

Mortality, Cancer Incidence and Hospitalization Among Residents of the Neighbourhoods of South Riverdale, The Beaches, and Comparison Communities

Prepared by

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EXECUTIVE SUMMARY

Background and Introduction

Residents of Toronto's South Riverdale and Beaches communities have been concerned about potential health effects of previous and current exposures to pollutants from local industries and from the Ashbridges Bay Treatment Plant (ABTP). South Riverdale and The Beaches are situated adjacent to each other in the southeast part of Toronto, bordering Lake Ontario. The Beaches community is located "downwind" of many of the industries and may thus have been subject to the same or possibly higher levels of industrial pollution. In the early 1990s, the former Metropolitan Toronto, wishing to make modifications to the ABTP operation, initiated an Environmental Assessment (EA) process as required under the Ontario Environmental Assessment Act.

This Health Status Study was commissioned by the City of Toronto in 2001. The study fulfills one of the agreements that came from a mediation process begun in 1998 between the City and the community to help finalize the ABTP EA. The Medical Officer of Health for the City of Toronto oversaw this study. A project advisory committee (PAC) with representatives from the local community, and environmental and health non-governmental organizations provided input on the study terms of reference and selection of consultants to undertake the research. As well, PAC members reviewed and provided comments on draft versions of this technical report. The project team, which oversaw the study, was composed of City staff, academic experts in the field and the Consultant, or principal investigator (PI).

The original aims for the health status study were to:

- Provide baseline data for these two communities on selected health outcomes which might be related to environmental exposures;
- Determine whether residents of these communities in the past experienced significantly different rates of illness and/or death relative to comparable neighbourhoods in the City of Toronto, and to the City of Toronto as a whole; and
- Identify specific health issues for potential further investigation/response in the event that rates of illness and/or death are significantly greater than expected.

This report will outline the results of the study and how they may be interpreted.

Methods

The health data investigated in this study were limited to those that could be gathered from vital statistics and administrative record databases, namely causes of death, causes of hospitalization, and cancer incidence. Assessing health from these types of records is preferable to assessing health from self-reported survey data because the information is viewed as being more objective.

The time period for which health data that could be linked to people living in these neighbourhoods were available varied depending on the database, as discussed below. Therefore the study only assessed health status historically and for a limited time frame (generally the 1980s and into the 1990s).

Because air pollution was the main concern of the residents, the types of health outcomes that were the focus of the study were those that are most likely to be linked with exposure from breathing in air pollutants. Inhalation, or breathing in pollution would be the most important route of exposure (that is, the way they would enter the body) for most people.

In choosing the health status study design it was understood that although this study can assess health differences in these neighbourhoods compared to others in the City, it does not allow for making exact conclusions about the causes of any observed health differences. One reason is that detailed information on how long or to how much of the different airborne pollutants any residents in the study areas were exposed to is not available. As well, there are no individual data on how common are other factors that influence health such as smoking, drinking, poor diet and some pre-existing health conditions or diseases.

A related study commissioned by the City at the same time, the Air Emission study (*Air Emissions From the Ashbridges Bay Treatment Plant*), estimated and modelled ABTP emissions for 17 chemicals which were given priority from a total of 186 chemicals potentially released from ABTP. (These 17 chemicals ranked highest for toxicity, volume of emissions, persistence, bioaccumulation, laboratory detection ability and human exposure potential.) While the Air Emission study's modelling results provided some information on the potential contribution of the ABTP to the air quality in the study neighbourhoods it cannot help determine actual exposures of the local residents. Nor is it possible to make conclusions in the current study based on the findings for the Air Emissions study.

Community representatives had identified "respiratory diseases, leukemia, brain tumours, hair loss, skin problems, skin cancers and sexual development problems" as being of concern to them. The PI and project team determined however, that based on the main types of pollutants that can be emitted from sewage sludge incinerators and on the knowledge from existing scientific studies of health effects from breathing those air pollutants, the study should focus on respiratory diseases (such as, asthma, pneumonia, obstructive lung disease), circulatory diseases (that is, heart attack, congestive heart failure, heart rhythm problems, stroke) and specific cancers (namely, leukemia, lung cancer and brain tumours). (Health effects from air pollutants such as particulate matter, carbon monoxide, nitrogen oxides and sulphur dioxide, are known to include hospitalization and death from respiratory and circulatory disorders. Particulate matter may also be associated with increased risk of lung cancer, while volatile organic compounds have been

associated with cancers, including leukaemia.) It is worth noting, however, that these illnesses or causes of mortality are known to have a wide range of other causes aside from air pollution, such as cigarette smoking, diabetes, high blood pressure and high cholesterol. As mentioned above, this study did not have the data available to determine which causes explain any observed health status differences. As a point of comparison (as is standard practice in such epidemiological studies) total non-accidental mortality, all cause hospitalizations, and mortality and incidence for all cancers were analysed as well.

Health status is also known to be related to neighbourhood social and demographic characteristics. Therefore, these health status data for The Beaches and South Riverdale communities were independently compared with other Toronto neighbourhoods where the social and demographic profiles were similar. This was to reduce the chances that observed differences in health status might be due to differences in education, income, unemployment or other socio-demographic or related factors that also influence health. South Riverdale and The Beaches, though geographically close communities, are very different socio-economically. The Beaches median household income of \$56,600 is compared to \$33,400 for South Riverdale (1996 Census data). South Riverdale also has a higher percent of its population identified as recent immigrants (14.1% versus The Beaches, 2.1%). As well, South Riverdale has higher rates of people who are unemployed (11.8% versus 6.2% for The Beaches) or have less than a Grade 9 education (17.4% versus 2.6% for The Beaches).

Appropriately matched comparison neighbourhoods were selected using a Principal Components analysis (PCA) of neighbourhoods in the former City of Toronto to identify those most similar to the study communities. (PCA is a way to mathematically re-organize complex samples of data with multiple variables. In this case, PCA simplified the process of matching neighbourhoods elsewhere in the former City of Toronto and choosing those closest in socio-demographic profile to the two study neighbourhoods.) Three socio-demographic variables (median household income, proportion of high school graduates, male unemployment rate) from the 2001 Canadian Census of Population were combined to calculate a single, composite measure called a Deprivation Index. The PCA allowed for two comparison neighbourhoods to be identified for The Beaches and three for South Riverdale (two Near Neighbours and one distant). None of the comparison communities is further identified.

As the study progressed it was clear that there were limitations to the data that could be used and the analyses that were completed for this study. Mortality analyses were conducted first, using data for the years 1979-1990, for the former City of Toronto, obtained from Toronto Public Health. The mortality data available stop at 1990 because after this time, the data verification process conducted at the Office of the Registrar General (ORG) was incomplete, meaning that many individual death records after that time lack a postal code. Without a postal code, a death record (or other health event record) cannot be linked to a specific neighbourhood and therefore is not usable for this study. As well, while the public health department under the former City of Toronto had mortality data including postal codes, the public health departments for the former municipalities (such as Etobicoke, North York, York, East York and Scarborough) did not have comparable, usable data for this same time period. This is the reason that comparison neighbourhoods could only be chosen from among neighbourhoods in the former City of

Toronto.

Cancer incidence data (that is, data on newly diagnosed cases of cancer) for residents of Metropolitan Toronto (“M” postal code), for the years 1979-1999, were received from Cancer Care Ontario (CCO). The data included the following individual variables: Diagnosis Code, Year of Birth, Year of Diagnosis, Sex, and Census Tract of their residence (to assign subjects to study neighbourhoods). However, data from 1979 to 1985 could not be used because of inconsistencies by CCO at that time in the recording of subjects’ postal codes. Therefore, only incident cases of cancer for the years 1985-1999 could be analysed. The diagnoses of interest included, 1) all cancer diagnoses combined; 2) lung cancer; 3) brain cancer; and, 4) cancers of the blood and lymphatics.

Hospitalization data for residents of Metropolitan Toronto (“M” postal code), 1985-1998, were received from the Ministry of Health and Long Term Care (MOHLTC). The data included individual level information such as a scrambled Health Insurance Number, age, sex, year of admission, Diagnosis Code, and Census Tract of the residence. Based on the International Classification of Disease (ICD)-9 diagnostic codes, hospital admissions for the following diagnoses of interest were requested: 1) all hospital admissions combined; 2) circulatory disease (ICD9: 401 - 448); 3) acute ischemic heart disease (heart attack, ICD9: 410-411); 4) respiratory disease (ICD9: ICD460 - 519); and 5) asthma (ICD9: 493).

The data for mortality, cancer incidence and hospitalization rates were analysed in two ways: 1) by direct standardization, and 2) by regression methodology. To compare rates between the study communities, the comparison communities, and the former City of Toronto, Directly Standardized Mortality Rates (SMRs), a weighted average of the age-specific rates, were calculated. The weights for this study were derived from the age distribution of the former City of Toronto as a whole. Age-standardization is necessary to control for rate differences that are related to the age make-up in a given community. (For example, it is understood that areas with higher proportions of people over the age of 65 will necessarily have higher death, hospitalization and cancer rates but generating age-standardized mortality rates controls for this.) Directly standardized rates were also calculated for cancer incidence and hospital admissions.

Regression analysis allows greater confidence when comparing rates between neighbourhoods because small number fluctuation is less of a problem in regression compared to Direct Standardization methods. Regression analysis also allows for calculating statistical significance of results. Regression modelling was also used to calculate Rate Ratios (also called Relative Risks) for death, cancer incidence or hospitalization for each study neighbourhood in comparison to its reference (or comparison) neighbourhood(s). In the case of regression analysis of hospital admissions, because some individuals had more than one hospital admission, the admissions data are thus not “independent”. To manage this the regression analysis of hospital admission data included calculations of “robust” estimates of variance.

Results

1. Mortality

All cause (non-accidental), circulatory, and respiratory disease mortality rates were significantly higher in The Beaches than in its two comparison neighbourhoods. There was no difference in cancer mortality rates.

All cause (non-accidental) and circulatory mortality rates were significantly higher in South Riverdale than in its comparison neighbourhoods. Mortality rates from respiratory disease were higher in South Riverdale, but not with statistical significance. Cancer mortality rates were higher in South Riverdale than in the distant comparison neighbourhood, but were similar to those in the Near Neighbourhoods.

For most cancer-related causes of mortality, there were small numbers of events (that is, cancer deaths) and therefore the ability to draw conclusions is limited.

Non-cancer mortality rates (that is, all non-accidental, circulatory and respiratory mortality) in The Beaches were lower than for the former City of Toronto as a whole. Cancer mortality in The Beaches was generally similar to that for the former City. Non-cancer mortality rates in South Riverdale were higher than the mortality rates for the former City of Toronto.

2. Cancer Incidence

The cancer incidence findings were similar to the cancer mortality results. That is, The Beaches had cancer incidence rates similar to its two comparison communities and South Riverdale's cancer incidence rates were similar to the two Near Neighbourhoods, but higher than for the one distant comparison community.

3. Hospitalization

All cause, circulatory, respiratory disease and asthma admission rates were significantly higher in The Beaches than in its comparison neighbourhoods.

All cause hospitalization rates in South Riverdale were the same as in Near Neighbourhood 2, but were significantly higher than in Near Neighbourhood 1 and the remote comparison neighbourhood. Circulatory disease admission rates were the same as in Near Neighbourhood 1, were significantly lower than in Near Neighbourhood 2, but were significantly higher than in the remote comparison neighbourhood. Hospital admission rates for respiratory disease were the same as in Near Neighbourhood 2, but were significantly higher than Near Neighbourhood 1 and the remote comparison neighbourhood. Asthma admission rates were the same as both Near Neighbours, but were higher than in the remote comparison neighbourhood. Hospitalization rates for South Riverdale therefore, are not consistently different compared to its two Near Neighbourhoods, though they are consistently, significantly higher compared to the one distant comparison community.

A qualitative summary of all results described above is provided in Table A below.

Health Event	The Beaches	South Riverdale
MORTALITY		
All Causes	Greater than comparison communities*	Greater than comparison communities*
Circulatory Disease	Greater than comparison communities*	Greater than comparison communities*
Respiratory Disease	Greater than comparison communities*	Greater than comparison communities
All Cancers ¹	No difference from comparison communities	No difference from Near Neighbours
CANCER INCIDENCE¹	No difference from comparison communities	No difference from Near Neighbours Greater than distant comparison community
HOSPITALIZATION		
All Causes	Greater than comparison communities*	Greater than Near Neighbour 1* No difference from Near Neighbour 2
Circulatory Diseases	Greater than comparison communities*	No difference from Near Neighbour 1 Lower than Near Neighbour 2
All Respiratory Diseases	Greater than comparison communities*	Greater than Near Neighbour 1* No difference from Near Neighbour 2
Asthma	Greater than comparison communities*	No difference from Near Neighbours 1 or 2 Greater than distant comparison community*

¹Because the numbers of cancer deaths and diagnoses were too small to make conclusions about differences according to specific types of cancer, only incidence of All Cancers is presented in the comparison above

* Denotes a difference that is statistically significant, meaning that the difference is unlikely to be related to chance factors. In this case, there was a less than 5% probability that the difference between groups could have occurred by chance alone. This is expressed as a p value < 0.05. Statistical significance, however, does not reveal the size of the difference or its clinical importance, that is, whether the difference is large enough to be a concern.

Discussion

The study found overall that non-cancer mortality and hospitalization rates were generally higher (often with statistical significance) in South Riverdale and The Beaches than in their respective comparison communities. Cancer incidence and mortality rates were generally similar between the two study neighbourhoods and their respective comparison communities. For these two groups of neighbourhoods, rates for mortality and hospitalization were highest in the South Riverdale group. Mortality rates were also higher in South Riverdale in comparison to the former City of Toronto as a whole.

The comparison communities were selected on the basis that they were of “similar” socio-economic status to each of the study communities. However, despite the efforts to match as closely as possible, socio-economic differences remained. Choosing comparison neighbourhoods for South Riverdale proved to be especially challenging. The distant comparison neighbourhood had a higher Deprivation Index score than South Riverdale (that is, it had lower socio-economic status), while the two Near Neighbourhoods were closer matches. (Despite early concerns that these two neighbouring communities might not be acceptable for comparison purposes because of their geographic proximity to South Riverdale, they were added to the analysis when results from the Air Emissions study indicated that the ABTP was not likely to influence air quality beyond The Beaches and South Riverdale.)

The study explored further the relationship between socio-economic factors and health events and found that there is a direct relationship between the Deprivation Index and mortality or hospitalization rates. That is, those neighbourhoods with lower Deprivation scores (in other words, higher income, education and employment levels) generally have lower mortality and lower rates of hospital admission and vice-versa. (The results of these additional analyses are presented in Table B and Figures A and B.) Since socio-economic factors are closely linked to health, the observed variation in mortality and hospitalization rates might be at least partly “explained” by these neighbourhood characteristics. The Beaches had mortality and hospitalization rates that were not necessarily greater than would be expected based on the differences in socio-economic characteristics with its comparison neighbourhoods. Recalling that mortality in The Beaches was better than the average for the former City, socio-economic factors are possibly the main explanation for higher rates of mortality and hospitalization in The Beaches compared to its comparison communities which have higher socio-economic status compared to The Beaches. This suggests that differences in socio-economic characteristics may be the primary explanation for the differentials in health profiles in The Beaches comparison group, though it does not entirely rule out a role for environmental exposures.

Neighbourhood	Census Year				Mortality Rate Ratio (95% CI)	Hospitalization Rate Ratio (95% CI)
	1981	1986	1991	1996		
The Beaches	-1.18	-1.39	-1.4	-1.51	0.85 (0.76 - 0.94)*	0.79 (0.72 - 0.87)*
Neighbourhood 19	-1.89	-2.16	-2.39	-2.32	0.75 (0.67 - 0.84)	0.58 (0.52 - 0.64)
Neighbourhood 43	-1.74	-1.70	-1.42	-1.49	0.76 (0.68 - 0.85)	0.69 (0.64 - 0.76)
South Riverdale	0.93	0.79	1.01	1.06	1.29 (1.17 - 1.42)+	0.97 (0.89 - 1.05)++
Near Neighbour 1	1.48	1.58	1.31	1.54	1.01 (0.90 - 1.12)	0.90 (0.83 - 0.98)
Near Neighbour 2	0.32	0.80	0.92	1.00	1.00 (REFERENCE)	1.00 (REFERENCE)
Neighbourhood 10	2.08	2.07	1.98	1.72	0.87 (0.78 - 0.97)	0.82 (0.74 - 0.90)

* The All Cause Rate Ratio was significantly higher in the Beaches than in Neighbourhood 19, and was of borderline significance ($P = 0.07$) in comparison with neighbourhood 43.

+ The All Cause Rate Ratio was significantly higher in South Riverdale than in any of the comparison neighbourhoods.

++ The All Cause Rate Ratio was significantly higher in South Riverdale than in Neighbourhood 10 and was of borderline significance ($P = 0.06$) with respect to Near Neighbour 1.

The situation is less clear for the South Riverdale group of neighbourhoods. Health status is shown to be generally poorer in the South Riverdale group of communities than in The Beaches group (with the exception of N10, the one distant comparison neighbourhood). All cause mortality rates were significantly higher in South Riverdale than in all three of its comparison communities, including the two with higher deprivation scores. Hospitalization rates were similar between South Riverdale and its larger Near Neighbour (NN2), but were higher than among the other two comparison neighbourhoods that were more “disadvantaged” (N10 and NN1). Although socio-economic differences may explain some of the higher mortality and hospitalization rates in South Riverdale, because the differences were inconsistent, other factors may be operating, possibly including environmental pollution.

The South Riverdale distant comparison neighbourhood (N10) as mentioned, was the one exception to the observed trend of a linear relationship between community Deprivation Index and health profile (as shown in Figures A and B). Though this neighbourhood was absolutely more “deprived” compared to South Riverdale, its health status (according to mortality and hospitalization rates) was better than expected and better than that of South Riverdale. The health status for N10 was in fact, closer to that for The Beaches a much less “deprived” community.

This result cannot easily be explained here, however, it raises questions about whether this community should be viewed as an outlier in the health status analysis.

Figure A. Relative Rates (Rate Ratios) of All Cause Mortality in relation to the Deprivation Score. The Reference neighbourhood for the comparisons (Rate = 1.0) is Near Neighbour Neighbourhood 2. The Relative Rates are derived from Regression analysis models adjusted for age, sex, and the Census period.

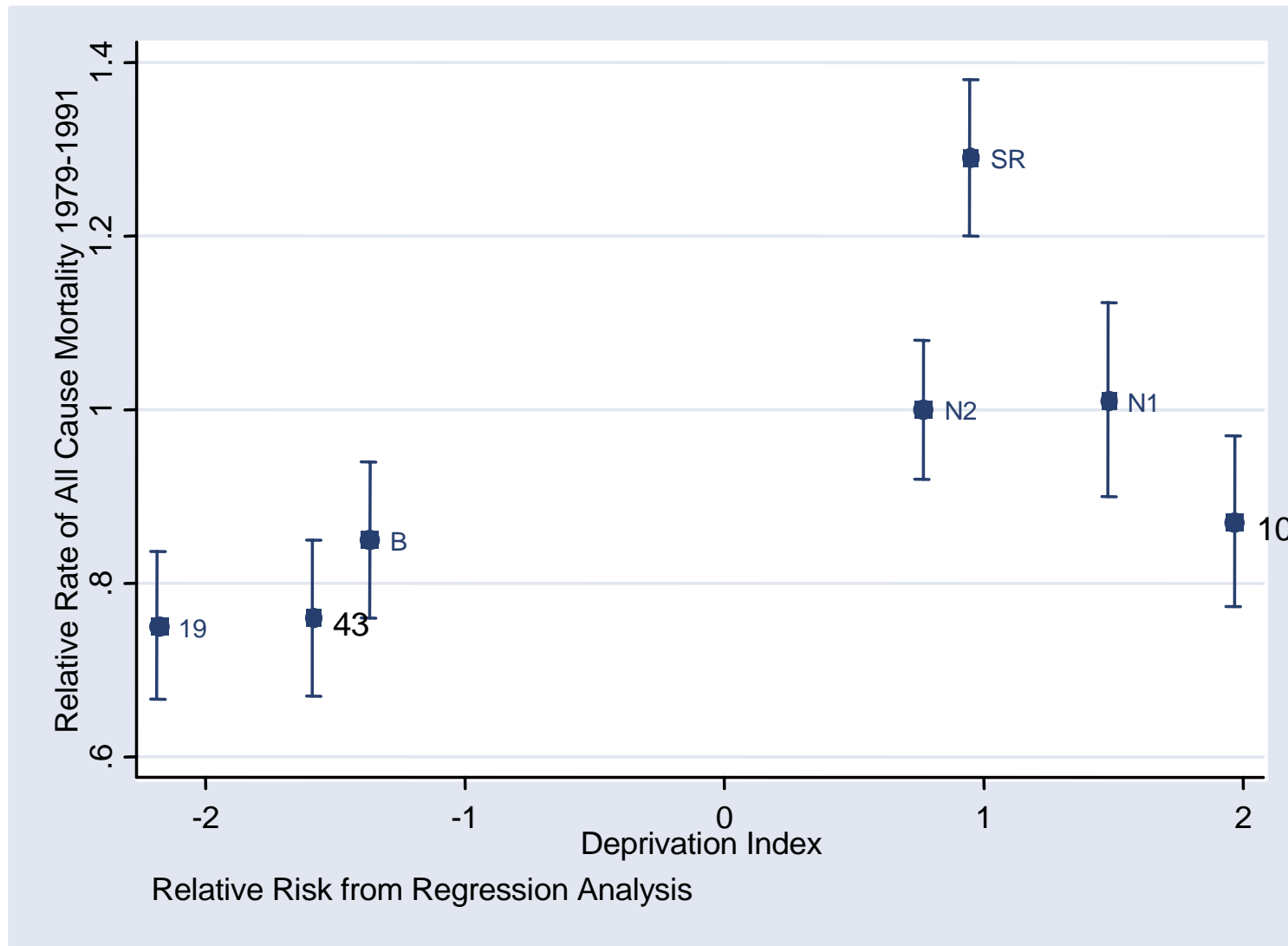
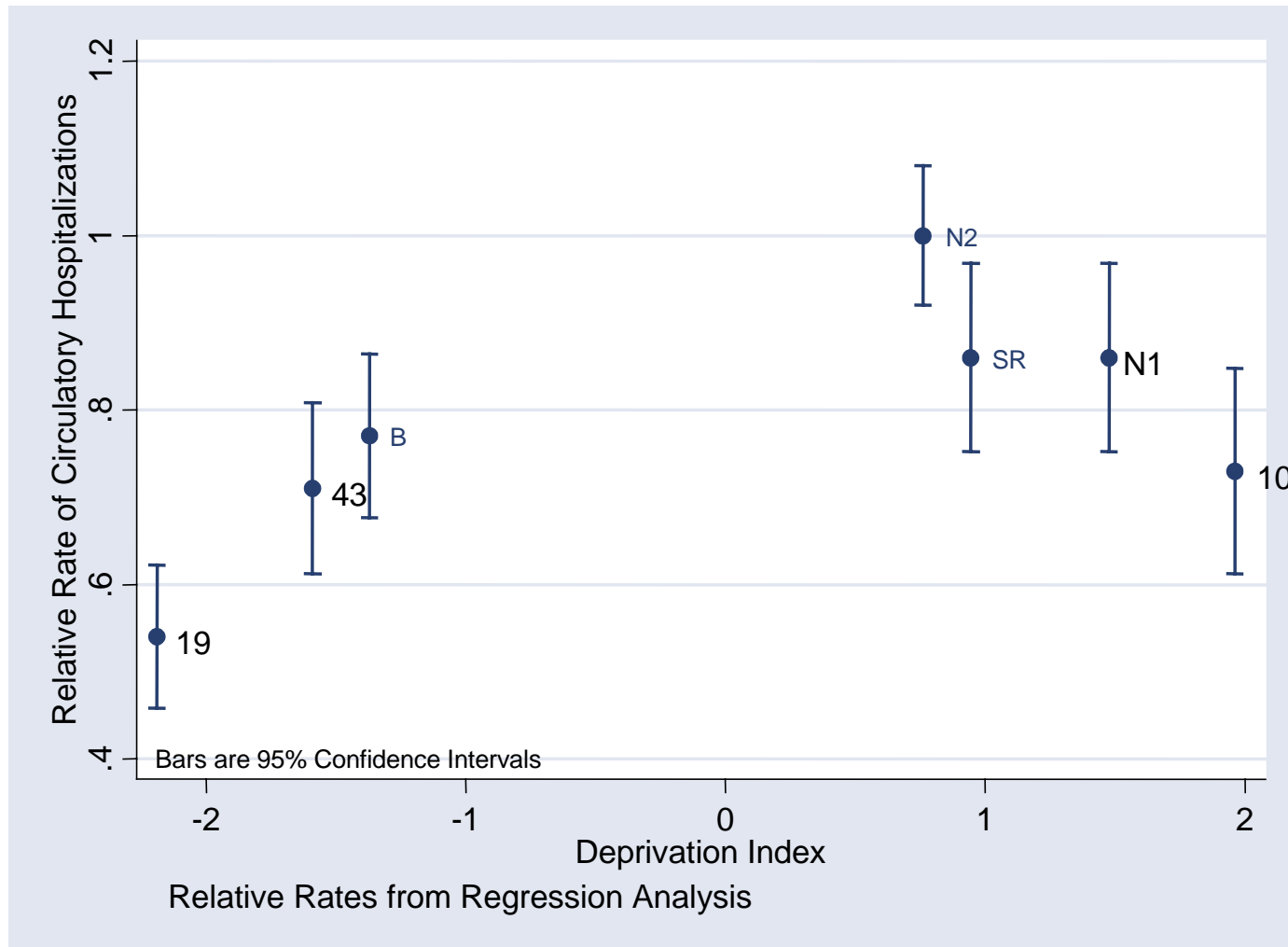


Figure B: Relative Rates (or Rate Ratios) of Circulatory Hospitalization in relation to the Deprivation Score. The Reference neighbourhood for the comparisons (Rate = 1.0) is Near Neighbourhood 2. The Relative Rates are derived from Regression analysis models adjusted for age, sex, and the Census period.



One possible environmental explanation for higher rates of hospitalization and death specifically from circulatory disorders could relate to lead exposure. Research in Europe indicates that ingested and inhaled lead may contribute to increased risks for circulatory disease. In studies conducted in the 1980s, high lead soil levels were found in South Riverdale and were known to be from air deposition related to a secondary lead smelter in the area. Though clean up efforts in the late 1980s were not exhaustive, the yard soil from homes with the highest lead contamination was remediated and affected households were decontaminated. It is possible, however, that soil lead levels are still higher in South Riverdale than elsewhere in the City because of the historical point source in the community. Lead in outside soil can make its way into the home and be found in indoor house dust (von Lindern et al, 2003). Ingested lead has been associated with abnormalities of the circulatory system (Cheng et al. 1998).

In studies of the relations between air pollution and mortality and hospitalization in Hamilton, Ontario, research has shown that there were strong associations between measures of air pollution, both ambient and traffic related, and deprivation (Jerrett et al, 2001; Finkelstein et al, 2003). Subjects living in more “deprived” neighbourhoods had greater exposure to air pollutants and experienced higher circulatory mortality and hospitalization rates. Although there is not, as yet, similar information for Toronto, it is conceivable that the same relationship holds for circulatory health events, deprivation and air pollution in Toronto as well.

In addition to the observation that matching of comparison and study neighbourhoods was not exact, there are other limitations that affect the study and the interpretation of the results. Most importantly, this is an “ecological” study, that is, it is a study of neighbourhoods rather than of individuals. Individual movement into or out of a neighbourhood and therefore, length of residence in these communities cannot easily be tracked. Consequently, it is not always possible to be certain that health events reflect long-term exposure to the environmental factors at play in these neighbourhoods.

Another limitation pertains to the small population sizes and statistical variability. The neighbourhood populations are between 10,000 to 20,000 subjects. These small sizes prevented a confident comparison of mortality or incidence rates from less common causes of death or diagnoses such as brain cancer and leukemia.

In addition, institutionalized individuals in the population base will have a health pattern that is different from other neighbourhood residents. Neighbourhoods containing several nursing homes might thus have higher mortality rates than neighbourhoods with fewer ones. Although some sources of information were consulted, it was not possible to determine definitively if the distribution of long-term care facilities is a factor influencing observed mortality or hospitalization in these communities.

Due to limitations in the data and the timing at which they became available for analysis (namely the limitations on mortality data), it was only possible to assess health status differences by comparison to the former City of Toronto as a whole, rather than for the entire former Metropolitan Toronto area. Therefore, the second original aim of the study was only partially fulfilled.

Finally, these data represent an analysis of health events in the recent past in these two communities. The data available do not allow for any conclusions as to what the current health profiles are for these communities or whether the observed differences are the same, smaller or larger at present.

Interpretation & Conclusions

This study has found that mortality (from 1979 to 1990) and hospitalization rates (from 1985 to 1998) were generally higher (often with statistical significance) in South Riverdale and The Beaches than in their comparison communities. In addition, where The Beaches had mortality rates lower than the former City of Toronto, in South Riverdale, mortality was higher compared to the former City. Though small numbers of cancer cases (from 1985 to 1999) and deaths (from 1979 to 1990) in all the neighbourhoods limit the conclusions that can be made, there appeared to be few differences in cancer mortality and incidence in South Riverdale and The Beaches relative to comparison communities.

The major concern of the residents in the study communities is that exposure to environmental pollutants has adversely affected their health. However, this is primarily a “descriptive” study done to compare event rates among the study communities and their comparison communities to assess whether rates of illness, death or hospitalization are higher. It is not possible here to provide definitive explanations for the differences in rates among neighbourhoods. Specifically, this study design did not allow for exact conclusions as to cause and effect relationships between local air quality and health status in the two study communities.

It appears that some of the variation in mortality and hospitalization rates, particularly in The Beaches and its comparison neighbourhoods, might be “explained” by differences in neighbourhood socio-economic characteristics, including income, education, and unemployment.

As well, it is conceivable that neighbourhood deprivation and pollution are strongly connected in Toronto as has been found for Hamilton neighbourhoods. If that is the case, it will be difficult to separate the relative contributions of socio-economic deprivation and environmental exposures to health status in these two communities. Only studies designed specifically to address the question of deprivation versus environmental exposure as the causal agents behind observed health inequalities would help answer this question. However, these types of studies involve a considerably greater commitment of time and money than the exploratory, descriptive work done in the present study.

While it is clear that some part of the health differences among the Toronto neighbourhoods studied are related to socio-economic differences among them, it is not possible to rule out the conclusion that differences in environmental exposures (whether from industrial emissions to air or from exposure to lead deposits in soil or dust) contributed to some portion of these differences in mortality and hospitalization rates.

The preceding outlines the results and interpretations of the health status study analysis. They reflect the work undertaken by the independent Consultant, Dr. Murray Finkelstein in discussion with the project team. Recommendations as to what is a reasonable course of further investigation or response in light of the findings summarized here are the purview of the Project team and City staff and are presented elsewhere (See Toronto Public Health, 2005).

INTRODUCTION & BACKGROUND

Since the early 1970s, residents of South Riverdale have been concerned about effects of local industries on the environment and their health. Of particular concern were the Canada Metals plant, the Ashbridges Bay Treatment Plant (ABTP), other incinerators, and the local rendering and tanning industries. The Beaches community is located “downwind” of many of these industries, and may thus be subject to the same or higher levels of industrial pollution. While many large industrial facilities have either closed or re-located as of the end of the 1990; the residents of these communities are concerned about what they have expressed as being the “cumulative effects” of previous and current exposures to pollutants from these industries, and have repeatedly requested a comprehensive health study on local residents. Having considered both the community needs and the feasibility/limitations of various study designs, Toronto Public Health determined that it was appropriate to facilitate a Health Status Study for South Riverdale and The Beaches communities in Toronto.

The initial aims of the Health Status Study were to:

- provide baseline data for the South Riverdale and the Beaches communities with respect to a list of health outcomes selected on the basis that they may be linked to residents’ exposures to local environmental contaminants;
- determine whether residents in these two communities have experienced significantly different rates of illness and/or death relative to comparable neighbourhoods in the City, and to the City as a whole;
- identify specific health issues for potential further investigation/response in the event that rates of illness/death are significantly greater than expected.

The plan for the study called for the investigation of mortality, hospitalization, and cancer incidence as health “endpoints”. It must be understood that this is a descriptive study and that the study is not intended to identify or test any causal relationship between health outcomes and risk factors. Of particular importance is the fact that there is no information on the level or duration of exposure of any individual residents in the community. Interested parties must be cautioned that if comparisons are made for a long list of health outcomes, it is likely that one or more outcomes may appear to be present in excess by chance alone (the problem of multiple comparisons).

The study plan was approved after internal review at Toronto Public Health and by a Research Ethics Board at McMaster University.

METHODS

HEALTH OUTCOMES

The design sent out to tender by the City limited ascertainment of health problems to those identifiable from administrative records: that is, mortality, cancer incidence, and hospitalization records maintained by government agencies. The health concerns that have been identified by the community representatives are: “respiratory diseases, leukaemia, brain tumours, hair loss, skin problems, skin cancers, and sexual development problems”. Many of these outcomes are amenable to analysis via Registry and administrative records; some, such as hair loss, skin problems, and most skin cancers are not. Hair loss and skin problems are not likely to be reported on hospitalization or mortality records and the only type of skin cancer generally reported to Cancer Care Ontario is melanoma.

The residents of these communities have been exposed to airborne industrial emissions and are concerned about past and residual effects upon their health. In order to cause health problems (leaving aside those problems attributable to stress and worry) toxic materials must contact the skin or enter the body. The main routes of entry to the body are passage through the skin, ingestion, and inhalation. The main route of ingestion is from contaminated soil, a problem primarily for young children, and the ingestion of contaminated food and water. Consumption of contaminated produce from a home garden is a potential source of exposure. However, there is no way of identifying residents who consumed home-grown food and these persons likely represent a minority of the population. The source of drinking water is offshore Lake Ontario and water is distributed throughout the Metro Toronto region, so intra-urban comparisons are not possible. We adopted the working hypothesis that the exposure route of primary concern is inhalational, recognizing that children might be exposed to pollutants through ingestion.

Sewage sludge incinerators potentially emit significant quantities of pollutants. The major pollutants emitted are:

- (1) particulate matter,
- (2) metals,
- (3) carbon monoxide (CO),
- (4) nitrogen oxides (NO_x),
- (5) sulfur dioxide (SO₂), and
- (6) unburned hydrocarbons.

Partial combustion of sludge can result in emissions of intermediate products of incomplete combustion, including toxic organic compounds. A sister-study has modeled emissions for the ABTP. The Air Emission Study (*Air Emission from the Ashbridges Bay Treatment Plant 2005*) focussed on 17

chemicals as appropriate for air dispersion modeling based on their rank for toxicity, emissions, persistence and bioaccumulation, on laboratory detection limits and on their human exposure potential.

The primary health effects associated with particulate matter, carbon monoxide, nitrogen oxides, and sulfur dioxide include hospitalization and death from respiratory (asthma, pneumonia, obstructive lung disease) and circulatory (heart attack, congestive heart failure, heart rhythm) disorders. Particulate matter might be associated with increased risk of lung cancer and volatile organic compounds with cancers including leukemia (Pope and Dockery, 1999).

It was proposed by the Principal Investigator, and accepted by the Project Advisory Committee, that the health outcomes of primary interest for the health study should be respiratory and circulatory disorders and cancer.

The following caution is offered. Industrial pollutants are likely to be responsible for only a small proportion of the total causes for these diseases in the community (Steenland et al. 2003). One of the major causes of respiratory disease is cigarette smoking. Circulatory disorders are caused by cigarette smoking, diabetes, high blood pressure, high cholesterol, and traffic pollution. It is very likely that the distribution of these risk factors is not uniform throughout the City of Toronto. Surveys have shown that residents of poorer neighbourhoods are more likely to be smokers and to have an adverse “heart health” profile (Choiniere et al, 2000). We do not have information about the distribution of these risk factors in the neighbourhoods of Toronto. We thus made use of census derived population-level surrogates, such as the levels of income and education, to attempt to balance these underlying risk factors between neighbourhoods. This adjustment cannot be perfect, and there is always the risk that any health differences observed between neighbourhoods will be attributable to differences in underlying risk profiles and not to environmental factors. This problem, called confounding, is always a concern in environmental epidemiology.

SELECTION OF COMPARISON NEIGHBOURHOODS

As mentioned above, the problem of confounding (the presence of differences between neighbourhoods in factors associated with health outcomes, other than those under study) is always a concern. As an extreme example, consider the question of whether lung cancer rates are increased in a neighbourhood where a factory emits puffs of asbestos dust (a known cause of lung cancer) into the air. Suppose that we wish to compare lung cancer rates in that neighbourhood with those in a comparison neighbourhood. Suppose further that only 1% of the residents of the exposed neighbourhood smoked cigarettes, while 80% of the residents of the comparison neighbourhood were heavy smokers. Interpretation of differences in lung cancer rates, and of the effects of asbestos exposure, is “confounded” by the differences in the rates of cigarette smoking.

Information about differences, among Toronto neighbourhoods, in many of the personal factors associated with health is not available. We are thus obliged to use “surrogate measures” to attempt to reduce confounding when analysing differences in health between neighbourhoods.

One well studied measure is socio-economic status. The association between social inequalities and differences in people’s health and well-being is well known (Diez Roux et al. 2001). Individuals of lower socio-economic status report poorer health, and have heavier health care utilization, than do individuals of higher socio-economic status (Finkelstein 2001). Smoking habit is also associated with socio-economic status (Shohaimi et al. 2003).

In previous work, my colleagues and I used a “Deprivation Index” to adjust for social inequalities between neighbourhoods. This was inspired by the work of Pampalon (Pampalon and Raymond 2000) who explored a Deprivation Index derived from Canadian census data. The indicators that he used were: the proportion of persons who have no high-school diploma; the ratio of employment to population; and, average income. Pampalon and colleagues found that life expectancy at birth and Standardized Mortality Ratios were associated with deprivation. In a study in Hamilton, my colleagues and I found that a Deprivation Index, derived from Principal Components analysis (Dunteman 1989) of household income, education, and unemployment rate was strongly associated with mortality from circulatory and respiratory diseases and lung cancer (Finkelstein et al. 2004). We thus used a similar Deprivation Index as the metric for matching neighbourhoods in Toronto.

Analysis and Selection

Information on the characteristics of Toronto neighbourhoods, as derived from 2001 Census data, were obtained from Toronto Public Health. A Principal Components analysis was undertaken with Neighbourhood Median Household Income, Proportion of High School Graduates, and Male Unemployment Rate as inputs. Two Principal Components were extracted, comprising 94% of the variance; Principal Component 1 (71%) and PC2 (23%). The coefficients for the Principal Components are given in the Table 1 below.

Table 1: Coefficient Matrix for Principal Components

	Component 1	Component 2
Logarithm of Median Income	-.443	0.029
Proportion Males Unemployed	.375	-0.823
Proportion Grade 9 Education or Less	0.362	0.886

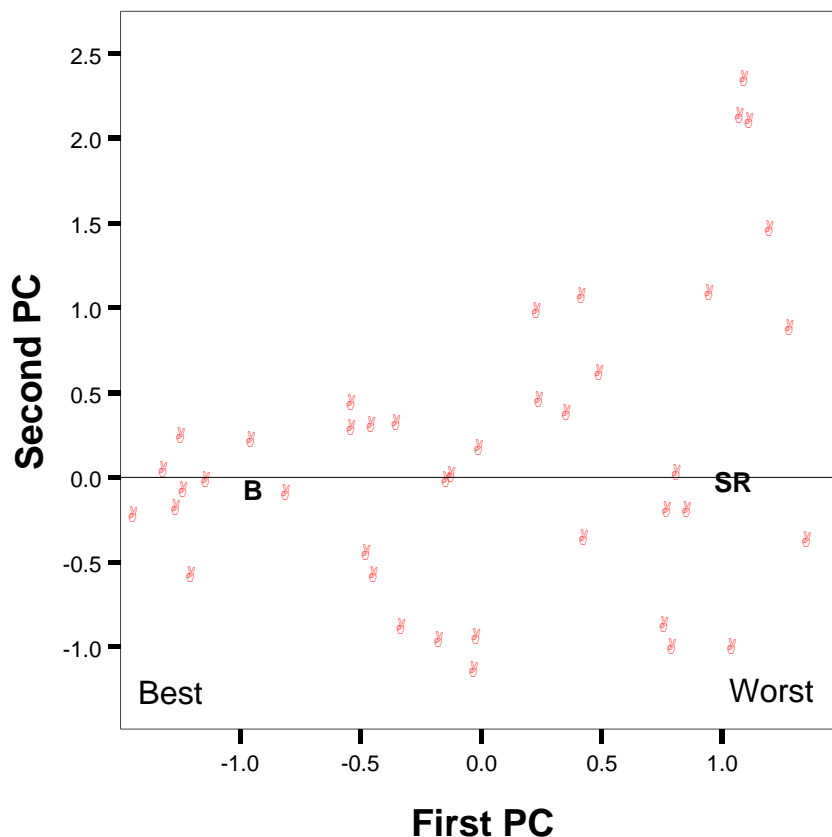


Figure 1. Principal Components Analysis for Neighbourhood Matching.

Neighbourhoods with poorer Deprivation Indices are to the right. The points immediately to the left of the labels show Beaches (B) and South Riverdale (SR). Each dot represents a separate neighbourhood from the former City of Toronto.

The First Principal Component usually expresses a weighted average of the input variables. In this instance, it expresses a “Disadvantage Index”. Since income enters with a negative sign, the higher the score, the greater the neighbourhood disadvantage. The second component expresses a relative difference among neighbourhoods between unemployment and education. In neighbourhoods in which these are balanced, PC2 will be close to 0. PC2 will be positive in neighbourhoods in which unemployment is relatively low in comparison to the education level, and vice versa. Figure 1 plots the Principal Component Scores of the neighbourhoods in the former City of Toronto. Neighbourhoods falling close together in the PC1-PC2 plane will be similar, and those separated will be dissimilar. Examination of Figure 1 shows that, for the Beaches, there is a cluster of neighbourhoods with similar

scores. There are fewer matching neighbourhoods for South Riverdale. Figure 2 shows The Beaches cluster expanded in scale

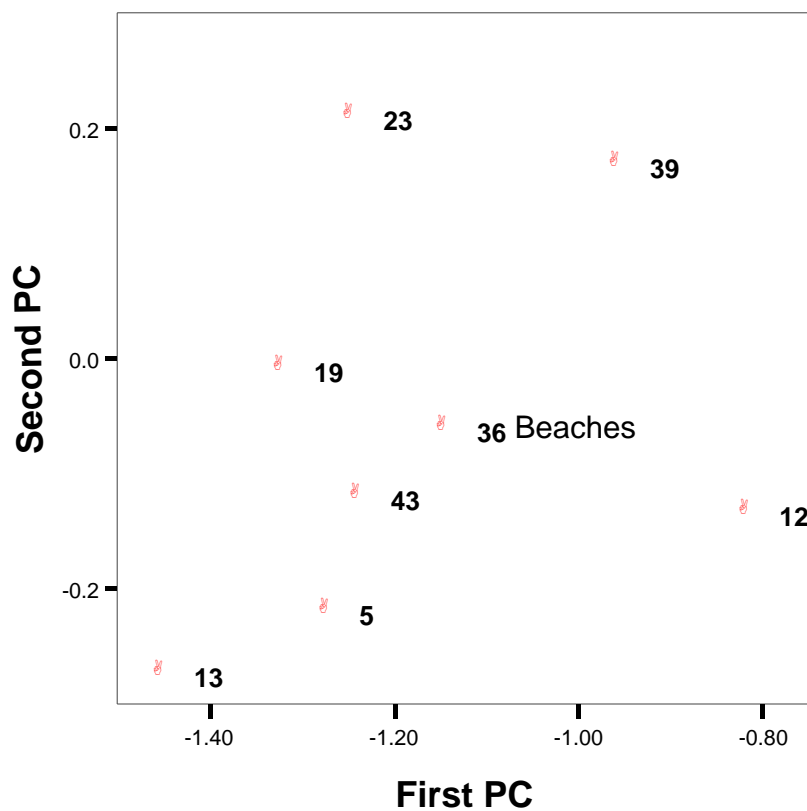


Figure 2. Principal Components Analysis for Matching Neighbourhoods to The Beaches

Neighbourhoods 19 and 43 are in close proximity in the plane of the Principal Components. They are not further identified.

Table 2 below compares the demographic characteristics of these neighbourhoods. The Beaches has the largest population. It can be seen that the neighbourhoods are reasonably well balanced with respect to income, education, immigration, and unemployment.

Table 2: Comparison of neighbourhood characteristics within The Beaches cluster**BEACHES CLUSTER**

AREA	Population Aged 20+	% Grade Nine or Less	% Lone Parent Family	% Age 65+	% Immigrants	Recent Immigrants
Neighbourhood 19	10235	2.34%	13.27%	10.99%	22.14%	2.06%
The Beaches	15720	2.70%	14.78%	9.26%	18.51%	2.34%
Neighbourhood 43	8535	1.35%	10.55%	11.43%	22.81%	3.11%

AREA	Median Household Income	Male Unemployment	% Low income Families	% Low Income Persons
Neighbourhood 19	121000	3.78%	4.05	6.09
The Beaches	106460	4.04%	6.26	10.97
Neighbourhood 43	106500	3.78%	3.94	7.90

Figure 3 below, shows the region around South Riverdale (SR) in the plane of the Principal Components. Near 1 (Neighbourhood 14) and Near 2 (Neighbourhood 3) are the nearest neighbours in statistical space, but they are also nearest neighbours geographically. Neighbourhoods numbers 27 and 10 are more distant spatially, but they are also more distant in statistical space.

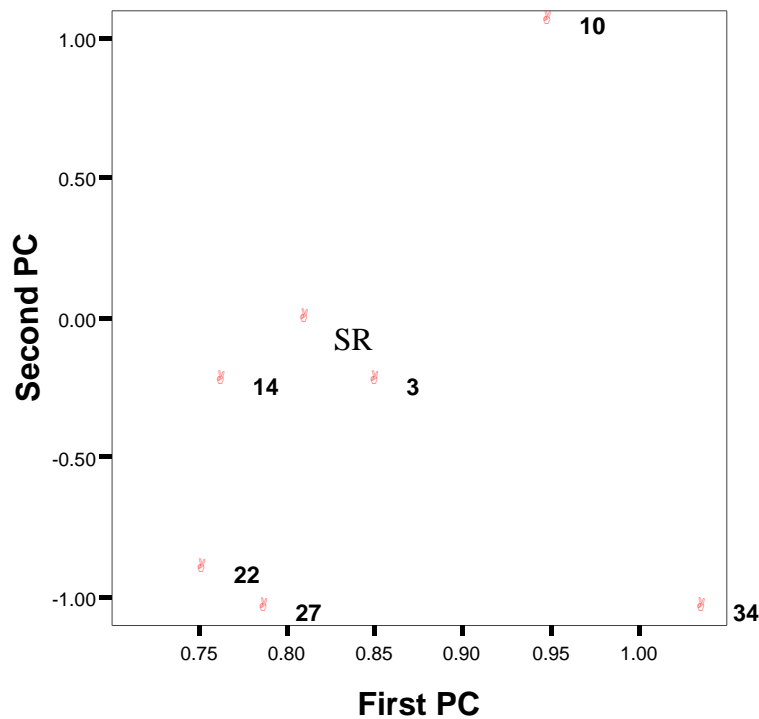


Figure 3. Principal Components Analysis for Matching Neighbourhoods to South Riverdale

Table 3 below compares the census characteristics of these neighbourhoods. It can be seen that the distance in statistical space is associated with more distant match of census characteristics. Neighbourhood 27 differs the most from South Riverdale on socio-economic factors

Table 3: Comparison of neighbourhood characteristics within South Riverdale cluster**1. South Riverdale CLUSTER**

AREA	Population Aged 20+	% Grade Nine or Less	% Lone Parent Family	% Age 65+	% Immigrants	Recent Immigrants
Near (1)	9285	15.35%	20.10%	11.58%	43.17%	8.26%
Near (2)	12120	13.24%	26.43%	10.87%	43.66%	7.86%
South Riverdale	20470	14.85%	23.44%	10.77%	44.89%	9.57%
Neighbourhood 10	10060	21.67%	18.68%	10.36%	55.77%	8.74%
Neighbourhood 27	14400	8.51%	26.70%	7.27%	63.63%	26.23%

AREA	Median Household Income	Male Unemployment	% Low income Families	% Low Income Persons
Near (1)	46300	8.59%	23.56	28.33
Near (2)	41833	7.89%	23.27	28.53
South Riverdale	41543	7.71%	22.52	27.32
Neighbourhood 10	40700	6.52%	20.57	23.16
Neighbourhood 27	38550	8.90%	41.02	46.29

The Terms of Reference for this study called for selecting a matching neighbourhood for each of The Beaches and South Riverdale neighbourhoods. For The Beaches, it was agreed by the Project Advisory Committee that Neighbourhoods 19 and 43 would be selected as comparison neighbourhoods. Using these two neighbourhoods will increase statistical power. Selecting matching neighbourhoods for South Riverdale was more problematic. Neighbourhoods Near (1) and Near (2) provide the best matches, but they are also geographic neighbours and it was hypothesized that their local air quality might also have been influenced by pollutants from ABTP. The more distant neighbourhoods, numbers 10 and 27 are poorer demographic matches. In discussion with the Project Team it was agreed that the differences between South Riverdale and Neighbourhood 27 were too great to enable reliable comparison. Since the objective of this study is to screen for health effects possibly associated with pollutant exposures, it was agreed that it was important to select comparison neighbourhoods where exposures from ABTP would not be expected to be a concern. Neighbourhood 10 was thus selected as the matching neighbourhood for South Riverdale.

Following presentation of the draft mortality report to the Project Advisory Committee, it was recommended that the two Near Neighbourhoods for South Riverdale also be included in the study since the Air Emission Study found that there was negligible pollutant impingement on these neighbourhoods. This has been done. All of the endpoint studies now include the two nearest neighbours in addition to Neighbourhood 10 as the comparison neighbourhoods for South Riverdale.

STATISTICAL ANALYSIS

1) Mortality Analysis

The major health outcomes for analysis are 1) All non-accidental mortality; 2) Circulatory mortality (ICD9 401-449); 3) Respiratory Disease mortality, (ICD9: 460-519); 4) All Cancer mortality; 5) Lung cancer mortality; 6) Brain Cancer mortality (ICD9: 191); and, 7) Mortality from Cancers of the Blood and Lymphatics (ICD9: 200 - 209).

The City of Toronto had mortality data (the Mortality Database), with postal code, from the former City of Toronto, from 1979-1990. The mortality data available stop at 1990 because after this time, the data verification process conducted at the Office of the Registrar General (ORG) was incomplete, meaning that many individual death records after that time lack a postal code. Without a postal code, a death record (or other health event record) cannot be linked to a specific neighbourhood and therefore is not usable for this study. As well, while the public health department under the former City of Toronto had mortality data including postal codes, the public health departments for the former municipalities (such as Etobicoke, North York, York, East York and Scarborough) did not have comparable, usable data for this same time period. This is the reason that comparison neighbourhoods could only be chosen from among neighbourhoods in the former City of Toronto.

Neighbourhood-specific mortality rates were calculated in two different ways: 1) by Direct Standardization and 2) by Regression methodology. In Direct Standardization, one computes age-specific mortality rates and then generates a single summary measure, the Directly Standardized Mortality Rate, as a weighted average of the age-specific rates. The weights for this study were derived from the age distribution of the former City of Toronto as a whole. The weights used in the analysis are displayed in Table 4 (Appendix 1). Direct Standardization can be “unstable” when the numbers of deaths in any age-group is small. If that age group receives a high weight, then a difference of one or two deaths can make a substantial difference to the Directly Standardized Summary Measure.

Direct Standardization forces no structure on the age-specific rates. In contrast, Poisson regression methodology presumes that the age-specific rates in the study and comparison neighbourhoods all differ by the same factor. That is, if mortality rates in neighbourhood A are 10% higher than in neighbourhood B, then they are assumed to be 10% higher for each age group. Small number fluctuation is less of a problem in Poisson regression since the assumption of a constant rate difference allows the “borrowing of information” from other age groups.

In the regression analyses we used the model $\text{Log}(\text{count}) = \text{age}_i + \text{sex} + \text{period}_i + \text{neighbourhood}$, offset(person-years). Interactions between neighbourhood and calendar period were tested. An assumption of the Poisson regression model is that the variance equals the estimated mean count. In real-world data this assumption is often violated and the model is found to be “over dispersed”, that is, the variance exceeds the mean. That was found to be the case in many of the models that we analysed. When this occurred, we replaced the Poisson regression model with a negative binomial regression model (NBRM) which addresses the overdispersion problem by adding a parameter, α , that reflects unobserved heterogeneity among the neighbourhoods. The NBRM is a model for discrete data in which the variance, $V(\mu) = \mu + \alpha \mu^2$. The NBRM, like the Poisson, is a “multiplicative” model - the coefficients give the proportional increase in outcome frequency per unit increase in the predictor variable.

2) Cancer Incidence Analysis

Cancer incidence data (the Cancer Incidence Database) for residents of Metropolitan Toronto (“M” postal code), 1979-1998, were received from Cancer Care Ontario (CCO). The data comprised individual level information that included Diagnosis Code, Year of Birth, Year of Diagnosis, Sex, and Census Tract of the residence. The Census Tract Data were used to assign subjects to study neighbourhoods.

On examination of the data it was discovered that the numbers of incident cases seemed anomalously low for the years 1979-1984. On consultation with staff at CCO it was determined that there were inconsistencies by CCO in the recording of subjects’ postal codes in the years prior to 1985. Those years were thus excluded and the cancer incidence study comprises incident cases of cancer during the years 1985-1999. The diagnoses of interest include 1) All Cancer Diagnoses combined; 2) Lung cancer; 3) Brain cancer; and, 4) Cancers of the Blood and Lymphatics. As with the mortality analysis,

neighbourhood-specific cancer incidence rates were calculated in two different ways: 1) By Direct Standardization and 2) by Regression methodology.

3) Hospitalization Analysis

Hospitalization data (the Hospitalization Database) for residents of Metropolitan Toronto (“M” postal code), 1985 -1999, were received from the Ministry of Health and Long Term Care (MOHLTC). The data comprised individual level information that included a scrambled Health Insurance Number, age, sex, year of admission, Diagnosis Code, and Census Tract of the residence. The Census Tract Data were used to assign subjects to study neighbourhoods. The diagnoses of interest include: 1) All Hospital Admissions combined; 2) Circulatory Disease (ICD9: 401 - 448); 3) Acute Ischemic Heart Disease (Heart Attack, ICD9: 410-411); 4) Respiratory Disease (ICD9: ICD460 - 519); and 5) Asthma (ICD9: 493).

As with the mortality analysis, neighbourhood specific hospitalization rates were calculated in two different ways: 1) By Direct Standardization and 2) by Regression methodology. There is an additional complication, however, because some individuals had more than one admission, and the admissions data are thus not “independent”. The lack of independence has implications for the estimation of the variability (variance) of the data. In the regression analyses we thus made use of the capability in the Stata statistical package to calculate “robust” estimates of variance.

DATA HANDLING

None of the information (mortality, cancer incidence, or hospitalization records) received was in identifiable form. Personal information included only age, sex, and Census Tract Number of the residence.

Mortality Data

The City provided a data file containing a listing of all deaths in the City from 1979 to 1990. For each subject, we had the age, sex, date, and cause of death. Each death had been assigned a neighbourhood code.

Census Data

Neighbourhood-specific information was abstracted from data for the Censuses of 1981, 1986, and 1991 obtained from McMaster University. Information in the Census is organized by Census Tract. These were combined into the appropriate Toronto neighbourhoods. These 3 Censuses were used to describe the calendar intervals 1979 to 1983, 1984 to 1988, and 1989 to 1990. Neighbourhood age-specific population sizes were obtained from the Census. Person-years at risk were approximated by multiplying the population sizes by 5 years for 1979-1983 and 1984-1988 and by 2 years for the period 1989-1990. The person-years are approximate because intercurrent births and deaths and in-migration and out-migration are ignored. Since only a small proportion of the population died in each interval,

and because the population sizes changed minimally between censuses, the approximations are very good.

Temporal Changes in Neighbourhood Characteristics

The original neighbourhood matching in the planning phase was based upon the Census of 2001. Table 5 (Appendix 1) shows the neighbourhood characteristics at the 1981, 1986, 1991, and 1996 censuses. The effect of inflation is apparent in the median Household incomes.

South Riverdale, Neighbourhood 10, and Near Neighbourhoods 1 and 2

These neighbourhoods had similar median incomes in 1981, but the income levels grew faster in South Riverdale subsequently. The percentage of recent immigrants has increased with the passage of time, whereas the percentage of the population with less than Grade 9 education has declined. Unemployment rates have increased.

The Beaches and Neighbourhoods 19 and 43

Median incomes were similar in The Beaches and Neighbourhood 43. The median income was higher in Neighbourhood 19. The percentage of recent immigrants was low in all three neighbourhoods. Education levels were similar. Unemployment was slightly higher in The Beaches.

RESULTS

MORTALITY

Comparison of Directly Standardized Rates

Layout of Results Tables

To save on space in this report, detailed tabulations of age and sex 1-specific mortality rates are presented only for All Cause Mortality (Tables 6-8, 16-17B). For all other outcomes, we present only the directly standardized summary rates. The detailed tables are presented (in Appendix 1) to give an impression of the details of the calculations and some idea of the size of the numbers involved. For each calendar period, the age and sex specific mortality rates are presented, followed by the Directly Standardized Summary Measure and its associated statistical uncertainty, the Standard Error. After the three calendar specific tables are presented, a Summary Table presents the information at a glance. Summary Tables are the mode of presentation for all other analyses of Standardized Rates.

It will be seen that the counts of deaths in many age and sex-specific entries in the Tables are very small. This fact introduces substantial statistical variability. Because of the potential instability of

directly standardized rates when numbers are small, tests of statistical significance are not reported in the comparison of the directly standardized rates. The testing of neighbourhood differences for statistical significance has been performed only in the Regression modeling analyses reported later.

A: The Beaches

1) All Nonaccidental Causes of Death Combined (Tables 6 – 9)

All Cause mortality rates for men and women residing in The Beaches were generally higher than those of the comparison communities, but were lower than the rate for the former City of Toronto as a whole. The higher rates were observed in all three calendar periods. When regression analysis was subsequently performed, there was no indication that the rate increase differed among the calendar periods.

2) Circulatory Mortality (Table 10)

Circulatory disease mortality rates for men and women residing in The Beaches were generally higher than those of the comparison communities, but were lower than the rate for the former City of Toronto as a whole. This differential appeared in all three calendar periods. Regression analysis subsequently showed that the rate differential was similar in each calendar period.

3) Respiratory Mortality (Table 11)

Numbers are small. Respiratory disease mortality rates for men residing in The Beaches were generally higher than those of the comparison communities, and were similar to those for the former City of Toronto as a whole. This differential appeared in all three calendar periods. Rates among women were similar to those in the other communities and were lower than those in Toronto (former City) as a whole.

4) Cancer Mortality (Tables 12 - 15)

Cancer mortality rates were similar to those in the other communities and to Toronto (former City) as a whole.

5) Lung Cancer Mortality (Table 13)

The counts of deaths were small. Lung cancer mortality rates among men tended to be higher than in the comparison neighbourhoods and similar to those in the former City as a whole. Rates among women were variable.

6) Brain Cancer Mortality (Table 14)

The counts of deaths were very small and essentially uninterpretable.

7) *Hematologic and Lymphatic Cancers (Table 15)*

The counts of deaths were very small. Rates were similar to those in the other communities and the former City as a whole.

B: South Riverdale

1) *All Causes of Death Combined (Tables 16 - 18)*

As discussed above, two Near Neighbour communities have been added to the comparison base that previously only included a more distant neighbourhood. All Cause mortality rates for men and women residing in South Riverdale were higher than those of the comparison communities, and were also higher than the mortality rates for the former City of Toronto as a whole. The higher rates were observed in all three calendar periods. When regression analysis was subsequently performed, there was no indication that the rate increase differed among the calendar periods.

2) *Circulatory Mortality (Table 19)*

Circulatory mortality rates for men residing in South Riverdale were similar to those of residents of the other neighbourhoods. Circulatory mortality rates among women were higher than those of the comparison communities and were also higher than the mortality rates for the former City of Toronto as a whole.

3) *Respiratory Mortality (Table 20)*

Numbers are small. Respiratory mortality rates for men residing in South Riverdale were similar to those of residents of the other neighbourhoods. Respiratory mortality rates among women were higher than those of the comparison communities and were also higher than the mortality rates for the former City of Toronto as a whole.

4) *All Cancer Mortality (Tables 21 - 24)*

Cancer mortality rates for men and women residing in South Riverdale were similar to those in the comparison communities.

5) *Lung Cancer Mortality (Table 22)*

The counts of deaths were small. Lung cancer mortality rates for men and women residing in South Riverdale were similar to those of the comparison communities.

6) *Brain Cancer Mortality (Table 23)*

The counts of deaths were very small and essentially uninterpretable.

7) *Hematologic and Lymphatic Cancers (Table 24)*

The counts of deaths were small. Rates of death from hematologic and lymphatic cancers were similar to those in the comparison communities.

Comparison of Rates by Regression Analysis

As discussed in the methods section, Poisson and Negative Binomial Regression are “multiplicative models”. The assumption is that the age-specific rates in the study neighbourhood are a constant multiple of the rates in the comparison neighbourhood(s). Examination of the tables of age-specific rates shows that this assumption is a reasonable one. Because of the small numbers of events for the individual cancer sites, we limited these analyses to All Causes of Death, Circulatory, Respiratory, and All Cancer mortality. We attempted to fit Poisson regression models (because the variance of the Poisson model is smaller than that of Negative Binomial models). When regression diagnostics indicated that the Poisson models were “over dispersed”, we fitted Negative Binomial models. These are indicated in the tables with “Neg Bin” or “NBR” notation.

The result statistic presented in the Tables is the “Rate Ratio”. This is the ratio of the mortality (or cancer incidence, or hospitalization) rate in this neighbourhood to the rate in the neighbourhood that serves as the Reference neighbourhood. So, for example, the Rate Ratio is 1.16 (in Table 25) when comparing The Beaches to Neighbourhood 19. This means that the mortality rate was 16% higher in The Beaches than in Neighbourhood 19. Rates of health events have some statistical variability about them, however. The size of this variability is estimated by the Confidence Interval, which is presented in parentheses beside the Rate Ratio. So, for example, for the comparison in Table 25, we have a rate ratio of 1.16 with 95% Confidence Interval (1.05 - 1.27). The 95% Confidence Interval is similar to the uncertainty measure presented in reports of political polls, where it might be stated that 53% of the population supports Party X, with a margin of error of 4% 19 times out of 20. Here we might say that we observed a rate ratio of 1.16 when comparing the Beaches to Neighbourhood 19. Nineteen times out of 20, in similar studies, we would find the rate ratio to lie between 1.05 and 1.27. If the 95% Confidence Interval does not contain the value 1.00, then the increase (or decrease) in the Rate Ratio is said to be *statistically significant*. It is important to note also that statistical significance, however, does not reveal the size of the difference or its clinical importance, that is, whether the difference is large enough to be a concern.

A: The Beaches

Table 25 shows the results of the regression analysis for the Beaches and comparison neighbourhoods. The “reference neighbourhood” is Neighbourhood 19. The last 2 columns give the mortality rate ratio

(and 95% Confidence Interval) for Neighbourhood 43 and for the Beaches. We tested for differences in rate ratios among the calendar periods. None of these differences were statistically significant. That is, we cannot reject the hypothesis that the rate ratios were constant from 1979 - 1990.

1) *All Causes of Death*

Mortality rates were similar in the two comparison neighbourhoods. For all years combined the Rate Ratio was 1.00, 95% Confidence Interval 0.90 to 1.11. The mortality rate in The Beaches was significantly higher than in the comparison communities. The rate ratio was 1.15 (1.07 - 1.25) combining both comparison communities as Reference. That is mortality rates were 15% higher in The Beaches than in the comparison neighbourhoods and if a similar study were repeated, the mortality rate would be found to be between 7% and 25% higher, 19 times out of 20.

2) *Circulatory and Respiratory Mortality*

Circulatory and respiratory mortality rates were significantly higher than in the comparison communities. For circulatory mortality, the rate was greater by 23% [(the rate ratio was 1.23 (1.11 - 1.36)] combining both comparison communities as Reference, and for respiratory mortality, the rate ratio was 1.41 (1.10 - 1.82) or 41% higher, combining both comparison communities.

3) *Cancer Mortality*

Because of the problem of small numbers of deaths from specific cancers, the regression analysis was only performed for mortality from All Cancers. There was no significant difference in mortality from All Cancers combined between the Beaches and the comparison communities.

B: South Riverdale

Table 26 shows the results of the Poisson analyses for South Riverdale and the comparison neighbourhoods. Near Neighbour 2 is the Reference Community because of its large population size. We also tested for individual differences between the rates for South Riverdale and the other communities. When significant differences were present, these are indicated by two asterisks in the columns for these other communities. We tested for differences in rate ratios among the calendar periods. None of these differences were statistically significant. That is, we cannot reject the hypothesis that the rate ratios were constant from 1979 to 1990.

1) *All Causes of Death*

The mortality rate in South Riverdale was significantly higher than in the comparison communities. There was no difference in mortality rates between Near 1 and Near 2. These were thus combined for the last comparison. The rate ratio, comparing South Riverdale to the two Near Neighbours combined was 1.25 (1.17 - 1.34) for all time periods combined; that is, the mortality rate was greater by 25%.

2) *Circulatory and Respiratory Mortality*

Circulatory and respiratory mortality rates were significantly higher than in the comparison communities.

3) *Cancer Mortality*

Mortality from All Cancers combined was significantly higher in South Riverdale than in comparison Neighbourhood 10. There were no significant differences between the Cancer mortality rates in South Riverdale and the two Near Neighbours.

CANCER INCIDENCE

Comparison of Directly Standardized Rates

A: The Beaches

1) *All Cancers Combined (Table 27)*

Cancer incidence rates were similar in The Beaches and comparison communities.

2) *Lung Cancer (Table 28)*

Lung cancer incidence rates were similar in The Beaches and comparison communities.

3) *Brain Cancer (Table 29)*

Numbers are small. Brain cancer incidence rates were similar in The Beaches and comparison communities.

4) *Hematologic and Lymphatic Cancer (Table 30)*

Incidence rates were similar in The Beaches and comparison communities.

B: South Riverdale

1) *All Cancers Combined (Table 31)*

Cancer incidence rates were similar in South Riverdale and comparison communities.

2) *Lung Cancer (Table 32)*

Lung cancer incidence rates were similar in South Riverdale and Near Neighbour 2, but were higher than in the other comparison communities.

3) *Brain Cancer (Table 33)*

Numbers are small. Brain cancer incidence rates were somewhat lower in South Riverdale than in the comparison communities.

4) *Hematologic and Lymphatic Cancer (Table 34)*

Incidence rates were similar in South Riverdale and comparison communities.

Comparison of Rates by Regression Analysis

Because of small numbers of events, these comparisons are limited to All Causes of Cancer combined.

A. The Beaches (Table 35)

Table 35 shows the results of the regression analysis for The Beaches and comparison neighbourhoods. The “reference neighbourhood” is Neighbourhood 19. The last 2 columns give the mortality rate ratio (and 95% Confidence Interval) for Neighbourhood 43 and for The Beaches. We tested for differences in rate ratios among the calendar periods. None of these differences were statistically significant. That is, we cannot reject the hypothesis that the rate ratios were constant from 1985 - 1999.

Incidence rates were similar in the two comparison neighbourhoods. The cancer incidence rate in The Beaches was similar to that in the comparison communities. The rate ratio was 0.96 (0.86 - 1.06) combining both comparison communities. Therefore there were no statistically significant differences.

B: South Riverdale (Table 36)

Table 36 shows the results of the regression analyses for South Riverdale and the comparison neighbourhoods. Near Neighbour 2, is the Reference Community because of its large population size. We also tested for individual differences between the rates for South Riverdale and the other communities. When significant differences are present, these are indicated by two asterisks in the columns for these other communities. We tested for differences in Rate Ratios among the calendar periods. None of these differences were statistically significant. That is, we cannot reject the hypothesis that the Rate Ratios were constant from 1985 to 1999.

Cancer incidence rates in the two other comparison communities were lower than in Near Neighbour 2. There were no significant differences between the cancer incidence rates in South Riverdale and the two Nearest Neighbours. Cancer incidence rates in Neighbourhood 10 were significantly lower than in South Riverdale.

HOSPITALIZATION RATES

This analysis makes use of hospitalization data, 1985 - 1998, provided by the Ministry of Health and Long Term Care.

Comparison of Directly Standardized Rates

A: The Beaches

1) All Causes of Hospitalization Combined (Table 37)

All Cause hospitalization rates for men and women residing in The Beaches were generally higher than those of the comparison communities. The higher rates were observed in all three calendar periods. When regression analysis was subsequently performed, there was no indication that the rate increase differed among the calendar periods.

2) Circulatory Hospitalization (Table 38)

Circulatory disease hospitalization rates for men and women residing in The Beaches were higher than those of one comparison community, but generally similar to those of the second.

3) Acute Ischemic Heart Disease (Heart Attack) Hospitalization (Table 39)

Heart attack hospitalization rates were generally similar to those in the comparison communities.

4) Respiratory Disease Hospitalizations (Table 40)

Respiratory disease hospitalization rates were generally higher than those in the comparison communities.

5) Asthma Hospitalization (Table 41)

Asthma hospitalization rates were mixed. Those in The Beaches were sometimes higher, and sometimes lower than those in the comparison communities.

Regression Analysis of Hospital Admission Rates

A: The Beaches

Table 42 shows the results of the regression analysis for The Beaches and comparison neighbourhoods. The "reference neighbourhood" is Neighbourhood 19. The last 2 columns give the mortality rate ratio (and 95% Confidence Interval) for Neighbourhood 43 and for The Beaches. We tested for differences in Rate Ratios among the calendar periods. None of these differences were statistically significant. That is, we cannot reject the hypothesis that the rate ratios were constant from 1985 - 1998.

1) *All Causes of Hospitalization*

All Cause hospitalization rates were significantly higher in The Beaches than in each of the comparison communities. Rates were significantly higher in Neighbourhood 43 than they were in Neighbourhood 19.

2) *Circulatory Hospitalization*

Circulatory hospitalization rates were significantly higher in The Beaches than in Neighbourhood 19. They were not significantly higher than the rates in Neighbourhood 43.

3) *Respiratory Hospitalization*

Respiratory hospitalization rates were significantly higher in The Beaches than in each of the comparison communities. Rates were significantly higher in Neighbourhood 43 than they were in Neighbourhood 19.

4) *Asthma Hospitalization*

Asthma hospitalization rates were significantly higher in The Beaches than in each of the comparison communities. Rates were significantly higher in Neighbourhood 43 than they were in Neighbourhood 19.

B: South Riverdale

1) *All Causes of Hospitalization Combined (Table 43)*

As discussed above, two Near Neighbour communities have been added to the comparison base that previously only included a more distant neighbour. All Cause hospitalization rates for men and women residing in South Riverdale were generally similar to those of the comparison communities.

2) *Circulatory Hospitalization (Table 44)*

Circulatory hospitalization rates for men and women residing in South Riverdale were generally similar to those of the comparison communities.

3) *Acute Ischemic Heart Disease Hospitalization (Table 45)*

Heart attack hospitalization rates for men and women residing in South Riverdale were generally similar to those of the comparison communities.

4) *Respiratory Disease Hospitalization (Table 46)*

Respiratory disease hospitalization rates for men and women residing in South Riverdale were generally higher than those of the comparison communities.

5) *Asthma Hospitalization (Table 47)*

Asthma hospitalization rates for men and women residing in South Riverdale were generally similar to those of the comparison communities.

Regression Analysis of Hospital Admission Rates

A: South Riverdale

Table 48 shows the results of the regression analysis for South Riverdale and comparison neighbourhoods. The "reference neighbourhood" is Near Neighbour 2.

1) *All Causes of Hospitalization*

All Cause hospitalization rates were similar in South Riverdale and Near Neighbour 2. They were significantly higher than in Near Neighbour 1 and Neighbourhood 10.

2) *Circulatory Hospitalization*

Circulatory hospitalization rates were significantly lower in South Riverdale than in Near Neighbour 2. They were similar to the rates in Near Neighbour 1, but significantly higher than the rates in Neighbourhood 10.

3) *Respiratory Hospitalization*

Respiratory disease hospitalization rates were similar in South Riverdale and Near Neighbour Number 2. They were significantly higher than in Near Neighbour 1 and Neighbourhood 10.

4) *Asthma Hospitalization*

Asthma hospitalization rates were similar in South Riverdale and Near Neighbours Numbers 1 and 2. They were significantly higher than in Neighbourhood 10.

SUMMARY OF RESULTS

The results of all the preceding analyses are summarized in Table 49.

1. Mortality

A. The Beaches

All Cause, Circulatory, and Respiratory disease mortality rates were significantly higher in The Beaches than in the comparison neighbourhoods. There was no difference in cancer mortality rates.

B. South Riverdale

All Cause, Circulatory, and Respiratory disease mortality rates were significantly higher in South Riverdale than in the comparison neighbourhoods. Cancer mortality rates were higher in South Riverdale than in the distant comparison neighbourhood, but were similar to those in the Near Neighbourhoods.

2. Cancer Incidence

The cancer incidence findings were similar to the cancer mortality results. That is, The Beaches was no different from its comparison neighbourhoods whereas South Riverdale was similar to its Near Neighbours (N1 & N2) but higher than N10, the distant comparison neighbourhood.

3. Hospitalization

A. The Beaches

All Cause, Circulatory, Respiratory disease and asthma admission rates were significantly higher in The Beaches than in the comparison neighbourhoods.

B. South Riverdale

All Cause hospitalization rates in South Riverdale were the same as in one Near Neighbour, but were significantly higher than in the second Near Neighbour and the remote comparison neighbourhood. Circulatory disease admission rates were the same as in one Near Neighbour, were significantly lower than in the second Near Neighbour, and were significantly higher than in the remote comparison neighbourhood. Respiratory disease admission rates were the same as in one Near Neighbour, but were significantly higher than in the second Near Neighbour and the remote comparison neighbourhood. Asthma admission rates were the same as in the Near Neighbours, but were higher than in the remote comparison neighbourhood.

South Riverdale thus presents a mixed comparison picture depending on the cause for hospital admission and on the comparison neighbourhood.

SOCIO-ECONOMIC CHARACTERISTICS AND HEALTH OUTCOMES

Rates of non-cancer adverse health events were generally higher in the study neighbourhoods than in their comparison neighbourhoods. Although we matched as best we could on socio-economic characteristics, the matching was not perfect. Could some of these health differences be attributed to residual socio-economic differences?

Community socio-economic characteristics are known to be associated with both mortality and morbidity rates, with more “deprived” communities experiencing higher rates of adverse health events. We used the method of Principal Components and the income, education, and unemployment data in Table 5 to compute a “Deprivation Index”. The First Principal Component, accounting for more than 90% of the variance, provided the Deprivation Index.

Table 50 shows the values for the Deprivation Indices computed at each of the Census years. It can be seen that there is some variability in the Deprivation Index within the two neighbourhood clusters over time. For example, until 1991, The Beaches was the most “deprived” neighbourhood in its group (that is, on average, lower income, education and employment levels compared to its two comparison neighborhoods.) In 1991 and 1996, The Beaches and Neighbourhood 43 were closely matched. South Riverdale was closely matched to Near Neighbourhood 2, but was less “deprived” than Near Neighbourhood 1 and Neighbourhood 10.

Table 51 adds the All Cause Mortality and Hospitalization Relative Risks (Rate Ratios) to the Deprivation Table. These are plotted in Figures 4 to 7. It can be seen that event rates were higher in the “higher deprivation” South Riverdale group of neighbourhoods than in the “lower Deprivation” Beaches group.

Within the Beaches group that includes The Beaches, neighbourhood differences can largely be explained by differences in the Deprivation Index, since a straight line can be fitted quite well to these three data points. The same is not true for the South Riverdale group, since neighbourhoods with higher Deprivation Indices have lower event rates than South Riverdale.

An apparently anomalous neighbourhood is Neighbourhood 10. This neighbourhood has the highest Deprivation Index, but event rates that are the lowest in its group. At this time, I am unable to explain why this occurs. This neighbourhood is a neighbourhood of immigrants, well over 50% of the population, and the majority from Portugal. Compared with the rest of Toronto, this neighbourhood has a higher proportion of immigrants but a lower proportion of recent immigrants, so the community is well-established. It would be interesting to explore further the reasons why the health experience in this neighbourhood is better than might be expected from its Deprivation Index.

DISCUSSION

We have found that non-cancer mortality and hospitalization rates were generally higher in South Riverdale and the Beaches than in their comparison communities. The comparison communities were selected on the basis that they were of “similar” socio-economic status. We calculated a Deprivation Index based upon neighbourhood values for Median Household Income, Unemployment, and Education. Table 50 showed that, despite the matching, some socio-economic differences remained.

This is primarily a “descriptive” study in which we compared event rates among the communities. It is not possible here to provide definitive explanations for the differences in rates between neighbourhoods. The focus of interest is on environmental contaminants, but we found that some of the variation in mortality and hospitalization rates, particularly in The Beaches and its comparison group might be “explained” by neighbourhood socio-economic characteristics, including income, education, and unemployment. Does this mean that environmental pollution was not a factor in these differences? Not necessarily. In studies of the relations between air pollution and mortality and hospitalization in Hamilton, Ontario we found that there were strong associations between measures of air pollution, both ambient and traffic-related, and deprivation (Finkelstein et al. 2003). Subjects living in more deprived neighbourhoods had greater exposure to air pollutants and experienced higher circulatory mortality and hospitalization rates. Although we do not, as yet, have similar information for Toronto, it is conceivable that neighbourhood deprivation and pollution are strongly connected in Toronto as well. If that is the case, it will be difficult to disentangle socioeconomic deprivation and environmental exposures in the causal chain leading to morbidity and mortality.

While attention has been paid to emissions from the Ashbridges Bay Treatment Plant, there were, historically, other industrial processes that emitted contaminants to the environment. In studies conducted in the 1980s, high lead soil levels were found in South Riverdale and were known to be from air deposition related to the local secondary lead smelter rather than the ABTP. Though clean up efforts in the late 1980s were not exhaustive, the yard soil from homes with the highest lead contamination was remediated and affected households were decontaminated. It is possible, however, that soil lead levels are still higher in South Riverdale than elsewhere in the City because of the historical point source in the community. Lead in outside soil can make its way into the home and be found in indoor house dust (von Lindern et al, 2003). Ingested lead has been associated with abnormalities of the circulatory system (Cheng et al. 1998).

There are additional limitations which affect the study and the interpretation of the results. Most importantly, this is an “ecological” study, that is, it is a study of neighbourhoods rather than individuals. Thus, although the boundaries of the neighbourhoods are fixed, individuals come and go, and we have no way of tracking them. Long-term residents may leave the neighbourhood and subsequently experience a health event elsewhere. Other individuals might move from elsewhere and shortly thereafter experience a health event while a resident of The Beaches or South Riverdale. While

such an event could be associated with recent emissions from the Ashbridges Bay Treatment Plant, it would not be associated with chronic exposures.

A particular problem has to do with institutions. Statistics Canada counts institutionalized individuals in the population base, but their health pattern is likely to be different from other neighbourhood residents. Neighbourhoods containing several nursing homes might thus have higher mortality rates than neighbourhoods with fewer ones. Although some sources of information were consulted, it was not possible to determine definitively if the distribution of long-term care facilities is a factor influencing observed mortality or hospitalization in these communities.

Another limitation pertains to the small population sizes and statistical variability. The neighbourhood populations are 15,000 to 20,000 subjects. These small sizes prevented a confident comparison of mortality rates from less common health events, such as incidence and mortality from brain cancer and leukemia.

CONCLUSIONS

We have found that mortality and hospitalization rates were generally higher in South Riverdale and The Beaches than in their comparison communities. The major concern of the residents is that exposure to environmental pollutants has adversely affected their health. This is primarily a “descriptive” study in which we compared event rates among the communities. It is not possible here to provide definitive explanations for the differences in rates between neighbourhoods. We have found that some of the variation in mortality and hospitalization rates, might be “explained” by neighbourhood socioeconomic characteristics, including income, education, and unemployment. The strong relation between the Deprivation Index and event rates for comparison group including The Beaches group suggests that differences in socioeconomic characteristics are the primary explanation for the differential. The situation is more complex for the South Riverdale group of neighbourhoods. All Cause Mortality rates were significantly higher in South Riverdale than those in the two nearest neighbours, including the one with a higher Deprivation Index. Hospitalization rates were similar between South Riverdale and its larger Near Neighbour, but were higher than among the other two comparison neighbourhoods with higher Deprivation Indices. It cannot be ruled out that differences in environmental exposures are contributing to these differences.

It is likely that neighbourhood deprivation and pollution are strongly connected in Toronto. If that is the case, it will be very difficult to disentangle socioeconomic deprivation and environmental exposures in the causal chain leading to morbidity and mortality without studies designed specifically to address the question of deprivation versus environmental exposure as the factors behind observed health inequalities.

The preceding outlines the results and interpretations of the health status study analysis. They reflect the work undertaken by the independent Consultant, Dr. Murray Finkelstein in discussion with the project team. Recommendations as to what is a reasonable course of further investigation or response in light of the findings summarized here are the purview of the Project team and City staff and are presented elsewhere (See Toronto Public Health, 2005).

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SUMMARY OF PEER REVIEW COMMENTS

Toronto Public Health (TPH) submitted a draft (January 2005) of the Health Status Study report for peer review by two academics with expertise in epidemiological study design, analysis and interpretation. The peer reviewers included two professors from the University of Toronto. Reviewer comments were considered by the Project Manager and by the Principal Investigator/Consultant, Dr. Murray Finkelstein. Dr. Finkelstein provided written responses to the peer review comments as per the terms of his contract with the City of Toronto. Peer review comments were very positive overall and did not raise anything that would cast doubt on the validity of the study. For the few questions posed of Dr. Finkelstein, he made appropriate changes where possible (i.e. where these did not raise issues outside the scope of the study or the report itself). Dr. Finkelstein's responses and subsequent changes to the report according to reviewers' comments were viewed by the Project Team and the peer reviewers to be satisfactory.

Because it is standard practice that the scientific peer review process protects the confidentiality of the reviewers themselves, specific comments are not attributed to the individual reviewers. In order to observe the ethical protocols outlined in Toronto Public Health's Policy for Evaluation and Other Research, this section provides only a summary and excerpted comments without attribution.

Overall comments

Both peer reviewers found the study to be very good as indicated by comments such as, "excellent", "carefully designed and meticulously carried out". The data management and analysis were deemed to have been conducted "according to a high standard in epidemiology and public health sciences", "by a true professional in the field at a high level of excellence". The study was described as representing "a major undertaking because data had to be obtained from multiple official sources".

Dr. Finkelstein's report itself was considered to be "well prepared", "excellent and well-written". The report was further described as providing results representing "an excellent synthesis of currently available data."

Reviewers commented that the conclusions drawn in the report "appear to be valid" and "include adequate cautionary against drawing cause-effect conclusions using such ecological data". One reviewer specified that "the author fulfilled the objectives set out for him by the City of Toronto."

Specific Comments

Methods

One reviewer wondered why the author did not use the following as outcome variables: acute ischemia (ICD9 410-411) and chronic ischemia (ICD9 412-414) combined, and congestive heart failure (which was highlighted in the text on page 10 as important).

Dr. Finkelstein responded:

I lumped because of the small number problem. I did carry out a Poisson regression analysis of acute MI, but the confidence intervals were very wide and the analysis was not very informative.

One reviewer wondered about what value is added by carrying out a Principal Components Analysis of the variables income, education and unemployment to produce a “Deprivation Index” as the way to select comparable comparison communities versus considering each of these three variables one at a time. The reviewer points out that “the link between health status and education may be through the latter’s association with income”.

Dr. Finkelstein’s response was:

The value of an Index is that you have to match on only one “value” rather than trying to balance on 3 variables in a large table. The visual display of the principal components helps the reader form an impression as to how “close” the neighbourhoods are.

And further:

Income is actually the main determinant of the Deprivation Index.

One reviewer wondered whether it was possible to create summary information for the outcome variables (mortality, cancer incidence and hospital discharge) plotted against potential confounders such as mean income and the Deprivation Index for each of the 41 census tracts as a way to choose the most appropriate comparison communities. As this reviewer further surmised, however, such an analysis was beyond the scope of what could be done according to the terms of reference for the study.

Results

One reviewer undertook to independently verify the results based on the data provide by Dr. Finkelstein. This reviewer made the suggestion to conduct further analysis [by calculation of standardized rate ratios (SRR) - the ratio of two directly standardized rates] to confirm the reviewer’s determination that “lung cancer mortality and lung cancer incidence also seem to be a problem in The Beaches and South Riverdale, compared to the selected comparison neighbourhoods”.

Dr. Finkelstein’s response was:

I performed Poisson regression analysis on the South Riverdale lung cancer data. There were no significant differences between South Riverdale and its near neighbours. The result has been added to Table 26.

This reviewer further suggested that Dr. Finkelstein consider “providing p-values or confidence intervals (for standardized rate ratios)”. These would inform the reviewer’s additional analysis (as described above) for which he noted he did not have adequate data to assess statistical significance of the additional results.

Dr. Finkelstein responded:

My conclusions are based upon the regression analyses and not on the standardized rates. I believe that regression analysis is much more stable with the small number of events available for analysis.

TPH further notes the report qualifies that conclusions about differences in cancer incidence or mortality rates are limited due to small numbers of cases/deaths.

On the issue of assessing whether the comparison communities were appropriate, one reviewer noted that “selection of a comparison community will always raise doubt about whether it was the best choice. Selecting more than one community does not always end the discussion as the author discovered. He has done an excellent job in attempting to explain the differences observed.”

Both reviewers commented on the format of reporting the regression analyses in a single table including Rate Ratios that were not of primary interest (i.e. comparisons within the comparison communities and not between the study community and each comparison community). One reviewer noted that the within-comparison community analyses were irrelevant, while the other suggested they may confuse interpretation. Dr. Finkelstein used double asterisks to identify those other communities whose Rate Ratios are different from those of South Riverdale. As well, he added a new table (Table 49 in the final report) which qualitatively describes all regression analyses for each health outcome and for each study community. This format is likely more understandable to the average reader than the individual output tables and TPH has included this table in the revised Executive Summary.

Interpretation

One reviewer raised a “general concern about the practice, everywhere evident, of adjusting for variables that may be influenced by the exposure being studied”. This reviewer’s comment is well founded, however it was not possible to adequately address it in the technical report by Dr. Finkelstein. In the cover report to the Board of Health, TPH raises a related concern in epidemiological studies of the relationship between socio-economic status and exposure to air pollutants and health effects. The report notes the hypothesis gaining support among researchers that low-income neighbourhoods not

only tend to have greater exposure but are also more susceptible to health effects from those exposures due to their already compromised health status.