

# **UNDERSTANDING THE SPATIAL RELATIONSHIP BETWEEN AIR POLLUTION AND SOCIAL DEPRIVATION IN THE UK**

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## **ABSTRACT**

In the UK, only a limited amount of research has been undertaken into the burden of air pollution on different social groups, most of which has occurred during the last five years. This paper focuses on a study undertaken by Netcen on behalf of the Department for the Environment, Food and Rural Affairs (DEFRA), to assess the spatial relationship between air pollution and social deprivation in selected urban areas of the UK. This study used simple correlation analysis, comparing average ward (NUTS 5) NO<sub>2</sub> and PM<sub>10</sub> concentrations with levels of deprivation. Positive correlations between social deprivation and air pollutant concentrations were observed in selected urban areas except Cardiff, with higher concentrations being associated with higher levels of deprivation. This paper briefly outlines other research in the UK that has followed this study, and highlights current research being undertaken by Netcen on behalf of DEFRA.

## **INTRODUCTION**

In recent years, only a limited amount of research has been undertaken in the field of environmental equity in the UK. Prior to 2000, such a subject did not feature highly on the research agenda, unlike in the USA where many studies have been undertaken. Environmental equity has risen up the UK policy agenda in the last 5 years, due to the prominence given to issues of social exclusion and neighbourhood renewal. In turn, this has driven the need for further research.

Environmental inequity arises where the environmental burdens (air pollution, noise, proximity to waste treatment sites / contaminated land etc.) disproportionately impact on the most vulnerable groups in society. For this paper, the focus is on air pollution concentrations in selected UK urban areas and how they differ in ward areas with differing levels of deprivation. Given the significant geographical variations in predicted exceedances of air pollution, there is potential for certain sectors of society to be differentially impacted by air pollution.

Two studies, undertaken by Netcen, provide some evidence to suggest that levels of air pollution tend to be higher in ward areas with higher level of deprivation. The first study, by King and Stedman in 2000 [2] reported that for there was tentative evidence for a general positive correlation between background air pollution (NO<sub>2</sub> and PM<sub>10</sub>) and deprivation index in London, Belfast and Birmingham but in Glasgow there was an inverse relationship. Port Talbot also shows a weak negative correlation for PM<sub>10</sub>, using PM<sub>10</sub> concentration data that include a contribution from local point sources.

In the second study by Pye et al. in 2001 [1], a positive correlation between air pollution and social deprivation was observed for all selected urban areas except Cardiff, in which no association was observed. In conclusion, the report stated that *for the areas of Greater London, Birmingham City District and Greater Belfast, it may be likely that targeted policies to reduce air pollution concentrations in areas where they are high could impact marginally more beneficially in more deprived communities, and therefore move towards reducing the apparent inequity.*

This paper provides a more detailed overview of the findings of the second Netcen study, briefly assesses other similar studies subsequently undertaken, and highlights current research being undertaken for DEFRA by Netcen in this field.

## STUDY OBJECTIVES

The broad objectives of the study by Pye et al. in 2001 [1] were same as those stated in the initial pilot study [2], which were to examine the distributional effects of NO<sub>2</sub> and PM<sub>10</sub>, the two pollutants for which the air quality objectives are expected to be the most challenging, in order to examine some aspects of the following issues:

- The links between the environment and inequality and, in particular, on whether environmental problems impact most heavily on the most vulnerable;
- The extent to which policies which seek to improve air quality will bring disproportionate benefits to the more vulnerable members of society.

The term ‘vulnerable’ in the context of this study is measured using an index of multiple deprivation. Therefore, ‘vulnerability’ will not necessarily reflect the demographic profile of a ward area (age, gender etc.) or the state of the health of the ward population. The inclusion of such parameters would be important if we were undertaking benefits analysis (e.g. the impact of air pollution in terms of deaths brought forward or cases of respiratory illness). However, this study was specifically aimed at assessing the relationship between two broad parameters – levels of air pollution and index of multiple deprivation.

## DATA SOURCES

There were two primary data sources needed for this analysis:

- Deprivation indices, developed by the Social Disadvantage Research Centre at Oxford University [3, 4, 5]
- Background and roadside NO<sub>2</sub> and PM<sub>10</sub> concentration data, based on a methodology described by Stedman et al [6, 7] and in associated documents [8].

The availability of a reasonably consistent set of deprivation indices allows for greater inter-regional comparison within this analysis. The indices are consistent both in terms of spatial

scale, having been compiled at the ward level, and in terms of the methodology used for constructing the indices.

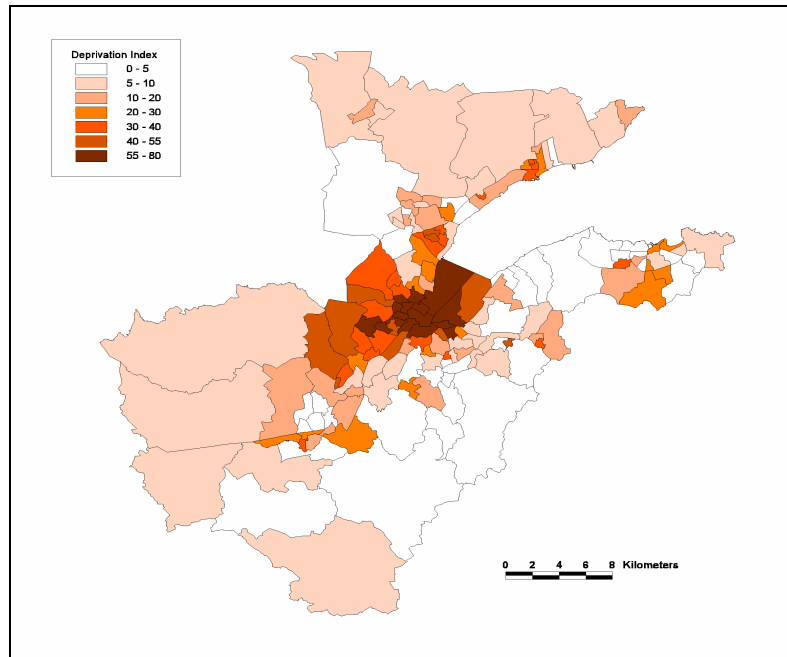
In each case, the index of multiple deprivation is made up of a set of domains, each representing a different aspect of deprivation. Individual domains are produced within each index, using a set of indicators. An example of a domain is employment, which is made up from indicators such as numbers of adults unemployed. The domains are combined in two stages to create the overall multiple deprivation index. Firstly, each domain is transformed to a standard distribution, using an exponential transformation method – as a result, every domain is converted to an identical distribution with the same maximum and minimum values. The domains are then weighted according to their relative importance and combined.

This study uses air quality data in both 1998 and the predicted reference case in 2010 (2010b) plus a 2010 ‘with measures’ case (2010wm). Details of both the current policies baseline reference case and the ‘with measures’ scenarios for 2010 are provided in report produced for DEFRA [6, 7, 8]. The ‘with measures’ case is the illustrative additional measures scenario and includes a range of possible additional measures to reduce PM<sub>10</sub> emissions from both traffic and stationary sources. Measure specifically aimed at reducing NO<sub>2</sub> concentrations have not been examined but the impact of the possible traffic measures to reduce PM<sub>10</sub> on NO<sub>2</sub> have been calculated.

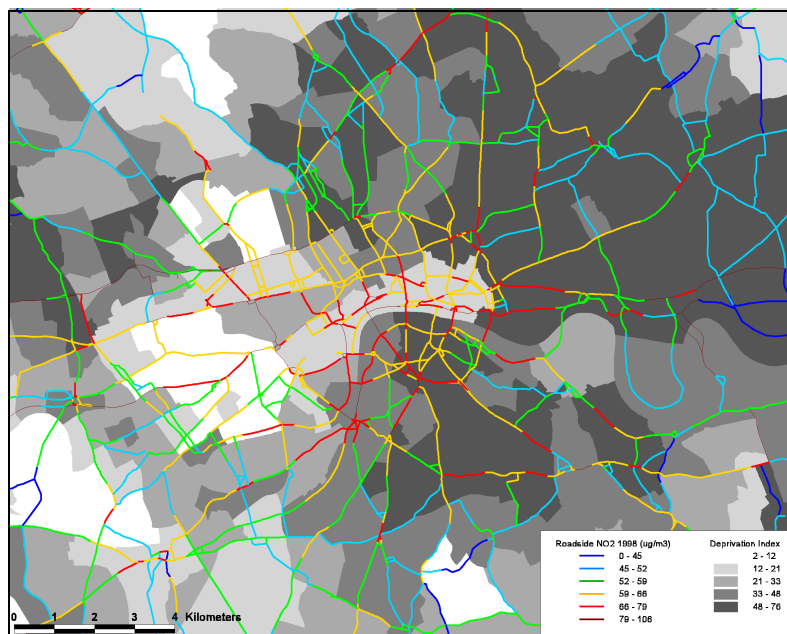
## **GEOGRAPHICAL ANALYSIS**

The urban areas of Greater London, Birmingham, Greater Belfast and Cardiff were used in the geographical analysis, in which the spatial relationship between air pollution and deprivation levels was assessed. The analysis was undertaken at a geographical resolution of ward area, with some limited analysis at a more detailed enumeration district level.

Figure 1 illustrates the deprivation levels by ward in Greater Belfast, with highest deprivation levels observed for Belfast District Authority. Average ward background pollutant concentrations were overlaid onto this deprivation coverage in a GIS model, and then correlated statistically. Figure 2 illustrates how roadside concentrations were overlaid on ward deprivation data within the GIS model.



**Figure 1** Greater Belfast Deprivation Index by Ward



**Figure 2** Roadside NO<sub>2</sub> concentrations in Central London vs. ward deprivation values

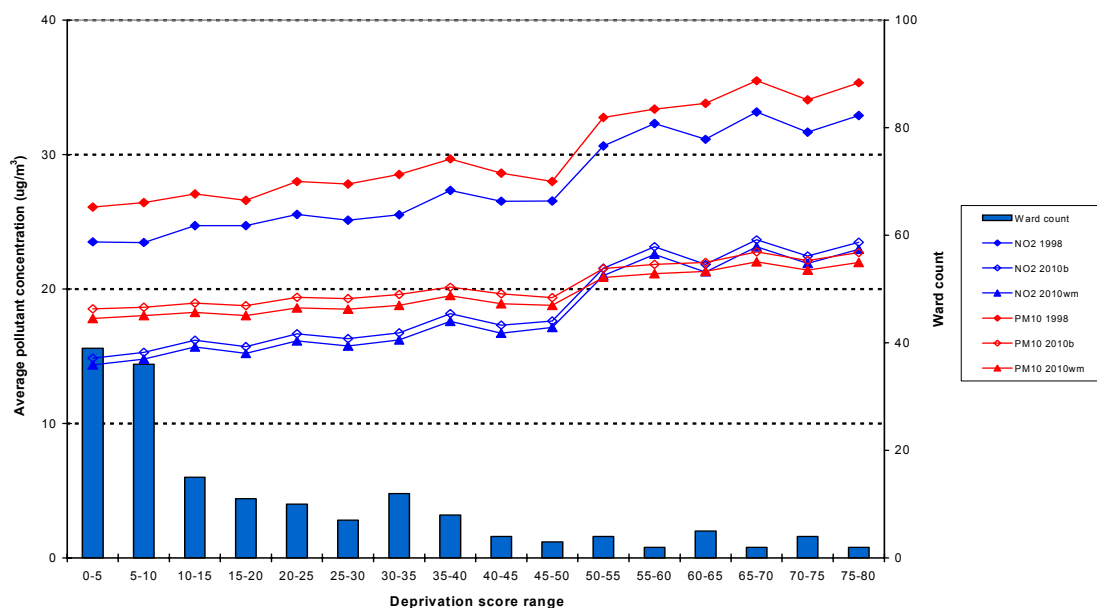
## STATISTICAL ANALYSIS

Five key statistical relationships were assessed as part of this study:

1. Correlation of multiple index scores with background NO<sub>2</sub> and PM<sub>10</sub> concentrations for 1998 and 2010 baseline / 'with measures' scenario, using scatter plots and banded averages.

2. Comparison of the above correlation across the three different regions.
3. Correlation of individual components of the deprivation indices with NO<sub>2</sub> and PM<sub>10</sub> concentrations.
4. Correlation between roadside concentrations and deprivation score in Greater London
5. Correlation with the predicted change in pollution concentrations between 1998 and 2010 baseline, and between 2010 baseline and 2010 'with measures'.

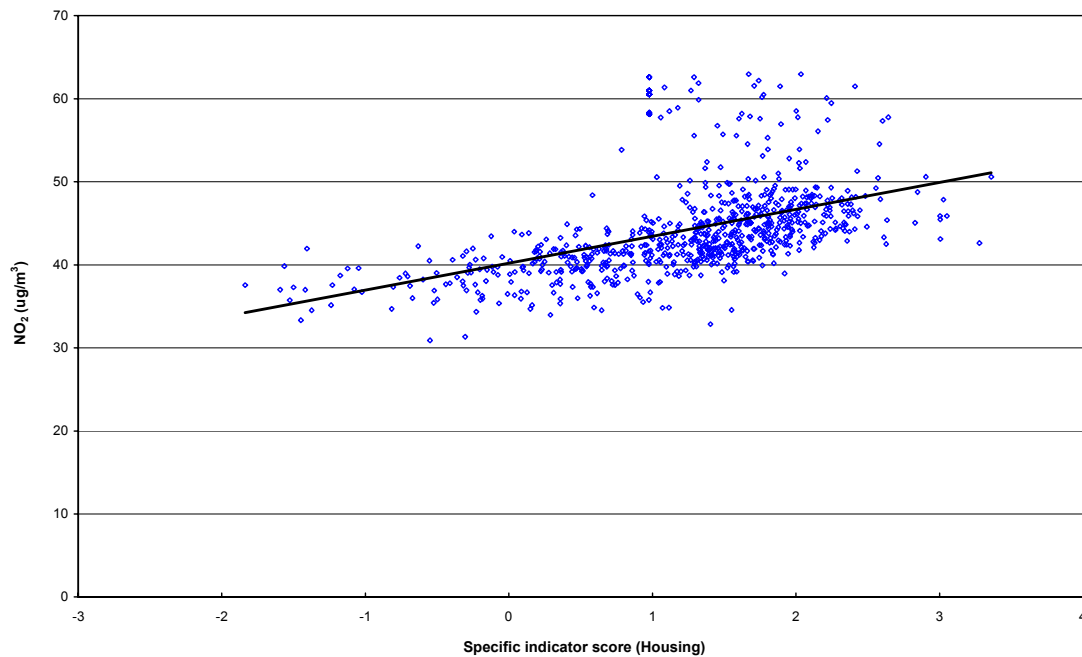
The analysis of deprivation versus background air quality concentrations for Greater Belfast is provided below in Figure 3. The assumption is that ward deprivation levels remain the same relative to each other over time.



**Figure 3** Average annual mean pollution concentrations by Deprivation Score range for Greater Belfast

The 1998 concentration levels are much higher than in 2010, and on average, lower in the less deprived ward classes. The absolute decrease in average concentrations between 1998 and 2010 is greater for the more deprived ward classes. It is important to note that a larger number of concentration values are averaged in the lower deprivation classes, due to a larger number of wards.

Analysis on the relationship between background air pollution and individual domains was also undertaken. The housing domain shows quite a strong positive correlation with background NO<sub>2</sub>. The access to services domain, however, shows an inverse relationship, with less deprived wards (as measured by access to services) experiencing higher pollutant concentrations.



**Figure 4** Greater London 1998 annual mean NO<sub>2</sub> versus Housing Deprivation domain

An overview of the findings from this study analysis are summarised in the next section.

## CONCLUSIONS

There are some general conclusions that can be drawn from the study analysis:

- For Greater London, Birmingham City District and Greater Belfast, there appears to be evidence for a positive correlation between NO<sub>2</sub> and PM<sub>10</sub> and social deprivation, with higher concentrations of these pollutants found in areas exhibiting higher levels of deprivation.
- There does not appear to any significant relationship between air pollution and social deprivation for Cardiff City Council, although there are some weak correlations between individual domains and specific pollutants.
- Individual domains within the multiple deprivation indices show very different trends when they are analysed on an individual basis against air pollutant concentrations. However, in general, most domains follow the trend of a positive correlation between pollutant concentration and deprivation index.
- Based on all analysis methodologies undertaken, there appear to be a weak positive relationship between roadside pollution and levels of deprivation.
- Variation in the spatial scale of analysis (ward and enumeration district levels) seems to have limited effect on the results.
- For the English cities, policies to reduce NO<sub>2</sub> and PM<sub>10</sub> could have greater benefits for more deprived communities based on the results from this analysis, and for central urban locations that have highest concentrations of these pollutants. This appears true for Greater Belfast although under the

2010 scenario where additional measures are included, such measures do not appear to have increased benefits for more deprived areas. This does not appear to be the case for Cardiff City Council, where policies to reduce air pollution could have greater marginal benefits for less deprived communities.

## **FURTHER RESEARCH**

Further research of environmental inequity in the UK has been undertaken since the publication of these two Netcen studies. In particular, two key studies that have considered air pollution include Mitchell and Dorling [9] and Walker et al. [10], both published in 2003. Mitchell and Dorling [9] carried out a ward-based analysis for Britain, and found that the most deprived areas tended to suffer above average levels of NO<sub>2</sub> pollution. They also noted that least deprived wards often also experienced above average exposure. This was also noted in the Netcen study [1], due to high traffic emissions in affluent wards within central London.

The Walker et al. study [10] was far more wide ranging, and also considered other aspects of environmental quality, including risk of flooding and proximity to regulated industrial installations. For the air quality part of the analysis, five different pollutants were considered. A strong relationship was again identified between poor air quality and social deprivation, with the most deprived wards experiencing the highest pollutant concentrations. For both England and Wales, above average concentrations were also found in least deprived wards. For England, the elevation above the average was much less than for the most deprived wards. However, in Wales, a different pattern was observed, with less deprived wards experiencing higher concentrations than most deprived wards. This was explained by urban households being less deprived on average, but located in the most polluted areas. Many pollution-poverty hotspots were also identified, where clusters of deprived wards are in areas experiencing above average concentrations.

Currently, Netcen is in the early phase of undertaking more analysis for DEFRA, sponsored by the Office for National Statistics' Neighbourhood Statistics Programme. The final report is expected to be published at the beginning of 2006. The work will focus on four key areas:

- Urban deprivation
- Rural deprivation
- Analysis of community proximity to point sources
- Assessment of health impacts and ward population susceptibility

The urban deprivation analysis will be similar to the two previous Netcen analyses but will include more pollutants (including Ozone) and urban areas (for all UK constituent countries). The rural analysis is less developed at this stage but will focus on identifying deprived rural communities that may have significant pollution exposure (due to domestic fuel burning or high levels of road transport).

Proximity analysis will be based on analysis already undertaken on concentration 'footprints' of the most significant point sources. In this context, 'significance' is meant in terms of highest ground level concentrations. The footprints show ground level concentrations in the

immediate area around the site. These will then be correlated with levels of ward deprivation, to determine whether the affected wards have deprivation levels above the regional / national averages. It may not necessarily be the communities directly adjacent to the point source that experience the high concentrations of air pollutants. The shape of the concentration footprint will depend significantly on dispersion characteristics and magnitude of emission releases. Analysis will also be undertaken to look at potential population susceptibility to air pollution impacts. Indicators of susceptibility will be formulated from the datasets on total ward population, age cohort profiles (e.g. numbers of people in different age ranges) and current overall state of health.

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