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Air Quality
CONSULTANTS

Air Pollution and Inequalities in London: 2019 Update

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1 Executive Summary

This report provides a snapshot analysis of the distribution of air quality across London and the relationship between exposure to air pollution, deprivation and ethnicity. It builds on previous work undertaken for the Greater London Authority (GLA), mainly by the consultants Aether. Previous studies found communities which have higher levels of deprivation, or a higher proportion of people from a non-white ethnic background, were more likely to be exposed to higher levels of air pollution. The previous study was based on 2013 data, this study is based on 2019 data.

Since 2013 there have been significant reductions in air pollutants in London, especially nitrogen dioxide (NO_2). The majority of these reductions have taken place since 2016. Between 2013 and 2016 there were no significant improvements in harmful NO_2 concentrations in London's air – with some areas actually getting worse. However, since 2016, thanks in part to bold policies to reduce pollution in the capital (including the Ultra Low Emission Zone and cleaning up the bus fleet) London-wide NO_2 has decreased by an average of 20 per cent, and London-wide particulate matter ($PM_{2.5}$) concentrations have reduced by an average of 15 per cent. This has led to reductions in exposure for all Londoners, and a reduction in inequality.

Key findings of this report are:

- In 2019, communities which have higher levels of deprivation, or a higher proportion of people from a non-white ethnic background, were still more likely to be exposed to higher levels of air pollution
- In 2019, in areas where the most deprived Londoners were likely to live the annual average NO_2 was 3.8 µg/m^3 higher than the least deprived areas or 13 per cent higher.
- For $PM_{2.5}$, areas where the most deprived Londoners were likely to live had annual average concentration 0.7 µg/m^3, or 6 per cent higher than the least deprived areas.
- Recent policies to improve air pollution have also reduced the inequality in exposure between different socioeconomic groups. This reduction is the greatest for NO_2, the pollutant which is most dominated by local sources. The difference between the most and least deprived reduced from 7.6 µg/m^3 in 2013 to 3.8 µg/m^3 in 2019, a reduction of 50 per cent.
- White ethnic groups are still more likely to be exposed to lower levels of air pollution and are the only group whose average exposure is lower than the overall London average.
- In 2019, annual average concentrations of NO_2 were on average between 16 and 27 per cent higher in areas where non-white people were most likely to live compared to areas where white people were most likely to live.
- Between 31 and 35 per cent of areas with the highest proportion of black and mixed/multiple ethnicities are in areas with higher levels of air pollution, reducing to 15-18 per cent for Asian ethnic groups and just 4-5 per cent for white ethnic groups.

- Again, recent policies to improve air pollution have also reduced the inequality in exposure between different ethnic groups. The difference in mean concentrations of NO_2 for areas where white and non-white groups were most likely to live reduces from 4.8-10.7 µg/m3 in 2013 to 4.0-6.9 µg/m^3 in 2019, a reduction in the inequality in exposure of between 15 and 37% since 2013.
- The highest concentrations of NO_2 experienced in each group have reduced substantially since 2013. The largest reductions have been for non-white groups and so the differences between them are now much smaller.
- In 2013, the range in the highest NO_2 concentrations across the ethnic groups was 22.5 µg/m^3 whereas in 2019 it was 5.9 µg/m^3, a reduction of 74%.

Note that the analysis looked at *population* level exposures and the overall distribution of air pollutant concentrations. This does not mean that any *individual* is necessarily exposed to higher or lower levels of air pollution based on their socio-economic status or ethnicity.

2 Introduction

While significant improvements have been made in recent years, air quality remains the greatest environmental risk to human health globally and in the UK[1]. Addressing poor air quality is one of the Mayor of London's key priorities, as is addressing health and social inequality. One of the key commitments given in 2018's London Environment Strategy[2] and London Health Inequalities Strategy[3] is that "*by 2050, London will have the best air quality of any major world city, going beyond the legal requirements to protect human health and minimise inequalities*."

This report provides a snapshot analysis of the distribution of air quality across London and the relationship between exposure to air pollution, deprivation and ethnicity. It builds on previous work undertaken for the Greater London Authority (GLA), mainly by the consultants Aether[4]. This includes:

- Air Pollution Exposure in London: Impact of the London Environment Strategy[5] (2019)
- Updated Analysis of Air Pollution Exposure in London (2017)[6]
- Analysing Air Pollution Exposure in London (2013)[7]

These reports established that in London there was a clear relationship between air quality and both deprivation and ethnicity, with those in more deprived communities being more likely to be exposed to higher levels of air pollution. People in non-white communities were also more likely to be exposed to higher levels of air pollution than white populations, although the effect was less marked. The 2019 report analysed the likely impact of the London Environment Strategy and demonstrated that, if the impacts of the Strategy were as predicted, there would be a beneficial impact on inequalities.

2.1 Air quality and inequality

The links between deprivation and poor health outcomes are well established, as are the links between air pollution and health effects, with the 2021 WHO Global Air Quality Guidelines[8] stating that:

1 Defra Clean Air Strategy, 2019; https://www.gov.uk/government/publications/clean-air-strategy-2019
2 https://www.london.gov.uk/what-we-do/environment/london-environment-strategy
3 https://www.london.gov.uk/what-we-do/health/london-health-inequalities-strategy
4 https://www.aether-uk.com/
5 https://www.london.gov.uk/sites/default/files/les_exposure_rpt_final2-rb.pdf
6 https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/updated-analysis-air-pollution-exposure-london-final
7 https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/analysing-air-pollution-exposure-london
8 World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329

"the burden of disease attributable to air pollution is now estimated to be on a par with other major global health risks such as unhealthy diet and tobacco smoking, and air pollution is now recognized ***as the single biggest environmental threat to human health.***[9]***"***

Over the last decade, there has also been a wealth of evidence linking markers of deprivation with higher exposure to air pollution, including the GLA reports listed above. The 2018 European Environment Agency report *Unequal exposure and unequal impacts: social vulnerability to air pollution, noise and extreme temperatures in Europe*[10] shows that the impacts of air pollution, alongside other environmental stressors, are not evenly distributed across society and are more likely to be borne by those from poorer or more deprived communities.

2.2 Analysing Air Quality and Inequality for 2019

The analysis presented in this report updates some of the work undertaken for the 2019 GLA report *Air Quality in London 2016 - 2020*[11], based on the London Atmospheric Emissions Inventory (LAEI), which has been used to provide estimates for concentrations of nitrogen dioxide (NO_2) and fine particulate matter ($PM_{2.5}$) for 2016 and the Mayors End of Term report on air quality in 2019. These estimates have been compared with the Index of Multiple Deprivation (IMD) and demographic information on ethnicity at the Lower Super Output Area (LSOA) level. Unlike the 2019 report, future concentrations have not been considered, nor has exposure at schools or other vulnerable locations.

Some comparisons between the findings of the 2019 report and those from this analysis have been carried out, indicating how the picture has evolved since 2013 (the base year for the 2019 report's analysis). However, there are some differences in the analytical approach between this study and the 2019 report and so such comparisons are necessarily indicative in nature.

Section 3 of this report describes the datasets used in the analysis and some of the uncertainties attached to the outcomes. Section 4 provides the outputs themselves, and Section 5 provides some commentary and summarises the key messages emerging from the work.

[9] World Health Organization (2021).WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. https://apps.who.int/iris/handle/10665/345329

[10] https://www.eea.europa.eu/publications/unequal-exposure-and-unequal-impacts/

[11] https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/air-quality-london-2016-2020

3 Data and Methodology

The datasets used for this project and their sources are described in Table 1.

Table 1: Datasets and sources used for the project

Dataset	Description	Source
NO_2 and $PM_{2.5}$ concentration estimates	Population weighted average concentrations of NO_2 and $PM_{2.5}$ at LSOA level (MER 2019)	Provided by TfL
Indices of Multiple Deprivation (IMD)	English Indices of Deprivation (ID) data for London at LSOA for the latest release (ID 2019)	https://data.london.gov.uk/dataset/indices-of-deprivation
Population estimates for 2019	Population estimates for 2019 at LSOA level (SAPE22DT2)	https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates
Ethnic group classifications	Ethnic group classifications at an LSOA level, based on the results of the 2011 census (qs201ew)	https://www.nomisweb.co.uk/census/2011/
Geospatial LSOA dataset	Geospatial UK wide LSOA dataset (2011 boundaries)	https://geoportal.statistics.gov.uk/datasets/

3.1 Lower Super Output Areas

For the purposes of the national census, the UK is divided into Output Areas (OAs), which consist of at least 40 but more usually around 125 households. They are delineated by a combination of postcode, ward and other electoral boundaries. However, some population statistics are not available at the OA level, and so larger Lower Super Output Levels (LSOA) have been used for this analysis. LSOAs are an amalgamation of OAs, containing 400-1,200 households. The 2011 census gives 4,835 LSOAs for London, shown in Figure 1.

Figure 1: London LSOAs from the 2011 Census

3.2 Index of Multiple Deprivation

Deprivation can take multiple forms. The Office of National Statistics (ONS) developed an index of deprivation which combines many of these forms: the Index of Multiple Deprivation (IMD)[12]. The IMD is made up of seven "domains" of deprivation, each of which is compiled from a number of indicators. These indicators and domains are then weighted according to their perceived contribution to overall deprivation. They include:

- Income deprivation
- Employment deprivation
- Health deprivation
- Air Pollution Exposure in London: Impact of the London Environment Strategy
- Disability, education, skills and training deprivation

[12] https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019

- Barriers to housing and services
- Crime and living environment deprivation.

The living environment includes air quality, houses without central heating and road traffic accidents involving pedestrians and cyclists. Air quality is included in the IMD, but it only makes up 1.5% of the total index which is not sufficient to bias the results. The overall scores for each domain are combined using the weightings to provide an overall IMD score.

3.3 Ethnicity data

Ethnicity data were taken from the 2011 Census at LSOA level. This provides the total population of the following ethnic groups within each LSOA: White, Asian/ Asian British, Black/ African/ Caribbean/ Black British, Mixed/ Multiple, and Other ethnic groups, which are in turn made up of ethnic sub-groups defined in Table 2.

Table 2: Ethnic group descriptor, 2011 Census

Ethnic Group	Sub-groups
White	White: English/Welsh/Scottish/Northern Irish/British White: Irish White: Gypsy or Irish Traveller White: Other White
Asian/Asian British	Asian/Asian British: Indian Asian/Asian British: Pakistani Asian/Asian British: Bangladeshi Asian/Asian British: Chinese Asian/Asian British: Other Asian
Black/African/Caribbean/Black British	Black/African/Caribbean/Black British: African Black/African/Caribbean/Black British: Caribbean Black/African/Caribbean/Black British: Other Black
Mixed/Multiple	Mixed/multiple ethnic group: White and Black Caribbean Mixed/multiple ethnic group: White and Black African Mixed/multiple ethnic group: White and Asian

	Mixed/multiple ethnic group: Other Mixed
Other ethnic groups	Other ethnic group: Arab Other ethnic group: Any other ethnic group

3.4 Air Quality Data

Air quality data were supplied to the project by Transport for London, in the form of annual average concentrations, for NO_2 and $PM_{2.5}$, for each OA and LSOA. These were, in turn, calculated from a 20m resolution grid, modelled using data from the 2019 GLA report Air Quality in London 2016 - 2020, based on the London Atmospheric Emissions Inventory (LAEI). The OA data were used to represent general exposures across London (OA data better represent peaks close to busy roads, etc.) whereas LSOA data were used in the comparisons with IMD and ethnicity data.

3.5 Initial data processing: Deciles

To provide a common basis on which these different datasets can be compared, each was divided into ten equal parts, or *deciles*, and ordered by magnitude. Thus, decile 1 has the lowest average value for the parameter in question and decile 10 the highest, i.e. highest IMD score (the least deprived) or highest pollutant concentration. This is the same process as was followed in the previous studies which allows some intercomparison of the results. However, it is possible that the LSOAs which fall into, say, decile 10 for any of the parameters are different to those in decile 10 for the earlier work.

For ethnicity data, the deciles are based on the relative number of people identifying as belonging to one of the five ethnic groups in an LSOA, rather than the absolute number. In other words, decile 10 for any ethnicity indicates the 10% highest population in an LSOA, by proportion, *for that ethnic group*. This means that it is possible for an LSOA to be marked as decile 10 for an ethnicity but that members of that ethnic group do not make up the majority of the population in that area, in absolute terms. This is, in fact, the case for the “mixed/multiple” and “other” ethnic groups, whose numbers are relatively small in comparison to other ethnic groups. It also means that areas can be marked as decile 7 or 8 for more than one ethnic group. Therefore, analysis for ethnicity has used only decile 10 areas to avoid overlap and double counting when considering the non-white population. This in turn means that the analysis can tend to focus on the extremes, as is discussed in the next section.

3.6 Uncertainty

There are inherent uncertainties in all of the datasets used for this analysis, including the air pollution data. Pollutant concentrations were based on a modelled 20m grid, with both the model, and the emissions data on which it is based, carrying a level of uncertainty. However, as with the other datasets used in this analysis, the project team has not undertaken a full uncertainty

assessment or sensitivity analysis. In terms of this assessment, the key uncertainties and assumptions are as follows:

- Aggregating data at the LSOA level could "smooth out" variation in the data. This will be the case for air pollution data, where high, near-source (e.g. roadside) concentrations will be smoothed out to produce levels closer to urban background. This means that, while the concentrations shown may be more representative of the levels to which the majority of the population is exposed, they are not those which would be used for checking compliance with Air Quality Objectives or Limit Values.
- Ethnicity data are taken from the 2011 census, the most up to date source, while pollutant, IMD and overall population data (used in calculating LSOA average concentrations) are for 2019. It is unlikely that the distribution of ethnicities will have been subject to major change between 2011 and 2019, but some change is possible. For this reason, the analysis has not focussed down on localities but maintained a London-wide focus, where the distribution patterns will remain broadly consistent.
- London has a highly mixed population. In order to undertake the analysis and identify the patterns shown in this report, the focus has tended towards the extreme ends of the data distribution, i.e. deciles 1 and 10. This tends to produce results that imply a more stratified distribution than is, in fact, the case. This is particularly so for ethnicity where decile 10 analysis labels areas as being a particular ethnicity when, in fact, that group may not make up the majority of the population.

4 Outputs

This report provides a snapshot analysis of air quality and its relationship with the distribution of both deprivation, as measured by the IMD, and ethnic identity, as expressed through the national census, from 2019. It follows on from the analysis undertaken previously by Aether, on behalf of GLA. The analysis in this report is more limited than the previous study, addressing comparisons between air quality, IMD and ethnicity for one year only (the previous study looked at schools and other vulnerable locations, and over multiple years).

This section sets out the outputs from the analysis while Section 4 provides some commentary on the results, including a simple comparison with the previous work undertaken by Aether.

4.1 Distribution of air pollution, population and ethnicity

Figures 2 and 3 show the distribution of (annual average) concentrations of NO_2 and $PM_{2.5}$ in London, by LSOA, in 2013, 2016 and 2019. The three years are shown to provide a context for comparisons with the outputs from previous reports. Both NO_2 and $PM_{2.5}$ show clear reductions in concentrations over the six-year period, with NO_2 showing the greatest reduction. Since 2013 there have been significant reductions in air pollutants in London, especially nitrogen dioxide NO2. The majority of these reductions have taken place since 2016. Between 2013 and 2016 there were no significant improvements in harmful NO2 concentrations in London's air – with some areas actually getting worse. Between 2016 and 2019, on average, London-wide NO_2 concentrations have reduced by 7.1 μgm^3, a reduction of 20 per cent and London-wide $PM_{2.5}$ concentrations have reduced by 2.3 μgm^3, a reduction of 15 per cent[13].

It is worth noting that concentration averages across LSOAs will tend to smooth out the peaks, although the major road network is still apparent, as is the tendency for higher concentrations to be experienced towards the centre of London and, for NO_2, around Heathrow Airport.

Figures 4 shows the distribution of deciles for IMD; note that a lower IMD score indicates higher deprivation, and so the darker shaded areas on the map have the highest level of deprivation (lowest IMD score).

Figure 5 shows the five main ethnic groups, by LSOA. Decile 10 describes the LSOAs with the top 10% highest population for that ethnic group, and could be described as the places where people who identify as being from that background are most likely to live.

[13] https://www.london.gov.uk/sites/default/files/air_quality_in_london_2016-2020_october2020final.pdf

Figure 2: Annual Mean NO_2 Concentrations at LSOA centres, 2013-2019

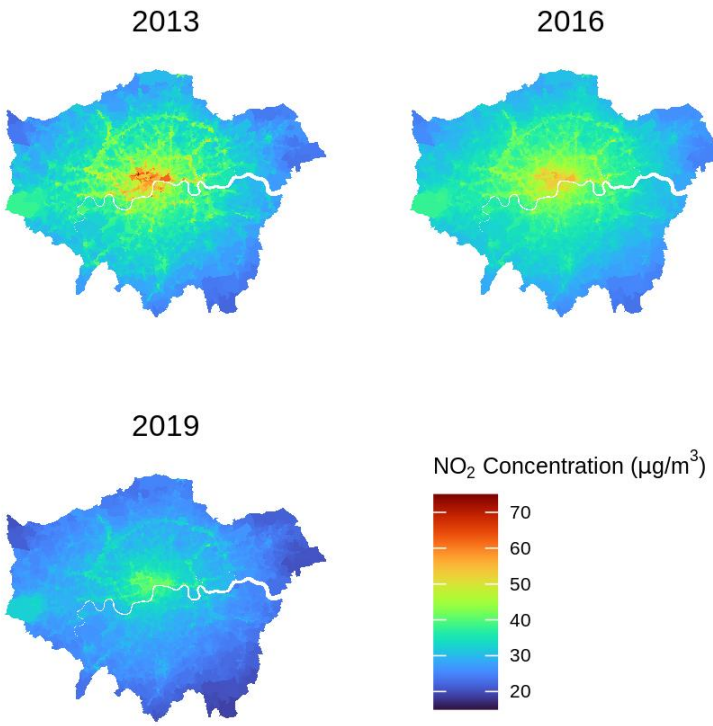


Figure 3: Annual Mean $PM_{2.5}$ Concentrations at LSOA centres, 2013-2019

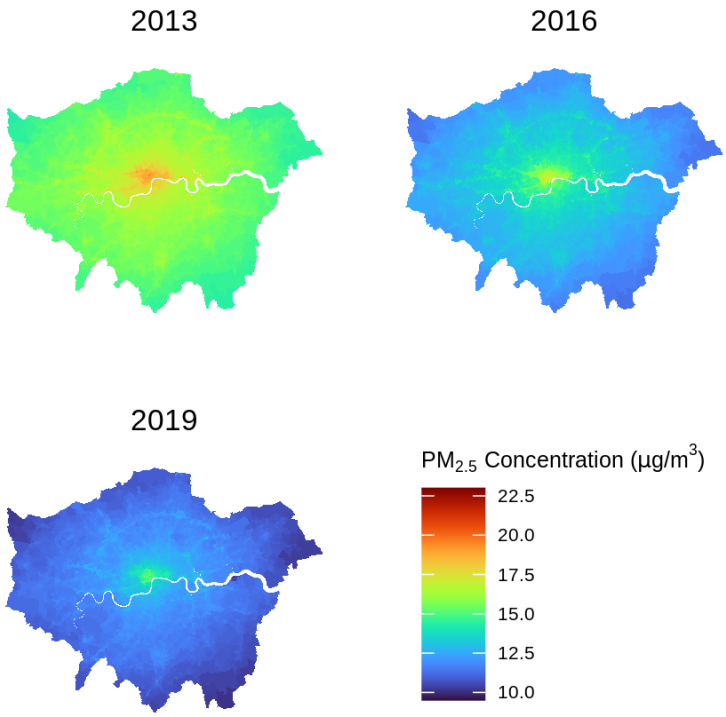


Figure 4: Geographical distribution of IMD (2019) deciles in London by LSOA

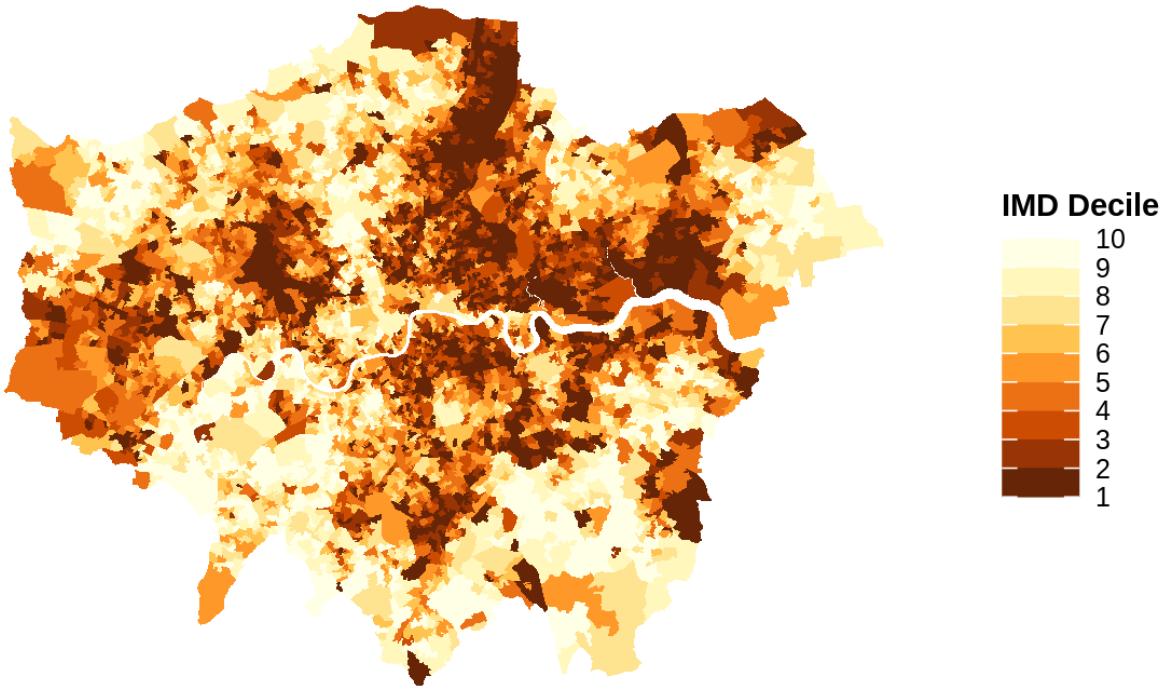
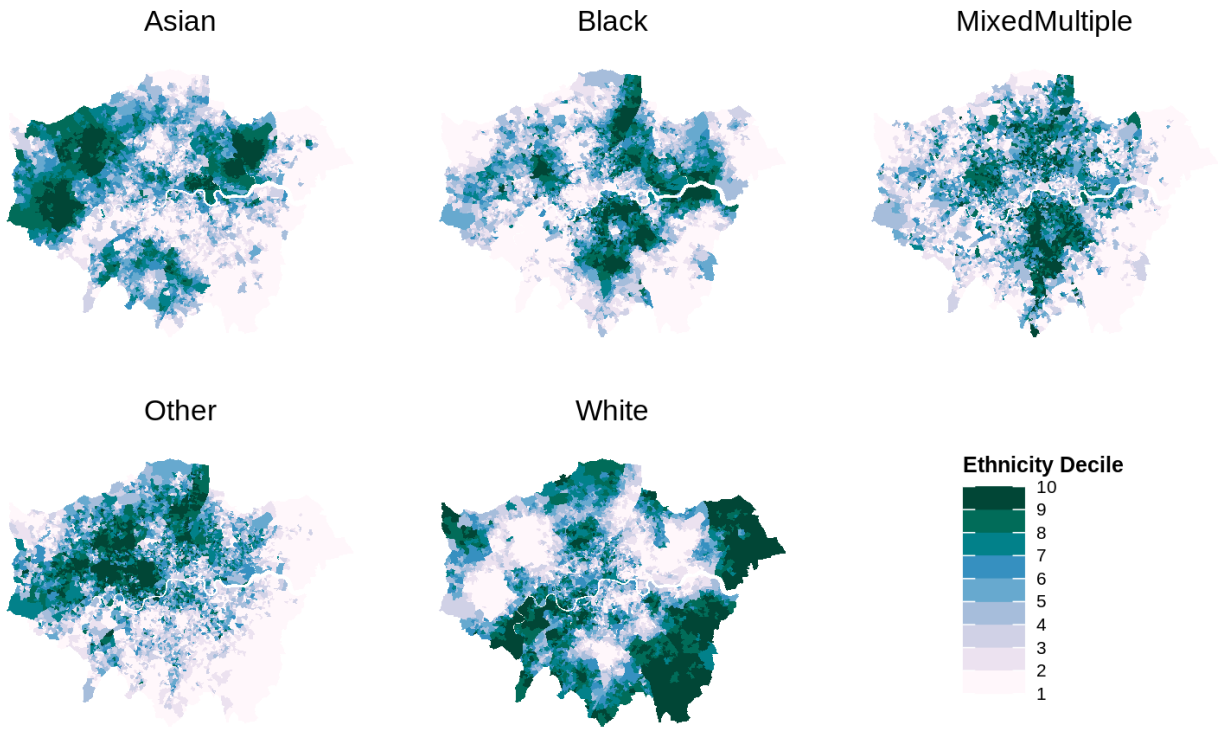


Figure 5: Geographical distribution of ethnic groups in London by LSOA decile, 2011 Census



4.2 Air pollution and deprivation

Air pollutant concentrations were assigned to each LSOA in each IMD decile and plotted using traditional "box and whisker" plots. In these, the average, or "mean", concentration across each decile is shown by the thick horizontal bar across each blue box, with the top and the bottom of the blue box representing the 25th and 75th centile, i.e. the central 50% of concentrations across LSOAs in that IMD decile. The blue box is a good indicator of the spread of the data points. The whiskers show the 2.5th and 97.5th centile and the crosses show the maximum concentration found in that IMD decile. IMD decile 1 is the most deprived and decile 10 the least deprived. The plot for NO_2 is shown in Figure 6 and the plot for $PM_{2.5}$ in Figure 7.

Table 3 shows the mean concentration values for each IMD decile, alongside the range in values and ratio of highest to lowest values across the deciles. For decile 1 (the most deprived) the annual average NO_2 was 3.8 µg/m^3 higher than for decile 10 (the least deprived), or 13% higher. For $PM_{2.5}$ decile 1 (the most deprived) the annual average was 0.7 ugm^3 higher than for decile 10 (the least deprived), or 6% higher.

Figure 6: Box and whisker plot for NO_2 concentrations across the 10 IMD deciles

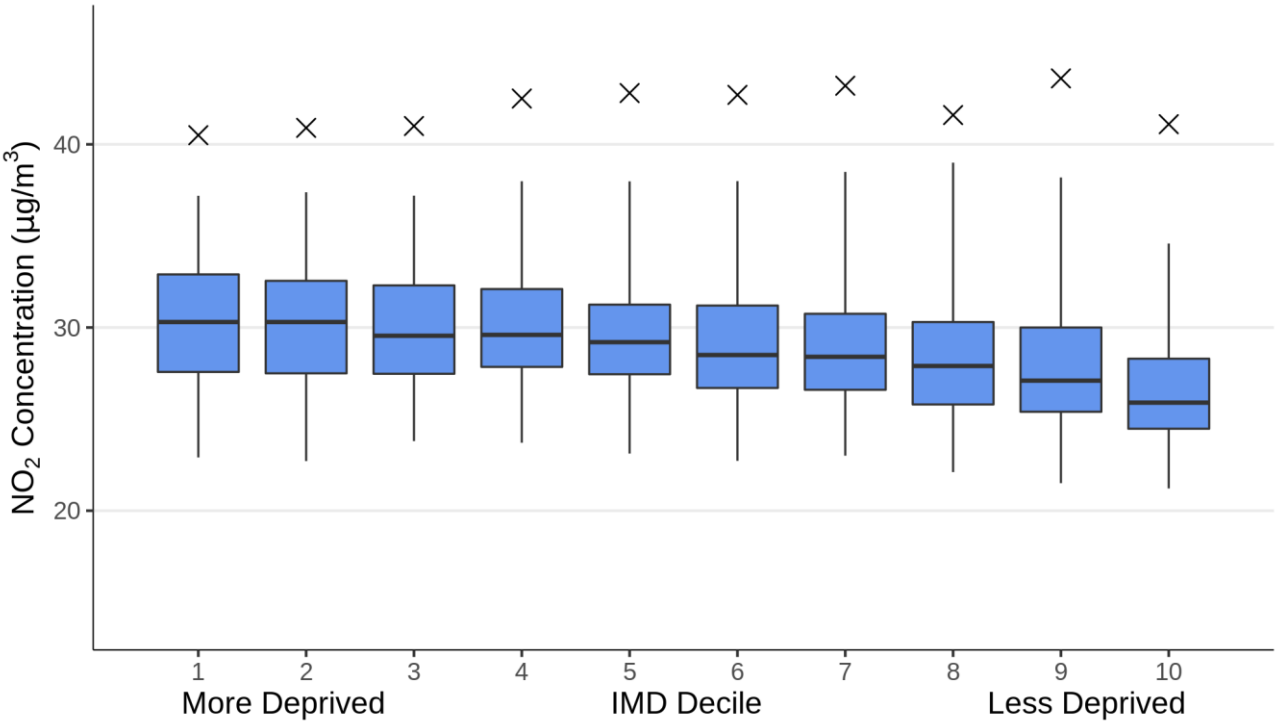


Figure 7: Box and whisker plot for $PM_{2.5}$ concentrations across the 10 IMD deciles

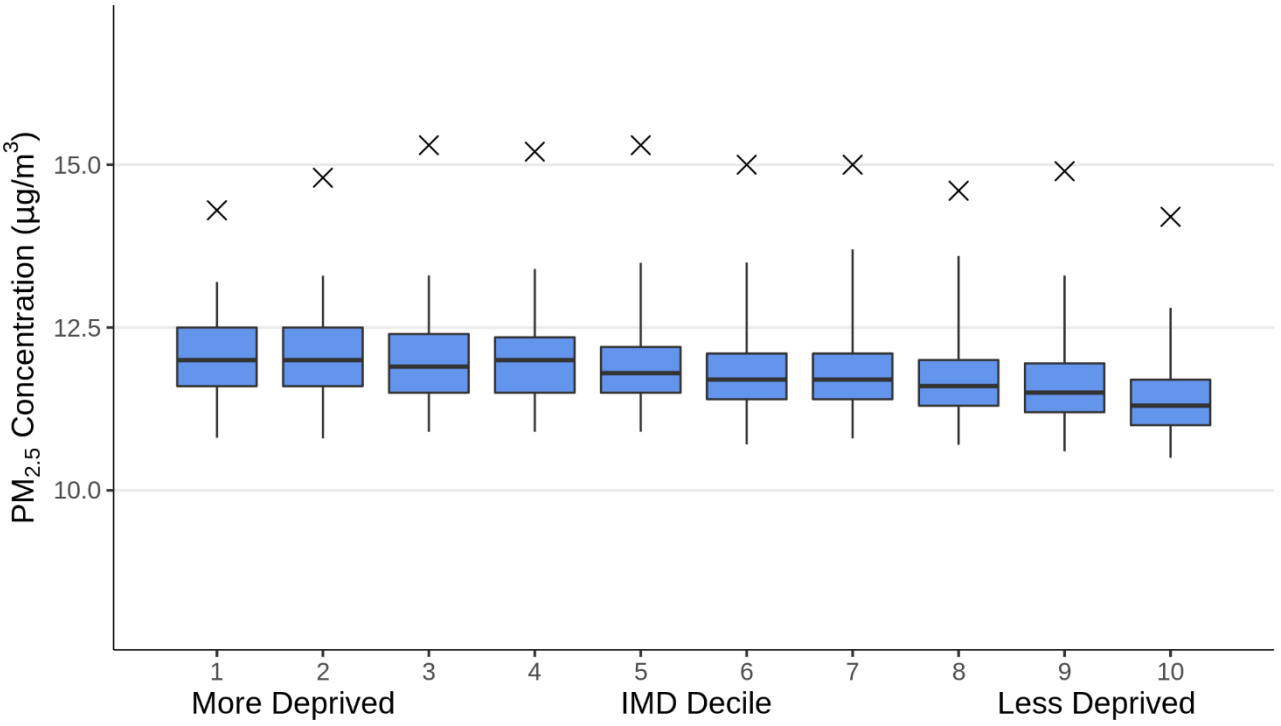


Table 3: Mean concentration values and ranges for NO_2 and $PM_{2.5}$ by IMD decile

Pollutant	IMD decile (µg/m³)										Increment, lowest to highest (µg/m³)	Ratio, lowest to highest
	1	2	3	4	5	6	7	8	9	10		
NO_2	30.3	30.1	29.9	30.1	29.6	29.2	29.0	28.4	28.0	26.5	3.8	0.87
$PM_{2.5}$	12.1	12.0	12.0	12.0	11.9	11.8	11.8	11.7	11.6	11.4	0.7	0.94

Box and whisker plots are not always easy to interpret, and Figures 8 and 9 provide an alternative representation, with the 2.5-97.5th and 25-75th percentiles shown as shaded regions and the mean values connected by dashed line. These figures use the same data, it has just been presented using a different graphical approach.

Figure 8: Data plot for NO_2 concentrations across the 10 IMD deciles

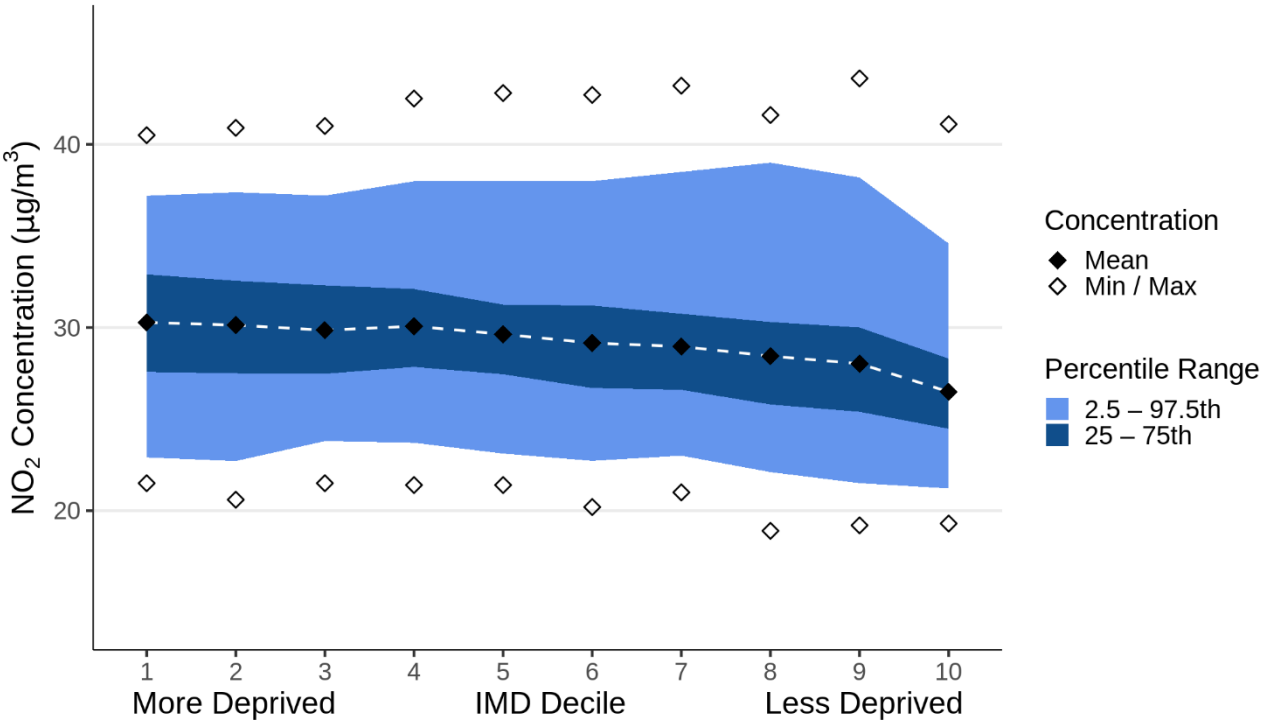
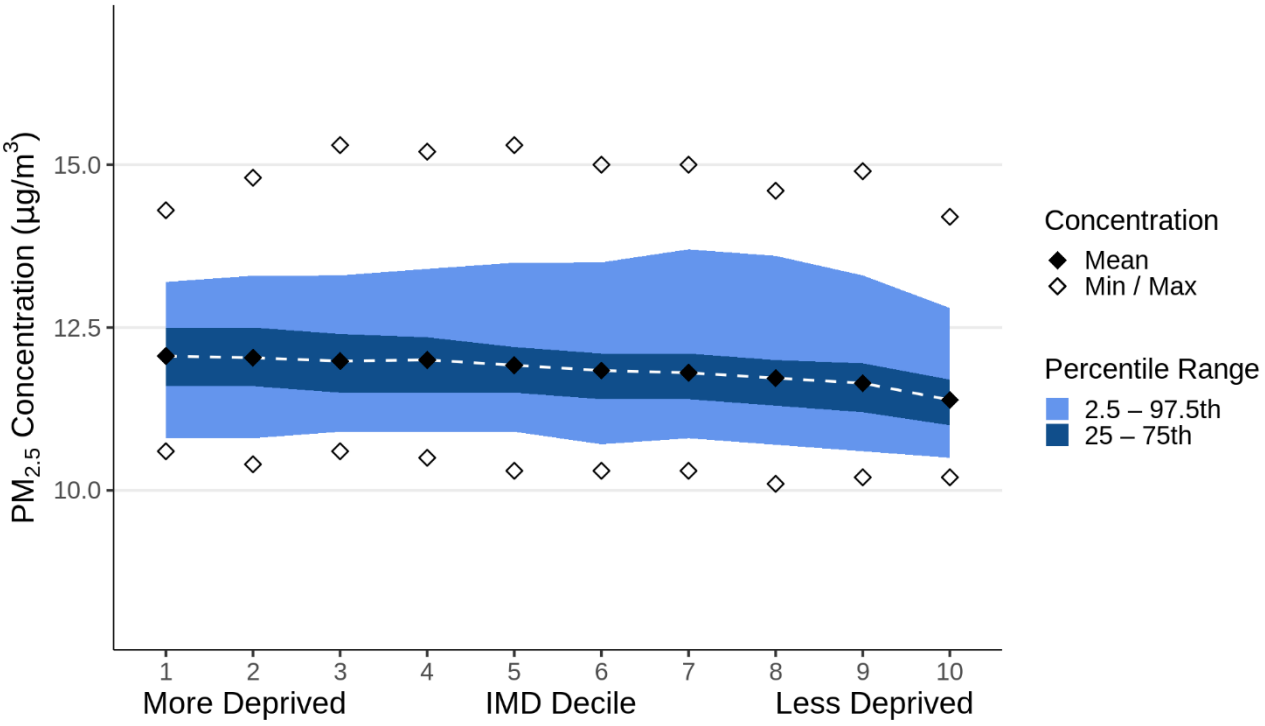


Figure 9: Data plot for $PM_{2.5}$ concentrations across the 10 IMD deciles



4.3 Air pollution and ethnicity

As mentioned previously, decile 10 covers those LSOAs with the top 10% highest population for that ethnic group, and could be described as the places where people from that background are most likely to live. The correlation between decile 10 areas for different populations and levels of air pollution has been analysed. Figures 10 and 11 show all of the LSOAs ranked by pollutant concentration for NO_2 and $PM_{2.5}$, with those areas identified as decile 10 for either white or non-white ethnic groups shaded either green or purple, respectively; grey shows those LSOAs which are not "decile 10" for any ethnic group. For both pollutants, there is a clear tendency for the LSOAs with lower concentrations to be decile 10 for the white ethnic group, whereas non-white ethnic group areas (decile 10) tend to have higher concentrations.

Figure 10: All London LSOAs ranked by NO_2 concentration and shaded by decile 10 ethnic group (white, non-white, neither)

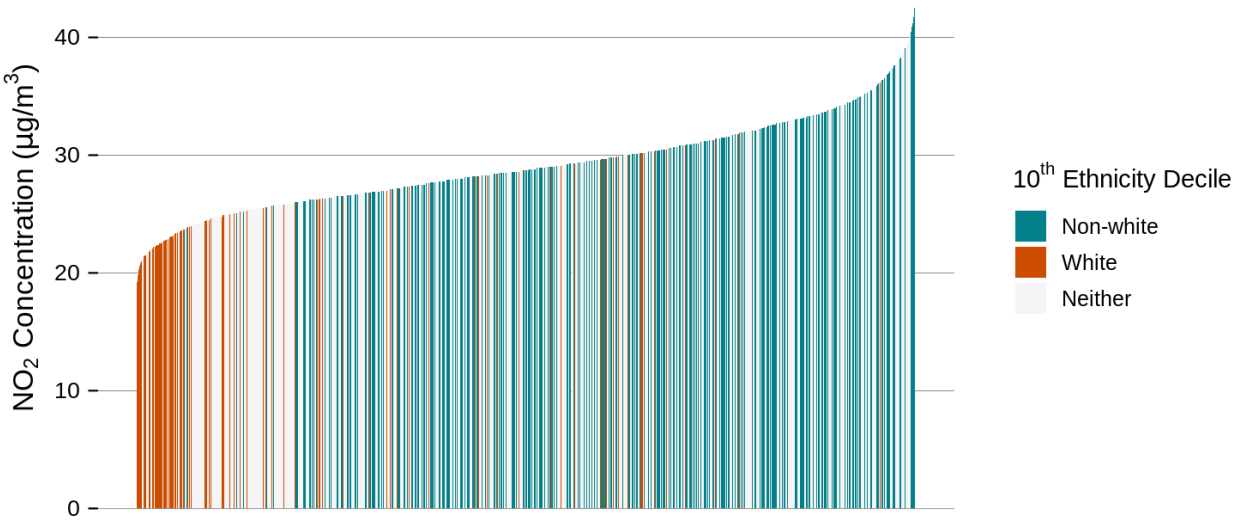


Figure 11 All London LSOAs ranked by $PM_{2.5}$ concentration and shaded by decile 10 ethnic group (white, non-white, neither)

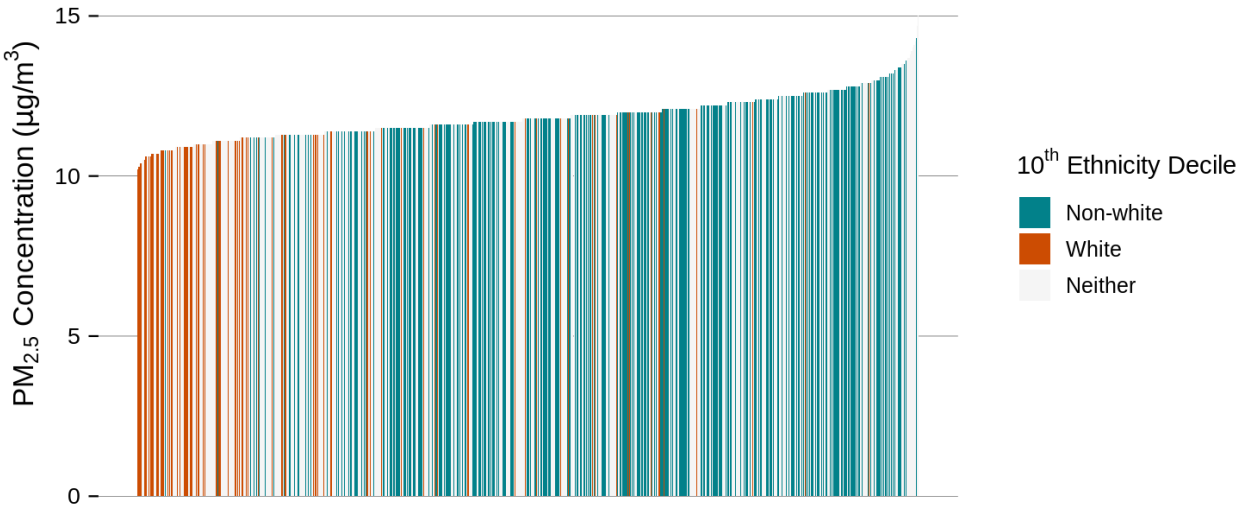


Table 4 shows the proportion of decile 10 areas for each of the five ethnic groups (or areas which each of the five ethnic groups are most likely to live), that also have higher levels of air pollution. High levels of air pollution in this instance are defined as the 25% of London LSOAs (i.e. 1,209 out of 4,835) with the highest concentrations for NO_2 and $PM_{2.5}$, respectively. Both the highest and the mean concentrations seen in decile 10 areas for each ethnic group are also shown. This gives a slightly different pattern, although decile 10 areas for white ethnicity showed the lowest peak concentrations for both pollutants, albeit with the difference being less pronounced.

Table 4: Proportion of decile 10 ethnicity areas with higher air pollution

Ethnicity	NO_2			$PM_{2.5}$		
	Decile 10s in highest conc. LSOAs	Highest conc. (µg/m³)	Mean conc. (µg/m³)	Decile 10s in highest conc. LSOAs	Highest conc. (µg/m³)	Mean conc. (µg/m³)
Asian	18%	40.5	29.3	15%	14.3	11.8
Black	32%	38.7	29.9	31%	13.4	12.0
Mixed/multiple	35%	39.7	30.2	36%	13.7	12.1
Other	53%	43.6	32.2	51%	15.2	12.3
Non-White	18-53%	38.7-43.6	29.3-32.2	15-51%	13.4-15.2	11.8-12.3
White	4%	37.7	25.3	5%	13.7	11.2

As was the case in previous years, areas where white Londoners were more likely to live had the lowest average concentrations for both NO_2 and $PM_{2.5}$. The ethnic group which has the highest annual average is the category "other", which had a mean annual average NO_2 of 32.2 µg/m^3. This is 27% higher than the mean NO_2 for the white ethnic group (25.3 µg/m^3). The lowest annual mean concentrations for a non-white ethnic group was for the Asian ethnic group, with an annual average of 29.3 µg/m^3, which is 16% higher than the average for the white ethnic group.

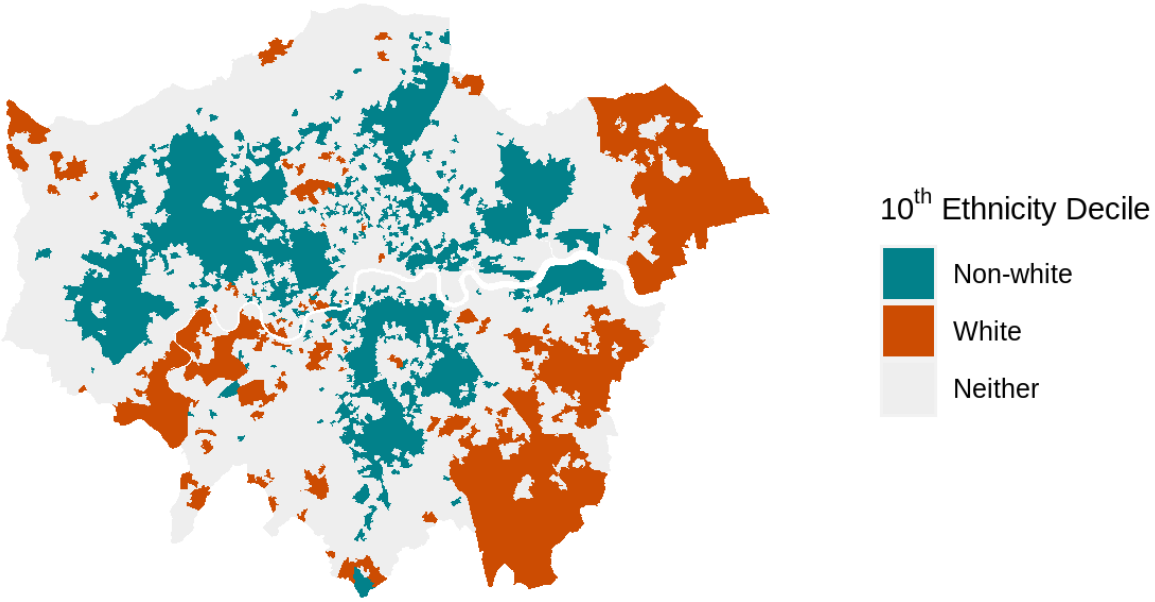
Areas where non-white groups were most likely to live were also far more likely to be amongst the most polluted areas in London (meaning the 25% of LSOAs with the highest annual average NO_2 concentrations) compared to areas where white groups were more likely to live. This varied by ethnic group, but between 18 – 53% of areas where non-white groups were most likely to live were amongst the most polluted areas in London, compared to just 4% for areas where white groups were most likely to live.

For $PM_{2.5}$, again areas where white groups were more likely to live had the lowest average annual average concentrations and were the least likely to be in the most polluted areas. However, the difference was less pronounced that for NO_2, with areas where non-white groups were most likely to live being on average 5 – 10 % higher for annual average $PM_{2.5}$ than areas where white groups are more likely to live. This is because concentrations of NO_2 are far more directly influenced by local emissions, and can vary widely across the city. $PM_{2.5}$ has a strong regional component, and so is more impacted by sources outside the city and varies less across the city.

The charts in Figures 10 and 11 and the results in

Table 4 clearly show that areas with a higher proportion of non-white residents are more likely to have higher levels of air pollution. However, London is a highly diverse city, and the population is in reality more mixed than can be represented by only looking at decile 10 (for ethnicity) areas. This could produce a greater difference than if the population is examined as a whole. Figure 12 shows how the decile 10 areas for white and non-white populations are distributed across London. Decile 10 areas for the white population are concentrated around the edges of Greater London, along the eastern side and in the south-west. Decile 10 areas for non-white groups are far more likely to be located towards the centre of the city which, as shown in Figures 2 and 3 are more likely to have higher levels of air pollution. The population is mixed and no areas are populated by only one ethnic group. Therefore, white people will be exposed to high levels of air pollution, just as non-white people will live in areas of low air pollution.

Figure 12: Geographical distribution of decile 10 areas for white, non-white and neither ethnicity



Another method to assess the inequality of exposure across different ethnic groups is presented below. A simple analysis was undertaken which proportionately assigned exposures to each ethnic group in each LSOA, according to their relative populations. This was based on the following equation:

$$\text{Total mean conc. [a]} = \frac{\text{(conc [a] LSOA1 x pop}^{n}\text{ [a] LSOA1) + (conc [a] LSOA2 x pop}^{n}\text{ [a] LSOA2) + (…etc)}}{\text{Total population [a]}}$$

Where [a] is the ethnic group, pop^n is the population and (conc) is the annual average concentration of either NO_2 or $PM_{2.5}$

This equation produces a simple distribution of the pollutant exposure according to ethnic group, with the results shown in Table 5. Again, the data shows that white population is likely to be exposed to lower levels of air pollution than the non-white population, although the differences are not as marked as in Table 4.

Table 5: "Simple" analysis showing average exposure to NO_2 and $PM_{2.5}$ for each ethnic group

Ethnicity	NO_2 (annual mean, µg/m^3)	$PM_{2.5}$ (annual mean, µg/m^3)
Asian	29.6	11.9
Black	29.7	12.0
Mixed/multiple	29.8	12.0
Other	30.7	12.1
White	29.0	11.8
London average	29.3	11.9

5 Analysis

5.1 Key messages from this analysis

The analysis presented in this report reaffirms the central messages from previous work. Communities which have higher levels of deprivation, or a higher proportion of people from a non-white ethnic background, are also more likely to be exposed to higher levels of air pollution, i.e. annual average concentrations of NO_2 and $PM_{2.5}$. As for all datasets of this size which are based on averages, some caution is needed in interpreting the results. The analysis undertaken has looked at *population* level exposures and the overall distribution of air pollutant concentrations. This does not mean that any *individual* is necessarily exposed to higher or lower levels of air pollution based on their socio-economic status or ethnicity.

Additionally, levels of air pollution vary, even within small areas, and personal exposure may be very different to that shown at the population level, being also dependent factors such as on indoor air quality. Personal choices and circumstances, such as smoking, types of heating and ventilation, cleaning and other products used, mean that levels of air pollution indoors can be higher than those outdoors, and result in very different exposure patterns for people living in the same area.

Nevertheless, the analysis demonstrates a clear increase in the probability of deprived and non-white communities being exposed to poorer air quality. In 2019, the mean annual average NO_2 concentration for the most deprived areas was 3.8 µg/m^3 higher than for the least deprived or 13% higher. For $PM_{2.5}$, annual average concentrations in the most deprived areas were 0.7 ugm^3 (or 6%) higher than for the least deprived. These are significant differences and could lead to an increase in adverse health outcomes for a population which is already more likely to suffer poor health.

In terms of ethnicity, in 2019, between 31 and 35% of areas with the highest proportion of black and mixed/multiple ethnicities are in areas with higher levels of air pollution (top 25%), reducing to 15-18% for Asian ethnic groups and just 4-5% for white ethnic groups. Looking at exposures across the populations, white ethnic groups are more likely to be exposed to lower levels of air pollution and are the only group whose average exposure is lower than the overall London average.

5.2 Comparison with previous work

The analysis in this report has followed a similar approach to that used in previous work undertaken for GLA by Aether. This allows some comparison with the results from that study, although there are differences and potential differences between the two studies:

- The previous work was undertaken using the emissions estimates for 2013 as the basis for air pollutant concentrations, whereas this report is based on estimates using the 2016 LAEI (updated for 2019). While the general patterns of air pollution will be the same, some of the details will be different.

- There are likely to be differences in the analytical approaches between the two studies – both analysed the data using the same statistical programming language (R) but the precise methods were developed independently.
- IMD data used in each study are from different years, and while both used the 2011 census as the source of ethnicity data, there are some minor differences in how populations for each LSOA are calculated. Therefore, while the areas identified as decile 10 will be mostly the same, it is not clear whether they are identical in both studies.

As a result of these differences, some caution is needed when the study outputs are compared.

Annual average concentrations of both NO_2 and $PM_{2.5}$ have reduced significantly since 2013, the base year used in the previous study. A precise comparison with the outputs from the previous work is not possible, but the reductions shown are broadly in line with what was predicted in that report, where projected air quality up to 2030 was analysed. However, the results presented in that report are generally for 2013 and 2030 (with and without the impact of the London Environment Strategy), and not for the years in between.

5.2.1 Deprivation

In 2013, the difference in annual average concentrations between the most and least deprived were estimated as being 7.6 µg/m^3 for NO_2 and 0.9 µg/m^3 for $PM_{2.5}$. The latest analysis indicated that policies to improve air pollution implemented since 2013 have also reduced the inequality in exposure between different socio-economic groups. This difference is the greatest for NO_2, the pollutant which is most dominated by local sources so in turn has been most reduced by local policies. The difference between the most and least deprived reduced from 7.6 µg/m^3 in 2013 to 3.8 µg/m^3 in 2019, a reduction of 50%. In 2013 the average concentration in the most deprived areas was 24% higher than the least deprived, this has reduced to 13%. Therefore, the level of inequality in exposure related to deprivation has reduced significantly.

5.2.2 Ethnicity

The picture in terms of ethnicity is more mixed. A summary comparison with 2013 outputs is shown in Table 6. In terms of the areas where people from the five ethnic groups are more likely to live (decile 10), the highest concentrations of NO_2 experienced in each group have reduced substantially since 2013. The largest reductions have been for non-white groups and so the differences between them are now much smaller. In 2013, the range in the highest NO_2 concentrations across the ethnic groups was 22.5 µg/m^3 whereas in 2019 it was 5.9 µg/m^3, a reduction of 74%. This indicates that inequality may be reducing significantly in the most polluted areas. In addition, the difference in mean concentrations of NO_2 for areas where white and non-white groups were most likely to live reduces from 4.8-10.7 µg/m3 in 2013 to 4.0-6.9 µg/m^3 in 2019, a reduction in the inequality in exposure of between 15 and 37%.

The 2013 report found that a significantly higher percentage of non-white decile 10 areas were in the top 25% most polluted (using annual average NO_2 concentrations as the metric) compared to

white areas. The pattern has been confirmed in the current report, and the results suggest that the effect has increased – from 13% to 15% for Asian, 20% to 32% for black and 30% to 35% for mixed/multiple – while the proportion for white ethnicity has stayed the same, at 4%.

This apparent increase could be due shifts in the relative levels of air pollution across the city, i.e. pollution improving more slowly in areas of larger non-white ethnic populations than other areas. However, this would be inconsistent with other findings in this report. A more likely explanation is methodological differences between this and the previous report, specifically in terms of how the "top 25%" air pollution is calculated. For example, if the top 25% is the 25% highest concentrations, this could produce a different number of LSOAs, depending in the peak concentration and the spread of concentrations below it. Thus, using this method, reducing the peak and restricting the range will bring more LSOAs into the top 25%.

Table 6: Summary of comparison results for ethnicity, 2013[14]-2019

Ethnicity	NO_2					
	Mean conc. 2013 ($\mu g/m^3$)	Difference to white ethnic group (2013) ($\mu g/m^3$)	Mean conc. 2019 ($\mu g/m^3$)	Difference to white ethnic group (2019) ($\mu g/m^3$)	Reduction in average NO_2 2013 - 2019	Reduction in difference 2013 - 2019
Asian	35.2	4.7	29.3	4.0	17%	15%
Black	37.7	7.2	29.9	4.6	21%	36%
Mixed/multiple	38.3	7.8	30.2	4.9	21%	37%
Other	41.1	10.6	32.2	6.9	22%	35%
Non-White	35.2 – 41.1	4.7 - 10.6	29.3 - 32.2	4.0 - 6.9	17 – 22%	15 – 37%
White	30.5	-	25.3	-	17%	-

[14] https://www.london.gov.uk/sites/default/files/les_exposure_rpt_final2-rb.pdf