Institute for Fiscal Studies

IFS Report

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Exposure to air pollution in England, 2003–23

Economic and Social Research Council

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Copy-edited by Judith Payne

Published by **The Institute for Fiscal Studies**

ISBN 978-1-80103-208-7

The authors gratefully acknowledge the support of the ESRC Centre for the Microeconomic Analysis of Public Policy (grant ES/T014334/1) and ESRC grant ES/Y002563/1.

Key findings

1. **Across people living in England, average exposure to fine particulate matter ($PM_{2.5}$) – the most harmful air pollutant, largely arising from transport, domestic woodburning and industrial emissions – fell by 54% between 2003 and 2023.**

2. **Almost everywhere in England is now below England's 2040 target for $PM_{2.5}$, but still falling short of the World Health Organisation's recommended limit.** The share of the English population exposed to levels of $PM_{2.5}$ above England's 2040 target fell from 99% in 2003 to less than 0.1% in 2023. However, 96% of people still live in areas above the WHO's more stringent recommended limit.

3. **Levels of $PM_{2.5}$ fell dramatically during the COVID-19 pandemic and have remained at these lower levels since.** Two-fifths of the decrease in $PM_{2.5}$ exposure over the last two decades occurred in 2020.

4. **Lower-income areas have persistently higher levels of air pollution than richer areas.** In 2023, individuals in the top 20% most deprived areas experienced 8% higher average $PM_{2.5}$ concentrations than those in the bottom 20%. There is no clear trend in this gap over the last two decades.

5. **Ethnic minorities were exposed to levels of air pollution 6% higher than average levels for white populations in 2023, down from 13% in 2003.** This fall in the 'ethnic pollution gap' was initially down to ethnic minorities moving to less polluted parts of the country (e.g. moving out of London to a smaller city). Since 2019, however, areas with large ethnic minority populations (namely London and the Midlands) have experienced substantial decreases in air pollution, further shrinking the gap.

1. Introduction

The harmful effects of air pollution on health are increasingly well known. Broadly, air pollution has been shown to damage many aspects of health, particularly for the elderly and young children (see Box 1). The World Health Organisation (WHO) has repeatedly lowered its recommended upper limit for concentrations of air pollutants as understanding develops (World Health Organisation, 2021). Moreover, more attention is being paid to how air pollution can coincide with and exacerbate existing inequalities, such as income and ethnic inequalities. This comes alongside increasing attention on climate policies to reduce greenhouse gas emissions. Such policies often also result in a reduction in local air pollution, making air pollution reduction a potential co-benefit of reaching net zero.

This report documents how local air pollution has changed across England over the last two decades, both geographically and across different income, age and ethnic groups. We study fine particulate matter ($PM_{2.5}$), which is the air pollutant most strongly associated with negative health impacts. The three largest sources of $PM_{2.5}$ in the UK are domestic burning of wood and other fuels (29.0% of total $PM_{2.5}$ emissions in 2022), road transport (17.9% of total $PM_{2.5}$ emissions in 2022) – predominantly exhaust pipe fumes – and industrial processes (16.5% of total $PM_{2.5}$ emissions in 2022) such as construction and steel manufacturing (Department for Environment, Food and Rural Affairs, 2024).

Box 1. The cost of air pollution

Based on epidemiological evidence, the World Health Organisation considers $PM_{2.5}$ as the most damaging air pollutant. $PM_{2.5}$ is made of tiny particles which can easily penetrate deep into the respiratory tract, pass into the bloodstream and enter the brain. These physiological pathways explain why $PM_{2.5}$ exposure is linked to an increase in respiratory and cardiovascular diseases, and to cognitive damage (Brook et al., 2010, Liu et al., 2017, Costa et al., 2019).

Both short-term exposure – over the course of a few hours to a few weeks – and long-term exposure – over the course of a few years to a lifetime – matter for health. Short-term exposure has been causally linked with increased emergency hospitalisations for cardiovascular and respiratory issues and with increased mortality. Long-term exposure has been associated with increased mortality from all causes, cardiovascular disease, respiratory disease and lung cancer. One study suggests that, in 2019, $PM_{2.5}$ exposure was associated with over 300,000 premature deaths in Europe (European Environment Agency, 2021), more than a third of the level of premature deaths caused by smoking (780,000; Institute for Health Metrics and Evaluation, 2021).

Children and the elderly are particularly at risk, with recent research establishing a causal link between pollution exposure in early life and asthma during childhood (Alexander and Schwandt, 2022; Klauber et al., 2024) and between exposure in old age and dementia (Bishop, Ketcham and Kuminoff, 2023) even at relatively low levels of air pollution.

Deryugina et al. (2019) study US data and find that an increase in $PM_{2.5}$ exposure caused higher levels of premature deaths and hospitalisations. If the same magnitude of effect were to hold in England, it would imply that a 1µg/m^3 increase in annual $PM_{2.5}$ exposure would lead to 3,400 more premature deaths and 8,800 inpatient hospitalisations among the 65+ population, with significant costs both in direct healthcare spending and in broader social costs. These estimates only account for the morbidity and mortality effects of pollution exposure in the very short term, within three days of exposure. Alexander and Schwandt (2022) find a causal effect on hospital admissions for children under 5. Again, if the same magnitude of effect holds in England, this would imply that a 1µg/m^3 increase in annual $PM_{2.5}$ exposure would lead to 5,250 asthma-related hospital admissions among children under 5. The estimates account for the effect of pollution exposure in the short term only, within three months of exposure.

2. Data and measurement

We use data produced by the Department for Environment, Food and Rural Affairs (DEFRA) on annual $PM_{2.5}$ concentrations, measured in $\mu g/m^3$ (micrograms per cubic metre) at the $1km^2$ grid level for the period 2003 to 2023. This is modelled ground-level air pollution data, meaning that DEFRA uses local air pollution measurements from pollution monitors, information on sources of air pollution (mostly industrial sites and traffic data), local geography and weather patterns, and a model of air pollution dispersion to produce estimates of local air pollution. To measure household characteristics, we use data from the 2001, 2011 and 2021 Censuses for England. We use the lowest level of geography at which key local characteristics can be measured – the lower layer super output area (LSOA). The geographic size of an LSOA varies with population density, but they are relatively small, comprising between 400 and 1,200 households. We restrict our analysis to England only.

We define an individual's $PM_{2.5}$ exposure as the average annual level of $PM_{2.5}$ in the LSOA where they live. This is an imperfect measure of an individual's true exposure for two reasons. First, they may work in or travel through areas with significantly higher or lower levels of air pollution, thus changing their overall exposure level. Second, their home may have particularly high or low levels of $PM_{2.5}$ relative to the rest of their LSOA. For example, if they use a wood burner in their home, this may increase their exposure to $PM_{2.5}$ in a way our data will not be able to pick up.

The income deprivation rank we use is produced by the Ministry of Housing, Communities and Local Government and includes information about, among other variables, income, employment and education. We use the share of the non-white population in the Census as our measure of the share of ethnic minorities at the LSOA level and also present results for more disaggregated ethnic minority groups.

Most of our results below consider the average exposure to $PM_{2.5}$ within groups. We create these averages by taking the average exposure (as defined above) of each individual within the respective group and averaging over these.

Effects of air pollution may be non-linear, with worse effects at high levels of exposure. Health authorities set maximal levels of permissible, or 'acceptable', $PM_{2.5}$ exposure (discussed further in Box 2). We therefore also consider the share of the population whose exposures is above $10\mu g/m^3$.

The threshold of 10µg/m^3 is the current annual mean concentration target for England. This threshold was introduced in 2023 and the target is to meet it in all areas of England by 2040. This level also used to be the WHO's recommended limit before it was lowered to 5µg/m^3 in 2021. The limits for the different nations in the UK, the EU and WHO, as well as an overview of air pollution policy since 2000, are discussed in Box 2.

Box 2. Regulatory thresholds and air pollution policies since 2000

UK policy on air pollution has strengthened substantially since 2000, often led by EU directives. Policy takes the form of direct legislation on the level of ambient air pollution, as well as legislation on the sources of air pollution, such as transport and industrial emissions.

Regulation of ambient air pollution, since 1995, has taken the form of legally binding limits for concentrations of major air pollutants at the annual level, as well as a short-term limit. In 2000, PM_{10} (particulate matter larger than $PM_{2.5}$) had a 24-hour mean limit of 50µg/m^3 not to be exceeded more than 35 times per year, and an annual mean limit of 40µg/m^3. An explicit limit for $PM_{2.5}$ was not introduced until 2008, initially set at an annual limit of 25µg/m^3 (with a lower target of 12µg/m^3 for Scotland) to be achieved by 2020, although EU legislation required that this limit be met by 2015. The UK's $PM_{2.5}$ limit is now an annual mean of 20µg/m^3, Scotland's limit is 10µg/m^3 and England has a target of 10µg/m^3 for 2040.

These ambient concentration limits impose legal thresholds. If an area is found to be above these limits as defined by having at least one monitoring station reporting concentrations above the limits, or expected to exceed these limits, the local authority must create a plan for how it is going to improve air quality to meet the limits.

The current legal limit and the 2040 target are both higher than the WHO's guidelines. In 2005, the WHO recommended an annual mean limit of 10µg/m^3. In 2021, the WHO revised its recommended limit downwards to 5µg/m^3 in response to the growing evidence of harmful effects of air pollution even at relatively low levels.

Air pollution policy also includes sectoral emissions regulation – imposing regulations on the main sources of air pollution. The three most important sources of air pollution in the UK are industrial emissions, transport emissions and domestic heating.

Industrial emissions were regulated by the Large Combustion Plants Directive, introduced in 2001, and then the Industrial Emissions Directive, introduced in 2010. These directives impose regulations on emissions of key pollutants from certain industrial plants such as power-generating plants and steelworks.

Transport emissions are regulated by ‘Euro’ standards, requiring new cars to meet certain emissions standards which are routinely made more stringent by the European Union. Other transport emissions policies during most of the period are largely confined to London’s transport policies (Congestion Charge Zone, Low Emission Zone, Ultra Low Emission Zone). ‘Clean air zones’ – areas that impose a fine or ban driving vehicles not meeting a certain Euro standard – have become much more widespread across the UK since 2020, and are now in place in eight cities including London.

Domestic heating is regulated by ‘smoke control areas’. Within these areas, which cover most large cities, fuels can only be burned in DEFRA-approved devices or, if not DEFRA-approved, only certain fuels can be burned. There has been a tightening of the regulations on the types of fuels and devices permitted in smoke control areas over the period. It is the local authority’s decision whether or not to declare a smoke control area. Most of the areas were established between 1956 and 1973, but some new or expanded smoke control areas have been announced in recent years.

3. Air pollution over time

The average level of air pollution exposure faced by an English resident has fallen significantly since 2003. Figure 1 displays the annual average $PM_{2.5}$ exposure, defined as a population-weighted average across small areas' (LSOAs') annual average. The dashed line indicates the 10μg/m^3 threshold (England's 2040 target). Figure 2 shows the share of the English population exposed to pollution levels above that threshold.

Both graphs show a large decrease in exposure to fine particulate pollution over the period, from a mean of roughly 15μg/m^3 in 2003 to under 7μg/m^3 in 2023. The share of the population facing $PM_{2.5}$ levels above 10μg/m^3 goes from close to 100% to 0%.[1] Progress is non-linear, with a sharp decrease in the 2003–07 period, followed by a period of slight increase until 2014, and a significant decrease in 2020.

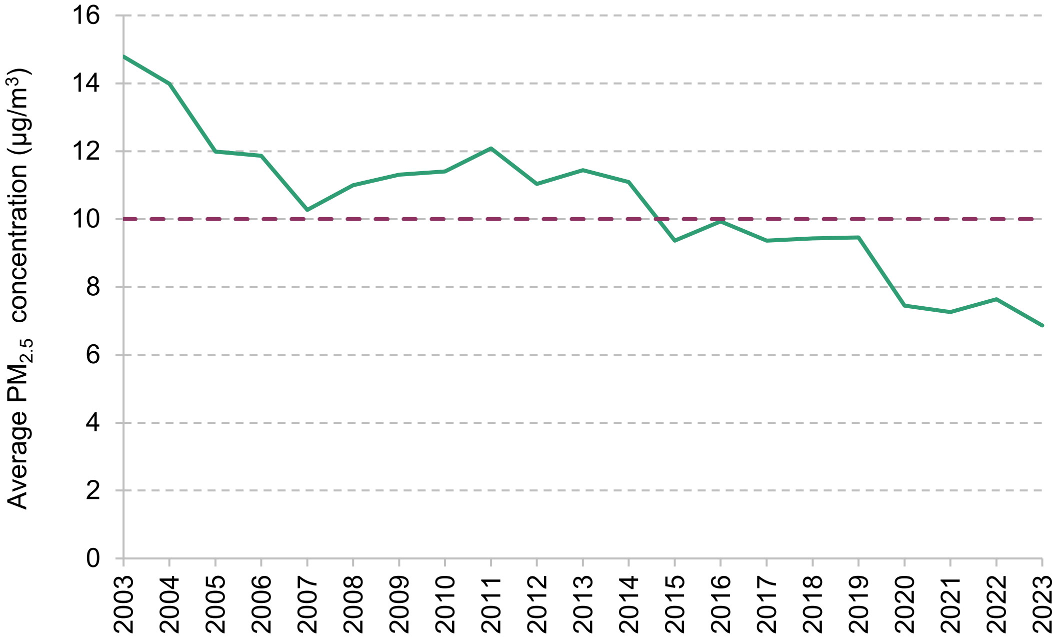
During the COVID-19 pandemic, air pollution fell dramatically and has remained at these lower levels since. In 2019, 35% of the population still faced $PM_{2.5}$ levels above England's target of 10μg/m^3. Average levels of $PM_{2.5}$ have fallen by 27% since 2019, and very few individuals remain exposed to more than 10μg/m^3. Two-fifths of the progress made on air pollution exposure over the last two decades occurred in the year 2020 alone.

Despite this substantial fall in levels of air pollution in recent years, the vast majority (96%) of England is above the World Health Organisation's recommended limit of 5μg/m^3. Levels of $PM_{2.5}$ above this level are associated with significant public health risks according to the WHO. This recommended limit was lowered from 10μg/m^3 in 2021 in response to growing evidence of damaging effects of $PM_{2.5}$ even at relatively low levels.

The fact that $PM_{2.5}$ did not rebound as England came out of the lockdown period of 2020 and 2021 is hard to explain. There are a few potential reasons that could have played a part in this persistence. Since 2020, several of the largest cities in England have introduced clean air zones, designed to dissuade people from driving the most polluting cars into cities. There has also been sluggish growth in the manufacturing sector, with the steel sector (one of the largest industrial sources of $PM_{2.5}$) not recovering to pre-pandemic production levels. Further work will look into the extent to which these changes explain the persistent drop in air pollution after the pandemic.

[1] There are still a small number of areas that have average concentrations of $PM_{2.5}$ above 10μg/m^3, but due to rounding this does not show up in the aggregate figure. There are around 5,000 people in England exposed to levels of $PM_{2.5}$ above 10μg/m^3.

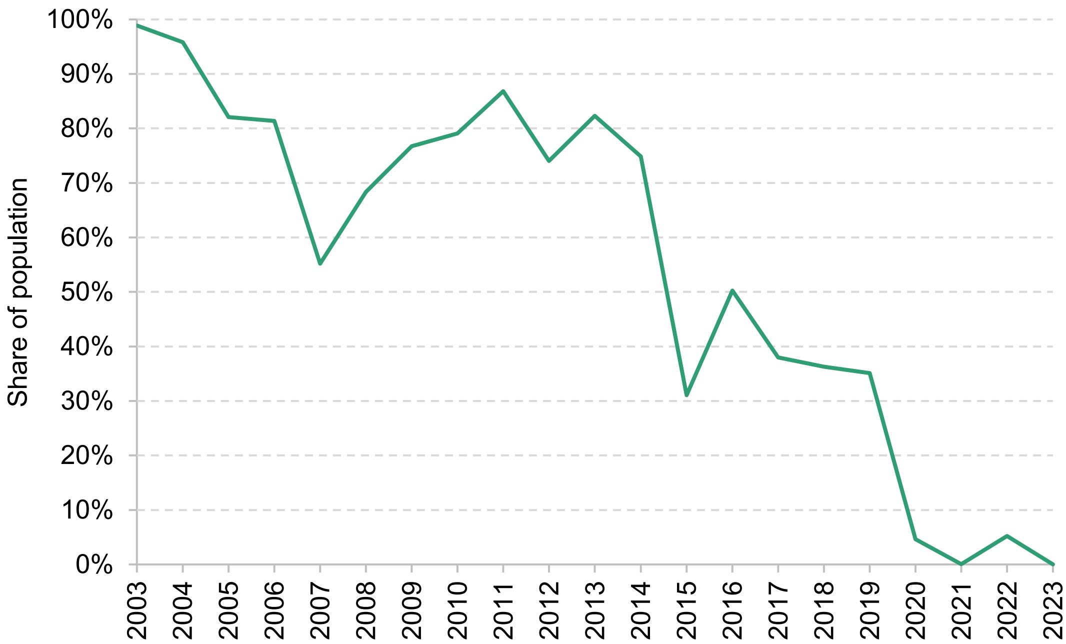
Figure 1. Average $PM_{2.5}$ exposure over time



Note: Each LSOA is weighted by its population size. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards. The 10µg/m^3 pollution threshold represents the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

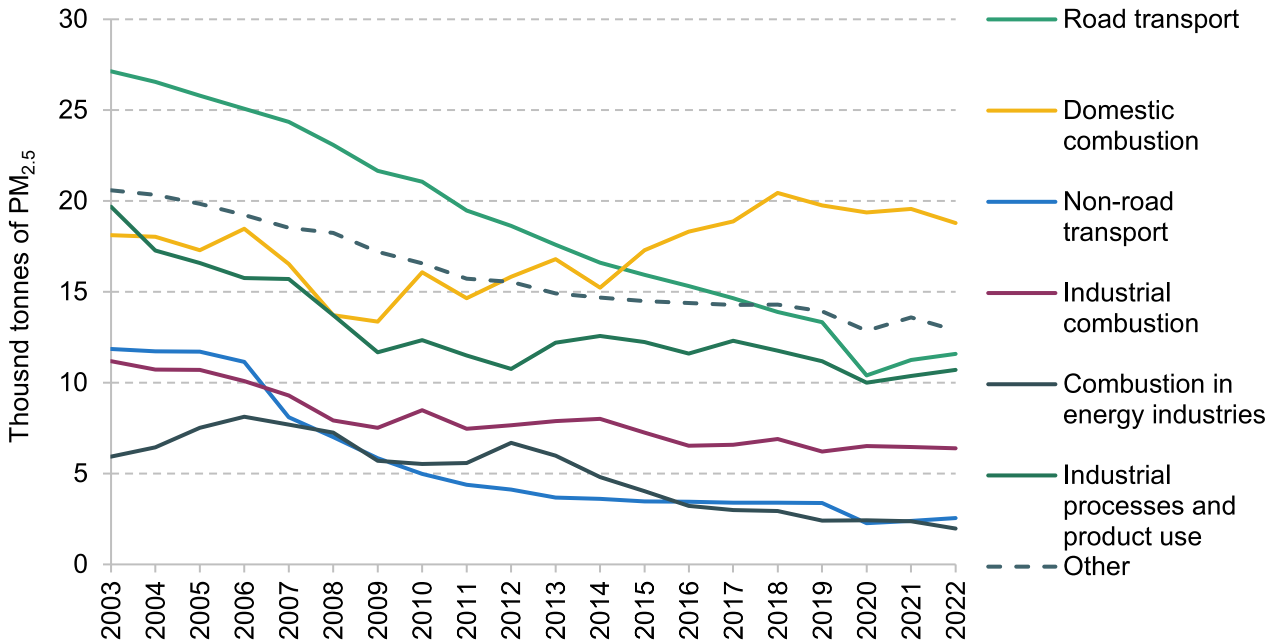
Figure 2. Share of population facing $PM_{2.5}$ levels above 10 µg/m^3



Note: Each LSOA is weighted by its population size. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

Figure 3. Emissions of $PM_{2.5}$ by source



Note: 'Other' includes other combustion, military aircraft and naval shipping, fugitive emissions from fuels, agriculture and waste. $PM_{2.5}$ is measured here as primary $PM_{2.5}$. Secondary $PM_{2.5}$, arising from reactions of other air pollutants after emission, is not included in these measures.

Source: DEFRA, emissions of air pollutants in the UK – particulate matter (PM_{10} and $PM_{2.5}$).

Figure 3 shows how emissions of $PM_{2.5}$ have changed over time, broken down by source. Emissions of $PM_{2.5}$ – i.e. how much fine particulate matter a certain sector is putting into the air – differ from the measures of ground-level $PM_{2.5}$ exposure used in Figures 1 and 2 earlier in three important ways.

First, the emissions may be dispersed by the wind or brought to the ground by rain, meaning a large emission of $PM_{2.5}$ may not translate into significantly higher amounts of $PM_{2.5}$ in the air we breathe.

Second, if the emissions take place far away from people (e.g. shipping emissions in the English Channel) then these emissions will not expose many people to higher levels of $PM_{2.5}$.

Finally, Figure 3 only measures so-called primary $PM_{2.5}$ – fine particulate matter that is directly emitted. $PM_{2.5}$ concentrations in the air include a lot of so-called secondary $PM_{2.5}$. Secondary $PM_{2.5}$ is fine particulate matter that is formed from other air pollutants, such as NO_2 and SO_2, emitted from various sources (including combustion in energy industries, industrial combustion and transport) that turn into $PM_{2.5}$ a few hours to a few days after being emitted. Considering only primary $PM_{2.5}$ tends to overestimate the importance of woodburning as opposed to transport and energy combustion.

The three largest sources of primary $PM_{2.5}$ in the UK are domestic burning of wood and other fuels (29.0% of total $PM_{2.5}$ emissions in 2022), road transport (17.9% of total $PM_{2.5}$ emissions in 2022), and industrial processes and product use (16.5% of total $PM_{2.5}$ emissions in 2022) such as construction and steel manufacturing. The only source of $PM_{2.5}$ emissions that has increased over the period is domestic combustion. Three-quarters of the domestic combustion emissions of $PM_{2.5}$ came from woodburning in 2022.

Air pollution over time by age group

Young children and older individuals are particularly vulnerable to the health effects of air pollution. Are they exposed to worse levels than the rest of the population? Figure 4 plots the average $PM_{2.5}$ exposure of children under 5 years of age and individuals over 65 over time. The overall pictures are very similar for the two groups and for the average population (Figure 1), because these age groups are fairly evenly distributed across England.

Figure 4. Average $PM_{2.5}$ exposure over time for children under 5 and adults over 65

Note: Each LSOA is weighted by the number of people in the respective age demographic to calculate the respective average $PM_{2.5}$ exposures. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards. The 10μg/m³ pollution threshold represents the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

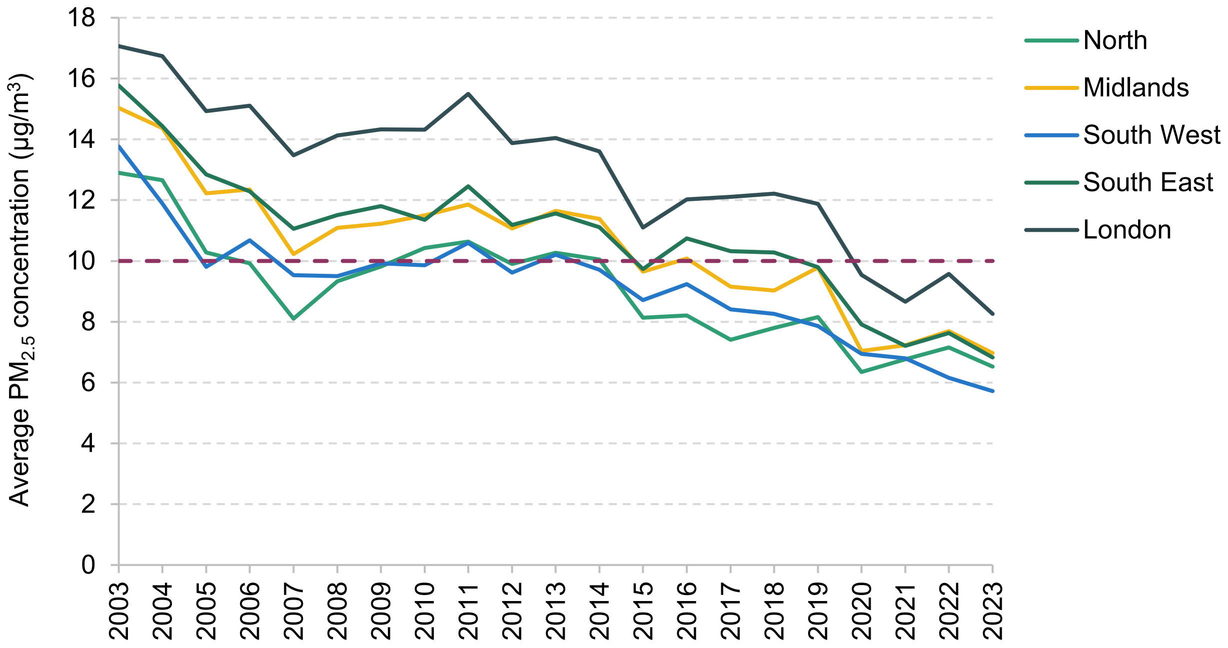
Air pollution over time by region

Figure 5 plots the evolution of average $PM_{2.5}$ exposure for each region of England separately. Table 1 presents average air pollution levels in 2003–04 and 2023 at a more disaggregated regional level.

The most striking takeaway is the difference between London and the other regions: air pollution exposure in London is consistently 15–30% higher than the average throughout the period. This can partly be explained by the fact that London is an overwhelmingly urban region, as air pollution is systematically higher in urban areas. However, since 2019, London has experienced a rapid fall in average levels of $PM_{2.5}$, falling by 30% between 2019 and 2023.

We see limited convergence across regions over time, although the absolute gap between the most polluted and least polluted regions has fallen, mostly since 2019. The regions with the biggest falls in $PM_{2.5}$ are the South West and the South East, with the North East seeing the smallest fall.

Figure 5. Average $PM_{2.5}$ exposure by region



Note: 'North' includes the North East, the North West and Yorkshire & the Humber. 'Midlands' is East and West Midlands. 'South East' is the South East and the East of England. The others are unchanged. The pollution average is a population-weighted average at the LSOA level. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards. The 10µg/m^3 pollution threshold is the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

Table 1. Average pollution and share of population over 10μg/m³ by region

Region	Average $PM_{2.5}$ (μg/m³), 2003–04	Average $PM_{2.5}$ (μg/m³), 2023	Share above 10μg/m³, 2003–04	Share above 10μg/m³, 2023	Change in average $PM_{2.5}$ exposure
North East	11.5	6.1	90%	0%	–47%
North West	12.8	6.5	94%	0%	–49%
Yorkshire & the Humber	13.4	6.8	100%	0%	–49%
East Midlands	14.7	7.5	100%	0%	–49%
West Midlands	14.7	6.7	100%	0%	–54%
South West	12.8	5.7	99%	0%	–55%
East of England	15.1	7.2	99%	0%	–52%
South East	15.1	6.6	99%	0%	–56%
London	16.9	8.3	100%	0%	–51%
England	14.4	6.9	98%	0%	–52%

Note: $PM_{2.5}$ averages are population-weighted at the LSOA level. We use 2001 population from the Census for 2003–04 and 2021 population for 2023. For the first period, we aggregate across two years, 2003 and 2004, for data-quality reasons. The 10μg/m³ limit is the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and UK Census, various years.

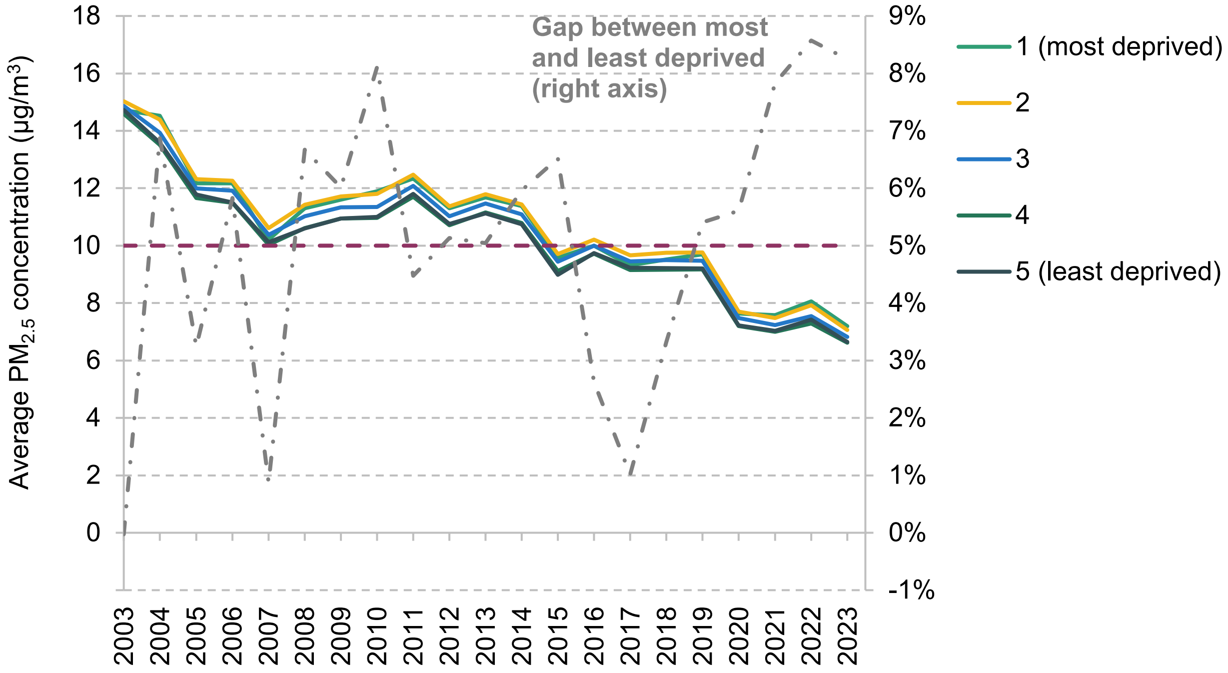
Air pollution over time by income deprivation level

We rank LSOAs using their income deprivation rank in 2019 (latest data available) and consider the average exposure to $PM_{2.5}$ in each quintile of income deprivation over time in Figure 6.[2]

The most deprived quintile consistently has higher $PM_{2.5}$ pollution levels than the least deprived quintile, and this gap has widened since 2017. Individuals in the most deprived quintile are exposed to average $PM_{2.5}$ concentration levels that are 8% higher than those in the least deprived quintile in 2023.

[2] We also redo this analysis ranking LSOAs by their income deprivation rank at the beginning of the period (2004) and the results remain almost exactly the same. The graph for 2004 income deprivation rank is Figure A1 in the appendix.

Figure 6. $PM_{2.5}$ exposure by income deprivation quintile



Note: Income deprivation quintiles are defined according to the 2019 English Index of Multiple Deprivation (IMD). The $PM_{2.5}$ average is a population-weighted average at the LSOA level within each quintile. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards. The 10µg/m³ pollution threshold is the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using the English Indices of Deprivation 2019, DEFRA $PM_{2.5}$ data and English Census, various years.

The relationship between income deprivation and air pollution is not simple: in several periods, the most deprived quintile faces lower air pollution levels than the second-most deprived quintile (see also Figures 9 and 10 later), and the least deprived quintile often had higher levels than the second-least deprived quintile. This is partly a result of several of the richest areas, such as Kensington & Chelsea, being in urban areas and some of the poorest areas being relatively rural.

Air pollution over time by ethnicity

Ethnic minorities were exposed to levels of air pollution 13% higher than average levels for white populations in 2003. This 'ethnic pollution gap' shrank to 6% by 2023. Figures 7 and 8 plot the average exposure to air pollution over time and the share of people facing levels above 10µg/m³ (England's 2040 target) respectively for different ethnic groups. Table 2 later presents average exposure by group in 2003–04 and 2023, as well as the ethnic pollution gap: the difference between average exposure to $PM_{2.5}$ faced by ethnic minorities and that faced by white people.

The gap between ethnic minorities and white people was substantial in the early 2000s: ethnic minorities were exposed to on average 1.8µg/m³ more $PM_{2.5}$ than white people – a 13% gap.

Both the levels of exposure and the gap are similar to those observed in the US by Currie, Voorheis and Walker (2023). Average exposure was 12.3µg/m^3 amongst the white population in the US in 2001, compared with 14.2µg/m^3 in England in 2003–04, and the 'racial pollution gap' (comparing black and white populations only) in the US was 1.5µg/m^3 in 2001.

Looking at Figure 7, we see that average exposure fell substantially for all groups, but more for ethnic minorities. This leads to the ethnic pollution gap being divided by four over the last two decades: by 2023, the gap is 0.4µg/m^3 with ethnic minorities exposed to on average 6% higher $PM_{2.5}$ levels than white people. This again is similar to the evolution in the US: Currie, Voorheis and Walker (2023) find that the racial gap is divided by three, though only over a 13-year period.

Figure 7. Average $PM_{2.5}$ exposure over time by ethnicity

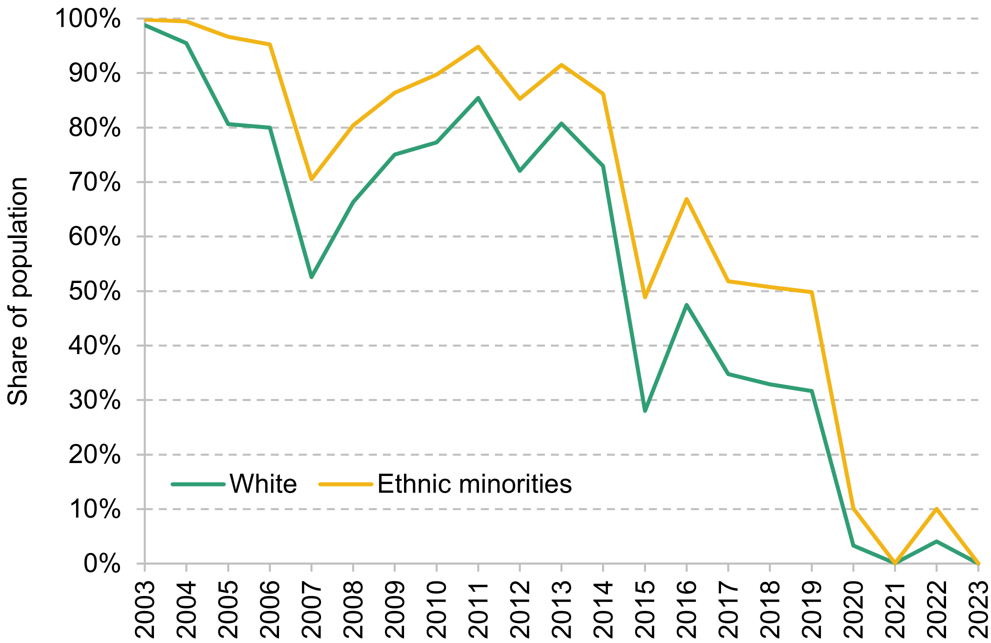
Note: Ethnic minorities are defined as those who report an ethnicity other than 'white'. Each LSOA is weighted by the number of people in the respective ethnicity demographic to calculate the respective average $PM_{2.5}$ exposures. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards. The 10µg/m^3 pollution threshold represents the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

Pollution exposure in England is particularly high for the black population: the black–white pollution gap was 2.6µg/m^3 in 2004 and fell to 0.5µg/m^3 by 2023. In general, however, there is a lot of similarity between different minority ethnic groups' exposure despite significant differences in ethnic groups' economic status (Mirza and Warwick, 2022).

Figure 8 presents the share of the population exposed to high levels (above 10µg/m^3). We see a particularly dramatic fall amongst ethnic minorities since the pandemic: in 2019, 50% of those individuals were exposed to more than 10µg/m³; by 2023, this number had fallen to close to zero.[3]

Figure 8. Share of population facing $PM_{2.5}$ levels above 10µg/m³ by ethnicity



Note: Ethnic minorities are defined as those who report an ethnicity other than 'white'. Each LSOA is weighted by the number of people in the respective ethnicity demographic. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards.

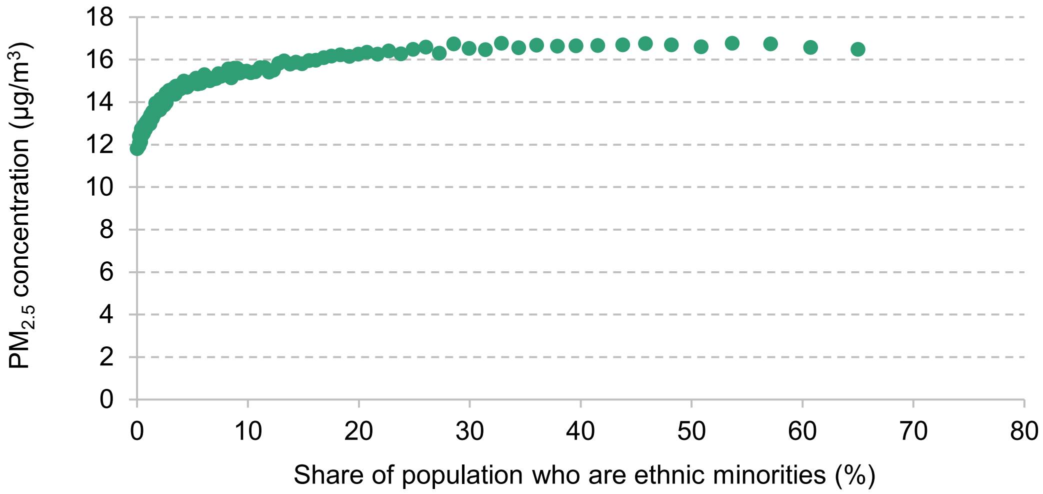
Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

Finally, Figures 9 and 10 plot the correlation between air pollution and the ethnic minority share or the income deprivation rank at the LSOA level, in the first and last periods. We see a clear positive correlation between the ethnic minority share and air pollution concentration. In 2023, the relationship (as measured by the correlation coefficient) is a third of what it was in 2003–04: a one standard deviation increase in the ethnic minority share was associated with an increase in $PM_{2.5}$ of 0.95µg/m³ in 2003–04 and of 0.31µg/m³ in 2023. In contrast, the correlation between the income deprivation rank and air pollution is weaker and getting slightly stronger over time.

3 Figures A3 and A4 in the appendix plot the distribution of exposure to air pollution for white and ethnic minorities people in 2003–04 and 2023 respectively. We see a clear downward shift over time for both groups, as well as a change in the shape of the distribution for ethnic minorities, with a much tighter distribution in 2023 than in 2003–04.

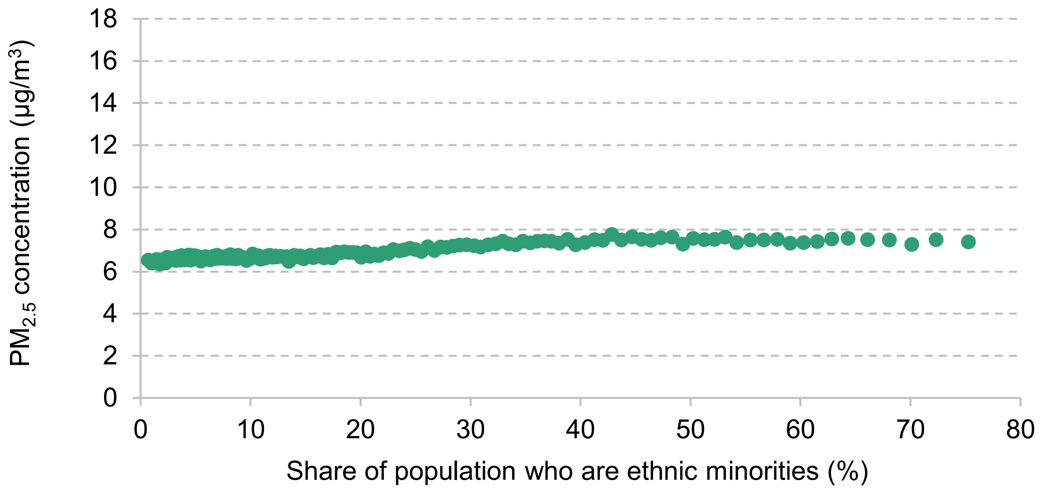
Figure 9. Correlation between ethnic minority population and air pollution levels, 2003-04 and 2023

Panel A. 2003–04



y = 0.95 * *x* (SD = 0.007)

Panel B. 2023



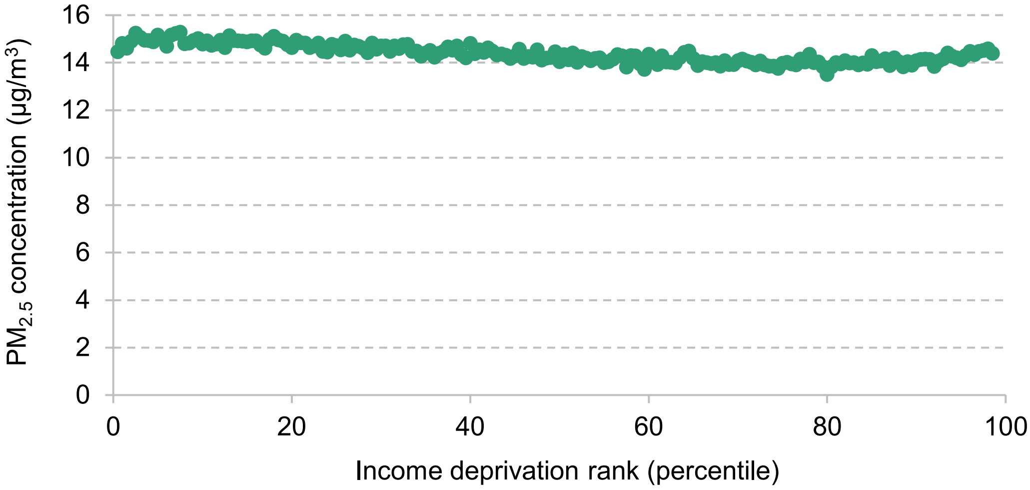
y = 0.31 * *x* (SD = 0.004)

Note: This figure displays the relationship between LSOA ethnic minority share and $PM_{2.5}$ levels in 2003–04 and 2023. We combine 2003 and 2004 data for data-quality reasons. Ethnic minorities are defined as those who report an ethnicity other than 'white'. We use 200 equally-sized bins and compute the population-weighted mean values using the Census 2001 and Census 2021 populations as weights for 2003–04 and 2023 respectively. The standardised linear regression coefficient shows the marginal pollution increase resulting from a 1 standard deviation increase in the share of population who are ethnic minorities.

Source: Authors' calculations using English Census 2001 and 2021 and DEFRA $PM_{2.5}$ data.

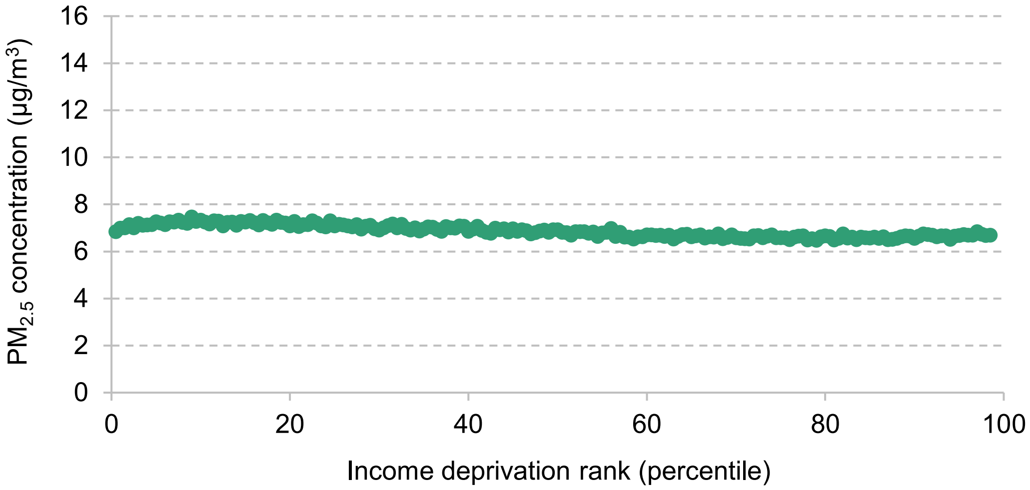
Figure 10. Correlation between income deprivation rank and air pollution levels, 2003–04 and 2023

Panel A. 2003–04



y = –0.22 * *x* (SD = 0.007)

Panel B. 2023



y = –0.29 * *x* (SD = 0.005)

Note: The higher the income deprivation rank, the less deprived the area is. This figure displays the relationship between LSOA income deprivation rank and $PM_{2.5}$ levels in 2003–04 and 2023. We combine 2003 and 2004 data for data-quality reasons. We use 200 equally-sized bins and compute the population-weighted mean values using the Census 2001 and Census 2021 populations as weights for 2003–04 and 2023 respectively. The standardised linear regression coefficient shows the marginal pollution increase resulting from a 1 standard deviation increase in the income deprivation rank.

Source: Authors' calculations using English Indices of Deprivation 2019, English Census 2001 and 2021 and DEFRA $PM_{2.5}$ data.

Explaining the fall in the ethnic pollution gap

The ethnic pollution gap has fallen in part due to ethnic minorities moving from more polluted areas to less polluted areas (i.e. moving away from London) and in part due to the areas where they live becoming less polluted. In the last two columns of Table 2, we perform a decomposition exercise to investigate the role played by these two factors. The first decomposition (in column 3) considers exposure to $PM_{2.5}$ in 2023 had the pollution level in each LSOA remained as it was in 2003–04. Any difference between columns 2 and 3 is therefore due to ethnic minorities and white populations being distributed differently across LSOAs in the two periods, and not pollution changes – a pure 'sorting' effect. The second decomposition (in column 4) considers exposure to $PM_{2.5}$ in 2023 holding constant the distribution of population by ethnic group across LSOAs as it was in 2003–04. This number tells us the average exposure in 2023 if the population and ethnic mix of each LSOA had not changed.[4]

Table 2. Observed and counterfactual $PM_{2.5}$ exposure by ethnic group

Group	(1) 2003–04 average $PM_{2.5}$ exposure (µg/m^3)	(2) 2023 average $PM_{2.5}$ exposure (µg/m^3)	(3) 2023 average $PM_{2.5}$ exposure, keeping pollution constant (µg/m^3)	(4) 2023 average $PM_{2.5}$ exposure, keeping population constant (µg/m^3)
White	14.2	6.8	14.2	6.8
Ethnic minorities	16.0	7.2	15.0	7.8
Ethnic pollution gap	1.8	0.4	0.8	1.0

Note: Ethnic minorities are defined as those who report an ethnicity other than 'white'. Columns 1 and 2 present the observed pollution exposures for white and ethnic minority populations averaged across the two respective periods. Column 3 is the counterfactual pollution exposure for the two groups if the pollution level in each LSOA in 2023 remained as it was in 2003–04. Column 4 is the counterfactual pollution exposure for the two groups if the two populations' geographic distribution in 2023 remained as it was in 2001.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

Table 2 shows that the movement of people of ethnic minorities away from polluted areas was more important in lowering their exposure to air pollution than falls in air pollution. In other words, even if air pollution had not fallen at all, the gap in air pollution exposure between white

[4] We hold both the total population and the share of ethnic minorities constant at the LSOA level, which implies that the average share of ethnic minorities in the population is held constant at its 2001 level too.

people and ethnic minorities would still have halved (as shown by comparing columns 1 and 3 of the table) because people of ethnic minorities have moved to less polluted areas. Since the pandemic, however, falling air pollution has been a more important channel than ethnic minorities moving to different areas.

All of the decrease in $PM_{2.5}$ exposure faced by white people can be explained by pollution levels falling: the average exposure in the counterfactual in 2023 in which air pollution is kept constant is the same as the observed average exposure in 2003–04. In contrast, part of the decrease in exposure faced by ethnic minorities can be explained by ethnic minority populations growing more in less polluted areas. Even in the absence of any change in air pollution in England, the average exposure to air pollution faced by ethnic minorities would have fallen by 1$\mu g/m^3$ on average. This implies that changes in sorting behaviours by ethnic group (such as ethnic minorities moving to less polluted areas) alone led to a reduction of the ethnic pollution gap over the period equal to 71% of the observed reduction in the gap. Changes in pollution levels while keeping the distribution of ethnic groups constant across LSOAs lead to a smaller decrease in the ethnic pollution gap, of 57% of the observed decrease.[5]

Table 3 shows the share of ethnic minorities in the population of each region in each Census year. We see that at the start of the period, ethnic minorities represented a small share of the population in all regions except London, the region with by far the highest air pollution levels (and, to a lesser extent, the West Midlands with roughly average air pollution levels). Looking across columns, we then observe ethnic minorities 'moving out' of more polluted regions over time, relative to the white population. The share of ethnic minorities increases in all regions, and doubles in England overall, between 2001 and 2021, but the smallest increases take place in more polluted regions (London, East Midlands) whilst the largest increases by far can be found in the North East and South West, two regions with much lower air pollution levels than average. This is consistent with findings from recent research documenting that in England, residential mobility is associated with air quality improvement on average, with a stronger effect for households with a migration background than for British natives (Rüttenauer et al., 2023). Overall, ethnic minorities are initially highly concentrated in one high-pollution region (London) but then spread out across English regions over the period. This plays a large role in explaining why the ethnic pollution gap falls over time.

5 By contrast, in the US, Currie, Voorheis and Walker (2023) find that most of the reduction in the gap can be explained by faster decreases in pollution in black neighbourhoods, in part because of the way the US's main air pollution legislation, the Clean Air Act, was implemented.

Table 3. Share of ethnic minorities in each region over time

Region	Share of ethnic minorities			Change, 2001 to 2021
	2001	2011	2021	
North East	2.4%	10.9%	21.4%	791.7%
North West	5.6%	7.6%	9.9%	76.8%
Yorkshire & the Humber	6.5%	12.2%	15.7%	141.5%
East Midlands	6.5%	4.9%	8.5%	30.8%
West Midlands	11.2%	20.6%	22.3%	99.1%
South West	2.3%	8.7%	15.2%	560.9%
East of England	4.9%	7.8%	9.5%	93.9%
South East	4.9%	8.7%	15.7%	220.4%
London	28.8%	39.2%	43.7%	51.7%
England	9.1%	14.6%	18.9%	107.7%

Note: Ethnic minorities are defined as those who report an ethnicity other than ‘white’.

Source: Authors’ calculations using English Census, various years.

4. Conclusion

Remarkable progress has been made in lowering average levels of $PM_{2.5}$ exposure across England. Almost everywhere in England is now below the target the UK government set England for 2040, well ahead of expectations. This progress has coincided with significant policy activity in this area – from tighter regulations on industrial plants to the proliferation of clean air zones in many of England's cities.

In this report, we have found a large drop in $PM_{2.5}$ over the last two decades, with a substantial fall during the COVID-19 pandemic. Between 2003 and 2023, the average annual level of $PM_{2.5}$ fell by 54% in England from around $14\mu g/m^3$ to under $7\mu g/m^3$, with half of that fall occurring since 2019. The lower levels of $PM_{2.5}$ in 2020 have persisted through to 2023 (latest data available).

Every region of England has seen its average level of $PM_{2.5}$ roughly halved over the period. Some regions, such as the South East and the South West, have seen slightly larger falls, while others, such as the North East, have seen slightly smaller falls. London consistently has the highest levels of $PM_{2.5}$, around 15–30% higher than the national average.

We have provided evidence that air pollution in England has been consistently higher for ethnic minorities over the last 20 years.[6] On average, ethnic minorities were exposed to levels of $PM_{2.5}$ 6% higher than those for white people in 2023, down from 13% in 2003. Others have shown that there is a 'race pollution gap' in the US – black individuals face substantially more air pollution than white individuals (Currie, Voorheis and Walker, 2023; Colmer et al., 2024). Campaigners have long raised concerns about ethnic minorities experiencing higher levels of air pollution (ClientEarth, 2021). There is a case that environmental policy, including that related to air pollution, should be part of policy efforts to narrow racial health gaps.

We have also documented a gap in levels of air pollution between the most and least deprived areas. Using the Ministry of Housing, Communities and Local Government's income deprivation rank, we show a gap of, on average, 5% between the most deprived 20% of areas (lower layer super output areas, LSOAs) and the least deprived 20%. Unlike the gap between ethnic minorities and white people, this gap shows no clear trend.

6 Brook, Zhang and Sammut (2023) document air pollution gaps by ethnicity for London only and the Health Foundation (2024) documents air pollution gaps by ethnicity for England in 2019.

There has been both significant policy action and substantial progress in lowering levels of $PM_{2.5}$ across England. At the same time, our understanding of the harms of $PM_{2.5}$, even at relatively low levels, has progressed rapidly. This report has shown that there are still sizeable inequalities in exposure to $PM_{2.5}$ across regions, by ethnicity and by income deprivation and that average levels of $PM_{2.5}$ are still above the WHO's recommended limit for 96% of England's population.

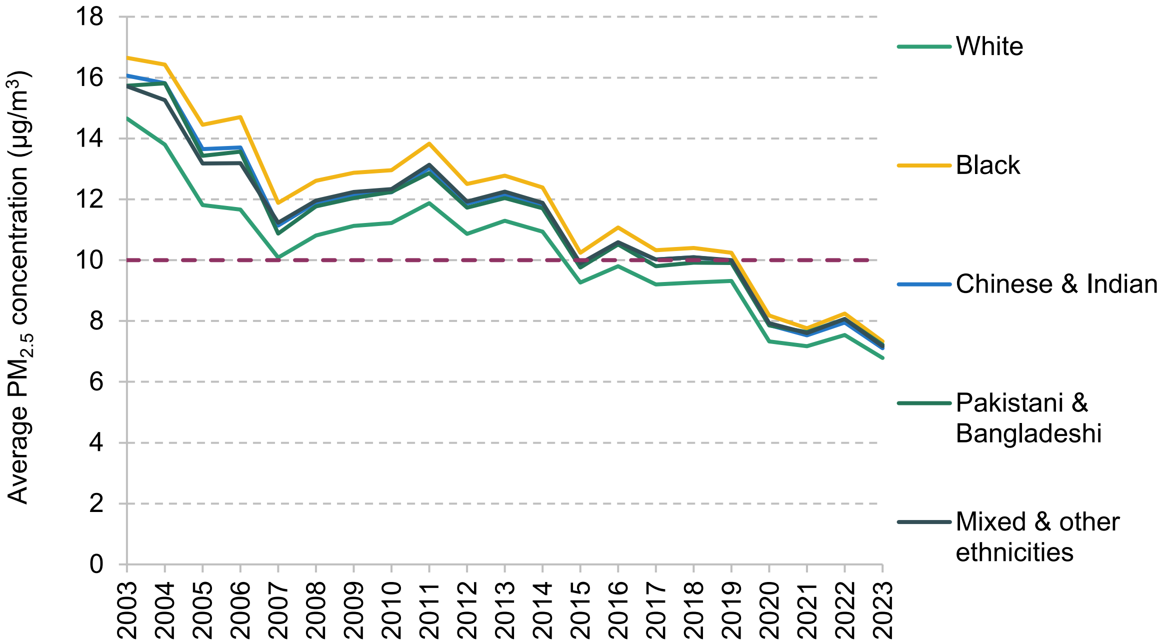
Appendix

Figure A1. Average $PM_{2.5}$ exposure over time by income deprivation quintile in 2004

Note: Income deprivation quintiles are defined according to the 2004 English Index of Multiple Deprivation (IMD). The $PM_{2.5}$ average is a population-weighted average at the LSOA level within each quintile. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards. The 10µg/m^3 pollution threshold represents the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using the English Indices of Deprivation 2004, DEFRA $PM_{2.5}$ data and English Census, various years.

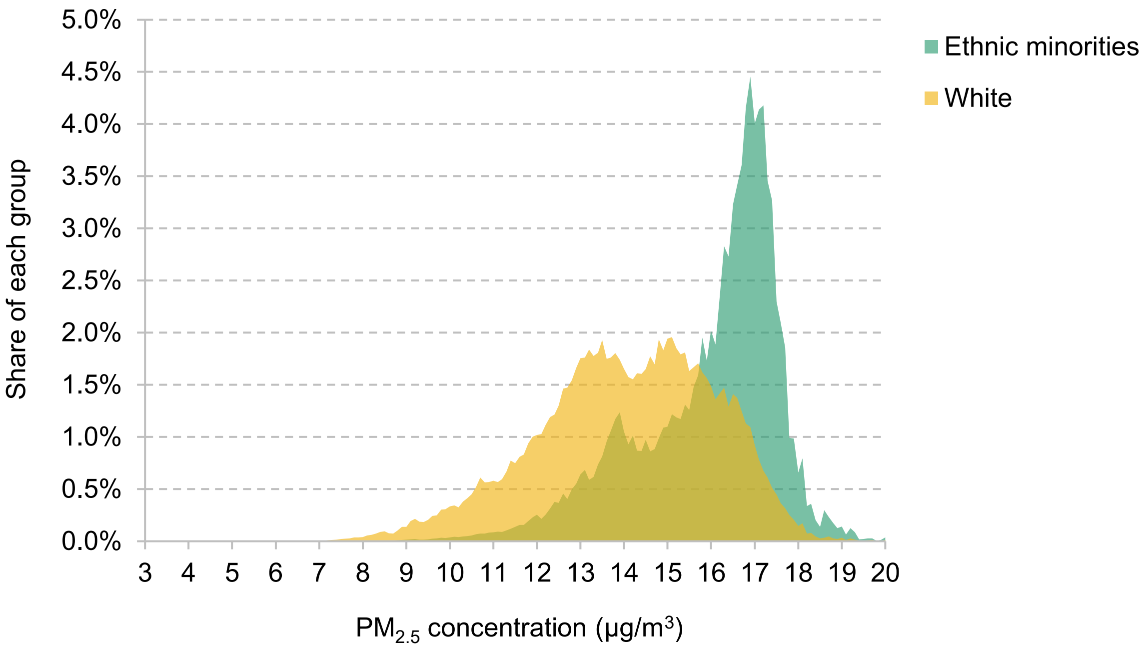
Figure A2. Average $PM_{2.5}$ exposure over time for different ethnic groups



Note: Each LSOA is weighted by the number of people in the respective ethnicity demographic to calculate the respective average $PM_{2.5}$ exposures. We use 2001 population from the Census until 2007, 2011 population for 2007 to 2016, and 2021 population for 2017 onwards. The 10µg/m^3 pollution threshold represents the government target for $PM_{2.5}$ in 2040 in England.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, various years.

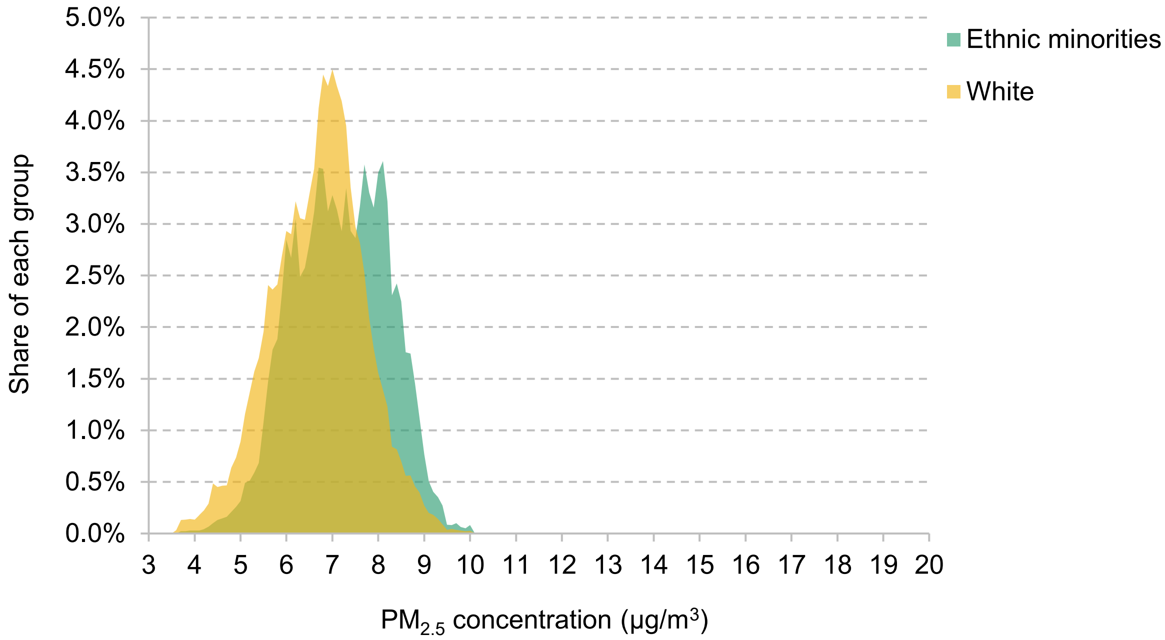
Figure A3. Distribution of $PM_{2.5}$ exposure in 2003–04, by ethnicity



Note: Data for 2003 and 2004 are combined for data-quality reasons. 'Ethnic minorities' refers to all people reporting an ethnicity other than 'white'.

Source: Authors' calculations using DEFRA $PM_{2.5}$ data and English Census, 2001.

Figure A4. Distribution of $PM_{2.5}$ exposure in 2023, by ethnicity



Note: ‘Ethnic minorities’ refers to all people reporting an ethnicity other than ‘white’.

Source: Authors’ calculations using DEFRA $PM_{2.5}$ data and English Census, 2021.

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