

# Socio-economic Correlates of Municipal-level Pollution Emissions on Montreal Island

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## ABSTRACT

**Background:** Differential exposure to environmental hazards is one component of the social gradient in health. Few studies have investigated the association between socio-economic characteristics and environmental hazards in a Canadian context. We assessed the relationships between pollution emissions and socio-economic characteristics for 27 municipalities on Montreal Island.

**Methods:** Pollution emissions were determined using Environment Canada's National Pollutant Release Inventory (NPRI) for the periods 1995-1996 and 2000-2001. Variables included the number of reporting industries, the average annual releases, and the average annual releases density. These data were cross-referenced with socio-economic data from the 1996 and 2001 Canadian Censuses, respectively.

**Results:** For both periods, pollution measures were inversely related to the average monthly amount of owners' major payments, the average income of households, the proportion of workers in the tertiary sector, and the proportion of individuals with a university education. Pollution measures were positively associated with the unemployment rate, the proportion of workers in the secondary sector, and the proportion of individuals with less than high school education.

**Conclusion:** Socio-economic characteristics are associated with municipal-level pollution emissions on Montreal Island. Whether higher emissions are indicative of higher pollution exposure requires further investigation.

**MeSH terms:** Socioeconomic status (SES); immigrants; environmental pollutants; urban population; Canada

*La traduction du résumé se trouve à la fin de l'article.*

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The existence of a social gradient in health – an association between social position and health status – is well established. Studies have shown higher rates of morbidity and mortality for disadvantaged populations compared to their more fortunate counterparts.<sup>1,2</sup> Individual characteristics as well as social and physical environmental attributes are commonly understood to underpin the social gradient in health.<sup>3,4</sup> For instance, differences in the quality of the physical environment help explain social differences in rates of cardiovascular diseases, respiratory diseases, and other health outcomes.<sup>5-7</sup>

Over the last decade, several American studies have investigated the social patterning of environmental hazards. These examinations, at times labelled “environmental equity, or environmental justice” studies, have shown relations between proportions of low-income and/or minority populations and exposure or proximity to pollution or sources of pollution.<sup>8-11</sup> Little research has investigated the question in a Canadian context, and the existing research essentially has focused on urban areas within the province of Ontario.<sup>5,12-16</sup> Taken together, US and limited Canadian studies provide tentative support for a relationship between social disadvantage, minority status and greater pollution exposure in urban areas. There is a need to evaluate such relations for other Canadian regions, in particular Quebec with its commitment to social policy solutions to redress or ameliorate class differentials in quality of life and well-being.

While other manifestations of social inequality have been subject to extensive debate with some attempts at intervention,<sup>17</sup> academics and policy-makers in Canada have directed limited attention to environmental inequalities, perhaps due to a paucity of data on the issue. Despite a widespread, *a priori* recognition that lower area-based socio-economic status is associated with greater pollution, scientific knowledge is needed: i) as a basis for further research into the role of environmental factors in contributing to the social gradient in health; and ii) to inform policy aimed at reducing the burden on disadvantaged populations already faced with increased risks from individual, social, and other environmental factors. The present study therefore sought to contribute to knowledge in this area by assessing potential linkages between pollution emissions and the socio-economic and

socio-cultural characteristics of 27 municipalities on the Island of Montreal.

## METHODS

### Area of interest

Montreal Island is the second most populated urban centre in Canada, with over 1.7 million inhabitants (2001).<sup>18</sup> Until 2001, the Island was divided into 29 municipalities (now boroughs) that provide the basis for local socio-economic and political decision-making (Figure 1). Of the 29 municipalities, 27 were included for analysis.

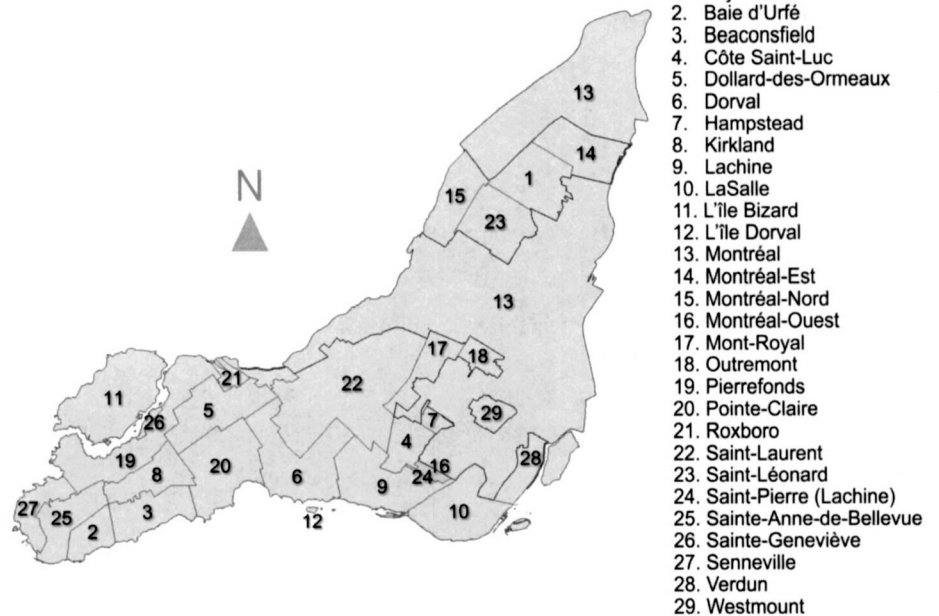
### Pollution data

Pollution emission data from the National Pollutant Release Inventory (NPRI), a publicly-accessible database overseen by Environment Canada since 1992, were used for analyses ([www.ec.gc.ca/pdb/npri/](http://www.ec.gc.ca/pdb/npri/)). The database includes emissions information from facilities that: (i) employed individuals for a total of 20,000 hours or more during the year; (ii) manufactured, processed, or otherwise used a NPRI-listed substance at a threshold of 10 tons at 1%; and (iii) did not engage exclusively in one of the activities excluded from the NPRI reporting requirements. In 1996, 176 substances were on the NPRI list, increasing to 265 by 2001.<sup>19</sup>

Pollution emissions do not themselves constitute risk measures (risk depends on toxicity and exposure determined by concentration, dose and frequency). Rather, such measures represent a *potential* for health risk. Indicators of potential health risk used in the analyses reported here are given in Table I. Releases include the total tons of on-site chemical releases (within facility boundaries) into the air, water, land, and underground. Facilities' civic addresses and postal codes were used to assign them to municipalities. Two separate periods, 1995-96 and 2000-01 were analyzed, with data averaged over each respective two-year interval to reduce the industrial reporting variability.

As shown in Table I, heterogeneity in pollution emissions exists across the Island's municipalities. Fourteen of the 27 municipalities included for analysis had reporting industries for both periods. Industries required to report to the NPRI do not necessarily emit pollutants into the

### Montreal Island, Province of Quebec, Canada



**Figure 1.** Geographical location of the 29 municipalities of Montreal Island (1996) L'île Dorval (12) was excluded from our study because of the limited socio-economic and socio-cultural data found for this municipality in the Census. 1996 data for Saint-Pierre (24) was combined with data for Lachine (9) in order to reflect the merger of these municipalities as reflected in the 2001 data.

Source: Adapted from an electronic map provided by the Ville de Montréal, 2006.

environment. Municipalities with at least one reporting industry can therefore have an emission value of zero. Municipalities with zero reporting industries were assigned emission values of zero.

### Socio-economic and socio-cultural data

Socio-economic and socio-cultural data from the 1996 and 2001 Canada Censuses, compiled by municipality by the Institut de la Statistique du Québec, were extracted for analyses (Tables II and III). These data are based on a 20% sample of the population by the Census. Several such measures have been used previously in analyses of socio-economic correlates of pollution releases.<sup>12,13,16</sup>

### Data analysis

The hypotheses that area-based socio-economic and socio-cultural characteristics are associated with number of reporting industries, average annual releases (tons), and average annual releases density (tons/km<sup>2</sup>) were tested using the nonparametric Kendall Tau (Ta) correlation coefficient (emissions data were not normally distributed). All statistical tests were two-tailed. Averaged emissions data for 1995-96 and 2000-01 were correlated with Census data

for 1996 and 2001, respectively. Two different time frames were used to provide a basis for assessing the reliability of descriptive relationships. For socio-cultural variables, the potential confounding influence of socio-economic status on pollution outcomes was manually evaluated by stratifying municipalities according to the average income of households (above or below the municipal median) for each of the two time periods analyzed. Alpha was set at 0.05.

## RESULTS

### Socio-economic characteristics and pollution emissions

Municipal-level associations between socio-economic characteristics and pollution measures are presented in Table IV. For most relationships, the strength of the association was low-to-moderate, with the Kendall Tau ranging between 0.2 and 0.3. For both time periods, the average monthly amount of owners' major payments was negatively associated with all pollution variables. Similarly, the average income of households was inversely related to pollution variables. The unemployment rate was positively related to pollution variables. The propor-

**TABLE I****Number of National Pollutant Release Inventory (NPRI) Reporting Industries and Pollution Releases for 14\* Municipalities of Montreal Island, 1995-1996 and 2000-2001**

Variable	N	1995-1996		2000-2001	
		Median	Range	Median	Range
No. of reporting industries (n)	14	8	(1 - 35)	8	(1 - 37)
Releases, annual average (tons)	14	66.9	(0 - 1149.7)	50.01	(0 - 1,052.5)
Releases density, annual average (tons/km <sup>2</sup> )†	14	5.77	(0 - 177.10)	2.8	(0 - 185.94)

\* 14 of 27 municipalities had reporting industries for both periods.

† Based on land area from the 1996 Census for 1995-1996 and on land area from the 2001 Census for 2000-2001.

Source: Compiled from the NPRI public database (1995-2002).

**TABLE II****Socio-economic Data for 27 Municipalities of Montreal Island, 1996 and 2001**

Variable	1996 Census		2001 Census	
	Median	Range	Median	Range
Population density (inhab./km <sup>2</sup> )	2,668.2	(122.3 - 7,396.3)	2,541.4	(129.5 - 7,551.9)
Ratio of % dwelling owners to % dwelling renters	1.0	(0.4 - 12.2)	1.0	(0.4 - 13.7)
Average gross rent (\$)	568	(497 - 1,283)	631	(503 - 1,468)
Gross rent spending 30% or more of household income on shelter costs (%)	40.0%	(20.0% - 60.6%)	34.5%	(0.0% - 49.1%)
Average owners' major payments, monthly (\$)	869	(585 - 1,273)	953	(743 - 1,526)
Owners' major payments spending 30% or more of household income on shelter costs (%)	17.2%	(11.5% - 30.4%)	16.6%	(9.6% - 26.4%)
Average Income of Households (\$)	54,523	(31,660 - 117,937)	63,437	(35,233 - 142,604)
Unemployment Rate (%)	8.6%	(4.3% - 16.5%)	6.3%	(1.8% - 11.9%)
Sector of activity - Secondary (manufacturing) (%)	19.1%	(9.8% - 28.3%)	18.3%	(8.4% - 28.2%)
Sector of activity - Tertiary (service) (%)	76.1%	(64.5% - 87.0%)	79.1%	(66.4% - 90.5%)
Less than High School (%)*	8.3%	(2.0% - 27.7%)	6.8%	(1.3% - 26.1%)
High School or Trades Certificates or Diplomas (%)*	32.4%	(17.5% - 50.4%)	32.7%	(15.6% - 54.6%)
College Diplomas (%)*	21.3%	(12.6% - 27.4%)	21.2%	(14.5% - 28.6%)
University (%)*	34.4%	(5.7% - 67.8%)	33.6%	(7.5% - 68.2%)

\*Level of schooling: Population aged 15 and over for the 1996 Census data / Population aged 20 and over for the 2001 Census data.

Source: Compiled from data provided by the Institut de la statistique du Québec from Statistics Canada Census Data, 1996 and 2001.

**TABLE III****Socio-cultural Data for 27 Municipalities of Montreal Island, 1996 and 2001**

Variable	1996 Census		2001 Census	
	Median	Range	Median	Range
English (%)*	43.6%	(6.9% - 83.2%)	40.6%	(4.8% - 76.1%)
French (%)*	41.1%	(6.3% - 89.7%)	42.2%	(12.3% - 91.9%)
Unofficial language (%)*	7.6%	(1.7% - 30.5%)	8.9%	(1.9% - 30.6%)
Immigrant population (%)†‡	22.6%	(2.5% - 46.4%)	23.5%	(3.2% - 48.5%)
North America (%)	1.1%	(0.0% - 3.4%)	0.7%	(0.0% - 2.8%)
Central & South America (%)	0.5%	(0.0% - 1.5%)	0.6%	(0.0% - 1.4%)
Caribbean and Bermuda (%)	0.7%	(0.0% - 6.9%)	0.7%	(0.0% - 8.7%)
Eastern Europe (%)	2.0%	(0.0% - 15.8%)	2.3%	(0.0% - 13.7%)
Northern & Western Europe (%)	3.5%	(0.3% - 11.7%)	3.3%	(0.7% - 12.7%)
Southern Europe (%)	2.0%	(0.6% - 20.0%)	2.1%	(0.0% - 19.0%)
Africa (%)	1.0%	(0.0% - 7.0%)	1.5%	(0.0% - 7.6%)
West Central Asia and the Middle East (%)	1.3%	(0.0% - 9.0%)	1.1%	(0.0% - 8.1%)
Eastern Asia (%)	0.7%	(0.0% - 3.2%)	1.2%	(0.0% - 3.7%)
Visible minorities population (%)§	10.6%	(1.1% - 36.2%)	11.9%	(1.3% - 38.1%)

\* Spoken language at home.

† Proportion of immigrants from the total population of the municipality.

‡ Immigrants refer to people who are or have ever been landed immigrants (people who have been permitted to live in Canada permanently) (Source: Census Dictionary); Certain immigrant regions of origin were grouped based on broad socio-economic similarity.

§ Proportion of visible minorities from the total population of the municipality.

|| Visible minorities are defined as persons, other than Aboriginals, who are not white in race or colour (Source: Census Dictionary). Source: Compiled from data provided by the Institut de la statistique du Québec from Statistics Canada Census Data, 1996 and 2001.

tion of workers in the secondary (manufacturing) sector was positively associated with pollution variables, while the proportion of workers in the tertiary (service) sector was negatively related to all pollution variables. The proportion of individuals with less than high school education was positively associated with measures of pollution, and the proportion of individuals with a university education was negatively linked to pollution

variables. Other socio-economic variables were not significantly or consistently associated with pollution variables throughout the two time periods.

### Socio-cultural characteristics and pollution emissions

The proportion of some immigrant populations showed associations with measures of pollution (data not shown). The propor-

tion of immigrants from North America was negatively associated with the average annual releases density for 1996, and this association was apparent for both low and high average household income strata when municipalities were dichotomized according to the median value for average household income (Low income  $T_1$ : -0.56,  $p=0.011$ ; High income  $T_2$ : -0.40,  $p=0.036$ ). A positive correlation was also apparent for

TABLE IV

## Relationships Between Census Socio-economic Variables and National Pollutant Release Inventory (NPRI) Pollution Variables for 27 Municipalities of Montreal Island

Variable	1996 Census vs. 1995-1996 NPRI			2001 Census vs. 2000-2001 NPRI		
	No. of Reporting Industries (n)	Releases, Annual Average (tons)	Releases Density, Annual Average (tons/km <sup>2</sup> )†	No. of Reporting Industries (n)	Releases, Annual Average (tons)	Releases Density, Annual Average (tons/km <sup>2</sup> )†
Ratio of % dwelling owners to % dwelling renters	T <sub>s</sub> -0.258	T <sub>s</sub> -0.204	T <sub>s</sub> -0.157	T <sub>s</sub> -0.218	T <sub>s</sub> -0.245	T <sub>s</sub> -0.238
Average gross rent (\$)	p-value 0.059	p-value 0.135	p-value 0.252	p-value 0.111	p-value 0.073	p-value 0.081
Average owners' major payments, monthly (\$)	0.219	0.198	0.177	0.186	0.218	0.225
	0.307	0.296	0.303	0.287	0.344	0.351
Average Income of Households (\$)	-0.31	-0.279	-0.231	-0.342	-0.361	-0.354
Unemployment Rate (%)	0.243	0.274	0.226	0.333	0.312	0.312
Sector of activity - Secondary (%)	0.271	0.306	0.327	0.251	0.299	0.347
Sector of activity - Tertiary (%)	-0.33	-0.347	-0.341	-0.329	-0.354	-0.374
Less than High School (%)*	0.291	0.033	0.045	0.257	0.279	0.299
High School or Trades Certificates or Diplomas (%)*	0.193	0.17	0.204	0.225	0.245	0.293
University (%)*	-0.278	-0.272	-0.265	-0.283	-0.306	-0.34

\* Level of schooling: Population aged 15 and over for the 1996 Census data / Population aged 20 and over for the 2001 Census data.

† Based on land area from the 1996 Census for 1995-1996 and on land area from the 2001 Census for 2000-2001.

the proportion of immigrants from Southern Asia and South East Asia (as a single classification) and the number of reporting industries for 2001, with Tau at 0.40 and 0.52 for high- and low-income strata, respectively ( $p < 0.05$ ). Visible minority populations (grouped as one category and disaggregated into the categories "Black", "South Asian", "South East Asian", "Chinese", "Korean", "Japanese", "Filipino", "Arab/West Asian" and "Latin American") and language spoken at home were not associated with pollution variables after stratification of municipalities by average household income.

## DISCUSSION

Associations between municipal-level socio-economic attributes and magnitude of industrial pollution releases were observed for Montreal Island. Unemployment, secondary sector employment, and proportion of individuals with less than high school education were associated with greater levels of pollution releases. In contrast, higher average amount of owners' major payments, higher average household income, tertiary sector employment and higher proportion of individuals with a university education were associated with lesser levels of pollution release (Table IV). These associations were consistent throughout the two time periods analyzed, even though the number of substances reported to the NPRI varied. The observed relationships between pollution release and socio-economic attributes align with reports from urban areas in the US,<sup>9,11</sup> and from other Canadian cities.<sup>13,16</sup>

Two general non-exclusive hypotheses have been put forward in the literature to explain environmental inequity: zoning or site location decisions unfavourable to disadvantaged and/or minority populations; and the migration of such populations to high-pollution areas because of manufacturing jobs or lower property/rent values.<sup>20</sup> The particular mechanisms linking socio-economic status to pollution outcomes vary according to the measures used (described elsewhere<sup>13,16,21</sup>). Knowledge of causal mechanisms would be improved by place-specific longitudinal and qualitative (especially historical) case studies.

Social disadvantage heralds an excess potential for the accumulation of multiple untoward exposures associated with negative health and social impacts. The unemployed,<sup>22</sup> those working in manufacturing,<sup>23</sup> and those with lower education and income experience higher rates of adverse health outcomes.<sup>24,25</sup> Such associations have been observed at the individual, household, and community levels.<sup>26,27</sup> Further research should link emissions exposure to actual health data, as well as consider the additive or multiplicative role of individual and social factors in exacerbating the impact of environmental pollution.<sup>28</sup> Multi-level models accounting for place-based variation in pollution emissions and socio-demographic factors, crossed with individual-level pollution exposure data, hold promise for future work in this area.

American studies have also shown that African Americans and Hispanics are more likely to live in areas with higher pollution release.<sup>8,10</sup> In Canada, while no associations have been found with broad categories such as "visible minorities" or "immigrants",<sup>12,13</sup> data broken down by ethnic group provide various compelling associations.<sup>12</sup> In our analysis of Montreal municipalities, the proportion of immigrants from Southern and South East Asia was associated with higher pollution releases, and this relationship was not confounded by household income. The implications of this relationship need to be considered with attention to individual and social contexts and corresponding risks that can modify the health impact of exposure to pollution. For example, in Quebec, individuals from Southern and South East Asia face adverse life circumstances apart from any untoward attributes of the areas in which they reside. They are largely over-represented in the manufacturing sector where they face increased physical, chemical and psychosocial health risk.<sup>29</sup> It is important, therefore, for future research to go beyond the ecological level in accounting for circumstances that may exacerbate the consequence of exposure to pollution emissions.

Our study has several limitations. First, it is ecological, subject to biases and cautions attendant to all analyses of higher level data alone. Second, it is based on data from large industries required to

report their emissions. It is possible that releases from facilities too small or exempt from reporting may collectively account for a considerable extent of releases for specific pollutants. While the present analysis looked at overall emissions, not at specific pollutants, those pollutants listed in the NPRI database (in 2001, 265 substances) represent only a portion of all possible environmental pollutants. Data accuracy may also be undermined by inadequate release estimation methodologies. Despite the presence of compliance promotion and enforcement efforts, responsibility for reporting is borne essentially by facilities, and smaller facilities may be unaware of reporting requirements. These factors could result in an underestimation of pollutant releases. Whether this bias influences the magnitude or the direction of the relations we found is unknown. The NPRI remains, nevertheless, a uniquely valuable source of pollution emission data. Various published studies have used data from the US equivalent – the Toxics Release Inventory – despite its similar limitations.<sup>11,30,31</sup> The study was descriptive in its aim, but hypothesis tests of the import of associations may reflect chance effects given the multiple tests conducted.

The finding that areas of Montreal Island with high concentrations of low socio-economic status residents are subject to high magnitudes of toxic releases does not necessarily mean that individuals are similarly exposed. Rather, the association indicates only a greater potential for exposure for this vulnerable population. Our study should be followed by other studies with more sophisticated designs to explore the reasons underpinning the associations observed here. Further studies should investigate industrial releases in terms of the toxicity levels of reported substances, and also estimate exposure to evaluate the potential impact of pollution releases in various Montreal municipalities.

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## RÉSUMÉ

**Contexte :** Les différences dans l'exposition aux risques environnementaux sont une des composantes du gradient social en matière de santé. Peu d'études ont étudié l'association entre les caractéristiques socioéconomiques et les risques environnementaux dans un contexte canadien. Nous avons évalué les relations entre les rejets de polluants et les caractéristiques socioéconomiques de 27 municipalités localisées sur l'île de Montréal.

**Méthode :** Les rejets de polluants ont été déterminés en utilisant l'Inventaire national des rejets de polluants (INRP) d'Environnement Canada pour les périodes 1995-1996 et 2000-2001. Les variables utilisées sont le nombre d'industries déclarantes, la moyenne annuelle de rejets et la densité annuelle moyenne de rejets de polluants. Ces données ont été croisées, respectivement, avec des données socioéconomiques des recensements canadiens de 1996 et de 2001.

**Résultats :** Au cours des deux périodes, les mesures de rejet de polluants étaient inversement liées à la moyenne mensuelle des principales dépenses des propriétaires, au revenu moyen des ménages, à la proportion d'ouvriers dans le secteur tertiaire, et à la proportion de personnes qui ont fait des études universitaires. Les mesures de pollution ont montré des associations positives avec le taux de chômage, la proportion d'ouvriers dans le secteur secondaire, et la proportion de personnes ayant un niveau d'étude inférieur au certificat d'études secondaires.

**Conclusion :** Des caractéristiques socioéconomiques sont associées aux mesures de pollution à l'échelle des municipalités de l'île de Montréal. Davantage de recherches sont nécessaires pour vérifier si des émissions plus importantes sont aussi associées à des expositions plus élevées.