Air Pollution Inequality in Boston

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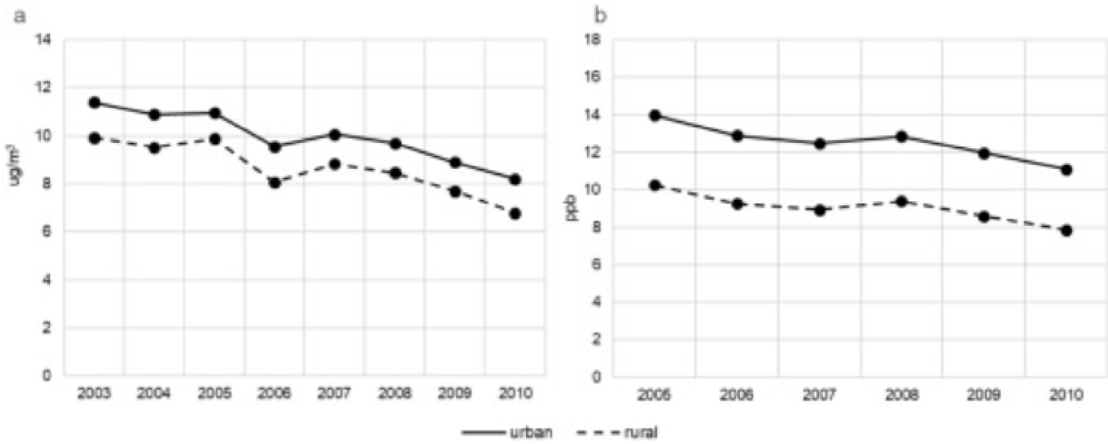
Introduction:

'"Although ambient air pollution concentrations have decreased across all of Massachusetts, these reductions had a higher relative impact on populations that were already in the lowest exposure categories, hence the increase in exposure inequality," says Patricia Fabian, SPH research assistant professor of environmental health and the study's senior author.'(Samuels, 2018)

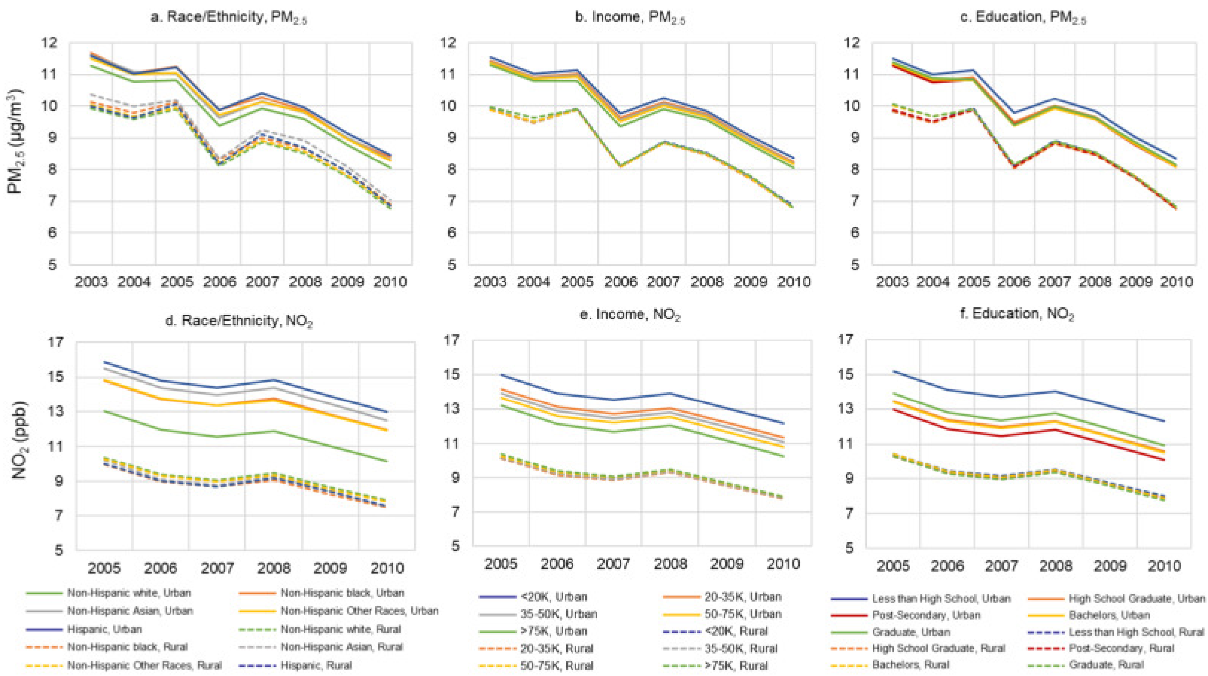
This paper is to show how Boston has been affected by the deforestation of trees in the past years, and how heat islands have been created due to that. We will analyze the neighborhoods of Boston, and get a closer look at how inequality has been caused in terms of air pollution and the environment in Boston. The data from 2000 and 2010 Census on race, income, educational attainment , and rural/urban land classification was used to calculate exposures using modeled PM2.5 concentrations from 2003 to 2010 and NO2 concentrations from 2005 to 2010. It was then quantitatively measured for relative inequality.

The results showed that for non-Hispanic black populations and non-hispanic white populations, the gap between exposure to PM2.5 decreased by 35 percent between 2005 and 2010, and for annual NO2 decreased by 24 percent between 2005 and 2010(Rosofsky, A., et. al., 2018).



Above shows Annual average PM2.5 concentrations in Massachusetts, 2003–2010 on the left and Annual average NO2 concentrations in Massachusetts, 2005–2010 on the right.

From the image above we can see how in urban areas the ppm of pollution drastically decreased, while for rural areas it was not the same.



Above shows the Population-weighted annual average PM2.5 (a–c) and NO2 (d–f) concentrations by Census 2010 and ACS 2006–2010 demographic and geographic Subpopulations.

‘In several of Boston’s lower-income neighborhoods, a lack of green space coupled with an abundance of concrete, steel, and buildings produces “heat islands” where summertime temperatures rise up to 7 degrees higher than the city’s average’ (Espinoza-Madrigal, et al., 2021).

Methods:

For this project, I used a bunch of datasets to make a valid argument for the topic. I made use of the Boston canopy tree heat metrics

Map CSV file - I will be using this in case any of the

Canopy Tree Change Assessment with Heat Metrics shape file -

The canopy tree change with heat metrics includes data about the heat index and mean temperatures of Boston as a shape file throughout the day, in the morning and in the evening.

Community Greenhouse Gas CSV file -

This dataset contains Protocol, Sector, Source, Year, and GHG Emission (mt. CO_2e). I only plan to use the commercial sector data because after sifting through the file I realized the commercial sector had the most green house gas emissions.

Boston Neighborhood shape file -

The Neighborhood boundaries data layer is a combination of zoning neighborhood boundaries, zip code boundaries and 2010 Census tract boundaries.

Boston canopy heat change assessment shape file -

The heat change in each neighborhood is characterized by morning, evening, average per day and the same is done for the heat indexes. Heat index is not the actual temperature of the day, but just how it feels like. I will not use that data because i feel it does not show an accurate representation of the temperature in a day.

The libraries I will use are - Sf, PROJ, rlang, ggplot2, dplyr, purrr, classInt, leaflet, RColorBrewer

Sf and proj were used to handle the shape files. I, then, used rlang to be used as a filter for my community greenhouse gas emissions dataset. I also used ggplot2 and test the initial shape file findings, which then I converted to leaflet format. I used classInt to create intervals in my Boston. I used dplyr to filter the datasets I was using. I used the purrr dataset to work with the vectors that I had created through the datasets. The leaflet library was used to create an interactive map with realistic features over which I can overlay the findings through my ggplot. RColorBrewer was just used to create the colors for my map.

First, I imported the map and canopy heat change data to use it to create the heat metrics data for Boston. I created class intervals of the mean temperature of the day with a 0.00001 difference, and set the style to quantile. After this, I created the popup for the leaflet to be Mean Temperature Density: with the same column. The function for the color is quantile, with colors between yellow and red. Subsequently, I went on to create the leaflet function by adding polygons which would be filled based on the mean temperature of the day, an opacity of 0.5, and a popup, and then the legend on the bottom-right side.

I continued the same process for the mean temperature in the morning and the evening.

```
canopy_change_spdf    211 obs. of 16 variables
  $ FID        : int  1 2 3 4 5 6 7 8 9 10 ...
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Above is the file showing the head column and some data regarding each

Here, I accessed the Week Boston Air Quality data from AirNow.gov and downloaded respective the tables. I first plotted a bar graph of each based on how the mode of each air quality and how many times it reaches that weekly or monthly.

UTC	AQI
######	30
######	25
######	27
######	30
######	35
######	44
######	31
######	37
######	40
######	37
######	37
######	32
######	38
######	34
######	39
######	30
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######	34
######	46
######	47
######	26
######	30
######	22
######	36
######	47
######	44
######	46
######	44

UTC	AQI
#########	30
#########	22
#########	36
#########	47
#########	44
#########	46
#########	44

Above is the monthly AQI data on the left and the weekly AQI data on the right

Thereafter, I downloaded the community gas emissions for Boston through analyze Boston, which I will use to find out if Boston has been making an actual effort to reduce emissions. I filtered the data to show me the table first with commercial and electrical, then with commercial and fuel oil, then with commercial and steam and finally with commercial and natural gas.

Protocol	Sector	Source	Year(Caler	GHG Emissions(mt CO2e)
Global Prc	Commerci	Electricity	2005	2,513,636
Global Prc	Commerci	Electricity	2006	2,193,105
Global Prc	Commerci	Electricity	2007	2,506,091
Global Prc	Commerci	Electricity	2008	2,458,906
Global Prc	Commerci	Electricity	2009	2,236,563
Global Prc	Commerci	Electricity	2010	2,261,843
Global Prc	Commerci	Electricity	2011	2,118,624
Global Prc	Commerci	Electricity	2012	1,883,819
Global Prc	Commerci	Electricity	2013	1,885,570
Global Prc	Commerci	Electricity	2014	1,905,547
Global Prc	Commerci	Electricity	2015	1,988,389
Global Prc	Commerci	Electricity	2016	1,790,583
Global Prc	Commerci	Electricity	2017	1,738,300
Global Prc	Commerci	Electricity	2018	1,630,233
Global Prc	Commerci	Electricity	2019	1,590,867

Global Prc	Commerci	Fuel Oil	2005	417,865
Global Prc	Commerci	Fuel Oil	2006	292,509
Global Prc	Commerci	Fuel Oil	2007	288,561
Global Prc	Commerci	Fuel Oil	2008	208,381
Global Prc	Commerci	Fuel Oil	2009	266,718
Global Prc	Commerci	Fuel Oil	2010	452,417
Global Prc	Commerci	Fuel Oil	2011	296,312
Global Prc	Commerci	Fuel Oil	2012	192,173
Global Prc	Commerci	Fuel Oil	2013	201,216
Global Prc	Commerci	Fuel Oil	2014	226,317
Global Prc	Commerci	Fuel Oil	2015	231,517
Global Prc	Commerci	Fuel Oil	2016	138,273
Global Prc	Commerci	Fuel Oil	2017	156,654
Global Prc	Commerci	Fuel Oil	2018	161,163
Global Prc	Commerci	Fuel Oil	2019	162,570

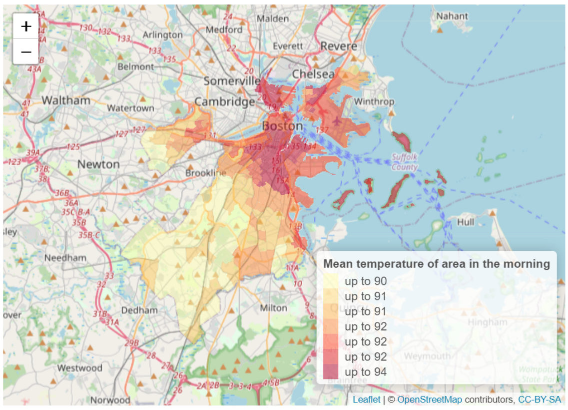
Global Prc	Commerci	Natural Ga	2005	1,082,796
Global Prc	Commerci	Natural Ga	2006	1,068,737
Global Prc	Commerci	Natural Ga	2007	1,124,786
Global Prc	Commerci	Natural Ga	2008	1,183,985
Global Prc	Commerci	Natural Ga	2009	1,109,123
Global Prc	Commerci	Natural Ga	2010	1,118,167
Global Prc	Commerci	Natural Ga	2011	1,150,003
Global Prc	Commerci	Natural Ga	2012	1,053,562
Global Prc	Commerci	Natural Ga	2013	1,185,444
Global Prc	Commerci	Natural Ga	2014	1,252,271
Global Prc	Commerci	Natural Ga	2015	1,349,883
Global Prc	Commerci	Natural Ga	2016	1,240,286
Global Prc	Commerci	Natural Ga	2017	1,239,513
Global Prc	Commerci	Natural Ga	2018	1,331,914
Global Prc	Commerci	Natural Ga	2019	1,321,707

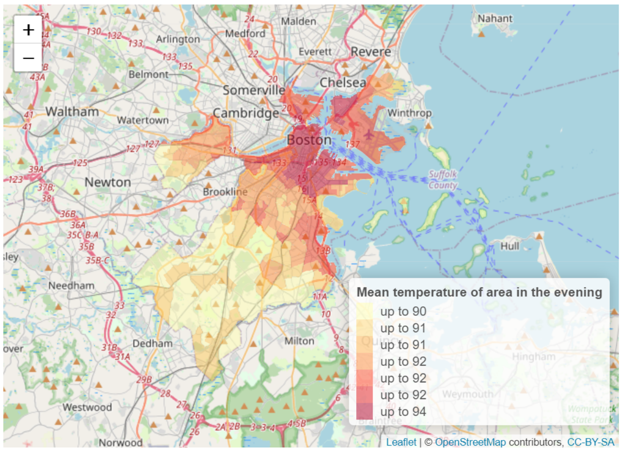
Global Prc	Commerci	Steam	2006	219,342
Global Prc	Commerci	Steam	2007	198,224
Global Prc	Commerci	Steam	2008	184,180
Global Prc	Commerci	Steam	2009	154,148
Global Prc	Commerci	Steam	2010	132,181
Global Prc	Commerci	Steam	2011	162,114
Global Prc	Commerci	Steam	2012	134,436
Global Prc	Commerci	Steam	2013	176,616
Global Prc	Commerci	Steam	2014	193,990
Global Prc	Commerci	Steam	2015	101,790
Global Prc	Commerci	Steam	2016	127,661
Global Prc	Commerci	Steam	2017	76,242
Global Prc	Commerci	Steam	2018	103,774
Global Prc	Commerci	Steam	2019	74,788

Above given are the data sets i used to convert into plotted bar graphs. First, the top left one is the Commercial and electricity plot. The top right one is commercial and fuel oil. The bottom left is the commercial natural gas data, and the bottom right is the commercial and steam data.

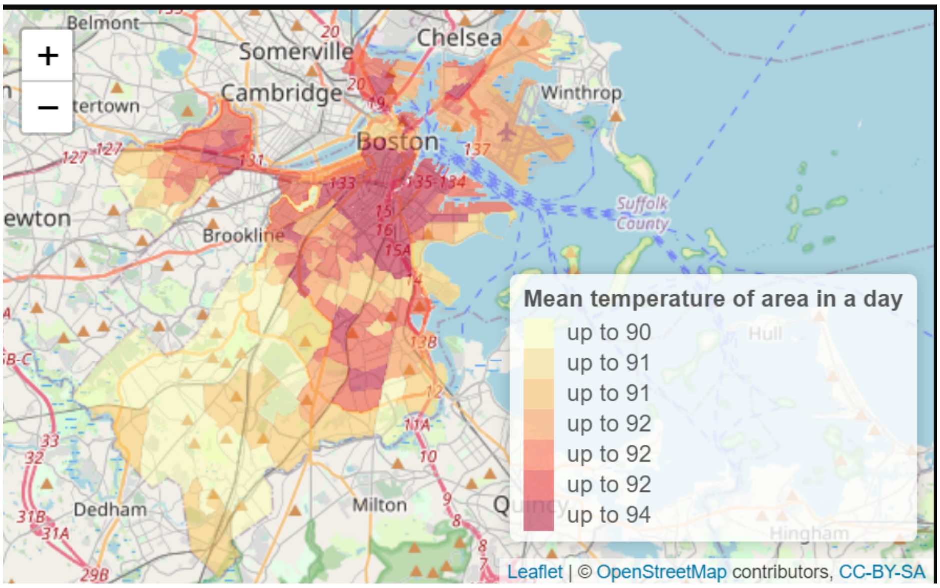
Results:

The results of my findings are that for the mean temperature during the day, we can see that the lower income neighborhoods of Boston have been much hotter than the less. This includes Downtown, Roxbury, Dorchester, and Chinatown. The temperature does not change even in the morning or at night



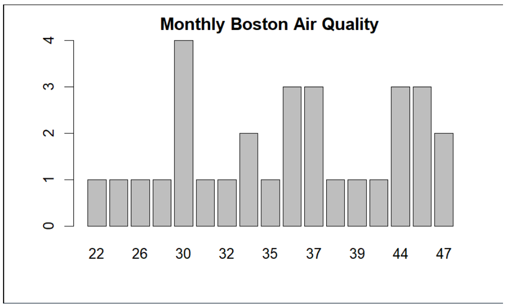


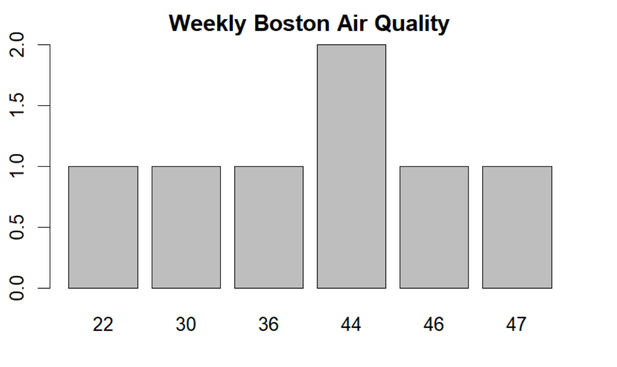
Above is the mean temperature of Boston's Neighborhoods in the morning and evening.



Above is the mean temperature of Boston's neighborhoods in day

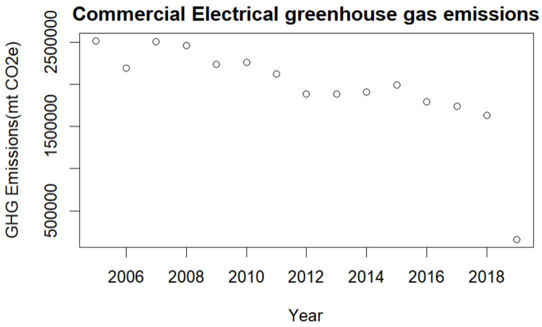
From this we can tell that Boston hasn't really had problems with the air quality in the past month. Reaching a maximum of 47 at most 2 times in the month of April 2022, the air quality has always been in the green zone.

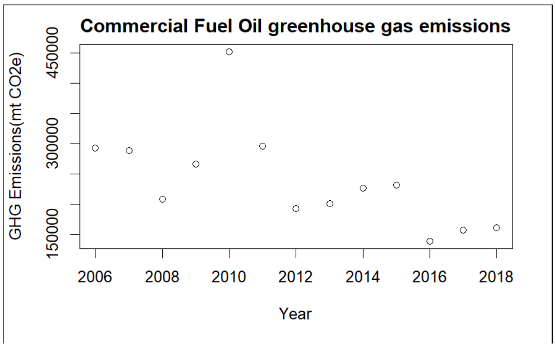


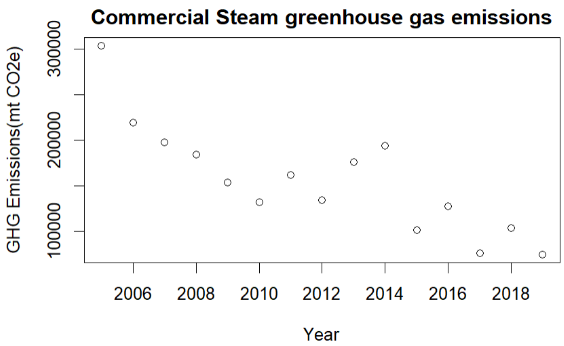


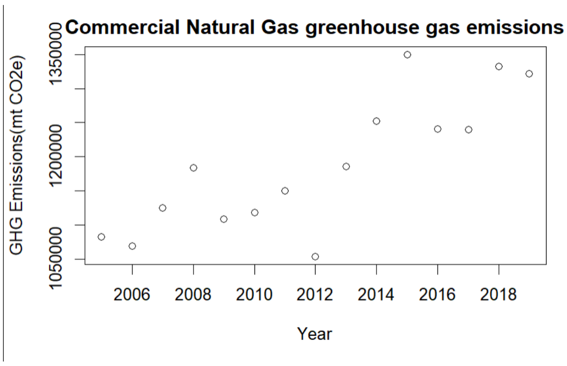
Above is the Monthly Boston Air quality in Boston on the left and on the right we have the weekly Boston air quality.

After this, the next data I used was the community greenhouse emissions data. What we can get from them is that overall, Boston has made an effort in efficiently reducing the overall emissions caused due to each.





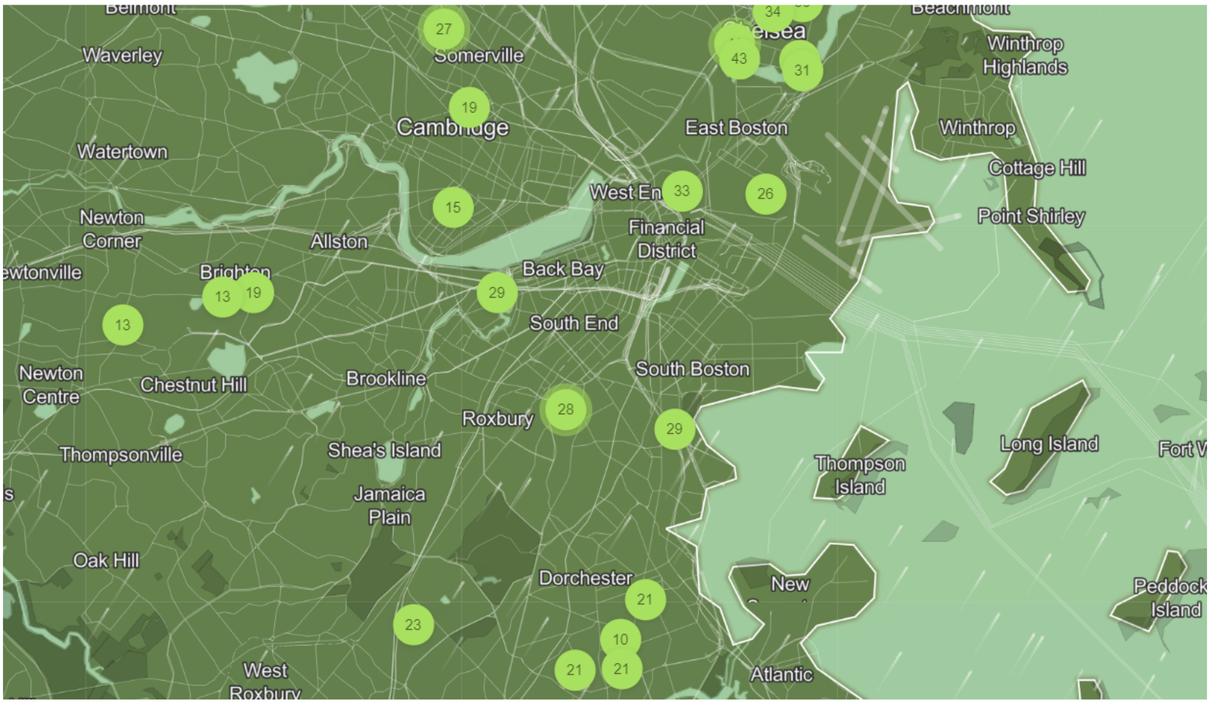




Above are the plots for emissions per year for each kind of major energy sources used commercially.

Discussion:

The picture below represents very well of how the findings in the mean temperature of a day in Boston relate to the air pollution and air quality of the area. The lower income regions have relatively higher air pollution than the higher income regions.



Above is a picture of the air monitors in Boston(IQAir, 2022). It shows the air monitors, fires, air quality and wind.

PM2.5 concentrations are more regional than local in nature because they are derived from a wide variety of sources, with a strong contribution from secondary pollutant formation and long-range transport (Zheng et al., 2002). NO2 tends to exhibit high interurban variability and is strongly linked to automobiles and other mobile sources.

PM2.5 exhibits less spatial variability in urban areas, leading to smaller exposure disparities compared to NO2(Clougherty et al., 2008).

I found one study which examined trends in racial ethnic disparities in exposure to neighborhood air pollution across the US while controlling for individual and neighborhood-level changed over time. The authors found that Black and Hispanic participants were disproportionately exposed to higher concentrations of NO2, PM2.5 and PM10 compared to white participants, and that concentrations decreased for all races over time (Kravitz-Wirtz et al., 2016).

The first question is what are the major causes of the air quality to decrease in Boston. Residents who live near major pollution sources, such as new construction, major roadways, transportation hubs, and industrial complexes like factories, refineries, power plants, or other fossil fuel burning complexes, are more likely to experience higher pollution levels. Commercial sources, including various types of industry and large residential complexes, make up the largest emission source, accounting for 51.6 percent of Boston air pollution.(boston.gov, 2017) “Transportation comprises the next largest emission source, contributing to 28.6 percent of Boston’s air pollution mix. Most US cities have a larger share of pollution attributed to this source, often around 50 percent. Boston’s relatively low transportation share owes to the city’s density and strong public transportation system. More than half of residents commute to work using a mode of transportation other than a car.” Personal household emissions, including residential heating, wood burning, and barbecues account for 19 percent of Boston’s air pollution mix, while wastewater treatment comprises the remaining 0.8 percent.(IQAir, 2022)

Of the 24 monitored cities in Massachusetts, Boston’s PM2.5 levels rank as the 11th worst in the state out of 24 included cities. Ozone is a highly corrosive and even small amounts of ozone react with the lungs, health effects can range from coughing and irritation to lung damage, cancer and early death.

Some of the most polluted places in Boston would be the under-resourced communities that tend to bear a disproportionate level of air pollution. This correlation is the direct neighborhood values, Airports, major, roadways, and industrial complexes are some examples of high-emission source which tend to be intentionally located near lower-income communities. The WHO employs a more stringent target, recommending annual PM2.5 exposure not exceed 10 micro grams per cubic meter, compared to the US standard of less than 12 micro grams per cubic meter. According to this, Boston would be considered above the threshold and unhealthy in 2018 due to its 10.1 micro grams per cubic meter(WDI, 2022)

‘In contrast, research from Asia, Africa, and other parts of the world revealed trends similar to that of North America, but research in these parts of the world is extremely limited. In Africa, for example, the only study, that met their inclusion criteria was an examination of particulate matter in four communities in Ghana’(Failey 2022).

A recent World Health Organization (WHO) assessment on the global burden of disease illustrates the growing interest in studying environmental health disparities, according to SES. This assessment found that environmental impacts on health are uneven across different social groups, and the greatest health burdens fall on low- and middle-income countries. Further, 23 percent of all global deaths are linked to the environment, which translates to 12.6 million deaths per year due to environmental causes.(A Pruss-Utsun)

In Suffolk County, Chelsea represents one such area that carries a heavier pollution burden than downtown Boston. Since it is between Logan airport and multiple industrial centers, it had been described by environmentalists as a troubling “sacrifice zone for the region” and as a community needing environmental justice, (DeCosta-Klipa N., 2020). A lot of the industrial areas like these has a huge amount of non-white groups that live in these neighborhoods, and research has shown that they get more affected by the poor air quality, which also causes more likelihood of getting a heart and lung disease as a result.

Boston's heat islands can cause prolonged periods of extreme temperatures and further cause heat related illnesses and even death. The most vulnerable to this kind of issue would be the elderly and little, young children, and the people who have been compromised by their immune system. This can only be done by creating more vegetation in the neighborhoods by increasing the trees and plants to cover the concrete or dark asphalt, which can absorb the heat and cause problems. The Boston neighborhoods that have been historically redlined have people of lower-income experiencing the effects of extreme heat and are not as likely to have access to air conditioning to escape it.

After researching for a bit, I found out that Seattle and Portland had taken steps to reduce the heat island effect in their own ways.

In Seattle, the new developments meet a landscaping "score" given by the property's zoning requirements. It includes green roofs, rain gardens, vegetated walls, trees and shrubs. In Portland, the zoning requirements in certain areas mandate that new buildings install ecological roofs to help mitigate urban heat islands, improve air quality, and increase urban green space.

The changes that I would like to see in Boston's Planning and Development Agency is that all the new construction should be required to produce better green space which can last longer and are more useful rather than simply aesthetically pleasing in areas. They should incentivize green roofs instead of dark asphalt or cement ones (Espinoza-Madrigal, et al., 2021).

One common thing that we notice is that the less privileged areas of Boston are always hotter than the more privileged parts. We should deepen our understanding of how social environmental factors work together to impact the health of vulnerable populations.

We must all work together towards solutions against heat islands. The problem of climate change demands bold, innovative solutions, and we challenge the city to break up heat islands and to “green” our communities, so Boston can be more livable for all.

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