Chapter 2

Compiling a Geographic Database to Study Environmental Injustice in Montréal: Process, Results, and Lessons

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ABSTRACT

Environmental injustice is a concept that emerged out of the social impacts of environmental degradation within the United States during the early 1980s. In the U.S., environmental injustice is frequently tied to race while in Canada and internationally, more attention has been paid to the correlations between income and environmental hazards. This chapter presents a pedagogical project that aimed to assess the degree and structure of environmental injustice in the city of Montréal, Canada. To reach this goal, a group of graduate students in a course entitled "GIS for Environmental Impact Assessment" (ENVS 663) at Concordia University, Montréal, gathered data on a large variety of socio-economic, health and environmental factors on the Island of Montréal and then attempted to spatially analyze whether there are local areas that suffer heightened risk for environmental injustices. Several neighbourhoods were noted as at risk in these studies, which points to a need for greater research and investigation into the levels of disparity in Montréal and the impacts that pollutants may have on the Island's most at-risk residents. Through this process students were also exposed to the multiples problems associated with the development of a comprehensive and relevant database in order to study complex environmental issues. Students were able to overcome some of these problems and to collectively compile a database that served as a point of departure for organizing an international workshop entitled *'Mapping' Environmental Issues in the City: Arts and Cartography Cross-Perspectives*.

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2.1 Introduction

Economic progress of society has long been associated with the creation of environmental "bads", or, as Aldo Leopold coined them, "regrettable necessities", that have the capacity to cause environmental problems, health issues and even human death (as cited by Buzzelli, 2008). Normally, pollutants are not evenly distributed in the air, soil, and water, and this inequality of distribution has frequently been found to place underprivileged social groups at heightened risk of exposure. This, in turn, has given rise to environmental injustices, which are defined as "the disproportionate exposure of communities of colour and the poor to pollution, and its concomitant effects on health and environment" (Maantay 2002, p. 161). This concept of environmental injustice also includes the more specific idea of environmental racism that argues that minority groups and aboriginal people tend to be at a greater risk of being affected by environmental hazards (Bullard 1990; Westra 2008). This occurs when specific segments of the population with heightened levels of deprivation suffer higher than normal morbidity and mortality statistics due to environmental effects[1]. These heightened levels of disease and/or death are often connected to the inequitable distribution of environmental health burdens associated with societal and economic development, and can include issues such as: pesticide use, air pollution, children's blood lead levels, toxins in food, hazardous waste facilities, hazardous releases (air and groundwater) and facility siting (White 1998).

Linked with this concept of environmental injustice is its more idealistic counterpart of environmental justice. Environmental justice is defined as the fair treatment and meaningful involvement of all people "regardless of race, colour, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (U.S. E.P.A., 2010).This chapter aims to enhance the greater understanding of the topic of environmental injustice through the development of a geospatial database. It will begin with a brief outline of the roots and evolution of environmental injustice as a concept, as well as its importance in Canada, and most significantly, Montréal. This chapter will then briefly present the history and geography of Montréal and explore previous local studies of environmental injustice. Subsequently the project of developing a geographic database on environmental injustice in Montréal that was undertaken by the ENVS 663 geographic information sciences class at Concordia University will be described. Following, this chapter will move to a discussion on the findings of this research and the challenges that existed. Overall, this chapter presents the development of the database that served as the reference for the participants of the workshop that was organized in Montréal in September 2011.

[1] In this context deprivation is defined as a set of circumstances that cause a person, family or group to be at an "observable and demonstrable disadvantage" in comparison to the local community, the larger society or even the national or global community (Townsend 1987, p. 125).

2.2 Environmental Injustice

2.2.1 Background

The concept of environmental injustice first emerged in the United States in the early 1980s when researchers such as Robert Bullard and Harvey White began investigating environmental decision making and policies that reflect the dominant power regimes in society and its institutions[2]. Researchers noted a social gradient in health levels, and, more specifically, that people that belonging to racial minorities and/or socioeconomically disadvantaged groups tend towards having inferior health when compared to their more affluent and advantaged counterparts (Pampalon and Raymond, 2002). Indeed, by the early 1990s an abundance of research had emerged that showed that Blacks, socio-economically disadvantaged, and working-class individuals were being subjected to disproportionately large amounts of pollution and other environmental stressors (externalities) in their neighbourhoods and their workplaces (Bullard, 1990).

The idea of environmental injustice continued to spread, and more research began to emerge through to the late 1990s and into the new century, moving beyond the American context and to a broader scope with attempts to understand the why "natural" events such as disease, are in reality, not natural at all but social (Robbins, 2005). Social scientists describe a "multidimensional web" of contextual forces and factors that create disproportionate vulnerability between and within neighbourhoods, cities, and countries (Bullard, 1990, p. 5; Robbins, 2005). Commonly cited risk-factors include occupation, education, value and type of land and dwelling, source and amount of income, government and private industry policies, and the racial and ethnic makeup of residents (Bullard, 1990; White, 1998).

The primary causes of environmental injustices include institutionalized racism; the co-modification of land, water, energy and air; unresponsive, unaccountable government policies and regulation; and lack of resources and power in affected communities (Ross, 2004). Proponents of environmentally degrading projects are rarely exposed to the externalities produced, nor are they usually required to take responsibility for their creation, while, in contrast, the less- wealthy, empowered, or dominant groups are frequently required to bear the burden of environmental degradation and associated negative health implications. Addressing the question of who profits from and who pays for "current environmental and industrial policies" is central within the analysis of environmental *in*/justice as well as the concomitant relationships between the dominant/affluent and the exploited segments of the population (Bullard, 1990, p. 98).

2.2.2 Environmental Injustice in Canada

Environmental injustice studies in Canada do not have as long a history as those in the United States, nevertheless, the "track record is small but growing" (Buzzelli *et al.*, 2003, p. 7). To date, the majority of the research in Canada has been concerned with environmental injustices related to air quality and attempting to understand the relationship between life expectancy and income (see Buzzelli *et al.*, 2003; Gower *et al.*, 2008; Crouse *et al.*, 2009).

Separate studies in cities such as Hamilton, Toronto and Montréal have found that there was air quality environmental injustice in each of these locations, but did not concur on the demographic groups that were at risk in each situation. In studies that were concurrently published in 2002, Ross and colleagues as well as Lobmayer and Wilkinson reported that there was a correlation between income levels and segregation in the United States, but that this was not the case in Canada. Since then the connection between income and life-expectancy and mortality in Canada has been further explored and it has been found that this relationship is not a simply linear, but rather that increased life expectancies were not related to higher income levels (Ross, 2008).

Despite this lack of a strong correlation between income and health levels in Canada, studies by Buzelli et al. (2003), Ross et al. (2003/2004), and Buzzelli and Jerret (2007) have shown that heightened levels of air pollutants exist in regions of lower socio-economic standing which tend to be in close proximity to major transportation corridors. These include areas where there are increased levels of single parent households and low education levels (Hamilton); where there are specific groups of visible minorities including Latinos, though the opposite observations were found for Black and Korean communities (Toronto); and where there are increased amounts of single-parent families with lower education levels and *contrary to previous research*, low incomes (Toronto). Canadian Aboriginal populations are commonly exposed to greater levels of environmental hazards than proximal non-aboriginal communities (Brody, 1997; Westra, 2008). There has also been research into the levels of environmental injustice in Montréal, but in preparation for exploring its particular Canadian nuances at the local level, this chapter will first briefly revisit Montréal's industrial history, political boundaries and social geography.

2.2.3 Montréal's Geography and Environmental Injustice

Montréal, Québec, is the second largest city in Canada, with 3.6 million people (Statistics Canada, 2006). The core of the city is located on a large island on the Saint-Lawrence River[2]. The history of the city is based upon its location as a trade

[2] The Island of Montréal has a population of just below two million inhabitants.

hub at the convergence of the Atlantic Ocean and the Great Lakes. Industrialization of Montréal began in earnest as it emerged as a key transportation link for North American trade over two hundred years ago upon the development of train and rail infrastructure and the Lachine Canal (1821), the forerunner of the St. Lawrence Seaway. This emphasis on Montréal as a key junction for local, national and international trade and shipping (Statistics Canada, 2006) has impelled the city's transition to a modern metropolis. Although this development has been a boon for the economy of Montréal, Québec and Canada, it has also been accompanied by increasing levels of pollution from the industries that support vehicles[3], these vehicles themselves[4], and from the industry that they support. Specifically, two major sources of pollutants in Montréal are the two oil refineries that exist on the east side of the island (Note: one was decommissioned in late 2010). There are numerous other point sources for pollutants in Montréal, and they are also primarily located in the eastern region of the island, as well as many linear road sources of air pollutants, as multiple highways criss-cross the island.

The social geography of the island has seen the proliferation of socially and materially advantaged inner cities on the slopes of Mount Royal since the 1800s with the language spoken in the home being the key point of differentiation within Montréal's neighbourhoods and boroughs. Historically the economic upper classes have been dominated by old Montréal-bred English-speaking families, with a modicum of French and others in the old-inner suburbs of Mont Royal, Outremont and Westmount (Ley, 1993). The middle classes are more mixed, whereas the lower economic stratum continues to be made up mainly of French and Irish Canadians and new immigrants (Buzzelli, 2008). The majority of the Francophone districts are located in the east of the island and in the southwest of the downtown core in the former industrial area near Lachine Canal. This includes regions like Pointe-Saint-Charles, Saint-Henri, Lachine, as well as other neighbourhoods such as Mercier, Hochelaga-Maisonneuve, Parc Extension and Montréal North which are the most economically deprived on the Island of Montréal (Langlois and Kitchen, 2001) (see Figure 2.1).

It has long been the case that the far west of the island has been primarily composed of wealthier Anglophone communities. Furthermore, there has been a recent turn towards the gentrification of lower class neighbourhoods in the south and east, like Saint-Henri, Pointe-Saint-Charles and Le Plateau (Ley, 1993). Although there are many discrete cultural neighbourhoods on the Island of Montréal as well as several regions of concentrated poverty, there are no true ethnic ghettos, nor ghettos of socially deprived groups as can be observed in large cities within the United States (Hatfield, 1997; Walks and Bourne, 2006). Additionally, there is no

[3] Including the petroleum industry and the creation and maintenance of the infrastructure.
[4] Including boats, trains, planes, automobiles, trucks, and ships.

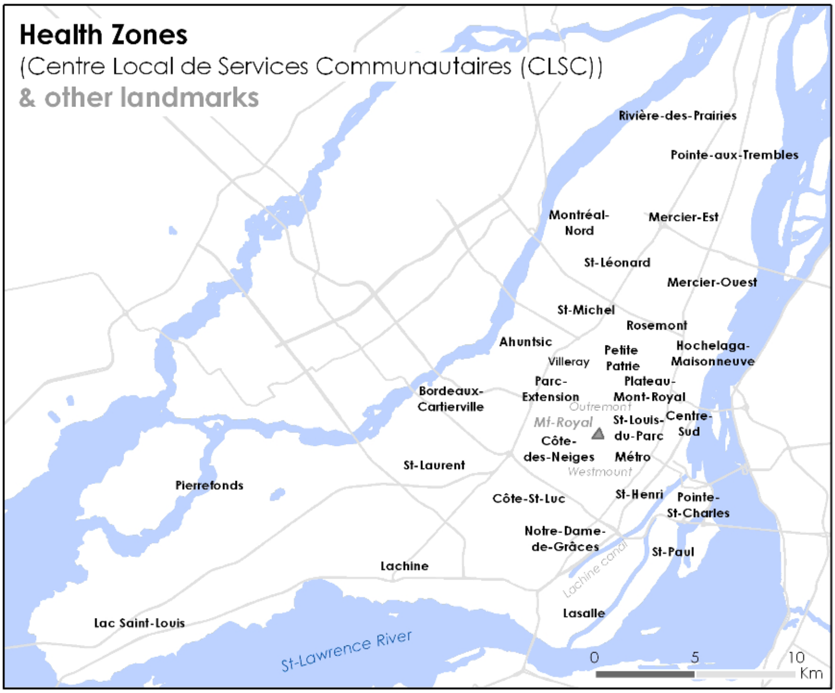

Figure 2.1 The 29 Centre Local de Services Communautaires (CLSC) zones on the island of Montréal.

direct correlation between social or financial deprivation and immigrant status or visible minority status in Montréal (Crouse *et al.*, 2009). Despite the lack of ethnic ghettos, per say, Montréal has been found to be a city with a higher level of income disparity between regions and with observable spatial economic segregation when compared to Canadian norms (Ross et al., 2000; Ross et al., 2002).

Increasing income disparities on the Island of Montréal are echoed by the region's life expectancies, which vary by "more than 13 years between different regions" (Crouse *et al.*, 2009, p 975), but determining what proportion of this disparity is due to local spatial variation of environmental hazards remains to be fully answered. The intricate history and geography of Montréal make it a complicated place to look for patterns of environmental injustice. In a 2009 article Crouse, Ross, and Goldberg compare socio-economic data with measured levels of nitrogen dioxide (NO_2), to gain insight into possible regions and groups that were disproportionately exposed to this common vehicular release toxin that is associated with negative respiratory health impacts. They found that deprivation and ethnicity are not directly related in Montréal in the same way as in many other North American metropolises. The specific neighbourhoods that they noted that had elevated concentrations of NO_2 were: Saint-Laurent, Mont Royal, and Westmount (all affluent), and Parc Extension and Lachine (low income) (Crouse *et al.,* p 979). The conclusions they drew from this set of results somewhat contradict the typical norms of environmental injustice, that is, of higher risk associated with higher deprivation. They found that the central locations of Montréal's educational institutions (UQAM, McGill and Concordia) and the unique set of centrally located affluent neighbourhoods have caused most risks for environmental hazards to cross social boundaries. This underscores the need to reflect upon the region specific social context of a location when interpreting associations between levels of deprivation and levels of environmental burden (Crouse *et al.* 2009).

It is this set of intriguing results that set the stage for the students of the graduate ENVS 663 class (Geographic Information Systems for Environmental Impact Assessment) of winter 2010 at Concordia University to further investigate environmental injustice in the city of Montréal. The attempt to achieve this objective was undertaken by first gathering a wide variety of data on different topics related to environmental injustice. The goal was to compile a database that can allow for a deeper analysis of the situation on the island of Montréal.

2.3 The Database Development

Data and databases are the base of any GIS project. Yet database development is usually the most challenging part of a GIS project. Given the wealth of data available, it is often assumed that all the necessary data required for a specific project exist, in the desired format, "somewhere" and just need to be accessed and compiled. In reality, existing geospatial databases almost never perfectly fit the requirement of a specific situation as will be illustrated in this section. The first pedagogical goal of this project was to expose students to the myth of the perfect database by asking them to compile a relevant geospatial database dedicated to the study of environmental injustice on the island of Montréal. The information that was desired was broken into five groups for collection: socio-demography, health indicators, air-quality, environmental hazards, and noise levels. The goal of each student group was then to develop a dataset on their own topic that would include spatial objects associated to the meaningful criteria. Each of these different datasets was then combined and analyzed in the second phase of the project that allowed for a more in depth study of the environmental injustice situation on the island of Montréal.

2.3.1 Sociodemographic Criteria: The Data is Accurate and Comprehensive

Socio-demographic data are the foundations for any environmental injustice study. In Canada, these data are collected and compiled by Statistics Canada through the census. They are collected every five years and available at a rather fine scale (e.g. dissemination area). Even if the systematic use of administrative limits in social sciences has been criticized because of its artificial representation of the reality (Harris and Hazen, 2006), and its lack of accuracy in studies of environmental injustice (Maantay 2002), it still provides a very good picture of the socio-demographic situation of a given area such as the island of Montréal (Figure 2.2). Students in this group compiled relevant demographic variables, including information on single parents, levels of education, income and amounts of visible minorities in each of Statistic Canada's dissemination areas. These data provide an overview of areas that may be especially vulnerable to environmental injustice, including Saint Michel, Park Extension, Cote des Neiges, Montréal North, and northeastern Saint-Laurent. These students found that generally the east, north, and southwest regions of the Island are more vulnerable than much of the west (Bimrah et al. 2010, 8)[5].

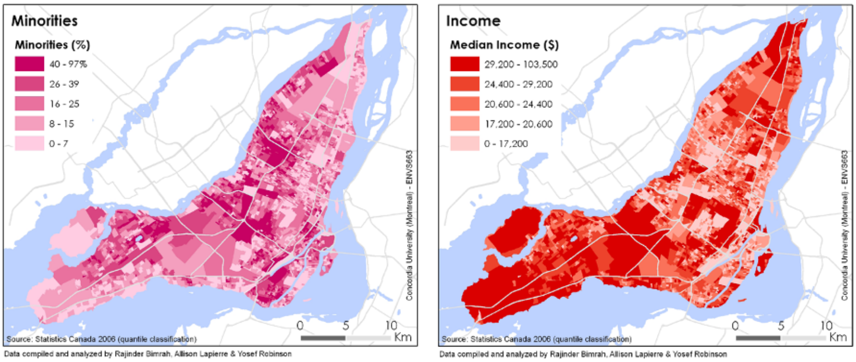

Figure 2.2 Percentage of minorities and average income on the island of Montréal.

2.3.2 Health Information: The Data is Not at the Proper Scale

The second student group focussed on health indicators. The goal of this group was to establish a link between health outcomes and environmental characteristics (Baxter et al. 2010, 4). The major problem with health data is that they are very difficult to access at a fine scale. While the need for health studies at fine scales

[5] For more details on the sociodemographic structure of Montréal, see also the chapter by Tom Weatherburn & Daniel Naud in this volume.

has been demonstrated (Ross et al. 2004), data are often only available at coarser scales due to privacy reasons. In the case of Montréal, relevant health data were only available for the 29 *Centre Local de Services Communautaires*[6] (CLSC), for the 2001 to 2005 period. These data include mortality, total incidences of cancer, lung cancer, respiratory health, incidence of cardiac disease and infant mortality and health (see Figure 2.3).

Students used the Environmentally Attributable Fraction of disease (EAF) (WHO 2006) as well as disease categories particularly indicative of environmental causes (Boyd and Genuis 2008) to define a relative EAF health index[7]. This index was calculated for each CLSC zones, emphasizing three regions with high presence of diseases indicative of environmental causes: Pointe-Saint-Charles, Saint-Henri and Centre Sud (Baxter et al. 2010).

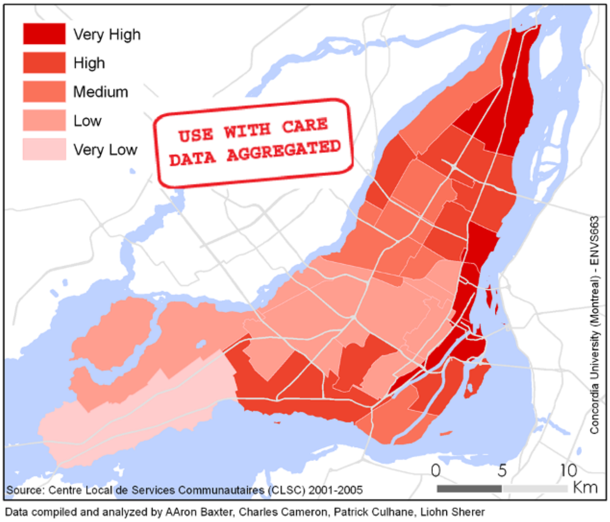

Figure 2.3 Presence of diseases indicative of environmental causes by health zones.

Given the scale discrepancy between the socio-demographic data (fine scale) and the health data (coarse scale), two students decided to aggregate the former to the health sectors (CLSC zones) in order to compare the relationships between socio-demographic profiles and health issues (see Figure 2.4). This comparison was done statistically and visually through the design of a table in which each criterion is classified using a quantile method, which allows the comparison of each health

[6] CLSC's are a form of community health care centre, with a total of 147 in the province of Quebec.
[7] The EAF was developed by the World Health Organization and is a combination of comparative risk assessment data and expert opinions to establish the percentage of mortality and morbidity that are thought to be caused by environmental causes (rather than hereditary).

NUM	CLSC_zone	% CARDIAC	% COPD (Pulmo)	% UNDERWEIGH	% PREMATURE	% RETARDATION	% MORTALITY	% RESPIRATORY MORT	% CANCER	% LUNG_CANCE	Median Income	% Low Income	% single parent	% unempl	% No Diploma	% New_immig
1	Lac-Saint-Louis	0.105	0.267	0.288	0.432	0.270	0.069	0.009	0.058	0.014	93862	9	14	5.9	7.0	3.0
2	Pierrefonds	0.086	0.267	0.390	0.468	0.486	0.083	0.009	0.061	0.017	73335	15	25	6.6	12.0	4.4
3	Dorval-Lachine	0.155	0.479	0.396	0.480	0.504	0.109	0.012	0.068	0.024	60338	22	32	6.4	20.0	4.5
4	LaSalle	0.149	0.463	0.324	0.438	0.504	0.089	0.012	0.072	0.022	55083	24	34	8.3	23.0	5.8
5	Pointe-St-Charles	0.144	0.825	0.474	0.600	0.618	0.133	0.019	0.081	0.043	40514	46	59	12.0	33.0	6.8
6	Verdun	0.139	0.652	0.372	0.474	0.486	0.106	0.017	0.079	0.033	49272	32	47	9.1	23.0	7.7
7	Saint-Henri	0.130	0.538	0.438	0.480	0.564	0.141	0.024	0.072	0.029	45165	42	60	10.0	19.0	5.7
8	Riviere-des-Prairies	0.112	0.385	0.366	0.444	0.498	0.083	0.010	0.065	0.019	63785	18	36	7.2	28.0	2.4
9	Pointe-aux-Trembles	0.123	0.518	0.426	0.492	0.456	0.118	0.016	0.074	0.032	59704	19	31	5.7	26.0	1.2
10	Mercier-Est/ Anjou	0.134	0.534	0.366	0.420	0.540	0.091	0.011	0.070	0.027	57153	23	33	6.5	23.0	4.7
11	Olivier-Guimond	0.136	0.554	0.342	0.474	0.486	0.110	0.015	0.067	0.025	57272	24	33	7.1	24.0	4.5
12	Hochelaga-Maisonneuve	0.111	0.693	0.396	0.450	0.600	0.149	0.022	0.076	0.038	41895	42	51	9.3	27.0	5.5
13	De Rosemont	0.140	0.584	0.366	0.438	0.528	0.088	0.009	0.068	0.025	52877	29	39	8.7	21.0	5.6
14	Saint-Leonard	0.144	0.515	0.336	0.426	0.528	0.071	0.008	0.069	0.021	49352	27	36	10.6	31.0	7.6
15	Saint-Michel	0.127	0.477	0.336	0.420	0.540	0.092	0.010	0.062	0.024	41627	37	47	12.4	38.0	9.1
16	Cote-des-Neiges	0.120	0.230	0.366	0.438	0.570	0.079	0.009	0.056	0.012	51447	34	38	10.2	11.0	13.9
17	Metro	0.114	0.283	0.312	0.390	0.534	0.082	0.012	0.064	0.015	67765	36	38	9.6	5.0	11.6
18	Parc-Extension	0.102	0.249	0.456	0.444	0.804	0.061	0.006	0.052	0.017	34223	53	54	18.1	41.0	18.1
19	Rene-Cassin	0.222	0.310	0.420	0.534	0.516	0.081	0.009	0.063	0.012	65458	24	35	7.4	13.0	8.2
20	NDG-Montreal-Ouest	0.130	0.276	0.318	0.408	0.504	0.084	0.010	0.060	0.018	55667	30	37	9.1	11.0	11.3
21	Saint-Louis-du-Parc	0.080	0.280	0.330	0.408	0.522	0.081	0.008	0.061	0.018	53426	36	46	7.9	15.0	5.5
22	Des Faubourgs	0.117	0.634	0.474	0.552	0.684	0.147	0.018	0.077	0.036	44102	45	53	9.0	19.0	6.5
23	Plateau Mont-Royal	0.079	0.420	0.264	0.366	0.492	0.118	0.013	0.066	0.030	57379	31	32	7.1	11.0	7.0
24	Bordeaux-Cartierville	0.134	0.267	0.360	0.426	0.522	0.080	0.007	0.061	0.014	49776	33	41	11.4	20.0	12.2
25	Saint-Laurent	0.140	0.287	0.354	0.450	0.540	0.071	0.007	0.061	0.016	53018	30	35	9.7	17.0	13.3
26	Villeray	0.137	0.490	0.330	0.408	0.606	0.079	0.009	0.065	0.027	48134	33	42	9.3	24.0	8.0
27	La Petite-Patrie	0.120	0.568	0.312	0.354	0.528	0.106	0.012	0.068	0.029	46269	34	43	8.3	20.0	5.3
28	Montreal-North	0.172	0.586	0.396	0.504	0.522	0.100	0.012	0.068	0.027	42881	38	49	12.5	34.0	7.9

Figure 2.4 *Presence of diseases indicative of environmental causes by health zones. In short, darker means higher risk of environmental injustice for the selected criteria, and vice-versa. From left to right the different columns mean rate (%) of cardiac disease, chronic obstructive pulmonary disease, underweight birth, premature birth, intrauterine growth retardation, mortality, mortality due to respiratory disease, cancer, and lung cancer. The following columns show some sociodemographic characteristics of these health zones (source: Statistics Canada 2006).*

zone across the different criteria. In this table the values have been colour coded based on their quantile rank for each criteria. In short, darker means higher risk of environmental injustice for the selected criteria, and vice-versa. This table emphasizes the existence of CLSC zones with both socio-economic and health indicators of risk of environmental injustice (e.g. 5. Pointe-Saint-Charles), zones with only one set of risks indicators, such as socio-demographic indicators (e.g. 9. Pointe-aux-Trembles), and zones with low risks (e.g. 1. Lac-Saint-Louis).

2.3.3 Air Quality: The Data is Not Available

As discussed previously, on the island of Montréal, air pollution comes mainly from traffic and industrial activities including petrochemical facilities located in the eastern part of the city. Air quality is measured across the island by 17 stations. Unfortunately the data are consistently available only for a dozen of these stations. Given the high spatial level of variability of air quality, there are not enough stations to be able to interpolate air quality on the entire island of Montréal. In order to deal with this problem, students chose two different options to create the air quality database: (1) use an air dispersion model based on traffic; and (2) replicate existing air quality measurements from a previous study.

The dispersion model used to assess the air quality is the California Line Source Dispersion Model (CALINE-4). It is based on the diffusion of gases, derived from the traffic volume and type of traffic. The emission of vehicles was estimated using the U.S. Environmental Protection Agency software Mobile 6.2c. Other inputs were meteorological data, prevalent wind directions and the recorded concentration of NO_2 from the 17 stations of the island. Based on these inputs, the program generates expected concentrations of NO_2 at receptor points. In total, the students created 133 receptor points across the island with NO_2 concentration values in ppm. These values were then interpolated in order to assess air quality variations across the entire island of Montréal (see Fournier et al. 2010 for more details). The main issue with this approach was the lack of traffic data for some sections of roads and highway, as well as the limited number of receptor points due to time constraints.

The second source of air quality data was derived from a the Crouse and colleagues study (2009) already discussed in this chapter, in which researchers had measured the level of NO_2 with Ogawa samplers in 129 dispersed locations on the island of Montréal between 2005 and 2006. This study was intended to provide estimates of intra-urban concentrations of ambient nitrogen dioxide (NO_2) that could subsequently be used in health studies of chronic diseases and long-term exposures to traffic-related air pollution. These data sounded perfectly for this project, but unfortunately it was not made available by the authors of the research. Since the results of this research had already been published, one of the students decided to extract

1001 points from a map appearing in the publication that represented the different ranges of NO_2 concentrations. These points were then interpolated with different methods (mainly IDW and kriging). The results map is one that is very similar to the one generated with the dispersion model (described previously) though with better coverage of the entire island. Although the values of the results are not accurate since they are derived from ranges instead of raw data, the amplitude of the phenomenon is respected and clearly shows the impact of the main highways on the concentration of NO_2 across the island of Montréal (see Figure 2.5).

2.3.4 Environmental Hazards: The Data is Complex

Rather than try to aggregate information on all possible environmental toxins, the environmental hazards group chose to focus more specifically on BTEX (benzene, toluene, ethyl benzene and xylene), a common set of toxins produced by industries,

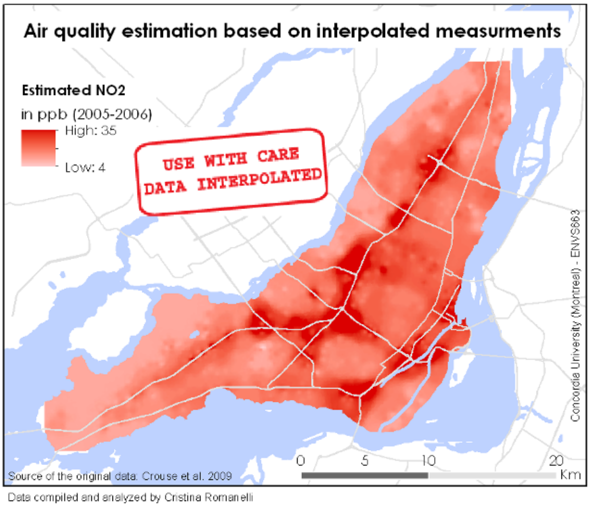

Figure 2.5 General estimates of NO2 based on interpolated data (based on an original map from Crouse et al. 2009).

mainly during petroleum refining[8]. According to the Canadian Council of Ministers of the Environment (CCME 2005), the presence of BTEX - and more specifically of benzene – has been particularly high in Montréal's East End area for decades, due to the presence of two major oil refineries. The main challenge associated with the study of environmental hazards is to assess "the possible implications that the cumulative exposure of simultaneous exposure will have for the environment and for human health" (Marsan et al. 2010, 4). Another challenge presented to this

[8] For a more extensive discussion on this topic see also the chapter by Glenn Brauen in this volume

group was to take into account the different forms of contamination, including air contamination, soil contamination and water contamination. Based on the available data, the students of this group focused on soil and air contaminants.

A list of 541 contaminated sites on the island of Montréal was provided by the Québec *ministère du développement durable, de l'environnement et des parcs*. The 40 chemicals listed for each sites are in terms of presence/absence and there are no concentrations available for individual chemicals. An ordinal BTEX index was created to correspond to the summation of the presence of benzene, toluene, ethyl benzene and xylene for each site. To make these data comparable to other data sets, it has been aggregated at the census level (dissemination area) (see Figure 2.6).

The information about the environmental toxins in the air was obtained from the 2008 National Pollutant Release Inventory (NPRI) which reported industrial sites that released toxins recognized as hazardous to human and environmental health. A weighted BTEX index was then developed to account for the quantitative differences that benzene, toluene, ethylbenzene, and xylene pose to human health following the accepted guidelines established within the United States' Occupational Health and

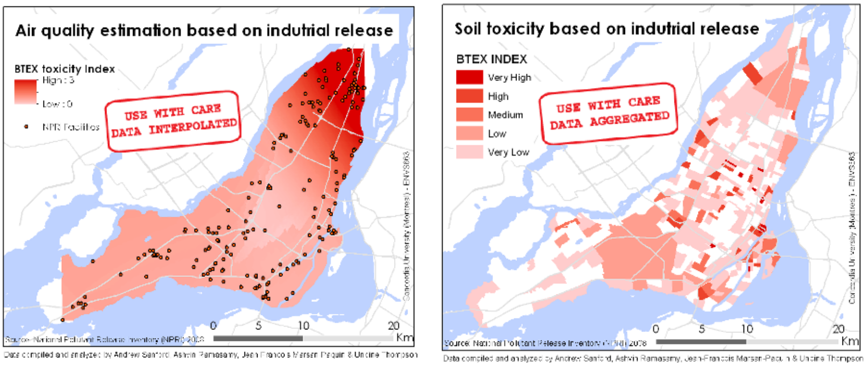

Figure 2.6 Aggregation of soil toxicity at the census track level (left) and interpolation of air quality based on industrial release (right).

Safety Administration (OSHA) standards (NIOSH 2005; Marsan et al. 2010). These data were then interpolated to create a continuous surface of BTEX on the island of Montréal, comparing different interpolation methods (e.g. IDW and kriging) and integrating prominent wind conditions.

The results of this group do not provide an entirely accurate picture of the situation of environmental hazards on the island of Montréal. Nevertheless they emphasize the presence of toxic legacy in soils on many parts of the city, including along the Lachine canal, which was the historical heart of Canadian transportation and industry, as well as the more recent geographical shift of heavy industry toward Montréal's disfavoured north-east (Marsan et al. 2010).

2.3.5 Noise Level: The Data Does Not Exist

Noise is often considered as a major source of dissatisfaction in residential areas, particularly noise originating from infrastructure and industry (Kluijver and Stoter 2002; see also the chapter by Jordan Lacey and Lawrence Harvey in this volume). Noise is also known to also have possible health effects. On the island of Montréal, it is primarily a product of traffic and transportation. The group focussing on noise concentrated on noise originating from transportation infrastructures, namely the airport, highways and commuter train lines. The spatial distribution of noise impact was determined in two steps "(1) Measurement, calculation or prediction of noise level at or near the source; and (2) Predicting noise levels at a distance from the source" (Bobyk et al. 2010, 1). As emphasized by the authors, the impact of noise on communities is affected by its intensity, its duration, the distance form noise source, the existence of barriers, the topography and the atmospheric conditions (Bobyk et al. 2010). These different elements make the modelling of noise in urban environments extremely complex (Farcas and Sivertun 2009). The complexity in this case was aggravated by the paucity of the information.

In order to derive noise level from roads and highways, students used traffic flow data from 1996 to 2008 provided by *Ministère du Transport de Québec* (MTQ 2008). Unfortunately these data were incomplete (60 out of 204 segments had no traffic value). The traffic flow had then to be estimated based on adjacent segments. A Road Traffic Noise Calculator (Java-program (XS4LL 1998)) was used to transform traffic into noise levels in dBA. Finally, a simple noise attenuation model was used to calculate noise propagation up to a distance of 210 m from the source (Canter, 1996). Train traffic was estimated using *Agence Métropolitaine de Transport de Montréal* (AMT) commuter line schedules and a formula based on the average number of trains per hour and the sound emitted by a passing train (Goff and Novak 1977).[9] The model developed previously for roads and highways was run again to produce a standardized map of railroad noise for a distance of 240 meters. Finally, the airport noise levels were provided by *Aéroports de Montréal*. Unfortunately, these data were not available in dBA, but in Noise Exposure Forecast (NEF). The combination of these different noise sources required their conversion into a common system based on impact significance (e.g. acceptable, low disturbance, unacceptable). A map of transportation noise impact on the island of Montréal derived from transportation sources was created. Given the many issues associated with the poor quality of the data available in this topic (e.g. lack of data, lack of parameters for running the noise models, different unit systems), it was decided to not incorporate it in the final database.

[9] Note: The data for freight trains were not available.

2.4 Discussion

Through this process, students were able to compile collectively a geographic database. Although this database had some obvious limitations (see Table 2.1), its development served three major goals: (1) Expose students to the complexity and flaws of database development; (2) Investigating the general trends in terms of environmental injustice in Montréal; and (3) Provide a point of departure for the exploration of the idea of mapping a database which was the topic of the workshop organized in Montréal in September 2010.

Table 2.1. Synthesis of the sources and quality of the data compiled in the database.

		Geography		Attributes		Overall	Source
		Scale	Unit	Content	Completeness		
Socio-demographic		Fine	DA	Rich	Complete	Good	1
Health		Coarse	CLSC zones	Rich	Complete	Fair	2
Air quality	Model	Fine	Source points	N/A	Incomplete	Poor	3
	NO2	Fair	Surface map	Fair	Complete	Fair	4
Hazard	Soil	Fine	Source points	Fair	Complete	Fair	5
	Air	Fine	Source points	Rich	Complete	Fair	6
Noise		Coarse	Line + isolines	Poor	Incomplete	Poor	7

1) Statistics Canada (2006); 2) Carrefour Montréal, Atlas Santé (2001-2005); 3) MTQ (1996-2008) + Ville de Montréal; 4) Crouse et al. (2009); 5) Ministère du développement durable; 6) NPRI (2008); 7) MTQ (1996-2008) + Aéroports de Montréal.

The process of compiling the database was clearly pedagogical. Throughout this process, students were exposed to the major issues related to database development such as: (a) the data have never been collected therefore they do not exist: Can they be assessed? (e.g. noise data across the island); (b) the data exist but they are not available for confidentiality reasons (e.g. Health data) or for other types of reasons (e.g. NO_2 data); (c) the data exist but is incomplete (e.g. road traffic); (d) the data exist, but not in the right format or at the proper scale (e.g. Health data for CLSC zones); (e) the data exist but not for the appropriate time period. It is also important to mention that a comprehensive database to study environmental injustice would include other types of data such as access to vegetation (see chapter by Hiên Pham and colleagues in this volume), pedestrian accidents, drinking water quality, and access to healthy food. This database is far from being comprehensive and perfectly accurate, but throughout the process of compiling it, students were re-examining their own notion of database comprehensiveness and accuracy in studying complex issues such as environmental injustices.

Beyond these limitations, the database was rich enough to be analyzed in more detail. This was the goal of the second part of this course project. Through GIS analysis and critical analysis of portions of the amalgamated data, students attempted

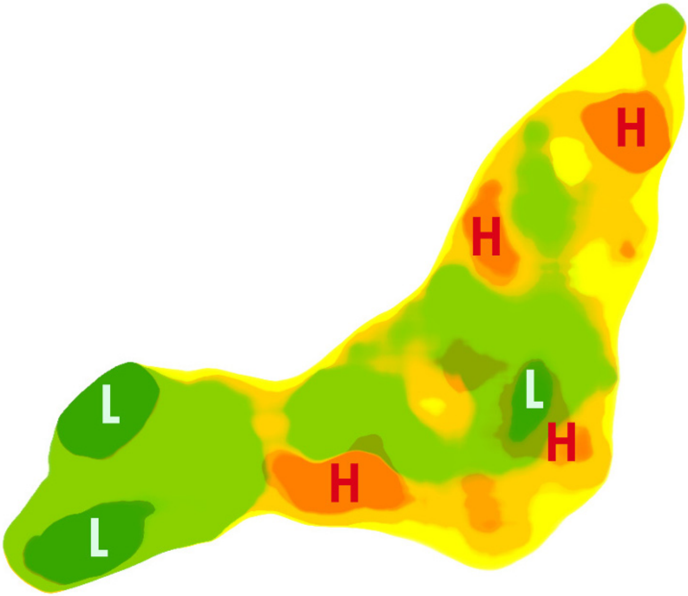

Figure 2.7 Attempt to visually mitigate the "overly precise" results due to the data limitation as well as to the limits of the methodology used to analyze these data.

Green zones (L) show areas of Low Risks of Environmental Injustice and the red zones (R), show areas of high risks (Author: Aaron Baxter. Used with permission).

to shed light onto the topic of environmental injustice in Montréal. Geospatial methods such as spatial interpolation (inverse distance weighting, kriging), and spatial statistics (e.g. clustering analysis) were used to investigate if any meaningful patterns would emerge from the data. Given the issues associated to the quality of the original data and the difficulty of comparing such a wide range of information, it was beyond the scope of this second part of the project to try to provide sound final results as is illustrated in Figure 2.7. Nevertheless, these different analyses allow sketching some general trends and pointing to some areas. A few of Montréal's neighbourhoods recurrently appear as regions that exhibit higher than average risk for environmental injustice. These neighbourhoods include, Pointe-Saint-Charles, Saint-Henri, Mercier-Hochelaga-Maisonneuve, as well as Parc Extension. These are areas that should be more carefully examined in order to gain a clearer understanding of the complicated dynamics of environmental injustice on the Island of Montréal.

The results also show the specificity of the situation on the island of Montréal. While criteria to study environmental injustice come from the United States where racial segregation is much more prevalent than in Montréal, the percentage of visible minorities did not appear has being a key element in defining areas at risk of environmental injustice, as also emphasized by Crouse, Ross, and Goldberg (2009). The possible issue of local Francophones living in the more environmentally hazardous areas of Montréal is definitely worthy of note, as it may reflect historical struggles between Francophones and Anglophones. This should certainly be expanded upon and critically analyzed further, as it may be able to help expand the larger understanding of environmental injustice and its underlying causes.

Finally, the last goal of this project was to provide a database that could serve as a point of departure to stimulate thought and discussion around the issue of mapping a database. This database was given to the participants of the workshop entitled *'Mapping' Environmental Issues in the City: Arts and Cartography Cross-Perspectives* that took place at Concordia University in September 2010. The goal of this workshop was to bring together international students, artists, cartographers, geographers and researchers from the humanities to further explore the meaning of mapping a specific database. Students of the class ENVS 663 had paved the path, and the participants in the workshop took it in many different directions as this volume illustrates.

2.5 Conclusion

This chapter has expanded upon the topic of environmental injustice as a way of approaching the uneven burden of health implications of negative externalities from development in general, and within Canada and Montréal more specifically. It has outlined the history of environmental injustice theory within the United States and its development in Canada and Montréal. The issue of environmental injustice is not straight forward in Montréal, as its historic and socio-economic context are unique in North America. The outcomes of the project presented in this chapter seem to point that there are areas of the city that are at heightened risk for health implications due to environmental "bads." What appears more clearly throughout this project is the possibility to compile a decent database by pulling together existing resources, as well as the simultaneous impossibility to develop a comprehensive and accurate database without producing our own data. As pointed out by Denis Wood (2010), the cost of compiling databases about the environment is insane, which explains why we have to rely so heavily on existing databases provided by institutions and governments to study the environment. Some of these data – at least in Canada - provide an accurate and comprehensive basis to study environmental issues (e.g. sociodemographic data), but most of these data are usually not available at the proper scale (e.g. Health data), or for the entire zone (e.g. Air quality and traffic), or with the relevant attributes (e.g. Environmental hazards), or for the appropriate period of time. Throughout this process the utopian goal of compiling a comprehensive and reliable database to study environmental issues unveiled slowly, as well as the many limitations of using GIS to address such a complex issue.

At the end of this chapter it is important to emphasize that sound studies of environmental injustice require much more than simply accurate data and sophisticated GIS analyses. It requires an in depth understanding of the historical, social, demographic and geographic situation both at the very local scale and at the transnational level as well. It requires inputs from many different domains of the arts, sciences and the humanities. This project was only a small step in the direction of exposing students to the complexity of developing a GIS database, which was already a respectable pedagogical achievement.

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