Air Quality Report in London City 2022

S/18/827

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1 Introduction

Air quality is a critical component of environmental health that directly impacts the well-being of humans and the environment. This report focuses on an explanatory data analysis of air quality trends in London, drawing on the data collected from 36 air monitoring sites throughout London. Data collected sites can be separated into two parts, one is sites located in boroughs of inner London and the other one is sites located in outer London. 27 data collecting sites were in the inner London area and 9 data collecting sites were in the outer London area.

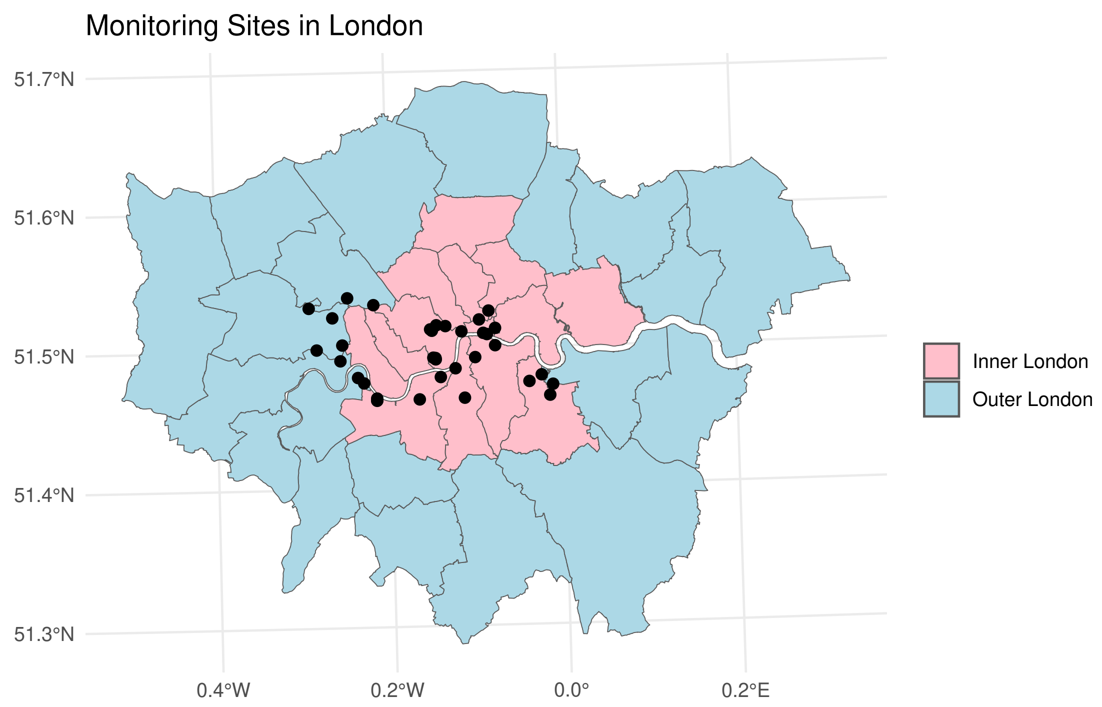

Figure 1: Geospatial Distribution of Air Monitoring Sites in London

The dataset, "London local data 2022", which includes hourly measurements of the key air pollutants mainly focused on NO_2, NO_x, NO, O_3, SO_2, PM_{10}, and $PM_{2.5}$. Collecting data starts from January 1, 2022, to December 31, 2022. The success of collecting data relies on the collaborative effort of various monitoring sites, each identified by a location name. The dataset complements the air quality data by measuring essential details about each monitoring site, including one or more air pollutants and specific substance measurements. This data set facilitates further examination of the air quality trends and allows a spatial understanding of the variation of pollutants across the different regions of London with time.

This report includes an analysis and discovery of trends in air quality over the specified time frame and location, identifying the potential air pollutants and the source of the pollutants. Also, this report provides insights that can reduce air pollution over time and take precautions based on that. Exploring the variation in pollutants across the different locations and understanding the correlation between them can be used to take precautions to reduce air pollution in certain areas.

2 Literature Review

London has a historical relation with air pollution. The city of London grappled with the spectre of air pollution over the centuries. Some air pollution events end up claiming thousands of lives. This reminds the London area is more vulnerable to this environmental hazard. Despite significant progress in recent decades, air pollution remains a pressing concern for London, impacting the health and well-being of its residents. This literature review delves into London air pollution, examining its sources. Through the given collected dataset analysis, aim to find the impact of air pollutants on recorded sites and the relationship between the sites and air pollutants, and air pollutants variation with time. Those findings can derive suggestions to mitigate the impact of air pollution.

The main sources of air pollution can be identified as traffic emissions, industrial activities and residential heating. Traffic emissions stand as a dominant trend, spewing nitrogen-based gases and particulate matter into the atmosphere. Studies by [Smoothing MCC data (psu.edu)] quantify this dominance in traffic emission, estimating that contributes over 50% of NO2 and P.M2.5 in the city. Industrial activities add another layer of pollutants. Factories and power plants emit sulfur dioxide SO2 and volatile organic compounds, further burdening air. Residential heating causes major air pollution during colder months, generating heat by burning fossil fuels and wood releasing PM into the air. This impacts both indoor and outdoor air quality.

3 Results and Discussion

This section provides an explanatory data analysis and explanation of data collected from air quality monitoring in London throughout the year 2022. This part seeks to trends and investigate potential consequences for public health and environmental policy by examining the collected data. By diving into the complexities of air pollutant concentrations and their temporal and location-wise variations, I want to provide useful insights that help to improve air quality and support sustainable urban development in London. The dataset includes measurements from a different number of monitoring sites for each parameter:

Parameter Name	Number of Sites
Nitrogen dioxide	35
PM10 particulate matter (Hourly measured)	23
PM2.5 particulate matter (Hourly measured)	5
Ozone	3
Sulphur dioxide	1

Table 1: Number of Monitoring Sites for Each Air Quality Parameter

3.1 Nitrogen oxides (NO_x, NO, NO_2)

Nitrogen dioxide (NO_2) and nitrogen oxide (NO) are the gases that are mainly produced during the burning of fossil fuels. When NO combines with some atmospheric gases, NO_2 can be also produced. The two gases are collectively referred to as nitrogen oxides (NO_x) due to the rapid and reversible nature of the above transformation process.

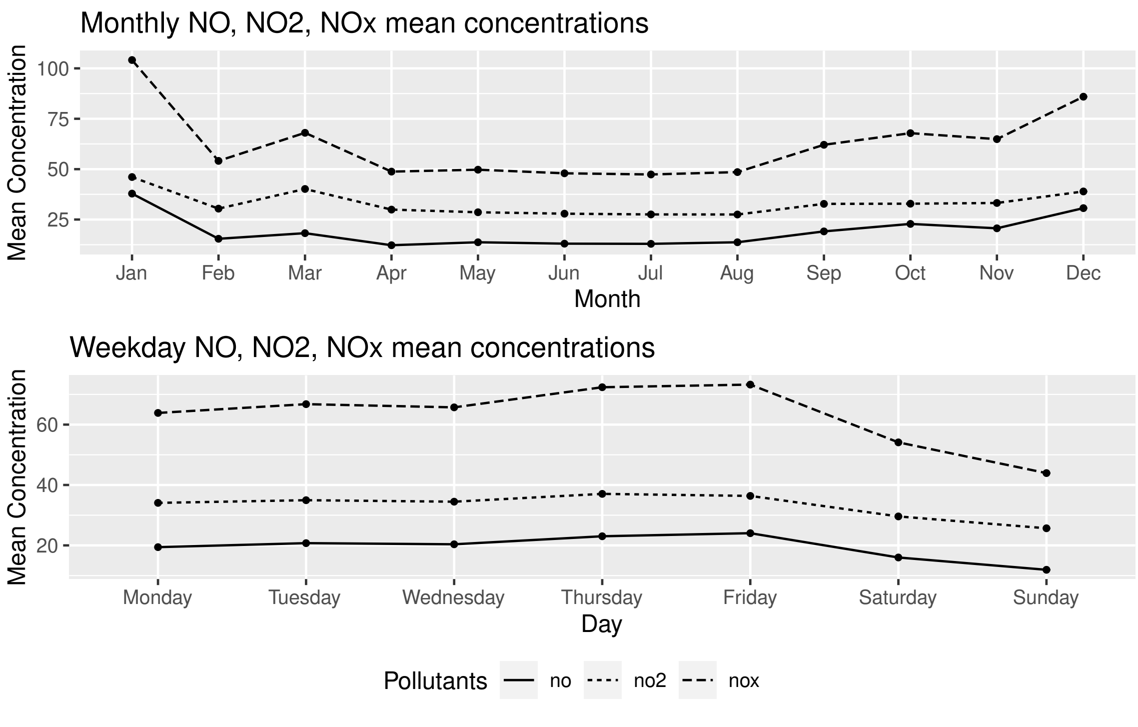

Figure 2: Temporal Variation in NO_x, NO, and NO_2 Concentrations: Monthly and Weekday Trends

For the temporal Variation in NO_x, NO, and NO_2 Concentrations presented in Figure 3.1, the measurements were collected from 33 air monitoring sites across London City. These site-specific measurements are detailed in Table reftab:no-no2-nox-concentrations-sites.

NO_x concentrations tend to be higher at the beginning and the end of the year compared to during the midterm of the year. This is likely to be primarily driven by high road traffic during the holiday seasons. Also, NO_x concentrations tend to be lower at the weekend compared to during weekdays. This is likely to be primarily driven by less road traffic at the weekends. In 2022, the Monday-to-Friday mean concentration at roadside sites was 68.39, which was 28.3% greater than the mean concentration at the weekend of 49.03.

Air Monitoring Site	**NO**	**NO_2**	**NO_x**
Brent - ARK Franklin Primary Academy	14.15	28.57	50.26
Brent - John Keble Primary School	11.54	27.52	45.21
City of London - Beech Street	16.53	40.57	65.91
City of London - Sir John Cass School	5.05	22.85	30.59
City of London - Walbrook Wharf	40.56	52.03	114.22
Ealing - Acton Vale	7.13	21.70	32.64
Ealing - Hanger Lane Gyratory	57.58	51.50	139.78
Ealing - Western Avenue	22.60	35.17	69.82
Greenwich - Blackheath	12.85	27.29	46.99
Hackney - Old Street	15.71	31.14	55.23
Hounslow Chiswick	18.90	30.75	59.72
Hounslow Gunnersbury	25.84	29.28	68.90
Lambeth - Bondway Interchange	14.90	28.90	51.74
Lambeth - Brixton Road	50.35	63.59	140.79
Lewisham - Deptford	4.98	19.09	26.73
Lewisham - Loampit Vale	40.32	38.38	100.21
Lewisham - New Cross	13.75	27.22	48.55
Richmond Upon Thames - Barnes Wetlands	2.06	14.29	17.44
Richmond Upon Thames - Castelnau	8.44	23.32	36.26
Southwark - Elephant and Castle	4.89	21.79	29.30
Southwark - Tower Bridge Road	20.74	29.95	61.75
Wandsworth - Battersea	10.76	27.09	43.59
Wandsworth - Lavender Hill (Clapham Jct)	17.06	34.71	60.85
Wandsworth - Putney	10.22	26.90	42.57
Wandsworth - Putney High Street	79.80	71.55	193.90
Wandsworth - Putney High Street Facade	29.03	46.53	91.04
Westminster - Cavendish Square	15.54	32.65	56.47
Westminster - Duke Street (Grosvenor)	8.73	31.64	45.03
Westminster - Ebury Street (Grosvenor)	7.00	24.81	35.67
Westminster - Elizabeth Bridge	17.95	34.02	61.55
Westminster - Oxford Street	22.90	37.21	72.32
Westminster - Oxford Street East	25.74	41.61	81.07
Westminster - Strand (Northbank BID)	9.54	34.92	49.55

Table 2: Average NO, NO_2, and NO_x Concentrations at Air Monitoring Sites

The Wandsworth - Putney High Street records the highest average concentration of air pollutants among 33 air monitoring sites in London City, with maximum recorded values 79.80 μg/m^3 for NO, 29.03 μg/m^3 for NO_2, and 15.54 μg/m^3 for NO_x. These high levels may be explained by urban characteristics, likely influenced by heavy traffic, industrial activities, and other sources of emissions commonly found in metropolitan areas.

In contrast, Richmond Upon Thames - Barnes Wetlands records the lowest concentration of air pollutants, featuring minimum values of 2.06 μg/m^3 for NO, 14.29 μg/m^3 for NO_2, and 17.44 μg/m^3 for NO_x. The suburban characteristic, likely less traffic and industrial activities and the presence of wetlands may contribute to the reduction of the air pollutant level.

3.2 Ozone (O_3)

Ozone is a gas that is toxic to the environment and human health. It can cause inflammation of the eyes, nose, throat, and respiratory tract. It can also set off asthma attacks. Furthermore, because ozone damages plants, especially valuable crops, it can harm the ecosystem. In addition, ozone plays a role in the creation of smog through its reactions with other molecules in the atmosphere. Thus, it is essential to track ozone levels to evaluate any threats to the environment and public health.

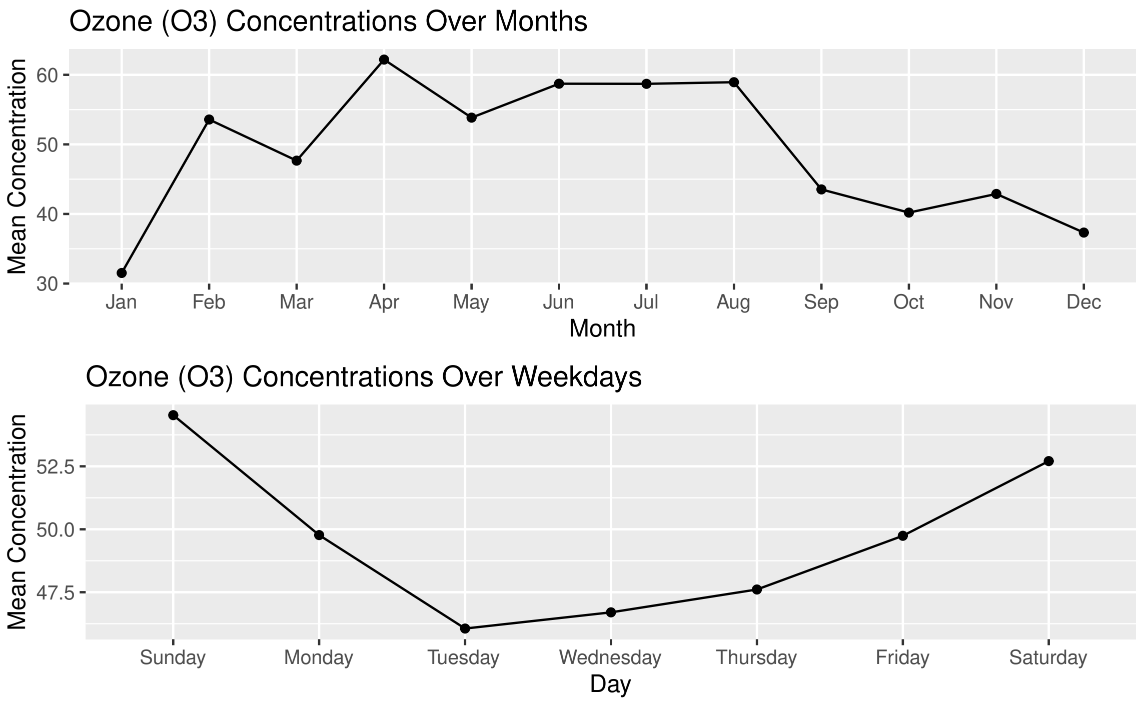

Figure 3: Temporal Variation in Ozone (O_3) Concentrations: Monthly and Weekday Trends

The O_3 index shows the monthly mean, averaged over all included sites that had monthly data capture greater than or equal to $30\mu g/m^3$ in 2022. For O_3 the greatest average concentrations tend to occur during the spring and summer months. Ozone is a secondary pollutant, meaning it is created in the atmosphere through a cycle of reactions of its precursors nitrogen oxides and volatile organic compounds (VOC), sunlight is also a key part of the ozone production cycle. In the summer stagnant air leads to the build-up of these precursor compounds, while more sunlight and higher temperatures increase the rates of reactions that generate ozone.

In 2022, the month that had the greatest ozone concentrations was April with monthly mean concentrations of $62.18\mu g/m^3$. The April‘s high temperature would have increased the rate of chemical reactions between ozone precursor pollutants that would have built up in the atmosphere.

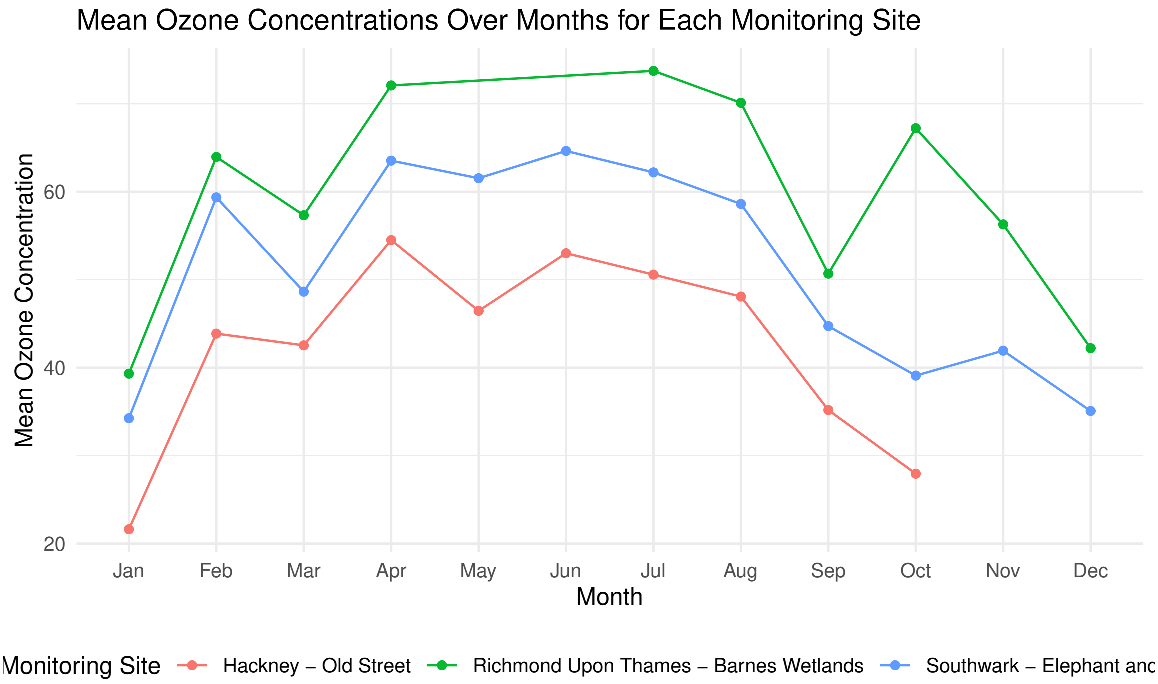

Figure 4: Average Ozone Concentrations at Air Monitoring Sites :Monthly Trend

The Ozone concentrations were monitored at three air monitoring sites in London City: Hackney - Old Street, Richmond Upon Thames - Barnes Wetlands, and Southwark - Elephant and Castle. The data analysis, represented in Figure 3.2, shows consistent trend of O_3 emission across all three sites.

Richmond Upon Thames - Barnes Wetland recorded higher O_3 emissions compared to the other two sites, peaking in July 2022. Noticeably, all three sites have a sudden fall-off in O_3 emission after February and August. The observed decreases may be caused due to changes in meteorological conditions, atmospheric composition, or variations in emission sources. It may be caused O_3 concentrations

The Spring and Summer seasons in London, with their higher temperatures and more sunlight, may be responsible for increased levels of Ozone concentrations in the middle of the year. These factors encourage the photo-chemical reactions that produce ozone. In contrast, decreased sunshine and colder temperatures throughout the winter may prevent ozone from forming, leading to lower Ozone concentrations at the beginning and end of the year.

3.3 Particulate Matter (PM)

Particulate matter (PM) is defined as everything in the air that is not a gas. As a result, it contains a wide range of chemical compounds and components, some of which may be harmful.

Many of the microscopic particles which make the PM have a possibility to enter the bloodstream, and lodge in the heart, brain, and other organs. Therefore, exposure to PM can harm health, particularly for sensitive groups like the young, old, and those with respiratory diseases. Based on the evidence about the impact on health, particles are categorized by size.

- PM_{10} : PM where particles are less than 10 micrometres in diameter
- $PM_{2.5}$: PM where particles are less than 2.5 micrometres in diameter

PM_{10} and $PM_{2.5}$ are frequently produced from various emission sources and have different chemical compounds. Much of $PM_{2.5}$ and a significant proportion of PM_{10} are mainly produced during the burning of fossil fuels or wood. PM_{10} also contains dust from construction sites, landfills and agriculture, wildfires and brush/waste burning, industrial sources, wind-blown dust from open lands, pollen and fragments of bacteria.

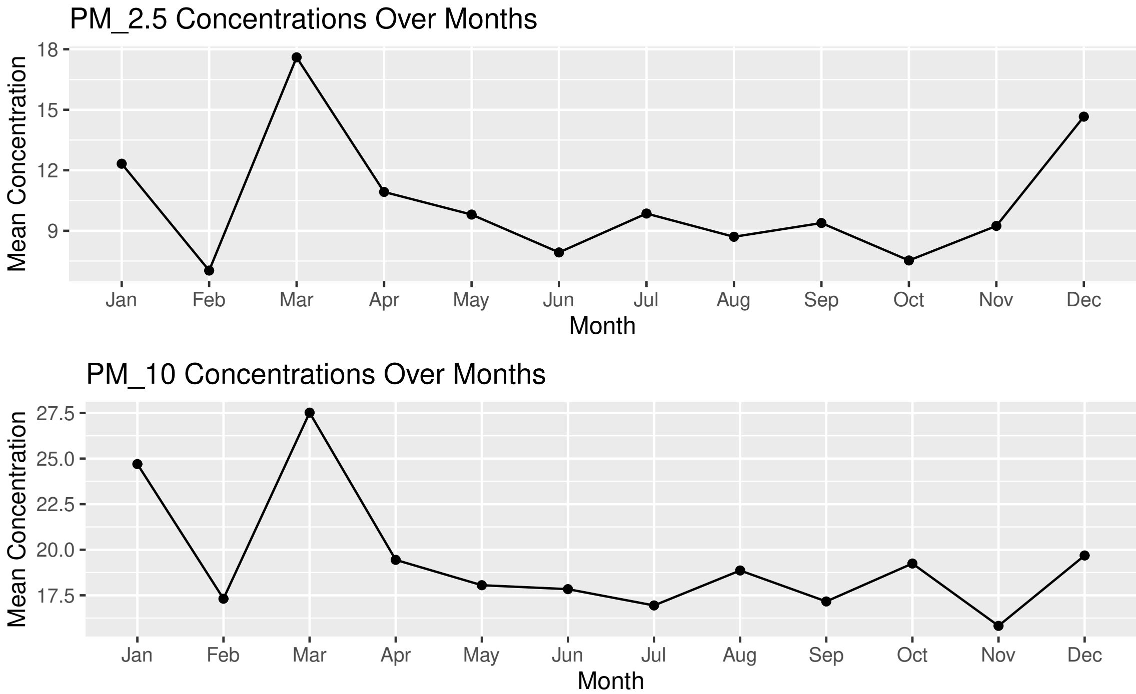

Figure 5: Temporal Variation in PM_{10} and $PM_{2.5}$ Concentrations:Monthly Trends

According to Figure **??** throughout the year 2022, both PM10 and PM2.5 exhibit a similar trend, reaching their peak concentrations in March. Notably, both pollutants exhibit considerable decreases in at February and November, suggesting the same source or regional air conditions during these months. Moreover, a more equal spread of particulate matter is found during these months based on the steady and relatively stable levels reported from April to October. Factors like variations in the weather, patterns of emissions, or the nature of air dispersion could be responsible for the noted trends during these times.

The observed lower concentrations of PM_{10} on weekends compared to weekdays can be attributed to reduced industrial and traffic activities, and decreased construction and commercial operations.

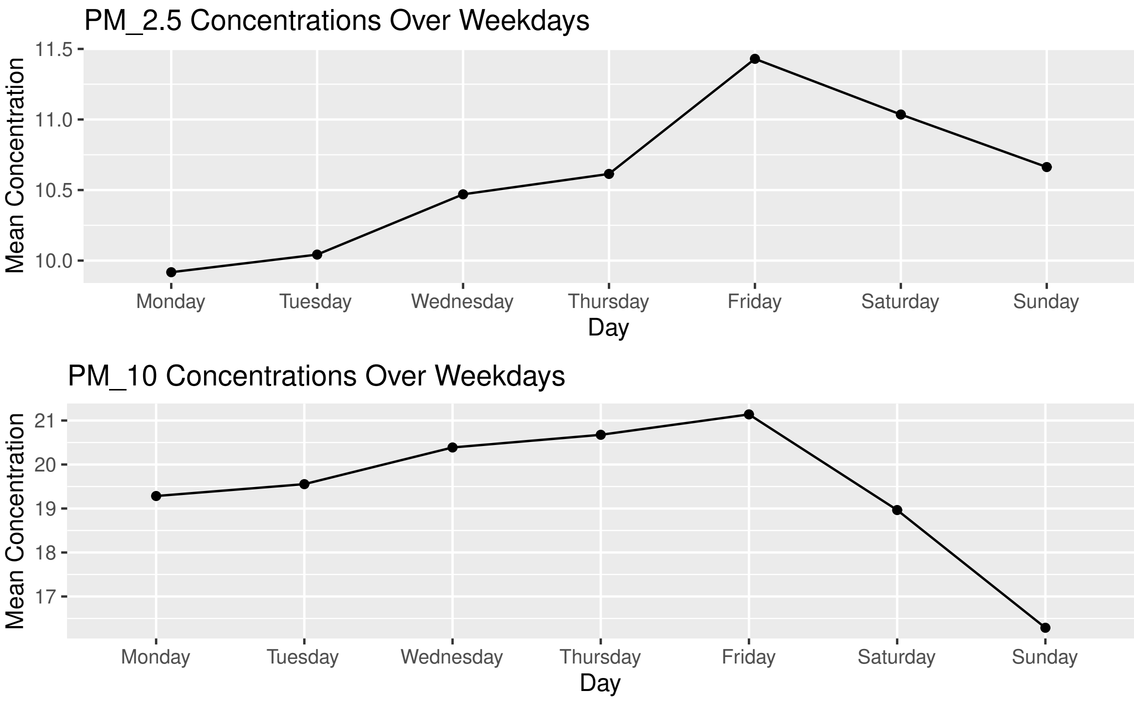

Figure 6: Temporal Variation in PM_{10} and $PM_{2.5}$ Concentrations:Weekday Trends

Similarly, there is a negative trend of concentrations of $PM_{2.5}$ on weekends. This variation underscores the complex interplay of human activities and environmental conditions influencing the levels of particulate matter in the air. In 2022, the Monday-to-Friday mean concentration at roadside sites was 68.39, which was 28.3% greater than the mean concentration at the weekend of 49.03.

The $PM_{2.5}$ concentrations were monitored at three air monitoring sites in London City: Hackney - Old Street, Hounslow Chiswick, and Westminster – Elizabeth Bridge while PM_{10} concentrations were monitored at 26 air monitoring sites in London City. The data analysis, represented in Figure 3.3, shows a consistent trend of $PM_{2.5}$ emission across all three sites. Hounslow Chiswick and Westminster – Elizabeth Bridge recorded higher $PM_{2.5}$ concentrations, peaking in March and December 2022. The Lambeth - Bondway Interchange has recorded the highest levels of PM10 among all 23 stations.

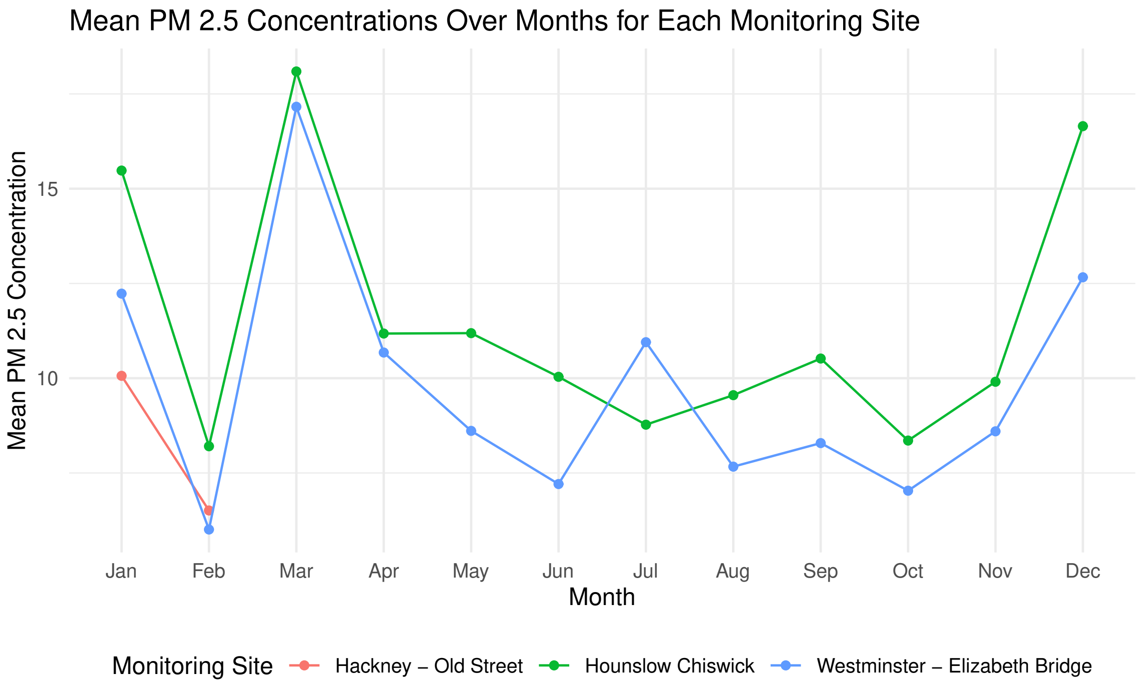

Figure 7: Average PM$_2$.5 Concentrations at Air Monitoring Sites :Monthly Trends

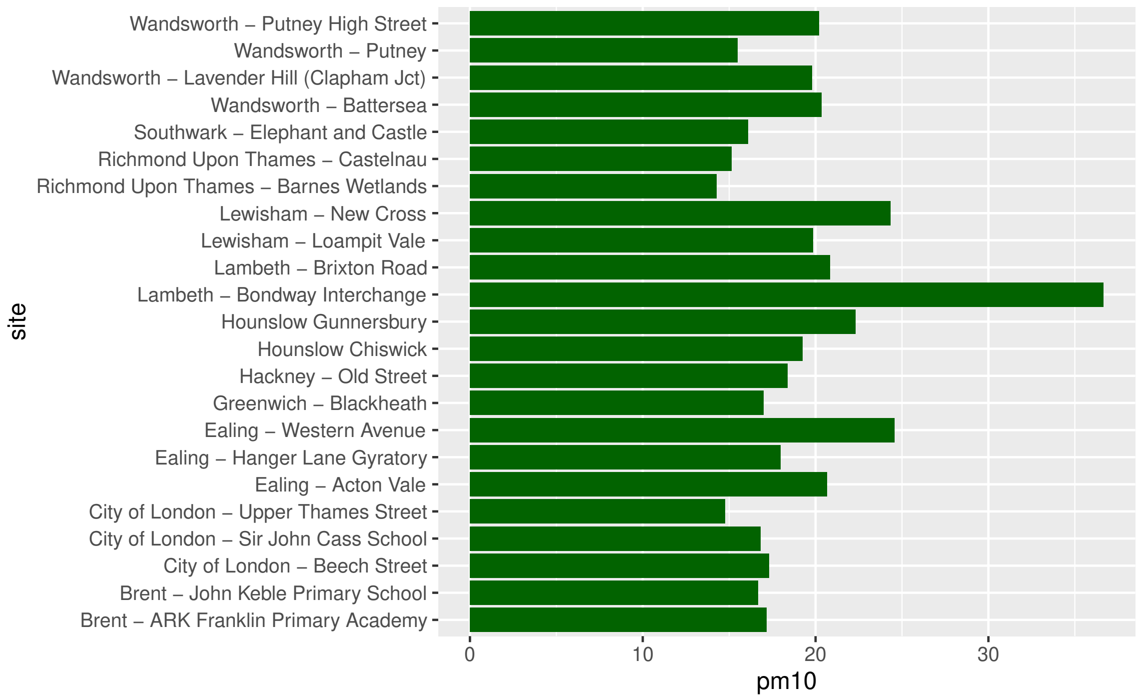

Figure 8: Average PM$_1$0 Concentrations at Air Monitoring Sites :Monthly Trends

3.4 Sulphur dioxide (SO_2)

Sulphur dioxide is a colourless gas with a distinctive odour, that is produced from burning fuels containing Sulphur. Short-term exposure to Sulphur dioxide can cause symptoms such as coughing, chest tightness, and airway tightening, with those who have asthma being especially vulnerable.

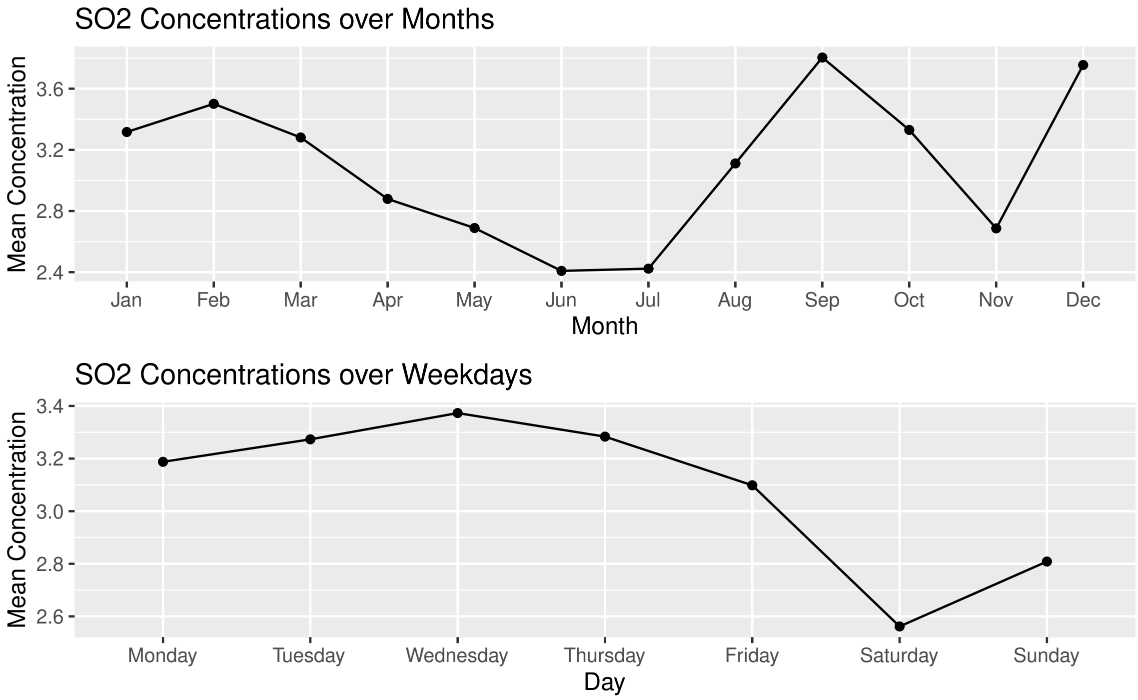

Figure 9: Temporal Variation in SO_2 Concentrations:Monthly and Weekday Trends

The only location where the levels of Sulphur dioxide (SO_2) are monitored is the Lambeth - Bondway Interchange. The results show a similar pattern of decreased SO_2 concentrations during the summer and spring seasons, with significant spikes in September and December. The SO_2 emissions are significantly higher during the weekdays than they are during the weekends, peaking on Wednesdays. This suggests a noticeable pattern of increasing SO_2 levels from Monday through Wednesday, then falling near the end of the week.

The decreased emissions on Saturdays and Sundays could be linked to a reduction in industrial activity during the weekend. Higher industrial activity in the middle of the week, possibly related to increased manufacturing or energy consumption, may be linked to Wednesday's greater SO2 levels. The downward trend that started on Wednesday might be related to a drop in industrial activity or a change in behaviour toward greener practices later in the week.

4 Conclusion

In summary, the study of London City air quality in the year 2022 offers significant insights. Throughout the report, we analysed several air pollutants such as Nitrogen oxides (NO_x, NO, NO_2), Ozone (O_3), Particulate Matter (PM10, PM2.5) and Sulphur dioxide (SO_2) at 36 different air monitoring sites.

The results show that there is a trend in Nitrogen oxide concentrations to higher at both the beginning and the end of the year 2022. Also, the particulate matter, both PM10, PM2.5, follows a similar trend throughout the year, with peak emission in March. Most likely it happens as a result of increased traffic on the rode during the holiday season. In Nitrogen oxides and PM, weekday concentrations are also greater than weekends.

At the Lambeth - Bondway Interchange, Sulphur dioxide levels show a visible upward trend of concentrations across the week, with a peak observed on Wednesday. This is showing the impact of high vehicle traffic and industrial activities on working days.

The Ozone emission increased during the Spring and Summer seasons, with April having the peak. This is due to more sunshine and higher temperatures. which promote the chemical reactions that produce Ozone. In particular, multiple monitoring sites often show similar patterns in Ozone levels.

In conclusion, the research offers significant information for authorities and the general public to better understand of trends in London City's air quality. During times of high pollution, particular efforts might be made to improve the quality of air. Furthermore, cleaner industrial practices could be promoted, and the awareness of reducing emissions of pollutants from different sources could be encouraged. By fixing these issues London City can create a healthier and more sustainable urban environment for its citizens.