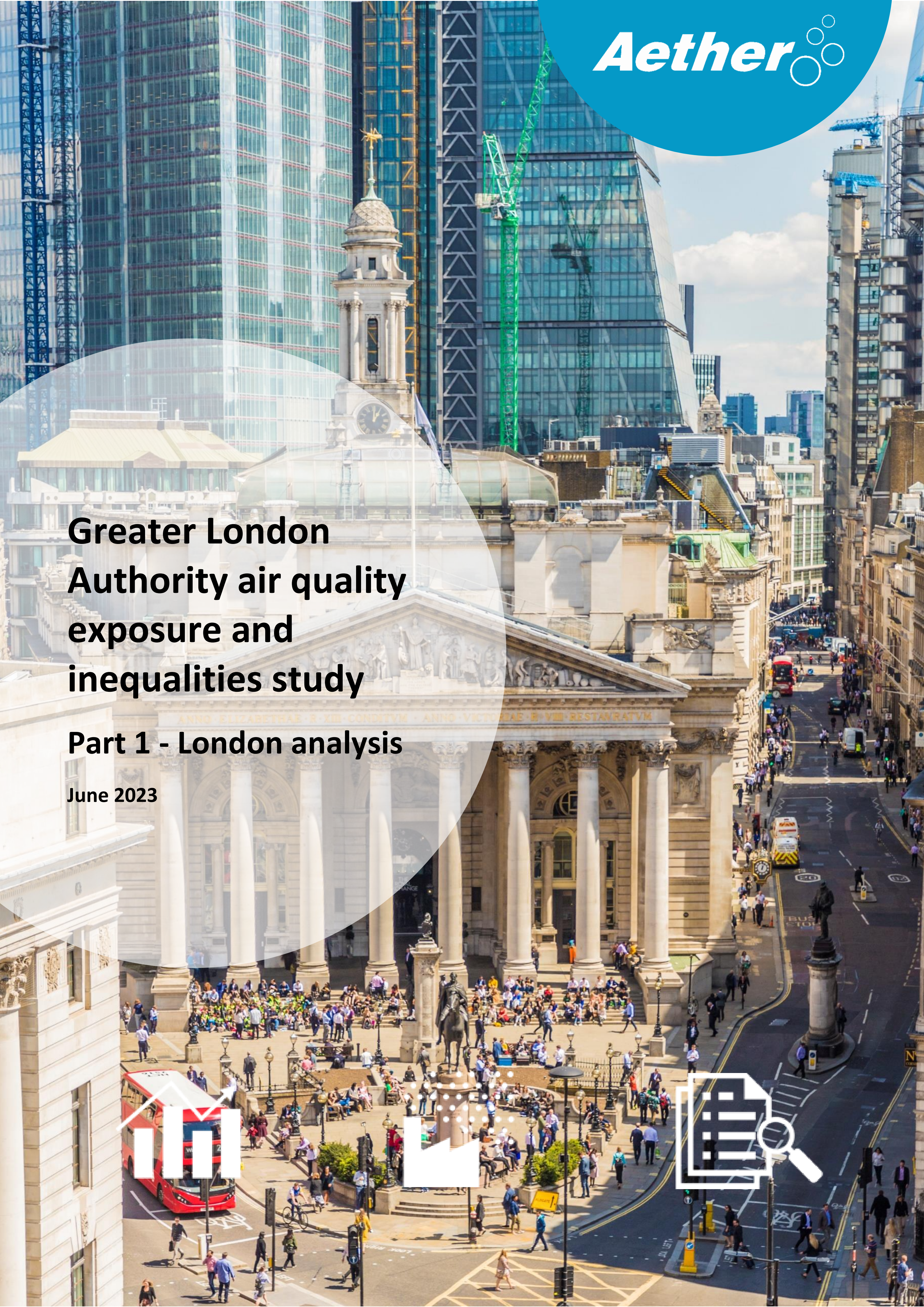

Greater London Authority air quality exposure and inequalities study

Part 1 - London analysis

June 2023

Title	GLA LAEI AQ Exposure and Inequalities study Part 1 - London analysis
Customer	Greater London Authority
Report Reference	2952 Part 1
Report Status	Final
Revisions	V1: for review by the GLA V2: updated draft following comments from GLA V3: after revisions made by GLA and final edits by Aether
File	FINAL GLA LAEI AQ Exposure and Inequalities study Part 1 - London analysis_20-6-23.docx

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Executive Summary

Background

Air quality is the largest environmental health risk in the UK, and the highest concentrations typically occur in London. The current Mayor of London has identified and delivered a range of actions to improve air quality and reduce exposure of Londoners to harmful pollution across London, including stricter legal obligations for new developments, the Non-Road Mobile Machinery Low Emission Zone, and the confirmed extension of the Ultra Low Emission Zone (ULEZ) to all London Boroughs in August 2023. This report considers the latest estimates of concentrations of air pollutants across London for recent and future years (2013, 2016, 2019, 2025 and 2030), to analyse the pattern of changes in exposure to poor air quality. The aim of the analysis is to determine if changes in exposure have been equitable across various population characteristics in London and what are likely changes in 2025 and 2030.

Approach

This report builds on analysis previously undertaken by Aether: *Analysing Air Pollution Exposure in London* (2013)[1], *Updated Analysis of Air Pollution Exposure in London* (2017)[2] and *Air Pollution Exposure in London: Impact of the Environment Strategy* (2019)[3], and by Air Quality Consultants (AQC): *Air Pollution and Inequalities in London: 2019* (2021)[4].

The initial analysis conducted in 2013, based on data from 2010, found significant exposure of the London population to levels of nitrogen dioxide (NO_2) above the EU limit value in the base year (2010) and predicted that this exposure would decline significantly by 2020. Populations living in the most deprived areas in London (based on the Index of Multiple Deprivation) were on average more exposed to poor air quality than those in less deprived areas. Analysis was also applied to primary schools and the results showed that 82% of schools exposed to NO_2 concentrations above the EU limit were deprived[5], this value dropped to 39% for schools that were exposed to concentrations below the EU limit.

The update of this analysis in 2017 was based on data from 2013. The analysis once again found significant exposure of the London population to levels of NO_2 above the EU limit value in the base year (2013) and predicted that this exposure would decline significantly by 2020. Similarly, it was again found that populations living in the most deprived areas were on average currently more exposed to poor air quality than those in less deprived areas. This time, analysis was also conducted on the relationship between ethnicity and air pollutant exposure, it was found that more exceedances of the of the NO_2 EU limit value are found in in areas with a high proportion of Black/ African/ Caribbean/ Black British, Mixed/Multiple (including White and Black Caribbean,

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[1] https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/analysing-air-pollution-exposure-london

[2] https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/updated-analysis-air-pollution-exposure-london-final

[3] https://www.london.gov.uk/programmes-and-strategies/environment-and-climate-change/environment-publications/air-pollution-london-impact-environment-strategy

[4] https://www.london.gov.uk/programmes-and-strategies/environment-and-climate-change/environment-publications/air-pollution-and-inequalities-london-2019

[5] Deprivation is defined here as >40% pupils being eligible for free school meals.

White and Black African, White and Asian and Other mixed) and Other ethnic groups (including Arab).

The second update of this analysis was in 2019, the baseline data year remained 2013, however the focus was on the impact of the London Environment Strategy policies and measures on modelled air quality concentrations in future years. Areas which have the highest numbers of Mixed/Multiple (using the same definition as above) ethnic group residents are more likely to have the highest levels of NO_2 in 2013, whereas those with the highest numbers of white residents are more likely to have lower concentrations. This time round, no significant link was found between air pollutant concentrations at schools and the level of eligibility for free school meals. Analysis of schools, hospitals and care homes found that facilities closer to central London receive the greatest relative improvement in air quality.

In 2021, analysis was conducted on data from 2019, which again found that areas with higher levels of deprivation are more likely to be exposed to higher levels of air pollution. Areas with the highest number of white residents were again more likely to be exposed to lower concentrations, however, since the previous analysis, these areas have experienced the smallest reductions in air pollutant concentrations. This analysis did not consider schools, hospitals or care homes.

This 2023 report, based on data for 2019, updates and expands on these previous studies. The key difference in this analysis is the assessment of exposure in future years using the latest projections from Transport for London (TfL) and the inclusion of analysis of diaspora communities and populations living near red routes. It is important to note that the impact of the 2023 expansion of the ULEZ is not considered in the projected concentrations for 2025 and 2030.

The study covers the Greater London Authority area only. The analysis was undertaken to assess the relationship between exposure to air pollution in London and five key social indicators:

- Index of Multiple Deprivation (IMD) scores
- Ethnicity patterns based on the Census data
- Diaspora community patterns based on the Census data[6]
- Vulnerable receptor locations: schools, hospitals and care homes
- Communities living along the Transport for London Road Network (TLRN) referred to as “red routes”.

The analysis has been undertaken for exposure to NO_2, and particulate matter (PM_{10} and $PM_{2.5}$) in the general exposure and red route exposure sections and for NO_2 and $PM_{2.5}$ for deprivation, ethnicity, diaspora and vulnerable receptor sections.

The analysis is primarily based on air pollution concentration data provided by TfL from the London Atmospheric Emissions Inventory (LAEI) at Output Area (OA) and Lower Super Output Area (LSOA) level and at vulnerable receptor location. Population data provided by TfL for all years was used to assess how exposure relates to air quality targets. The current UK legal limits and World Health Organization (WHO) guidelines and

[6] A diaspora community in this analysis refers to output areas in which at least 8% of the population have a shared country of birth outside the UK.

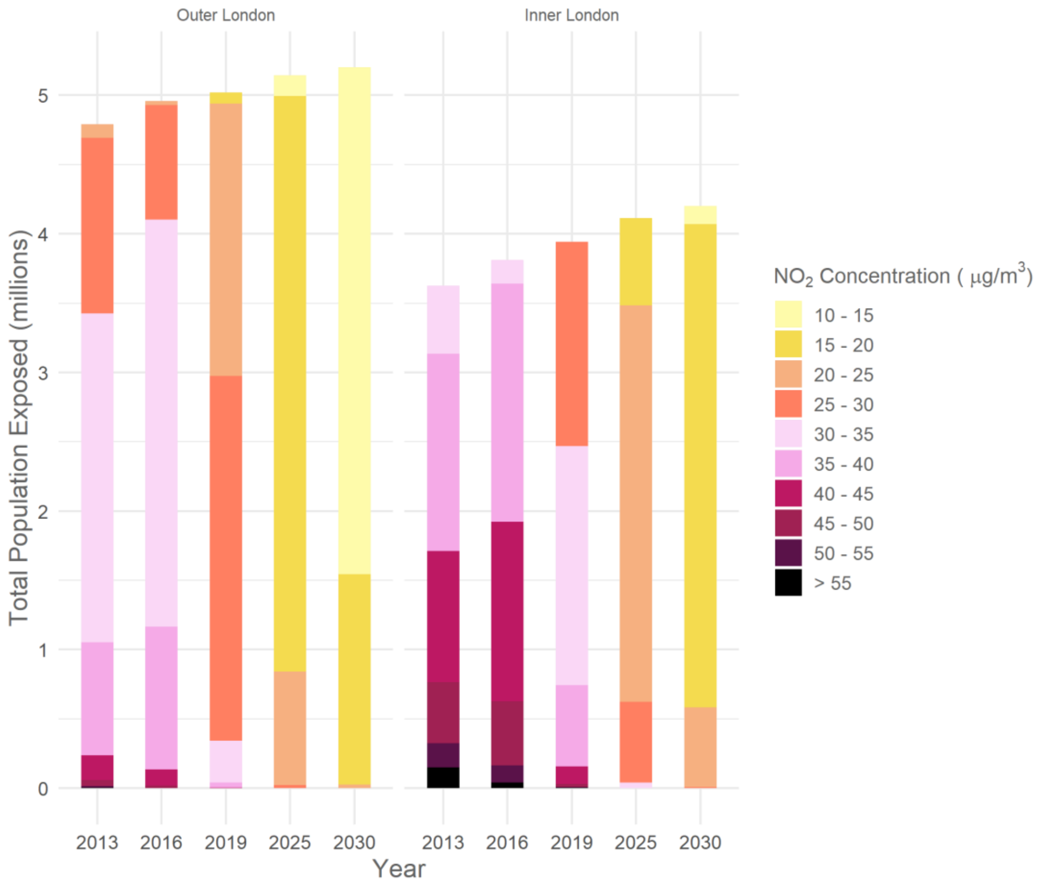
interim targets for NO_2 and $PM_{2.5}$ form the basis of the assessment (**Table ES.1**). The stringent concentration guidelines recommended by the WHO reflect the growing health evidence about the adverse health effects of air pollution, including at low concentrations. The new WHO air quality guidelines reflect the best available health evidence and WHO's recommendations continue to be recognised globally as the targets that should be met to protect public health. The Mayor has long made the case for UK air pollution limits for all air pollutants to be aligned with the WHO recommended air quality guidelines. In the London Environment Strategy, the Mayor committed to achieving annual mean concentrations of 10 µg/m^3 of $PM_{2.5}$ by 2030, a full decade before the new UK legal limits.

The WHO air quality guidelines for NO_2 and $PM_{2.5}$ were not achieved anywhere in London in 2019, and the forecasts show that they are not expected to be achieved anywhere in London in either 2025 or 2030, without significant further action being taken. Recognising that many places throughout the world are not yet close to achieving the latest guidelines, the WHO also introduced a series of "interim targets" designed to be used as incremental steps towards meeting the air quality guidelines. Therefore, in this study, the WHO interim targets have been used to assess progress.

Table ES. 1 UK legal limits and WHO guidelines for annual mean concentrations of NO_2, $PM_{2.5}$ and PM_{10}

Pollutant	Target	Concentration (annual mean)	Date to be achieved
Nitrogen Dioxide (NO_2)	UK legal limit	40 µg/m^3	01.01.2010
	WHO interim target 3	20 µg/m^3	N/A
	WHO guideline	**10 µg/m^3**	**N/A**
Particulate Matter (PM_{10})	UK legal limit	40 µg/m^3	01.01.2005
	WHO guideline	**15 µg/m^3**	**N/A**
Particulate Matter ($PM_{2.5}$)	WHO interim target 4 and UK legal limit	10 µg/m^3	01.01.2040 (London has committed to reach by 2030)
	WHO guideline	**5 µg/m^3**	**N/A**

Figure ES. 1 Population exposure for NO_2 in 2013, 2016, 2019, 2025 and 2030 in Inner and Outer London



General exposure

While progress has been made to reduce air pollution concentrations, most markedly since 2016, the whole population of London is forecast to remain exposed to NO_2 and $PM_{2.5}$ concentrations above the recommended WHO air quality guidelines in 2030, unless further significant action is taken to reduce concentrations:

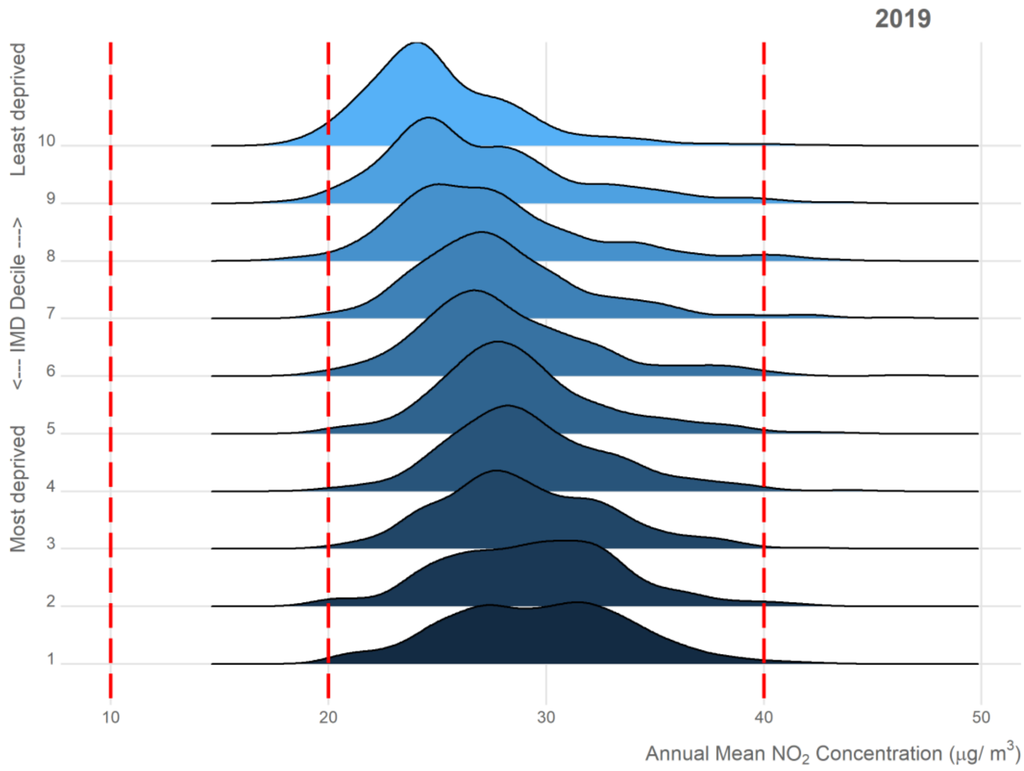
- The average annual mean concentration in London for NO_2, PM_{10} and $PM_{2.5}$ will approximately halve between 2013 and 2030, though the rate of reductions are forecast to slow from 2025 without further action.
- The rate of reduction between 2016 and 2030, in comparison, is 57% for NO_2, but only a third for PM_{10} and $PM_{2.5}$, since there was a significant fall in PM concentration but not NO_2 between 2013 and 2016 in that data.
- Although by 2030, the whole population of London will continue to be exposed to NO_2 concentrations exceeding the WHO annual average guideline of 10 µg/m^3, improvements are expected as only 6% (600,000) of London's population will remain exposed to concentrations exceeding the NO_2 WHO interim annual average target of 20 µg/m^3.
- 38% (3.6 million) of the population of London will continue to be exposed to PM_{10} concentrations exceeding the WHO annual average guideline of 15 µg/m^3 in 2030.
- 4% (400,000) of the population will still be exposed to $PM_{2.5}$ concentrations exceeding the WHO interim target of 10 µg/m^3 by 2030.

Deprivation

The most deprived communities of London still more commonly live in the most polluted areas, however concentrations have declined faster in areas of deprivation and more markedly since 2016. Again, unless further significant action is taken, the differential of pollution experienced between the least and most deprived will remain.

- For NO_2, the difference in average NO_2 concentration between the most and least deprived deciles reduced from 7.7 to 4.4 µg/m^3 between 2013 and 2019, showing that the inequalities have reduced. The forecasts show that the exposure differential between the most and least deprived then continues to reduce but at a slower rate, with the difference at 2.8 µg/m^3 in 2025, and 2.2 µg/m^3 in 2030.
- The most deprived areas saw decreases in annual mean NO_2 and $PM_{2.5}$ concentrations of 24% and 33%, respectively, with 19% and 33% reductions in the least deprived areas, between 2013 and 2019.
- The 10% most deprived areas (LSOAs) in London make up 16% of the highest concentration areas, and as deprivation decreases, representation in the highest concentration areas decreases linearly. Very similar results are observed across Inner and Outer London, and for NO_2 and $PM_{2.5}$ in this respect.
- One exception to the general trend of average, higher concentrations in more deprived areas is seen in Outer London where concentrations are higher in middle IMD deciles than in the highest deprivation deciles.

Figure ES. 2 Average NO_2 exposure distributions within IMD Deciles NO_2 in 2019; red dotted lines show current UK legal limit (40 µg/m^3), WHO interim target (20 µg/m^3) and WHO guideline (10 µg/m^3).

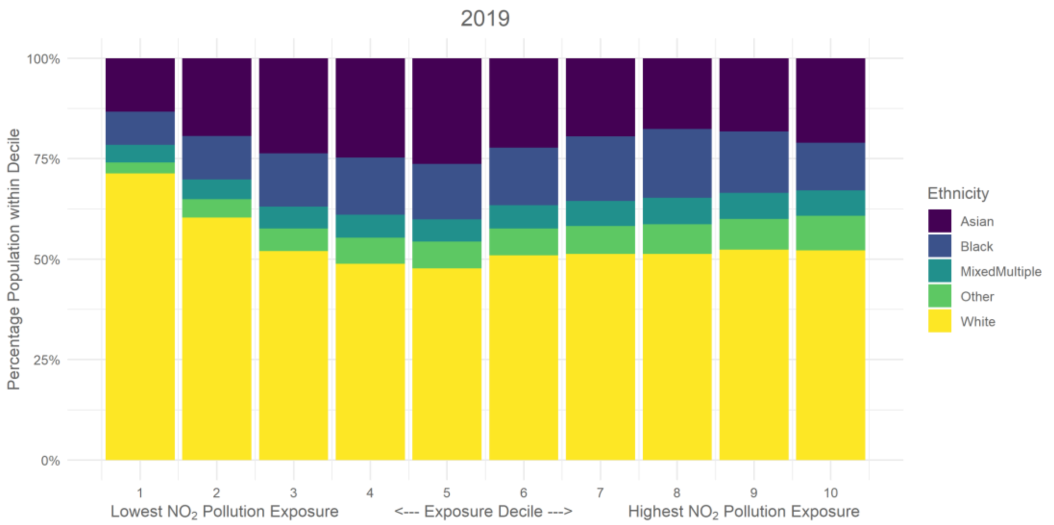


Ethnicity

The areas in London with the lowest NO_2 and $PM_{2.5}$ concentrations have a disproportionately white population. The inequalities in exposure to air pollution experienced between ethnic groups are much more pronounced in Outer London than Inner London. Despite progress towards meeting the WHO targets, the disparity in exposure by ethnicity is not expected to change over time without further significant action.

- The areas in London with the lowest air pollution concentrations have a disproportionately white population. This inequality has reduced a small amount between 2013 and 2019, but is not forecast to reduce much further by 2030 unless further action is taken.
- The exposure inequalities experienced between ethnic groups are much more pronounced in Outer London than Inner London. In Outer London, the lowest NO_2 concentration decile comprises a 71% white population, whereas in Inner London, the lowest NO_2 concentration decile is 56% white, in 2019.
- White and Asian populations are less likely to live in the most polluted areas in comparison to the general population, whereas Black, Mixed Multiple and Other populations are more likely to live in the most polluted areas. Furthermore, the forecast shows there will be little discernible change over time without further action being taken.
- Areas of London within the top 50% of concentration levels, for both NO_2 and $PM_{2.5}$, generally have a fairly representative spread of the population by ethnicity.

Figure ES 3 Percentage of population of each ethnicity group by NO_2 Concentration deciles 2019



Diaspora communities

Diaspora communities tend to reside in areas where there are higher concentrations of pollutants than the London average.

- The diaspora regional groups with the highest levels of exposure to NO_2 and $PM_{2.5}$ are North America, Middle East and Eastern Asia.
- Although there have been improvements in air quality for all groups, the distribution has changed very little from 2013 to 2019, and similar trends are expected to continue up to 2030 without further action being taken.
- There is variation in exposure between diaspora communities, that has largely remained consistent over time. However, we have seen a significant fall since 2016 in NO_2 concentrations but not for $PM_{2.5}$. The average NO_2 concentration in diaspora communities is 2.3 µg/m^3 higher than the London average and $PM_{2.5}$ levels of 0.4 µg/m^3 higher than the London average in 2019. The figures for 2013 were 3.4 µg/m^3 higher than the London average for NO_2 and 0.4 µg/m^3 for $PM_{2.5}$. For 2030 the difference is forecast to be 1.2 µg/m^3 higher for NO_2 and 0.3 µg/m^3 for $PM_{2.5}$.

Vulnerable receptor sites

For all years analysed between 2013 and 2030, all schools, hospitals and care homes will remain exposed to concentrations of NO_2 and $PM_{2.5}$ above the WHO guideline annual mean, unless further action is taken.

- However, progress has been made and the number of vulnerable receptors exposed to concentrations above the WHO interim target annual mean concentrations (20 µg/m^3 and 10 µg/m^3 for NO_2 and $PM_{2.5}$, respectively) reduces significantly by 2030.
- For NO_2, in 2013 and also in 2016, 100% of schools, hospitals and care homes were exposed to concentrations above the WHO interim guideline of 20 µg/m^3. This is forecast to reduce to 7%, 28% and 2%, respectively, in 2030. This is a reduction of 93%, 72% and 98% respectively.
- For $PM_{2.5}$ the percentage of schools, hospitals and care homes exposed to concentrations above the WHO interim target of 10 µg/m^3 is forecast to reduce from 100% for all to 5%, 20% and 1%, respectively, over the same period. This is a reduction of 95%, 80% and 99% respectively.
- Schools in Inner London are on average exposed to higher concentration of air pollution compared with schools in Outer London and this remains consistent over time, however only 51 (4% Inner London) schools in Inner London remained in exceedance of the legal limit for NO_2 in 2019 and this is forecast to be none in 2025.
- There is a weak but positive correlation in 2019 between the percentage of pupils eligible for free school meals and the levels of air pollution that a school is exposed to (excluding private schools where no pupils are eligible for free school meals). This relationship is forecast to weaken over time as the range of air pollutant concentrations that schools are exposed to decreases.

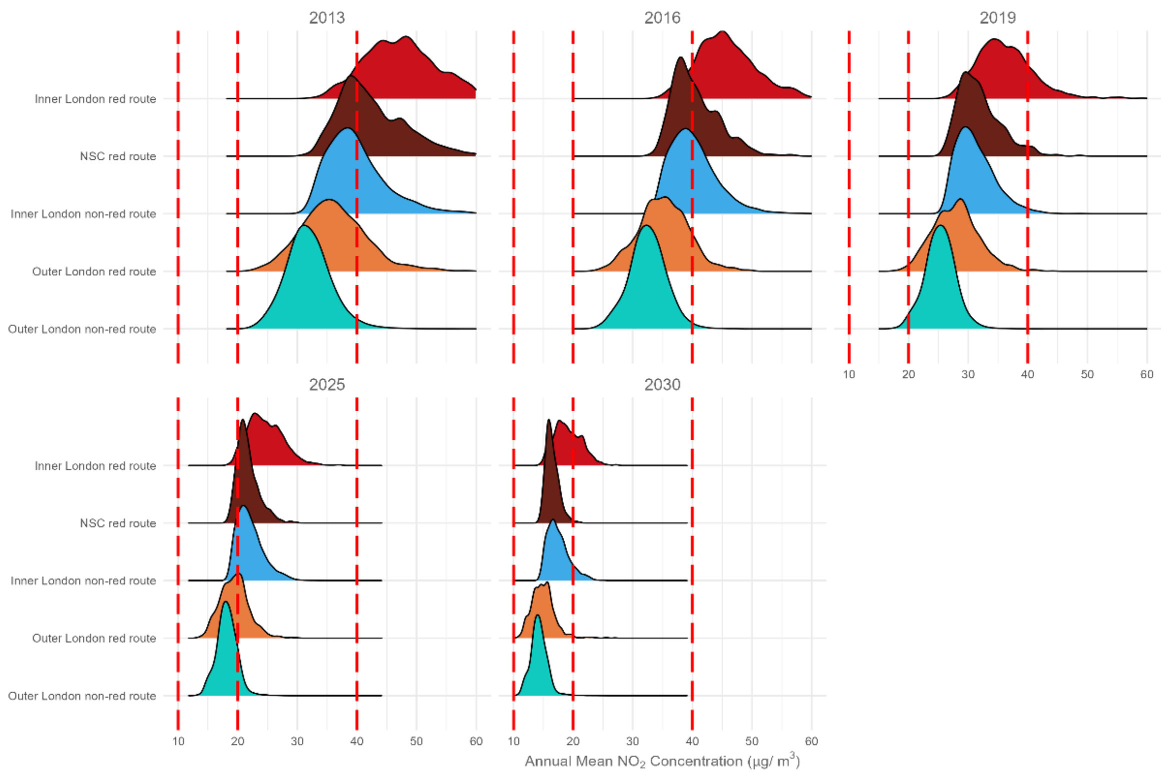
Red routes

Communities living along red routes are exposed to higher air pollutant concentrations, though these concentrations are expected to reduce over time. The red route population exposed to NO_2 concentrations exceeding the WHO interim

guideline is forecast to reduce from 100% (1.1 million) in 2016 to 76% (1 million) in 2025 and to 19% (0.2 million) in 2030. Red routes are designed for main traffic and are likely to be the last places in London to meet the WHO interim targets unless further action is taken.

- All red routes across Inner and Outer London exceed the WHO guidelines for all years studied. The remaining areas of London to meet the WHO interim targets for NO_2 and $PM_{2.5}$ and WHO guideline for PM_{10} are projected to be the Inner London red routes.
- The average air pollution concentrations are higher along red routes when compared to the Inner and Outer London averages. In 2019, the average NO_2 concentrations in Inner and Outer London red route OAs were 12% and 13% higher than the respective London average. A similar but less pronounced pattern is seen for PM_{10} and $PM_{2.5}$.
- 95% of the population exposure to NO_2 concentrations above the WHO interim target in 2030 are in Inner London, which represents over a third of the Inner London red route population compared to 10% of the Inner London non-red route population.
- Almost the entire (99%) population exposed to concentrations above the $PM_{2.5}$ WHO interim guideline in 2030 are in Inner London or along the North and South Circular. This represents over a third of the 2030 Inner London red route population, compared to 5% of the Inner London non-red route population.
- No link between deprivation and red routes was identified by this methodology.

Figure ES. 4 Annual mean concentrations at OA Level for NO_2 by red route group, 2013, 2016, 2019, 2025 and 2030. The dotted red lines represent the NO_2 WHO guideline, interim target and UK legal limit



Conclusion

Overall, whilst the current and projected improvement in air quality across London has and will continue to benefit everyone, clear inequalities in exposure to poor air quality remain. The most deprived communities of London are still more likely to be found in the highest pollutant concentration areas. The areas in London with the lowest NO_2 and $PM_{2.5}$ concentrations have a disproportionately white population, and diaspora communities are more likely to live in an area with higher pollution concentrations than the London average. Despite clear progress towards meeting the WHO interim targets, the future projections show none of these inequalities are expected to change over time without further action. For all years analysed between 2013 and 2030, all schools, hospitals and care homes remain exposed to concentrations of NO_2 and $PM_{2.5}$ above the WHO guideline annual mean. Whilst the majority of London is projected to be exposed to NO_2 and $PM_{2.5}$ concentrations below the WHO interim targets, communities living along red routes in Inner London are much more likely to still be exposed to concentrations above the WHO interim targets in 2030. Further policy developments, such as the expansion of the ULEZ to be London-wide may lead to greater reductions in air pollution and reduce inequalities in exposure.

Contents

Tables

Figures

Glossary

AQC	Air Quality Consultants
DMRB	Design Manual for Roads and Bridges
EU	European Union
FSM	Free school meals
GIS	Geographic Information System
GLA	Greater London Authority
IMD	Index of Multiple Deprivation
LAEI	London Atmospheric Emissions Inventory
LES	Low emissions strategy
LEZ	Low Emission Zone
LSOA	Lower Super Output Area
NO_2	Nitrogen dioxide
NRMM	Non-Road Mobile Machinery
NSC	North-South Circular
OA	Output Area
ONS	Office of National Statistics
$PM_{2.5}$	Particulate matter with a particle diameter <= 2.5 microns
PM_{10}	Particulate matter with a particle diameter <= 10 microns
PP	Pupil premium
RR	Red route
TfL	Transport for London
TLRN	Transport for London Road Network
ULEZ	Ultra Low Emission Zone
WHO	World Health Organization

1 Introduction

Air pollution has received increased attention in recent years and the scale of health impacts - equivalent to tens of thousands of deaths per year in the UK alone - marks it out as “the largest environmental health risk in the UK”[7]. The World Health Organization (WHO) highlights that there is no evidence of a safe exposure threshold of $PM_{2.5}$ concentrations below which no damaging health effects are seen[8]. In general, London faces the greatest air quality challenges in the UK, due to both its size, density and its proximity to continental Europe. The current Mayor of London, Sadiq Khan, has identified and delivered air quality as a policy priority, implemented the world’s first Ultra Low Emission Zone (ULEZ), accelerated the electrification of vehicles including the bus and taxi fleet and the London Plan 2021[9] contains a range of actions to improve air quality in London through stricter legal obligations for new developments and the Non-Road Mobile Machinery (NRMM) Low Emission Zone (LEZ). In addition, the extension of the ULEZ to all London Boroughs is planned from 29th of August 2023[10] .

This report considers the latest estimates of concentrations of air pollutants across London for recent and future years, to analyse the pattern of changes in exposure to poor air quality. The historic concentration estimates (2013, 2016, 2019), show improvements in air quality resulting from the impact of Mayoral policies, including earlier versions of the LEZ, the congestion zone and the central London ULEZ. The estimates for 2025 and 2030 include the expansion of the ULEZ to Inner London in 2021 and expected impacts of recent and forthcoming tighter regulation together with ongoing vehicle turnover, but do not include the expected impact of the expansion of the ULEZ London-wide in 2023.

The aim of the analysis is to determine if changes in exposure have been equitable across various population characteristics in London, building upon previous analysis undertaken by Aether on behalf of the Greater London Authority (GLA): *Analysing Air Pollution Exposure in London* (2013)[3], *Updated Analysis of Air Pollution Exposure in London* (2017)[2] and *Air Pollution Exposure in London: Impact of the Environment Strategy* (2019)[1] and by Air Quality Consultants (AQC): *Air Pollution and Inequalities in London: 2019* (2021)[4]. These previous studies examined changes in exposure to air pollution for the London population in terms of deprivation, ethnicity, and for vulnerable receptors (represented by schools, hospitals and care homes).

The initial analysis conducted in 2013, based on data from 2010, found significant exposure of the London population to levels of NO_2 above the EU limit value in the base year (2010) and predicted that this exposure would decline significantly by 2020. Populations living in the most deprived areas in London (based on the Index of Multiple Deprivation) were on average more exposed to poor air quality than those in less deprived areas. Analysis was also applied to primary schools and the results showed that 82% of schools exposed to NO_2 concentrations above the EU limit were deprived[11], this

[7] Consultation draft of the Clean Air Strategy, Defra, 2018

[8] https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

[9] https://www.london.gov.uk/sites/default/files/the_london_plan_2021.pdf

[10] https://lruc.content.tfl.gov.uk/ulez-expansion-2023-guide.pdf

[11] Deprivation is defined here as >40% pupils being eligible for free school meals.

value dropped to 39% for schools that were exposed to concentrations below the EU limit.

The update of this analysis in 2017 was based on data from 2013. The analysis once again found significant exposure of the London population to levels of NO_2 above the EU limit value in the base year (2013) and predicted that this exposure would decline significantly by 2020. Similarly, it was again found that populations living in the most deprived areas were on average currently more exposed to poor air quality than those in less deprived areas. This time, analysis was also conducted on the relationship between ethnicity and air pollutant exposure, it was found that more exceedances of the of the NO_2 EU limit values are found in in areas with a high proportion of Black/ African/ Caribbean/ Black British, Mixed/Multiple (including White and Black Caribbean, White and Black African, White and Asian and Other mixed) and Other ethnic groups (including Arab).

The second update of this analysis was in 2019, the baseline data year remained 2013, however the focus was on the impact of the London Environment Strategy policies and measures on modelled air quality concentrations in future years. Areas which have the highest numbers of Mixed/Multiple (using the same definition as above) ethnic group residents are more likely to have the highest levels of NO_2 in 2013, whereas those with the highest numbers of white residents are more likely to have lower concentrations. This time round, no significant link was found between air pollutant concentrations at schools and the level of eligibility for free school meals. Analysis of schools, hospitals and care homes found that facilities closer to central London receive the greatest relative improvement in air quality.

In 2021, analysis was conducted on data from 2019, which again found that areas with higher levels of deprivation are more likely to be exposed to higher levels of air pollution. Areas with the highest number of white residents were again more likely to be exposed to lower concentrations, however, since the previous analysis, these areas have experienced the smallest reductions in air pollutant concentrations. This analysis did not consider schools, hospitals or care homes.

This 2023 report also considers the exposure of recent immigrant diaspora communities[12] and populations living along Transport for London Road Network (TLRN) “red routes”, (hereafter referred to as red routes), which are identified by their red no-stopping lines on the highway and signs along the route. The analysis compares the exposure of the various population groups to the various pollution concentration levels defined by UK legal limits and WHO guidelines for NO_2, PM_{10} and $PM_{2.5}$ listed in **Table 1**.

In 2005, London made the commitment to reach an annual mean concentration of 10µg/m^3 for $PM_{2.5}$ by 2030, which was the WHO guideline at the time. In 2021, the WHO revised the guideline down to 5µg/m^3 and amended 10µg/m^3 to become an interim target. The rest of the UK is committed to reaching the 10µg/m^3 interim target by 2040.

[12] A diaspora community in this context refers to output areas in which at least 8% of the population have a shared country of birth outside the UK.

Table 1 UK legal limits and WHO guidelines for annual mean concentrations of NO_2, $PM_{2.5}$ and PM_{10}

Pollutant	Target	Concentration (annual mean)
Nitrogen Dioxide (NO_2)	UK legal limit	40 µg/m^3
	WHO interim target 3	20 µg/m^3
	WHO guideline	**10 µg/m^3**
Particulate Matter (PM_{10})	UK legal limit	40 µg/m^3
	WHO guideline	**15 µg/m^3**
Particulate Matter ($PM_{2.5}$)	WHO interim target 4 and UK legal limit	10 µg/m^3
	WHO guideline	**5 µg/m^3**

1.1 Air quality inequalities

The links between exposure to poor air quality and adverse health outcomes, including heart disease, stroke, lung cancer, chronic and respiratory diseases such as asthma, are well established[13], underscored by an evidence base which is both mature and extensive. There is growing literature on the role in which exposure to poor air quality plays in health inequality, including the previous analyses undertaken on behalf of the GLA mentioned above. It. It has been found that demographic groups that already experience greater ill-health due to material deprivation and economic stress can be exposed to higher air pollution resulting in health inequalities being exacerbated[14].

The second part of this project reviews published evidence of how inequality in air pollution exposure has changed over time in other cities and how they can be compared to London.

1.2 The London Plan 2021

The latest London Plan, published in 2021, is the overall strategic plan for London, setting out an integrated economic, environmental, transport and social framework for the development of London, covering the years from 2019 to 2041. The London Plan is underpinned by the concept of Good Growth - growth that is socially and economically inclusive and environmentally sustainable. Under the Good Growth aim 3[15], it is stated that planners and developers must "seek to improve London's air quality, reduce public exposure to poor air quality and minimise inequalities in levels of exposure to air pollution".

As part of the evidence base to support the strategy, Transport for London (TfL) published the London Atmospheric Emissions Inventory (LAEI) 2019, which includes modelling for an assessment of future air quality in London, based on current trends and regulations. This modelling for the future years of 2025 and 2030 does include the 2021

[13] Fuller, G et al. (2023) Impacts of Air Pollution Across the Life Course.

[14] Verbeek, T. (2019) Unequal residential exposure to air pollution and noise: A geospatial environmental justice analysis for Ghent, Belgium, SSM - Population Health, Volume 7

[15] The Good Growth aims are: 1 Building strong and inclusive communities; 2 Making the best use of land; 3 Creating a healthy city; 4 Delivering the homes Londoners need; 5 Growing a good economy; 6 Increasing efficiency and resilience.

expansion of the ULEZ to Inner London but does not include the impact of the expansion of the ULEZ due in August 2023. Therefore, the future years in this report reflect the expected improvements in air quality resulting from the continued uptake of electric vehicles and improving Euro emissions standard engines for new vehicles. Also reflected in the future years are the strengthening of emission standards for the LEZ for heavy vehicles and the tightening of regulations such as NRMM LEZ and the new Air Quality Positive and updated Air Quality Neutral requirements for new developments.

1.3 Report outline

Section 2 of this report addresses the datasets used, their origin and how they were used for the analysis. It also sets out some of the key assumptions and uncertainties regarding these datasets.

Sections 3 - 7 set out the outputs from the analysis, with the key messages detailed at the start of each subsection, which address:

- **General exposure:** how air pollution exposure is distributed across the whole London population and the changes shown over time
- **Deprivation:** the relationship between historical and projected levels of air quality and the Index of Multiple Deprivation (IMD)
- **Ethnicity:** how the distribution of ethnic groups across London correlates with historical and projected distribution of air quality
- **Diaspora communities**: the exposure levels in output areas (OAs) identified for each diaspora community are compared against the overall London population exposure distribution
- **Vulnerable receptors:** how the historical and projected air quality across London changes at the location of “vulnerable receptors” as represented by schools, nurseries, hospitals and care homes
- **Red routes:** the exposure levels within OAs along red routes are compared with all London OAs.

Section 8 summaries the key messages from the analysis.

2 Data and Methods

Due to the complex nature of this analysis, data are required from a variety of sources. This section outlines the sources of the various data relating to air quality pollutants, deprivation, population, ethnicity, vulnerable receptor locations and red routes.

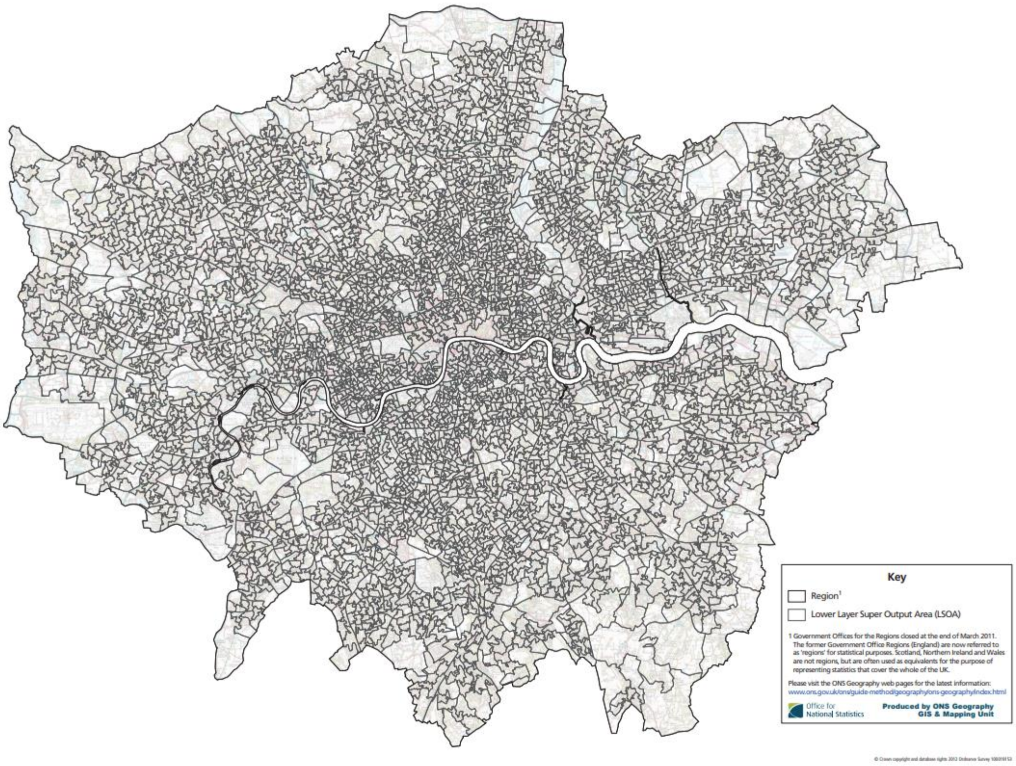
2.1 Geographical basis

The analysis used for this study was primarily based on data for OAs and Lower Super Output Areas (LSOAs). These are geographical units defined as part of the UK national census and used as the basis for official, small area statistics. The boundaries of OAs are defined by a combination of UK postcode, ward and other electoral boundaries and the minimum size requirement, i.e., that they should have a minimum of 40 households and 100 residents, with a recommended size of 125 households. For the 2011 census, there were 181,408 OAs making up England and Wales. LSOAs are an amalgamation of OAs aimed at improving small area statistics. In England and Wales, LSOAs contain 1-3000 residents and between 400 and 1200 households. For the 2011 census, there were 34,753 LSOAs in England and Wales, of which 4,829 are in London. **Figure 1** shows the 2011 LSOAs for London that were used in this analysis as the air quality data was available in this format. In the 2021 Census 2021, some changes were made to 2011 OAs as a result of population and household changes since 2001. Additionally, around 200 OA boundaries were selectively realigned to ward boundaries. This resulted in 4,835 LSOAs and 25,053 OAs in London in the 2021 census. The mapping between the 2011 and 2021 OAs available from the 'OA (2011) to OA (2021) Lookup' from the Office of National Statistics (ONS)[16] was used in order to combine the 2021 Census data with the air quality data at the 2011 OA resolution. Therefore, all of the analysis is based on the 2011 OAs and LSOAs.

In addition to the London-wide assessment, Inner and Outer London were considered separately, with areas within the north-south circular (NSC) representing "Inner London" and areas outside the NSC representing "Outer London".

[16] https://geoportal.statistics.gov.uk/datasets/ons::oa-2011-to-oa-2021-to-local-authority-district-2022-for-england-and-wales-lookup/explore

Figure 1 Lower Super Output Areas in London used for the 2011 Census Air quality pollutant concentrations



TfL provided annual mean concentrations maps for NO_2, PM_{10} and $PM_{2.5}$ at a 20m x 20m resolution across London for the years 2013, 2016, 2019 (the most recent historical year) and projections for 2025 and 2030[17]. The concentration data are in the form of updated maps based on the latest 2019 London Atmospheric Emissions Inventory (LAEI) emissions estimates. It should be noted that there are uncertainties associated with future concentration estimates, primarily due to the sensitivity of the these to changes in base year meteorology, uncertainty in road transport emission factors which are continually improved in order to reflect improved understanding of real world emissions especially from road transport, alongside uncertainty in emissions factors and activity data for the many different sources which are included in order to estimate London's air pollution. However future estimates of concentrations provide the necessary trends in order to understand how these may impact population exposure. In addition, it should be noted that the projections do not consider the 2023 expansion of the ULEZ.

In order to combine the pollution concentration data with population statistics, the pollution maps have been aggregated to OAs and LSOAs by calculating an average air pollution concentration within each OA and LSOA based on the 20m x 20m grid squares that it covers. This analysis was provided by the Strategic Analysis team at TfL. The OA averages have been used to take into account concentration peaks at roadside locations. The concentration data was used to determine the air pollution exposure of the total population and has been combined with the census data. The average concentrations for LSOAs were used to compare air quality concentrations with the selected inequality

[17] The data was not publicly available at the time of writing this report. It will be available in the future at: https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2019

indicators as some of indicators were only available at an LSOA level. PM_{10} concentrations were not available for future years at LSOA level and therefore has not been included in the deprivation analysis.

In common with previous studies[18], the approach undertaken in this study first presents the pollutant concentrations and how they have, and are expected to, change over time. Exposure to air pollution has been assessed in comparison with the air quality targets presented in **Table 1**.

2.2 Index of Multiple Deprivation

The ONS regularly publishes an established measure of deprivation known as the Index of Multiple Deprivation (IMD). IMD data across London for 2019 and 2015 are available at LSOA resolution[19]. The IMD data for 2015 was used in the analysis for the years 2013 and 2016, and 2019 data used for later and projected years. 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 given a weighting according to their determined contribution to overall deprivation. The domains are:

- Income deprivation
- Employment deprivation
- Health and disability deprivation
- Education, skills and training deprivation
- Barriers to housing and services
- Crime
- Living environment deprivation

The living environment domain includes air quality, houses without central heating or in poor condition, and road traffic incidents involving pedestrians and cyclists. Air quality is included in the IMD, but it only makes up approximately 1.5 % of the total index and therefore it is not enough to bias the results. The overall scores for each domain have been combined using the weightings to provide an overall IMD score.

The air pollution concentration data was combined with IMD and Census data to assess inequalities in exposure of different groups. Where available, data from the 2021 Census has been used and the latest IMD data from 2019 has been used for 2019 and the future years, with 2015 IMD data applied to the earlier years.

For the analysis for this study the LSOAs were ranked by IMD score and the rankings used to divide the LSOAs into decile (10%) ranges within which average pollution exposure and comparisons to the air quality guidelines were considered using the air pollutant concentration data. Simultaneous density plots of concentration exposure for each deprivation decile were then used in order to clearly show the entire distributions. This analysis was also performed for Inner and Outer London in 2019. Statistics are also provided on how the population living in the 30% most polluted LSOAs is spread across the deprivation deciles, and the range of concentrations that the 90% of the population closest to the mean are exposed to in each decile.

[18] https://www.london.gov.uk/sites/default/files/les_exposure_rpt_final2-rb.pdf
[19] https://data.london.gov.uk/dataset/indices-of-deprivation#

Whilst other deprivation datasets are available, the IMD 2019 dataset has been used as it is the most recent and widely used, official, government compiled, broad based and geographically detailed dataset which is very appropriate for the analysis for this study.

2.3 Population data and projections

TfL provided population data and future estimates for each OA and LSOA in 2013, 2016, 2019, 2025 and 2030. Stacked bar charts were generated to show the change in exposure of the total population to air quality. The relationship between air pollution and age was also assessed based on the 2011 census[20].

2.4 Ethnicity data

Data from the 2011 and 2021 censuses were used as the source for the total population of the following ethnic groups: White, Asian/ Asian British, Black/ African/ Caribbean/ Black British, Mixed/ Multiple, and Other ethnic groups as defined in **Table 2**. Data from the 2011 census was used for analysis of air pollution exposure in years 2013 and 2016; and 2021 census data was used for analysis for the years 2019, 2025 and 2030. Since concentration data are available for the 2011 Census OA boundaries, some mapping was performed for the 2021 ethnicity census data. Using the ONS dataset 'OA (2021) to OA (2011) to Local Authority district for England and Wales Lookup'[21], each 2021 Census OA was assigned a corresponding 2011 Census OA, which was successful in the case of 98% of OAs.

This analysis is based on the ethnicity data reported by individuals in the 2011 and 2021 censuses. This is different to information on country of birth, which is used in the diaspora community analysis (see section 2.8), based on the locations where at least 8% of the population have a shared country of birth outside the UK.

For the analysis for this study, the LSOAs were divided into deciles from lowest to highest pollution concentration and assessed against the population of ethnic groups within those air quality deciles using stack bar charts. This analysis was also performed for Inner and Outer London in 2019.

[20] Age statistics by OA from the 2021 census were not available at the time of writing this report.
[21] https://geoportal.statistics.gov.uk/datasets/ons::oa-2011-to-oa-2021-to-local-authority-district-2022-for-england-and-wales-lookup/explore

Table 2 The ethnic groups and their corresponding sup-groups, taken from the 2021 Census[22]

Ethnic Group	Sub-groups
White	White: English/Welsh/Scottish/Northern Irish/British White: Irish White: Gypsy or Irish Traveller White: Roma 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, Black British, or Caribbean background
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

2.5 Schools

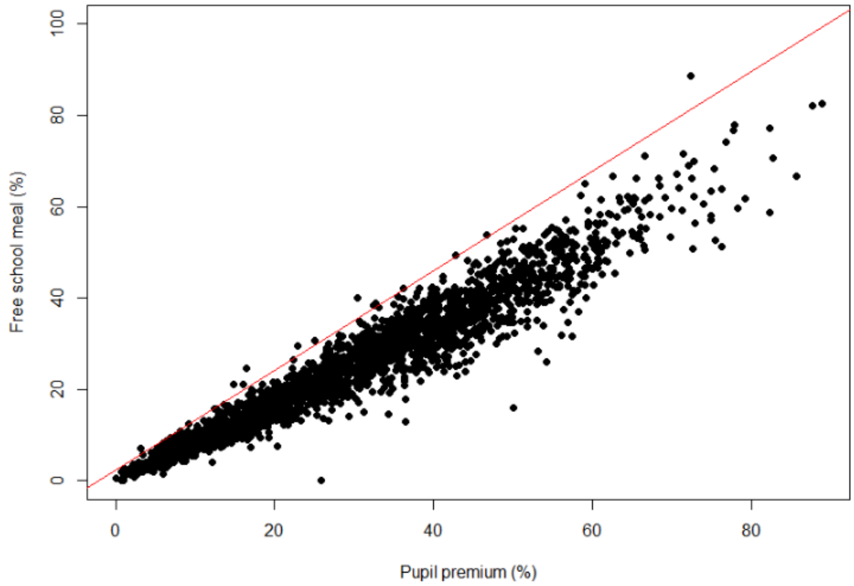
TfL provided an update of the dataset used in the previous studies, giving average pollution concentrations within 150m of schools using the 2013, 2016, 2019, 2025 and 2030 air pollution maps to assess air pollution exposure. A 150m radius was used to maintain consistency with the previous analysis for schools. Only NO_2 and $PM_{2.5}$ concentration data was available for this analysis.

Eligibility to free school meals (FSM) was considered in the previous studies as a proxy measure of deprivation for school populations. After comparing the dataset for this measure with that on pupil premium (PP) funding, it was decided to again use the FSM metric. The FSM dataset is more complete, it includes data on 3,267 schools in London, compared to 2,466 for PP. It also includes entries for those with zero percentage FSM, so therefore has more information on those with lower levels of deprivation. The FSM dataset also has the advantage of geographic (Easting/Northing) information. There is a high level of correlation between the FSM and PP datasets (see **Figure 2** below) and therefore both are expected to show similar results. Both the FSM and PP datasets were provided by TfL.

[22] https://www.ethnicity-facts-figures.service.gov.uk/style-guide/ethnic-groups

FSM data for 2022 has been obtained for all schools in London (primary, secondary and 16+) from the London Data Store[23]. The 2022 FSM data was applied to all years in the analysis. Note that the number of schools is slightly different from the earlier studies, reflecting an updated dataset.

Figure 2 Percentage of children eligible for pupil premium (PP) plotted against the percentage of children eligible for free school meals (FSM)



Note: Only schools in London with data available on both PP and FSM are included.

2.6 Nurseries, hospitals and care homes

The school data includes local authority nurseries, which were also examined separately and compared with the school dataset as a whole. A similar analysis as conducted for schools was also performed for hospitals and care homes; the exposure of each of these sites to NO_2 and $PM_{2.5}$ was considered.

2.7 Diaspora communities

This study also included an analysis of disparities in air pollution exposure between diaspora communities and the London average. Diaspora communities are defined in this study as output areas in which at least 8% of the population have a shared country of birth outside the UK. This was done using the Consumer Data Research Centre (*CDRC)* Dataset of OAs, which is calculated from Census data[24].

In order to show differences between exposure of OAs with diaspora communities and those without, the data was divided into subsets of areas that contain diaspora communities and those that don't, and stacked bar charts were used to show differences between communities in terms of percentage of diaspora falling into different concentration ranges, these being manually defined 5 µg/m^3 ranges. This was

[23] https://data.london.gov.uk/
[24] https://julie.geog.ucl.ac.uk/~ollie/maps.cdrc.ac.uk/#/metrics/countryofbirth/default/BTTTFFT/11/-0.1943/51.5706/

done across regional groupings, and within these groupings for individual countries. Statistics are also provided on the distribution of concentrations across years for individual countries.

Data on diaspora communities at OA level was only available from the 2011 Census at the time of writing this report.

2.8 Red routes

TfL provided Geographic Information System (GIS) data on road centre lines for red routes. This data was used to identify a subset of OAs along the red routes (hereafter referred to as 'red route OAs') to be included in the analysis. This defined 'communities' within close proximity to the red routes (approximately within 200m based on Design Manual for Roads and Bridges (DMRB) air quality guidance[25]), to be analysed compared to London averages. These locations are where the traffic emissions from the road are most likely to influence the air pollutant concentration. The following subsets of OAs were compared: red route OAs in Inner London, red route OAs along the NSC, red route OAs in Outer London, non-red route OAs in Inner London and non-red route OAs in Outer London.

OAs vary substantially in size depending on the density of population. Some OAs in Outer London are particularly large. An initial sensitivity analysis was conducted to assess the range of air pollutant concentrations in red route OAs. The impact of larger red route OAs, which stretch relatively far from a red route, were not expected to be representative of the impact of red routes on air pollutant exposure. **Figure 3** below presents the red routes (red lines) and the OAs which overlap with a red route, shown in blue.

Based on the results of a sensitivity analysis, the 5 % of these red route OAs which stretch furthest from a red route were removed from the analysis. They are not considered to be representative of exposure to the elevated concentrations along red routes. The red route OAs included in and removed from the analysis are highlighted in **Figure 4**.

For the purpose of the analysis, the red route OAs were allocated to one of three groups: Inner London red routes, NSC red routes or Outer London red routes. These groups were compared to Inner London non-red route OAs and Outer London non-red route OAs.

[25] https://www.standardsforhighways.co.uk/dmrb/search/10191621-07df-44a3-892e-c1d5c7a28d90

Figure 3 Red routes in London (red line) and OAs which overlap with a red route (highlighted in blue)

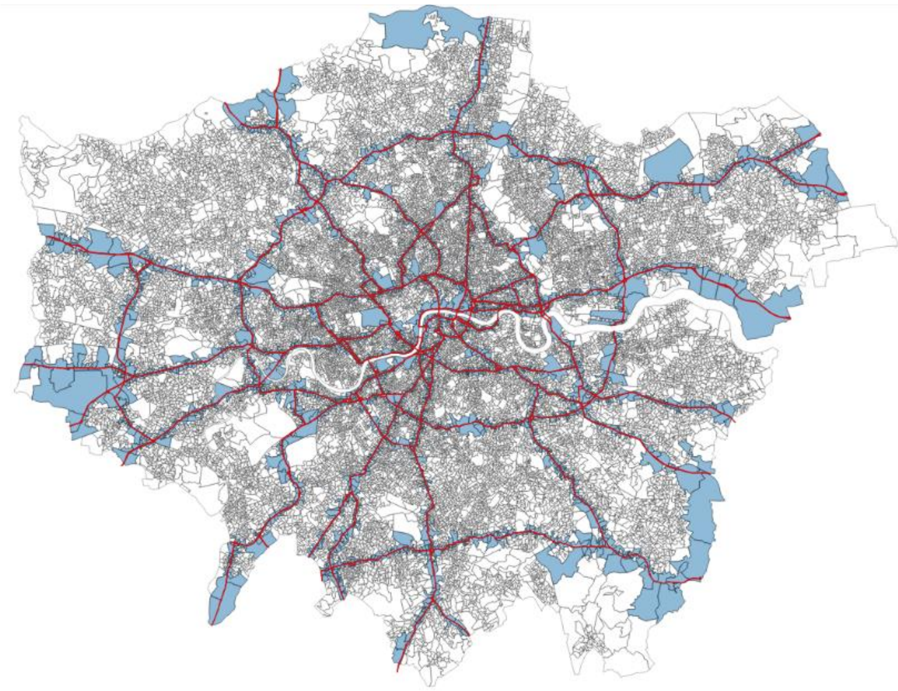
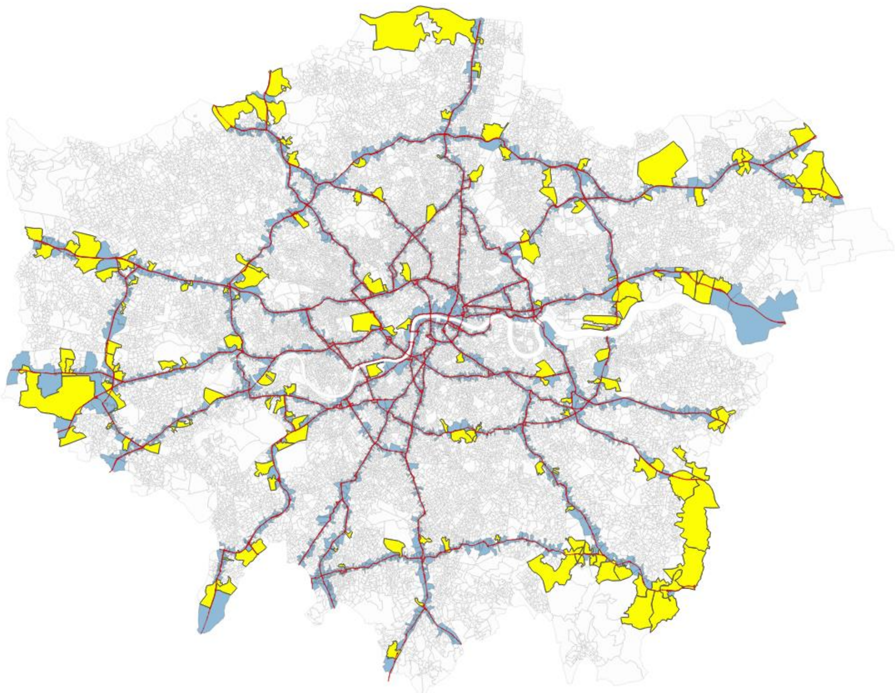


Figure 4 Selection of red route OAs to be included in the analysis (highlighted in blue) and red route OAs which were excluded based on their distance to a red route (highlighted in yellow)



2.9 Uncertainty and assumptions

There are inherent uncertainties in the process of producing emissions estimates and in the calculation of air quality concentrations using dispersion models. These uncertainties are amplified when they are used to project into the future, with the added uncertainty of how policies and measures will be delivered and their effectiveness. However, given that these activities are undertaken outside this study, it is not intended to examine them in any detail here. It is worth noting that no sensitivity analysis of future concentrations has been undertaken as part of this study.

Various datasets have been used in the analysis for this study, with different base years. For example, census data are from the 2011 and 2021 censuses and therefore do not completely reflect population patterns in the study years. Moreover, no attempt has been made to interpolate or extrapolate the population characteristics provided in census data (ethnicity, age, sex) as this would only increase uncertainty. Likewise, data on the IMD rating for each LSOA (2019 base year) is assumed to remain unchanged for the future years, as is the number and location of schools, nursey schools, hospitals, and care homes. The only dataset which varies for future years other than air pollution concentrations is the population. This means that the population is assumed to grow but that distribution of IMD ratings, proportion of different ethnic groups resident in each area and the number and location of schools, etc. remains unchanged. This is unlikely to be the case in reality, but it is not possible to provide any assessment of the impact this assumption could have on the study's outputs.

Using LSOAs and even OAs as the basic geographical unit means that statistics become normalised across areas in a way that might not reflect reality. In particular, air pollution concentrations, even at OA level, may not capture the full range of concentrations to which residents are exposed. Thus, where areas are described as, for example, being below the UK Air Quality legal limit for annual mean NO_2 concentrations, that does not necessarily mean that there are no locations within the area that exceed that value. Use of the smaller OAs captures such peaks far better than the larger LSOAs but are still subject to variations in concentrations across their areas. Using annual mean statistics reduces this effect but does not eliminate it.

3 General exposure analysis

General Exposure: key messages

- The whole population of London is forecast to continue being exposed to NO_2 and $PM_{2.5}$ concentrations exceeding the WHO Guidelines in 2030.
- The average annual mean concentration in London for NO_2, PM_{10} and $PM_{2.5}$ will approximately halve between 2013 and 2030, though reductions are forecast to slow from 2025 without further action.
- By 2030, only 6% of the population of London will be exposed to concentrations exceeding the NO_2 WHO interim guideline of 20 µg/m^3.
- 38% of the population of London will be exposed to PM_{10} concentrations exceeding the WHO guideline still in 2030.
- Almost the whole population will be exposed to $PM_{2.5}$ concentrations below the WHO interim target of 10 µg/m^3 by 2030.

This section describes the general concentration and exposure pattern for NO_2, PM_{10} and $PM_{2.5}$.

3.1 Air quality pollutant concentrations

The maps in **Figure 5**, **Figure 6** and **Figure 7** show the average concentrations in each OA across London, colour coded according to magnitude. Note that the scale varies for each pollutant. In 2030, all locations are projected to still be above the WHO guidelines for NO_2 and $PM_{2.5}$ of 10 and 5 µg/m^3, respectively. In contrast, over half of all OA are projected to be within the PM_{10} WHO guideline of 15 µg/m^3 by 2030.

All three maps show a familiar pattern of higher concentrations towards the centre of London, with both key arterial roads and Heathrow Airport clearly visible. For all pollutants, there is a decrease in concentrations across the time period.

The rate of change in concentrations through time is further demonstrated in **Figure 8, Figure 9** and **Figure 10**, which show the difference in concentrations across London between 2013 - 2016 and 2016 – 2019, 2016 – 2025, 2016 – 2030. The future years were compared with 2016 to more clearly demonstrate the changes in concentrations over the timeseries. Note the differing scales used for each pollutant.

Between 2013 and 2030 the average annual mean concentration in London for all pollutants is projected to fall by approximately 50 %. For NO_2, on average concentrations slightly increased between 2013 and 2016, but from 2016 onwards there is a consistent improvement in concentrations. An average reduction of 8 µg/m^3 in NO_2 concentrations occurred in the three years between 2016 and 2019 and a similar improvement is projected between 2019 and 2025. This improvement is projected to continue between 2025 and 2030, but at half of the rate compared to 2019 to 2025. For PM_{10} and $PM_{2.5}$, average annual mean concentrations have consistently improved since 2013. As for NO_2, the rate of improvement is predicted to slow, with less than half the improvement seen in the three years between 2016 and 2019 occurring during the 6 years between 2019 and 2025. In contrast to NO_2, in some areas PM_{10} and $PM_{2.5}$ concentrations are predicted to increase in 2025, and in 2030 for PM_{10}, indicating that further action is required to reduce future particulate concentrations.

Figure 5 Average concentrations at OA Level for NO_2, 2013, 2016, 2019, 2025 and 2030

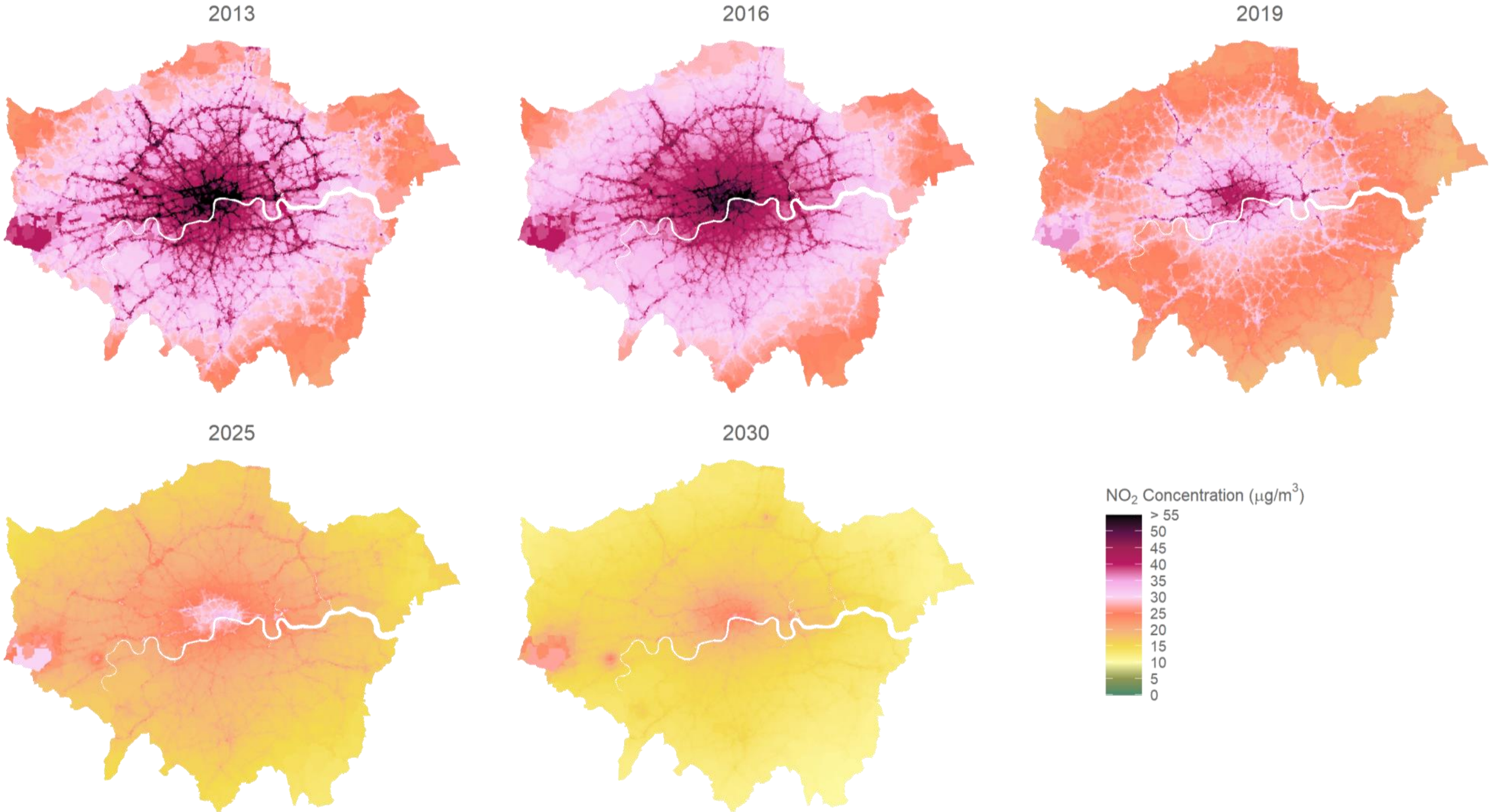


Figure 6 Average concentrations at OA Level for PM_{10}, 2013, 2016, 2019, 2025 and 2030

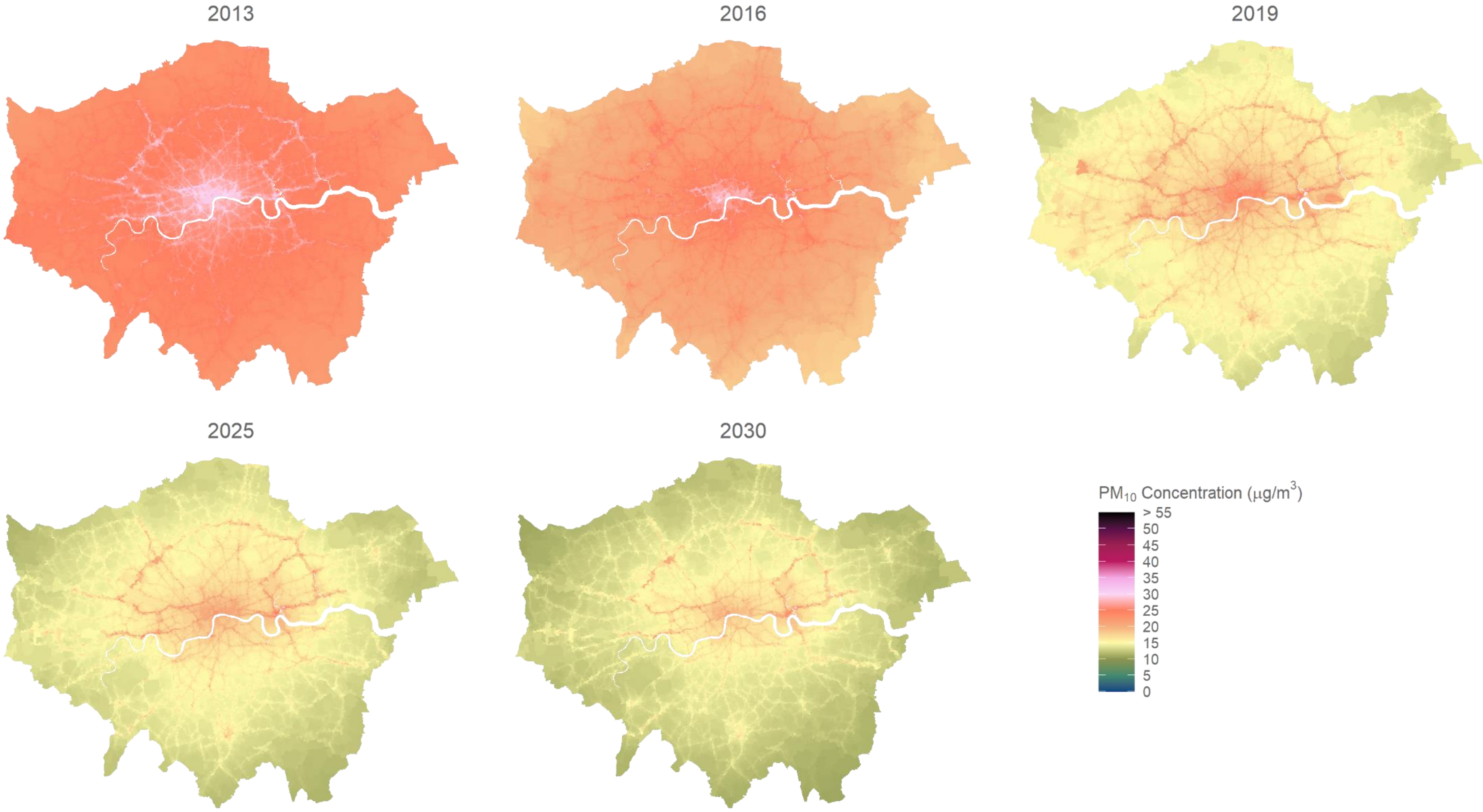


Figure 7 Average concentrations at OA Level for $PM_{2.5}$, 2013, 2016, 2019, 2025 and 2030

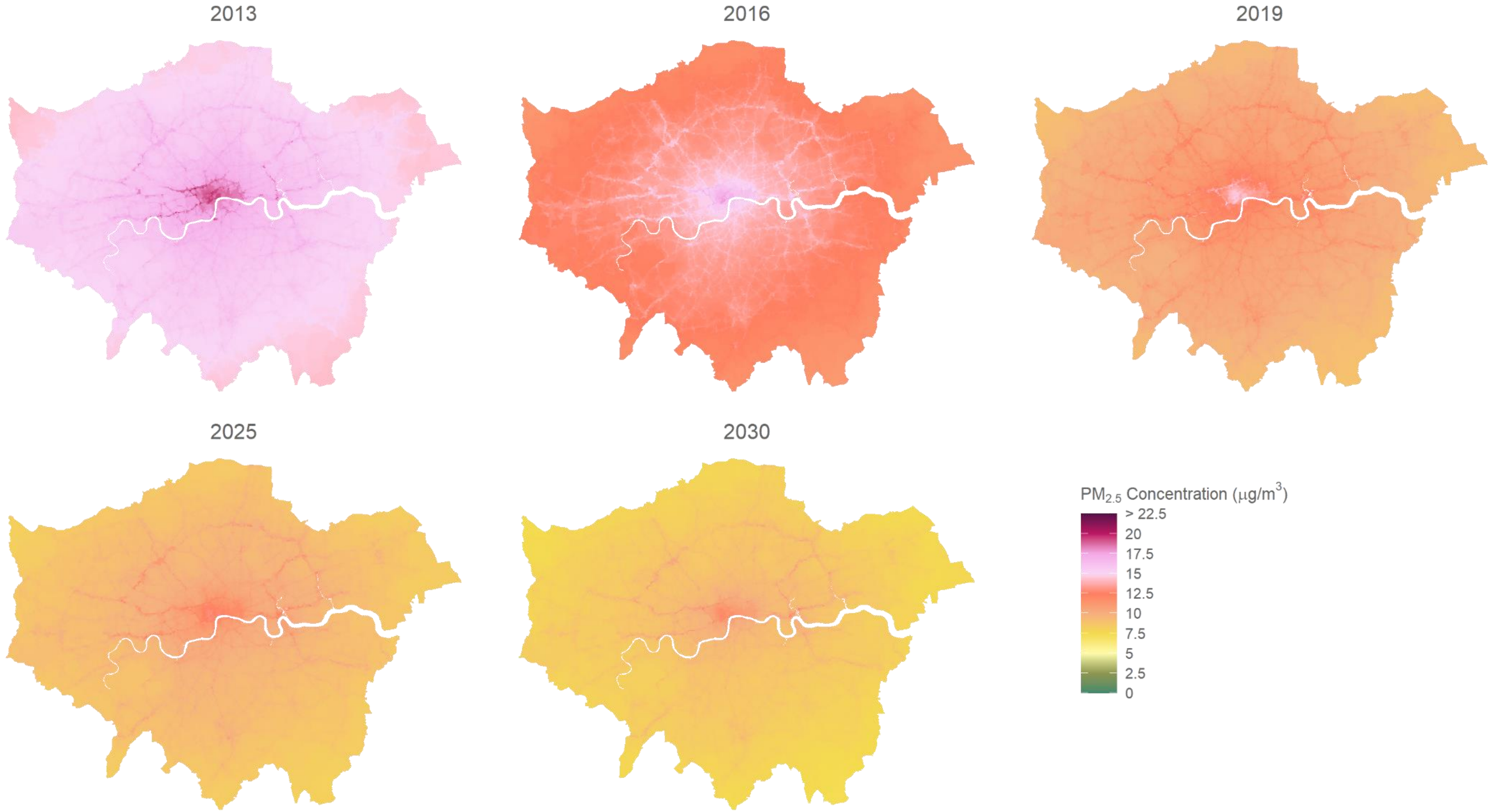


Figure 8 Difference in concentrations in NO_2 between 2013 - 2016, 2016 -2019, 2016 – 2025 and 2016 – 2030

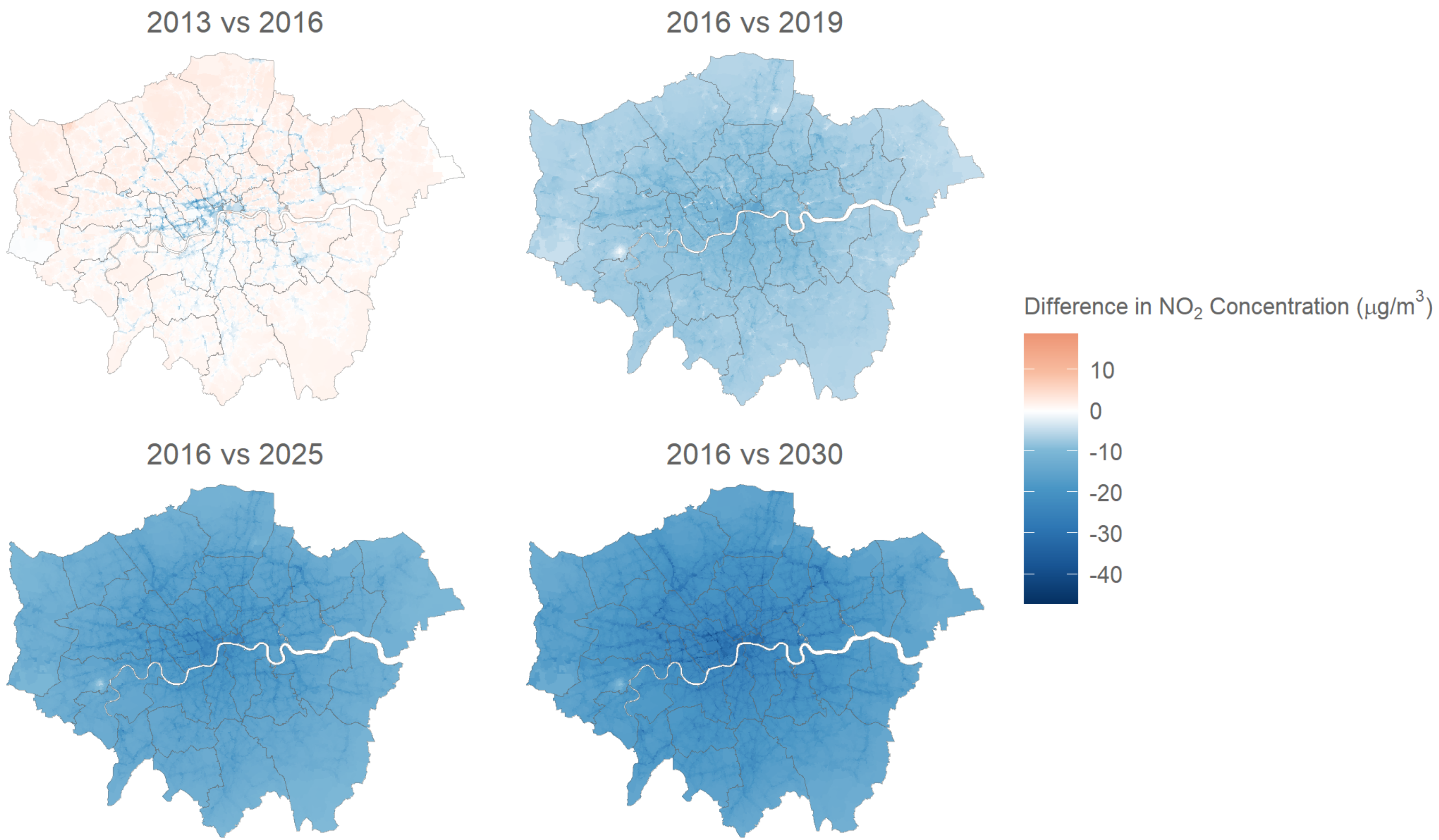


Figure 9 Difference in concentrations in PM_{10} between 2013 - 2016, 2016 -2019, 2016 – 2025 and 2016 – 2030

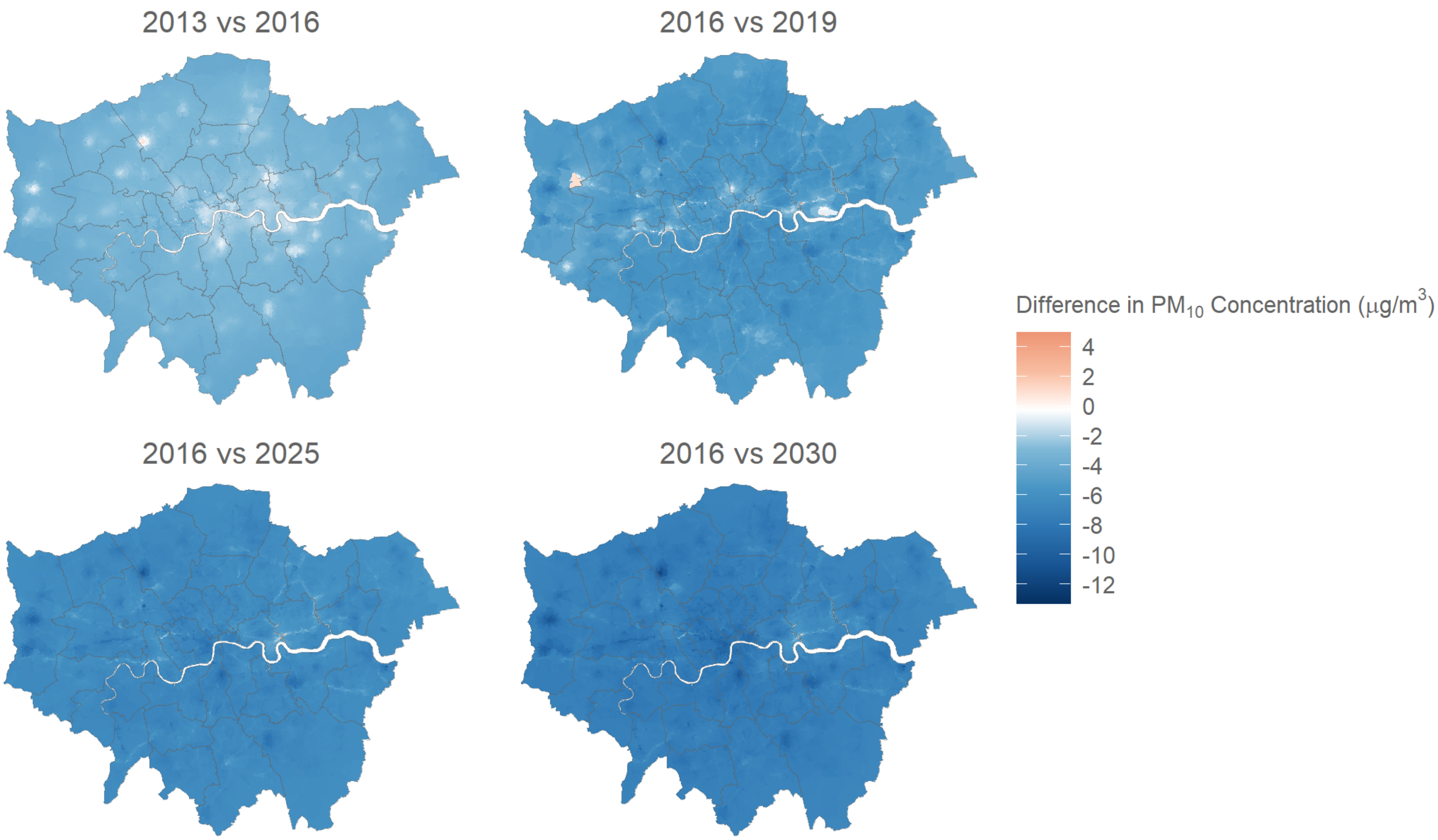
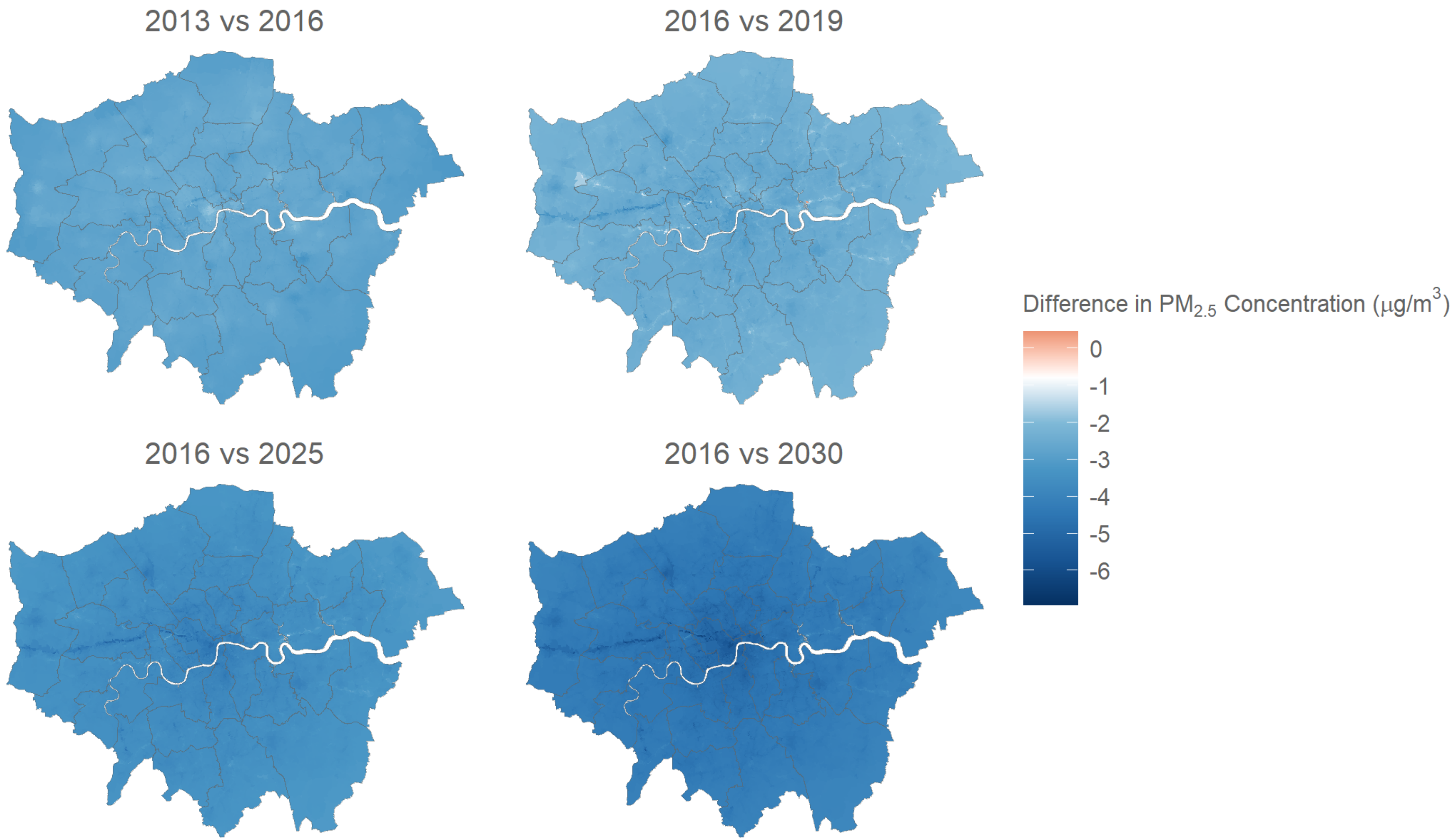


Figure 10 Difference in concentrations in $PM_{2.5}$. between 2013 - 2016, 2016 -2019, 2016 – 2025 and 2016 – 2030



3.2 Population exposure

The way in which the concentration changes are reflected in population exposure is illustrated by the figures below. These show the total number of people exposed to different concentrations over time. This analysis is based on the population in each OA. The height of the bars reflects the projected growth in London's resident population.

For NO_2, as seen in **Figure 11,** all areas in London exceed the WHO guideline of 10 µg/m^3 annual average NO_2 in all of the years assessed. Almost half (47%) of the population are still in exceedance of the WHO interim target of 20 µg/m^3 annual average NO_2 in 2025 and by 2030 this is forecast to reduce to 6% of the population. Exceedances of the 40 µg/m^3 annual mean UK legal limit greatly reduce from 2016 and are eliminated by 2025.).

Figure 11 Population exposure for NO_2 in 2013, 2016, 2019, 2025 and 2030

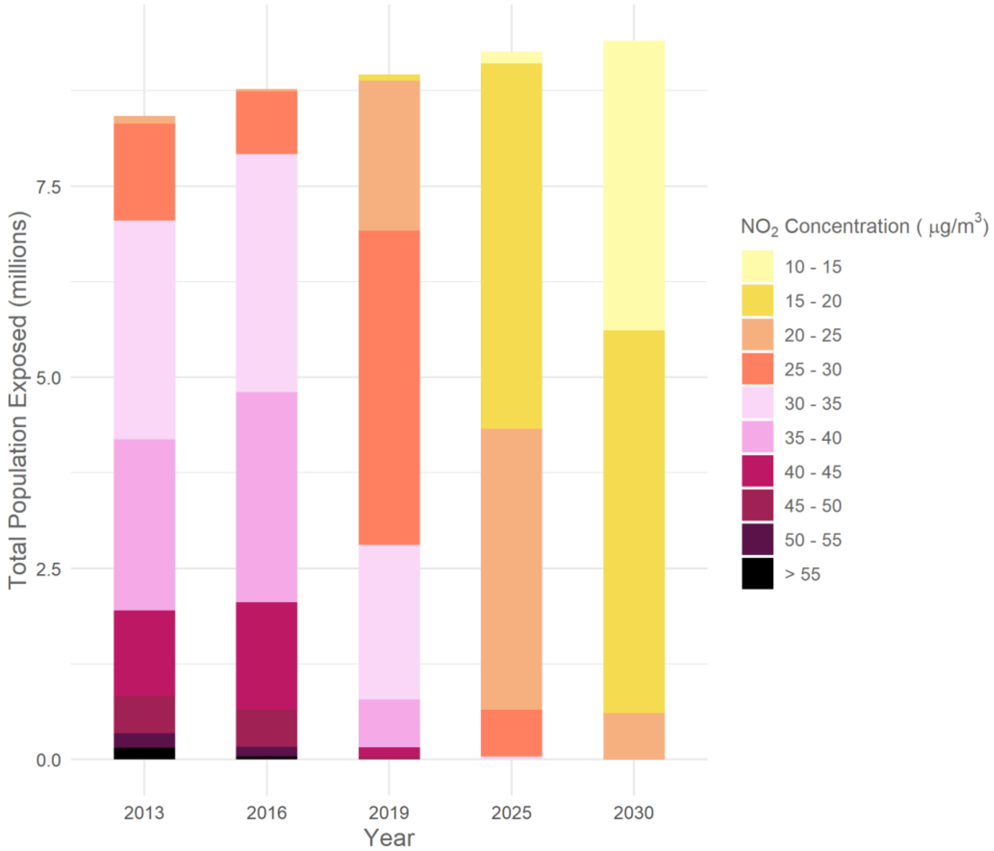


Table 3 Population exposure for NO_2 in 2013, 2016, 2019, 2025 and 2030

Annual mean NO_2 concentration	Population in millions (and percentage of total)				
	2013	2016	2019	2025	2030
> 40 µg/m^3 (exceed UK legal limit)	2.0 (23 %)	2.1 (23 %)	0.2 (2 %)	0.001 (0 %)	-
20 – 40 µg/m^3 (UK legal limit)	6.5 (77 %)	6.7 (77 %)	8.7 (97 %)	4.3 (47 %)	0.6 (6 %)
10 - 20 µg/m^3 (WHO interim target)	-	-	0.1 (1 %)	4.9 (53 %)	8.8 (94 %)
< 10 µg/m^3 (meeting WHO guideline)	-	-	-	-	-

The exposure patterns for PM_{10} and $PM_{2.5}$ are presented in **Figure 12** and **Figure 13.**

In contrast to NO_2, particulate matter generally has a lower concentration gradient, i.e., the concentration tends not to vary as much over the same time period. However, even small reductions in population exposure to particulate matter can have significant, long term health benefits.

Figure 13 shows that the whole population is forecast to still be exposed to $PM_{2.5}$ concentrations in exceedance of the WHO guideline of 5 µg/m^3 by 2030, unless further action is taken to reduce this. The period 2019 – 2030 shows a large reduction in $PM_{2.5}$ exposure in relation to the WHO interim target of 10 µg/m^3 annual average $PM_{2.5}$ with 90% of the population exposed to concentrations exceeding the target in 2019 compared to 4% of the population forecast to be exposed to concentrations in exceeding the target in 2030. Average exposure to PM_{10} concentrations has been lower than the UK legal limit in recent years and, however 38% of the population will still be exposed to PM_{10} concentrations above the WHO guideline 15 µg/m^3 in 2030.

Figure 12 Population exposure for PM_{10} in 2013, 2016, 2019, 2025 and 2030

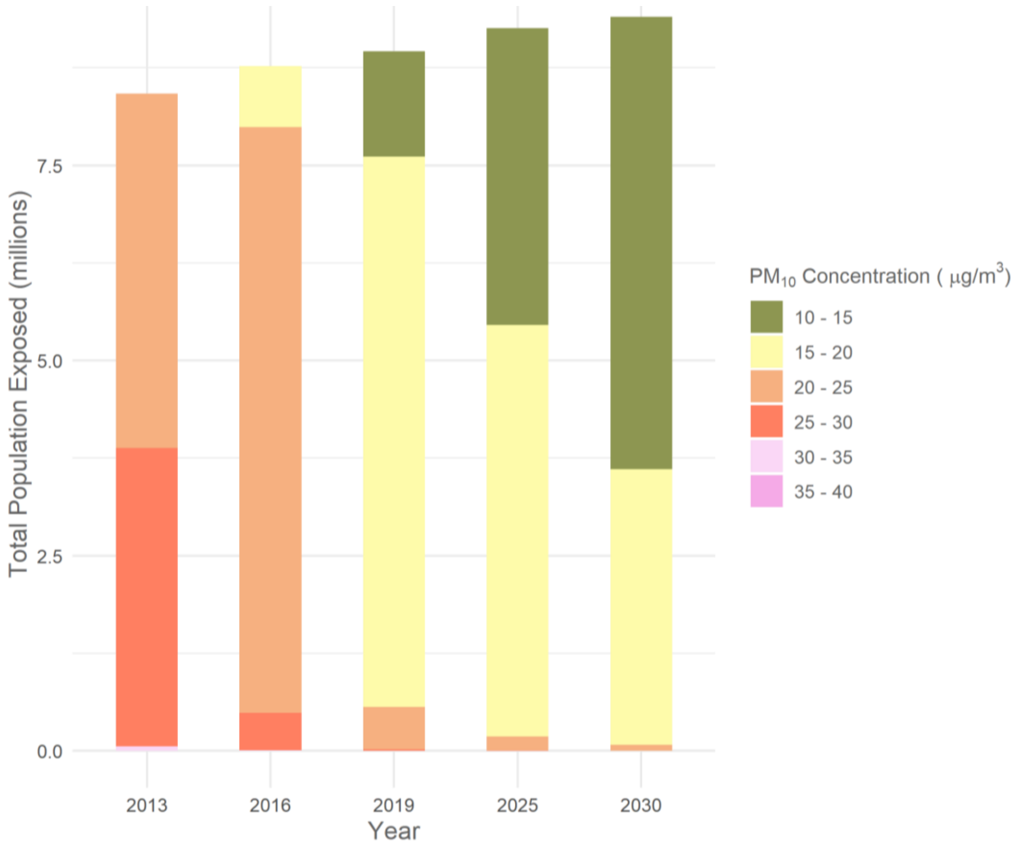


Table 4 Population exposure for PM_{10} in 2013, 2016, 2019, 2025 and 2030

Annual mean PM_{10} concentration	Population in millions (and percentage of total)				
	2013	2016	2019	2025	2030
> 40 µg/m^3 (exceed UK legal limit)	-	-	-	-	-
15 – 40 µg/m^3 (UK legal limit)	8.4 (100 %)	8.8 (100 %)	7.6 (85 %)	5.5 (59 %)	3.6 (38 %)
< 15 µg/m^3 (meeting WHO guideline)	**-**	**-**	**1.4 (15 %)**	**3.8 (41 %)**	**5.8 (62 %)**

Figure 13 Population exposure for $PM_{2.5}$ in 2013, 2016, 2019, 2025 and 2030

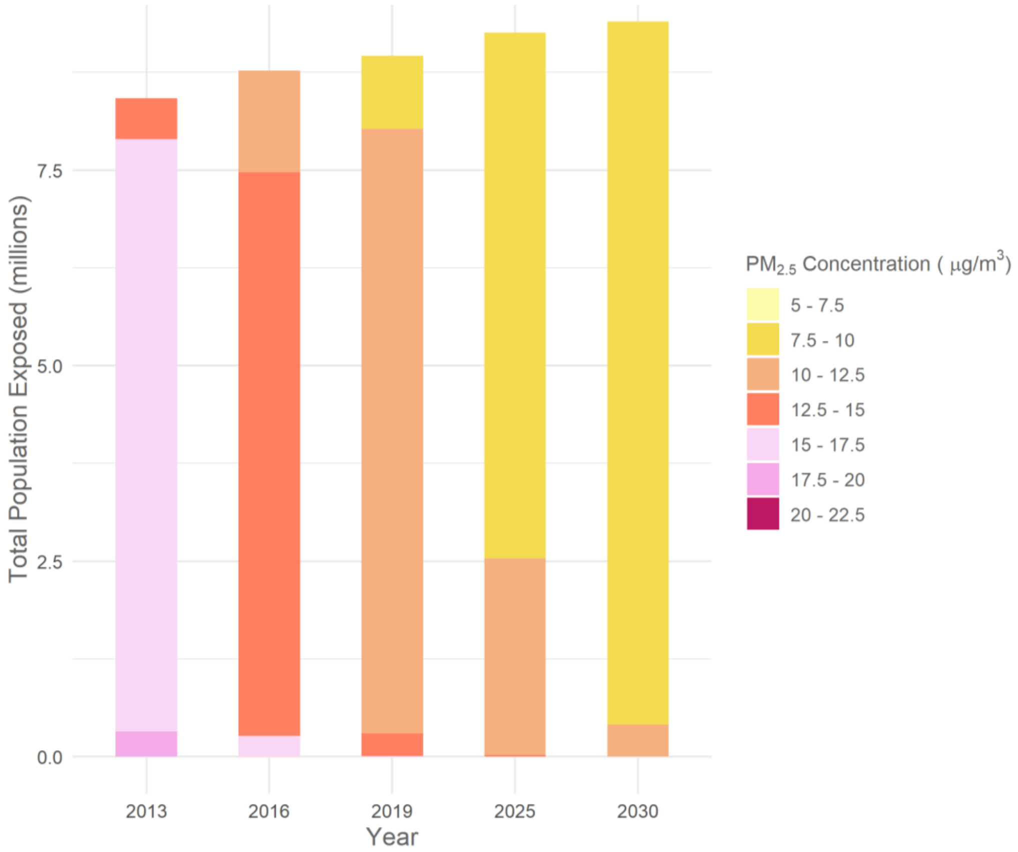


Table 5 Population exposure for $PM_{2.5}$ in 2013, 2016, 2019, 2025 and 2030

Annual mean $PM_{2.5}$ concentration	Population in millions (and percentage of total)				
	2013	2016	2019	2025	2030
> 10 µg/m^3 (above WHO interim target)	8.4 (100 %)	8.8 (100 %)	8.0 (90 %)	2.5 (27 %)	0.4 (4 %)
5 - 10 µg/m^3 (WHO interim target)	-	-	0.9 (10 %)	6.7 (73 %)	9.0 (96 %)
< 5 µg/m^3 (meeting WHO guideline)	-	-	-	-	-

When comparing the exposure of populations of Inner and Outer London, in **Figure 14**, there is a clear pattern for all pollutants, with the Inner London population being exposed to higher concentrations. For NO_2, the majority of the population is projected to be exposed to concentrations below the WHO interim target of 20 µg/m^3 by 2030. In Outer London, only 1% (30,000 people) are predicted to still be exposed to concentrations above the WHO interim target of 20 µg/m^3, compared to 14% (600,000 people) in Inner London. There is a similar trend for PM_{10} and $PM_{2.5}$.

Figure 14 Population exposure for NO_2 in 2013, 2016, 2019, 2025 and 2030 in Inner and Outer London

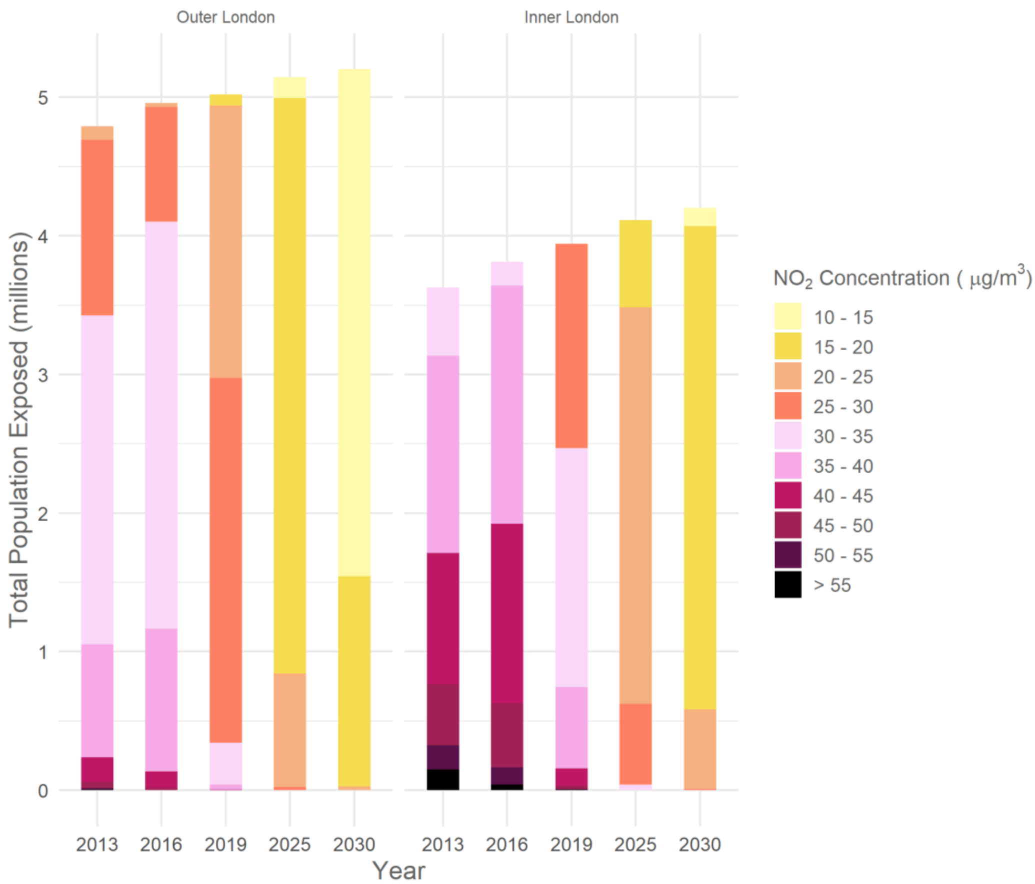


Table 6 Population exposure for NO_2 in 2013, 2016, 2019, 2025 and 2030 in Inner and Outer London

NO_2 Concentration	OA Location	Population in millions (and percentage of Inner/ Outer London population)				
		2013	2016	2019	2025	2030
> 40 µg/m^3 (exceed UK legal limit)	Inner London	1.7 (47 %)	1.9 (50 %)	0.2 (4 %)	0.0 (0 %)	-
	Outer London	0.2 (5 %)	0.1 (3 %)	0.0 (0 %)	-	-
20 – 40 µg/m^3 (UK legal limit)	Inner London	1.9 (53 %)	1.9 (50 %)	3.8 (96 %)	3.5 (85 %)	0.6 (14 %)
	Outer London	4.6 (95 %)	4.8 (97 %)	4.9 (98 %)	0.8 (16 %)	0.03 (1 %)
10 - 20 µg/m^3 (WHO interim target)	Inner London	-	-	-	0.6 (15 %)	3.6 (86 %)
	Outer London	-	-	0.1 (2 %)	4.3 (84 %)	5.2 (99 %)
< 10 µg/m^3 (WHO guideline)	**Inner London**	-	-	-	-	-
	Outer London	-	-	-	-	-

4 Air pollution exposure and deprivation

Exposure and deprivation: key messages

- The 10% most deprived LSOAs make up 16% of the most polluted areas, and as deprivation decreases, representation in the highest concentration areas decreases linearly. Very similar results are observed across Inner and Outer London, and for NO_2 and $PM_{2.5}$ in this respect.
- For NO_2, the difference in average NO_2 concentration between the most and least deprived deciles reduced from 7.7 to 4.4 μg/m^3 between 2013 and 2019, showing that the inequalities have reduced. The forecasts show that the exposure differential between the most and least deprived then continues to reduce but at a slower rate, with the difference at 2.8 μg/m^3 in 2025, and 2.2 μg/m^3 in 2030.
- The most deprived deciles saw decreases in NO_2 and $PM_{2.5}$ concentrations of 24% and 32% respectively and the least deprived 19% and 33%, between 2013 and 2019.
- One exception to the trend of higher concentrations in higher deprivation areas on average is that concentrations on the whole are higher in middle IMD deciles than in the highest deprivation deciles in Outer London.

This section considers the relationship between air pollution exposure and deprivation in London, in particular using the Index of Multiple Deprivation (IMD) measure.

Each LSOA in London has been allocated to a deprivation decile, defined as 10 percent groups of LSOAs ranked by their IMD scores. Each decile contains around 483 LSOAs and for each decile the average air pollution concentration and other statistics have been calculated from the air pollution concentrations in those LSOAs based on the data provided by TfL (see **Section 2**). Air pollution data for each deprivation decile has then been summarised to show the variation in pollution exposure across the social gradient of deprivation. This has been done for 2013, 2016, 2019, 2025 and 2030 for NO_2 and $PM_{2.5}$.

Figure 15 to **Figure 17** below show the distribution of IMD scores, divided into 10 deciles, for London in 2015 and 2019, as well as the difference between the years. The 2015 IMD scores are used in conjunction with the 2013 and 2016 air quality data and the 2019 scores with the 2019, 2025 and 2030 air quality data in the following analysis. The darker colours indicate higher levels of deprivation.

Figure 15 LSOAs in London shaded according to IMD Deciles, 2015

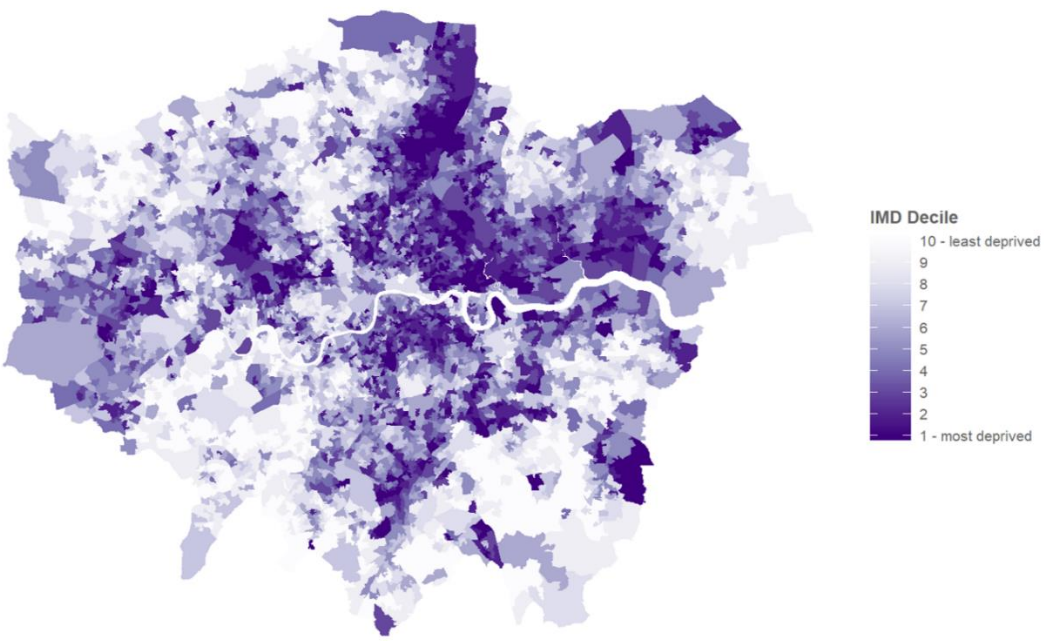


Figure 16 LSOAs in London shaded according to IMD Deciles, 2019

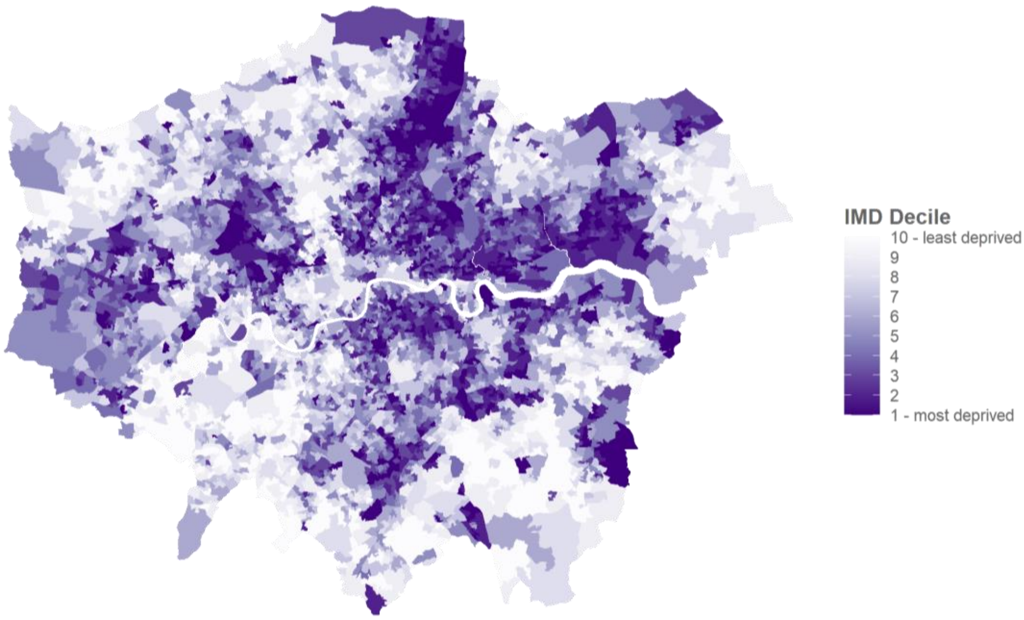
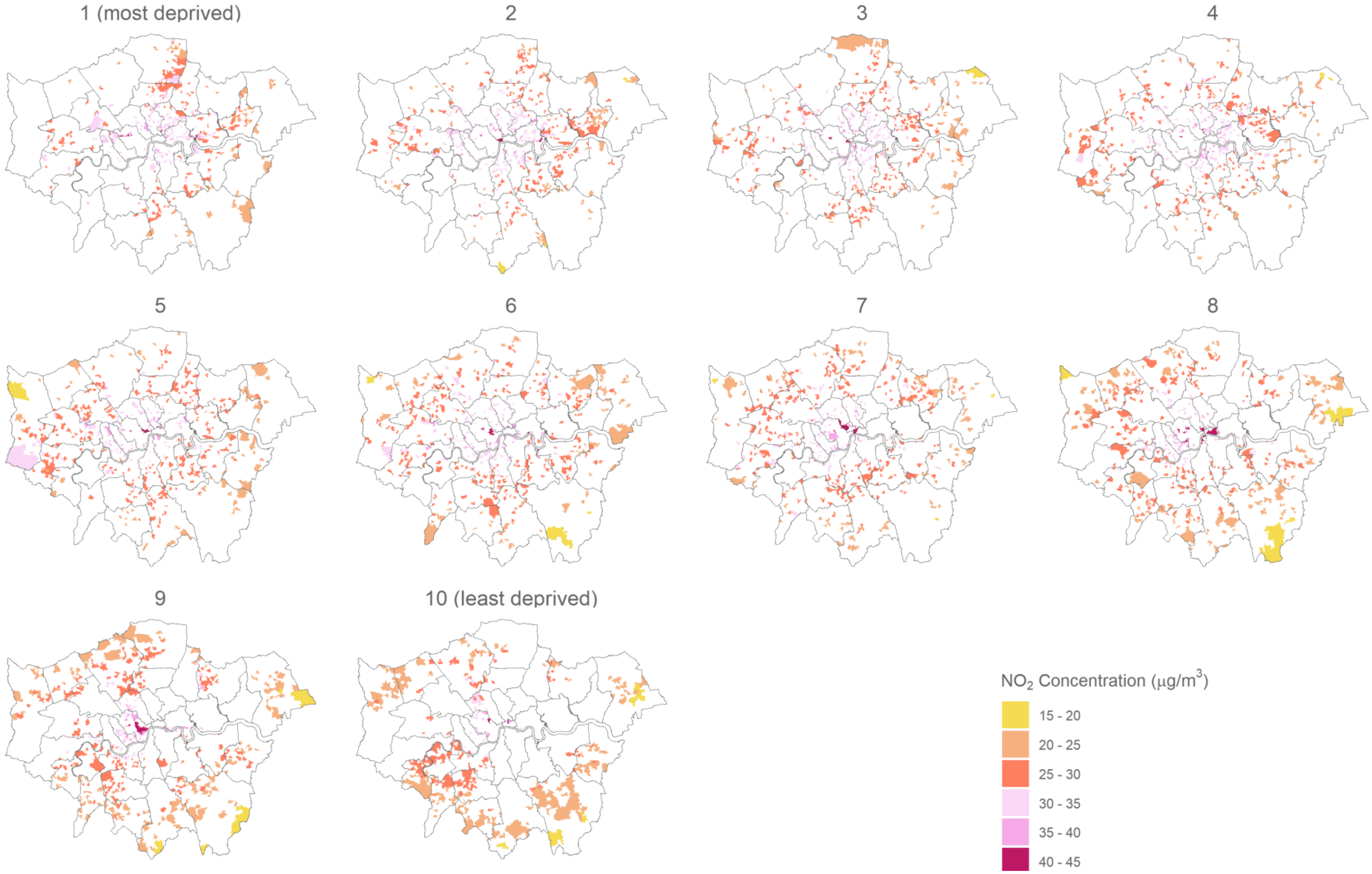


Figure 17 Differences between 2019 and 2015 for LSOAs in London according to IMD Deciles

The figures above show that there have been reductions in deprivation particularly in the centre and northeast, with increases in deprivation seen more across Outer London. Many LSOAs have moved by at least one decile from 2015 to 2019.

Figure 18 below shows the NO_2 concentrations for LSOAs in each deprivation decile geographically for 2019. For each decile map, LSOAs within that decile are coloured according to their pollutant concentration levels. These maps may be useful in answering specific questions about the interaction between concentrations and deprivation in different areas. What is seen is that across all deprivation deciles, central OAs have the highest levels of concentrations, whereas those in Outer London have lower levels. Furthermore, it appears that OAs in Outer London which are more deprived tend to have higher levels of concentrations.

Figure 18 Maps for NO_2 and $PM_{2.5}$ concentration within each IMD decile, in 2019



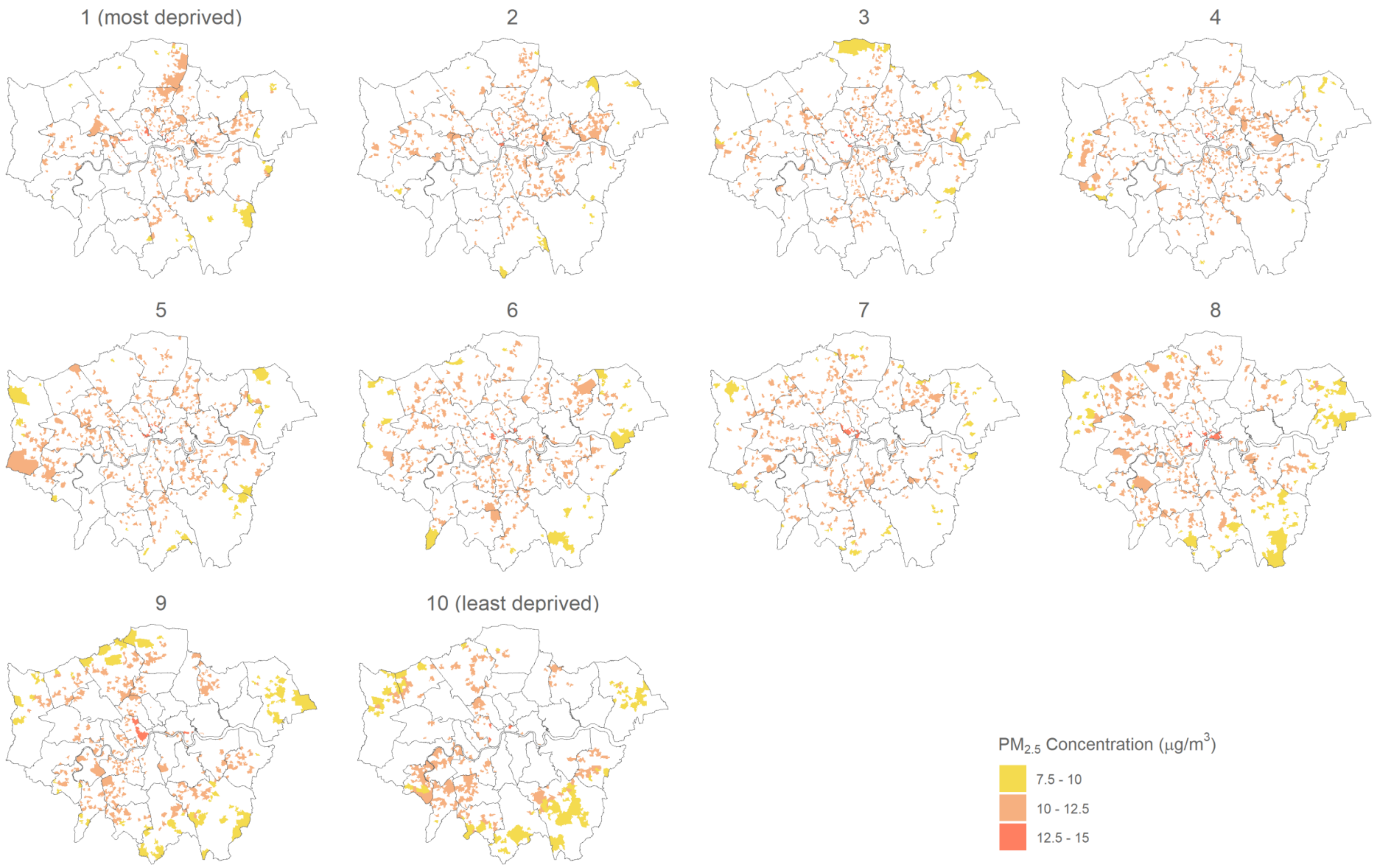

1 (most deprived)
2
3
4
5
6
7
8
9
10 (least deprived)
PM2.5 Concentration (µg/m3)
7.5 - 10
10 - 12.5
12.5 - 15

Table 7 provides the mean exposure by IMD decile across years for both NO_2 and $PM_{2.5}$. The increment in mean concentration between the lowest deprivation decile and the highest is falling over time, showing a reduction in inequalities predicted over time.

Table 7 Mean exposure (µg/m³) by deprivation (IMD) decile across all years for NO_2 and $PM_{2.5}$

Pollutant	IMD decile										Difference, lowest to highest µg/m³ (%)
	1 (most deprived	2	3	4	5	6	7	8	9	10 (least deprived)	
NO_2											
2013	39.1	37.9	37.8	37.3	36.7	36.2	36.1	35.3	33.8	31.4	7.7
2016	39.0	37.8	37.7	37.3	36.7	36.3	36.1	35.4	34.2	32.0	7.0
2019	29.7	29.5	29.1	29.3	28.8	28.3	28.1	27.5	27.0	25.3	4.4
2025	20.9	20.8	20.6	20.8	20.4	20.0	19.9	19.5	19.1	18.1	2.8
2030	16.4	16.4	16.2	16.4	16.1	15.7	15.6	15.2	15.0	14.2	2.2
$PM_{2.5}$											
2013	16.3	16.2	16.1	16.1	16.0	15.9	15.9	15.8	15.7	15.4	0.9
2016	13.6	13.5	13.5	13.4	13.3	13.2	13.2	13.1	13.0	12.7	0.9
2019	11.0	11.0	10.9	10.9	10.9	10.8	10.7	10.7	10.6	10.3	0.7
2025	9.9	9.8	9.8	9.8	9.7	9.7	9.6	9.5	9.5	9.2	0.7
2030	9.0	9.0	8.9	8.9	8.9	8.8	8.8	8.7	8.6	8.4	0.6

For NO_2, the difference in average NO_2 concentration between the most and least deprived deciles reduced from 7.7 to 4.4 µg/m³ between 2013 and 2019, showing that the inequalities have reduced. The forecasts show that the exposure differential between the most and least deprived then continues to reduce but at a slower rate, with the difference at 2.8µg/m³ in 2025, and 2.2 µg/m³ in 2030. The most deprived decile saw a larger absolute and percentage reduction in levels than the least deprived. This effect was more pronounced than for $PM_{2.5}$, with the most deprived decile experiencing a 9.4 µg/m³ reduction in NO_2 concentrations, or 24%, between 2013 and 2019, whereas the least deprived decile saw a 6.0 µg/m³ or 19% reduction.

For $PM_{2.5}$, the difference in average $PM_{2.5}$ concentration between the lowest and highest IMD deciles has had much less variation than for NO_2. The difference in average concentrations between the most and least deprived did not change between 2013 and 2016 but has reduced slightly since and is predicted to continue reducing more slowly to 2030 unless further action is taken specifically to reduce the inequalities.

Figure 19 and **Figure 20** below show the frequency distribution of air quality concentrations in 2019 within each of the deprivation deciles, with decile 1 corresponding to most deprived areas, and red lines showing relevant UK legal limit and WHO guideline levels. **Figure 21** splits the graph for NO_2 into inner and outer London (these graphs for $PM_{2.5}$ are largely similar).

Figure 19 Average NO_2 exposure distributions within IMD Deciles NO_2 in 2019; red dotted lines show current UK legal limit (40 µg/m^3), WHO interim target (20 µg/m^3) and WHO guideline (10 µg/m^3) levels.

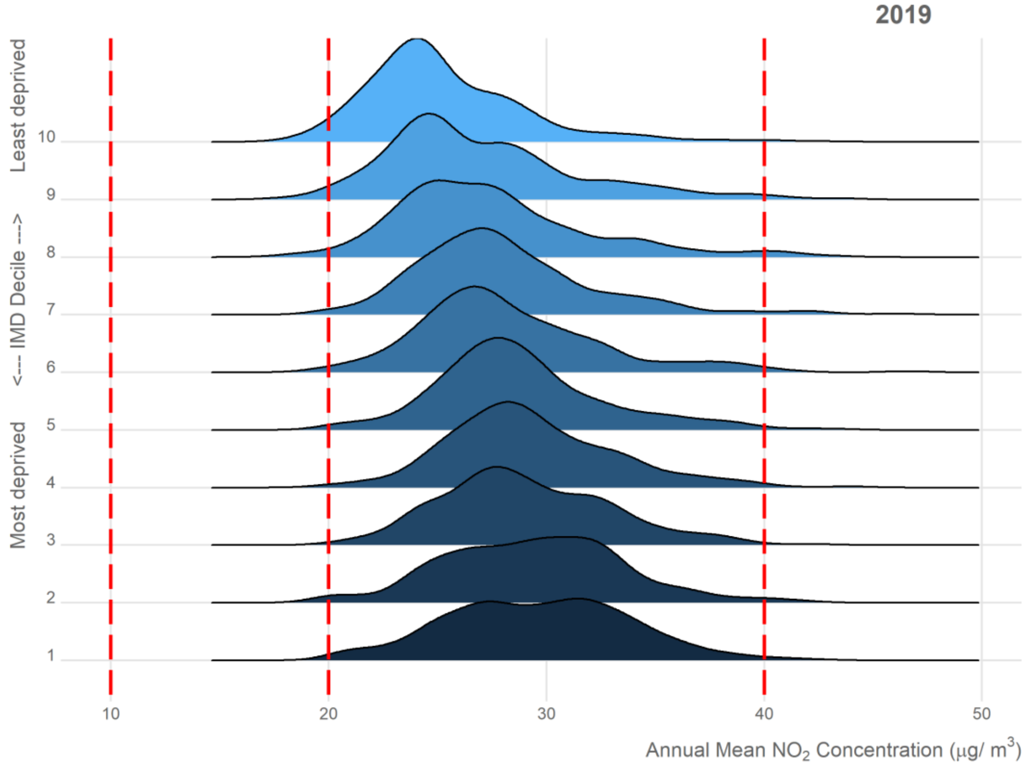


Figure 20 Average $PM_{2.5}$ exposure distributions within IMD Decile in 2019; red dotted line shows current WHO interim target (10 µg/m^3) and WHO guideline (5 µg/m^3) levels

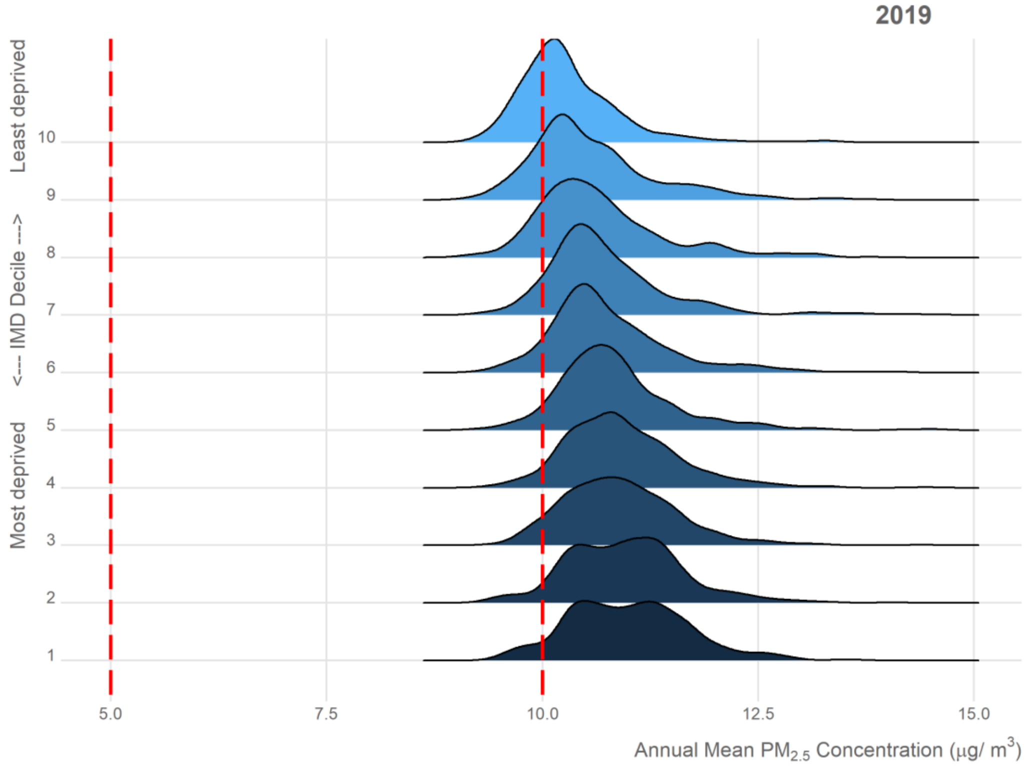
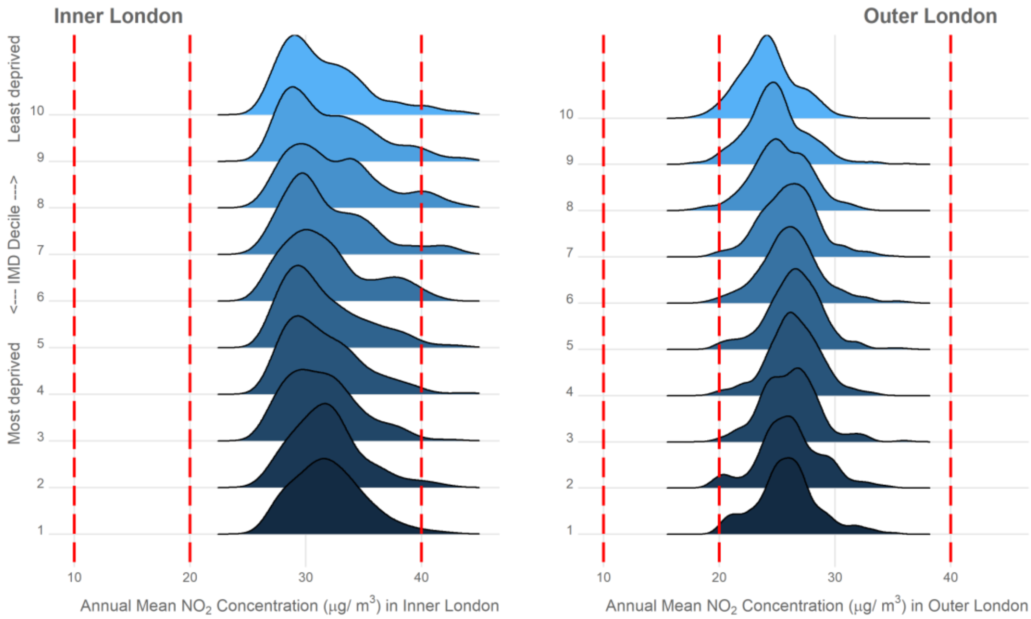


Figure 21 Average NO_2 exposure distributions within IMD Deciles in 2019, split into Inner and Outer London; red dotted lines show current UK legal limit (40 µg/m^3), WHO interim target (20 µg/m^3) levels and WHO guideline (10 µg/m^3) levels.



These graphs show that mean concentrations, for both NO_2 and $PM_{2.5}$, increase as we move to the more deprived deciles, meaning that the most deprived areas are, on average, exposed to the highest pollution concentrations. They also show how much variation there is in concentration within deprivation deciles, and whether there are large amounts of outliers. Deciles 1 to 3 (the most deprived) are more variable than most others, meaning that there is a wider spread of concentrations. There is a second smaller peak in the distributions of some of the lower deprivation deciles, decile 8 in particular, which could correspond to less deprived areas in central London where higher concentrations are seen.

Figure 21 shows that concentrations on the whole are higher in middle IMD deciles than in the highest deprivation deciles in Outer London. One explanation could be that middle IMD decile LSOAs tend to be in areas in Outer London that are nonetheless closer to Central London than those in other deciles, which is suggested by **Figure 18**.

Figure 22 and **Figure 23** below give the exposure distributions within IMD deciles across the 5 years in the dataset.

Figure 22 Average NO_2 exposure distributions within IMD Deciles across years; red dotted lines show current UK legal limit (40 µg/m^3), WHO interim target (20 µg/m^3) and WHO guideline (10 µg/m^3) levels.

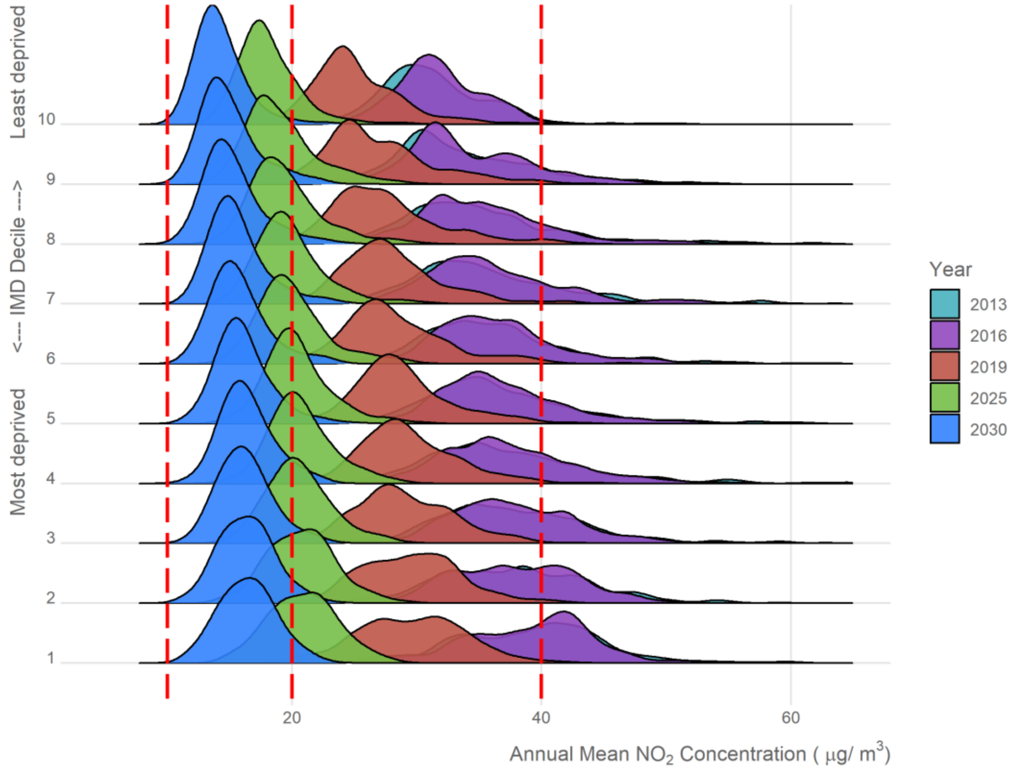
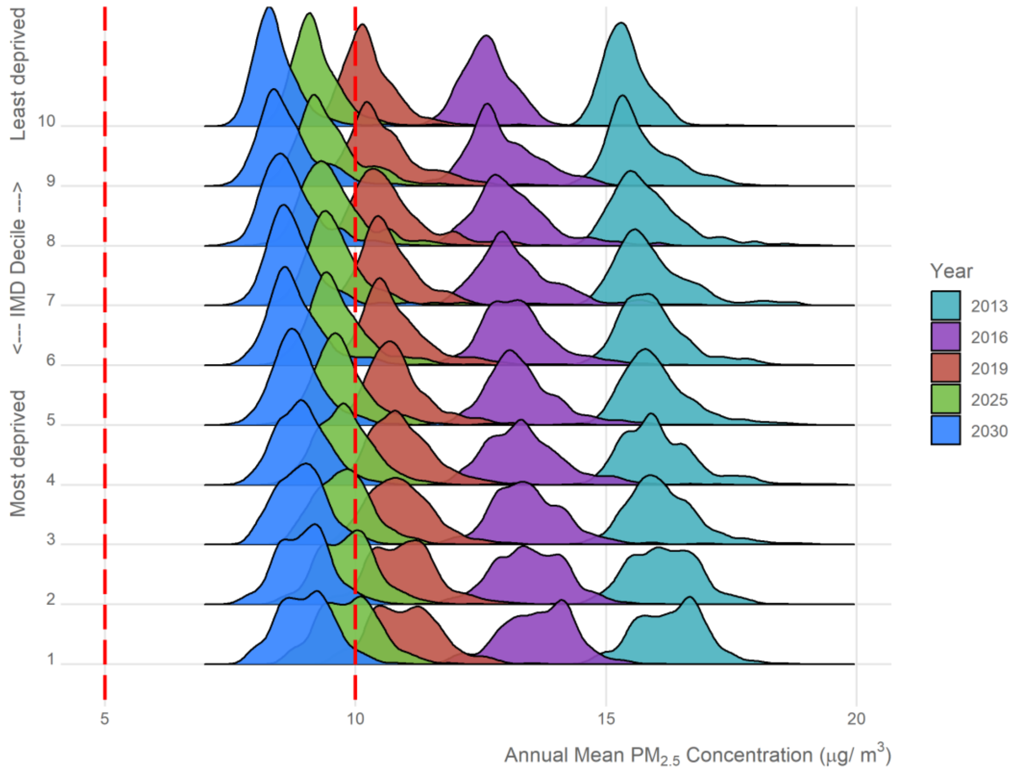


Figure 23 Average $PM_{2.5}$ exposure distributions within IMD Decile across years; red dotted line shows current WHO interim target (10 µg/m^3) and WHO guideline (5 µg/m^3) levels.



These graphs show changes between the given years. For NO_2 there was clearly not much change between 2013 and 2016, but there was a shift to lower concentrations across the board for $PM_{2.5}$. For both pollutants there has been a similar shift to lower concentrations across all deciles between 2016 and 2019, but with overlap of the distributions, and more deprived deciles still having a relatively higher concentration on average. Going into the future years, it can be seen that there is projected to be less variation in pollution concentrations within each of the IMD deciles in general in future years as air pollution becomes less variable across London.

Table 8 below shows the population's distribution across the IMD deciles within the 30% most polluted LSOAs in Inner London and in Outer London for 2019, in terms of NO_2 and $PM_{2.5}$, to show the current status. If exposure to air pollution was equally distributed according to deprivation levels, then each of the IMD deciles in the table below would have 10% of population. However, the percentages of population in the most deprived deciles are higher than those in the least deprived, showing that more deprived people are more likely to live in areas of higher air pollution for both Inner and Outer London and for both NO_2 and $PM_{2.5}$.

Table 9 shows the population's distribution across the IMD deciles within the 30% most polluted LSOAs in the whole of London over different years for NO_2, to consider the trend. The results for $PM_{2.5}$ show the same pattern.

Table 8 Distribution of the population living in the 30% most polluted LSOAs, in terms of IMD in 2019 (Note columns sometimes do not add to 100% due to rounding)

Deprivation Decile	NO_2		$PM_{2.5}$	
	Inner London	Outer London	Inner London	Outer London
10 (least deprived)	3%	6%	2%	5%
9	8%	9%	9%	7%
8	10%	9%	9%	9%
7	9%	8%	8%	8%
6	8%	8%	9%	8%
5	10%	9%	10%	10%
4	13%	11%	12%	12%
3	11%	11%	12%	12%
2	13%	12%	13%	12%
1 (most deprived)	16%	16%	16%	16%

Table 9 Distribution of the population living in the 30% most polluted (NO_2) LSOAs, in terms of IMD (Note columns sometimes do not add to 100% due to rounding)

Deprivation Decile	2013	2016	2019	2025	2030
10 (least deprived)	1%	1%	3%	3%	3%
9	6%	6%	7%	6%	6%
8	7%	7%	8%	7%	7%
7	9%	9%	8%	8%	8%
6	9%	8%	9%	9%	9%
5	10%	10%	10%	10%	10%
4	12%	12%	12%	12%	13%
3	13%	13%	12%	12%	13%
2	15%	15%	15%	15%	15%
1 (most deprived)	18%	19%	16%	16%	16%

The results for 2019 (**Table 8**) show that the situation is broadly very similar across Inner and Outer London, and for NO_2 and $PM_{2.5}$, with high percentages of population of the most polluted LSOAs in the most deprived deciles, and a steady decrease moving towards the less deprived deciles.

Table 9 shows there is has been a small change in these inequalities from 2016 to 2019 for example there is a small fall in percentage in the most deprived decile seen in 2019, with a corresponding increase in the least deprived decile. However, there is no further change forecasted in the projected years indicating that further action is necessary to reduce the inequalities in deprivation and exposure to poor air pollution.

5 Air pollution exposure compared with ethnicity and diaspora communities

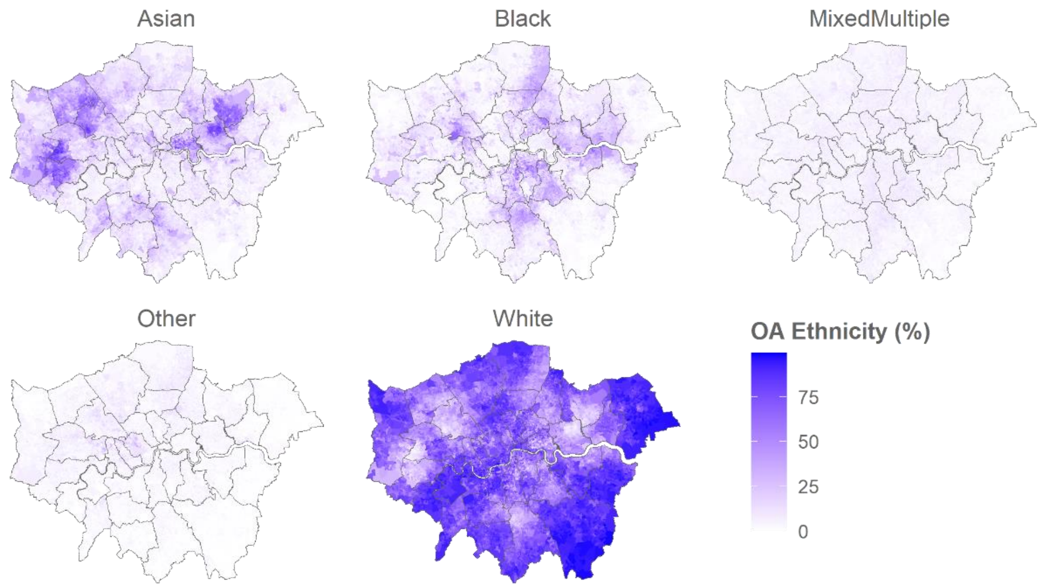
5.1 Exposure compared with patterns of ethnicity

Exposure and ethnicity: key messages

- The areas in London with the lowest air pollution concentrations have a disproportionately white population. This inequality has reduced between 2013 and 2019 but is not forecast to reduce much further by 2030 unless further action is taken.
- The inequalities are much more pronounced in Outer London than Inner London. In Outer London, the lowest concentration decile in terms of NO_2 is 71% white, whereas in Inner London, the lowest concentration decile with any OAs at all in Inner London is 56% white, in 2019.
- White and Asian populations are less likely to live in the most polluted areas in comparison to in the general population, whereas Black, Mixed Multiple and Other populations are more likely, and there is little discernible change observed over time without further action being taken.
- The half of OAs with higher concentrations generally have a fairly representative spread of the population by ethnicity.

The distributions of the five main ethnic groups of the 2021 census are shown in **Figure 24** below. **Table 2** of section 2.5 of this report sets of out sub-groups comprising each ethnic group.

Figure 24 Population distributions by OA for five ethnic groupings in London, 2021



To compare air pollution exposure of people in different ethnic groups, deciles were constructed which group the OAs of London into 10 air quality levels, from lowest pollution concentrations (decile 1) to highest concentrations (decile 10).

Figure 25 and **Figure 26** show the proportions of the population within each ethnic group falling into each of these air pollution deciles for 2013, 2019 and 2030 for NO_2 and $PM_{2.5}$. **Table 10** and **Table 11** provide the accompanying statistics. The years 2016 and 2025 have been excluded here, so that it is possible to compare the most recent data to the past and to future projections within the same graphic more easily.

Figure 25 Percentage of population of each ethnicity group by NO_2 concentration deciles (2013, 2019 and 2030)

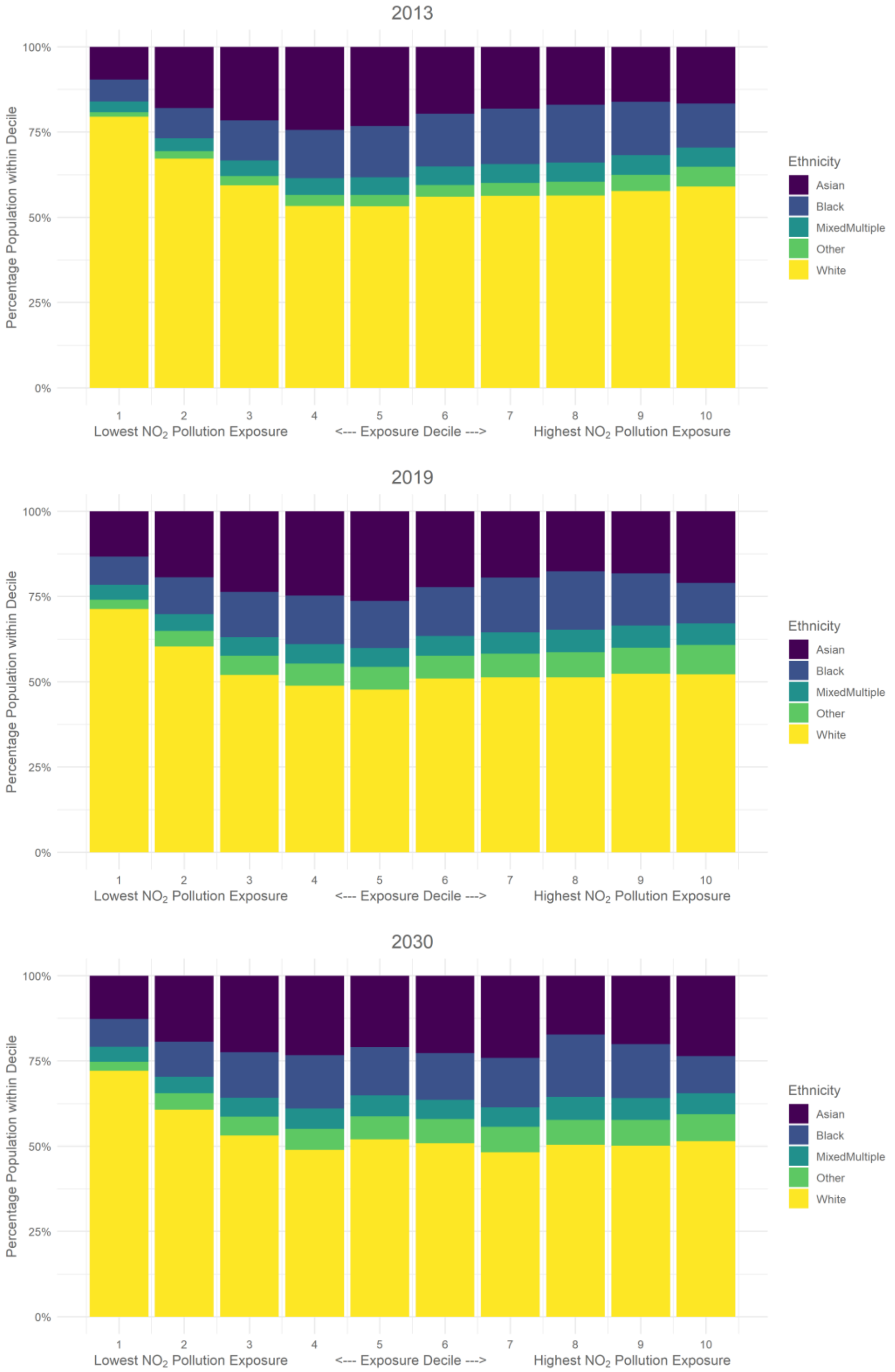


Figure 26 Percentage of population of each ethnic group by $PM_{2.5}$ concentration deciles (2013, 2019 and 2030)

It can be seen that the areas in London with the lowest air pollution concentrations have a disproportionately white population and this inequality is not expected to reduce much further by 2030 according to current projections, meaning that further work is needed to tackle the issue. The inequality reduced between 2013 and 2019 (with the lowest concentration decile going from 80% white to 71% white, the second lowest decile from 67% white to 60%, and the third from 59% to 52%), however it is important to note that some of this can be explained by the percentage of the London population that is white declining from 60% to 54% in this period. There is a fairly representative spread of white populations over the highest polluted half of the distribution in all years.

The Asian population had its highest representations in the 4-6th lowest NO_2 concentrations exposure deciles in 2013, which moved towards the 3rd and 4th lowest in 2019. There is a higher representation in the highest concentration deciles in 2019, but also in the lowest, signifying that population growth has gone to areas at both ends of the NO_2 concentration range. Similar results are observed for $PM_{2.5}$, and a continuation of these trends is expected up to 2030 for both pollutants.

The black population had a fairly even spread of representation across the higher deciles, 4 to 9, with lower representation in the lowest concentration deciles for both NO_2 and $PM_{2.5}$ in 2013, moving into the 3rd decile for NO_2 in 2019. This is expected to continue into 2030. The Mixed Multiple and Other Ethnic groups have their highest representations in the highest pollution areas in general in all years.

Table 10 Proportion of NO_2 concentration deciles by ethnicity for 2013, 2019 and 2030

Ethnicity	Proportion of pollutant concentration decile									
	1	2	3	4	5	6	7	8	9	10
2013										
Asian	10%	18%	22%	24%	23%	20%	18%	17%	16%	17%
Black	6%	9%	12%	14%	15%	15%	16%	17%	16%	13%
MixedMultiple	3%	4%	5%	5%	5%	5%	6%	6%	6%	6%
Other	1%	2%	3%	3%	3%	3%	4%	4%	5%	6%
White	80%	67%	59%	53%	53%	56%	56%	56%	58%	59%
2019										
Asian	13%	19%	24%	25%	26%	22%	19%	18%	18%	21%
Black	8%	11%	13%	14%	14%	14%	16%	17%	15%	12%
MixedMultiple	4%	5%	5%	6%	6%	6%	6%	7%	6%	6%
Other	3%	5%	6%	6%	7%	7%	7%	7%	8%	9%
White	71%	60%	52%	49%	48%	51%	51%	51%	52%	52%
2030										
Asian	13%	19%	22%	23%	21%	23%	24%	17%	20%	24%
Black	8%	10%	13%	16%	14%	14%	15%	18%	16%	11%
MixedMultiple	4%	5%	6%	6%	6%	6%	6%	7%	6%	6%
Other	3%	5%	6%	6%	7%	7%	7%	7%	8%	8%
White	72%	61%	53%	49%	52%	51%	48%	50%	50%	52%

Table 11 Proportion of $PM_{2.5}$ concentration deciles by ethnicity for 2013, 2019 and 2030

Ethnicity	Proportion of pollutant concentration decile									
	1	2	3	4	5	6	7	8	9	10
2013										
Asian	10%	19%	22%	23%	23%	23%	17%	14%	16%	17%
Black	6%	9%	10%	13%	16%	16%	17%	18%	17%	11%
MixedMultiple	3%	4%	4%	5%	5%	5%	6%	6%	6%	5%
Other	1%	2%	3%	3%	3%	4%	4%	4%	5%	6%
White	79%	66%	60%	55%	53%	52%	57%	58%	57%	61%
2019										
Asian	14%	21%	26%	26%	22%	22%	19%	18%	17%	21%
Black	8%	10%	12%	14%	15%	15%	16%	18%	16%	11%
MixedMultiple	4%	5%	5%	6%	6%	6%	6%	7%	7%	6%
Other	3%	5%	6%	7%	6%	6%	7%	7%	8%	8%
White	70%	59%	51%	48%	51%	50%	52%	51%	52%	53%
2030										
Asian	15%	22%	27%	24%	21%	19%	20%	18%	18%	22%
Black	8%	9%	11%	14%	15%	16%	16%	18%	17%	12%
MixedMultiple	4%	5%	5%	6%	6%	6%	6%	7%	7%	6%
Other	3%	5%	6%	6%	6%	7%	7%	7%	7%	8%
White	69%	59%	51%	50%	52%	52%	51%	51%	51%	52%

Figure 27 and **Figure 28** present this analysis for 2019 but with the population split into Inner and Outer London. Note that there are no areas in Inner London in concentration deciles 1 or 2 (i.e. the lowest concentration for NO_2 and $PM_{2.5}$).

Figure 27 Percentage of population of each ethnicity group by NO_2 Concentration deciles for Outer and Inner London in 2019

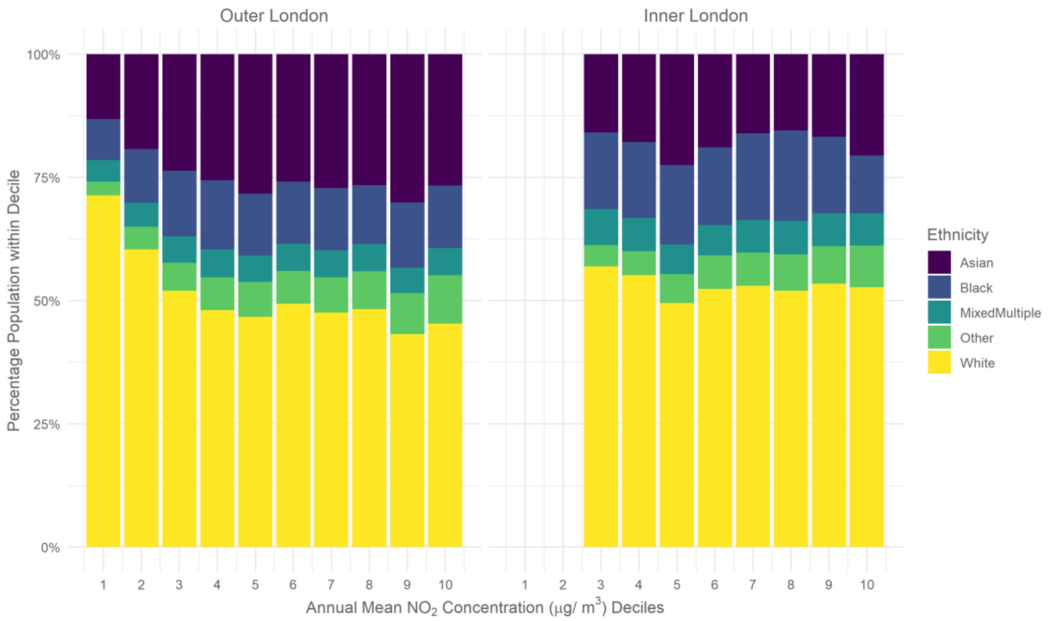
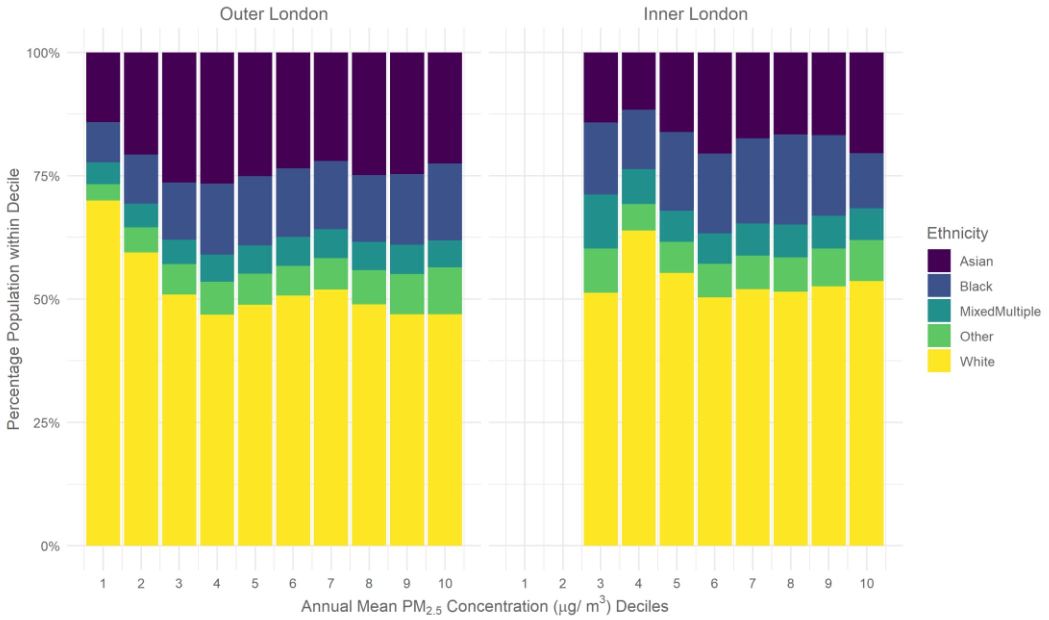


Figure 28 Percentage of population of each ethnicity group by $PM_{2.5}$ concentration deciles for Outer and Inner London in 2019



The inequalities in exposure of different ethnicities in areas of lower pollution are more pronounced in Outer London than Inner. There is a more equal distribution of the different ethnicity groups for concentration deciles in Inner London. For Outer London, the white population has higher representation in the areas of lowest air pollution in terms of both pollutants. In Outer London, the lowest concentration decile in terms of NO_2 is 71% white, whereas in Inner London, the lowest concentration decile with any OAs at all in Inner London is 56% white (For $PM_{2.5}$ the figures are 70% and 51%). In the higher half of the concentration deciles the distribution is less variable.

Finally, **Table 12** below shows the percentage makeup of the population by ethnicity for the 30% most polluted areas in terms of NO_2, versus the general population of London. If the percentage in the 'most polluted' column is higher than in the corresponding 'population' (Pop.) column, it means that the given ethnicity is overrepresented in the most polluted areas. **Table 12** provides further evidence that White and Asian populations are underrepresented in the most polluted areas in comparison to in the general population, whereas Black, Mixed Multiple and Other populations are overrepresented, and crucially there is little discernible change observed over time adding to the evidence for taking further action. The results for $PM_{2.5}$ are similar.

Table 12 Percentage makeup of the population by ethnicity, for 30% most polluted OAs (NO_2) vs population of London (2013, 2019 and 2030)

Ethnicity	% in Pop 2013	% in Most Polluted 2013	% in Pop 2019	% in Most Polluted 2019	% in Pop 2030	% in Most Polluted 2030
Asian	18%	17%	21%	19%	21%	20%
Black	13%	15%	14%	15%	14%	15%
Mixed Multiple	5%	6%	6%	6%	6%	7%
Other	3%	5%	6%	8%	6%	8%
White	60%	58%	54%	52%	54%	51%

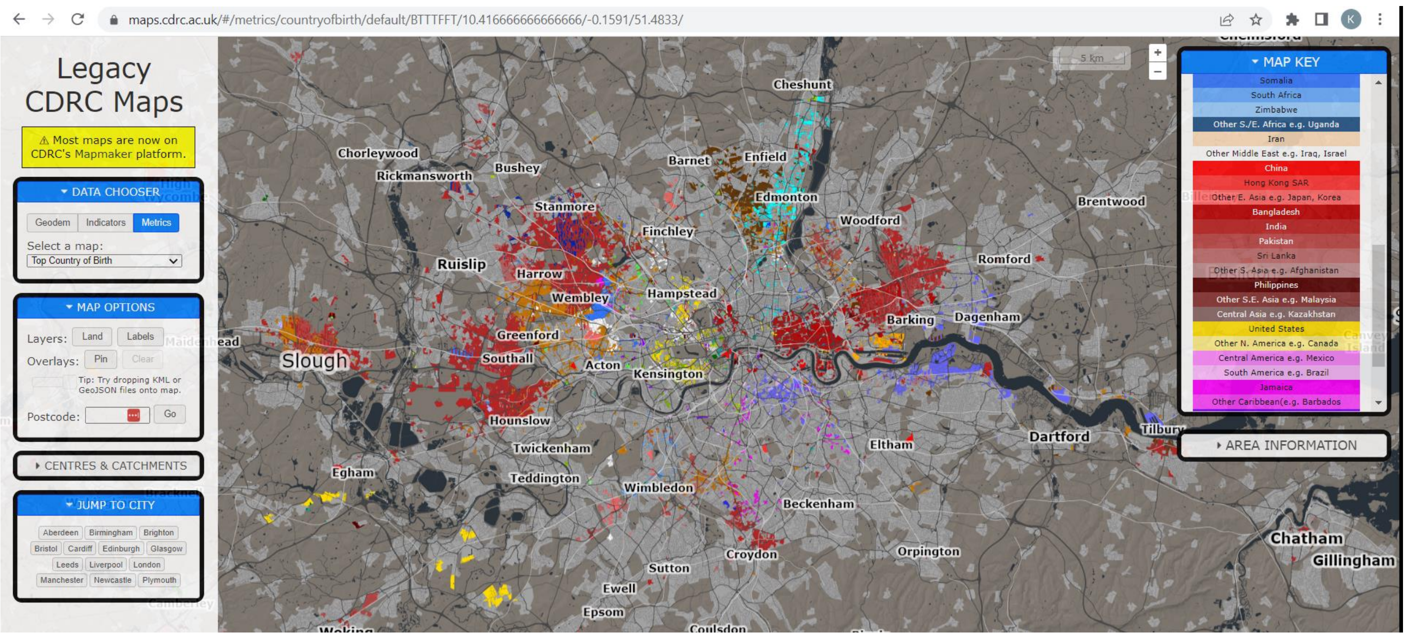
5.2 Exposure in diaspora communities

Exposure and diaspora communities: key messages

- The diaspora groups with the highest levels of exposure to NO_2 and $PM_{2.5}$ are North America, Middle East and Eastern Asia.
- Although there have been improvements in air quality for all groups, the distribution has changed very little from 2013 to 2019, and similar trends are expected to continue up to 2030.
- There is variation in exposure between diaspora communities and this has largely remained consistent over time. The average NO_2 concentration in diaspora communities is 2.3µg/m^3 higher than the London average and $PM_{2.5}$ levels of 0.4µg/m^3 higher than the London average in 2019. The figure for 2013 are 3.4µg/m^3 higher than the London average for NO_2 and 0.4µg/m^3 for $PM_{2.5}$. For 2030 the difference is forecast to be 1.2µg/m^3 higher for NO_2 and 0.3 µg/m^3 for $PM_{2.5}$ so the overall trend is not expected to change without further action.

In this analysis, an OA is counted towards a diaspora community if greater than 8% of the population is of that diaspora, as per the analysis caried out by the Consumer Data Research Centre (CDRC)[26]. The data are illustrated in **Figure 29** which is a screen shot from the CDRC website.

Figure 29 Illustration of the diaspora dataset for London



The following figures show the proportions of the population within NO_2 and $PM_{2.5}$ concentration brackets which belong to diaspora country groups. The diaspora have then been grouped by region for the data to be summarised in **Figure 30** and **Figure 31**. The UK is included in these figures as a country of birth in order to represent the London average, for comparison, since all OAs include at least 8% UK-born residents.

[26] https://maps.cdrc.ac.uk/#/metrics/countryofbirth/default/BTTTFFT/10.09457808623068/-0.1172/51.4722/

It is clear that the diaspora groups with the highest exposure to both NO_2 and $PM_{2.5}$ are North America, South America, the Middle East and Eastern Asia. Although there have been improvements across the board, the distribution has changed very little from 2013 to 2019, and similar trends are expected to continue up to 2030.

The finding that East Asian diaspora are one of the highest exposed diaspora might appear at odds with the finding that in terms of general exposure the Asian population is not generally in the highest exposed groups (see section 5.1). However the difference is likely to be because the vast majority of those classed as of Asian ethnicity are not first generation immigrants from Eastern Asia, and so the high concentrations experienced by this later group, have a relatively small effect on the Asian ethnicity group as a whole.

Table 13 provides the average concentrations of NO_2 and $PM_{2.5}$ in OAs containing each existing diaspora community representing greater than 8% of the population of each diaspora group, for 2013, 2019 and 2030 compares the average concentrations in these communities to the London average, and highlights communities with particularly high or low average concentrations.

The average NO_2 concentrations for diaspora communities are consistently higher than the London average. In 2019 the average NO_2 concentration for diaspora community OAs was 30.7µg/m^3 (London average is 28.4µg/m^3) and $PM_{2.5}$ levels of 11.2µg/m^3 (London average 10.8µg/m^3). The figures for 2013 are 39.8µg/m^3 (36.4µg/m^3) for NO_2 and 16.4µg/m^3 (16µg/m^3) for $PM_{2.5}$, where the London averages are in brackets. The figures for 2030 are 17µg/m^3 (15.8µg/m^3) and 9.1µg/m^3 (8.8µg/m^3) for NO_2 and $PM_{2.5}$ respectively, the overall trend is not expected to change without further action being taken. The second column provides the number of output areas that were classed as diaspora community OAs for each country to give a frame of reference. For example, the average NO_2 concentrations for Spanish diaspora groups is consistently one of the highest each year however there are only two OAs that are classed as Spanish diaspora communities therefore the result is unlikely to be significant.

Figure 30 NO2 Concentration deciles against the percentage of population of each diaspora group for 2013, 2019 and 2030

Figure 31 $PM_{2.5}$ Concentration deciles against the percentage of population of each diaspora group for 2013, 2019 and 2030

Table 13 NO_2 and $PM_{2.5}$ mean concentrations by diaspora community; pink indicates the 5 communities with the lowest concentrations in that year, orange the 5 highest for that year, and yellow any that are above the London average

Diaspora	Number of OAs	Concentration µg/m³					
		NO_2 2013	NO_2 2019	NO_2 2030	$PM_{2.5}$ 2013	$PM_{2.5}$ 2019	$PM_{2.5}$ 2030
London Average	25053	36.4	28.4	15.8	16	10.8	8.8
Australia	30	47.1	35.1	18.8	17.1	11.9	9.6
Bangladesh	866	40.8	32.4	18.4	16.6	11.5	9.5
China	58	45.1	34.4	19.5	17	11.9	9.8
France	137	48.5	35.8	19.4	17.4	12.1	9.8
Germany	6	34.2	26.7	15.2	15.7	10.4	8.5
Ghana	38	36.2	28.5	15.9	16	10.8	8.9
Hong Kong	4	47	36.7	21.6	17.4	12.4	10.1
India	2109	34.6	27.7	15.7	15.7	10.6	8.7
Iran	27	44.8	34.5	17.9	16.7	11.6	9.3
Ireland	53	38.6	30.6	16.9	16.2	11.1	9
Italy	21	46.4	35	19.4	17.3	12.1	9.8
Jamaica	134	36.8	28.2	15.6	16.1	10.8	8.8
Kenya	134	31.2	25.4	14.2	15.3	10.3	8.4
Lithuania	54	36.1	18.5	16.8	15.9	10.9	9
Nigeria	619	36.2	28.2	15.9	16	10.8	8.9
Pakistan	606	35.3	27.9	15.5	15.9	10.7	8.9
Philippines	47	42	31.7	17.4	16.5	11.3	9.2
Poland	831	37.5	29.2	16	16	10.8	8.8
Portugal	35	43.5	32.4	17.8	16.8	11.4	9.3

Diaspora	Number of OAs	Concentration µg/m³					
		NO_2 2013	NO_2 2019	NO_2 2030	$PM_{2.5}$ 2013	$PM_{2.5}$ 2019	$PM_{2.5}$ 2030
Romania	84	33.9	26.9	14.8	15.7	10.5	8.6
Somalia	130	39.5	30.3	17	16.2	11	9
South Africa	80	36.6	28.2	15.4	16	10.8	8.8
Spain	2	49.8	37.2	19.5	17.5	12.3	9.9
Sri Lanka	338	33.5	26.7	14.9	15.6	10.5	8.6
Turkey	321	36.6	28.9	15.9	15.9	10.8	8.9
United States	269	46.6	35.2	19.4	17.2	11.9	9.7
Average all diaspora	-	39.8	30.7	17	16.4	11.2	9.1

6 Exposure at vulnerable receptor sites

Exposure and vulnerable groups: key messages

- For all years analysed between 2013 and 2030, all schools, hospitals and care homes remain exposed to concentrations of NO_2 and $PM_{2.5}$ above the WHO guideline annual mean (10 µg/m^3 and 5 µg/m^3, respectively) inferring that further action is needed to ensure all schools, hospitals and care homes have healthy air.
- However, progress has been made and the number of vulnerable receptors exposed to concentrations above the WHO interim guideline annual mean concentrations (20µg/m^3 and 10µg/m^3, for NO_2 and $PM_{2.5}$, respectively) reduces significantly by 2030.
- For NO_2, in 2013 and also in 2016, 100% of schools, hospitals and care homes were exposed to concentrations above the WHO interim guideline of 20 µg/m^3, this is forecast to reduce to 7%, 28% and 2%, respectively, in 2030. This is a reduction of 93%, 72% and 98% respectively.
- For $PM_{2.5}$ the percentage of schools, hospitals and care homes exposed to concentrations above the WHO interim target of 10 µg/m^3 is forecast to reduce from 100% to 5%, 20% and 1%, respectively, over the same period. This is a reduction of 95%, 80% and 99% respectively.
- Schools in Inner London are on average exposed to higher concentration of air pollution compared with schools in Outer London and this remains consistent over time.
- There is a weak but positive correlation between the percentage of pupils eligible for free school meals and the levels of air pollution that a school is exposed to (excluding private schools where no pupils are eligible for free school meals). This relationship weakens over time as the range of air pollutant concentrations that schools are exposed to decreases.
- The trend of increasing concentrations of NO_2 and $PM_{2.5}$ towards the centre of the city and decreasing over time is also reflected in hospital and care home data.

Data were provided by TfL on air pollution concentrations within 150m[27] of schools (including local authority nurseries), hospitals and care-homes in London, using the 2013, 2016, 2019, 2025 and 2030 LAEI air pollution maps. This analysis includes all such sites in London for which TfL and GLA have location data.

6.1 Schools

The schools analysed cover all phases of education; this data set includes state nurseries, primary schools, secondary schools, 16 + institutions and all-through schools. **Figure 32** below shows the NO_2 concentration at each school in London for each of the years studied. The maps clearly show the reduction in concentrations seen and forecasted over the study period.

Table 14 shows the total numbers of schools that are exposed to annual mean concentrations above the WHO guideline. Comparisons have also been made against the

[27] 150m was used to provide consistency with previous analysis for schools.

WHO interim target and UK legal limit for NO_2 to track progress. All schools within London remain exposed to concentrations above the WHO guideline (10 µg/m³) and this is forecast to remain for all studied years unless further action is taken to reduce concentrations. However, progress has been made, in 2013 100% of schools were exposed to NO_2 concentrations exceeding the WHO interim target (20 µg/m³), this is forecast to reduce to 6.9% in 2030; when 214 schools in Inner London and 5 in Outer London will remain in exceedance of the interim target.

In 2013, 25% of schools were exposed to NO_2 concentrations above the UK legal limit, this reduced to 2% in 2019; all of these remaining schools are in Inner London.

Table 14 Schools within London that are exposed to NO_2 concentrations above the UK legal limit (40 µg/m³), WHO interim target (20 µg/m³) and WHO guideline (10 µg/m³)

NO_2 Concentration	OA Location	Number of schools				
		2013	2016	2019	2025	2030
> 40 µg/m³ (exceed UK legal limit)	Outer London	59	30	-	-	-
	Inner London	679	696	51	-	-
20 – 40 µg/m³ (UK legal limit)	Outer London	1589	1618	1726	280	5
	Inner London	641	624	1365	1228	214
10 - 20 µg/m³ (WHO interim target)	Outer London	-	-	36	1482	1757
	Inner London	-	-	-	188	1202
< 10 µg/m³ (WHO guideline)	**Outer London**	-	-	-	-	-
	Inner London	-	-	-	-	-

Figure 33 below shows the $PM_{2.5}$ concentration at each school in London for each of the years studied. **Table 15** below shows the numbers of schools that are exposed to annual mean concentrations above the WHO guideline for $PM_{2.5}$ and also WHO interim target to track progress. All schools within London remain exposed to concentrations above the WHO guideline (5 µg/m³) for all studied years.

In 2013, 100% of schools were exposed to $PM_{2.5}$ concentrations above the WHO interim target (10 µg/m³), this drops to 5.1% of all schools in 2030; this is split between 161 schools in Inner London and 2 in Outer London.

Table 15 Schools within London that are exposed to $PM_{2.5}$ concentrations above the WHO interim target (10 µg/m³) and WHO guideline (5 µg/m³)

$PM_{2.5}$ Concentration	OA Location	Number of schools				
		2013	2016	2019	2025	2030
> 10 µg/m³ (above interim target)	Outer London	1648	1648	1426	41	2
	Inner London	1320	1320	1416	877	161
10 - 5 µg/m³ (WHO interim target)	Outer London	-	-	336	1721	1760
	Inner London	-	-	-	539	1255
< 5 µg/m³ (WHO guideline)	**Outer London**	-	-	-	-	-
	Inner London	-	-	-	-	-

For both NO_2 and $PM_{2.5}$, progress has been made with the number of schools exposed to annual mean concentrations above the WHO interim target fall from 100% in 2013 to less than 7% by 2030, but all schools remain exposed to concentrations above the WHO guideline for all studied years inferring that further action is needed to ensure all schools have healthy air. Schools in inner London are on average exposed to higher concentrations of air pollution compared with schools in Outer London, most of the schools that remain exposed to concentrations above the WHO interim target by 2030, are in inner London.

In terms of the distribution of exposure to NO_2, and $PM_{2.5}$, the pattern is similar to that for the population as a whole, i.e. increasing towards the centre of the city and decreasing over time. This distribution and its change over time is shown in **Figure 32**, and **Figure 33** below.

Figure 32 Map showing annual average NO_2 concentrations within 150m of schools in London, in 2013 2016, 2019, 2025 and 2030

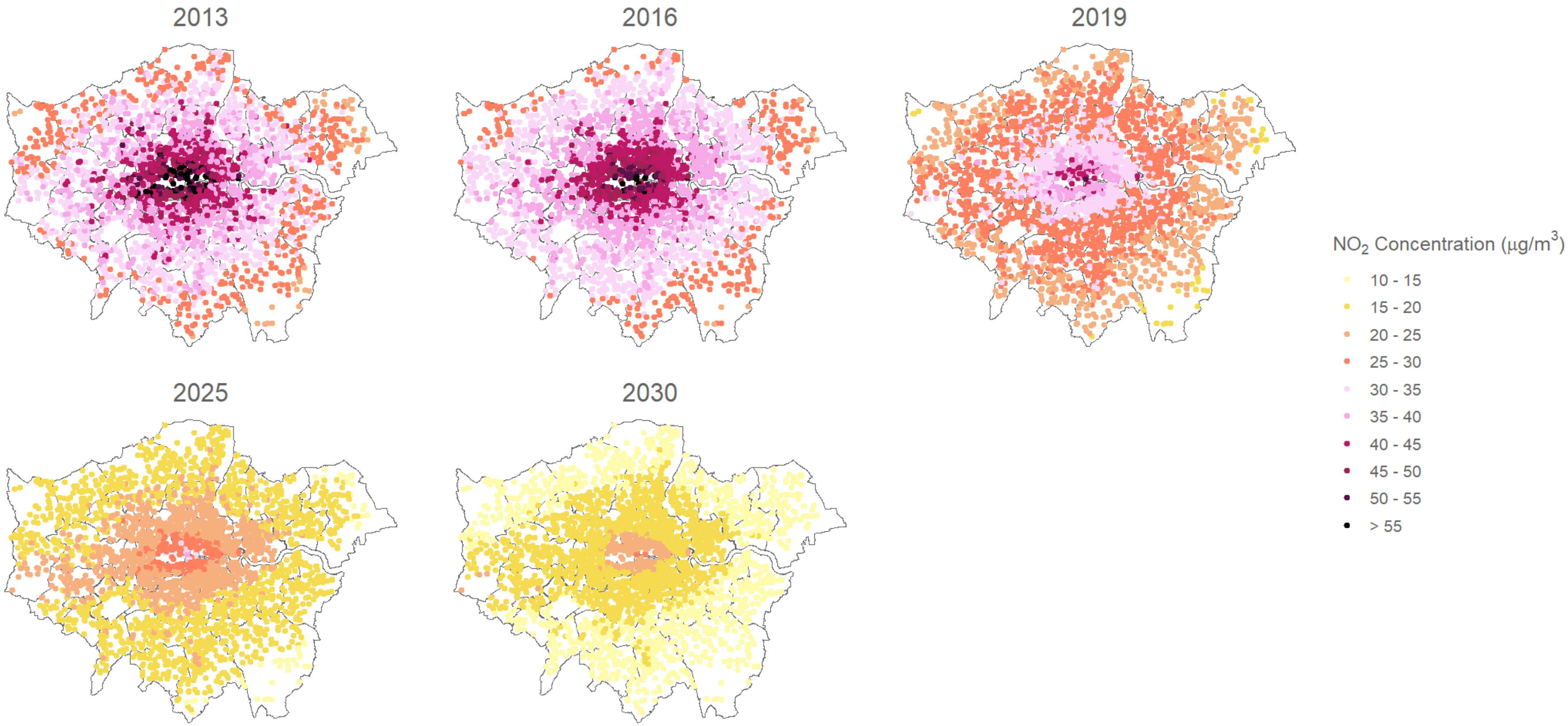


Figure 33 Map showing annual average $PM_{2.5}$ concentrations within 150m of schools in London, in 2013 2016, 2019, 2025 and 2030

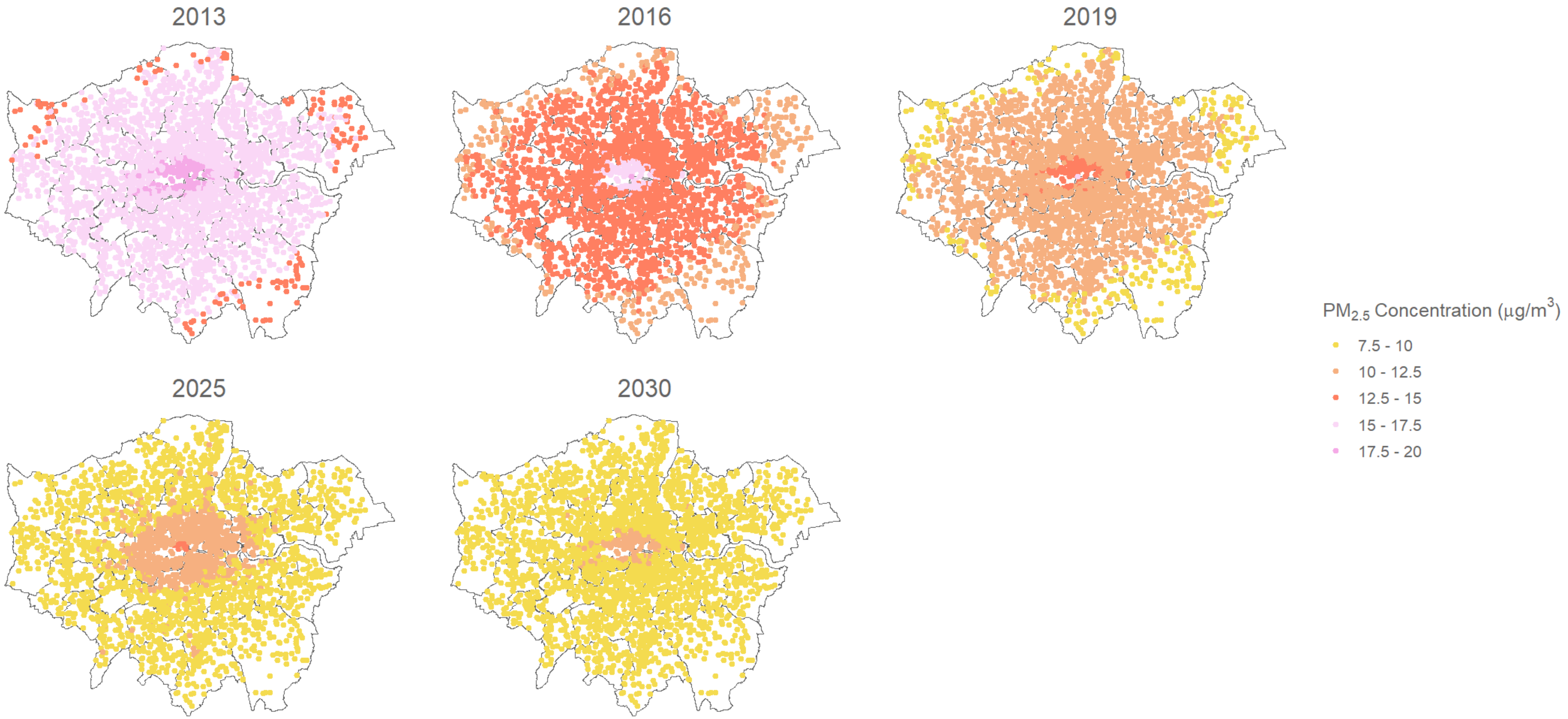


Figure 34 Map showing annual average NO_2 concentrations within 150m of local authority nurseries in London, in 2013 2016, 2019, 2025 and 2030

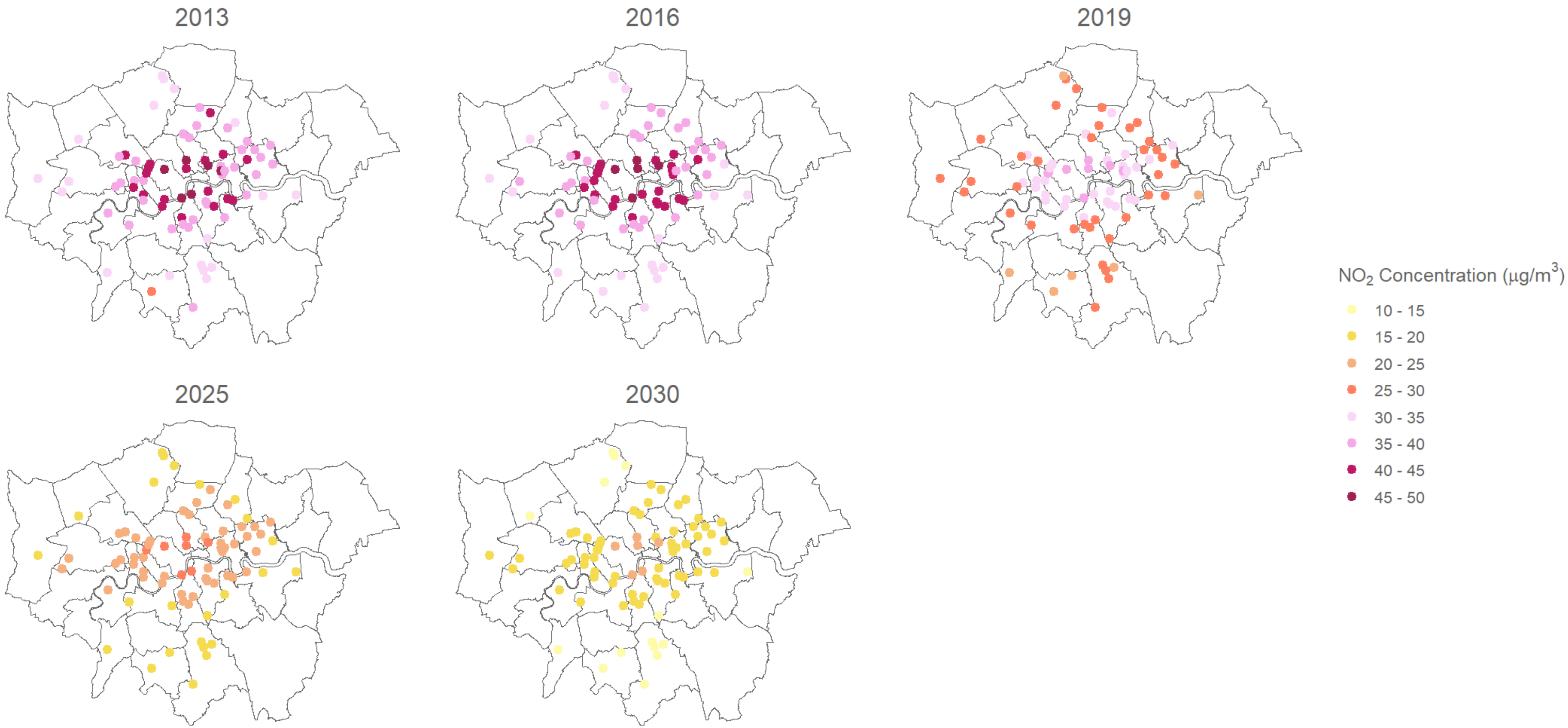
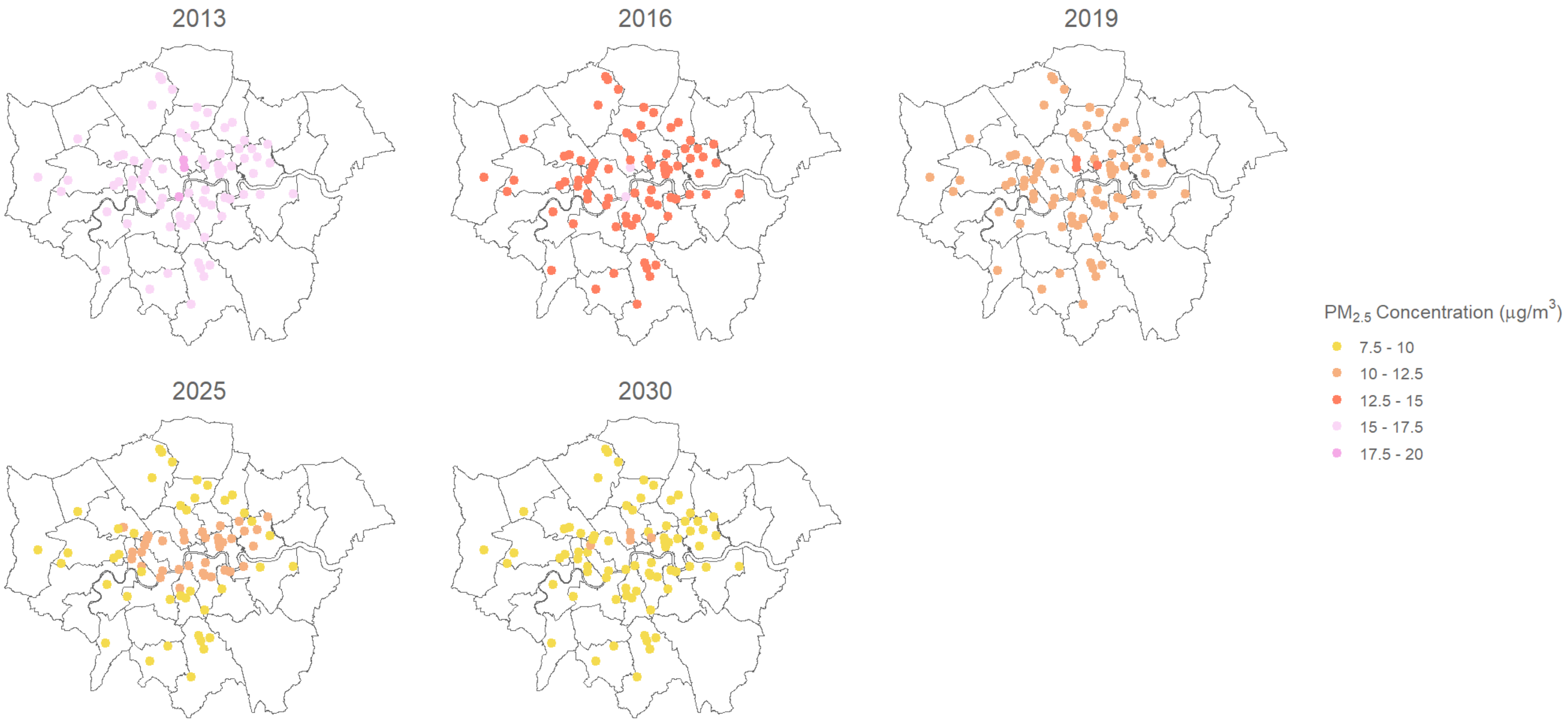


Figure 35 Map showing annual average $PM_{2.5}$ concentrations within 150m of local authority nurseries in London, in 2013 2016, 2019, 2025 and 2030



6.2 Nurseries

All nurseries within London remain exposed to concentrations above the WHO guideline (10 µg/m^3) and this is forecast to remain for all studied years unless further action is taken to reduce concentrations. The trend of increasing concentrations of NO_2 and $PM_{2.5}$ towards the centre of the city and decreasing over time is also seen in local authority nurseries, above in **Figure 34** and **Figure 35**. The number of local authority nurseries analysed is small compared to the total school data set (79 nurseries compared with 2,968 schools analysed in 2013) the range of pollutant concentrations that they are exposed to is compared to the range that all schools are exposed to, as seen in **Figure 32** and **Figure 33.**

Table 16 The range of exposure to pollutant concentrations at schools and local authority nurseries

Institution	Pollutant	Pollutant concentration range (µg/m^3)				
		2013	2016	2019	2025	2030
Schools	NO_2	22.5 - 73.4	23.9 - 62.1	17.7 - 50.7	13.4 - 35.4	10.7 - 27.3
Nurseries	NO_2	29.6 - 49.7	30.4 - 47.9	22.8 - 38.6	16.7 - 27.1	13.1 - 21.9
Schools	$PM_{2.5}$	14.4 - 19.8	11.4 - 17.5	9.1 - 15.2	8.2 - 13.5	7.5 - 12.3
Nurseries	$PM_{2.5}$	15.2 - 17.7	12.5 - 15.3	10 .0- 12.9	9.0 - 11.4	8.2 - 10.4

6.2.1 Schools and Nurseries with Free School Meals

Analysis was also undertaken to assess the relationship between deprivation and air pollution exposure at schools and local authority nurseries, using eligibility for free school meals as a measure of deprivation. In the 2013 report, Analysing Pollution Exposure in London[28], an association was reported between deprivation at schools and air pollution concentrations. This association was based on an analysis of the schools with exposure above and below the annual average NO_2 UK legal limit and the proportion of these that were classed as deprived, based on the level of free school meal eligibility. The previous analysis for the 2013[28] report found that of the primary schools in areas exceeding the legal limit for NO_2, 82% were deprived schools. In contrast, of the primary schools that were not exposed to above UK legal limit concentrations of NO_2, 39% were deprived. This showed a valid association between high air pollution and a measure of deprivation for 2013.

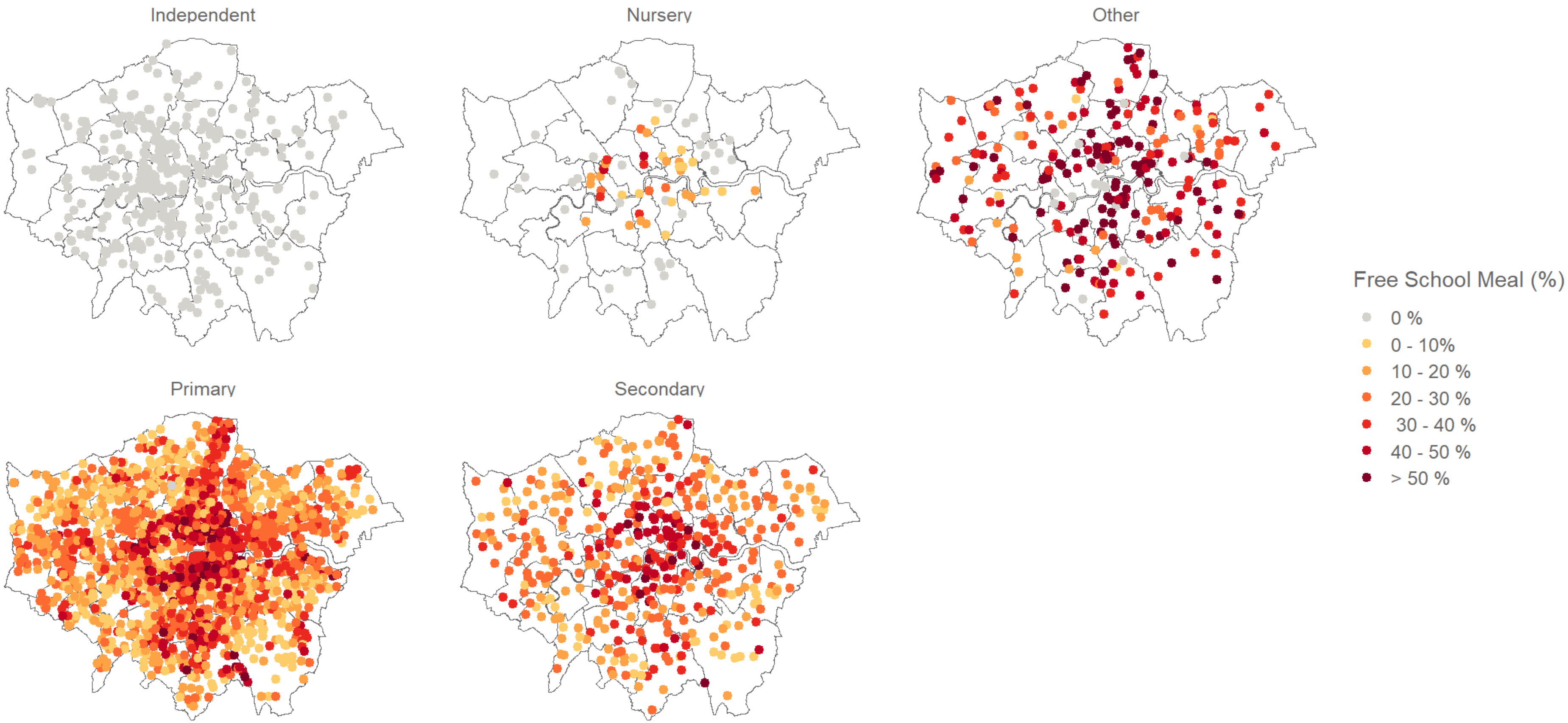
With the 2019 data there is some trend towards greater deprivation (by this measure) towards the centre of London, however, the pattern is somewhat more evenly distributed than that for air pollution, as seen in **Figure 36** also illustrates how the distribution of free school meal eligibility varies by phase of education[29]. Independent (private) schools do not offer free school meals, and therefore are not included in the analysis in on the relationship between percentage of pupils eligible for free school meals and air pollution exposure shown in **Figure 37**. There is a slight positive

28 www.london.gov.uk/sites/default/files/analysing_air_pollution_exposure_in_london_-_technical_report_-_2013.pdf

29 “Other” schools include pupil referral units, foundation special schools, community special schools, city technology colleges, non-maintained special schools, academy special converters, free schools and academy alternative provision schools.

correlation between percentage of free schools meals and the annual air pollutant concentration at the school, which can be more obviously seen, for example, when examining the schools above the UK legal limit (40µg/m^3) for NO_2 in 2013 and 2016. However, in later years for NO_2 and for all years for $PM_{2.5}$, the range of concentrations is limited so that any trend is less defined.

Figure 36 Map showing the distribution pattern for free school meal eligibility at schools across London, by phase of education



Note: "Other" schools include pupil referral units, foundation special schools, community special schools, city technology colleges, non-maintained special schools, academy special converters, free schools and academy alternative provision schools.

Figure 37 Annual average NO2 5 concentrations against % of pupils eligible for free school meal for schools, excluding independent schools (private schools) which do not offer free school meals, for Inner (red) and Outer (blue) London

6.3 Hospitals

Similar analysis was undertaken for hospitals in London as that done for schools**. Figure 38,** below, shows the pattern of annual average concentrations of NO_2 for hospitals in 2013, 2016, 2019, 2025 and 2030. The 2013 map clearly shows that hospitals in central London tend to be exposed to higher concentrations of NO_2 which, given their need to be readily accessible and thus positioned near main roads, is perhaps not surprising. As with earlier analysis, concentrations greatly reduce in future years.

As seen in **Table 17,** below, all hospitals within London remain exposed to concentrations above the WHO guideline (10 µg/m^3) for all studied years. While 100% of hospitals are exposed to concentrations above the WHO interim target (20 µg/m^3) in 2013, this drops to 28% by 2030. The number of hospitals exposed to concentrations above the UK legal limit (40µg/m^3) for NO_2 falls from in 39% 2013 to 0% by 2025.

Table 17 Hospitals within London that are exposed to NO_2 concentrations above the UK legal limit (40 µg/m^3), WHO interim target (20 µg/m^3) and WHO guideline (10 µg/m^3)

NO_2 Concentration	Number of hospitals				
	2013	2016	2019	2025	2030
> 40 µg/m^3 (exceed UK legal limit)	112	114	26	-	-
20 – 40 µg/m^3 (UK legal limit)	172	170	254	164	79
10 - 20 µg/m^3 (WHO interim target)	-	-	4	120	205
< 10 µg/m^3 (meeting WHO guideline)	-	-	-	-	-

Table 18, below, shows that all hospitals within London remain exposed to concentrations above the WHO guideline (5 µg/m^3) for all studied years. In 2013, 100% of hospitals were exposed to $PM_{2.5}$ concentrations above the WHO interim target (10 µg/m^3), this drops to 20% in 2030.

Table 18 Hospitals within London that are exposed to $PM_{2.5}$ concentrations above the WHO interim target (10 µg/m^3) and WHO guideline (5 µg/m^3)

$PM_{2.5}$ Concentration	Number of hospitals				
	2013	2016	2019	2025	2030
> 10 µg/m^3 (above interim target)	284	284	264	118	58
10 - 5 µg/m^3 (WHO interim target)	-	-	20	166	226
< 5 µg/m^3 (meeting WHO guideline)	-	-	-	-	-

6.4 Care Homes

Similar analysis was undertaken for care homes in London as that done for schools. **Figure 39**, below, shows the pattern of annual average concentrations of NO_2 for care homes in 2013, 2016, 2019, 2025 and 2030. The 2013 map clearly shows that care homes in central London tend to be exposed to higher concentrations of NO_2. Note also that there appears to be an area to the west of Central London where there are no care homes. A simple search shows that there are care homes in this area and so there is an apparent gap in the supplied data for care homes west of central London. It is not known at this stage the reason for this gap. Analysis was also undertaken for $PM_{2.5}$, showing a similar, although less distinct, pattern. The results are not included in this report but are available on request from the authors.

As seen in **Table 19,** below, all care homes within London remain exposed to concentrations above the WHO guideline (10 µg/m^3) for all studied years. While 100% of care homes are exposed to concentrations above the WHO interim target (20 µg/m^3) in 2013, this drops to 2% by 2030. The number of care homes exposed to concentrations above the UK legal limit (40µg/m^3) for NO_2 falls from in 16% 2013 to 0% by 2025.

Table 19 Care homes within London that are exposed to NO_2 concentrations above the UK legal limit (40 µg/m^3), WHO interim target (20 µg/m^3) and WHO guideline (10 µg/m^3)

NO_2 Concentration	Number of care homes				
	2013	2016	2019	2025	2030
> 40 µg/m^3 (exceed UK legal limit)	83	78	-	-	-
20 – 40 µg/m^3 (UK legal limit)	442	447	519	158	9
10 - 20 µg/m^3 (WHO interim target)	-	-	6	367	516
< 10 µg/m^3 (meeting WHO guideline)	-	-	-	-	-

Table 20, below, shows that all care homes within London remain exposed to concentrations above the WHO guideline (5 µg/m^3) for all studied years. In 2013, 100% of care homes were exposed to $PM_{2.5}$ concentrations above the WHO interim target (10 µg/m^3), this drops to 1% in 2030.

Table 20 Care homes within London that are exposed to $PM_{2.5}$ concentrations above the WHO interim target (10 µg/m^3) and WHO guideline (5 µg/m^3)

$PM_{2.5}$ Concentration	Number of care homes				
	2013	2016	2019	2025	2030
> 10 µg/m^3 (above interim target)	525	525	465	93	3
10 - 5 µg/m^3 (WHO interim target)	-	-	60	432	522
< 5 µg/m^3 (meeting WHO guideline)	-	-	-	-	-

Figure 38 Map showing annual average NO_2 concentrations within 150m of hospitals in London, in 2013, 2016, 2019, 2025 and 2030

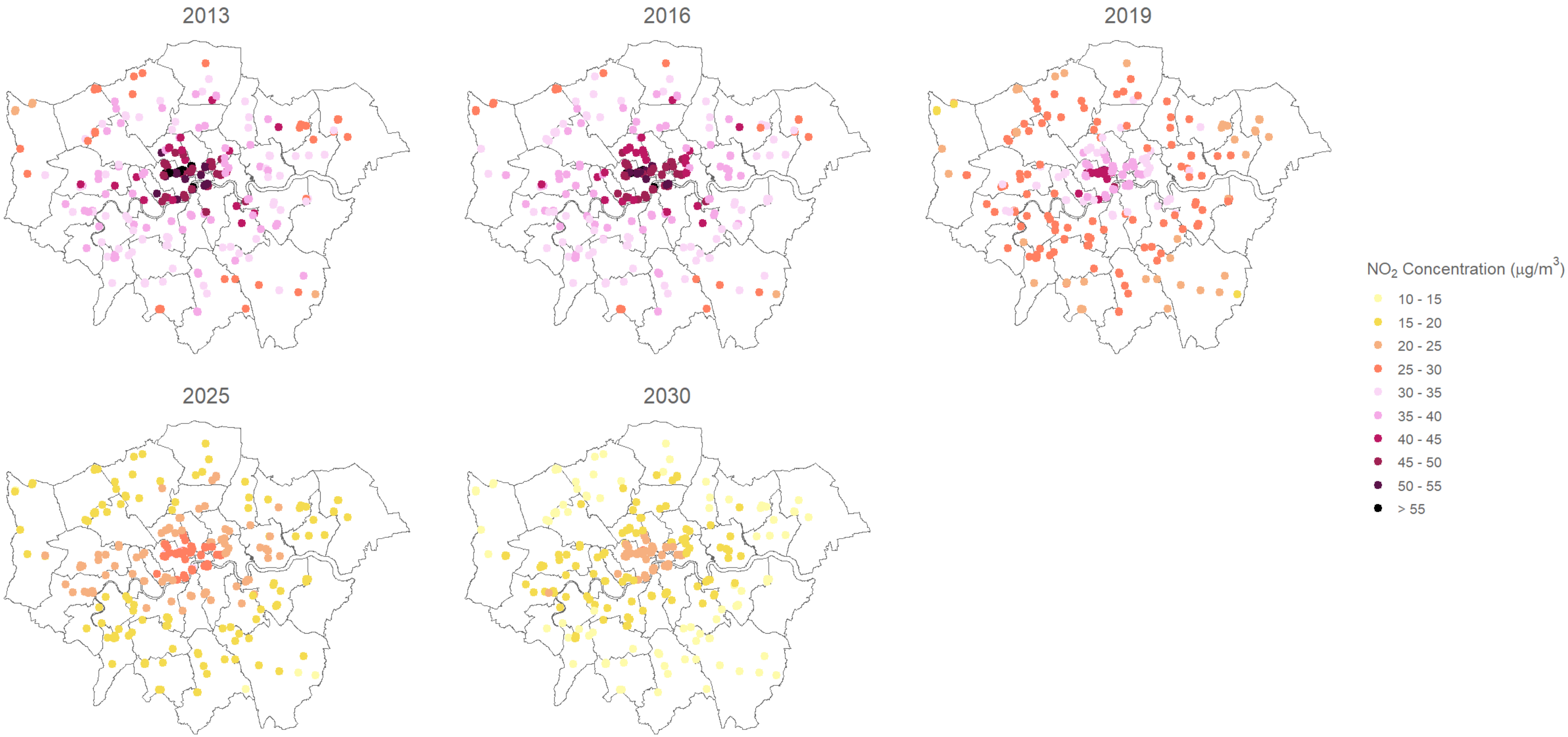
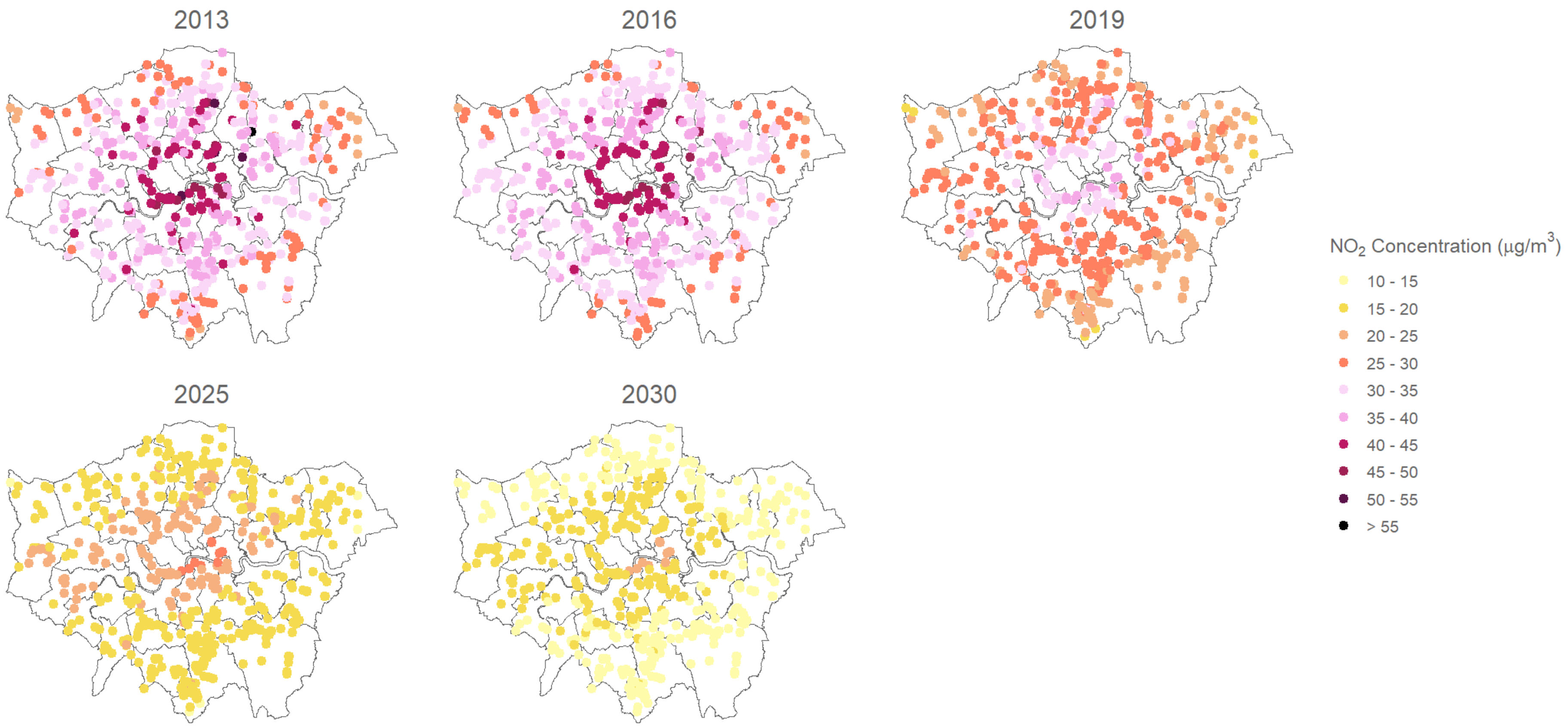


Figure 39 Map showing annual average NO_2 concentrations within 150m of care homes in London, in 2013, 2016, 2019, 2025 and 2030



7 Exposure along red routes

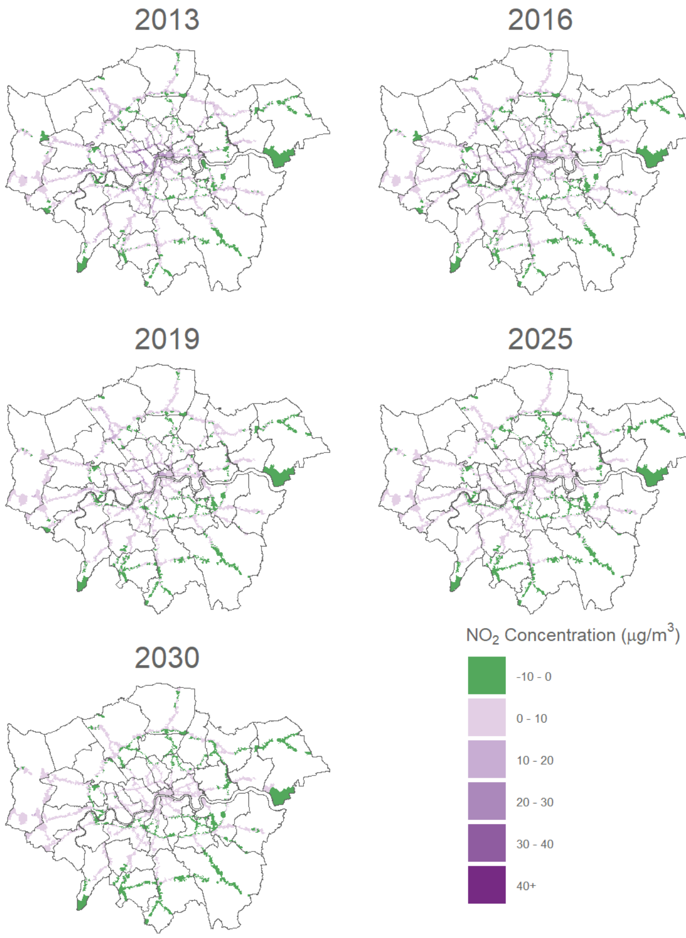
Exposure along red routes: key messages

- All red routes exceed the WHO guidelines for all years studied and the last areas of London to meet the WHO interim targets for NO_2 and $PM_{2.5}$ and WHO guideline for PM_{10} are projected to be the Inner London red routes.
- The average air pollution concentrations are higher along red routes when compared to the Inner and Outer London averages. In 2019, the average NO_2 concentration in Inner and Outer London red route OAs were 12% and 13 % higher than the respective London average. A similar but less pronounced pattern is seen for PM_{10} and $PM_{2.5}$.
- 95% of the population exposed to NO_2 concentrations above the WHO interim target in 2030 are in Inner London, and represent over a third of the Inner London red route population compared to 10% of the Inner London non-red route population.
- Almost the entire (99%) population exposed to concentrations above the $PM_{2.5}$ WHO interim guideline in 2030 are in Inner London or along the North and South Circular (NSC). This represents over a third of the 2030 Inner London red route population, compared to 5% of the Inner London non-red route population.
- No link between deprivation and red routes was identified by this methodology.

Red routes are the network of major roads in London managed by TfL, identified by their red no-stopping lines on the highway and signs along the route. As described in **Section 2.8**, OAs which overlap with red routes were selected for the analysis, and based on the results of a sensitivity analysis, the 5% of red route OAs which stretch furthest from a red route were excluded. The final selection of red route OAs are shown in **Figure 4**.

An initial comparison of the concentrations along red routes is presented in **Figure 40**. OA red routes in Inner London have been compared with the Inner London average annual mean concentration and Outer London OA red routes with the Outer London average. Locations where concentrations which are lower than the average are shown in green, and locations where concentrations which are higher than the London average are shown in purple. Concentrations in red route OAs are higher compared to the respective Inner or Outer London average in all years and there is a similar disparity between red route OAs in Inner and Outer London. In 2019, the average NO_2 concentration in Inner and Outer London red route OAs were 12% and 13% higher than the respective London average. A similar but less pronounced pattern is seen for PM_{10} and $PM_{2.5}$.

Figure 40 Difference in NO_2 concentrations in red route OAs compared to the Inner and Outer London average in 2013, 2016, 2019, 2025 and 2030. The average concentrations are shown in the table below the figure.



Location	Average annual NO_2 concentration ($\mu g/m^3$)				
	2013	2016	2019	2025	2030
Inner London	41.5	41.0	32.0	22.4	17.7
Outer London	32.4	32.8	25.6	18.3	14.3

7.1 Population exposure along red routes

Figure 41, **Figure 42** and **Figure 43** below present the difference in concentration in red route OAs in the context of population exposure for NO_2, PM_{10} and $PM_{2.5}$, respectively. People living on red routes are exposed to concentrations above the WHO guidelines for all years studied and furthermore a higher proportion of the red route population are exposed to higher concentrations compared to non-red route population. For example, in 2019 only 1% of the non-red route population are in a location in exceedance of the NO_2 UK legal limit value (40 $\mu g/m^3$) compared to 10% of the red route population. Whilst exposure to poor air pollution is projected to improve across all locations over the timeseries, the red route OAs are the most likely to remain above the WHO NO_2 and $PM_{2.5}$ interim targets by 2030 and will be the last areas in London to meet them.

In 2030, there is a similar pattern for all pollutants. For NO_2, 19% of the red route community, representing 250,000 people, are still exposed to higher than the WHO interim target in 2030 compared to 4% of the non-red route population. In terms of proportion of the population, the disparity between red routes and non-red route exposure is very similar to the difference in exposure in Inner compared to Outer London populations (see **Section 3.2**).

Figure 41 Proportion of population exposure for NO_2 in 2013, 2016, 2019, 2025 and 2030 in non-red route OAs compared to red route OAs

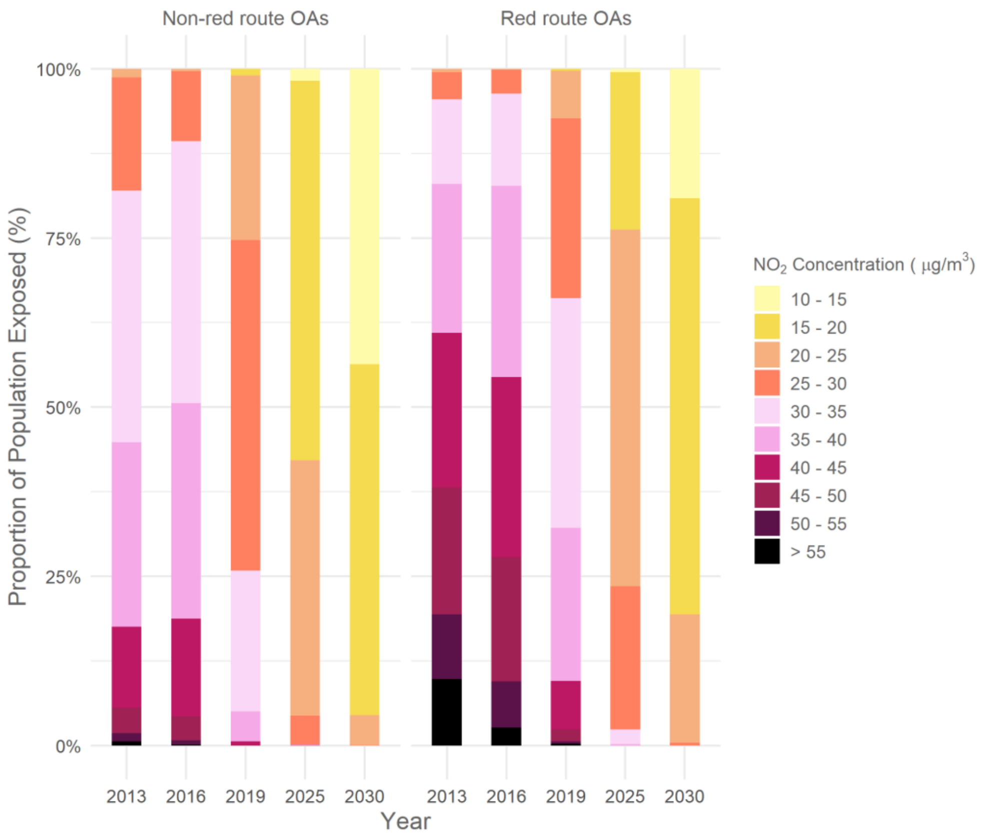


Table 21 Population exposure for NO_2 in 2013, 2016, 2019, 2025 and 2030 in non-red route OAs compared to red route OAs

NO_2 Concentration	OA Location	Population in millions				
		2013	2016	2019	2025	2030
> 40 µg/m^3 (exceed UK legal limit)	Non-red route	1.3 (18 %)	1.4 (19 %)	0.0 (1 %)	0.001 (0 %)	-
	Red route	0.7 (61 %)	0.6 (54 %)	0.1 (10 %)	-	-
20 – 40 µg/m^3 (UK legal limit)	Non-red route	6.0 (82 %)	6.2 (81 %)	7.6 (98 %)	3.4 (42 %)	0.4 (4 %)
	Red route	0.4 (39 %)	0.5 (46 %)	1.1 (90 %)	1.0 (76 %)	0.2 (19 %)
10 - 20 µg/m^3 (WHO interim target)	Non-red route	-	-	0.1 (1 %)	4.6 (58 %)	7.8 (96 %)
	Red route	-	-	0.004 (0 %)	0.3 (24 %)	1.0 (81 %)
< 10 µg/m^3 (meeting WHO guideline)	**Non-red route**	-	-	-	-	-
	Red route	-	-	-	-	-

Figure 42 Proportion of population exposure for PM_{10} in 2013, 2016, 2019, 2025 and 2030 in non-red route OAs compared to red route OAs

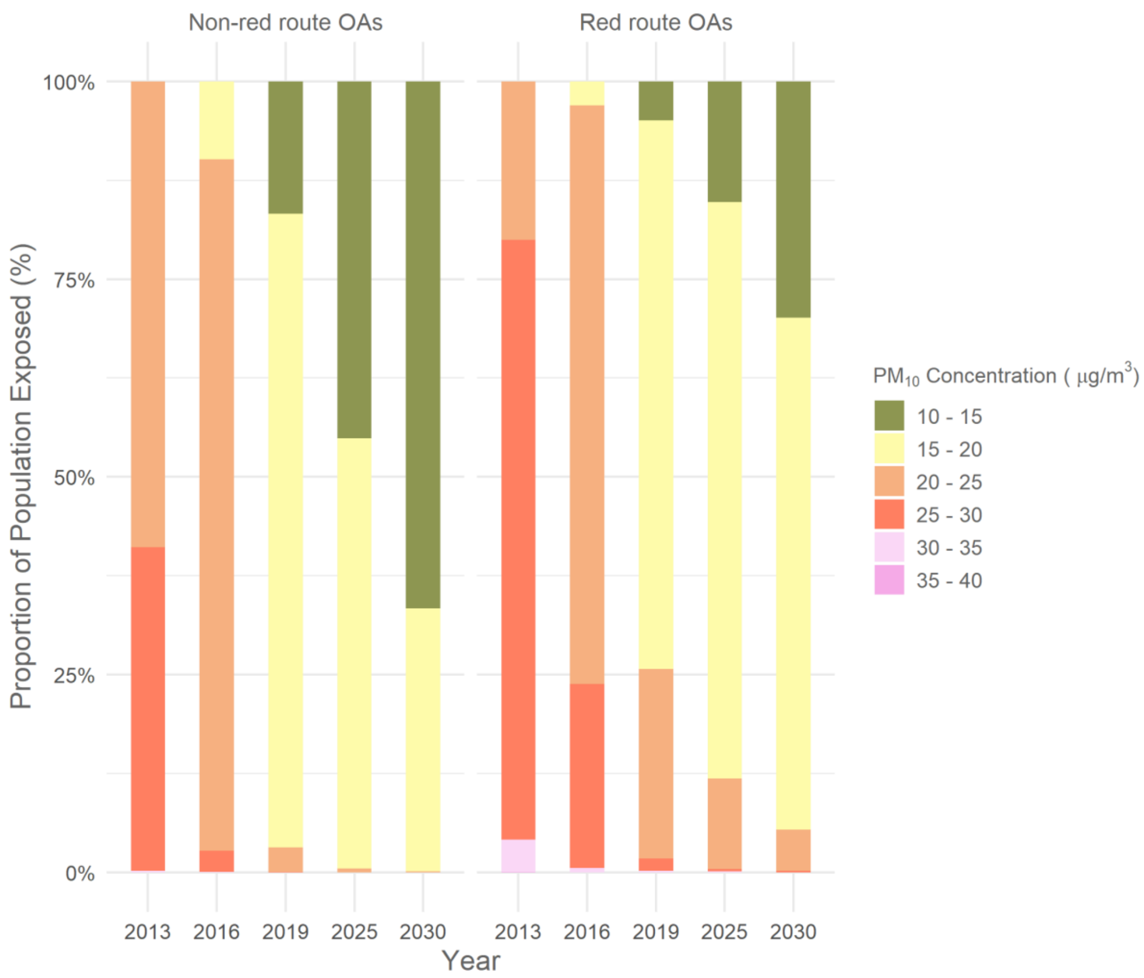


Table 22 Population exposure for PM_{10} in 2013, 2016, 2019, 2025 and 2030 in non-red route OAs compared to red route OAs

PM_{10} Concentration	OA Location	Population in millions				
		2013	2016	2019	2025	2030
> 40 µg/m³ (exceed UK legal limit)	Non-red route	-	-	-	-	-
	Red route	-	-	-	-	-
15 – 40 µg/m³ (UK legal limit)	Non-red route	7.3 (100 %)	7.6 (100 %)	6.4 (83 %)	4.4 (55 %)	2.7 (33 %)
	Red route	1.1 (100 %)	1.2 (100 %)	1.2 (95 %)	1.1 (85 %)	0.9 (70 %)
< 15 µg/m³ (meeting WHO guideline)	**Non-red route**	**-**	**-**	**1.3 (17 %)**	**3.6 (45 %)**	**5.4 (67 %)**
	Red route	**-**	**-**	**0.1 (5 %)**	**0.2 (15 %)**	**0.4 (30 %)**

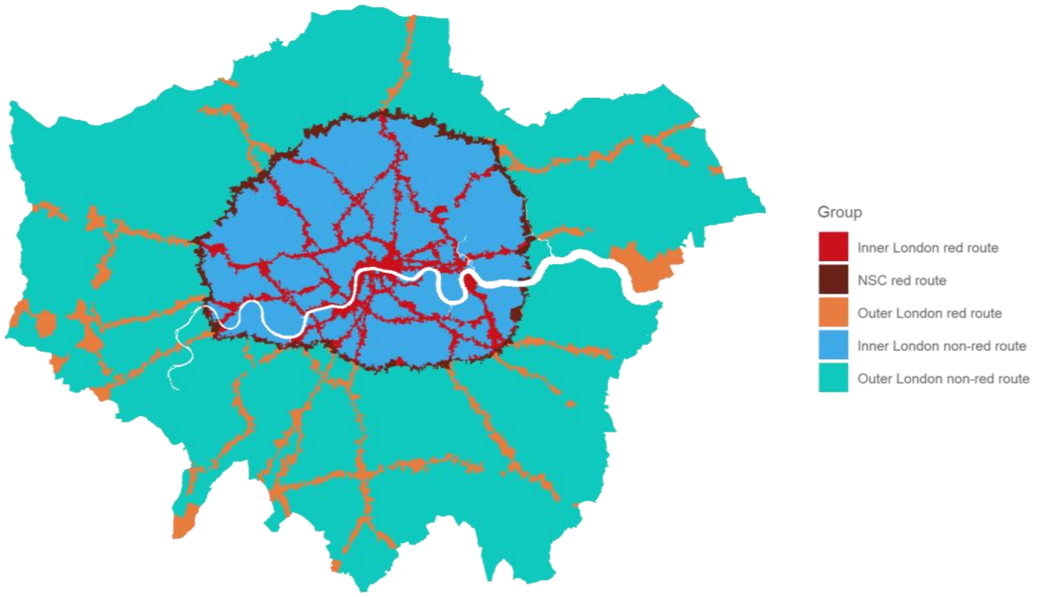
Figure 43 Proportion of population exposure for $PM_{2.5}$ in 2013, 2016, 2019, 2025 and 2030 in non-red route OAs compared to red route OAs

Table 23 Population exposure for $PM_{2.5}$ in 2013, 2016, 2019, 2025 and 2030 in non-red route OAs compared to red route OAs

$PM_{2.5}$ Concentration	OA Location	Population in millions				
		2013	2016	2019	2025	2030
> 10 µg/m³ (above interim target)	Non-red route	7.3 (100 %)	7.6 (100 %)	6.9 (89 %)	1.8 (22 %)	0.2 (2 %)
	Red route	1.1 (100 %)	1.2 (100 %)	1.2 (96 %)	0.7 (59 %)	0.2 (18 %)
< 5 µg/m³ (WHO guideline)	Non-red route	-	-	0.9 (11 %)	6.2 (78 %)	7.9 (98 %)
	Red route	-	-	0.0 (4 %)	0.5 (41 %)	1.0 (82 %)
< 5 µg/m³ (meeting WHO guideline)	**Non-red route**	-	-	-	-	-
	Red route	-	-	-	-	-

The OAs have been allocated to one of five groups to compare the concentrations between red routes and non-red routes and Inner and Outer London (see **Figure 44**).

Figure 44 Red route groups



The average annual mean concentrations for each red route group is presented in **Figure 45**, **Figure 46** and **Figure 47** In these figures the improvement in concentrations for all pollutants between 2013 and 2030 is clear, alongside the variability between each group. The highest concentrations are in Inner London red route OAs and the lowest concentrations in Outer London non-red route OAs. In 2013 and 2016, most of the Inner London red route OAs are in exceedance of the UK NO_2 legal limit, unlike the other groups. However, the red route population represents a relatively small proportion of the total population (see tables above).

The red route OAs account for most of the locations which are still in exceedance of the UK NO_2 legal limit in 2019 and above the WHO NO_2 interim target in 2030. A similar NO_2 concentration distribution is seen for NSC red routes and Inner London non-red route OAs, but by 2030 there is a greater improvement in concentrations along the NSC compared to Inner London.

The trend for NO_2 is reflected for PM_{10} in comparison to the WHO guideline. However, higher PM_{10} concentrations are maintained across the time period in OAs on the NSC compared to Inner London non-red route OAs. For $PM_{2.5}$, the move towards and then below the WHO interim target is clearly visible. As for NO_2, Inner London red route OAs are where the majority of exceedances remain by 2030.

Figure 45 Annual mean concentrations at OA Level for NO₂ by red route group, 2013, 2016, 2019, 2025 and 2030. The dotted red lines represent the WHO guideline, interim target and UK legal limit

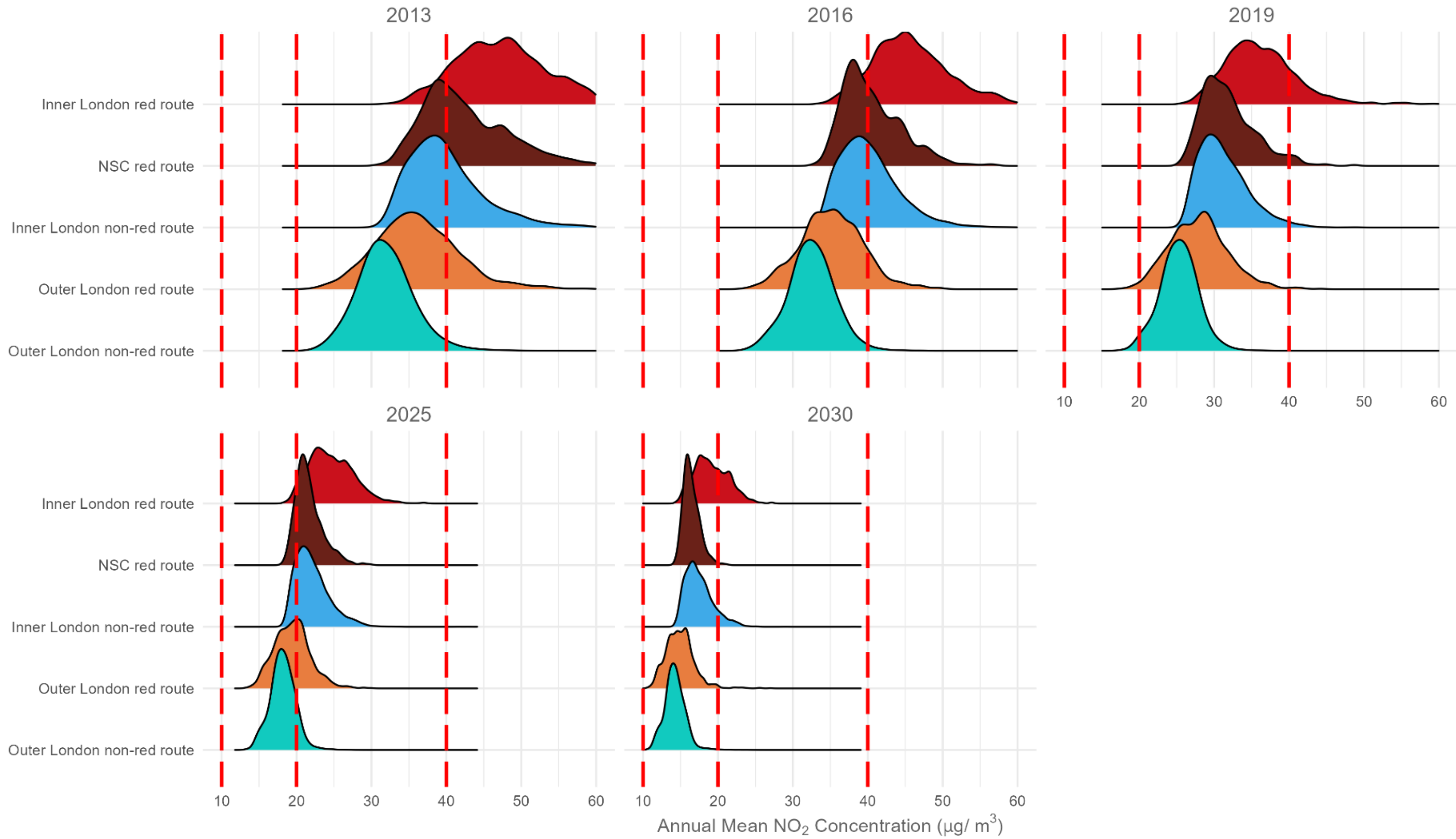


Figure 46 Annual mean concentrations at OA Level for PM_{10} by red route group, 2013, 2016, 2019, 2025 and 2030. The dotted red line represents the WHO guideline.

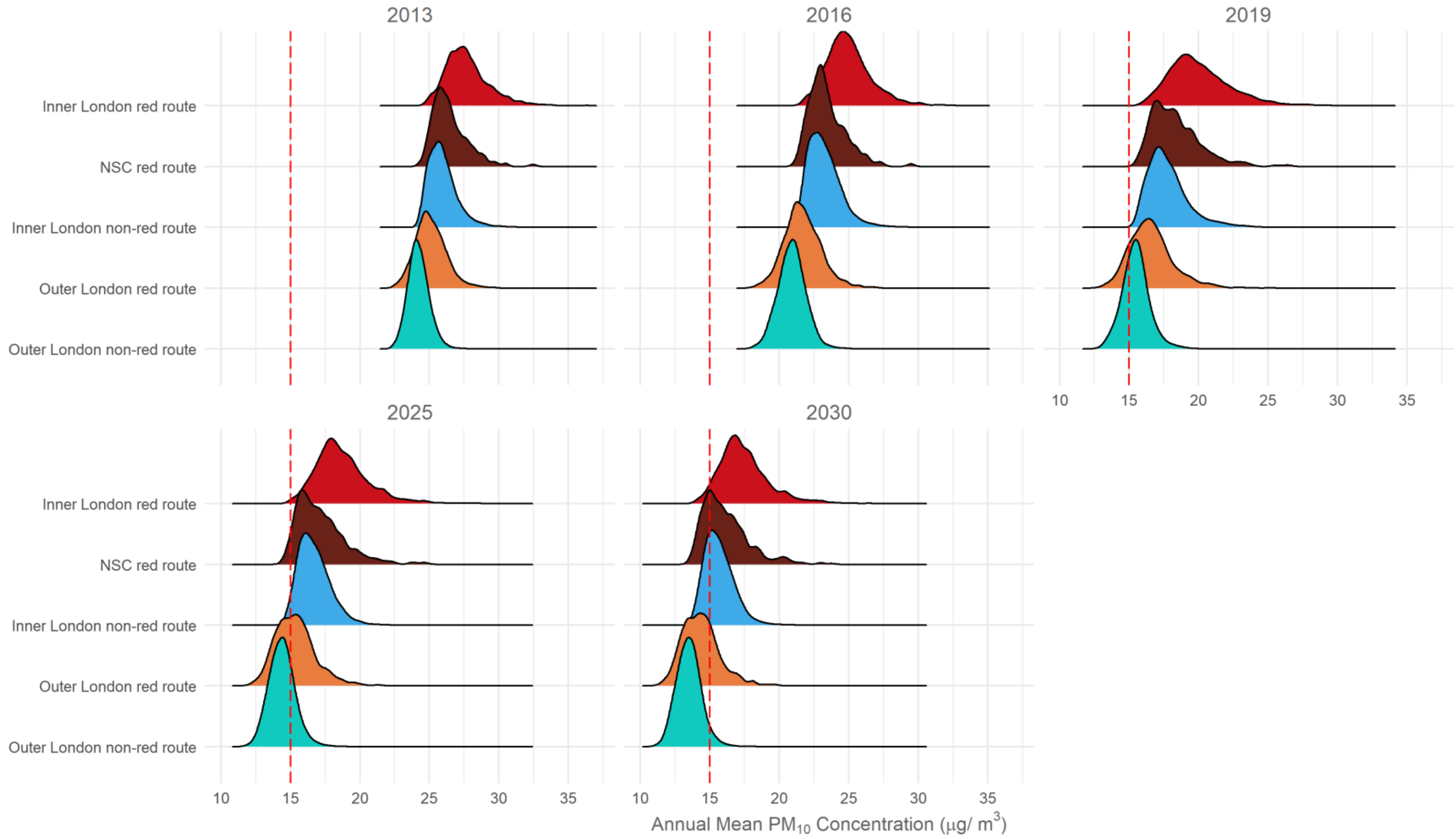
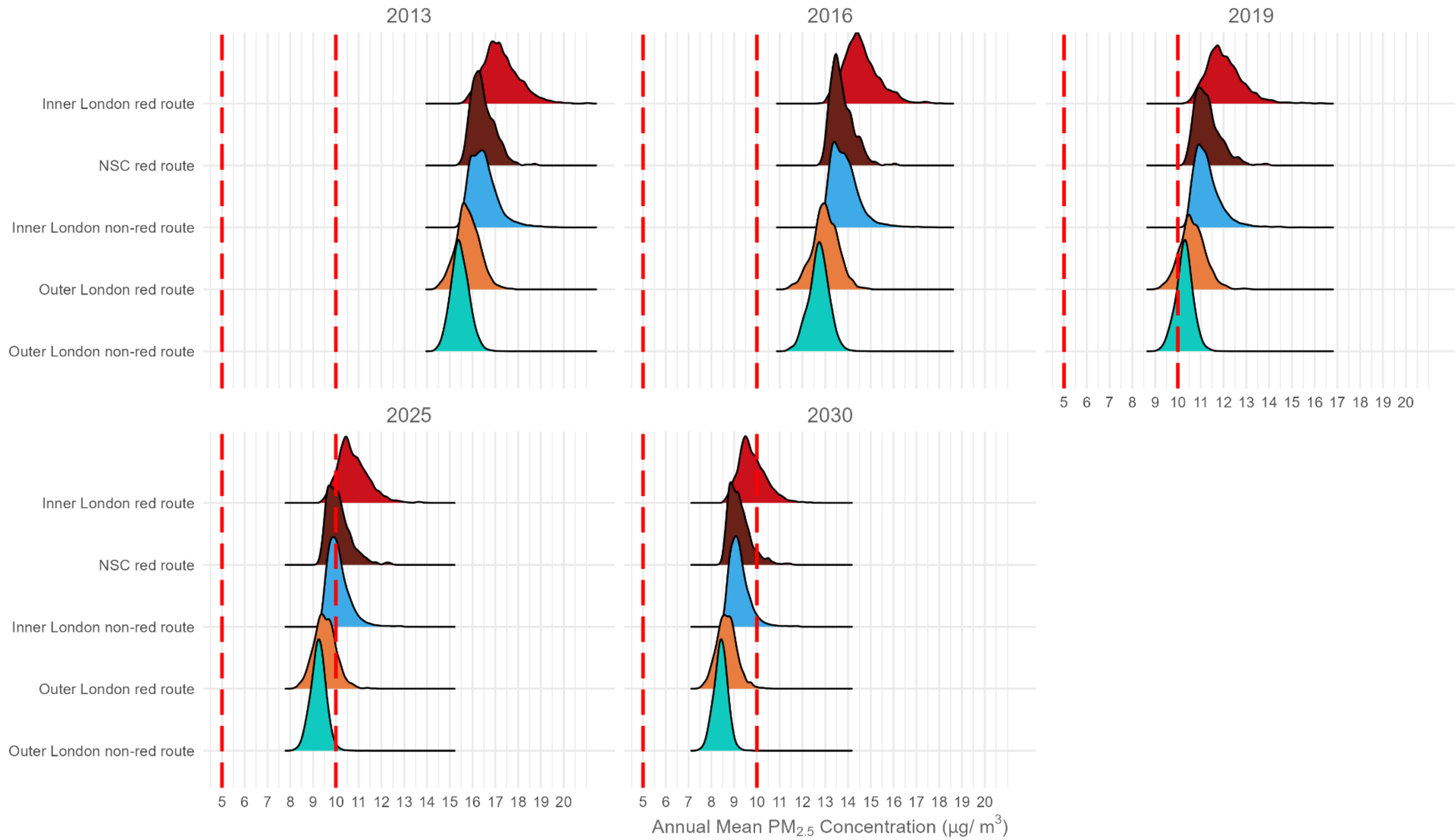


Figure 47 Annual mean concentrations at OA Level for $PM_{2.5}$ by red route group, 2013, 2016, 2019, 2025 and 2030. The dotted red lines represent the WHO guideline and interim target.



7.2 Red routes and deprivation

The red route analysis has been combined with the LSOA deprivation data. The table below shows the proportion of the population in each of the red route groups in the most deprived (IMD deciles 1 – 3) and least deprived (IMD deciles 8 – 10) LSOAs. It should be noted that the red route groups are defined at the OA level and in some cases one LSOA includes multiple red route groups. No clear trend is identified between red routes and higher deprivation with data at this scale. This is expected to be due to the red route OAs only representing a relatively small area.

Table 24 Distribution of the red route group populations within the 30% most and least deprived areas

Red route group	Proportion population in 30% most deprived areas	Proportion of population in 30% least deprived areas
Inner London non-red route	42%	18%
Inner London red route	45%	18%
NSC red route	36%	25%
Outer London non-red route	22%	39%
Outer London red route	19%	41%

8 Conclusions

This report of exposure to air pollution and consideration of inequalities in London builds upon previous analysis. An assessment of exposure among diaspora and red route communities has been included for the first time. The analysis has been undertaken for exposure to NO_2, PM_{10} and $PM_{2.5}$ in the general exposure and red routes sections, and for NO_2 and $PM_{2.5}$ in the deprivation, ethnicity, diaspora and vulnerable receptor sections. The projected reductions in concentrations in 2025 and 2030 reflect the expected improvements in air quality resulting from the continued uptake of electric vehicles, improving Euro emissions standard engines for new vehicles, tightening regulations such as the NRMM LEZ and the ULEZ and its expansion to Inner London in 2021. The projections do not include the expected impact of the expansion of the ULEZ London-wide in 2023.

The current UK legal limits and World Health Organization (WHO) guidelines and interim targets for NO_2 and $PM_{2.5}$ formed the basis of the assessment. The stringent concentration guidelines recommended by the WHO reflect the growing health evidence about the adverse health effects of air pollution, including at low concentrations. The new WHO air quality guidelines reflect the best available health evidence and WHO's recommendations continue to be recognised globally as the targets that should be met to protect public health.

The average concentration in London for NO_2, PM_{10} and $PM_{2.5}$ is projected to approximately halve between 2013 and 2030. This improvement in air pollutant concentrations means that by 2030, almost the whole population of London will be exposed to concentrations below the NO_2 and $PM_{2.5}$ WHO interim target. However, no areas of London currently meet the WHO guidelines for these pollutants, and no areas of London are projected to meet the WHO guidelines by 2030. For PM_{10}, over half the population of London is expected to be exposed to concentrations below the PM_{10} WHO guideline by 2030. Exposure to poor air quality remains higher in Inner London compared to Outer London across the time period, with only 1% (30,000 people) predicted to be still exposed to NO_2 concentrations above the WHO interim target in 2030, compared to 14% (600,000 people) in Inner London. Approximately 95% of the population exposed to concentrations above the NO_2 and $PM_{2.5}$ WHO interim targets in 2030 are in Inner London.

The 10% most deprived areas (LSOAs) are disproportionately represented in the highest pollution concentration areas, and as deprivation decreases, representation in the highest concentration areas decreases as well. Very similar results are observed across Inner and Outer London, and for NO_2 and $PM_{2.5}$ in this respect. There has not been much change in this measure from 2013 up to 2019, with a small fall in percentage in the most deprived decile seen in the highest concentration areas in 2019 (3 percentage points), and a corresponding increase in the least deprived decile (2 percentage points). The most deprived deciles saw decreases in NO_2 and $PM_{2.5}$ concentrations of 24% and 32% respectively and the least deprived 19% and 33%, between 2013 and 2019. One exception to the trend of higher concentrations in higher deprivation areas on average is that concentrations on the whole are higher in middle IMD deciles than in the highest deprivation deciles in Outer London. There is not much change in the distribution of concentrations across deprivation levels projected up to 2030, indicating more work needs to be done to tackle inequalities in air pollution and deprivation.

The areas in London with the lowest air pollution concentrations in terms of NO_2 and $PM_{2.5}$ have a disproportionately white population. This inequality has reduced a little between 2013 and 2019, with for example the 10% of OAs with lowest concentration going from 80% to 71% white, while the percentage of London that is white went from 60% to 54%, but is not expected to reduce much further by 2030, without further action. The difference is much more pronounced in Outer London than Inner. In Outer London, the lowest concentration decile in terms of NO_2 is 71% white, whereas in Inner London, the lowest concentration decile with any OAs at all in Inner London is 56% white. White and Asian populations are underrepresented in the most polluted areas in comparison to in the general population, whereas Black, Mixed Multiple and Other populations are overrepresented, and there is little discernible change observed over time. The half of OAs with higher concentrations generally have a fairly representative spread of the population by ethnicity.

The diaspora groups with the highest levels of exposure to NO_2 and $PM_{2.5}$ are North America, Middle East and Eastern Asia. Although there have been improvements in air quality for all groups, the distribution has changed very little from 2013 to 2019, and similar trends are expected to continue up to 2030. There is variation in exposure between diaspora communities that have largely remained consistent over time. The average diaspora community is located in an OA with NO_2 concentration levels of 30.7µg/m^3 (London average is 28.4µg/m^3) and $PM_{2.5}$ levels of 11.2µg/m^3 (London average 10.8µg/m^3) in 2019. The figures for 2013 are 39.8µg/m^3 (36.4µg/m^3) and 16.4µg/m^3 (16µg/m^3), where the London averages are in brackets. The figures for 2030 are 17µg/m^3 (15.8µg/m^3) and 9.1µg/m^3 (8.8µg/m^3), so the overall trend is not expected to change without further work.

For all years analysed between 2013 and 2030, all schools remain exposed to concentrations of NO_2 and $PM_{2.5}$ above the annual mean WHO guideline annual mean. However, concentrations reduce considerably over time. For NO_2, in 2013, 100% of schools were exposed to concentrations above the WHO interim target, dropping to 7% in 2030. For $PM_{2.5}$ the percentage of schools exposed drops from 100% to 5% over the same time period. Schools in Inner London are on average exposed to higher concentrations of air pollution compared with schools in Outer London and this remains consistent over time.

There is a weak correlation between higher levels of exposure to air pollution at schools and increasing percentage of pupils eligible for free school meals. This relationship weakens over time as the range of air pollutant concentrations that schools are exposed to decreases. However, over time, schools in Inner London remain exposed to higher concentrations on average compared with schools in Outer London. The trend of increasing concentrations of NO_2 and $PM_{2.5}$ towards the centre of the city and decreasing over time is also reflected in hospital and care home data.

The average air pollution concentrations are higher along red route OAs when compared to the respective Inner or Outer London average. Red route OAs were grouped as either being within Inner London, along the NSC or in Outer London to enable a more detailed analysis. The last areas of London to meet the WHO interim targets for NO_2 and $PM_{2.5}$ and WHO guideline for PM_{10} are projected to be the Inner London red routes. As concentrations improve over time, the differences in exposure in the different red route OA groups reduces in comparison to the WHO guidelines. However, clear differences in the exposure of the different red route OA groups remain. The population that is still exposed to concentrations above the NO_2 WHO interim target in 2030 represents over a third of the Inner London red route population, compared to 10% of the Inner London non-red route population. Similar results are seen for $PM_{2.5}$, with a third of the Inner London red route population, compared to 5% of the Inner London non-red route population exposure to concentrations above the $PM_{2.5}$ WHO interim target in 2030.

Overall, whilst the current and projected improvement in air quality across London benefit everyone, clear inequalities in exposure to poor air quality remain. The most deprived areas of London are overrepresented in the highest pollutant concentration areas. The areas in London with the lowest NO_2 and $PM_{2.5}$ concentrations have a disproportionately white population, and the average diaspora community lives in an area with higher concentrations of pollutants than the London average. Despite clear progress towards meeting the interim targets, none of these statements are expected to change over time without further action. For all years analysed between 2013 and 2030, all schools, hospitals and care homes remain exposed to concentrations of NO_2 and $PM_{2.5}$ above the WHO guideline annual mean. Whilst the majority of London is projected to be exposed to NO_2 and $PM_{2.5}$ concentrations below the WHO interim targets, communities living along red routes in Inner London are much more likely to still be exposed to concentrations above the WHO interim targets in 2030. Further policy developments, such as the expansion of the ULEZ to be London-wide may lead to greater reductions in air quality and reduce inequalities in exposure.

Appendix 1 Comparison with previous analysis

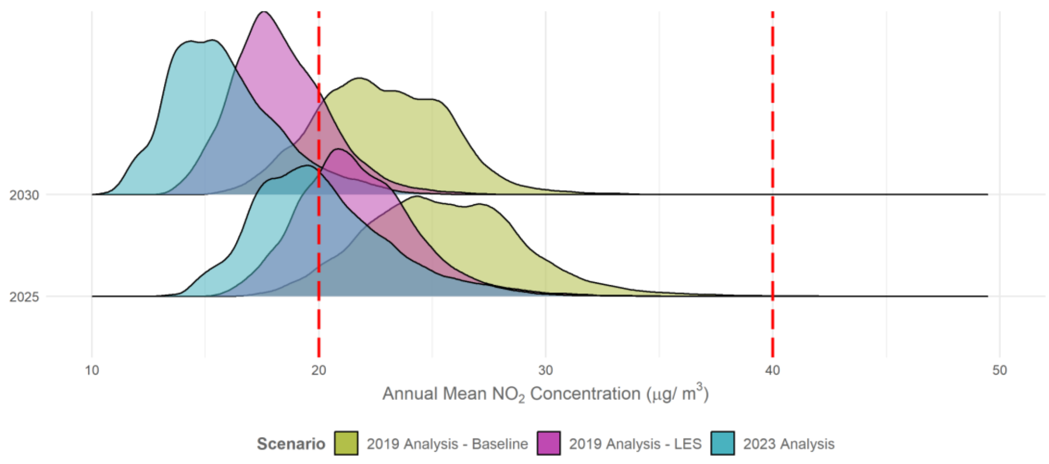
8.1.1 A.1 Air quality concentrations

Figure A.1 below demonstrates the difference in projected NO_2 concentrations in 2025 and 2030 used in this analysis (2023 Analysis) and the analysis undertaken in 2019 Aether (2019 analysis). In the 2019 analysis, two scenarios were included, a baseline and a scenario with the low emissions strategy (LES). The projected concentrations used in this 2023 analysis are lower than both the baseline and LES scenarios included in the 2019 analysis for both 2025 and 2030. Therefore, the differences in exposure discussed are expected to be smaller compared to the previous 2019 analysis. The reasons for the difference in projected concentrations in the 2019 analysis compared to the 2023 analysis presented in this report are discussed below.

In October 2020, City Hall published an initial assessment of London's air quality in 2019. The modelling for this was undertaken by King's College London and was based on the LAEI 2016, alongside a new Mayor's Evaluation Report snapshot model for 2019 (MER2019). It is important to note that the MER2019 was not a full LAEI model, but rather a snapshot, since, due to the time required to compile the input datasets, the full data for the LAEI 2019 was not yet available. This meant that some input data for MER2019 had been scaled from previous years. In addition, some of the monitoring data against which the MER2019 was validated was still provisional at the time. As a result, greater uncertainty was associated to the MER2019 results compared to typical LAEI modelling results.

With the updated LAEI 2019, we now have a more complete understanding of emissions and concentrations for 2019. Therefore, whilst the MER2019 and LAEI 2019 analysis are very similar, there have been some minor changes in results. For example, the number of state primary and secondary schools that are located in areas exceeding legal pollution limits is now estimated to be 20 rather than 14. Nonetheless the scale of improvement – a 96% reduction from 450 schools in 2016 – remains significant.

Figure A.48 Comparison of the distribution of NO_2 concentrations in 2025 (bottom) and 2030 (top) of the 2023 analysis presented here compared to the 2019 analysis. LES = Low emissions strategy.



8.1.2 A.2 Air pollution exposure and deprivation

Table A.1 below compares the difference in average concentrations in the year 2019 by IMD decile in this analysis (current 2023 analysis) and the previous analysis undertaken by AQC in 2021[30]. The air pollutant concentrations in this analysis are lower across the deciles. For NO_2 there is a larger spread for the 2023 analysis than in the previous 2021 analysis, with a greater decrease in concentrations for less deprived deciles.

Table A.1 Exposure in 2019 by deprivation decile in the current analysis presented in this report compared with the previous analysis undertaken by AQC in 2021

Pollutant	IMD decile (µg/m³)										Increment, lowest to highest (µg/m³)
	1	2	3	4	5	6	7	8	9	10	
Previous analysis (2021)											
NO_2	30.3	30.1	29.9	30.1	29.6	29.2	29.0	28.4	28.0	26.5	3.8
$PM_{2.5}$	12.1	12.0	12.0	12.0	11.9	11.8	11.8	11.7	11.6	11.4	0.7
Current analysis (2023)											
NO_2	29.7	29.5	29.1	29.3	28.8	28.3	28.1	27.5	27.0	25.3	4.4
$PM_{2.5}$	11.0	11.0	10.9	10.9	10.9	10.8	10.7	10.7	10.6	10.3	0.7

[30] https://www.london.gov.uk/programmes-and-strategies/environment-and-climate-change/environment-publications/air-pollution-and-inequalities-london-2019

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