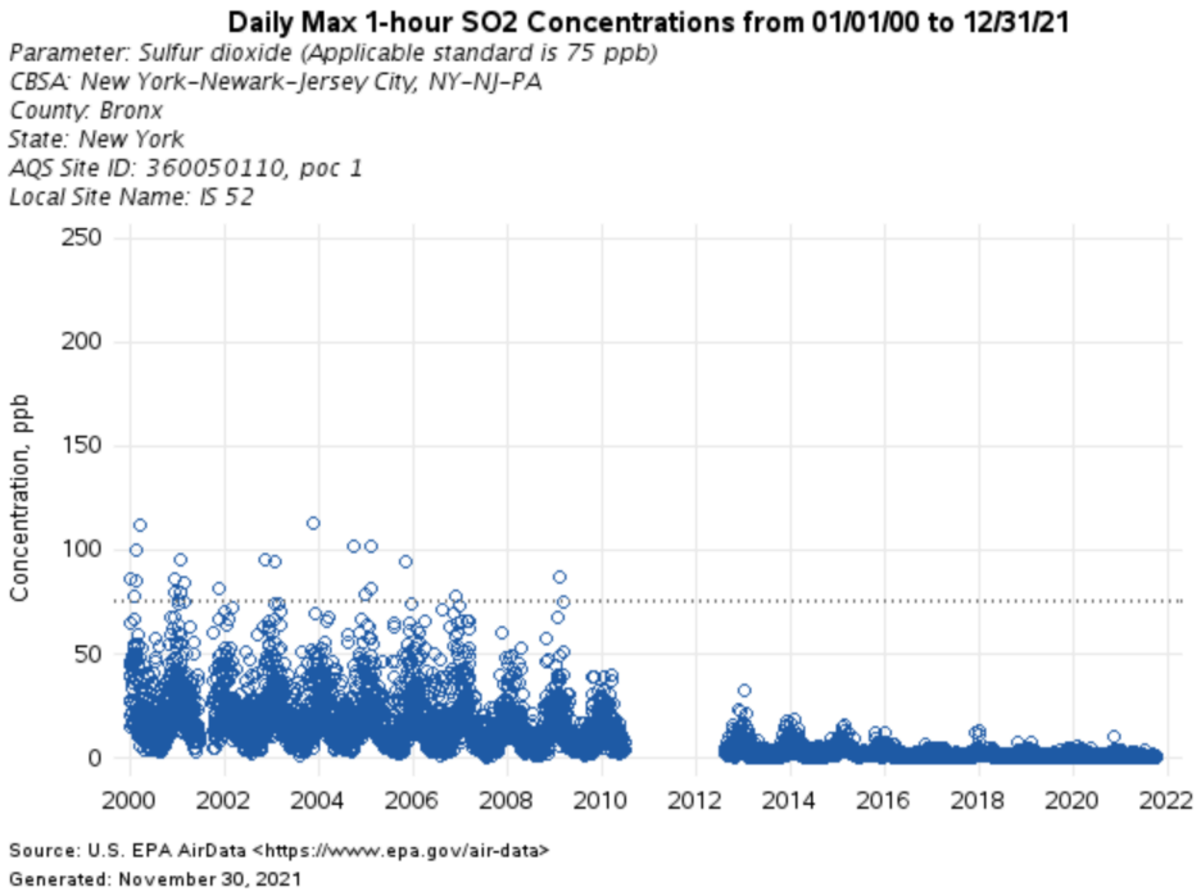
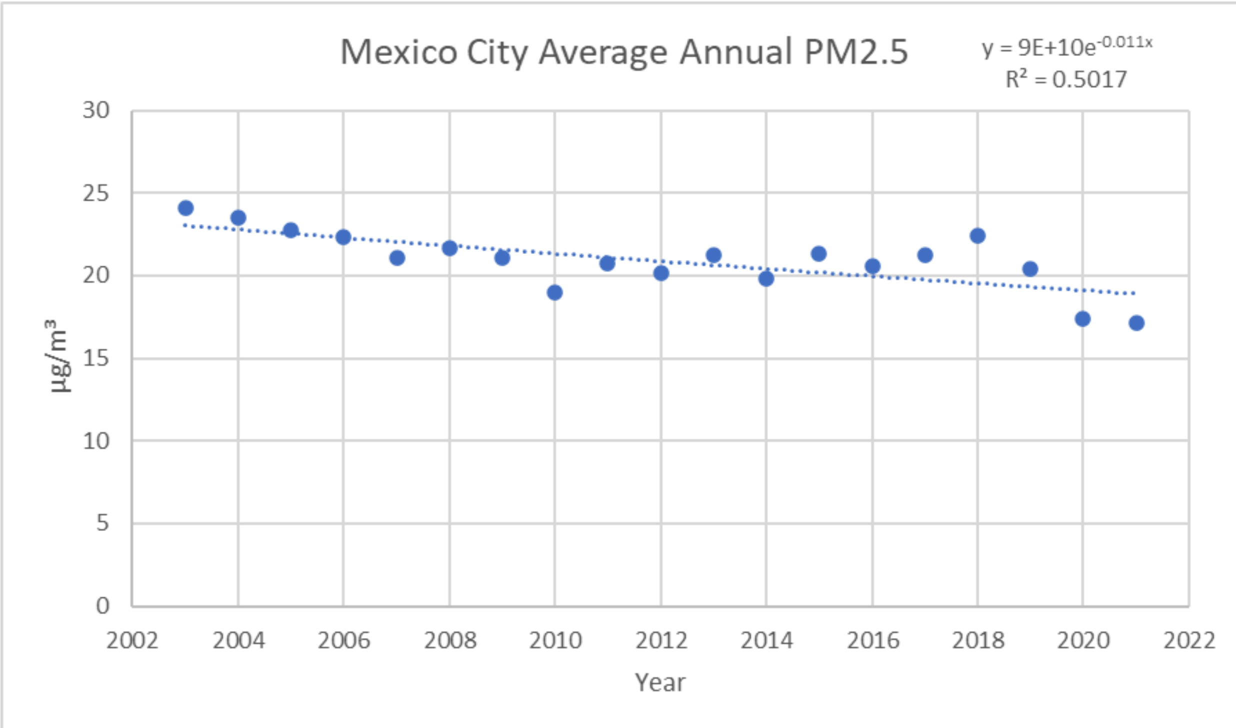


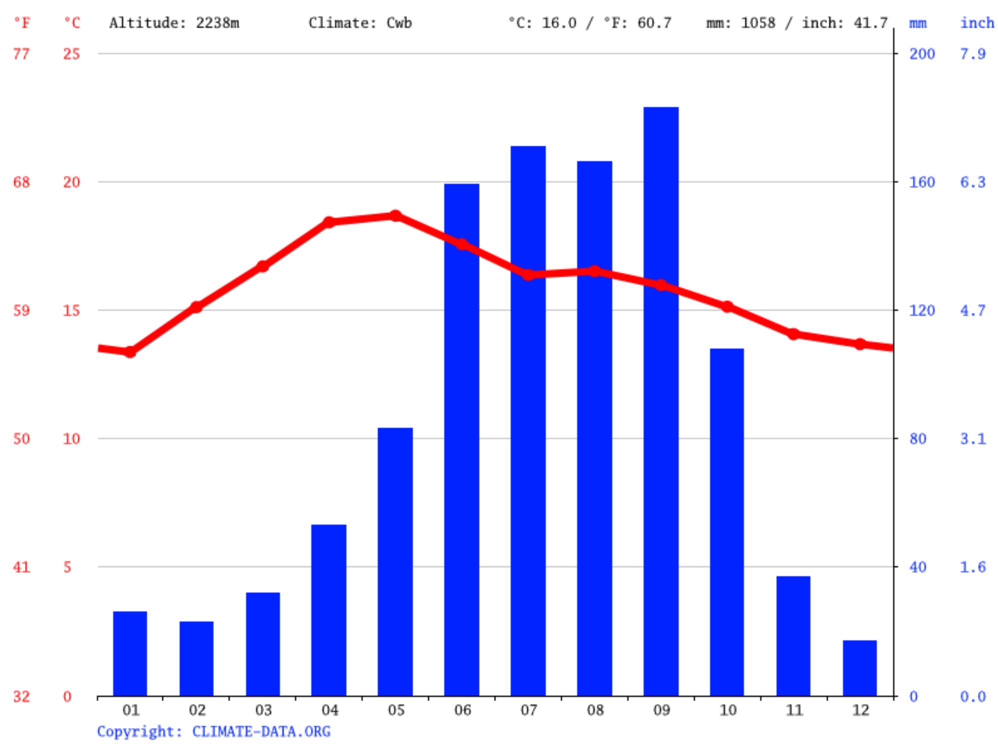
Figure 3: the evolution of high, medium, and low-capacity transportation modes over time for Mexico City (Zegras, 2000).



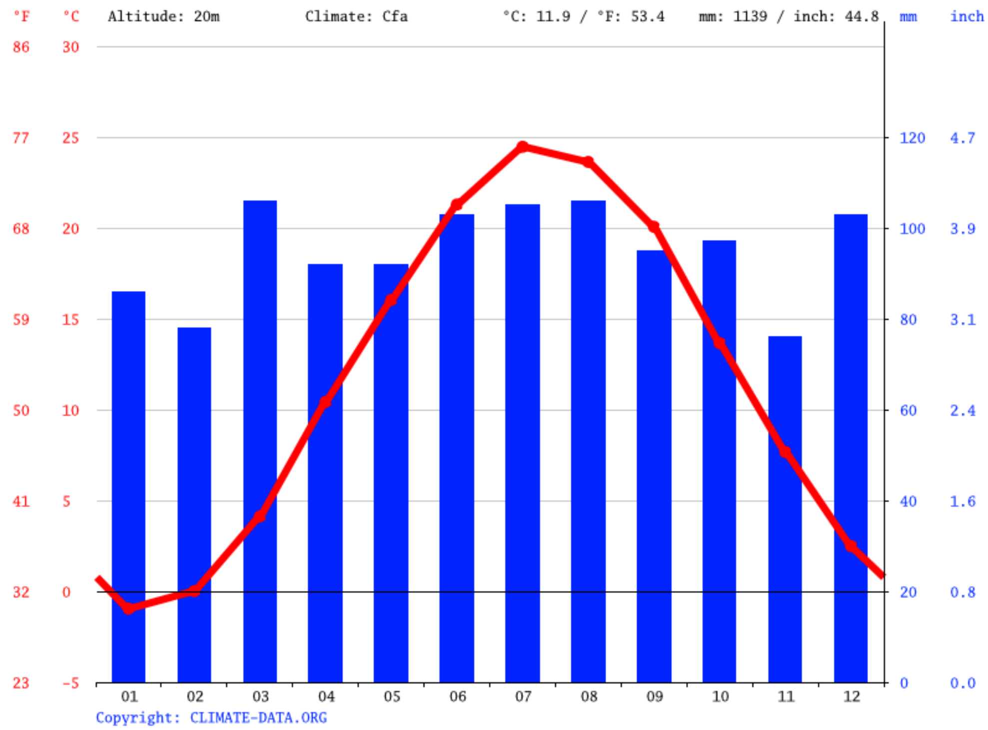
Graph 2: displays the data collected by the EPA showing the maximum 1-hour concentrations in parts per billion of SO2 per day from the year 2000. (www.epa.gov/air-data)



Graph 3: Depicts the data of the annual concentration of PM2.5 in Mexico City. There has been a downtrend, shown by the formula in the top of the graph. (Dirección de Monitoreo Atmosférico - Gobierno De La Ciudad De México)



Graph 4: Climate Graph showing the average monthly precipitation and temperature for Mexico City. The average monthly temperature wavers between 55-65°F. The precipitation is very low in the late and early months, however, becomes much more prevalent in the middle of the year. (climate-data.org)



Graph 5: Climate graph showing the average monthly precipitation and temperature for New York City. New York City does not maintain a steady temperature, however, it receives a steady average amount of precipitation per month, usually ranging between 3-4 inches. (climate-data.org)

Results

The EPA reports air pollution data on the six main pollutants, one of which is PM2.5. New York City's PM2.5 data, shown in Graph 1. New York City's PM2.5 has decreased steadily the past two decades. 2001 particle pollution was just over 18μg/m³, and 2018 had just under 10. PM2.5 is the pollutant we are looking at in particular, and it can be put into the atmosphere in many ways.

Data from NYC OpenData air quality surveillance from NYC Environment and Health Data estimates that an average of 48 people have died citywide per 100,000 people in New York City annually between 2005 and 2015; though the average has decreased over the decade by almost half (*Air Quality*, n.d.). The same data shows PM2.5-Attributable Cardiovascular Hospitalizations (Adults 40 Yrs and Older) averaged from 2005 to 2015 estimated to be 18 people in the city for every 100,000. PM2.5-Attributable Asthma Emergency Department Visits also per 100,000 people in the city, had an average of 73 across the same ten years, though notably has not been estimated over 100 people since 2009. PM2.5-Attributable Respiratory Hospitalizations (Adults 20 Yrs and Older) estimate per 100,000 people between 2005-2015 average is 14.35 people per year, though it has decreased since 2005; 2005 it was estimated to be almost 20 people, and it decreased to 11 since 2012.

As of a 2010 report, *New York City's Green Dividend*, New York City's miles driven per person is 9, which is considerably smaller than the median of 24.9 for metropolitan areas of the country (Cortright, 2010). Figures 1 and 2 show the amount of people in New York City that commute in different ways. Figure 1 breaks down how many people take different forms of public transportation over time, which is useful to show the trend over time, and it provides the population so the trend of people taking public transport can be compared to the population growth. For example, more people are taking the subway in the past three decades, even more than the population is growing. In recent years, when the population didn't grow, the number of people stayed proportional to the population. Figure 2 shows the mode by which the citizens of NYC travel by percentage of population that travels each way; this data is only from 2010, though it can be useful to compare the percentage of population that commutes via a personal vehicle. The biggest percent of people walk in NYC, though it is followed closely by driving in a car (30.7% and 30.2% respectively).A full 20.5% of people travel via subway and another 11.5% use the bus, so there is 31.6% of the population of New York City that uses public transportation to get around. Graph 3 shows the daily maximum SO2 from 2000 to 2021, though there was no monitoring for 2012. There is a notable downward trend over the two decades, and a dramatic decrease in maximum SO2 points over the time period, dropping off around 2015 where the points are more condensed and SO2 maximums are all below 25ppb.

Graph 3 shows the annual mean PM2.5 for each year from January 2003 to October of 2021 in Mexico City. Each point was found by averaging weekly PM2.5 measurements taken from each station within the entire metropolitan area of Mexico City for each year on record. Once annual mean was calculated, each year was used to calculate the running average of PM2.5 for the city. The running average between 2003 and 2021 was found to be 20.94 µg/m³. There is little continuity in the data points in Graph 3, this is reflected in the R^2 squared value (0.5017) which shows inherent fluctuation in the data as it trends downward.

Figure 3 is a model showing the evolution of transportation modes between the years 1983 and 1995. The data is organized into three different categories: low-capacity private modes, medium-capacity public modes, and high-capacity public modes. The model shows a massive drop in medium-capacity public modes such as large busses, a smaller yet considerable reduction in high-capacity public modes, and a massive expansion of low-capacity private modes of transportation. The use of private automobiles remained roughly the same, however the expansion of Colectivos (minibuses) was a substantial contributor to this explosion in less efficient transportation modes.

Graph 4 is a basic climate graph showing the average temperature as well as precipitation per month for Mexico City. This graph depicts how Mexico City's more tropical latitude provides dry winters along with rainy summers in general for any given year. Not only that but the temperature remains relatively high and does not show much seasonality. The climate graph for New York (graph 5) shows us what is essentially the opposite. Precipitation by month is very consistent as well as abundant, whereas temperature shows a high degree of seasonality over the course of one year.

Discussion

New York City and Mexico City both have decreasing PM2.5 trends over the last few decades. NYC's PM2.5 went from 18 to 10µg/m^3 between 2001 and 2018 (Graph 1), and Mexico City had a similar decrease of values close to 25µg/m^3 in 2003 to about 17 in 2021 (Graph 3). Although Mexico City has significantly higher values than NYC, they both decrease about the same amount. There are regulations in place so that new industry is further from cities and old plants closer can be closed. There are also better standards for emissions in general for both places, so cars and plants both produce less emissions than before (EPA, n.d.). Mexico City's PM2.5 pollution is worse than NYC's because it has a higher amount of precursor pollutants, and its climate is less consistently suited to decrease the amount of particulate matter in the atmosphere. Consistent and frequent precipitation in New York promotes the reduction of particulate matter through wet deposition. Citizens in Mexico City can expect elevated levels of exposure to PM2.5 in the winter months as the region experiences a dry season with little change in temperature. Mexico City has unique topography and a larger area to get around, so there is more distance to commute, which means more car emissions and miles traveled. New York City has more people who walk and take the subway rather than taking smaller colectivos.

We can assume the greater portion of ambient PM2.5 for both cities is a product of certain precursor pollutants such as Sulfur Dioxide and Nitrogen Oxides. As industry becomes more efficient and distances itself from the inner city, ambient SO2 inevitably trends downward. Although Graph 2 only shows 1-hour max measurements for the Bronx, its steep downward trend suggests a correlation with Graph 1. This drop off in SO2 can also be attributed to decreased use of coal burning along with new technologies such as shakers being implemented in power plants nationwide.

Industry is also the main contributor of SO2 in Mexico City, however SO2 is likely not the main precursor pollutant contributing to the city's dangerous levels of PM2.5 (Gobierno De La Ciudad De México, n.d.). In the 1980s as well as into the 90s, Mexico City saw a major shift in transportation modes from more efficient busses and trains to far less efficient minibuses and taxis (Figure 3). This trend is largely due to Mexico's inability as a country to maintain both private and public sector bus systems for extended periods of time. Both the government of Mexico City and the national government have failed to " guarantee a transparent market for potential bus company investors/operators," (Zegras, 2000). What have now become known as Colectivos, or minibuses, have exploded in popularity based on Figure 3. This switch from medium capacity modes of transportation to low-capacity modes can be attributed to "A convergence of liberalization policy, employment policy, poor management of and cost recovery in alternatives and the decaying institutional capacity in the DF led to an explosion of the 'informal sector' public transportation system – represented by colectivos," (Zegras, 2000). Based on this information, we can infer that Nitrogen Oxides along with other gasses associated with automobile emissions make up the majority of precursor pollutants that turn into PM2.5 in Mexico City.

The data backed our hypothesis: as there is a downward trend of PM2.5, and Mexico City does have more because of secondary pollutants in the atmosphere that are released by a larger amount of cars on the road and without periodic rain to abate them.

In the future, the PM2.5 will continue to go down, especially in Mexico City, as eventually it will probably hit a low plateau at whatever value the regulation stops. As cars are further electrified and public transportation is pushed for in the midst of a changing climate, emissions from remaining cars on the road will continue to decrease, and with it some of the precursor pollutants that react to form PM2.5 in the atmosphere. Health effects from PM2.5 will decrease more as they have been, too. In both cities, there will be fewer deaths and hospitalizations from respiratory issues caused by the small particles. The world and populations will be a little better for the decrease in pollution, even if it is just PM2.5.

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