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The application of three methods to measure the statistical association between different social groups and the concentration of air pollutants in Montreal: A case of environmental equity

Mathieu Carrier [a,*], Philippe Apparicio [a], Anne-Marie Séguin [a], Dan Crouse [b,1]

[a] Centre Urbanisation Culture Société, Institut national de la recherche scientifique, 385 Sherbrooke Street East, Montréal, Québec H2X 1E3, Canada
[b] Department of Geography, 805 Sherbrooke Street West, Montréal, Québec, H3A 0B9, Canada

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ABSTRACT

Analyzing the spatial dispersion of pollutants has led researchers to develop measures in order to determine whether certain population groups are disproportionately exposed to these hazards. A proxy of the distance from major roads, mathematical modelling, and exposure as established by pollutant measurement are three of the main techniques developed to determine environmental inequity with regard to a particular group in the broader population. A number of the studies performed have concluded that the low-income population and, to a lesser extent, visible minorities tend to reside in the most polluted areas. The main objective of this article is to compare the results obtained from three techniques for analyzing the spatial concentration of pollutant emissions on the Island of Montreal. The second objective is to determine whether groups vulnerable to air pollutants—namely, individuals under 15 years old and the elderly—and those who tend to be located in the most polluted areas—i.e., visible minorities and the low-income population—are affected by environmental inequities associated with air pollution. The results obtained from the three techniques for evaluating environmental equity firstly show that there are differences between these techniques. Secondly, they show that the groups selected based on age are not affected by environmental inequities. Finally, they indicate that the low-income population and, to a lesser extent, visible minorities in Montreal more frequently live near major roads and in areas with higher pollutant concentrations.

1. Introduction

In urban areas, vehicular exhaust along transportation networks is the primary source of ambient air pollution, including nitrogen oxides (NO_x) and, to a lesser degree, carbon monoxide (CO) and particulate matter (PM). Both short- and long-term exposure to urban air pollution can be harmful to human health (Brunekreef and Holgate, 2002). Moreover, living within 200 m of a major road is considered a potential risk to cardiovascular health (Brugge et al., 2007; Rioux et al., 2010), and for the development of asthma (Jerrett et al., 2008; McConnell et al., 2006) and lung development deficits among children

* Corresponding author. Tel.: +1 514 499 4046.
E-mail addresses: mathieu.carrier@ucs.inrs.ca (M. Carrier), dlcrouse@gmail.com (D. Crouse).
[1] Tel.: +1 514 398 4111.

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(Gauderman et al., 2007). Previous studies have argued that the combination of socioeconomic inequalities and exposure to air pollutants contributes to physiological vulnerability among members of low-income households (Brulle and Pellow, 2006; Kohlhuber et al., 2006; O'Neill, 2007). Other studies have noted that the health impacts of pollution are greater among children and the elderly. Indeed, children are more vulnerable to the effects of exposure to air pollutants because their organs and nervous systems are not fully developed (Bolte et al., 2009) and they breathe in more air per unit of body mass (Landrigan et al., 2004). In the case of the elderly, this vulnerability to air pollution is heightened due to their reduced immunity to disease particularly as a result of the aging of their vital organs. In addition, because children and the elderly are less mobile, they are more confined to their residential environments (Day, 2010; Greenberg, 1993; Philipps et al., 2005). If these environments offer poor conditions, these groups will be more affected than those in other age categories.

1.1. Environmental equity and air quality

The literature on environmental equity focuses especially on the distribution of nuisances and resources, which, because of the unequal spatial distribution of different social groups, leads to an increased exposure to risks or to less access to beneficial elements for certain populations. The current view associated with environmental equity can be defined as follows: "Environmental justice policies seek to create environmental equity: the concept that all people should bear a proportionate share of environmental pollution and health risk and enjoy equal access to environmental amenities" (Harner et al., 2002). Studies performed in various countries have shown that low-income households tend to be exposed to substantially higher levels of ambient pollution than more affluent households, even though they have fewer vehicles (Brainard et al., 2002; Chakraborty, 2009; Kingham et al., 2007; Morello-Frosch et al., 2001). Results from environmental equity research related to ethnic minorities vary between countries and by context (Ringquist, 1997). For example, in the United States, a number of studies (e.g., 2009; 2002; 2001) have shown positive associations between the presence of ethnic minorities and concentrations of air pollutants. In Canada, however, with the exception of Latin Americans in Hamilton, Buzzelli and Jerrett (2004, 2007) found no relationship between the proportions of ethnic minorities and concentrations of ambient pollution in the cities of Hamilton and Toronto. In a previous study in Montreal, Crouse et al. (2009b) found only weak positive associations between exposure to nitrogen dioxide (NO_2) and the percentage of visible minorities at the census tract level.

Despite their physiological vulnerability to exposure to air pollution, the categories of children and the elderly have been addressed less often in environmental equity studies. Chaix et al. (2006) have nonetheless reported that children under 15 years old from low-income households in Malmö, Sweden, were in general exposed to higher NO_2 levels than children of the same age with higher socioeconomic status. As for the population over 65 years of age, Brainard et al. (2002), Mitchell and Dorling (2003), and Chakraborty (2009) found no environmental inequity experienced by children in relation to air pollution exposure in Birmingham (United Kingdom) and Tampa Bay (United States). Collins et al. (2011), on their part, examined disparities linked to risks of cancer from pollutant emissions in El Paso, Texas, and concluded that Hispanics aged 65 and older were more likely to develop various health problems compared with the white population of the same age. So, studies on children and the elderly have arrived at different conclusions in different geographical contexts.

1.2. Local measurements of air pollution

In the past 20 years or so, various methodological approaches have been proposed for evaluating pollutant exposure among vulnerable groups by using spatial analysis methods. First among these is proximity to sources that generate air pollutants, an approach that has often involved defining "buffer zones" ranging from 0 to 300 metres (m) around major roads (Amram et al., 2011; Bae et al., 2007; Cesaroni et al., 2010; Chakraborty, 2006; Chakraborty et al., 1999; Green et al., 2004; Gunier et al., 2003; Houston et al., 2006; Jacobson et al., 2005) or creating density indices based on road network hierarchy (Houston et al., 2004). To evaluate environmental equity, logistic regression is often modelled with a binary dependent variable indicating whether a census tract or city block is located at least n metres from a section of highway (200 m, for example), and with independent variables describing the proportions of targeted groups (e.g., ethnic minorities) within buffers of various radii. This approach has come under criticism, however, as the use of a binary variable may conceal substantial variations in exposure in terms of concentration. Two different city blocks may, for instance, be located within 200 m of a highway: one at 10 m, and the other at 190 m. Furthermore, some blocks may be located at the same distance from the highway (50 m, for example), but be surrounded by very different overall lengths of highway sections within a 200-m radius. To solve this problem, some authors (Apparicio et al., 2008; Gunier et al., 2003; Houston et al., 2004; Rioux et al., 2010) recommend creating density indices, based on either traffic volume or roadway hierarchy.

The second most frequently used technique is mathematical modelling. This approach consists in estimating pollutant concentrations based on data relating to traffic volumes as well as meteorological information such as temperature, wind force, and wind direction (Kingham and Dorset, 2011). The advantage of this technique is that it enables the generation of a spatial dispersion map for air pollutants on a large scale: for example, a given city However, some authors, such as Kingham and Dorset (2011), point out that the accuracy of these models can vary significantly depending on the data and parameters integrated into the model, and particularly according to meteorological factors. A few studies have used a mathematical dispersion model to study environmental equity. Their general aim is to measure statistical associations between pollutant levels such as PM_{10} (Kingham et al., 2007; Pearce and Kingham, 2007), NO_2 (Brainard et al., 2002; Chaix et al., 2006; Kruize et al., 2007; Mitchell and Dorling, 2003), or several pollutants (Briggs et al., 2008) obtained through modelling, on the