MAYOR OF LONDON

Estimation of changes in air pollution in London during the COVID-19 outbreak

Response to the UK Government's Air Quality Expert Group call for evidence

April 2020

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Published by
Greater London Authority
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minicom 020 7983 4458
ISBN
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Introduction

On 4 April 2020 the UK Government's Air Quality Expert Group (AQEG), acting on a request from the Department of Environment, Food and Rural Affairs, called for evidence to address a set of urgent short-term questions related to recent and ongoing changes in UK air quality. For more information please see: https://uk-air.defra.gov.uk/news?view=259.

The following document is London's response to this call for evidence. It will aim to address two of the key questions identified AQEG:

- What sectors or areas of socioeconomic activity do you anticipate will show a decrease in air pollution emissions, and by how much? Are there any emissions sources or sectors which might be anticipated to lead to an increase in emissions in the next three months?
- Can you provide estimates for how emissions and ambient concentrations of NOx, NO_2, PM, O_3, VOC, NH_3 etc may have changed since the COVID outbreak? Where possible please provide data sets to support your response.

This report covers the period to from 1 January 20 April 2020. As requested by AQEG the evidence has been kept brief, with additional context and data provided in the Appendix.

This evidence has been published alongside the Central London ULEZ Ten Month Report which outlines the improvements in air pollution in London in the period preceding the COVID-19 outbreak.

It is important that the change in air pollution concentrations as a result of COVID-19 measures are framed in the context of London's normal seasonal pattern for pollutants and the substantial improvements in London's air quality in recent years, in particular in central London where the Ultra Low Emission Zone has already significantly reduced concentrations of pollutants, as demonstrated in Figure 1.

Figure 1 shows the change in hourly average NO_2 at all sites in central London, from the period January – April. The red line shows the hourly trends in NO_2 in central London from 1 January 2017 – 20 April 2017 (before changes associated with the central ULEZ took full effect). The green line shows the hourly trends in NO_2 in central London from 1 January – 15 March 2020, with the ULEZ in place. The blue line shows the hourly trends in NO_2 in central London from 16 March – 20 April 2020, with COVID-19 measures in place.

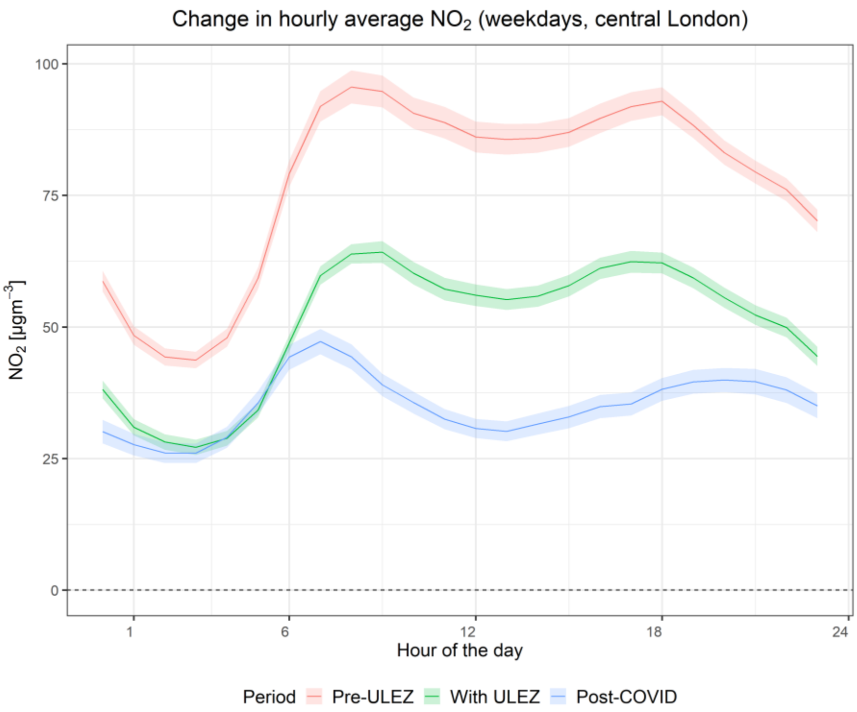

Figure 1. Change in hourly average NO_2 in central London

In 2020, before measures to address the COVID outbreak were introduced, hourly average NO_2 at all sites in central London had already reduced by over one third (35 per cent) compared to the same period in 2017. Since 16 March 2020 there has been an additional reduction of 26 per cent. As will be shown later in this report the reduction is even higher at roadside sites.

In recent years policies and measures have been introduced in London (including Low Emission Bus Zones, the ULEZ and changes to the taxi fleet) that have resulted in significant improvements in air quality. Other studies have compared air quality in the post-COVID period to the same period for previous years. Whilst this may be appropriate for other locations, it is not appropriate for London due to the significant recent improvements which pre-date the COVID outbreak. This analysis instead compares the periods 1 January - 15 March 2020 and 16 March 2020 - 20 April 2020.

Changes in emissions

COVID-19 is likely to impact the majority of emissions sources in London including road transport, aviation, construction, domestic and commercial heating and commercial cooking. A breakdown of emissions sources in London is provided in Figure A 1 - Figure A 6 in the Appendix. Please note, these only account for emission sources within London. As evidenced in the next chapter, transboundary sources (over which London has no control) appear to have been less impacted by stricter COVID-19 measures. This includes emissions from agriculture. Particulates derived from ammonia are the single largest contribution to imported background pollution in London. Agriculture is the dominant source of ammonia emissions in the UK, accounting for around 87 per cent of all emissions. Unlike most other air pollutants, emissions of ammonia have been rising since 2013.

Data is not yet available for many sectors, with the exception of transport, for which Transport for London has good data. Other major emissions sources which are likely be significantly reduced are construction, commercial cooking and commercial heating.

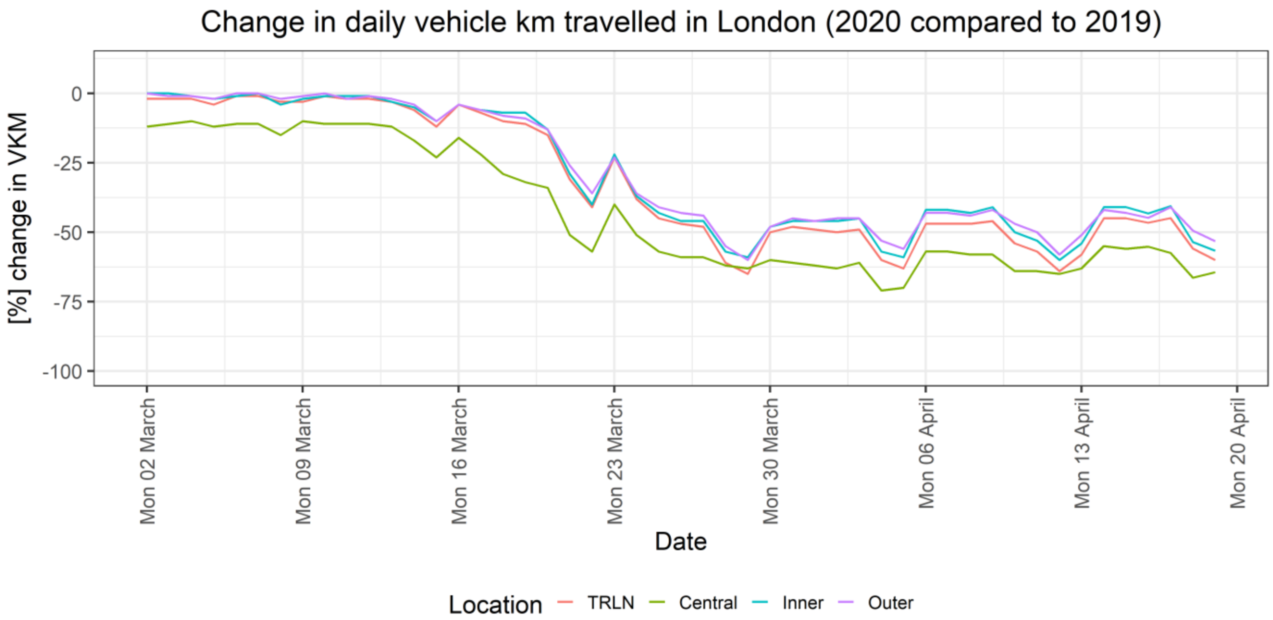

Figure 2. Change in daily vehicle km travelled in London (TfL, 2020)

Road transport accounts for around half of London’s NOx emissions and a third of PM emissions. Since the beginning of March road traffic in London has reduced by around 50 per cent Londonwide. Figure 2 shows the percentage reduction in vehicle kilometres travelled in 2020 compared to the comparable day in 2019. Please note, the central London ULEZ, which was introduced in April 2019, had already reduced traffic in the central zone by approximately 10 per cent.

Departure from usual travel behaviour began around Monday 16 March, when the UK Government strongly recommended social distancing and home working where possible.

Changes in concentrations

The following analysis uses data from London's automatic air quality monitoring stations (which are also used for statutory reporting) to assess the changes in concentrations of nitrogen dioxide (NO_2), NOx, ozone (O_3) and particulate matter ($PM_{2.5}$, PM_{10}) since Monday 16 March 2020. At this early stage the changes in air pollution (both positive and negative) reported here cannot be attributed solely to the COVID pandemic because the period before and after were subject to different meteorological conditions, which have not been corrected for in this analysis.

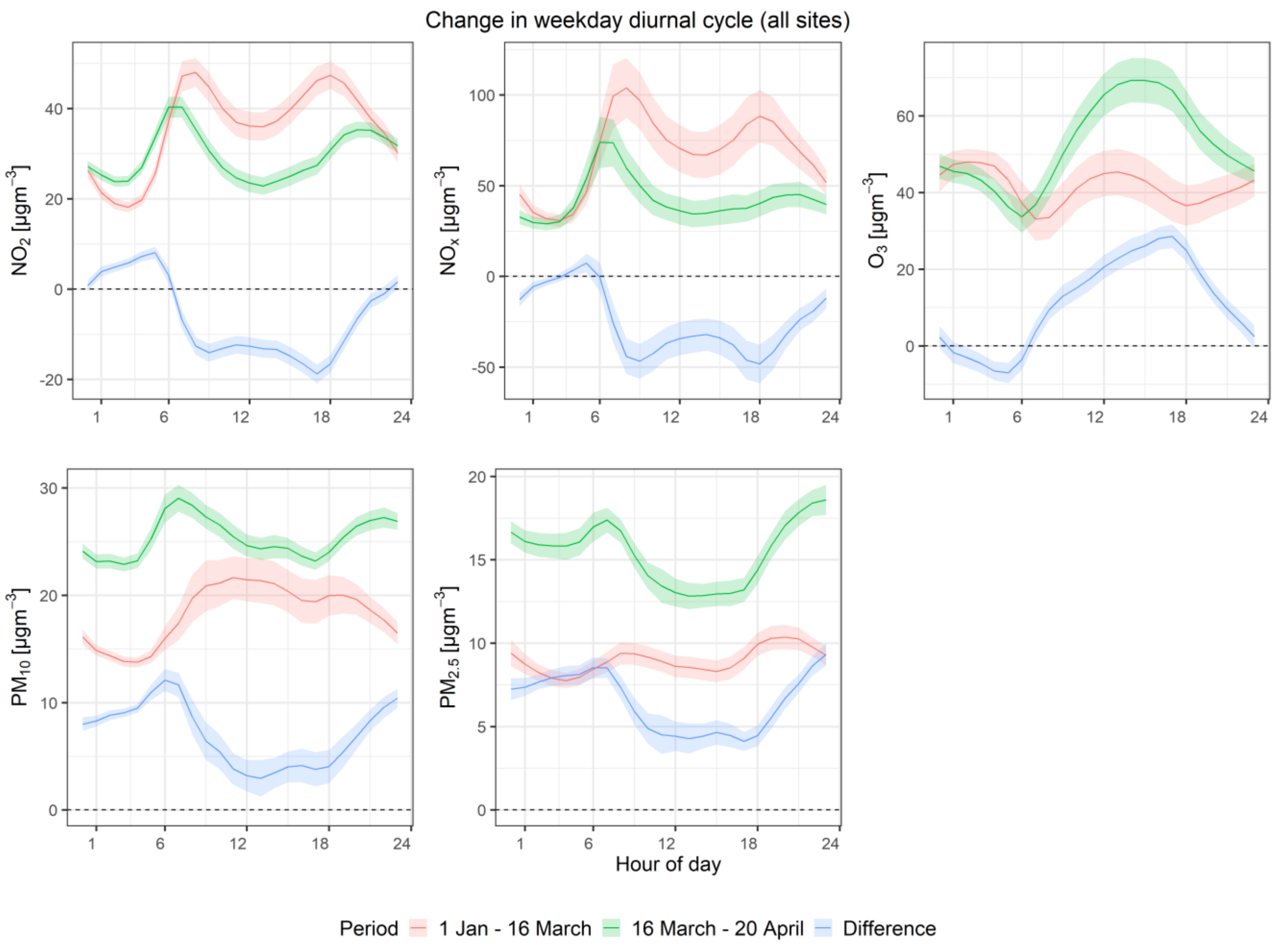

Figure 3. Change in diurnal cycle of pollutants since 16 March 2020

Figure 3 shows the change in hourly average NO_2, NO_x, O_3, PM_{10} and $PM_{2.5}$ in the period since 16 March, compared to the period 1 January to 16 March. The key findings are there have been overall reductions in NO_2 and NO_x, and increases in O_3, PM_{10} and $PM_{2.5}$. In addition, London has had a number of particulate pollution episodes since 16 March. This highlights that London's poor air quality is not solely related to road transport. To improve London's air quality further action is required on other sources, including domestic burning and agricultural emissions. The following sections provide more detailed analysis by pollutant.

Nitrogen dioxide (NO_2)

There has been a significant reduction in NO_2 since 16 March, these changes are in addition to the reductions already delivered by the central London ULEZ and other policies. The greatest reductions have been measured at kerbside and roadside sites in central and inner London. Daily average NO_2 has reduced by around 40 per cent at roadside sites in central London, and 20 per cent elsewhere. This is despite a slight increase in NO_2 measured at regional background sites outside of London. NO_2 has significantly reduced at some of London's busiest locations. At Oxford Street daily average NO_2 has reduced by 23 ugm^{-3}, a reduction of 47 per cent. Similarly, Marylebone Road has reported a reduction of 26 ugm^{-3}, a reduction of 48 per cent.

The reduction in NO_2 has not been uniform throughout the day. Figure 3 shows changes in daily, hourly and monthly NO_2 at roadside sites in inner London before and after the 16 March. Since 16 March there has been an increase in hourly average NO_2 between the hours of around 00:00 – 05:00, followed by a decrease during the day.

Statistical analysis can be used to identify the proportion of NO_2 at roadside sites which is directly attributable to traffic, removing the impact of changes in background concentrations. This is known as the roadside increment. The roadside increment of NO_2 has reduced by around 52 per cent in central London and 25 per cent in the rest of London.

For more data on changes in concentrations of NO_2 please see Appendix 3.

NOx

There have been even larger reductions in NOx concentrations. As with NO_2 the greatest reduction has been at kerbside and roadside sites. Kerbside sites in inner London have measured a 71 μgm^3 reduction in daily average NOx, a reduction of 47 per cent. Roadside sites in central London have measured a reduction of 62 μgm^3, a reduction of 56 per cent.

For more data on changes in concentrations of NO_x please see Appendix 4.

Ozone (O_3)

Daily average O_3 has increased at all 23 sites included in this analysis. In the period since 16 March there has been a 6 µgm^3 (11 per cent) increase in daily average O_3. This is not unusual for this time of year (see Appendix 5). However, the increase at many London sites far exceeds the increase in regional background. For example, at Marylebone Road (the only O_3 kerbside monitoring station included in this analysis) daily average O_3 increased by 24 µgm^3 (119 per cent). Other roadside sites and background sites in inner and central London measured increased in daily average O_3 of between 30 – 50 per cent. This indicates the increase in O_3 may also be being driven by the reduction in NOx emissions.

The World Health Organization guideline limit for O_3 is an 8-hour mean of 100 µgm^3. Since 16 March 9 sites in London have recorded an 8-hour mean over the WHO recommended limit. The EU legal air quality limit value for ozone is 120 µgm^3 over an 8-hour mean and no site in London exceeded this during the period.

For more data on changes in concentrations of O_3 please see Appendix 5.

Fine particulate matter ($PM_{2.5}$)

In the period since 16 March there have been a number of moderate particulate matter episodes, resulting in a 69 per cent (4.6 µgm^{-3}) increase in daily average $PM_{2.5}$ at regional background sites outside of London. This is not unusual for this time of year (see Appendix 6). Spring time is often the worst time of the year for particulate pollution in London, spring time episodes are associated with agriculture emissions which can travel long distances.

All site types within London measured an increase in daily average $PM_{2.5}$ since the 16 March of between 1 – 3 µgm^3 (14 – 43 per cent). However, the relative increase at sites in London are significantly less than for the regional background sites. This indicates there has been a reduction in the London local contribution to $PM_{2.5}$, and this is countering some of the regional increase. The reduction in local contribution is likely to be a result of a decrease in local emissions from transport, construction and (in central London) commercial cooking. However, King's College London have stated concentrations may have been influenced by an increase in domestic garden and wood burning within London during the lockdown period.

It is possible to estimate the reduction in London's local contribution to $PM_{2.5}$ by assuming changes measured at the regional background sites represent the true change in background (4.6 μgm^{-3}). The difference between the change measured at the London sites and the change at a regional level provides an estimate for the reduction in London local contribution. The reduction in daily average local contribution varied by site type and locations, with an average of 2 μgm^{-3} across all sites which would represent an approximate 10 per cent reduction. The estimated reduction in the local contribution at some roadside sites, for example Euston Road, was over 3 μgm^{-3}, equating to a reduction of over 20 per cent.

The World Health Organization guideline limit for $PM_{2.5}$ is a 24-hour mean of 25 μgm^{3}. Since 16 March nearly all sites in London (and regional background sites) have recorded a daily mean over the WHO recommended limit.

For more data on changes in concentrations of $PM_{2.5}$ please see Appendix 6.

Particulate matter (PM_{10})

Similarly, there was a 74 per cent (8 μgm^{-3}) increase in daily average PM_{10} at regional background sites outside of London in the period since 16 March. Again, the daily average increase at sites within London was significantly lower than this, central London roadside and kerbside sites reported no change in daily average PM_{10} and industrial sites in inner London reported a small decrease. This indicates that there has been a significant reduction in London sources of PM_{10}. As is the case for $PM_{2.5}$ the reduction in local contribution is likely to be a result of a decrease in local emissions from transport, construction and (in central London) commercial cooking.

For more data on changes in concentrations of PM_{10} please see Appendix 7.

Appendix 1. Methodology

All air quality data analysis was performed using the open source statistical software R.

The period of comparison in this analysis is 1 January 2020 to 15 March 2020 and 16 March 2020 to 19 April 2020. The 16 March has been chosen as the split because this is when the UK Government recommended social distancing and working from home where possible and also when Transport for London report a departure from usual travel behaviour (see Figure 2).

London has an established weekly pattern for pollutants. Therefore, reductions in this analysis are calculated using comparable weekdays only. For example, the average reduction on Friday 20 March was calculated by averaging all Fridays between Monday 1 January and Monday 16 March and then subtracting the daily average for Friday 20 March.

Comparison to regional background

Both the period before, and the period after COVID-19 measures were introduced are subject to natural variability, complicated by the fact the spring is often the worst time of the year for many pollutants in London. Changes at rural (regional background) sites outside of London have been used to apportion between natural variability and impact of COVID-19 measures. The regional sites used for this are:

- Lullington Heath (LH), AURN
- Rochester Stoke (ROCH), AURN
- Chilbolton Observatory (CHBO), AURN

Appendix 2. Emissions sources in London

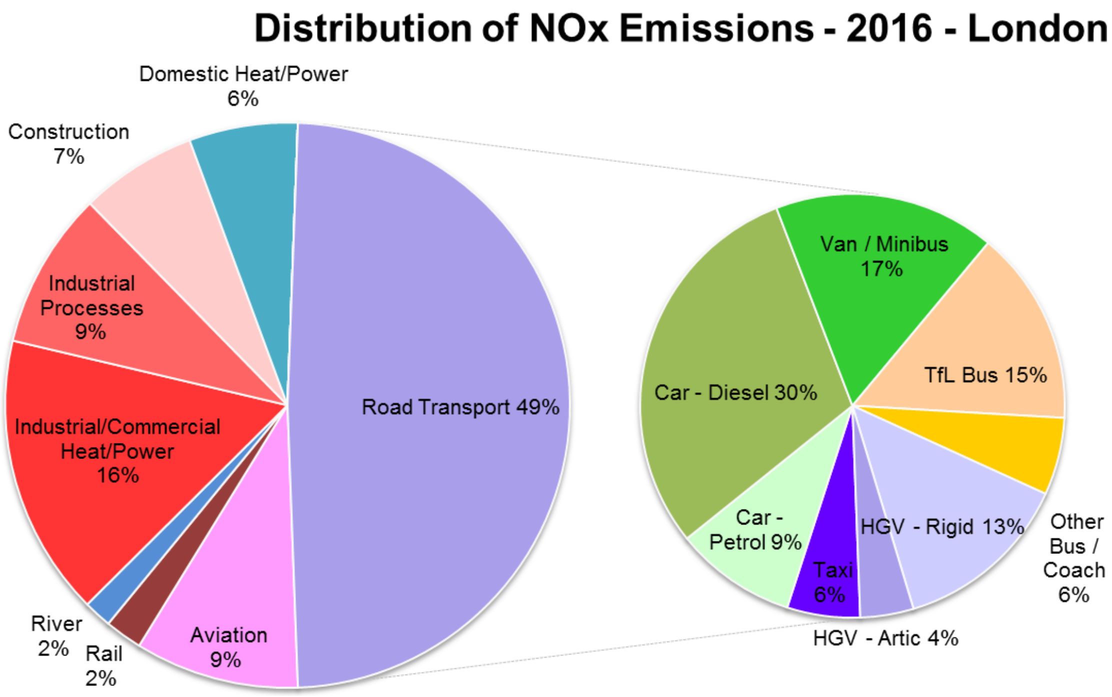

Figure A 1. Source apportionment of NOx emissions in London (LAEI 2016)

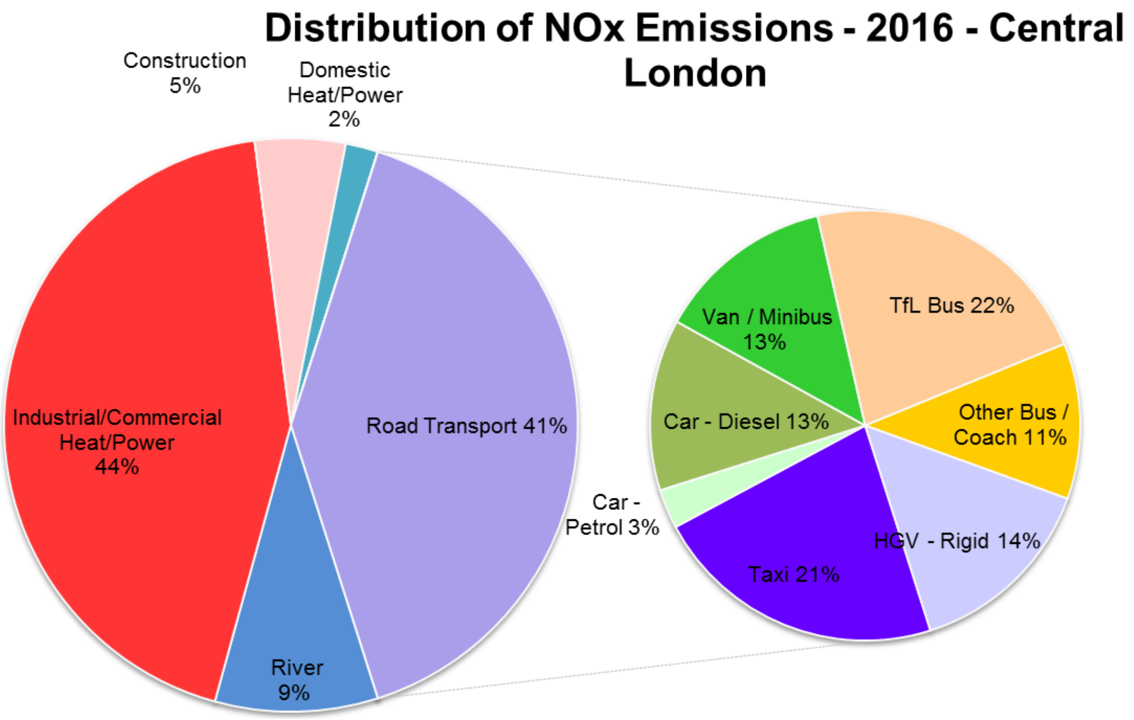

Figure A 2. Source apportionment of NOx emissions in Central London (LAEI 2016)

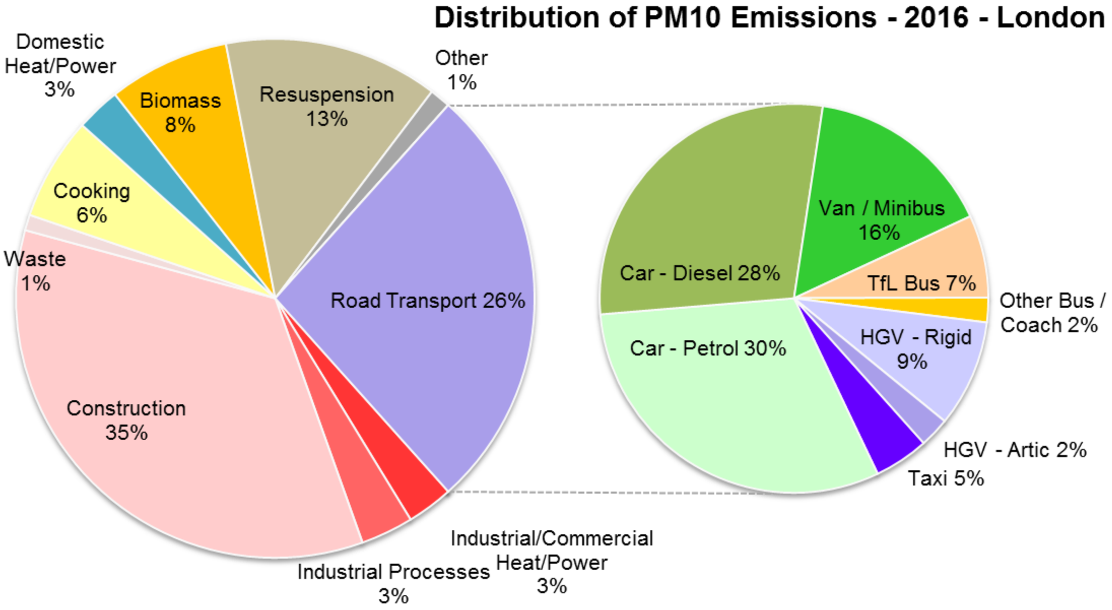

Figure A 3. Source apportionment of PM_{10} emissions in London (LAEI 2016)

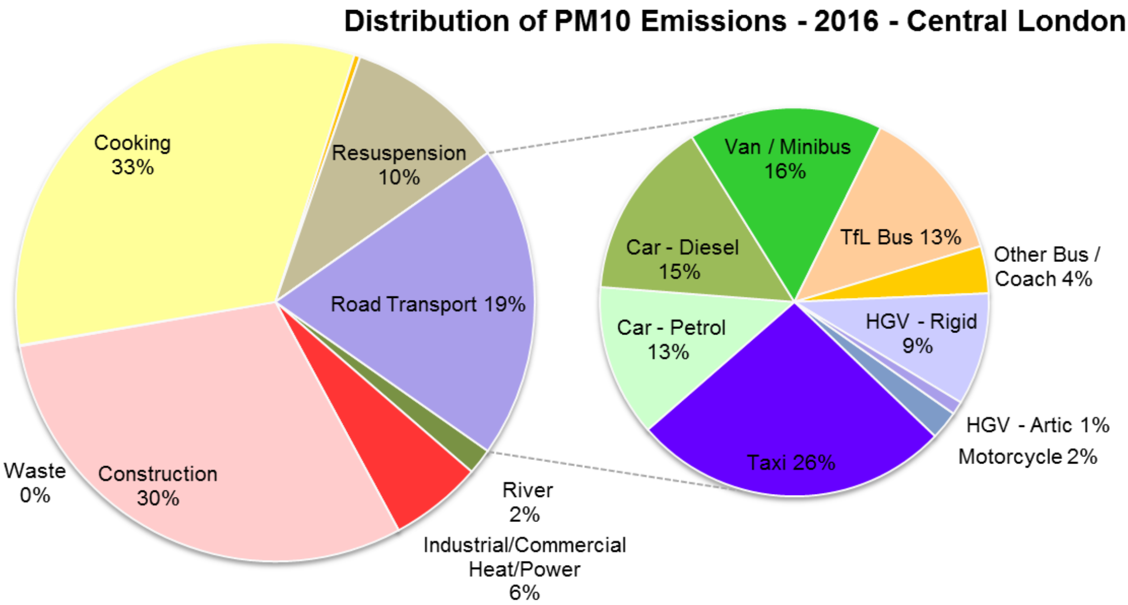

Figure A 4. Source apportionment of PM_{10} emissions in central London (LAEI 2016)

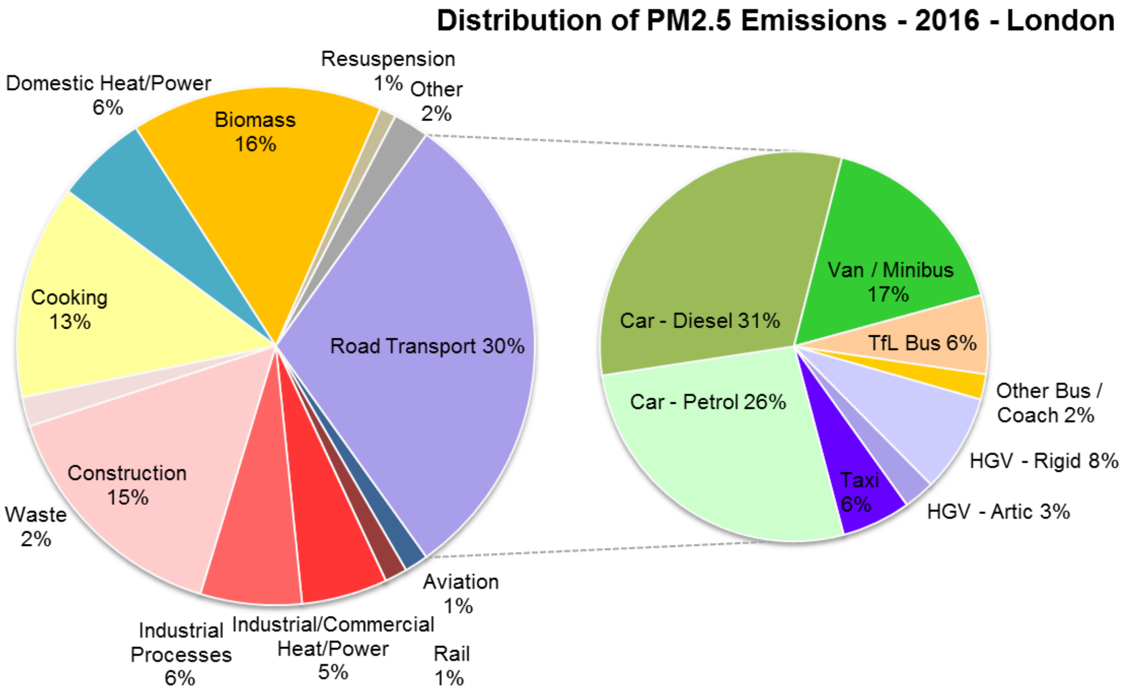

Figure A 5. Source apportionment of $PM_{2.5}$ emission in London (LAEI 2016)

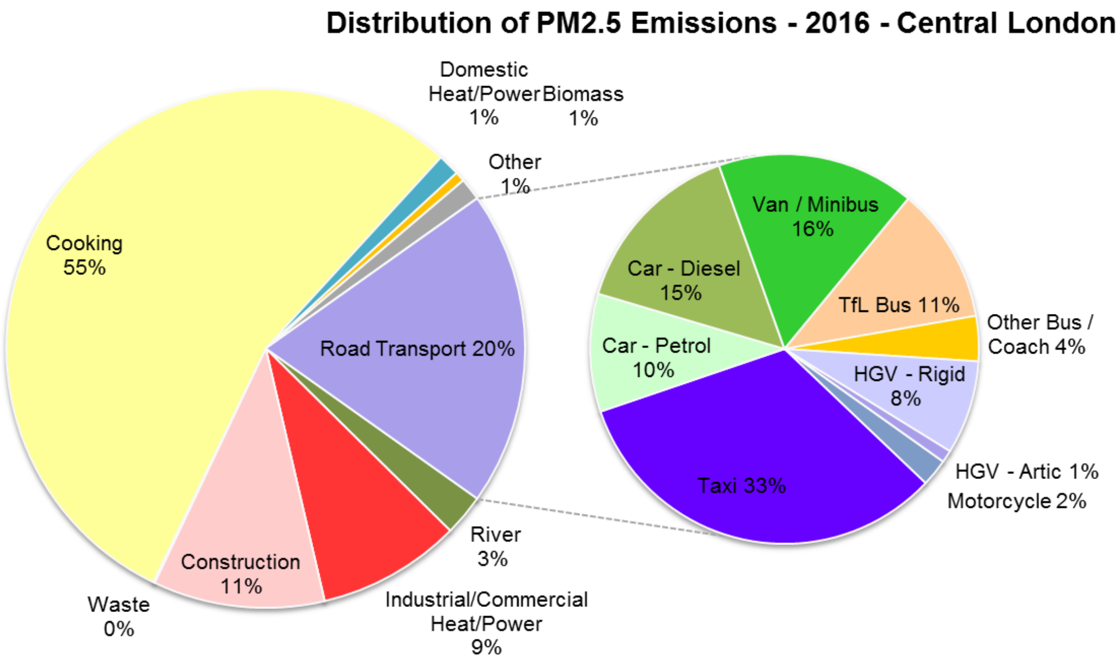

Figure A 6. Source apportionment of $PM_{2.5}$ emissions in central London (LAEI 2016)

Appendix 3. NO_2 data

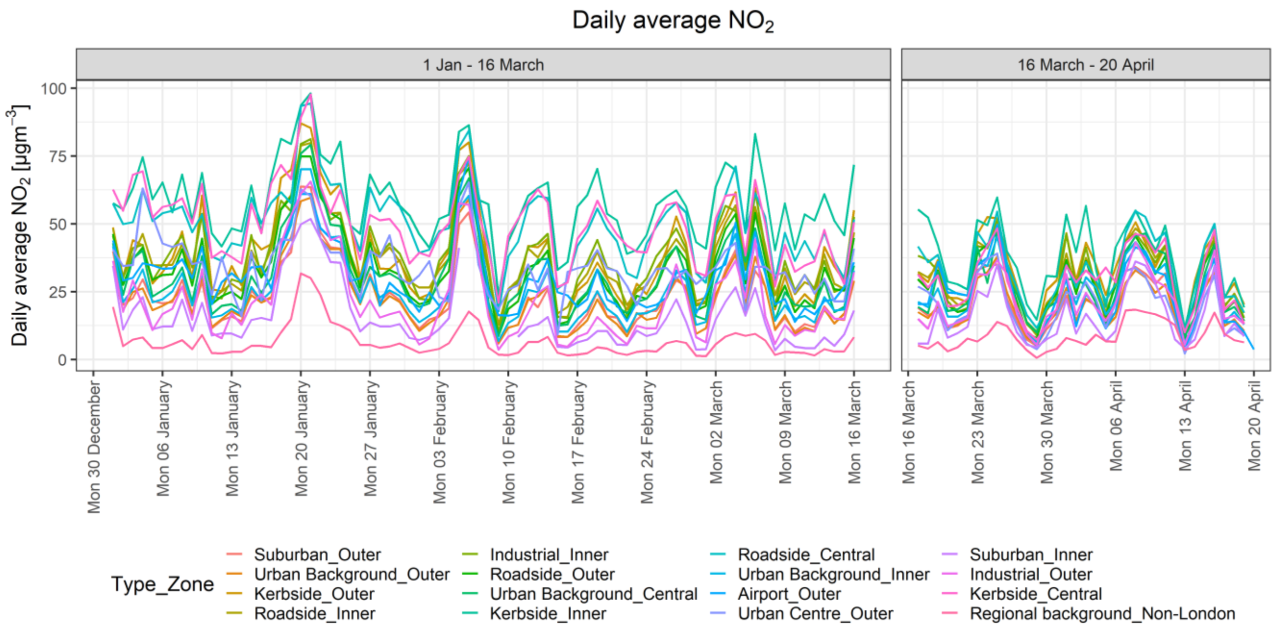

Figure A 7. Daily average NO_2 in London [2020]

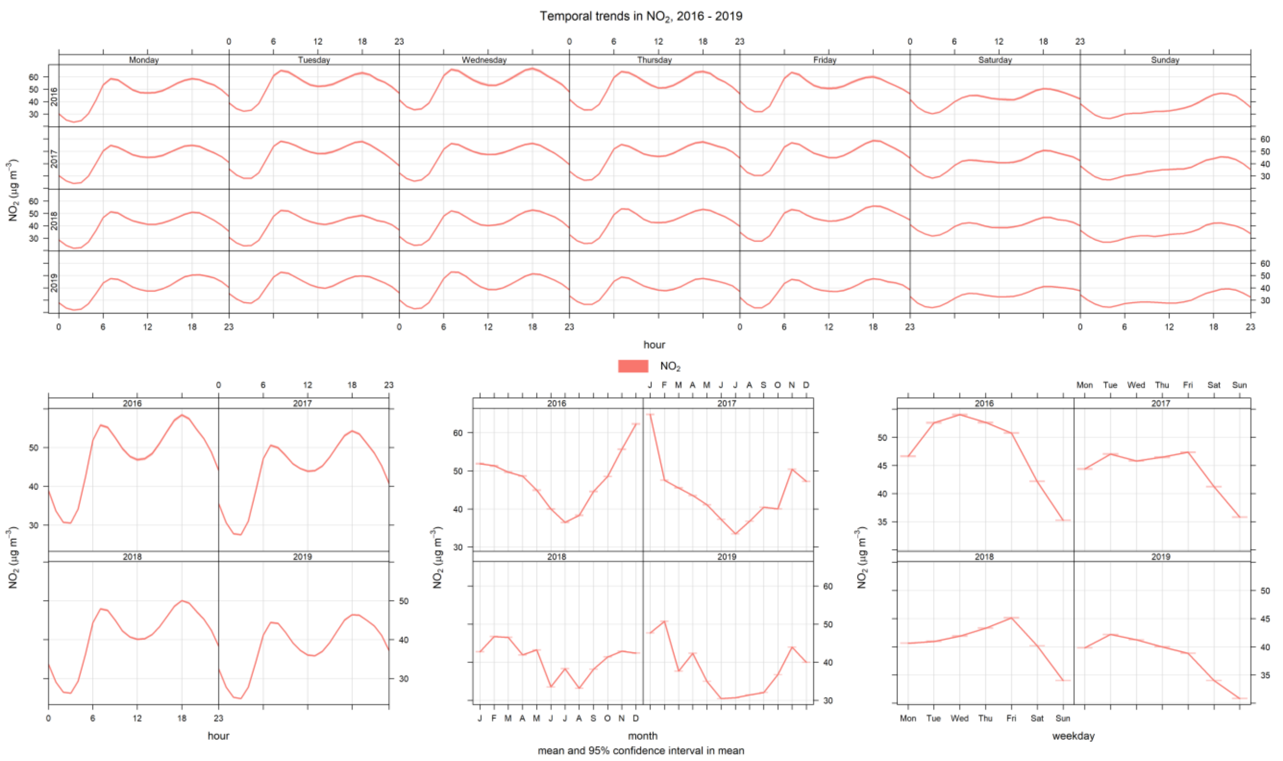

Figure A 8. Temporal trends in NO_2 in London [2020]

Table A 1. Change in daily average NO_2 since 16 March, grouped by site type and location

Type, Location	Change in daily average [µgm^{-3}]	Change in daily average [%]	Number of sites
Kerbside, Central	-23.5	-47%	1
Roadside, Central	-19.3	-38%	6
Kerbside, Inner	-17.1	-30%	4
Urban Centre, Outer	-12.7	-38%	1
Industrial, Inner	-8.6	-23%	3
Roadside, Inner	-7.8	-18%	30
Urban Background, Central	-6.5	-20%	4
Kerbside, Outer	-6.4	-15%	5
Airport, Outer	-6.0	-18%	2
Roadside, Outer	-6.0	-17%	22
Suburban, Outer	-4.4	-16%	7
Urban Background, Outer	-4.1	-18%	10
Urban Background, Inner	-3.2	-14%	15
Suburban, Inner	-1.6	-11%	1
Industrial, Outer	-1.3	-2%	2
Regional background, Non-London	0.0	+31%	3

Appendix 4. NO_x data

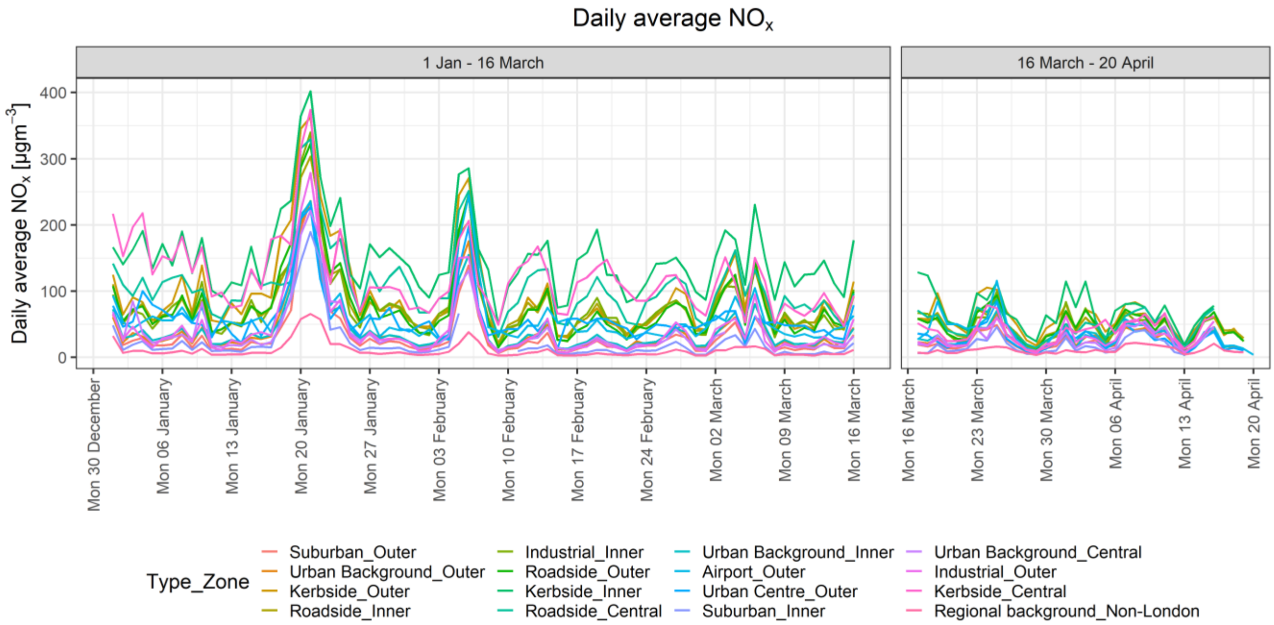

Figure A 9. Daily average NO_x in London [2020]

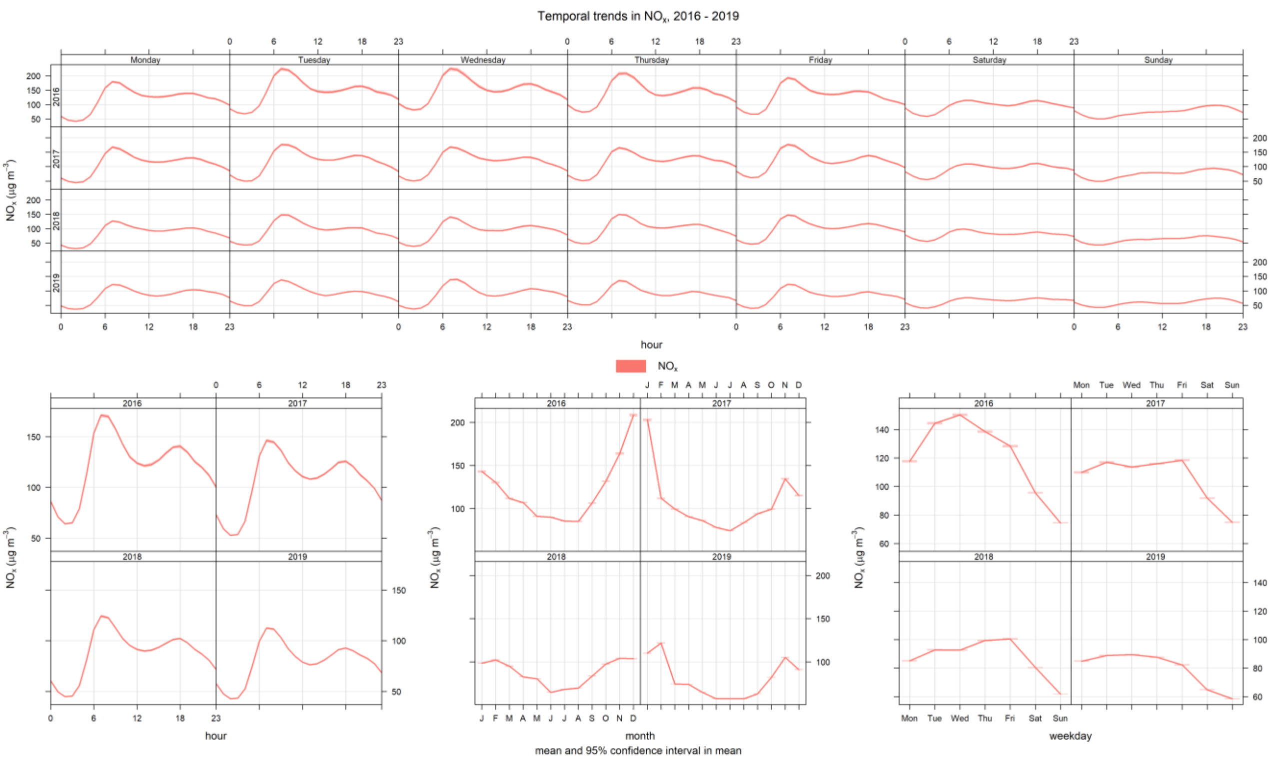

Figure A 10. Temporal trends in NO_x in London [2016 – 2019]

Table A 2. Change in daily average NO_x since 16 March, grouped by site type and location

Type, Location	Change in daily average [μgm^{-3}]	Change in daily average [%]	Number of sites
Kerbside, Central	-85	-69%	1
Kerbside, Inner	-71	-47%	4
Roadside, Central	-62	-56%	6
Kerbside, Outer	-33	-32%	4
Industrial, Inner	-32	-40%	3
Roadside, Inner	-30	-35%	29
Roadside, Outer	-29	-34%	21
Urban Centre, Outer	-28	-48%	1
Airport, Outer	-20	-32%	2
Urban Background, Central	-15	-37%	1
Urban Background, Outer	-14	-33%	10
Industrial, Outer	-14	-27%	2
Urban Background, Inner	-13	-31%	14
Suburban, Outer	-11	-32%	6
Suburban, Inner	-7	-31%	1
Regional background, Non-London	-1	8%	4

Appendix 5. O_3 data

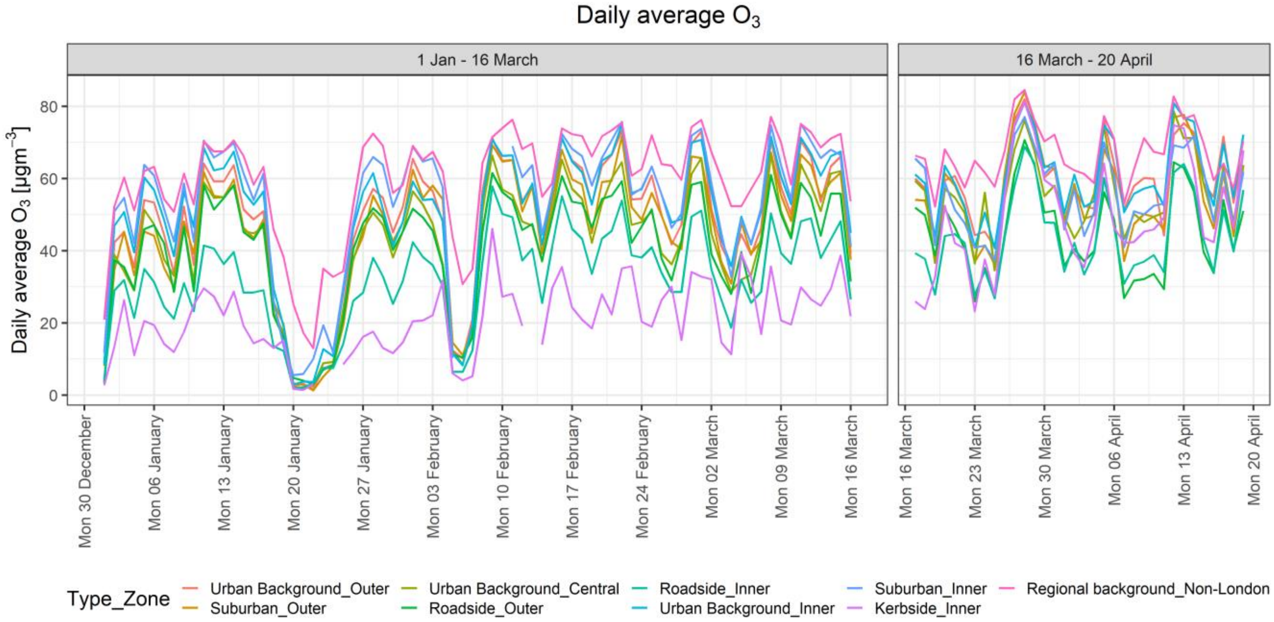

Figure A 11. Daily average O_3 in London [2020]

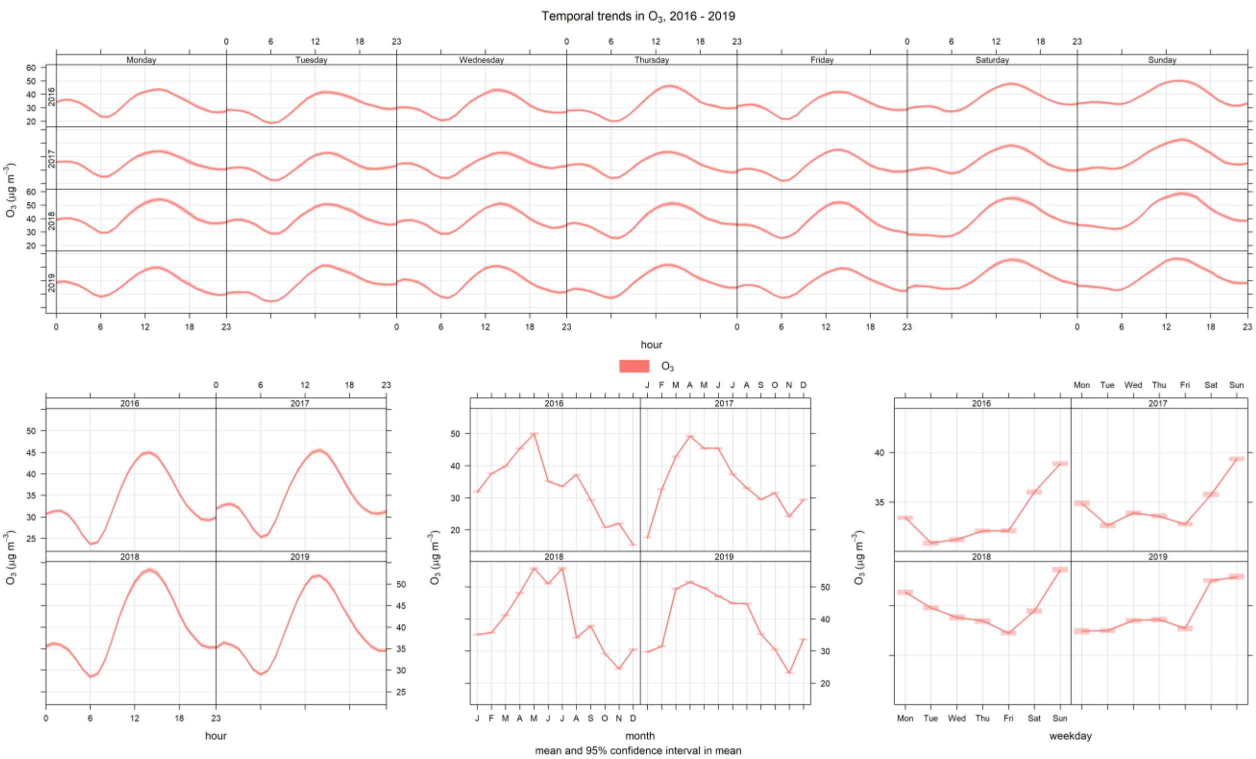

Figure A 12. Temporal trends in O_3 in London [2016 – 2019]

Table A 3. Change in daily average O_3 since 16 March, grouped by site type and location

Type, Location	Change in daily average [μgm^{-3}]	Change in daily average [%]	Number of sites
Kerbside, Inner	+24	+119%	1
Suburban, Outer	+11	+27%	3
Urban Background, Central	+10	+26%	2
Urban Background, Outer	+9	+20%	2
Roadside, Inner	+9	+32%	5
Urban Background, Inner	+8	+17%	4
Regional background, Non-London	+6	+11%	3
Roadside, Outer	+4	+12%	2
Suburban, Inner	+1	+3%	1

Appendix 6. $PM_{2.5}$ data

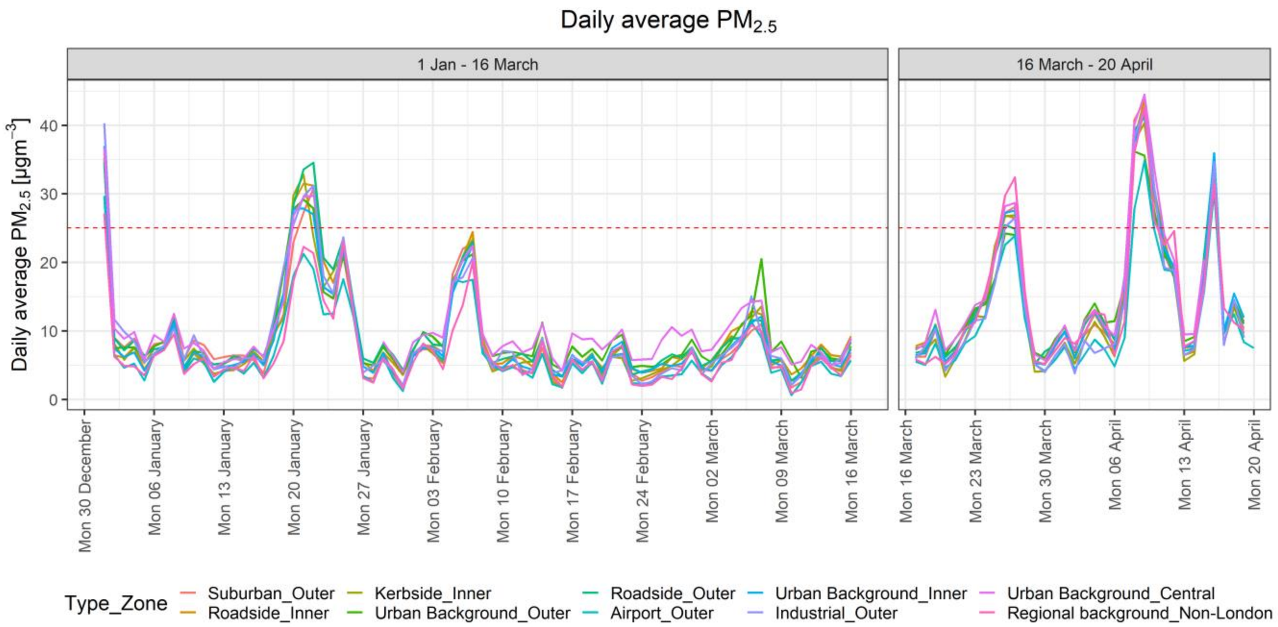

Figure A 13. Daily average $PM_{2.5}$ in London [2020]

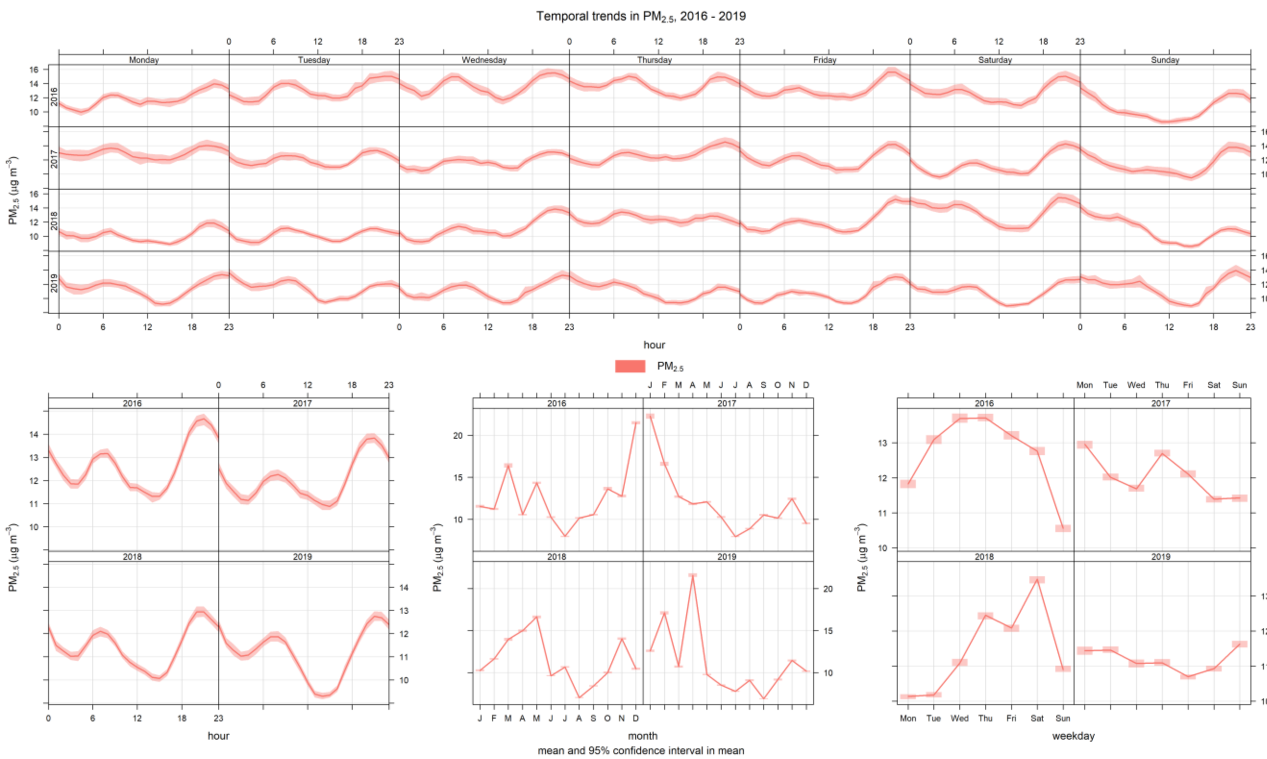

Figure A 14. Temporal trends in $PM_{2.5}$ in London [2016 – 2019]

Table A 4. Change in daily average $PM_{2.5}$ since 16 March, grouped by site type and location

Type, Location	Change in daily average [μgm^{-3}]	Change in daily average [%]	Number of sites
Regional background, Non-London	+4.6	+69%	2
Suburban, Outer	+3.3	+43%	3
Urban Background, Inner	+2.7	+37%	6
Roadside, Inner	+2.6	+31%	7
Roadside, Outer	+2.4	+30%	5
Airport, Outer	+2.3	+36%	2
Urban Background, Central	+2.3	+25%	1
Urban Background, Outer	+2.0	+22%	2
Kerbside, Inner	+1.6	+18%	2
Industrial, Outer	+1.2	+14%	1

Appendix 7. PM_{10} data

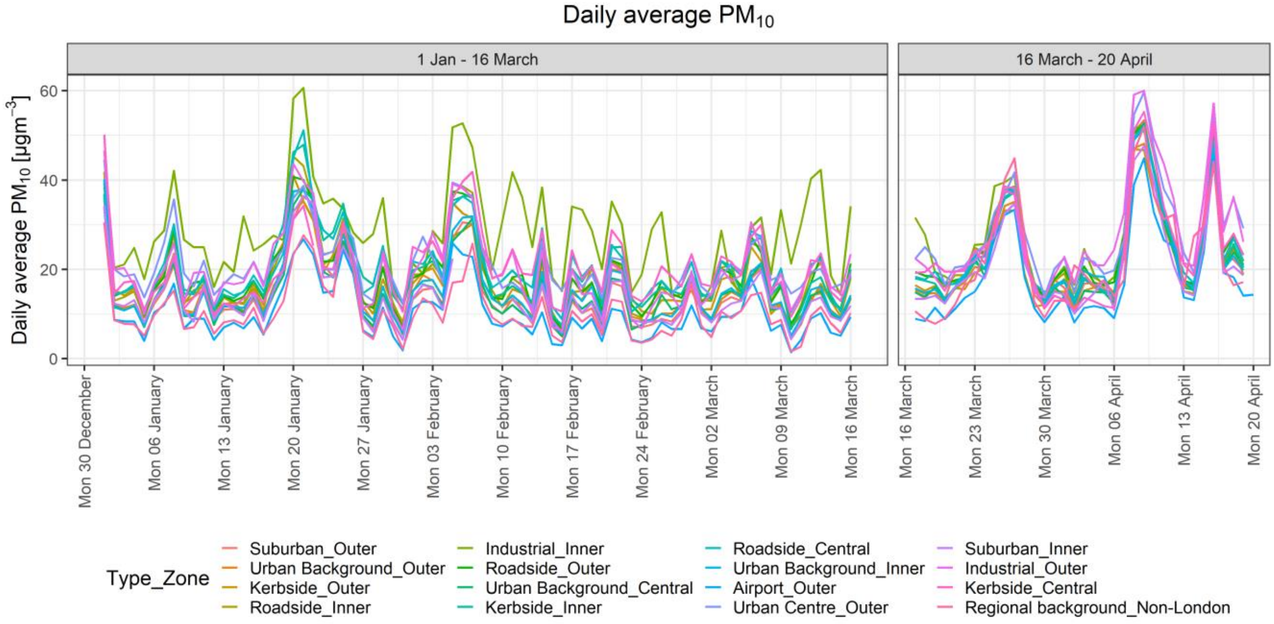

Figure A 15. Daily average PM_{10} in London [2020]

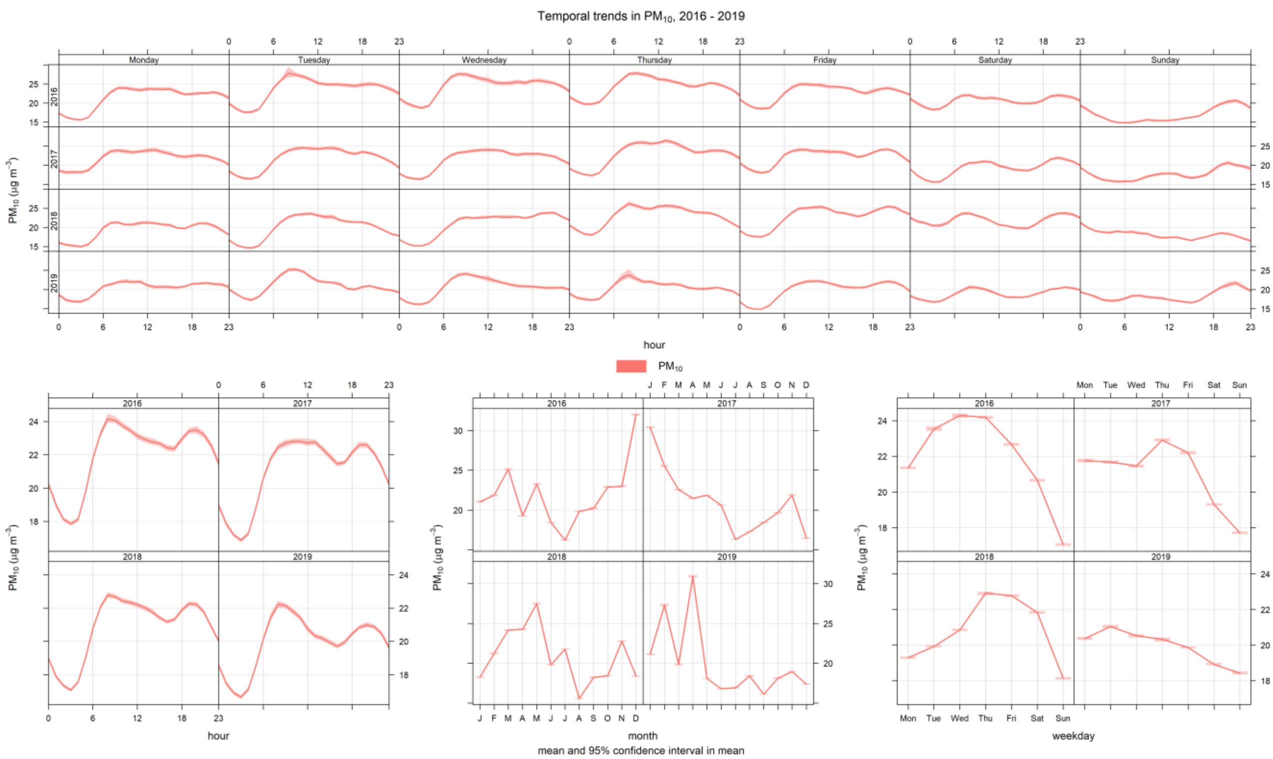

Figure A 16. Temporal trends in PM_{10} in London [2016 – 2019]

Table A 5. Change in daily average $PM_{2.5}$ since 16 March, grouped by site type and location

Type, Location	Change in daily average [μgm^{-3}]	Change in daily average [%]	Number of sites
Regional background, Non-London	+7.6	+74%	2
Suburban, Outer	+5.5	+40%	6
Urban Background, Inner	+4.3	+30%	10
Airport, Outer	+4.2	+42%	2
Urban Background, Central	+3.8	+27%	3
Suburban, Inner	+3.5	+28%	1
Roadside, Outer	+2.8	+17%	16
Urban Background, Outer	+2.8	+21%	9
Roadside, Inner	+2.8	+18%	22
Industrial, Outer	+2.6	+14%	1
Urban Centre, Outer	+2.2	+11%	1
Kerbside, Outer	+0.8	+6%	4
Roadside, Central	+0.0	+1%	4
Kerbside, Central	0.0	+1%	1
Kerbside, Inner	-0.2	0%	4
Industrial, Inner	-3.8	-4%	5

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