Investigation of Seasonality and Weather on Urban and Rural Pollution

Thomas S. Peachey

School of Physics, University of Bristol.

This report summarises an investigation into pollution levels and their relationship with weather at two sites; one 'urban' (Marylebone Road in central London)[3] and one 'rural' (Rochester Stoke in Kent).[5][6] Using publicly available data from DEFRA[7] in the period from January 2018 to February 2021, PM2.5 and PM10 (see appendix A) pollution levels were compared between the two sites and the effects of weather on these measurements were investigated using data from the Meteostat website.[2] PM10 levels were found to vary significantly over the course of the day, especially at the urban site, peaking around and just after the 'rush hour' periods. This pattern was also observed to a lesser degree with PM2.5 pollution. Over the course of a week the data is relatively uniform with minor peaks on Thursday for the urban site and Saturday for the rural site. Over the course of a year particulate pollution at both sites is highest in spring, peaking in April. Additionally, correlations were calculated for temperature, precipitation and wind speed vs pollution level were calculated. The correlations relating to both temperature and precipitation were present but not overly significant, however a moderate negative correlation was established between wind speed and pollution levels particularly for PM2.5 pollution.

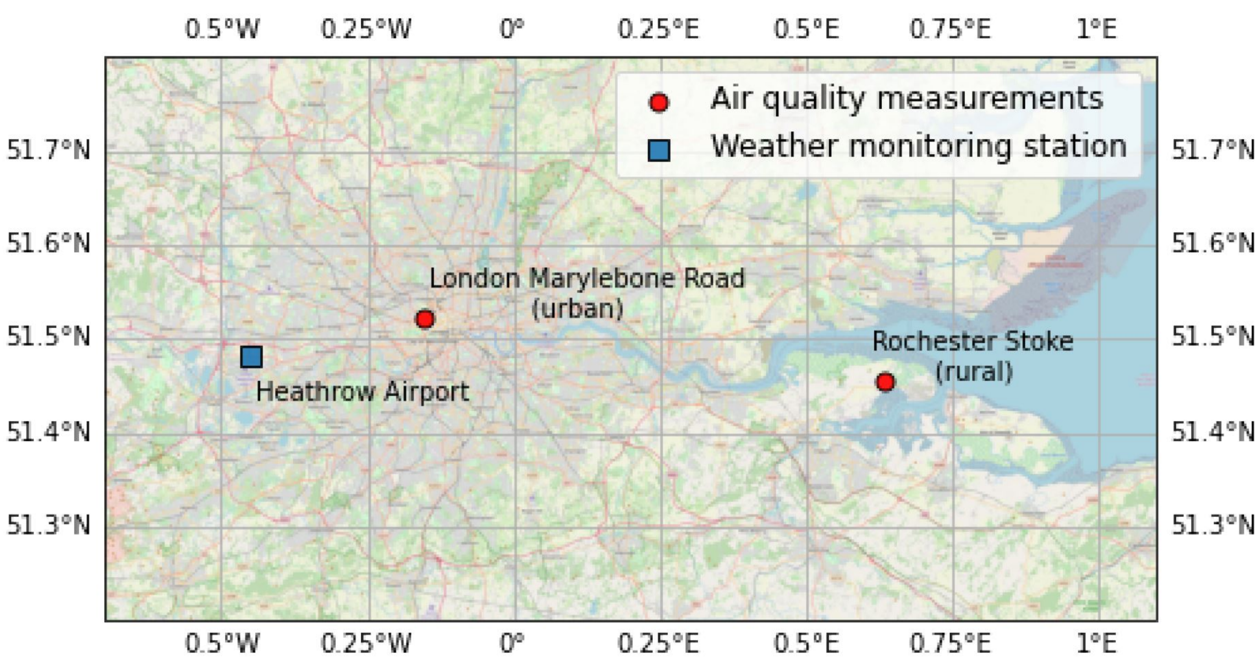


FIG. 1. A geographical map showing the location of the sampling sites the data has been sourced from[4]

I. INTRODUCTION

Pollution levels are an incredibly important aspect of atmospheric science, especially when it comes to the health of human beings exposed. This report aims to ascertain periodic patterns of harmful particulate emissions across various three timescales; one day, one week and one year. These periods are significant as time of day, time of week and time of year all drive human activity and it is hypothesised that these will consequently drive emission levels. This report also aims to determine if there is any significant relationship between weather conditions and PM pollution levels. It is expected that the most significant relationship is between pollution and weather will come from wind speed, as wind is a direct phenomenon within the medium that carries this pollution. It is likely that higher wind speeds will act to disperse PM, particularly localised concentrations and thus lower the measured concentrations.

The first period being investigated is pollution levels of both PM10 and PM2.5 over the course of the day. This first period is notable as it is expected that pollution levels will lower significantly at night when human activity is a at minimum. Additionally there is the hypothesis that there will be multiple peaks over the course of the day, particularity a peak around or just after morning and afternoon rush hours is expected. Transport for London's definition of peak times (corresponding to transport fare prices) will be used - Monday to Friday between 06:30 and 09:30, and between 16:00 and 19:00.[8]

The second period investigated is the course of the week. Modern society tends to people organising around a 5 day work week Monday through Friday with a weekend. This is likely to drive pollution levels as both PM produced by combustion engines due to commuting and industrial PM sources will likely follow a cycle as a result.

The final period investigated is pollution levels over the course of the year. The hypothesis here is that human activity may increase during warmer seasons and this may also have a relationship with weather. However one issue that may offset this is the increased use of fossil fuel energy production during colder seasons, where there is less solar power being generated and more demand for electrical power used to heat inhabited spaces.

II. ANALYSIS AND DISCUSSION

The general distribution of the data used in this report can be seen in figure 2. The mean pollution levels in the urban site are significantly higher across both PM10 and PM2.5. However both sites stay within low to moderate levels of PM for 99% of the the time period analysed.

Period - Day

As can bee seen in figure 3 there are in fact clear peaks in both PM10 and PM2.5 pollution around and just after the rush hour periods in the urban site. This pattern is significantly reduced in the rural site, which is to be expected as it is considered 'background'. In Rochester the main peak is around 9pm however the morning peak is still somewhat present. Additionally the overall rush hour peak pattern is perhaps diluted by data from the weekend where traffic as well as industry and consequently pollution is potentially reduced and likely more continuously distributed across the day.

Period - Week

Again a periodic pattern can be seen in the weekly data in figure 4. There is a clear peak especially at the urban site on Thursdays with pollution dropping to lower levels on the weekend, being at their lowest on Sunday. At the urban site, the Thursday peak is present to a degree however unexpectedly pollution levels are actually on average higher on the weekend with peak on Saturday. The cause of this is hard to determine; potentially pollution levels lag behind London to the west with PM being blown in by west to east winds over the course of several days.

Period - Year

In figure 5 the data in this case shows a very similar pattern for both sites; there is a strong peak in April for both PM10 and PM2.5 with lesser peaks in November. The cause of this is again difficult to determine, one hypothesis is that the spring peak is driven by pollen. Pollen is technically a type of Particulate Matter however most intact pollen grains are larger than 10 um, therefore they don't usually fall into the PM10 or PM2.5 category.[9] A phenomenon more common in recent years is high levels of PM from sources outside of the UK particularly in the spring season. Nationwide spikes in PM levels around the spring have been attributed to Dust blown to the UK from the Sahara desert as well as industrial and agricultural pollution from mainland Europe.[11]

The Effects of Weather

In order to ascertain a relationship between various weather conditions and PM concentrations, a simple table of correlations has been produced from the entire dataset. Spearman's coefficient was chosen as it is less sensitive than the Pearson correlation to strong outliers.[10] From the notable correlations highlighted in yellow, it is clear to see that as hypothesised, there is moderate negative relationship between wind speed and PM concentration and that wind speed is the condition most related to pollution levels compared to other conditions.

It is additionally notable that On average PM2.5 concentration is more correlated than PM10, this is possibly explained by the fact that smaller and therefore lighter particles can be more easily dispersed by air currents than heavier particles which tend to settle.

Another further point of interest is that pollution in the rural site is much more negatively correlated with wind speed than at the urban site especially PM2.5 (-0.378 vs -0.302). One explanation for this could be the nature of the environment each monitoring station is located in. Marylebone road in London is heavily built up with large, tall buildings; these can act as a wind break diminishing the flow of air currents on the street level where emissions are produced, dampening the dispersing effect wind has.

III. CONCLUSIONS

To conclude, as hypothesised, there is significant seasonality and periodicity in the concentrations of PM over the time period analysed. Data shows very prominent peaks in the spring time, an explanation of which would benefit from further analysis. The potential effects of weather are also apparent in the data especially in regard to wind speed. The dispersal hypothesis has is supported by evidence especially in the rural environment with a negative correlation of -0.378.

Appendix A: Particulate Matter

Airborne particulate matter (PM) includes a wide range of particle sizes and different chemical constituents. It consists of both primary components, which are emitted directly into the atmosphere, and secondary components, which are formed within the atmosphere as a result of chemical reactions. Of greatest concern to public health are the particles small enough to be inhaled into the deepest parts of the lung. PM of greatest concern to human health are PM10 and PM2.5 – particles of less than 10 and 2.5 micrometres in diameter, respectively.[1]

II. REFERENCES

[1] Glossary of terms, **Department for Environment, Food and Rural Affairs** *https://uk-air.defra.gov.uk/air-pollution/glossary*

[2] London Heathrow Airport weather station **Meteostat** *https://meteostat.net/en/station/03772*

[3] Site Information for London Marylebone, **Department for Environment, Food and Rural Affairs** *https://uk-air.defra.gov.uk/networks/site-info?uka*$_id = UKA00315$

[4] Map of data sources **Rachel Tunnicliffe - University of Bristol School of Chemistry**

[5] Site Information for Rochester Stoke, **Department for Environment, Food and Rural Affairs** *https://uk-air.defra.gov.uk/networks/site-info?site*$_id = ROCH$

[6] Site environment types, **Department for Environment, Food and Rural Affairs** *https://uk-air.defra.gov.uk/networks/site-types*

[7] Data Source, **Department for Environment, Food and Rural Affairs** *https://uk-air.defra.gov.uk/data/data*$_selector_servicemid$

[8] TFL fares Information page **Transport for London** *https://tfl.gov.uk/fares/find-fares/tube-and-rail-fares*

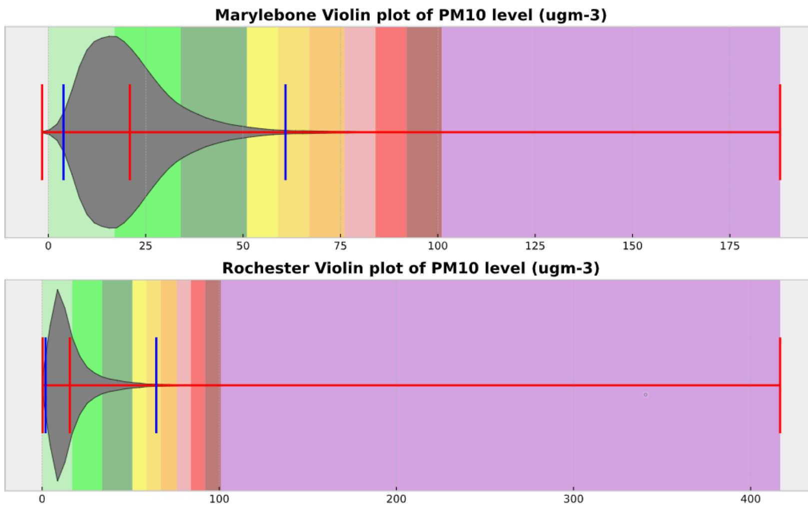
[9] Air Pollution, Pollen Allergies: What's the Link? **Dr. Yvonne Boose - BreezoMeter** *https://blog.breezometer.com/pollen-api-air-pollution-difference*

[10] Research design and statistical analysis **Myers, Jerome L; Well, A. (Arnold) - Lawrence Erlbaum Associates** *https://archive.org/details/researchdesignst00jero*$_935$

[11] The UK particulate matter air pollution episode of March–April 2014: more than Saharan dust **M Vieno, MR Heal, MM Twigg, IA MacKenzie, CF Braban, JJN Lingard, S Ritchie, RC Beck, A Móring, R Ots - Institute of Physics Environmental Research Letters** *https://iopscience.iop.org/article/10.1088/1748-9326/11/4/044004*

PM_{10} Particles

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
µg/m³	0-16	17-33	34-50	51-58	59-66	67-75	76-83	84-91	92-100	101 or more



$PM_{2.5}$ Particles

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
μgm^{-3}	0-11	12-23	24-35	36-41	42-47	48-53	54-58	59-64	65-70	71 or more

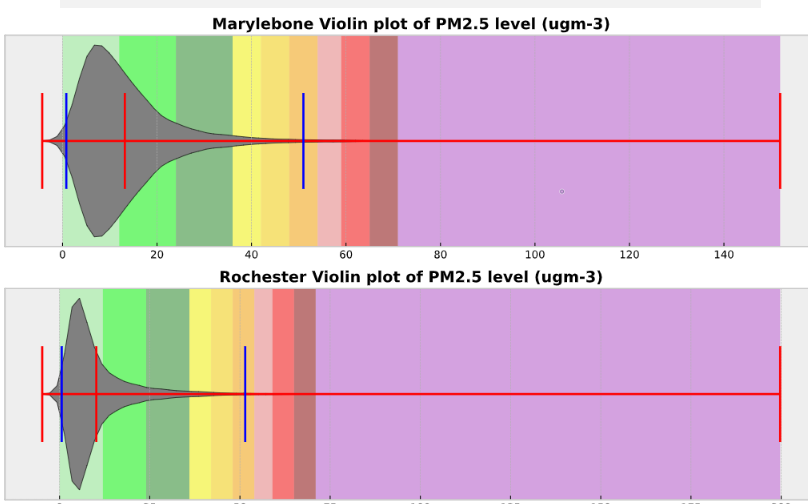


FIG. 2. Violin plots showing the distribution pollution levels across the entire data-set. The red lines represent the minimum, mean and maximum data points. The blue lines represent the 1% to 99% quantiles showing the range the vast majority of the data lies within.

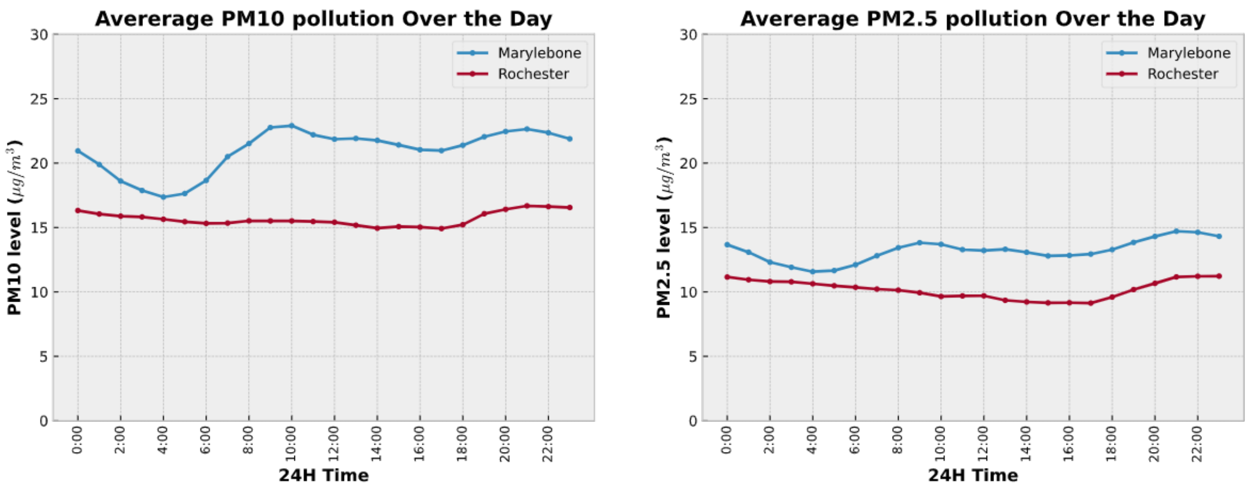


FIG. 3. Graphs showing the average pollution levels over the course of the day at both sites

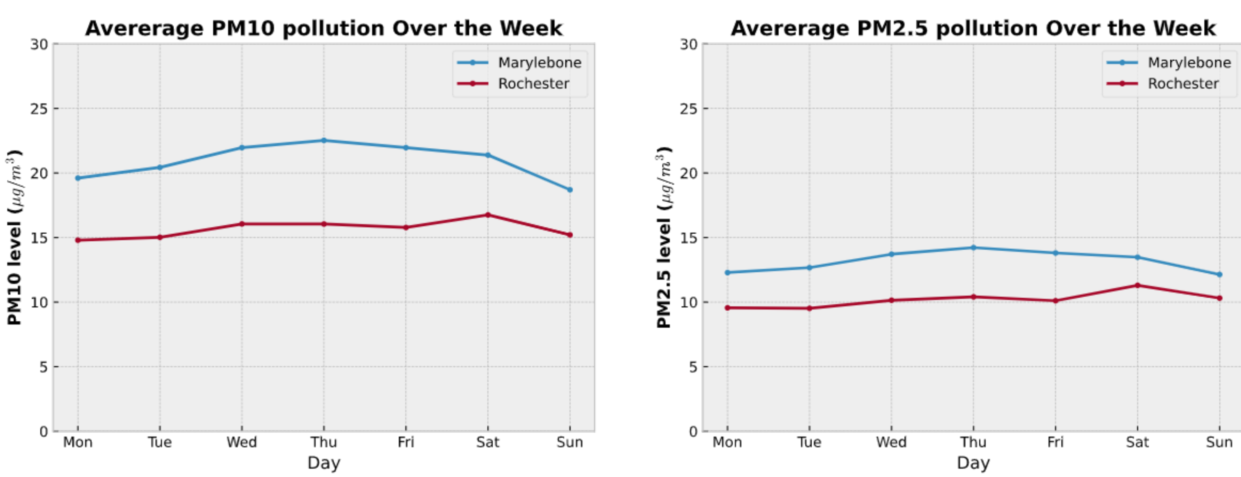


FIG. 4. Graphs showing the average pollution levels over the course of the week at both sites

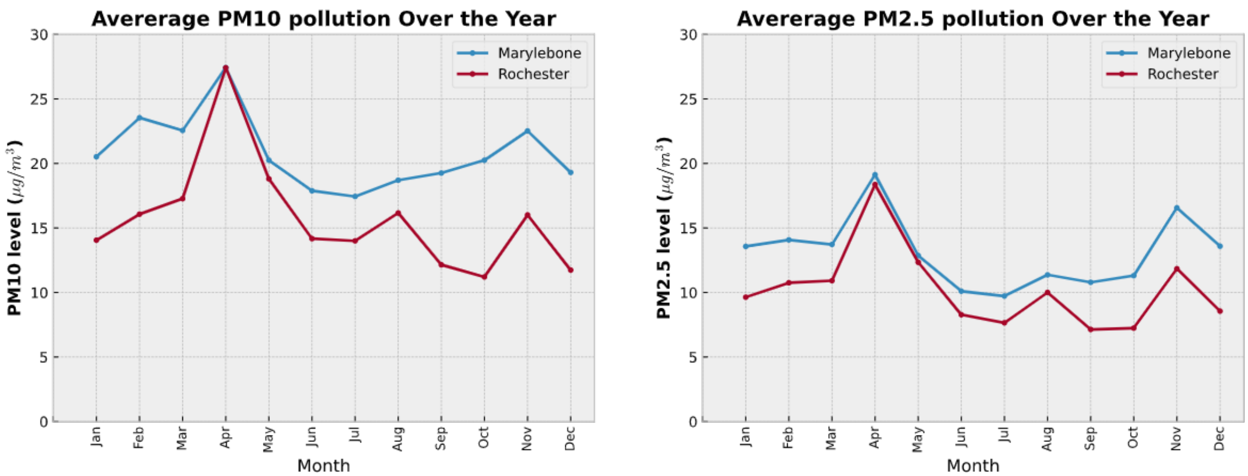


FIG. 5. Graphs showing the average pollution levels over the course of the year at both sites

Correlation Table of Weather vs Pollution

	Temperature (degrees C)	Precipitation (mm)	Wind speed (km/h)	Pressure (hPa)
Marylebone PM10	-0.006	-0.179	-0.191	0.141
Marylebone PM2.5	-0.067	-0.138	-0.302	0.16
Rochester PM10	0.013	-0.163	-0.296	0.216
Rochester PM2.5	-0.058	-0.154	-0.378	0.237

FIG. 6. Table of Spearman's rank correlation coefficient, calculated between weather conditions and PM pollution at each site.