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Ambient air pollution concentration in Montreal and environmental equity: Are children at risk at school?

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ABSTRACT

The analysis of ambient air quality in the environments around elementary schools is an important issue, as children are at school for a large part of the day. This article has two objectives: first, to compare the proportion of major roads and NO_2 concentration levels in city blocks where there are schools with the situation in the rest of the Island of Montreal; and second, to see whether there are significant differences in these pollution indicators according to the levels of socioeconomic deprivation at these schools.

Montreal's 319 elementary schools were geocoded in a geographic information system (GIS). Two types of pollution indicators based on the types of roads and NO_2 concentrations were calculated within a 200-m radius of each city block centroid on the Island of Montreal and of the main building of each elementary school.

Elementary schools, regardless of their level of socioeconomic deprivation, are located in city blocks where there are fewer major roads than in, and generally similar concentrations of NO_2 to, the rest of the Island of Montreal. However, NO_2 concentrations near elementary schools are positively and significantly associated with levels of deprivation at these schools.

This study highlights an issue of environmental equity, in showing that students from socioeconomically disadvantaged backgrounds tend to attend elementary schools located in more polluted environments.

1. Introduction

Pollutant emissions are one of the major pollutants in urban areas and affect people's quality of life on a number of levels (Briggs et al., 2008; Brunekreef and Holgate, 2002; Hoek et al., 2002). Air pollution also contributes to health inequalities, and the authorities must develop adequate social inclusion policies towards the most vulnerable populations to these pollutants. Vehicular exhaust is the main source of harmful particles that have a detrimental impact on health, especially nitrogen oxides (NO_x) (Cesaroni et al., 2008; Crouse et al., 2009a) and, to a lesser extent, carbon monoxide (CO) (Houston et al., 2004; Rioux et al., 2010). Recent observations in regard to NO_2 levels in the United Kingdom report that the spatial concentrations of this pollutant have stabilized in recent years. These observations could undermine the authorities' objective of reducing NO_2 concentrations in urban areas (Carslaw et al., 2011).

The highest concentrations of these pollutants are generally found within 200 m of highways and major roads (Brugge et al., 2007). Studies have shown that children are more vulnerable to the effects of high concentrations of various air pollutants due to the fact that their organs and nervous systems are not fully developed (Bolte et al., 2009) and that they inhale more air per unit of body mass (Landrigan et al., 2004), and because of their limited mobility, which tends to restrict them to their residential area (Day and Wager, 2010). A number of studies around the world have also shown that children who attend schools located less than 200 m from a major road, that is, in areas where traffic densities are high and where there are high levels of traffic-related pollutants, are more likely to develop problems associated with asthma and to have reduced lung function (Brunekreef et al., 1997; Clark et al., 2010; Gauderman et al., 2007; Jerrett et al., 2008; Kim et al., 2008). For example, Brunekreef et al. (1997) found that a residential location near major motorways in the Netherlands may lead to reduced lung function in children.

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The literature on environmental and social equity has focused on the health impacts of the spatial distribution of environmental burdens, and on the lack of amenities experienced by low-income households and ethnic or racial groups in different countries (Schweitzer and Stephenson, 2007; Walker, 2011). Numerous studies have shown that low-income households tend to be located in the most polluted areas in Canada (Buzzelli and Jerrett, 2007; Crouse et al., 2009b), the United States (Chakraborty, 2006, 2009; Pastor et al., 2001), the United Kingdom (Brainard et al., 2002; Mitchell and Dorling, 2003) and New Zealand (Kingham et al., 2007). In the same vein, other studies have looked at the social impacts of transportation infrastructure (Feitelson, 2002; Hodgson et al., 2013; Thomopolous and Grant-Muller, 2013). More recently, the literature on environmental and social equity has increasingly examined other population groups such as children and older people due to their physiological vulnerability to air pollution (Walker, 2009). Nevertheless, few studies on environmental and social equity and transportation have explored whether children are exposed to high concentrations of air pollutants (Brainard et al., 2002; Crouse et al., 2009b; Mitchell and Dorling, 2003).

This analysis focusing on Montreal has been inspired by these studies on air pollution and social impacts in transportation from the perspective of environmental and social equity. It concentrates, however, on an evaluation of air quality in the environments around elementary schools. Only a few studies in environmental and social equity have emphasized intra-group differences in terms of the exposure to air pollutants.

2. Schools, air pollution, environmental and social equity

Numerous studies have been conducted in order to evaluate the association between air quality around schools and various outcomes such as academic performance (Clark et al., 2010; Zahran et al., 2009), mental health (Evans, 2003) and respiratory problems (McConnell et al., 2010; Pastor et al., 2006). In that perspective, the characterization of the socioeconomic status of children attending schools located in areas that are most affected by traffic-related air pollution has become a topic of considerable interest in the literature on environmental and social equity because of the amount of time that children spend at school (Sampson, 2012).

A number of U.S. studies have shown that children from low-income backgrounds and Hispanic or African-American communities are more likely to attend schools that are located near major roads and in the most polluted areas. In California, Green et al. (2004) showed that public schools located within 150 m of a major road with daily traffic of over 50,000 vehicles were more frequently attended by ethnic minorities (Hispanics and Blacks) and students from low-income households. In other American cities, Chakraborty and Zandbergen (2007) and Stuart and Zeager (2011) in Tampa Bay, and Wu and Batterman (2006) in Detroit found that schools with a high level of deprivation were positively associated with a proximity to major roads and a higher concentration of nitrogen dioxide (NO_2). A recent study by Amram et al. (2011) on large Canadian urban areas notes that 22% of schools in the most deprived quintile at the census tract level are located less than 75 m from a major road, compared with 13% of schools in the least deprived quintile. Moreover, a study in Malmo, Sweden shows that children under 15 years of age from low-income households are more exposed to higher concentrations of NO_2 in their home and school environments (Chaix et al., 2006).

3. Research objectives

The literature has emphasized the finding that children from low-income households or of low socioeconomic status are more likely than those from more well-off households to attend schools that are located near major roads, where concentrations of pollutants are higher (Amram et al., 2011; Chakraborty and Zandbergen, 2007). This situation is an important issue for understanding health inequalities and developing appropriate social inclusion policies for transportation, as children are vulnerable to pollutants in their environment in two ways. On the one hand, the incomplete development of their organs and nervous systems increases their risks of developing various health problems if they are exposed to high concentrations of pollutants. On the other hand, because children—and especially children from low-income backgrounds—are less mobile, they are more likely to stay in their residential environments.

To our knowledge, no study on environmental and social equity has compared the levels of traffic-related pollutants in the environments around schools with the levels in a larger control area. The emphasis has often been placed on the differences in pollutant concentrations between schools according to their socioeconomic composition. This study has two objectives. It first attempts to determine whether Montreal elementary schools are located in city blocks that are more polluted than in the rest of the Island of Montreal. We then develop an assessment of environmental and social equity by establishing whether the most disadvantaged elementary schools show higher pollution indicators than schools in more well-off areas.

4. Methodology

A number of methodological issues have been raised in the literature in order to determine, with considerable precision, the existence of environmental inequities for a given population group. Among the important criteria for a rigorous evaluation of environmental and social equity, Walker (2010) emphasizes the issue of the choice of the scale of analysis. In concrete terms, this spatial division has to be as fine as possible in order to obtain a good degree of variability of the indicator of exposure to the environmental nuisance across the spatial units in the area under study. This concept of the modifiable areal unit problem (MAUP) has largely been addressed in the literature in environmental and social equity (Bowen, 2002; Schweitzer and Stephenson, 2007), and recently in the literature on transportation (Wang et al., 2011). An inadequate choice of the scale of analysis could lead to errors and misinterpretations, as reported in Bowen (2002). Walker (2010) also considers it appropriate to compare the levels of exposure to the nuisance examined in the target group with the levels for a control group, in order to establish whether these levels are in fact higher in the target group. Consequently, in the context of this study, it is important to select the appropriate spatial division and control groups in order to determine whether or not the elementary schools are located in more polluted environments.

4.1. Study area, targeted groups and scale of analysis

This study focuses on the Island of Montreal, which has 1.88 million inhabitants and covers 499 km^2. This territory is part of the Montreal census metropolitan area (CMA), which is the second most populous metropolis in Canada (with 3.92 million inhabitants). We have only considered the Island of Montreal because air pollution data were only available in that geographic area. More specifically, this study focuses on the environment around Montreal's 319 public elementary schools, excluding schools in Île-Bizard (with a population of 17,950 inhabitants), where no air pollution measurements had been taken (Fig. 1).

We selected two control groups—children between 5 and 12 years old, and the total population—the numbers of which were extracted by Statistics Canada from the 2011 census, at the