The Effect of COVID-19 Social and Travel Restrictions on UK Air Quality – 27 March Update

27 March 2020

Experts in air quality management & assessment

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1 Introduction

1.1 Air Quality Consultants Ltd (AQC) published a report on 20 March 2020 that presented an analysis of trends in air quality to investigate whether the COVID-19 social and travel restrictions had influenced air quality across the UK. That report found no obvious influence at that point in time. More stringent restrictions have since been implemented, and more time has elapsed within which trends might materialise, so the analysis has been updated to investigate whether any trends are apparent up to 27 March 2020.

1.2 The analysis has also been updated to consider more pollutants, with $PM_{2.5}$ and Ozone (O_3) concentrations now included. Furthermore, changes to the approach to the deweathering of the measured data have been incorporated to better isolate any trends in concentrations as a result of recent direct emissions reductions.

1.3 There is a widespread expectation that concentrations of NOx, NO_2, PM_{10} and $PM_{2.5}$ will have reduced significantly over the last two weeks. Much of the published evidence for this has focused on comparing concentrations measured during two matched periods of time without consideration of confounding factors such as meteorology. It does seem likely that traffic emissions will have fallen, but effects may be more complex than this. For example, avoidance of public transport might increase private car trips and there is anecdotal evidence of increased urban wood burning. It is also important to consider that the relationship between primary emissions and ozone concentrations is complex, and a reduction in urban NOx might be associated with an increase in urban ozone.

1.4 The analysis has primarily focussed on roadside pollutant concentrations, on the assumption that social and travel restrictions are likely to influence roadside pollutant concentrations the most.

2 Methodology

2.1 Openair software[1] has been used to download all measured nitrogen oxides (NOx), nitrogen dioxide (NO_2) and PM_{10} [2] data from 2020 from the UK Automatic Urban and Rural (AURN), Scottish Air Quality (SAQN), Welsh Air Quality (WAQN) and King's College London (KCL) networks. Data were downloaded on the morning of Friday 27 March, with the end date set as midnight of the night before; it should be noted that the final hour of data available varied by site and data network, so the average concentrations calculated for the later hours of 26 March may be based on less sites than the rest of the period, and should thus be treated with greater caution.

2.2 Duplicate sites (for example those that exist in more than one of the networks) have been removed, as have all sites with a data capture rate of less than 90% over 2020 to date. Data that represent an average of multiple sites (i.e. the "London Mean Roadside" and "Sussex Mean Roadside" data in the KCL data) have also been removed.

2.3 The average concentration across all sites (188 roadside sites for NOx, 192 for NO_2, 125 for PM_{10}, 61 for $PM_{2.5}$ and 13 for O_3, and, separately, 57 urban background sites for O_3) has been calculated for each hour of the year, and these have been plotted to see whether any recent trends are obvious.

2.4 Trends in pollutant concentrations are also often masked by meteorological and seasonal effects[3], thus the analysis has moved on to incorporate the removal of such effects, using the 'deweather' function in the openair software. This has been used to create sets of modelled concentrations with the influence of wind speed, wind direction, temperature, relative humidity, atmospheric pressure (where available), hour of the day, day of the week and week of the year removed. The deweathered models have been built using multiple years of pollutant concentration and meteorological parameter data and then sampled using the 2020 meteorological data to identify whether changes in concentrations might be due to meteorological effects, or if they represent the underlying trend in concentrations as a result of changes in emissions.

2.5 Where AQC's previous report considered the "London Mean Roadside" from the KCL network, this report has focussed on impacts at selected specific sites (London Marylebone Road and Manchester Oxford Road). No other roadside sites had been analysed at the time of writing and no preference has been given to sites that might or might not show a downward trend; the two sites were selected simply for their prominence in terms of being located in major urban centres. While the London Marylebone Road is a true roadside site, located adjacent a busy A-road, Manchester Oxford Road is a more nuanced site, being located adjacent to road in central Manchester that is accessible for buses, taxis and permit holders only for most of the day. With public transport continuing to operate, but to a reduced schedule, this site presents an interesting alternative scenario for likely emissions reductions.

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1 Carslaw, D.C. and Ropkins, K. (2012) 'openair - An R package for air quality data analysis', *Environmental Modelling & Software,* vol. 27-28, pp. 52-61.

2 Particulate matter with an aerodynamic diameter of less than 10 µm.

3 Gellatly, R. and Marner, B. (2020) *Nitrogen Oxides Trends in the UK 2013 to 2019*, Available: https://www.aqconsultants.co.uk/CMSPages/GetFile.aspx?guid=af089039-6a2f-49b5-9533-fe31205f3134

2.6 Ambient concentrations are affected by a large number of factors and it is thus usually difficult to determine the precise cause of changes in pollutant concentrations. Similarly, reductions in emissions from one source can be masked by other changes. This note does not provide a comprehensive analysis of the changes in emissions. It is intended to provide preliminary information regarding trends in measured concentrations during the initial phases of COVID-19 social restrictions in the UK.

3 Results

Nationwide Roadside Concentrations

3.1 Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5 present the average hourly NO_2, NOx, PM_{10}, $PM_{2.5}$ and O_3 concentrations, respectively, measured at roadside sites across the UK in 2020 up to the end of 26 March. There are no obvious signals in the raw concentrations that might be attributed to recently imposed social and travel restrictions.

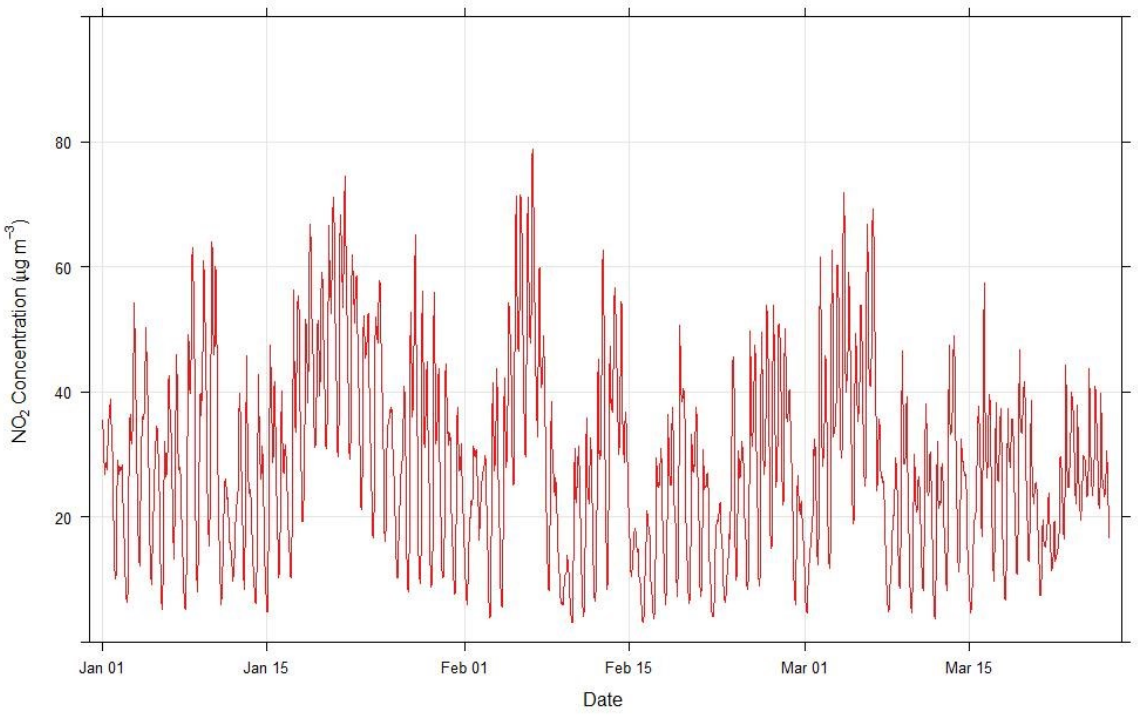

Figure 1: Average UK Roadside NO_2 Concentrations in 2020

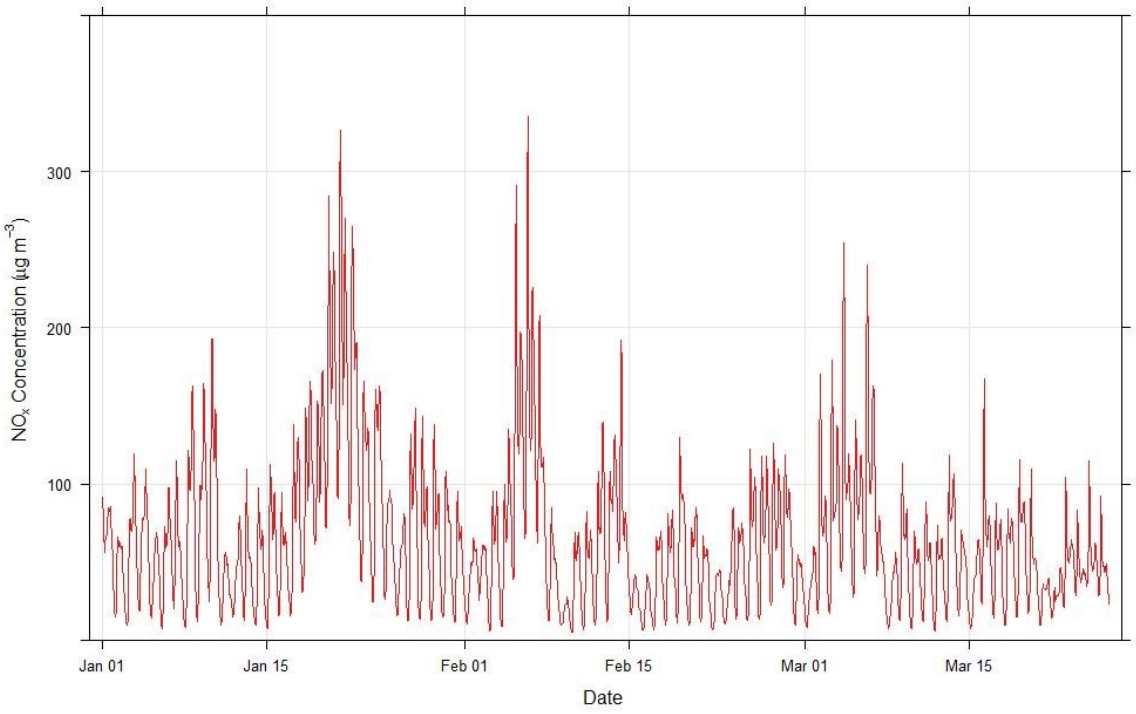

Figure 2: Average UK Roadside NOx Concentrations in 2020

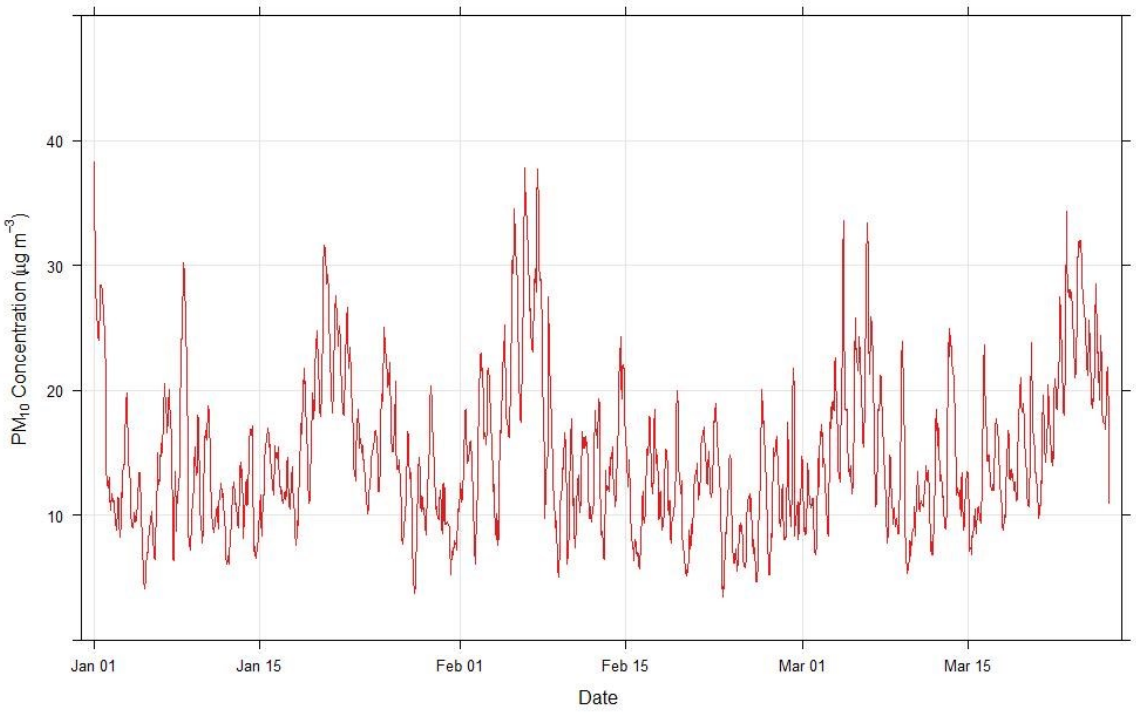

Figure 3: Average UK Roadside PM_{10} Concentrations in 2020

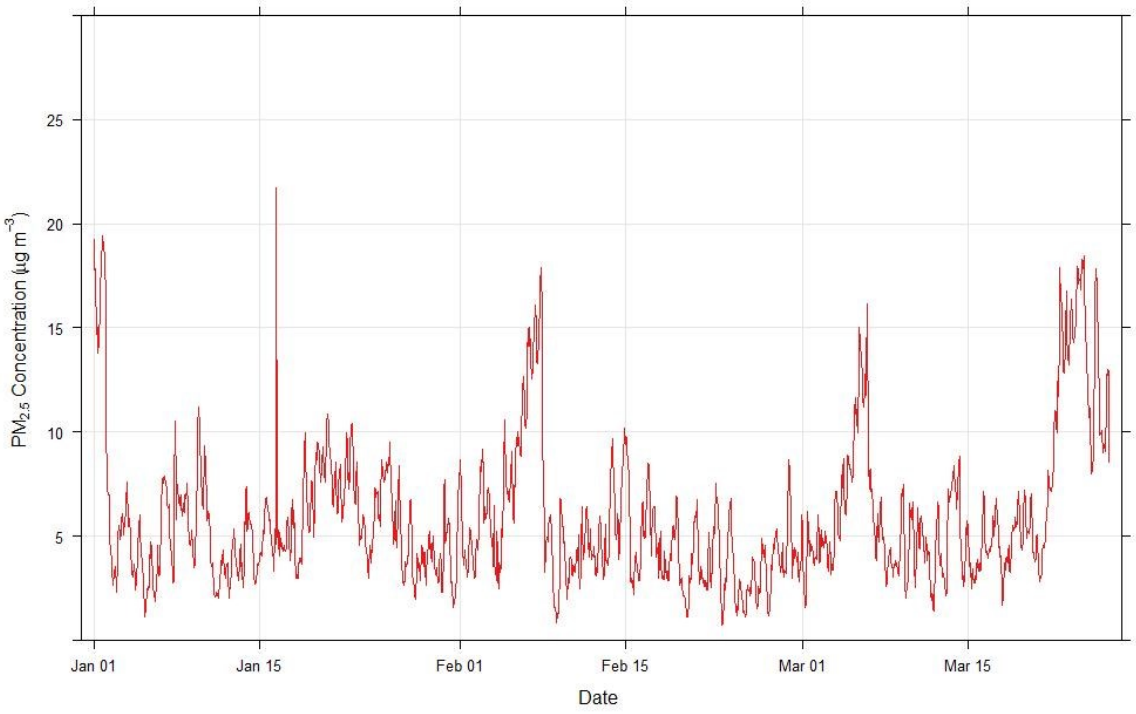

Figure 4: Average UK Roadside $PM_{2.5}$ Concentrations in 2020

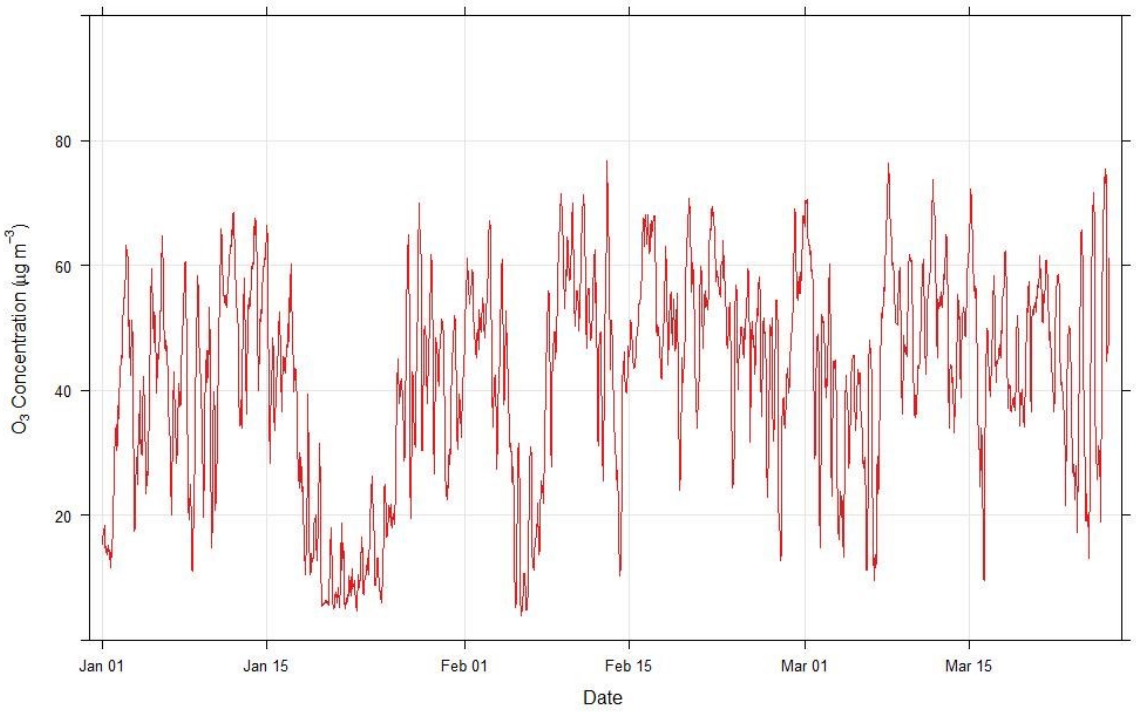

Figure 5: Average UK Roadside O_3 Concentrations in 2020

Nationwide Urban Background O_3 Concentrations

3.2 Figure 6 presents the average hourly O_3 concentrations measured at urban background sites across the UK in 2020 up to the end of 26 March. Again, there are no obvious signals in the raw concentrations that might be attributed to recently imposed social and travel restrictions.

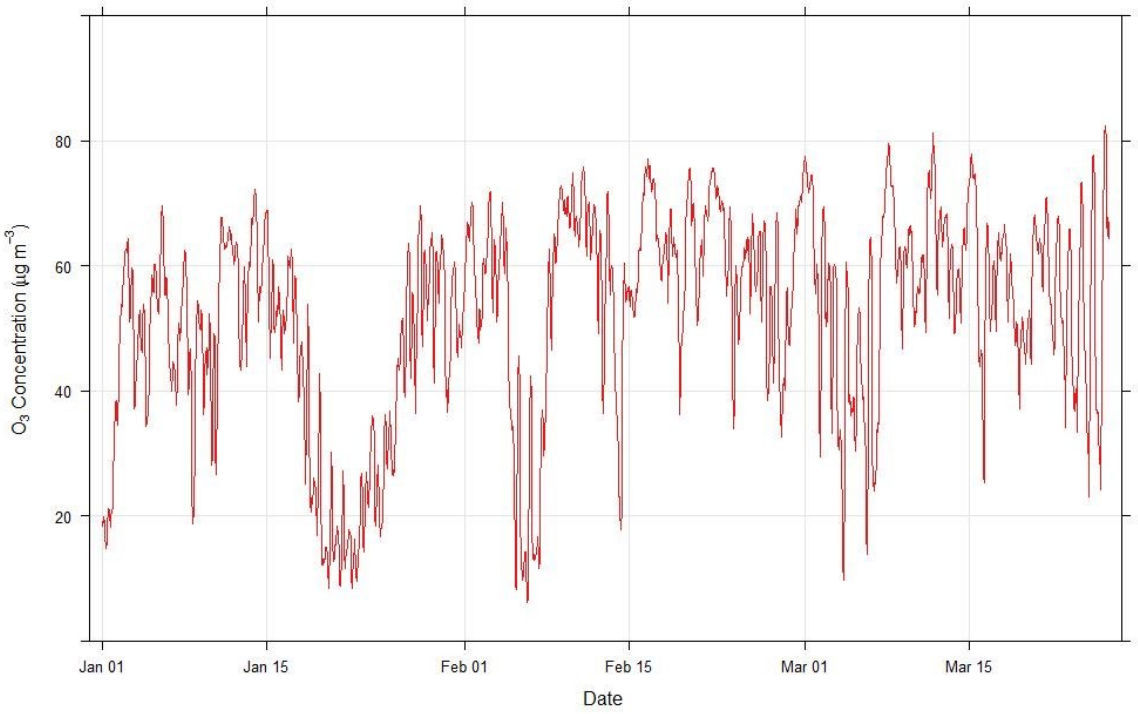

Figure 6: Average UK Urban Background O_3 Concentrations in 2020

London Marylebone Road Concentrations

3.3 Figure 7 to Figure 11 present plots of raw roadside concentrations at the London Marylebone Road AURN site. The period since 17 March does, visually, appear to be atypical; although measured concentrations were mostly within the range of those recorded prior to this date.

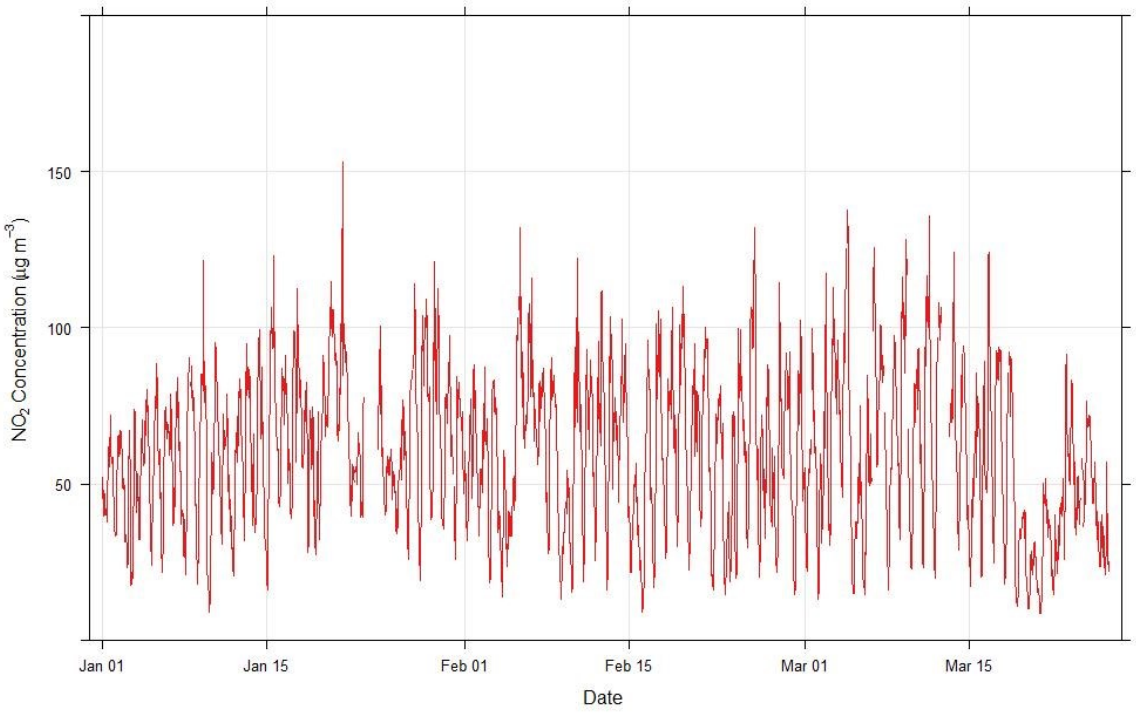

Figure 7: NO_2 Concentrations at London Marylebone Road in 2020

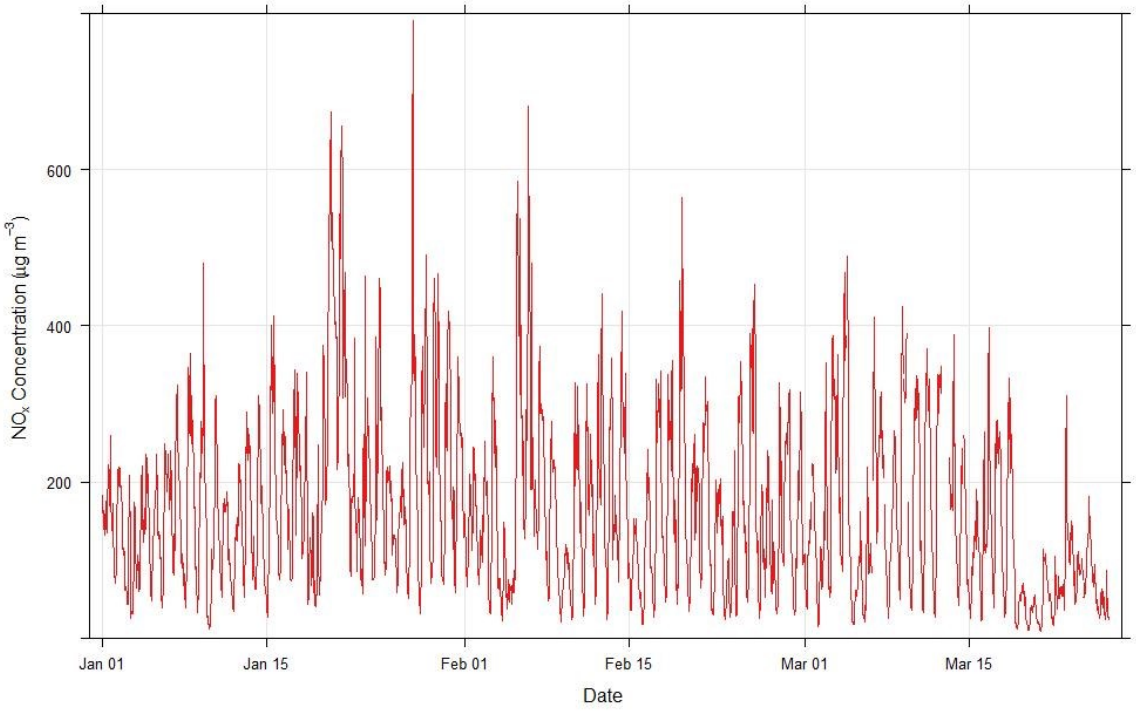

Figure 8: NOx Concentrations at London Marylebone Road in 2020

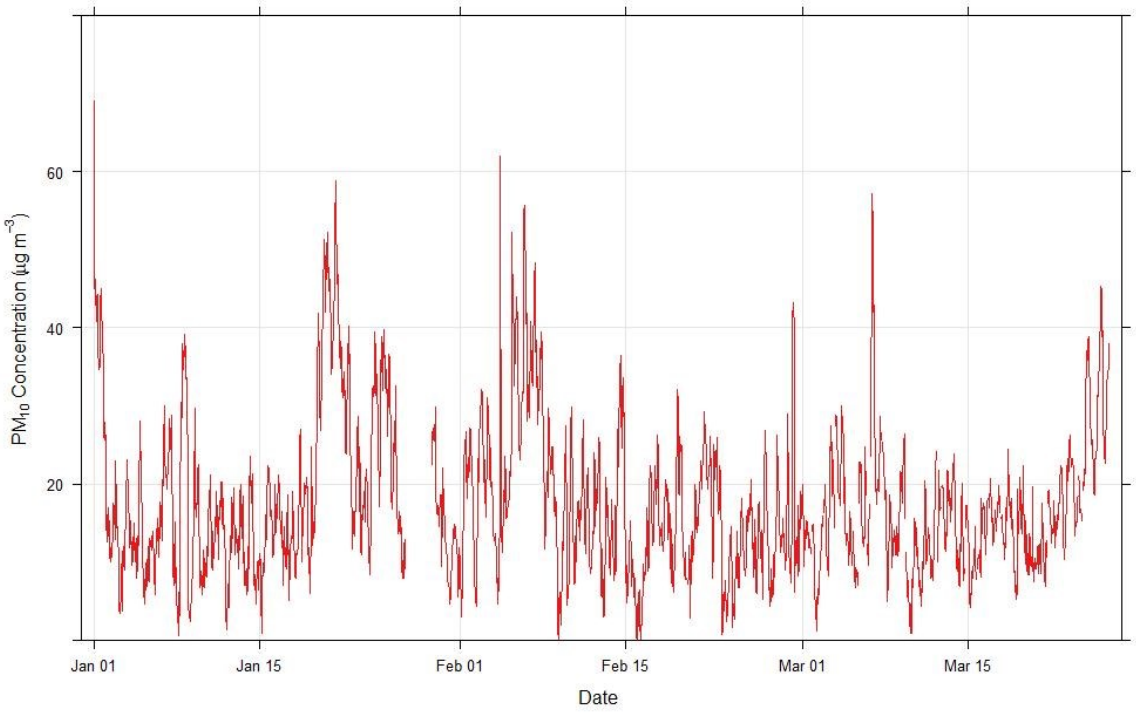

Figure 9: PM_{10} Concentrations at London Marylebone Road in 2020

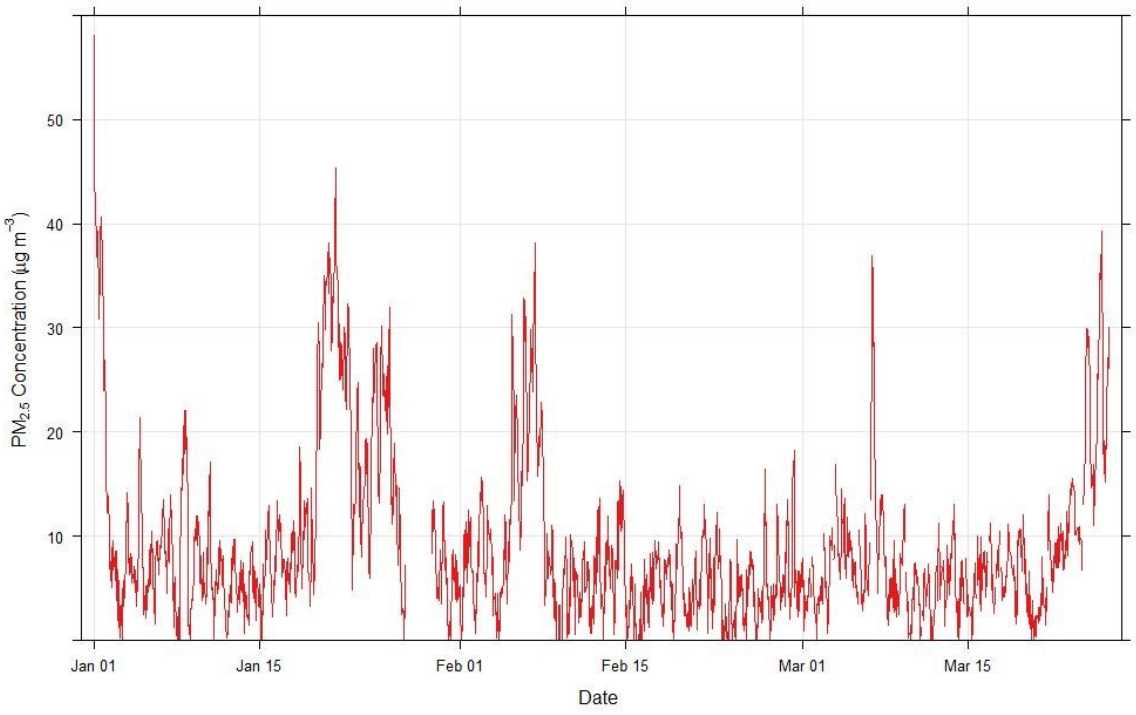

Figure 10: $PM_{2.5}$ Concentrations at London Marylebone Road in 2020

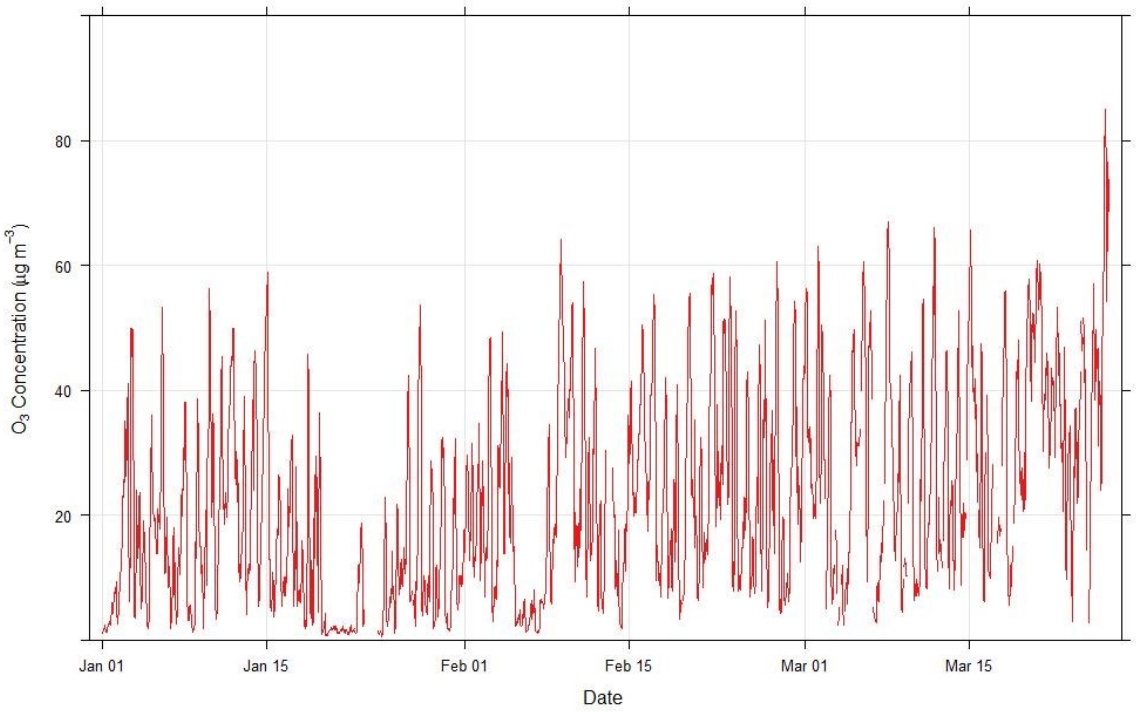

Figure 11: O_3 Concentrations at London Marylebone Road in 2020

"Deweathered" Concentrations

3.4 Figure 12 to Figure 16 present similar plots to those in Figure 7 to Figure 11, but in this case the data has been "deweathered" to isolate the trend in concentrations that will have occurred primarily as a result of the trend in emissions, following the approach described in Paragraph 2.4. There appear to be obvious reductions in both NOx and NO_2 concentrations since the COVID-19 related social and travel restrictions were imposed, especially in the last two days. A potentially corresponding increase in O_3 is also visible. There are no obvious trends in PM_{10} and $PM_{2.5}$ concentrations.

3.5 Predicted NOx concentrations have reduced from around 175 µg/m^3 to around 120 µg/m^3, a roughly 30% reduction, while NO_2 concentrations have reduced from around 60 µg/m^3 to around 48 µg/m^3, a roughly 20% reduction.

3.6 The predictions have been made using a deweather model built using measured concentration data from the London Marylebone Road site alongside meteorological data from Heathrow Airport over the period 1 January 2010 to 26 March 2020, and sampled using the 2020 portion of the meteorological data to predict the concentrations in the graphs shown. In order to ensure that the apparent reductions can reasonably be attributed to emissions reductions and not any changes in weather conditions (such as the recent warm spell), a separate deweather model has been built using only measurements to 31 December 2019. This model has then been sampled using the same 2020 meteorological data as described above, and the resultant concentrations are shown in Figure 17 and Figure 18. These graphs show what are effectively straight lines, with no recent reductions

in concentrations. This suggests that the reductions identified in Figure 12 and Figure 13 are driven by changes in emissions.

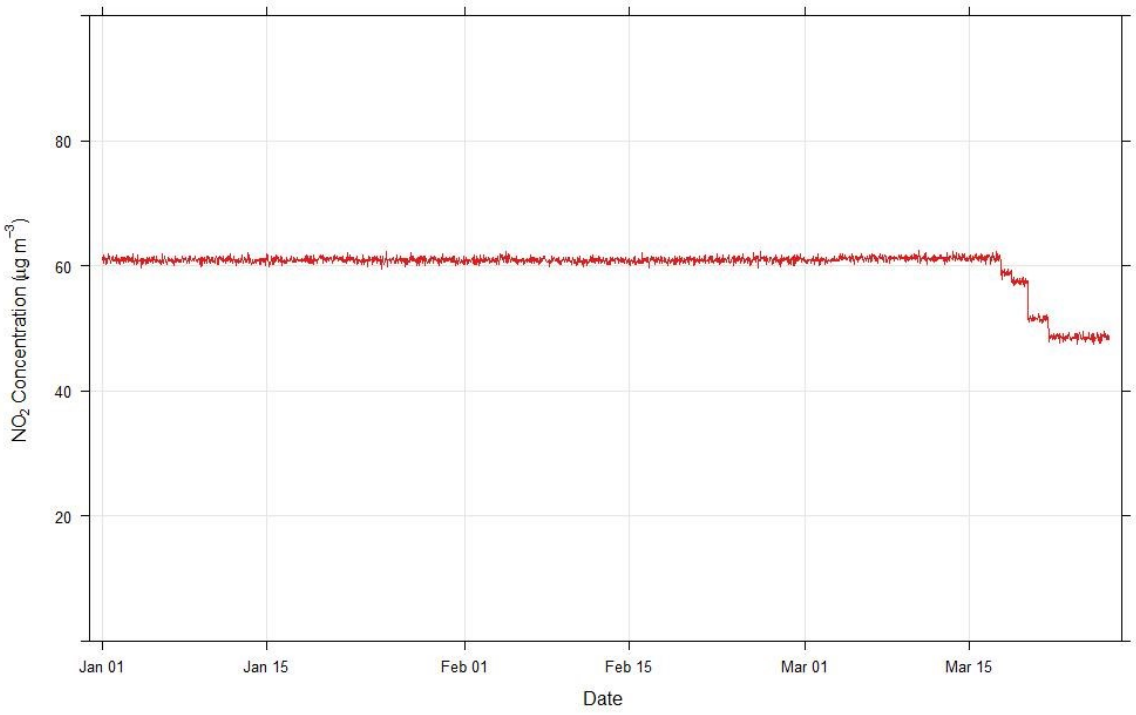

Figure 12: Deweathered NO_2 Concentrations at London Marylebone Road in 2020

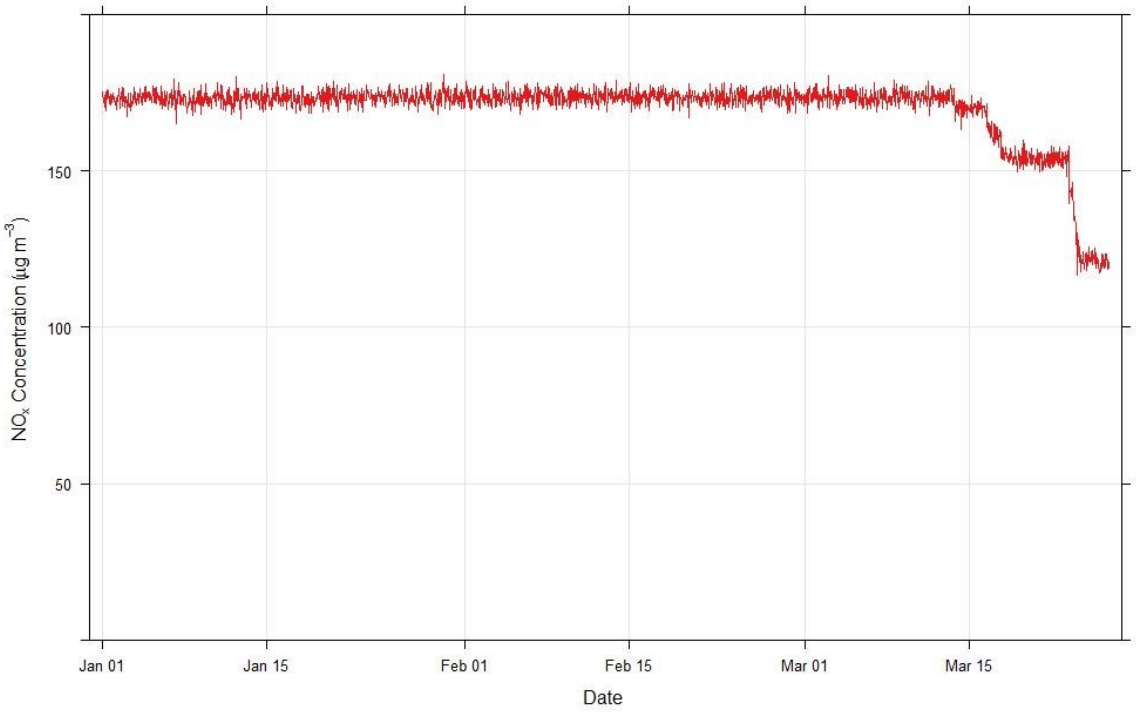

Figure 13: Deweathered NOx Concentrations at London Marylebone Road in 2020

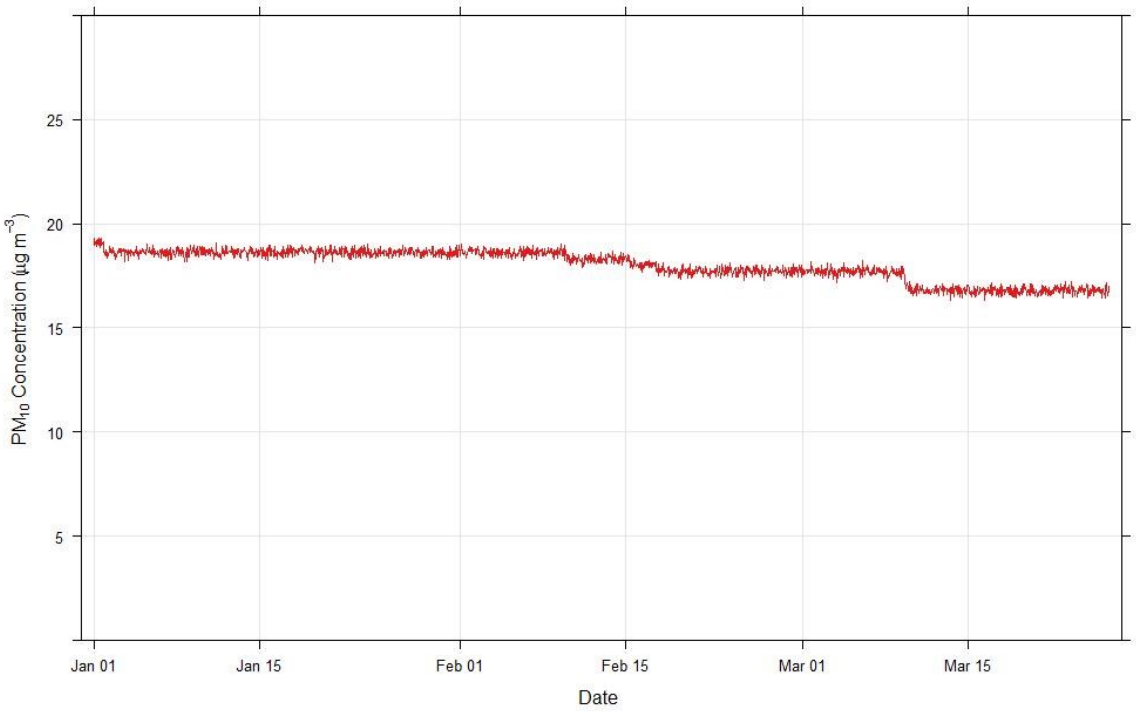

Figure 14: Deweathered PM_{10} Concentrations at London Marylebone Road in 2020

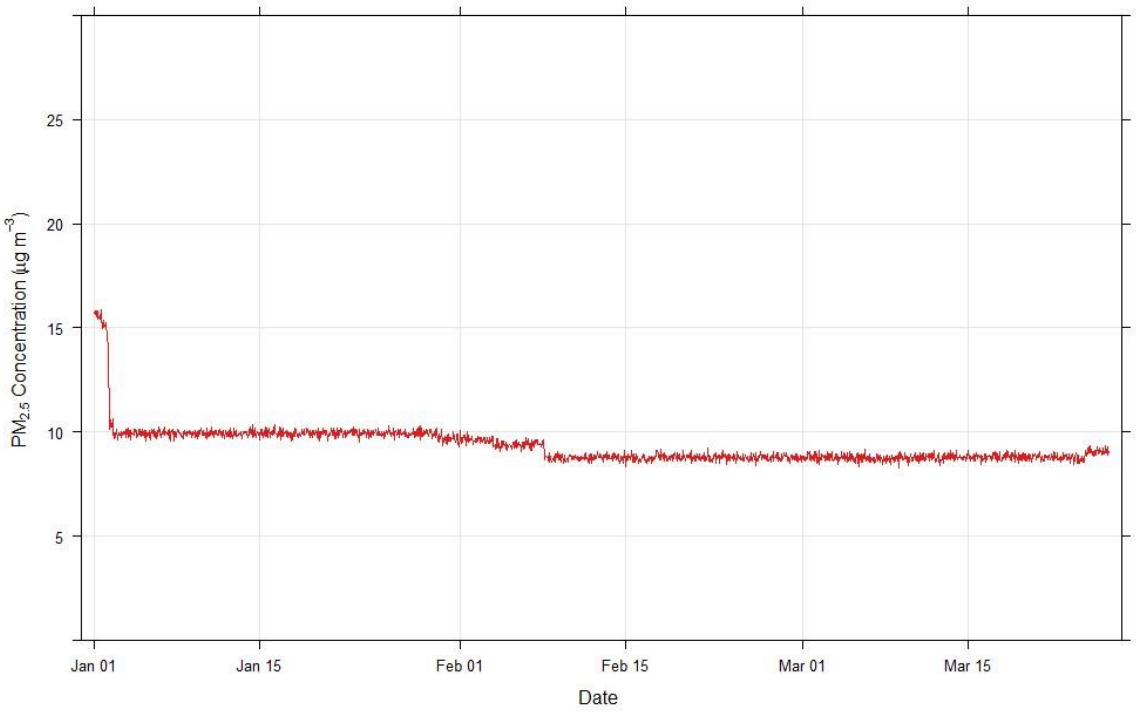

Figure 15: Deweathered $PM_{2.5}$ Concentrations at London Marylebone Road in 2020

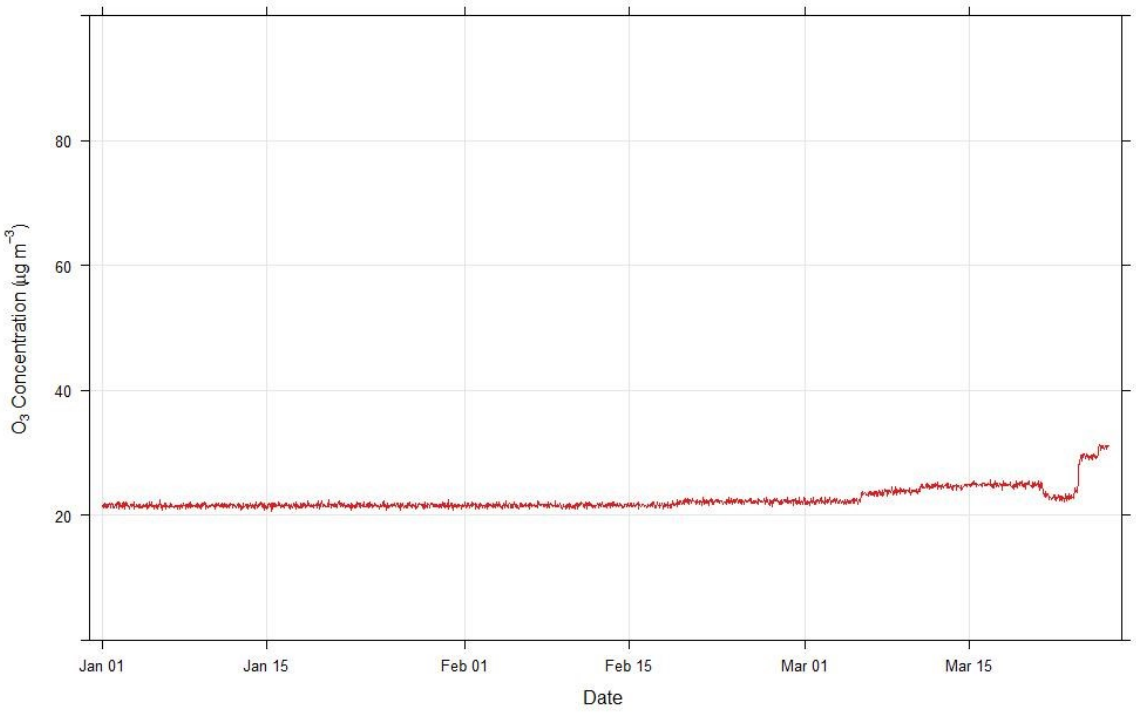

Figure 16: Deweathered O_3 Concentrations at London Marylebone Road in 2020

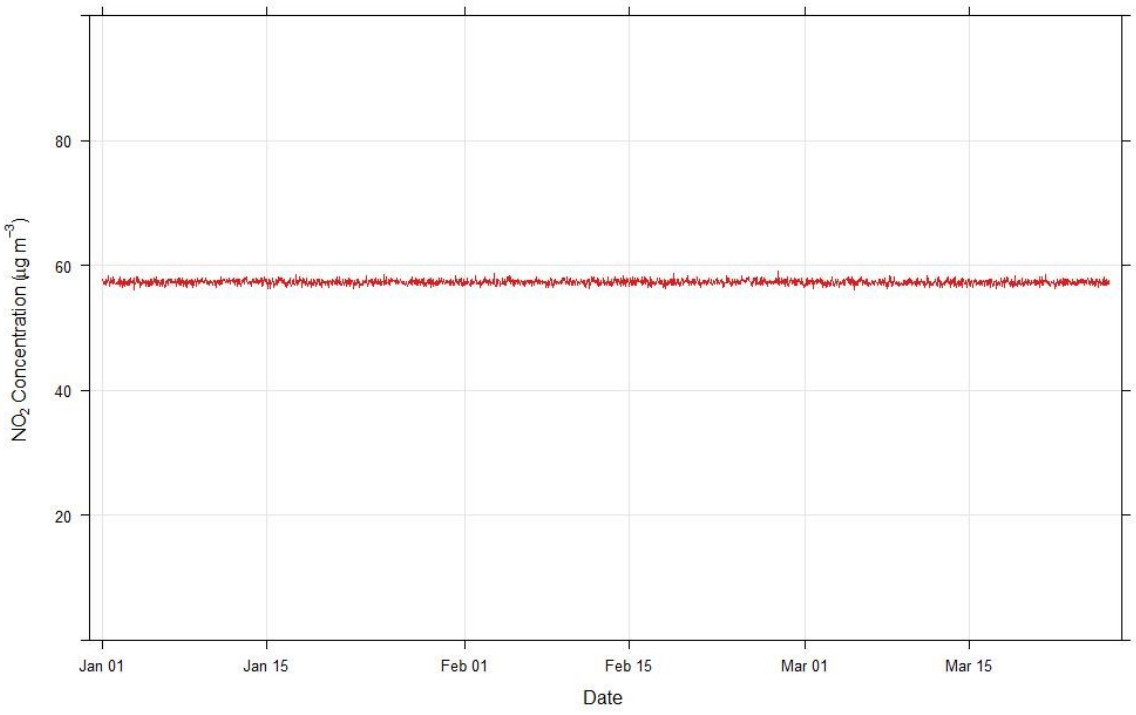

Figure 17: Deweathered NO_2 Concentrations at London Marylebone Road in 2020 Using a Model Based on 2010 to 2019 Measured Concentrations Only

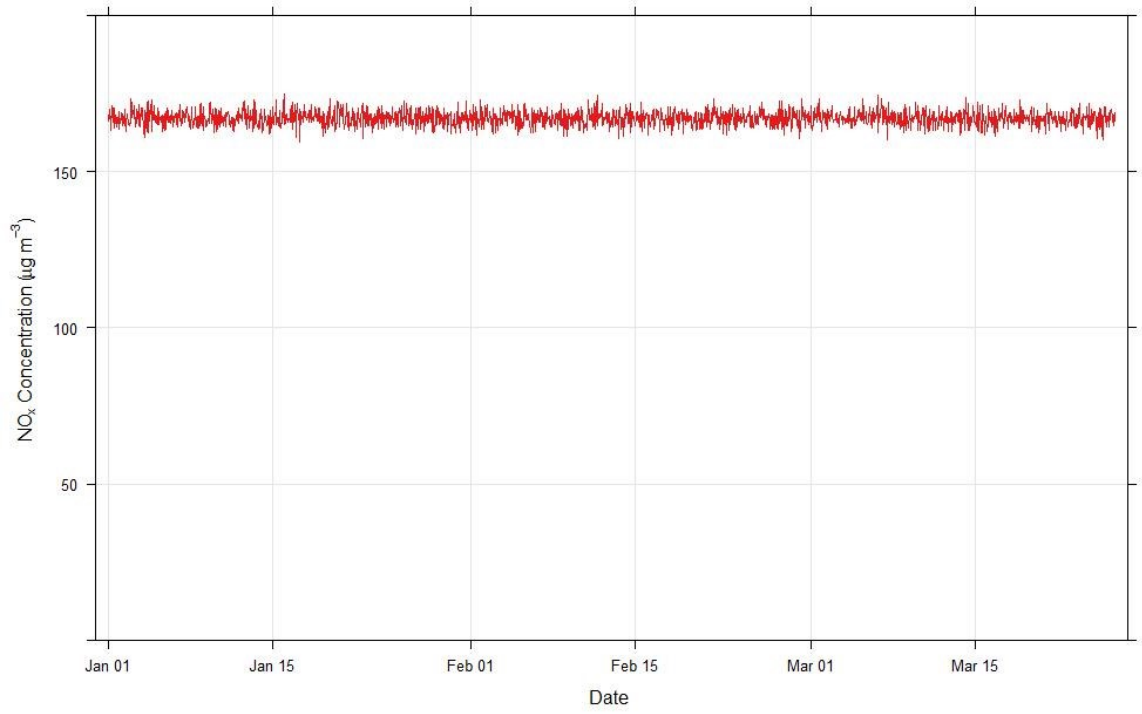

Figure 18: Deweathered NOx Concentrations at London Marylebone Road in 2020 Using a Model Based on 2010 to 2019 Measured Concentrations Only

Manchester Oxford Road Concentrations

3.7 Figure 19 to Figure 21 present plots of raw roadside NO_2, NOx and PM_{10} concentrations at the Manchester Oxford Road monitoring site (which does not measure $PM_{2.5}$ or O_3), with data having been downloaded from the Air Quality England network via the openair software. There are, once again, no obvious signals in the concentrations that might be attributed to recently imposed social and travel restrictions.

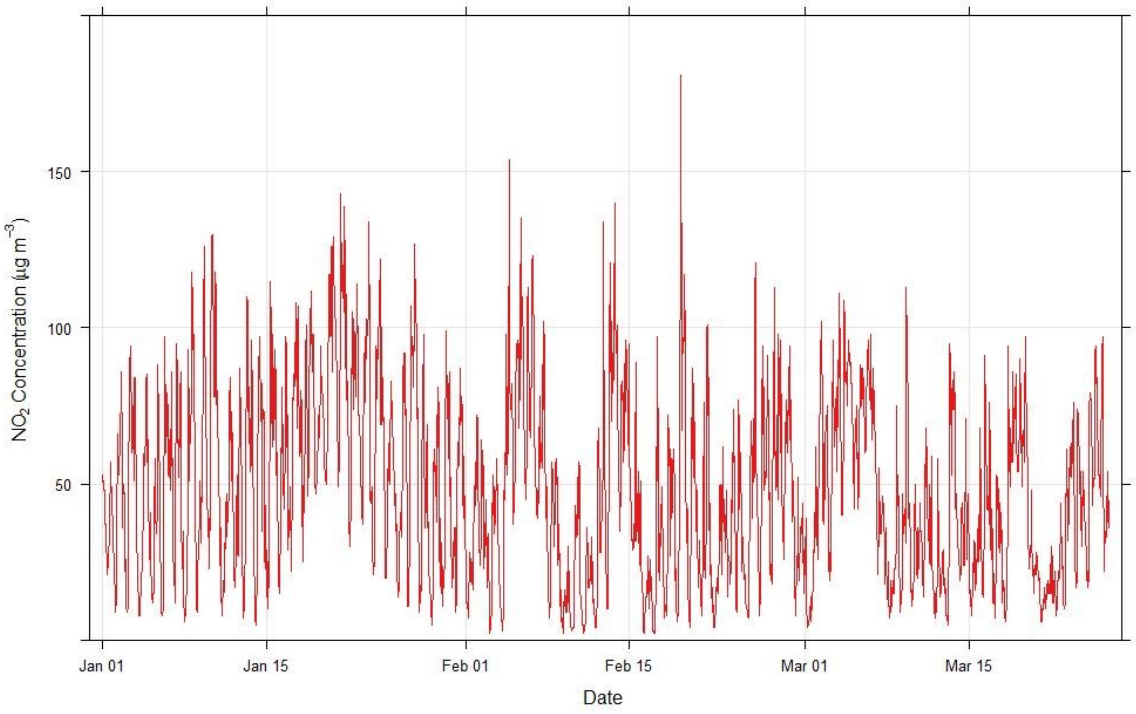

Figure 19: NO_2 Concentrations at Manchester Oxford Road in 2020

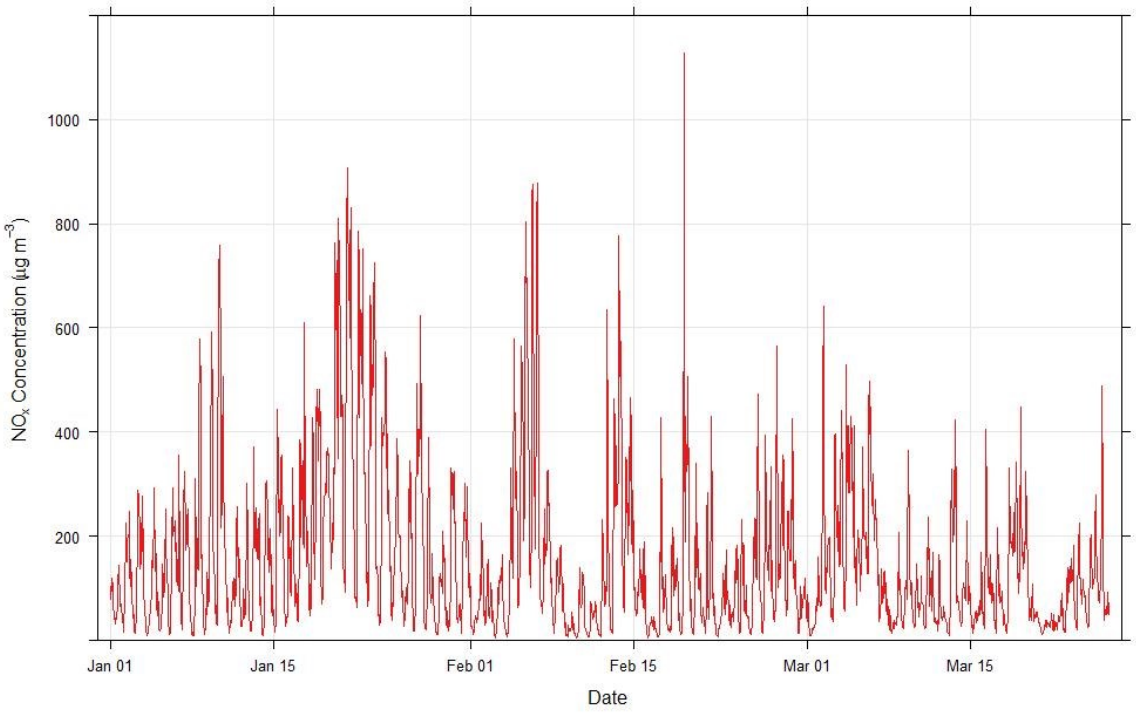

Figure 20: NOx Concentrations at Manchester Oxford Road in 2020

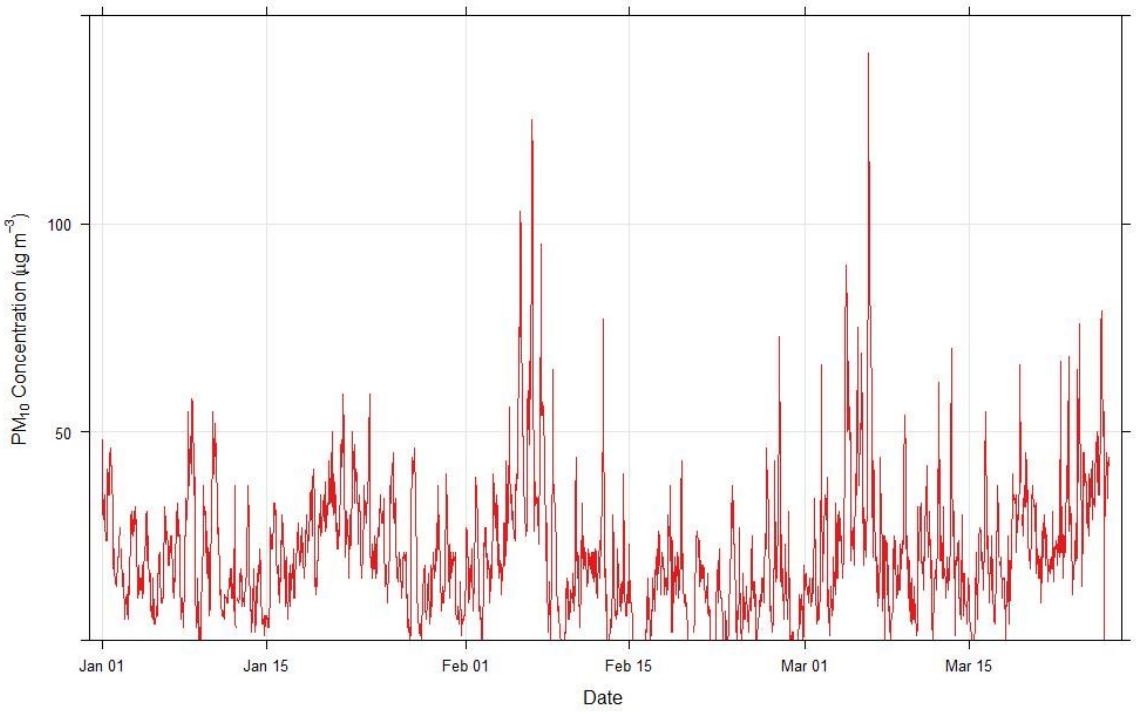

Figure 21: PM_{10} Concentrations at Manchester Oxford Road in 2020

"Deweathered" Concentrations

3.8 Figure 22 to Figure 24 present the "deweathered" concentrations for Manchester Oxford Road. There appear to be obvious reductions in both NOx and NO_2 concentrations since the COVID-19 related social and travel restrictions were imposed. The reductions are not as great as at London Marylebone Road, but it is obvious that concentrations have reduced.

3.9 There are no such reductions for PM_{10}.

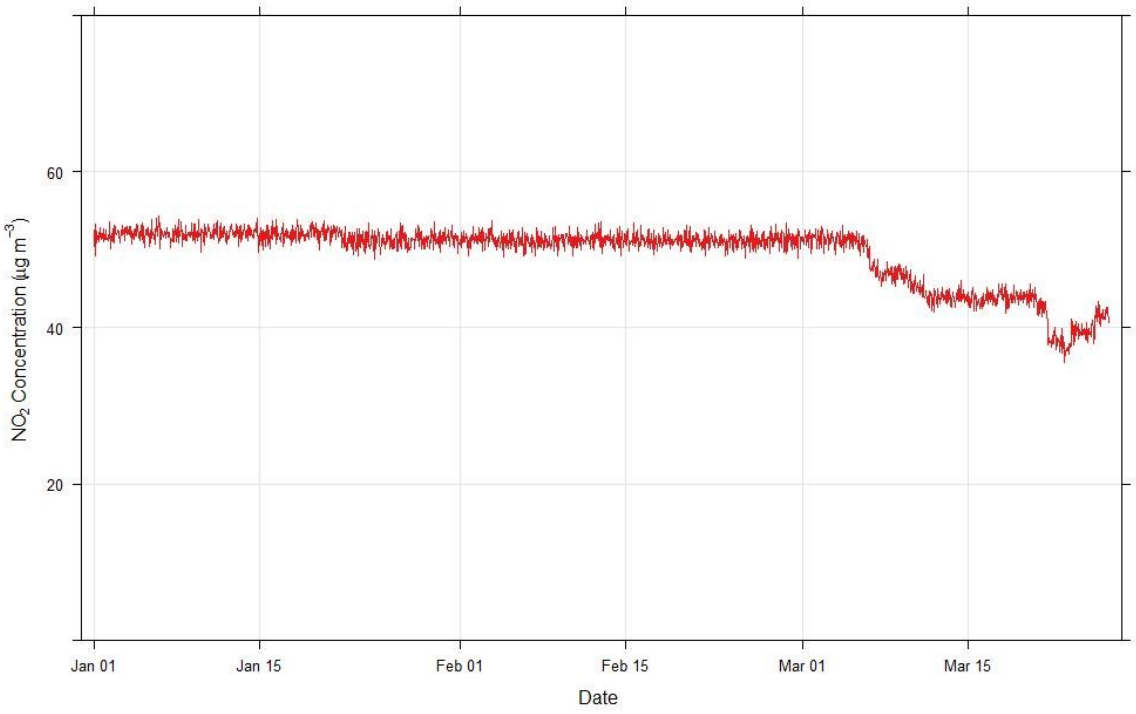

Figure 22: Deweathered NO_2 Concentrations at Manchester Oxford Road in 2020

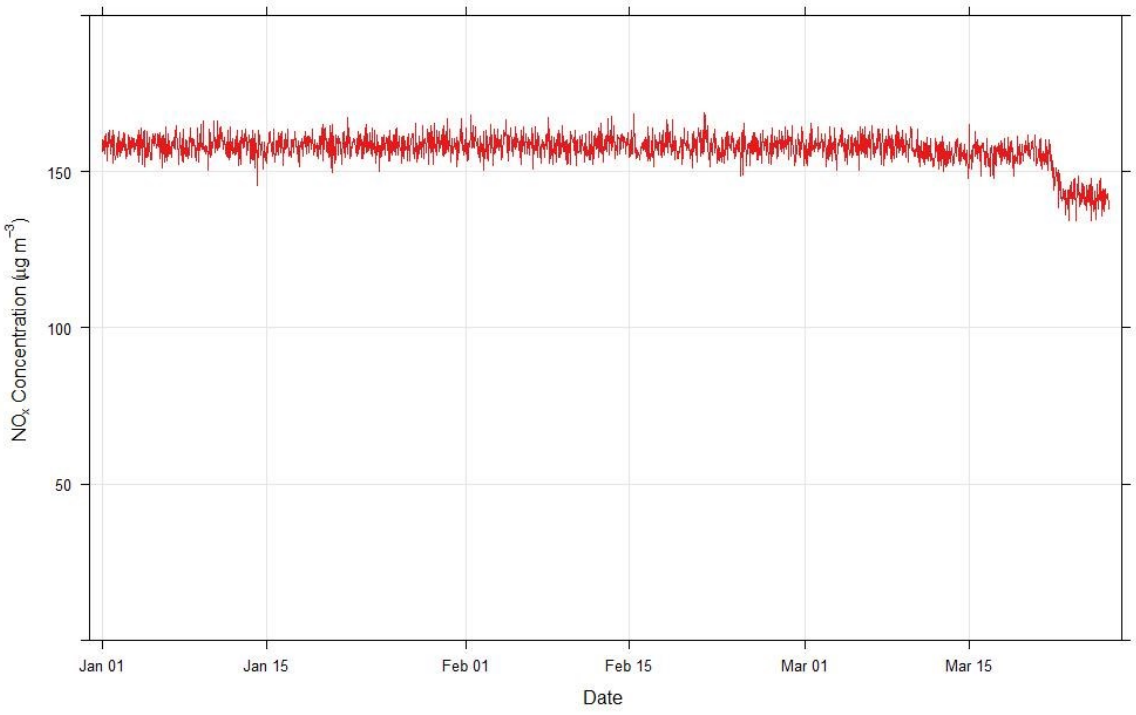

Figure 23: Deweathered NOx Concentrations at Manchester Oxford Road in 2020

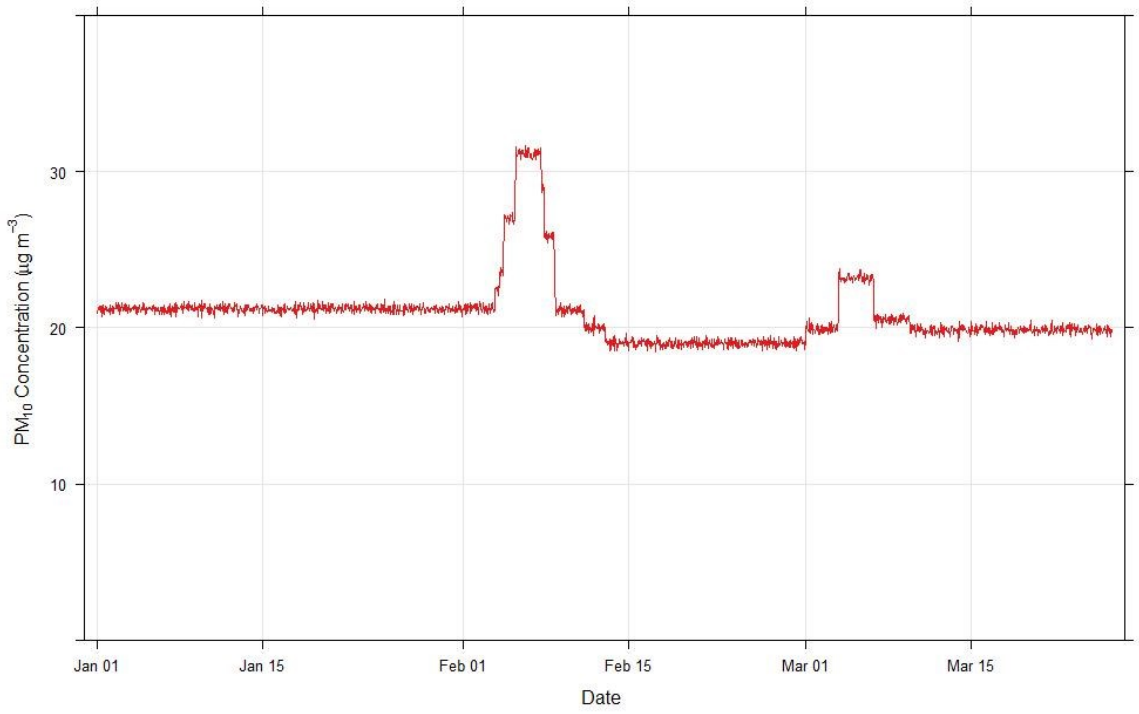

Figure 24: Deweathered PM_{10} Concentrations at Manchester Oxford Road in 2020

4 Summary and Conclusions

4.1 There is widespread reporting of reductions in NOx and NO_2 concentrations as a result of the COVID-19 pandemic. However, much of the published evidence for this has focused on comparing concentrations measured during two separate periods of time without consideration of confounding factors such as meteorology. This analysis has provided a preliminary attempt to isolate some of the variation caused by meteorology from the measured ambient concentrations.

4.2 Analysis of trends in raw NOx, NO_2, PM_{10}, $PM_{2.5}$ and O_3 concentrations in 2020 to date has identified no obvious influence from the social and travel restrictions implemented in the UK in response to the COVID-19 pandemic. However, isolating and removing meteorological and seasonal effects has demonstrated a substantial reduction in NOx and NO_2 concentrations at two key roadside monitors, with concentrations at London's Marylebone Road reducing by as much as 30% for NOx and 20% for NO_2; most likely as a direct result of emissions reductions attributable to the social and travel restrictions. The reductions are smaller at Manchester Oxford Road, but still obvious, and it would be reasonable to expect similar reductions in roadside concentrations at urban roadside sites across the UK.

4.3 There is some evidence for a small increase in roadside O_3 concentrations, which might be a response to reduced roadside NOx concentrations, but it is too early to see if this is significant. There are currently no obvious trends in PM_{10} or $PM_{2.5}$ concentrations.

4.4 AQC will seek to update this analysis over the coming weeks/months to establish whether COVID-19 related social and travel restrictions continue to affect air quality in the UK, and whether concentrations reduce further, likely expanding the analysis to consider concentrations in more UK cities.