University of Strathclyde Glasgow

Socioeconomic inequalities in air pollutant exposure in Glasgow

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Introduction

The goal of this report is to examine environmental inequalities present in the Glasgow City Council area, specifically looking at two main pollutants, both of which come primarily from vehicle emissions: nitrogen oxides (NO_X) and small particulate matter (PM2.5). These two pollutants are significant because they are either known to cause or highly correlated with a variety of health problems. Glasgow City is notable, because it is the most populated city in Scotland. It also - unsurprisingly - has the highest concentrations of these pollutants. It is also an interesting case study because of high rates of socioeconomic inequalities, which can influence health even further.

Health is the primary motivation for evaluating the relationship between air quality and markers of inequality, although this paper does not evaluate intercorrelations between air quality, inequality, and health. Instead, this paper evaluates rates of income inequality and ethnic makeup in Glasgow City data zones, and compares them to annual mean NO_X and PM2.5 concentrations. We also examine air pollution levels at state funded schools based on the proportion of pupils that are from ethnic minorities or living in deprived areas.

There are a variety of reasons to focus on these two groups: for one, health and income inequality are highly correlated, with people living in low income areas in Glasgow facing extreme differences in health outcomes. It may be more difficult for low income households to escape the effects of environmental inequalities, for instance, by purchasing housing with access to green space. People from different ethnic backgrounds also face substantial health and socioeconomic inequalities. Ethnic minority populations have higher rates of poverty and have worse health outcomes in certain areas (for instance, higher rates of type 2 diabetes among people from Black, Caribbean, and South Asian backgrounds), although data on racialised inequalities are limited in Scotland (Public Health Scotland, 2023).

It is important for council areas to be aware of the different levels of pollutants different groups experience when making policy decisions. Ultimately, decisions which lower air pollution are a positive for the entire community, but some decisions are likely to benefit some groups more than others.

Key findings

- People from ethnic minority backgrounds are significantly more likely to live in areas with the highest rates of NO_X and PM2.5 concentrations.
- Students from ethnic minority backgrounds are more likely to attend schools in areas with higher pollutant concentrations than white Scottish or British students.
- Given changes in Glasgow's ethnic demography, which has grown from 11.3% to 19.6% of the council's population over the last ten years, this is an important area to monitor further.
- There is not a clear relationship between neighbourhood income deprivation and air pollution, although the 10% least deprived neighbourhoods have significantly higher concentrations of NO_X.

Background

Air pollution and health

Air pollutants can have a large impact on health, with small particulate matter (PM2.5) and nitrogen dioxide (NO_2) and other nitrogen (NO_X) being the most significant. These generally come from vehicle emissions and wear.

Although pollution is very much a health concern, the UK has relatively good air quality on a global scale, with Scotland generally having lower levels of harmful air pollutant concentrations compared to other UK countries (Davies, 2022; IQAir, 2023). As a result, people living in Scotland may not experience health problems to the severity of other countries, or it may be difficult to prove a link between some diseases and pollutant levels in countries with relatively clean air. While pollutant concentrations in Glasgow are high relative to Scotland, they are low on a global scale, and have reduced over time. However, some studies have found a demonstrable link to respiratory problems, either in Scotland or in countries with similar levels of pollution. PM2.5 has an especially large body of literature showing associations between exposure and a variety of poor health outcomes, such as asthma and chronic obstructive pulmonary disease (COPD) (Table 1). These outcomes are also more likely to affect sensitive populations, such as the elderly, children, and pregnant women (Walker et al., 2023).

Table 1: Outdoor air pollutants, air quality guidelines, and associated health outcomes

Pollutant	WHO safe annual mean pollutant exposure guideline	Associated health outcomes	Demonstrably associated health outcomes in Scotland
PM2.5	5 µg/m³	Behavioural problems, breast cancer mortality, cardiovascular disease and mortality, cognition problems, dementia, mental health conditions, motor delay, neonatal disorders, respiratory mortality, type 2 diabetes	All-cause mortality, respiratory mortality, cardiovascular disease, cardiovascular mortality
NOX		Cognition problems, mental health conditions, respiratory disease	
NO2	25 µg/m³	Asthma incidence, worsened COPD outcomes	

Source: *(Scottish Government, 2023; WHO, 2022)*

Indoor air pollution has much of the same overall health impacts as outdoor air pollution, although enclosed spaces tend to have a more diverse range and higher concentration of pollutants. In addition, indoor sources, particularly those related to human behaviour (i.e., cooking or smoking) can cause significant pollution peaks. Ventilation is a critical factor as it can dictate the rate of dissipation of air pollution. People also spend the majority of their time indoors, especially in the UK, so indoor pollutants can be a serious health risk. These health outcomes are also more significant for vulnerable populations (National Institute for Health and Care Excellence, 2020).

Outdoor pollution can also affect indoor pollution. Buildings with more ventilation or draughts have lower concentrations of indoor air pollution but higher levels of outdoor air pollution. Making buildings more airtight, in contrast, increases indoor pollutant concentrations while reducing the amount of outdoor pollution exposure. This is something of a double-edged sword: making homes more airtight makes them more energy efficient and reduces exposure to outdoor pollutants, but may actually make indoor air quality worse (Scottish Government, 2023).

Air pollution and inequality

In many countries, poorer people living in urban areas experience worse air quality than those on higher incomes. This relationship is not as straightforward in urban areas in the UK, where low- and high-income neighbourhoods alike tend to experience higher levels of pollution than middle income areas. This is generally because middle income households can afford to move away from polluted areas to suburban areas, which may also have more access to green space. Wealthier households, however, are able to afford higher-priced housing in trendier, more densely populated areas (Bailey et al., 2018). Even within the UK, there is a wide range of environmental inequalities in urban areas, so research into local inequalities need to be considered on a case-by-case basis.

Previous research into Scottish cities found that regions in Glasgow with higher levels of income deprivation had generally higher concentrations of PM2.5 (Bailey et al., 2018; Ferguson et al., 2021).

This is an important issue to consider in Scotland, and in Glasgow in particular, because of its high levels of health and socioeconomic inequality. Health is highly correlated to household income, with people in poorer households having notably worse health outcomes compared to wealthier people.

Glasgow has a higher concentration of income-deprived neighbourhoods[1] than anywhere else in Scotland, low-income neighbourhoods are disproportionately located in Glasgow. One fourth of the most deprived areas[2] in Scotland are located within Glasgow City Council (Scottish Government, 2020). Meanwhile, Glasgow has the lowest life expectancy of any Scottish local authority, and has exceptionally large gaps in life expectancies between deprived and non-deprived neighbourhoods (Scottish Government, 2022). Men born in Govan, for instance, can expect to live 15 years less than men born just a few miles away in Pollokshields. These gaps have been consistent for the better part of a century and are more extreme than cities with similar levels of deprivation, such as Manchester or Liverpool (Whyte, Young and Timpson, 2021).

Household income inequalities are more extreme among different demographics. For instance, 33% of children living in Glasgow City were in relative poverty in 2023, well above the Scottish average of 21%. Glasgow has the highest number and proportion of children living in relative poverty (DWP, 2024). Differences in household income in childhood are closely correlated to differences in health outcomes. Children are also disproportionately exposed to a higher concentration of air pollution at school, with around 60% of pollutant exposure coming from travelling to and being in school, which accounts for 40% of a child's day (Edwards et al., 2018). In total, there are over 82,300 students enrolled in around 216 state funded primary and secondary schools across the city (Scottish Government, 2024).

Additionally, in Scotland, people from ethnic minority backgrounds are more than twice as likely to be in poverty than people from a white background (Scottish Government, 2024). Although it's not clear how many people from an ethnic minority are in poverty in Glasgow, it is worth noting that Glasgow has the highest proportion and largest population of non-white ethnic minorities living in Scotland (Scotland Census, 2024). There are limited studies into the level of pollutants people from different ethnic backgrounds experience in Glasgow, although in Scotland, people from ethnic minorities are exposed to significantly higher concentrations of particulate matter and nitrogen dioxides (Sayers et al., 2023). Furthermore, data on racialised health inequality is limited in Scotland, although there is work being done to improve this moving forward (Public Health Scotland, 2023). At the same time, the share of the ethnic minority population in Glasgow grew from 11.6% of the total population in 2011 to 19.3% in 2022 (Scotland Census, 2024).

1 Income deprivation, which is a measure from the Scottish Index of Multiple Deprivation (SIMD), is a proxy for understanding relative household income levels.

2 25.45% of Scotland's most deprived 20% of data zones are located in Glasgow City as of 2020.

Data and Methodology

This paper examines modelled mean annual concentrations of PM2.5 and NO_x within Glasgow City Council data zones. Background mapping data on mean annual pollutant concentrations are provided by the UK Department for Environment Food and Rural Affairs (DEFRA). This study uses DEFRA's 2022 projections, which are modelled based on observed traffic and meteorological data from 2018. 2022 was chosen as a base year for comparability with 2022 Scottish census data.

Mean annual PM2.5 and NO_x concentrations are not provided at a data zone level, which is the smallest geographical level of socioeconomic data that is published by the Scottish Government. Instead, pollutant concentrations are provided in the form of a centre point of a $1km^2$ grid for the entire UK. In order to estimate the average annual concentration for an irregularly-shaped data zone, we used geographic information system (GIS) software to overlay the $1km^2$ grid with data zone boundaries. The average pollutant levels within data zones are based on the weighted proportion of a grid that falls within that data zone. For instance, if 75% of a data zone is covered by Grid A, and 25% is covered by Grid B, the average pollutant concentration within that data zone is the sum of 75% of the pollutant concentration in Grid A and 25% of the pollutant concentration in Grid B.

There are some limitations with this methodology. Notably, there is not information about population dispersion within a data zone. It may be the case that a data zone has a lower average pollutant concentration than that which people actually experience. Furthermore, the most recent background air quality data from DEFRA is from 2018, meaning that any behavioural changes, such as the number of miles that cars travelled in 2022, or changes in weather patterns since then have not been captured.

In order to understand inequalities in air pollutant exposure, we isolated two variables: income inequality and ethnic background.

Income deprivation is based on the number and proportion of people living within a data zone that are considered "income deprived" according to the Scottish Index of Multiple Deprivation (SIMD, 2020). It is not possible to determine the number of students living in income deprived or low income households. Instead, the Scottish Pupil Census publishes the number of students living in the 20% most deprived Scottish data zones. This data is only available for students attending state funded schools. This does not mean that these students necessarily live in income-deprived or low-income households, although income deprivation is a key indicator in determining multiple deprivation indices. Comparisons between students living in deprived areas and income deprivation should be treated with some caution.

Ethnicity data at a data zone level is provided by the 2022 Scottish census. Ethnicity in schools comes from the 2022-2023 Scottish Pupil Census, which aggregates students into "White-British;" "White-Other," which includes white minority[3] groups; and "Minority Ethnic," which includes students from nonwhite, mixed, or multiple ethnic groups.

Table 2: Data sources

Indicator	Granularity	Source	Source year(s)
Outdoor air quality (NO_x, PM2.5)	$1km^2$ blocks	DEFRA	2022 (modelled from 2018 data)
Proportion of households that are income deprived	Data zone (2011)	SIMD	2020
Ethnic minority populations	Data zone (2011)	Scottish census	2022
Ethnic minority and multiple deprivation student populations	Individual school	Scottish pupil census	2022-2023

3 White minority groups include "White - Gypsy/Traveller," "White - Irish," "White - Polish," and "White - Other"

Results

Ethnicity and air pollution in Glasgow City

NO_x and PM2.5 are generally concentrated in the city centre, which is bordered by two major motorways: the M8 and M74.

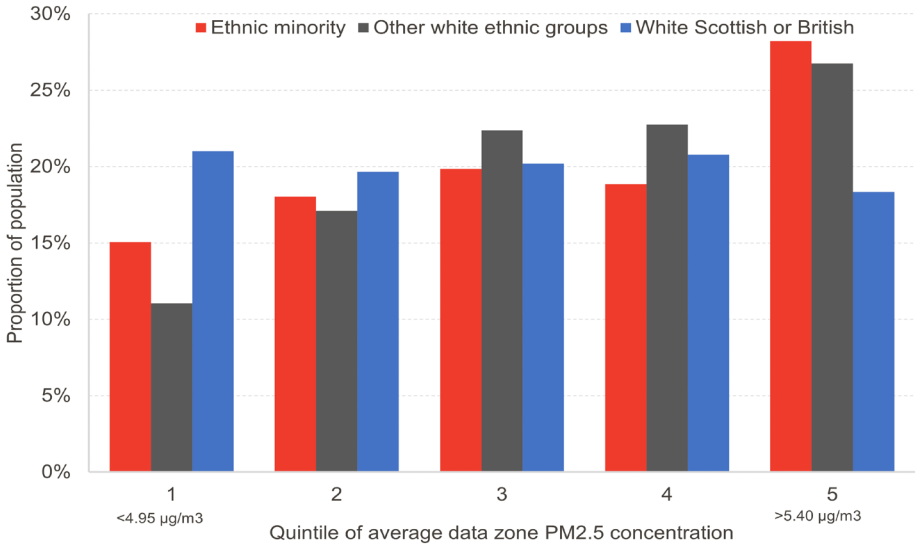
The majority of people from ethnic minority backgrounds live in data zones near the city centre. These neighbourhoods tend to be more polluted, and as a result, people from ethnic minorities are more likely to live in polluted areas compared to people from white British or white Scottish backgrounds.

All ethnic minority groups, including people from white minority groups are more likely to live in the data zones with the highest concentrations of NOX and PM2.5. White Scottish people are, in contrast, more likely to live in the areas with the lowest pollutant concentrations (Charts 1 & 2). Interestingly, people from white minority groups closely mirror the patterns of people from other ethnic minority groups. The same is true for people from other British backgrounds (*See Annex 1 and 2*).

People from Indian backgrounds are the most likely to live in the most polluted areas: 34% of Indian, Indian Scottish, or Indian British people in Glasgow live in the 10% of neighbourhoods with the highest NO_x concentrations, and 27% live in the neighbourhoods with the highest PM2.5 concentrations (*See Annex 1 and 2*).

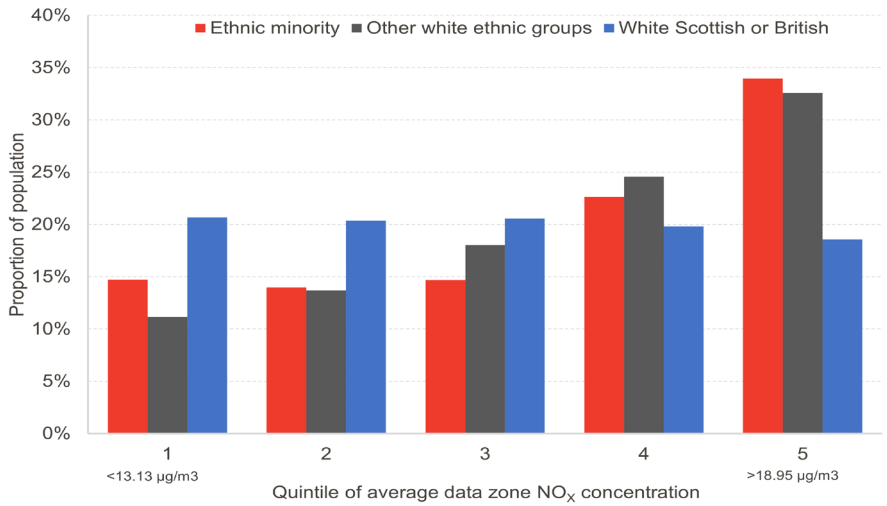
School catchment areas mirror neighbourhood populations, and as a result, schools with high ethnic minority populations are similarly situated around highly polluted city centre areas. Students from ethnic minorities are therefore likely to experience high levels of pollution both at home and at school. These students are also more likely to experience high levels of NO_x than white Scottish or British students. Exposure to PM2.5 is less linear for ethnic minority students, although more than 25% of these students attend school in the most polluted areas (Charts 3 & 4).

Chart 1: Number of people from ethnic minority backgrounds by decile of PM2.5 annual mean concentration



Source: *Author's analysis of data from the Scottish Census (2024), DEFRA, and the SIMD (Scottish Government, 2020)*

Chart 2: Number of people from ethnic minority backgrounds by decile of NO_x annual mean concentration



Source: *Author's analysis of data from the Scottish Census (2024), DEFRA, and the SIMD (Scottish Government, 2020)*

Chart 3: Annual mean PM2.5 concentrations at school for students by ethnic group

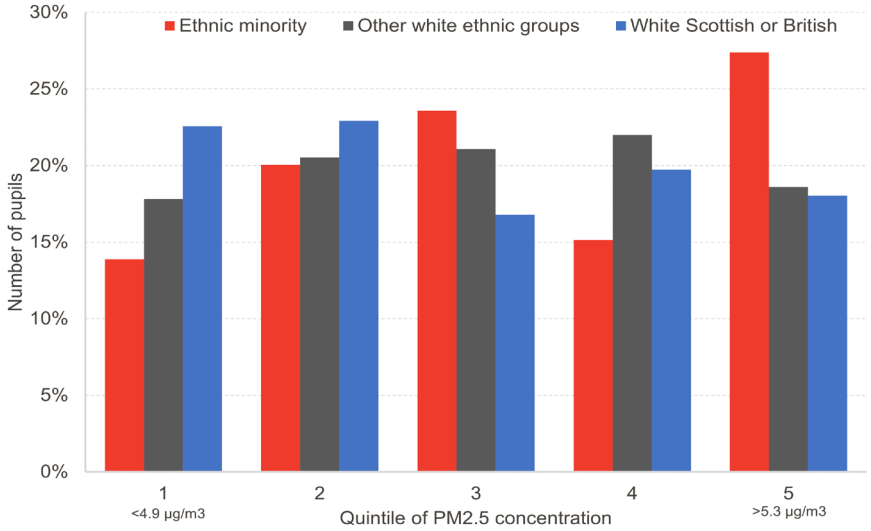
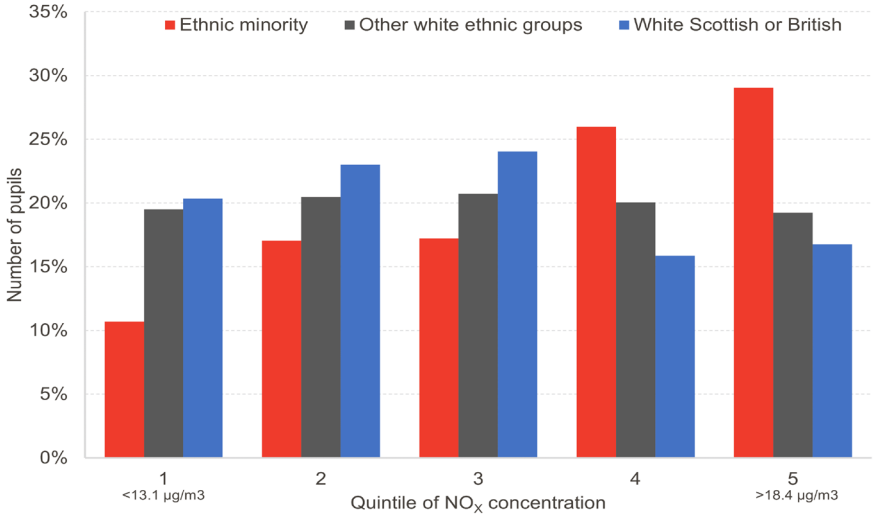


Chart 4: Annual mean NO_x concentrations at school for students by ethnic group



Source: *Author's analysis of data from the Scottish Pupil Census (Scottish Government, 2024), DEFRA, and the SIMD (Scottish Government, 2020)*

Income inequality and air pollution in Glasgow City

A previous study of the Glasgow travel to work area found that areas with a higher proportion of income-deprived people generally had higher levels of air pollution between 2004 and 2012 (*See Bailey et al., 2018*). In 2022, people living in the least deprived 10% of data zones experienced the highest concentrations of NO_x. On average, less than 5% of people living in these data zones were considered income deprived, but it should be noted that this does not mean that these areas are necessarily higher income than other areas on average. Beyond that, there is no evident relationship between income deprivation and pollution. Charts 5 & 6 illustrate this relationship, where an increasing line would indicate that areas with a higher proportion of income deprived people live in areas with higher median pollutant concentrations.

Similarly, there is no clear relationship between students living in the 20% most deprived areas and air pollutant concentrations. Students living in non-deprived areas are slightly more likely to attend schools in the most polluted areas, however (Charts 7 & 8).

Chart 5: Deciles of income deprivation by the average proportion of each decile which is income deprived and median PM2.5 concentration

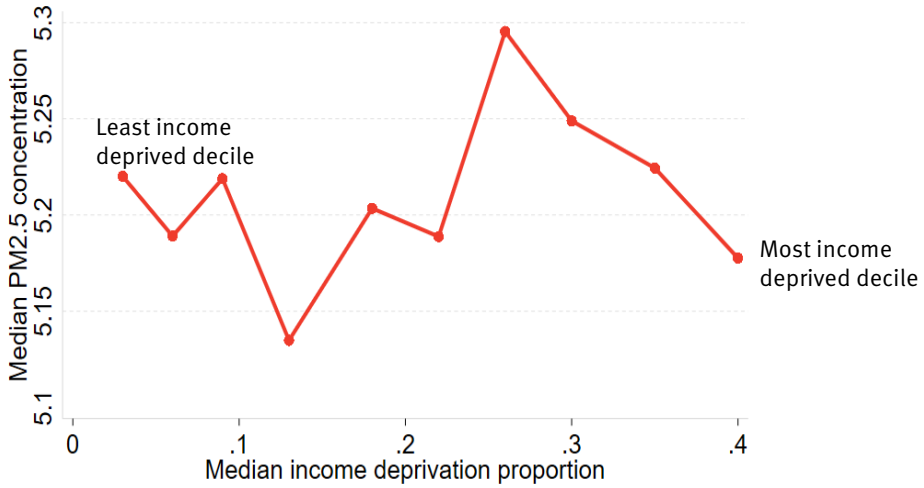
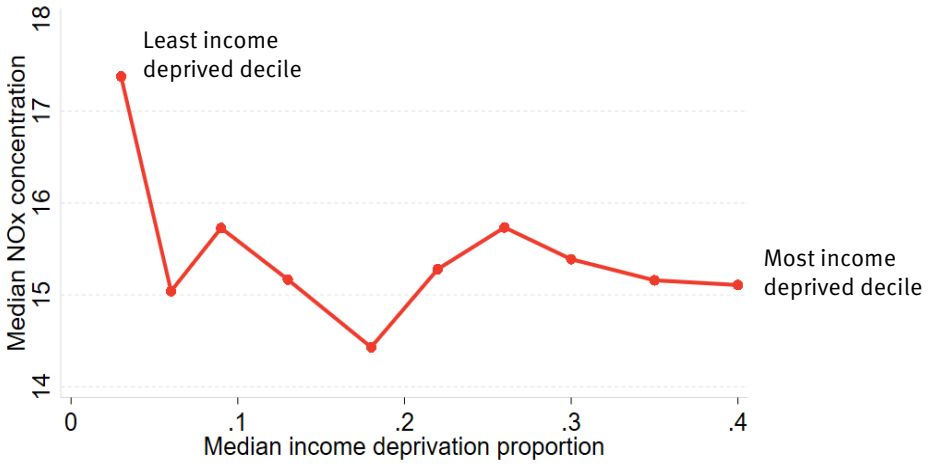


Chart 6: Deciles of income deprivation by the average proportion of each decile which is income deprived and median NO_x concentration



Source: *Author's analysis of data from DEFRA and the SIMD (Scottish Government, 2020)*

Chart 7: Annual mean PM2.5 concentrations at school for students living in the 20% most deprived areas compared to other students

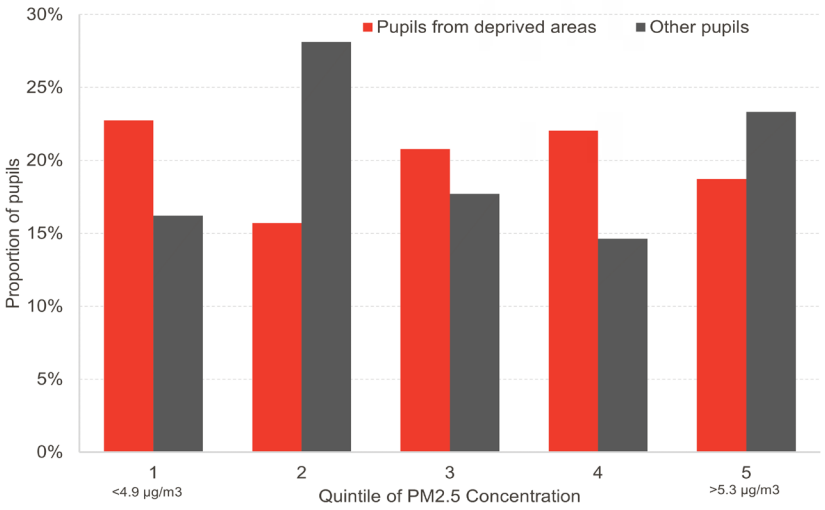
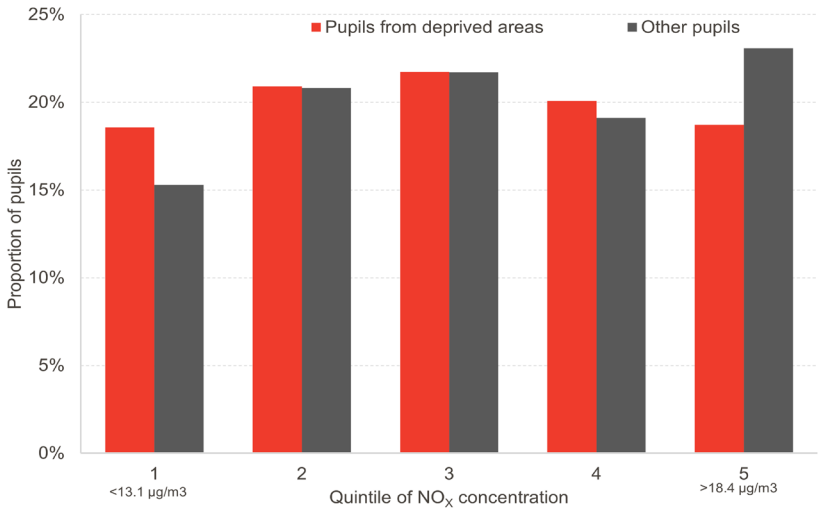


Chart 8: Annual mean NO_x concentrations at school for students living in the 20% most deprived areas compared to other students



Source: *Author's analysis of data from the Scottish Pupil Census (Scottish Government, 2024), DEFRA, and the SIMD (Scottish Government, 2020)*

Discussion

In 2022, ClimateXChange published a report with an overview of environmental inequalities that people across Scotland face. Notably, people from minority groups are significantly more likely to live in areas with above average outdoor air pollution compared to white people. Since then, the Scottish census came out with updated estimates on ethnic backgrounds, finding that, in Glasgow City Council, the ethnic minority population (excluding white minorities) grew from under 12% to nearly 20% of the local authority population between 2011 and 2022. This is a larger proportionate change in population than either the metropolitan area or Scotland as a whole experienced over the same time period: Scotland's ethnic minority population grew from 8.2% of the total population to 12.9%, whilst the Glasgow travel-to-work area grew from 7.3% of the total population to 12.5% (Scotland Census, 2024).

People from minority backgrounds are disproportionately likely to live in areas with high concentrations of outdoor pollutants, notably particulate matter (PM2.5) and nitrogen oxides (NO_x), which generally come from vehicle emissions and wear.

People from white minority backgrounds are also significantly more likely to live in polluted areas than people from white Scottish or British backgrounds.

This is significant because these pollutants can have a serious impact on individual health. While Glasgow has lower concentrations of health-affecting air pollutants compared to other large cities in the UK, it has higher concentrations than anywhere else in Scotland. Nonetheless, inequalities in outcomes are important to monitor when creating new environmental policies, and published studies into different outcomes for the growing ethnic minority population in Scotland are few and far between.

Children are especially sensitive to the health outcomes from poor air quality, and are exposed to a disproportionate volume of air pollution travelling to and being in school. Unsurprisingly, primary and secondary school students experience similar levels of air pollution at school and at home. This means that a disproportionate number of students from ethnic minority backgrounds go to schools in areas with higher levels of air pollution.

Finally, there is some evidence that the least income-deprived neighbourhoods have the highest concentrations of NOX, although there is not generally a clear relationship between income and pollutant concentrations in general. This is surprising, given that one previous study found that areas with higher rates of income deprivation generally had higher rates of air pollution in the greater Glasgow metropolitan area. This difference in findings likely comes down to these boundaries, but by focusing on Glasgow City Council, we are able to isolate areas relevant to local policy makers.

Annex

1. Proportion of total ethnic group populations by neighbourhood decile of NO_x concentration

Decile of NO_x concentration	1	2	3	4	5	6	7	8	9	10
Maximum annual mean NO_x concentration (in µg/m³)	**11.9**	**13.1**	**14.0**	**14.5**	**15.3**	**16.2**	**17.3**	**19.0**	**21.1**	**32.0**
White Scottish or Other White British	10%	10%	10%	10%	10%	10%	9%	11%	10%	9%
White minority	5%	6%	7%	7%	9%	9%	10%	15%	15%	18%
Pakistani, Pakistani Scottish or Pakistani British	14%	8%	8%	8%	4%	7%	22%	5%	12%	12%
Indian, Indian Scottish or Indian British	6%	5%	6%	5%	4%	6%	8%	9%	16%	34%
Chinese, Chinese Scottish or Chinese British	4%	4%	6%	5%	6%	9%	8%	9%	21%	29%
Other Asian	7%	7%	8%	6%	6%	9%	11%	11%	16%	18%
African, African Scottish, African British, or other African	7%	7%	9%	6%	8%	12%	11%	13%	11%	15%
Caribbean or Black, Caribbean or Black Scottish, Caribbean or Black British	4%	10%	9%	9%	8%	12%	9%	12%	13%	15%
Mixed or multiple ethnic groups	7%	7%	7%	7%	6%	9%	10%	14%	15%	18%
Arab, Arab Scottish or Arab British	5%	6%	7%	4%	7%	8%	10%	10%	18%	24%
Other ethnic groups	7%	7%	9%	7%	6%	9%	10%	11%	15%	19%

Source: *Author's analysis of data from the Scottish Census (2024), DEFRA, and the SIMD (Scottish Government, 2020)*

2. Proportion of total ethnic group populations by neighbourhood decile of PM2.5 concentration

Decile of PM2.5 concentration	1	2	3	4	5	6	7	8	9	10
Maximum annual mean PM2.5 concentration (in µg/m³)	**4.80**	**4.94**	**5.08**	**5.15**	**5.23**	**5.28**	**5.32**	**5.41**	**5.58**	**6.56**
White Scottish or Other White British	11%	10%	9%	10%	10%	10%	10%	11%	10%	9%
White minority	4%	7%	7%	10%	9%	13%	11%	11%	13%	14%
Pakistani, Pakistani Scottish or Pakistani British	12%	10%	10%	11%	14%	13%	5%	9%	9%	8%
Indian, Indian Scottish or Indian British	7%	5%	7%	8%	8%	6%	6%	9%	18%	27%
Chinese, Chinese Scottish or Chinese British	4%	4%	6%	8%	8%	7%	12%	18%	14%	19%
Other Asian	7%	8%	11%	9%	9%	10%	9%	10%	13%	15%
African, African Scottish, African British, or other African	8%	7%	9%	8%	8%	12%	10%	10%	14%	15%
Caribbean or Black, Caribbean or Black Scottish, Caribbean or Black British	6%	8%	11%	9%	9%	11%	10%	9%	14%	13%
Mixed or multiple ethnic groups	7%	7%	8%	11%	10%	10%	9%	11%	13%	13%
Arab, Arab Scottish or Arab British	5%	6%	10%	7%	8%	8%	7%	12%	15%	21%
Other ethnic groups	8%	7%	11%	10%	8%	11%	9%	10%	12%	15%

Source: *Author's analysis of data from the Scottish Census (2024), DEFRA, and the SIMD (Scottish Government, 2020)*

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