Urban Physical Environments and Health Inequalities

Factors Influencing Health

Canadian Institute for Health Information
Institut canadien d'information sur la santé

Who We Are

Established in 1994, CIHI is an independent, not-for-profit corporation that provides essential information on Canada's health system and the health of Canadians. Funded by federal, provincial and territorial governments, we are guided by a Board of Directors made up of health leaders across the country.

Our Vision

To help improve Canada's health system and the well-being of Canadians by being a leading source of unbiased, credible and comparable information that will enable health leaders to make better-informed decisions.

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About the Canadian Population Health Initiative

The Canadian Population Health Initiative (CPHI), a part of the Canadian Institute for Health Information (CIHI), was created in 1999. CPHI's mission is twofold:

- To foster a better understanding of factors that affect the health of individuals and communities; and
- To contribute to the development of policies that reduce inequities and improve the health and well-being of Canadians.

As a key actor in population health, CPHI

- Provides analyses of Canadian and international population health evidence to inform policies that improve the health of Canadians;
- Commissions research and builds research partnerships to enhance understanding of research findings and to promote analysis of strategies that improve population health;
- Synthesizes evidence about policies and programs, and analyzes evidence on their effectiveness;
- Works to improve public knowledge and understanding of the determinants that affect individual and community health and well-being; and
- Works within CIHI to contribute to improvements in Canada's health system and the health of Canadians.

A council of respected researchers and decision-makers from across Canada guides CPHI in its work. As of December 2010, the following individuals were members of CPHI's Council:

- **Cordell Neudorf**, Chair, CPHI Council; Chief Medical Health Officer, Saskatoon Health Region, Saskatchewan
- **David Allison**, Medical Officer of Health, Eastern Health Region, Newfoundland and Labrador
- **André Corriveau**, Chief Medical Officer of Health, Alberta Health and Wellness
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- **Gregory Taylor** (ex officio), Director General, Office of Public Health Practice, Public Health Agency of Canada

About the Canadian Institute for Health Information

CIHI collects and analyzes information on health and health care in Canada and makes it publicly available. Canada's federal, provincial and territorial governments created CIHI as a not-for-profit, independent organization dedicated to forging a common approach to Canadian health information. CIHI's goal: to provide timely, accurate and comparable information. CIHI's data and reports inform health policies, support the effective delivery of health services and raise awareness among Canadians of the factors that contribute to good health.

As of December 2010, the following individuals were members of CIHI's Board of Directors:

- **Brian Postl**, Chair, CIHI Board; Dean of Medicine, University of Manitoba
- **John Wright** (ex officio), President and Chief Executive Officer, Canadian Institute for Health Information
- **Luc Boileau**, President and Chief Executive Officer, Institut national de santé publique du Québec
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- **Gerry Predy**, Chair, Expert Advisory Group; Senior Medical Officer of Health, Alberta Health Services
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Please note that the analyses and conclusions presented herein do not necessarily reflect those of the individual members of the CIHI Board, CPHI Council, expert advisory group or peer reviewers, or of their affiliated organizations.

Project Team

A number of people and teams were involved in the development of this report. In particular, we wish to acknowledge the CPHI staff members who made up the core project team for this report:

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- **Diana Ridgeway**, Senior Analyst
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Executive Summary

This report builds on previous research to explore two aspects of the urban physical environment known to negatively affect health: outdoor air pollution and heat extremes. Major sources of outdoor air pollution, such as industrial polluters and motor vehicle emissions, and factors that contribute to the formation of urban and micro-urban heat islands can be influenced through policy, programs and urban design.

The report's first chapter provides an overview of the literature on the relationship among outdoor air pollution, socio-economic status and health inequalities. It also presents new Canadian analyses of residential proximity to known pollution sources and hospitalization rates for diseases of the circulatory and respiratory systems.

The second chapter of this report reviews the literature on heat extremes, socio-economic status and health inequalities. It uses Montréal and Toronto as case studies to illustrate the presence of heat islands and micro-urban heat islands in large Canadian cities and their relationship with area-level socio-economic status. Finally, it presents new analyses that explore emergency department visits and hospitalizations related to circulatory and respiratory diseases during hot days and short heat waves.

The literature reviewed and the new analyses conducted for this report show that those who are already more vulnerable to poor health may be at increased risk of being exposed to the effects of air pollution and heat extremes because of the areas in which they live.

New CPHI analyses of outdoor air pollution, socio-economic status and health service utilization show that hospitalization rates for respiratory and circulatory diseases are higher in areas that are closer to pollution-emitting facilities. This relationship is strongly mediated by socio-economic status and may reflect the fact that residents of lower socio-economic status areas are more likely to face other health inequities. When examining the rates of hospitalization for residents from the lowest socio-economic areas only, however, rates of hospitalization for both respiratory and circulatory diseases were found to significantly decrease with increased residential distance from a pollution-emitting facility.

New CPHI analyses of heat extremes and health service utilization show that hospitalization rates in Toronto and Montréal, and visits to emergency departments in Toronto, did not significantly increase on hot days or during short heat waves for either respiratory or circulatory diseases.

This report is the first in a two part-series on urban physical environments and health inequalities by the Canadian Population Health Initiative. A second report will build on this analytical work by reviewing and providing a synthesis of interventions in the urban physical environment that may influence health and health inequalities.

Introduction

More and more Canadians are choosing to live in cities. In fact, four out of every five Canadians (nearly 25 million people) now live in urban areas.[1] According to Statistics Canada, more than 90% of the population growth that occurred between 2001 and 2006 took place in Canada's largest cities.[1]

We know from previous research that health inequalities exist between and within Canada's cities. Many of these inequalities have been associated with differences in socio-economic status and the availability and quality of social networks, as well as how the built environment is designed.[2–7]

This report considers health inequalities associated with socio-economic status and the physical environment in urban settings. It builds on previous research to explore two aspects of the urban physical environment known to negatively affect health: outdoor air pollution and heat extremes. These topics are of particular interest because major sources of outdoor air pollution, such as industrial polluters and motor vehicle emissions, and factors that contribute to the formation of urban and micro-urban heat islands can be influenced through policy, programs and urban design.

This report is the first in a two-part series on urban physical environments and health inequalities by the Canadian Population Health Initiative (CPHI). This first report presents new analyses and provides an overview of research published on the topic. A second report will build on this analytical work by reviewing interventions in the urban physical environment that may influence health and health inequalities. The purpose of the policy review will be to synthesize the current state of knowledge and give illustrative examples of the types of interventions that have been implemented in various jurisdictions across Canada to help inform action in the areas of population health, health inequalities and urban physical environments.

This report builds on previous CPHI research that uses the lens of place to examine links among the urban environment, socio-economic status and health. You are invited to consult our 2008 report, *Reducing Gaps in Health: A Focus on Socio-Economic Status in Urban Canada*, which examines health and socio-economic inequalities within Canada's largest cities, and our 2006 report, *Improving the Health of Canadians: An Introduction to Health in Urban Places*, which focuses on the links among urban neighbourhoods, housing, indoor air quality and health.[2, 3]

Readers wanting to know more about the health and determinants of health of rural Canadians will find *How Healthy Are Rural Canadians? An Assessment of Their Health Status and Health Determinants* of interest.[8]

Electronic copies of all three reports can be accessed free of charge on our website at www.cihi.ca/cphi.

How Is This Report Organized?

This report is organized in two chapters. The first chapter reviews the literature on the relationship among outdoor air pollution, socio-economic status and health inequalities. It also presents new analyses of residential proximity to known sources of pollution and hospitalization rates for diseases of the circulatory and respiratory systems.

The second chapter of this report reviews the literature on heat extremes, socio-economic status and health inequalities. It then uses Montréal and Toronto as case studies to illustrate the presence of heat islands and micro-urban heat islands in large Canadian cities and their relationship with area-level socio-economic status. Finally, it presents new analyses that explore the relationship between heat waves and hospitalizations related to circulatory and respiratory diseases.

Who Is This Report For?

This report is aimed at those with a concern for health and health service utilization, socio-economic status and the urban physical environment. These may be researchers or policy- and decision-makers from the health sector with an interest in how the urban physical environment influences the health of residents in their jurisdictions. They may also be researchers or policy- and decision-makers from non-health sectors who want to understand how decisions, programs and interventions relating to planning and development can affect the health service use and health outcomes of urban residents. As this report will ultimately demonstrate, concerted efforts in multiple fields are required to improve the health of urban Canadians.

Notes on Terminology and Methodology

Health inequality, disparity or inequity? "Health inequality" and "health disparity" have the same meaning: they refer to *differences* between individuals or groups of people in health status, presence of disease, access to health care or health outcomes, regardless of the cause of these differences. The term "health inequity" refers to the presence of disparities in health or in the major social determinants of health that are unnecessary or avoidable between population groups with different social advantages (such as wealth, power, prestige, education, gender, ethnicity or religion). It underlines an ethical principle closely related to human rights and social justice in health. Inequities in health systematically put groups of people who may already be socially disadvantaged at further disadvantage with respect to their health.[9]

Urban physical environments: Urban physical environments can be broadly defined to include the built environment, which includes buildings, public spaces and infrastructure for transportation, and the ambient environment, which includes air, water quality and noise, among other things. For the purposes of this report, two aspects of the urban physical environment with known effects on circulatory and respiratory health were retained for closer examination: outdoor air pollution and heat extremes in urban areas.

Urban areas: From a methodological standpoint, urban areas can be defined differently for different analyses. For example, urban areas may denote pockets of densely populated areas that meet a certain population density requirement.[10] Alternatively, urban areas may be used to represent contiguous areas where a defined core region of a certain total population exists and where a degree of integration between the core and surrounding areas is present for employment purposes, regardless of population density. This latter definition is used by Statistics Canada to identify Canada's census metropolitan areas.

According to the 2006 census, more than two-thirds (68%) of the Canadian population resides in 33 census metropolitan areas. Their distribution across the country is presented in Appendix A. Each of these metropolitan areas has a total population of more than 100,000 and an urban core of at least 50,000 residents.[11] Several independent and legally incorporated cities may be included within a single census metropolitan area when there is a high degree of spatial integration between the cities. This is the case, for example, for the cities of Surrey, Brampton and Dorval, among many others, that are included within the Vancouver, Toronto and Montréal census metropolitan areas, respectively. For the purposes of this report, census metropolitan areas are considered to represent urban Canada and the term "large cities" is used to denote the areas and cities included within the boundaries of Canada's 33 census metropolitan areas.

This report presents new analyses based on a number of sources, including data from hospitalization records in CIHI's Discharge Abstract Database and the ministère de la Santé et des Services sociaux du Québec's MED-ÉCHO database, the Canadian census, Natural Resources Canada's thermal satellite imagery and Environment Canada's National Pollutant Release Inventory and daily climate data.

Highlights of the methodologies used to analyze the data are presented throughout the text. A more detailed data and analysis methodology paper can be obtained from www.cihi.ca/cphi or by sending an email to cphi@cihi.ca.

Socio-economic status: Like urban areas, the socio-economic status of individuals and areas can be defined in different ways for different analyses. To operationalize the socio-economic status of urban residents and their areas of residence, this report uses the Deprivation Index from the Institut national de santé publique du Québec (INSPQ). This area-based index allows for the monitoring of inequalities in health when individual socio-economic information is not readily available (such as in the case of hospitalization records). The INSPQ's Deprivation Index was built using six variables to include both material and social aspects of socio-economic status shown to be related to health (such as income, education, employment and family structure). It is calculated based on Statistics Canada's census information at the dissemination area level.[12] Dissemination areas are small areas of approximately 400 to 700 people who share similar socio-economic and demographic characteristics.

To create the socio-economic status groups examined in this report, each dissemination area within a census metropolitan area was ranked by its overall Deprivation Index score and grouped into quintiles totalling approximately 20% of the metropolitan area's population. The resulting five groups are referred to in this report as the lowest, lower-middle, middle, upper-middle and highest socio-economic status areas.

Health, health service utilization and hospitalization rates: The data on hospitalization rates presented in this report serves as a proxy for health outcomes and health service utilization but does not necessarily reflect the overall health and health status of individuals. Multiple factors can influence hospitalization rates, such as the prevalence of underlying conditions, access to primary health care and preventive community services, and health behaviours like smoking, physical activity and seeking treatment. Likewise, the hospitalization rates presented in this report may or may not coincide with mortality statistics, given that mortality rates are also determined by a series of factors that may or may not be the same as those that influence hospitalization rates. On the whole, health status and outcomes, health service utilization and hospitalization rates all demonstrate a socio-economic gradient: individuals with lower socio-economic statuses tend to have worse outcomes on a range of health measures than individuals with higher socio-economic statuses.

Chapter 1
Outdoor Air Pollution, Socio-Economic Status and Health Inequalities

Chapter Overview

This chapter reviews the relationship among outdoor air pollution, socio-economic status and health inequalities by summarizing previously published results on the topic and presenting new analyses of Canadian data.

Previously published research shows that

- Individuals and families with a low socio-economic status are more likely to be exposed to outdoor air pollution; they may also be more vulnerable to the health effects of this exposure.
- Rates of hospitalization tend to be higher among individuals and families residing in areas defined by low socio-economic status.

New CPHI analyses show that

- More than 1 million urban Canadians living in lower socio-economic status areas are within 1 kilometre of a pollution-emitting facility; in comparison, approximately 325,000 people living in higher socio-economic status areas are within this distance.
- Rates of hospitalization for respiratory and circulatory diseases tend to increase in areas closer to a pollution-emitting facility. This relationship, however, is strongly associated with socio-economic status and may reflect the fact that residents of lower socio-economic status areas are more likely to face other health inequities and have poor health outcomes due to a combination of health risk factors.
- For residents of the lowest socio-economic areas, rates of hospitalization for respiratory and circulatory diseases significantly decrease with increased residential distance from a pollution-emitting facility.

Everyone is affected by air quality. Air quality, however, is not the same everywhere, and some areas are closer than others to sources of outdoor air pollution. What effect does this have on the health of urban Canadians? Are some people more likely to be exposed to air pollution than others? Is the health of some urban residents more vulnerable to air pollution exposure?

This chapter of the report explores the relationships among outdoor air pollution, socio-economic status and the health of urban Canadians. First, it provides a summary of the current literature on outdoor air pollution and its links to socio-economic status and health inequalities. This review of the literature provides context for new analyses that examine the relationships between health service utilization for diseases of the circulatory and respiratory systems, socio-economic status and residential proximity to major sources of air pollution, such as pollution-emitting facilities.

Sources of Air Pollution in Urban Environments

Outdoor air pollution in urban areas originates from a number of sources, including industrial facilities such as power stations, refineries, smelters and manufacturers, and from traffic-related emitters such as airplanes and motor vehicles.[13–15] These contributors to poor air quality are known as stationary or point sources and line sources of pollution. Five pollutants in particular have been identified by research as harmful to health. Box 1 outlines their nature and origin, while Table 1 (on page 20) summarizes their known links to circulatory and respiratory diseases.

Box 1

Major Pollutants and Their Origin

Environment Canada tracks a number of air contaminants, heavy metals and organic pollutants that lead to poor outdoor air quality through the National Pollutant Release Inventory (see Box 4 on page 17). This report examines five of these major pollutants released by industrial facilities and motor vehicles that have been shown through research to have an effect on circulatory and respiratory health (see Table 1 on page 20): fine particulate matter, sulphur dioxide, nitrogen dioxide, volatile organic compounds and carbon monoxide.[16]

- **Particulate matter** is a complex mixture of suspended particles and droplets often classified by size.[17, 18] These might include sulphate, nitrate, silicon, elemental carbon, organic carbon matter, and sodium and ammonium ions in varying concentrations.[19] While particulate matter originates from a number of natural processes, fine particulate matter is released mostly through combustion processes and industrial releases.[18]
- **Sulphur dioxide** is commonly released by industrial point polluters, such as coal- and fuel oil–burning power stations.[17]
- **Nitrogen dioxide** is a major constituent of air pollution. Emissions from motor vehicles and other forms of transportation account for 80% to 90% of the release of nitrogen oxide, the chemical basis for nitrogen dioxide.[20]
- **Volatile organic compounds** exist in the air as a result of various natural and manmade processes. Vegetation and soil release large quantities of volatile organic compounds, while industrial processes, such as the production and transportation of petroleum products, also contribute amounts into the outdoor air.[21]
- **Carbon monoxide** is produced primarily by the incomplete combustion of fossil fuels. Outdoor carbon monoxide most often originates from motor vehicles.[22]

Airborne contaminants can vary as much within a single city as they do across multiple urban areas.[23] Research has shown that many of these pollutants are found at higher concentrations in high-traffic areas and in areas close to major roadways. For example, a Canadian study that measured nitrogen dioxide concentrations at 100 locations across Toronto found that 19 locations had higher-than-average concentrations of nitrogen dioxide, of which 15 were in close proximity to expressways and 4 were in high-traffic corridors.[24] An earlier study in Toronto had similar findings and showed higher concentrations of carbon monoxide, nitric oxide, nitrogen dioxide and ozone at a site with high traffic volume (average daily vehicle count of 70,000) compared with sites with medium (average daily vehicle count of 30,000) or low (average daily vehicle count of 2,000) traffic volumes.[25] In line with these Canadian findings, an American study that measured the concentration of traffic-related pollutants at 10 different locations over a 19-week period found that concentrations of various traffic-related pollutants were generally higher for locations that were downwind and within 300 metres of a major roadway, compared with those that were upwind or further away.[26]

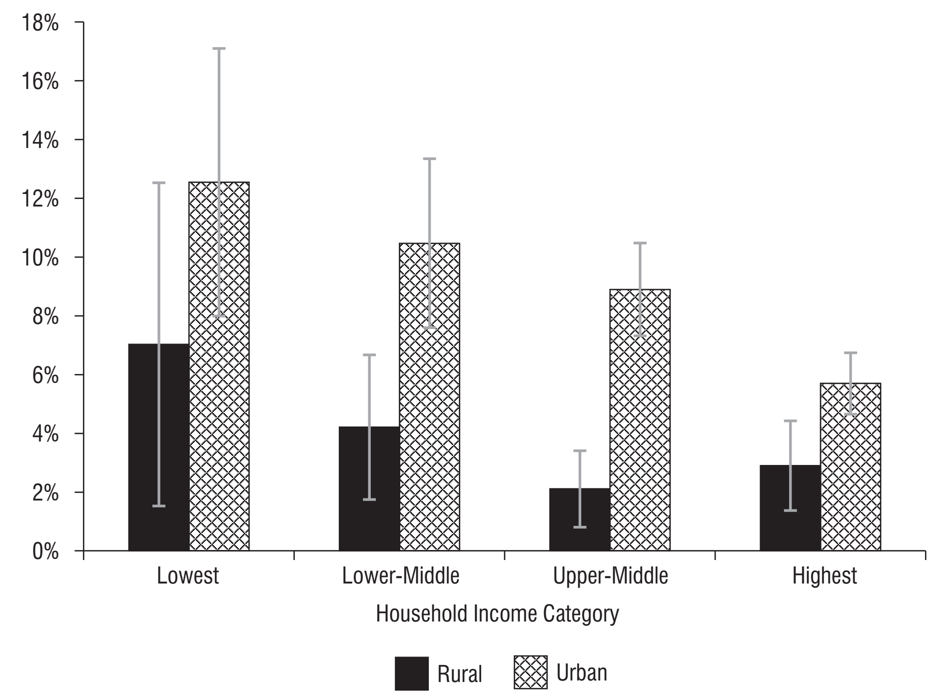
The distribution of air pollution within urban areas can also be influenced by regional-scale air masses (which can carry fine particles and ozone over long distances) and by the number of local ambient sources of pollution, such as industrial sites and stationary motor-related facilities. Additional characteristics of fixed sources of emissions such as stack height, exit velocity of pollutant gases and stack gas temperature have an effect on the relative distribution and concentration of airborne pollutants.[27] These characteristics can be modified by local emissions regulations.

Box 2

Perceptions of Pollution in Urban Versus Rural Areas

Figure 1 shows that Canadians in the lowest-income households in urban areas were more likely than the highest-income households to report that levels of noise and pollution in their neighbourhoods were too high. Compared with rural residents, urban residents of similar income groups were more likely to report noise and pollution levels that were too high, except for the lowest-income group, where the difference between urban and rural Canadians was not statistically significant.

Figure 1: Percentage of Urban and Rural Adults Who Reported That Their Neighbourhoods Were Too Noisy or Polluted, by Household Income Category, 2006–2007



Note
Error bars indicate 95% confidence intervals.
Source
National Population Health Survey, 2006–2007, Statistics Canada.

Distribution of Sources of Outdoor Air Pollution in Relation to Area Socio-Economic Status

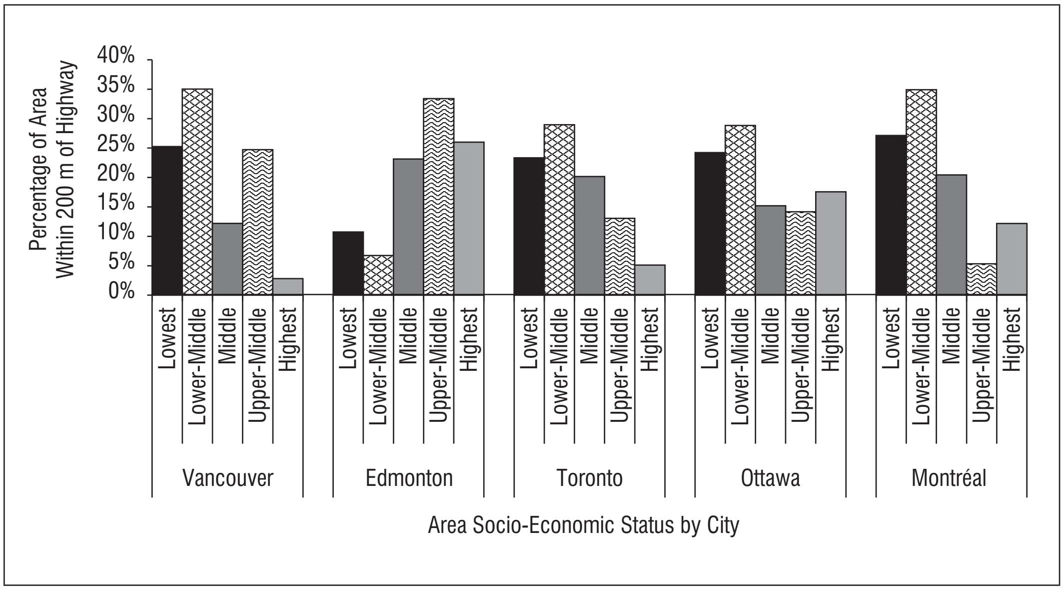
Canadian and international research has shown that air pollution exposure varies according to socio-economic status, with lower socio-economic groups disproportionately exposed to air pollution and to the environmental mechanisms that lead to inequalities in health.[28–30]

Residential patterns are one of the mechanisms through which exposure to pollution is more likely among individuals with a lower socio-economic status. Lower-income families and individuals are more likely to settle in areas near sources of pollution because the cost of housing in these areas tends to be less prohibitive than in other areas. For example, when it comes to air pollution created by motor vehicles, Canadian and American studies have demonstrated that lower socio-economic status neighbourhoods are often situated closer to areas of high traffic density, thereby exposing residents of these neighbourhoods to higher levels of traffic-related pollution. A Hamilton, Ontario, study of 5,228 residents age 40 and older found that a higher percentage of people living in close proximity to high-traffic roadways were from lower socio-economic status neighbourhoods and that pollution levels were higher in those neighbourhoods.[98] A California study found similar results for children younger than 15. It estimated neighbourhood exposure to traffic-related emissions by examining traffic density and family income values and found that children from the lowest income quartile were on average five times more likely than children from the highest income quartile to live in areas with high traffic density.[31]

New Analyses of Residential Proximity to Major Roadways and Socio-Economic Status

CPHI chose five Canadian cities as case studies to further examine the association between proximity to major roadways and socio-economic status: Vancouver, Edmonton, Toronto, Ottawa and Montréal. Within each city, a section of a major highway was selected for residential proximity analyses. Highway sections were identified based on average annual daily traffic data obtained from the provincial transport ministries, which indicated that they are high traffic-density areas within each respective city. The socio-economic status of residential areas within 200 metres of the highway sections was then examined (see Box 3 on page 14 for more details). Figure 2 shows the percentage of land area from each socio-economic status group that fell within 200 metres of part of a major highway in each city. Figure 3 in the report and figures B.1 to B.4 in Appendix B give a visual representation of the portion of highway retained in each city and the distribution of area socio-economic status within 200 metres of the highways.

Figure 2: Socio-Economic Status Distribution of Dissemination Areas Within 200 Metres of Sections of Major Highways in Five Cities, 2006



Notes
All five cities are presented within the same graph to facilitate the publication of results. Because each section of highway is of a different length and various traffic volume data sources were used, comparisons between cities should not be made.
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Sources
Ontario Ministry of Transportation, 2006; City of Edmonton, Transportation Department, 2007; Transport Québec, 2008; British Columbia Ministry of Transportation and Infrastructure, 2009; and Census of Canada, 2006.

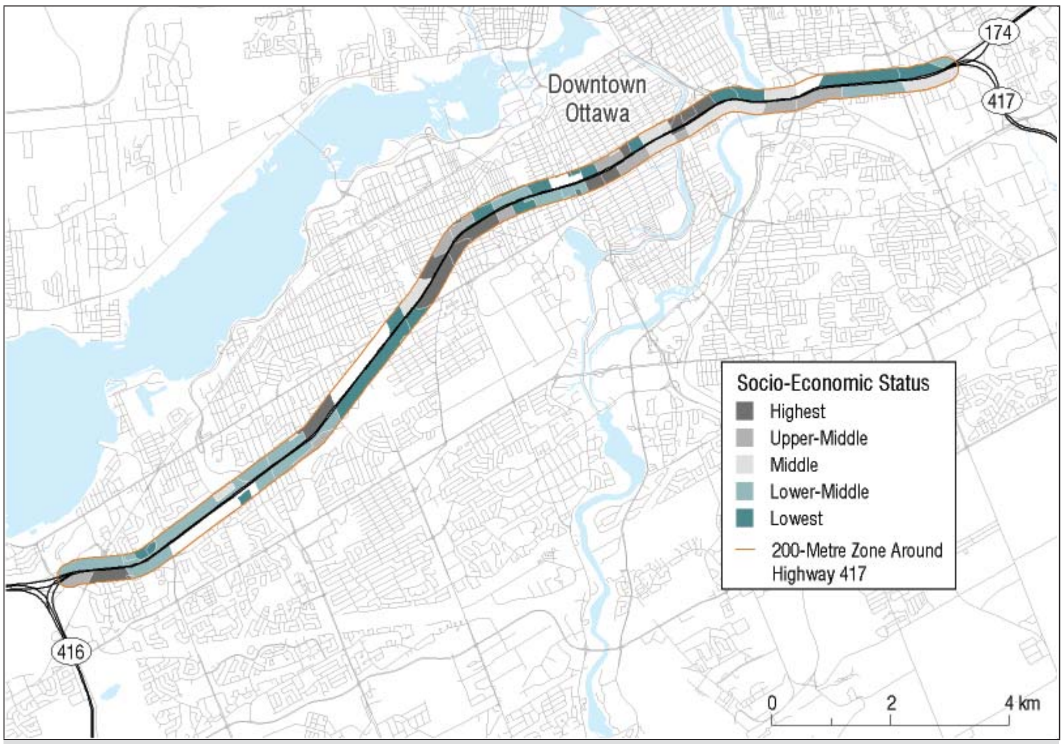
For the most part, the analyses of the selected cities show that a higher percentage of low, compared with high, socio-economic status residential areas were within 200 metres of major highways. The picture is clearest for Toronto and Montréal, where the proportion of the lowest socio-economic status areas within 200 metres of the highway was 3.5 and 2.8 times, respectively, the proportion of the highest socio-economic status areas. In Vancouver, low (lowest and lower-middle combined) socio-economic status areas covered more than twice as much of the area within the 200-metre zone as high (upper-middle and highest combined) socio-economic status areas (60% versus 28%). Similarly in Ottawa, 53% of the 200-metre zone around the selected portion of highway was represented by low socio-economic status areas, compared with 31% of high socio-economic status areas. Edmonton was found to be an exception, as the relationship between socio-economic status and residential proximity to highways was opposite to that found in the other cities. The high socio-economic status areas comprised more than three times the area within the 200-metre zone as the low socio-economic areas (60% versus 18%). The pattern observed in Edmonton could be a reflection of the stretch of highway examined; in contrast to the other cities, in Edmonton the section of the highway does not pass through the central part of the city but instead passes through suburban areas (see Figure B.2 in Appendix B). Typically, the proportion of low to high socio-economic status areas is higher for central compared with suburban parts of cities.

Box 3

Understanding Residential Proximity to Highways and Pollution-Emitting Facilities Analyses

A geographic information system (GIS) was used to identify the areas in close proximity to major highways and pollution-emitting facilities. Each analysis method is described below.

Figure 3: Socio-Economic Status Distribution of Dissemination Areas Within 200 Metres of a Selected Portion of Highway 417 in Ottawa, 2006



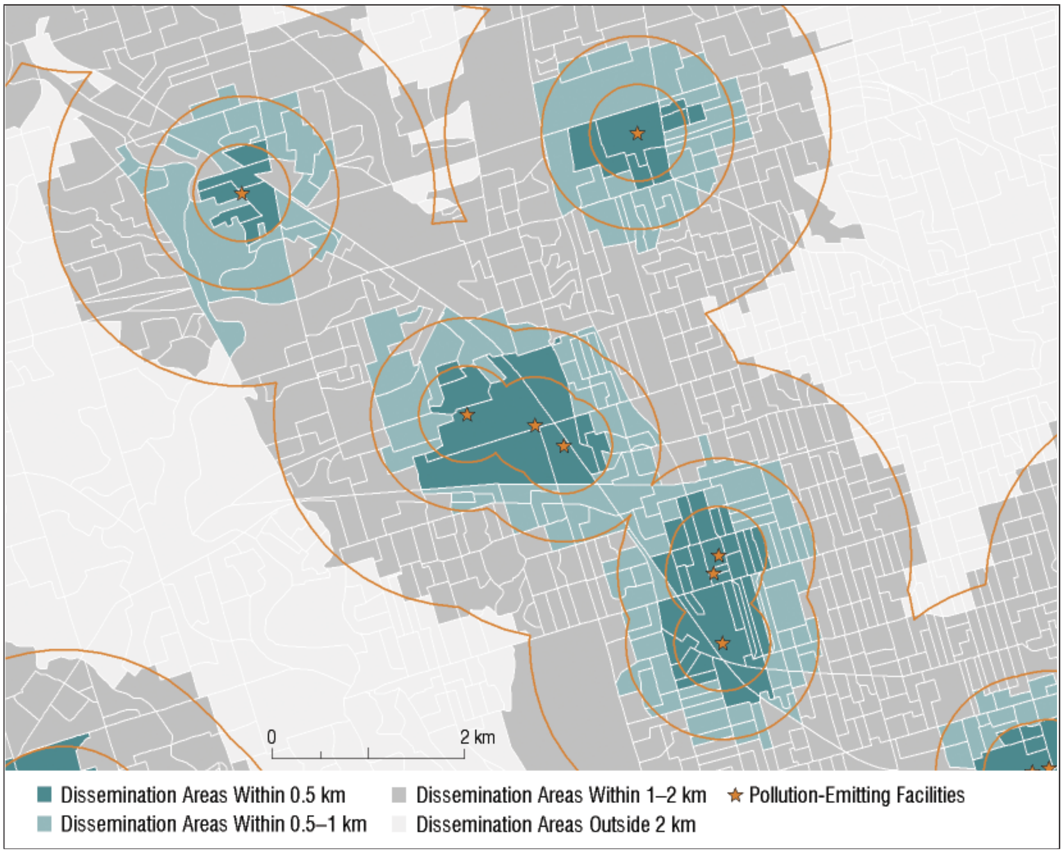
Proximity to Major Highways

Average annual daily traffic values were obtained from provincial ministries of transportation to identify high-volume sections of highways within each of the five case study cities (Vancouver, Edmonton, Toronto, Ottawa and Montréal). A GIS was then used to calculate the percentage of the zone within 200 metres of the highways that encompassed dissemination areas of each socio-economic status group (lowest, lower-middle, middle, upper-middle and highest, based on the INSPQ Deprivation Index). Figure 3 illustrates the section of highway chosen for Ottawa and the socio-economic status of the dissemination areas that lie within 200 metres of the highway. Figures B.1 to B.4 in Appendix B show similar maps for Vancouver, Edmonton, Toronto and Montréal.

Proximity to Pollution-Emitting Facilities

A GIS was also used to categorize the distance between dissemination areas and pollution-emitting facilities identified in Canada's National Pollutant Release Inventory that are in urban areas. Dissemination areas were classified as within 0.5 kilometres of a pollution-emitting facility, between 0.5 and 1 kilometre, between 1 and 2 kilometres and beyond 2 kilometres from a pollution-emitting facility, depending on where the centre of the dissemination area fell in relation to the pollution source (see Figure 4). A small number of larger dissemination areas (occurring mostly in the urban fringes of cities) had surfaces that overlapped more than one distance category. They were nonetheless categorized according to where the centre of the dissemination area was located.

Figure 4: Assigning Dissemination Areas to Distance Categories From Pollution-Emitting Facilities

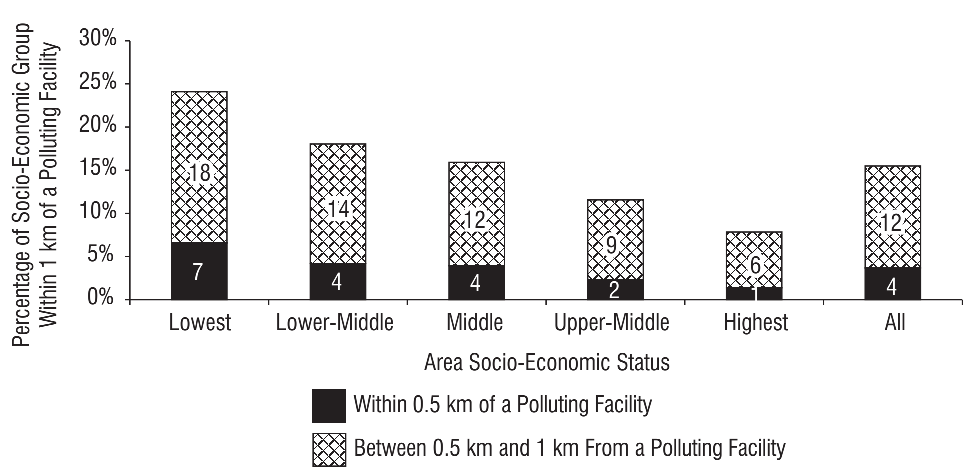


Note
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Sources
Census of Canada, 2006, Statistics Canada; National Pollutant Release Inventory, 2007, Environment Canada.

New Analyses of Residential Proximity to Pollution-Emitting Facilities and Socio-Economic Status

New CPHI analyses also examined patterns of residential proximity to pollution-emitting facilities (that is, point sources of pollution) and socio-economic status using data from the National Pollutant Release Inventory (see Box 4). These analyses found that among the approximately 21 million people in Canada's urban regions, 16% lived within 1 kilometre of a pollution-emitting facility (Figure 5). However, people from the lowest socio-economic status areas were more likely to live within 1 kilometre of a pollution-emitting facility than were those from the highest socio-economic status areas (25% of the lowest socio-economic status areas were within 1 kilometre versus 7% of the highest socio-economic status areas). This translates roughly to 1.03 million urban Canadians from the lowest socio-economic status areas versus 328,000 from the highest socio-economic status areas living within 1 kilometre of a fixed source of outdoor air pollution. If pollution-emitting facilities were equally distributed among all socio-economic areas, one would expect a proportionate number of residents (647,000) within each socio-economic status group to live within 1 kilometre of a pollution-emitting facility.

Figure 5: Percentage of Socio-Economic Status Group in Urban Areas Living Within 1 Kilometre of a Pollution-Emitting Facility, 2006



Note
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Sources
Census of Canada, 2006, Statistics Canada; National Pollutant Release Inventory, 2007, Environment Canada.

Box 4

Information on Point Sources of Pollution in Canada

The National Pollutant Release Inventory is a publicly accessible inventory of major pollutants released into the air, water and land by stationary facilities in Canada. It is a legislated inventory that is managed by Environment Canada. In the last year, more than 300 listed substances from 8,700 Canadian facilities were tracked. The inventory acts as a resource for regulating and facilitating the reduction of toxic pollutant emissions across the country.[32]

Only facilities that were located in large Canadian cities and that emitted one of the five pollutants known to have an impact on respiratory or circulatory health (fine particulate matter, sulphur dioxide, nitrogen dioxide, volatile organic compounds and carbon monoxide; see Box 1 and Table 1) were included in the CPHI analyses presented in this chapter.

A number of environmental factors beyond pollutant type and toxicity have an effect on spatial patterns of air pollution and air quality. For example, the direction and magnitude of prevailing winds influence the mechanisms by which pollutants are carried from their sources (whether they be point or line sources).[33] In addition, pollutant travel is affected by the size and state of the pollutants (for example, gaseous versus particulate solids). Because wind speed and trajectory vary on a small scale, they are complex variables to incorporate at a large scale, such as for pan-Canadian analyses. Therefore, they were not included in our analyses.

Outdoor Air Pollution and Health Inequalities

A number of studies have examined the links between outdoor air pollution and health. The literature reviewed here provides a summary of the evidence base linking exposure to common air contaminants and negative health outcomes, such as increased mortality risk, increased hospitalization and poor circulatory and respiratory health (see Table 1 on page 20). Many of these findings also demonstrate that certain pollutants pose a health risk for particular subgroups of the urban population who may be more vulnerable to being exposed to these pollutants as well as to the effects of this exposure because of their age, employment status, income or education level or because of the socio-economic status of their neighbourhood.

Research evidence suggests that outdoor air pollution has important health repercussions for mortality risk and hospitalization rates. In Canada, air pollution has been attributed to approximately 5,900 premature deaths per year in eight large metropolitan areas combined (Toronto, Montréal, Vancouver, Calgary, Ottawa, Quebec City, Hamilton and Windsor).[13, 34] Between 2008 and 2031, chronic exposure to air pollution is expected to contribute significantly to the number of premature deaths—an increase of 83% over this period—and the related costs will accumulate to approximately $250 billion.[35] In Toronto alone, approximately 1,700 premature deaths and 6,000 hospitalizations annually are attributed to chronic air pollution exposure.[36] More than a quarter of these (440 premature deaths and 1,700 hospitalizations) are associated specifically with traffic-related air pollution.[37]

Canadian research has shown that health outcomes and outdoor air pollution levels are linked with area socio-economic status. As noted previously, lower socio-economic status areas are more likely to be in close proximity to sources of outdoor air pollution such as major highways and pollution-emitting facilities. Low-income residents of Hamilton whose neighbourhood experienced high levels of suspended particulate matter had more than double the risk of dying from causes other than accidents compared with higher-income individuals living in neighbourhoods with lower particulate levels.[17] The same study found that lower-income individuals living in areas with high levels of sulphur dioxide were more than three times more likely to die from cardiopulmonary-related causes than higher-income individuals living in areas with lower levels of the pollutant.[17]

Individual-level factors related to low socio-economic status, such as unemployment, certain types of employment (for example, manufacturing) and having a high school education or less, are also associated with living in areas that regularly experience heightened concentrations of industrial pollutants in Montréal.[29] Another study of Montréal found that differences in hospitalization rates among socio-economic groups were partially explained by the higher levels of pollution exposure experienced by lower socio-economic status individuals.[38]

Box 5

Literature Search Methods

While the information presented in this report is not a systematic review, systematic methods were used to search the academic and grey literature base to identify studies that examined the links among the urban physical environment, socio-economic status and health inequalities. A literature search methods paper that outlines the databases searched and the keywords used is available from www.cihi.ca/cphi or upon request to cphi@cihi.ca.

Box 6

Traffic-Related Noise Pollution and Health

Living close to major roadways increases the risk of exposure to outdoor air pollution and to traffic-related noise pollution. There is an evidence base supporting the association between traffic-related noise pollution and unwanted health outcomes, particularly those related to cardiovascular and mental health. European studies have demonstrated an increased risk of cardiovascular complications with exposure to high road traffic noise in both children and adults. For example, a 2005 German study found that male subjects living on streets with high traffic noise, measured as a sound pressure level above 70 decibels (dB), showed an increased risk of myocardial infarction, or heart attack, compared with those who lived on streets with lower traffic noise (60 dB or lower).[39] A 2008 Serbian study of children age 3 to 7 living in downtown Belgrade found a higher prevalence of both hypertensive values of blood pressure and higher heart rates in children exposed to high traffic noise (greater than 45 dB) compared with children residing in quieter areas (45 dB or lower).[40]

Research has also demonstrated the link between high road traffic noise and mental health outcomes. Although not exclusive to urban areas, a 2001 study of 115 children in Austria found that those from neighbourhoods exposed to high traffic noise (greater than 60 dB) reported greater stress symptoms over the previous week compared with children from quieter neighbourhoods (less than 50 dB).[41]

While urban Canadians with a low socio-economic status are more likely to be exposed to outdoor air pollution, they may also be more vulnerable to the effects of this exposure. A Canadian study showed that, compared with high-income individuals in low-pollution areas, there is a 162% greater risk of mortality for low-income individuals in high-pollution areas. There is also increased mortality risk for low-income individuals in low-pollution areas (82%) and for high-income individuals in areas with high pollution levels (33%).[17] In another Canadian study, exposure to nitrogen dioxide was positively associated with asthma hospitalization rates among lower socio-economic status boys age 6 to 12; this association was not observed for boys in the higher socio-economic status group.[42] This study also found that lower socio-economic status girls age 6 to 12 exposed to sulphur dioxide were more frequently hospitalized for asthma than girls in the higher socio-economic status group with similar levels of exposure.[42]

Table 1: Summary of the Effects of Outdoor Air Pollution on Circulatory and Respiratory Health

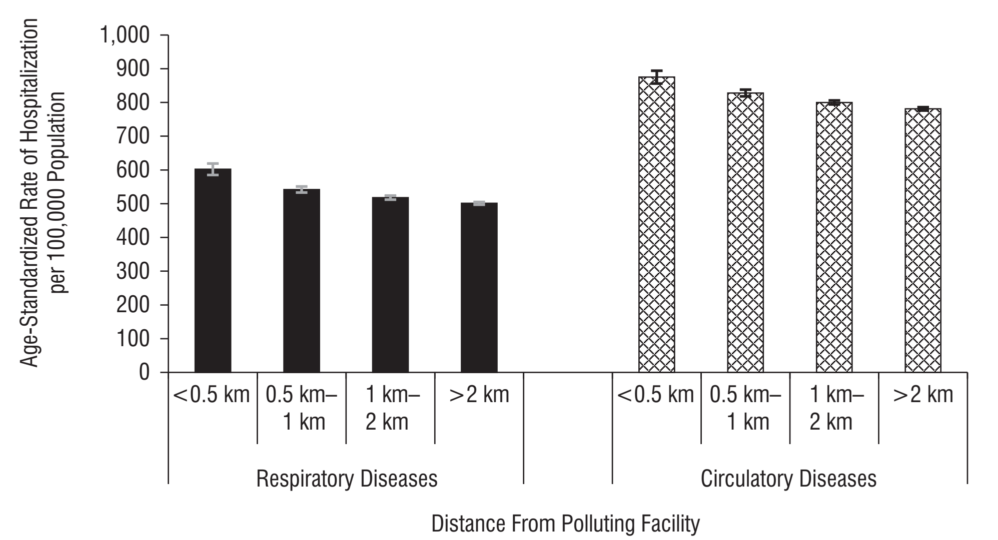
Ambient Air Pollution	Highway and Traffic-Related Air Pollution
Increases in common airborne pollutants have been significantly linked to higher rates of daily mortality in the Netherlands[43] and Canada[44] as well as to respiratory and circulatory mortality rates in Australia.[45]	A 2006 Canadian study of Montréal island residents age 60 and older found that the odds of being hospitalized for a respiratory diagnosis increased for residents living near medium- or high-level traffic.[49]
Incremental increases in airborne particulate matter have been linked to increases in hospital admissions for cardiovascular diseases[18, 46] and for total, respiratory and cardiovascular mortality.[46, 47]	A 2007 U.S. study of 3,677 children found that children who lived within 500 metres of a freeway had a greater incidence of respiratory problems, compared with children who lived at least 1,500 metres from a freeway.[50] Local exposure to both freeways and regional air pollution had a negative effect on lung-function development.[50]
Higher levels of ozone have been associated with an increased risk for daily mortality within particular groups of the population, including women and seniors.[48]	A 2006 Swiss study found that adults who never smoked and who lived in close proximity to a main roadway had a 34% increased risk of wheezing with breathing problems, while every 100-metre increase in distance from the closest major roadway was associated with a 12% decrease in risk for attacks of breathlessness.[51]
Daily variations in nitrogen dioxide concentrations have been positively associated with fluctuations in daily mortality rates in 12 of Canada's largest cities.[20] Incrementally higher levels of sulphur dioxide have also been associated with increases in pre-existing respiratory illnesses and respiratory mortality, while incrementally higher levels of nitrogen dioxide have been associated with increases in respiratory illness morbidity but not mortality rates.[15]	A 2003 U.S. study found that males living near a major roadway were more likely to report persistent wheeze, chronic cough and chronic phlegm problems, compared with residents living further away from the roadway.[52]

New Analyses of Residential Proximity to Pollution-Emitting Facilities and Hospitalizations for Circulatory and Respiratory Diseases

To further our understanding of outdoor air pollution and health, new analyses were conducted to examine residential proximity to pollution-emitting facilities in Canada's largest cities and health service utilization. Based on the review of the literature presented in this chapter of the report, two classes of diseases shown to be sensitive to the effects of pollutants were investigated: diseases of the circulatory and respiratory systems. To complete this analysis, CPHI used data from the National Pollutant Release Inventory to identify pollution-emitting facilities in urban areas (see Box 4) and hospitalization records from both CIHI's Discharge Abstract Database and the ministère de la Santé et des Services sociaux du Québec's MED-ÉCHO database to act as a proxy for health and to measure health service utilization.

The results of this analysis show that residents from areas closer to pollution-emitting facilities were more likely to be hospitalized for diseases of the respiratory and circulatory systems than residents from areas further away from the pollution source (see Figure 6). Hospitalization rates for circulatory diseases and respiratory diseases were 12% higher and 20% higher, respectively, in areas within 0.5 kilometres of a pollution-emitting facility than in areas more than 2 kilometres away. This resulted in a rate of hospitalization that was approximately 100 per 100,000 population higher for each disease in areas within 0.5 kilometres from a pollution-emitting facility than in areas 2 kilometres or more from a pollution-emitting facility. On the whole, admissions to hospital were more frequent for circulatory diseases than respiratory diseases, but in both cases a similar gradient existed, whereby as the distance from the source of pollution increased the rates of hospitalization decreased.

Figure 6: Age-Standardized Rates of Hospitalization for Diseases of the Respiratory and Circulatory Systems, by Residential Proximity to a Pollution-Emitting Facility, 2007–2008

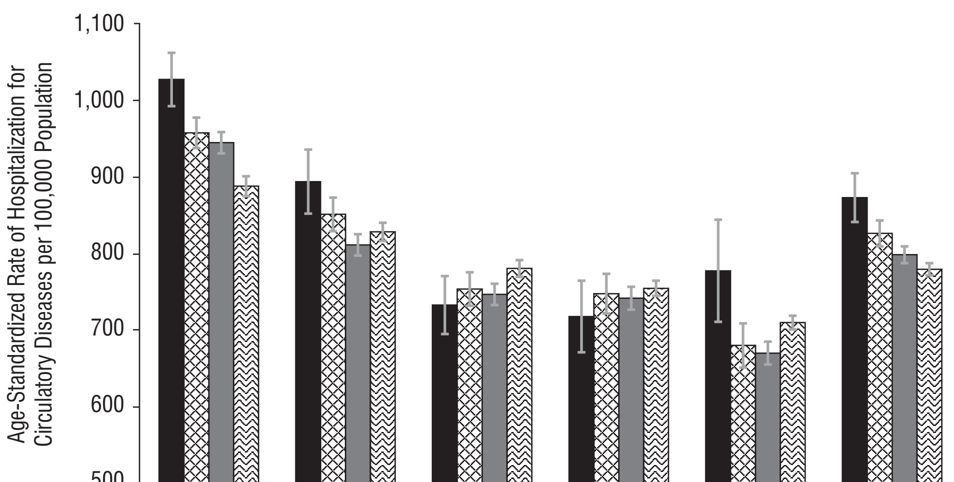


Notes
Error bars indicate 95% confidence intervals. If the error bars between two rates do not overlap, the difference between the rates is considered to be statistically significant with a 5% margin of error.
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Sources
Discharge Abstract Database, 2007–2008, Canadian Institute for Health Information; Fichier des hospitalisations MED-ÉCHO, 2007–2008, ministère de la Santé et des Services sociaux du Québec; National Pollutant Release Inventory, 2007, Environment Canada.

New Analyses of Residential Proximity to Pollution-Emitting Facilities, Socio-Economic Status and Hospitalizations for Circulatory and Respiratory Diseases

Since lower socio-economic status areas are more likely to be within close proximity of pollution-emitting facilities (as noted previously; see Figure 5) and lower socio-economic status areas generally tend to have higher rates of hospitalization, new CPHI analyses also examined health service use according to residential distance from a pollution source and area socio-economic status simultaneously. The results of these analyses are shown in Figure 7 for rates of hospitalization due to diseases of the circulatory system and Figure 8 for diseases of the respiratory system.

Figure 7: Age-Standardized Rates of Hospitalization for Diseases of the Circulatory System, by Residential Proximity to a Pollution-Emitting Facility and Socio-Economic Status of the Area of Residence, 2007–2008



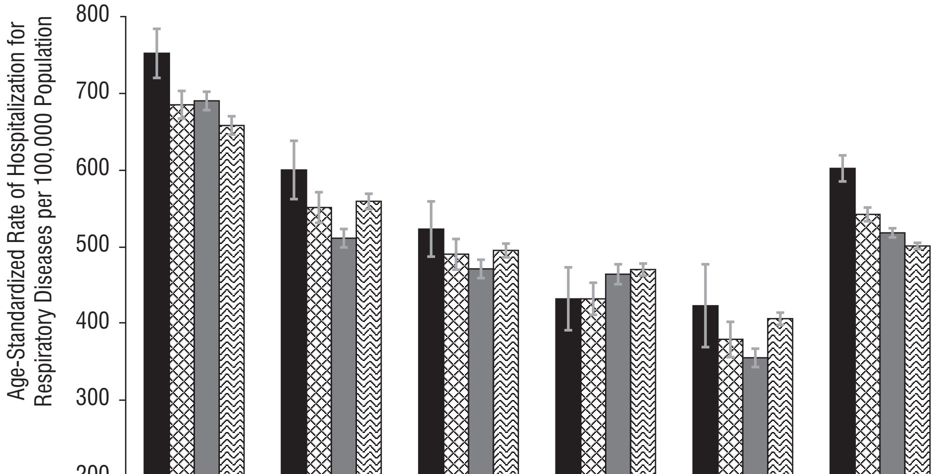
	Lowest	Lower-Middle	Middle	Upper-Middle	Highest	All
<0.5 km	1,030	896	734	719	779	875
0.5 km–1 km	960	853	755	749	681	828
1 km–2 km	947	813	748	743	671	800
>2 km	890	830	782	756	711	781

Notes
Error bars indicate 95% confidence intervals. If the error bars between two rates do not overlap, the difference between the rates is considered to be statistically significant with a 5% margin of error.
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Sources
Discharge Abstract Database, 2007–2008, Canadian Institute for Health Information; Fichier des hospitalisations MED-ÉCHO, 2007–2008, ministère de la Santé et des Services sociaux du Québec; National Pollutant Release Inventory, 2007, Environment Canada.

Figures 7 and 8 demonstrate that as distance from the source of pollution increased, overall rates of hospitalizations for both circulatory and respiratory diseases decreased for all socio-economic status groups combined.

The relationship between hospitalization rates and residential proximity to a pollution-emitting facility, however, varied for the different socio-economic status groups. For example, rates of hospitalization for circulatory and respiratory diseases in the lowest socio-economic status areas were 16% and 14% higher, respectively, in areas closest to the pollution-emitting facilities than in areas with the same socio-economic profile that were more than 2 kilometres away. Higher socio-economic status areas (middle, upper-middle and highest) were not associated with reduced hospitalization rates with increasing distance from pollution-emitting facilities.

Figure 8: Age-Standardized Rates of Hospitalization for Diseases of the Respiratory System, by Residential Proximity to a Pollution-Emitting Facility and Socio-Economic Status of the Area of Residence, 2007–2008



	Lowest	Lower-Middle	Middle	Upper-Middle	Highest	All
<0.5 km	752	600	523	432	423	602
0.5 km–1 km	685	551	490	432	379	542
1 km–2 km	690	511	471	464	355	518
>2 km	658	559	495	470	406	501

Notes
Error bars indicate 95% confidence intervals. If the error bars between two rates do not overlap, the difference between the rates is considered to be statistically significant with a 5% margin of error. Area socio-economic status defined using INSPQ's Deprivation Index, 2006.

Sources
Discharge Abstract Database, 2007–2008, Canadian Institute for Health Information; Fichier des hospitalisations MED-ÉCHO, 2007–2008, ministère de la Santé et des Services sociaux du Québec; National Pollutant Release Inventory, 2007, Environment Canada.

Figures 7 and 8 also show that the gap in rates of hospital admission for circulatory and respiratory diseases between residents of the lowest socio-economic areas and those from the highest socio-economic areas was more pronounced within 0.5 kilometres of pollution sources than in areas further away. For admission to hospital for circulatory and respiratory diseases, there was a 32% and 78% increase, respectively, in the rates of hospitalization for residents of the lowest socio-economic status areas compared with residents of the highest socio-economic status areas that were located within 0.5 kilometres of a pollution-emitting facility. The difference in rates of hospitalization between the lowest and highest socio-economic areas was 25% and 62%, respectively, in the areas that were 2 kilometres or more from a pollution source.

Chapter Summary and Key Messages

The results of CPHI's new analyses examining the relationship between outdoor air pollution, socio-economic status and health inequalities in Canada corroborate previous findings from social and health research. In particular, this study found that residential proximity to pollution-emitting facilities poses a health risk for particular subgroups of the urban population. It also found that lower socio-economic status areas are more likely to be close to pollution-emitting facilities and major roadways. This study contributes new knowledge by simultaneously considering the relationship between air pollution, socio-economic status and health service utilization.

Key findings from new CPHI analyses:

- For all socio-economic status groups combined, rates of hospitalization for respiratory and circulatory diseases increase with closer residential proximity to a pollution-emitting facility. Examination of this relationship for each socio-economic status category separately reveals that this gradient holds true and is significant only for the lowest socio-economic status areas. These findings suggest that residential proximity to a pollution source is not as closely related to hospitalizations for circulatory and respiratory diseases as socio-economic status itself. In other words, the higher hospitalization rates observed among individuals from lower socio-economic areas living in closer proximity to pollution-emitting facilities can mostly be explained by the fact that residents of lower socio-economic status areas are more likely to face health inequities and have poor health due to a combination of psychosocial, behavioural and medical factors that affect health.
- Rates of hospitalization for respiratory and circulatory diseases significantly decrease with residential distance from a pollution-emitting facility only for residents from the lowest socio-economic areas. This observation suggests that people from lower socio-economic areas may indeed be more vulnerable to the ill health effects of air pollution and that distance from a pollution source acts as a protective factor for residents of the lowest socio-economic status areas only.

These results are based on large amounts of data obtained from reliable data sources, but it is important to keep a few points in mind when drawing conclusions:

- Due to technical limitations (for example, different sources of information that made linkage impossible), other variables that are known to influence health, such as psychosocial and behavioural factors, were not accounted for as plausible factors that could influence the observed relationships among pollution, socio-economic status and health inequalities.

- As noted earlier, the data on hospitalization rates presented in this report serves as a proxy for health outcomes and health service utilization but does not necessarily reflect the overall health and health status of individuals. Multiple factors can influence hospitalization rates, such as the prevalence of underlying conditions, access to primary health care and preventive community services, and health behaviours like smoking, physical activity and seeking treatment.
- Likewise, the hospitalization rates presented in this report may or may not coincide with mortality statistics, given that mortality rates are also determined by a series of factors that may or may not be the same as those that influence hospitalization rates.

Chapter 2
Heat Extremes, Socio-Economic Status and Health Inequalities

Chapter Overview

This chapter reviews the relationship among heat extremes, socio-economic status and health inequalities by summarizing previously published results on the topic and presenting new analyses of Canadian data.

Previously published research shows that

- Mortality rates are higher during periods of hot weather and some individuals, including seniors and those who do not have adequate housing, are more vulnerable to the effects of heat extremes.
- Health effects of hot weather are becoming an increasing global public health challenge and a concern in urban Canada.
- Built and natural environments influence the way the physical environment responds to heat and thereby contribute to within-city temperature differences.
- Access to cooler spaces and/or green space can mitigate the harmful health effects of heat extremes.

New CPHI analyses show that

- Land surface temperatures vary significantly within a city; neighbourhoods with more built and artificial surfaces, such as those near city centres, reach much hotter temperatures than those with more natural vegetation coverage.
- The lowest socio-economic status areas in Montréal and Toronto are more likely to reach high temperatures and are less likely to have green space, compared with the highest socio-economic status areas.
- Individuals and families with a lower household income are less likely to have air conditioning.
- Hospitalization rates in Montréal and Toronto, and emergency department visits in Toronto, for respiratory and circulatory diseases were not found to significantly increase on hot days or during short heat waves.

Research consistently shows higher mortality rates during hot days and heat waves than during less hot days.[55–58] These increases have been observed when examining all non-injury mortality, as well as for specific classes of disorders, including circulatory and respiratory disorders.[58–60] The health effects of hot weather are of increasing concern in urban Canada. Climate projections suggest that hot days will become more frequent in the 21st century in Canadian cities such as Montréal,[61] Toronto, Fredericton and London,[62] as well as globally.[63] The annual number of days where the temperature exceeds 30°C is likely to quadruple in some areas of southern

Canada between 2005 and 2050.[62] Given these trends, heat-related mortality is projected to increase in Canadian cities such as Montréal[64] and Quebec City,[65] as well as in American cities such as New York[66, 67] and Philadelphia.[67]

This chapter provides an overview of some of the factors that contribute to risks of poor health during periods of heat extremes. It describes the ways that the urban physical environment contributes to elevated temperatures and uses satellite data for Montréal and Toronto to explore relationships between elements of the physical environment, land surface temperatures and socio-economic status. Health service utilization for diseases of the circulatory and respiratory systems is then measured on hot days and during short heat waves and compared to days that were not as hot.

Factors Contributing to Vulnerability During Heat Extremes

In hot weather, some individuals are more likely than others to become ill or to die.[55, 68, 69] Factors that increase risk are those that affect exposure, sensitivity and access to treatment.[68] Individuals who do not have adequate housing are more likely to be at risk due to exposure to heat. For example, in a 2003 heat wave in France, those living in dwellings with no thermal insulation had a greater risk of dying.[70] In Arizona, homeless individuals have been found to be at increased risk of heat-related death during excessive heat events.[71]

Individual risk factors related to sensitivity to heat include age, pre-existing medical conditions and taking medications that affect the ability to regulate one's body temperature.[60, 68, 70] Young children and older adults are especially vulnerable to heat stress[68] and heat-related mortality.[60, 69] Finally, individuals may be more vulnerable to the effects of heat extremes if they have poorer access to treatment, have mobility problems or are socially isolated.[70, 72]

Vulnerability to heat also varies among neighbourhoods. Some characteristics, of a more vulnerable neighbourhood include socio-economic characteristics, a high proportion of seniors and buildings without air conditioning.[73] A study of southern Quebec published in 2005 examined temperature data and social vulnerability, combining measures of area-level poverty, education, age and social isolation.[61] This study identified areas that will be at high risk in the mid-21st century due to the high number of hot days projected and high levels of social vulnerability.[61] The most densely populated areas, including Montréal, its suburbs and the corridor from Montréal to Quebec City, had the highest projected public health risk during hot weather events. Another study of Montréal showed that risk of death on warm summer days is greater for residents of areas with higher land surface temperatures.[55]

Heat and the Urban Physical Environment

The built environment in urban and suburban areas leads to changes in the way that the physical environment responds to heat.[54] Urban areas tend to be warmer than rural areas, a difference referred to as an urban heat island.[53] The built environment contributes to urban heat islands and heat retention in urban areas in several ways, including the following:

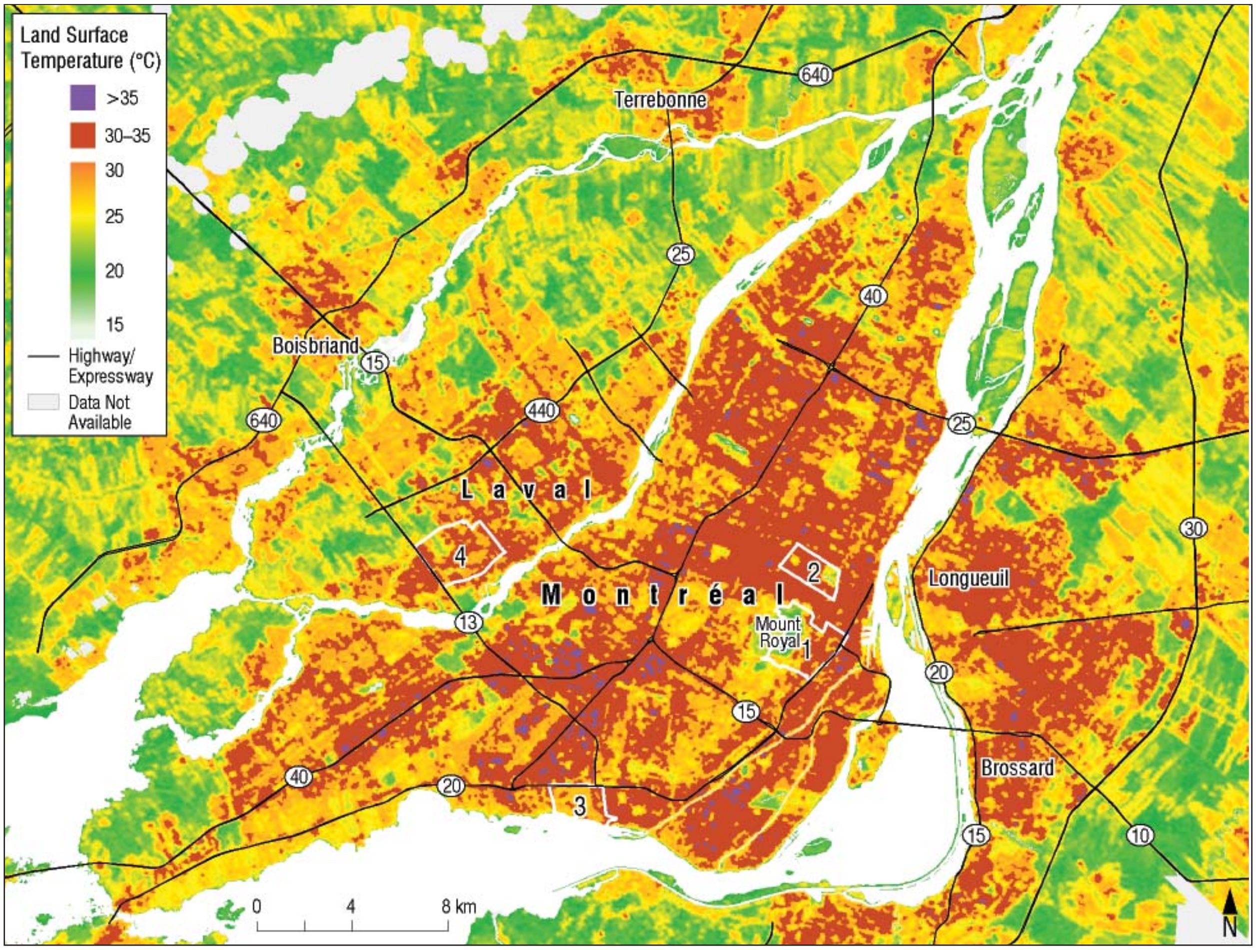
- Concrete, asphalt and other artificial surfaces increase surrounding air temperatures by storing and then releasing absorbed solar energy as heat;[54]
- Artificial surfaces replace natural surfaces, such as vegetation and soil, that provide shade and help heat dissipate;[54] and
- Tall buildings, despite providing some shade to surrounding areas, serve as air-flow barriers or canyons and heat traps that slow the rate at which cities cool off at night.[53, 74]

A study of New York City and surrounding parts of New York and New Jersey found that urban areas were on average 4°C warmer in the summer than rural areas.[75] Other work has shown that the largest temperature differences between urban and rural areas are typically observed at night, because rural areas cool off more quickly than urban areas.[53, 76] Urban–rural and urban–suburban temperature differences are affected by many factors, including local weather, geographic features and aspects of the built environment described above.[53, 75, 77] Within cities both large and small, there are neighbourhoods where heat stored in buildings, roadways and parking areas results in pockets of higher temperatures known as micro-urban heat islands.[55, 78]

New Analyses Examining the Presence of Urban Heat Islands in Canadian Cities

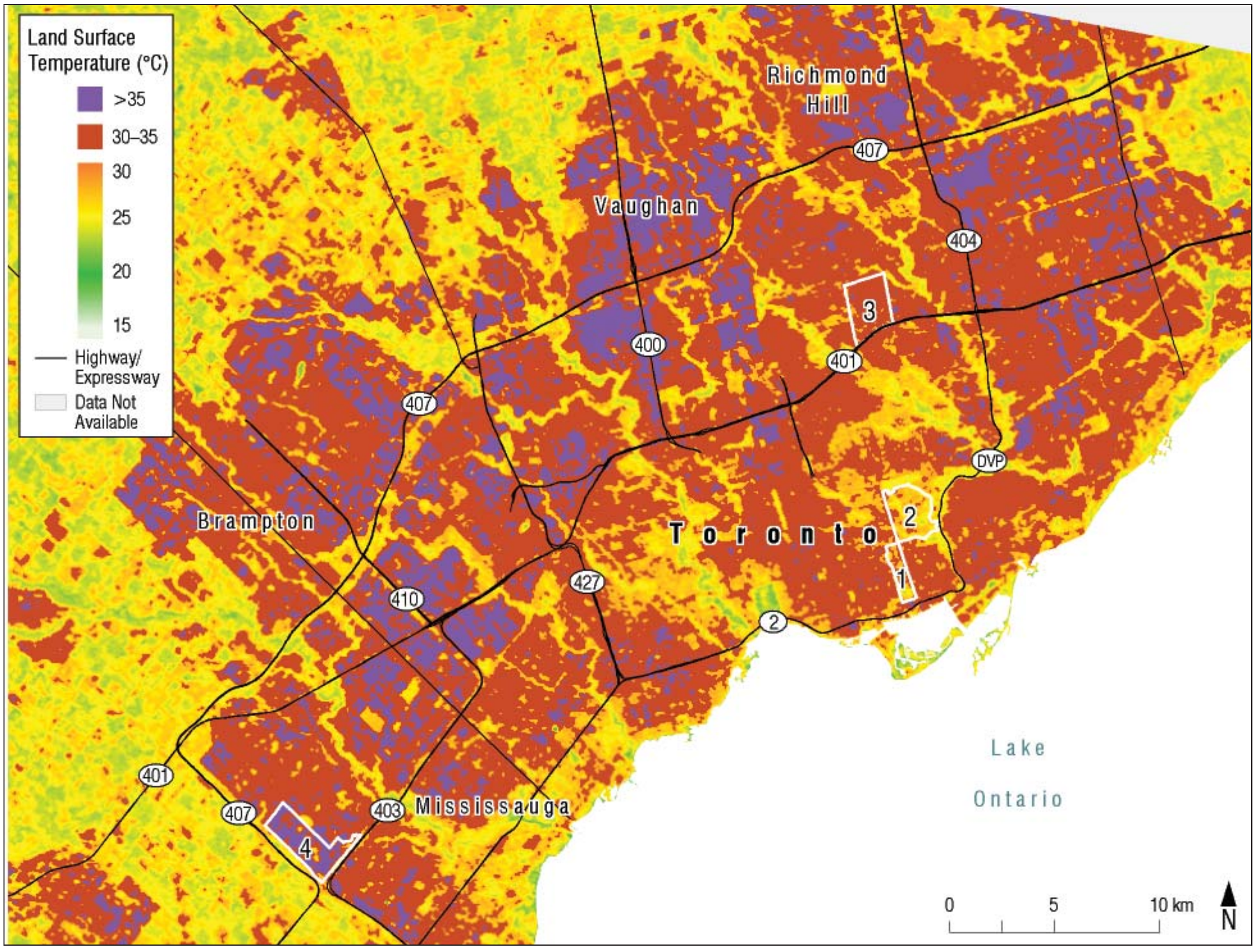
To examine the presence of summertime urban and micro-urban heat islands in the Canadian context, CPHI analyzed four neighbourhoods from Montréal and Toronto and explored the relationships between land surface temperatures and characteristics of the urban physical environment. The locations of the neighbourhoods are shown in figures 9 and 10. Central and suburban neighbourhoods were selected to represent a range of urban design patterns. While the data presented here captures one moment in time for each city, it is expected that data from other hot days would produce comparable distribution patterns of land surface temperatures within each city (although land surface temperatures can vary according to weather conditions, such as wind and cloud cover).[53]

Figure 9: Land Surface Temperature Map of Montréal, 2008



Note
Neighbourhoods outlined: 1. Métro Centre; 2. Plateau Ouest; 3. Lachine Ouest; 4. Chomedey Ouest.
Source
Satellite imagery from Landsat Thematic Mapper, July 5, 2008, Baudouin and Martin, Université du Québec à Montréal.

Figure 10: Land Surface Temperature Map of Toronto, 2008



Note
Neighbourhoods outlined: 1. Bay Street Corridor; 2. Rosedale–Moore Park; 3. Willowdale East; 4. Churchill Meadows.
Source
Satellite imagery from Landsat Thematic Mapper, September 3, 2008, Natural Resources Canada.

In both Montréal and Toronto, neighbourhoods with a higher proportion of built and artificial surfaces to natural environments were the hottest. Figures 9 and 11 show land surface temperature distribution for the central portion of Montréal. The highest temperatures (greater than 35°C) are shown in purple and are observed on the island of Montréal, which includes the downtown core and the inner suburbs. Areas further from the city centre tended to have lower surface temperatures, illustrating an urban heat island effect. Closer examination of the areas with the hottest temperature with high-resolution satellite imagery reveals that they encompass mostly industrial facilities, followed by dense commercial and residential developments in the downtown core area. For example, extremely hot temperatures (greater than 35°C) occurred near highway 40, between highways 13 and 15, which is an area characterized by industrial buildings, parking lots and little green space. On the island of Montréal, the coolest areas were large green spaces and parks, such as Mount Royal Park, which was nearly 20°C cooler than the hottest areas in the nearby downtown. The neighbourhood of Plateau Ouest (Figure 11) is an example of a dense residential neighbourhood with green spaces that were much cooler than other parts of the neighbourhood. Thermal and satellite images of additional Montréal neighbourhoods are shown in Appendix C.

Land surface temperatures also varied significantly within Toronto (see Figure 10). As in Montréal, areas covered by industrial facilities and their parking lots, with very little natural vegetation, were among the hottest. For example, the region surrounding the intersection of highways 401, 410 and 403 contains large expanses of industrial land use that were extremely hot (greater than 35°C). Extreme temperatures were also observed in a ring of suburban areas. Removing natural vegetation for land development and lacking a mature tree canopy may contribute to high land surface temperatures in newer suburban neighbourhoods. Churchill Meadows (Figure 12) is an example of a recently developed suburb, with 90% of dwellings constructed between 1991 and 2006. The satellite view suggests that the neighbourhood has less vegetation and higher temperatures than neighbourhoods characterized by older dwellings and a more mature tree cover, such as Rosedale–Moore Park (Figure 12), which is a well-established neighbourhood with only 14% of dwellings constructed between 1991 and 2006. An example of land surface temperatures in the neighbourhood of Willowdale East is shown in Figure C.2. Excluding rural regions, some of the coolest areas in Toronto were the vegetated river valleys that can be seen in Figure 10 as narrow swaths of yellow and green, generally oriented in a north–south direction. Some urban areas immediately adjacent to Lake Ontario also had cooler temperatures due to the cooling effect of the lake breeze.[79]

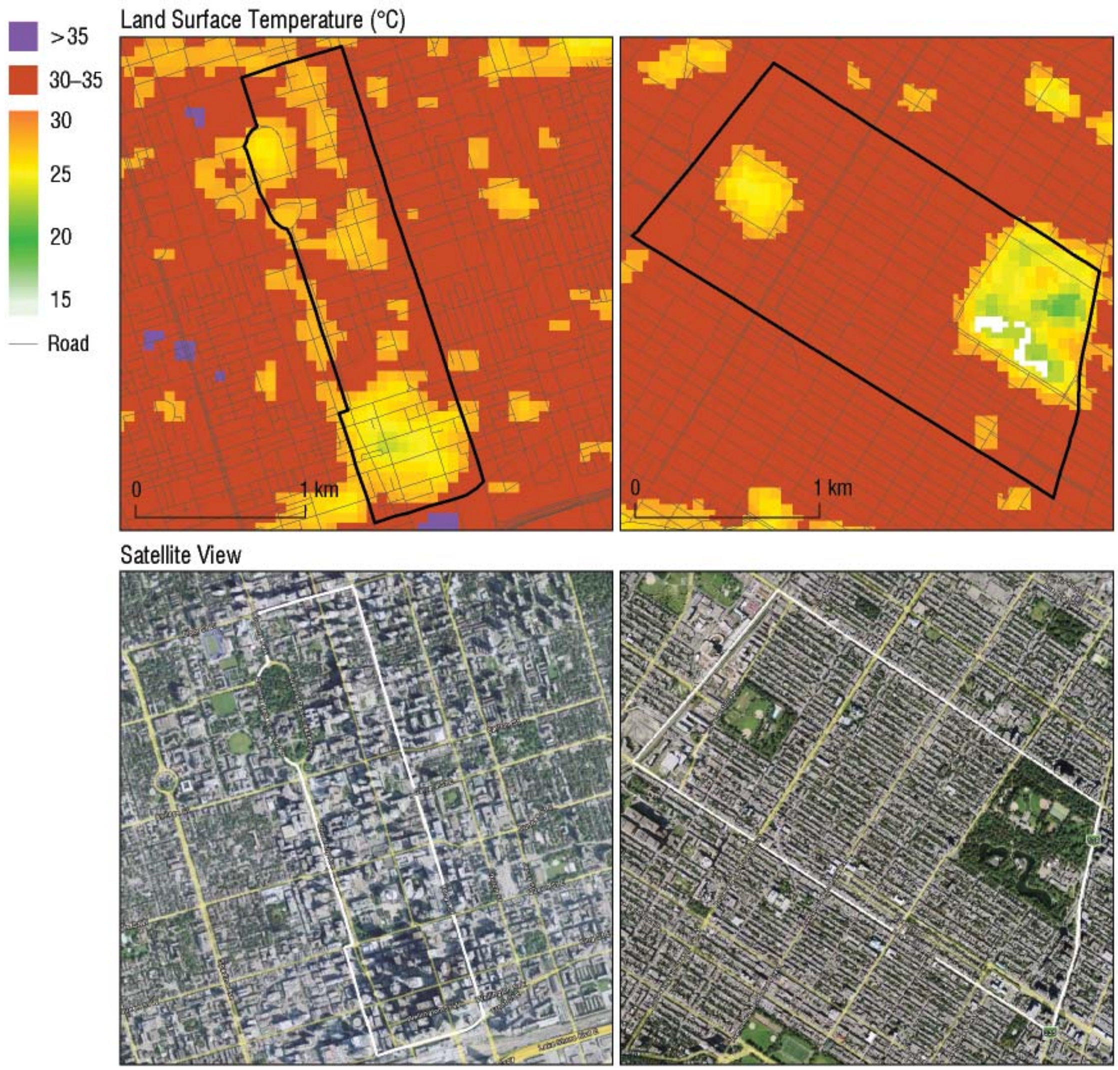
Box 7

The Relationship Between Land Surface and Air Temperatures

Although land surface temperature is not perfectly correlated with air temperature, it is an indicator of urban heat island intensity, particularly during nighttime periods.[80]

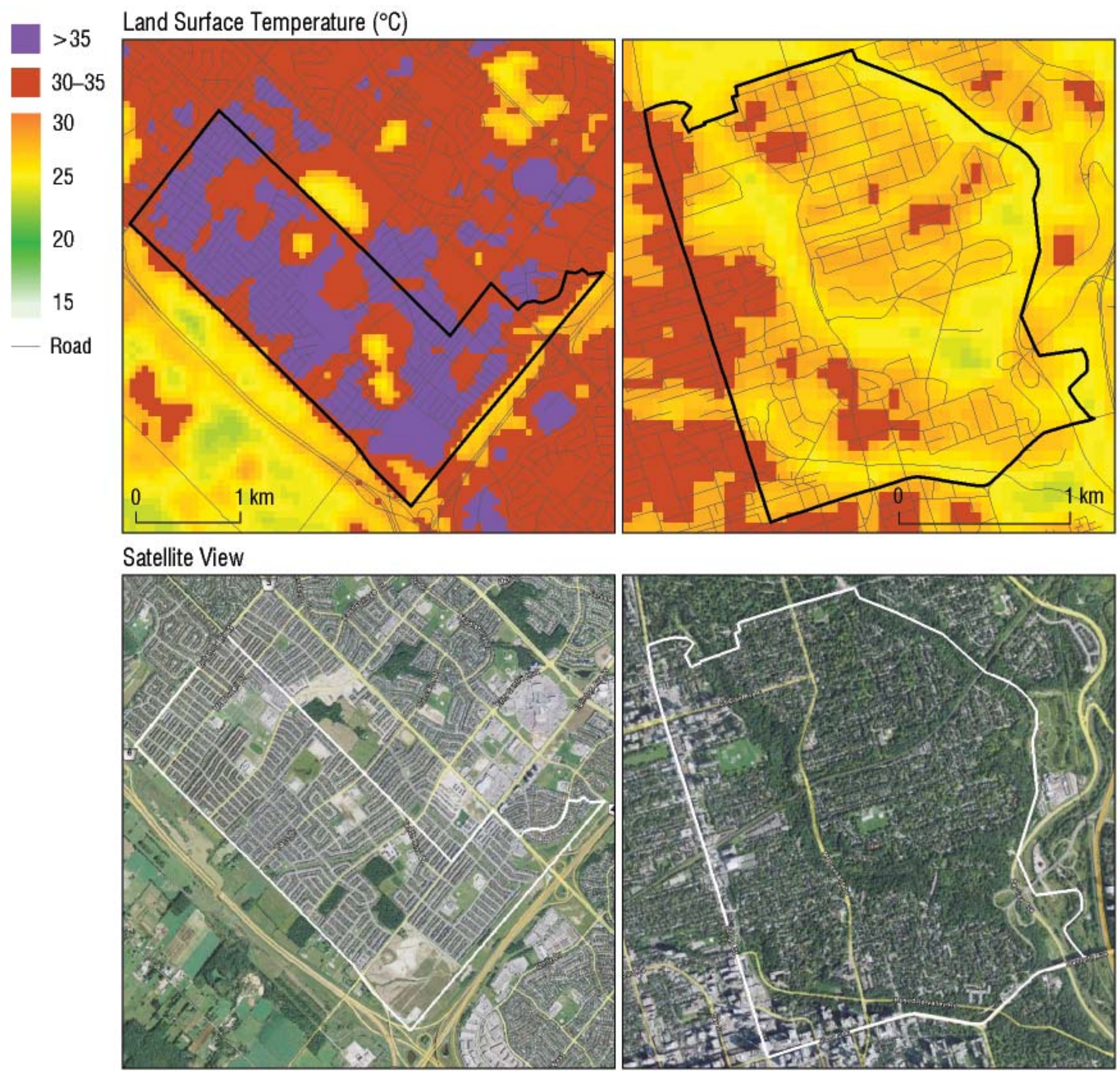
Air temperature data in urban areas is limited to the locations of air monitoring stations, making it difficult to acquire a complete understanding of how air temperature varies within a city. In contrast, land surface temperature data acquired from thermal satellite imagery can provide complete coverage of urban areas, allowing for analysis and visualization of temperature variation among small areas, such as neighbourhoods. Land surface temperature data can help identify hot spots and illustrate the structure of the urban heat island.[73]

Figure 11: Thermal and Satellite Images for Central Neighbourhoods, Toronto and Montréal



Note
Bay Street Corridor, Toronto (left), and Plateau Ouest, Montréal (right).
Sources
Thermal image for Montréal from Landsat Thematic Mapper, July 5, 2008, Baudouin and Martin, Université du Québec à Montréal; thermal image for Toronto from Landsat Thematic Mapper, September 3, 2008, Natural Resources Canada; satellite images from Google Earth (Image ©2010 DigitalGlobe, ©2010 Google).

Figure 12: Thermal and Satellite Images for Suburban and Central Neighbourhoods, Toronto



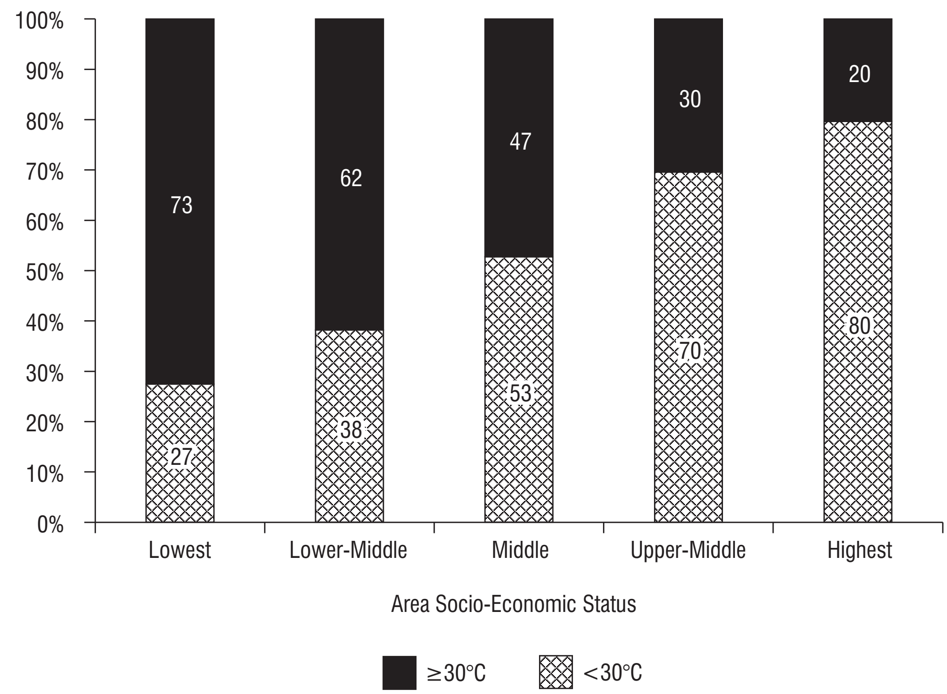
Note
Churchill Meadows (left) and Rosedale-Moore Park (right).
Sources
Thermal imagery from Landsat Thematic Mapper, September 3, 2008, Natural Resources Canada; satellite images from Google Earth (Image ©2010 DigitalGlobe, ©2010 Google).

The temperature maps presented in figures 9 to 12 show micro-urban heat islands detected using daytime land surface temperatures. High daytime land surface temperatures correlate with higher air temperatures at night,[80] when stored heat is released. During hot weather events, the air temperature may not cool sufficiently at night in micro-urban heat islands to offer relief from the heat. Research has shown that prolonged heat exposure without nighttime relief contributes to increased mortality risk.[81] A study of heat-related mortality in Toronto found that during prolonged heat episodes, mortality risk was higher later in the episode.[82] When interpreting land surface temperatures, it is also important to note effects of urban form. Tall buildings cast shadows that create shade during some portions of the day. In the Bay Street corridor (Figure 11), for example, these shadows are shown as very dark spots on the satellite view and correspond to lower daytime temperatures. At night, however, when heat released from the built environment warms the air and high building density prevents heat from dissipating, the temperature may not cool as much as in other areas. Thus, both daytime micro-urban heat islands and areas where tall buildings are prominent are more likely to have higher temperatures at night than other areas.

New Analyses of Area Heat and Socio-Economic Status: Case Studies of Montréal and Toronto

To further explore the relationship between micro-urban heat islands and socio-economic status, new CPHI analyses examined whether lower socio-economic status areas have higher surface temperatures than higher socio-economic areas. Micro-urban heat islands were identified when dissemination areas had temperatures of 30°C and greater. In Montréal, lower socio-economic status areas were more likely to reach land surface temperatures of 30°C than the highest socio-economic status areas. As Figure 13 shows, only 20% of the highest socio-economic status areas had a mean temperature of 30°C or greater, while more than 70% of the lowest socio-economic status areas exceeded that threshold.

Figure 13: Percentage of Montréal Dissemination Areas With Land Surface Temperatures of 30°C or More, by Socio-Economic Status



Notes
Analyses are based on dissemination areas for which temperature data was available (5,079 out of 6,082). Some dissemination areas do not have land surface temperature data available because cloud cover obstructed the view of the satellite sensor during image acquisition or imagery did not cover the entire census metropolitan area.
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Source
Satellite imagery from Landsat Thematic Mapper, July 5, 2008, Baudouin and Martin, Université du Québec à Montréal.

Compared with the highest socio-economic status areas, the lowest socio-economic status areas had more than 10 times the odds of reaching or exceeding 30°C (see Table 2). A clear gradient exists, where the proportion of areas reaching the 30°C threshold increased as socio-economic status of the areas decreased. These findings are consistent with a study of socio-economic status and land surface temperatures in Montréal, where socio-economic status was measured as average dwelling values.[55] This study found that higher area socio-economic status was moderately correlated with lower land surface temperature.[55]

Table 2: Odds Ratios of Land Surface Temperature Reaching 30°C or More, in Relation to Highest Socio-Economic Status Areas in Montréal and Toronto, 2008

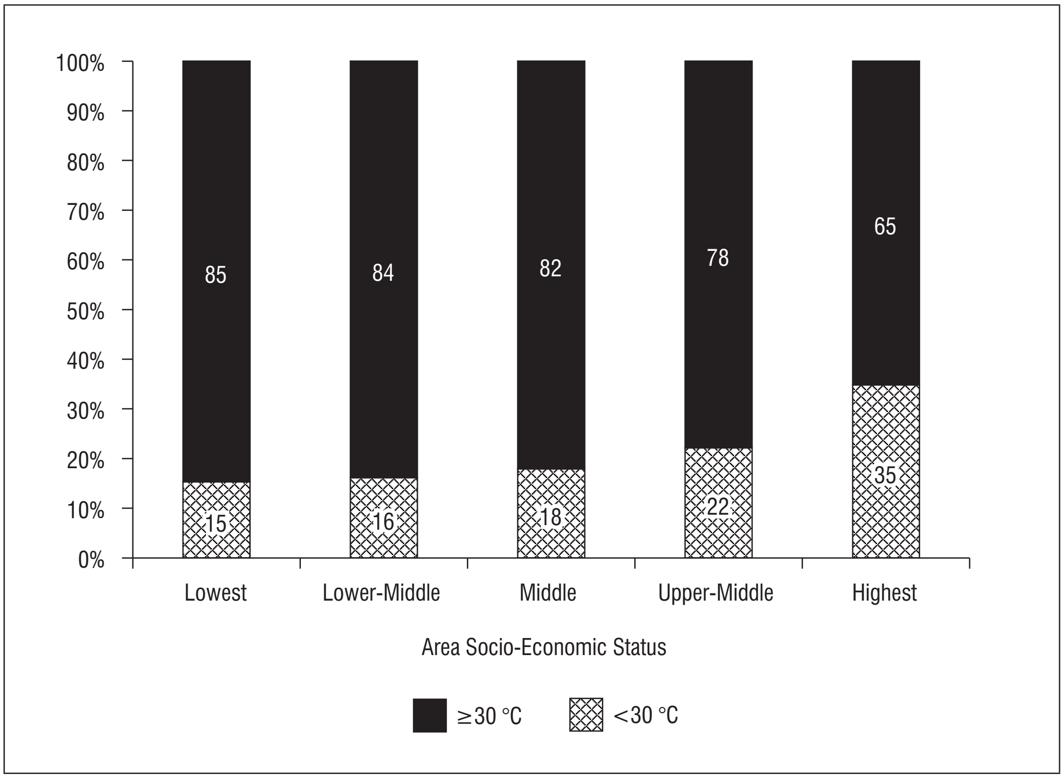
	Socio-Economic Status Group	Odds Ratio (Confidence Interval)
Montréal	Lowest	10.4 (8.5–12.6)
	Lower-Middle	6.3 (5.2–7.7)
	Middle	3.5 (2.9–4.3)
	Upper-Middle	1.7 (1.4–2.1)
Toronto	Lowest	3.0 (2.4–3.6)
	Lower-Middle	2.8 (2.3–3.4)
	Middle	2.5 (2.1–2.9)
	Upper-Middle	1.9 (1.6–2.2)

Notes
The reference group is the highest socio-economic status group.
Analyses are based on dissemination areas for which temperature data was available (5,079 out of 6,082 in Montréal and 6,210 out of 7,012 in Toronto). Some dissemination areas do not have land surface temperature data available because cloud cover obstructed the view of the satellite sensor during image acquisition or imagery did not cover the entire census metropolitan area.
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Source
Satellite imagery from Landsat Thematic Mapper, July 5, 2008, Baudouin and Martin, Université du Québec à Montréal (Montréal) and September 3, 2008 (Toronto), Natural Resources Canada.

For Toronto, CPHI analyses show that greater proportions of lower socio-economic status areas reached or exceeded 30°C than did higher socio-economic status areas, but the gradient was not as pronounced as in Montréal. In fact, there was little difference among the four lower socio-economic status groups; the proportion of areas that exceeded 30°C ranged from 78% to 85%. Both in Montréal and Toronto, the highest socio-economic status areas had the lowest proportion of areas reaching or exceeding 30°C (in the case of Toronto, it was 65%; see Figure 14). In Toronto, the odds that the lowest socio-economic status areas would reach or exceed 30°C were three times higher than in the highest socio-economic status areas.

Some of the observed differences between Montréal and Toronto may be attributed to the distribution of socio-economic status and land surface temperature in the suburbs surrounding the city of Toronto, such as Mississauga, Brampton and Vaughan. These suburban areas in Toronto tend to consist of higher socio-economic status groups and show characteristics of newer developments, such as a higher percentage of concrete, asphalt and other artificial surfaces compared with the amount of natural vegetation (for an example, see Figure 12).[83]

Figure 14: Percentage of Toronto Dissemination Areas With Land Surface Temperatures of 30°C or More, by Socio-Economic Status



Notes

Analyses are based on dissemination areas for which temperature data was available (6,210 out of 7,012). Some dissemination areas do not have land surface temperature data available because cloud cover obstructed the view of the satellite sensor during image acquisition or imagery did not cover the entire census metropolitan area.

Area socio-economic status defined using INSPQ's Deprivation Index, 2006.

Source

Satellite imagery from Landsat Thematic Mapper, September 3, 2008, Natural Resources Canada.

New Analyses of Heat Extremes and Hospitalization Rates for Diseases of the Respiratory and Circulatory Systems

This section explores health services utilization by analyzing whether hospitalizations for respiratory and circulatory diseases increased on hot days and during the two days following hot days, given that heat effects may be delayed. Hot days were defined as days when the maximum apparent temperature exceeded 32°C. Apparent temperatures above 32°C are associated with heat-related symptoms, such as sunstroke and heat exhaustion.[84] For these analyses, CPHI used data from May 1 to September 30 for the years 2005 to 2008. The threshold of 32°C and the May-to-September time frame were chosen based on previous research conducted in Toronto that explored the effects of heat stress on mortality.[56]

Box 8
Defining Apparent Temperature

Apparent temperature reflects a combination of air temperature and humidity.[85] It was calculated from hourly data of air temperature and dew point temperature captured at weather stations at Toronto's Pearson International Airport and Montréal's Pierre Elliott Trudeau Airport.

As Table 3 illustrates, in Toronto and Montréal, between 2005 and 2008, the average number of hospitalizations due to respiratory or circulatory diseases did not increase on hot days (apparent temperatures of 32°C or more) compared with the days prior to hot days and the days immediately following hot days. Similarly, visits to emergency departments in Toronto did not increase during hot days, nor did hospitalizations for respiratory and circulatory diseases increase during heat waves (three or more days of apparent temperatures of 32°C or more).

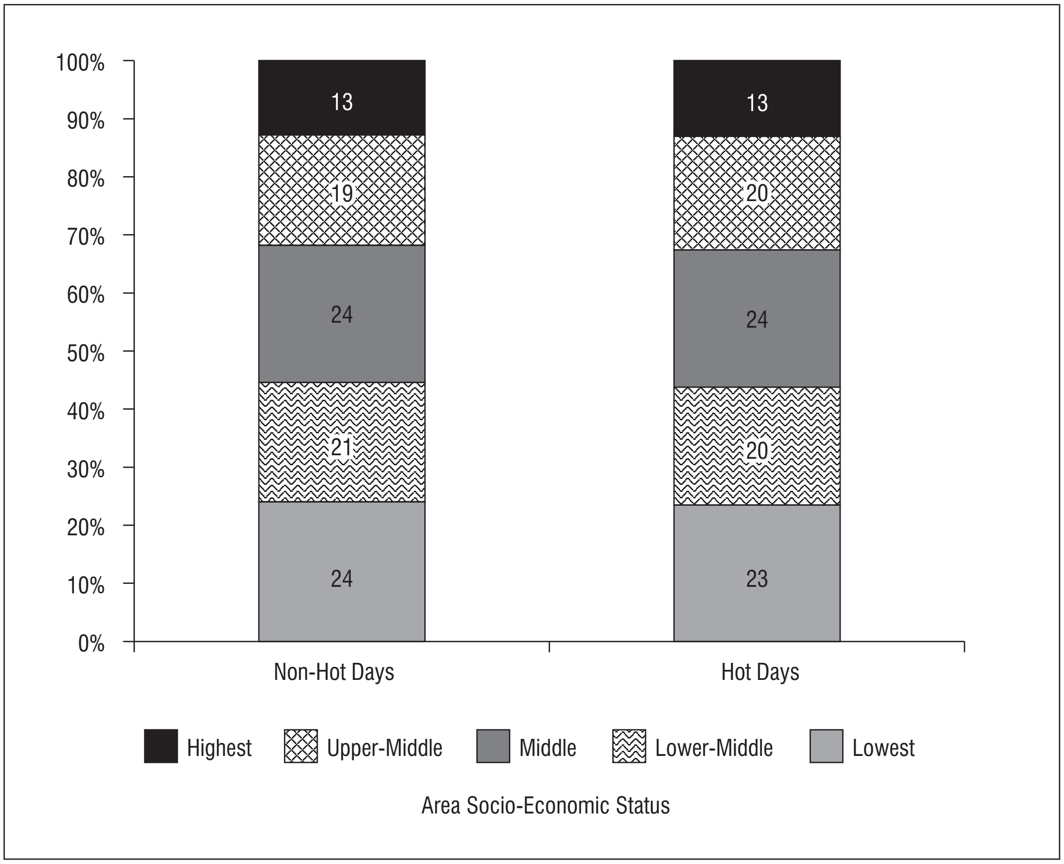
Table 3: Average Number of Respiratory and Circulatory Hospitalizations per Day, May to September, 2005 to 2008

	Average Number of Hospitalizations per Day, May to September, 2005 to 2008			
	Toronto		**Montréal**	
	Respiratory Diseases	**Circulatory Diseases**	**Respiratory Diseases**	**Circulatory Diseases**
Apparent Temperature Equal to or Less Than 32°C	58	118	47	94
Apparent Temperature Higher Than 32°C	56	117	42	93

Sources
Discharge Abstract Database, 2005–2006 to 2008–2009, Canadian Institute for Health Information; Fichier des hospitalisations MED-ÉCHO, 2005–2006 to 2008–2009, ministère de la Santé et des Services sociaux du Québec; National Climate Data and Information Archive, 2005 to 2008, Environment Canada.

Additional analyses show that the distribution of hospitalization rates according to socio-economic status on hot and non-hot days did not differ significantly. For example, as Figure 15 illustrates, the percentage of respiratory hospitalizations in Toronto attributed to the highest socio-economic status areas was the same on hot and non-hot days (13%). This pattern was the same for each socio-economic status group, including the lowest socio-economic status group, for both Toronto and Montréal.

Figure 15: Percentage of Total Respiratory Hospitalizations on Hot and Non-Hot Days, by Socio-Economic Status Group, Toronto, 2005 to 2008



Note
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Sources
Discharge Abstract Database, 2005–2006 to 2008–2009, Canadian Institute for Health Information; National Climate Data and Information Archive, 2005 to 2008, Environment Canada.

The results of this analysis show that apparent temperatures above 32°C were not associated with increased respiratory or circulatory hospitalizations in Toronto or Montréal. A previous study of emergency admissions in London, England, also found that cardiovascular admissions did not increase during periods of higher temperatures; however, admissions for respiratory problems did increase due to elevated admission rates for adults age 75 and older.[86]

The effect of heat on hospitalizations has been shown in previous studies to vary by geographical location.[87] Differences in health and social services may be potential contributors to this heterogeneity.[87] For example, a multi-city European study showed that high temperatures particularly affect respiratory admissions for seniors.[87] Cities that have better social services for seniors or more effective heat warnings targeted to seniors may be less likely to show increased respiratory admissions on hot days. Other aspects of heat warning systems that may contribute to hospitalization rate differences are the criteria for issuing warnings, advice provided, communication channels used and interventions such as opening cooling centres.

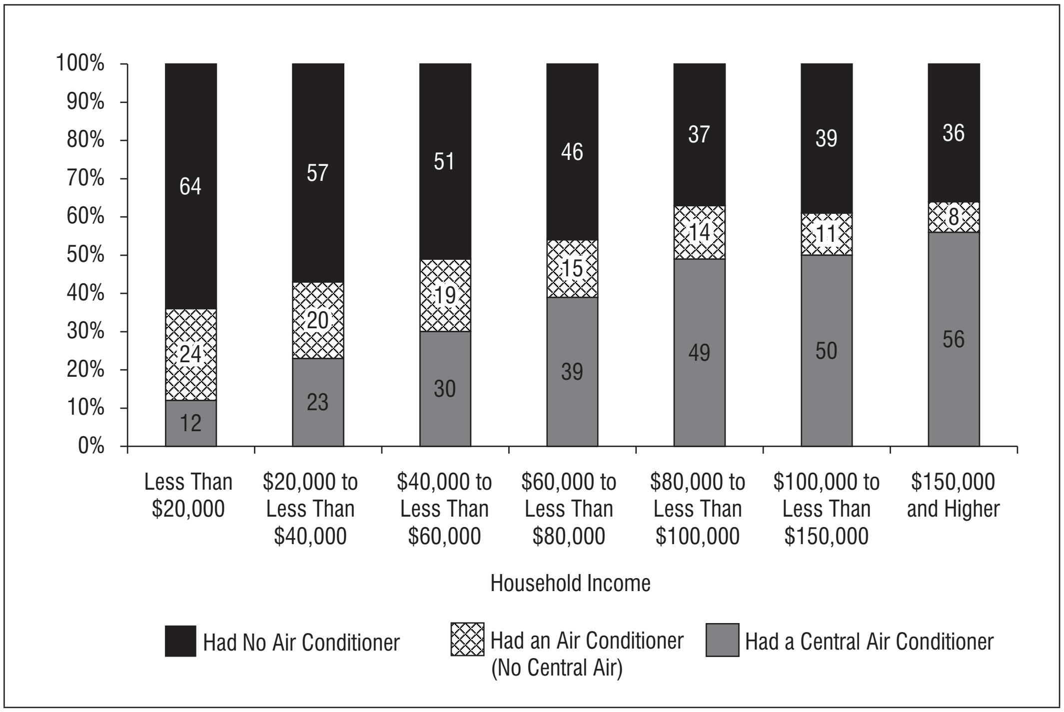
The new analyses of heat extremes and health service utilization in Toronto and Montréal shown above did not find significant increases in hospitalization rates and visits to emergency departments on hot days or during short heat waves for either respiratory or circulatory diseases. While the analyses presented in this report did not examine the potential reasons for this absence of differences, one potential explanation could be the existence of heat response plans in major Canadian cities. Heat response plans, such as those in place in Toronto and Montréal, bring together officials from public health and meteorology to forecast and plan for hot days and their effects on the public, particularly for vulnerable individuals such as seniors, the homeless and those living in poor-quality or precarious housing. Toronto's Heat Health Alert System, launched by Toronto Public Health in 2001, is currently being evaluated for effectiveness by Health Canada and Toronto Public Health.[88] During a heat event, the city provides detailed information to the media and the public, supports street outreach programs, provides hospitals with hot weather resource packages and coordinates city cooling centres.[89] Montréal implemented a similar heat warning plan in 2004, and provides outreach services such as water distribution, cooling centres and door-to-door visits to individuals considered vulnerable during extreme weather events.[90]

Mitigating Strategies

Public health efforts to reduce the effect of heat on health include identifying areas at elevated risk due to a combination of environmental, socio-economic and other factors.[61, 73, 91] Interventions can reduce the effect of extreme heat, for example, by increasing access to cooling centres and educating the public about coping with hot weather.[89] Adaptation strategies can mitigate risk of heat-related illness and death. Protective factors that have been identified include air conditioning[92] and vegetation around one's dwelling, which affects a building's interior temperature by providing shade.[70] Behaviours such as visiting cool environments and dressing lightly have also been shown to decrease risk.[70, 92]

In Canada's largest cities, lower-income households are less likely to have air conditioning. Analysis of the 2007 Households and the Environment Survey shows that the proportion of dwellings with air conditioning increased with household income. Figure 16 shows the percentage of households with air conditioning in Canada's large cities.[93] Respondents from the two highest income groups reported central air conditioning in 50% and 56% of dwellings, compared with 12% reported by respondents in the lowest income group.[93] Lower-income populations may thus benefit more from public health interventions such as cooling centres.

Figure 16: Percentage of Households With Air Conditioning in Canada's Largest Cities, 2007



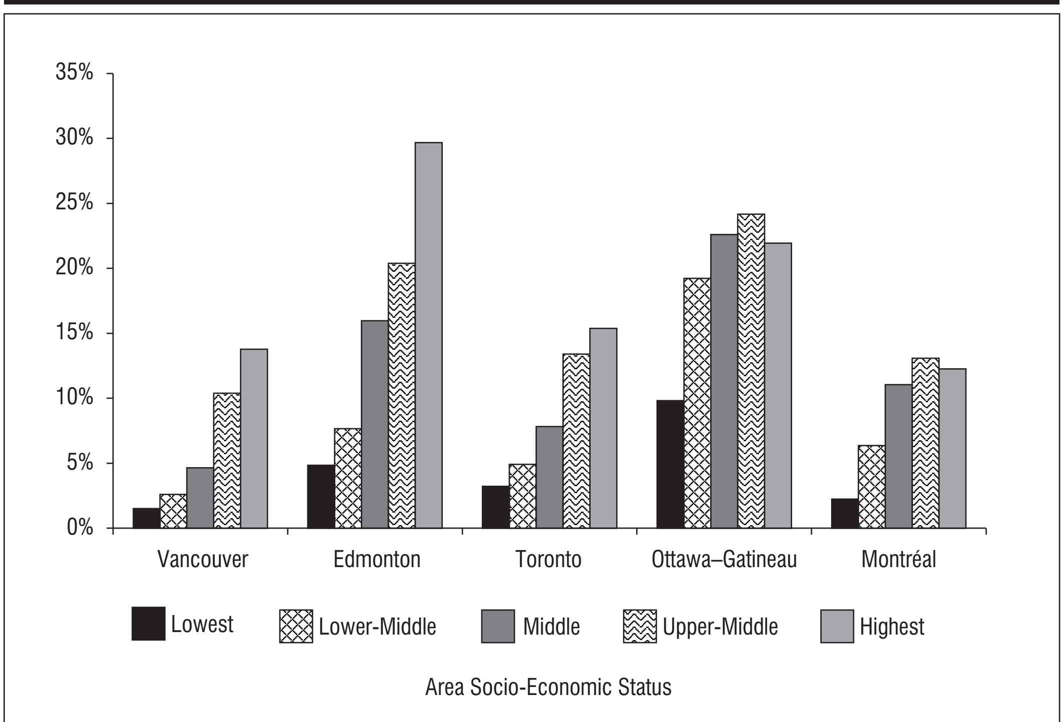
Source
Households and the Environment Survey, 2007, Statistics Canada (custom tabulation).[93]

Green spaces and vegetated areas can also be used as part of strategies with the dual aims of mitigating air pollution and heat extremes. As noted elsewhere in this report, urban vegetation has been shown to lower the temperature of urban environments and cool the interiors of private dwellings. Public green spaces, in addition to having a positive effect on physical activity levels and mental health,[94, 95] may also be places for neighbourhood residents without access to air conditioning to find temporary relief from the heat during extreme hot weather. Urban vegetation also functions as an air purifier to improve air quality and reduce the amount of airborne toxic pollutants. While trees are the best type of vegetation for cleaning and improving polluted air, all types of green space can have a beneficial influence on factors that affect health.

The quality and availability of green space within the built environment is an increasingly important issue as Canada's urban areas expand.[1, 96] A lack of green space in urban neighbourhoods is correlated with negative health outcomes, such as increased cardiovascular disease.[30] The development of dense built environments and infrastructure in Canada has diminished the amount of natural areas within municipalities, with only approximately 2% to 10% of land reserved as designated green space.[97] As shown in Figure 17, the amount of green space land cover varies both among cities and within them.

Analyses of green space land cover data for five Canadian cities show that there were large differences in the percentage of green space between the lowest and highest socio-economic areas within those cities. In Vancouver, Edmonton and Toronto, a clear positive gradient existed: the higher the socio-economic level, the more green space there was in the area. Edmonton had the highest difference in green space between lowest and highest socio-economic areas, at 25 percentage points. While the highest socio-economic areas in Edmonton had more green space than in other cities listed, there was little green space in its lowest socio-economic areas. Aside from Ottawa, the lowest socio-economic areas in each city had no more than 5% green space. Because of the federal greenbelt initiative begun in the 1950s, Ottawa was unique. It had a relatively higher percentage of green space in all socio-economic areas, and there was little difference between the middle, upper-middle and highest socio-economic areas. In fact, the percentage of green space in the lowest and lower-middle socio-economic areas of the city was twice as much as in the other cities examined.

Figure 17: Percentage of Area Classified as Green Space by Socio-Economic Status Area for Select Canadian Cities



Note
Area socio-economic status defined using INSPQ's Deprivation Index, 2006.
Source
Natural Resources Canada, 2000.

Chapter Summary and Key Messages

The new analyses examining the distribution of micro-urban heat islands in Canadian cities provide support for the growing concern that some urban residents might be more at risk of being exposed to extreme heat conditions and their health effects. Elements of the urban built and natural environments respond differently to heat extremes, thereby either worsening or buffering against the potential health effects of hot weather. Inequalities in the structure and design of physical environments result in the unequal distribution of micro-urban heat islands within cities. To analyze this variation in the distribution of micro-urban heat islands within Canadian cities, CPHI used data for Toronto and Montréal as case studies.

Key findings from new CPHI analyses:

- Comparisons of the physical composition of different areas within cities reveal the contribution of the built and natural environments to the heat island effect. Neighbourhoods with higher proportions of built and artificial surfaces rather than greener spaces are the hottest.
- Differences in the structure and design of urban physical environments exist between areas of low and high socio-economic status and correspond to variations in land surface temperatures. In Montréal, the lowest socio-economic status areas had more than 10 times the odds of the highest socio-economic status areas to reach high temperatures. In comparison, lowest socio-economic areas in Toronto had three times the odds. These findings highlight the fact that people whose health might already be more vulnerable on account of a combination of demographic, psychosocial and/or behavioural factors might be at increased heat-related health risk because of the physical environments in which they live.
- While hot weather has been linked with increased mortality rates, hospitalization rates in Montréal and Toronto and emergency department visits in Toronto for respiratory and circulatory diseases were not found to significantly increase on hot days or during short heat waves.

Conclusions

This report considers health inequalities associated with socio-economic status and the physical environment in Canadian urban settings. In particular, it examines the relationships among health, socio-economic status, outdoor air pollution and heat extremes. It presents new analyses of urban heat islands and residential proximity to known pollution sources, such as industrial facilities and major roadways. It also examines these physical environmental factors in relation to socio-economic status and health service utilization using Canadian data.

Together, the literature reviewed and the new analyses conducted for this report have shown that the built and natural environments influence how air pollution and extreme heat are distributed within our cities. Further examination of this distribution shows that those who are already more vulnerable to poor health may be at increased risk of being exposed to the effects of air pollution and heat extremes because of the areas in which they live. Specifically, a greater proportion of lower socio-economic status areas in Canadian cities are located within close proximity to pollution-emitting facilities and high-traffic roadways than higher socio-economic status areas. They are also less likely to be covered by green spaces and are more prone to micro-urban heat island effects than higher socio-economic status areas.

Thus, individuals and families living in lower socio-economic status areas are more likely to be exposed to outdoor air pollution and extreme heat. Previous research has shown that they may also be more vulnerable to the negative health effects of these environmental factors, despite similar levels of exposure. This has been demonstrated through higher rates of morbidity and mortality from circulatory and respiratory illnesses.

New CPHI analyses of air pollution, socio-economic status and health service utilization show that hospitalization rates for respiratory and circulatory diseases are higher in areas closer to fixed sources of pollution. This may be a reflection of the fact that rates of hospitalization tend to be higher among individuals and families residing in areas defined by lower socio-economic status, which are also more likely to be close to pollution-emitting facilities. However, when examining rates of hospitalization for residents from the lowest socio-economic status areas only, rates of hospitalization for both respiratory and circulatory diseases significantly decrease with increased residential distance from a pollution-emitting facility. This observation suggests that people from lower socio-economic status areas, who are already at a health disadvantage compared with residents of higher socio-economic status areas, may indeed be more vulnerable to the effects of air pollution on health and that distance from a pollution source acts as a protective factor.

The effect of heat on hospitalization and mortality rates has been shown in previous studies. New CPHI analyses of heat extremes and health service utilization in Toronto and Montréal, however, show that hospitalization rates and visits to emergency departments did not significantly increase on hot days or during short heat waves for either respiratory or circulatory diseases during the summers of 2005 to 2008. While the analyses presented in this report did not examine the potential reasons for this absence of differences, one potential explanation could be the existence of heat response plans that provide informational services and outreach programs. Toronto and Montréal, for example, have implemented heat response plans and warning systems to forecast and plan for hot days and heat waves and their effects on the public. A formal evaluation of the effectiveness of the components of these programs is under way and may shed further light on the relationship between health service utilization and heat extremes in Canadian cities.

Limitations and Directions for Future Research

The relationships among urban physical environments, socio-economic status and health inequalities are complex, and the data required to support an analysis of these relationships in urban Canada is incomplete. As a consequence, this study relied on certain approximations to create as complete a picture as possible at this time. Some of these approximations included using area socio-economic status to estimate individual and family-level socio-economic status, using hospitalization rates as a proxy for health outcomes and health service utilization, and using dissemination areas to estimate the distance between pollution sources and residences. The analyses were also unable to account for all the factors that might mediate the relationship between urban physical environments and health inequalities beyond the socio-economic status of the area of residence (for example, factors such as housing quality, amount of time residing in the same location and individual psychosocial and behavioural factors). By creating more data sources and better linkages between them, researchers might be better positioned to answer these questions in the future.

Upcoming Work on the Urban Physical Environment and Health Inequalities

This analytical report on urban physical environments and health inequalities is part of a larger collection of work on the themes of place and health and reducing gaps in health (for a list of related work, see There's More on the Web!).

To support CIHI's strategic direction of increasing actionable population health analyses, CPHI will build on this analytical body of work by reviewing interventions targeting health in the context of the urban physical environment. The purpose of this review will be to highlight and synthesize the current state of knowledge and identify a range of options that may help to improve health and reduce health inequalities through interventions related to the urban physical environment. The review and synthesis will also highlight gaps in knowledge and practice, and consider factors relevant to the implementation of change.

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  - High-resolution maps that can be zoomed in on for closer examination
  - Literature search methodology paper
  - Data and analysis methodology paper
- Analysis in Brief: *Hospitalization Disparities by Socio-Economic Status for Males and Females* (released October 2010)
- *Exploring Urban Environments and Inequalities in Health*—33 census metropolitan area data briefs (released May 2010) and companion products:
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- *Improving the Health of Canadians: An Introduction to Health in Urban Places* (released November 2006) and companion products:
  - Summary report
  - PowerPoint presentation
- G. Paradis et al., eds., *Canadian Journal of Public Health: Place and Health Research in Canada* 98, Suppl. 1 (July/August 2007).
- *Housing and Population Health: The State of Current Research Knowledge* (released June 2004)

For More Information

CPHI's analyses explore patterns of health within and between population groups to foster a better understanding of factors that affect the health of individuals and communities. We also seek out and summarize evidence about what works at a policy and program level to contribute to the development of policies that reduce inequities and improve the health and well-being of Canadians.

Urban Physical Environments and Health Inequalities is available in both official languages on CIHI's website at www.cihi.ca/cphi. To order paper copies of the report, please contact

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Appendix A

Figure A.1: Location of Canada's 33 Census Metropolitan Areas, 2006

Appendix B

Figure B.1: Socio-Economic Status Distribution of Dissemination Areas Within 200 Metres of a Selected Portion of Highway 1 in Vancouver

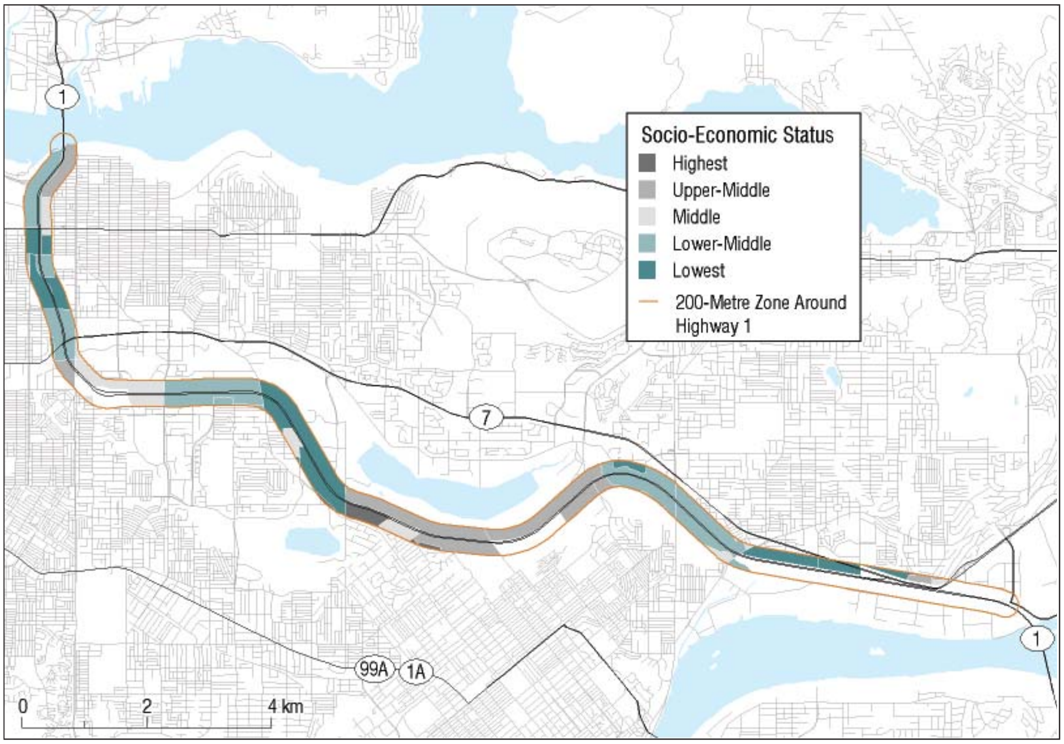


Figure B.2: Socio-Economic Status Distribution of Dissemination Areas Within 200 Metres of a Selected Portion of Highways 2 and 14 in Edmonton

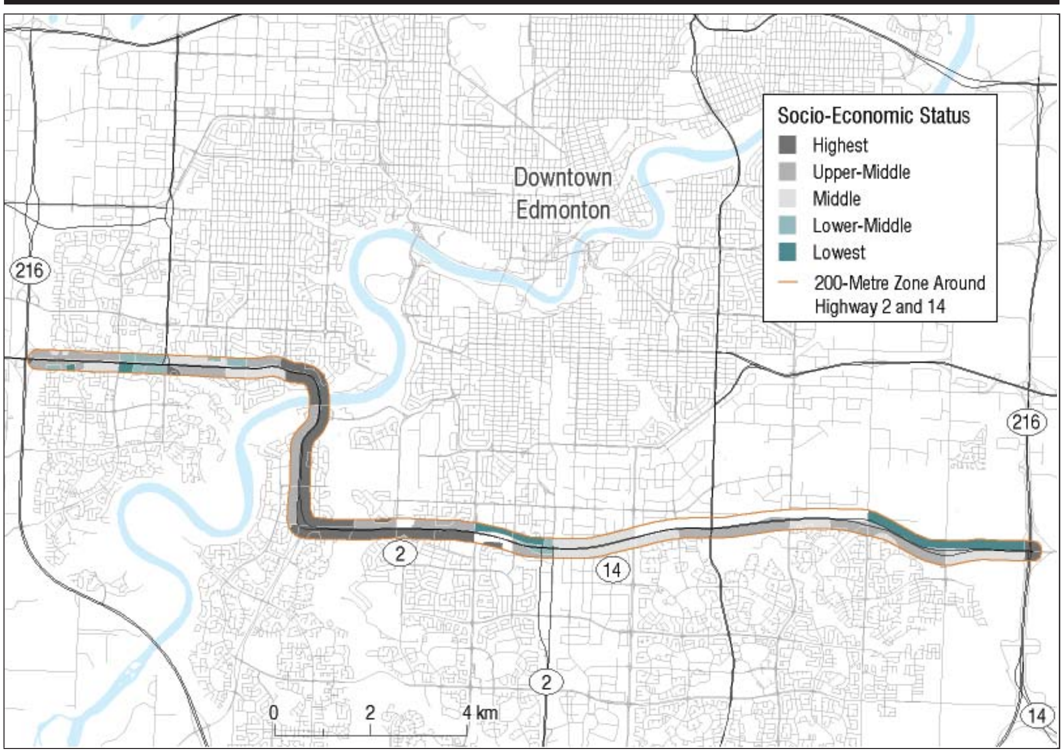


Figure B.3: Socio-Economic Status Distribution of Dissemination Areas Within 200 Metres of a Selected Portion of Highway 401 in Toronto

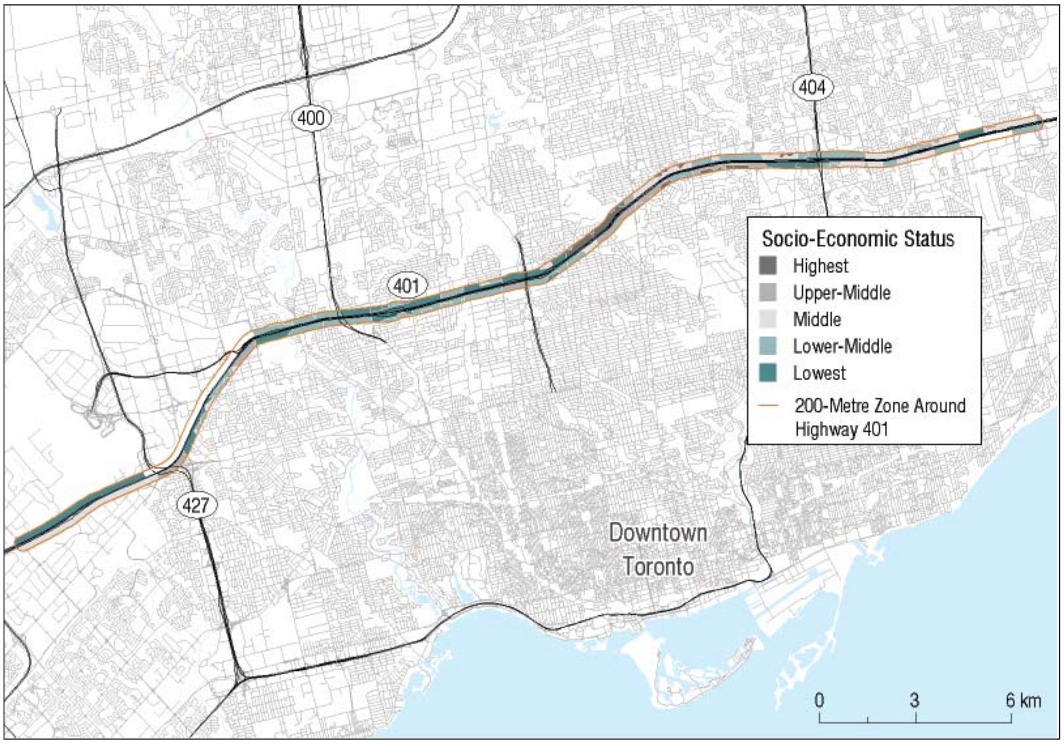
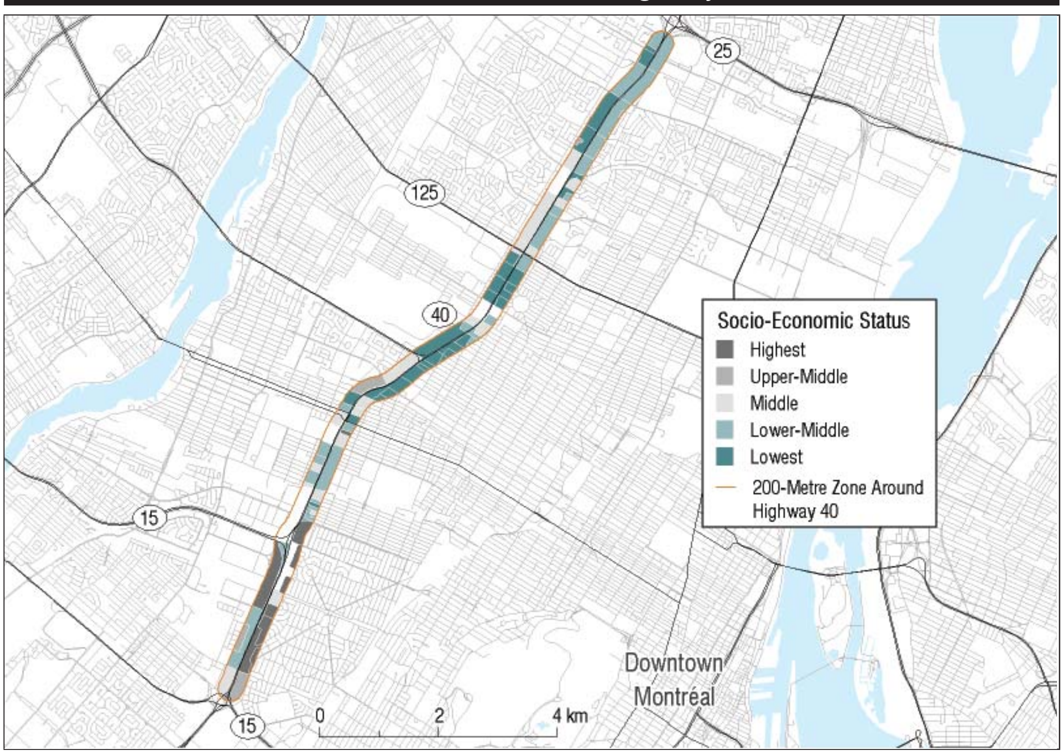
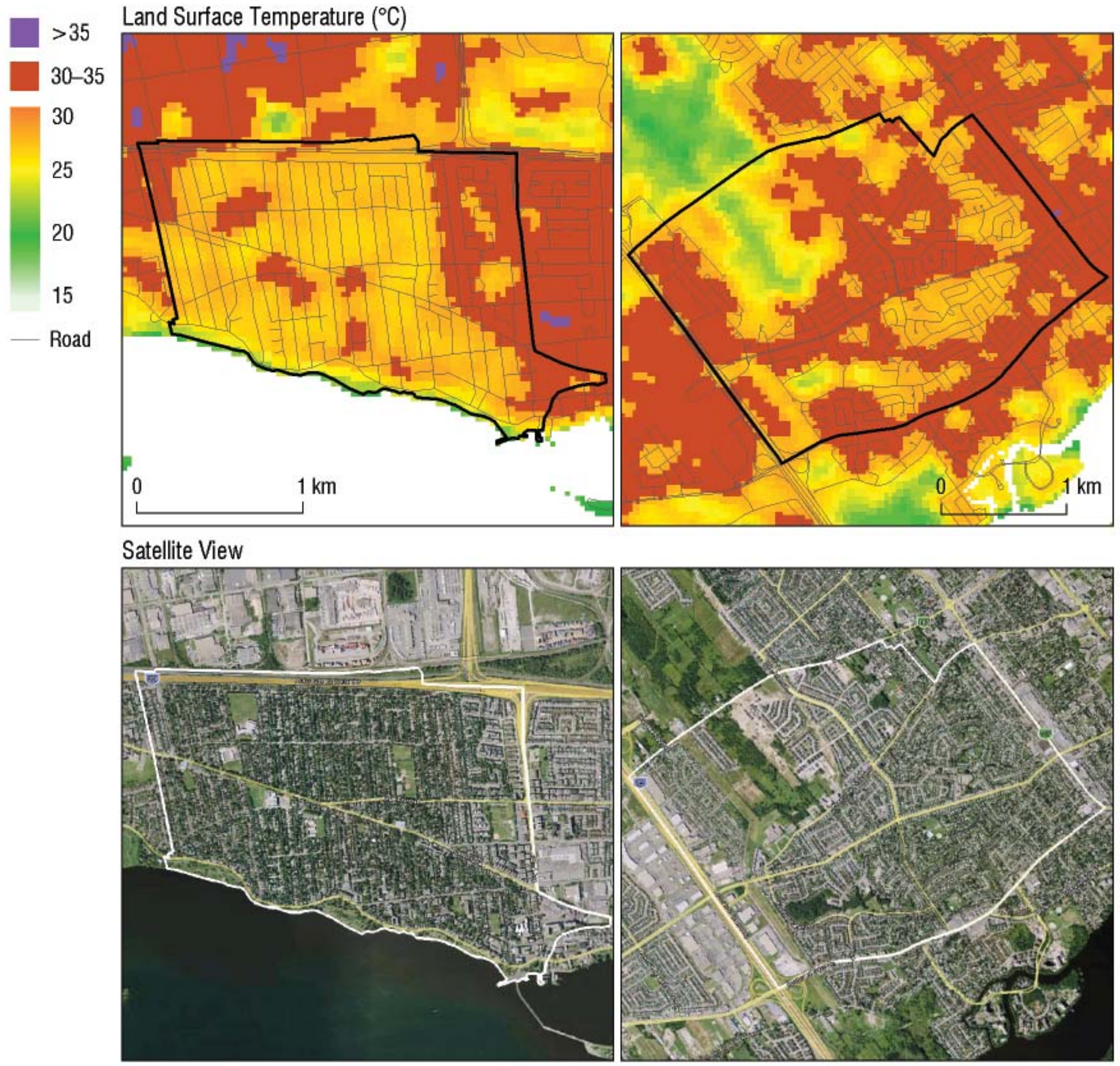


Figure B.4: Socio-Economic Status Distribution of Dissemination Areas Within 200 Metres of a Selected Portion of Highway 40 in Montréal



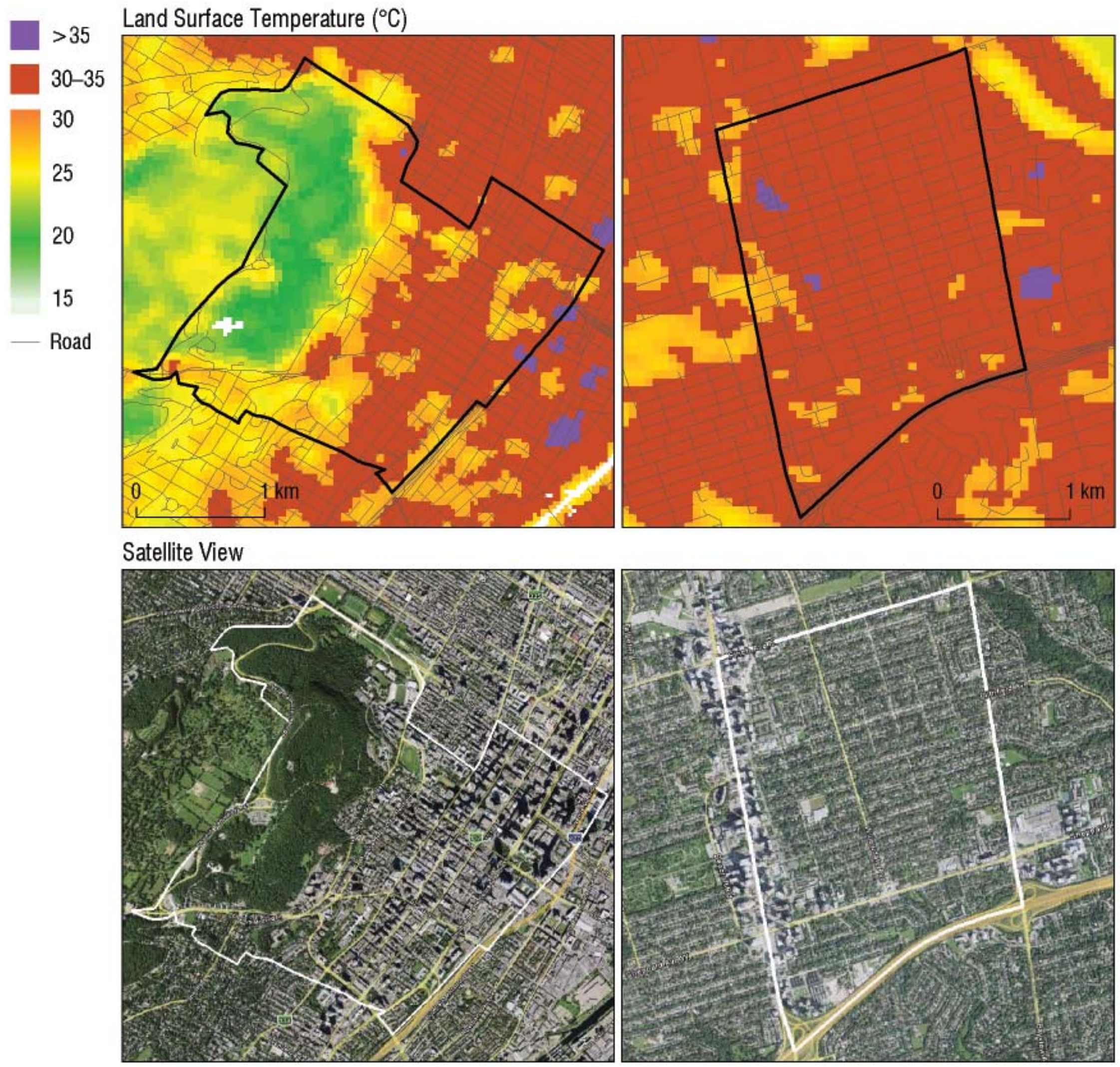
Appendix C

Figure C.1: Thermal and Satellite Images of Two Suburban Neighbourhoods in Montréal



Note
Lachine Ouest (left) and Chomedey Ouest (right).
Sources
Thermal images from Landsat Thematic Mapper, July 5, 2008, Baudouin and Martin, Université du Québec à Montréal; satellite images from Google Earth (Image ©2010 DigitalGlobe, ©2010 Google).

Figure C.2: Thermal and Satellite Images of Central (Montréal) and Suburban (Toronto) Neighbourhoods



Note
Métro Centre, Montréal (left), and Willowdale East, Toronto (right).
Sources
Thermal image for Montréal from Landsat Thematic Mapper, July 5, 2008, Baudouin and Martin, Université du Québec à Montréal; thermal image for Toronto from Landsat Thematic Mapper, September 3, 2008, Natural Resources Canada; satellite images from Google Earth (Image ©2010 DigitalGlobe, ©2010 Google).

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