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Air quality and social deprivation in four French metropolitan areas—A localized spatio-temporal environmental inequality analysis

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ABSTRACT

Several studies have documented that more deprived populations tend to live in areas characterized by higher levels of environmental pollution. Yet, time trends and geographic patterns of this disproportionate distribution of environmental burden remain poorly assessed, especially in Europe. We investigated the spatial and temporal relationship between ambient air nitrogen dioxide (NO_2) concentrations and socioeconomic and demographic data in four French metropolitan areas (Lille in the North, Lyon in the center, Marseille in the South, and Paris) during two different time periods. The geographical unit used was the census block. The dependent variable was the NO_2 annual average concentration ($\mu g/m^3$) per census block, and the explanatory variables were a neighborhood deprivation index and socioeconomic and demographic data derived from the national census. Generalized additive models were used to account for spatial autocorrelation. We found that the strength and direction of the association between deprivation and NO_2 estimates varied between cities. In Paris, census blocks with the higher social categories are exposed to higher mean concentrations of NO_2. However, in Lille and Marseille, the most deprived census blocks are the most exposed to NO_2. In Lyon, the census blocks in the middle social categories were more likely to have higher concentrations than in the lower social categories. Despite a general reduction in NO_2 concentrations over the study period in the four metropolitan areas, we found contrasting results in the temporal trend of environmental inequalities. There is clear evidence of city-specific spatial and temporal environmental inequalities that relate to the historical socioeconomic make-up of the cities and its evolution. Hence, general statements about environmental and social inequalities can be made.

1. Introduction

Environmental justice first emerged in the United States and Canada where it is now an important part of environment and public health policy assessment (Jerrett et al., 2001; Bowen, 2002; Fairburn et al., 2009; Laurent, 2011). The concept draws attention to the questions of whether certain socioeconomic groups, including the economically and politically disadvantaged, bear a disproportionate burden of environmental externalities, and whether policies and practices that relate to sources of nuisances and pollution or, conversely, to wholesome environments (e.g., green spaces), are equitable and fair (Bowen, 2002; Braubach, 2013).

A number of ecological studies dealing with environmental equity (or justice) have investigated this topic and assessed population exposure to environmental pollution and socioeconomic characteristics using data collected at different geographic scales. As expected, many studies conclude that groups with a low socioeconomic status tend to be more highly exposed to air pollutants and toxicants, due especially to the proximity of their homes to pollution sources (e.g. high-traffic roads, industrial facilities and waste disposal sites) (Finkelstein et al., 2005; Chaix et al., 2006; Marshall, 2008; Briggs et al., 2008; Yanosky et al., 2008; Diekmann and Meyer, 2010; Viel et al., 2010; Brochu et al., 2011; Bell and Ebisu, 2012; Laurian and Funderburg, 2013).

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More recently, the issue of uneven distribution of environmental pollution across populations with different socioeconomic status entered into discussions in Europe, specifically in The Netherlands (Kruize et al., 2007), Finland (Rotko et al., 2001), Sweden (Chaix et al., 2006), Germany (Kohlhuber et al., 2006), the UK (Namdeo and Stringer, 2008; Mitchell and Dorling, 2003; Fairburn et al., 2009; Walker, 2010; Jephcote and Chen, 2012), Italy (Forastiere et al., 2007), and France (Laurian, 2008; Havard et al., 2009; Laurian and Funderburg, 2013). In contrast with American studies, inconsistent results were obtained in Europe. For instance, while some report that populations with low socioeconomic status are more exposed to air pollutants (Kruize et al., 2007; Namdeo and Stringer, 2008), others find that populations with middle socioeconomic status experience higher levels of air pollution (Havard et al., 2009), or show an inverse relationship (Forastiere et al., 2007). The methodological diversity of these studies and the variety of their settings may partly explain the heterogeneity of their results. This heterogeneity might also express the diversity of the urban make-up both across and within European countries (Deguen and Zmirou-Navier, 2010). According to an Organization for Economic Co-operation and Development report (OECD Report, 2004), more studies are needed in Europe to improve our understanding of the underlying mechanisms of environmental inequality.

A decreasing trend of urban air pollution has been observed in most European countries during the last two decades, an effect of national regulations, in compliance with the European directives (1999/30/EC, 2008/50/EC). Despite air quality improvements, air pollution remains a major public health research field, particularly in consideration of social justice. Some neighborhoods in urban areas are characterized by concentrations of socially and materially deprived populations. In addition, previous studies demonstrate that trends in ambient air quality can create disparities across neighborhoods (O'Neill et al., 2003; Jerrett et al., 2005).

In this context, our work concerns two issues. First, we will identify whether urban neighborhoods are characterized by an uneven distribution of ambient air concentrations of nitrogen dioxide (NO_2) according to the level of deprivation in four large French metropolitan areas. Second, we will investigate the time trends of environmental inequalities by comparing two time periods during the last decade (2002–2005 and 2006–2009) during which a general pattern of air pollution reduction was observed. We will address three underlying questions: (1) Are environmental inequalities comparable across the four French cities, with regards to air pollution? (2) How do environmental inequalities change over the time? (3) Do the socioeconomic markers of environmental inequalities differ between the two study periods?

Nitrogen dioxide was selected because it is known to be a good tracer of urban air pollution generated by traffic and because its spatial heterogeneity is recognized to be greater than for other air pollutants (Jerrett et al., 2004). It is also a pollution indicator for which exposure varies substantially among socioeconomic groups (Yanosky et al., 2008; Crouse et al., 2009; Diekmann and Meyer, 2010; Branis and Linhartova, 2012; Vrijheid et al., 2012). Strengths of the study include the small spatial scale of the analysis which reduces the residual autocorrelation between spatial units, the comprehensive modeling of the urban distribution of NO_2 concentrations, and the use of the same statistical methodology for the 4 major metropolitan areas.

2. Materials and methods

2.1. Study area and setting

Our study is an ecological study using the smallest geographical level unit with available socioeconomic data in France. The statistical unit is the sub-municipal French census block (called IRIS "Îlot Regroupé pour l'Information Statistique") defined by the National Institute of Statistics and Economic Studies (INSEE, 2013). This geographical unit averages 2000 inhabitants and is constructed to be as homogenous as possible in terms of socio-demographic characteristics and land use. The census blocks' surface areas are 1.2 km² (±2.1) for the Lille, North of France, 4.1 km² (±6.3) for the Lyon, Center-East of France, 2.0 km² (±4.6) for the Marseille, South of France and 0.3 km² (±0.6) for the Paris metropolitan areas. The spatial analysis of environmental inequalities were stratified by two periods of 4 years (2002–2005 and 2006–2009) to assess trends over time within the four metropolitan areas.

Fig. 1 presents the study areas with Lille, Marseille, Lyon and Paris. The Paris metropolitan area includes the city of Paris and three surrounding departments (named "petite couronne"). These four metropolitan areas have been chosen because they exhibit important differences regarding socioeconomic and demographic characteristics (Table 1).

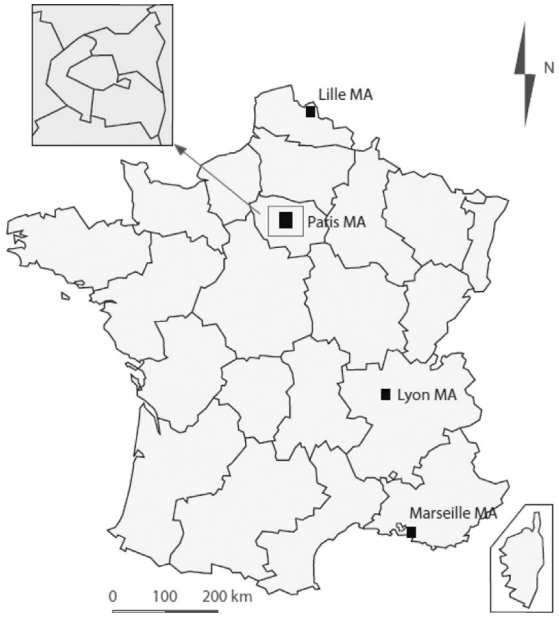

Fig. 1. Location of the four metropolitan areas in France.

	Number of Census Blocks	Number of municipalities	Population in 2008 (inhabitants)
Lille	504	85	1.193.244
Paris	2749	412	10.354.675
Lyon	511	58	1.281.971
Marseille	628	52	1.715.096