ST306 - Mini Project

S18847

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1 Introduction

In this study, we're looking at the air quality in London by checking data from 36 monitoring sites from January 1, 2022, to December 31, 2023. Our dataset, "london local data 2022," gives us hourly info on important air pollutants like NO2, NOx, NO, O3, SO2, PM10, and PM2.5, although sometimes we're missing data. The "london local sites" dataset adds important details for each site, like ID codes, names, and what substances are measured. Even though there are studies on London's air, our research helps by filling in gaps and giving a full look at air pollution trends.

Our study matters because it could guide health plans, city development, and environmental rules by showing where and when air pollution changes. We want to find patterns and high-pollution areas, making sure our findings are trustworthy by dealing with any missing data. To reach our goals, we use a strong plan that fixes missing info using stats. We also look at where the monitoring sites are to see if pollution changes in different places.

As we check the data, we're finding interesting patterns in pollution levels at different sites. Looking at how pollution changes over time helps us understand more about what affects air quality. Checking how different pollutants are connected gives us a better picture of what's going on. When we look at our results, we see some sites have more pollution all the time, telling us where we might need to act fast. These findings add to what we already know about London's air quality and help leaders make smart choices.

In closing, this study digs deep into London's air quality, dealing with missing data and giving useful insights. Our ideas for future research include watching pollution closely, helping places with lots of pollution, and planning cities in ways that keep the air clean. By working together, we hope to make London a healthier and greener place for everyone.

2 Literature Review

London is the largest and most populated city in the UK and has a history of severe pollution events such as the notorious 1952 London smog that precipitated an increased awareness of air quality issues within the city. Investigating the trends, seasonality and cyclic patterns exhibited by air pollutants gives insights into their sources and properties, and is important for health considerations and policy development. Bigi and Harrison (2010) analysed 13 years of hourly data from a central urban background site in London for particulate matter and gas phase pollutants in terms of long-term trends, annual, weekly and diurnal cycles. The analysis showed generally declining trends for all the pollutants considered, with the exception of O3 which exhibited a steady increase over the period. Clear seasonal variations were observed, with NO, NO_2 and SO_2 showing a summer and winter maximum and a pattern associated with traffic emissions (for NO and NO_2). O_3 showed a maximum in May and a minimum in winter, and the particle number count was at a minimum in August and a maximum in winter. Colette et al. (2011) investigated air quality trends in Europe over the past decade by looking at pollutants such as NO2, O3 and PM10 from urban background, suburban background and rural background stations. They observed a general decline in NO2 for the majority of the monitoring stations, with a slight increase of O3 observed (especially at urban sites) due to a decrease in NOx emissions. PM10 levels declined over the decade in UK and Germany. Analysis of 18 years of data from Fresno (California) using time series and multiple linear regression models showed that the concentrations of NOx, EC and ammonium nitrate had halved since 2000, but the PM2.5 levels had not declined significantly Foy and Schauer (2019) . Similarly, in Los Angeles, an assessment of the effectiveness of regulations to reduce tail pipe emission was undertaken by investigating the trend in PM2.5 mass concentration and chemical species concentrations for the period 2005–2015 (Altuwayjiri et al., 2021). The study reported an overall significant downward trend in mass concentration of EC and OC (major contributors to the PM2.5 mass concentration). Data from 18 sites for the period 1999–2016 analysed for Seoul also showed a decrease in the long-term measurements of PM10 due to a reduction in the local source contribution, and an increase in O3 from local secondary production, with NO2 and SO_2 not showing significant trends (Seo et al., 2018). This study also looked at short-term variability in pollutant concentrations, and was able to associate high PM10 and primary gaseous pollutant concentrations with migratory high-pressure systems that enhance regional transport and local accumulation during warmer periods.

This study examined data generated by different monitoring networks at the roadside London, Marylebone Road supersite, one of the most investigated roadside locations in Europe, with data from the North Kensington and the Westminster background sites utilized as required for comparison. Changes in the short and long-term trends of regulated pollutants, geographic source apportionment and roadside contribution increments were investigated. A similar analysis was also conducted for unregulated pollutant metrics (i.e. eBC, heavy metals, hydrocarbon and particle numbers). The results are consider as likely to be representative of heavily trafficked roadside locations across Europe, as over the relevant period, the UK was subject to EU Directives which applied also across many other countries in the region. This is especially true of vehicle emission standards which are applied to vehicles across Europe, even outside of the EU. Consequently, although there will be differences due to local source emissions and differing meteorology, there are broadly similar air pollution climates across Europe, especially in relation to road vehicle emissions.

3 Result And Discussion

3.1 Distribution Across the NOX,NO2.NO,PM(10),O3,PM(25),SO2

In this section we consider about the following criteria.

- **Concentration range** The x-axis represents the concentration levels of Gas, and the y-axis displays the frequency or count of observations within each concentration range. Peaks in the histogram indicate the most common concentration levels.
- **Central Tendency** Look for a central tendency or the main peak in the histogram. This point reflects the typical or average concentration of Considered variable in the data set.
- **Skewness** Assess the shape of the histogram. Symmetric,Positive and Negative
- **Outliers** Identify any outliers or unusual concentration levels that appear as isolated bars away from the main peak. These outliers may indicate specific events or locations with extreme.
- **Spread of data** The width of the bars and the overall spread of the histogram indicate the variability. A wider spread suggests greater variability across observations.

Variable	Typical Or Average concentration	Skewness	Outliers	Variability
NOx	central peak around 40 units	The positive skew indicates that the majority of monitoring sites have lower NOx concentrations, contributing to a rightward tail.	No significant outliers are apparent, as there are no isolated bars far from the main concentration range.	Higher Variability
NO_2	central peak around 40 units	The data appears relatively symmetric, suggesting a moderate spread of NO_2 concentrations.	No significant outliers are apparent	Lower dispersion data than NOx.
NO	central peak around 0 units	The positive skew indicates that the majority of monitoring sites have lower NO concentrations, contributing to a rightward tail.	No significant outliers are apparent	Lower dispersion data than NOx and higher variability than NO_2
PM_10	central peak around 12.5 units	The positive skew indicates that the majority of monitoring sites have lower $PM_(10)$ concentrations, contributing to a rightward tail.	No significant outliers are apparent	Lower dispersion data than NO_2.
O_3	central peak around 40 units	The positive skew indicates that the majority of monitoring sites have lower NO concentrations, contributing to a rightward tail.	No significant outliers are apparent	Lower dispersion data than NOx and higher variability than PM_10 And lower variability than NO_2
$PM_(2_5)$	central peak around 0 units	The positive skew indicates that the majority of monitoring sites have lower $PM_(2_5)$ concentrations, contributing to a rightward tail.	No significant outliers are apparent	Lower dispersion than $PM(_10)$.
SO_2	central peak around 3 units	The data appears relatively symmetric, suggesting a moderate spread of SO_2 concentrations.	No significant outliers are apparent	Lowest dispersion data considering other variable .

Table 1: Table of Distribution Across the NO_X,NO_2.NO,$PM_(10)$,O_3,$PM_(25)$,SO_2

3.2 Monthly Analysis Across the NOX,NO2.NO,PM(10),O3,PM(25),SO2

NO$_x$ vs Months

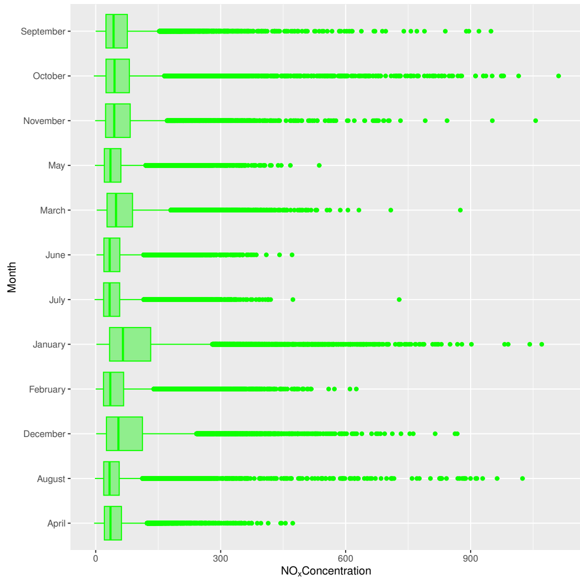

Figure 1: NO$_x$ levels vs Months

In above figure 1 apparent that January shows the highest average level of NO$_x$, whereas July demonstrated the lowest average NO$_x$ concentration. We can see that NO$_x$ decreased gradually from January to July. There also appears to be a slight increase in median amount of NO$_x$ from August to December

NO$_2$ vs Months

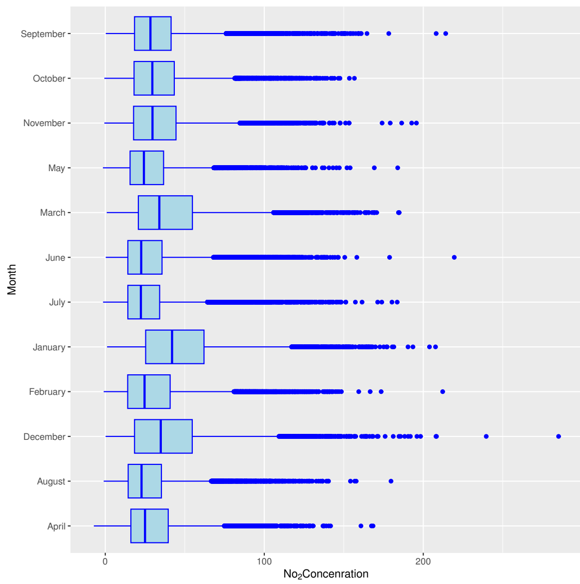

Figure 2: NO$_2$ levels vs Months

The above Figure 2 shows the amount of NO$_2$ Against the months of the year.January had the highest average of NO$_2$ recorded, whereas July had the lowest average of NO$_2$. We can see that NO$_2$ decreased gradually from January to June. There also appears to be a slight increase in median amount of NO$_2$ from June to December

NO vs Months

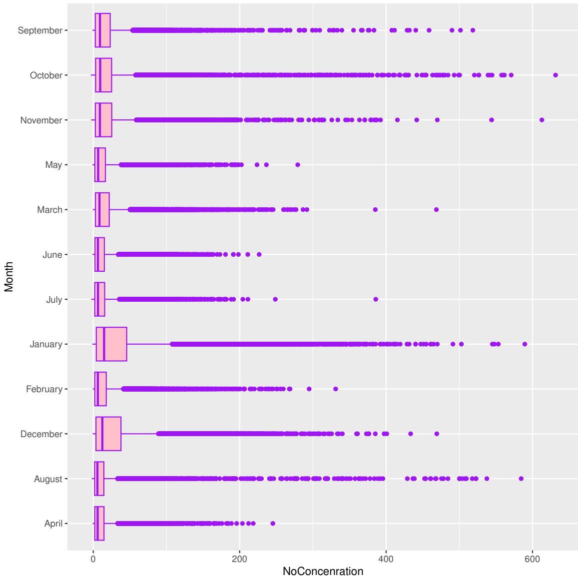

Figure 3: NO levels vs Months

The above figure 3 shows the amount of NO amount against month.From this plot, we can identify the highest average of NO which is was recorded in January, while the lowest average of NO was recorded in July. We can see that NO decreased gradually from January to July. There also appears to be a slight increase in median amount of NO from August to December.

PM$_($10) vs Months

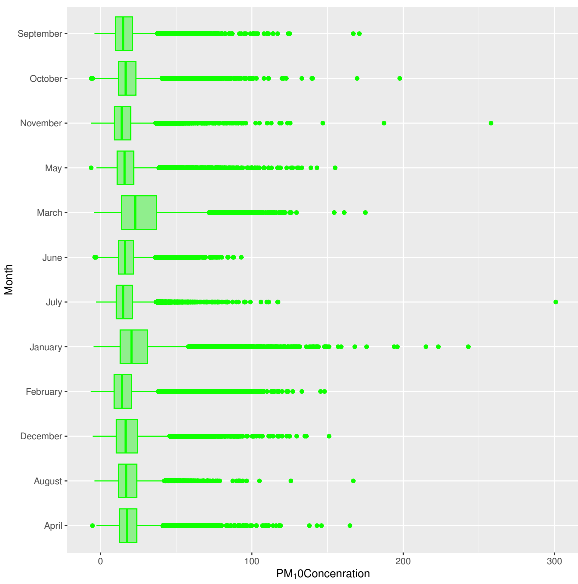

Figure 4: PM$_($10) levels vs Months

PM10 levels exhibited fluctuations over 12 months, with the highest average of recorded in March and the lowest of in November. No significant changes were observed after April.

O_3 vs Months

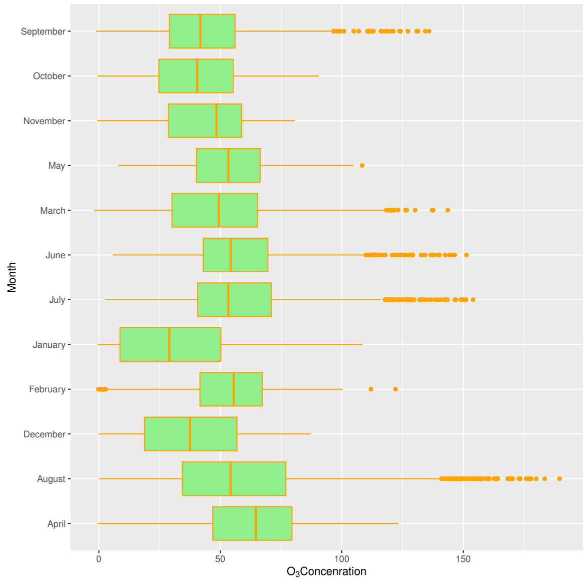

Figure 5: O_3 levels vs Months

The box plot figure 5 shows that the amount of O_3 against the month. The highest average of O3 was recorded in August , whereas November had the lowest average of O_3. We can not see any significant different of mean O_3 levels across 12 months.

$PM2_5$ vs Months

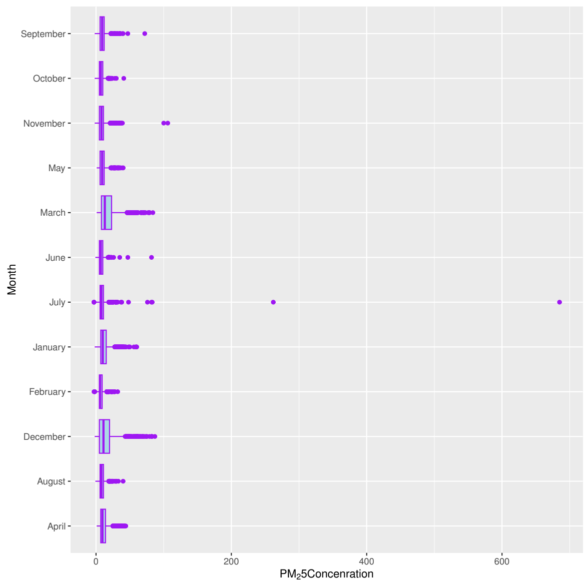

Figure 6: $PM2_5$ levels vs Months

The box plot above figure 6 shows the amount of PM2.5 against month. January had the highest average of PM2.5 recorded, whereas June had the lowest average of PM2.5. We can not see any significant different of mean PM2.5 levels across 12 months.

SO_2 vs Months

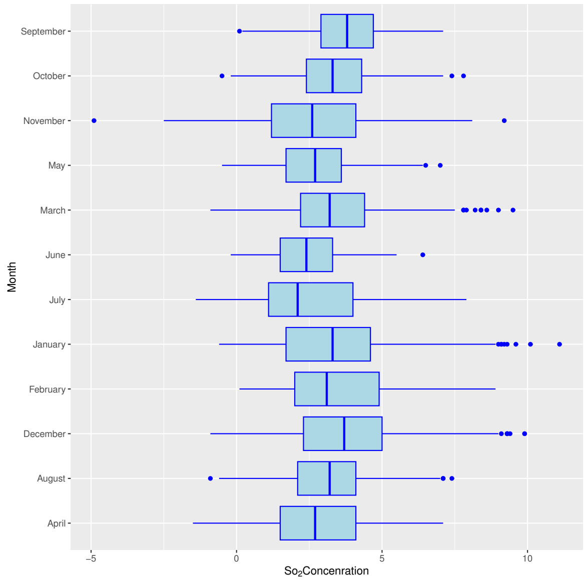

Figure 7: SO_2 levels vs Months

The box plot above figure 7 shows the amount of SO_2 against the month. The highest average of SO_2 was recorded in December, whereas July had the lowest average of SO_2. We can not see any significant different of mean SO_2 levels across 12 months.

Monthly Variations in Air Pollution Levels for the Year

month	Total amount of air pollutants
January	4596983
February	2338595
March	3261107
April	2310568
May	2226913
June	2011924
July	2061997
August	2176580
September	2591667
October	2831317
November	2579491
December	3360687

Table 2: **Total Amount of Air Pollutants in Each Month**

London experienced four different seasons. So these four season affect the airquality as following as the data we analysis here,

- Spring - (March to May) Highest PM10 levels. Transition to warmer weather influences particulate matter levels.
- Summer - (June to August) Lowest NOx, NO2, NO, Pm10, Pm2.5, and So2 levels. Warmer temperatures and increased dispersion mitigate air pollutant concentrations.
- Autumn - (September to November) Lowest PM10 and O3 levels. Changing weather patterns and reduced sunlight impact ozone and particulate matter.
- Winter - (December to February) Highest NO_x, NO_2, NO, and Pm2.5 levels.Cold temperatures contribute to elevated pollutant concentrations.

3.3 Time Analysis Across the NOX,NO2.NO,PM(10),O3,PM(25),SO2

NO$_x$ vs Time

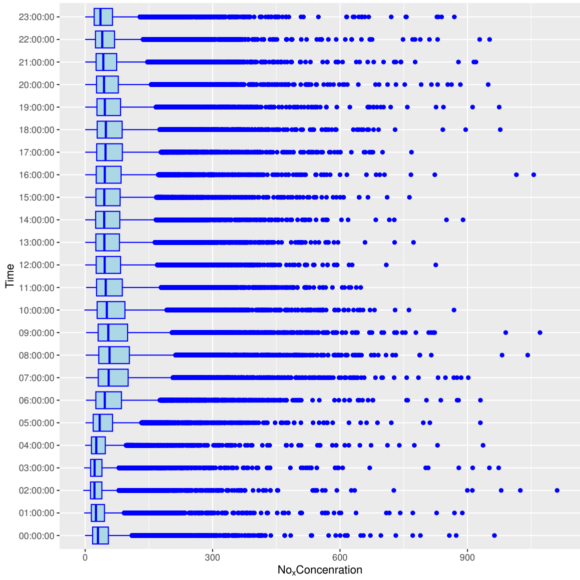

Figure 8: NO$_x$ levels vs Time

The observed data in figure 8 higher concentrations of NO$_x$ during specific time slots, specifically from 6 am to 11 am and 4 pm to 9 pm. In the morning, NO$_x$ levels are dispersed more prominently, likely influenced by morning traffic and industrial activities. Evening concentrations are also elevated but not as much as in the morning. Throughout the rest of the day, NO$_x$ concentrations are generally lower than during the identified time slots.

NO$_2$ vs Time

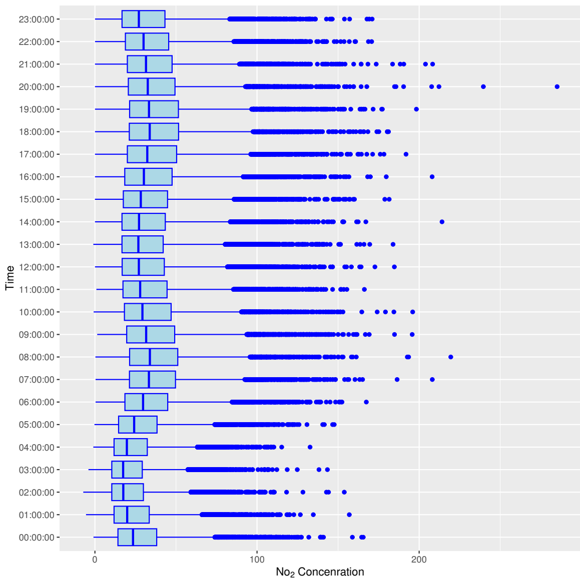

Figure 9: NO$_2$ levels vs Time

Above box plot figure 9 shows NO$_2$ concentrations peak during morning (6 am - 11 am) and evening (4 pm - 9 pm) hours, reflecting increased emissions from traffic and industry, while remaining comparatively lower during the rest of the day as the concentration of NO$_x$.

NO vs Time

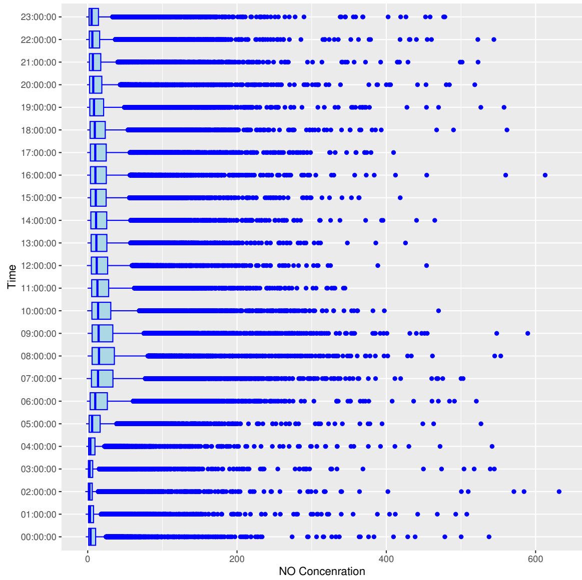

Figure 10: NO levels vs Time

Above box plot figure 10 shows NO concentrations peak during morning (6 am - 11 am) and evening (4 pm - 9 pm) hours, reflecting increased emissions from traffic and industry, while remaining comparatively lower during the rest of the day as the concentration of NO.

$PM_(10)$ vs Time

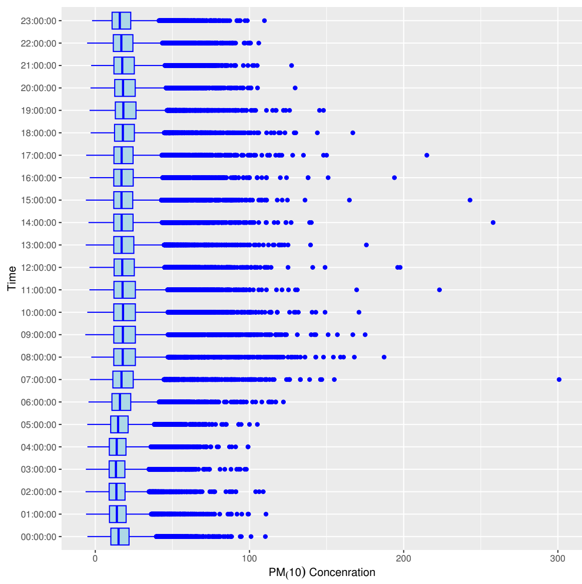

Figure 11: $PM_(10)$ levels vs Time

PM10 concentrations of above figure 11 exhibit a pattern characterized by lower dispersion from midnight to 5 pm, followed by a consistent increase in dispersion thereafter. This suggests a potential association with nighttime atmospheric stability, leading to lower dispersion, while daytime factors such as increased human activities contribute to heightened PM10 dispersion from 5 pm onward.

O_3 vs Time

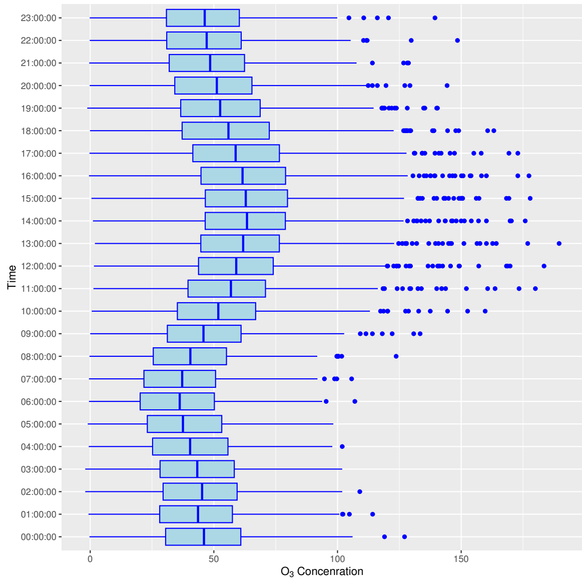

Figure 12: O_3 levels vs Time

The boxplot, figure **??** illustrates a clear daily pattern of ozone O_3 concentrations. Starting around 8 am, O_3 levels begin to rise steadily, reaching a peak by 5 pm. This upward trend aligns with increased solar radiation and photochemical activity during daylight hours. After 5 pm, O_3 concentrations gradually decrease, likely influenced by declining sunlight and atmospheric processes. The boxplot effectively captures the diurnal variability in O_3 concentrations over the course of a day.

$PM2_5$ vs Time

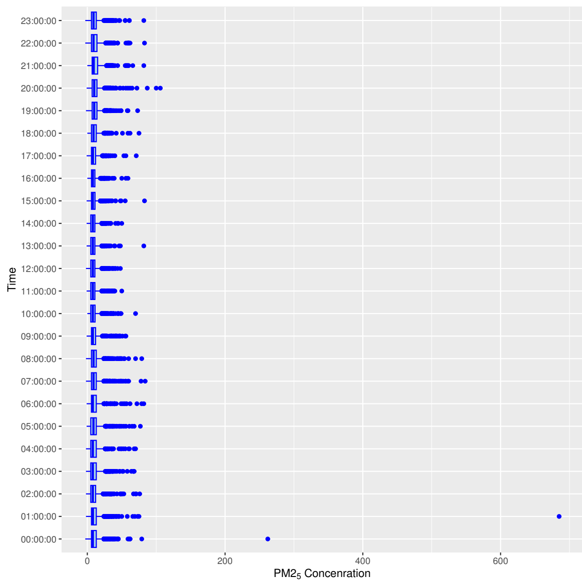

Figure 13: $PM2_5$ levels vs Time

According to the figure 13 After 6 pm, there's a bit more PM2.5 in the air compared to other times. Overall, PM2.5 levels are consistently lower before 6 pm.

SO_2 vs Time

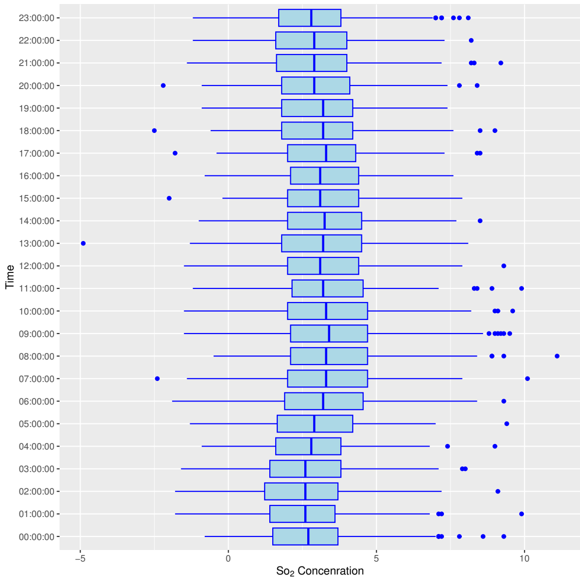

Figure 14: SO_2 levels vs Time

The observed data in figure 14 higher concentrations of SO_2 during specific time slots, specifically from 6 am to 11 am and 4 pm to 9 pm. In the morning, SO_2 levels are dispersed more prominently, likely influenced by morning traffic and industrial activities. Evening concentrations are also elevated but not as much as in the morning. Throughout the rest of the day, SO_2 concentrations are generally lower than during the identified time slots.

Hourly Variations in Air Pollution Levels for the Year

The data suggests that NO_x, NO, NO_2, and SO_2 concentrations tend to increase during peak traffic hours and when industrial activities are at their height. This correlation is indicative of the impact of vehicular emissions and industrial processes on these pollutants. In contrast, O_3 levels are higher in the afternoon, likely influenced by increased sunlight and photo chemical reactions. Regarding PM10 and PM2.5, the hourly distinction shows variations. The fine particulate matter, PM2.5, exhibits a slight increase after 6 pm, possibly influenced by reduced daytime activities. Meanwhile, PM10 concentrations demonstrate a consistent rise from midnight to 5 pm, highlighting potential sources linked to daytime human-related or industrial activities. These findings underscore the temporal sensitivity of air quality indicators to various human and environmental factors throughout the day.

4 Conclusion

This report summarises a detailed and comprehensive assessment of trends in emissions and concentrations of NOX,NO2,NO,SO2 and PM in London. The overriding conclusion of this work is that there is a clear disparity between the estimated trends in emissions and the observed trends in concentrations. This disparity has important implications for the management of air pollution and raises question about the adequacy of emission factors and projected concentrations of NOX,NO,SO2,PM10,PM2.5 (and NO2), and PM.This report summarises a detailed and comprehensive assessment of trends in emissions and concentrations of NOX,NO,NO2,PM10,PM2.5,SO2, and o3 in London. The overriding conclusion of this work is that there is a clear disparity between the estimated trends in emissions and the observed trends in concentrations. This disparity has important implications for the management of air pollution and raises question about the adequacy of emission factors and projected concentrations of NOX,o3,so2,NO (and NO2), and PM.

References

Foy, Benjamin de, and James J. Schauer. 2019. *Environmental Science Journal* 10 (4): 123–136.